Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)

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Marshall Grazing Incidence X-ray Spectrometer (MaGIXS)

- MaGIXS is a sounding rocket experiment to observe the Sun in Soft X-rays
- Launch - Spring 2020

Scientific objective : Constrain the timescales of heating in quiescent active region structures using high temperature spectral lines

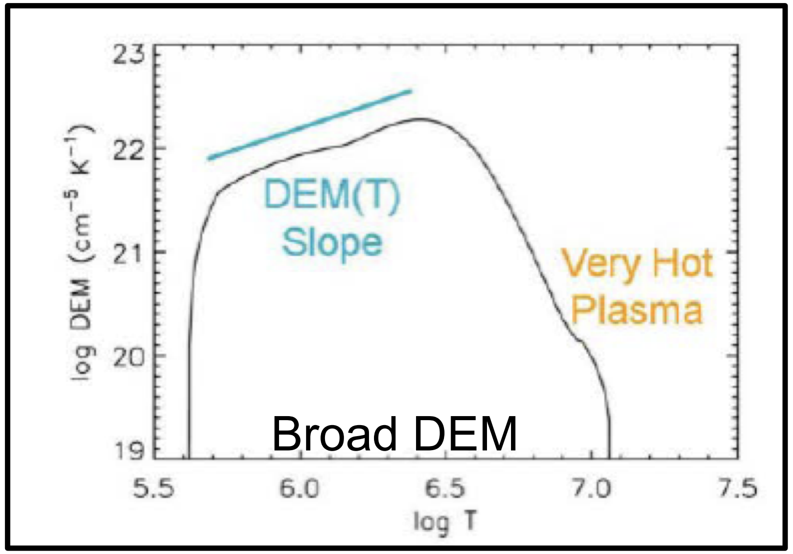
Outline

- Scientific motivation for MaGIXS
    - Demonstrate sensitivity of MaGIXS to determine high temperature plasma
- Instrument design
    - Challenges involved
- Instrument status – alignment and calibration

MaGIXS – Scientific motivation

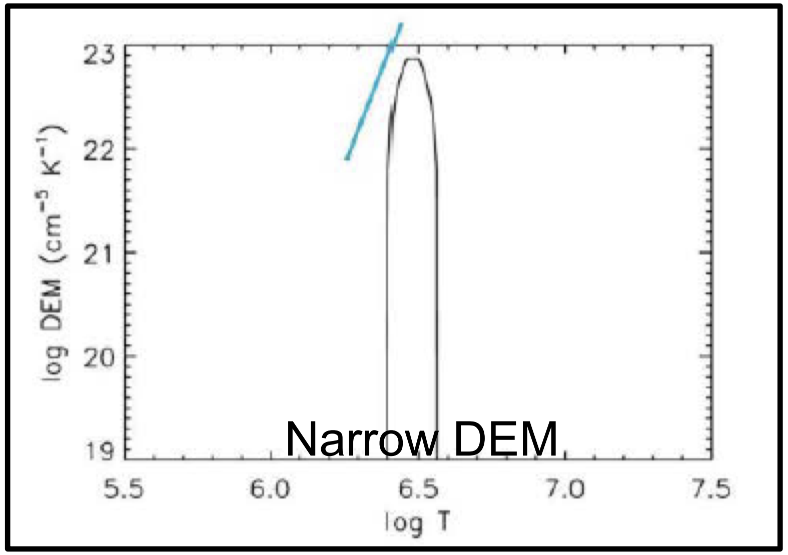
Observational Discriminators

Low-frequency heating



- High temperature plasma > 7MK
- Consistent with Reconnection mechanism
- Strong Fe XVII emission and steady Fe XVIII and Fe XIX emission

