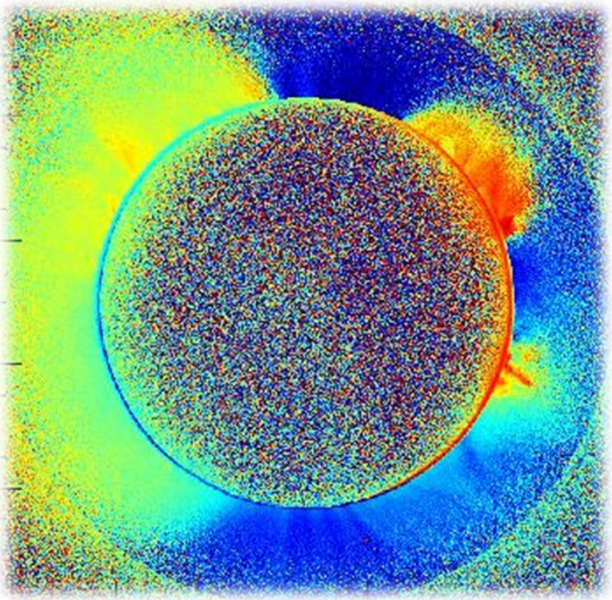
Space and Ground-based Coronal Spectro-polarimetry

Silvano Fineschi
Alessandro Bemporad, Gerardo Capobianco,
Jessica Girella
INAF –Osservatorio Astrofisico di Torino, Italy
Jan Rybak
Lomnicky Stit Observatory, Slovakia

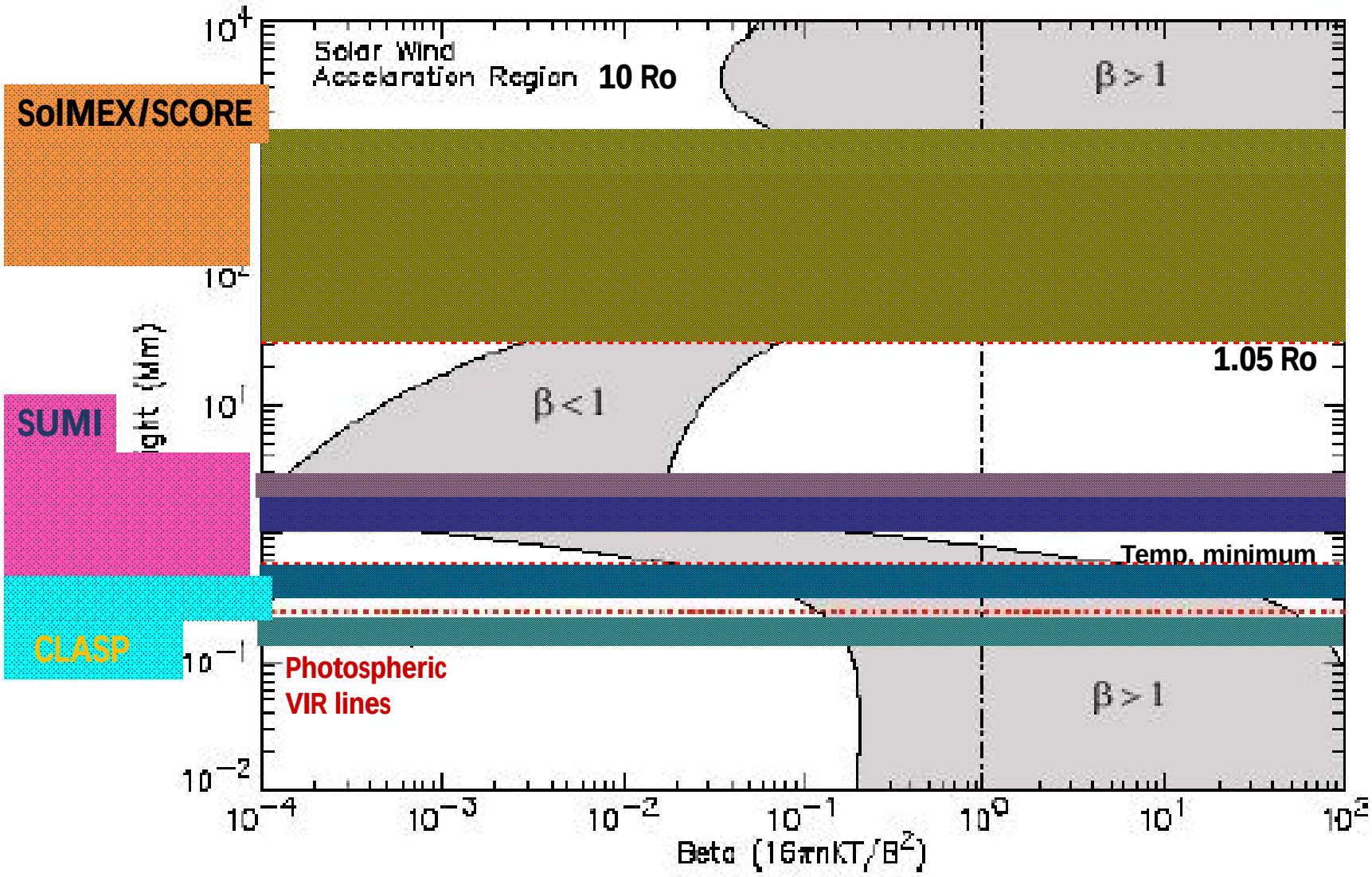


Moscow (RU) – 8 August 2014; COSPAR-14-E2.1-0001-14:
THE SCIENCE WITH FUTURE SOLAR MISSIONS, FROM THE SUN TO THE HELIOSPHERE

OUTLINE

- Hanle effect of line linear polarization by resonance scattering as diagnostics tool to probe the coronal magnetic fields
- 2010 Eclipse observations of the coronal FeXIV 530.3 nm linear polarization.
- Hanle effect interpretation and comparision with froward modeling
- Future spectro-polarimeters for ground- and space-based coronal magnetometers

Beta



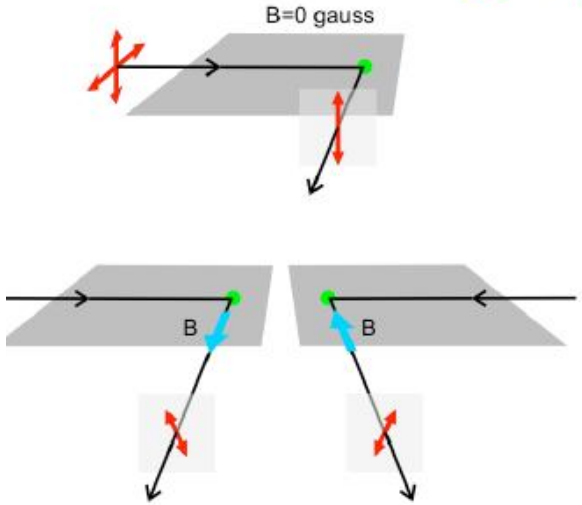
Probing Coronal Magnetism with Space EUV/UV/VIR Polarimetry

Hanle Effect (tutorial)

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

90° scattering geometry

$\odot B$



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?

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

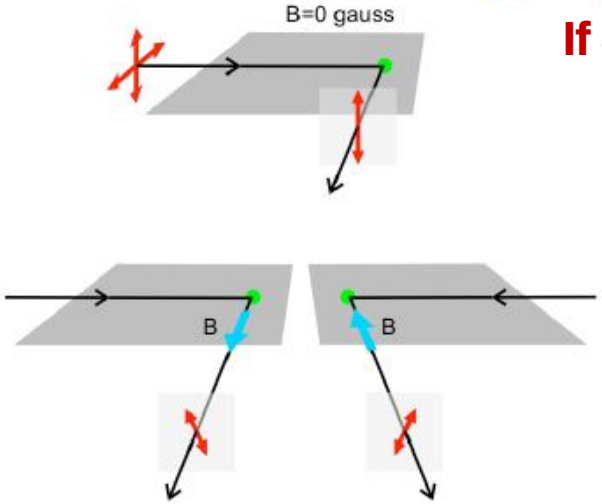
Magnetic splitting of the Level = Natural width of the Level

$\omega_{\text{Larmour}} \sim A$

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?

