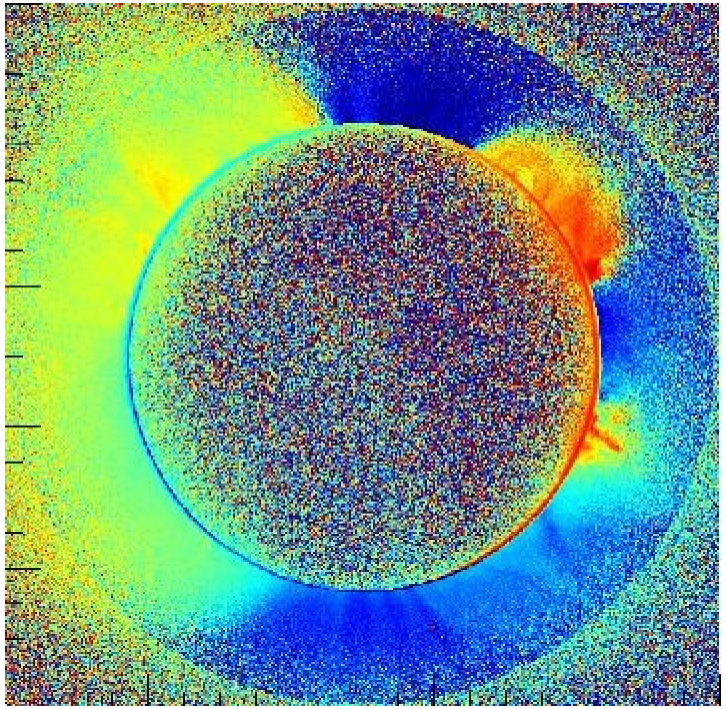
Coronal Spectro-polarimetry with the Turin Lyot-Filter



Silvano Fineschi

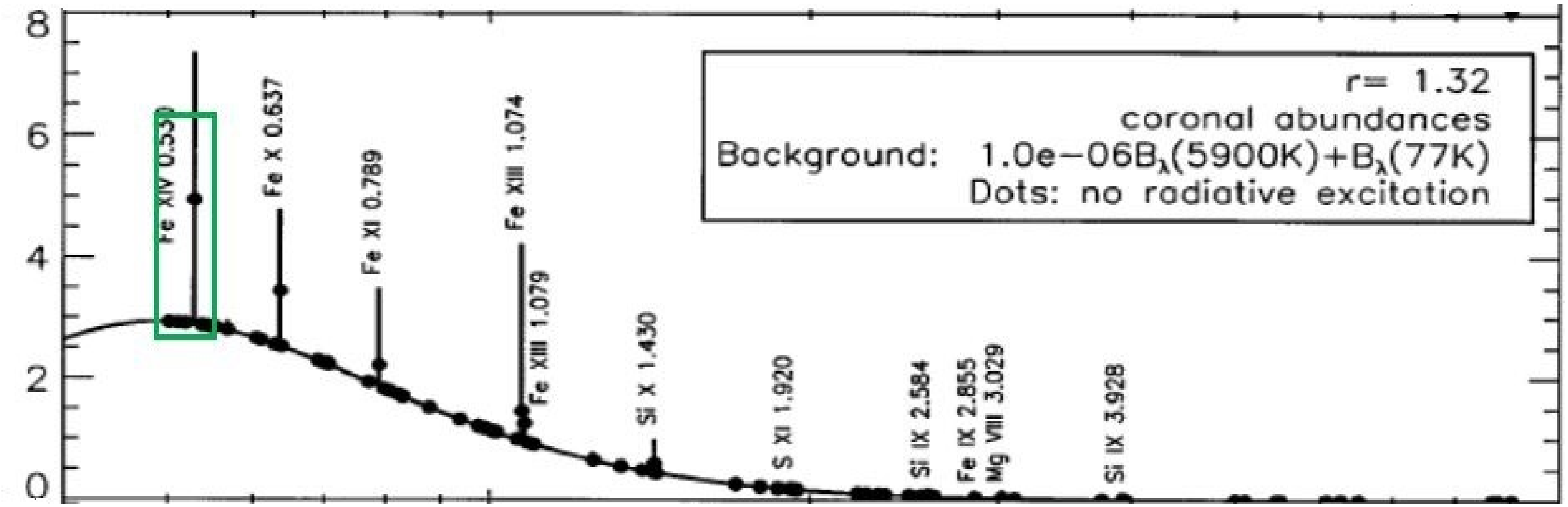
INAF – Astrophysical Observatory of Torino, Italy

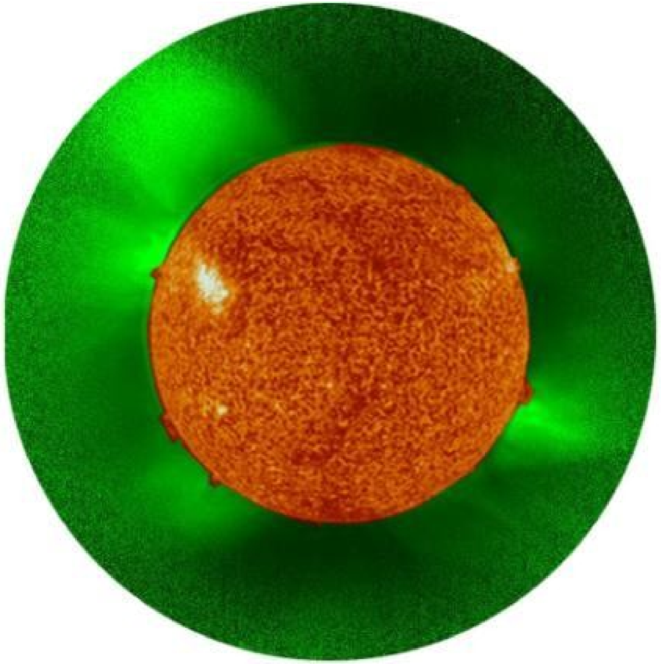
Future of Polarimetry - Brussels (B) – 21-23 September 2015

OUTLINE

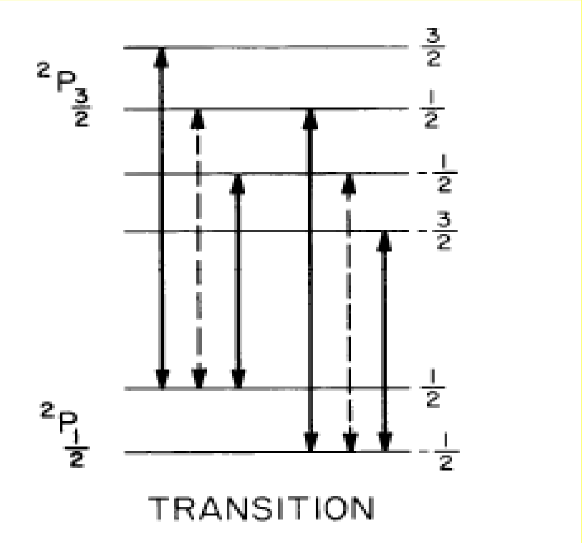
- Hanle effect of line linear polarization by resonance scattering as diagnostics tool to probe the coronal magnetic fields
- Turin Liquid Crystal spectro-polarimeter for Coronal Magnetography (CorMag)
- 2010 Eclipse observations of the coronal FeXIV 530.3 nm linear polarization.
- CorMag at Lomnicky Observatory – STSM of COST Action MP1104
- Future spectro-polarimeters for ground- and space-based coronal magnetometers

Fe XIV 530.3 nm ("Green Line")





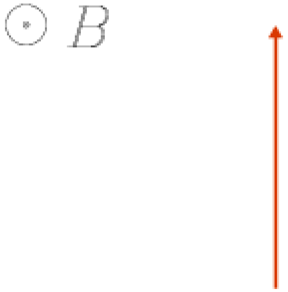
FeXIV line 530.3 nm (configuration $3s^2\,3p$) is a magnetic dipole transition:
$^2P_{3/2} \rightarrow {}^2P_{1/2}$

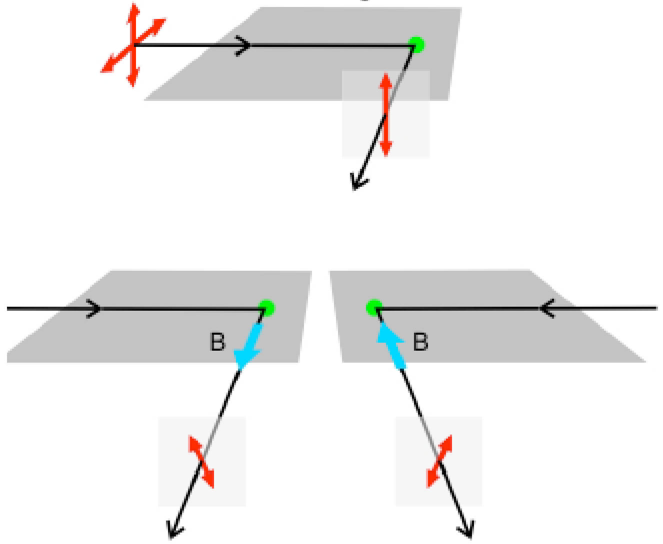


Hanle Effect (tutorial)

The impact of the Hanle effect on the linear polarization produced by scattering processes

90° scattering geometry





The Hanle effect **REDUCES** the amplitude of the line scattering polarization signal

(i.e.,Stokes Q decreases with respect to the B=0 G case) !

The Hanle effect **ROTATES** the direction of linear polarization

(i.e., Stokes U is NON-ZERO) !

Critical Hanle field?

$$\underbrace{8.79 \times 10^6\, g_L\, B(\text{gauss})}_{\text{Magnetic splitting of the Level}} \sim \underbrace{1/\text{Lifetime}}_{\text{Natural width of the Level}}$$

Magnetic splitting of the Level = Natural width of the Level

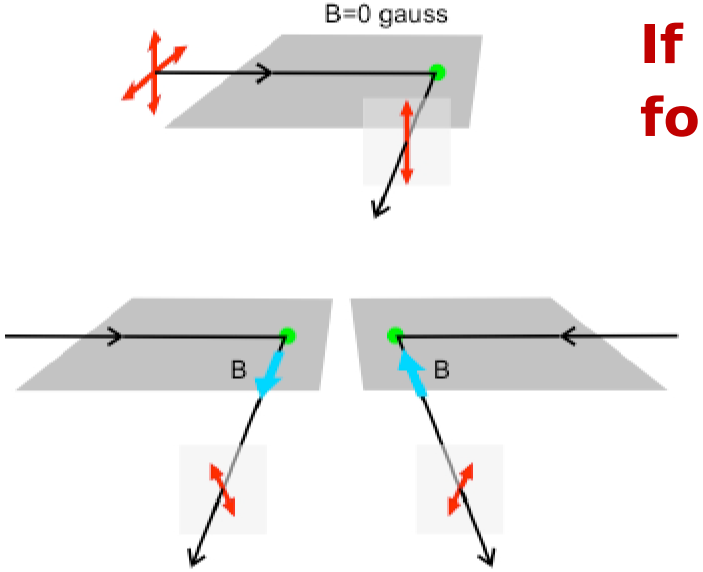
$\omega_{Larmour} \sim A$

Hanle Effect (tutorial)

The impact of the Hanle effect on the linear polarization produced by scattering processes

$\odot B$

90° scattering geometry



If $\omega_{Larmour}$ >> A (VIR forbidden lines)

The Hanle effect REDUCES the amplitude of the line scattering polarization signal

(i.e.,Stokes Q decreases with respect to the B=0 G case) !