High-frequency heating

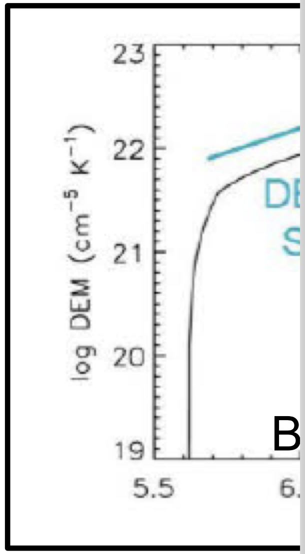


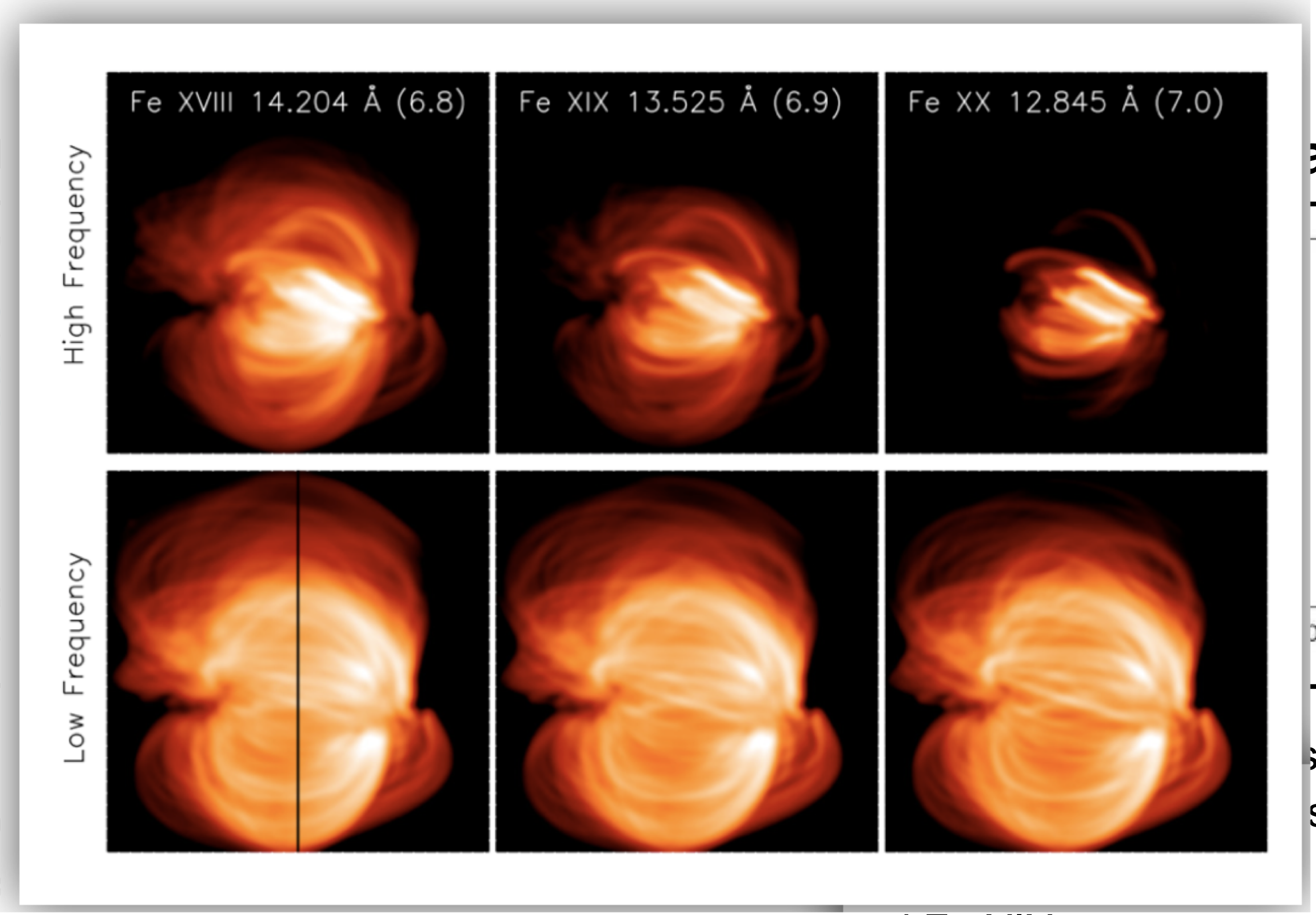
- No high temperature plasma
- Consistent with wave dissipation
- Steady Fe XVII emission and weak Fe XVIII and Fe XIX