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

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*
- $3\cos^2\vartheta v - 1 = 0$

  $(\vartheta v = 1/\sqrt{3} = 54.7°)$

Van Vleck angle

$\theta_v = 54.7$ deg

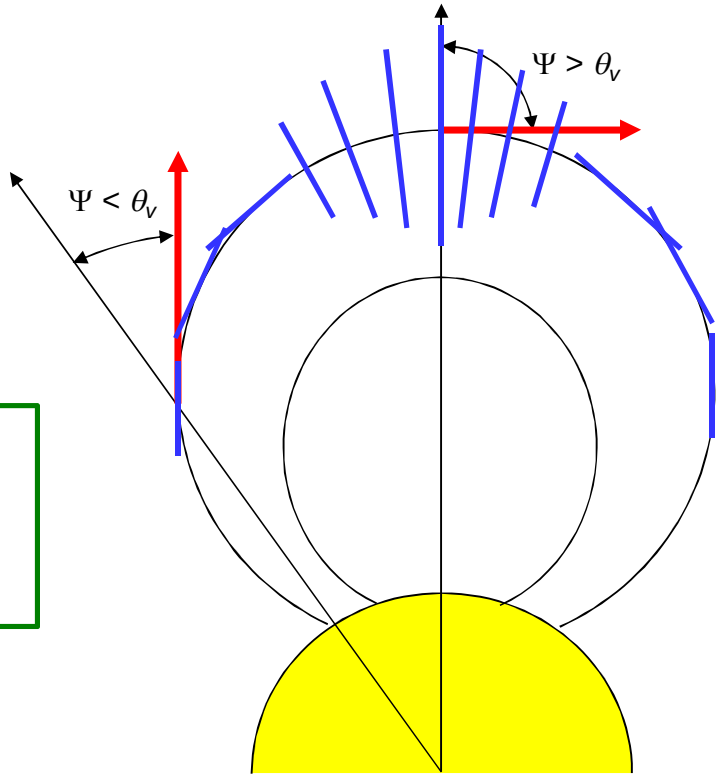
$\Psi = \theta_v$, **P=0**

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

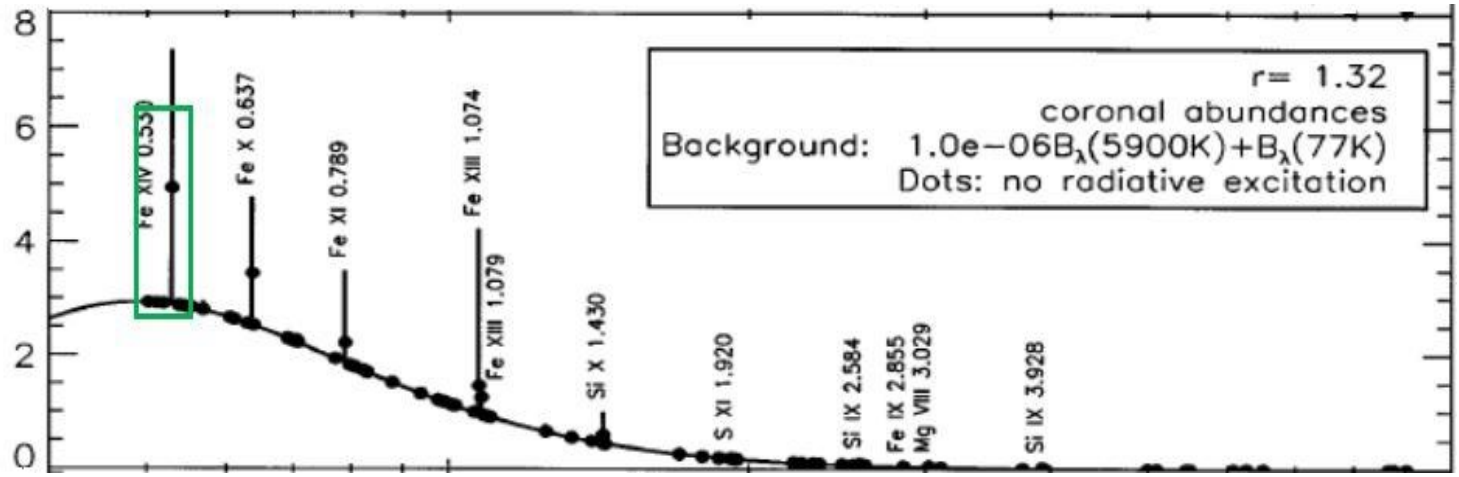
$\Psi > \theta_v$, $\Rightarrow$ **LP $\perp$ *B***

"Saturated" Hanle effect

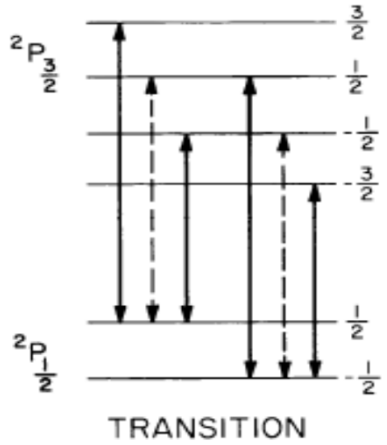
$\omega_{Larmour} >> A$



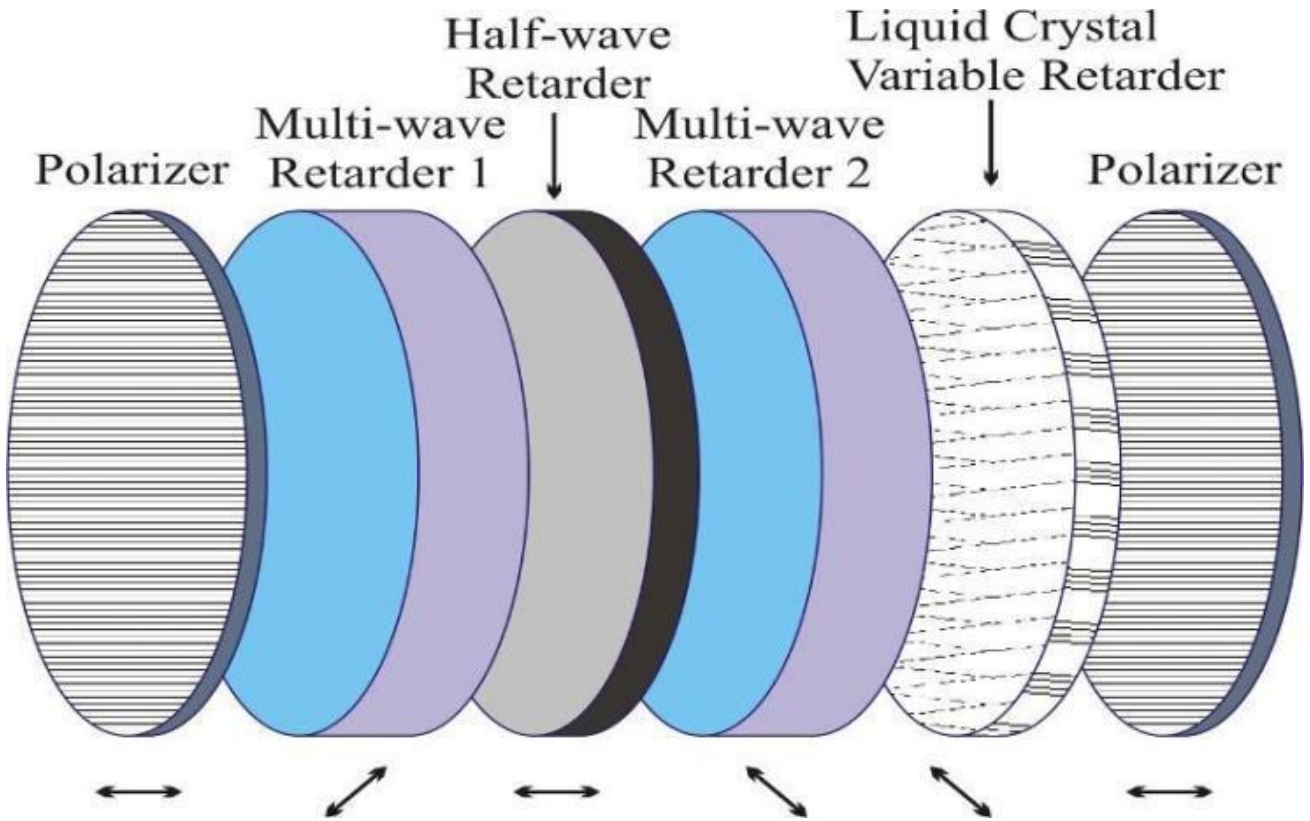
Fe XIV 530.3 nm (“Green Line”)



