Community of
European Solar Radio Astronomers

CESRA 2016: Solar Radio Physics from the Chromosphere to Near Earth

13-17 June 2016, Hôtel Dupanloup
(Centre International Universitaire pour la Recherche – Université d'Orléans)

Orléans (France)

Programme and abstracts

UNIVERSITE D'ORLEANS
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CESRA, the Community of European Solar Radio Astronomers, organizes triennial workshops on investigations of the solar atmosphere using radio and other observations. Although special emphasis is given to radio diagnostics, the workshop topics are of interest to a large community of solar physicists. The format of the workshop combines plenary sessions and working group sessions, with invited review talks, oral contributions, and posters. The CESRA2016 workshop, this year with a special emphasis on the complementarity of space-based and ground-based radio observations, will provide the community a place to discuss the exciting new science opportunities that arise from, for example, the Solar Orbiter and Solar Probe Plus missions, the new and future radio instruments like ALMA, E-OVSA, EVLA, LOFAR, MUSER, and SKA, and the plans to design and build a European spectroheliograph.

Acknowledgements

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CESRA 2016 Orléans: Programme overview

Monday 13 June – Friday 17 June 9:00-12:30

- Plenary session (*Grande salle de réception*, 1st floor)

Monday 13 June and Tuesday 14 June, afternoon: working group meetings

- WG 1: Particle acceleration and transport - *Salle de séminaire 2* (Max Jacob; ground floor)
- WG2: CMEs, shock waves and their radio diagnostics - *Salle de séminaire* 1 (ground floor)
- WG3: Fine structures and radio wave propagation - *Grande salle de réception* (1st floor)
- WG4: Space weather - *Salle de réunion 1* (1st floor)

Monday 18:00-20:00 Welcome reception

Tuesday 18:00-19:00 CESRA business meeting (*Grande salle de réception*, 1st floor)

Wednesday 14:00-20:00 Excursion (choose one of the two excursions)**:**

- Loire castle in Blois
- Carolingian church Germigny-des-Prés and village of St. Benoît sur Loire

Thursday 14:00-18:00 Instrument forum (WG rooms, to be announced)

- SKA (chair: E. Kontar) - *Grande salle de réception* (1st floor)
- Other instruments (TBD)
- ESOLAR (chair: P. Gallagher) - *Salle de séminaire 2* (Max Jacob; ground floor)

CESRA 2016 Orléans: Programme of the plenary sessions

Monday, June 13, 2016

TIME	EVENT
09:00 - 09:30	Opening session (Grande salle de réception (1st floor))
09:30 - 10:20	Plenary session (Grande salle de réception (1st floor)) - S. Pohjolainen
09:30 - 10:00	Particle acceleration and transport - *Gregory Fleishman, New Jersey Institute of Technology*
10:00 - 10:20	Electron acceleration at slow-mode shocks in the magnetic reconnection region in solar flares - *Gottfried Mann, Leibniz-Institut für Astrophysik Potsdam*
10:20 - 10:50	Coffee break
10:50 - 12:30	Plenary session (Grande salle de réception (1st floor)) - NN
10:50 - 11:20	Space Weather Effects of Solar Radio Bursts - *Dale Gary, Center for Solar-Terrestrial Research - New Jersey Institute of Technology*
11:20 - 11:50	High frequency physics and sub-THz emission - *Guillermo Gimenez de Castro, Centro de Rádio Astronomia e Astrofísica Mackenzie*
11:50 - 12:10	Polarisation of solar flares at millimetre wavelengths - *Adriana Valio, Mackenzie University (WITHDRAWN)*
12:10 - 12:30	Properties of Gyrosynchrotron Emission in a Shrinking Flaring Loop - *Victor Melnikov, Central Astronomical Observatory at Pulkovo of RAS*
12:30 - 14:00	Lunch
14:00 - 18:00	WG3: Fine structures and radio wave propagation (Grande salle de réception (1st floor)) - Alexander Warmuth & Hamish Reid
14:00 - 18:00	WG4: Space weather (Salle de réunion 1 (1st floor)) - Christophe Marqué & Thierry Dudok de Wit
14:00 - 18:00	WG2: CMEs, shock waves and their radio diagnostics (Salle de séminaire 1 (ground floor)) - Alexander Nindos & Bojan Vrsnak
14:00 - 18:00	WG 1: Particle acceleration and transport (Salle de séminaire 2 (Max Jacob; ground floor)) - Miroslav Barta & Nicole Vilmer
15:30 - 16:00	Coffee break
18:00 - 19:30	Welcome reception

Tuesday, June 14, 2016

TIME	EVENT
09:00 - 10:30	Plenary session (Grande salle de réception (1st floor))
09:00 - 09:30	Type II Radio Emission From Sun To Earth And In The Lower Corona - *Joachim Schmidt, School of Physics, University of Sydney*
09:30 - 09:50	Fine structure of a type II radio burst observed by LOFAR - *Jasmina Magdalenic, Royal Observatory of Belgium*
09:50 - 10:10	Analysis of combined ARTEMIS-NRH observations of fine structures in type IV bursts - *Costas Alissandrakis, University of Ioannina*
10:10 - 10:30	Observations of a CME-related type IV burst with LOFAR *A. Kuznetsov, E. Kontar*
10:30 - 11:00	Coffee break
11:00 - 12:30	Plenary session (Grande salle de réception (1st floor))
11:00 - 11:30	Interplanetary radio signatures and Solar Orbiter capabilities - *Milan Maksimovic, LESIA, Observatoire de Paris*
11:30 - 11:50	Radio triangulation of solar radio emissions: STEREO/Waves measurements - *Vratislav Krupar, Institute of Atmospheric Physics CAS, Imperial College London*
11:50 - 12:10	Large coronal loops and solar radio J-bursts imaged using LOFAR - *Hamish Reid, School of Astronomy and Physics, University of Glasgow*
12:10 - 12:30	CME observations using LOFAR: Latest results from interplanetary scintillation and Faraday rotation - *Fallows Richard, Netherlands Institute for Radio Astronomy*
12:30 - 14:00	Lunch
14:00 - 18:00	WG3: Fine structures and radio wave propagation (Grande salle de réception (1st floor)) - Alexander Warmuth & Hamish Reid
14:00 - 18:00	WG4: Space weather (Salle de réunion 1 (1st floor)) - Christophe Marqué & Thierry Dudok de Wit
14:00 - 18:00	WG2: CMEs, shock waves and their radio diagnostics (Salle de séminaire 1 (ground floor)) - Alexander Nindos & Bojan Vrsnak
14:00 - 18:00	WG 1: Particle acceleration and transport (Salle de séminaire 2 (Max Jacob; ground floor)) - Miroslav Barta & Nicole Vilmer
15:30 - 16:00	Coffee break
18:00 - 19:00	CESRA business meeting

Wednesday, June 15, 2016

TIME	EVENT
09:00 - 10:30	Plenary session (Grande salle de réception (1st floor))
09:00 - 09:30	Electron beam-plasma instability in the randomly inhomogeneous solar wind - *Vladimir Krasnoselskikh, Laboratoire de physique et chimie de l'environnement et de l'espace*
09:30 - 09:50	Self-consistent particle-in-cell simulations of fundamental and harmonic radio plasma emission mechanisms - *David Tsiklauri, Queen Mary, University of London*
09:50 - 10:10	Fine Spectral Structures of Solar Radio Type-I Bursts observed by AMATERAS - *Kazumasa Iawi, National Institute of Information and Communications Technology*
10:10 - 10:30	Imaging spectroscopy of fine structures with LOFAR: implication for radio wave propgation - *Eduard Kontar, University of Glasgow*
10:30 - 11:00	Coffee break
11:00 - 12:30	Plenary session (Grande salle de réception (1st floor))
11:00 - 11:30	Coronal waves, shocks, and associated radio signatures - *Alexander Warmuth, Leibniz Institute for Astrophysics Potsdam*
11:30 - 11:50	Mult-viewpoint Observations of a Widely Distributed Solar Energetic Particle Event: the Role of EUV Waves and Shock Signatures - *Alexander Nindos, Physics Department, University of Ioannina*
11:50 - 12:10	Radio Diagnostics of electron acceleration sites during the eruption of a flux rope in the solar corona - *Eoin Carley, Trinity College Dublin [Dublin], Laboratoire d'études spatiales et d'instrumentation en astrophysique*
12:10 - 12:30	LOFAR observations of the quiet solar corona - *Christian Vocks, Leibniz-Institut für Astrophysik Potsdam*
12:30 - 14:00	Lunch
14:00 - 19:00	Excursion to Blois (Loire castle) or to St. Benoit sur Loire/Germigny des Prés - (choice to be made on Monday)

Thursday, June 16, 2016

TIME	EVENT
09:00 - 10:30	Plenary session (Grande salle de réception (1st floor))
09:00 - 09:20	Solar Observations with the Jansky Very Large Array - *Timothy Bastian, National Radio Astronomy Observatory*
09:20 - 09:40	Early Observations with the Expanded Owens Valley Solar Array - *Dale Gary, Center for Solar-Terrestrial Research - New Jersey Institute of Technology*
09:40 - 10:00	ALMA solar observing modes - *Ivica Skokic, Astronomical Institute of the Czech Academy of Sciences*
10:00 - 10:20	Observation and modelling of the solar atmosphere in the mm and sub-mm wavelength ranges - *Roman Brajsa, Hvar Observatory, Faculty of Geodesy, University of Zagreb*
10:20 am - 10:50 am	Coffee break
10:50 am - 12:30	Plenary session (Grande salle de réception (1st floor))
10:50 - 11:10	Observations with MUSER - *Yihua Yan, Key Lab of Solar Activity, National Astronomical Observatories, Chinese Academy of Sciences*
11:10 - 11:30	Solar observations with the Murchison Widefield Array - *Divya Oberoi, National Centre for Radio Astrophysics, Tata Institute of Fundamental Research*
11:30 - 11:50	LOFAR Solar Imaging - *Frank Breitling, Leibniz-Institut für Astrophysik Potsdam*
11:50 - 12:10	First observations with the Siberian Radioheliograph - *Alexey Kuznetsov, Institute of Solar-Terrestrial Physics SB RAS*
12:10 - 12:30	Solar radio monitoring at Nançay: status and future perspectives - *Karl-Ludwig Klein, Station de radioastronomie de Nançay, Laboratoire d'études spatiales et d'instrumentation en astrophysique*
12:30 - 14:00	Lunch
14:00 - 15:30	Instrument forum (Grande salle de réception (1st floor)) - SKA (1) - E. Kontar
14:00 - 15:30	Instrument forum (Salle de séminaire 1 (ground floor)) - Other instruments
15:30 - 16:00	Coffee break
16:00 - 18:00	Instrument forum (Grande salle de réception (1st floor)) - SKA (2) - E. Kontar
16:00 - 18:00	Instrument forum (Salle de séminaire 2 (Max Jacob; ground floor)) - ESOLAR - P. Gallagher
20:00 - 22:00	Conference dinner

Friday, June 17, 2016

TIME	EVENT
09:00 - 10:30	Plenary session (Grande salle de réception (1st floor))
09:00 - 09:45	WG1 report: Particle acceleration and transport - *Miroslav Barta, Astronomical Institute of the Czech Republic - Nicole Vilmer, Laboratoire d'études spatiales et d'instrumentation en astrophysique*
09:45 - 10:30	WG3 report: Fine structures and radio wave propagation - *Alexander Warmuth, Leibniz-Institut für Astrophysik Potsdam - Hamish Reid, University of Glasgow*
10:30 - 11:00	Coffee break
11:00 - 12:10	Plenary session (Grande salle de réception (1st floor))
11:00 - 11:40	WG2 report: CMEs, shock waves, and their radio diagnostics - *Alexander Nindos, University of Ioannina - Bojan Vrsnak, Hvar Observatory, Faculty of Geodesy, University of Zagreb*
11:40 - 12:10	WG4 report: Space weather - *Christophe Marqué, Royal Observatory of Belgium - Thierry Dudok de Wit, Laboratoire de Physique et Chimie de l'Environnement et de l'Espace*
12:10 - 12:30	Closing of the meeting (Grande salle de réception (1st floor))

Working group schedules

CESRA 2016 WG 1: **Particle acceleration and transport**
(Miroslav Barta, Nicole Vilmer)

Monday, June 13:
Moderator (Nicole Vilmer)

New enhancements of the GX simulator for studying solar flares and active regions
Gelu Nita

Microwave polarization as a detection tool for magnetic twist in solar flares
Mykola Gordovskyy, Philippa Browning, Eduard Kontar, Rui Pinto, Nicole Vilmer

Joint radio, EUV and X-ray analysis of the 2013 November 5 cold flare
Galina Motorina, Eduard Kontar, Gregory Fleishman

Search and statistical analysis of "cold" solar flares using X-ray and microwave data
Alexandra Lysenko, Alexander Altyntsev, Valentin Pal'shin, Natalia Meshalkina, Dmitriy Zhdanov, Gregory Fleishman

Diagnostics of the acceleration modulation process based on quasi-periodic variations of flare emissions
Elena Kupriyanova, Hamish Reid, Larisa Kashapova, Irina Myagkova
(poster)

Interaction of three parallel propagating Alfven waves
Khalil Daiffallah, Fabrice Mottez **(poster)**

Open discussion: microwave diagnostics of electron acceleration and transport

Tuesday, June 14:
Moderator(Miroslav Barta)

CME-related particle acceleration regions during a simple eruptive event near solar minimum
Carolina Salas Matamoros, Karl-Ludwig Klein, Alexis Rouillard

