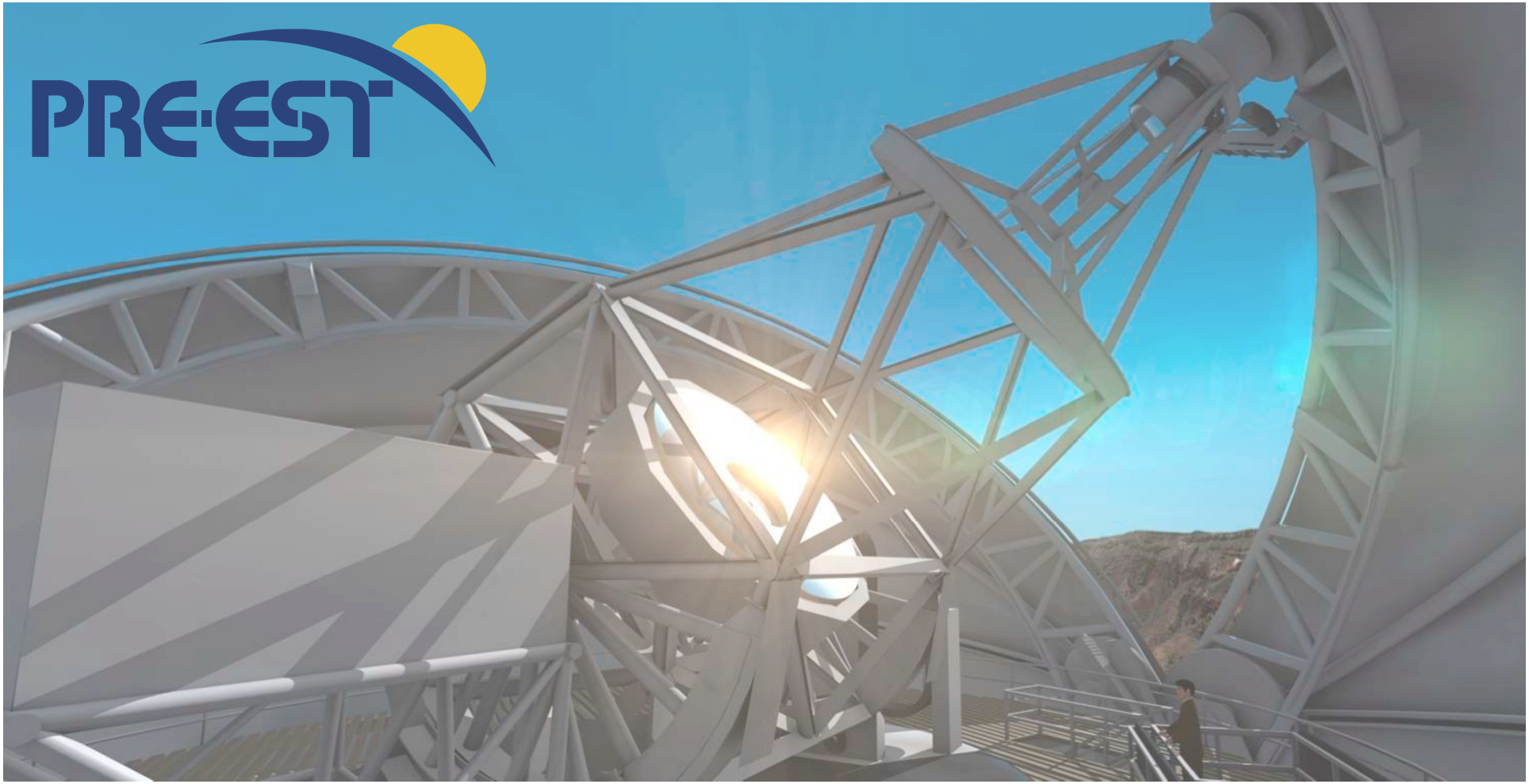


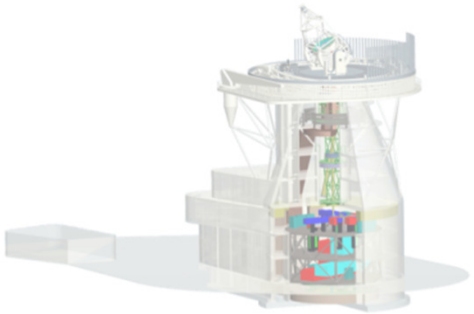
EST Multiwave-length diagnostics

Christoph Kuckein

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 739500"

Outline

- Why „multi-wavelength observations“?
- Coordinated observations nowadays
- Recent examples based on multi-wavelength analysis
- Why we need EST?



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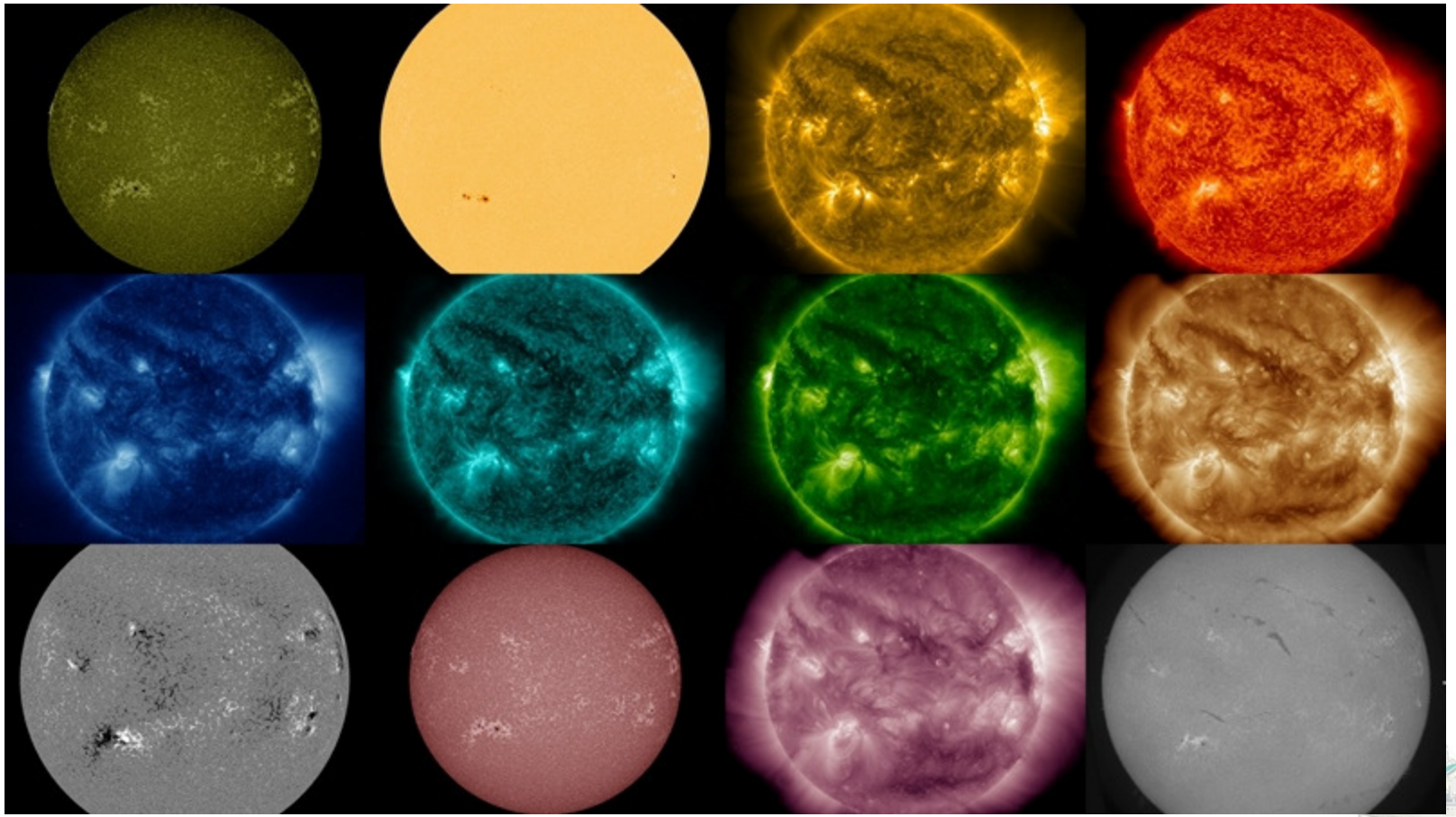
Why multiwavelength?