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



Turin - Liquid-crystal Tunable Lyot Filter for Solar Coronagraphy



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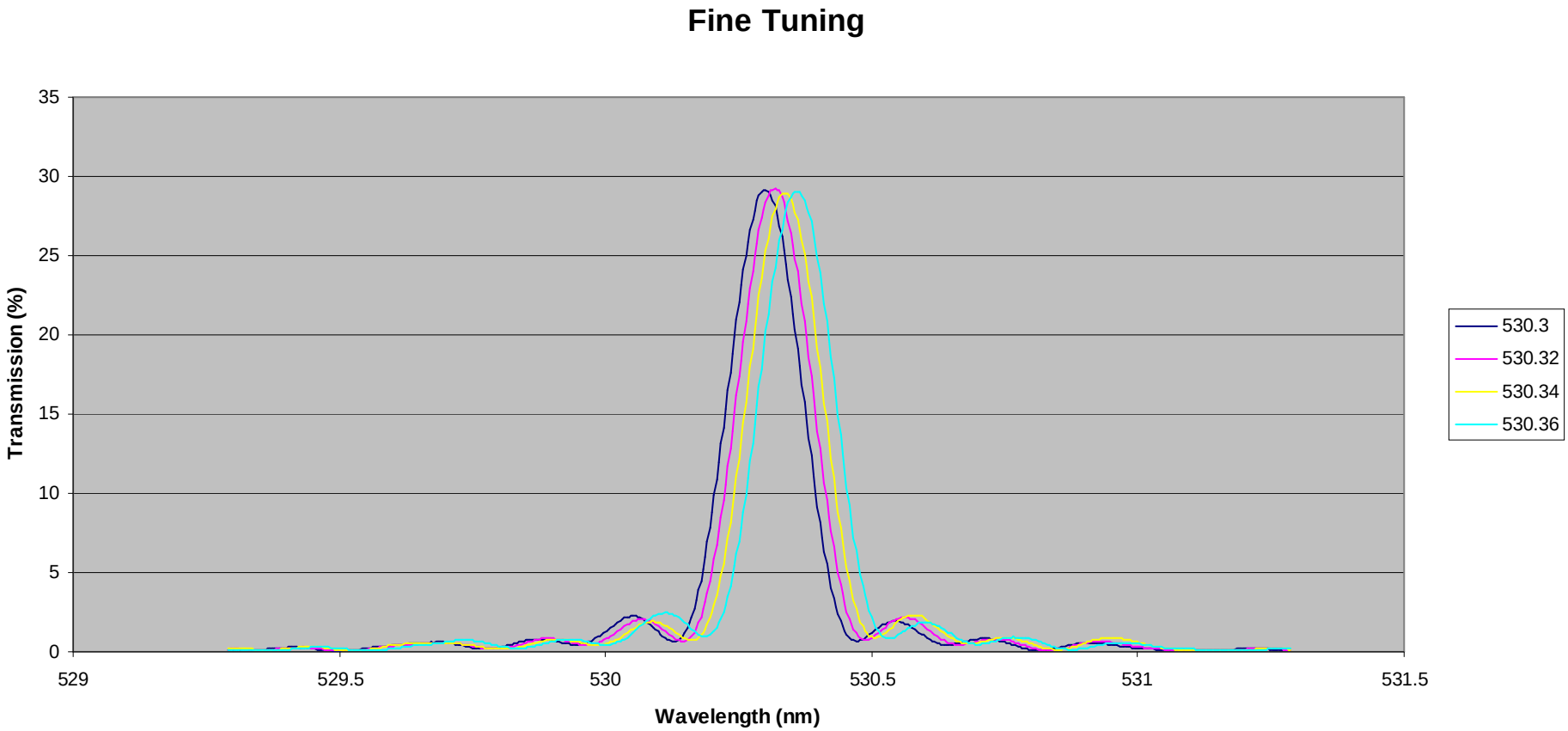
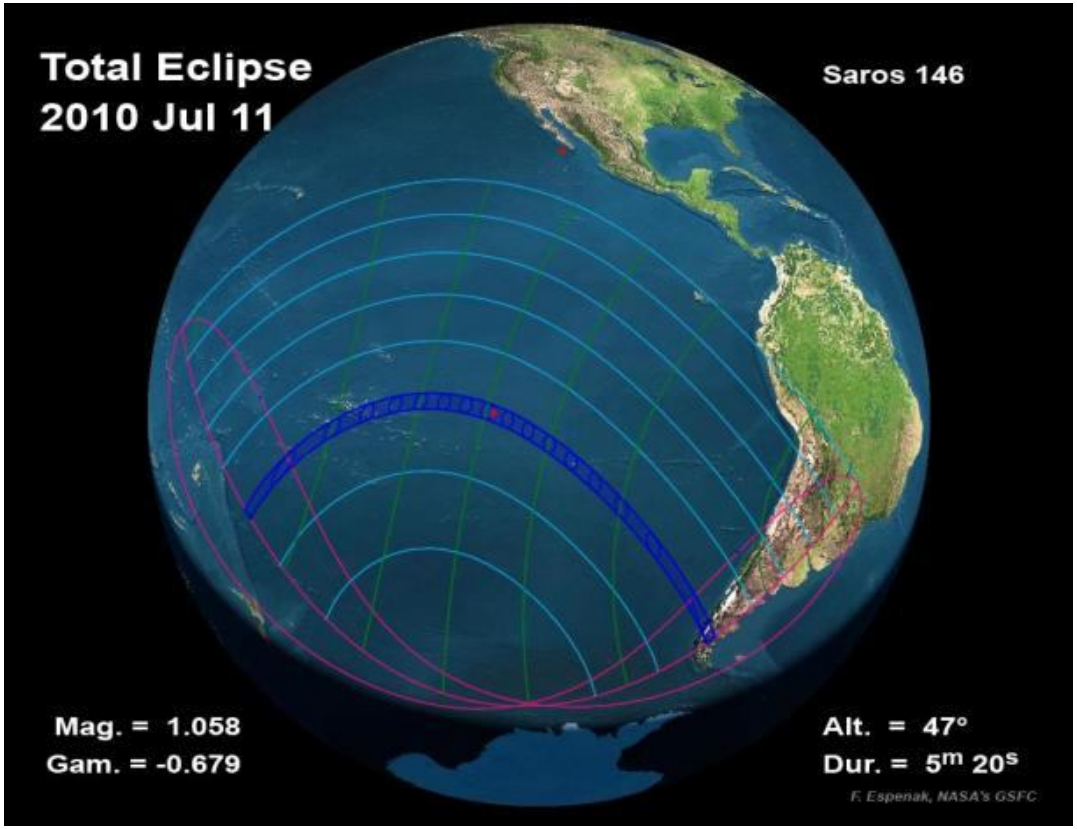
Turin - Liquid-crystal Tunable Lyot Filter Perfomances

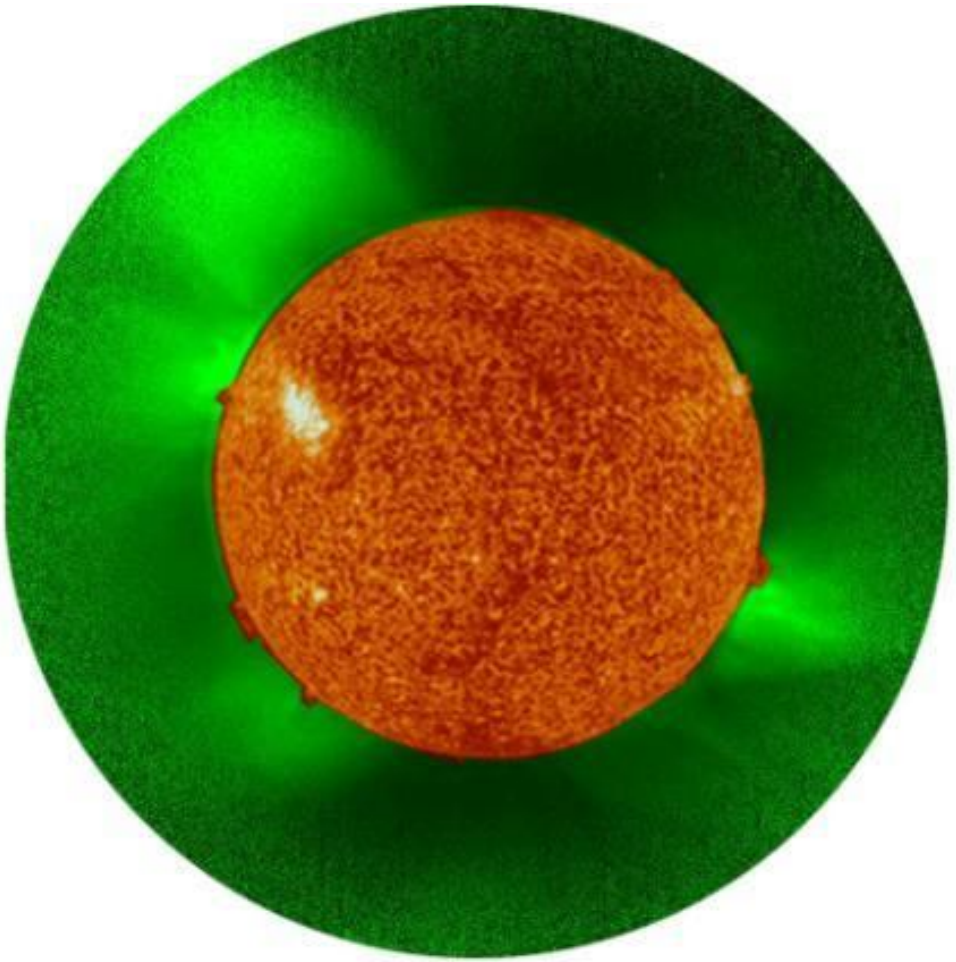


Turin – Coronal Magnetograph - CorMag



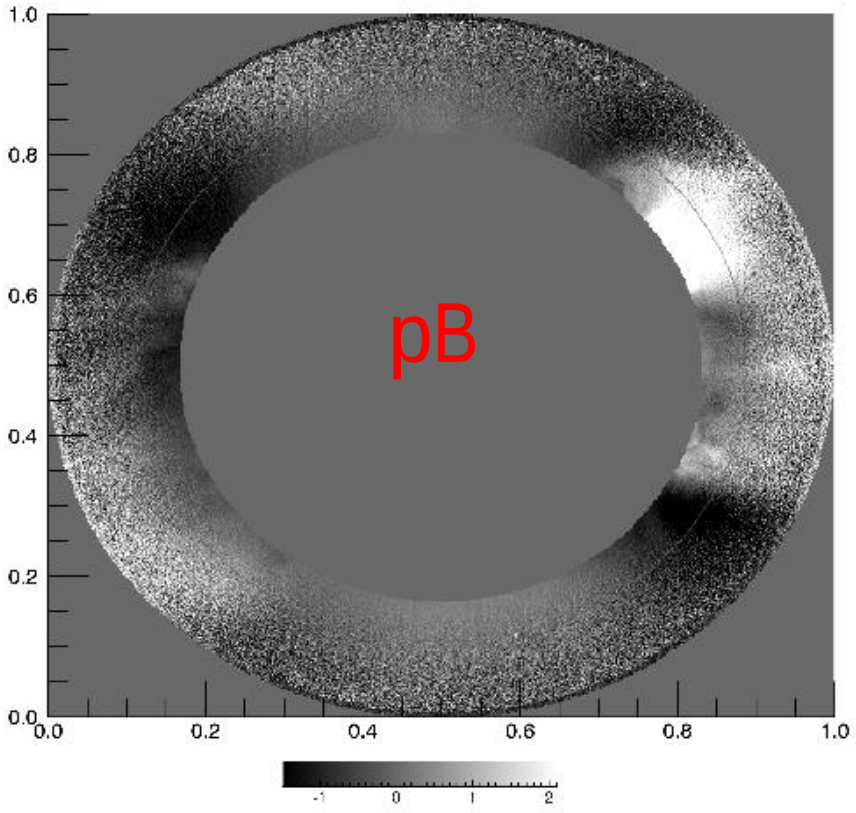
The CorMag was operated during the total solar eclipse of July, 11th 2010 on Tatakoto Atoll (French Polynesia)