Intensity distribution and onset delays of nearly relativistic electron events
Andreas Klassen, Nina Dresing, Raul Gomez-Herrero, Bernd Heber, Reinhold Mueller-Mellin

Non-thermal electrons in solar flares: Hot-Corona Cold Chromosphere Model
Eduard Kontar, Natasha Jeffrey, A. Gordon Emslie, Nic Bian

Energetic electrons in the solar atmosphere as diagnosed from their radio and hard X-ray signatures
Nicole Vilmer, Hamish Reid

Different scaling for the coronal and chromospheric flare fluence
Matthieu Kretzschmar **(poster)**

Solar research with ALMA: ARC as your supporting infrastructure
Miroslav Barta (poster)

Open discussion: Electrons at the sun and in the interplanetary medium

WP2: CMEs, shock waves, and their radio diagnostics (A. Nindos, B. Vrsnak)

Monday, June 13

Coronal Mass Ejections, Associated Shocks and their Interactions with the Ambient Medium
M. Pick, G. Stenborg, P. Zucca, P. Demoulin, A. Lecacheux, A. Kerdraon

Triangulation of the Continuum-like Radio Emission in a CME-CME Interaction Event
J. Magdalenic, M. Temmer, V. Krupar, C. Marque, A. Veronig, B. Vrsnak

Interplanetary Type IV Bursts (POSTER)
A. Hillaris, C. Bouratzis, A. Nindos

Open Discussion on the Nature of Radio Emission of CMEs and Shocks
(moderator: A. Nindos)

Tuesday, June 14

First observation of a solar type II radio burst below 50 MHz with the tied array beam mode of LOFAR
P. Zucca, D. Morosan, P. Gallagher, F. Richard, A. Rouillard, J. Magdalenic, K.-L. Klein

A Special Solar Type II Radio Burst Observed with LOFAR
F. Breitling, R. Fallows, G. Mann, C. Vocks, M. Bisi, P. Gallagher, A. Kerdraon, J. Magdalenic, A. Mackinnon, H. Rucker, A. Konovalenko, C. Marque, E. Kontar, B. Dabrowski, A. Krankowski, H. Reid, B. Thide)

Studying the Characteristics of Shock Waves Associated with CMEs Using Solar Radio Bursts (POSTER)
K. Alielden, A. Mahrous

Observations of Near-Simultaneous Split-Band Solar Type-II Radio Bursts at Low Frequencies (POSTER)
H. Krishnan, R. Ramesh, C. Kathiravan

Open Discussion on Formation and Propagation of CME-driven Shocks
(moderator: B. Vrsnak)

WG2 Conclusions

CESRA 2016 WG 3: Fine structures and radio wave propagation
(Alexander Warmuth, Hamish Reid)

Monday, June 13:

The Propagation of Jet Related Type III Radio Bursts in the Solar Corona
Diana Morosan

On a solar type III radio burst observed with LOFAR
Gottfried Mann, Richard Fallows, Frank Breitling, Christian Vocks, Mario Bisi, Peter Gallagher, Alain Kerdraon, Jasmina Magdalenic, Alec MacKinnon, Helmut Rucker, Alexandr Konovalenko, Christophe Marque, Eduard Kontar, Bartosz Dabrowski, Andrzej Krankowski, Hamish Reid, Bo Thide

Solar flare accelerated electrons from high and low radio frequencies
Hamish Reid, Larisa Kashapova

Thermal plasma diagnostics and the origin of sub-THz solar bursts
Yuriy Tsap, Galina Motorina, Viktoria Smirnova, Alexander Morgachev,Valeriy Nagnibeda, Sergey Kuznetsov, Vladimir Ryzhov
(poster)

Metric Fiber Bursts Observed with the Artemis-IV RadioSpectrograph
Costas Bouratzis, Alexander Hillaris, Costas Alissandrakis, Panagiota Preka-Papadema, Xenophon Moussas, Panagiotis Tsitsipis, Athanasios Kontogeorgos
(poster)

The first results of the 2D solar observations obtained by Irkutsk incoherent scatter radar
Mariia Globa, Hamish Reid, Larisa Kashapova, Roman Vasilyev, Valentin Lebedev, Dmitriy Kushnarev, Andrey Medvedev
(poster)

Open discussion: constraining electron propagation and plasma parameters

Tuesday, June 14:

Automatic Detection and Measurement of Spectral Fine Structures Using Higher Order Statistical Estimators
Gelu Nita, Dale Gary

Interpretation of Tadpole Structures in the Solar Radio Radiation
Gottfried Mann, Viktor Melnik, Helmut H. O. Rucker, Alexandr Konovalenko

Structure and polarization of large spots with RATAN-600 and the NoRH
Costas Alissandrakis, Vladimir Bogod, Tatyana Kaltman, Natalia Peterova

Solar plasma diagnostics: magnetosphere of active regions with RATAN-600 microwave observations
Tatyana Kaltman, Vladimir Bogod, Leonid Yasnov, Alexei Stupishin, Anatoly Korzhavin, Natalia Peterova
(poster)

Modeling of solar atmosphere parameters above the active region using RATAN-600 radiotelescope observation
Alexey Stupishin, Vladimir Bogod, Tatyana Kaltman, Leonid Yasnov
(poster)

Broadband microwave sub-second pulsations and magnetoacoustic waves in an expanding coronal loop (2011 August 10 flare)
Hana Meszarosova, Jan Rybak, Larisa Kashapova, Peter Gomory, Susanna Tokhchukova, Ivan Myshyakov
(poster)

Studying the Characteristics of Shock waves associated with CMEs using solar radio bursts
Khaled Alielden, Ayman Mahrous
(poster)

Open discussion: fine structures in solar radio emission

WG3 conclusions

WG4 on Space Weather

Monday and Tuesday, 14:00-18:00, in *salle de reunion* (1st floor)

Conveners: Christophe Marqué (Royal Observatory of Belgium) and Thierry Dudok de Wit (University of Orléans)

We plan to have a series of oral presentations, with ample time for interactions, and at the end of each theme an open discussion to address open issues and future plans. For each presentation, we foresee approximately 15’ presentation time + questions. There will be no posters.

Monday 14:00-18:00

Variability: origins, short- and long-term (moderators C. Marqué and T. Dudok de Wit)

- T. Dudok de Wit et al., *Synoptic observations at centimetric wavelengths for a better description of solar forcing of the upper atmosphere*
- C. Salas Matamoros et al., *Microwave emission as a proxy of CME speed in ICME arrival time predictions*
- K. Iawi et al., *Observation of the Solar Chromosphere at 2.6 mm*
- C. Alissandrakis et al., *Structure and polarization of large spots with RATAN-600 and the NoRH*

Automated detection of solar radio bursts (moderator T. Dudok de Wit)

- H. Salmane, *An automated solar radio burst detection method to extract major bursts (type II, III and IV) from dynamic spectra*
- G. Nita et al., *Automatic Detection and Measurement of Spectral Fine Structures Using Higher Order Statistical Estimators*

Open discussion

Tuesday 14:00-18:00

Space weather effects (moderator C. Marqué)

- P. Zucca et al., *Microwave observations for forecasting energetic particles from the Sun*
- D. Gary et al., *Space weather effects or radio bursts*
- M. Pick et al., *Statistical analysis of solar events associated to SSCs over one year of solar maximum during cycle 23*
- C. Marqué et al., *The impact of the November 4th 2015 event on air traffic radars*
- Kumar Singh et al., *Investigation of sub-ionospheric VLF signal anomalies leading to geomagnetic storm using artificial neural network and statistical approach*

Open discussion

Abstracts

The abstracts are ordered as follows:

- Plenary session (in the order of presentation, see time table above)
- Instrument session (plenary session in the order of presentation, followed by posters in alphabetical order of the first author)
- Oral contributions to the working groups, alphabetical order within each working group)
- Poster contributions (alphabetical order)

Monday June 13

Plenary session

Particle acceleration and transport

Gregory Fleishman*[1]

[1]New Jersey Institute of Technology (NJIT) – United States

Abstract

The Sun is arguably the best astrophysical laboratory to study particle acceleration because of the relative proximity of the star and high efficiency of particle acceleration. A key difficulty of probing the particle acceleration at the sun is that we often observe the accelerated particles not in the very acceleration region, but from a remote location; thus, properties of the accelerated particles are modified by transport effects. The few reported detections of the flare acceleration sites raise new fundamental questions of exactly how flare energization works. What are the main driving physical parameters that control the initial partition between the nonthermal and thermal energies? Do waves or turbulence play a role? What is the role of the nonthermal particles in the flare energy release and plasma heating? What is the favorable magnetic morphology? In this talk I give a brief review of most likely acceleration mechanisms and most relevant transport effects and their observational signatures in radio and X-ray domains.

*Speaker

Electron acceleration at slow-mode shocks in the magnetic reconnection region in solar flares

Gottfried Mann*[1], Henry Aurass , Hakan Oenel , and Alexander Warmuth

[1]Leibniz-Institut für Astrophysik Potsdam (AIP) – An der Sternwarte 16, 14482 Potsdam, Germany

Abstract

A solar flare appears as an sudden enhancement of the emission of electromagnetic radiation of the Sun covering a broad range of the spectrum from the radio up to the gamma-ray range. That indicates the generation of energetic electrons during flares, which are considered as the manifestation of magnetic reconnection in the solar corona. Spacecraft observations in the Earth's magnetosphere, as for instance by NASA's MMS mission, have shown that electrons can efficiently accelerated at the slow-mode shocks occurring in the magnetic reconnection region. This mechanism is applied to solar flares. Then, under coronal circumstances, enough electrons with energies > 30_~keV are generated in the magnetic reconnection region as required for the hard X-ray radiation during solar flares as observed by NASA's RHESSI mission.

*Speaker

Space Weather Effects of Solar Radio Bursts

Dale Gary*[1] and Gelu Nita[1]

[1]Center for Solar-Terrestrial Research - New Jersey Institute of Technology (CSTR-NJIT) – 323 Martin Luther King Boulevard, 101 Tiernan Hall, Newark, NJ 07102-1982 U.S.A., United States

Abstract

The effects of solar radio noise on wireless navigation and communications systems have been clearly demonstrated in a few cases, with the most serious being outages of the Global Positioning System (GPS) over the entire sunlit hemisphere of the Earth in December 2006. We review what is known about both the actual observed effects and assessments of the prevalence of such effects in the future, and point out the need for better monitoring of solar bursts. We also discuss strategies for reducing or mitigating the threat of solar radio noise on wireless technological systems.

*Speaker

High frequency physics and sub-THz emission

Guillermo Gimenez De Castro*†[1]

[1]Centro de Rádio Astronomia e Astrofísica Mackenzie (CRAAM) – Rua da Consolação 896 01302-907 Sao Paulo,SP, Brazil

Abstract

If we consider high frequency as the frequency frontier of astronomical detectors imposed by the current technology, a broad band above 100 GHz and below the IR can be included. The interest in this particular spectral range can be measured in the number of new facilities that are being constructed or already installed in the last 15 years. The expectation for solar physics is to unveil the dynamics of very high energy particles during flares, and / or to diagnose low atmospheric layers. But in essence is the curiosity to see where nobody has seen before. In this talk we review the last 15 years of continuous high frequency observations, their interpretations and the perspectives for the years to come. The most impressive results were obtained during flares: it is now accepted the existence of a different spectral component at high frequencies that is visible only during some flares. Different speculations have been made to explain this second spectral component, but the lack of a more detailed description in frequency, in polarization and in spatial distribution have precluded a definite conclusion. The episodic characteristic draws more relevance to the new spectral component for it must be due to a very peculiar origin. Although our focus are flares; we also present relevant and previously unknown characteristics of quiescent structures at these high frequencies. In the next years we hope to address some of the present observing mentioned deficiencies, since the ALMA interferometer with its receivers from 100 to 1000 GHz, is starting to offer solar observations and the LLAMA single dish antenna, to start working in a couple of years and with a similar receiver setup as ALMA, is preparing a solar observing program. Moreover, THz telescopes are being built and may start sooner rather than later to give new insights in this spectral realm.

