See **https://en.wikipedia.org/wiki/Category:Missions_to_the_Sun**

The Mission to Investigate Interplanetary Structures and Transients (MIIST)

The Need for Near-Earth Multi-Spacecraft Heliospheric Measurements and an Explorer Mission to Investigate Interplanetary Structures and Transients in the Near-Earth Heliosphere. **Review**

Lugaz, N., Lee, C.O., Al-Haddad, N. et al.
Space Sci Rev 220, 73 (**2024**).
https://doi.org/10.1007/s11214-024-01108-8
https://link.springer.com/content/pdf/10.1007/s11214-024-01108-8.pdf

Table 1
Comparison of the Main Meter-wave Solar Radio Observation Instruments[a]

No.	Station/Country/Activation Time	Longitude and Latitude	Antenna	Frequency Range (MHz)	Temporal Resolution (s)	Frequency Resolution	Current State
1	Humain/ Belgium/2016	E5°15′ N50°12′	6 m paraboloid	45–450	~0.084	~4200 channels 98 kHz	Working
2	HSRS/ Belgium/2015	E5°15′ N50°12′	6 m paraboloid	275–1495	0.25	~12,500 channels	Working
3	HiRAS/ Japan/1996	E141° N36°	LPDA, 10 m and 6 m paraboloid	25–70, 70–500 500–2500	3–4	501 channels	2016 closed
4	Yamagawa/ Japan/2016	E130°617 N31°204	...	70–1024, 1024–9000	0.008	31.25 kHz, 1000 kHz	working
5	Learmonth/ Australia/	E114°6′ S22°13′	...	25–180	3	~128 kHz	Working
6	ARTEMIS-IV/ Greece/1996	E22°41′ N38°49′	7 m paraboloid	110–650	0.1	630 channels	Working
7	IZMIRAN/ Russia	E37°19′ N55°28′	...	25–270	0.04	200 kHz	2019 closed
8	Culgoora/ Australia/1992	E150° S30°	Three telescopes	18–1800	3	...	Working
9	Phoenix-3/ Switzerland	E8° N47°	7 m paraboloid	100–5000	0.2	61 kHz	Working
10	YNAO/ China/2012	E102° N24°	11 m paraboloid	70–700	0.08	200 kHz	Working
11	CSRH-I/ China/2016	E115° N42°	40 4.5 m paraboloid	400–2000	0.025	64 channels	Working
12	CSO/ China/2016	E122°30 N36°84	6 m paraboloid	150–500	0.005–0.01	3-320 kHz	2021 closed

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SPEARHEAD

Through a detailed analysis of very high-energy particle observations from the most important heliophysics missions combined with ground based measurements, **SPE**cification, **A**nalysis & **R**e-calibration of High Energy p**A**rticle **D**ata – **SPEARHEAD** will provide answers to three science questions:

SERPENTINE https://serpentine-h2020.eu

Solar energetic particle analysis platform for the inner heliosphere

SERPENTINE will generate five different catalogs of transient phenomena related with SEP events and a series of new level-3 data products for the Solar Orbiter and BepiColombo missions.

The multiview observatory for solar terrestrial science (MOST)

N. **Gopalswamy**1* , S. Christe1 , S. F. Fung1 , Q. Gong1 , J. R. Gruesbeck1 , +++

Journal of Atmospheric and Solar-Terrestrial Physics, Volume 254, article id. 106165. **2024**
https://arxiv.org/pdf/2303.02895
https://ntrs.nasa.gov/api/citations/20220013621/downloads/GopalswamyNat_MOST_WP.pdf

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MeerKAT **(Jonas & MeerKAT Team 2016; Chen et al. 2021) is a new-generation instrument located in the MeerKAT National Park in the Northern Cape of South Africa**
Spectroscopic Imaging of the Sun with MeerKAT: Opening a New Frontier in Solar Physics
Devojyoti **Kansabanik**, Surajit Mondal, Divya Oberoi, James O. Chibueze, N. E. Engelbrecht, R. D. Strauss, Eduard P. Kontar, Gert J. J. Botha, Ruhann Steyn
ApJ **961** 96 **2024**
https://arxiv.org/pdf/2307.01895.pdf
https://iopscience.iop.org/article/10.3847/1538-4357/ad0b7f/pdf

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The Multiview observatory for solar terrestrial science (MOST),
Gopalswamy, N., Christe, S., Fung, S. F., Gong, Q., Jian, L., Kanekal, S. G., et al.
in The decadal survey for solar and space physics (Heliophysics), 2024–2033. Submitted White Paper.
(**2022**).
https://ntrs.nasa.gov/api/citations/20220013621/downloads/GopalswamyNat_MOST_WP.pdf

and

The Faraday Effect Tracker of Coronal and Heliospheric Structures (FETCH) Instrument
Elizabeth **Jensen**, Nat Gopalswamy, Lynn Wilson III, Lan Jian, Shing Fung, +++
Front. Astron. Space Sci., 10:1064069. **2023**
https://www.frontiersin.org/articles/10.3389/fspas.2023.1064069/pdf

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Monitoring fast solar chromospheric activity: the MeteoSpace project
Jean-Marie **Malherbe**, Thierry Corbard, Gaële Barbary, Frédéric Morand, Claude Collin, Daniel Crussaire, Florence Guitton
Experimental Astronomy, **2022**, pp.1-22
https://arxiv.org/pdf/2301.13480.pdf

Polarimeter to UNify the Corona and Heliosphere (PUNCH, DeForest et al., 2022) is a NASA Small Explorer mission to observe the corona and heliosphere from 6-180 Rs using simultaneous observations from four spacecraft in a Sun-synchronous orbit. PUNCH is scheduled to launch in April of **2025**
https://punch.spaceops.swri.org
DeForest, C., Killough, R., Gibson, S., Henry, A., Case, T., et al. 2022, In 2022 IEEE Aerospace Conference (AERO), pp. 1–11.