The Hanle effect ROTATES the direction of linear polarization

(i.e., Stokes U is NON-ZERO) !

⇓

P is // or ⊥ **B**

Critical Hanle field?

$8.79 \times 10^6\, g_L\, B(\text{gauss}) \sim 1/\text{Lifetime}$

Magnetic splitting of the Level = Natural width of the Level

$\omega_{Larmour} \sim A$

Polarization vector
Van Vleck angle

Line Polarization Vector

- Linear polarization changes sign
- $3\cos^2\theta_v - 1 = 0$ $(\theta_v = 1/)$

Van Vleck angle

$\theta_v = 54.7$ deg

$\Psi = \theta_v$, P=0

$\Psi < \theta_v$, $\Rightarrow$ LP // *B*

$\Psi > \theta_v$, $\Rightarrow$ LP $\perp$ *B*

- Linear polarization changes sign
- $3\cos^2\vartheta_v - 1 = 0$ $(\vartheta_v = 1/\sqrt{3} = 54.7°)$

Van Vleck angle

$\theta_v = 54.7$ deg

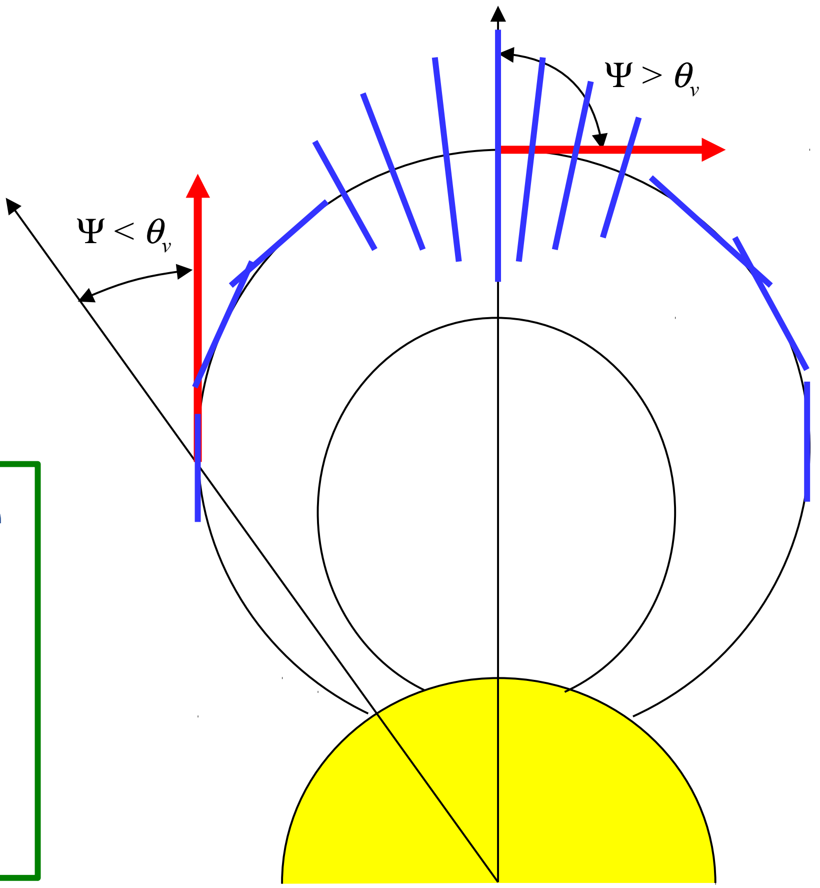
$\Psi = \theta_v$, P=0

$\Psi < \theta_v$, $\Rightarrow$ LP // *B*

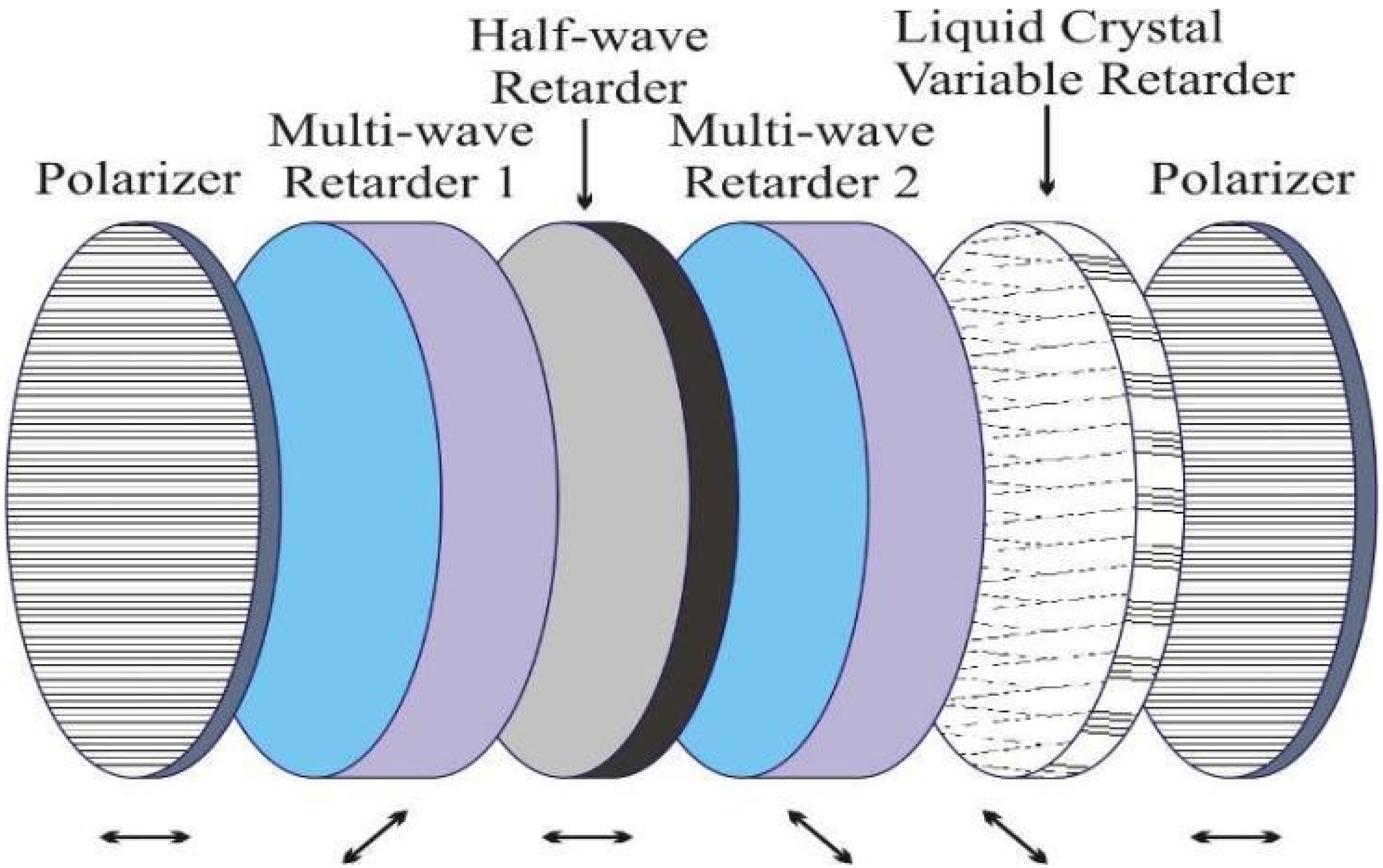
$\Psi > \theta_v$, $\Rightarrow$ LP $\perp$ *B*

