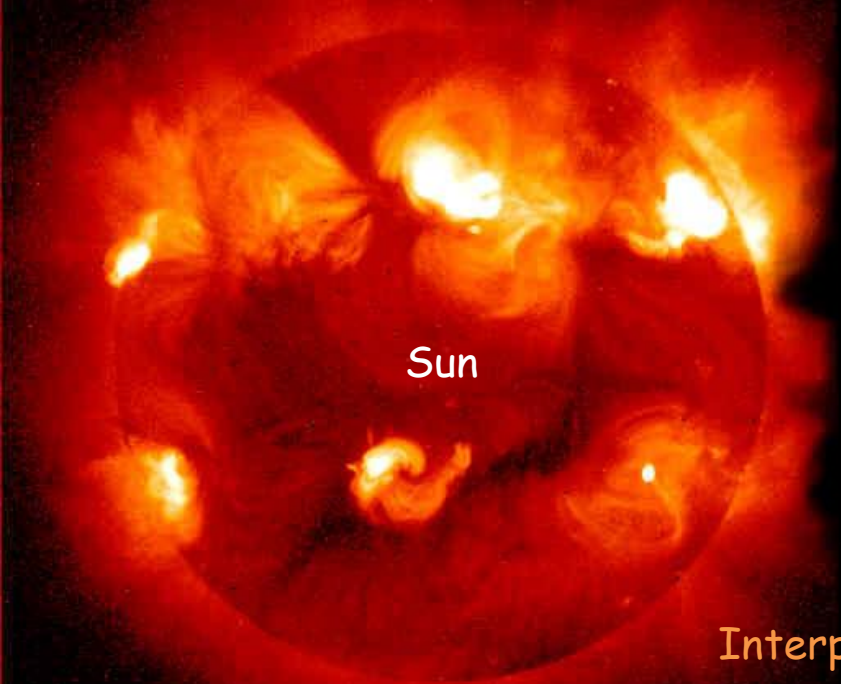


# An automated Solar Monitor at Calern observatory for Space Weather

Thierry Corbard & METEOSPACE team



Sun

### Interplanetary Space:

- Solar Wind (1-100 part/cm<sup>3</sup>, 200-800 km/s)
  - Constant outflow from the sun
  - Electrons and protons
- Disturbances from the sun produce waves and shocks in the solar wind

### Interplanetary Space

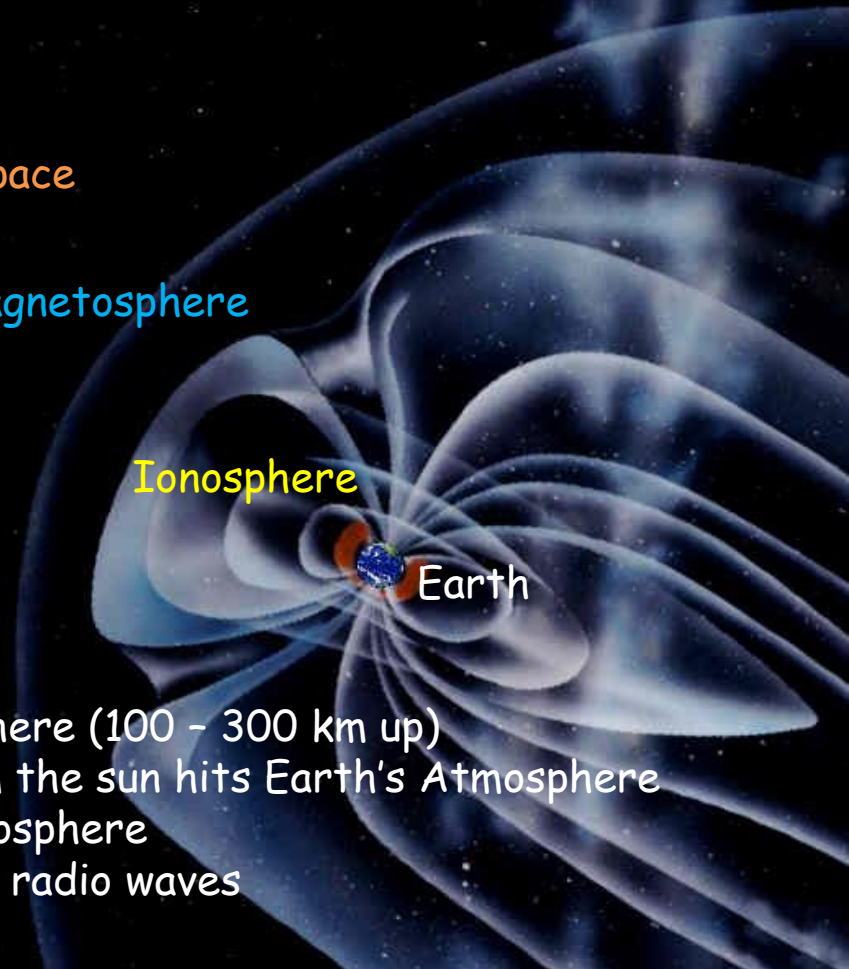
### Magnetosphere:

- Created by Earth's magnetic field
- Deformed by the Solar Wind
  - Particles (electrons and protons) trapped on magnetic field lines

### Ionosphere:

- Layer of electrons at the top of the atmosphere (100 - 300 km up)
- Formed when extreme ultraviolet light from the sun hits Earth's Atmosphere
- Strongly affected by changes in the magnetosphere
- Critical in the reflection and transmission of radio waves

