

# Space Research at Hvar Observatory

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# History of Hvar Observatory

in 1967 agreement on scientific and technical cooperation between Czechoslovakia and Yugoslavia was signed;  
in 1972 Hvar Observatory was founded



Astronomical Institute of the Czechoslovak Academy of Sciences, Ondřejov:

B. Valníček, V. Bumba, L. Perek, V. Rajský, F. Šorm, K. Havliček

Yugoslav representatives: P. Djurković, F. Dominko, L. Randić, P. Terzić

Faculty of Geodesy, University of Zagreb:

L. Randić, V. Petković and later V. Ruždjak

# Some milestones in the history of Hvar Observatory

- 1812: the fortress Napoljun built
- 1903: Zagreb Observatory founded
- 1969: initial meeting held at Faculty of Geodesy, Zagreb
- 1972: Hvar Observatory founded
- 1977: Hvar Observatory Bulletin founded
- 1982: First Hvar Astrophysical Colloquium (HAC) held
- 1989: IAU Coll. 117 “Dynamics of Quiescent Prominences” held in Hvar
- 1989: 65-cm telescope moved into new dome outside of the fortress
- 1991: contract between ministries of science, Croatia and Austria signed
- 1991 – 1993: observations stopped because of the war; resumed in 1994
- 1992: Croatian Astronomical Society (CAS) founded
- 1997: 1-m ACT official inauguration
- 2006: Hvar Observatory Bulletin (HOB) → Central European Astrophysical Bulletin (CEAB)
- 2012: 40 years of Hvar Observatory, solar and stellar conferences held
- 2017: Hvar Observatory (45 y), HOB (40 y), XV HAC (35 y), CAS (25 y), ACT (20 y)



# Construction of Hvar Observatory





# Hvar 65 cm stellar telescope

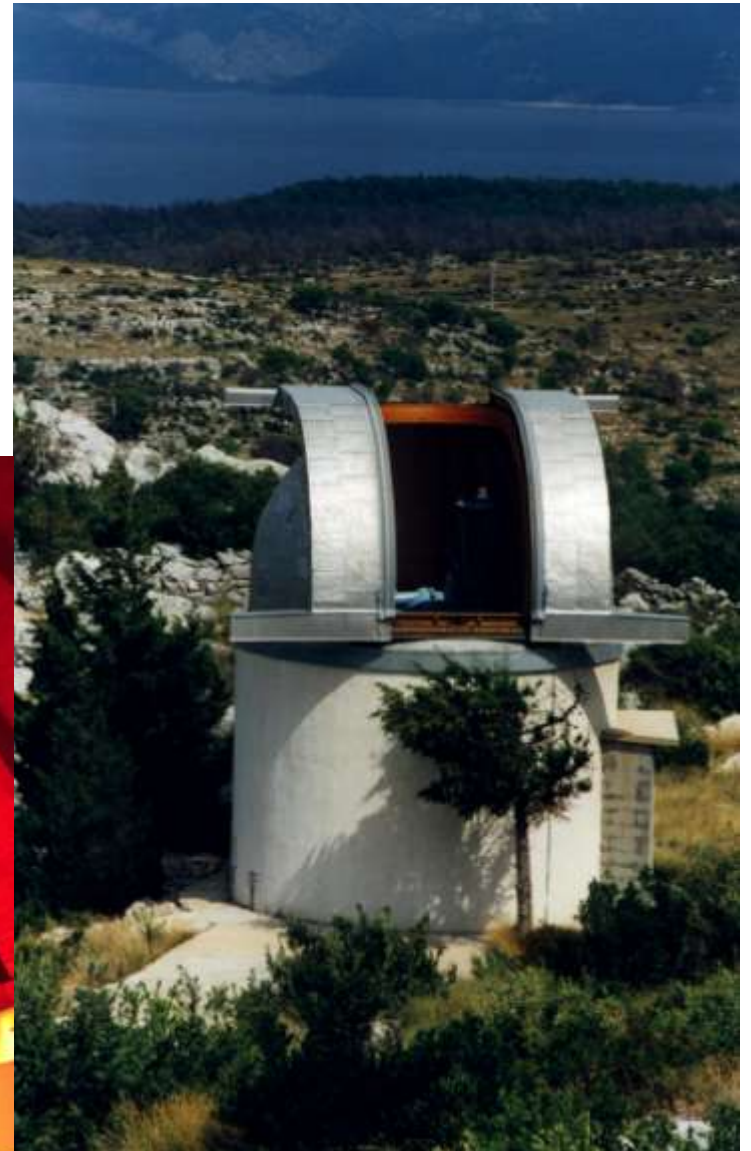
- installed in 1972
- mirror of 650 mm, Cassegrain telescope
- focal ratio  $f/11.2$
- photometry of Be and eclipsing variable stars





# Hvar 65 cm stellar telescope

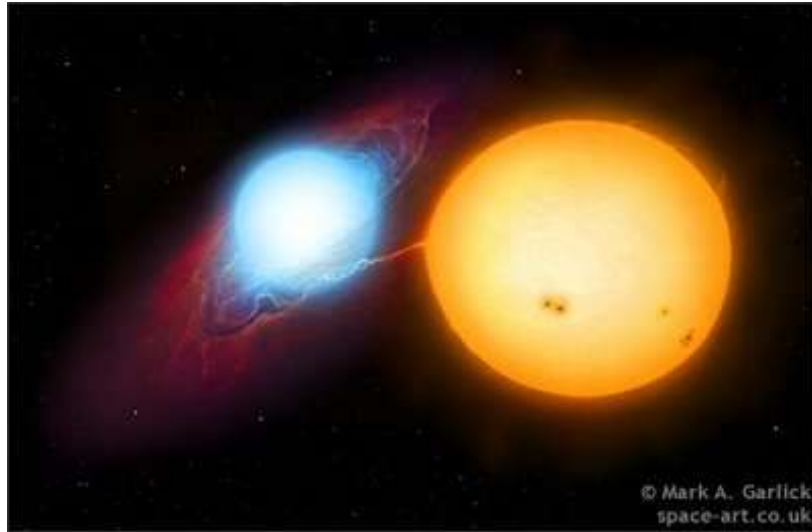
relocated in the new dome in  
1989 because of light pollution  
from Hvar