Solaris: A Focused Solar Polar Discovery-class Mission to achieve the Highest Priority Heliophysics Science Now

Donald M. **Hassler**, Sarah E Gibson, Jeffrey S Newmark, Nicholas A. Featherstone, +++
White Paper **2023**
https://arxiv.org/ftp/arxiv/papers/2301/2301.07647.pdf

The Aditya-L1 mission of ISRO
Durgesh **Tripathi**, D. Chakrabarty, B. Raghvendra Prasad, A. Nandi, A. N. Ramaprakash, Nigar Shaji, K. Sankarasubramanian, R. Satheesh Thampi, V. K. Yadav
The Era of Multi-Messenger Solar Physics Proceedings IAU Symposium No. 372, **2022** G. Cauzzi & A. Tritschler, eds.
https://arxiv.org/pdf/2212.13046.pdf

МНОГОВОЛНОВЫЙ СИБИРСКИЙ РАДИОГЕЛИОГРАФ
Алтынцев А.Т., С.В. Лесовой, М.В. Глоба, А.В. Губин, А.А. Кочанов, В.В. Гречнев и др.
*Солнечно-земная физика. **2020**. Т. 6. № 2, с. 37-50*
http://ru.iszf.irk.ru/images/9/98/%D0%96%D0%A1%D0%97%D0%A4_6_1_2020_37-50.pdf

SCOSTEP's Projects
Variability of the Sun and Its Terrestrial Impact - VarSITI
International Study of Earth-affecting Solar Transients – ISEST

PREdictability of the variable Solar–Terrestrial cOupling – PRESTO 2019-2024
https://www.issibern.ch/wp-content/uploads/2020/03/SCOSTEP_Taikong13.pdf

The coronal solar magnetism observatory (COSMO).

Coronal spectral diagnostics: The coronal solar magnetism observatory (COSMO).
Landi E, Gibson SE, Tomczyk S, Burkepile J, de Toma G, Zhang J, Schad T, Kucera TA, Reeves KK and Cremades H
(**2022**) Front. Astron. Space Sci. 9 :1059716.
doi: 10.3389/fspas.2022.1059716
https://www.frontiersin.org/articles/10.3389/fspas.2022.1059716/pdf

Scientific objectives and capabilities of the Coronal Solar Magnetism Observatory†
Authors
S. **Tomczyk**, E. Landi, J. T. Burkepile, R. Casini, E. E. DeLuca, Y. Fan, S. E. Gibson, H. Lin, S. W. McIntosh, S. C. Solomon, G. de Toma, A. G. de Wijn, J. Zhang
JGR Volume 121, Issue 8 August 2016 Pages 7470–7487 **2016**
https://sci-hub.ru/10.1002/2016JA022871

Physics of the Solar Corona. Advanced Course - The Era of RHESSI, STEREO, Hinode, and SDO – 2014
Aschwanden, M.J. 2014, Springer ... (in preparation) **Book**
Chapter 1: **Solar Missions 2000-2015, File**
http://www.lmsal.com/~aschwand/publications/publ.html

Orbiting Solar Observatory **OSO**-1 to OSO-8 (1962-1975),
Skylab (1973-1974),
the Geostationary Operational Environmental Satellites (**GOES**) series (1974-present),
the Solar Maximum Mission (**SMM**) (1980-1989),
the Compton Gamma-Ray Observatory (**CGRO**) (1991-2000),
the **Yohkoh** mission (1992-2000),
the CORONAS-I mission (1994-2001),
CORONAS-F (2001-2005),
CORONAS-Photon (2009),

the Solar and Heliospheric Observatory (SOHO) (1996-present), and
the TRACE mission (1998-2010).

the Ramaty High Energy Solar Spectroscopic Imager (RHESSI) mission (2002-present),
the Solar Terrestrial Relations Observatory (STEREO) mission (2006-present),
the Hinode mission (2006-present),
the Solar Dynamics Observatory (SDO) mission (2010-present),

A short interruption when the SOHO spacecraft lost its pointing from 25 June to 22 October 1998 with normal operations resuming only in March 1999.

IRIS (Interface Region Imaging Spectrograph) is a NASA Small Explorer Mission to observe how solar material moves, gathers energy, and heats up as it travels through a little-understood region in the sun's lower atmosphere.
https://www.nasa.gov/mission_pages/iris/index.html

Solar Orbiter
http://sci.esa.int/solar-orbiter/
It was selected as the first medium-class mission of ESA's Cosmic Vision 2015-2025 Programme.
Solar Orbiter launch moved to Oct 2018
The Solar Orbiter mission -- Science overview **Review**
D. Müller, O.C. St. Cyr, I. Zouganelis, et al.
A&A **2020**
https://arxiv.org/pdf/2009.00861.pdf

Solar Probe Plus (NASA)
http://solarprobe.jhuapl.edu
The launch window opens for 20 days starting on July 31, 2018.

ESA

Missions in the Cosmic Vision 2015-2025 Programme	
L1 mission	JUICE
L2 mission	ATHENA
M1 mission	Solar Orbiter
M2 mission	Euclid
M3 mission	PLATO
S1 mission	CHEOPS
S2 mission	SMILE

