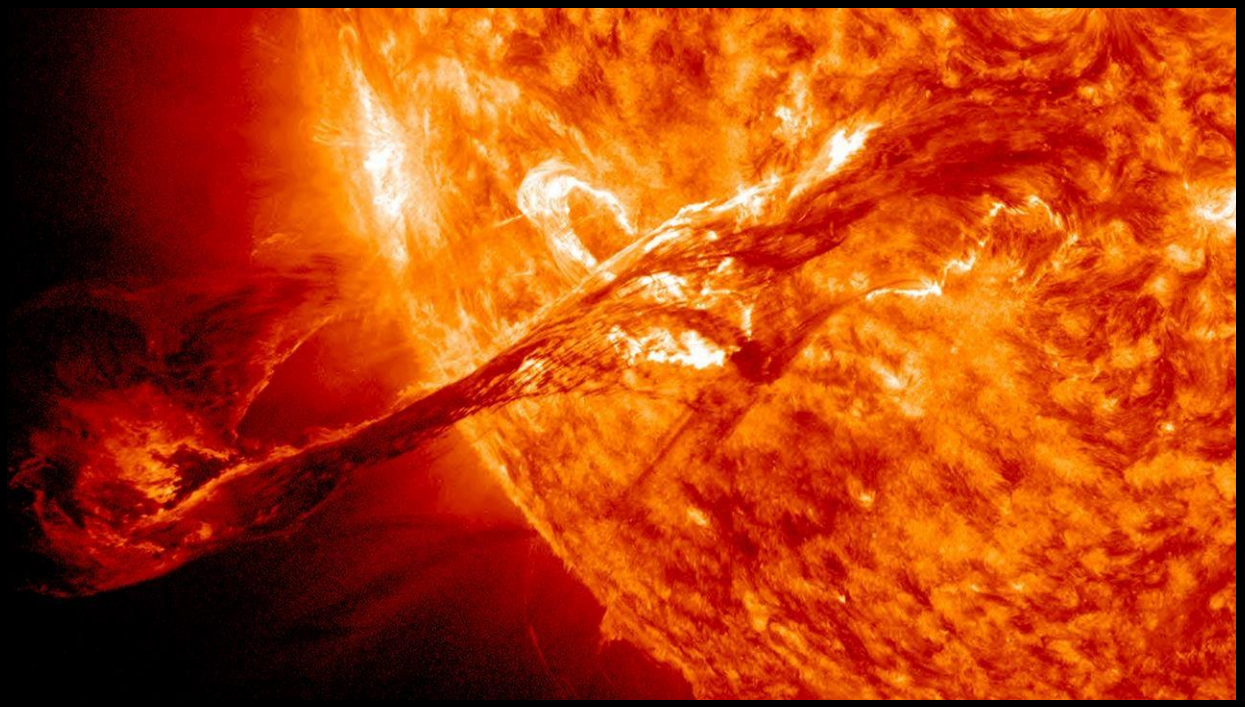
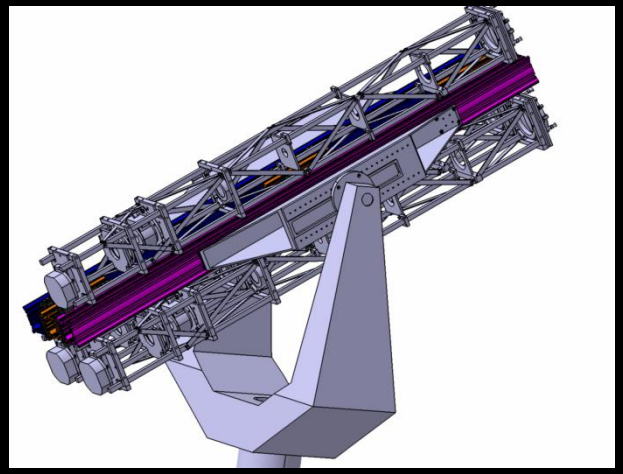
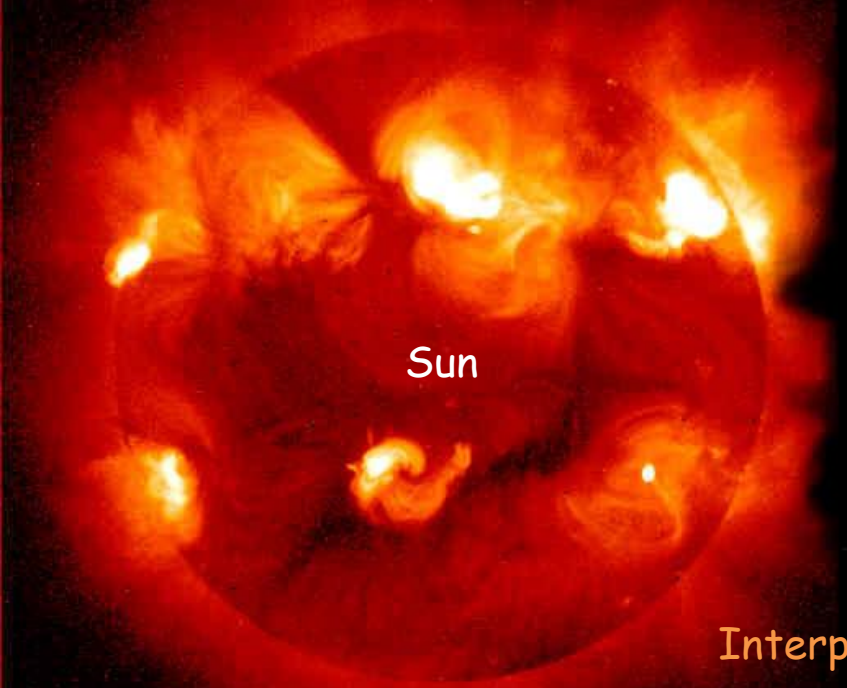




