Space and Ground-based Coronal Spectro-polarimetry: Synergies

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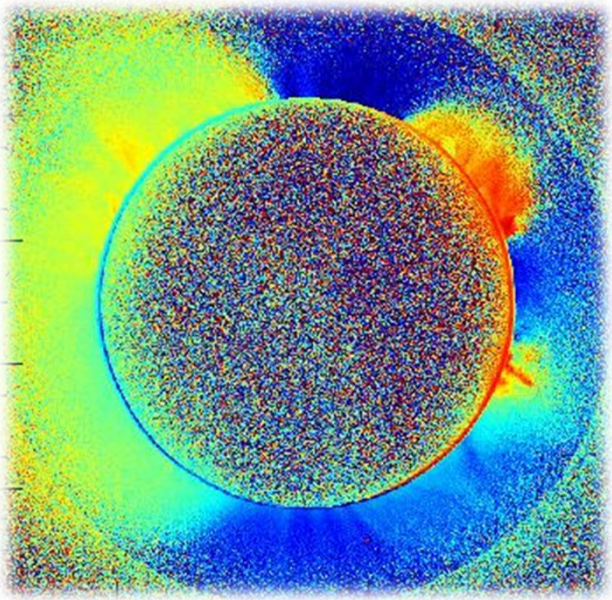


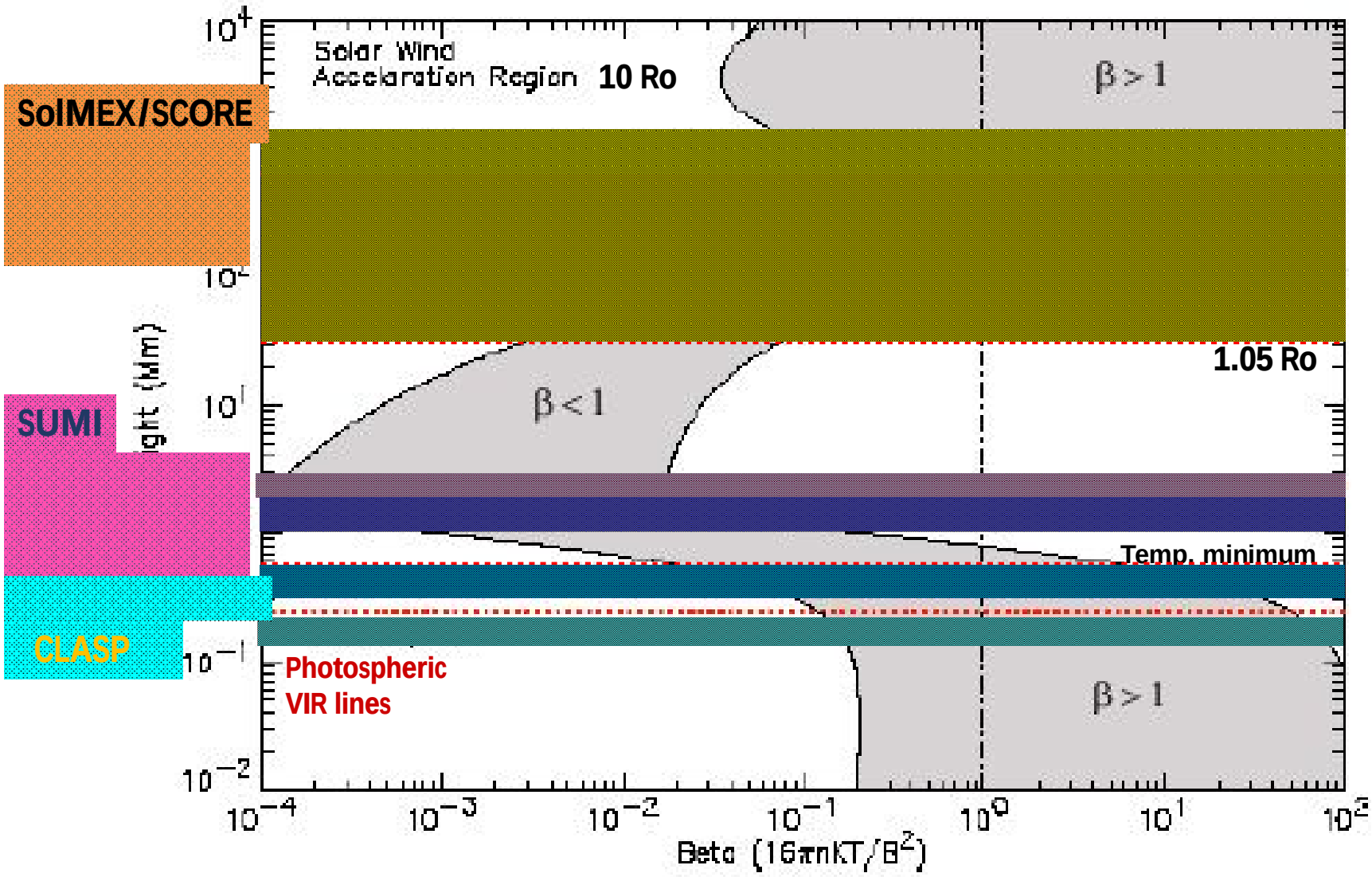
Toulouse (F)– 4-6 November 2014

The magnetic solar corona as revealed by polarimetry

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



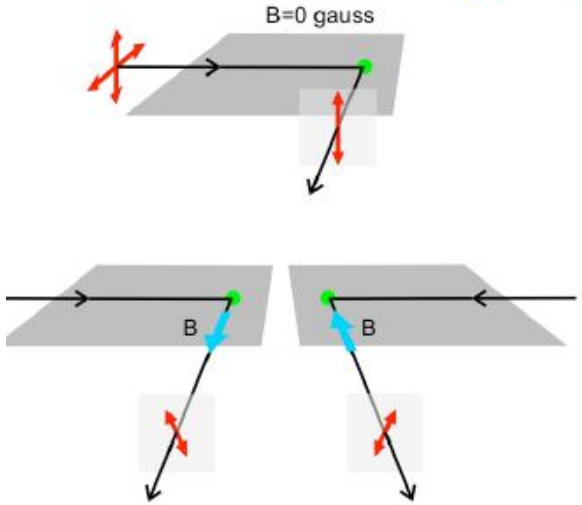
Probing Coronal Magnetism with Space EUV/UV/VIR Polarimetry

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

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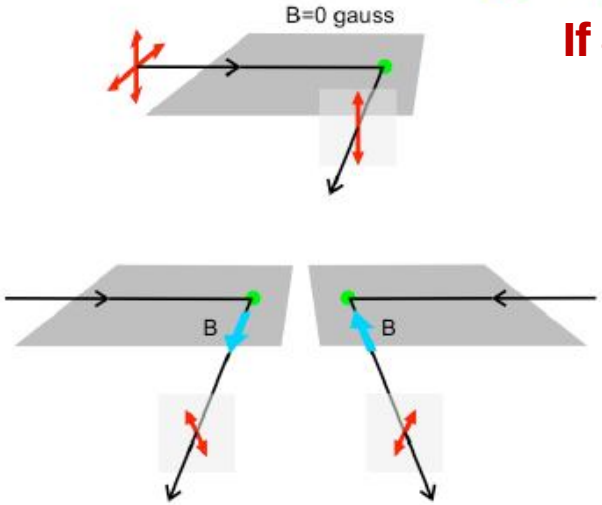

90° scattering geometry

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

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⇓

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

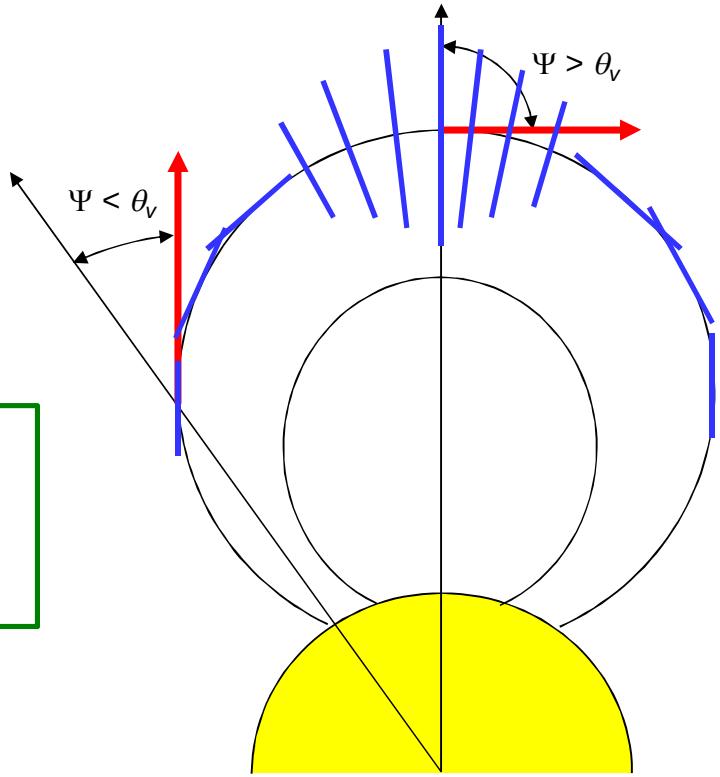
$\Psi = \theta_v$, **P=0**

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

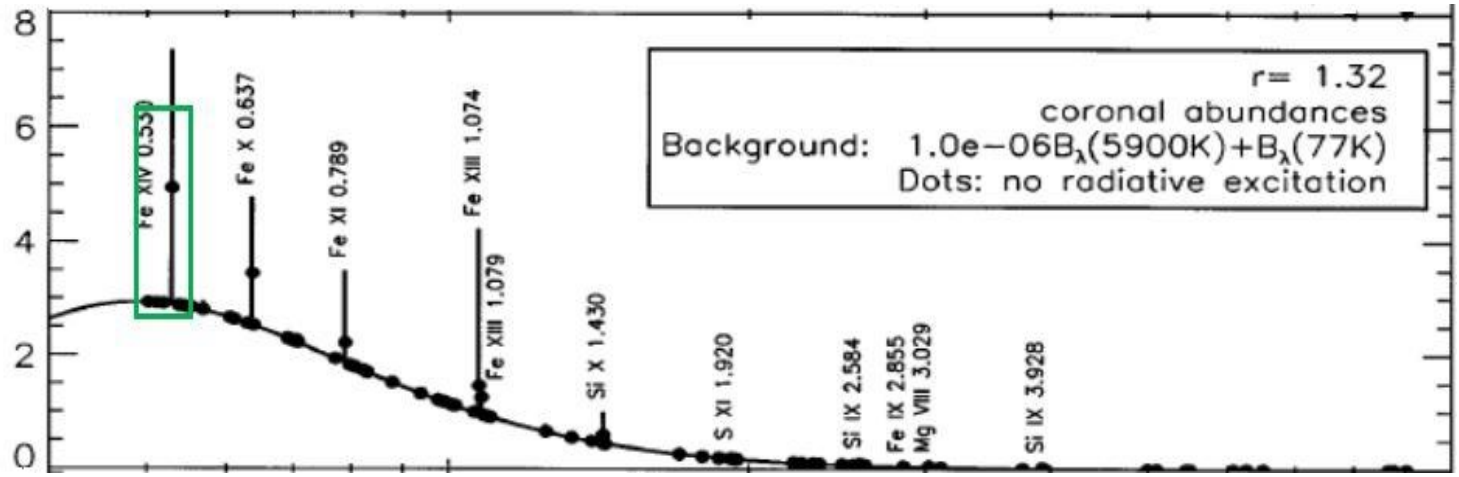
$\Psi > \theta_v$, $\Rightarrow$ **LP $\perp$ *B***