See SolarNews Volume 2016 Number 24 15 December 2016

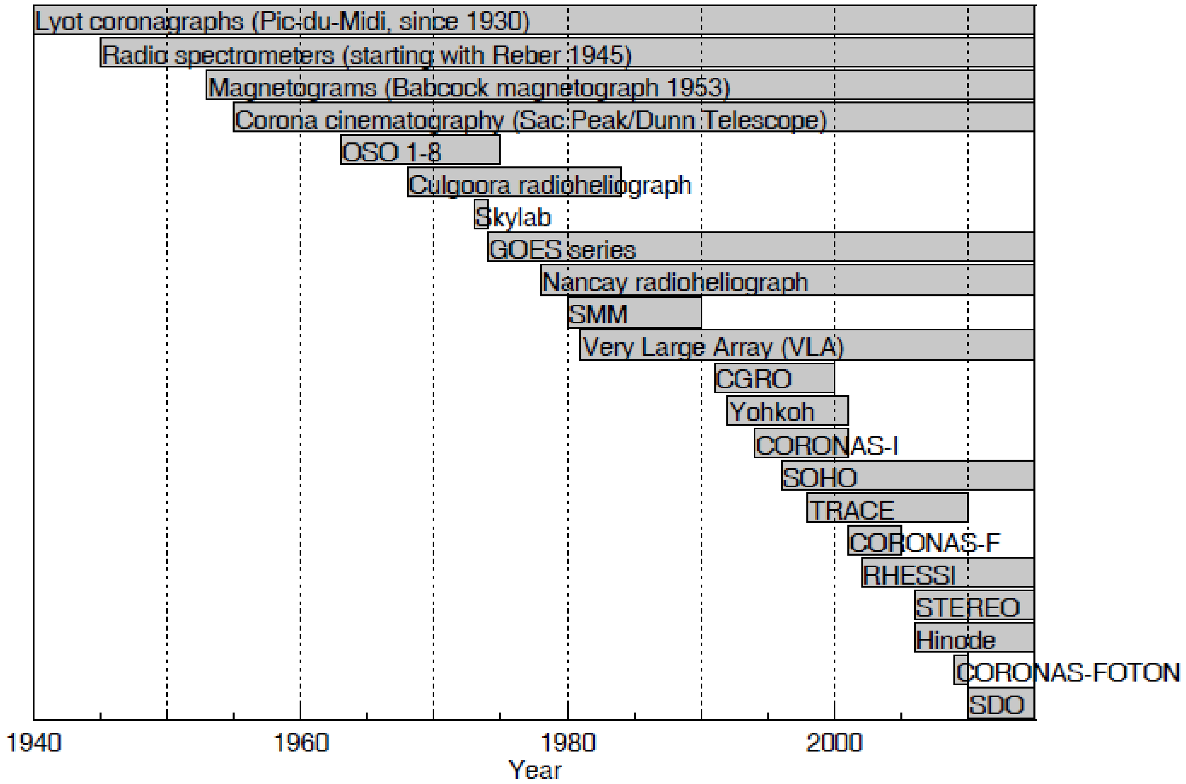
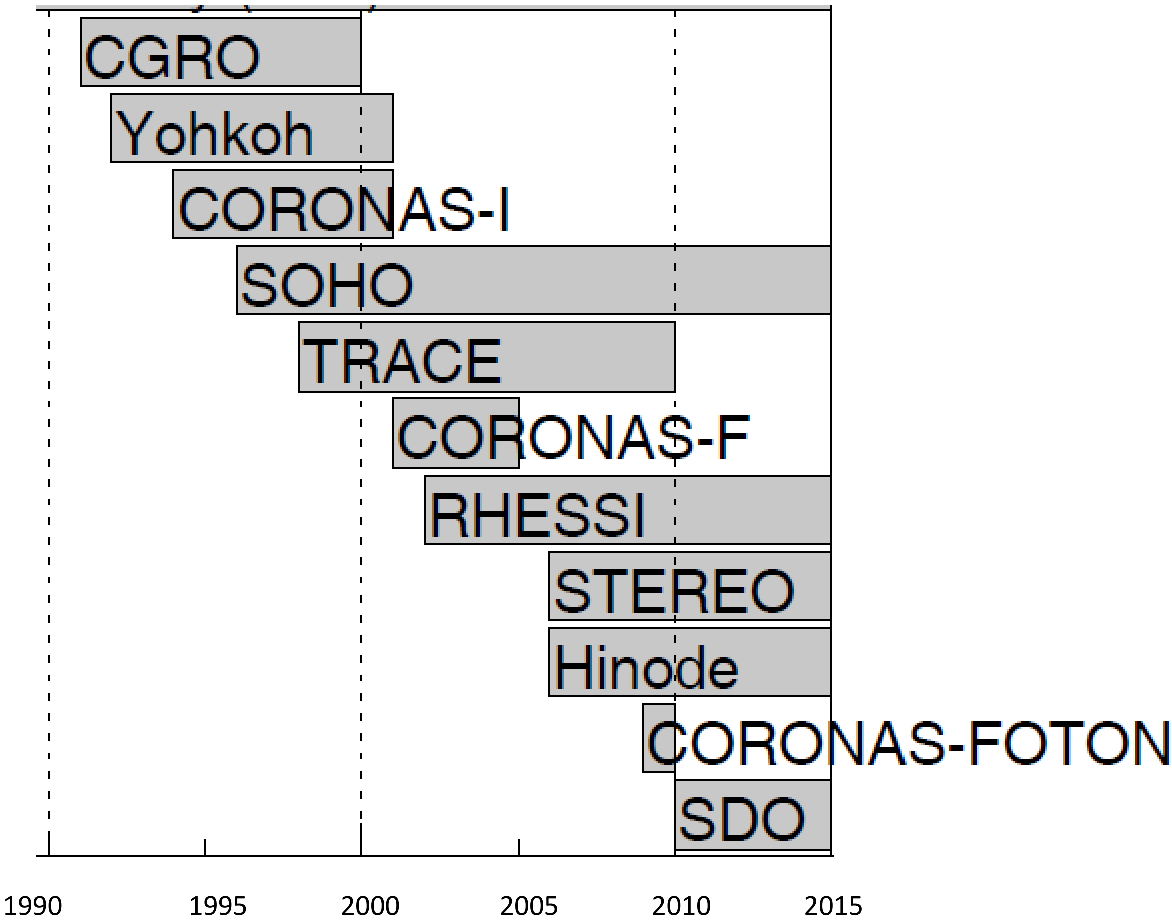


Figure 1.1: The operation periods of major ground-based instruments and solar-dedicated space missions during the era of 1940-2015. Note that a number of solar missions are still fully functional at the time of writing (SOHO, RHESSI, STEREO, Hinode, SDO).



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The COronal Solar Magnetism Observatory (COSMO) HAO
https://www2.hao.ucar.edu/sites/default/files/users/sheryls/_COSMO%20-%20Heliophysics%20White%20Paper_.pdf

DSCOVR: Deep Space Climate Observatory
http://www.nesdis.noaa.gov/DSCOVR/
http://www.ngdc.noaa.gov/dscovr/portal/index.html#/

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The Joint Next Generation Solar Physics Mission's Science Objectives Team (NGSPM-SOT)
Toshifumi Shimizu
SolarNews 11 Aug **2016**
The joint Next Generation Solar Physics Mission's Science Objectives Team (NGSPM-SOT) has been formed based on the agreement among NASA, JAXA and ESA for the study of a possible multilateral solar physics mission concept. The objectives of this NGSPM-SOT are to a) develop the science goals for NGSPM, b) assess how these scientific goals are aligned with JAXA, ESA and NASA agency priorities, c) assess the required measurements necessary to meet the science goals, d) assess the top-level observational (mission design) strategy for the NGSP mission to accomplish the scientific goals, e) identify the minimum performance for the mission systems, and f) deliver a science report that supports the generation of documents suitable for input into any future joint Announcement of Opportunity or Call for Missions. The final report will be delivered to the agencies in summer next year.