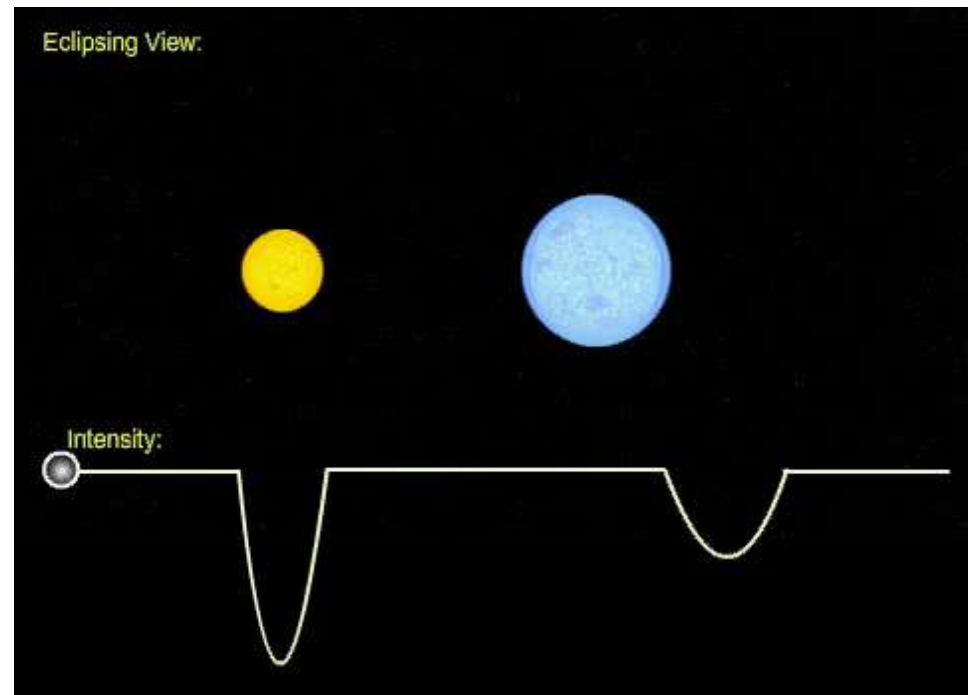


# Eclipsing variable stars

## Algol (Beta Perseus)

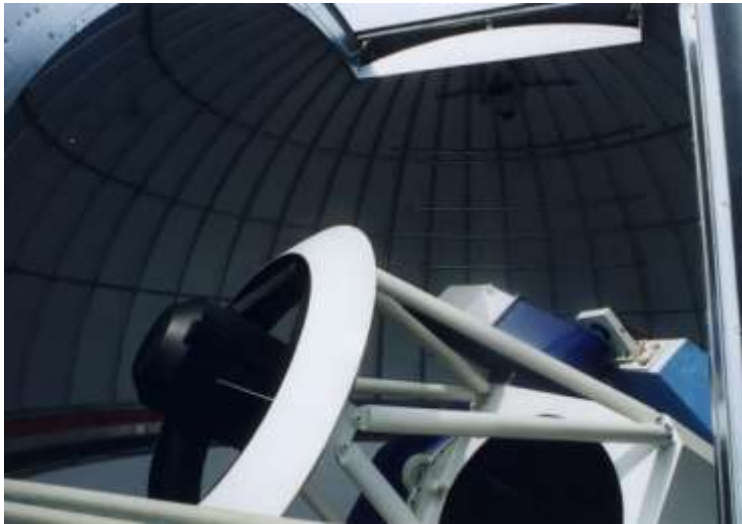


stellar photometry is performed  
in close cooperation with  
colleagues from AICAS, Ondrejov,  
Czech Republic



# 1 m Austrian-Croatian Telescope (ACT)

- installed in 1997
- primary mirror 1060 mm u Ritchey-Chretien telescope
- two secondary mirror 400 mm (f/6.8) and 260 mm (f/15)
- English mounting, computer controlled telescope guiding
- equipped with CCD camera

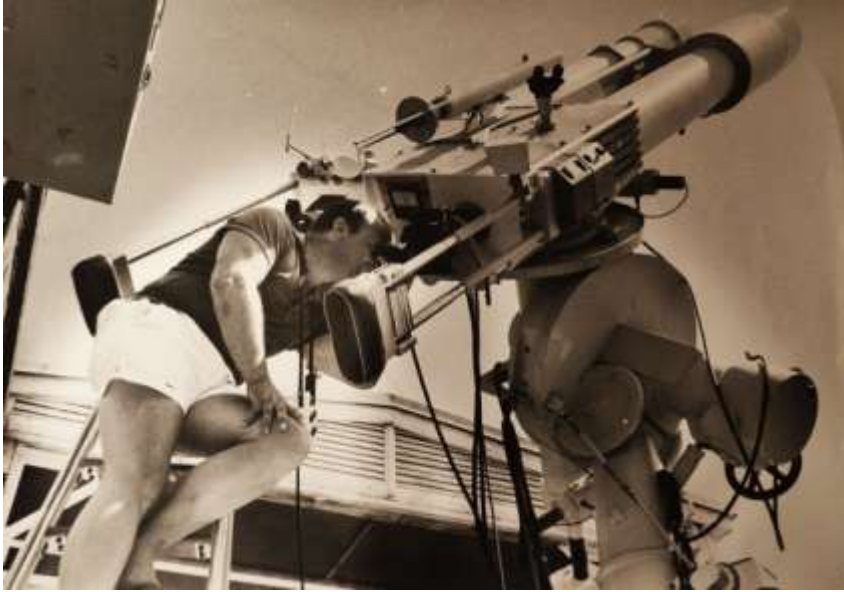








# Double solar telescope at Hvar



- installed in 1972
- in 1997 photography → video system
- in 2004 video system → 1Mpix CCD cameras



# Double solar telescope at Hvar



- modernization: in 2010 4th imaging system was installed: 4MPix Pulnix TM-4200GE 12-bit CCD cameras
- high resolution images of active regions and prominences on the Sun
- close cooperation with University of Graz, Austria and its Kanzelhöhe Solar Observatory