### Magnetosphere



Ionosphere

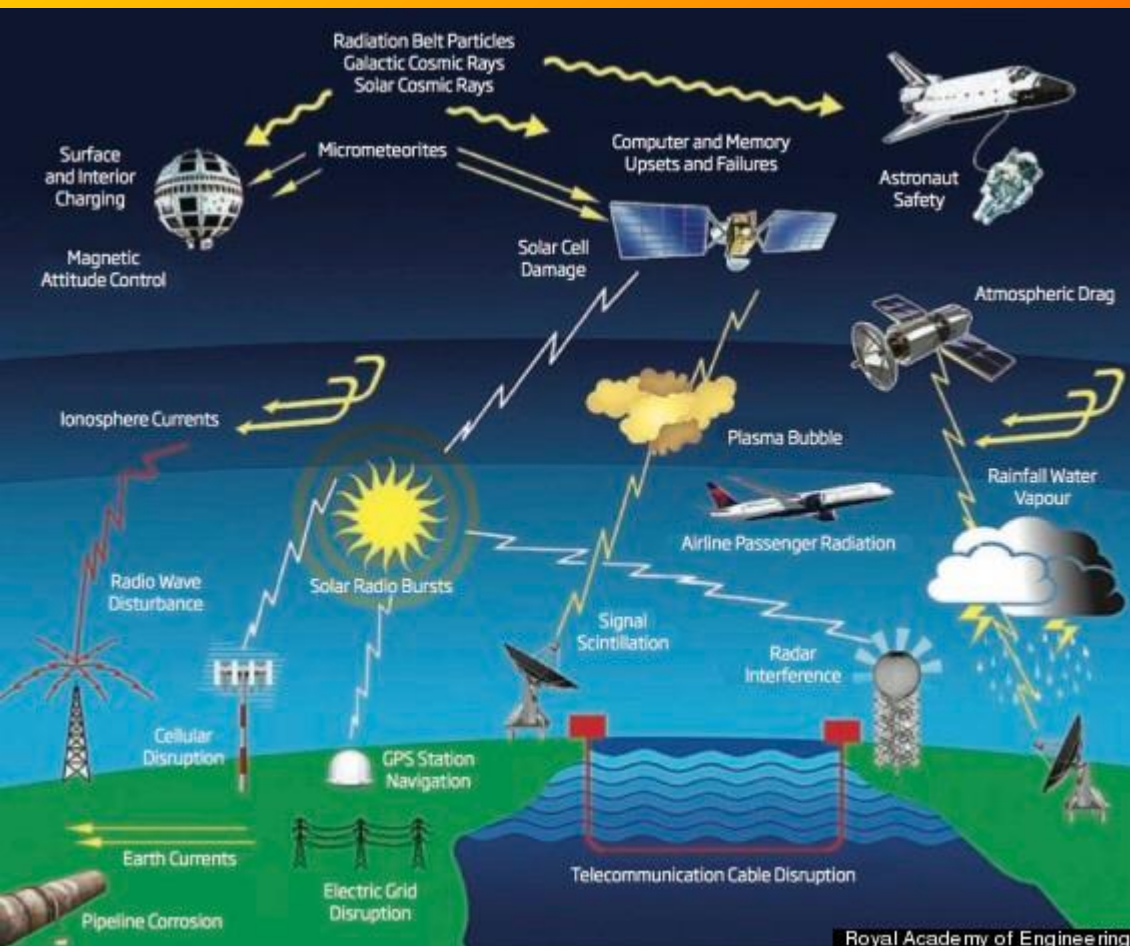
Earth

# Sequence Of Events

## Active Region on the Sun Erupts

1. Solar Flare (x-ray)
2. Shock (energetic particles)
3. Coronal Mass Ejection (particles and fields)

- X-rays reach Earth in **8 minutes** (speed of light) => **Radio Blackouts**
- Energetic Particles reach Earth in **15 min to 24 hours** => **Radiation Storms**
- Coronal Mass Ejection reaches Earth in **1-4 Days** => **Geomagnetic Storms**



## Impacts:

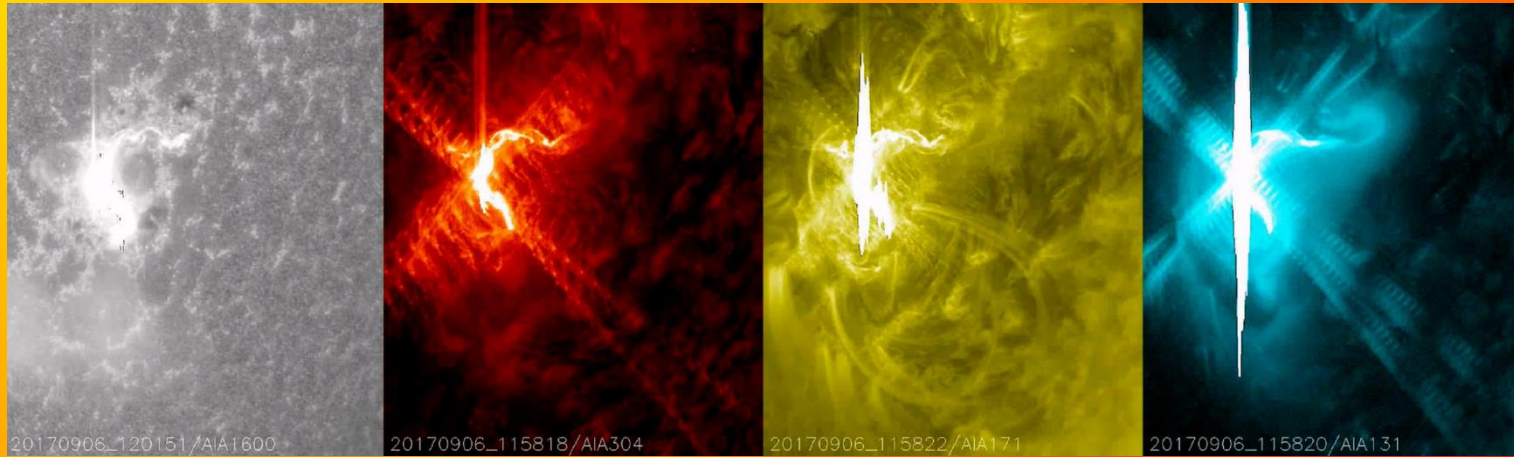
- ✓ Airline communication
- ✓ HF radio operators
- ✓ Satellite Communications
- ✓ Military Communications
- ✓ Astronauts (radiation)
- ✓ Satellite failures
- ✓ Electric Power Grids
- ✓ Increased Satellite Drag
- ✓ Aurora