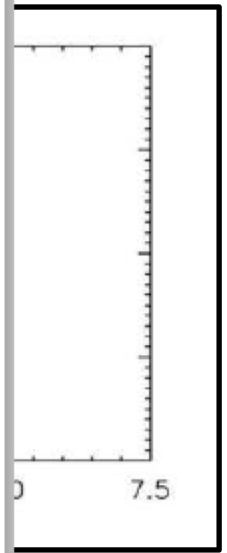
Klimchuk 2017

MaGIXS – Scientific motivation

Low-frequ ... **ating**







- High tempe
- Consistent
- Strong Fe X
  and Fe XIX emission

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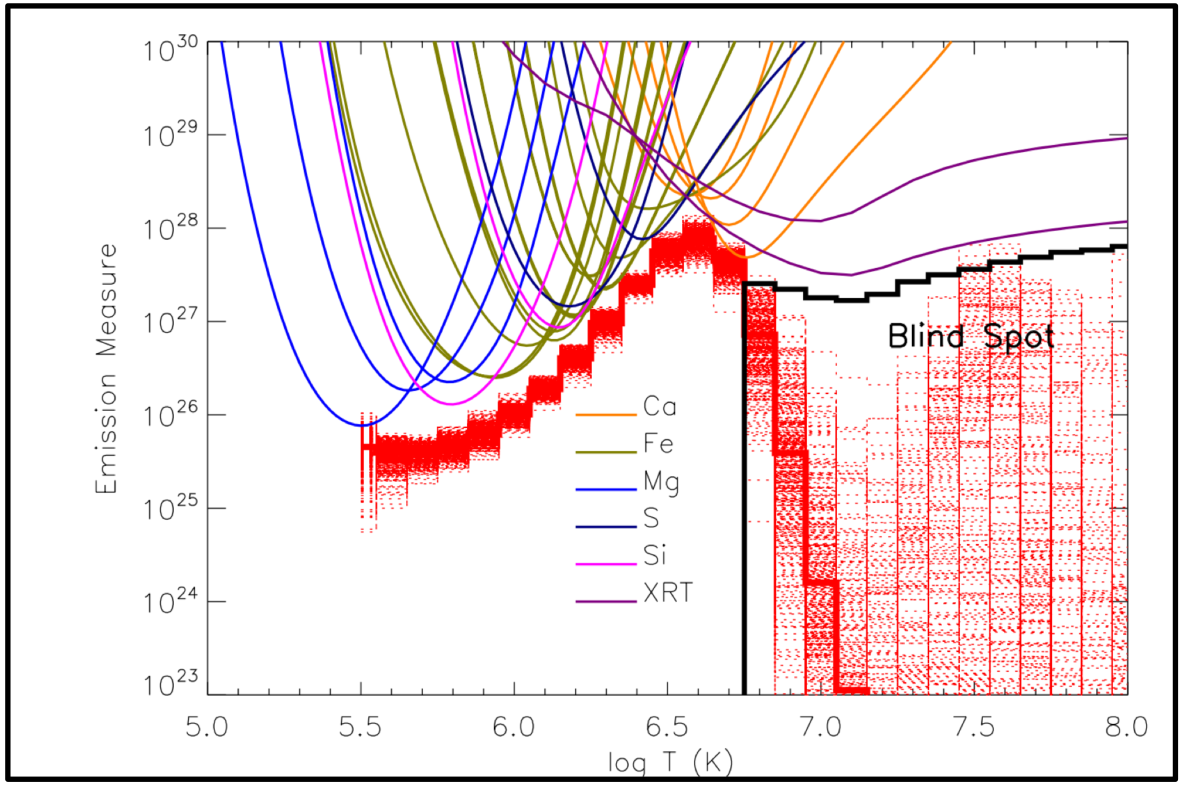
sipation
and weak Fe XVIII
and Fe XIX

Klimchuk 2017

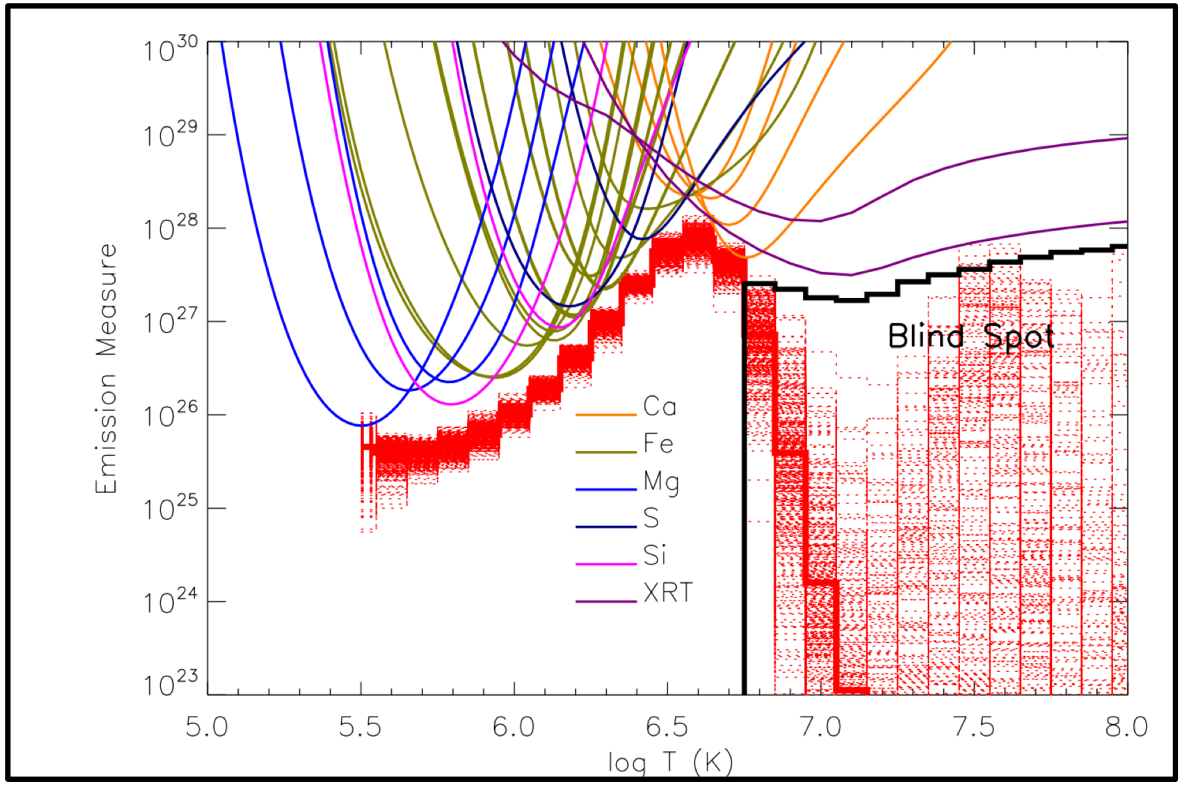
High temperature, Low emission measure plasma