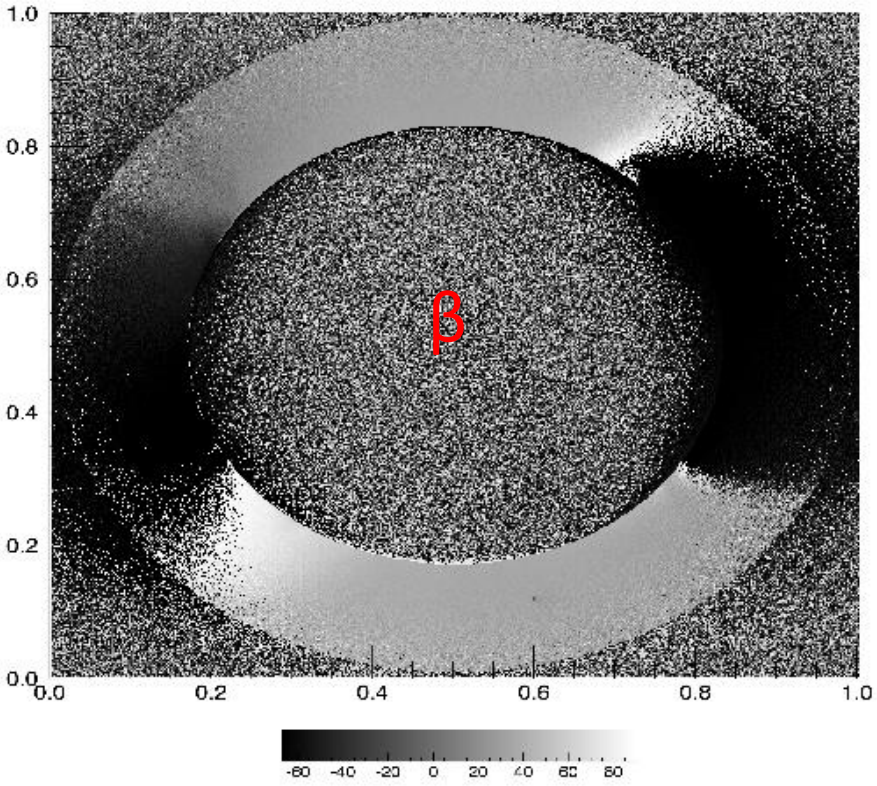
2010 Eclipse Results of CorMag



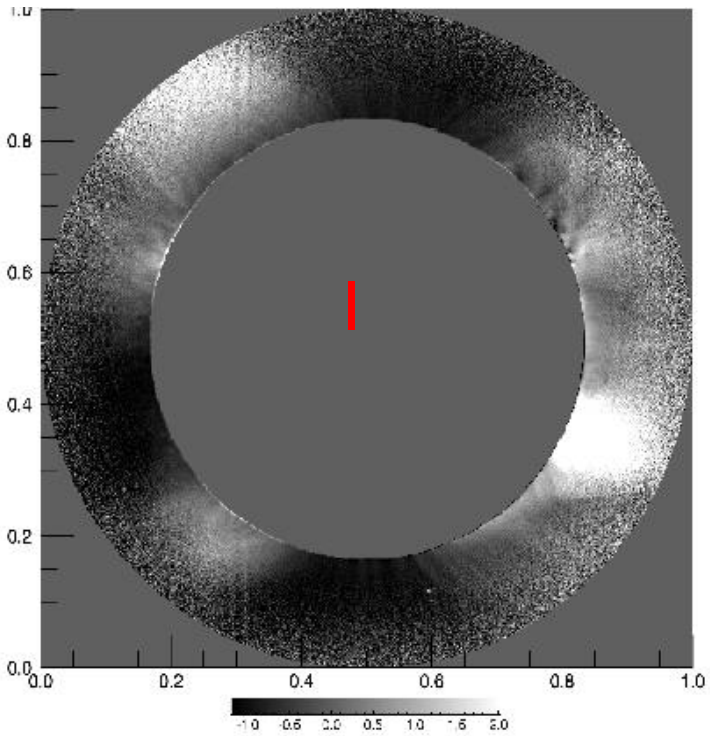
K-corona Polarization Vector

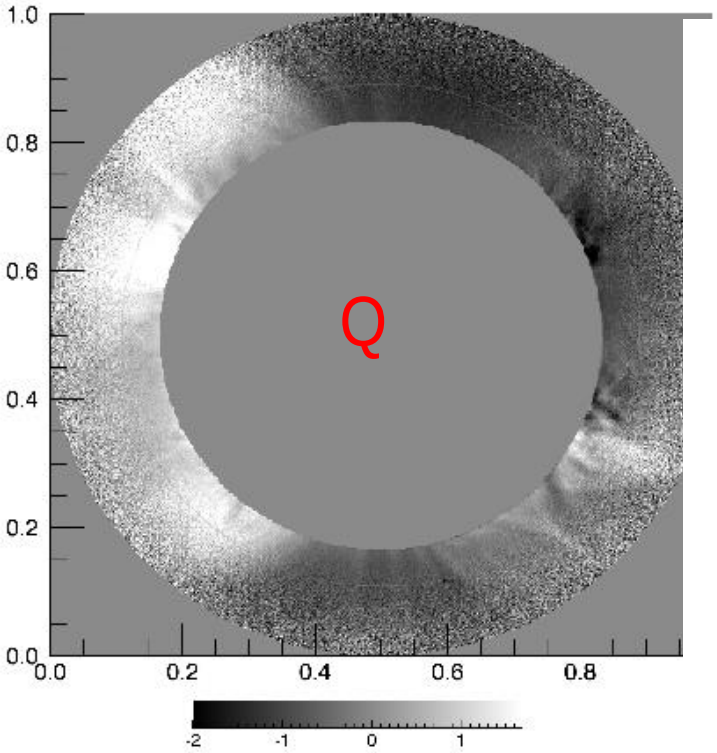
$$\beta = \frac{1}{2} tan^{-1} \frac{U}{Q}$$