# An automated Solar Monitor at Calern observatory for Space Weather

Thierry Corbard & METEOSPACE team



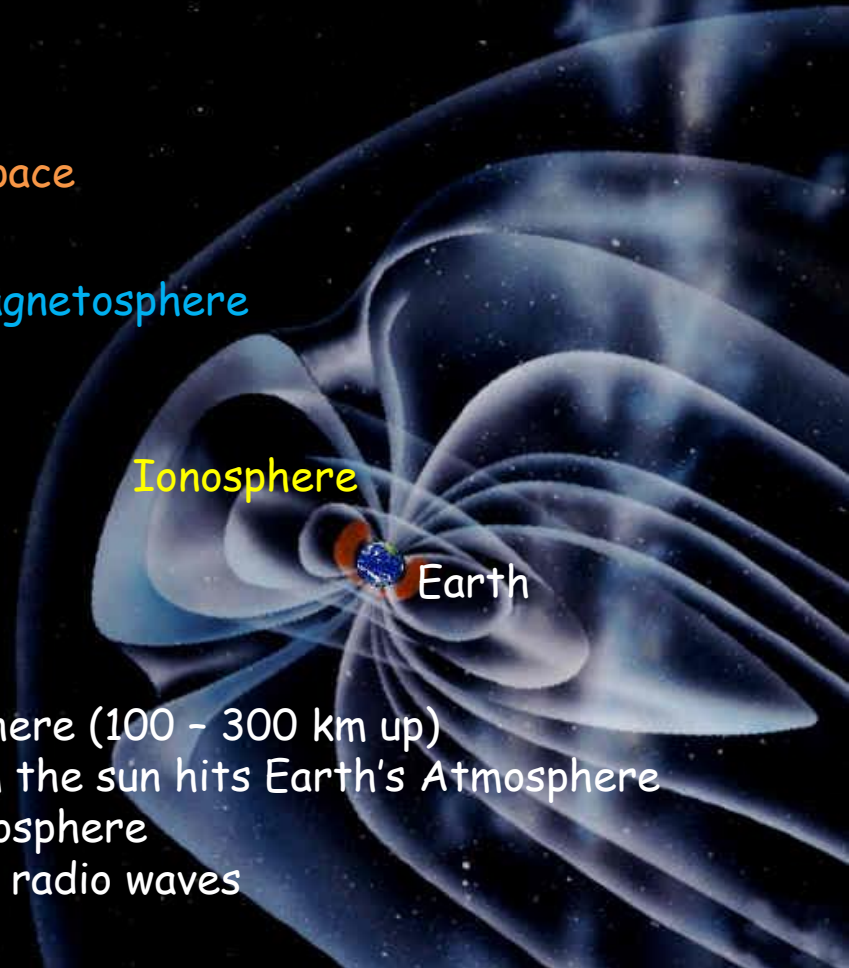

Interplanetary Space:

- Solar Wind (1-100 part/cm3, 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:

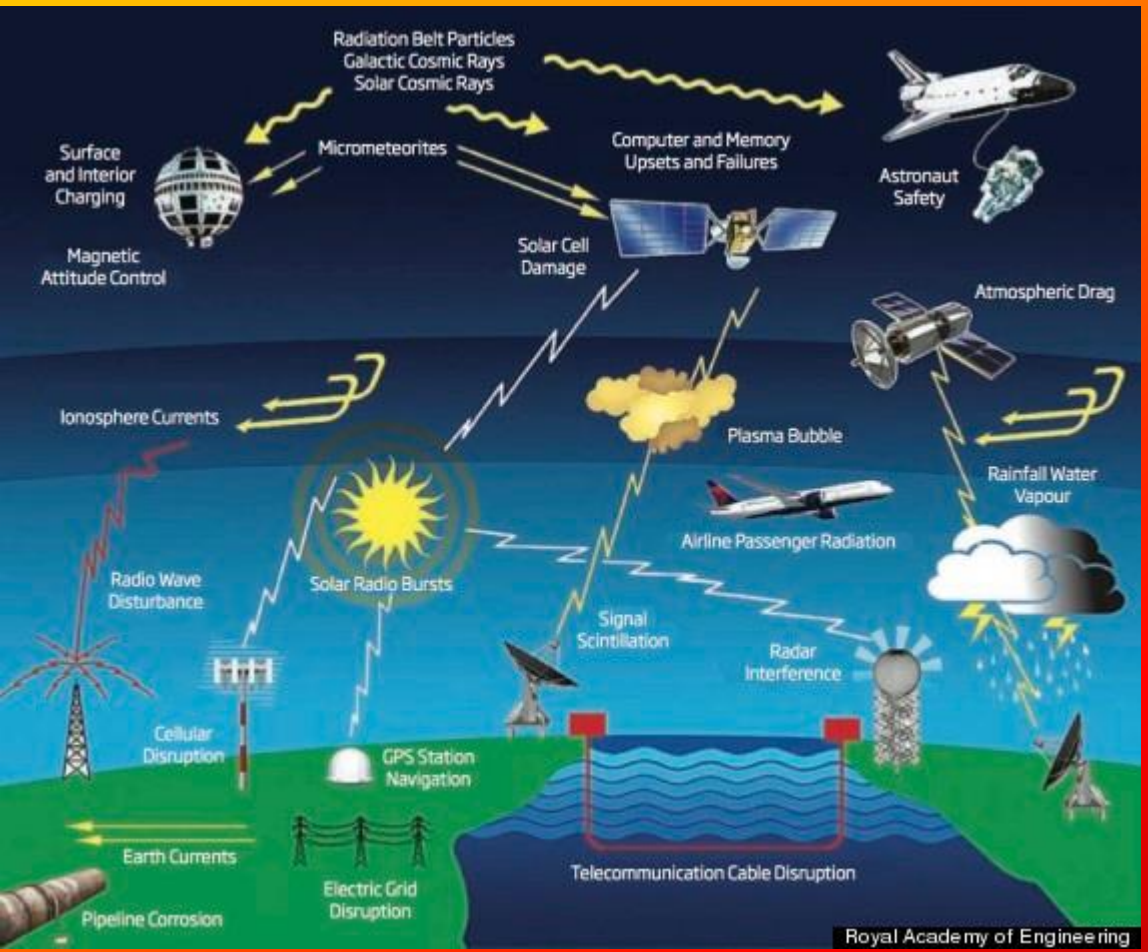
- Layer of electrons at the top of the atmosphere (100 – 300 km up)
- Formed when extreme ultraviolet light from the sun hits Earth's Atmosphere
- Strongly affected by changes in the magnetosphere
- Critical in the reflection and transmission of radio waves