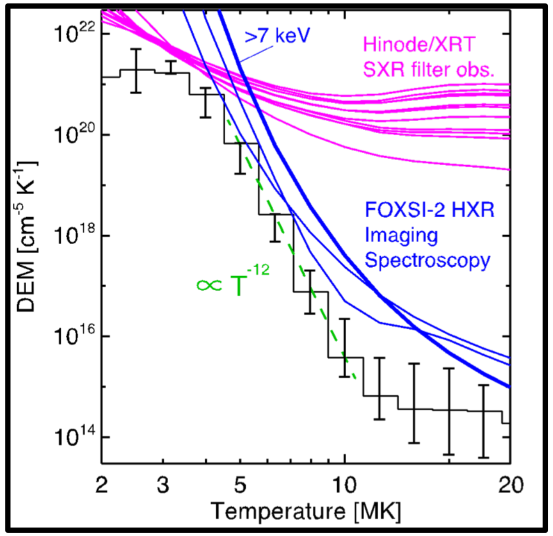


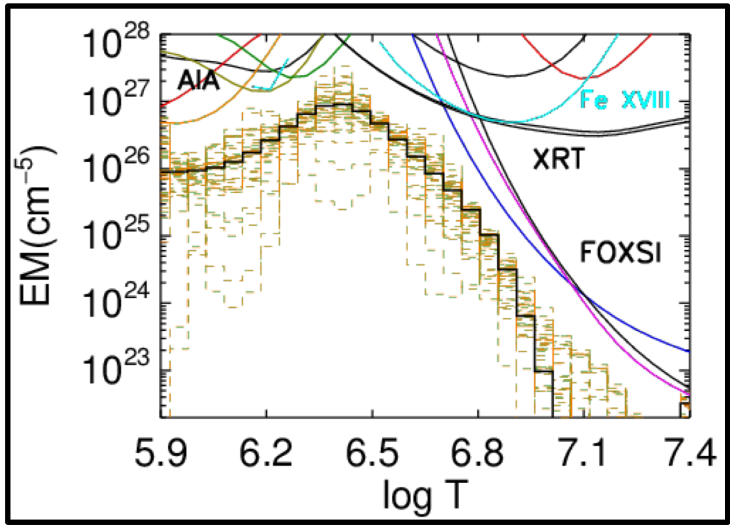
- Amount of plasma at temperatures >5MK is not accurately known
- Current space instrumentation has a “blind-spot” for high temperature emission

Winebarger et al. 2012;