- **What can we do to protect against space weather?**
  - **Research, monitoring, worst-case planning**

# Available Dynamic Data: SDO (NASA) satellite

Continuum and highly ionised Fe lines (high temperatures). No chromospheric lines

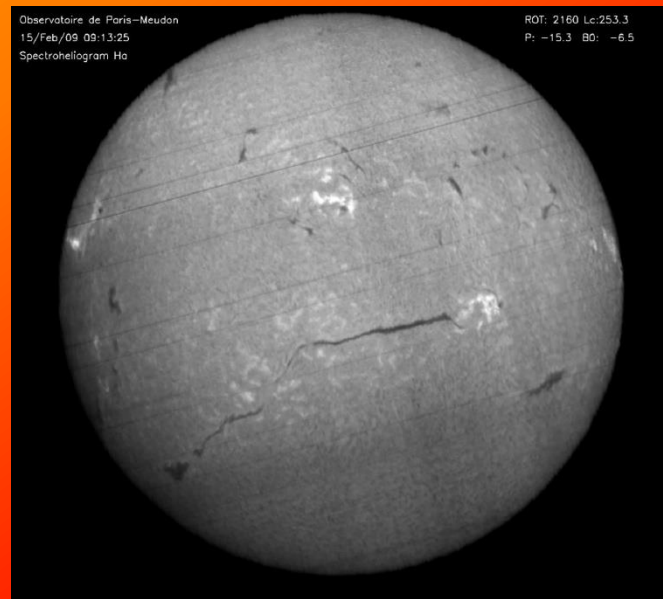
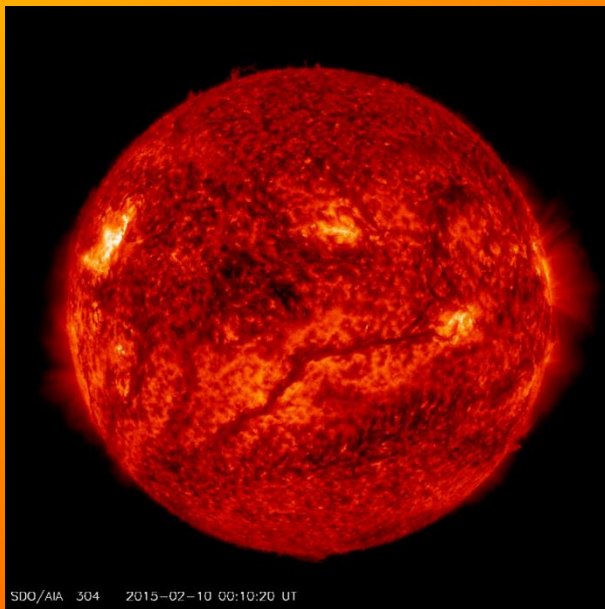


$10^4$  K

$10^5$  K

$10^6$  K

$10^7$  K



Filaments are associated to CME and their evolution is one of the the main phenomena that occur before solar eruptions .

HeII 80000K only corridors visible

H $\alpha$  8000K All kinds of filaments visible

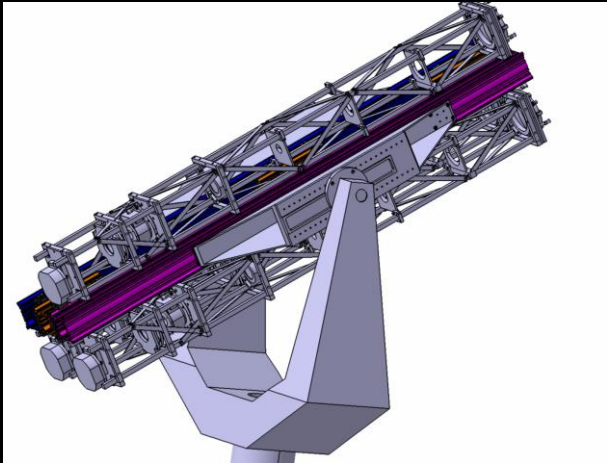


Automated and continuous optical observation of dynamical phenomena at the source of solar activity: flares, *associated Moreton waves, Coronal Mass Ejection onset, filaments instabilities*

### 3 automated refracting telescopes at Calern (OCA)

#### Chromospheric monitor

- H $\alpha$ , 10 s cadence, Fabry P $\acute{e}$ rot DayStar 0.5  $\text{\AA}$
- H $\alpha$ , 10s cadence (blue wing)
- CaII K, interference filter 1.5  $\text{\AA}$