*Speaker

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Polarisation of solar flares at millimetre wavelengths

Douglas Silva[1], Paulo Simoes[2], and Adriana Valio*[1]

[1]Mackenzie University (Mackenzie) – CRAAM Rua da Consolacao, 896 Sao Paulo, SP, 01302-907, Brazil
[2]University of Glasgow (Glasgow Univ.) – Glasgow G12 8QQ Scotland, United Kingdom

Abstract

Solar flares are characterized by a sudden release of magnetic energy that accelerates particles producing emission throughout the entire electromagnetic spectrum and plasma heating. It is believed that a fraction of these accelerated particles are injected into bipolar magnetic fields. Measurements of right and left circularly polarized brightness temperature of flares at the frequencies of 45 and 90 GHz yield degrees of circular polarization that reached 5 to 40 % and were opposites at 45 and 90 GHz, always being reversed for the events. The interpretation of these results may be associated with the asymmetry of the field strength of magnetic loop legs. Here, we study the magnetic field configuration and energy distribution of accelerated particles in solar flares. For the study of these solar flares, we used the observations of the telescopes POEMAS (POlarization Emission of Millimeter Solar Activity), that monitor the Sun at 45 and 90 GHz with circular polarization. To study the interaction between the particles and magnetic field we applied a 3D model of a magnetic loop. Numerical simulations were performed and produced sources at 45 and 90 GHz in a three dimensional magnetic loop with maximum intensity in opposite polarities of a dipole loop. The simulations also reproduced the degree of polarization and radio spectra observed in each event. Thus, by means of the simulations, we obtained the location of 45 and 90 GHz sources with predominant intensities in opposite magnetic polarities and with reversed degree of polarization

*Speaker

Properties of Gyrosynchrotron Emission in a Shrinking Flaring Loop

Victor Melnikov*†[1] and Leonid Filatov[2]

[1]Central Astronomical Observatory at Pulkovo of RAS (Pulkovo Observatory) – 65/1 Pulkovskoe Shosse, Saint Petersburg 196140, Russia

[2]Radiophysical Research Institute (NIRFI) – 25/12a Bolshaya Pecherskaya, Nizhniy Novgorod 603950, Russia

Abstract

Shrinking flaring loops recently became a popular topic in the solar flare physics. The flare loop shrinkage has not been predicted by so called the standard solar flare model. The standard model predicts just the opposite behavior, namely the expansion of a system of flaring loops during the flare development. The purpose of our work is modeling the microwave emission of such loops and comparing the obtained properties with the observed ones. First of all we model the dynamics of various parameters of nonthermal electrons injected into a non-stationary shrinking magnetic trap. The electron energy and pitch angle non-stationary spatial distributions in an extensive inhomogeneous magnetic trap have been obtained by numerically solving the non-stationary Fokker–Planck kinetic equation. It is shown that the high energy electrons are effectively accumulated and accelerated at the top of the shrinking trap due to the first order Fermi and betatron acceleration mechanisms. Spatial and temporal properties of gyrosynchrotron emission characteristics have been calculated for the obtained electron distributions. Specifically, the obtained solutions make it possible to explain the radio brightness peak that is frequently observed at the top of solar flare loops. Also, we found unexpectedly long time delays between emission light curves from the looptop and footpoint regions. The properties obtained are compared with the properties of the shrinking microwave loops for some flares observed with Nobeyama Radioheliograph.

*Speaker

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Tuesday June 14

Plenary session

Type II Radio Emission From Sun To Earth And In The Lower Corona

Joachim Schmidt*[1] and Iver Cairns†[1]

[1]School of Physics, University of Sydney (physics/usyd) – School of Physics University of Sydney NSW 2006 Australia, Australia

Abstract

Type II radio emission is an important tracer of Coronal Mass Ejections (CMEs), shocks, and electron acceleration in the solar corona and the inner heliosphere. We focus first on the simulation of a CME event and the related radio emission on 29 November to 1 December 2013, observed with STEREO and Wind, where the radio emission was observed intermittently from about 10 solar radii to 1 AU. The predictions agree very well with the observations: the frequencies are within 20 per cent of the observations, the intensities within a factor of 10 over the observed range of 6 orders of magnitude, and the time within 5%. We show that the intermittent bursts of radio emission occur predominantly when the magnetic field in a large enough volume is close to perpendicular to the normal of the CME-driven shock front. Additional causes are the growth of the radio-emitting volume upstream of the shock front and other variations of the local plasma parameters. We also simulated a CME event in the lower corona on 7 September 2014, which led to a metric split-band type II burst observed by the Murchison Widefield Array (MWA). Again, we find excellent agreement between the observed and simulated radio emissions. We can show that the splitting of the bands is due to two spatially separated radio sources existing, one closer to the nose and one closer to a flank of the driven shock, which emit at different frequencies. The results suggest that we are close to quantitatively understanding type II solar radio bursts.

*Speaker
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Fine structure of a type II radio burst observed by LOFAR

Jasmina Magdalenic*[1], Christophe Marque[2], Richard Fallows[3], Gottfried Mann[4], Christian Vocks[5], and Lofar Solar Ksp Core Members

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Abstract

The M2.0 class flare peaking at 15:10 UT on August 25, 2014 originated from the NOAA AR 2146, at that moment situated close to the west solar limb. The flare was associated with coronal dimmings, an EIT wave, a halo CME, and a type II radio burst observed in the meter to decameter wavelengths.
A metric type II burst was observed by the LOFAR (LOw Frequency ARray) radio interferometer. The type II burst shows strong fragmentation of the radio emission, and although fine structure of type II burst was already reported, the richness of the fine structures observed in the August 25, 2014 event is unprecedented due to outstanding frequency and time resolutions, and exceptional sensitivity of LOFAR.

The fine structures within the type II burst are morphologically very similar to the ones usually seen superposed on type IV continuum emission. Together with herringbone structures, inverted J-bursts and U-bursts, we observed also narrowband bursts similar to simple narrowband super short structures (Magdalenic et al., 2006), i.e. spike-like, dot-like, sail-like and flag-like bursts, and a number of various unclassified bursts.
The main characteristics of the fine structures observed within the type II burst are compared with the characteristics of type IV burst fine structures in the same wavelength range. We demonstrate how LOFAR observations bring new insight into the physics of coronal shock waves and their radio signatures, and therefore also new challenges for the theory of the electron acceleration at the shock waves in the solar corona.

*Speaker

Analysis of combined ARTEMIS-NRH observations of fine structures in type IV bursts

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Abstract

We are conducting a systematic study of millisecond fine structures embedded in type IV bursts, based on the high sensitivity, high time resolution (10 ms) observations with the acoustico-optic receiver (SAO) of the ARTEMIS radio spectrograph. For a selected sample of our events we have analysed simultaneous observations with the Nançay Radioheliograph (NRH), which can provide 2D positional information with a smaller time resoluton (125 ms). We computed 1D images using the EW and NS baselines of the NRH, in order to obtain the maximum resolution; this is about a factor of two better than the resolution of the 2D images. Here we will present results on spike and fiber bursts; we compare the position, the size and the brightnes temperature of the fine structure with those of the continuum source and we will discuss the physical implications of our results.

*Speaker
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Observations of a CME-related type IV burst with LOFAR

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Abstract

We present the first observations of a moving type IV solar radio burst with the LOw Frequency ARray (LOFAR). The burst was observed for about 2 hours on 20 June 2015 in the frequency range of 30-80 MHz with high spectral, temporal and spatial resolution. The dynamic spectrum consisted of multiple aperiodic short (_˜5 s) broadband pulses; the emission demonstrated an overall negative frequency drift of about 10 kHz/s. Radio imaging revealed a loop-like structure over the limb, with three dominant emission sources: two footpoints and the loop top. The loop size was of about two solar radii; it slowly ascended with the speed of up to 100 km/s. The radio brightness distributions both along and across the loop were frequency-dependent: high- and low-frequency emissions originated predominantly from different footpoints, and higher-frequency emission originated from slightly lower heights. We conclude that gyrosynchrotron radiation of weakly-relativistic electrons (with the energy of _˜50 keV) in a magnetic field of a few Gauss can be responsible for almost all observed emission features. However, some short and very bright narrowband spikes require a coherent (e.g., maser) emission mechanism. All observed emission characteristics seem to be affected strongly by the propagation effects. The most likely origin of the accelerated electrons is a shock formed at a boundary of an expanding magnetic arch.

*Speaker
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Interplanetary radio signatures and Solar Orbiter capabilities

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Abstract

I will review firstly the science objectives of the Radio & Plasmas Waves (RPW) instrument on the Solar Orbiter mission. Among those the study of the connectivity between the solar corona and the inner Heliosphere as close as from 0.3 AU is of prime importance. I will then present the RPW technical capabilities which will allow in-situ and remote sensing measurements related to the above objectives.

*Speaker

Radio triangulation of solar radio emissions: STEREO/Waves measurements

Vratislav Krupar*[1,2], Eastwood Jonathan[1], Oksana Kruparova[2], Ondrej Santolik[2,3], Jan Soucek[2], Jasmina Magdalenic[4], Vourlidas Angelos[5], Milan Maksimovic[6], Xavier Bonnin[6], Volker Bothmer[7], Niclas Mrotzek[7], Adam Pluta[7], David Barnes[8], Jackie Davies[8], Juan Carlos Martinez Oliveros[9], and Stuart Bale[9]

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Abstract

We present an analysis of radio signatures associated with a CME-driven shock on 29 November 2013. We benefit from comprehensive in situ and remote sensing observations of the CME, combining white-light, radio, and plasma measurements from four different vantage points. We have successfully applied a radio direction-finding technique to type II and type III bursts detected by two identical widely separated radio receivers onboard the STEREO spacecraft. We performed the radio triangulation to localise radio sources in the interplanetary medium. The derived locations of the type II and type III bursts are in general agreement with the white light CME reconstruction. We find that the radio emissions arise from the flanks of the CME, and are most likely associated with the CME-driven shock.

*Speaker

Large coronal loops and solar radio J-bursts imaged using LOFAR

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Abstract

Solar radio U or J-bursts are believed to be signatures of electron beams propagating along closed magnetic loops. Although, like type III bursts they are generated by electron beams, J-bursts are rather rare events. J-bursts with a turnover around 40 MHz imply large magnetic loops on the scale of a solar radius. The density in such loops is normally too low for EUV or X-ray observations. Using LOFAR between 30-80 MHz we image a sequence of three J-bursts with a continuous frequency coverage, a huge improvement over the previous observations. From the centroids of the radio sources we obtain a fit to a magnetic loop of 1 solar radii in altitude and around 1.4 solar radii in length from base to apex. The density within the magnetic loop appears much higher and varying slower than the density models inferred from type III radio bursts. Such conditions could be the reason why we do not observe as many J-bursts or U-bursts as we would expect from the closed magnetic flux in the low corona.

*Speaker
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CME observations using LOFAR: Latest results from interplanetary scintillation and Faraday rotation

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[5]University of San Diego, California (UCSD) – United States
[6]University of New Mexico, Albuquerque – United States

Abstract

Several observations using the Low Frequency Array (LOFAR - a radio telescope centred on the Netherlands with stations across Europe) have been undertaken to observe the passage of CMEs through interplanetary space. By measuring the interplanetary scintillation (IPS) of compact radio sources as a CME passes across the lines of sight, the velocity and relative density of the various components from nose to prominence material can be assessed. Observations of Faraday rotation (FR) in signals from polarised sources such as pulsars can be used as a remote-sensing method of determining magnetic fields: If the contributions from the interstellar medium and Earth's ionosphere can be accurately assessed and subtracted, this can act as a remote probe of the heliospheric magnetic field, representing one of the only methods by which global measurements of this parameter could be made. Here, we summarise the initial results of dedicated LOFAR observations designed to observe the full passage of several CMEs using measurements of IPS and present the first tentative results from attempts to determine heliosperic magnetic field parameters during the passage of a CME.

*Speaker

Wednesday June 15

Plenary session

Electron beam-plasma instability in the randomly inhomogeneous solar wind

Vladimir Krasnoselskikh*[1], Andrii Voshchepynets† , Catherine Krafft , and Alexandre Volokitin

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Abstract

We propose a new model that describes effects of plasma density fluctuations in the solar wind on the relaxation of the electron beams ejected from the Sun during the solar flares. The density fluctuations are supposed to be responsible for the changes in the local phase velocity of the Langmuir waves generated by the beam instability. We use the property that for the wave with a given frequency the probability distribution of density fluctuations uniquely determines the probability distribution of phase velocity of wave. We replace the continuous spatial interval by a discrete one, consisting of small equal spatial subintervals with linear density profile. This approach allows us to describe the changes in the wave phase velocity during the wave propagation in terms of probability distribution function. Using this probability distribution, we describe resonant wave particle interactions by a system of equations, similar to a well-known quasi-linear approximation, where the conventional velocity diffusion coefficient and the wave growth rate are replaced by the averaged in the velocity space. The averaged diffusion coefficient and wave growth rate depend on a form of the probability distribution function for the density fluctuations. This last distribution is obtained from the spectrum of the density fluctuations measured aboard ISEE satellites when they were in the solar wind. It was shown that the process of relaxation of electron beam is accompanied by transformation of significant part of the beam kinetic energy to energy of the accelerated particles via generation and absorption of the Langmuir waves. We discovered that for the very rapid beams with beam velocity vb> 15vt, where vt is a thermal velocity of background plasma, the relaxation process consists of two well-separated steps. On first step the major relaxation process occurs and the wave growth rate almost everywhere in the velocity space becomes close to zero or negative. At the second stage the system remains close to the state of marginal stability long enough to explain how the beam may be preserved traveling distances over 1 AU while still being able to generate the Langmuir waves.

*Speaker

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Self-consistent particle-in-cell simulations of fundamental and harmonic radio plasma emission mechanisms

David Tsiklauri*[1] and Jonathan Thurgood[2]

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Abstract

Aims. The simulation of three-wave interaction based plasma emission, thought to be the underlying mechanism for Type III solar radio bursts, is a challenging task requiring fully-kinetic, multi-dimensional models. This paper aims to resolve a contradiction in past attempts, whereby some studies indicate that no such processes occur.
Methods. We self-consistently simulate three-wave based plasma emission through all stages by using 2D, fully kinetic, electromagnetic particle-in-cell simulations of relaxing electron beams using the EPOCH2D code.