The team members consist of 4 NASA appointed members (David McKenzie, Ted Tarbell, John Raymond, Sara Gibson), 4 ESA appointed members (Louis R. Bellot Rubio, Mats Carlsson, Lyndsay Fletcher, Sami Solanki) and 4 JAXA appointed members (Kiyoshi Ichimoto, Kanya Kusano, Hirohisa Hara, Toshifumi Shimizu). Shimizu chairs the team. All the members are points of contacts with the worldwide community; they will engage with the community, and collect ideas to build up the best optimized science goals and mission design options.

The team has started to review the Solar-C science objectives and will develop the revised set of science goals for the next generation solar physics in a couple of months. At the Solar-C science meeting in Nagoya, Japan on September 10 (attached to Hinode-10,hinode.stelab.nagoya-u.ac.jp/Hinode10/), the team will introduce its activity so far to the participants of the meeting. To develop the best science goals, the meeting will be a good opportunity to get feedback from the community.

See SolarNews 1 Oct **2016** **http://solarnews.nso.edu/2016/20161001.html**

The "**Spectrometer Telescope for Imaging X-rays" (STIX) (Krucker et al. 2013)**, is an instrument to be flown onboard the ESA/NASA **Solar Orbiter mission (Muller et al. 2013)** within the ESA Cosmic Vision program.
Krucker, S., Benz, A. O., Hurford, G. J., et al. 2013, Nuclear Instruments and Methods in Physics Research A, 732, 295
Solar Orbiter will be launched in October 2018 and it will start its science program after a 3 year cruise phase.

The **"Micro Solar-Flare Apparatus" (MiSolFA) (Casadei 2014)** is a compact X-ray detector being developed in Switzerland, in collaboration with the French STIX team and with the Italian Space Agency, to be operated in low-Earth polar orbit at the next solar maximum.
Casadei, D. 2014, Proc. 2014 Nucl. Sci. Symp. and Med. Im. Conf., Seattle, USA

The SOLAR-C Mission
the Solar UV-Vis-IR Telescope (SUVIT), the EUV Spectroscopic Telescope (EUVST) and the High Resolution Coronal Imager (HCI) resolution (0.1"–0.3")
http://aspbooks.org/publications/504/299.pdf

Solar Polar Diamond Explorer (SPDEx): Understanding the Origins of Solar Activity Using a New Perspective
A. **Vourlidas**, P. C. Liewer, M. Velli, D. Webb
White paper submitted in response to ideas for the Next Generation Solar Physics Mission Concepts
2018
https://arxiv.org/ftp/arxiv/papers/1805/1805.04172.pdf

L5 missions

Earth-Affecting Solar Causes Observatory (EASCO): A potential International Living with a Star Mission from Sun–Earth L5
http://www.sciencedirect.com/science/article/pii/S1364682611000149

Carrington-L5 mission
https://www.ras.org.uk/news-and-press/2664-carrington-l5-a-uk-mission-to-provide-5-day-space-weather-forecasts
http://www.swpc.noaa.gov/sites/default/files/images/u33/CarringtonL5_SWPC_SWE_Week_Final.pdf

INvestigation of Solar-Terrestrial Activity aNd Transients (**INSTANT**) mission, **L5 point**
http://www.sciencedirect.com/science/article/pii/S1364682616301456

Radio instruments

https://en.wikipedia.org/wiki/**List_of_radio_telescopes**

Chashan Broadband Solar millimeter spectrometer (CBS) working from 35 to 40 GHz.

The first flare observation with a new solar microwave spectrometer working in 35-40 GHz

F. **Yan**, Z. Wu, Z. Shang, B. Wang, L. Zhang, Y. Chen

ApJ **2022**

https://arxiv.org/pdf/2212.12314.pdf

Gauribidanur Radio Interferometer Polarimeter (GRIP; Ramesh & Sastry 2005; Ramesh et al. 2008) at 80 MHz

Solar Physics with the Square Kilometre Array **Review**

A. **Nindos**, E.P. Kontar, D. Oberoi

Advances in Space Research Volume 63, Issue 4, 15 February 2019, Pages 1404-1424

https://arxiv.org/pdf/1810.04951.pdf

Table 1: Instruments capable of performing solar radio spectroscopic imaging

Instrument	Frequency Range (GHz)	Spectral Resolution (MHz)	Time Resolution (msec)	Angular Resolution (″)	Solar dedicated
EOVSA	1-18	50	20	3-57	Yes
GMRT	0.15-1.50	0.05	100	2-20	No
LOFAR	0.03-0.24	0.1	10	60-540	No
LWA	0.02-0.08	0.008	1	2-8[a]	No
MUSER	0.4-15	25	25-200	1.3-50	Yes
NoRH	17, 34	1700	100	6-12	Yes
NRH	0.15-0.45	23-48	250	18-240	Yes
MWA	0.08-0.30	0.04	500	16-60	No
Siberian RH	4-8	10	560	15-30	Yes
VLA	1-50	1	100	1-35	No

[a] Currently only two LWA stations have been deployed; the angular resolution cited here refers to the originally envisaged array.

The **solar-dedicated instruments** include the upgraded **Expanded Owens Valley Solar Array (EOVSA**; see Gary et al., 2012), the **Mingantu Ultrawide Spectral Radioheliograph (MUSER**; see Yan et al., 2016), the **Nan¸cay Radioheliograph (NRH**; see Kerdraon & Delouis, 1997), the **Nobeyama Radioheliograph (NoRH**; see Nakajima et al., 1994), and the upgraded **Siberian Radioheliograph (Siberian RH**; see Lesovoi et al., 2014) while **the general-purpose instruments** include the expanded **Karl G. Jansky Very Large Array (VLA**; see Perley et al., 2011), the **Low Frequency Array (LOFAR**, e.g. van Haarlem et al., 2013), the **Murchison Widefield Array (MWA**, see Tingay et al., 2013; Bowman et al., 2013), the **Long Wavelength Array (LWA**; see Ellingson et al., 2009), and the **Giant Metre-wave Radio Telescope (GMRT**; see Swarup et al., 1991).