- rich data archive at Faculty of Geodesy in digital form



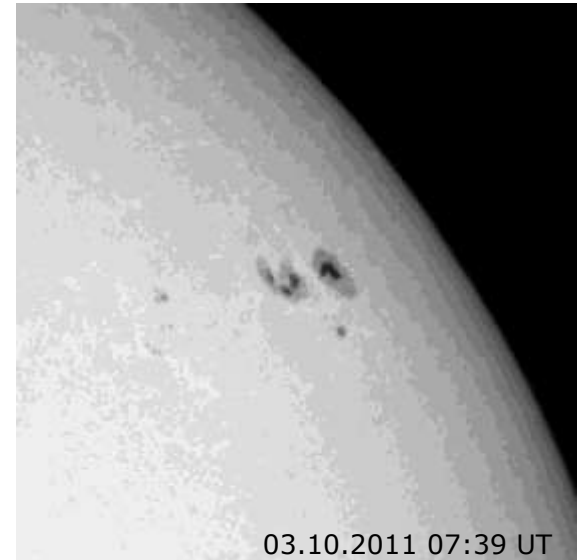
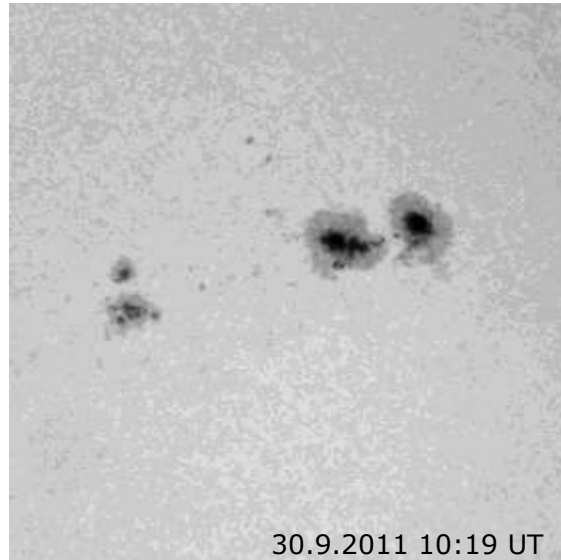
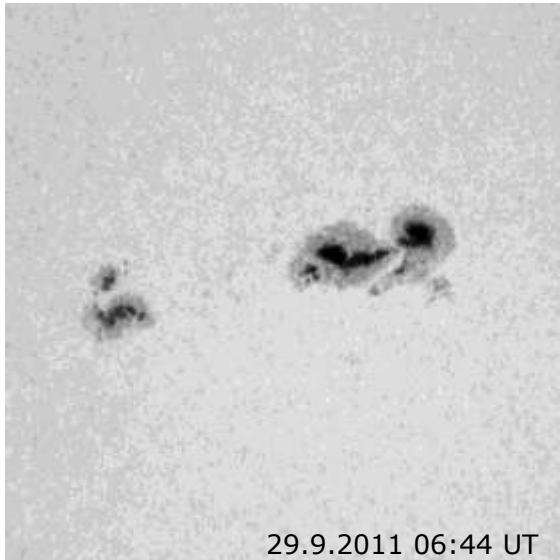
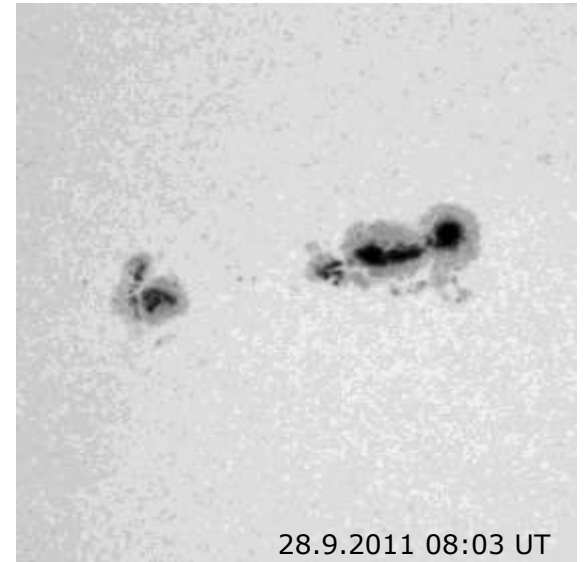
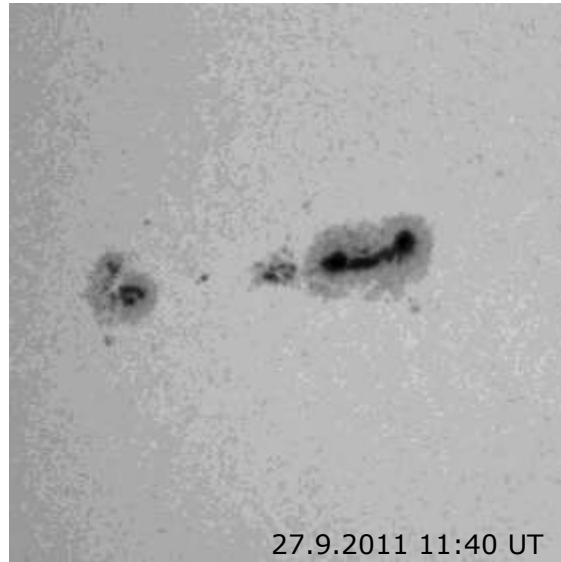
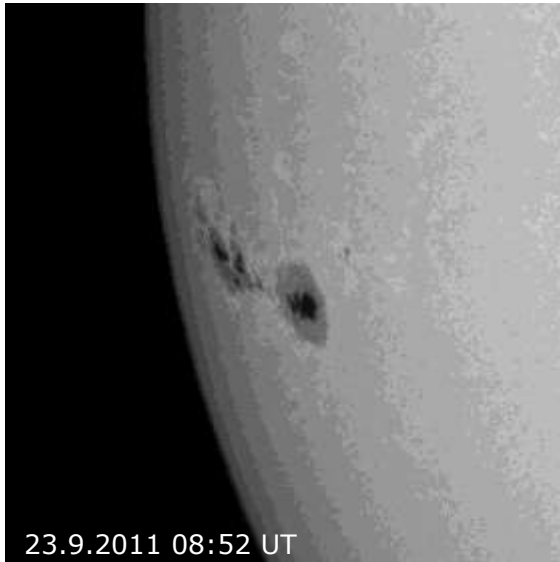
new imaging system from 2010