26/01/2016 12:12



26/01/2016 17:35

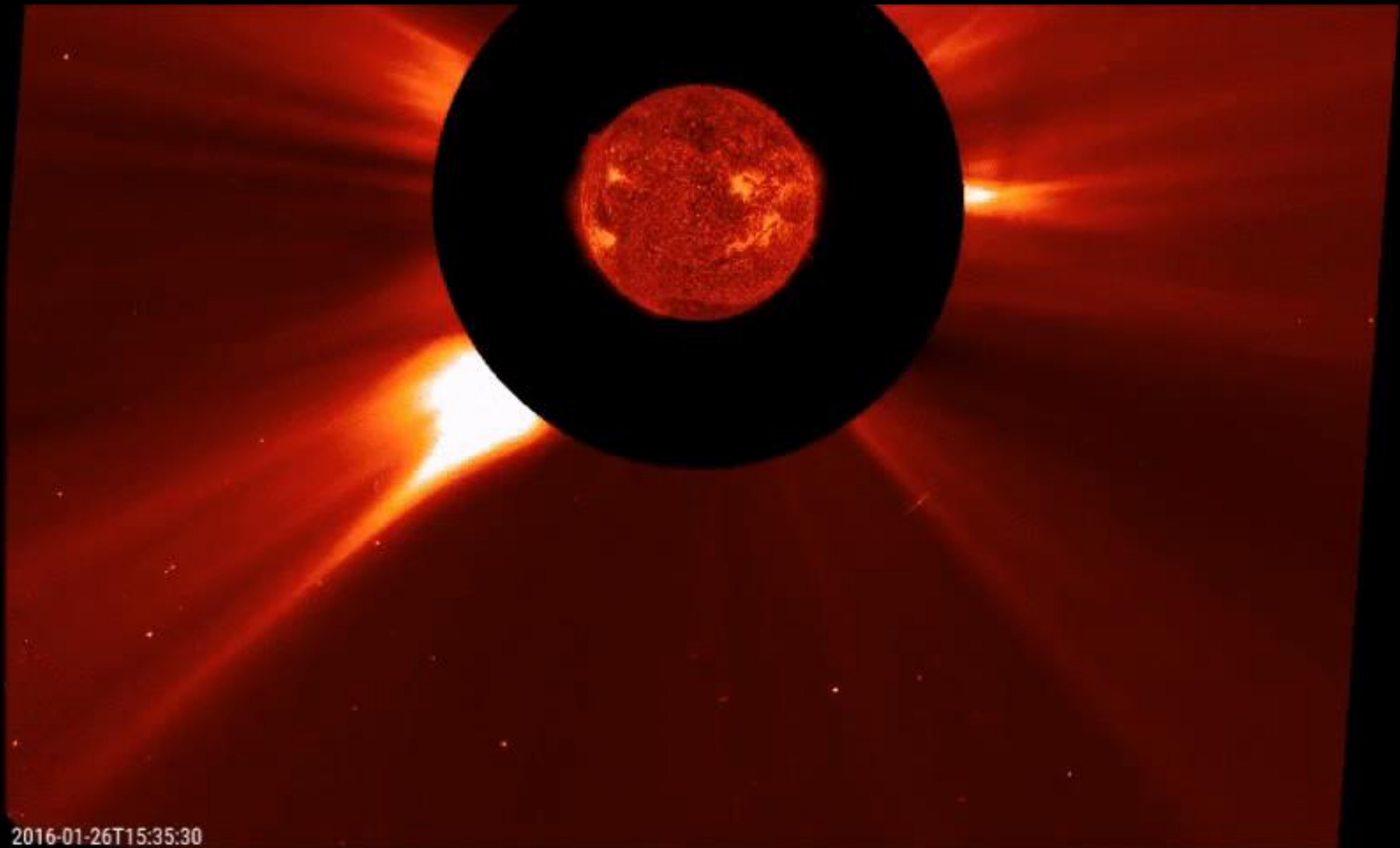


26/01/2016 18:07

LUNA/OP/OCA

**MeteoSpace**

**Automated and continuous optical observation of dynamical phenomena at the source of solar activity: flares, *associated Moreton waves, Coronal Mass Ejection onset, filaments instabilities***

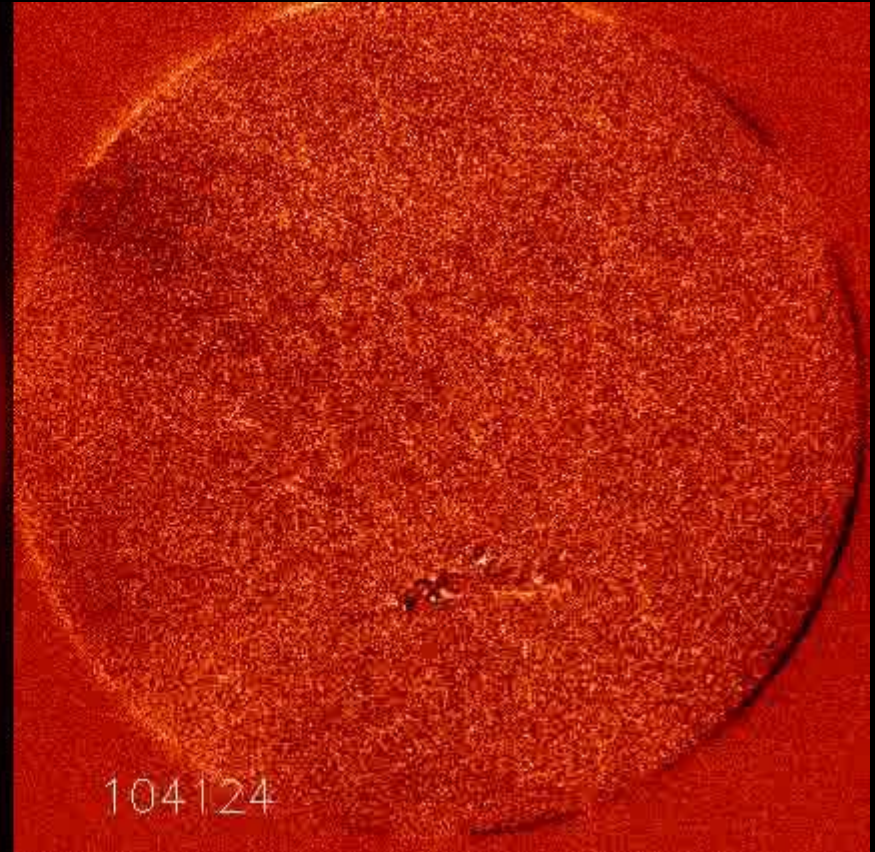


# Moreton Waves observed in the blue wing of H-alpha With the old Lyot Filter at Meudon observatory

Instantaneous  
Intensity



Running  
difference







# A collaborative project

Three main partners :