"Saturated" Hanle effect

$\omega_{Larmour} >> A$



Turin - Liquid-crystal Tunable Lyot Filter for Solar Coronagraphy

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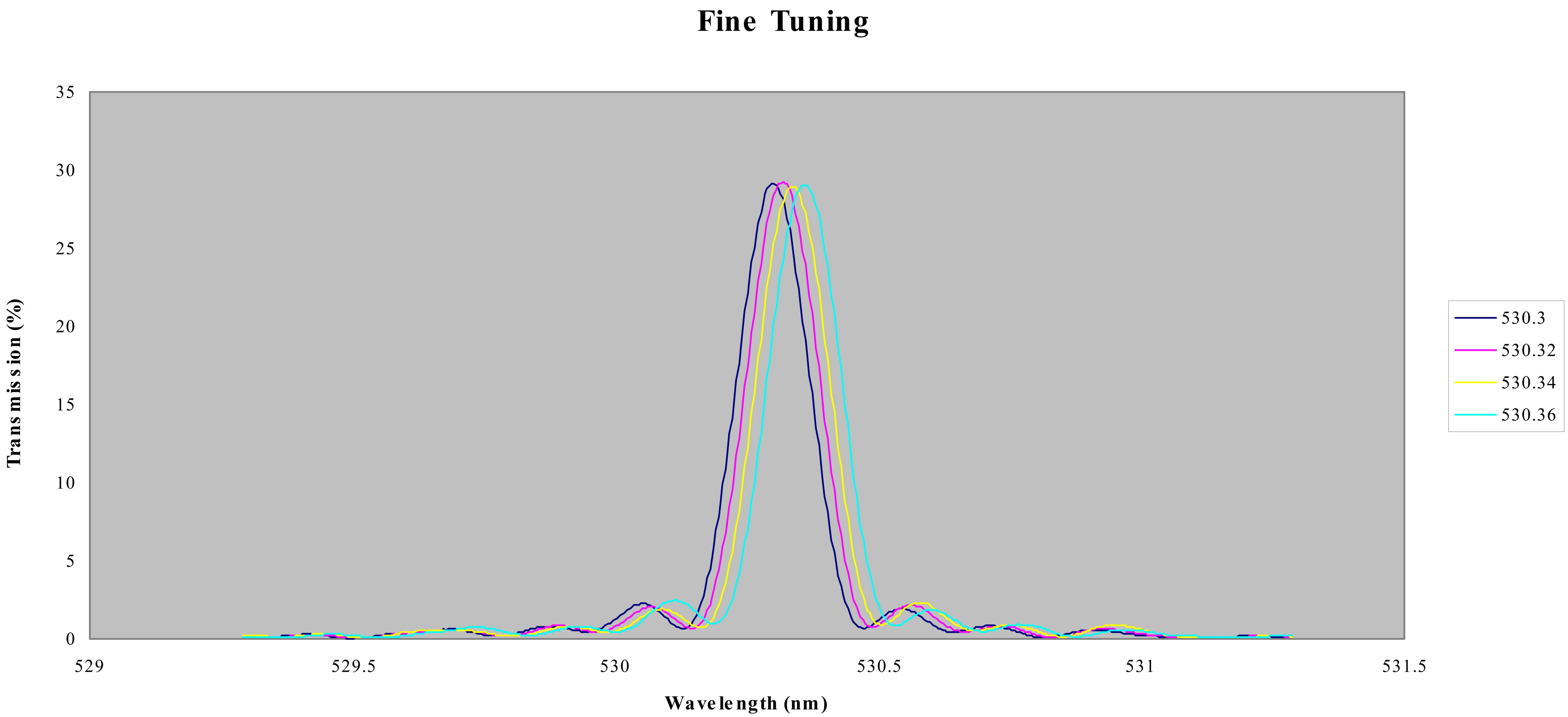
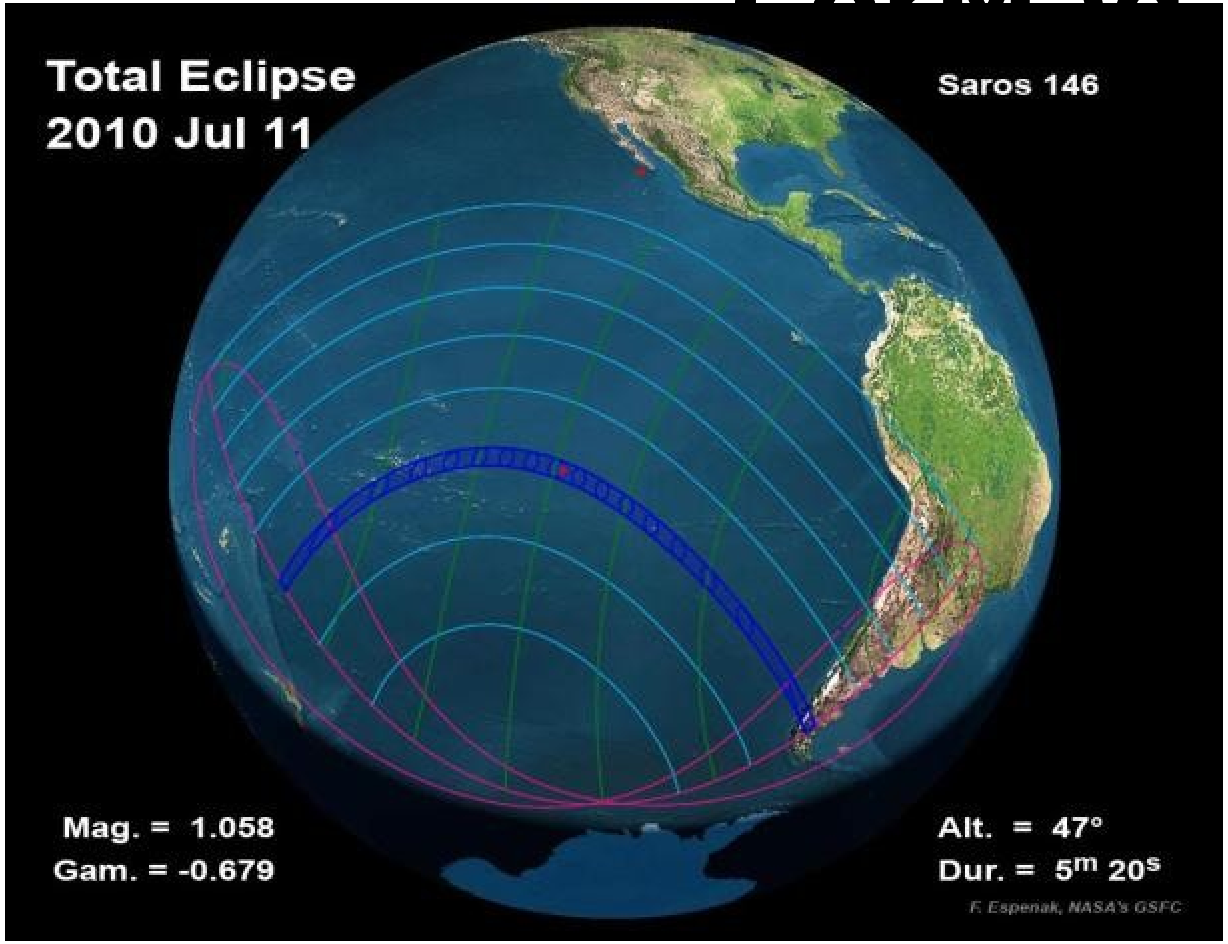
Turin - Liquid-crystal Tunable Lyot Filter Perfomances

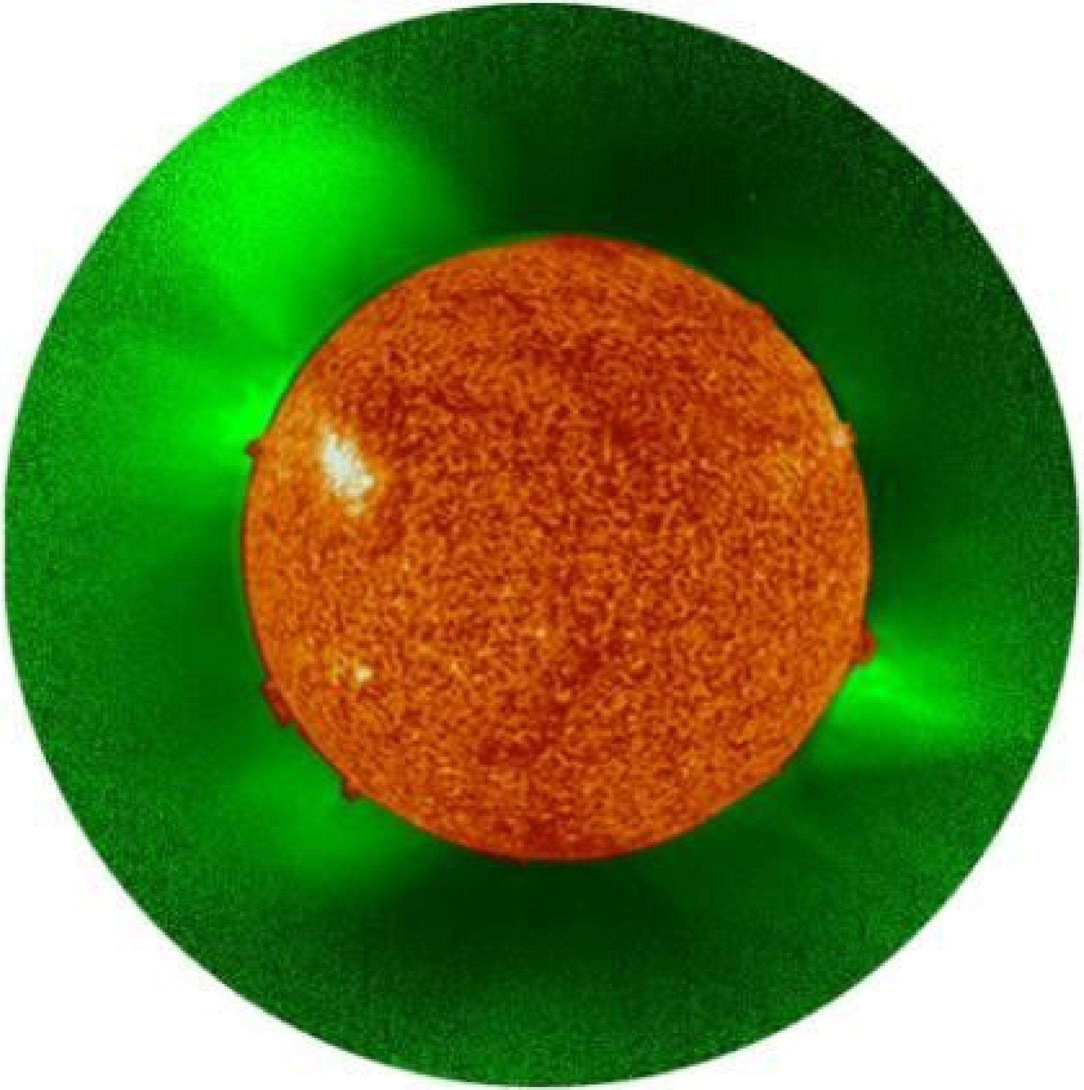


Turin – Coronal Magnetograph - CorMag

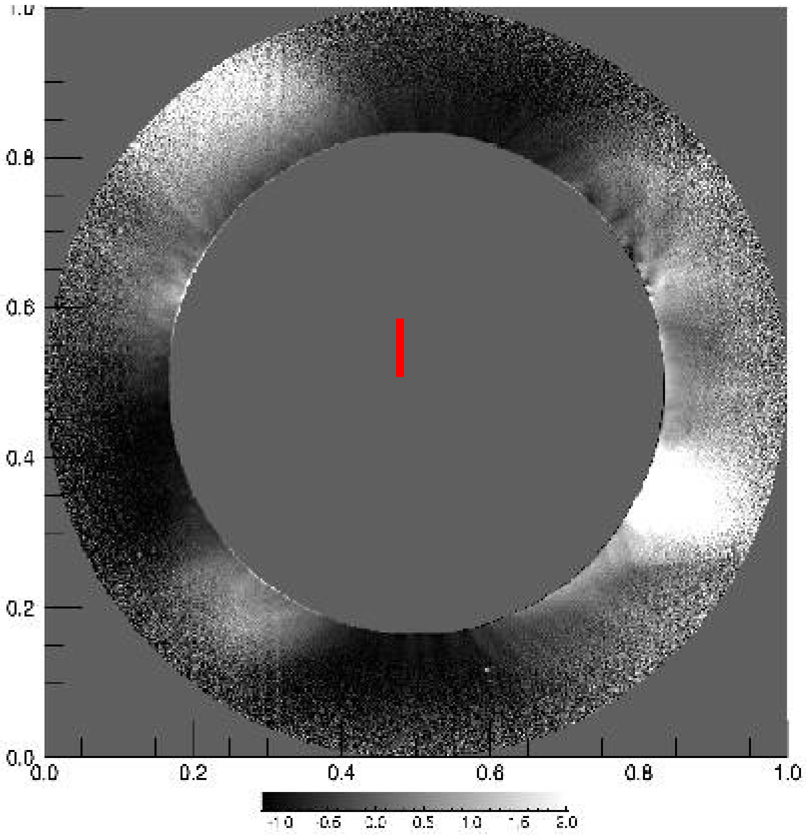


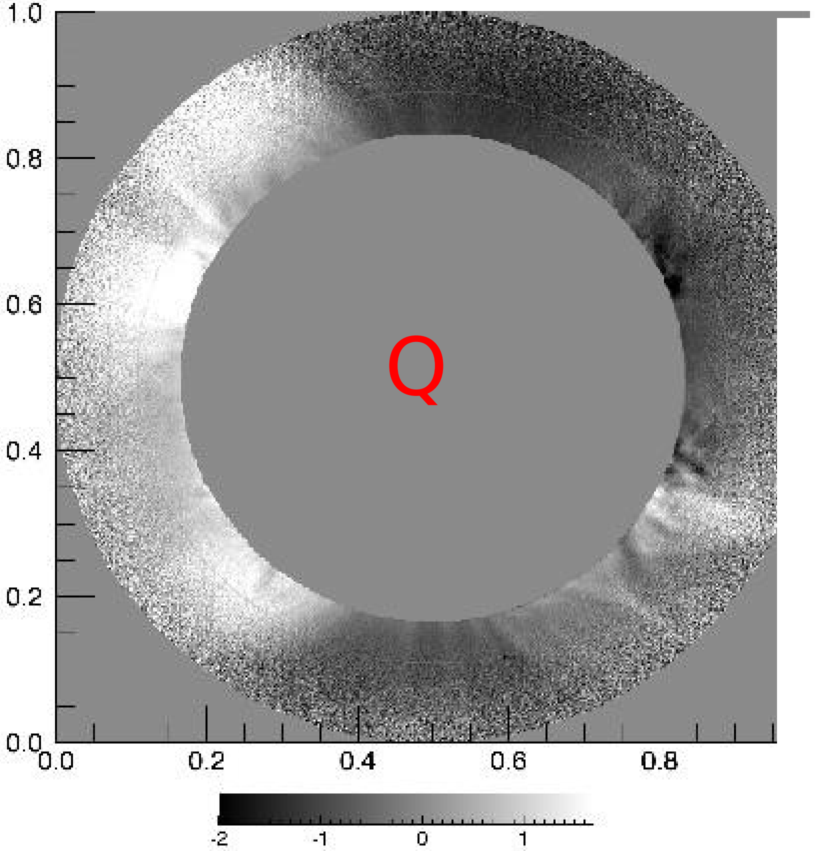
The CorMag was operated during the total solar eclipse of July, 11th 2010 on Tatakoto Atoll (French Polynesia)