control room

# Solar photosphere: sunspot group

AR 11302







**HVAR SOLAR TELESCOPE**

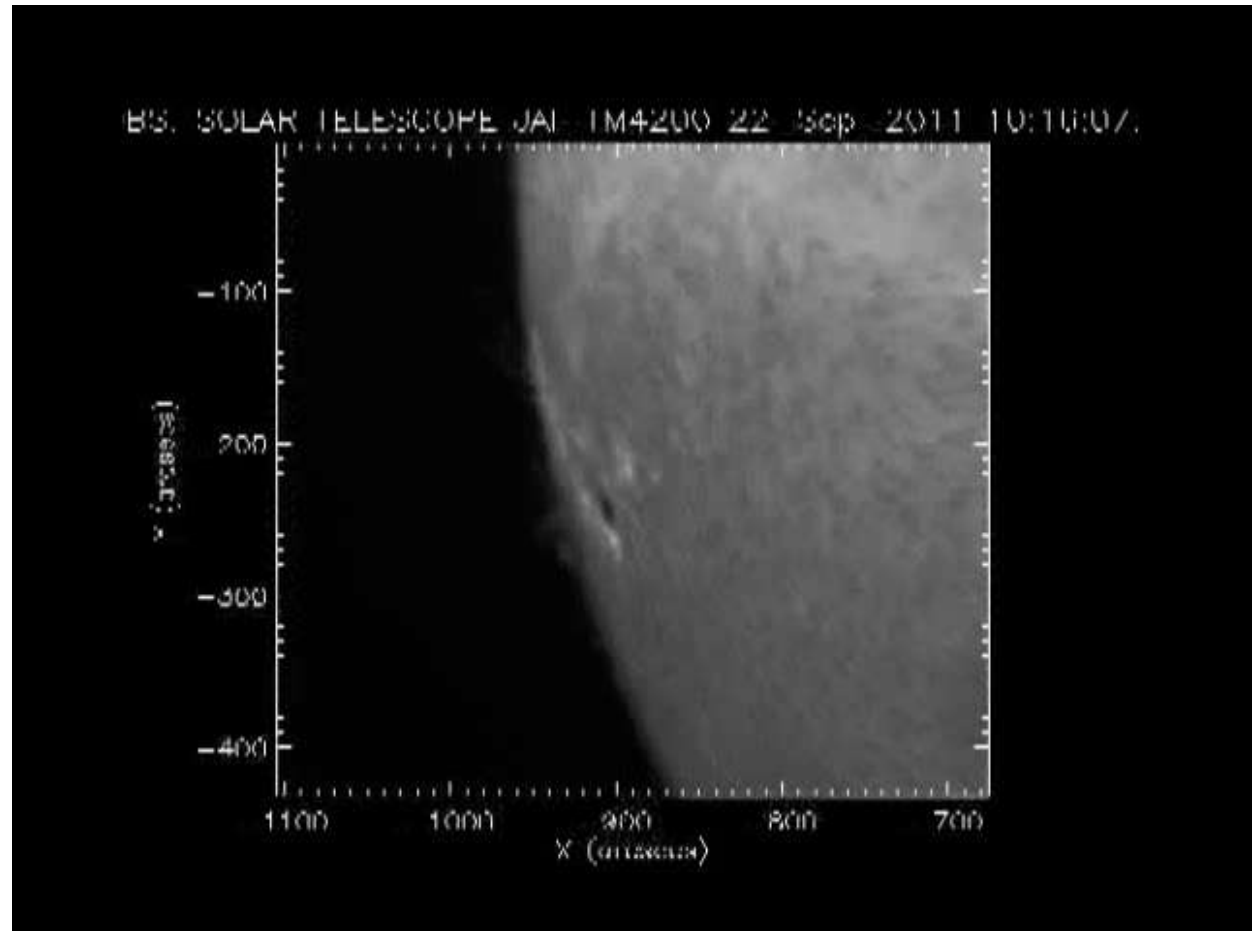
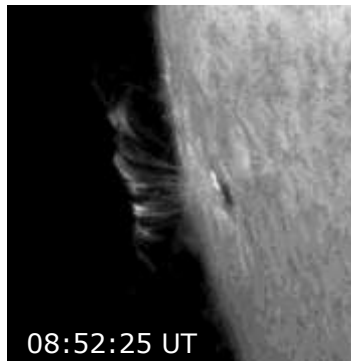
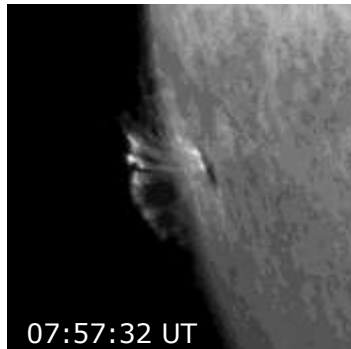
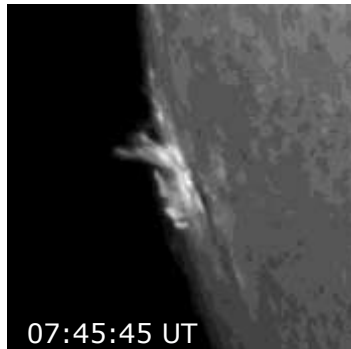
**Photosphere**