- Paris Observatory (OP)
- Côte d'Azur Observatory (OCA)
- LUNA technology

Dual Objectives:

1. Research on solar activity
2. Operational aspects

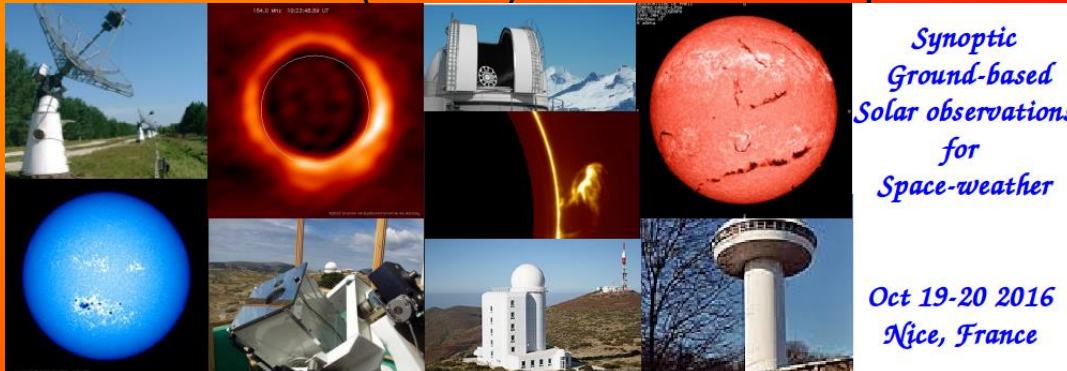


Supported by

- French Air-Force (CDAOA) FEDOME project
- UCA JEDI
- French National Program on Sun-Earth connection(PNST)
- CNES

International context :

- Ground based network : GONG (USA) and Global H-alpha networks
- Space observatories : Solar Dynamic Observatory (USA) and upcoming Solar-Orbiter (NASA) but no chromospheric observations



Federation of French Ground-based solar observations

Ground-based Support to Solar Orbiter



The International Civil Aviation Organization (ICAO) is planning to open an operational activity in Space-Weather in 2018.

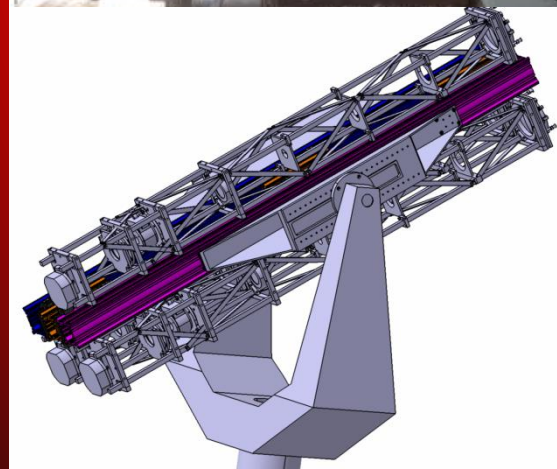
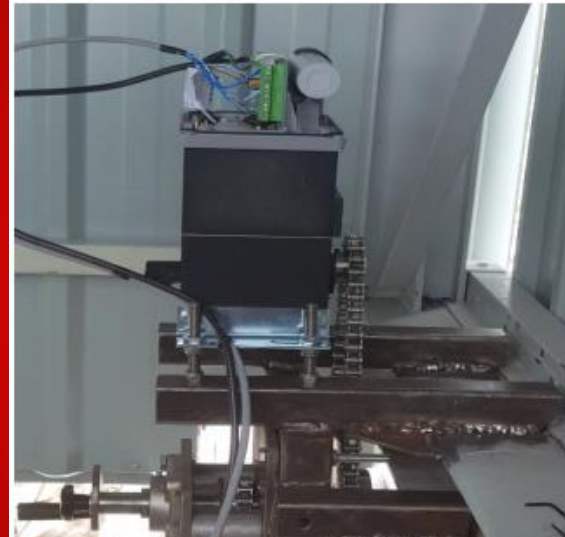
DGAC has provided a list of potential data provider including METEOSPACE for optical data.