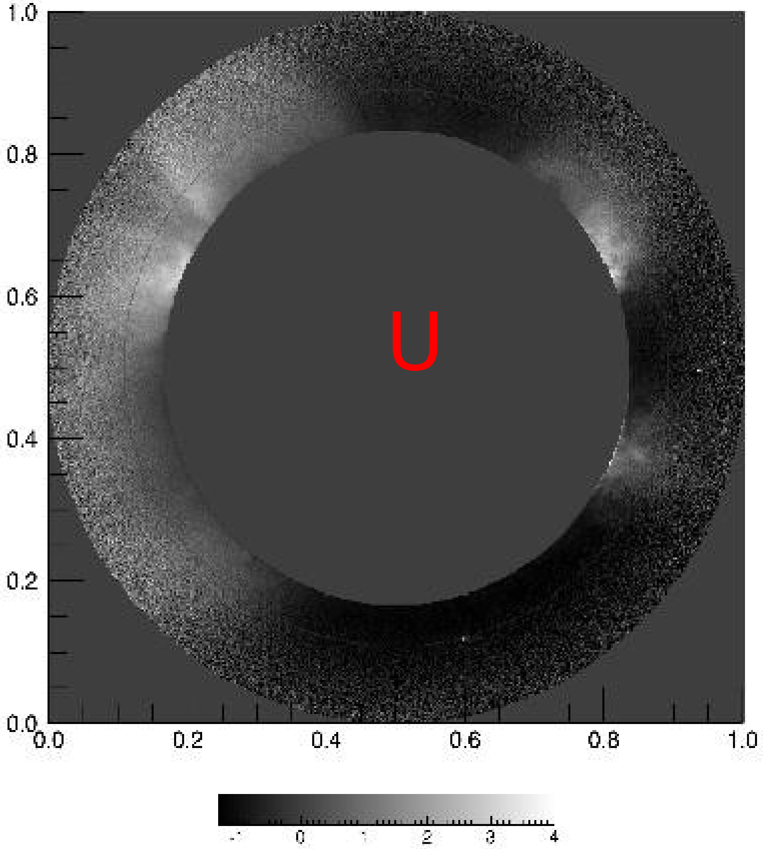
2010 Eclipse Results of CorMag



Measured Stokes Paramenters of FeXIV Line

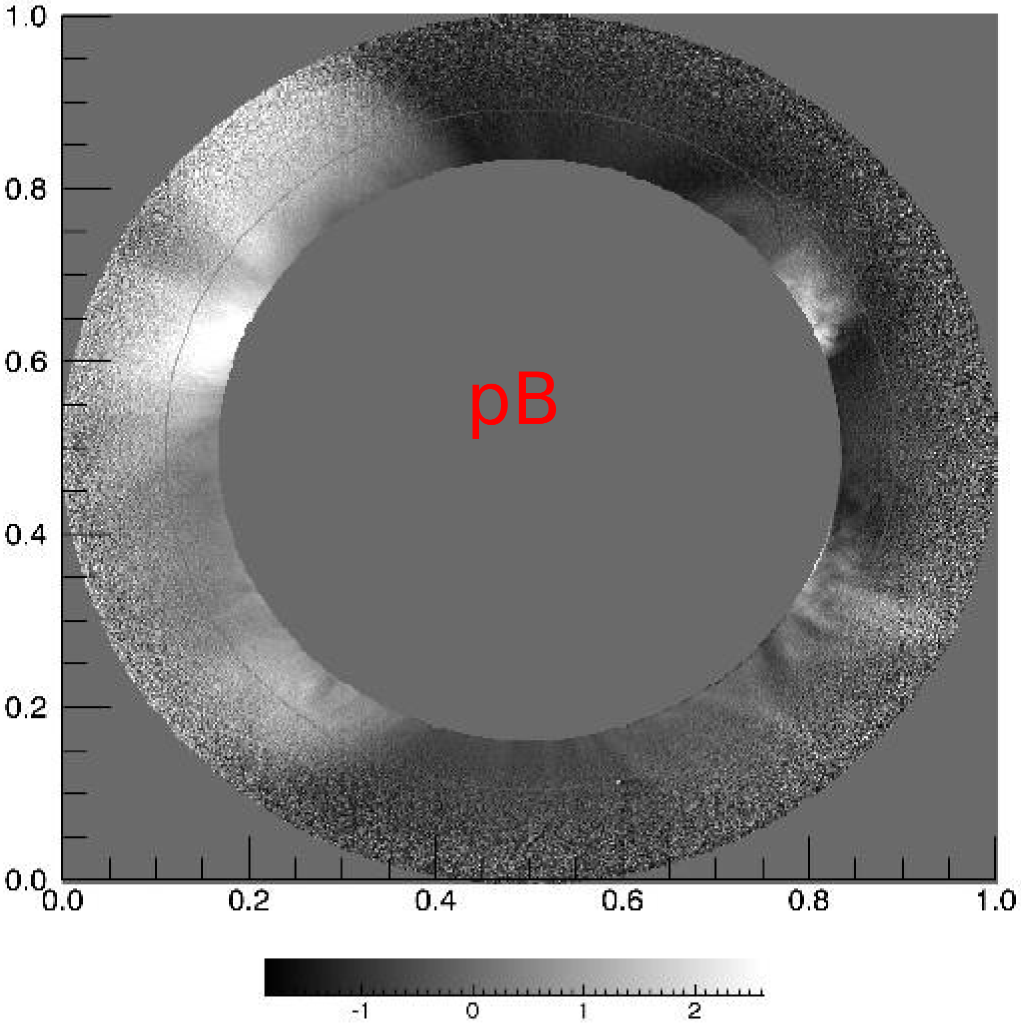


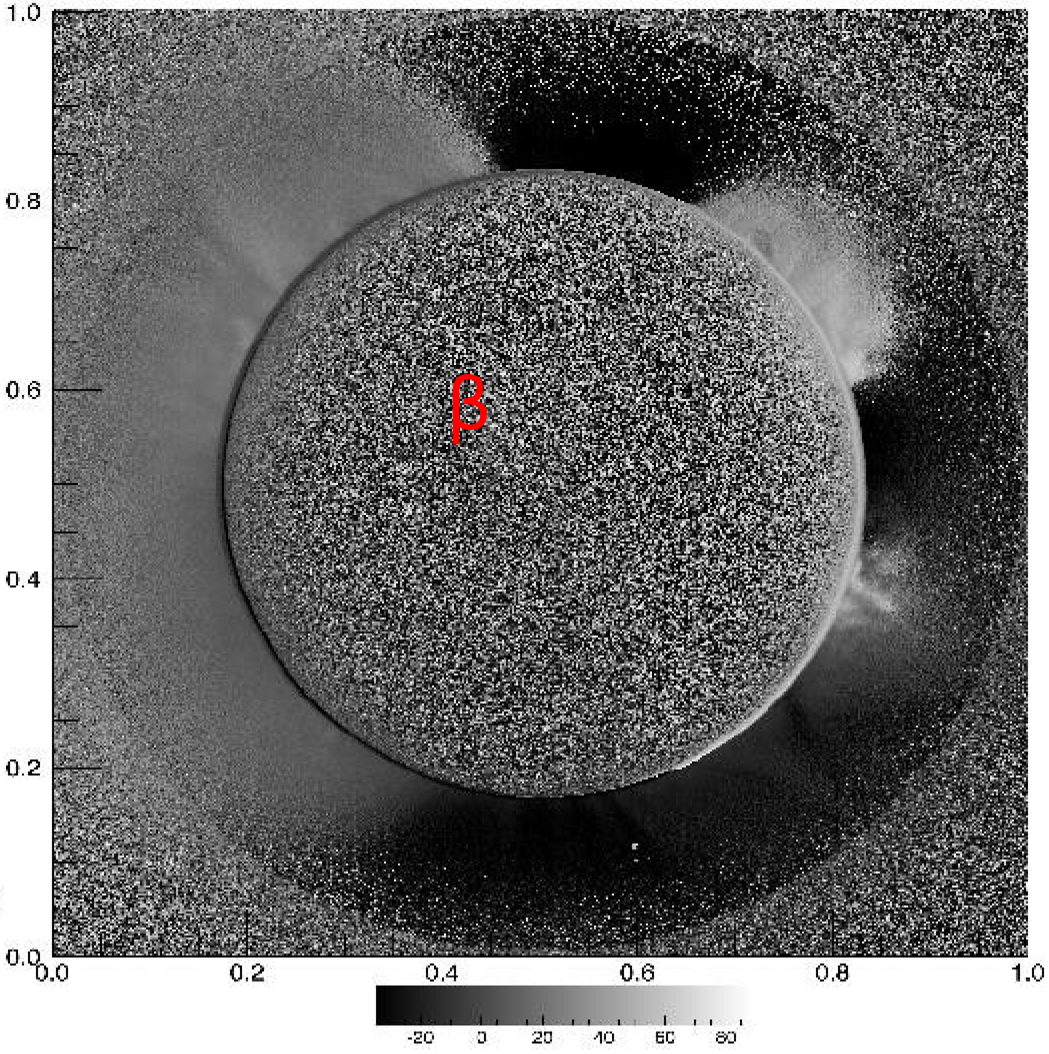




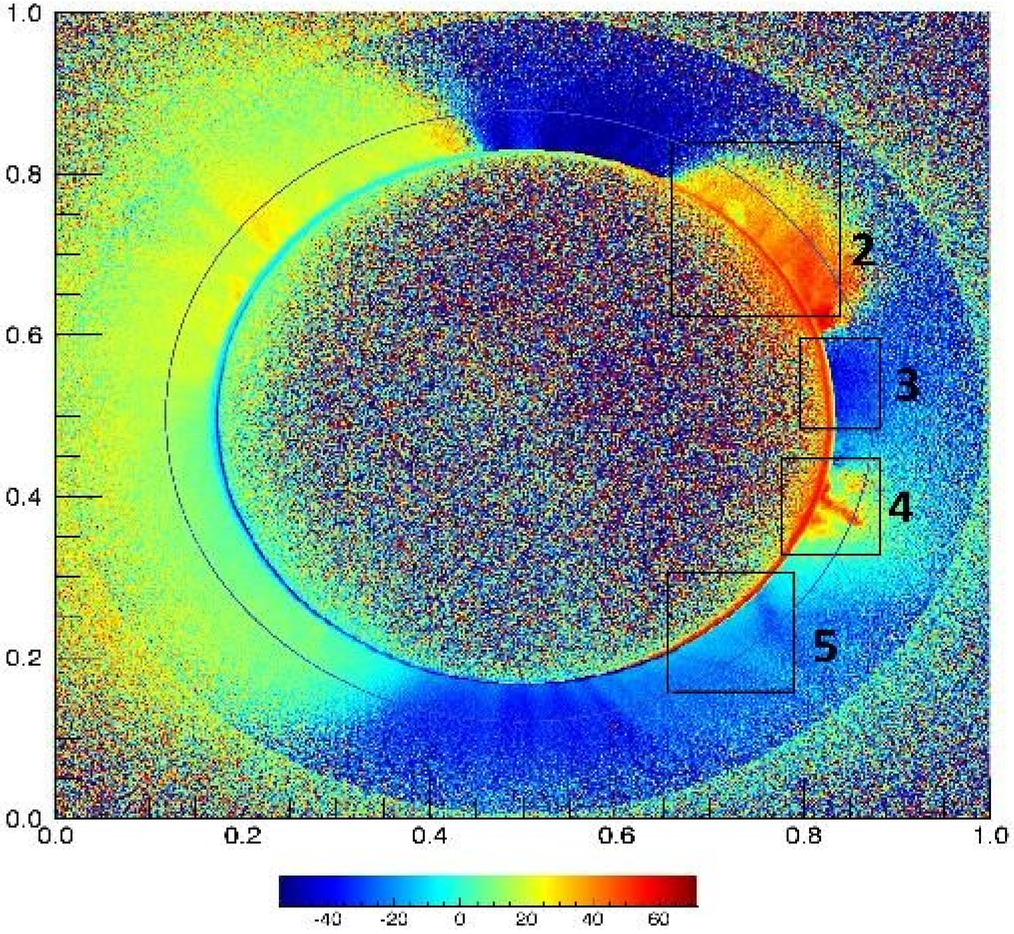