**Sunspot group: 11302**

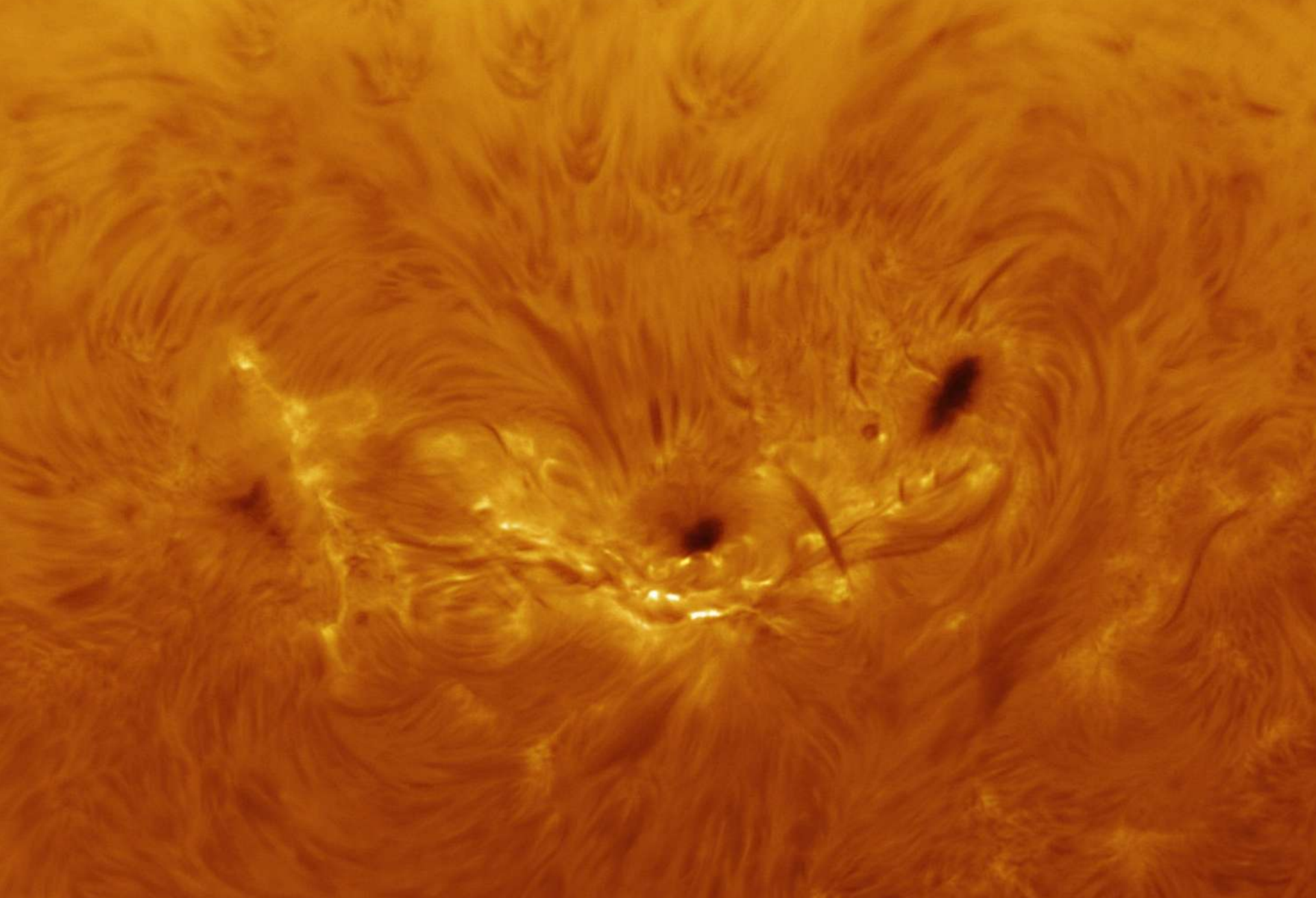
**23.09.2011, 08:52 UTC**

# Solar chromosphere ( $H\alpha$ )

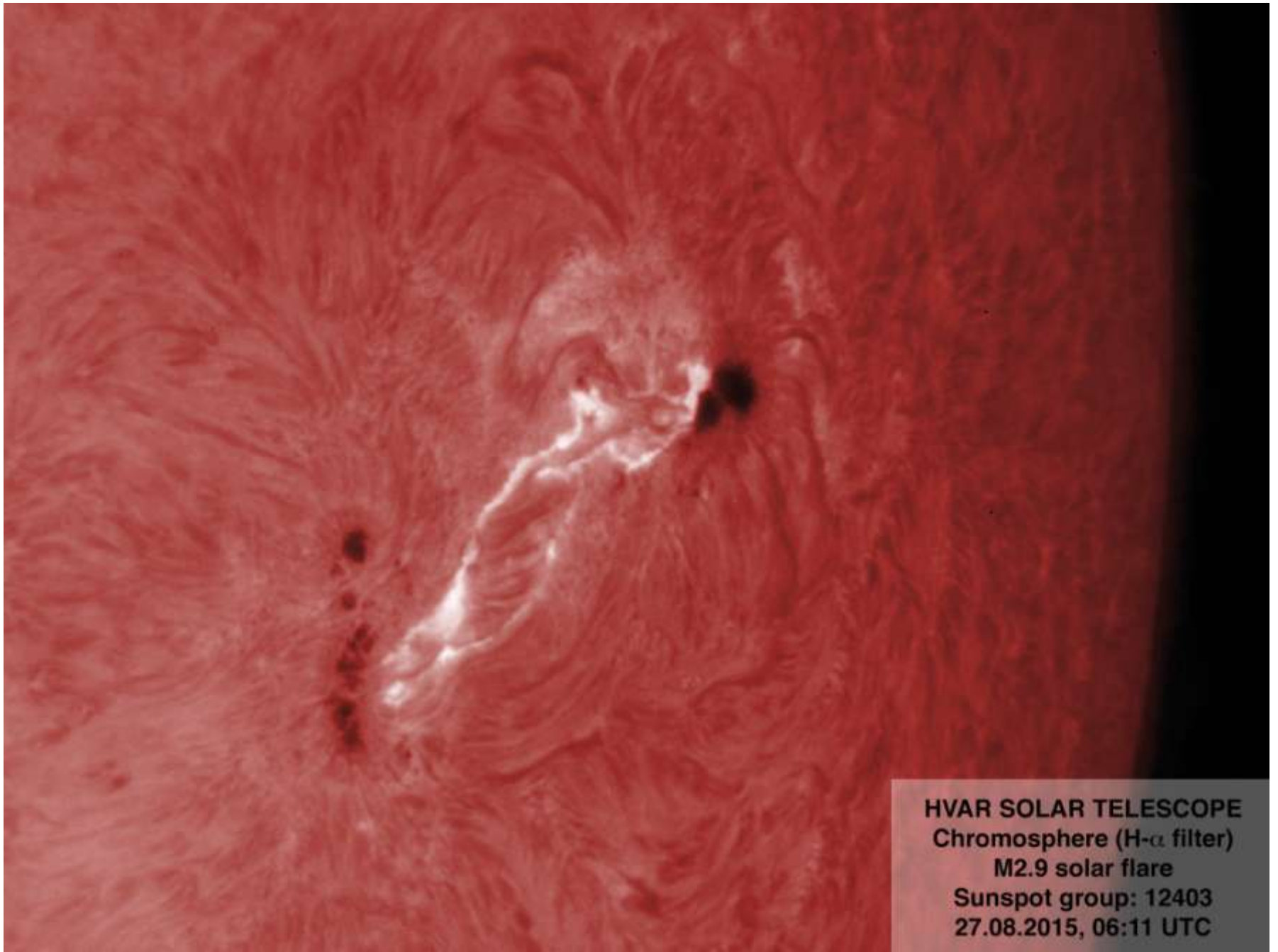
22 Sept. 2011, sunspot group 11302, X1.4 flare