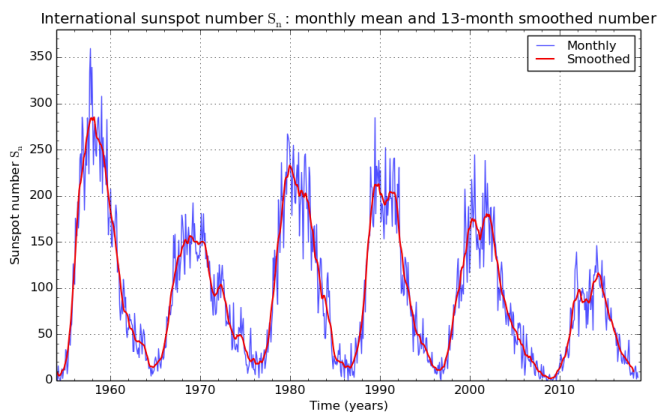
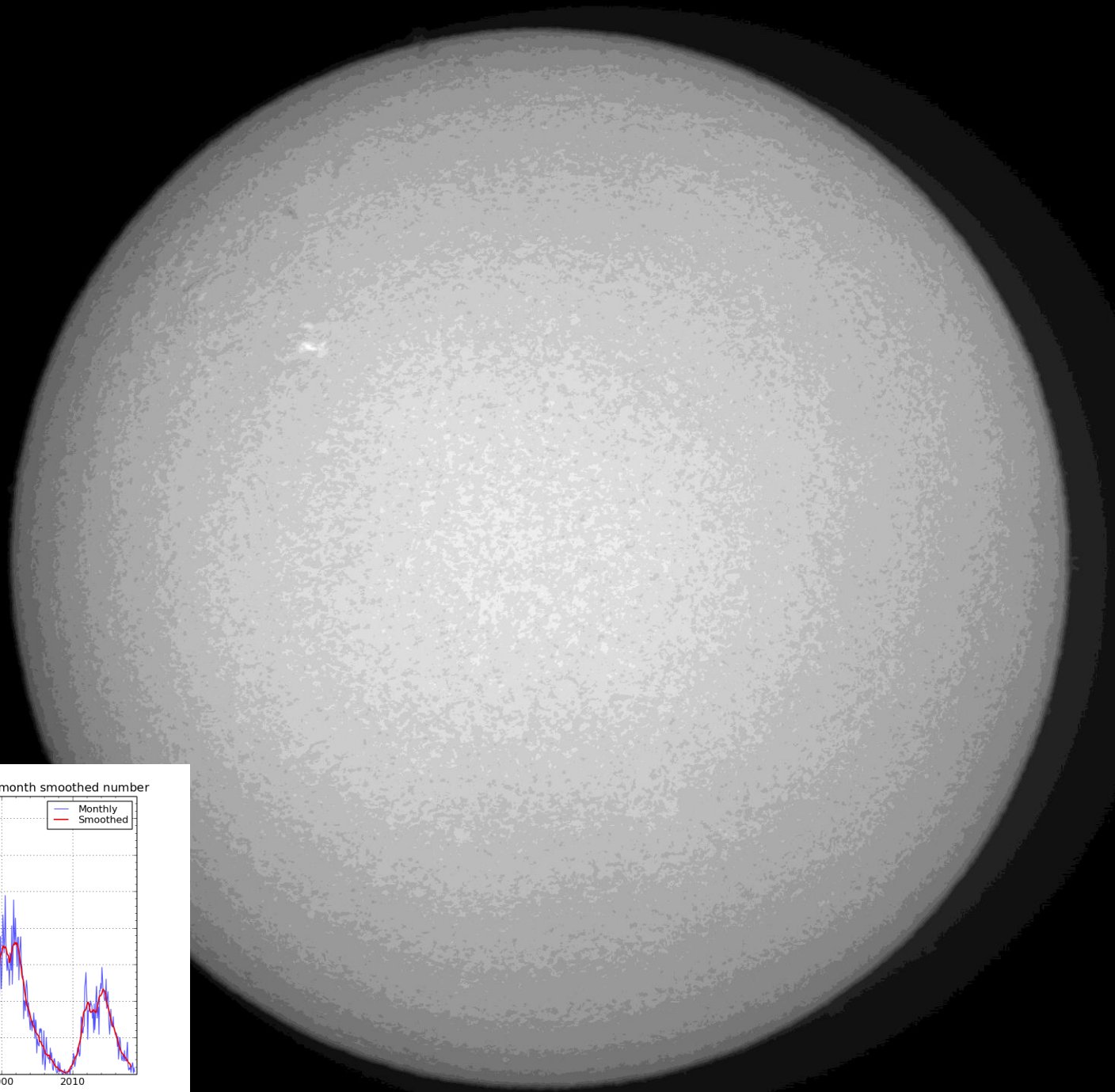
LUNA/OP/OCA



# Project completion schedule



2018/09/10 Image  
from METEOSPACE  
prototype (Meudon)