# Sequence Of Events

**Active Region on the Sun Erupts**

1. **Solar Flare (x-ray)**
2. **Shock (energetic particles)**
3. **Corornal 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:

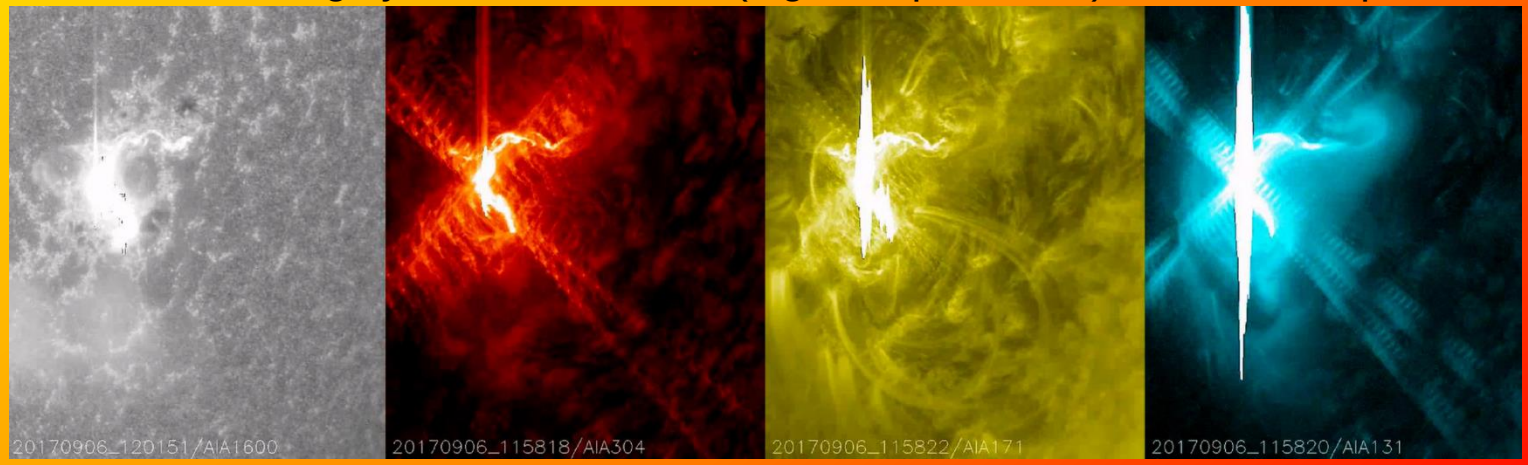
- ✓ Airline communication
- ✓ HF radio operators
- ✓ Satellite Communications
- ✓ Military Communications
- ✓ Astronauts (radiation)
- ✓ Satellite failures
- ✓ Electric Power Grids
- ✓ Increased Satellite Drag
- ✓ Aurora


- **What can we do to protect against space weather?**

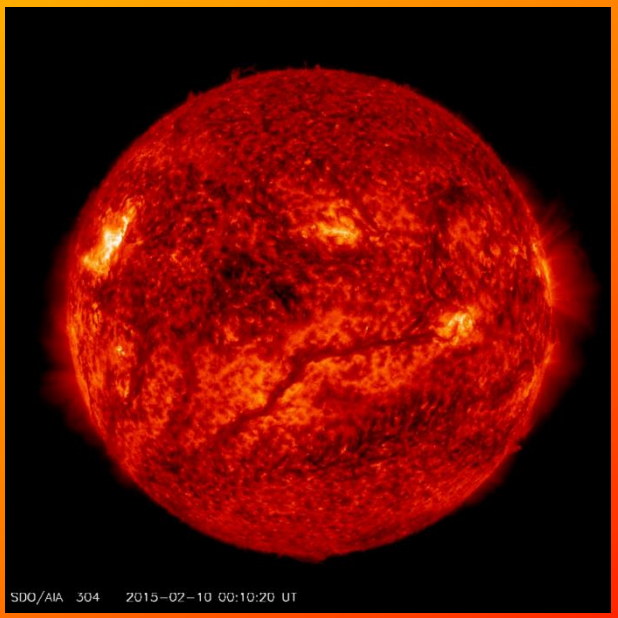
  - **Research, monitoring, worst-case planning**