New generation or upgraded radio telescopes, either solar-dedicated or non-solar-dedicated, have (will) come into use, including **ALMA, E-OVSA, EVLA, GMRT, LOFAR, MUSER, and MWA**, as well as the Ukrainian radio telescopes **UTR-2, URAN, and GURT**, the radio spectrometers aboard Stereo spacecraft, and the future SKA.

A new high-resolution radio spectropolarimeter instrument operating in the frequency range of **15 – 85 MHz** has recently been commissioned at the Radio Astronomy Field Station of the Indian Institute of Astrophysics at Gauribidanur, 100 km north of Bangalore,

Spectropolarimetric Observations of Solar Noise Storms at Low Frequencies

V. **Mugundhan**, R. Ramesh, C. Kathiravan, G. V. S. Gireesh, Aathira Hegde

Solar Physics March **2018**, 293:41

https://link.springer.com/content/pdf/10.1007%2Fs11207-018-1260-2.pdf

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the solar radio dynamic **spectrograph at the *Chashan Solar Observatory* (CSO)**. 150 – 500 MHz, The resolutions of the obtained radio dynamic spectral data are 10 ms and 160 kHz

Harmonics of Solar Radio Spikes at Metric Wavelengths

S. W. Feng, Y. Chen, C. Y. Li, B. Wang, Z. Wu, X. L. Kong, Q. F. Du…'

Solar Physics March **2018**, 293:39

A Solar Radio Dynamic Spectrograph with Flexible Temporal-spectral Resolution

Qing-Fu **Du**, Lei Chen, Yue-Chang Zhao, Xin Li, Yan Zhou, Jun-Rui Zhang, Fa-Bao Yan, Shi-Wei Feng, Chuan-Yang Li, Yao Chen

Research in Astronomy and Astrophysics **17** 098 **2018**

https://arxiv.org/pdf/1706.07915.pdf

https://iopscience.iop.org/article/10.1088/1674-4527/17/9/98/pdf

The observation and research of the solar radio emission have unique scientific values in solar and space physics and related space weather forecasting applications, since the observed spectral structures may carry important information about energetic electrons and underlying physical mechanisms. In this study, we present the design of a novel dynamic spectrograph that is installed at the Chashan solar radio station operated by Laboratory for Radio Technologies, Institute of Space Sciences at Shandong University. The spectrograph is characterized by the real-time storage of digitized radio intensity data in the time domain and its capability to perform off-line spectral analysis of the radio spectra. The analog signals received via antennas and amplified with a low-noise amplifier are converted into digital data at a speed reaching up to 32 k data points per millisecond. The digital data are then saved into a high-speed electronic disk for further off-line spectral analysis. Using different word length (1 k - 32 k) and time cadence (5 ms - 10 s) for the off-line fast Fourier transform analysis, we can obtain the dynamic spectrum of a radio burst with different (user-defined) temporal (5 ms - 10 s) and spectral (3 kHz ~ 320 kHz) resolution. This brings a great flexibility and convenience to data analysis of solar radio bursts, especially when some specific fine spectral structures are under study. **2016-07-18/19**

Table 1 Parameters of solar radio observing system in the world

Station name/Country /Construction time	Latitude and longi-tude/Observation time	Antennas	Observation frequency band (MHz)	Time resolution (s)	Frequency resolution (channel number) (Hz)
AMATERAS /Japan/2010	E141N38 20-06 UT	2∗16.5∗31 m of the rectan-gular paraboloid : 1023m^2	150-500	0.01	61 kHz (16384 channels)
BIRS[1]/Australia /1997	E147S43 20-06 UT	23 element log-periodic structure	5-65	3	268 kHz
Artemis[2] IV/Greece /1996	E22N38.5 (06-16UT)	7 m paraboloid + LPDA (100-650MHz); Anti-V-shaped dipole antenna (20-100MHz)	20-100, 100-650	0.1, 0.01 (270-450)	1. 630 channels(20-650) 2. 128 channels(270-450)
OOTY[3]-Callisto/ India	E76N11 02-12UT	Linear polarization single group LPDA	45-870	0.25	200 channels
Bleie[4]/ Switzerland	E8N47 (06-16)	7 m paraboloid, LPDA	170 - 870	0.25	200 channels
GBSRBS/ US /2004	W79N38	10-80: LPDA 80-850: 13.7 m 800-3000: 3 m	10-3000	1	
San Vito/ Italy	E18N41 (06-16)	Non-tracking Semi-Bicone, LPDA	25-75, 75-180	3	HP8591ESpectrum ana-lyzer
Yunnan Observatory[5]	102E,24N	11 m parabolic antenna	70-700	0.002	200 kHz
Chashan Solar Radio Observatory	122E,36N	6m parabolic antenna	150-500	0.005-0.01	3 k-320 k (flexible)

1. Bill Erickson and Hilary Cane's BIRS system on Bruny Island suffered a serious hardware failure in 2015 January and may not be reparable, so there is no new BIRS data since then.
2. http://artemis-iv.phys.uoa.gr/Artemis4 list.html
3. http://www.e-callisto.org/
4. http://soleil.i4ds.ch/solarradio/
5. http://secchirh.obspm.fr/instruments.php#ynao

The **Atacama Large Millimeter/submillimeter Array (ALMA)** is an international partnership of the European Southern Observatory (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan, together with NRC (Canada), NSC and ASIAA (Taiwan), and KASI (Republic of Korea), in cooperation with the Republic of Chile. ALMA -the largest astronomical project in existence- is a single telescope of revolutionary design, composed of 66 high precision antennas located on the Chajnantor plateau, 5000 meters altitude in northern Chile.
http://www.almaobservatory.org/

LOFAR (от англ. **LOw Frequency ARray** — «низкочастотная [антенная] решётка») — радиоинтерферометр, разрабатывающийся нидерландским институтом ASTRON (нидерл. ASTRonomisch Onderzoek in Nederland) и планируемый к использованию радиообсерваторией ASTRON. Этот проект предполагает создание интерферометрической решетки из радиотелескопов, распределенной по Европе.
The Low-Frequency Aperture Array (LFAA) covers the lowest frequency band for the SKA, from 50MHz up to 350MHz in the Baseline Design. It is an aperture array consisting of over a quarter of a million wide bandwidth antennas of a single design. The configuration is very close packed with 75% of the antennas within a 2km diameter core and the remaining collecting area situated on three spiral arms, extending out to a radius of 50km and enabling higher spatial resolution observations. http://www.lofar.org/

https://www.skatelescope.org/lfaa/   http://www.lofar-uk.org/about.html

Long Wavelength Array (LWA-1, http://lwa.phys.unm.edu/).
LWA-1 is an array of 256 dipoles collocated with the Very Large Array in the US state of New Mexico, and observes at a frequency range of 10–88 MHz (Taylor, G. B., Ellingson, S. W., Kassim, N. E., et al. 2012, JAI, 1, 1250004).