FeXIV Line Polarization Vector

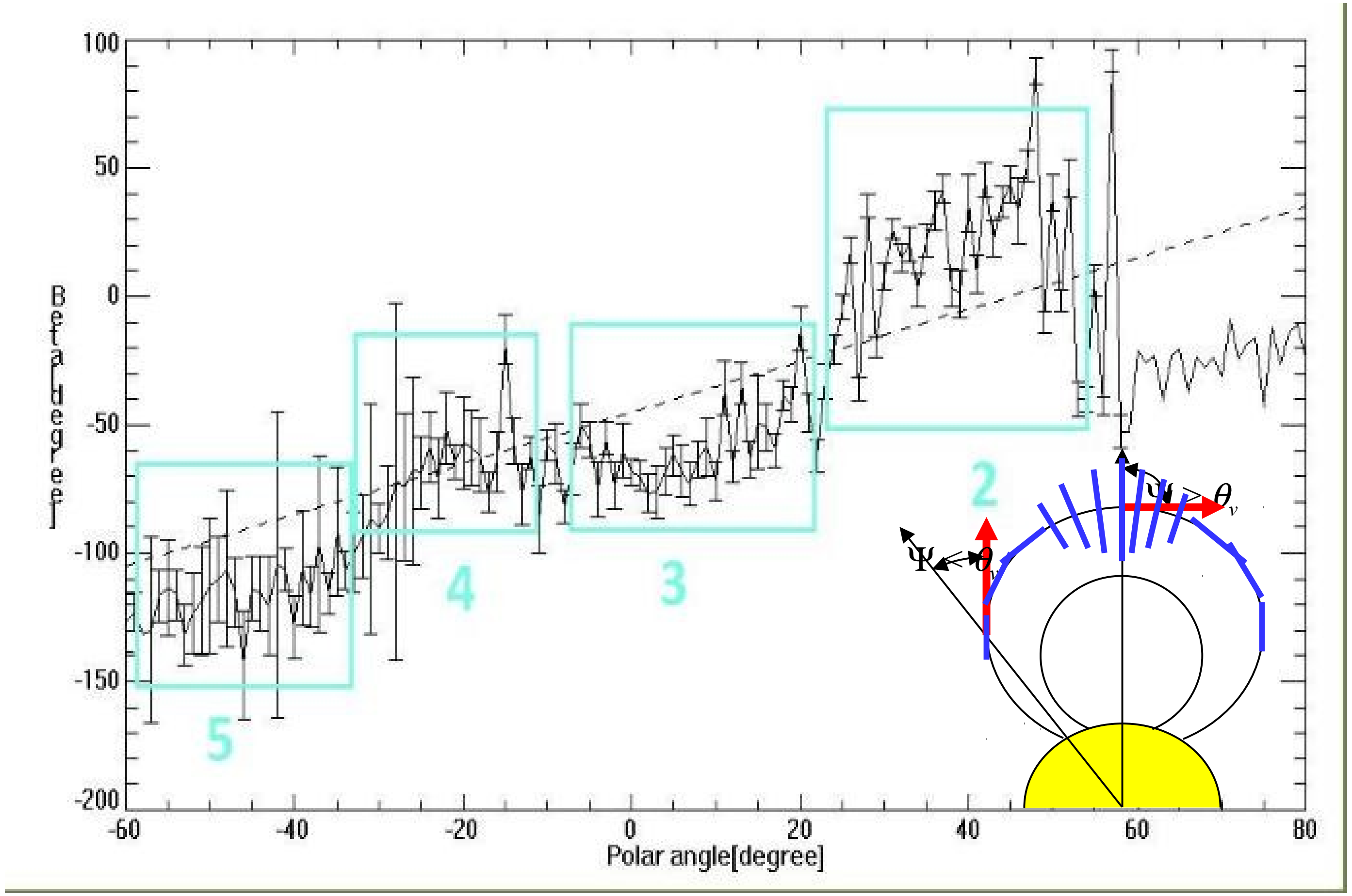
$$\beta = \frac{1}{2}\tan^{-1}\frac{U}{Q}$$



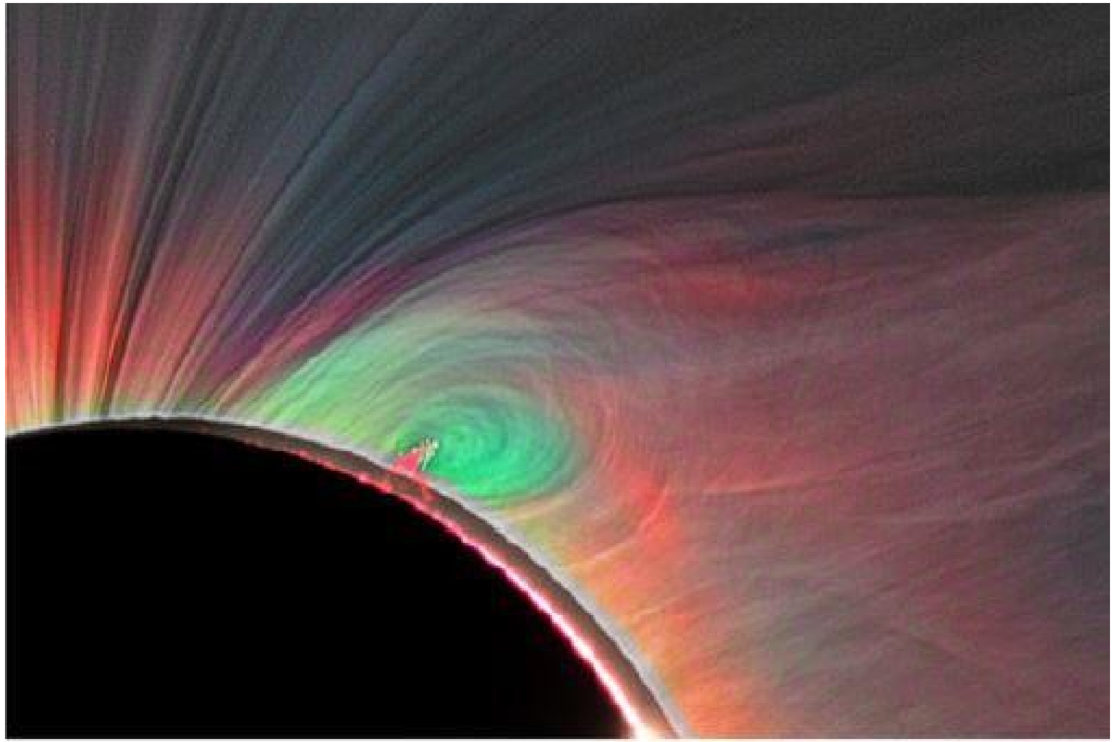


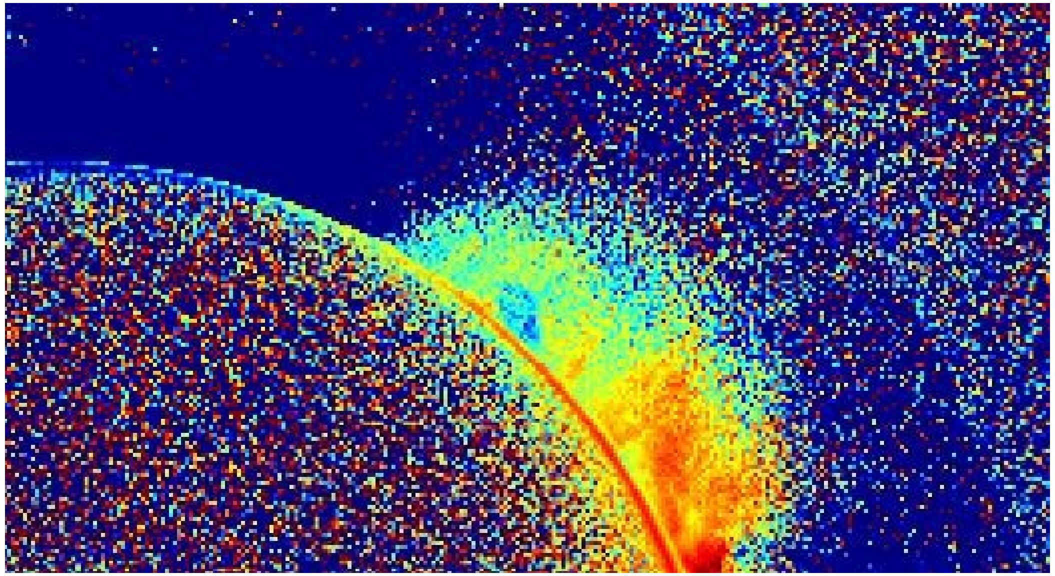
«Saturated» Hanle effect in the Coronal FeXIV Line