High temperature, Low emission measure plasma







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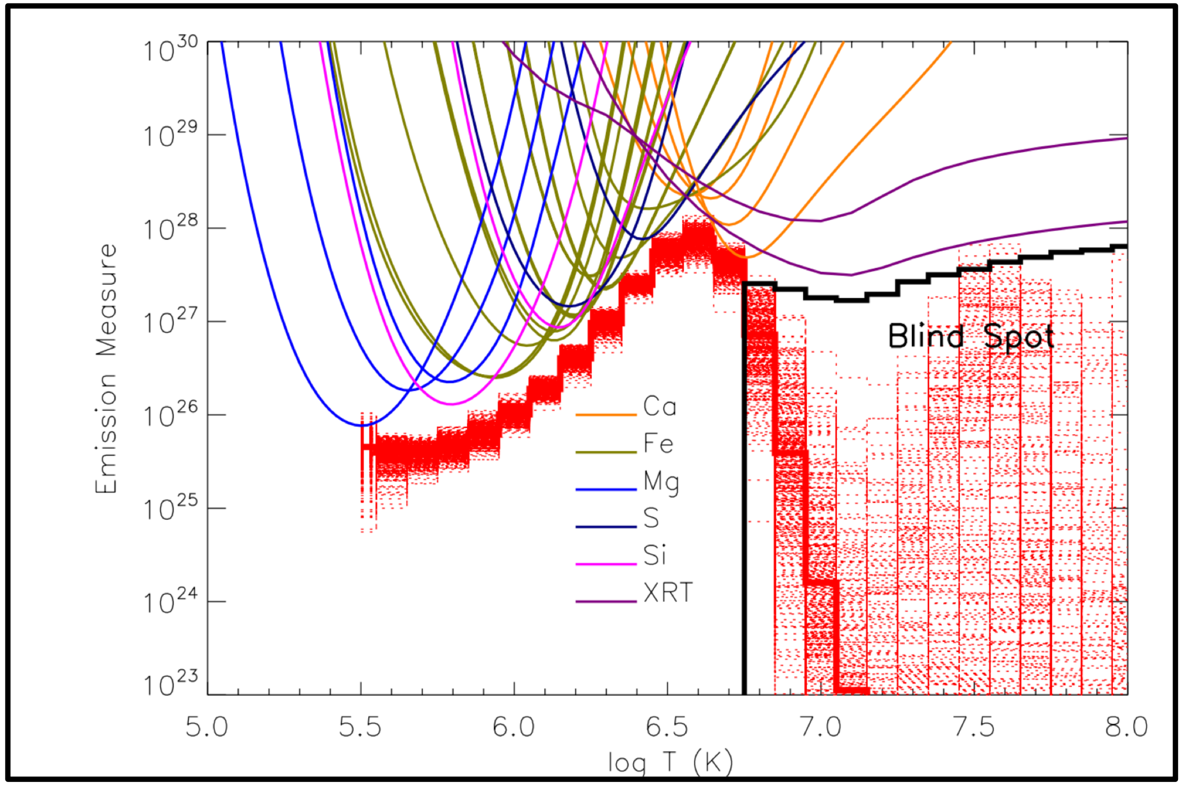
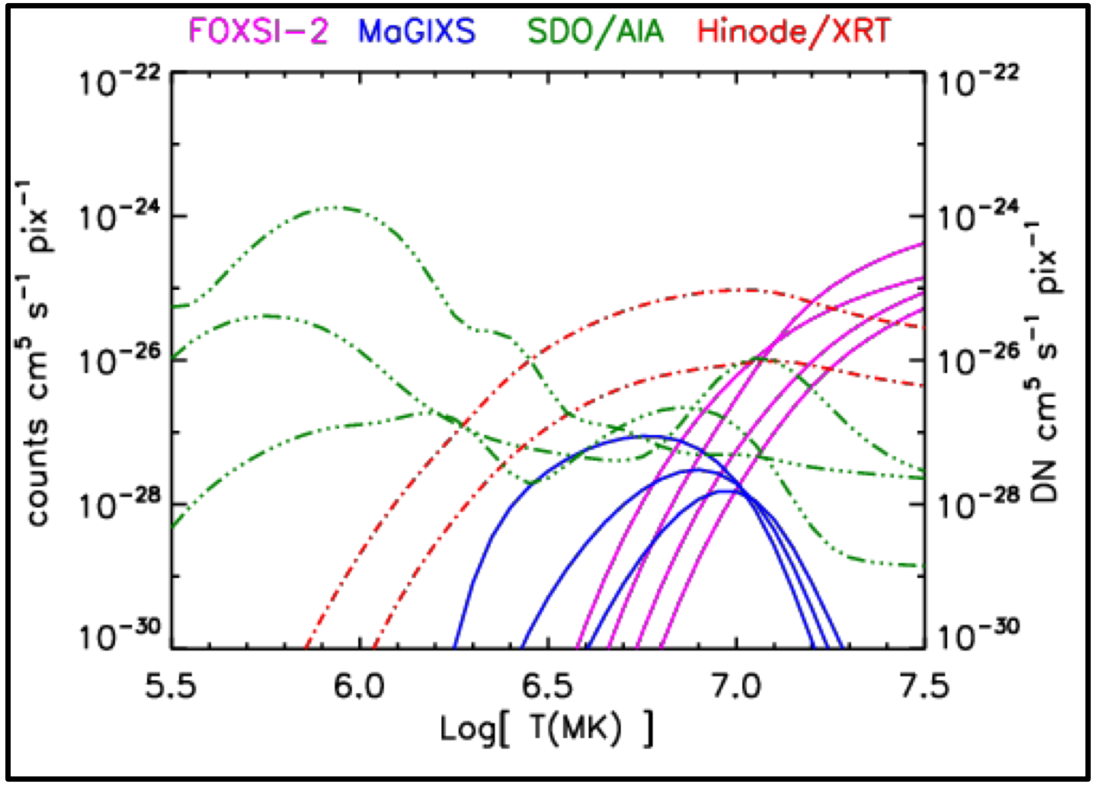
Winebarger et al. 2012; Ishikawa et al. 2017; Athiray et al. (to be submitted)