SKA (Square Kilometre Array — «[антенная] решётка [площадью] в квадратный километр») — международный проект по созданию крупнейшего в мире радиоинтерферометра.
The SKA telescope will be co-located in Africa and in Australia. https://www.ska.ac.za/
https://issuu.com/ska_telescope/docs/contact_12
https://ui.adsabs.harvard.edu/abs/2019AdSpR..63.1404N/abstract

Solar physics with the Square Kilometre Array
Nindos, A. , Kontar, E. P. , Oberoi, D.
Advances in Space Research, Volume 63, Issue 4, p. 1404-1424. **2019**
https://arxiv.org/pdf/1810.04951.pdf
https://sci-hub.ru/10.1016/j.asr.2018.10.023

Table 1
Instruments capable of performing solar radio spectroscopic imaging.

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LWA	0.02–0.08	0.008	1	2–8[a]	No
MUSER	0.4–15	25	25–200	1.3–50	Yes
NoRH	17, 34	1700	100	6–12	Yes
NRH	0.15–0.45	23–48	250	18–240	Yes
MWA	0.08–0.30	0.04	500	16–60	No
Siberian RH	4–8	10	560	15–30	Yes
VLA	1–50	1	100	1–35	No

[a] Currently only two LWA stations have been deployed; the angular resolution cited here refers to the originally envisaged array.

The **Chinese Spectral Radioheliograph—CSRH** at multiple frequencies in the decimetric to centimeter wave range with ~100 antennas of 2–5 m is proposed.
http://link.springer.com/article/10.1007/s11038-008-9254-y

Mingantu Spectral Radioheliograph for Solar and Space Weather Studies
Yihua **Yan**, Zhijun Chen, Wei Wang, Fei Liu, Lihong Geng, Linjie Chen, Chengming Tan, Xingyao Chen, Cang Su, and Baolin Tan
Front. Astron. Space Sci., 8:584043. **2021** |
https://doi.org/10.3389/fspas.2021.584043
https://www.frontiersin.org/articles/10.3389/fspas.2021.584043/full
The Chinese Spectral Radioheliograph (CSRH) covering 400 MHz-15 GHz

Expanded Owens Valley Solar Array (EOVSA) - a solar-dedicated microwave imaging array operating in the frequency range 2.5-18 GHz. The array consists of a total of 15 antennas, including the two 27-m antennas with He-cooled receivers for sensitive calibration, and thirteen 2.1-m antennas that each view the entire disk of the Sun. The system includes a completely new control system, broadband signal transmission, and high-speed digital signal processing, using new technology developed for the Frequency Agile Solar Radiotelescope (FASR).
http://adsabs.harvard.edu/abs/2014AAS...22412360G
However, EOVSA is only a small array with merely 13 antenna elements. Its angular resolution is limited to _60’ ’ /GHz and its snapshot image dynamic range is limited to a few _10:1.

Expanded Very Large Array (EVLA) A Radio Telescope for the 21st Century A set of eight new dish antennas, added to the current 27-antenna system, will allow the VLA to produce images with ten times greater detail.
http://www.nrao.edu/pr/2000/evla/

Frequency Agile Solar Radiotelescope - http://fasr.org/

Frequency Agile Solar Radiotelescope: A Next-Generation Radio Telescope for Solar Physics and Space Weather

Dale E. **Gary**, Bin Chen, James F. Drake, Gregory D. Fleishman, Lindsay Glesener, Pascal Saint-Hilaire, Stephen M. White

White Paper submitted to the Solar and Space Physics 2024 Decadal Survey **2022**

https://arxiv.org/pdf/2210.10827.pdf

broadband imaging spectroscopy across the entire _0.2–20 GHz with a sub-second time resolution (potentially down to milliseconds in a "bursty" mode), and the >2 order of magnitude increase in the number of baselines results in an improvement of the imaging dynamic range by at least two orders of magnitude (from a few_10:1 for EOVSA to several _1,000:1) thanks to its extremely clean PSF (point-spread function or "synthesized beam" in radio astronomy; see white paper by Mondal et al. 2022).

Assembly of Metric-band Aperture Telescope and Real-time Analysis System (AMATERAS)

IPRT/AMATERAS: A New Metric Spectrum Observation System for Solar Radio Bursts

K. **Iwai** · F. Tsuchiya · A. Morioka · H. Misawa

Solar Phys. Volume 277, Number 2, 447-457, **2012, File**

A new radio spectropolarimeter for solar radio observation has been developed at Tohoku University and installed on the *Iitate Planetary Radio Telescope* (IPRT) at the Iitate observatory in Fukushima prefecture, Japan. This system, named AMATERAS (*the Assembly of Metric-band Aperture TElescope and Real-time Analysis System*), enables us to observe solar radio bursts in the frequency range between 150 and 500 MHz. The minimum detectable flux in the observation frequency range is less than 0.7 SFU with an integration time of 10 ms and a bandwidth of 61 kHz. Both left and right polarization components are simultaneously observed in this system. These specifications are accomplished by combining the large aperture of IPRT with a high-speed digital receiver. Observational data are calibrated and archived soon after the daily observation. The database is available online. The high-sensitivity observational data with the high time and frequency resolutions from AMATERAS will be used to analyze spectral fine structures of solar radio bursts.