"Saturated" Hanle effect

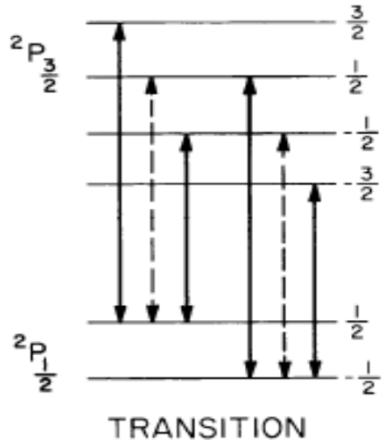
$\omega_{Larmour} >> A$



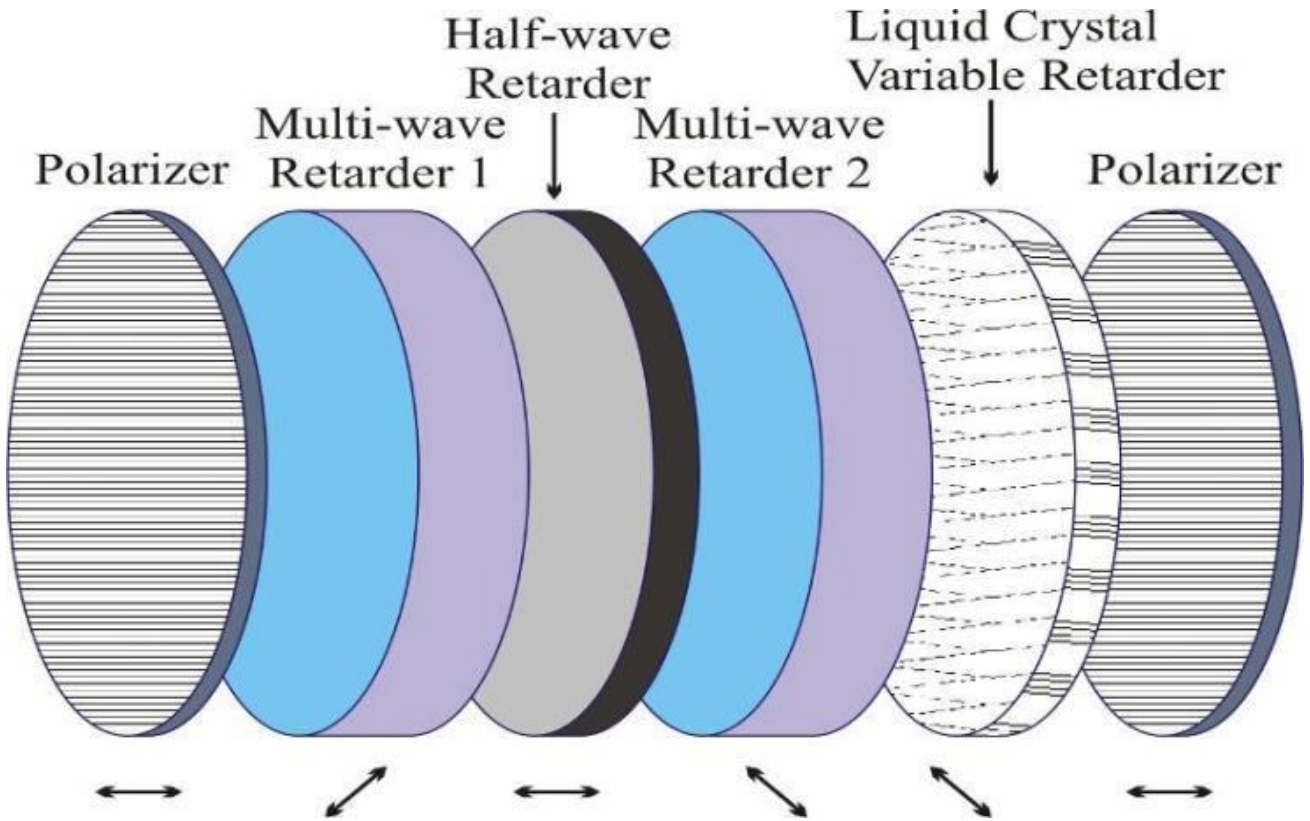
Fe XIV 530.3 nm (“Green Line”)



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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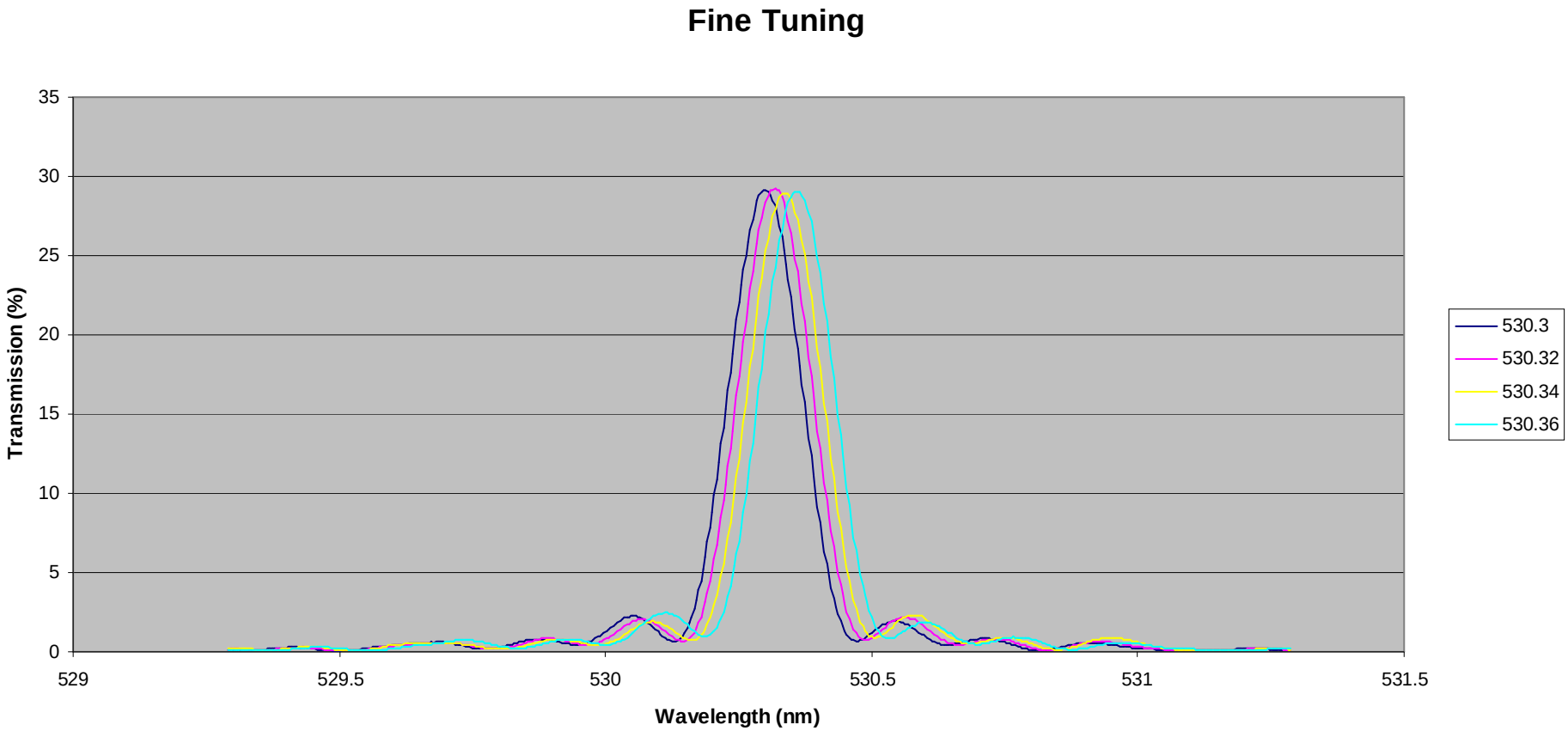
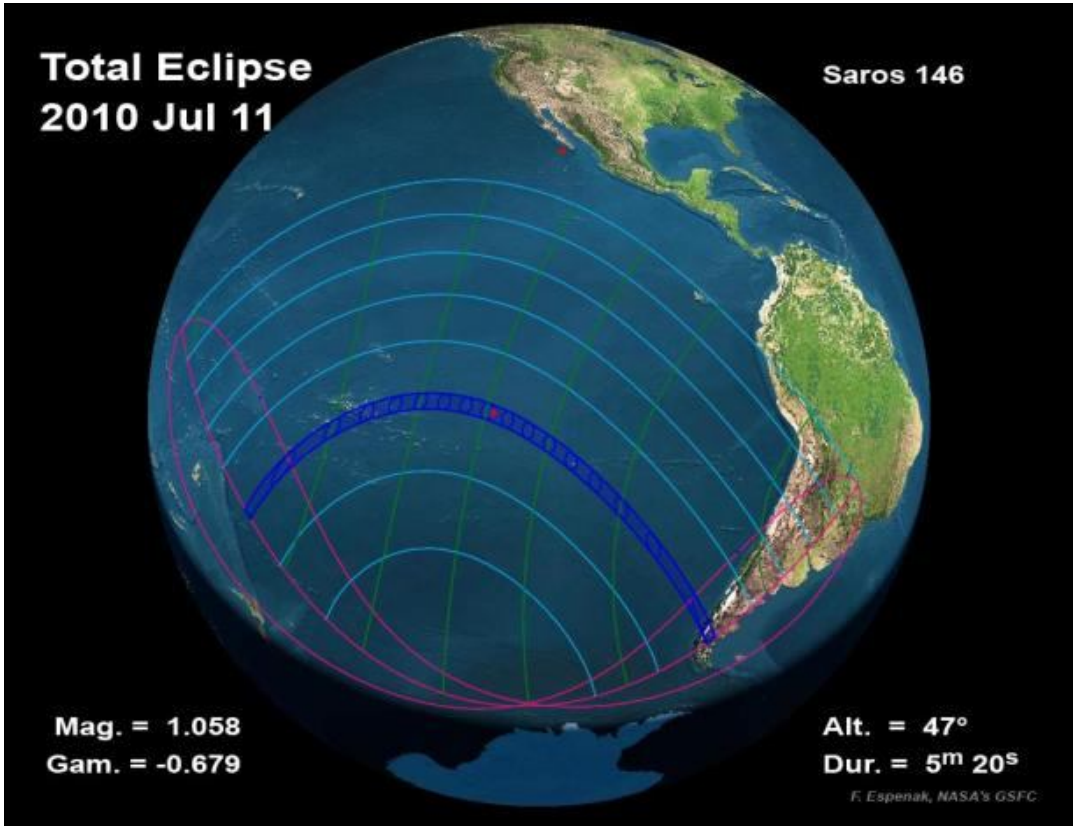
Turin - Liquid-crystal Tunable Lyot Filter Perfomances