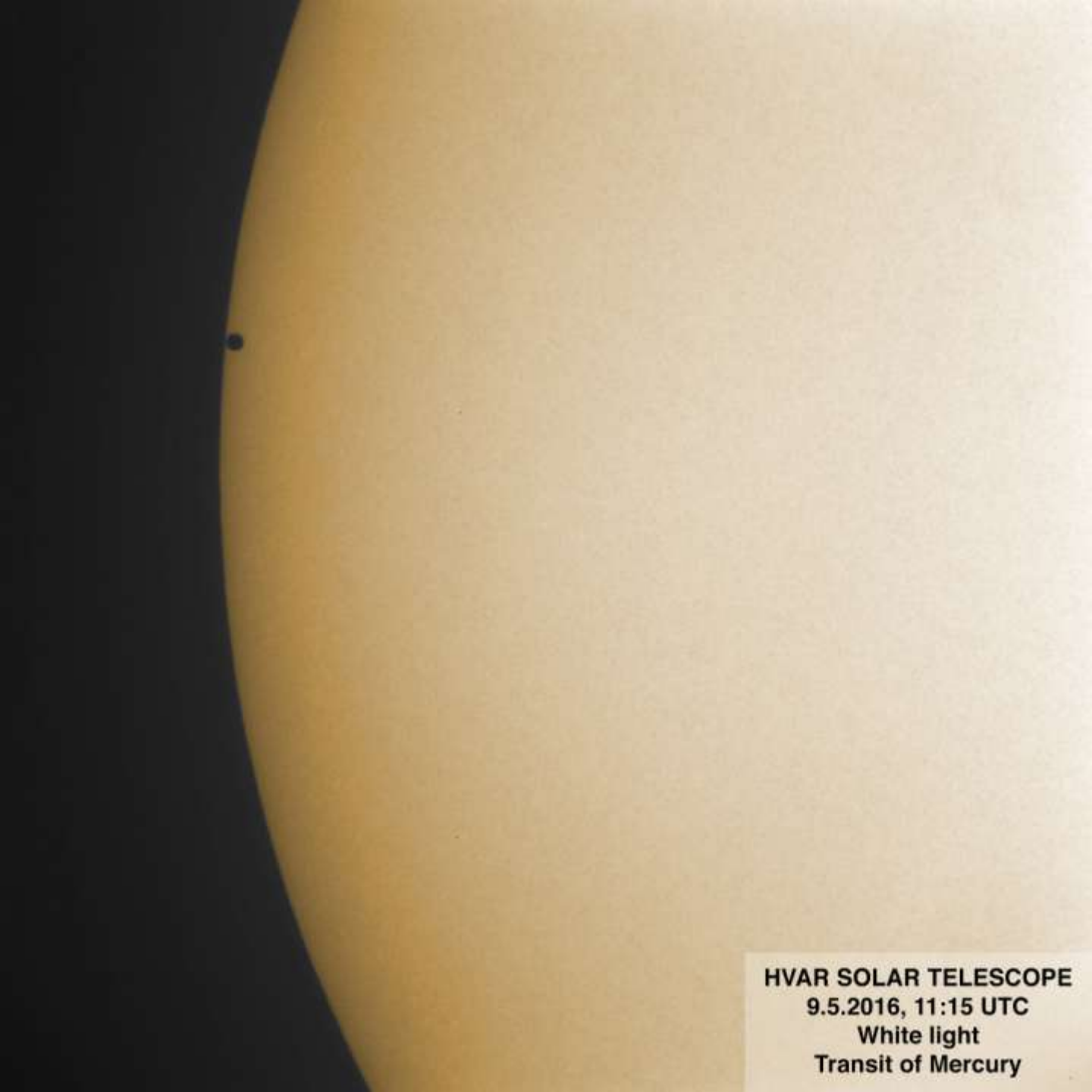




**Solar chromosphere, active region, 4 July 2012, 11:55 UTC, AR 11515**



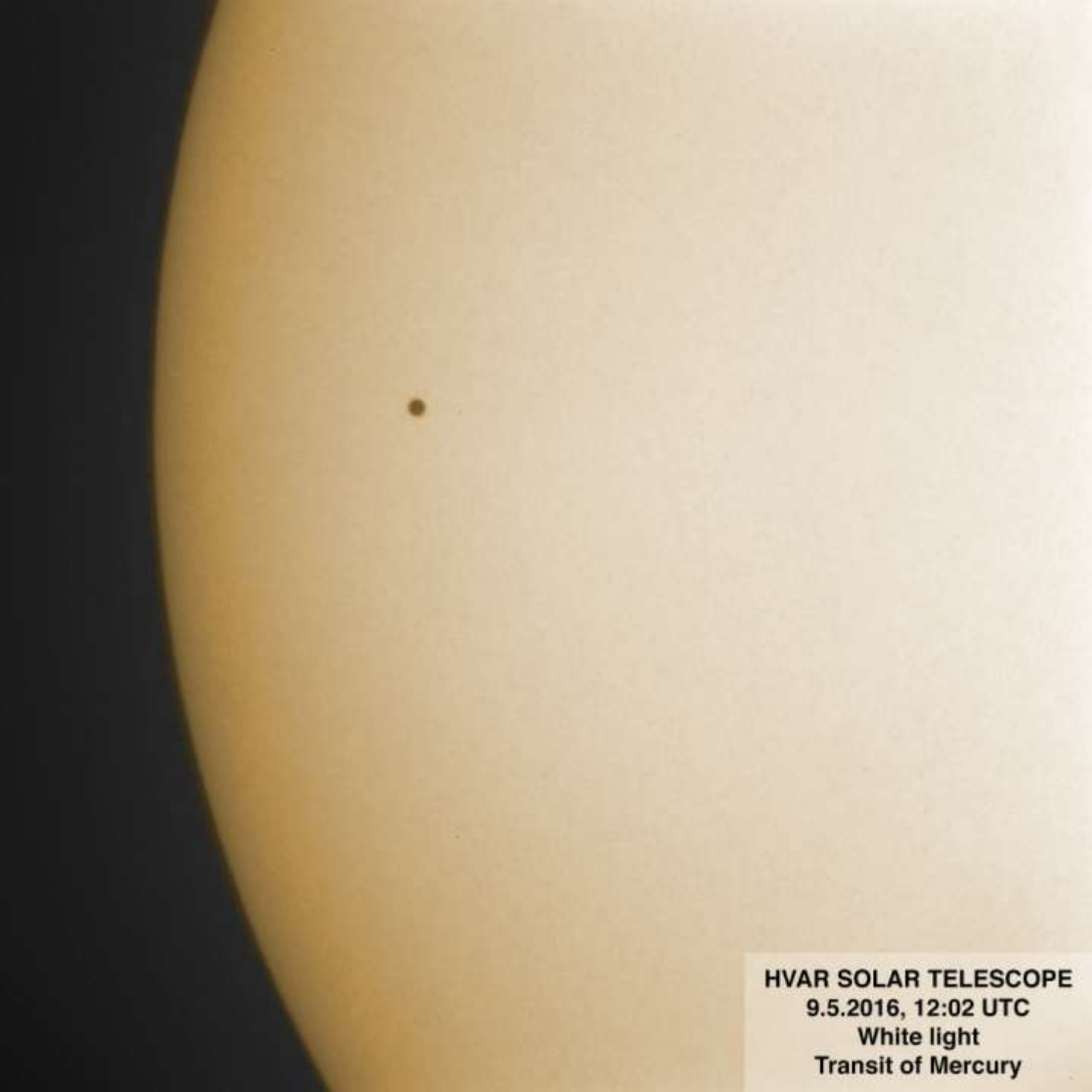
**HVAR SOLAR TELESCOPE**  
**Chromosphere (H- $\alpha$  filter)**  
**M2.9 solar flare**  
**Sunspot group: 12403**  
**27.08.2015, 06:11 UTC**