SDO and GONG images at different wavelengths

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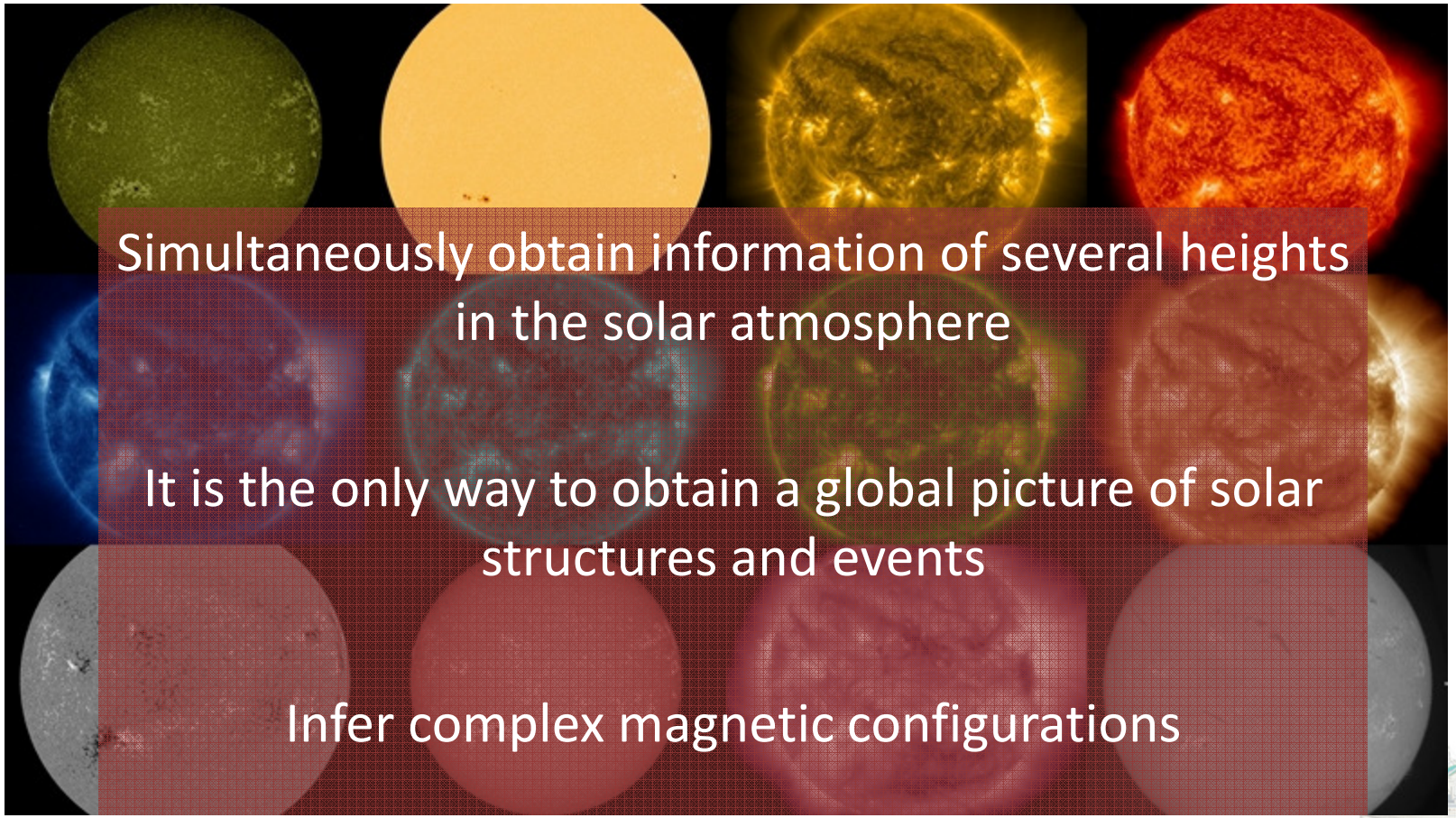
AIP

Why multiwavelength?



SDO and GONG images at different wavelengths

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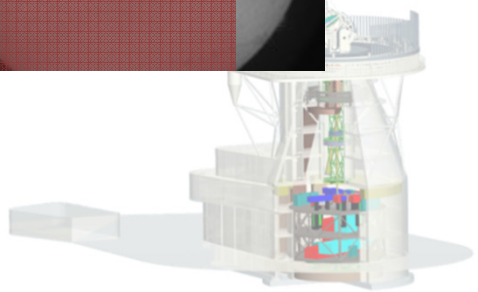
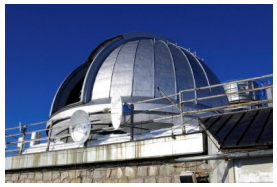
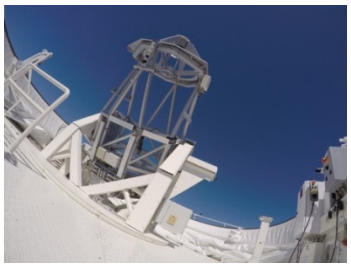
AIP



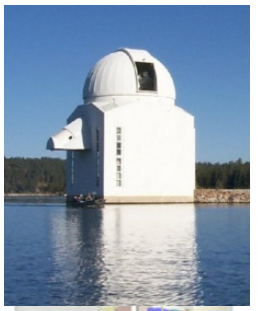
Telescopes

- Space: SDO, Hinode, IRIS, RHESSI, STEREO, ...
- Ground based high-res: GREGOR, VTT, THEMIS, SST, DST, NST@BBSO, NVST, Lomnicky Peak, ...







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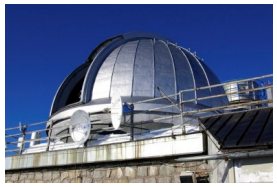
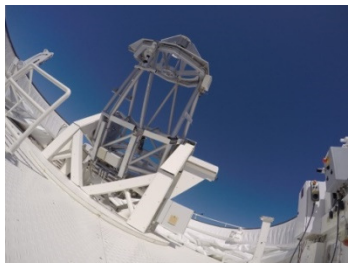
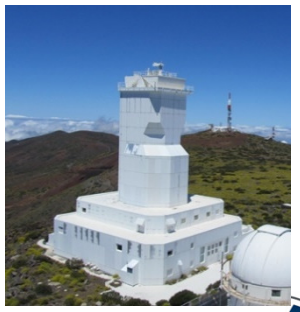
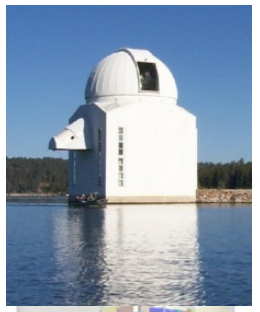
Telescopes

– Currently, largely-covered high-resolution multi-wavelength observations are only possible by coordinating several ground-based and space telescopes









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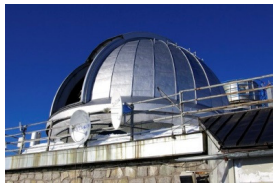
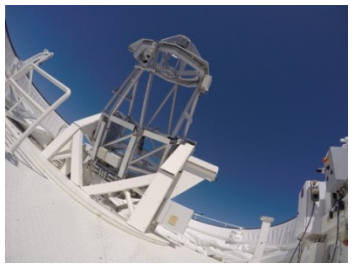
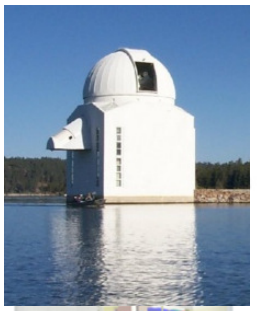
Telescopes

- Disadvantages:
  - Coordination itself (no worldwide TAC)
  - Different weather and seeing conditions
  - Telescopes are located in different time zones
  - Alignment between data, ...





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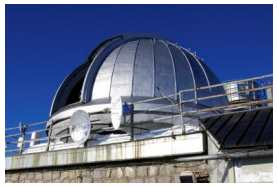
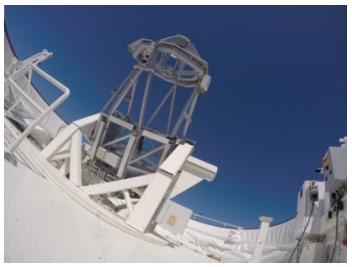
Coordinated campaigns

- Kuckein et al. (May 2018):
  - Ground based: GREGOR, VTT, SST, NVST, Lomnicky Peak
  - Spectral lines from ground: Ca H 3968,

  blue cont. 4505, Na 5890 or Fe 5434, Fe 6302,

  Hα, TiO, Ca 8542, Si 10827, He 10830, Ca 10839
  - Space: IRIS, SDO







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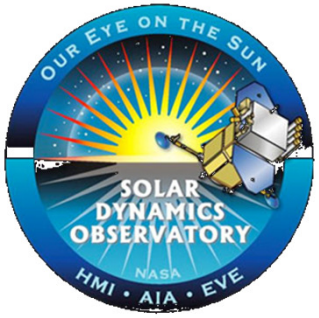
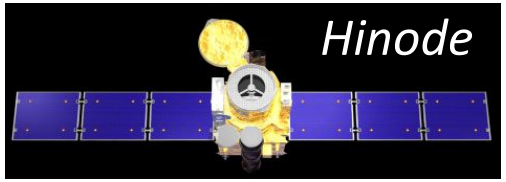
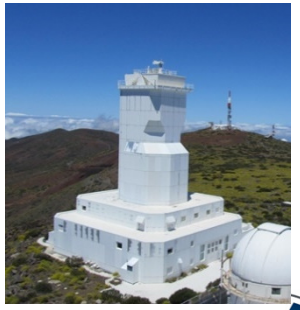
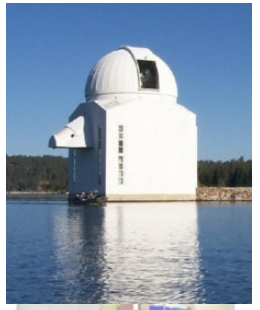
Coordinated campaigns