Results. Here we present the results of two simulations; Run 1 ($n\mathrm{b}/n0 = 0.0057$, $v\mathrm{b}/\Delta v\mathrm{b} = v\mathrm{b}/V\mathrm{e} = 16$) and Run 2 ($n\mathrm{b}/n0 = 0.05$, $v\mathrm{b}/\Delta v\mathrm{b} = v\mathrm{b}/V\mathrm{e} = 8$), which we find to permit and prohibit plasma emission respectively. We show that the possibility of plasma emission is contingent upon the frequency of the initial electrostatic waves generated by the bump-in-tail instability, and that these waves may be prohibited from participating in the necessary three-wave interactions due to frequency conservation requirements. In resolving this apparent contradiction through a comprehensive analysis, in this paper we present the first self-consistent demonstration of fundamental and harmonic plasma emission from a single-beam system via fully kinetic numerical simulation. We caution against simulating astrophysical radio bursts using unrealistically dense beams (a common approach which reduces run time), as the resulting non-Langmuir characteristics of the initial wave modes significantly suppresses emission. Comparison of our results also indicates that, contrary to the suggestions of previous authors, an alternative plasma emission mechanism based on two counter-propagating beams is unnecessary in an astrophysical context. Finally, we also consider the action of the Weibel instability which generates an electromagnetic beam mode. As this provides a stronger contribution to electromagnetic energy than the emission, we stress that evidence of plasma emission in simulations must disentangle the two contributions and not simply interpret changes in total electromagnetic energy as evidence of plasma emission.
J.O. Thurgood, D. Tsiklauri, "Self-consistent particle-in-cell simulations of fundamental and harmonic radio plasma emission mechanisms", Astron. Astrophys. 584, A83 (2015)

*Speaker

Fine Spectral Structures of Solar Radio Type-I Bursts observed by AMATERAS

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Abstract

Fine spectral structures of solar radio bursts contain information of radio wave generations and propagations. We investigated the fine spectral structures of solar radio type-I bursts using the radio telescope AMATERAS. AMATERAS is a ground-based solar radio telescope for spectropolarimetry in the metric range. The observation band of this telescope is 150–500 MHz with a 10 ms accumulation time and a 61 kHz bandwidth. The spectral characteristics, such as the peak flux, duration, and bandwidth, of the individual burst elements were satisfactorily detected by the highly resolved spectral data of AMATERAS. The peak flux of the type-I bursts followed a power-law distribution with a spectral index of 2.9-3.3, whereas their duration and bandwidth were distributed more exponentially. There were almost no correlations between the peak flux, duration, and bandwidth. That means there was no similarity in the shapes of the burst spectral structures. We defined the growth rate of a burst as the ratio between its peak flux and duration. There was a strong correlation between the growth rate and peak flux. These results suggest that the free energy of type-I bursts that is originally generated by nonthermal electrons is modulated in the subsequent stages of the generation of nonthermal electrons, such as plasma wave generation, radio wave emissions, and propagation. The variation of the timescale of the growth rate is significantly larger than that of the coronal environments. These results can be explained by the situation wherein the source region may have the inhomogeneity of an ambient plasma environment, such as the boundary of open and closed field lines, and the superposition of entire emitted bursts was observed by the spectrometer.

*Speaker

Imaging spectroscopy of fine structures with LOFAR: implication for radio wave propgation

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Abstract

The solar radio bursts observed at frequencies below 300 MHz sometimes demonstrate fine structures, so that the dynamic spectrum of the burst looks like a collection of multiple stria, so called type IIIb bursts. Recent observations with LOFAR allow us to determine the location of individual stria and determine how they evolve in space at the time scales less than 0.5 sec. In this work, we present the first imaging observations of stria evolution for a well observed type IIIb-type III event and show how the spatial characteristics of the burst emitted at fundamental and harmonic are related to the spectral features in the range 30-80 MHz. The implication for poorly understood escape and propagation of radio waves will be presented.

*Speaker

Coronal waves, shocks, and associated radio signatures

Alexander Warmuth*[1]

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Abstract

For over half a century there has been indirect evidence for large-scale waves and shocks propagating through the solar corona. High-cadence space-based observations, available for nearly decade now, have indeed revealed globally propagating wave-like perturbations in the solar corona. These observations have revealed a wealth of information about these phenomena, but have also sparked major controversies about their physical nature and their cause. I will review how the different observational characteristics have both constrained existing models and have led to the development of new models. In the discussion, I will emphasize two issues: the currently growing consensus on the physical nature of coronal waves, and the question of how type II radio bursts fit into the picture.

*Speaker

sciencesconf.org:cesra2016:108968

Mult-viewpoint Observations of a Widely Distributed Solar Energetic Particle Event: the Role of EUV Waves and Shock Signatures

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Abstract

On 2012 March 7, two large eruptive events occurred in the same active region within 1 hr from each other. Each consisted of an X-class flare, a coronal mass ejection (CME), an extreme-ultraviolet (EUV) wave, and a shock wave. The eruptions gave rise to a major solar energetic particle (SEP) event observed at widely separated (˜120◦) points in the heliosphere. From multi-viewpoint energetic proton recordings we determine the proton release times at *STEREO B* and *A* (*STB*, *STA*) and the first Lagrange point (L1) of the Sun–Earth system. Using EUV and white-light data, we determine the evolution of the EUV waves in the low corona and reconstruct the global structure and kinematics of the first CME's shock, respectively. We compare the energetic proton release time at each spacecraft with the EUV waves' arrival times at the magnetically connected regions and the timing and location of the CME shock. We find that the first flare/CME is responsible for the SEP event at all three locations. The proton release at *STB* is consistent with arrival of the EUV wave and CME shock at the *STB* footpoint. The proton release time at L1 was significantly delayed compared to *STB*. Three-dimensional modeling of the CME shock shows that the particle release at L1 is consistent with the timing and location of the shock's western flank. This indicates that at L1 the proton release did not occur in low corona but farther away from the Sun. However, the extent of the CME shock fails to explain the SEP event observed at *STA*. A transport process or a significantly distorted interplanetary magnetic field may be responsible.

*Speaker

Radio Diagnostics of electron acceleration sites during the eruption of a flux rope in the solar corona

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Abstract

Electron acceleration in the solar corona is often associated with flares and the eruption of twisted magnetic structures known as flux ropes. However, the locations and mechanisms of electron acceleration during the eruption is still subject to much investigation. Observing the exact sites and mechanisms of electron acceleration can help confirm how the flare and eruption are initiated and evolve. Here we use observations from the Nançay Radioheliograph and the Atmospheric Imaging Assembly to analyse an erupting flux rope on 2014-April-18. Our analysis shows evidence for a pre-formed flux rope which slowly rises and becomes destabilised at the time of a C-class flare, plasma jet and 110 keV electron beam acceleration close to the rope center. As the eruption proceeds, further 5 keV electron acceleration occurs above the flux rope as it interacts with the overlying magnetic environment. Energetic electrons then propagate with the erupting structure and fill the erupting volume, eventually allowing the flux rope legs to be clearly imaged from 150–445 MHz. Following the conclusions of Joshi et al. (2015), our analysis shows that the positions of electron acceleration throughout the event is consistent with a tether-cutting or flux cancellation scenario taking place inside a fan-spine structure.

*Speaker

LOFAR observations of the quiet solar corona

Christian Vocks*†[1], Gottfried Mann[1], Frank Breitling[1], Richard Fallows[2], Mario Bisi[3], Peter Gallagher[4], Alain Kerdraon[5], Jasmina Magdalenic[6], Alec Mackinnon[7], Helmut Rucker[8], Alexander Konovalenko[9], Christophe Marque[6], Eduard Kontar[7], Bartosz Dabrowski[10], Andrzej Krankowski[10], Hamish Reid[7], and Bo Thide[11]

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[11]Uppsala University – Sweden

Abstract

LOFAR is a novel radio interferometer consisting of a central core near Exloo in the Netherlands, remote stations in the Netherlands, and international stations. It observes in two frequency bands, the low band of 10 – 90 MHz, and the high band of 110 – 250 MHz. The Key Science Project "Solar Physics and Space Weather with LOFAR" aims at observing the Sun with LOFAR. Solar radio radiation in the low and high band emanates from the upper and middle corona, respectively. The solar corona is not a simple layer with barometric density profile, but highly structured due to coronal magnetic fields. The density of the coronal plasma can be estimated by several means, e.g. coronograph data or radio occultation measurements of spacecraft signals. But they leave a gap in the high corona, at a solar distance of a few solar radii. This region is of special interest, since it is where the transition from a hydrostatic corona to the supersonic solar wind is located. If the Sun is observed at a given radio frequency, then the corona becomes opaque below the density level where that frequency corresponds to the local plasma frequency. Since the refractive index of the coronal plasma approaches zero there, diffraction effects also need to be considered. We will present LOFAR observations of the quiet Sun at different low-band frequencies. The diameter of the radio Sun increases with decreasing frequency, as expected. But the quiet Sun does not appear as a disk with constant brightness temperature. A derivation of the coronal height, where the observed frequency equals the local plasma frequency, requires fitting ray-tracing simulations, which include wave refraction and free-free emission and absorption, to intensity profiles from the images. We'll present first results for a polar coronal density and temperature profile derived from LOFAR low band images.

*Speaker
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Thursday June 16
Instrumentation
Plenary session

Solar Observations with the Jansky Very Large Array

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Abstract

The Jansky Very Large Array (JVLA) represents a significant upgrade in capabilities for solar observing at centimeter wavelengths. With its new suite of receivers and an advanced correlator, the JVLA can now image solar phenomena radio frequencies over significant bandwidths with high spectral and temporal resolution. The JVLA can currently observe at frequencies from 1-8 GHz; progress is being made to extend the range to 1-18 GHz. Some examples of recent work will be presented, including observations of a solar active regions and of radio bursts associated with solar flares. Looking forward to the era of Solar Probe Plus and the Solar Orbiter missions, the JVLA is also doing a pilot study of solar wind tomography using the multitudes of background radio sources that are now accessible thanks to its great sensitivity.

*Speaker

Early Observations with the Expanded Owens Valley Solar Array

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Abstract

The Expanded Owens Valley Solar Array (EOVSA) is a newly expanded and upgraded, solar-dedicated radio array consisting of 13 antennas of 2.1 m diameter equipped with receivers designed to cover the 1-18 GHz frequency range. Two large (27-m diameter) dishes are being outfitted with He-cooled receivers for use in calibration of the small dishes. During 2015, the array obtained observations from dozens of flares in total power mode on 8 antennas. Since February 2016, it has begun taking solar data on all 13 small antennas with full interferometric correlations, as well as calibration observations with the first of the two large antennas equipped with its He-cooled receiver. The second He-cooled receiver is nearly complete, and will be available around the time of the meeting. We briefly review the commissioning activities leading up to full operations, including polarization and gain measurements and calibration methods, and resulting measures of array performance. We then present some early imaging observations with the array, emphasizing the remarkable temporal and spectral resolution of the instrument, together with joint RHESSI hard X-ray and SDO EUV observations.

*Speaker

ALMA solar observing modes

Ivica Skokic*[1] and Alma Solar Development Team[2]

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[2]ALMA – Chile

Abstract

Atacama Large Millimeter/submillimeter Array (ALMA) is a new powerful interferometer built jointly by Europe, North America, East Asia and Chile. Designed for observations of a wide range of phenomena in a 84-950 GHz frequency range, ALMA is also capable of observing the Sun and opened recently for solar proposals. In this talk recent test and comissioning efforts will be covered and available solar observing modes, their capabilities, limitations and future plans will be described.

*Speaker

Observation and modelling of the solar atmosphere in the mm and sub-mm wavelength ranges

Roman Brajsa*[1]

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Abstract

Various solar features can be identified in emission or absorption on maps of the Sun in the millimeter and submillimeter wavelength ranges. Several examples of such maps, where active regions, filaments and coronal holes can be seen on solar disk, are presented and compared with images obtained at other wavelength ranges. Additionally, the center-to-limb function is analysed on full-disk solar maps. Thermal bremsstrahlung and gyromagnetic (cyclotron) radiation mechanism are important for explaining the observed phenomena, although the latter process would requier an unusually large megnetic field, especially when going to the shorter wavelengths. A numerical procedure for calculating the brightness temperature for a given wavelength and model atmosphere, which integrates the radiative transfer equation for thermal bremsstrahlung, is used for interpretation of observational findings. The models are developed for different structures in the solar atmosphere in a broad wavelength range (0.3 mm - 10 mm), closely related to that of the Atacama Large Millimeter/submillimeter Array (ALMA) and Metśahovi Radio Observatory (MRO). The results are compared with available test measurements (ALMA) and regular solar measurements with MRO. An important conclusion is that thermal bremsstrahlung is the dominant radiation mechanism in the millimeter and submillimeter wavelength ranges which can explain previous observations. In the very near future it will be possible to compare the numerical results with new observations of the ALMA radio telescope.

*Speaker

Observations with MUSER

Yihua Yan*[1]

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Abstract

Radio imaging spectroscopy over wide range wavelength in dm/cm-bands will open new windows on solar flares and coronal mass ejections by tracing the radio emissions from accelerated electrons. The Chinese Spectral Radioheliograph (CSRH) with two arrays in 400MHz-2GHz /2-15GHz ranges with 64/532 frequency channels have been established in Mingantu Observing Station, Inner Mongolia of China, since 2013 and is in test observations now. CSRH is renamed as MUSER (MingantU SpEctral Radioheliograph) after it's accomplishment. In this talk we present the initial observations with MUSER. *CSRH Team includes: Yihua Yan (PI), Zhijun Chen, Wei Wang, Fei Liu, Lihong Geng, Jian Zhang*, Linjie Chen, Sijie Yu, Donghao Liu, Sha Li, Jing Du, Cang Su and Baolin Tan, Huang Jing, Chengming Tan etc., from NAOC (*Peking University, Beijing, China). CSRH was supported by National Major Scientific Research Facility R&D Program ZDYZ2009-3

*Speaker

Solar observations with the Murchison Widefield Array

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Abstract

The Murchison Widefield Array (MWA), the low frequency SKA precursor located in the exquisitely radio quiet Western Australia, has been operational since mid-2013 and includes solar science among its key science objectives. Its large number of elements distributed over a small footprint make it exceptionally well suited for high fidelity imaging over small time and frequency integrations. In addition, its architecture allows distributing its 31 MHz of bandwidth over 80 to 300 MHz in 24 discreet chunks. These features allow MWA to trace the evolution of solar emission in morphology, time and also over a large frequency range with good time and frequency resolution. This talk will show examples of imaging and non-imaging analysis of MWA data to highlight the variety of interesting solar science which can be pursued with them.