High temperature, Low emission measure plasma





MaGIXS is complementary to FOXSI
MaGIXS bridges gap between XRT - FOXSI

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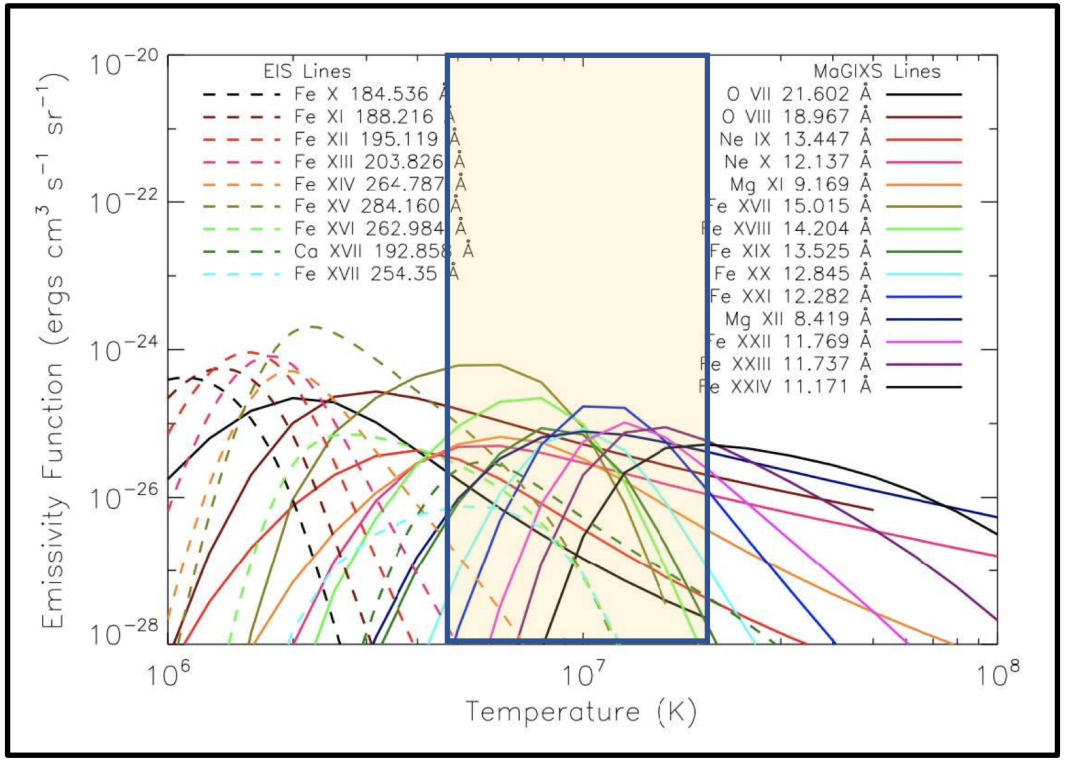
Winebarger et al. 2012; Ishikawa et al. 2017; Athiray et al. (to be submitted)

High temperature, Low emission measure plasma

MaGIXS key spectral lines

Fe ion	Wavelength (A)	Log Max temperature
FeXVII	15.01	6.6
FeXVIII	14.21	6.8
FeXIX	13.53	6.95
Ne IX	13.45	6.6
O VII	21.60	6.3

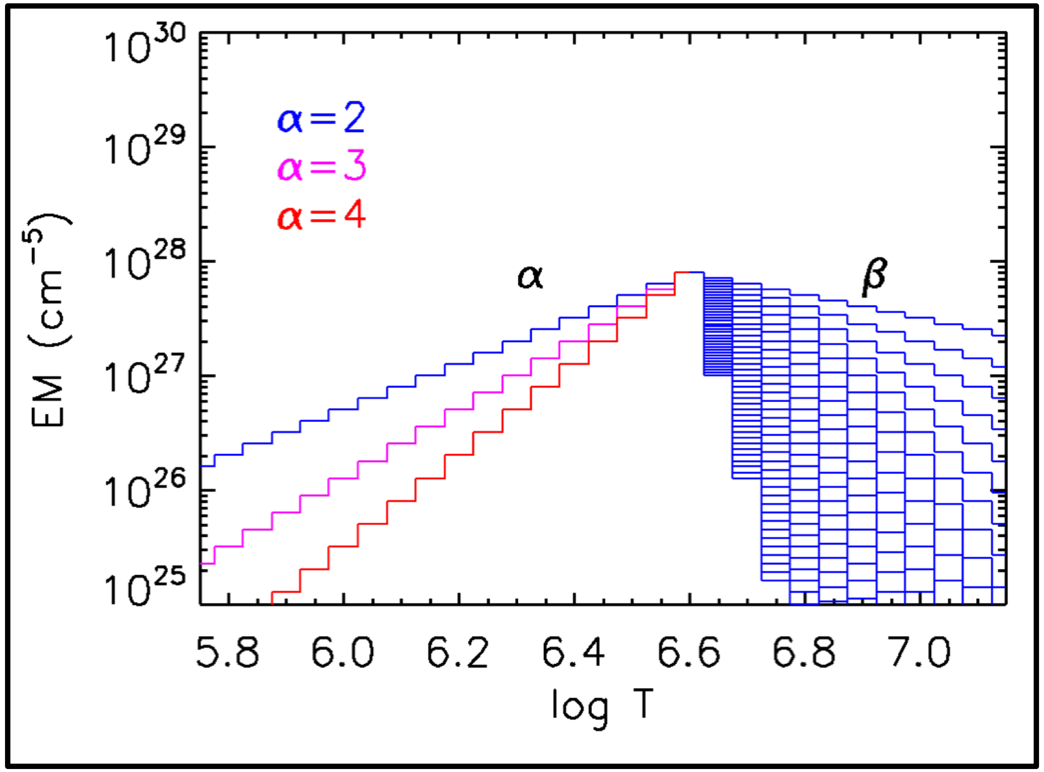


- High temperature spectral lines are chiefly observed in Soft X-rays (0.5 to 2 keV)
- The spectral lines are closely spaced and require high resolution X-ray spectrometer
- MaGIXS will observe in this wavelength including important Fe XVII, XVIII and XIX lines, which are diagnostic for high temperature plasma **with same optical path**