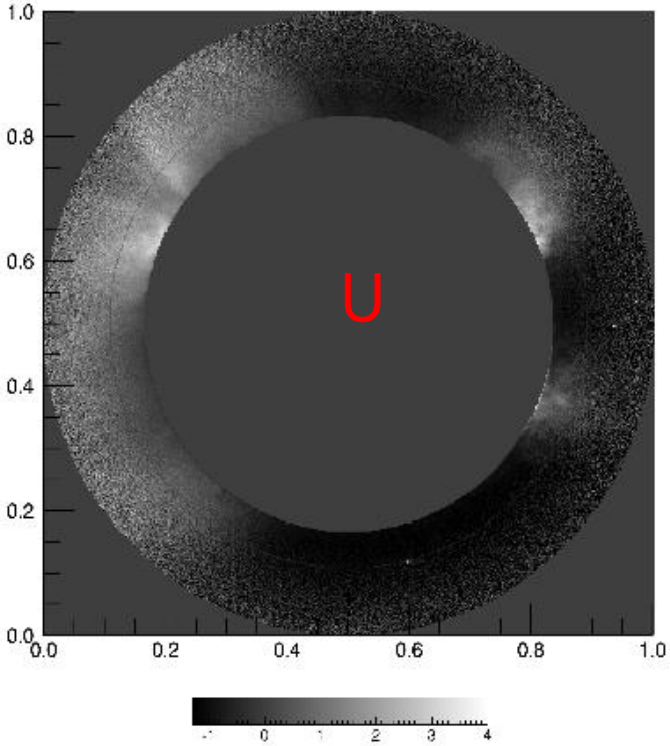




Measured Stokes Paramenters of FeXIV Line

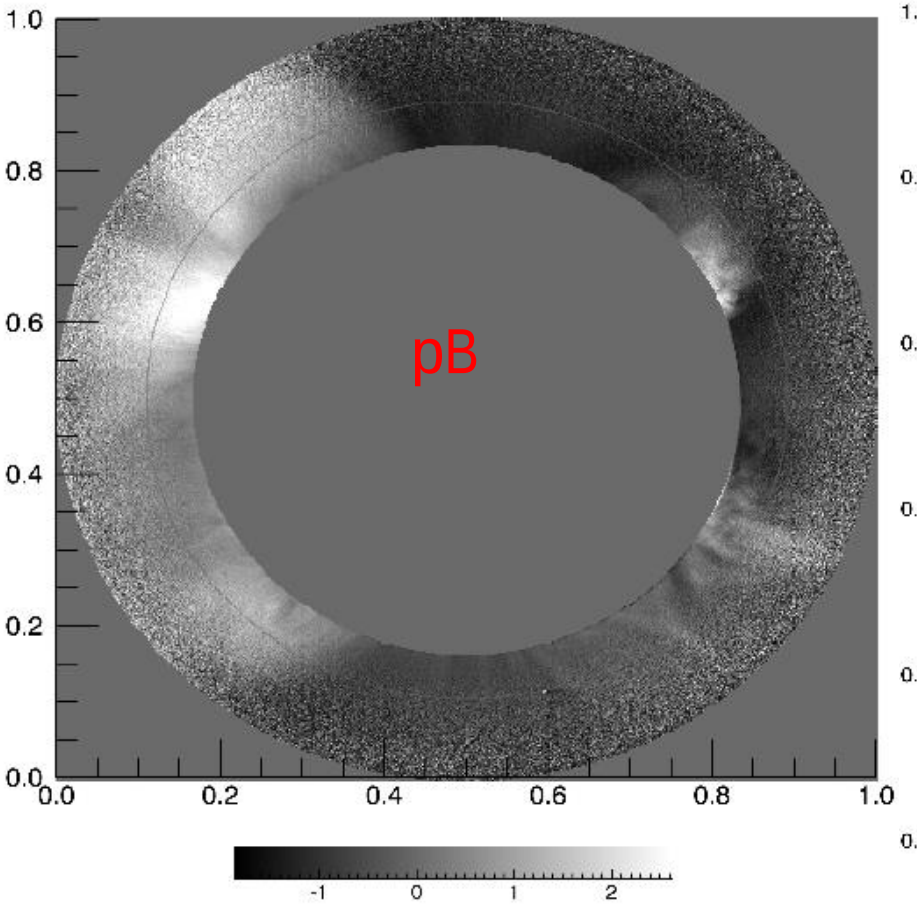


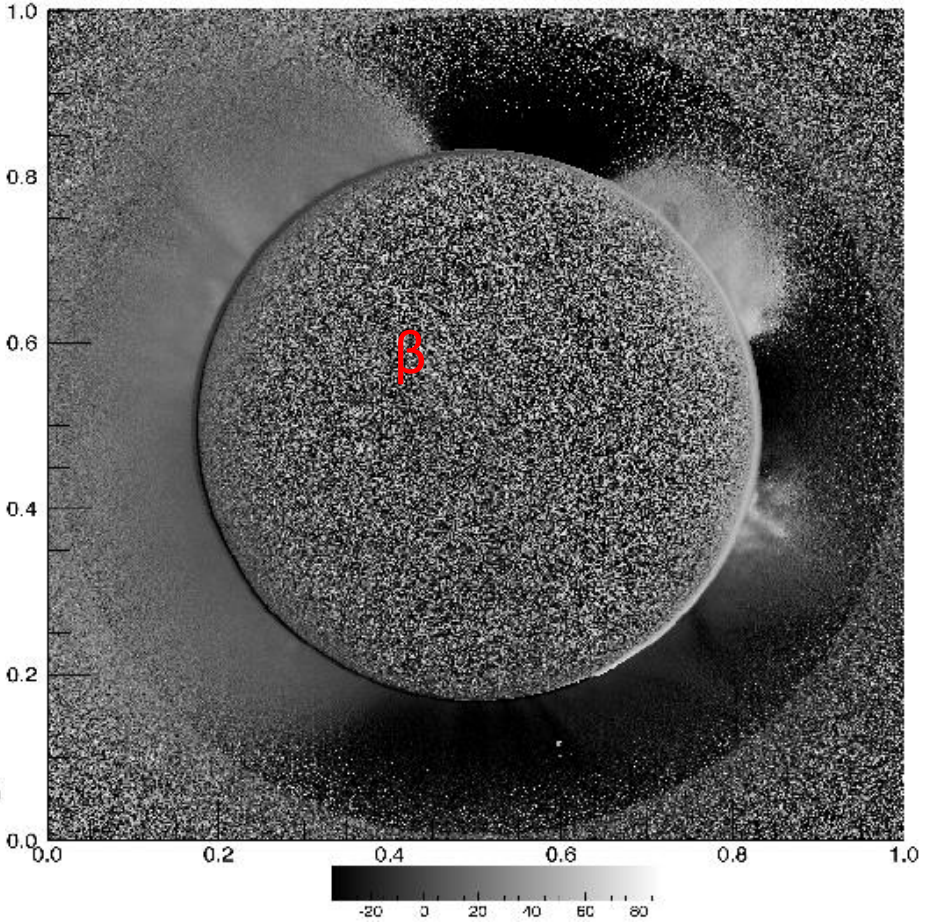




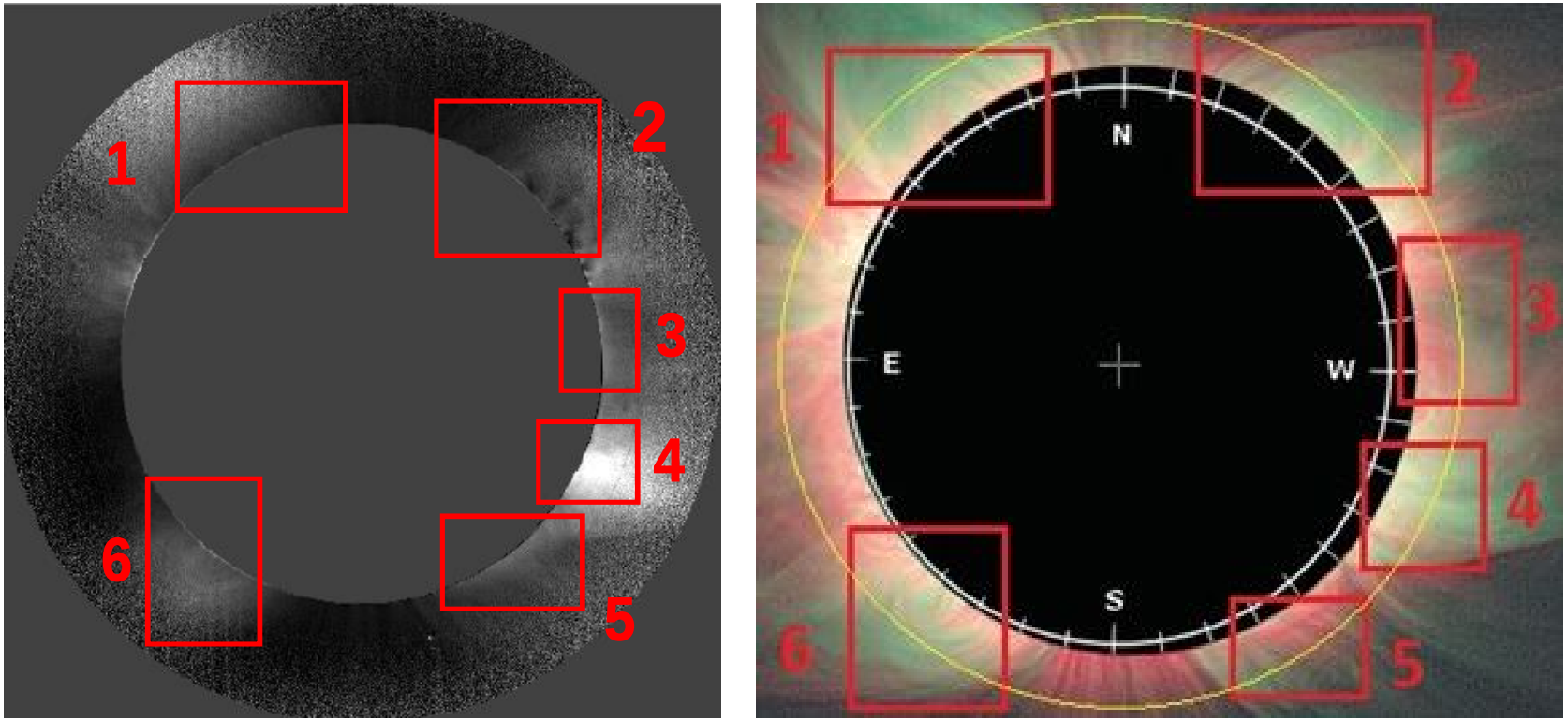
FeXIV Line Polarization Vector

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



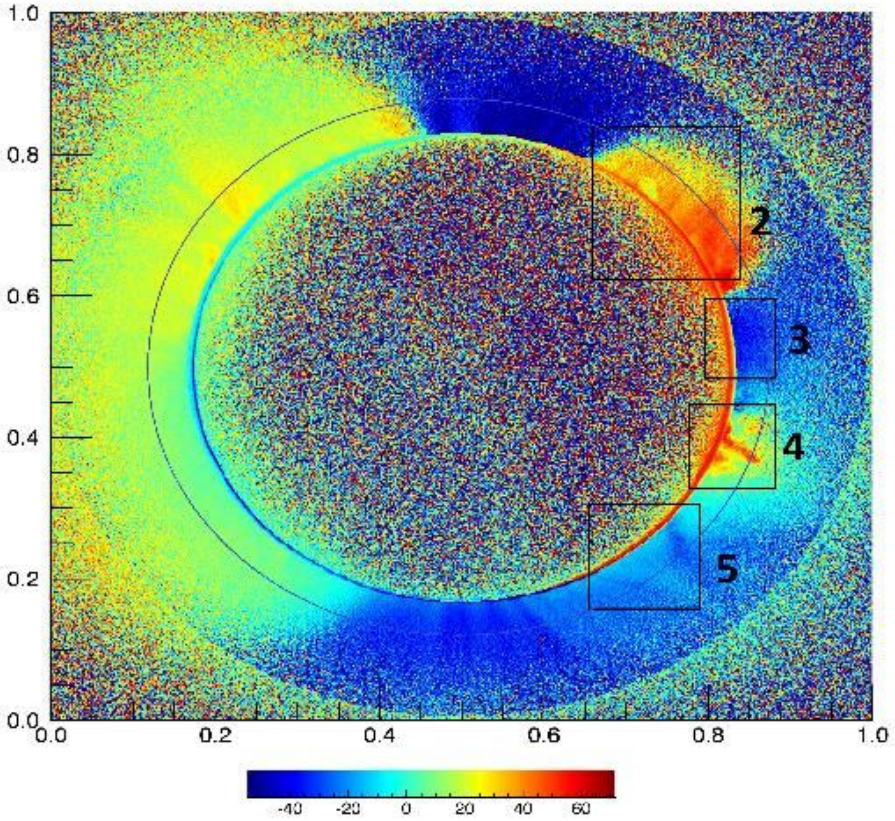