# Available Dynamic Data: SDO (NASA) satellite

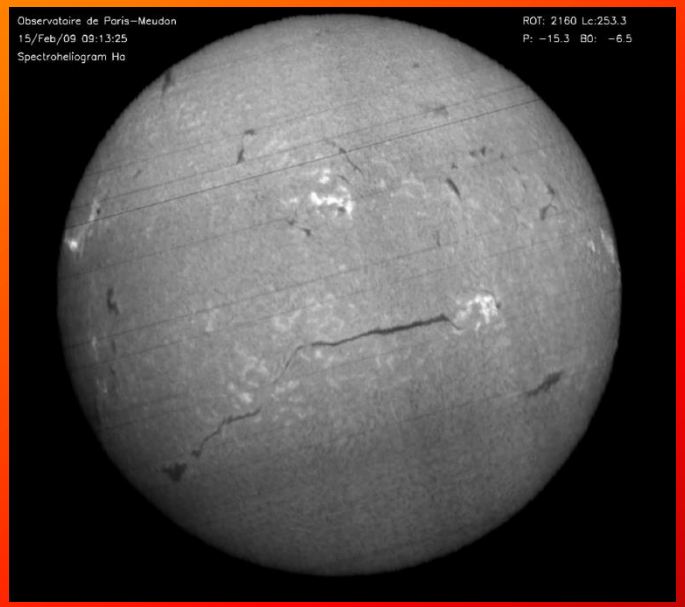
Continum and highly ionised  Fe lines (high temperatures). No chromospheric lines




$10^4$ K  $10^5$ K  $10^6$ K  $10^7$ K




HeII 80000K only corridors visible




Hα 8000K All kinds of filaments visible

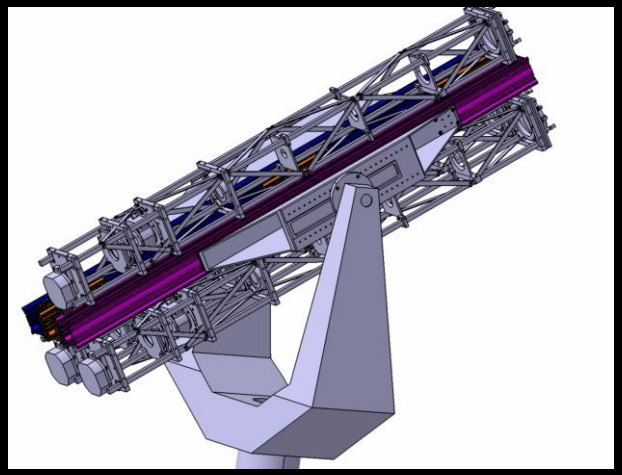
Filaments are associated to CME and their evolution is one of the the main phenomena that occur before solar eruptions .

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***

## 3 automated refracting telescopes at Calern (OCA)



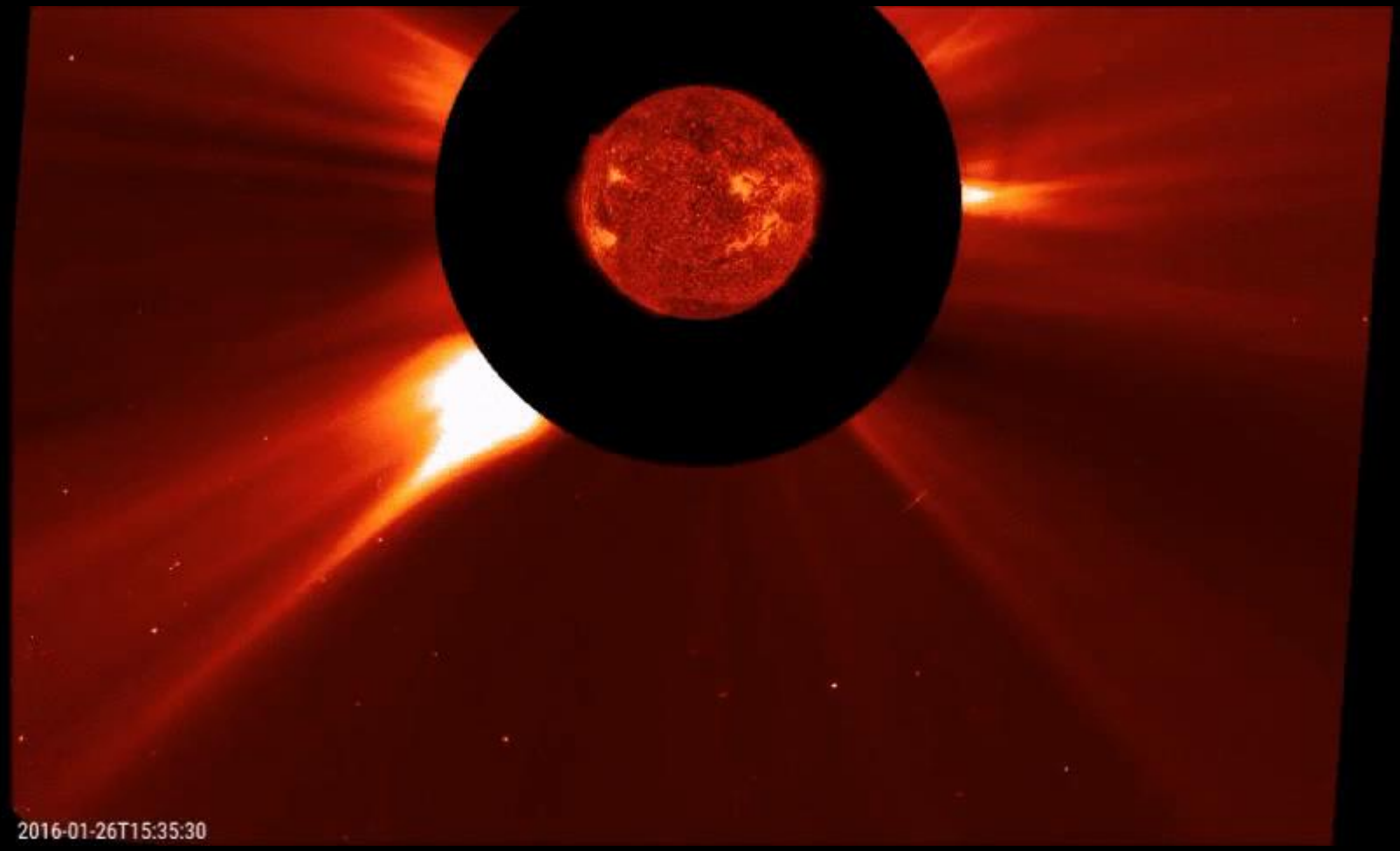
## Chromospheric monitor

- Halpha, 10 s cadence, Fabry Pérot DayStar 0.5 A
- Halpha, 10s cadence (blue wing)
- CaII K, interference filter 1.5 A