*Speaker
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LOFAR Solar Imaging

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Abstract

LOFAR is a novel digital radio interferometer for imaging radio sources in the frequency range from 10 to 90 and 110 to 250 MHz with high time and frequency resolution. The LOFAR Key Science Project (KSP) "Solar Physics and Space Weather with LOFAR" uses it for solar observations. I will discuss aspects of solar imaging with LOFAR and present some results.

*Speaker

First observations with the Siberian Radioheliograph

Sergey Lesovoi[1], Alexander Altyntsev[1], Eugene Ivanov[1], Victor Grechnev[1], Alexey Gubin[1], Larisa Kashapova[1], Alexey Kochanov[1], Alexey Kuznetsov[*†1], Natalia Meshalkina[1], and Dmitry Zhdanov[1]

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Abstract

The Siberian Radioheliograph (SRH) is a new multiwavelength instrument developed as a successor of the Siberian Solar Radio Telescope. The instrument is located in the Badary Valley, 220 km from Irkutsk, Russia. SRH is a T-shaped antenna array designed for imaging observations of the Sun at many frequencies simultaneously. At the first stage, it will contain 96 antennae operating in the frequency range of 4-8 GHz, with the angular resolution up to 13" at 8 GHz and the time resolution of 1 s. In 2016, we have started daily single-frequency observations with the 48-antenna core of the array. This configuration provides the angular resolution of about 40-50" at 8 GHz and the sensitivity of about 100 K; the working frequency is software-controlled. We have obtained the calibrated images of the quiet Sun, active regions and flares, as well as the light curves of flaring microwave sources with high time resolution. In this report, we present the results of the first observations with the SRH and discuss the plans and perspectives of its future development.

[*]Speaker

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Solar radio monitoring at Nançay: status and future perspectives

Karl-Ludwig Klein*[1,2], Abdallah Hamini[3], Christian Fabrice[2], Gabriel Auxepaules[2], Sophie Masson[3], Dominique Benoist[2], Guy Kenfack[2], and Christophe Taffoureau[2]

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Abstract

The Nançay radio observatory has been carrying out dedicated radio observation at the Sun for many years. The three presently available instruments conduct spectrography (1000-140 MHz: ORFEES spectrograph; 80-10 MHz: Decametre Array NDA) and imaging at selected frequencies in the 150-45_˜MHz band (Radioheliograph NRH). This set of instruments observes the Sun during about 7 hours per day centred around noon. An assessment of the present status, recent work and perspectives for the coming years will be given:
1) The NRH is in a phase of major upgrading, comprising the data acquisition system, the replacement of the correlator, which will provide all correlations between the available antennae, and the maintenance of the focal systems. This work has led to an interruption of the observing service since more than a year. It is ongoing. Observational tests of the new systems are to start in May.

2) The ORFEES spectrograph is a new instrument, built with support by the French Air Force. It was put into operation in 2012.

3) The NDA shares observing time between the Sun and Jupiter. Its capacity of spectrography with high sensitivity has been extended to lower frequencies by a new data acquisition system that identifies and reduces terrestrial interference, and allows observations down to 10_˜MHz, depending on the state of the ionosphere. This allows ideally a seamless connection with spectrography from space.
Overview plots and to some extent data can be accessed via the dedicated web site radio-monitoring.obspm.fr, which also shows observations of other radio observatories. A dedicated database for the distribution of all solar data taken in Nançay is under construction. The programmatic workshop of the Astronomy and Astrophysics branch of the French research organisation CNRS concluded in 2014 to the importance of solar monitoring at radio frequencies in Nançay as a ground-based support for the coming Solar Orbiter mission.

*Speaker

Instrumentation Posters

Solar research with ALMA: ARC as your supporting infrastructure

Miroslav Barta*†[1]

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Abstract

Regular observations of the Sun will start with coming Cycle 4. This goal has been accomplished by effort of Solar ALMA Development Team. Its European part has been formed by the Czech node of the European ALMA Regional Center (ARC) hosted by the Astronomical Institute in Ondrejov.
The main role of the ARC nodes is to provide supporting infrastructure for the ALMA users in all stages of their ALMA-oriented projects. Based on the long-term experience of the Czech ARC node with the ALMA solar observing mode development the node provides a unique opportunity for solar physics community in entire Europe as a primary contact support spot.
We will present the results of solar mode development, the SW tools for preparation of solar-oriented proposals, services of the ARC node to the user community, ALMA capabilities for upcoming Cycle_˜4 and expectation for the next Cycle 5.

*Speaker
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High Dynamic Range Observations of Solar Coronal Transients at Low Radio Frequencies With a Spectro-Correlator

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Abstract

A new antenna system with a digital spectro-correlator that provides high temporal, spectral, and amplitude resolutions has been commissioned at the Gauribidanur Observatory near Bangalore in India. Presently, it is used for observations of the solar coronal transients in the scarcely explored frequency range ≈30–15 MHz. The details of the antenna system, the associated receiver setup, and the initial observational results are reported. Some of the observed transients exhibited quasi-periodicity in their time profiles at discrete frequencies. Estimates of the associated magnetic field strength (B) indicate that B ≈ 0.06–1 G at a typical frequency such as 19.5 MHz.

*Speaker

Japanese new solar radio spectrograph: from Hiraiso to Yamagawa

Yuki Kubo*[1], Kazumasa Iwai*[1], Hiromitsu Ishibashi[1], and Shinichi Watari[1]

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Abstract

Solar radio burst is one of the most important events for not only space weather forecasting but also investigating high-energy phenomena in solar corona. The MHz range radio observations are useful to detect the shock wave formation in the solar corona and to estimate shock strength and speed, which is essential parameter in space weather forecasting. On the other hand, the GHz range radio observations are useful for studying high energy phenomena such as particle acceleration in solar flares. While the MHz solar radio bursts, especially type II and III bursts, are radiated via mode conversion of Langmuir waves excited by high energy electrons, the GHz solar radio bursts are synchrotron radiation emitted by high energy electrons at lower corona. These high energy electrons are accelerated at reconnection regions in solar flare and shock waves in solar corona. Therefore, MHz and GHz solar radio waves are closely related each other through the accelerated high energy electrons. So, wide frequency range (MHz to GHz) radio wave observations with high time resolution are required to comprehensively understand high energy phenomena in solar corona. We have been operating solar radio spectrograph called HiRAS for over twenty years in Hiraiso Solar Observatory, National Institute of Information and Communications Technology (NICT), but the system has been decrepit and radio wave environment in Hiraiso is getting worse. So, we have developed wide band (70MHz-9GHz) and high resolution (8msec) solar radio spectrograph in Yamagawa radio observation facility, NICT for space weather forecasting and for obtaining science data. In this presentation, we introduce current status of development of Japanese new solar radio spectrograph in NICT.

*Speaker

Solar observations at the Humain Radio Astronomy Station in Belgium

Christophe Marque*[1], Jasmina Magdalenic[1], and Antonio Martinez Picar[1]

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Abstract

The Royal Observatory of Belgium performs daily solar radio observations for scientific and operational purposes at the Humain Radio Astronomy Station. Dynamic spectra that record non thermal emissions associated with solar eruptive events are produced in the range 45 - 1500 MHz. Two instruments are currently operated: an e-Callisto receiver covers the lower part of the band (45 - 440 MHz), and since the summer of 2015 a new digital receiver, named HSRS and based on a SDR device, monitors the upper part (275 - 1500 MHz). This poster presents these two instruments and gives examples of observations and instructions about accessing and processing the data. We briefly discuss the ongoing instrumental developments.

*Speaker

Numerical simulations of reception properties of Solar Orbiter/RPW electric antennas.

Mykhaylo Panchenko*[1], Georg Fischer[1], and Wolfgang Macher[1]

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Abstract

Solar Orbiter is an ESA mission that is planned to be launched in October 2018. The mission will enter an elliptical orbit around the Sun with a perihelion as low as 0.28 AU. The Radio and Plasma Waves (RPW) experiment is dedicated to measure magnetic and electric fields using a number of sensors and antennas, and it will determine the characteristics of electromagnetic and electrostatic waves in the solar wind up to 16 MHz. The overall performance of radio instruments aboard spacecraft depends crucially on the knowledge of the true antenna properties. We report the results of analysis of the reception properties of RPW E-field antennas. Studies were performed using numerical solutions of the underlying field equations by means of electromagnetic simulation software tools. Additionally, due to the attitude of the spacecraft it is expected uneven antenna solar illumination, which, in turn will result in a thermal bending effect. Using the computer simulations we have defined the influence of the thermal bending of the antennas on resulting effective antenna length vector. Corresponding calculations have been performed for various possible thermal bending which corresponds to different distances to the Sun.

*Speaker

SPADE: Small Phase Array Demonstrator for Solar Radio Astronomy Observations

Antonio Martínez Picar*†[1], Christophe Marque[1], and Jasmina Magdalenic[1]

[1]STCE - Royal Observatory of Belgium (STCE - ROB) – Brussels, Belgium

Abstract

The Royal Observatory of Belgium manages a radio astronomy facility in Humain, 120 km southeast of Brussels. Since 2008 the station is monitoring the Sun's activity in the frequency range of 45 – 1493 MHz. However, the evolving RFI situation in Europe, the prospect that digital signal processing can improve the quality of the collected scientific data, and that an array of simple antennas reduces the inherent risk of mechanical failures motivated us to design and build SPADE: a prototype of a phased array which includes eight low-frequency antennas and that will use Software Defined Radio receivers. SPADE will use digital techniques for RFI management and controlling the beam-forming operation, and produce dynamic spectrum observations of the Sun in the range of 20 – 80 MHz.

*Speaker

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WG1
Particle acceleration and transport

Contributions

Microwave polarisation as a detection tool for magnetic twist in solar flares

Mykola Gordovskyy*[1], Philippa Browning[1], Eduard Kontar[2], Rui Pinto[3], and Nicole Vilmer[4]

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Abstract

Reconnecting twisted coronal loops are a good alternative to the standard model for explaining some types of solar flares. Particularly, they can be a good candidate for interpreting smaller flares observed in isolated coronal loops. Furthermore, twisted flux ropes often form an essential element of the standard model for larger, eruptive flares. Therefore, it is important to be able to identify twisted magnetic fields in the flaring corona.

We explore various observational features obtained using coupled MHD and test-particle models of thermal and non-thermal plasmas in reconnecting twisted coronal loops, developed using the Lare3D and GCA codes, and GX simulator. It is shown, that both thermal (EUV and SXR) and non-thermal (HXR and microwave) emission can be used for observational detection of twisted loops. In particular, I will discuss the microwave emission from twisted loops, and use of the cross-loop circular polarisation gradient of gyrosynchrotron emission (Sharykin & Kuznetsov 2016; Gordovskyy et al. 2016) as a potential detection tool, and its limitations for different field configurations and loop orientations.

*Speaker

Intensity distribution and onset delays of nearly relativistic electron events observed by closely-spaced STEREO spacecraft

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Abstract

We present multi-spacecraft observations of four solar electron events using measurements from the Solar Electron Proton Telescope (SEPT) and the Electron Proton Helium INstrument (EPHIN) onboard the STEREO and SOHO spacecraft, respectively, occurring between 11 October 2013 and 1 August 2014, during the approaching superior conjunction period of the two STEREO spacecraft. At this time the longitudinal separation angle between STEREO-A (STA) and STEREO-B (STB) was less than 72○. The parent particle sources (flares) of the four investigated events were situated close to, in between, or to the west of the STEREO's magnetic footpoints.

The STEREO measurements revealed a strong difference in electron peak intensities (factor 12) showing
non-expected intensity distributions at 1 AU, although the two spacecraft had nominally nearly the same angular magnetic footpoint separation to the flaring active region (AR) or their magnetic footpoints were both situated eastwards from the parent particle source.
Furthermore, the events detected at the two STEREO imply a strongly unexpected onset timing with respect to each other: i.e. the spacecraft, best connected to the flare, detected a later arrival of electrons than the farther separated one.

These facts led us to suggest a concept of a rippled peak intensity distribution at 1 AU formed by narrow peaks (fingers) superposed on a quasi-uniform Gaussian distribution. Additionally, two of four investigated solar energetic particle (SEP) events show a so-called circumsolar distribution and their characteristics make it plausible to suggest a two-component particle injection scenario forming an unusual, non-uniform intensity distribution at 1 AU.

*Speaker

Non-thermal electrons in solar flares: Hot-Corona Cold Chromosphere Model

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Abstract

Extending previous studies of nonthermal electron transport in solar flares, which include the effects of collisional energy diffusion and thermalization of fast electrons, we present an analytic method to infer more accurate estimates of the accelerated electron spectrum in solar flares from observations of the hard X-ray spectrum. Unlike for the standard cold-target model, the spatial characteristics of the flaring region, especially the necessity to consider a finite volume of hot plasma in the source, need to be taken into account in order to correctly obtain the injected electron spectrum from the source-integrated electron flux spectrum (a quantity straightforwardly obtained from hard X-ray observations). We present the new model and show that the effect of electron thermalization can be significant enough to nullify the need to introduce an ad hoc low-energy cutoff to the injected electron spectrum in order to keep the injected power in non-thermal electrons at a reasonable value. Hot-Corona Cold Chromosphere Model provides much needed the upper limit on the power and acceleration rate of electrons in solar flares.