See http://aoswa.nict.go.jp/workshop_3/program/pdf/S3/S3-5.pdf

CSO spectrograph

A Solar Radio Dynamic Spectrograph with Flexible Temporal-spectral Resolution

Qing-Fu **Du**, Lei Chen, Yue-Chang Zhao, Xin Li, Yan Zhou, Jun-Rui Zhang, Fa-Bao Yan, Shi-Wei Feng, Chuan-Yang Li, Yao Chen

Research in Astronomy and Astrophysics **2017**

https://arxiv.org/pdf/1706.07915.pdf

Table 1 Parameters of solar radio observing system in the world

Station name/Country /Construction time	Latitude and longi-tude/Observation time	Antennas	Observation frequency band (MHz)	Time resolution (s)	Frequency resolution (channel number) (Hz)
AMATERAS /Japan/2010	E141N38 20-06 UT	2∗16.5∗31 m of the rectan-gular paraboloid : $1023m^2$	150-500	0.01	61 kHz (16384 channels)
BIRS[1]/Australia /1997	E147S43 20-06 UT	23 element log-periodic structure	5-65	3	268 kHz
Artemis[2] IV/Greece /1996	E22N38.5 (06-16UT)	7 m paraboloid + LPDA (100-650MHz); Anti-V-shaped dipole antenna (20-100MHz)	20-100, 100-650	0.1, 0.01 (270-450)	1. 630 channels(20-650) 2. 128 channels(270-450)
OOTY[3]-Callisto/ India	E76N11 02-12UT	Linear polarization single group LPDA	45-870	0.25	200 channels
Bleie[4]/ Switzerland	E8N47 (06-16)	7 m paraboloid, LPDA	170 - 870	0.25	200 channels
GBSRBS/ US /2004	W79N38	10-80: LPDA 80-850: 13.7 m 800-3000: 3 m	10-3000	1	
San Vito/ Italy	E18N41 (06-16)	Non-tracking Semi-Bicone, LPDA	25-75, 75-180	3	HP8591ESpectrum ana-lyzer
Yunnan Observatory[5]	102E,24N	11 m parabolic antenna	70-700	0.002	200 kHz
Chashan Solar Radio Observatory	122E,36N	6m parabolic antenna	150-500	0.005-0.01	3 k-320 k (flexible)

1. Bill Erickson and Hilary Cane's BIRS system on Bruny Island suffered a serious hardware failure in 2015 January and may not be reparable, so there is no new BIRS data since then.
2. http://artemis-iv.phys.uoa.gr/Artemis4_list.html
3. http://www.e-callisto.org/
4. http://soleil.i4ds.ch/solarradio/
5. http://secchirh.obspm.fr/instruments.php#ynao

Gauribidanur RAdioheliograPH (GRAPH; Ramesh et al. 1998, 1999a, 2006b) at 80 MHz, and the **Gauribidanur RAdio SpectroPolarimeter** (GRASP; Kishore et al. 2015) in the frequency range 440-40 MHz

Murchison Widefield Array (MWA) - radio interferometer operational in the frequency range from 80 to 300 MHz, in Western Australia, see Lonsdale et al. (2009) and Tingay et al. (2013).

The Murchison Widefield Array: The Square Kilometre Array Precursor at Low Radio Frequencies
Tingay, S. J.; Goeke, R.; Bowman, J. D.; Emrich, D.; Ord, S. M.; …
Publications of the Astronomical Society of Australia, **2013**, Volume 30, id.e007 21 pp.
https://www.cambridge.org/core/services/aop-cambridge-core/content/view/S1323358012000070
https://arxiv.org/pdf/1206.6945.pdf

ARTEMIS IV Multichannel solar radiospectrograph operated by the University of Athens
http://secchirh.obspm.fr/instruments.php

NRH Nancay Radioheliograph (NRH) http://secchirh.obspm.fr/instruments.php

ORFEES radiospectrograph http://secchirh.obspm.fr/instruments.php
The ORFEES radio-spectrograph (Observations Radio pour Fedome et l'Etude des Eruptions Solaires) is the result of a partnership between the Paris Observatory and the Air Force French. It is dedicated to the observation of the solar corona between 144MHz and 1000MHz. The ORFEES radio-spectrograph is located at longitude 2°11'29 East and latitude 47°22'51 North. Based on a new type of digital receiver (Roach 1 map from the University of Berkeley, USA), the first observations were made in the spring of

2012.

ORFEES has a parabolic dish of diameter 5 m and log-periodic dipoles array. The spectral domain is separated into five bands of 170 MHz. Ten spectra are recorded per second (total intensity, horizontal and vertical polarization). The radio telescope is operated automatically and tracks the Sun from ~8:00 till ~16:00 UT every day.

Solar radio spectrometer of Yunnan Observatories
http://secchirh.obspm.fr/instruments.php
The metric solar radio spectrometer is located in Fuxian Solar Observatory (102°.57 E, 24°.34 N) of Yunnan Observatories (YNAO). The spectrometer includes a 11-meter meshed parabolic antenna and a digital FFT spectrometer . The working frequency range is 70-700 MHz (see Gao et al. 2014).

Spectrographs in Humain Observations **from Humain (Belgium)**
http://secchirh.obspm.fr/instruments.php
Three spectrographs are currently installed.

- One is a Callisto spectrograph from the e-Callisto network. It covers the band 45 - 447 MHz. The Callisto spectrograph is connected to a log-periodic antenna mounted as piggy bag on the side of the dish.
- One, named HSRS is a SDR-based instrument used as a spectrograph. It covers the band 275 - 1495 MHz. The HSRS instrument is connected to a log-periodic antenna placed at the focus of the parabolic dish.i
- ARCAS is a digital spectrometer based on a Software Defined Radio receiver configured to scan the band 45 - 450 MHz. It has been set up on October 27 2016, in parallel to the Callisto receiver already in operation. Both instruments share the same receiving antenna via a splitter.

Gauribidanur Low-frequency Solar Spectrograph (GLOSS)
http://secchirh.obspm.fr/instruments.php 40 - 440 MHz
is operated by the Indian Institute of Astrophysics at the Gauribidanur radio observatory, about 100 km north of Bangalore.