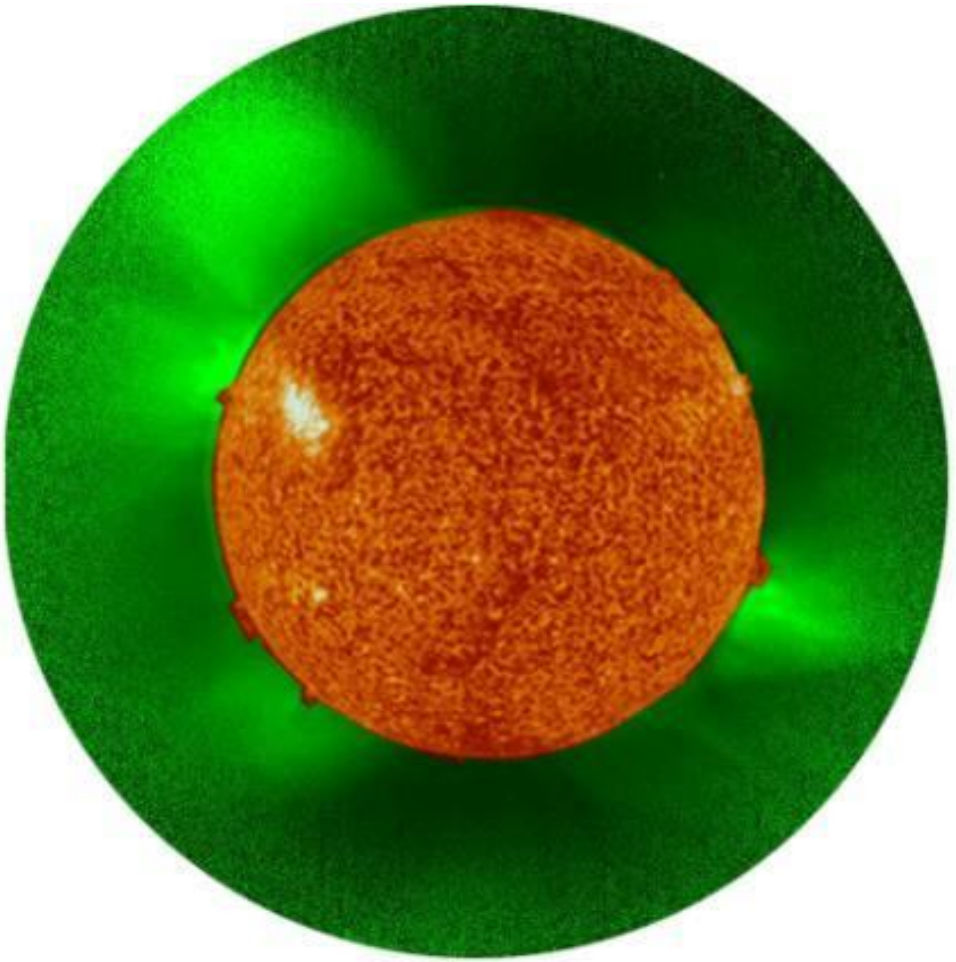


Turin – Coronal Magnetograph - CorMag

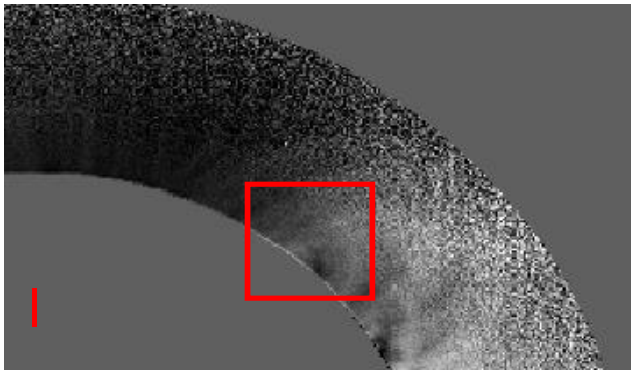


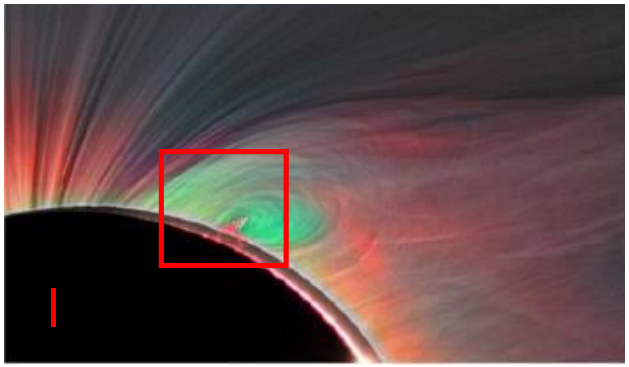
The CorMag was operated during the total solar eclipse of July, 11th 2010 on Tatakoto Atoll (French Polynesia)

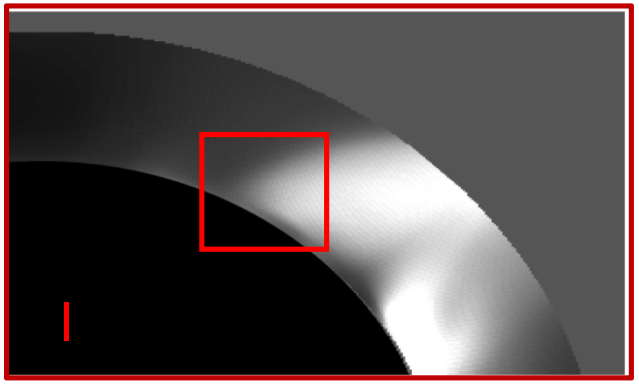
2010 Eclipse Results of CorMag



Forward modeling
vs
CorMag observations

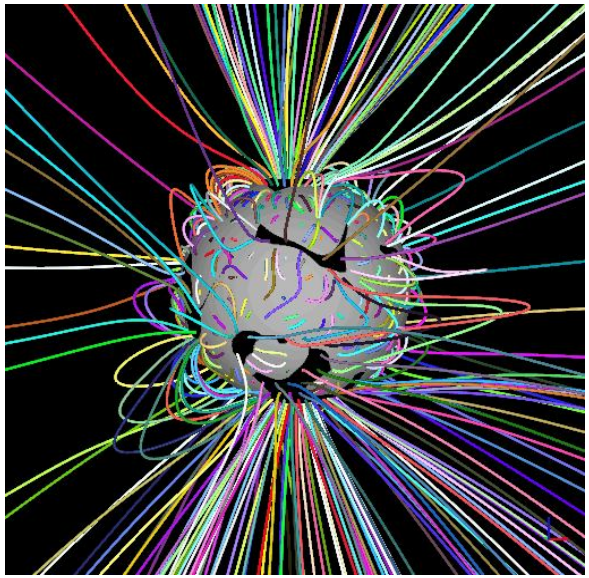


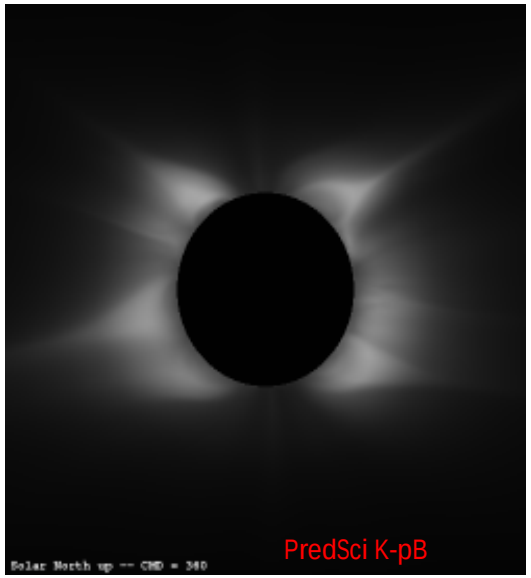


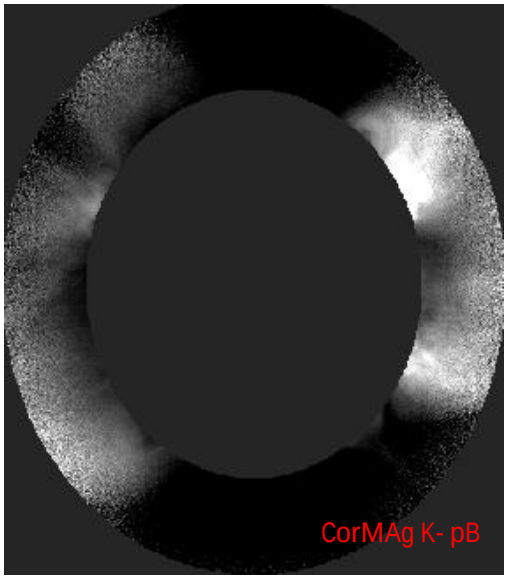


Model of global solar magnetic field based on extrapolation from photospheric magnetograms (averaged over a Carrington rotation do) not include transient structures