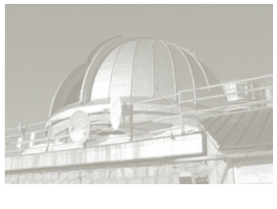
- Verma et al. (September 2016):
  - Ground based: GREGOR, VTT, NST, DST
  - Spectral lines from ground: Ca K, G-band 4307, blue cont. 4505, Hβ, Fe 5434, Na 5890, Fe 6173, Hα, TiO, Ca 8542, Si 10827, He 10830, Ca 10839
  - Space: IRIS, Hinode, SDO

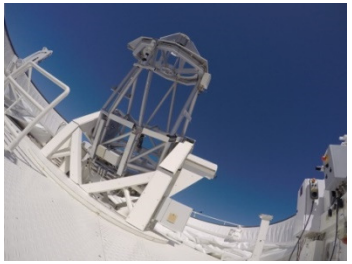


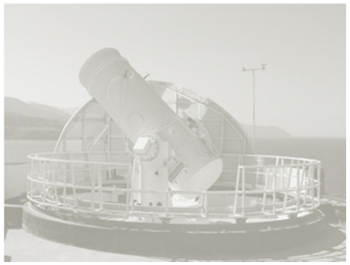












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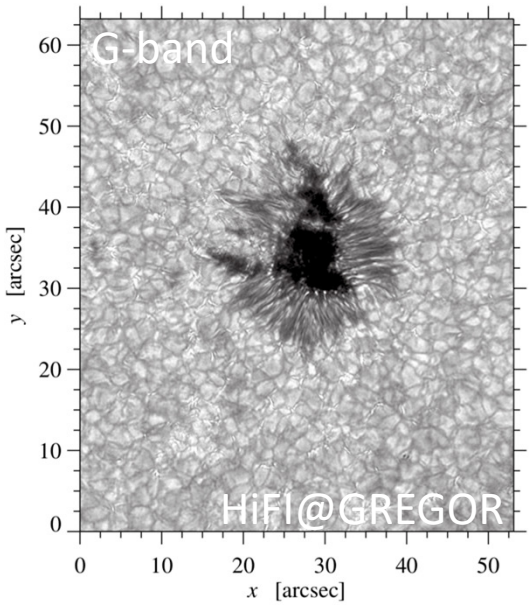
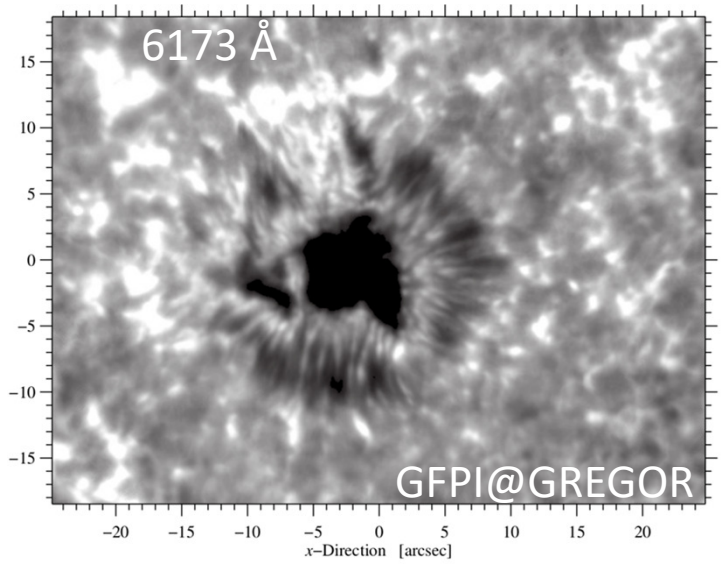
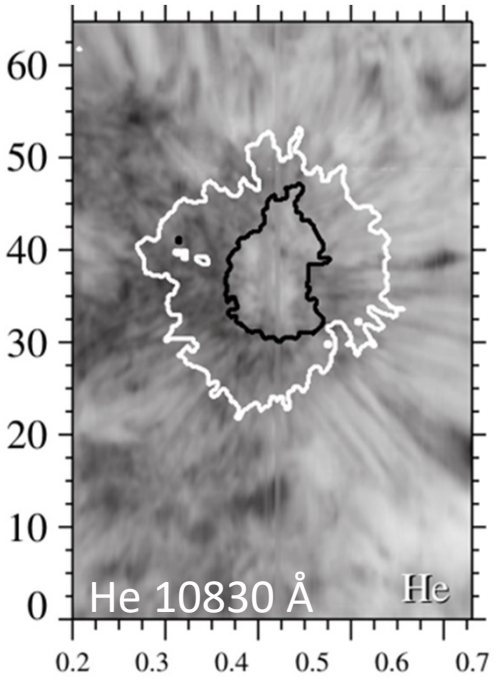
Coordinated campaigns

– Verma et al. (September 2016):
  - Examples: GREGOR, VTT, Hinode

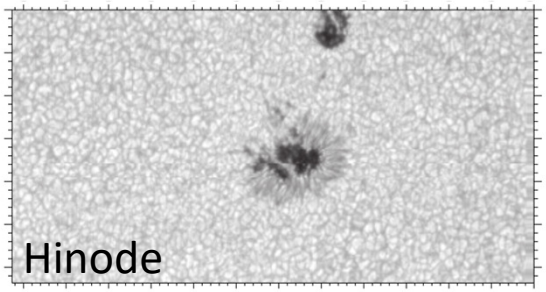


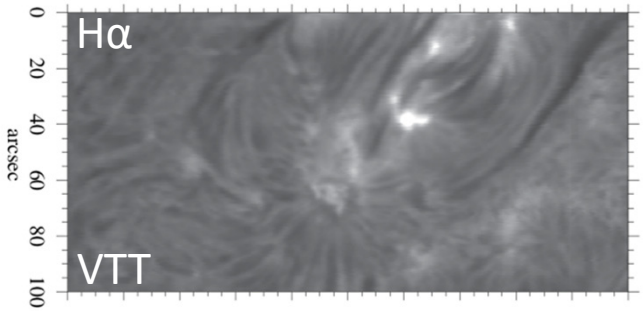


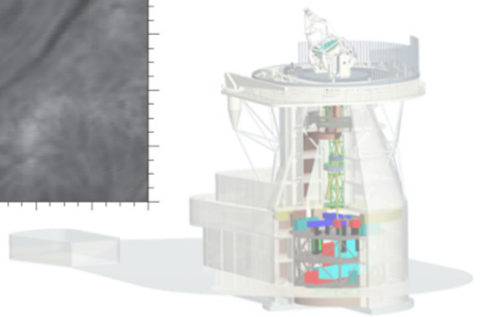
Verma et al. 2018



GRIS@GREGOR







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EST multi-wavelength capabilities

„One ring to rule them all“

(*J. R. R. Tolkien's The Lord of the Rings*)

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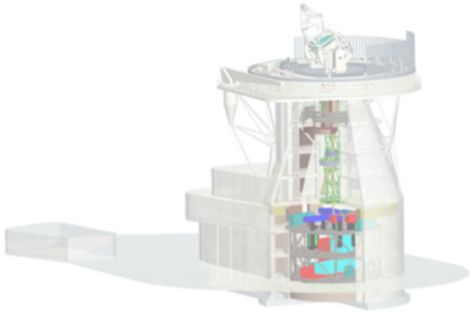
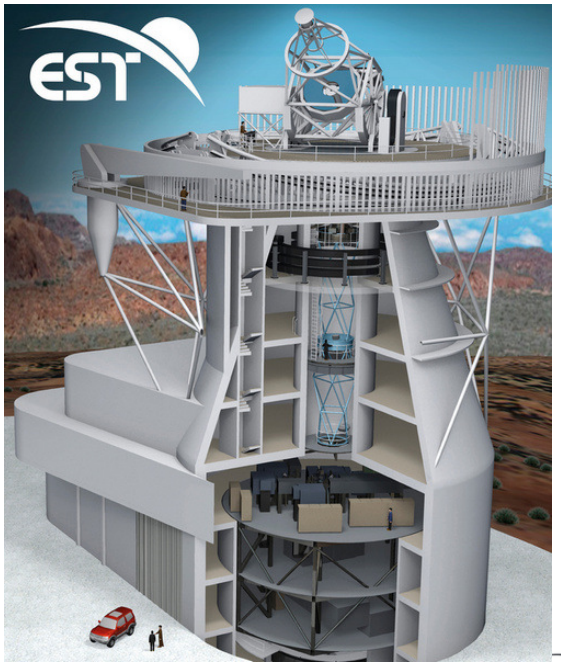