Sensitivity of MaGIXS for high temperature plasma

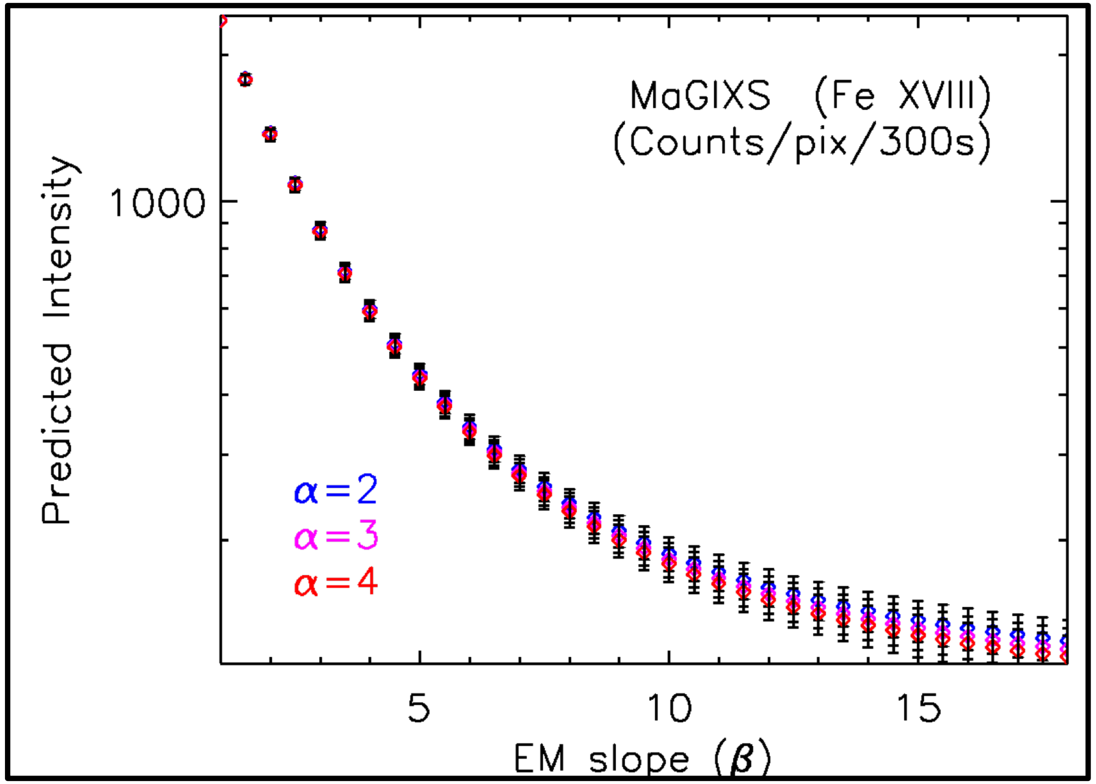
Can we determine high temperature Emission Measure (EM) slope using MaGIXS line intensity ratio?

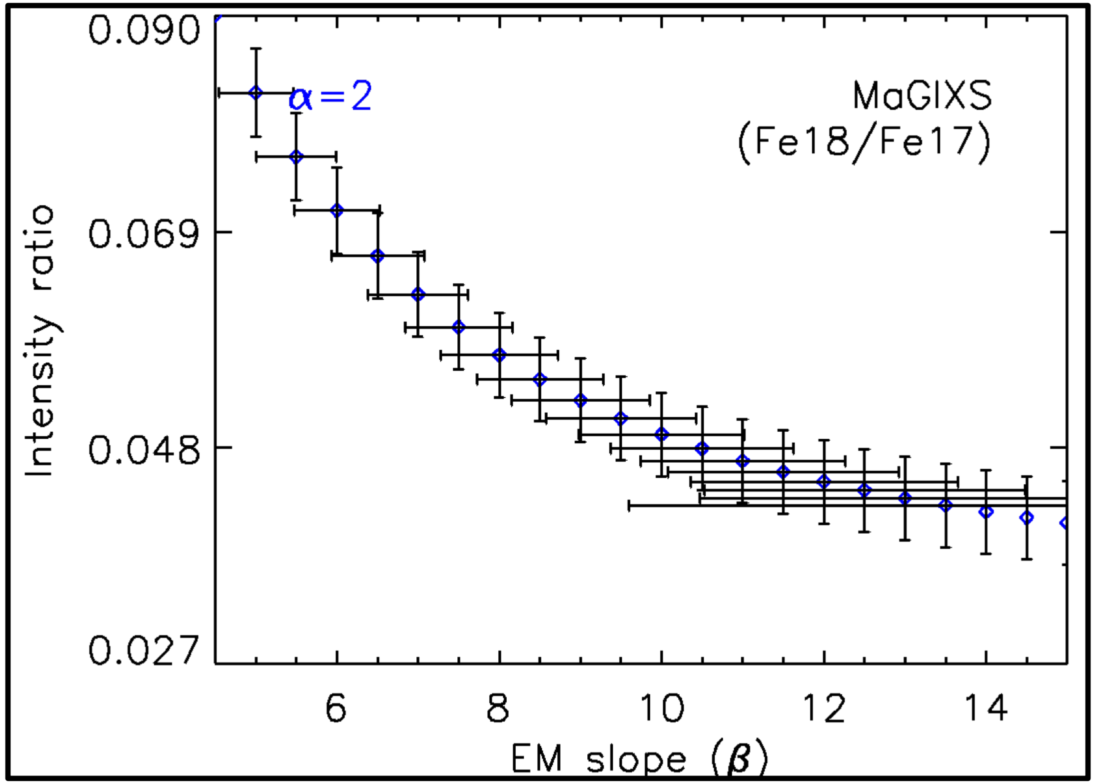
- Assumed series of EM distributions with range of α and β
- Predict MaGIXS spectra for different EM distributions
- Investigate MaGIXS line intensity as a function of EM slopes