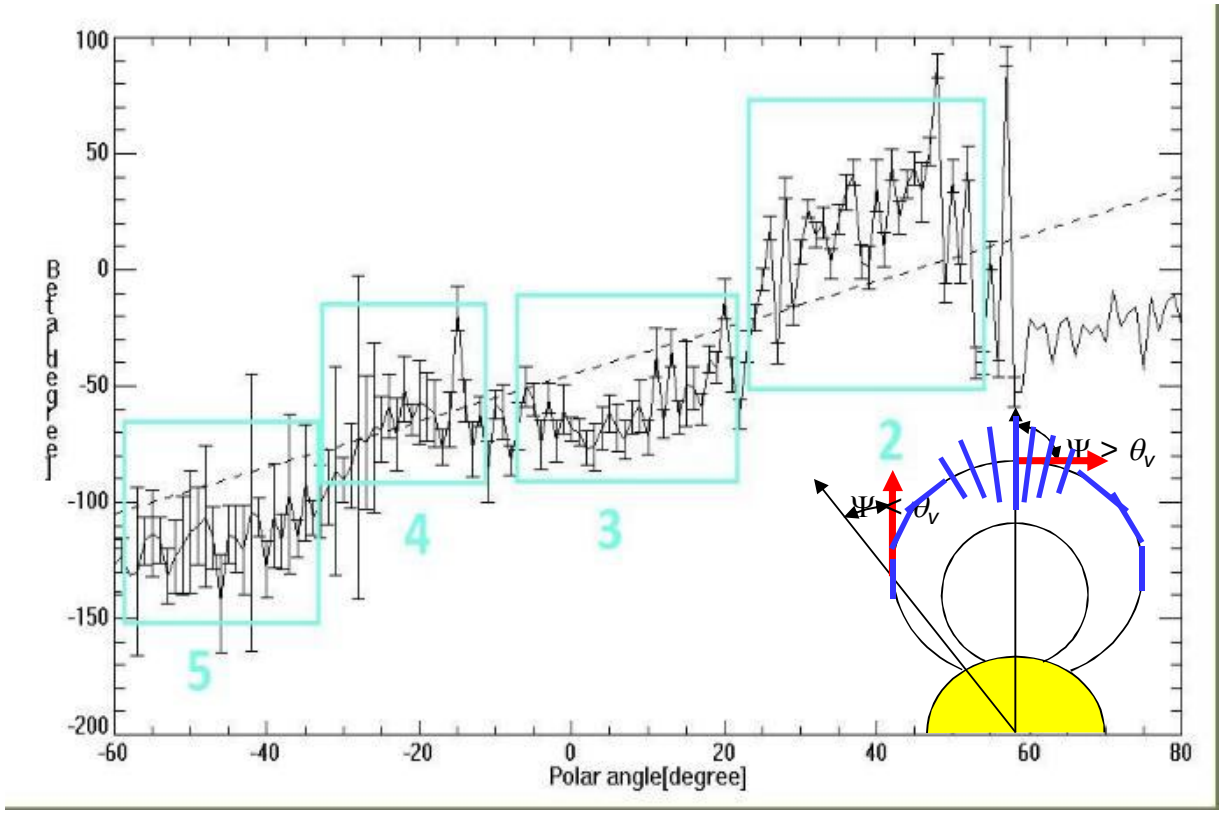
E corona: CorMag vs High resolution images



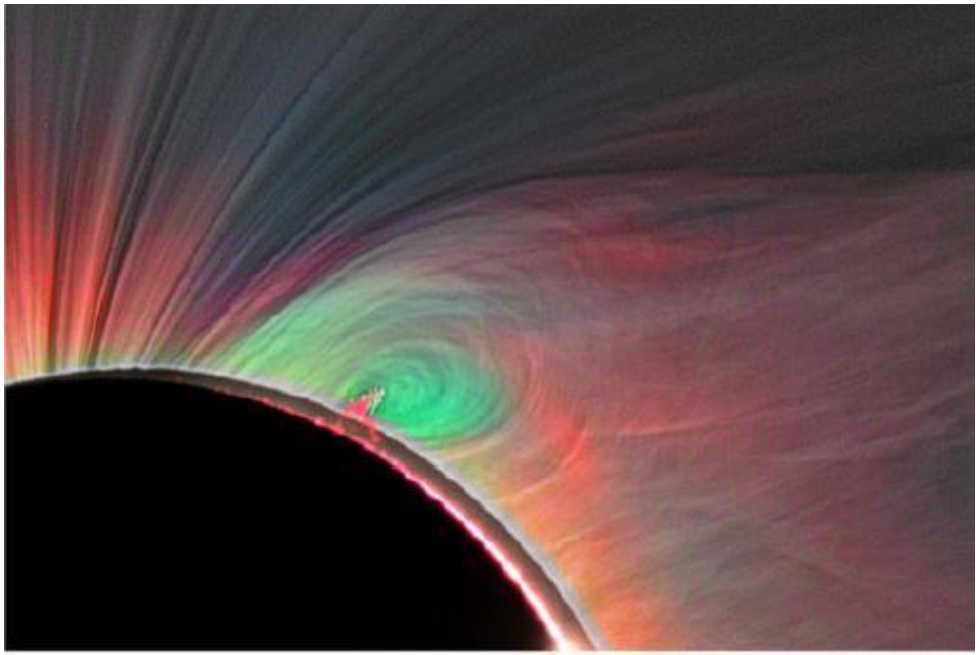
Left: CorMag spatial resolution 12.4''.
Right M. Druckmuller spatial resolution 1''.

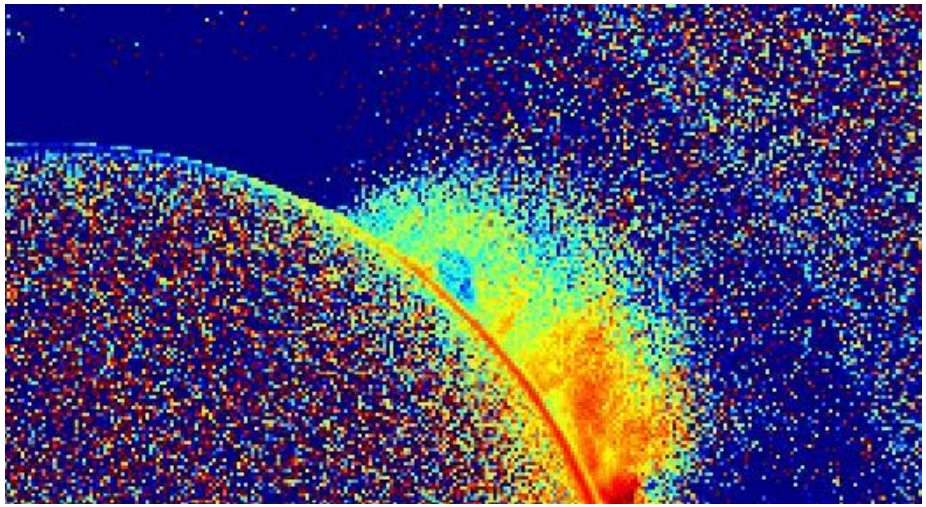
«Saturated» Hanle effect in the Coronal FeXIV Line