LUNA/OP/OCA

MeteoSpace

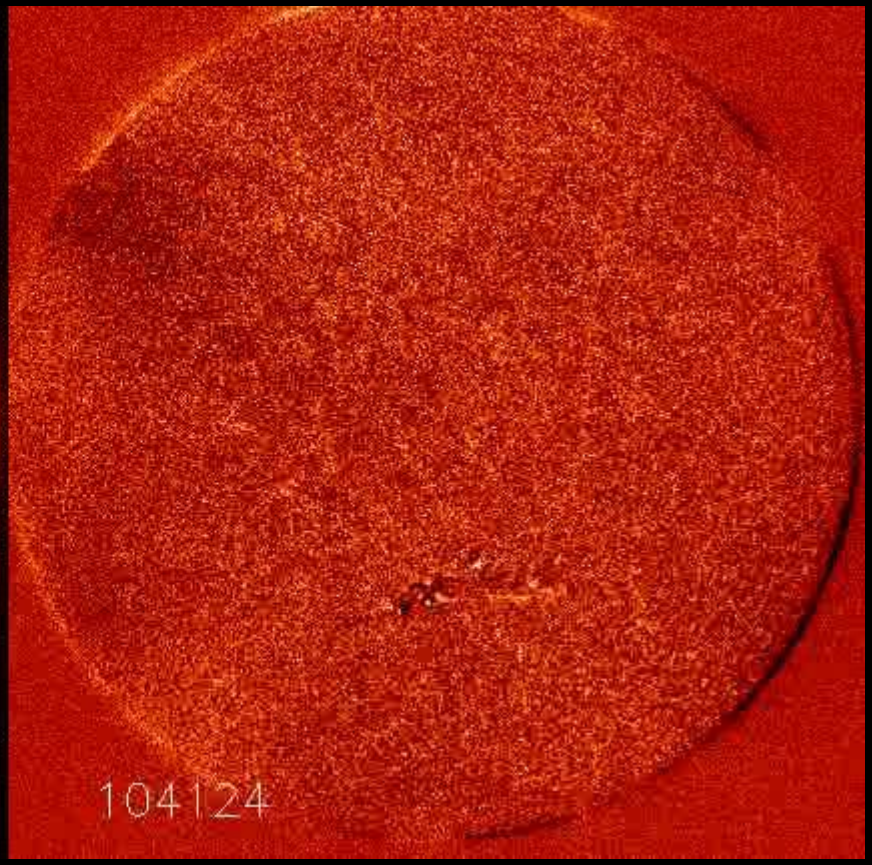
**Automated and continuous optical observation of dynamical phenomena at the source of solar activity: flares, *associated Moreton waves, Coronal Mass Ejection onset, filaments instabilities***



# 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

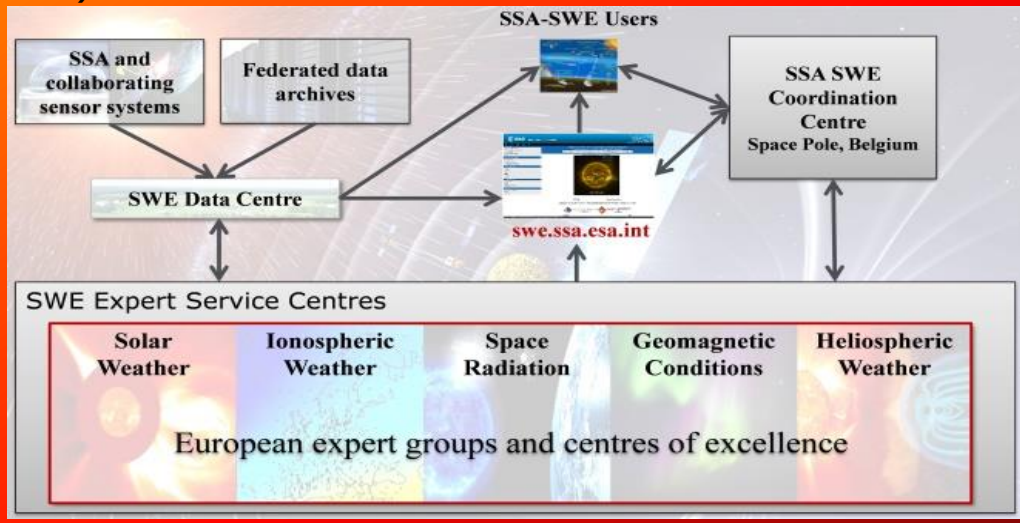

Federation of French Ground-based solar observations

Ground-based Support to Solar Orbiter

# French contribution to space-Weather: an extremely timely subject

The Space Situational Awerness (SSA) program of ESA :

- Survey and tracking of objects in Earth orbit
- Monitoring space weather (SWE segment)
- Watching for NEOs




France was not contributing to the phase 2 of the program but it has integrated the phase 3 in Dec. 2016

In 2017

- ✓ INSU has set up a group for developing a « National structure in space weather »
- ✓ CNES has created its own Working Group on Space-Weather