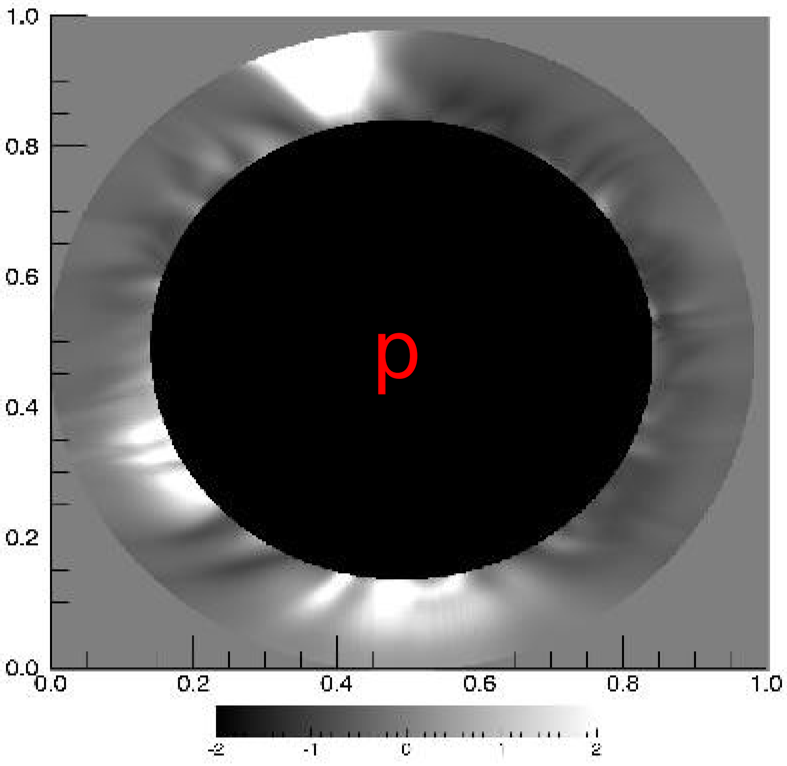
Coronal Cavity



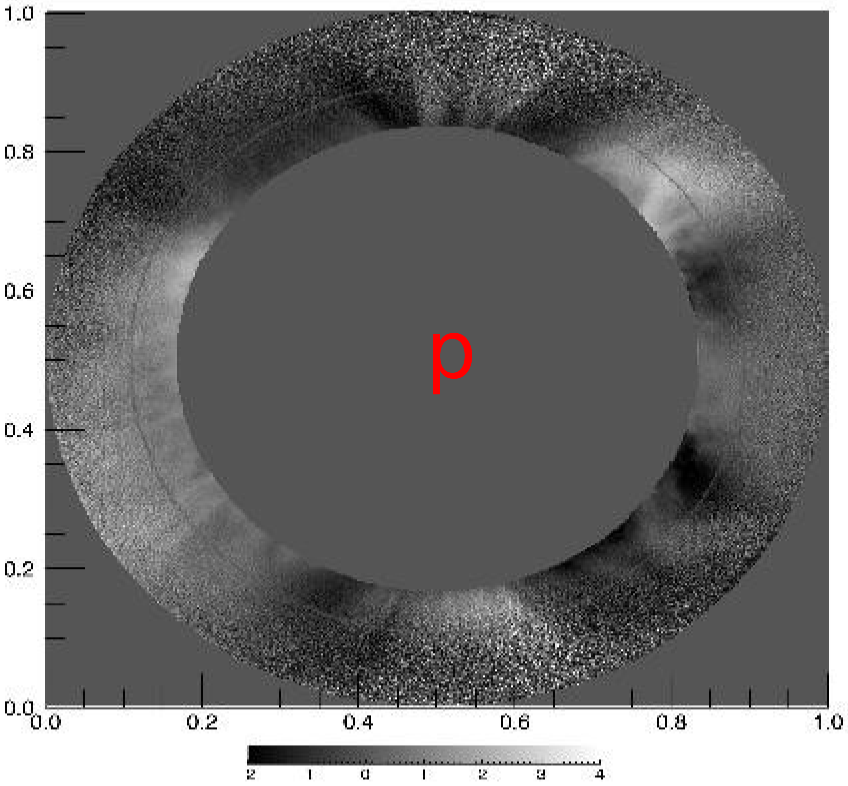


Left: M. Druckmuller imaging (spatial resolution 1’’).
Right: CorMag polarization vector

E Corona Forward modeling (LOS) vs CorMag observations

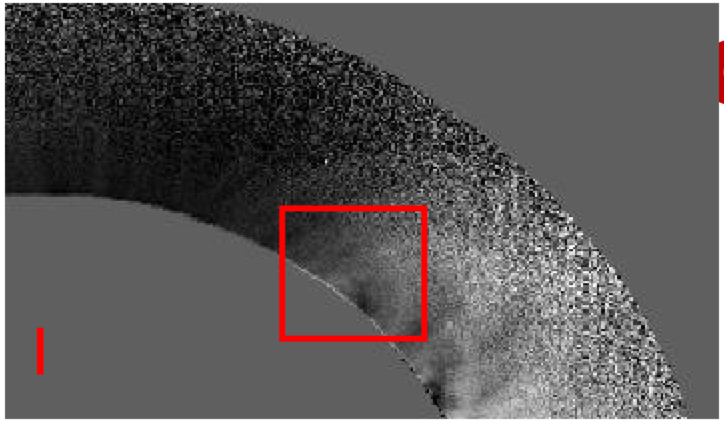


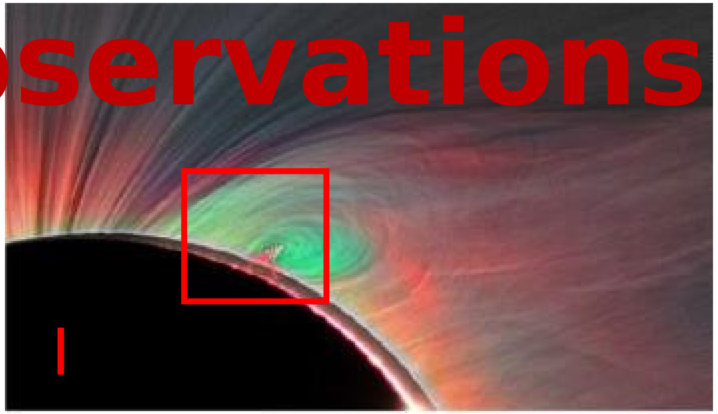
Forward modeling:
Predictive Science MHD model &
FORWARD Code (S. Gibson)

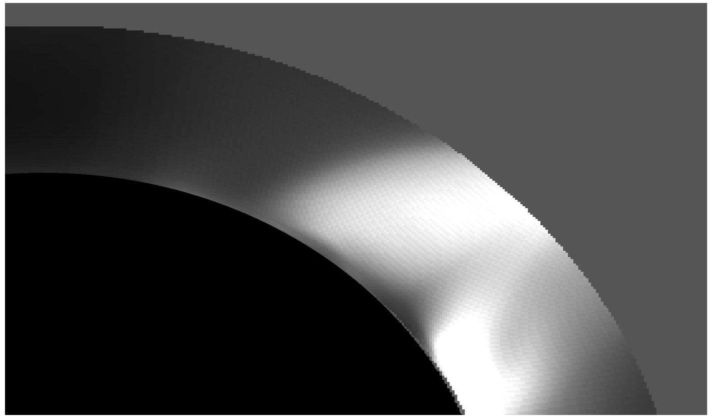


CorMag
Observations

US High Altitude Observatory
Forward modeling vs observations





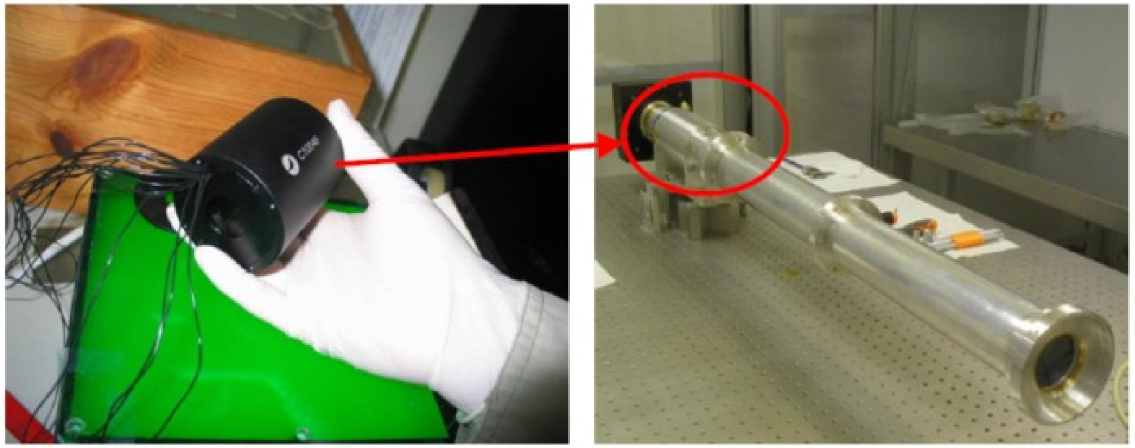


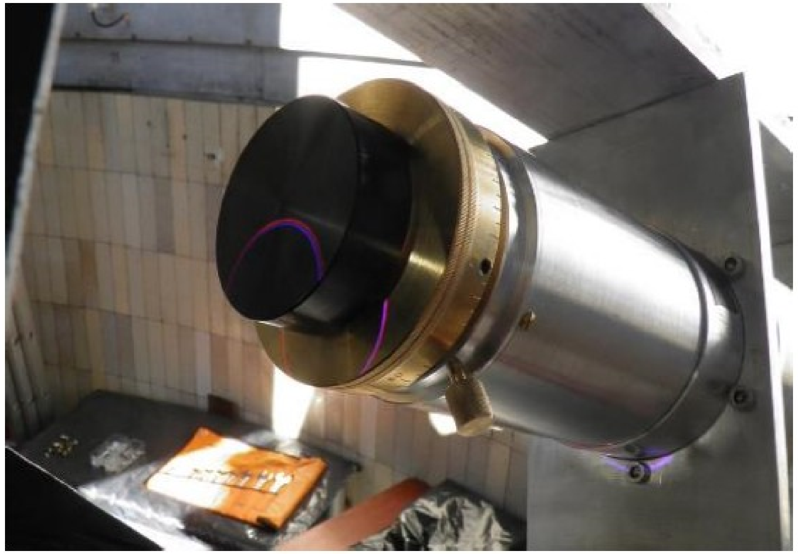
Model of global solar magnetic field based on extrapolation from phototospheric magnetograms (averaged over a Carrington rotation do) not include transient structures

INAF-Turin CorMag (Italy) at Lomnicky Stit Observatory (Slovakia)