Forward modeling
vs
CorMag observations

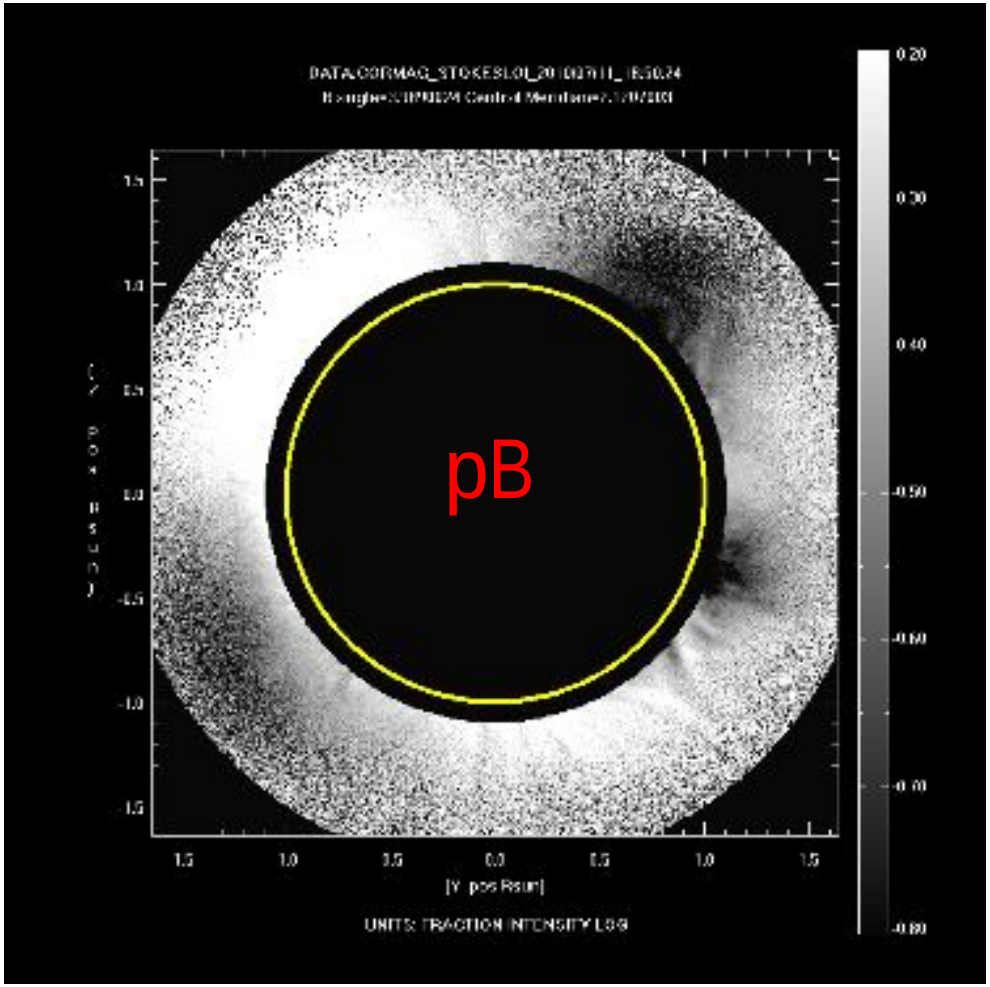


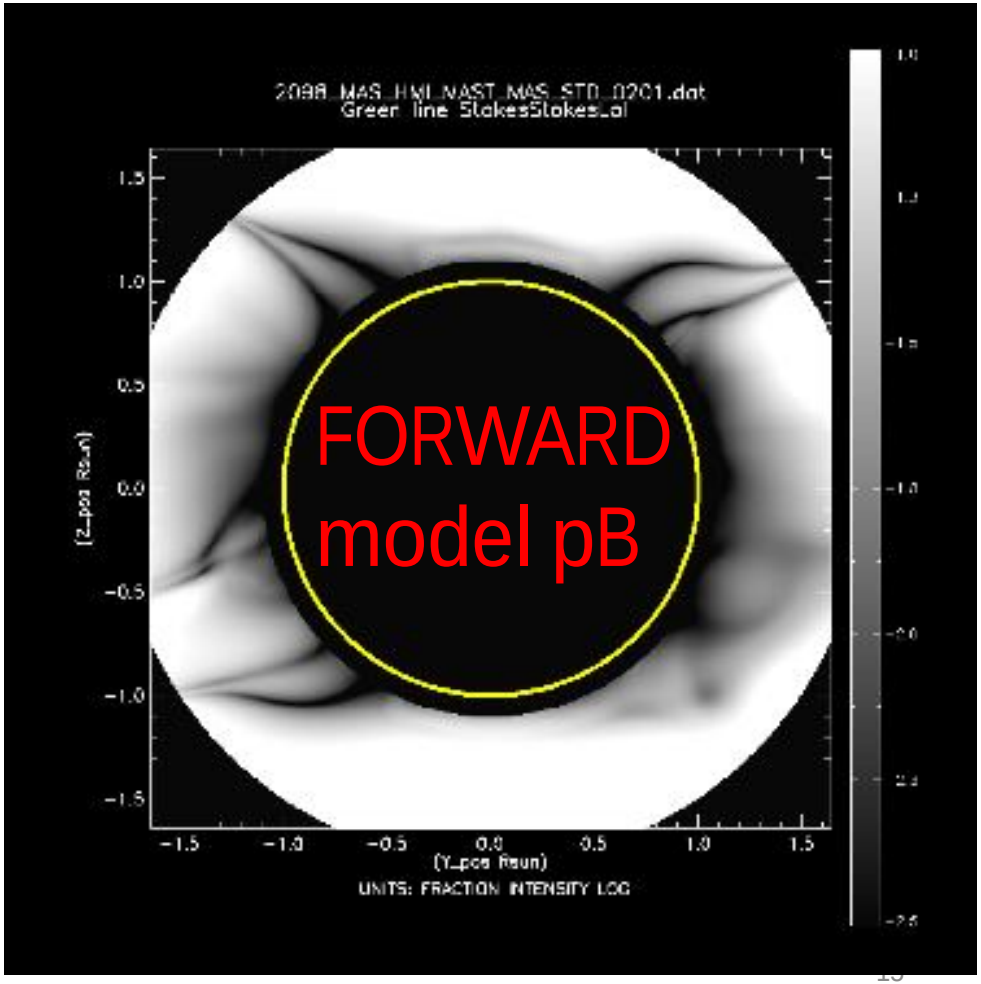




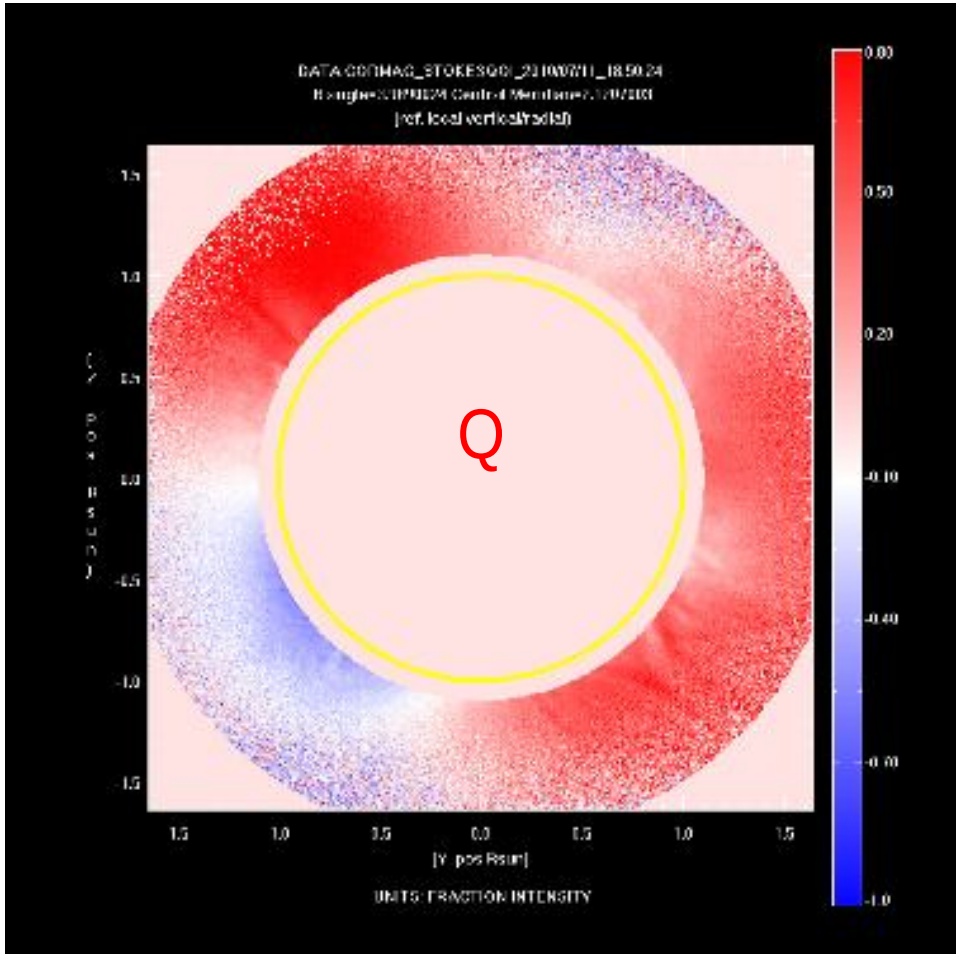
Left: Predictice Scence B model extrapolation.
Center: Synthetic pB emission from Predictive Science.
Right: pB measured by CorMag.

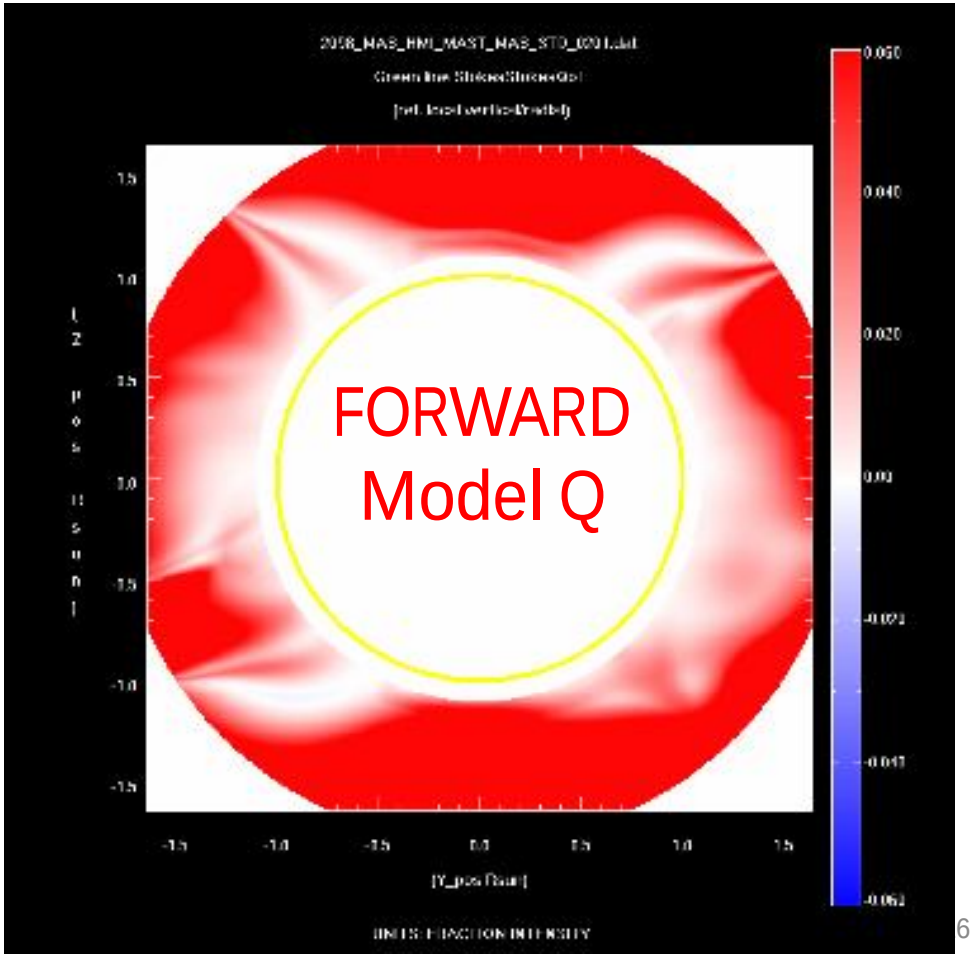
E-corona Polarization Degree (pB/B)