*Speaker

Search and statistical analysis of "cold" solar flares using X-ray and microwave data

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Abstract

There is a subclass of solar flares that show noticeable nonthermal emission followed by only a modest or delayed heating. Such events are referred to as "cold" solar flares here for brevity. Some examples of such flares were described earlier as case studies. Those studies show that the reasons of such a behavior may be quite different from each other in various cold flares and may involve either dense or tenuous plasma in flaring loop(s), suppressed chromospheric evaporation, and interaction between system of flare loops. We undertook a systematic search for cold solar flare candidates using Hard X-ray (HXR) data from Konus-Wind and Soft X-ray (SXR) data from GOES. The formal criterion of an event to be flagged as a cold flare candidate was the absence of reported GOES event at the time of Konus-Wind trigger. This way, we found 41 events-candidates from 05/1998 to 02/2014. For these events we put together all available microwave data from different instruments including OVSA, NoRP, RSTN, and BBMS. We obtained temporal and spectral parameters of HXR, SXR, and microwave emissions of the candidates along with their energetics in HXR and examined different relationships between these characteristics. In the X-ray domain, a comparison has been made between our flare subset and a reference set composed of C and M GOES class flares detected by Konus-Wind in the trigger mode. We present the statistical results and examine which of our cold flare candidates demonstrate suppressed or delayed heating and discuss the likely causes of the apparent lack or delay of the thermal response.

This work was supported in part by RFBR grants 15-02-01089, 15-02-03717, 15-02-03835, 15-02-08028, and 16-02-00749 and NSF grant AGS-1262772 and NASA grant NNX14AC87G to New Jersey Institute of Technology. The authors acknowledge the Marie Curie PIRSES-GA-2011-295272 RadioSun project.

*Speaker
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Joint radio, EUV, and X-ray analysis of the 2013 November 5 cold flare

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Abstract

Solar flares, transient brightenings in the solar atmosphere seen throughout electromagnetic spectrum, demonstrate remarkable variety of the energy partitions between the thermal and nonthermal components. There are flares with a dominating or purely thermal component, i.e., with little or no non-thermal electrons visible. These flares strongly contrast with the flares in which the nonthermal component clearly dominates over the thermal one. Therefore, there is a puzzle as what leads to such extreme phenomena as purely 'thermal' and purely 'non-thermal' flares. It has recently been recognized that some flares with dominating nonthermal component are in fact 'cold flares' (Bastian et al. 2007; Fleishman et al. 2011; Masuda et al. 2013) in which no or so modest thermal plasma response is detected that these events are not even listed as GOES flares. Here we analyze a 05-Nov-2013 cold flare with a combination of radio (NoRH, NoRP, SSRT, BBMS), X-ray (RHESSI), and EUV (SDO) data to understand the relationship between the thermal and nonthermal components in this flare in detail. Before, there were no analysis of cold flares employing both RHESSI and SDO/AIA data, where RHESSI provides information of non-thermal energetic particles, and SDO/AIA characterizes the thermal response at lower temperatures, approximately 0.6 MK – 16 MK. The microwave spectral and imaging data taken from Nobeyama and BBMS/SSRT instruments put significant additional constraints on the magnetic field and number density at the source of the flare. With these data we build a consistent detailed picture of particle acceleration and plasma heating in this cold flare and attempt a 3D modeling of the flaring volume. Based on this analysis, we arrive at important conclusions about the energy release, particle acceleration, and plasma heating in solar flares.

*Speaker

New enhancements of the GX Simulator for studying solar flares and active regions

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Abstract

Study of solar active regions and flaring loops requires analysis of imaging data obtained in multiple wavelength domains with differing spatial resolution, in a framework supplied by advanced 3D physical models. To facilitate such studies, we have developed our simulation package, GX Simulator, which we maintain, continuously enhance, and distribute through the SolarSoft repository, (ftp://sohoftp.nascom.nasa.gov/solarsoft/packages/GX Simulator/). The object-based architecture of the GX Simulator, which runs on Windows, Mac and Unix platforms, offers important capabilities including the abilities to import 3D density and temperature distribution models, or to assign to each individual voxel numerically defined Differential Emission Measure distributions; to apply parametric heating models involving average properties of the magnetic field lines crossing a given voxel volume; to create magnetic flux tubes and populate them with user-defined nonuniform thermal plasma and anisotropic, nonuniform, nonthermal electron distributions; to compute and investigate the spatial and spectral properties of radio, EUV, and X-ray emission calculated from the model, and to compare the model-derived images and spectra with observational data. The application integrates shared-object libraries containing fast free-free, gyrosynchrotron, and gyroresonance emission codes developed in FORTRAN and C++, and soft and hard X-ray and EUV codes developed in IDL. In this presentation we report on the most recent added capabilities, such as non-uniform grid rendering from an arbitrary viewing perspective and enhanced options of importing observational maps (both CEA and SHARP SDO maps are now supported), which will be part of the soon to be released new version of the tool. This work was partially supported by NSF grants AGS-1250374, AGS-1262772, NASA grant NNX14AC87G, the European Commission through the FP7 HESPE network (FP7-2010-SPACE-263086), the Marie Curie International Research Staff Exchange Scheme "Radiosun" (PEOPLE-2011-IRSES-295272), RFBR grants 15-02-01089, 15-02-03717, 15-02-03835, 15-02-08028.

*Speaker

CME-related particle acceleration regions during a simple eruptive event near solar minimum

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Abstract

An intriguing feature of many solar energetic particle (SEP) events is the detection of particles over a very extended range of longitudes in the Heliosphere. This may be due to peculiarities of the magnetic field in the corona, to a broad accelerator, to cross-field transport of the particles, or to a combination of these processes. The eruptive flare of the 26th of April 2008 offered an opportunity to study relevant processes under particularly favorable conditions, since it occurred in a very quiet solar and interplanetary environment. This allowed us to investigate the physical link between a single well-identified Coronal Mass Ejection (CME), electron acceleration as traced by radio emission, and the production of SEPs. We conduct a detailed analysis combining radio observations (Nançay Radioheliograph and Decameter Array, Wind/WAVES spectrograph) with remote-sensing observations of the corona in extreme ultraviolet (EUV) and white light as well as in-situ measurements of energetic particles near 1AU (SoHO and STEREO spacecraft). By combining images taken from multiple vantage points we were able to derive the time-dependent evolution of the 3-D pressure front developing around the erupting CME. Magnetic reconnection in the post-CME current sheet accelerated electrons that remained confined in closed magnetic fields in the corona, while the acceleration of escaping particles can be attributed to the pressure front generated ahead of the expanding CME. The CME accelerated electrons remotely from the parent active region, due to the interaction of its laterally expanding flank, traced by an EUV wave, with the ambient corona. SEPs detected at one STEREO spacecraft and SoHO were accelerated later, when the frontal shock of the CME intercepted the spacecraft-connected interplanetary magnetic field line. The injection regions into the Heliosphere inferred from the radio and SEP observations are separated in longitude by about 140 . The observations for this event show that it is misleading to interpret multi-spacecraft SEP measurements in terms of one acceleration region in the corona. The different acceleration regions are linked to different vantage points in the interplanetary space.

*Speaker

Energetic electrons in the solar atmosphere as diagnosed from their radio and Hard X-ray signatures.

Nicole Vilmer*[1] and Hamish Reid*†

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Abstract

Efficient particle acceleration is observed in association with solar flares. X-ray and radio emissions provide valuable information on the properties of electron acceleration, interaction and propagation in the solar atmosphere. In particular, radio emission from electron beams produced in association with solar flares provides crucial information on the relationship and connections between energetic electrons in the corona and electrons measured in situ. In this talk, we will address the question of the relation between escaping electrons that generate type III emissions in the corona and in the interplanetary medium and electrons confined to the lower atmosphere of the Sun that produce HXRs.

We will present here the results of a study based on ten years of data (2002-2011) starting with a selection of 'coronal' type III bursts above 100 MHz. We use X-ray flare information from RHESSI (flares above 6 keV) to produce a list of more than 300 coronal type III bursts associated with X-ray emissions (see Reid and Vilmer, 2016). For these associated events, we will characterize the relative timings, the X-ray and radio intensities and the associated GOES class. We will also examine the percentage of the 'coronal' type III bursts associated with an interplanetary signature (i.e. an interplanetary type III burst detected below 12 MHz by the Wind/Waves experiment) and whether the association between coronal types III and interplanetary types III depends on the characteristics of the propagating electron beams.

We will further describe how these studies can be continued in the future using the combination of ground-based measurements with Solar Orbiter and Solar Probe + observations.

*Speaker

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WG2
CMEs, shock waves, and their radio diagnostics

Contributions

A special solar type II radio burst observed with LOFAR

Frank Breitling*[1], Richard Fallows[2], Gottfried Mann[3], Christian Vocks[4], Mario Bisi[5], Peter Gallagher[6], Alain Kerdraon[7], Jasmina Magdalenic[8], Alec Mackinnon[9], Helmut Rucker[10], Alexandr Konovalenko[11], Christophe Marque[12], Eduard Kontar[9], Bartosz Dabrowski[13], Andrzej Krankowski[13], Hamish Reid[9], and Bo Thide[14]

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[9]University of Glasgow – United Kingdom
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[11]Institute of Radio Astronomy – Ukraine
[12]Royal Observatory of Belgium – Belgium
[13]University of Warmia and Mazury in Olsztyn – Poland
[14]Uppsala University – Sweden

Abstract

On March 16, 2016, a special type II radio burst was observed in the frequency range 20-80 MHz with LOFAR. The type II burst shows the typical fundamental-harmonic structure. Because of the high sensitivity of LOFAR, the 3rd harmonic was measured. Additionally, a lot of herringbones were observed in both the fundamental and harmonic band. A preliminary evaluation of the burst is presented.

*Speaker

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Triangulation of the continuum-like radio emission in a CME-CME interaction event

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Abstract

We present a study of the radio emission associated with the complex interaction of two coronal mass ejections (CMEs), successively launched from the same active region (NOAA AR 11158), on February 14 and February 15, 2011.
Although this CME-CME interaction event was widely studied (e.g. Temmer et al., 2014, Maricic et al., 2014, Mishra & Srivastava, 2014) none of the analyses determined the origin of the associated continuum-like radio emission observed in the decameter-to-hectometer frequency range. The continuum-like emission patch has a particular morphology and might be considered either as a continuation of the decametric type II radio emission associated with the second CME, either as a continuation of the type III radio bursts associated with a flare from NOAA AR 11158. This ambiguity additionally complicates the question on the possible origin of the continuum-like emission. The association of this type of continuum-like radio emission and the CME-CME interaction was up to now established only by their temporal coincidence (Gopalswamy et al., 2001), which is not applicable in this event due to a complex and long-lasting interaction of the CMEs.
The radio triangulation study (see also Magdalenic et al., 2014) provided us with the 3D source positions of the continuum-like emission and the associated type II burst, which were compared with the positions of the interacting CMEs. First results indicated that the continuum-like radio emission is not the continuation of the type III radio bursts, but it is also not the radio signature of the CME-CME interaction.

*Speaker

Coronal Mass Ejections, Associated Shocks and their Interactions with the Ambient Medium

Monique Pick*[1]

[1]LESIA, Observatoire de Paris – Observatoire de Paris – France

Abstract

M. Pick, G. Stenborg, P. Zucca, P. Démoulin, A. Lecacheux, A. Kerdraon
LESIA, Observatoire de Paris, CNRS, UPMC Univ. Paris 06
This presentation is a contribution to the understanding of the role of the coronal environment in the development of CMEs and of the associated shocks. This study has benefited from multi-wavelength imaging observations and radio spectral data over a large frequency range. We selected events launched far from the local vertical direction and we followed step by step their progression from the low corona into higher altitudes, detected in white light. The availability of images from a combination of EUV imagers in quadrature combined with radio imaging observations allowed us to identify the successive complex interactions (e.g., compression, reconnection) between the CMEs and the ambient medium. For one event, the CME resulted from the interaction of an eruptive jet with the surrounding medium; the progression of this CME was closely associated with the occurrence of two successive type II bursts from distinct origins. Two other events originating from their source in the north hemisphere, underwent a large deflection in the low corona and finally emerged in the southern hemisphere following with a radial direction. We shall briefly discuss the potential implication of this results for space weather purposes.

*Speaker

First observation of a solar type II radio burst below 50 MHz with the tied array beam mode of LOFAR

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Abstract

Type II radio bursts are evidence of shocks in the solar atmosphere emitting radio waves ranging from metric to kilometric lengths. These shocks may be associated with coronal mass ejections (CMEs) reaching super-Alfvenic speeds. Radio imaging of the decameter wavelengths is now possible with the Low Frequency Array (LOFAR), opening a new radio window to study coronal radio shocks leaving the inner solar corona and entering the interplanetary medium and understand their association with CMEs.

Here, we study a coronal shock associated with a CME and type II radio burst to determine the locations that shocks are excited in relation to the propagating CME and the ambient medium Alfven speed. The type II shock imaging and spectra were obtained using 91 simultaneous tied-array beams of LOFAR while the CME was observed by the Large Angle and Spectrometric Coronagraph (LASCO) on board the Solar and Heliospheric Observatory (SOHO).