EST multi-wavelength capabilities

„One telescope to observe them all“

(*EST*)



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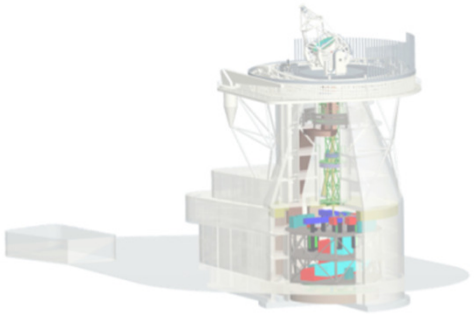

Science cases based on multi-wavelength analysis

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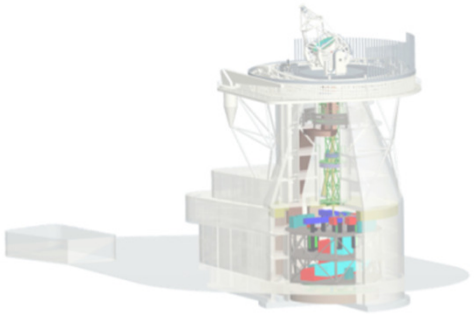
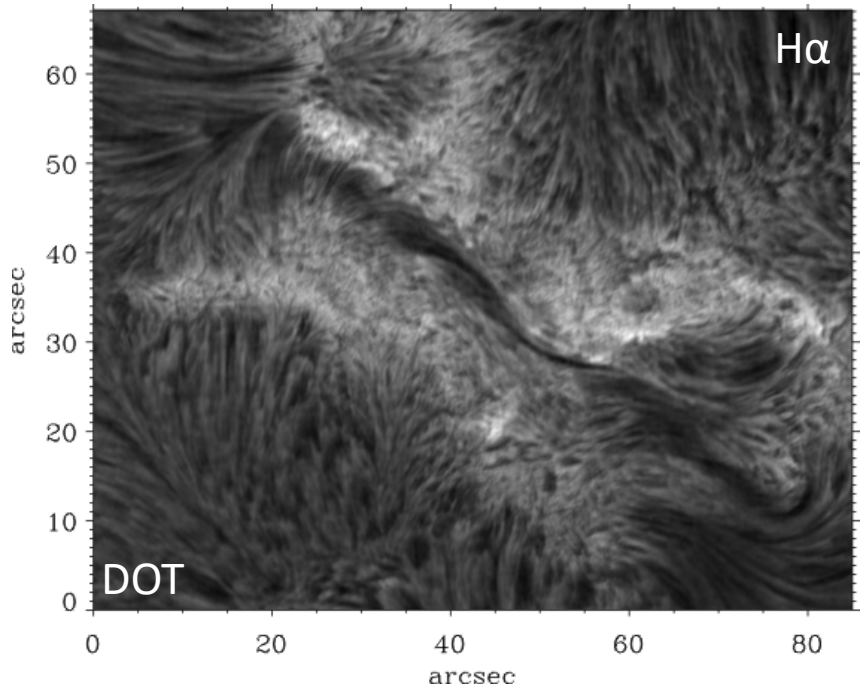
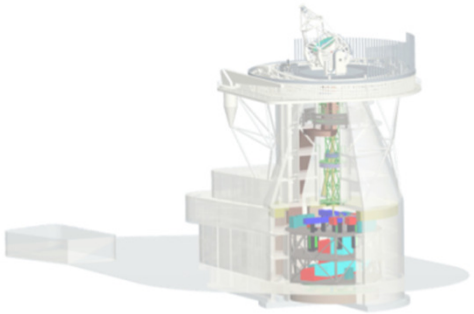


„Active region filaments“





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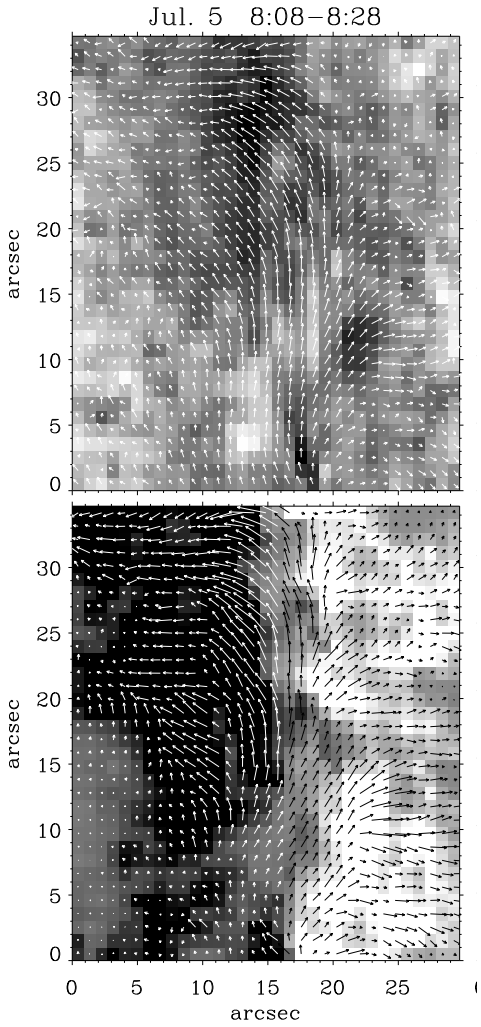
AR filaments

Chromosphere

Photosphere

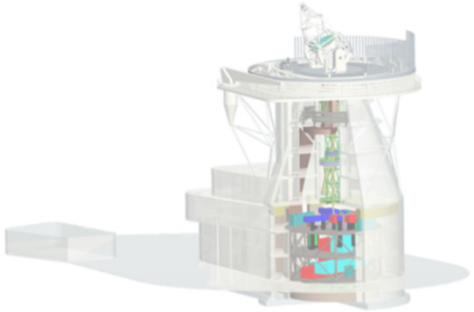


Kuckein et al. 2012

Multiwavelength study of an AR filament in the photospheric Si I 10827 Å line and in the chromospheric He I 10830 Å triplet

Full-Stokes spectropolarimetric observations with the Tenerife Infrared Polarimeter @ VTT (Tenerife)

High-resolution imaging simultaneously with the DOT (La Palma)



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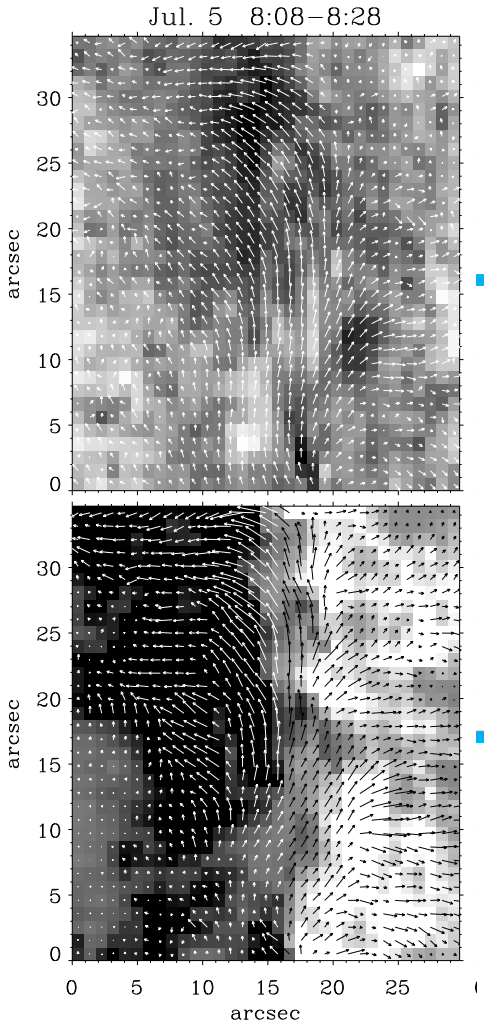
AIP