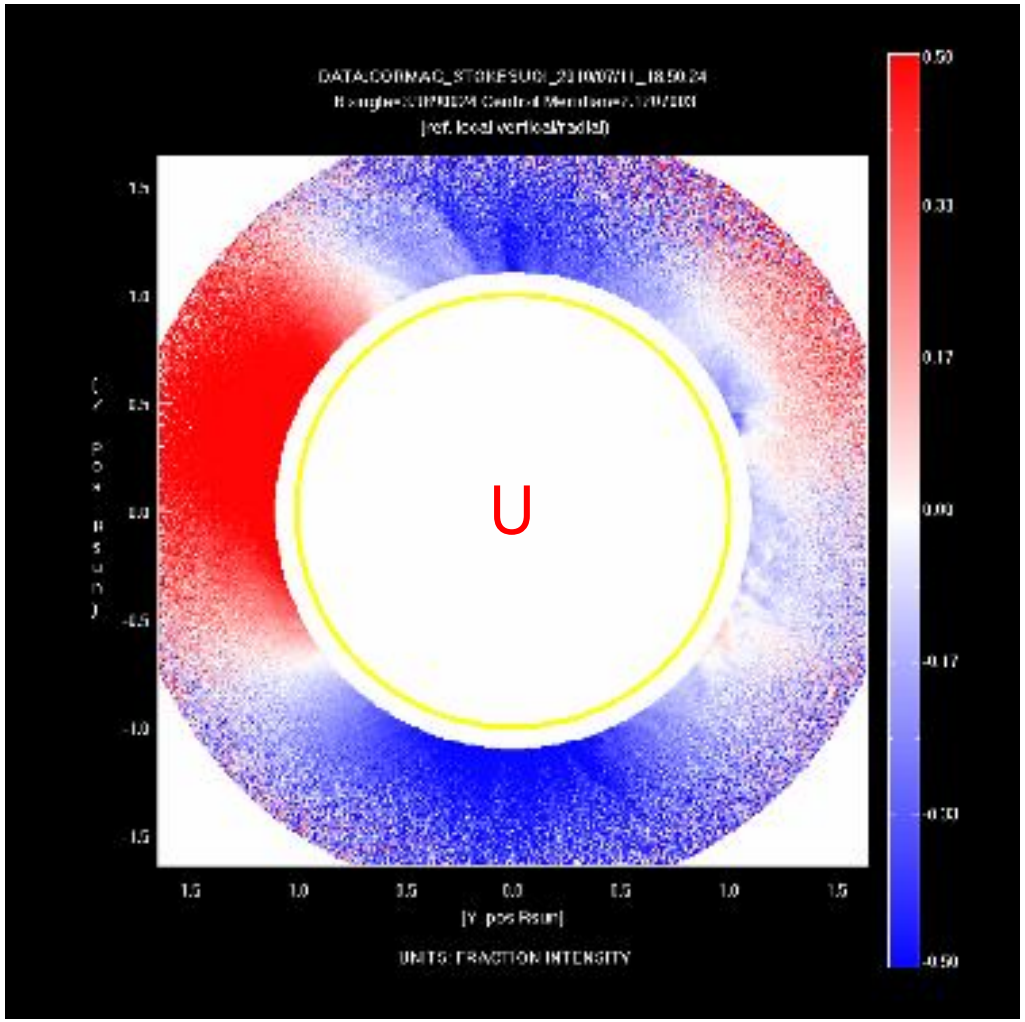


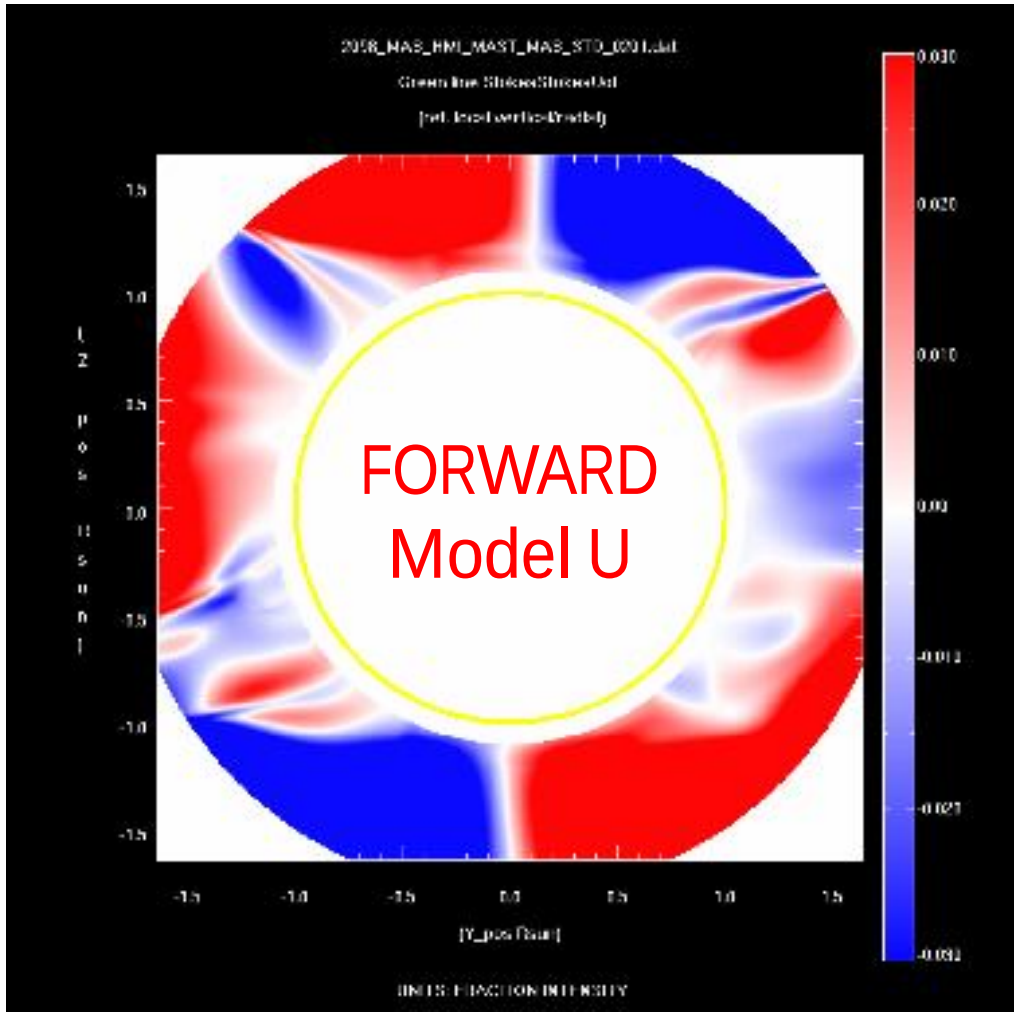
Measured Stokes Paramenters of FeXIV Line (Q/I)



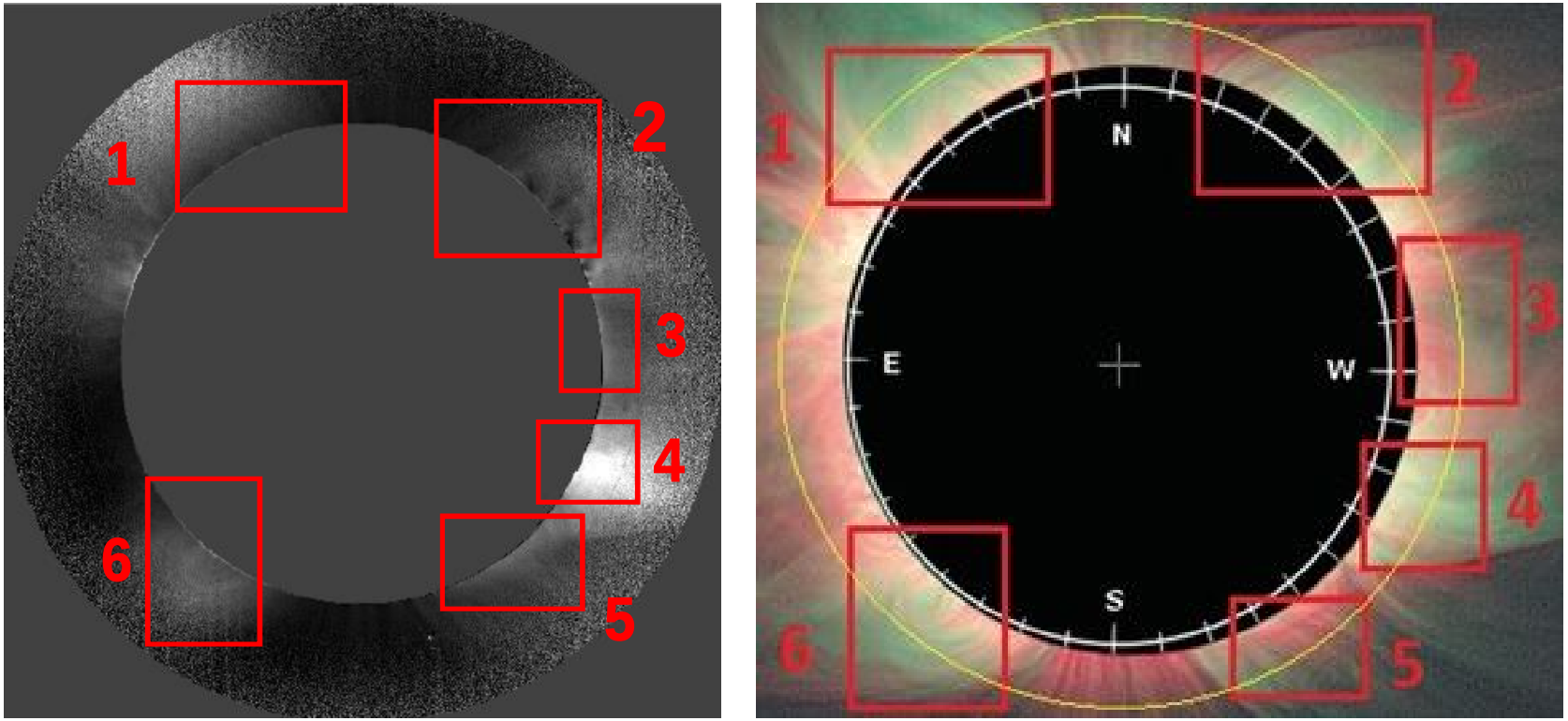


Measured Stokes Paramenters of FeXIV Line (U/I)