DSCOVR: Deep Space Climate Observatory
http://www.nesdis.noaa.gov/DSCOVR/
http://www.ngdc.noaa.gov/dscovr/portal/index.html#/

Real Time Solar Wind
http://www.ngdc.noaa.gov/dscovr/portal/index.html#/

(The NASA Advanced Composition Explorer (ACE) satellite)

Solar Telescopes

The Daniel K. Inouye Solar Telescope (**DKIST**, formerly the Advanced Technology Solar Telescope, **ATST**)
http://dkist.nso.edu/
See http://dkist.nso.edu/ , https://arxiv.org/pdf/1612.02348v1.pdf

European Solar Telescope (EST)
http://www.idom.com/project/european-solar-telescope-est/

The Chinese Giant Solar Telescope (CGST). an 8-meter aperture
http://aspbooks.org/publications/504/293.pdf

GREGOR is a 1.5 meter on-axis solar telescope at the Observatorio del Teide in Tenerife operated in PI mode.
Schmidt, W., von der Lühe, O., Volkmer, R., et al. 2012, Astron. Nachr., 333, 796
Denker, C., von der Lühe, O., Feller, A., et al. 2012, Astron. Nachr., 333, 810

A new multi-wavelength solar telescope: Optical and Near-infrared Solar Eruption Tracer (ONSET)
Fang, Cheng; Chen, Peng-Fei; Li, Zhen; Ding, Ming-De; Dai, Yu; Zhang, Xiao-Yu; Mao, Wei-Jun; Zhang, Jun-Ping; Li, Ting; Liang, Yong-Jun; Lu, Hai-Tian
Research in Astronomy and Astrophysics, Volume 13, Issue 12, article id. 1509-1517 (**2013**).
https://arxiv.org/pdf/1307.4533.pdf

Next Generation Solar Physics Mission–Science Objectives Team (NGSPM-SOT) – Final Report
hinode.nao.ac.jp/SOLAR-C/SOLAR-C/Documents/NGSPM_report_170731.pdf

Appendix C

Existing facilities

Facility Description

CURRENT (not exhaustive, ground-based high resolution facilities restricted to ≥ 1m**)**

Hinode Optical spectropolarimetry, EUV spectroscopy, SXR imaging
IRIS UV spectroscopy and imaging
NuSTAR Astronomical X-ray satellite with solar capability
Proba-2 EUV imager, radiometers
RHESSI Hard X-ray spectroscopy and imaging
SDO UV/EUV imaging, EUV irradiance, helioseismic & magnetic imager
SOHO Coronagraphs, radiometer, heliospheric imager and *in situ* instruments remain
STEREO Two-spacecraft mission, EUV imagers, coronagraphs, heliospheric imagers, particles
GOES X-ray spectral irradiance, particle data, full-disk EUV imaging
NST 1.6m ground-based optical/NIR, imaging and spectropolarimetry
SST 1m ground-based optical telescope, imaging and spectropolarimetry
NVST 1m ground-based solar optical telescope, imaging and spectroscopy
GREGOR 1.5 m ground-based solar optical telescope, imaging and spectropolarimetry
BiSON Network of optical telescopes for low-degree helioseismology
MLSO Ground-based coronagraphs and polarimeter, full-disk imaging
NSO-Synoptic Chromospheric and photospheric magnetograms, helioseismic measurements
ALMA mm-wave array with solar capabilities
LOFAR Low-frequency radio astronomy array with solar capabilities
Nobeyama Radio interferometer, 17 GHz and 34 GHz

IN CONSTRUCTION

Solar Orbiter
Out of the ecliptic, solar encounter mission. EUV imaging & spectroscopy, visible spectropolarimetry, coronagraphs and in-situ instruments. Launch

February 2019
Parker Solar
Probe
Solar encounter mission, *in-situ* instruments, heliospheric imager. Launch
August 2018
Proba-3 Formation flying coronagraph, launch late 2018
DKIST 4m ground-based optical/NIR. First light 2020
EOVSA Frequency-agile 15-element radio interferometer, 1-18 GHz
CHSR Frequency-agile 100-element radio interferometer, 0.4-15 GHz
FUTURE POSSIBILITIES
EST 4m ground-based optical/NIR
FASR Frequency-agile ~200-element radio interferometer, 0.5 MHz - 21 GHz
COSMO LC 1.5m ground-based visible/NIR coronagraph/polarimeter

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Aditya L1 is an Indian solar observation satellite to be placed at the Sun-Earth Lagrangian point L1.
http://space.skyrocket.de/doc_sdat/aditya-1.htm

2018 Heliophysics Missions of Opportunity

https://soma.larc.nasa.gov/2018HelioMO/

14.1. Solar Eruptive Events (SEE) 2020 Mission Concept
https://arxiv.org/pdf/1805.03248.pdf

Focusing Optics X-ray Solar Imager (FOXSI)
http://grips.ssl.berkeley.edu

Gamma-Ray Imager/Polarimeter for Solar flares (GRIPS)
http://grips.ssl.berkeley.edu

Solar Physics from Unconventional Viewpoints **Review**
Sarah E. **Gibson**, Angelos Vourlidas, Donald M. Hassler, Laurel A. Rachmeler, Michael J Thompson, Jeffrey Newmark, Marco Velli, Alan Title, Scott W. McIntosh
frontier **2018**
https://arxiv.org/pdf/1805.09452.pdf **File**
2 EXTRA-SUN-EARTH-LINE OBSERVATIONS TO DATE
3 SCIENCE ENABLED BY EXTRA-SUN-EARTH-LINE OBSERVATIONS
4 SPACE-WEATHER SIGNIFICANCE OF EXTRA-SUN-EARTH-LINE OBSERVATIONS
5 DISCOVERY SPACE
6 FUTURE MISSIONS AND GAP ANALYSIS

The Advanced Space-based Solar Observatory (ASO-S)
https://doi.org/10.1038/s41550-021-01593-9
https://www.nature.com/articles/s41550-021-01593-9
http://www.raa-journal.org/issues/all/2019/v19n11/
http://aso-s.pmo.ac.cn/en_index.jsp

https://www.researchgate.net/profile/Li-Feng-35/publication/300254035_ASO-S_Advanced_Space-based_Solar_Observatory/links/5a711c24a6fdcc33daa9efeb/ASO-S-Advanced-Space-based-Solar-Observatory.pdf
See http://aso-s.pmo.ac.cn/en_index.jsp

Advanced Space-based Solar Observatory (ASO-S): an overview
Wei-Qun **Gan**, Cheng Zhu, Yuan-Yong Deng, Hui Li, Yang Su, Hai-Ying Zhang, Bo Chen, Zhe Zhang, Jian Wu, Lei Deng, ...
Research in Astronomy and Astrophysics (RAA) **2019** Vol. 19 No. 11, 156(8pp)
http://www.raa-journal.org/raa/index.php/raa/article/view/4428/4955

ASO-S successfully launched on 9 October, 2022