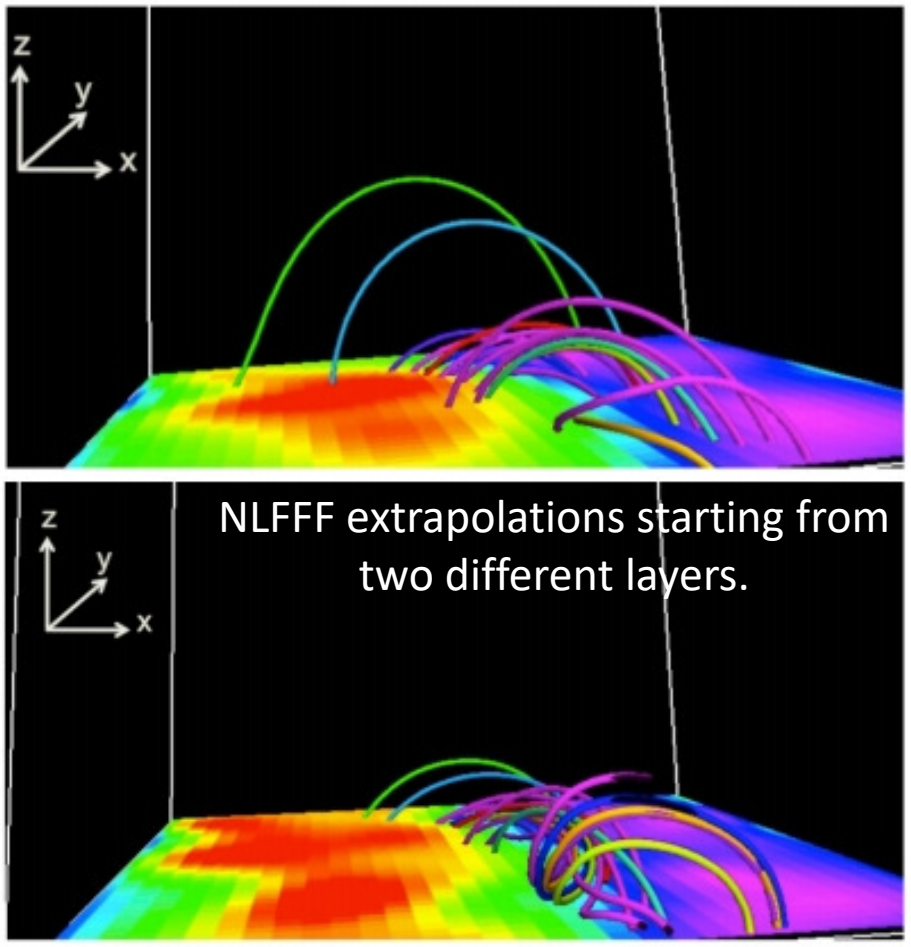
AR filaments

Chromosphere

Photosphere



Kuckein et al. 2012



Chromosphere

Photosphere

Yelles Chaouche et al. 2012

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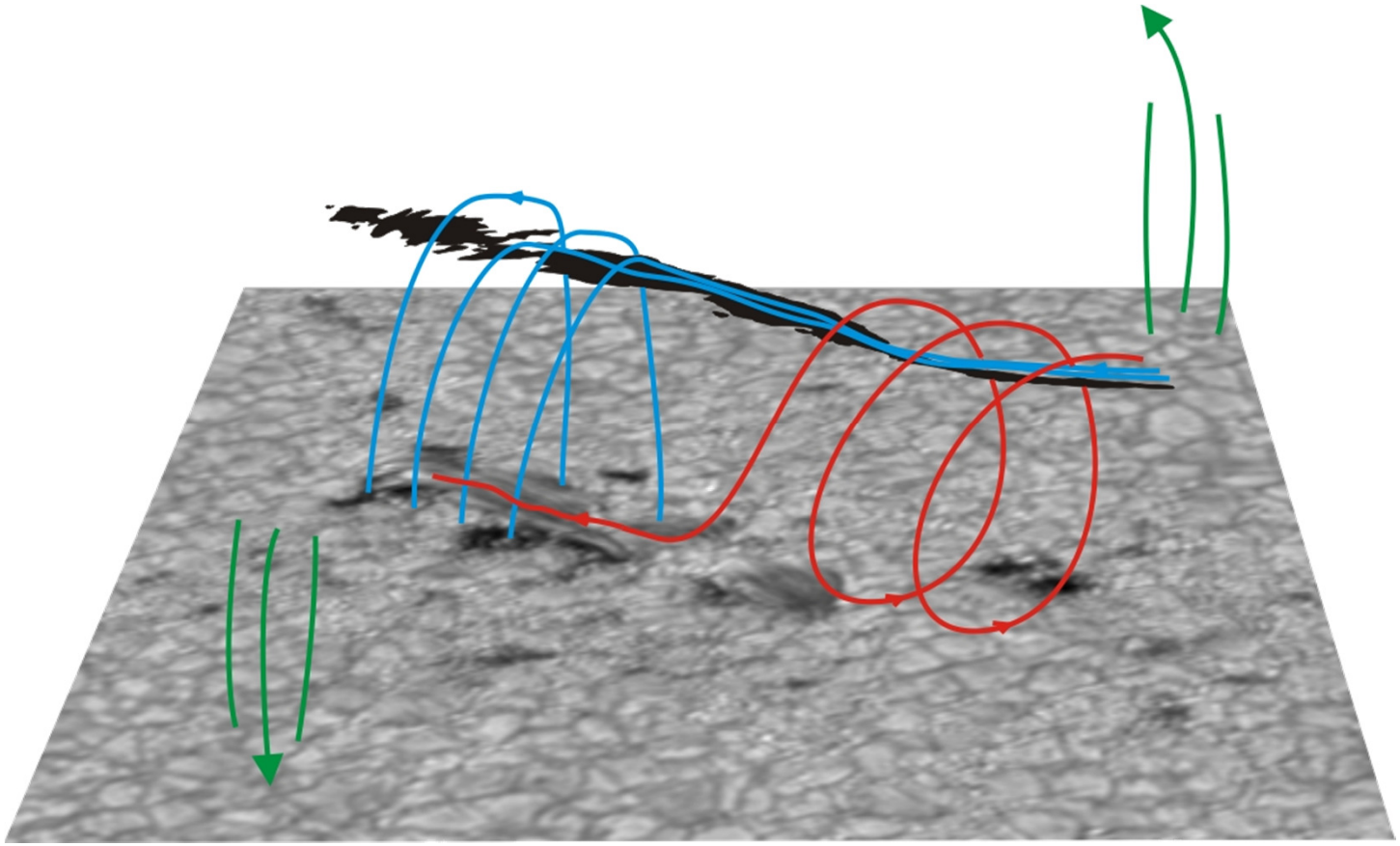
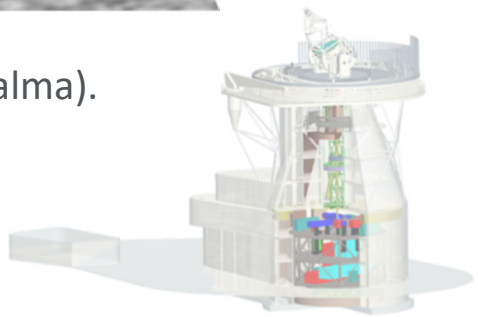
AIP

AR filaments



Surface image corresponds to a continuum image from the DOT (La Palma).
Figure taken from Kuckein et al. 2014.



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„Arch filament system“

Formation of an AFS observed at GREGOR & SST

(2015 April 17)

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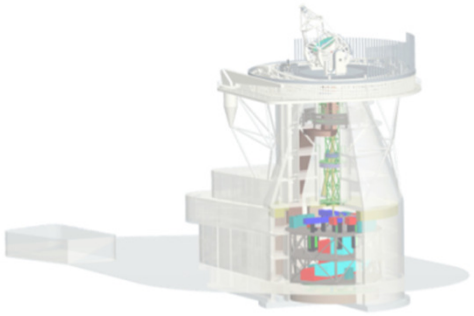
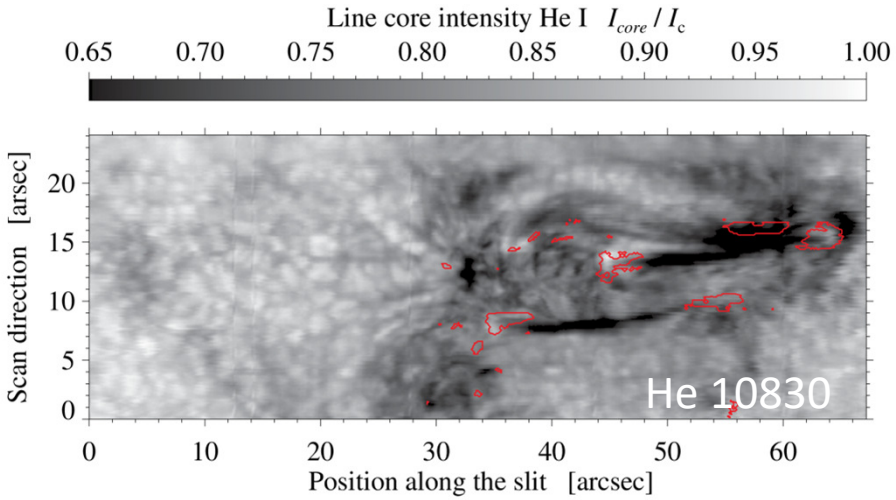