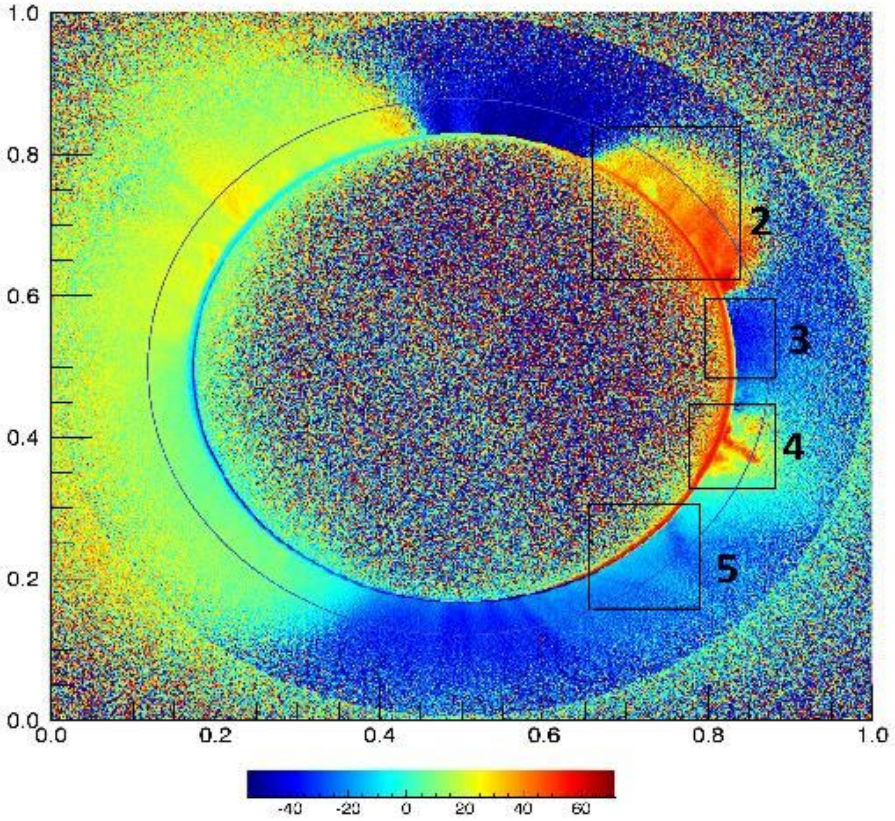


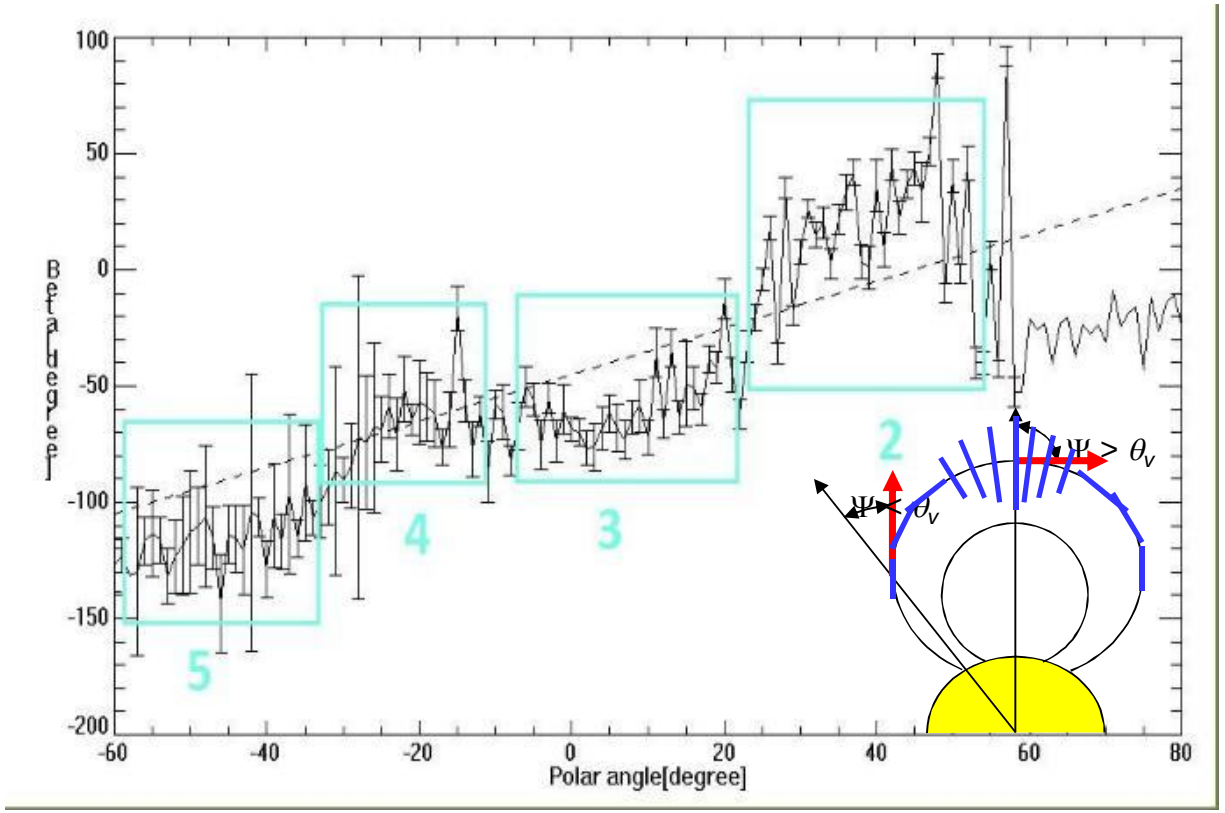
E corona: CorMag vs High resolution images



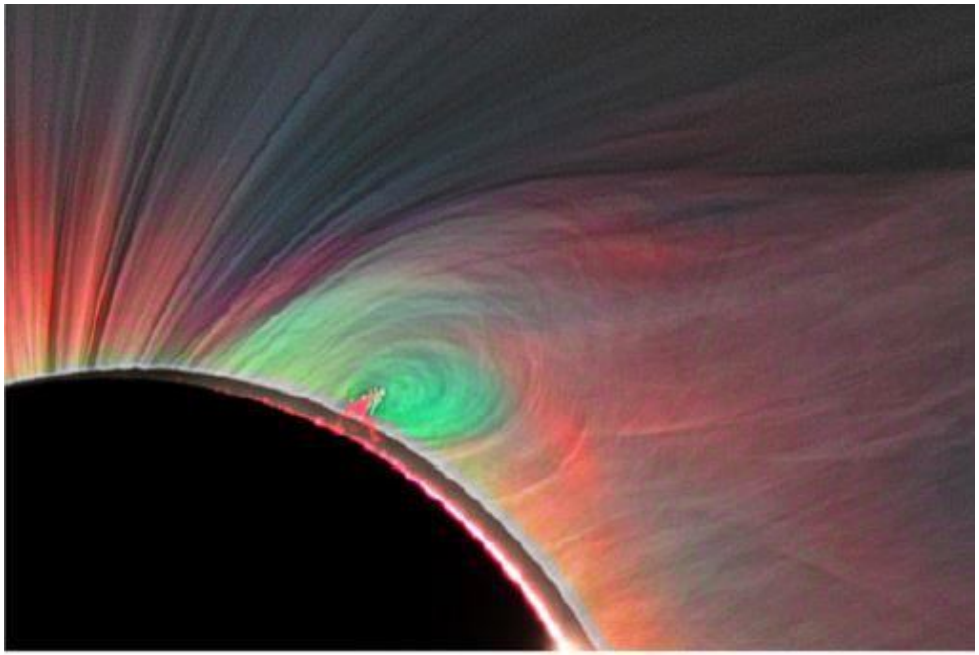
Left: CorMag spatial resolution 12.4''.
Right M. Druckmuller spatial resolution 1''.

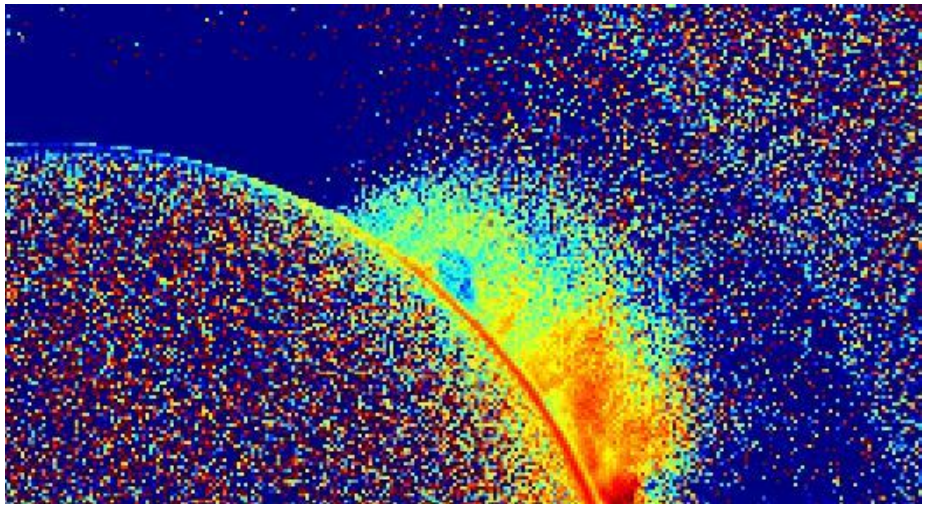
«Saturated» Hanle effect in the Coronal FeXIV Line





Coronal Cavity

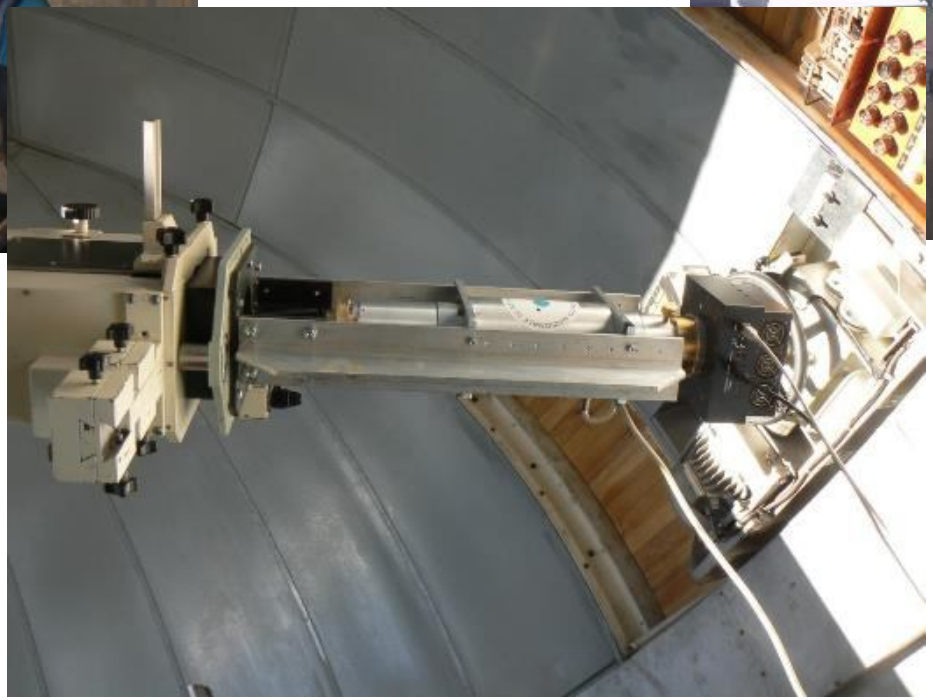




Left: M. Druckmuller imaging (spatial resolution 1”).
Right: CorMag polarization vector direction (res. 12.4”).