The radio emission associated with the type II shock was found to be located at the flank of the CME in a region where the Alfven speed reaches a local minimum. Using the tied array beam observing mode of LOFAR we were able to locate the type II radio shock position between 45 and 65 MHz and relate it to the expanding flank of a CME and a second CME leaving the inner corona.

*Speaker

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WG3
Fine structures
and radio wave propagation

Contributions

Structure and polarization of large spots with RATAN-600 and the NoRH

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Abstract

In spite of their moderate spatial resolution, synoptic instruments such as the RATAN-600 radio telescope and the Nobeyama Radioheliograph can resolve large sunspots. In this report we present some typical cases and we discuss the physical information that can be derived from the structure, in terms of the orientation of the magnetic field and the variation of physical conditions across the spot. We also present results on the structure of the large-scale magnetic field of active regions form the analysis of multi-wavelength observations of circular polarization inversion. Finally we will provide information about the height of formation of sunspot-associated emission from observations of rising and setting sunspots.

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Interpretation of Tadpole Structures in the Solar Radio Radiation

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Abstract

The new spectrometer on the Ukrainian radio telescope UTR-2 allows to observe the solar radio radiation at low frequencies (10-30 MHz) with a high spectral and temporal resolution. Tadpole structures were observed as special fine structures in the solar radio radiation. They show a fast drift (-2.13 MHz/s) in the dynamic radio spectrum. They appear as an ensemble of tadpoles drifting slowly (-8.3 kHz/s) from high to low frequencies. The tadpoles are interpreted as shock accelerated electron beams in the high corona. These electron beams are considered to be generated by shock drift acceleration. The comparison of the theoretical calculations and the observations leads to the conclusion that the shock associated with the tadpoles must be quasi-perpendicular.

*Speaker

On a solar type III radio burst observed with LOFAR

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Abstract

A long lasting solar type III radio burst was observed in the frequency range 55-20 MHz in the spectrometer mode with LOFAR on March 16, 2016. The evaluation of the dynamic spectrum reveals that the type III burst is not generated by a monoenergetic electrons beam, but by an ensemble of electrons.

*Speaker

The Propagation of Jet Related Type III Radio Bursts in the Solar Corona

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Abstract

The Sun is an active star that produces large-scale energetic events such as solar flares and coronal mass ejections and numerous smaller scale events such as solar jets. The reconfiguration of the solar magnetic field in the corona is believed to be the cause of most solar energetic events. Here, we did a comprehensive study on a solar jet using data from the Solar Dynamics Observatory (SDO) and radio data from the Low Frequency Array (LOFAR) and the Nançay Radioheliograph (NRH). We observed a jet that occurred in the northern hemisphere which had a high velocity (514 km s-1) and it was associated with a radio source in the form of a Type III radio burst observed over a broad frequency range of 35–298 MHz by both LOFAR and NRH. There is evidence that the Type III radio burst travelled along a large closed magnetic field loop as opposed to open magnetic field lines. Newly emerged magnetic flux is also observed in the vicinity of the Type III and the jet. The first multi-frequency image of a solar Type III burst imaged with both LOFAR tied-array imaging at low frequencies and NRH at higher frequencies is presented here, showing the importance of radio imaging in the analysis of solar eruptive events.

*Speaker

Automatic Detection and Measurement of Spectral Fine Structures Using Higher Order Statistical Estimators

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Abstract

Efficient automatic detection of spectral fine structures and accurate estimation of their characteristics is a key ingredient of any systematic study involving spectrally rich solar events. Many algorithms employed for the purpose of automatic detection of such transient features often rely on arbitrarily defined thresholds relative to an averaged background level. As an alternative to using such rather empirical methods, we demonstrate the feasibility of employing higher order statistical estimators such as the Sample to Model Ratio [Nita et al. 2014, ApJ, 789 (2), 152] and the Generalized Spectral Kurtosis [Nita and Gary 2010, MNRAS, 406(1), L60-L64], for which detection thresholds having user-defined probabilities of false alarm can be analytically defined. The ability of these statistical tools to provide accurate estimates of the spectral and temporal characteristics of the detected transients is illustrated using data obtained during the prototyping phase of Expanded Owens Valley Solar Array.

This work was partially supported by NSF grant AST-1312802 and NASA grant NNX14AK66G.

*Speaker

Solar flare accelerated electrons from high and low radio frequencies

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Abstract

Electrons accelerated during solar flares are known to produce microwaves at GHz frequencies through the gyrosynchrotron mechanism and type III radio bursts at MHz and kHz frequencies through plasma emission. Despite of their common origin, these frequency ranges are rarely analysed together. We examine the solar flare on the 29th June 2012 in radio frequencies over six orders of magnitude from 16 GHz to 20 kHz to understand better the spatial, temporal and spectral properties of the flare electron acceleration. Of particular interest in the flare is the fine structure observed in the gyrosynchrotron emission. We find this correlates with the type III emission above 100 MHz on scales of a few seconds indicating to a common accelerator. We found that peaks of the type III emission time profiles are delayed with respect to the peaks seen in the gyrosynchrotron. Using this delay and the radio image centroids we infer the location of an acceleration region in the low corona, close to the gyrosynchrotron emission.

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WG4
Space weather

Contributions

Synoptic observations at centimetric wavelengths are needed for a better description of solar forcing on the upper atmosphere

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Abstract

While the F10.7 index (flux at 10.7 cm) is probably the most widely used proxy for solar activity, radio emissions at other centimetric wavelengths are also good tracers. In particular, the radio flux at 30 cm has an important contribution from thermal emissions, making it more sensitive to solar features such as plages an faculae. In contrast, the F10.7 index has a strong contribution from gyroemissions, and is a better proxy for the energetic part of the UV spectrum.
By replacing the F10.7 index by the 30 cm flux, we recently found that the performance of the DTM2013 model for satellite drag improves. By using blind source separation, we showed how the solar rotational variability in these centimetric wavelengths is made out of three contributions, one of which is thermal.

These properties of the 30 cm flux have motivated us to set up a prototype service that collects daily values at several wavelengths from the Nobeyama radio observatory, pre-processes them, and finally delivers them in near real-time (with a forecast) for upper atmospheric modelling.
Here we discuss the differences between the F10.7 index and other centimetric wavelengths, and show why it is essential to consider multi-wavelength observations for achieving a better description of solar forcing on the upper atmosphere.

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The impact of the November 4th 2015 event on air traffic radars

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Abstract

On November 4th 2015, NOAA AR 12443 produced a relatively modest M3.7 flare associated with one of the strongest L-band radio burst since 2011. This event had a severe impact on ATC radars operated in Sweden, triggering the closure of the swedish airspace for a couple of hours. We will present here the ongoing effort to analyse this event and to explain why these radars were so severely affected.

*Speaker

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Microwave emission as a proxy of CME speed in ICME arrival time predictions

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Abstract

The propagation of a coronal mass ejection (CME) to the Earth takes between about 13 hours and several days. Observations of early radiative signatures of CMEs therefore provide a possible means to predict the arrival time of the CME near Earth. The fundamental tool to measure CME speeds in the corona is coronography, but the Earthdirected speed of a CME cannot be measured by a coronagraph located on the Sun-Earth line. Various proxies have been devised, based on the coronographic measurement. As an alternative, we explore radiative proxies. In the present contribution we investigate if microwave observations can be employed as a proxy for CME propagation speed. Caroubalos (1964) had shown that the higher the fluence of a solar radio burst near 3 GHz, the shorter is the time lapse between the solar event and the sudden commencement of a geomagnetic storm. We reconsider the relationship between CME speed and microwave fluence for limb CMEs in cycle 23 and early cycle 24. Then we use the microwave fluence as a proxy of CME speed of Earth-directed CMEs, together with the empirical interplanetary acceleration model devised by Gopalswamy et al. (2001), to predict the CME arrival time at Earth. These predictions are compared with observed arrival times and with the predictions based on other proxies, including soft X-rays and coronographic measurements.

*Speaker

An automated solar radio burst detection method to extract major bursts (type II, III and IV) from dynamic spectra

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Abstract

The Sun, and particularly its outer atmosphere, the corona, is a source ofelectromagnetic emissions (EUV, X-rays, radio) and of energetic electrically charged particles. The high-energy emissions may lead to major space weather events that affect space borne and possibly airborne technology and radio communications depending on wave propagation in the ionosphere.

This work aims at developing an automatic method for the detection of solar radio bursts in dynamic spectra (Time-Frequency images) in the space environment of the Earth.

This method starts by eliminating unwanted signals (Radio-Frequency Interference RFI, Calibration...). Then, a time-frequency median filter followed by a magnitude-gradient median filter is applied to improve the quality of the dynamical images to be interpreted and to emphasis solar radio bursts. When the previous preprocessing phase is finished, an automated solar radio burst detection system is applied. This system is based on a hierarchical procedure with adaptive constant-false- alarm-rate (CFAR like) aimed to detect separately the spectra of major solar bursts with or without insignificant events.

To evaluate the performance of our method, a semi-automatic software package is developed to create a data set of all possible events (type II, III or IV) that could be recognized. Finally, both our proposed system and the Automated Radio Solar Burst Identification System (ARBIS) proposed by Lozbin are discussed and evaluated.

In this study we use the solar radio spectral data provided by the decametric spectrograph

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of the Nançay radio astronomy station.

This work is developed within the framework of the ORME project (Observations Radioastronomiques pour la Météorologie de l'Espace), funded by the French Agence Nationale pour l a Recherche (ASTRID programme).

Radio imaging of chromospheric magnetic field

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Abstract

Free-free opacity of circularly polarized radio waves depends on magnetic field strength and its direction. By combining this fact and steep temperature gradient, optically thick radio emission coming from the upper chromosphere is polarized. Radio brightness temperature of right-handed-circularly-polarized emission is deviated from that of left-handed-circularly-polarized emission. Using this mechanism, we can measure magnetic field strength at the upper chromosphere. Inversion of polarization degree into magnetic field strength (line-of-sight component) is very simple and it is not influenced by Doppler Effect because of continuum emission. Radio images taken by the Nobeyama Radioheliograph at 17 GHz are used to get magnetic field images at the upper chromosphere. Measurement of very weak polarized signal is required to get chromospheric magnetic field outside strong active regions.

*Speaker

Investigation of sub-ionospheric VLF signal anomalies leading to geomagnetic storm using artificial neural network and statistical approach

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Abstract

A quantitative study of geomagnetic storms on the sub-ionospheric VLF/LF (Very Low Frequency/ Low Frequency) signals recorded during the ascending phase of 24th solar cycle between 2009 and 2014 is being done. Statistical parameters namely, average signal amplitude, variability of the signal amplitude (trend), and nighttime fluctuation were calculated daily during the period of observation for NWC-Varanasi, transmitter–receiver propagation path. These parameters show significant deviation from their mean values during the storm period with an occurrence rate of anomaly between 30 and 40% presumably due to the auroral energetic electron precipitation. Further artificial neural network (ANN) based model training, testing and validation data sets were constructed based on 110 intense and moderate geomagnetic storms following halo CMEs during the ascending phase of 24th solar cycle. Result shows a significant enhancement to occurrence rate of anomaly between 70 and 80% using ANN. The statistical and artificial neural network based investigation of occurrence of ionospheric anomalies during geomagnetic storm and non-storm time periods are basic and important information not only to identify the space weather effects toward the lower ionosphere but also to separate various external physical causes of lower ionospheric disturbances. Perhaps the most intriguing aspect of these investigations is that the occurrence rate of finding the anomalies using ANN is just doubled.

*Speaker

Microwave observations for forecasting energetic particles from the Sun

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Abstract

Predicting when solar energetic particles (SEPs) will hit Earth, and in what concentrations and energies, is important to mitigating space weather hazards ranging from communications outages to high radiation levels on polar aircraft routes. The university of Malaga developed a forecast tool for SEPs called UMASEP. This tool uses time derivatives of the proton profile observed in space and of the soft X-ray flux to predict if a SEP event is to occur, and how it will evolve. In the frame of the HESPERIA project, funded by the Horizon 2020 programme of the European Union, we conduct an extensive study on the use of microwave observations to replace or accompany the soft X-ray first derivative in the SEP forecast. In addition, we are conducting a study to predict the hardness of the energy spectrum of the incoming protons at Earth employing microwave spectral properties, using a method devised by I. Chertok and collaborators. This contribution is to present first results on the two subjects, using a sample microwave observational period of 3 months and a sample of 15 test events: (1) We constructed an uninterrupted time profile over three months using the four RSTN stations of the US Air Force, and fed this profile into the UMASEP scheme instead of the soft X-ray observations. (2) We tested the capability of the microwave spectral characteristics on the incoming proton energy forecast by comparing predicted and observed proton spectra in interplanetary space for 15 events between 2003 and 2006. These tests are preliminary, and are to be extended to a large data set in the coming months.
Acknowledgement: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 637324.

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Posters
(science WGs)

Studying the Characteristics of Shock waves associated with CMEs using solar radio bursts.