Coronal Cavity

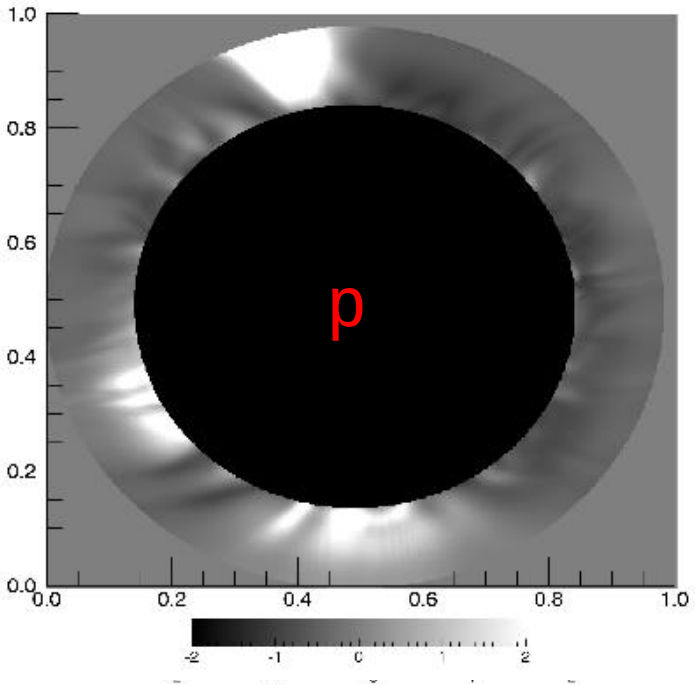




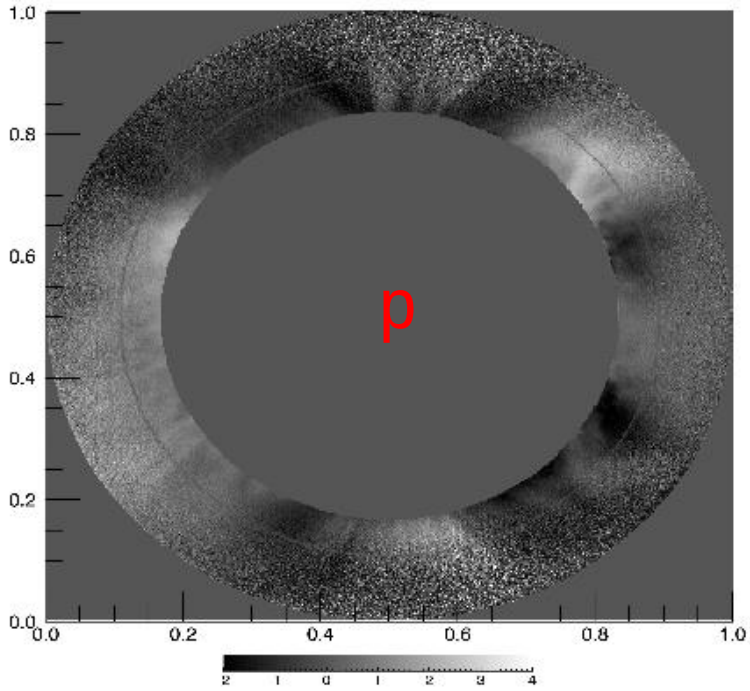
Left: M. Druckmuller imaging (spatial resolution 1”).
Right: CorMag polarization vector direction (res. 12.4”).

SDO/ AIA : (171 Filter)

E Corona Forward modeling (LOS)
vs
CorMag observations

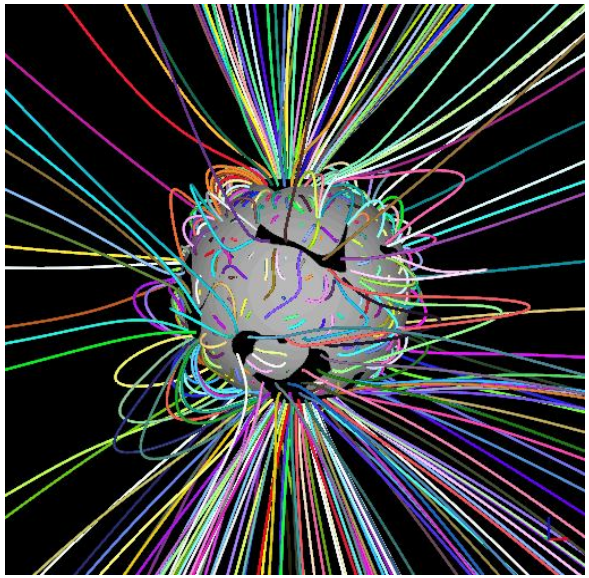


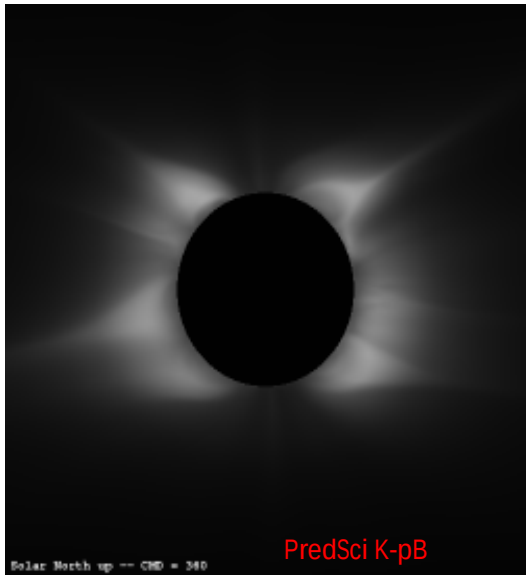
Forward modeling:
Predictive Science MHD model &
FORWARD Code (S. Gibson)

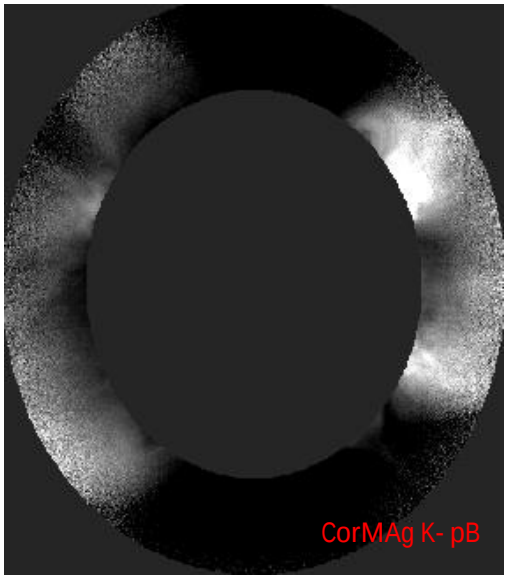


CorMag
Observations

Forward modeling
vs
CorMag observations

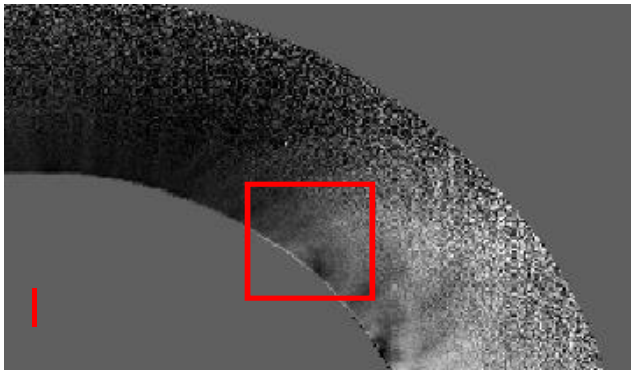


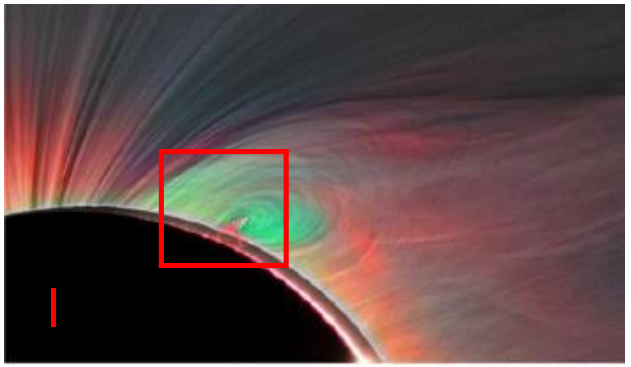


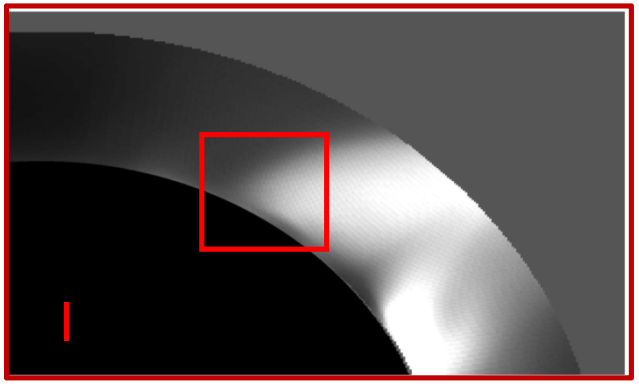


Left: Predictice Scence B model extrapolation.
Center: Synthetic pB emission from Predictive Science.
Right: pB measured by CorMag.