SDO/ AIA : (171 Filter)

CorMag at
Lomnicky Stit Observatory (Slovakia)



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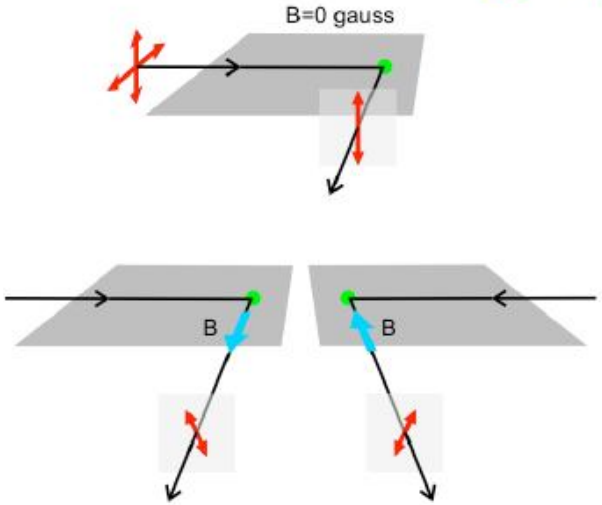

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$\omega_{\text{Larmour}} \sim A$

Physical mechanisms that control the polarization of the spectral lines that originate in the solar atmosphere

The Zeeman effect

B

Scattering processes and the Hanle effect

UV (permitted) lines: B_{los} ;θ_{los}

VIR (forbidden) lines: θ_{los}

Scattering and Superradial Doppler-dimming effect

UV lines: Effect of **B** on ions **v** (i.e., kinetic $T_{\perp}$ & $T_{//}$)

Hanle effect Sensitivity

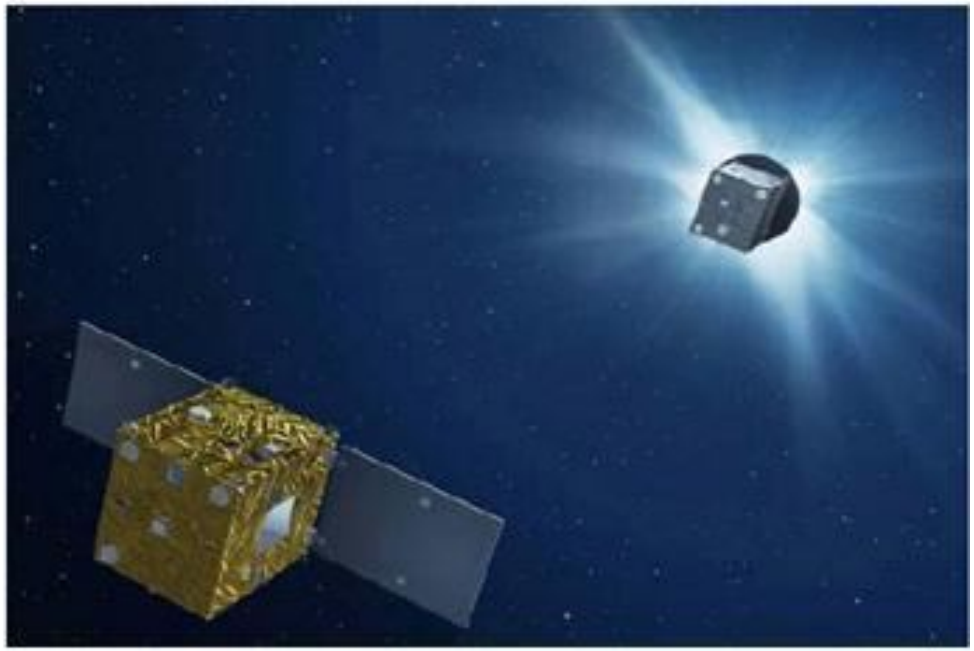
$$A\ [10^7\ s^{-1}] \sim 0.88 \cdot g_J \cdot B\ [G]$$

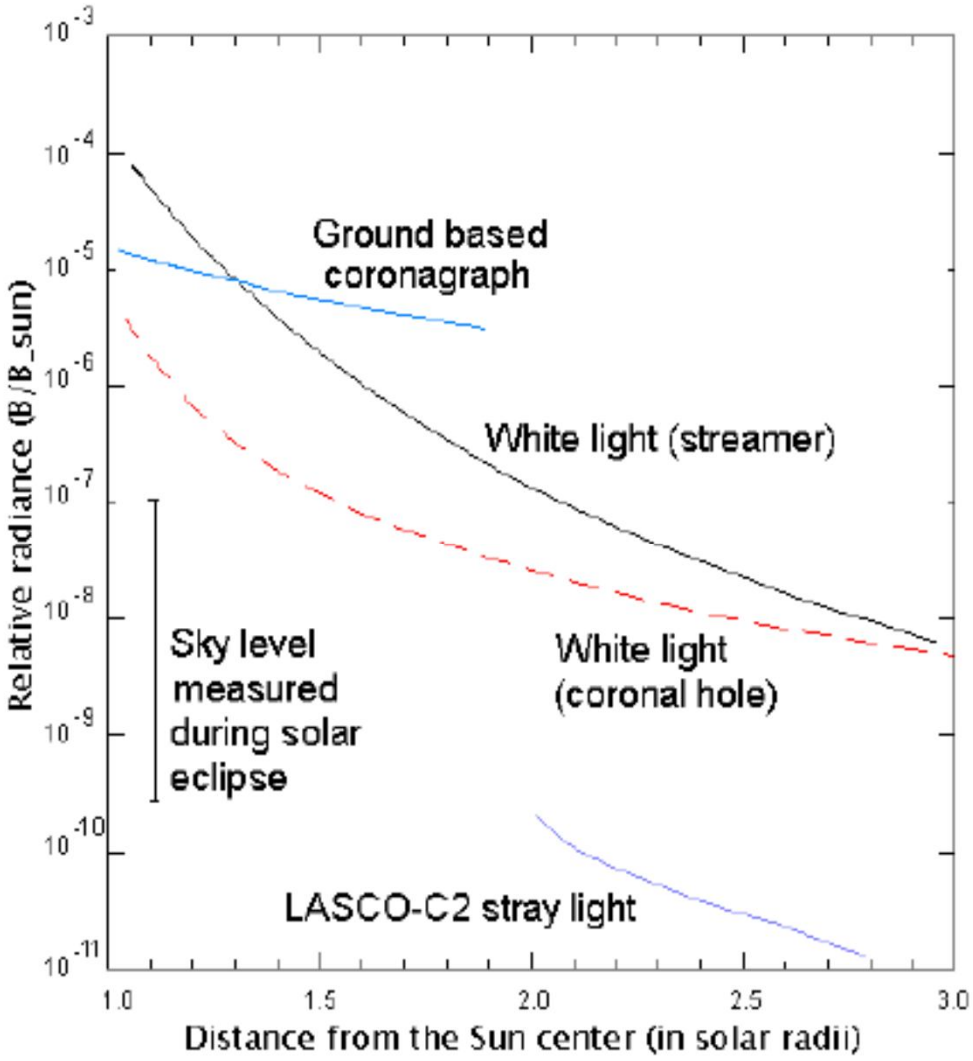
Spectral line	λ (Å)	A_{12} (10^7 Hz)	B_{Hanle} (gauss)
H I Ly-γ	972	6.82	1 – 7
H I Ly-β	1025	16.7	2 – 20
H I Ly-α	1216	62.7	10 – 70
O VI	1032	41.6	6 – 50

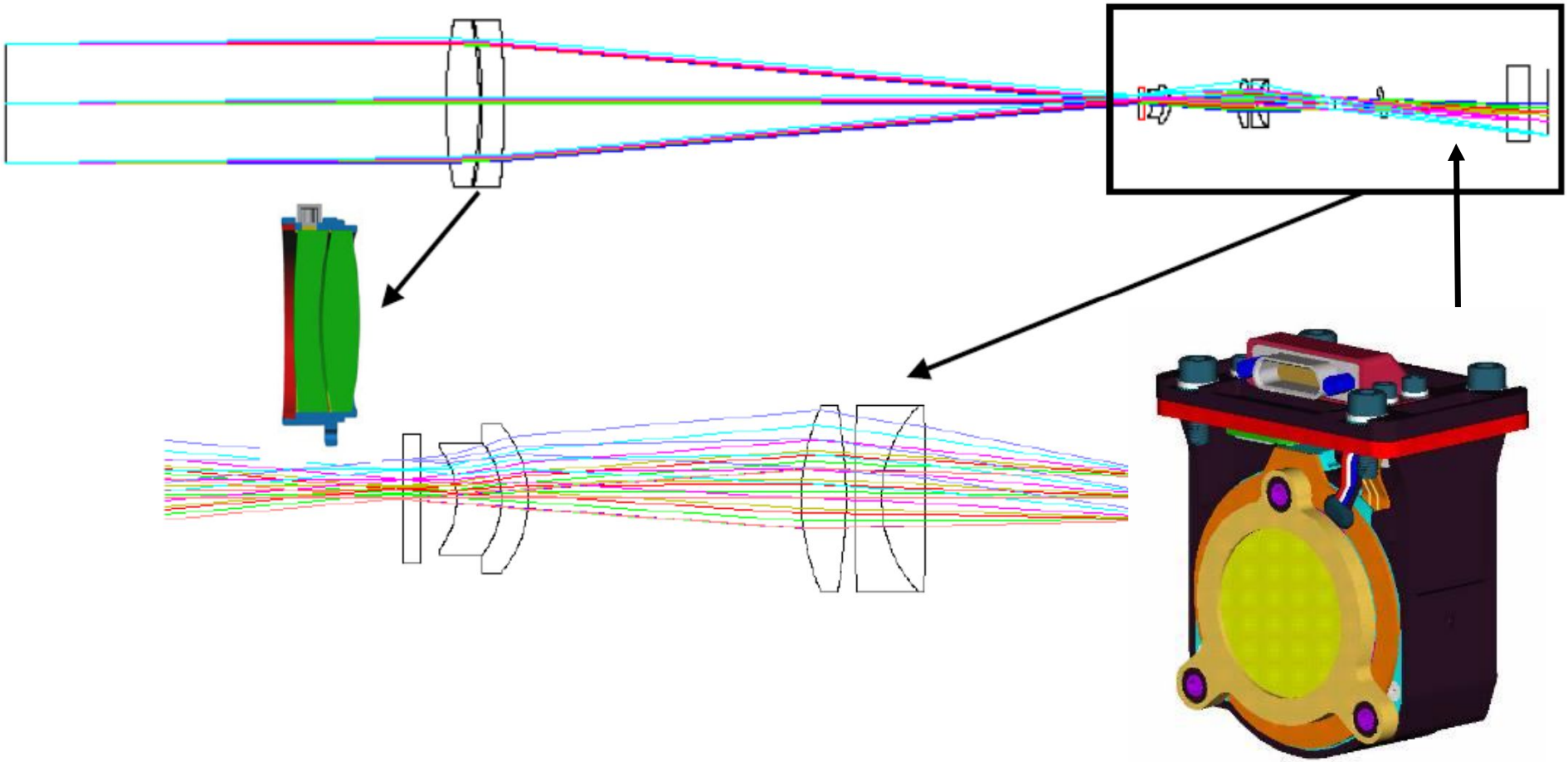
$A_{FeXIII} = 14$ Hz $\Rightarrow B_{Hanle} \sim 0.2$-2 μG