COST Short Term Scientific Missions
LSO contact: Dr. Jan Rybak

- October 2013
- April 2014
- June 2014
- September 2015

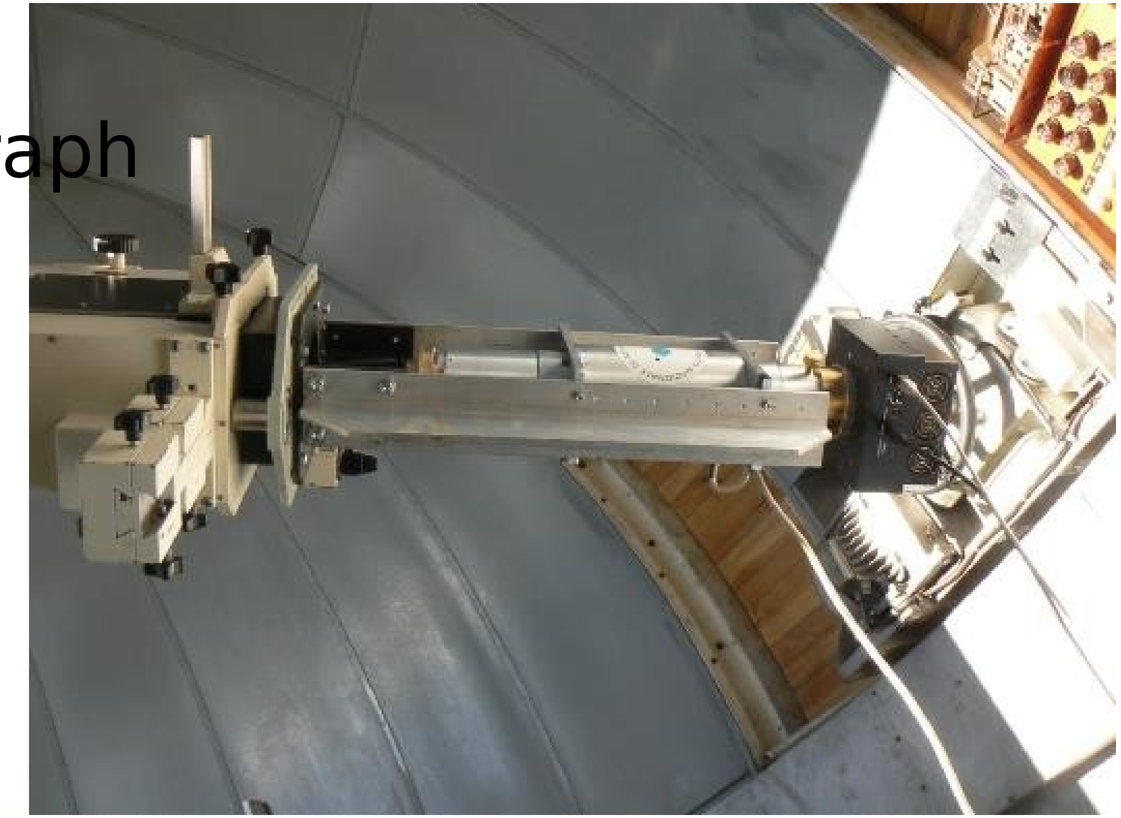


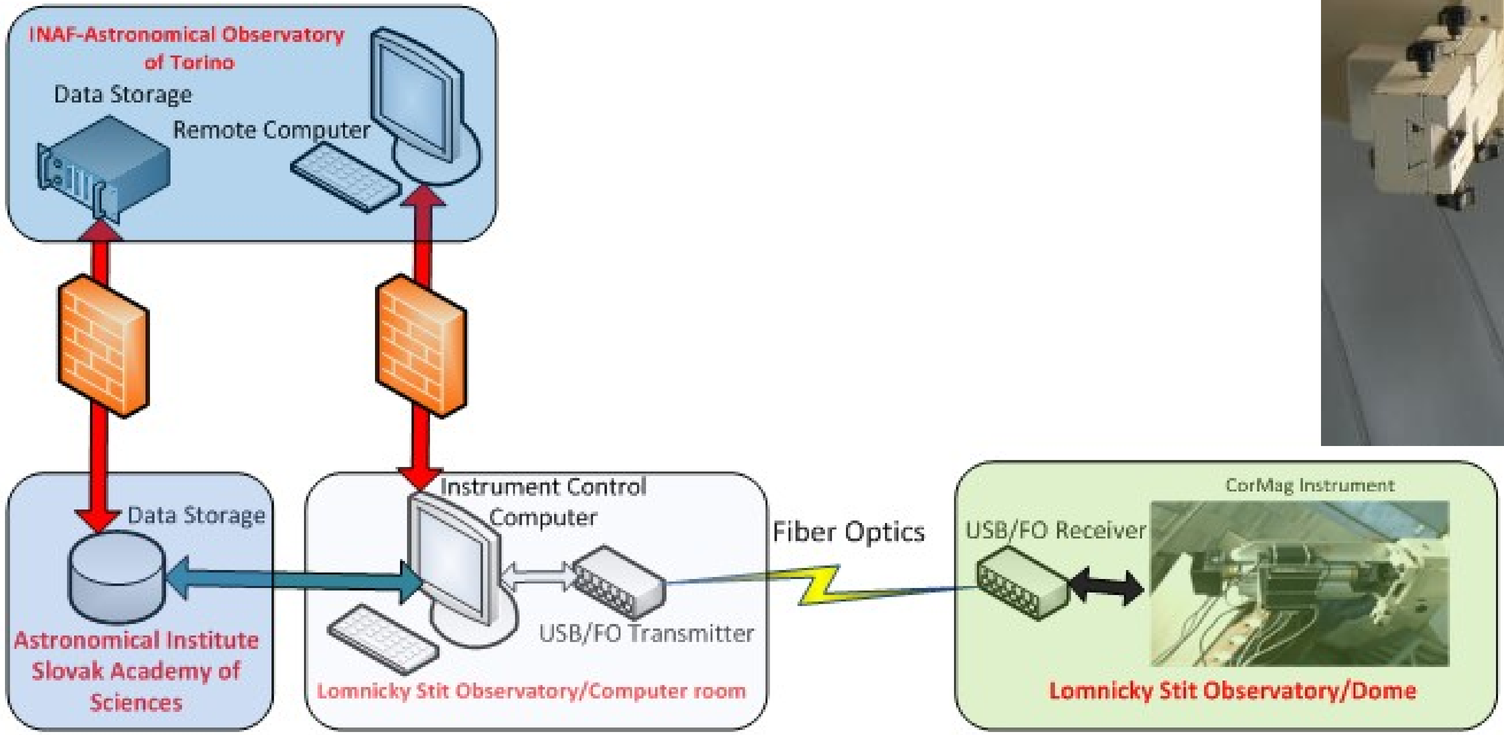


Turin CorMag at
Lomnicky Stit Observatory (Slovakia)

STSM October 2013, April 2014:

- Opto-mech coupling filter-coronagraph
- Control & Data Acquisition system



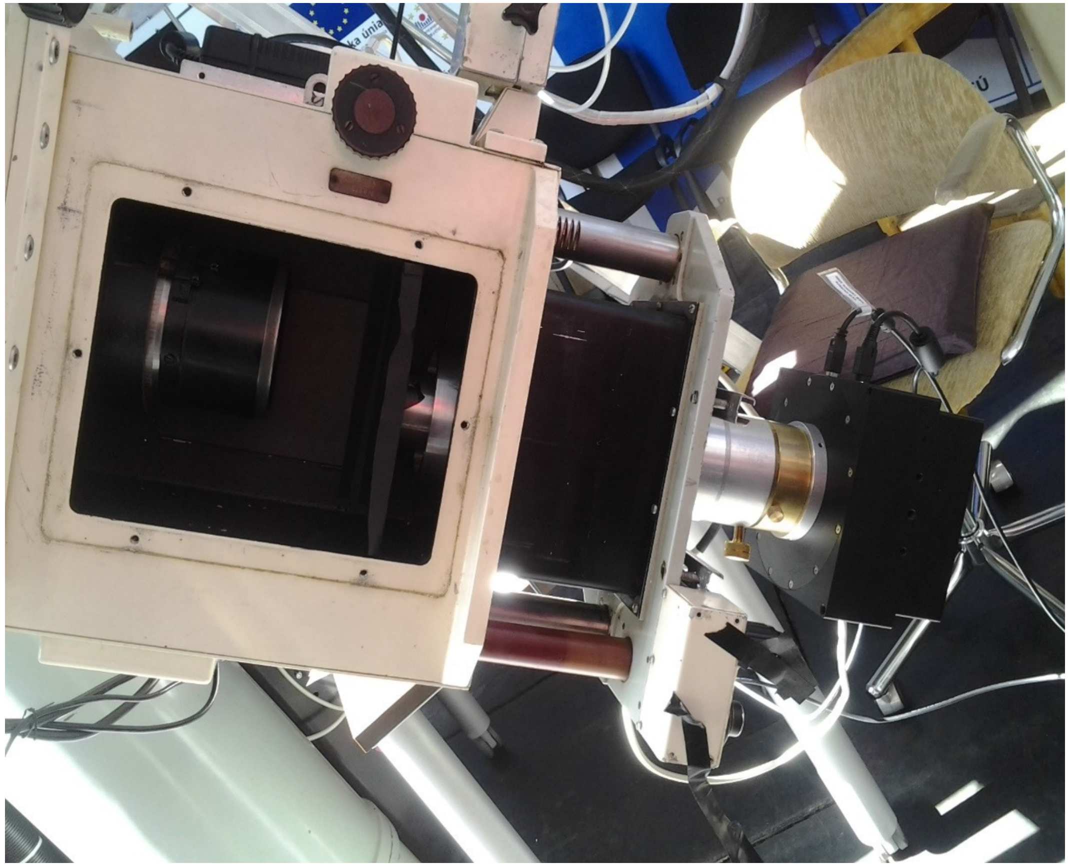


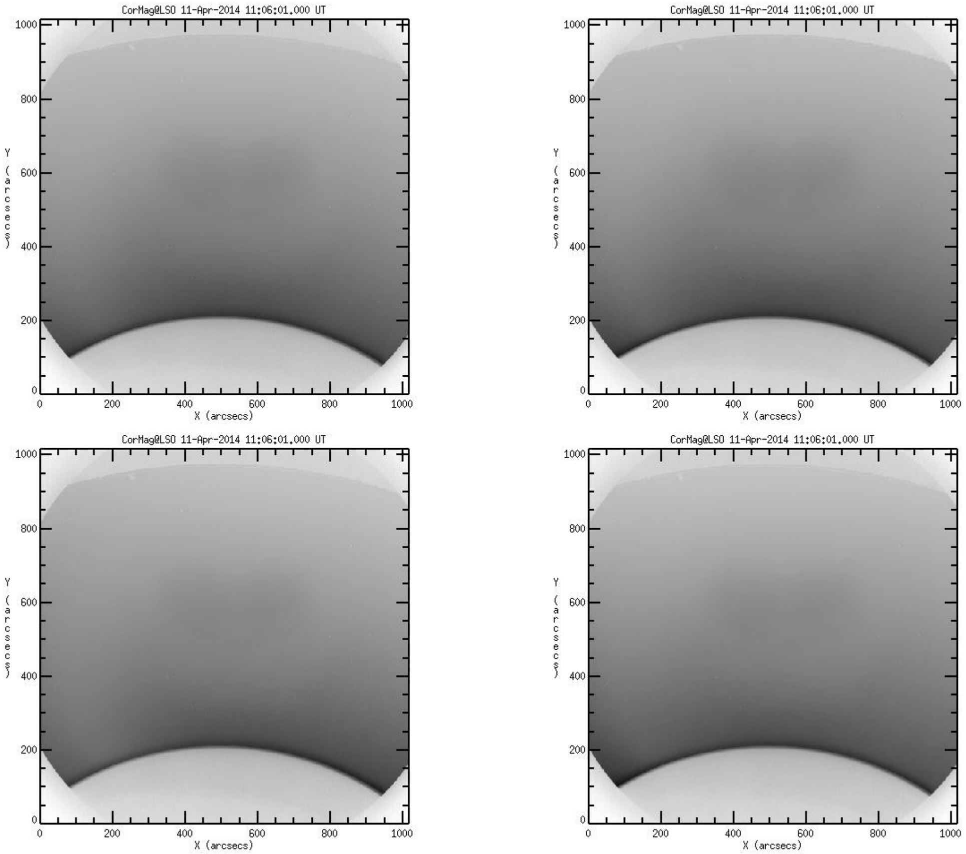
Turin CorMag at Lomnicky Stit Observatory (Slovakia)