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Abstract

Fast CME/shocks propagating in the Corona and the interplanetary medium can generate metric and kilometric Type II radio emissions at the local plasma frequency and/or its harmonic, respectively. So these radio emissions provide a means of remotely tracking CME/shocks. We apply analysis technique, using the frequency drift of metric spectrum obtained by ground station e-Callisto (Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory) in Space Weather Monitoring Center (SWMC) – Helwan University, and estimated by using electron density model the propagation speed of CME/shocks in the corona, and the km-TII spectrum obtained by the WIND/WAVES experiment, to infer, at some adequate intervals, the propagation speed of CME/shocks in the interplanetary medium. We applied this technique on five CME/shocks. We combine these results with previously reported speeds from coronagraph white light and interplanetary scintillation observations, and in-situ measurements, to study the temporal speed evolution of the five events. The speed values obtained by the metric and km-TII analysis are in a reasonable agreement with the speed measurements obtained by other techniques at different heliocentric distance ranges. The combination of all the speed measurements show a gradual deceleration of the CME/shocks as they propagate to 1 AU. This technique can be useful in studying the evolution and characteristics of fast CME/shocks when adequate intervals of km-TII emissions are available.

*Speaker

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Metric Fiber Bursts Observed with the Artemis-IV RadioSpectrograph

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Abstract

We analyzed fifteen metric type-IV events accompanied by intermediate drift bursts, observed by the ARTEMIS-IV radio spectrograph and recorded with the SAO high resolution (100 samples per second) receiver; fourteen events occurred in the 1999-2005 period and one in 2010. Computational tools were developed for the extraction of the fiber emission from the background and other emissions and for the objective measurement of the bulk parameters of fiber burst groups, such as 1-D and 2-D autocorrelation, cross correlation, radial integration of power spectrum and wavelet analysis. We thus measured the drift rate, the instantaneous spectral width, the duration at fixed frequency, the periodicity and the variation of the drift rate and the duration with frequency and time. In addition, particular types of intermediate drift bursts, such as fast drift bursts and ropes, have been studied and compared with the values of typical fibers. Finally, we discuss our results in terms of current theoretical models.

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Interaction of three parallel propagating Alfvén waves

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Abstract

We investigate the non-linear interaction of three parallel propagating Alfvén waves in uniform plasma . Numerical simulations with a particle in cells (PIC) code show a formation of non-propagating parallel electric fields at the region of two Alfvén waves crossing. This process (APAWI) causes a significant modulation of the plasma density giving rise to cavities and electron depletions (Mottez, 2012, 2015). Given that, we propagate a third wave packet through the region where the cavities are created, which is equivalent to the interaction of Alfvén wave with inhomogeneous plasma. The simulations show a formation of electron vortices and strong beams, depending on the polarities of waves and their amplitudes. This process might be relevant in regions of close magnetic field lines where waves can be trapped, like in coronal loops, earth and planetary magnetospheres.

*Speaker

The first results of the 2D solar observations obtained by Irkutsk incoherent scatter radar

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Abstract

The Irkutsk Incoherent Scatter Radar (IISR) is used for a variety of different purposes such as the study of the ionosphere, monitoring of space debris and radioastronomy. The IISR detects emission in the 150 – 162 MHz frequency range. The operation of the directivity pattern (DP) is performed by the frequency scanning technique. We have developed the method of IISR data processing that allows reconstructing radio brightness distributions of the Sun and we present the first results obtained with this method. The question of the possible instrumental origin of the obtained distribution was studied by the comparison of the results with observations from the Nançay Radioheliograph. We show that comparison with quiet Sun observations and radio noise storms display a good agreement from both instruments.

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†Speaker

Interplanetary Type IV Bursts

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Abstract

We study the characteristics of moving type IV radio bursts which extend to the hectometric wavelengths (interplanetary type IV or type IVIP bursts) and their relationship with energetic phenomena on the Sun. Our dataset comprised 48 Interplanetary type IV bursts observed by the Wind/WAVES in the 13.825 MHz-20 KHz frequency range. The dynamic spectra of the RSTN, DAM, ARTEMIS-IV, Culgoora, Hiraiso and IZMIRAN radiospectrographs were used to track the evolution of the events in the low corona; these were supplemented with SXR flux recordings from GOES and CME data from LASCO. Positional information for the coronal bursts were obtained by the Nançay radioheliograph (NRH). We examined the relationship of the type IV events with coronal radio bursts, CMEs and SXR flares. The majority of the events (45) were characterized as compact; their duration was on average 106 min. This type of events were, mostly, associated with M and X class flares (40 out of 45) and fast CMEs; 32 of these events had CMEs faster than 1000 km/s. Furthermore, in 43 compact events the CME was, possibly, subject to reduced aerodynamic drag as it was propagating in the wake of a previous CME. A minority (3) of long lived type IVIP bursts was detected, with durations from 960 min to 115 hours. These events are referred to as extended or long duration events and appeared to replenish their energetic electron content, possibly from electrons escaping from the corresponding coronal type IV bursts. The latter were found to persist on the disk, for tens of hours to days. Prominent among them was the unusual Interplanetary Type IV Burst of 2002 May 18-23 which is the longest event in the Wind/WAVES catalog. The 3 extended events were, usually, accompanied by a number of flares, of GOES class C in their majority, and of CMEs, many of which were slow and narrow.

*Speaker

Observation of the Solar Chromosphere at 2.6 mm

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Abstract

The main emission mechanism of the Sun at millimeter wavelengths is thermal free-free emission from the chromosphere. The opacity of thermal free-free emission depends on the density and temperature profiles in the atmosphere. In addition, the Rayleigh-Jeans law is applicable for these wavelength ranges. Hence, the observation of the radio brightness temperature at millimetric range can be a good diagnostics of the solar chromosphere. In this paper, we report on the single-dish observation of the Sun at 115 GHz (2.6 mm) using the Nobeyama 45 m telescope, whose typical spatial resolution is 15" at 115 GHz. We enabled the solar observation by detuning the SIS mixer to prevent the saturation of the receiver system. We observed a solar sunspot which is usually surrounded by bright plage regions. We removed the plage effect using the deconvolution of the telescope's side lobes. The observed result suggests that the sunspot umbra is darker than the quiet region by a minimum of 100 K at 115 GHz. This result is inconsistent with current sunspot models, which predict a higher brightness temperature of the sunspot umbra at this wavelength. This inconsistency suggests that the temperature of the region at which the 115 GHz radio emission becomes optically thick should be lower than that predicted by the models. ALMA has better beam shapes and more accurate calibration system than those of our observation. Therefore, ALMA will facilitate important progress in not only interferometry, but also single-dish observations of the Sun.

*Speaker

Solar plasma diagnostics: magnetosphere of active regions with RATAN-600 microwave observations

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Abstract

The active regions on the Sun are the complex 3-D formations, including the totality of magnetic phenomena: the configuration of the spots on the photosphere and the magnetic structure extending through the chromosphere into the corona with different substructures of closed and open magnetic fields. The spectral-polarization microwave measurements with RATAN-600 test the physical conditions in the various structures of the active regions magnetosphere measuring their emission spectra, degree of polarization, brightness temperature and size. We present the possibilities to analyse thermal cyclotron radiation of the spots, the bremsstrahlung emission of the plages and coronal loops, and long lasting nonthermal processes of energy release in stable active regions. We demonstrate this by examples of recent observations of several active regions.

*Speaker

Different scaling for the coronal and chromospheric flare fluence

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Abstract

Solar flares radiate energy at all wavelengths, but are best observed at " hot " (coronal) wavelengths where the contrast is larger. Consequently, the flare classification relies on soft X-ray observations made by the GOES 0.1nm-0.8nm passbands. There are however evidence that most of the flare energy is radiated by the colder layers of the Sun, in particular in the chromosphere, and at longer wavelengths. We have investigated if the contribution of " chromospheric emissions " changes with the size of the flares as measured in Soft X-rays. We used high-cadence TSI measurements and chromospheric extreme-ultraviolet (EUV) observations by SDO/EVE and found evidences for a larger contribution of the chromospheric radiation when considering smaller soft X-ray flares. In other words, the ratio of chromospheric to coronal emission appears to increase when going from X-class flares to smaller flares. This result can be interpreted by the different geometry of the coronal and chromospheric emission regions.

*Speaker

Observations of Near-Simultaneous Split-Band Solar Type-II Radio Bursts at Low Frequencies

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Abstract

We report ground-based radio spectral and polarimeter observations of two successive split-band Type-II bursts that occurred on 20 February 2014 at low frequencies (less than 100 MHz) in association with a solar coronal mass ejection (CME). The temporal interval between the onset of the two bursts was very small, $\approx$ one minute. Both of the bursts exhibited fundamental–harmonic structure. The coronal magnetic-field strength [B] in the upstream region of the associated magnetohydrodynamic (MHD) shock, estimated from the split-band observations, is in the range B $\approx$ 1.3–1.1 G over the radial distance [r] interval r $\approx$ 1.49 − 1.58 R for the first Type-II burst, and B $\approx$ 1.3–1.0 G over r $\approx$ 1.49 − 1.64 R for the second Type-II burst. Based on the results obtained, we show that the first and the second Type-II bursts in the present case were likely due to MHD shocks generated by the near-simultaneous interaction of two different regions of the aforementioned CME with a preceding CME and a pre-existing coronal streamer.

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Diagnostics of the acceleration modulation process based on quasi-periodic variations of flare emission

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Abstract

We studied a solar flare with pronounced quasi-periodic pulsations detected in the microwave, X-ray, and radio bands. We used the methods of correlation, Fourier, and wavelet analyses to examine the temporal fine structures and relationships between the time profiles in each wave band. We found that the time profiles of the microwaves, hard X-rays and type III radio bursts vary quasi-periodically with the common period of 40–50_˜s. The average amplitude of the variations is high, above 30% of the background flux level and reaching 80% during the flare maximum. We did not find the periodicity in either the thermal X-ray flux component or source size dynamics. Our findings indicate that the detected periodicity is likely to be associated with periodic dynamics in the injection of non-thermal electrons, {that can be produced by periodic modulation of magnetic reconnection.

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Broadband microwave sub-second pulsations and magnetoacoustic waves in an expanding coronal loop (2011 August 10 flare)

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Abstract

The complex microwave dynamic spectrum and the expanding loop images of the 2011 August 10 GOES C2.4 solar flare are analyzed with a help of SDO/AIA/HMI, RHESSI and STEREO/SECCHI-EUVI imaging data. The complex radio spectrum shows broadband sub-second pulsations of temporal period range 0.1-1.5 s and is lasting about 70 s in frequency range 4-7 GHz. These pulsations have no polarization and no measurable frequency drift. In these pulsations are found signatures of fast sausage magnetoacoustic waves with the characteristic periods of 0.7 and 2.0 s. The location of the radio source at 5.7 GHz shows that this radio event belongs to the expanding coronal loop with twisted sub-structures observed in 131, 94, and 193 A SDO/AIA channels. The EUV intensity of the expanding loop increases just before the radio source triggering. Two EUV bi-directional flows are linked with the start time of the loop expansion close to the radio source and they are propagating with velocities in range of 30-117 km/s. The periodic regime of the electron acceleration in a model of the quasi-periodic magnetic reconnection might be convenient for an explanation of physical properties and behaviour of the sub-second pulsations under study.

*Speaker

Modeling of solar atmosphere parameters above the active region using RATAN-600 radiotelescope observation

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Abstract

This work is devoted to estimation of solar atmosphere parameters (electron density and temperature) above the active region based on the observation of polarized radioemission on RATAN-600 radiotelescope and on the 3-component photosphere magnetic field (SDO/HMI). We choose some number of active regions, including ones with high polarization degree on the high frequencies (which indicates the small contribution of free-free emission). Photosphere magnetic field 180-degrees ambiguity was resolved, then 3D model of the magnetic field was reconstructed in chromosphere and corona (first in potential approach, then in non-linear force-free approach).
To estimate electron density and temperature height profiles we suggest an iterative fitting method, based on the calculation of free-free and cyclotron radioemission in the 2-18 GHz range, convolution of radiomaps with the telescope diagram and comparison with observed scans by several parameters (flux values, shape of the spectra, size of source). Effective code for radioemission calculations was developed.

It was shown that the height of the transition region is 1-1.5 Mm lower, while electron density and temperature are 2 times greater than ones in the basic model of quiet Sun.
On the base of these estimations some future steps are discussed: possibility of the effective diagnostic of the solar atmosphere parameters, influence of inhomogenity on the modeling results, possibility of 2D radiomaps using.

*Speaker

Thermal plasma diagnostics and the origin of sub-THz solar bursts

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Abstract

Solar flares on the 4 and 5 July 2012 observed with GOES, SDO, RHESSI, and the Bauman Moscow State Technical University Radio RT-7.5 are considered. Sub-THz fluxes increases with frequency between 93 and 140 GHz for both events. Diagnostics of low energy (20-100 keV) accelerated electrons using RHESSI X-ray observations and collisional thick target model was carried out. As it follows from AIA/SDO regularization technique for recovering the differential emission measure thermal plasma with the temperature > 0.5 MK can not be responsible for the observed millimeter free-free emission due to the low spectral fluxes. This contradicts calculations of millimeter emission for the isothermal model based on GOES observations. Both different sensitivity of instruments onboard these satellites with respect to the temperature and the multi-thermal nature of flare plasma could explain the obtained discrepancy. Numerical calculations have shown that a positive spectral slope of millimeter emission from the 4 and 5 July 2012 solar flares can be caused by the free-free emission of plasma with the temperature about 0.1 MK and the generation of gyrosynchrotron emission of high energy (> 100 keV) electrons in the solar chromosphere, respectively. The detailed analysis of spatial and temporal evolution of hard X-ray emission has shown that non-thermal pulsations from the 5 July 2012 solar flare are connected with the displacement of the sources during the flare energy release. The probable mechanisms of electron acceleration in solar flares in the light of the planning of solar ALMA observations are discussed.

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