Forward modeling
vs
CorMag observations



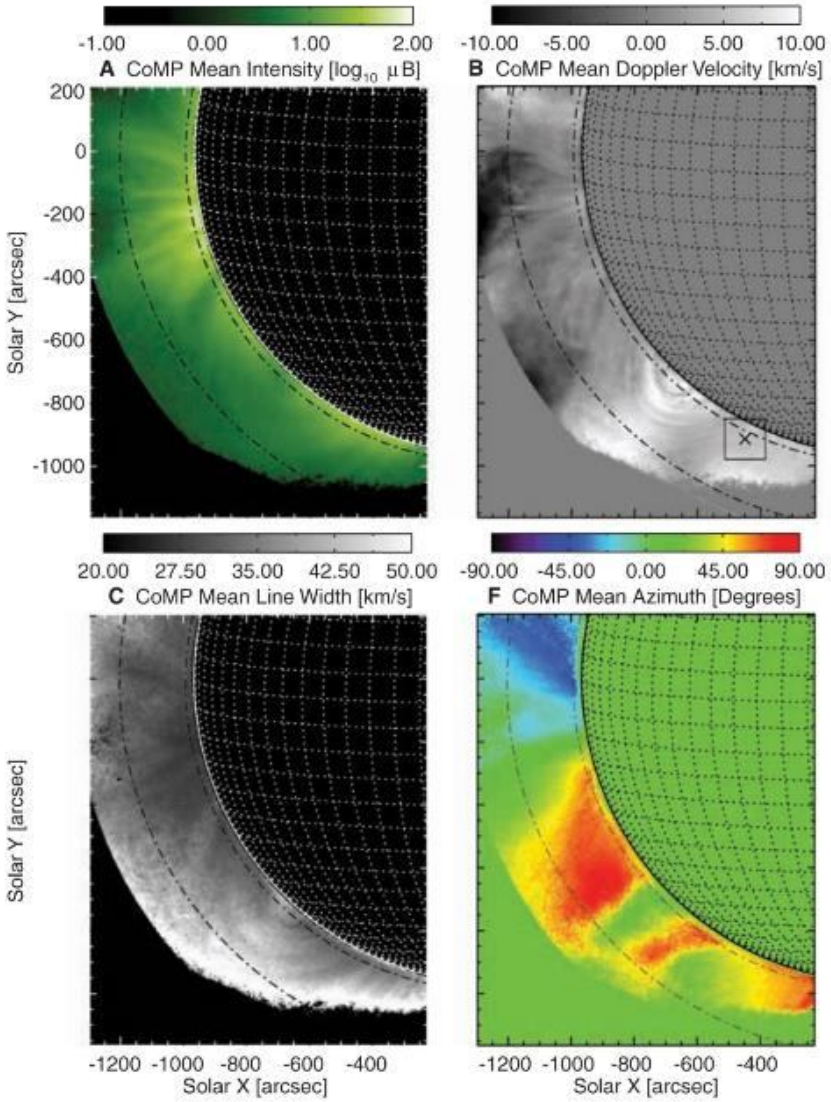




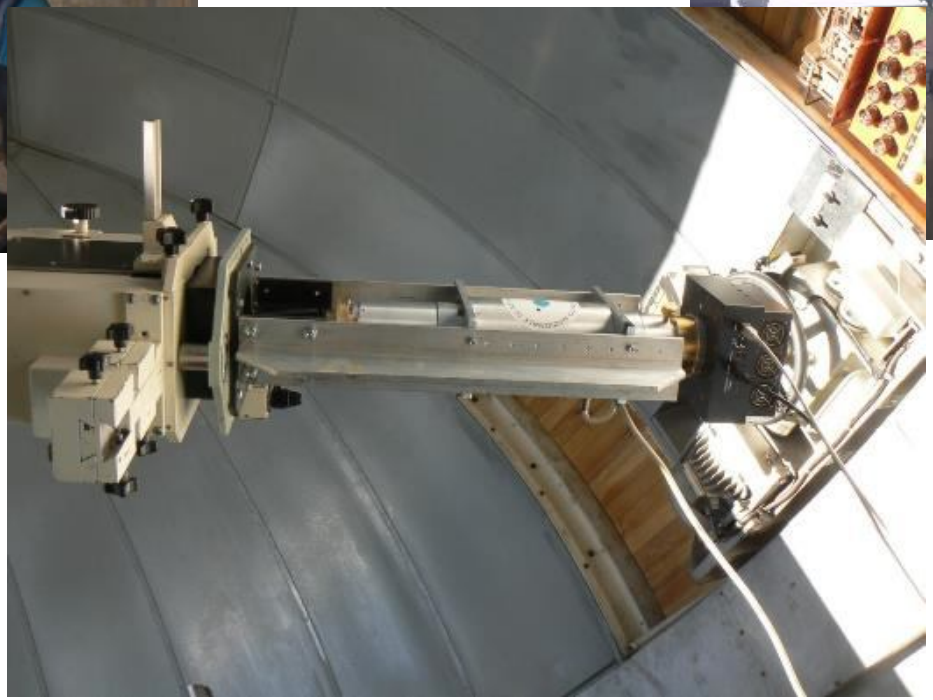
Model of global solar magnetic field based on extrapolation from photospheric magnetograms (averaged over a Carrington rotation do) not include transient structures

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

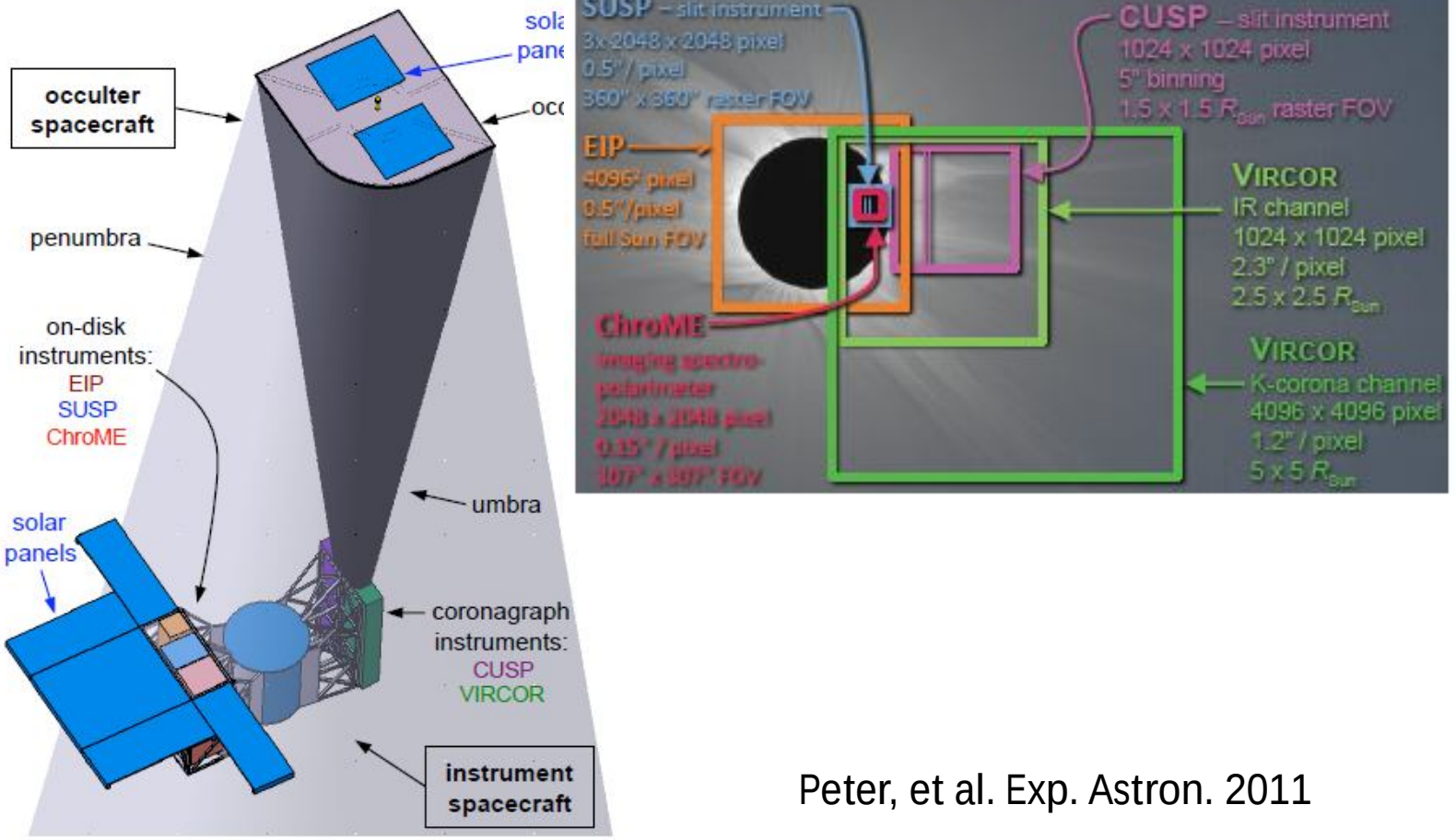
S. Tomczyk, *et al.*
Science 317, 1192 (2007);



CorMag at
Lomnicky Stit Observatory (Slovakia)



SolmeX – COMPASS
(ESA M-mission Proposals – 2007 and 2010)



Peter, et al. Exp. Astron. 2011

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

- New space optics for solar physics (LC-based spectropolarimetry optics)
- New ground- and space-based observatories with visible-light spectro-polarimetry