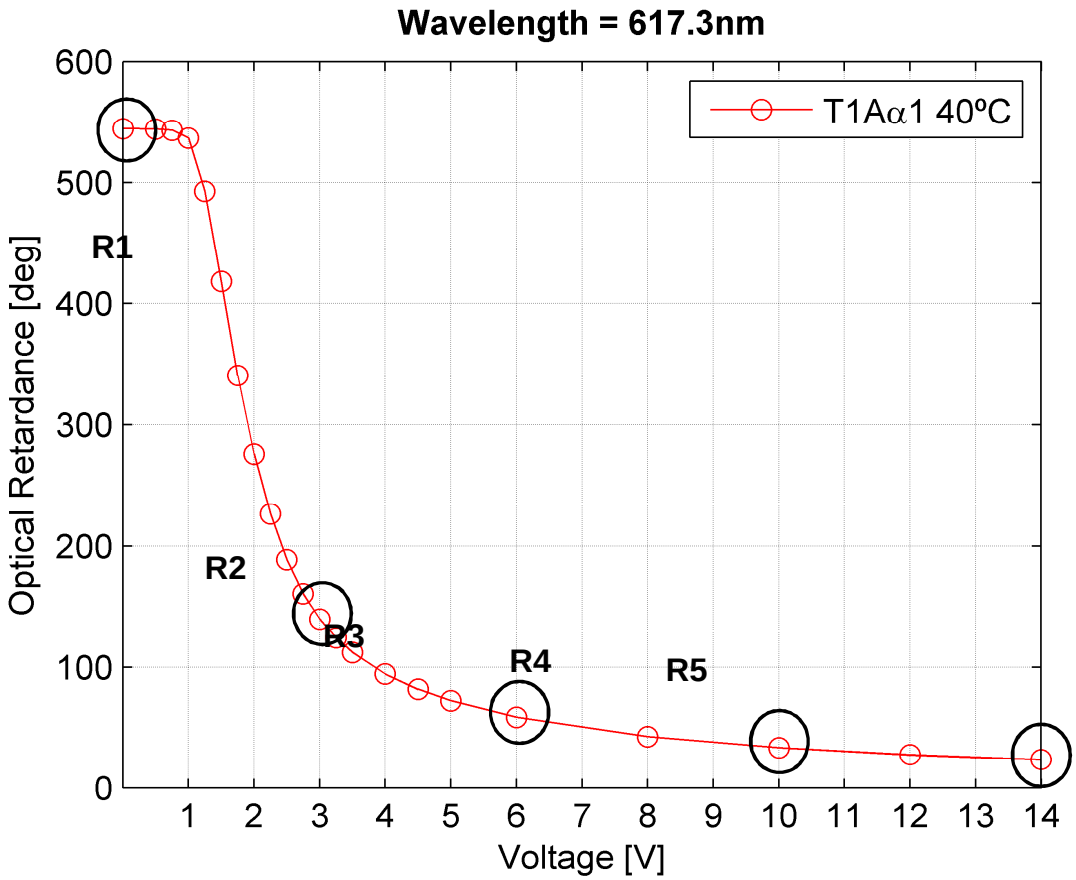
$A_{FeXIII} << B_{corona}$ (“saturated” Hanle effect)

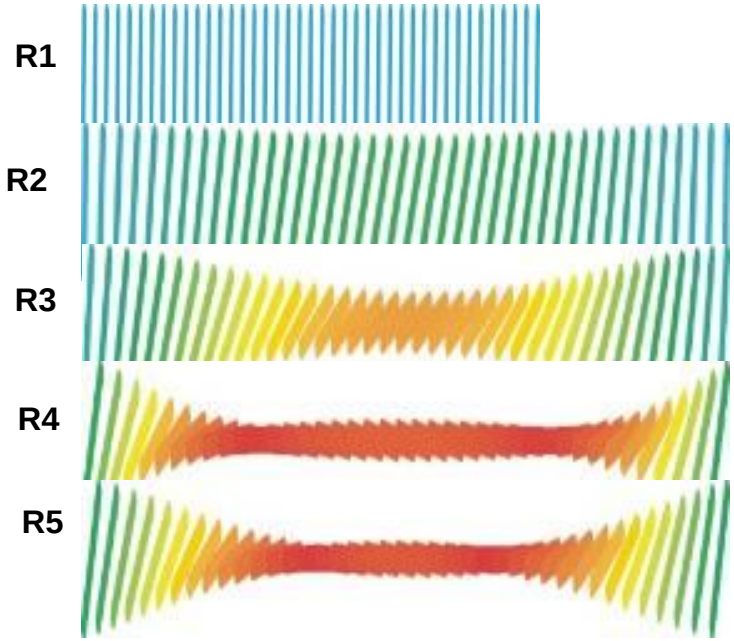
Proba-3 – ASPIICS Coronagraph

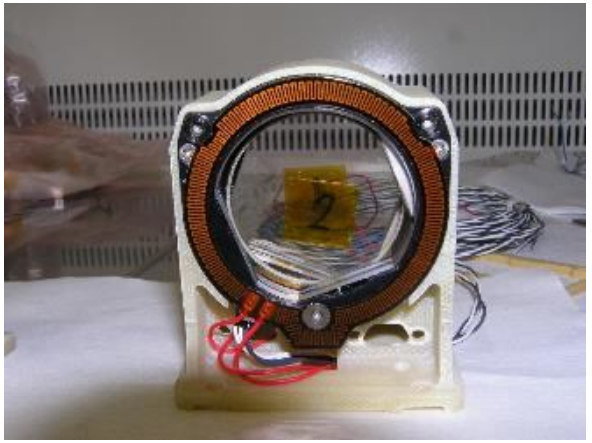



Ground based coronagraph
White light (streamer)
White light (coronal hole)
Sky level measured during solar eclipse
LASCO-C2 stray light
Relative radiance (B/B_sun)
Distance from the Sun center (in solar radii)
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
1.0
1.5
2.0
2.5
3.0




Wavelength = 617.3nm
T1Aα1 40ºC
Optical Retardance [deg]
Voltage [V]
R1
R2
R3
R4
R5
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14


R1
R2
R3
R4
R5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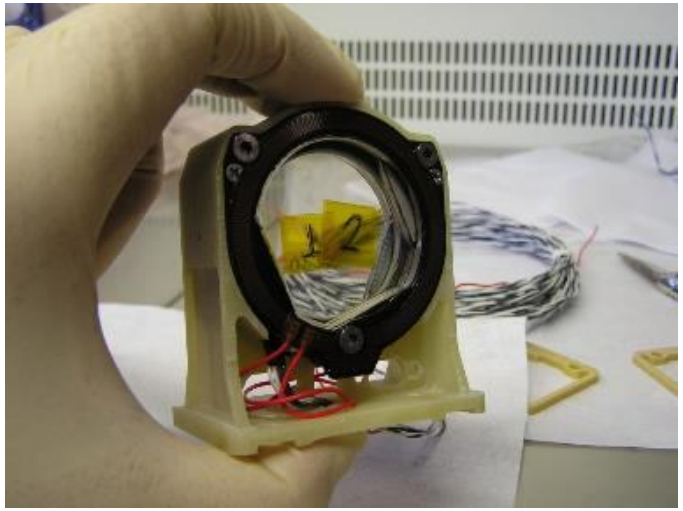
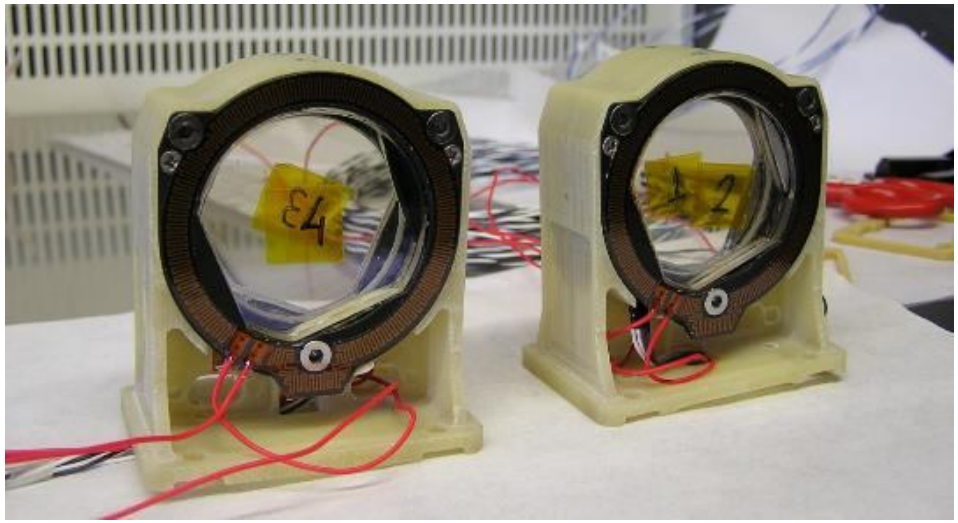
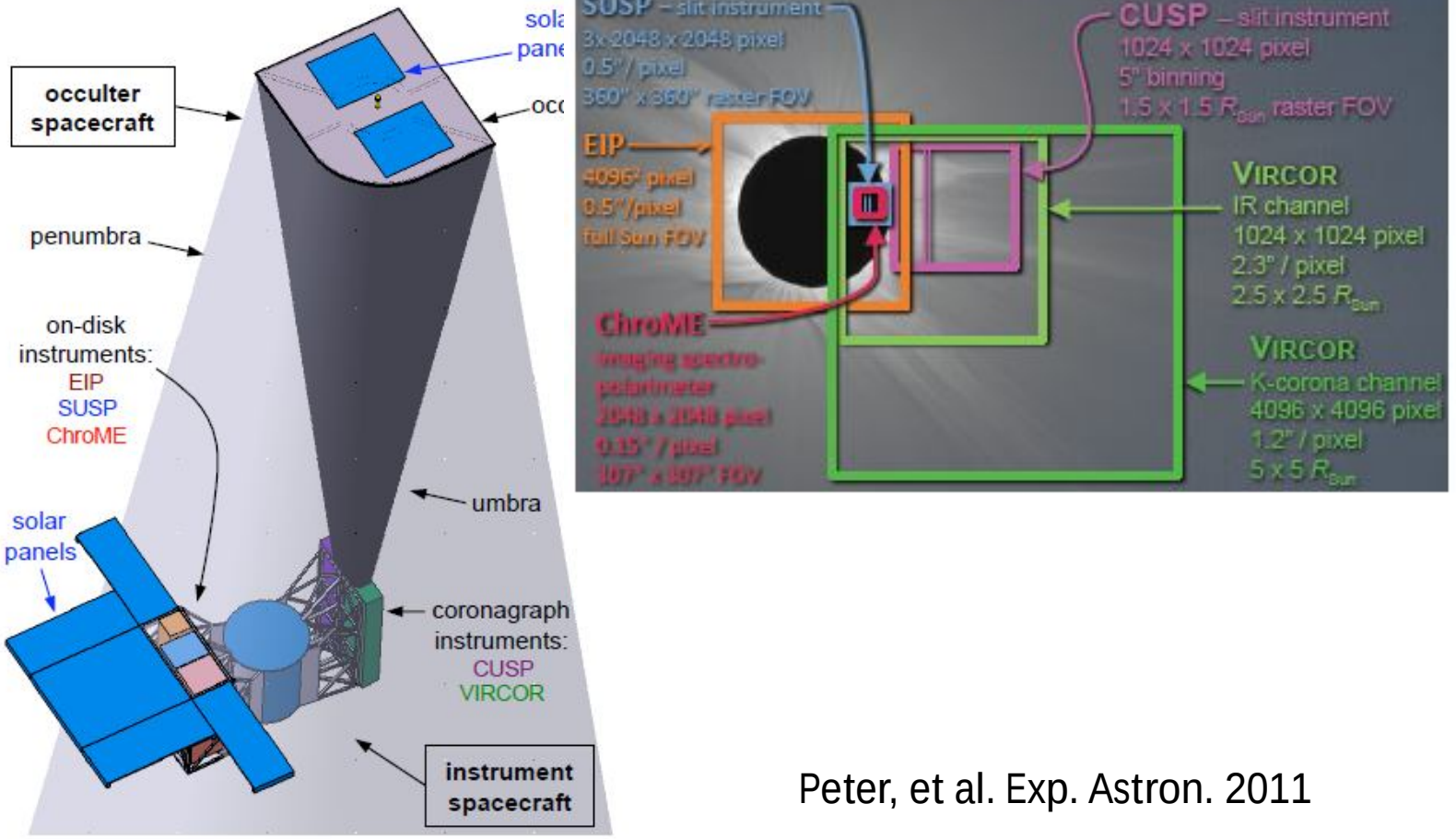

1 2


E4
1 2

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