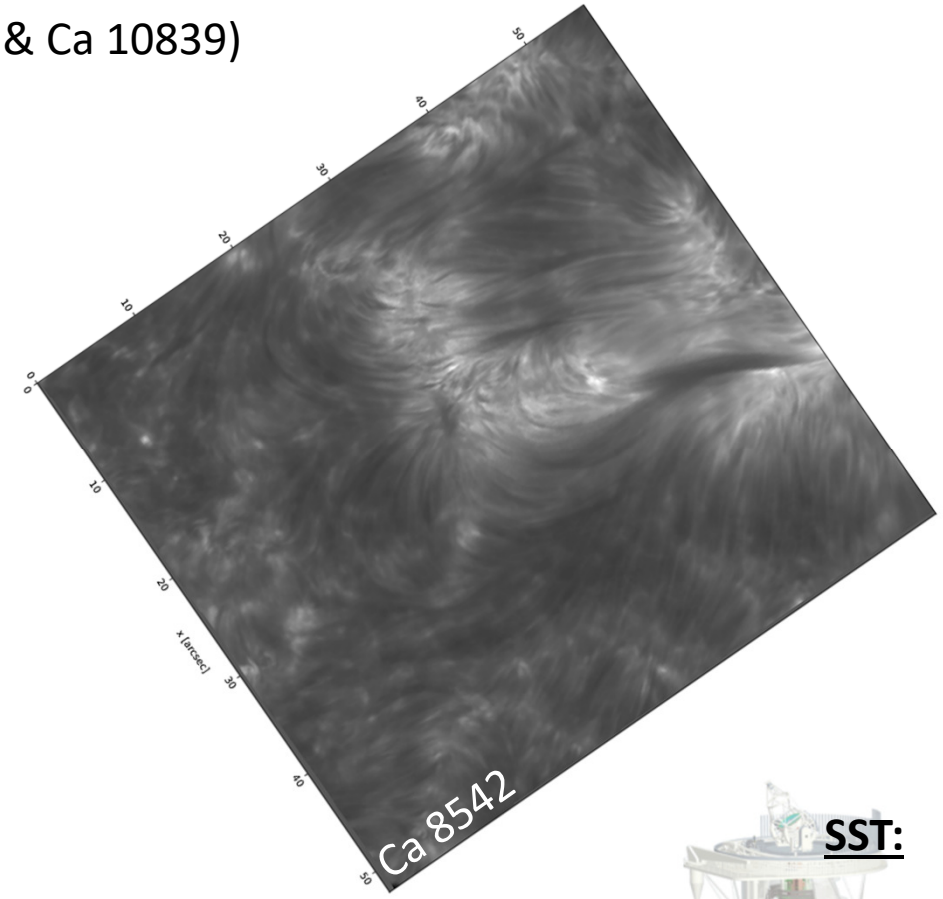
Arch filament system

GREGOR:

GRIS fast slit spectroscopy (Si 10827, He 10830 & Ca 10839)

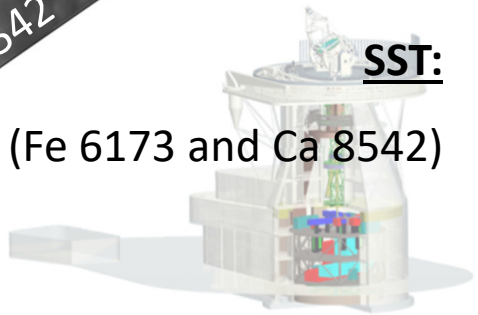


González Manrique et al. 2018 (in preparation)



SST:

CRISP imaging spectropolarimetry (Fe 6173 and Ca 8542)



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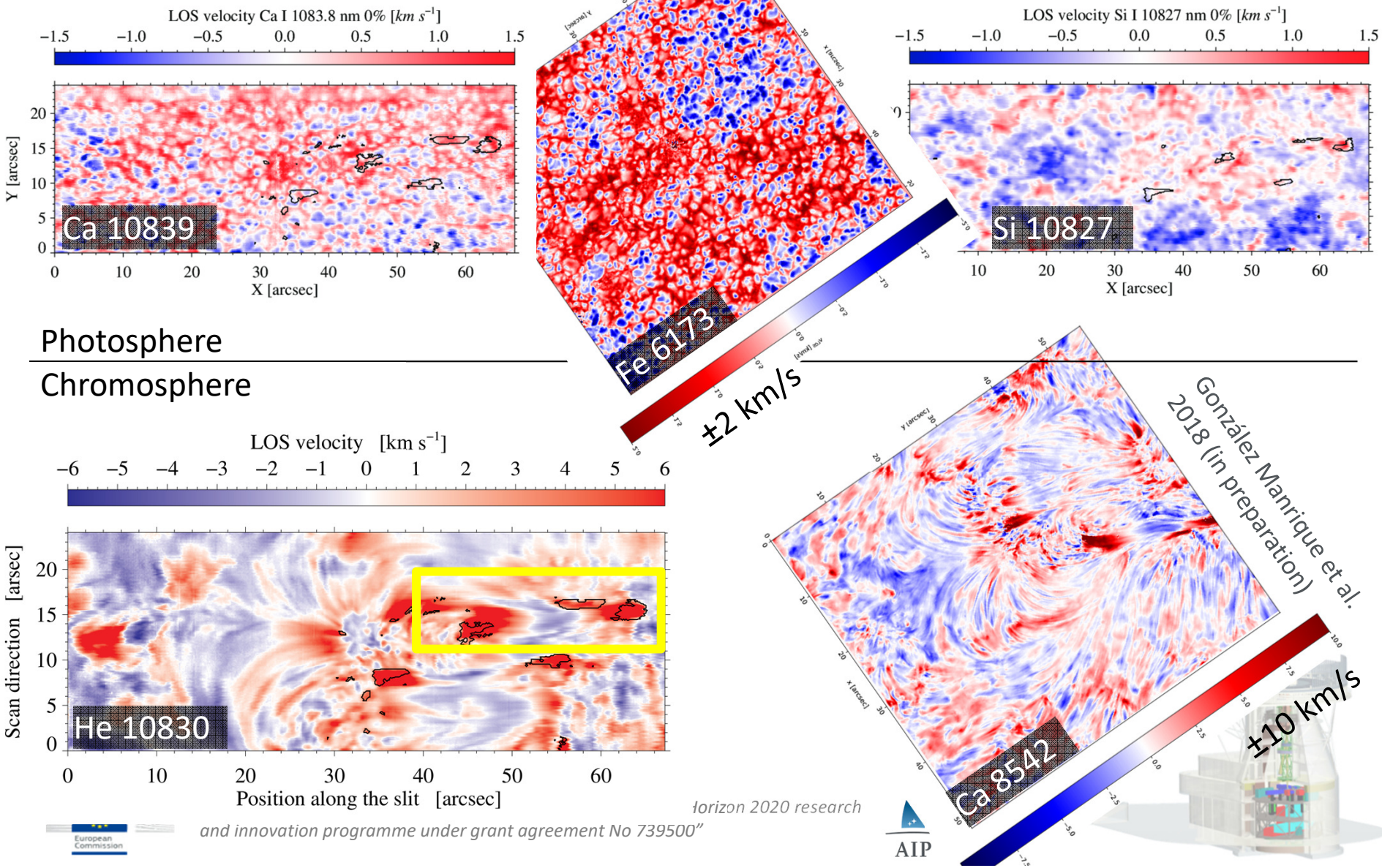
Arch filament system



Horizon 2020 research and innovation programme under grant agreement No 739500"

„Flares“

X1 flare

(2014 March 29; best covered flare)

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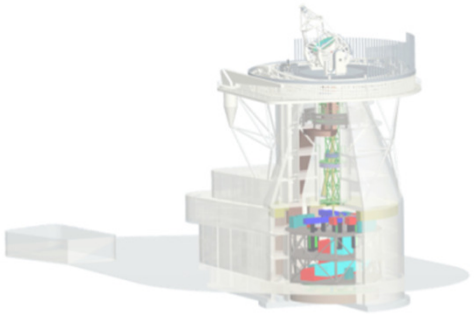
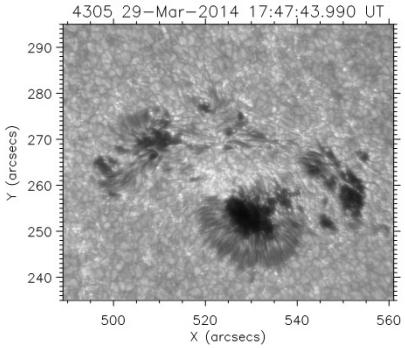
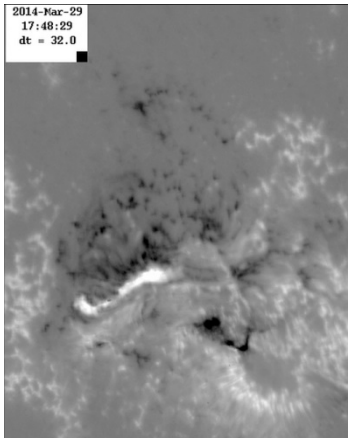


X1 flare (2014 March 29)



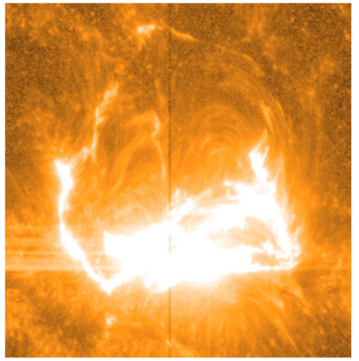


Dunn Solar Telescope (observing campaign):

- IBIS (Fe 6302, Ca 8542 polarimetry, Hα Intensity)
- FIRS (He 10830 spectropolarimetry)
- Imaging: Ca K & G-band

IRIS:

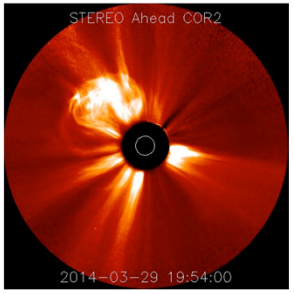
- Slitjaw 1400, 2796, 2832
- 8-step raster (FUV+NUV)



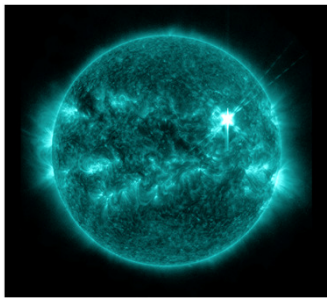
Hinode:

- SP raster (just finished when flare began)
- Na IV shutterless
- Ca H intensity
- EIS, XRT

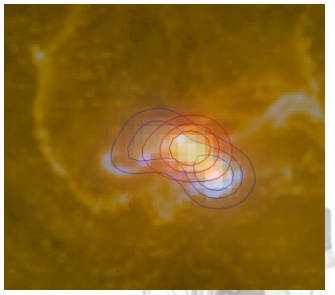
STEREO:



SDO:



RHESSI:



- Kleint, ApJ 834, 26, 2017
- Kleint et al, ApJ 2015, 2016
- Judge et al, ApJ 796, 85, 2014
- Heinzel & Kleint, ApJL 794, 24, 2014
- Young et al, ApJ 799, 218, 2014

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AIP

„Magnetic flux emergence“

Emergence from the photosphere to the corona

(2013 September 25)

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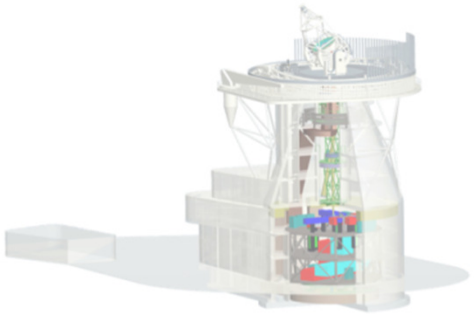


Emergence from the photosphere to the corona

Swedish Solar Telescope (SST)

CRISP

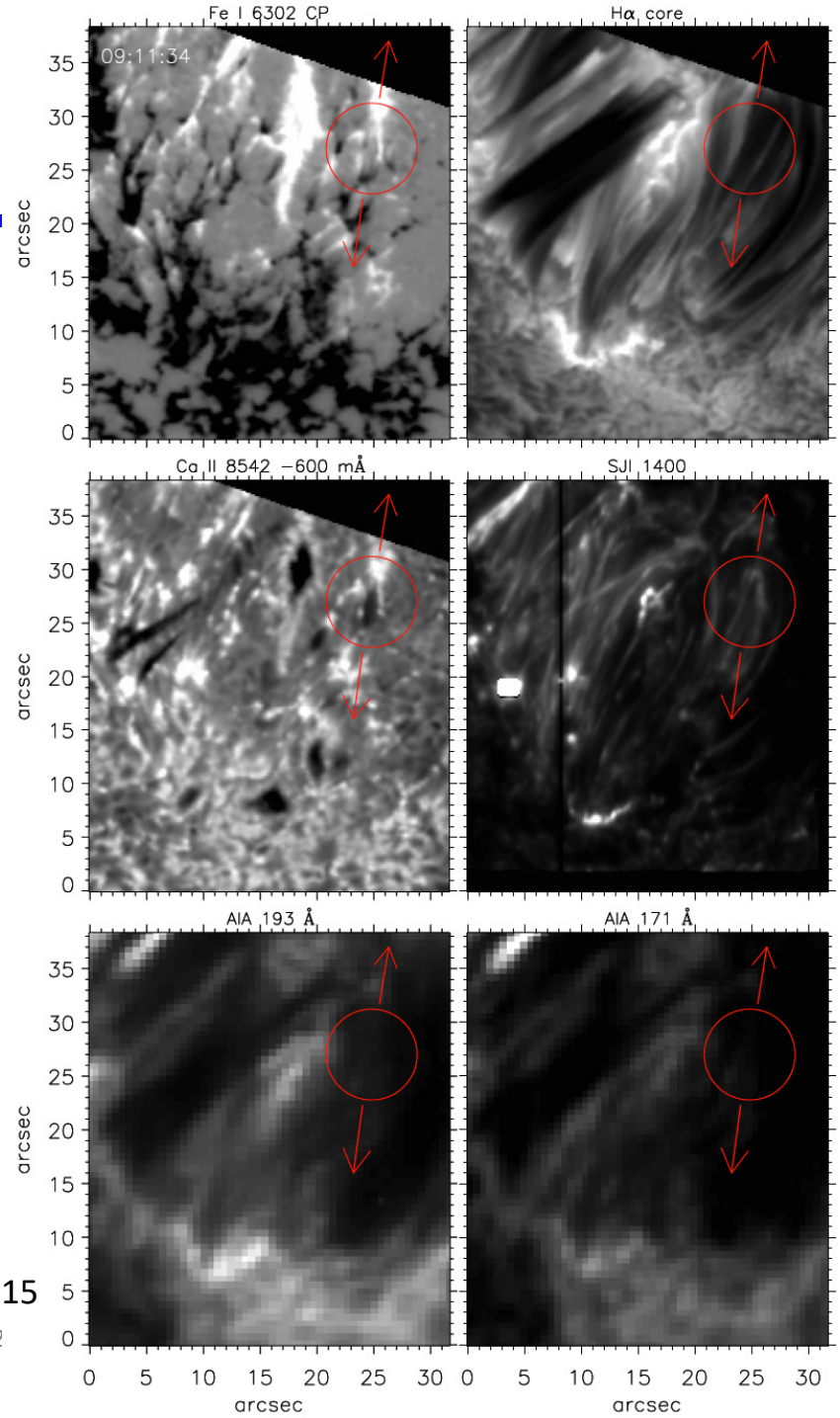
- Fe 6302.5 Å (polarimetry)
- 6563 Å and Ca II 8542 Å (Intensity)

IRIS

- Slit-jaw images:
  - 1330 (TR), 1400 (TR), 2796 (upper chrom.) and 2832 Å (photosphere)
- Rasters in 3 spectral windows:
  - FUV 1: 1331.6 - 1358.4 Å (C II)
  - FUV 2: 1380.6 - 1406.6 Å (Si IV)
  - NUV: 2782.6 - 2833.9 Å (Mg II k)

SDO

- AIA
  - 171 Å (Fe IX, upper TR)
  - 193 Å (Fe XII, corona)
  - 304 Å (He II, chromosphere & TR)
- HMI photospheric magnetograms



Ortiz et al. 2014, 2016
de la Cruz Rodríguez et al. 2015

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„Oscillations“

Height variation of the cutoff frequency in the sunspot umbra

(2017 June 17)

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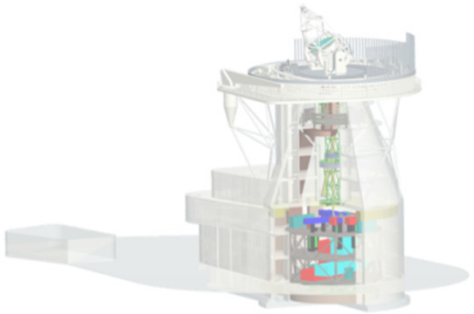
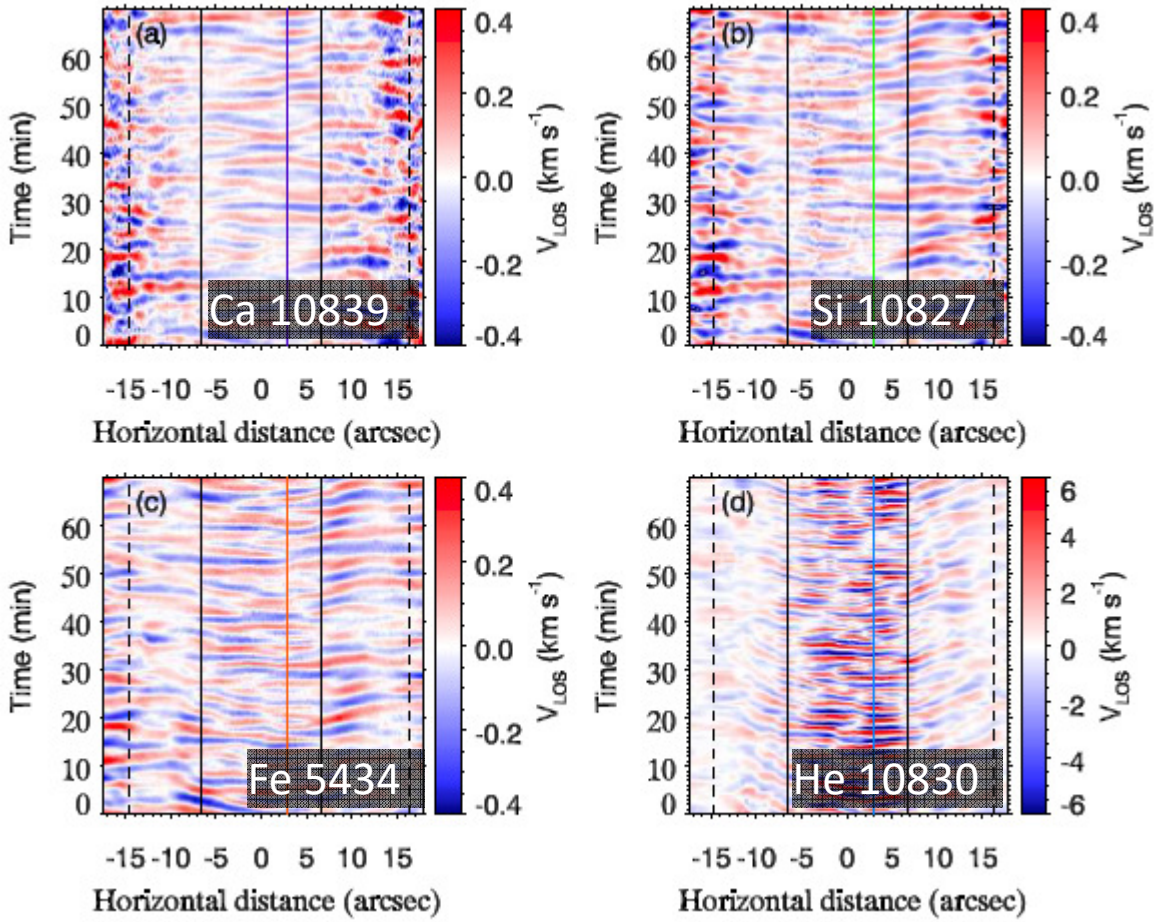