**HVAR SOLAR TELESCOPE**  
**9.5.2016, 11:15 UTC**  
**White light**  
**Transit of Mercury**



**HVAR SOLAR TELESCOPE**  
**9.5.2016, 11:25 UTC**  
**White light**  
**Transit of Mercury**



**HVAR SOLAR TELESCOPE**  
**9.5.2016, 12:02 UTC**  
**White light**  
**Transit of Mercury**





**HVAR SOLAR TELESCOPE**  
**9.5.2016, 11:14 UTC**  
**H-a filter**  
**Transit of Mercury**



**HVAR SOLAR TELESCOPE**  
**9.5.2016, 11:30 UTC**  
**H-a filter**  
**Transit of Mercury**



**HVAR SOLAR TELESCOPE**  
**9.5.2016, 12:03 UTC**  
**H-a filter**  
**Transit of Mercury**

# Solar prominences and solar flares

- Prominences (filaments): clouds of colder and denser ionized gas in the solar atmosphere held by magnetic field
- Solar flares – sudden eruptions of hot gas in the solar atmosphere
- Coronal Mass Ejections

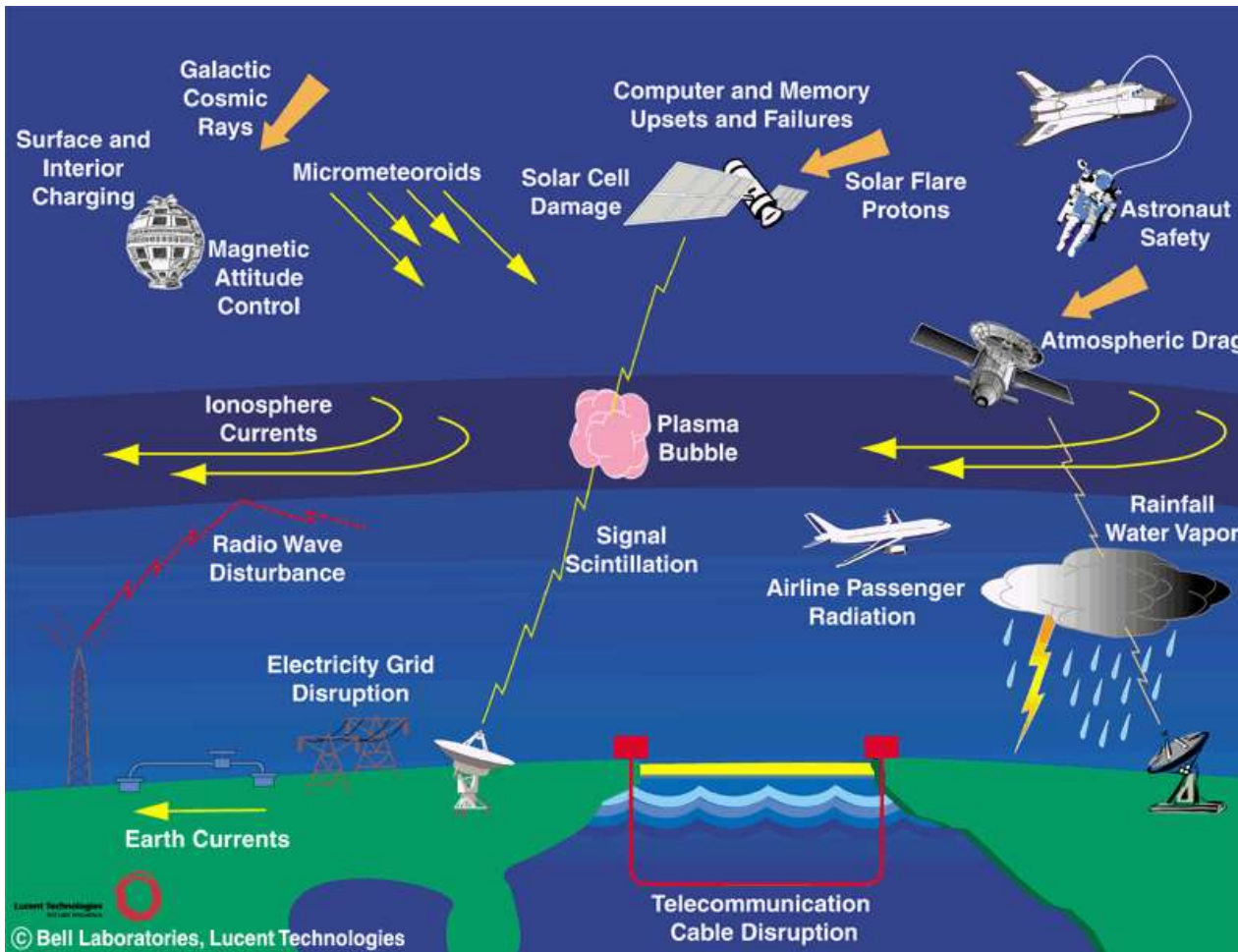


Prominence  
30 March 2010  
SDO (NASA)



# Influence on the Earth

## Space Weather – prediction tools



Effects on astronauts, pilots, space missions, communication satellites, power supply lines, electronic devices and climate on Earth...



- **S**olar-**T**ERrestrial **I**nvestigations and **A**rchives, EU FP7
- GOALS: link between solar physics and geophysics, creation of data base, comparison between modeling and observations
- 1 November 2008 – 31 October 2011
- Partners from 11 countries: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Hungary, Poland, Russia





- COronal MAss Ejections and Solar Energetic Particles
- EU FP7
- GOALS: investigation of the CME and solar flare influence on interplanetary space and development of an automatic alarming system
- 1 February 2011 – 31 January 2014
- Partners from 8 countries: Austria, Belgium, Croatia, Denmark, Greece, India, UK, USA



- Environment for **H**uman **E**xploration and **RO**botic **E**xperimentation in **S**pace, EU FP7
- GOALS: investigation of interplanetary space and solar influence on manned and unmanned space missions
- 1 March 2012 – 28 February 2015
- Partners from 14 countries: Austria, Belgium, Canada, Croatia, Finland, France, Germany, Hungary, Italy, Poland, Russia, Switzerland, UK, USA





# Croatia is joining ESA

## → CROATIA



### Organisation of Space Activities

In July 2013 the Republic of Croatia became the latest country to join the European Union. This has opened new opportunities to participate in various European research and development initiatives, including those in the field of Space, for the Croatian scientific community and a pool of dedicated and innovative entrepreneurs. In April 2014 the Ministry of Science and Education, as the national authority with chief responsibility over Space policy, formally expressed an interest in becoming a partner with the European Space Agency (ESA). The signing of the Cooperation Agreement between the Republic of Croatia and ESA is foreseen upon conclusion of negotiations, which are currently underway. Meanwhile, Croatian stakeholders have continued to actively participate in EU research and Space-related programmes such as FP7, H2020, Galileo/EGNOS and Copernicus, and in other activities described in this text.