Green=finished ; orange = on going ; rouge = to be done

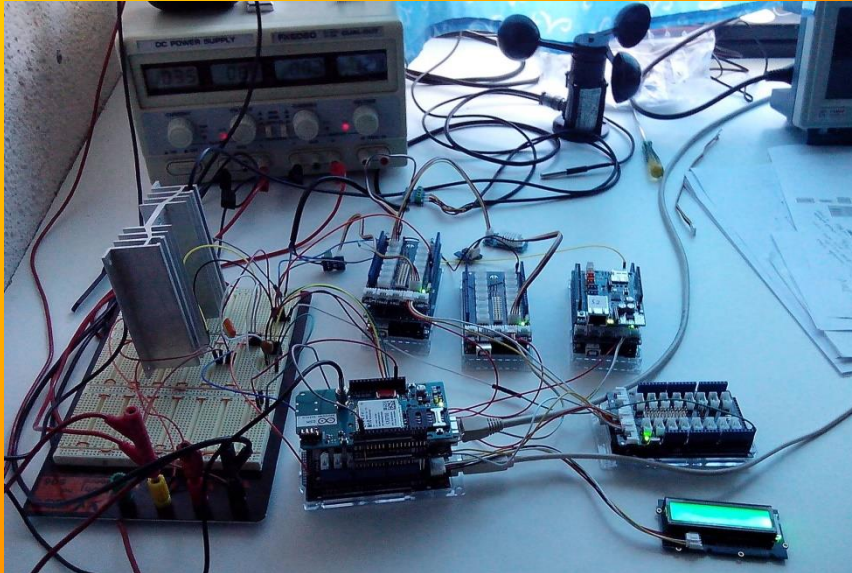
Shelter completed Nov 15 2018

Instrument delivered May 1st 2019

Planning général METEOSPACE	15/9	30/9	15/10	31/10	15/11	30/11	15/12	31/12	15/1	31/1	15/2	28/2	15/3	31/3	15/4	30/4	15/5	31/5	15/6	31/6	15/7	31/7	15/8	31/8
<b>Bâtiment (OCA)</b>					J3											J4								
Appels d'offre																								
Réalisation dalle				?	?																			
Réalisation VRD																								
Réalisation murets porteurs / protec.																								
Pose rails guidage toit																								
Installation structure toit mobile																								
Bardage / étanchéité																								
Installation volet roulant																								
Installation armoire électrique																								
Installation moteur toit																								
Réalisation armoire de commande																								
Installation capteurs fin de course																								
Installation armoire de commande																								
Installation réseau (interne)																								
<b>Automatisation (OCA)</b>																								
Etude capteurs																								
Etude automate																								
Prototype automate / tests labo																								
Validation vraie grandeur																								
Achats/mise en oeuvre capteurs																								
Réalisation rack automate																								
Logiciel automate																								
Interfaces pilotage /acq																								
Mode remote																								
Tests mode auto																								
<b>Monture (Meudon / OCA)</b>																								
Fabrication monture																								
Recette monture																								
Livraison monture																								
Mise en œuvre électronique																								
Logiciel monture																								
Installation monture sur site																								
Intégration capteurs sécurité																								
Tests et mise en station																								
<b>Instruments (Meudon)</b>																								
Etude optique																								
Etude caisson																								
Prototype lunette																								
Réalisation optique																								
Réalisation caisson																								
Logiciel acquisition																								
Intégration instruments																								
Livraison instruments																								
Mise en place et réglages instrument																								
Tests / Première lumière																								
<b>Informatique générale (OCA)</b>																								
PCs bâtiment Météospace																								
Onduleurs bâtiment Météospace																								
Etude du centraliseur																								
Acquisition du centraliseur																								
Logiciels centraliseur																								
Acquisition serveur données + DD																								
Logiciel serveur de données																								
IHM instruments																								
IHM serveur de données																								