M June 2014:

hanged filter-coronagraph optical coupling: collimated beam => focu

rst light

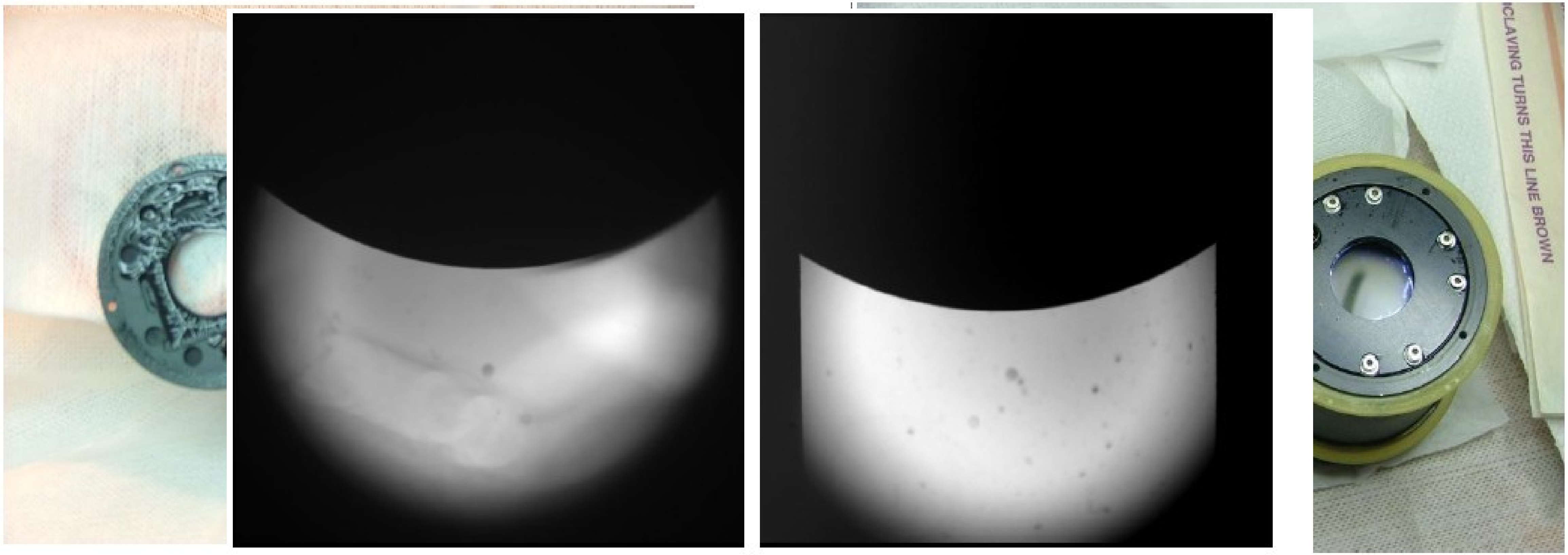




Turin CorMag at
Lomnicky Stit Observatory (Slovakia)

M September 2015:

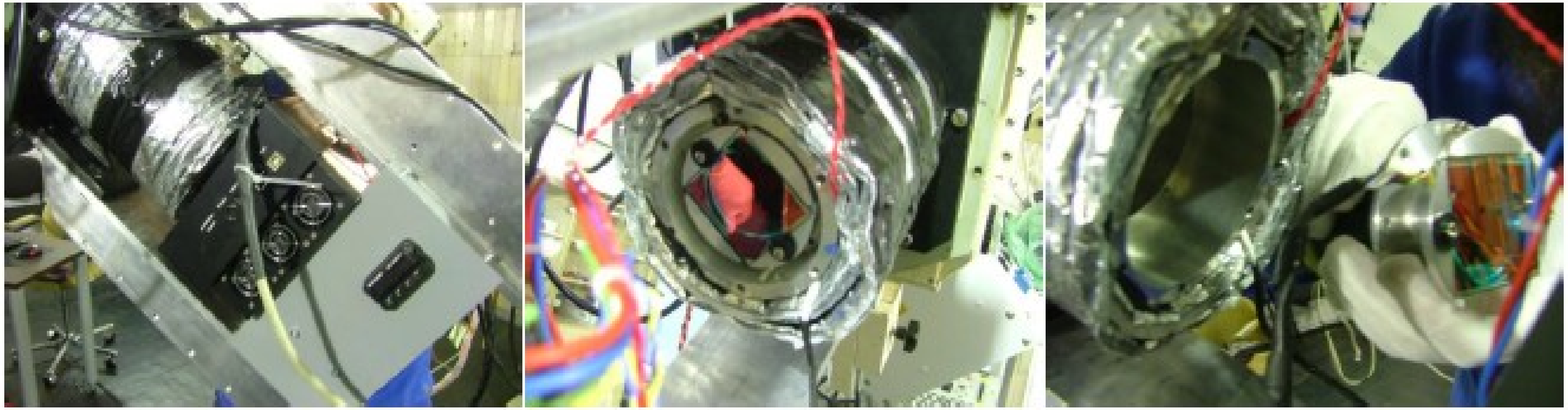
Cleaned Turin-filter from optical oil leak => removed parasitic ghosts



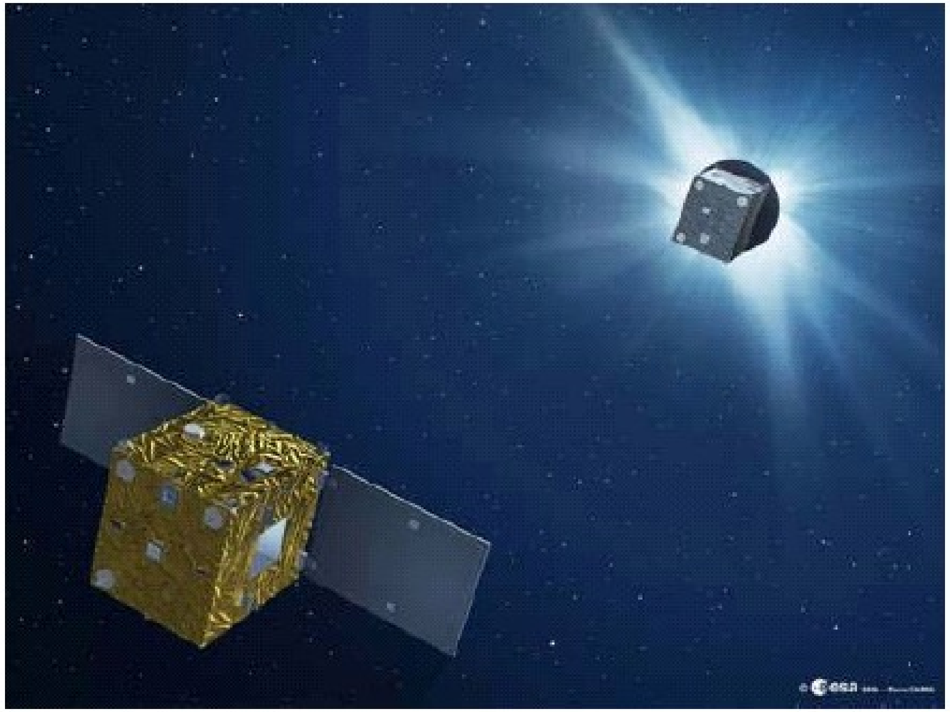
Turin CorMag at
Lomnicky Stit Observatory (Slovakia)

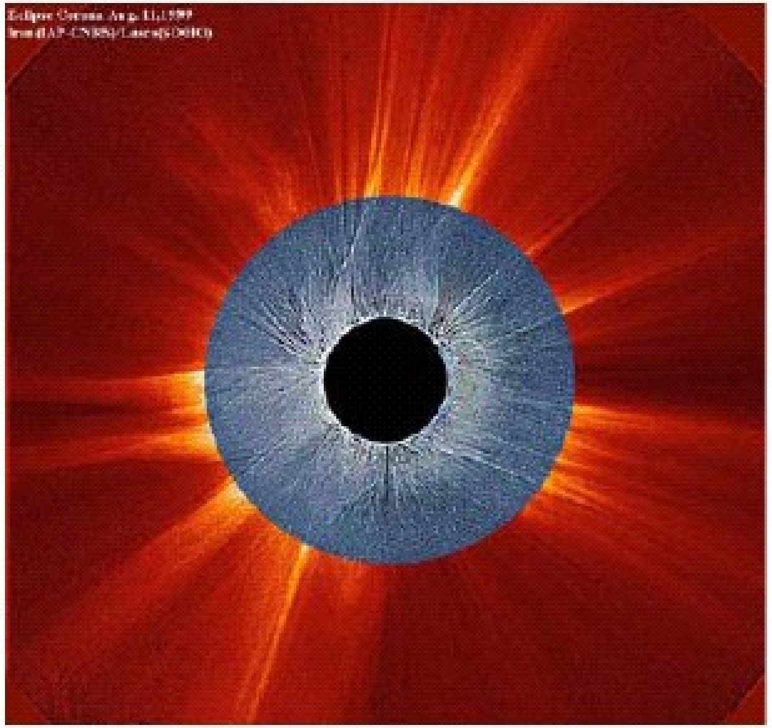
Lesson learned:

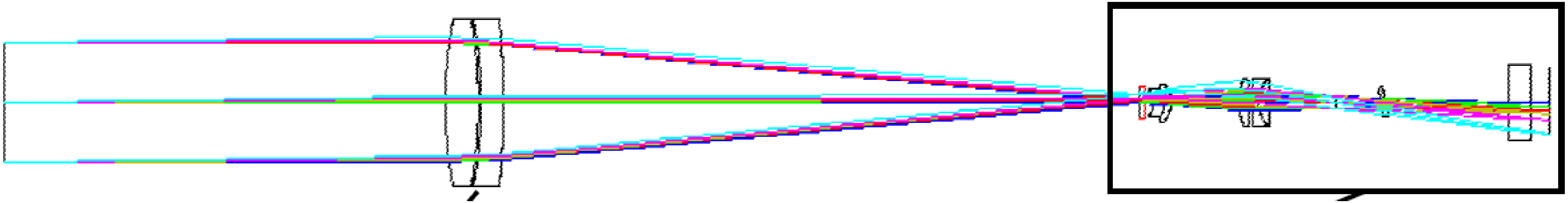
- Optical coupling Filter-Coronagraph => single system
- Climatic conditions: thermal, coronal sky is rare.
- Instrumental cleanliness for coronal observations (both Filter & Coronagraph)



ESA PROBA-3 Formation-Flying







Summary

Spectro-polarimetry of coronal line-emission in the visible-light wavelength spectrum («forbidden lines») have demonstrated to yield a valuable diagnostics tool of the coronal magnetic field

- Turin CorMag installed at one of the two the coronagraphs of the Lomnicky Stit Observatory thanks to COST Action 1104 STSM.
- Ground based coronagraphs provides valuable «test-beds» for new space-based observatories with visible-light spectro-polarimetry

HAO CoMP
LC Lyot filter
& Polarimeter
(FeXIII 1074-7 nm)

S. Tomczyk, *et al.*
Science 317, 1192 (2007);