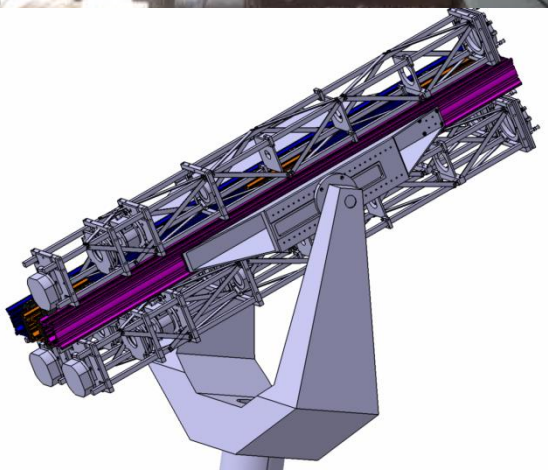
The International Civil Aviation Organization (ICAO) is planning to open an operational activity in Space-Weather in 2018.
DGAC has provided a list of potential  data provider including METEOSPCE for optical data.

FEdération des
DOnnées de
Météorologie
de l'Espace

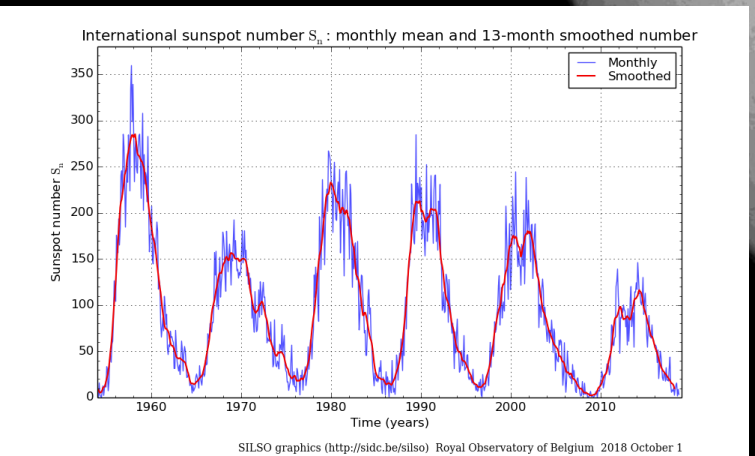
LUNA/OP/OCA

MeteoSpace

# Project completion schedule



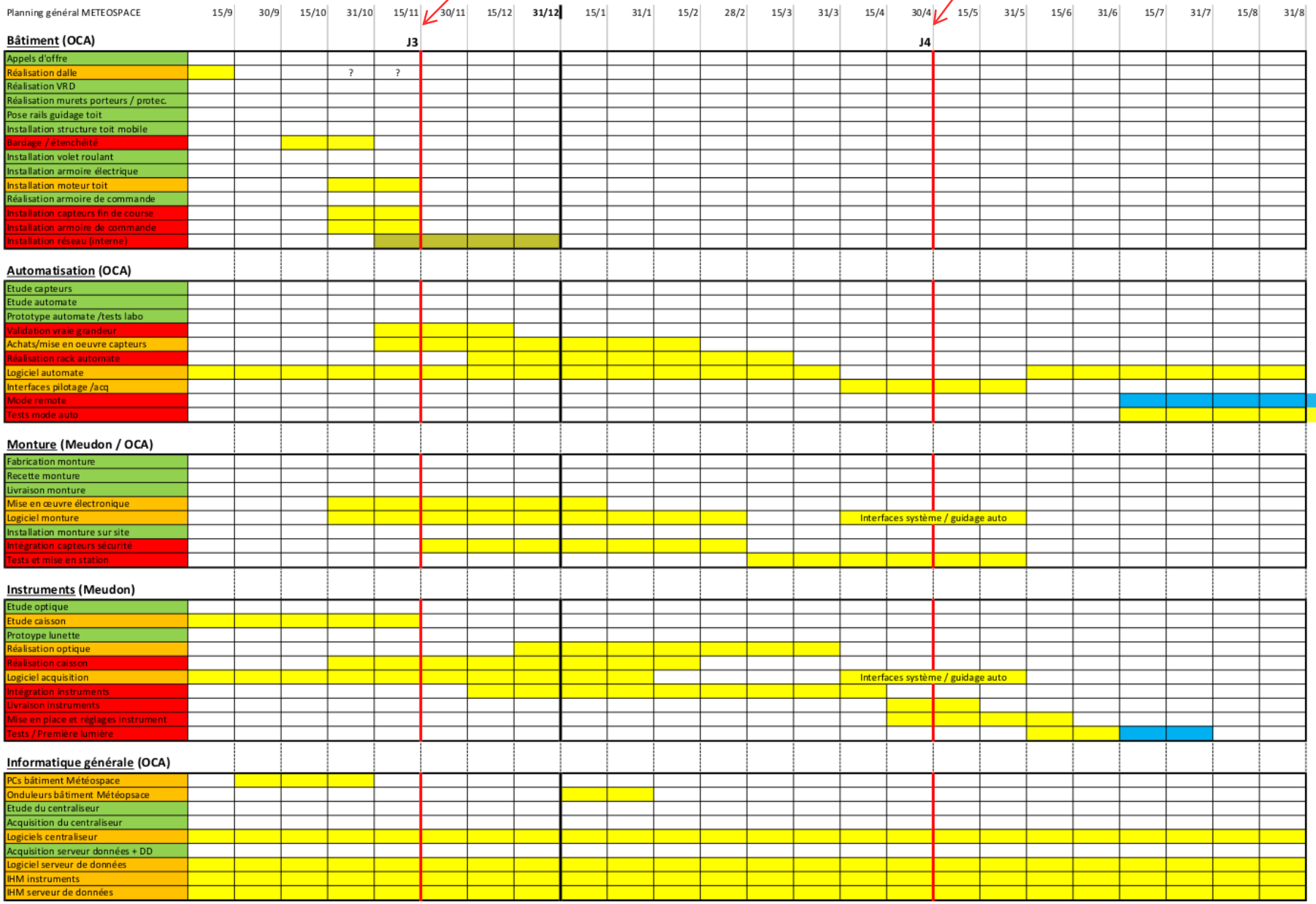
2018/09/10 Image from METEOSPACE prototype (Meudon)