Height variation of the cutoff frequency in the umbra

GREGOR combining 2 instr.:

- GRIS sit-and-stare slit spectropolarimetry (Si 10827, He 10830 & Ca 10839)
- GFPI imaging spectroscopy (Fe 5434)
- Sampled heights ~ 60 km, 340 km, 510 km
- Conclusions: evidence of the variation of the cutoff frequency with height in a sunspot umbra



Felipe , Kuckein, & Thaler 2018 (A&A accepted)

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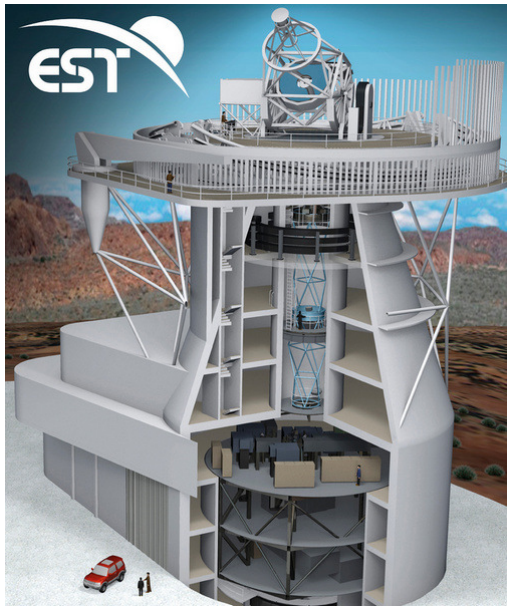
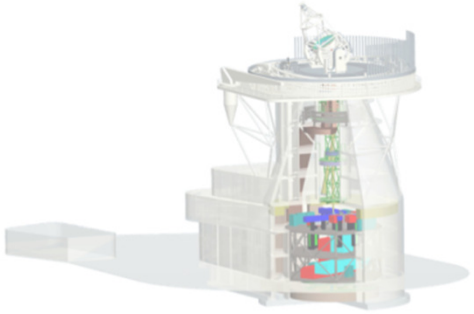
AIP

EST multi-wavelength capabilities

Summary of multi-wavelength analysis

- Track plasma flows across several heights of the solar atmosphere to study the dynamics of solar features and energetic events.
- Infer the vector magnetic field at different heights → input for NLFFF extrapolations.





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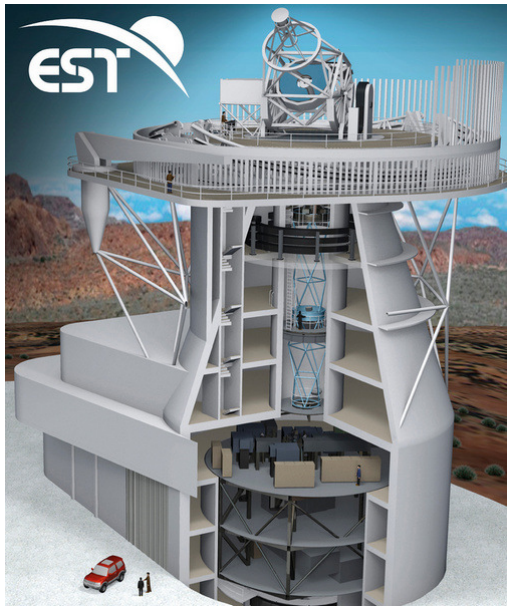
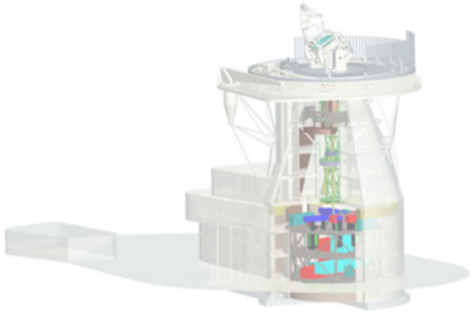
EST multi-wavelength capabilities

Why we need EST?

- Currently, co-observations with other telescopes is difficult and combining their data is very time consuming and needs to be done individually for each data set.
- We have seen that the **multi-wavelength analysis is crucial nowadays to further understand our Sun**.
- EST will observe in many spectral lines at the same time, using the most suitable instruments for each line to achieve the science goal. Combining different instruments becomes much easier.





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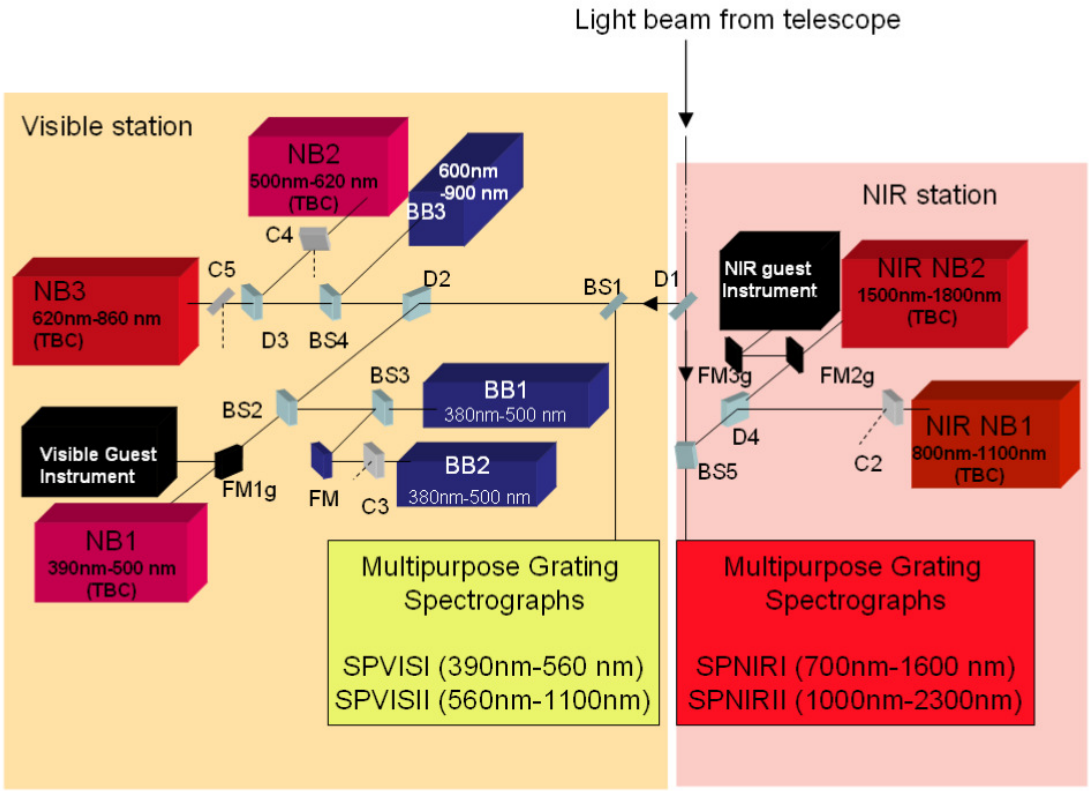
EST multi-wavelength capabilities



Conceptual design report (2011) (obsolete!)

Design will be updated following the recomendations of the Science Requirement Document written by the Science Advisory Group (SAG)

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Thanks

Christoph Kuckein

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