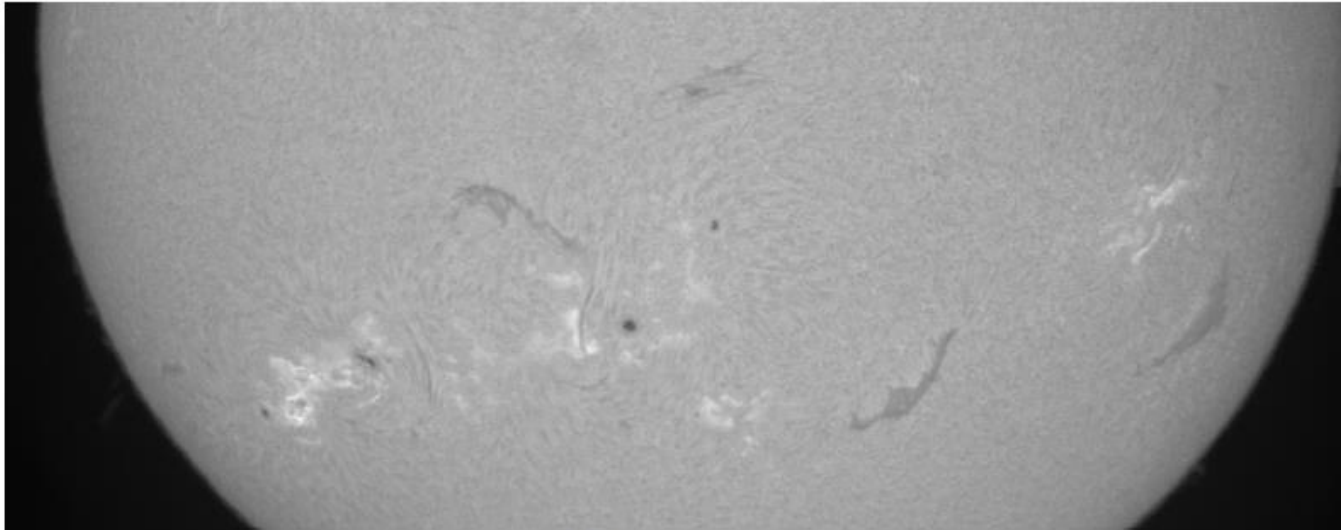
Switch to opérationnaml mode

# Project completion schedule

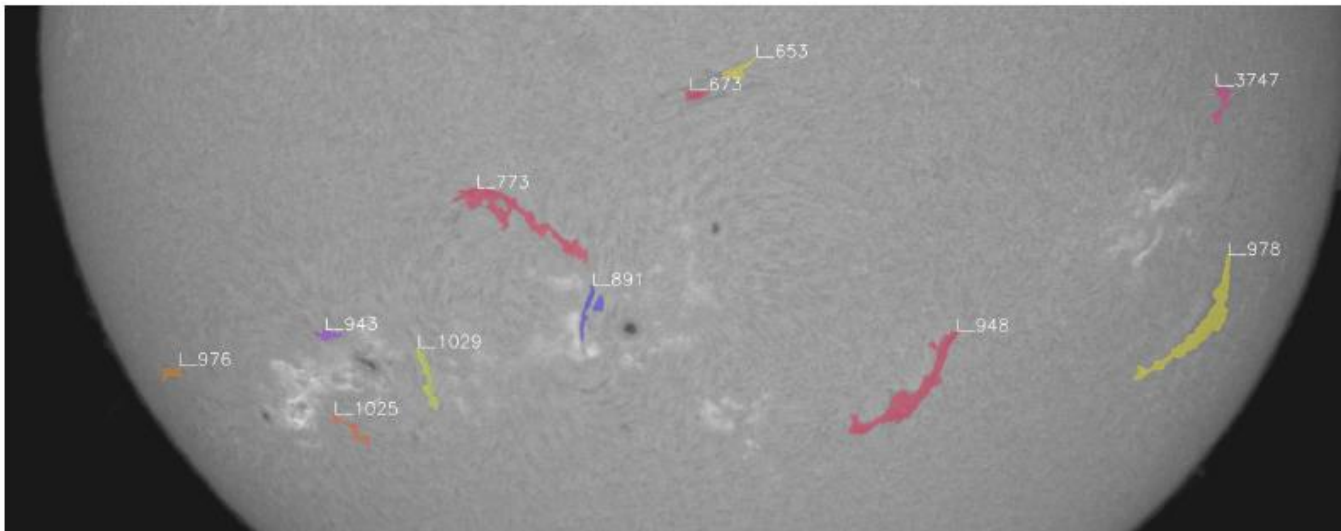


- Automated system for shelter control will be installed and tested during winter 2018-2019 (Financed by UCA JEDI Academy 3)  
Contribution of an engineering student for 2 months during summer 2017
- The second H-alpha DayStar filter (Financed by UCA JEDI Academy 3) has been ordered (9 months delay) and will be integrated to the telescope in 2019.

# Automatic filament detection in sequences



(a) Input image

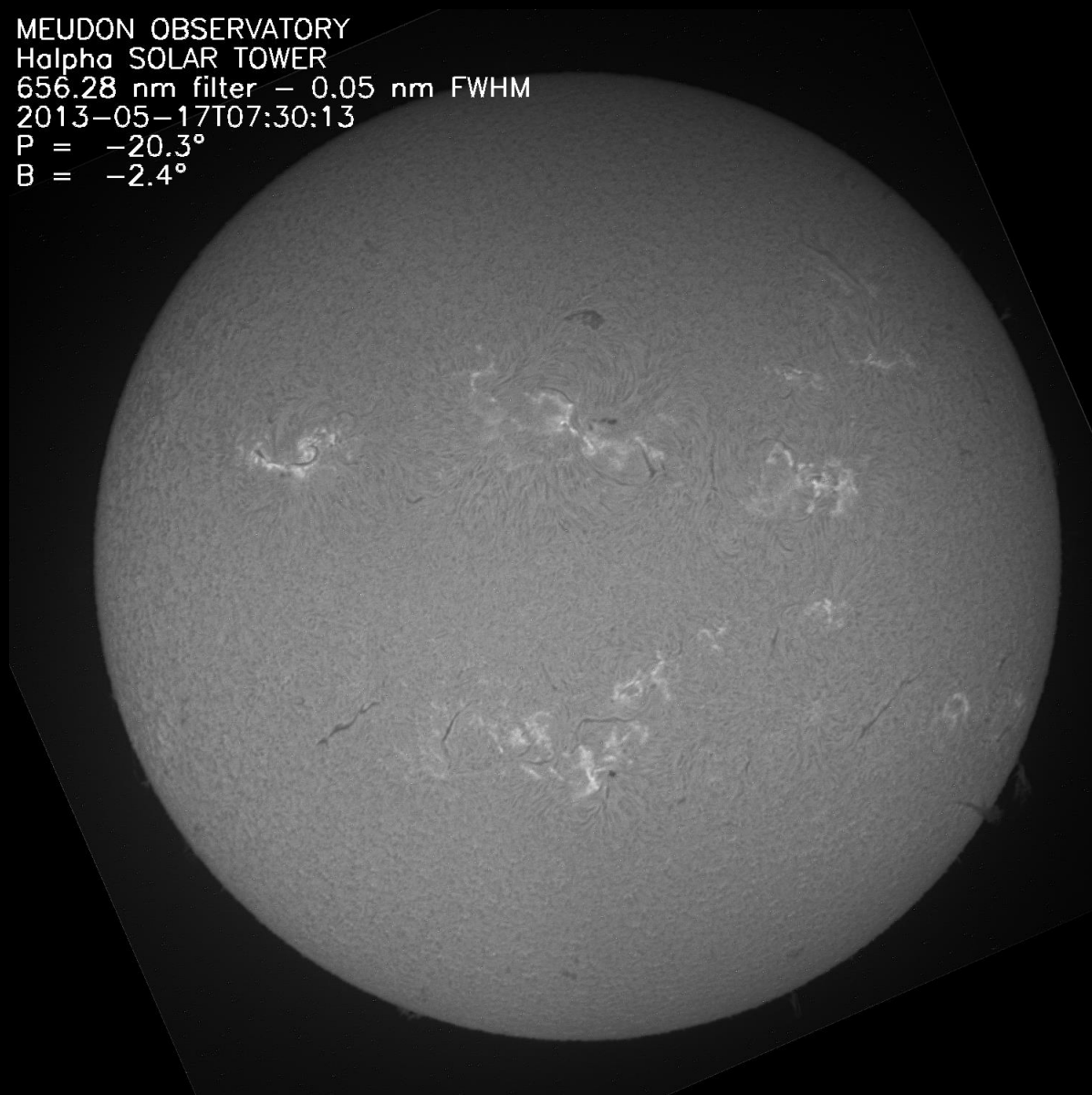


(b) Filament detection result



# Image stacking

MEUDON OBSERVATORY  
H $\alpha$  SOLAR TOWER  
656.28 nm filter – 0.05 nm FWHM  
2013-05-17T07:30:13  
P =  $-20.3^\circ$   
B =  $-2.4^\circ$



THANKS FOR YOUR SUPPORT !!