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

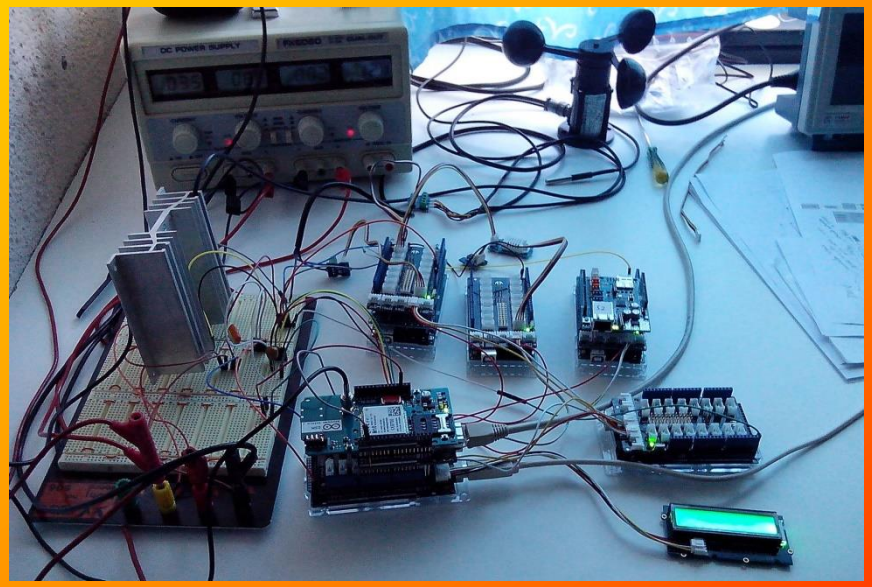
**Shelter completed Nov 15 2018**

**Instrument delivered May 1st 2019**




Switch to opérationnaml mode

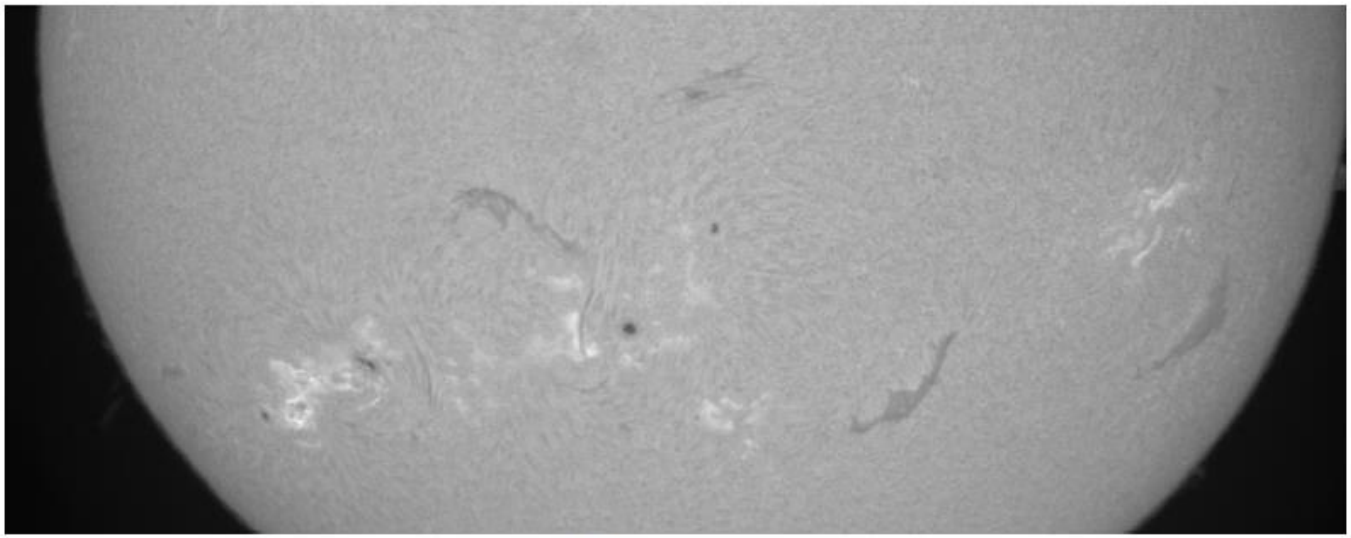
# Project completion schedule



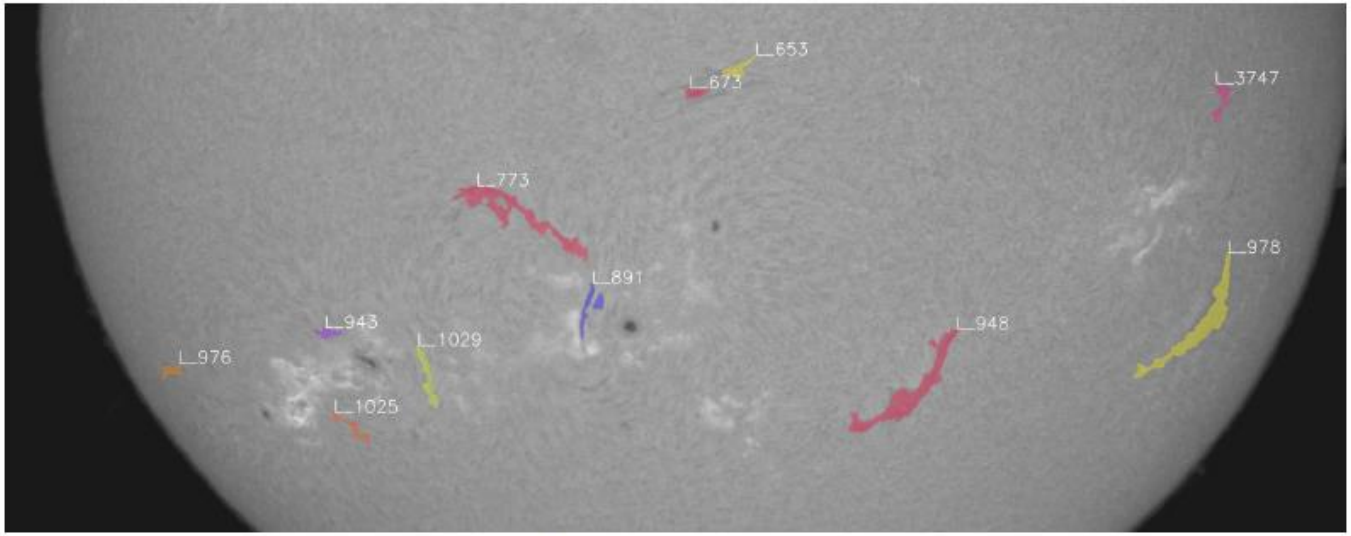