The Ministry of Science and Education is the central institution in Croatia responsible for research policy and is the main Space authority in Croatia. The mission of the Ministry of Science and Education is to facilitate the development of the science, technology and innovation system. The Ministry monitors and establishes scientific, professional and technological cooperation with foreign

#### CONTACT POINT ON SPACE TECHNOLOGY R&D

For Space Policy:

Ministry of Science and Education  
Donje Svetice 38, Zagreb,  
Republic of Croatia

Mr. Hrvoje Pavletić  
alanhrvoje.pavletic@mzo.hr

For H2020 Space:

Agency for Mobility and EU Programmes  
Frankopanska 26, Zagreb,  
Republic of Croatia

Ms. Mirjana Vuk (NCP)  
mirjana.vuk@mobilnost.hr

countries and international organizations such as ESA, according to international agreements. In the field of Space, cooperation with institutions such as the Ministry of Economy and the Croatian Chamber of Economy (e.g. on ESA), or the Agency for Mobility and EU Programmes (e.g. on H2020 Space) is particularly important.

### Space Strategy and Major Programmes

Although at the moment Croatia does not have a Space Strategy, Space is an inherent part of strategic documents such as the Croatian Research and Infrastructure Roadmap (2016) and the Croatian Smart Specialization Strategy 2014-2020. In both documents, establishing cooperation with the European Space Agency is specified.

The signing of the initial Agreement between the Republic of Croatia and the European Space Agency (ESA) Concerning Space Cooperation for Peaceful Purposes will require no financial contribution on the part of Croatia. The signing of the agreement will facilitate, among other things, an exchange of scientists and engineers, as well as information and contacts between related industries. In large, the successful implementation of the Cooperation Agreement is expected to provide a significant boost to the Croatian Space sector, in both industry and research. It is seen as the

first step that will lead to the subsequent accession of Croatia into the European Cooperating State Agreement, and which will prepare all relevant stakeholders for participation in ESA programmes.

Furthermore, Croatia has expressed interest to participate in the Space Surveillance and Tracking Programme (SST), as it possesses strong foundations in research capacities and in the information technology sector, encompassing communications, data analysis and other areas as well. As already noted, the Republic of Croatia participates in EU research and Space-related programmes, although it currently does not take part in ESA mandatory or optional programmes. It should also be mentioned that Croatia has been a full member of EUMETSAT since 2007. This has enabled industrial stakeholders to participate in the construction of meteorological satellites.



## Space Technology R&D

There are a number of Space technology research and development activities taking place in Croatia, particularly in the areas of earth observation and satellite communications. An important research establishment in the field of earth observation is Hvar Observatory, the result of successful multi-year cooperation between Croatia and Austria. Run by the Faculty of Geodesy of the University of Zagreb, it is the only professional astrophysical observatory in Croatia, comprising two stellar telescopes and a double solar telescope on the island of Hvar located on the Adriatic Sea, where optimal climate conditions are fulfilled. Astrophysical research at Hvar Observatory includes solar and stellar physics, as well as Space weather studies and physics of the heliosphere. The Faculty of Geodesy of the University of Zagreb is the National Copernicus Relay and Copernicus Academy representative for Croatia. Research activities of the Faculty of Geodesy are devoted to the computation of the national geoid as a combination of satellite and gravimetric measurements. Other faculties also conduct research activities based on Copernicus data. For example, the Faculty of Mechanical Engineering and Naval Architecture of the University of Zagreb is working on developing an application for monitoring temperature fields of urban areas, specifically the Zagreb metropolitan area. Meanwhile, the Faculty of Transport and Traffic Sciences of the University of Zagreb actively performs activities related to GALILEO (i.e. GNSS systems). Other research areas and topics, which Croatian individual scientists have been particularly successful in, include exploration of space physics, space weather, astroparticle physics and robotics. The Croatian Science Foundation also supports excellent research with applications

possible in the Space domain. One example is a scientific project on numerically efficient algorithms for embedded systems that is conducted at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb.

Croatian companies have achieved marked success in the area of satellite software development. Amphinicy is one such company, which has gained international recognition as a provider of complex tailor-made software solutions and all-around software support for the satellite industry. The firm's customer base includes international Space and humanitarian agencies such as ESA and the German Aerospace Centre, leading satellite operators and global satellite service providers, teleports and Space mission operation centres, satellite equipment manufacturers and other important stakeholders in the industry. The company has been recognized as an innovative company on a number of occasions and is listed among the most innovative companies in the EU. Furthermore, Amphinicy is a beneficiary of the H2020 SME Instrument Phase 1 and holds three EU Seals of Excellence for innovative products. Another firm, GDI Gisdata, has developed and implemented a specialized software solution for precision agriculture – GDI Localis for Agriculture. The application helps users to manage their work processes related to fields and food production. The company is currently implementing the project 'Monitoring Crops from Space – Precision Agriculture Solution'. In addition, the firm Croatiael has been engaged in professional satellite communications for more than two decades. Mir-eo is yet another Croatian company, working on the development of GPS navigation and telematics software.



Figure 80 • Hvar Observatory is a professional astrophysical observatory run by the University of Zagreb and is the result of successful multi-year cooperation between Croatia and Austria.

# Summary and Conclusion

- stellar physics: photometry of variable stars, various types (e.g., Be stars, eclipsing binary stars, ...); Hvar-Ondrejov photometric archive, search for extrasolar planets
- solar physics: solar rotation and activity, solar chromosphere, flares, prominences, CME, solar-terrestrial physics, space weather
- strong international cooperation: observatories, satellites
- projects: domestic and international, e.g., partners in 4 EU FP7 projects, 1 EU Horizon 2020 project, and 1 ESO project
- fellowships: 1 Alexander von Humboldt, 1 Marie Curie
- awards: 1 Kristian Birkeland Medal for Space Weather and Space Climate
- supervising diploma works, master theses, PhD theses
- scientific output: NASA/ADS: > 670 papers; > 8300 citations (up to end 2017)