- Automated system for shelter control will be installed and tested during winter 2018-2019 (Financed by UCA JEDI Academy 3) Contribution of an engineering student for 2 months during summer 2017

- 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



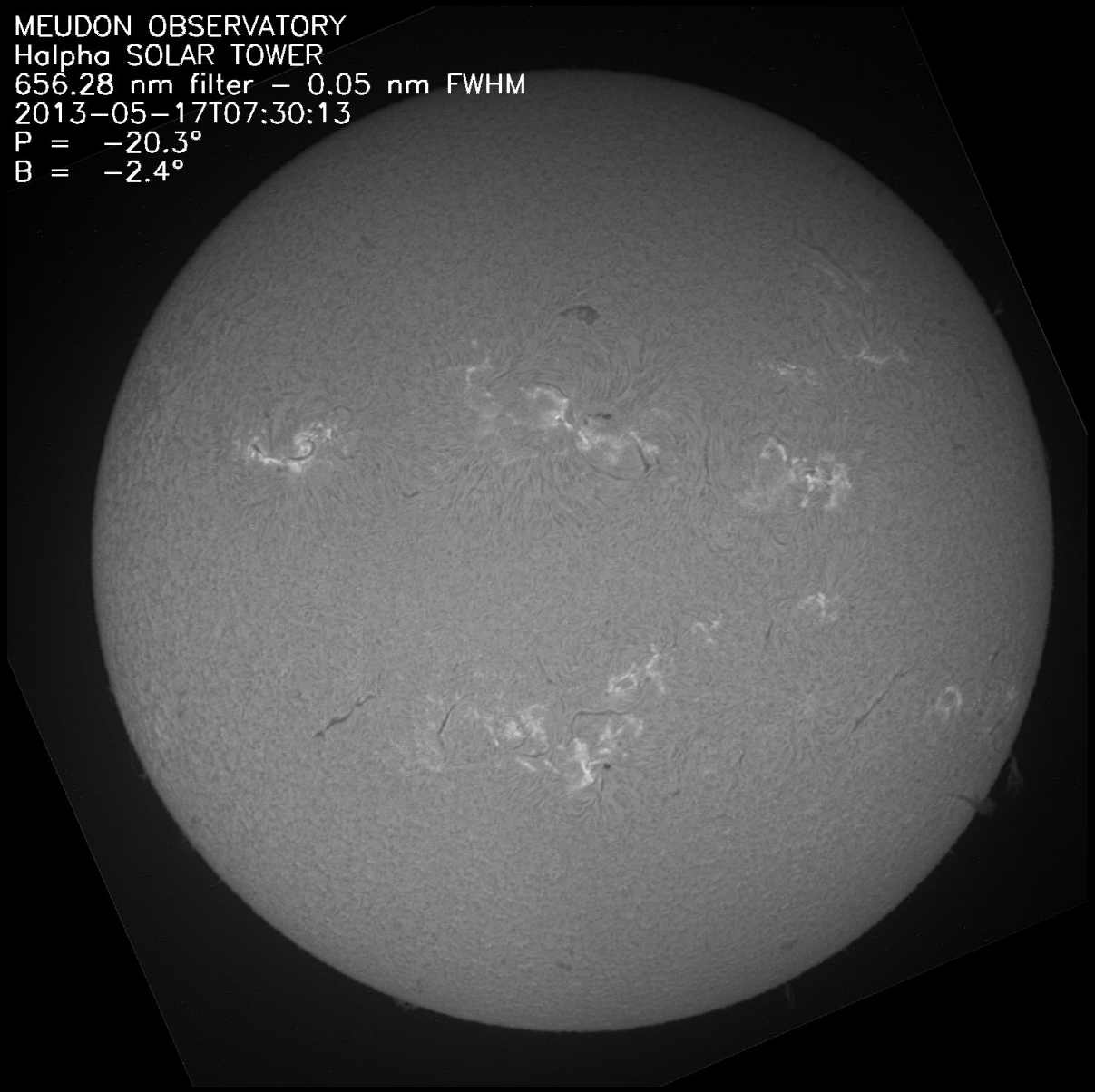
(a) Input image




(b) Filament detection result

Riegler† et al.

# Image stacking



THANKS FOR YOUR SUPPORT !!