Athiray et al (to be submitted)

Sensitivity of MaGIXS for high temperature plasma





Athiray et al (to be submitted)

- Selected MaGIXS line intensity is sensitive to β and less sensitive to **α**
- Ratio between two line intensity from MaGIXS can be used as a proxy to determine β
- The uncertainty in β will be more tightly constrained than has been in previous studies

MaGIXS sounding rocket experiment

GOAL : Constrain the timescales of heating in quiescent active region structures using high temperature spectral lines

- MaGIXS - Science and Instrument requirements
  - Energy range – 6 to 24Å (0.5 to 2 KeV)
  - Target – Medium sized active region
  - Spatial resolution < 5” (coherent structure in AR)
  - Spectral resolution < 0.1Å
  - Relative uncertainty in the MaGIXS response function to contribute < 10% to the uncertainty of β

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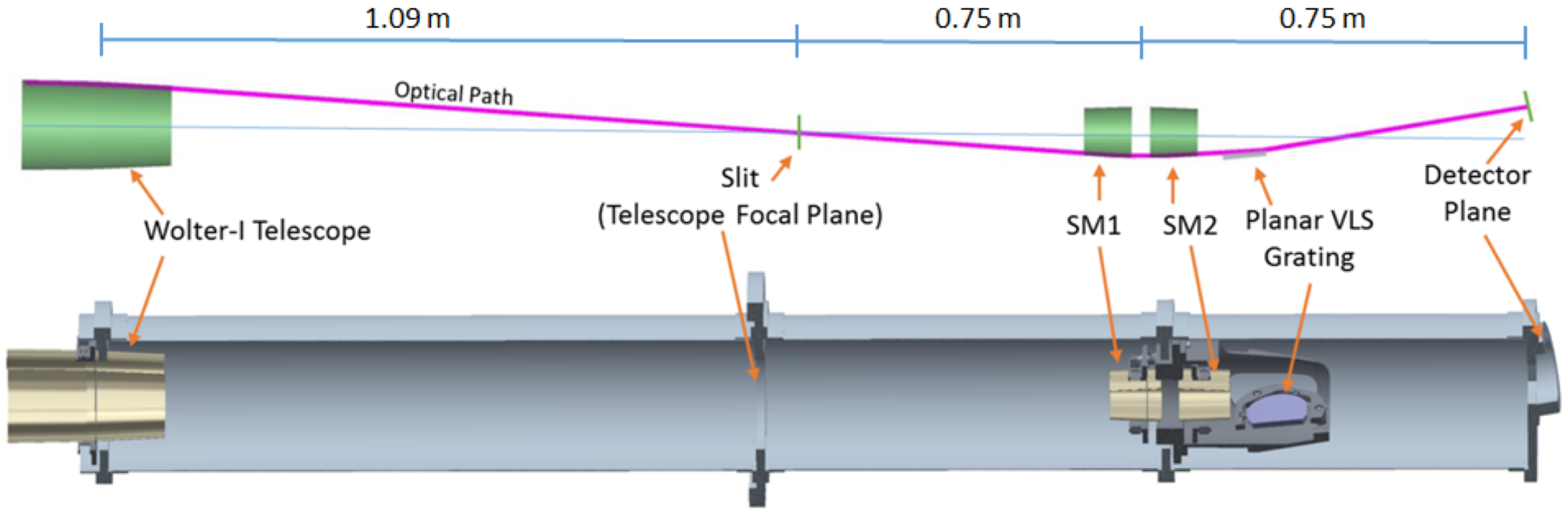
- Instrument design
  - Challenges involved
- Instrument status – alignment and calibration

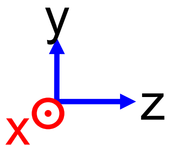
MaGIXS Optics design

Telescope
- Wolter I type
- Electroformed Nickel
- Focal length = 1090 mm
- Diameter = 150 mm
- Graze angle = 1.0°

Spectrometer system
- Electroformed Nickel finite conjugate mirror pair
- Focal length = 594 mm



Grating and Camera
- Planar varied-line-space grating
- CCD detector: flight heritage system (CLASP, Hi-C)



MaGIXS Instrument design (MSFC, SAO)

Optical path dimensions

Instrument structure:

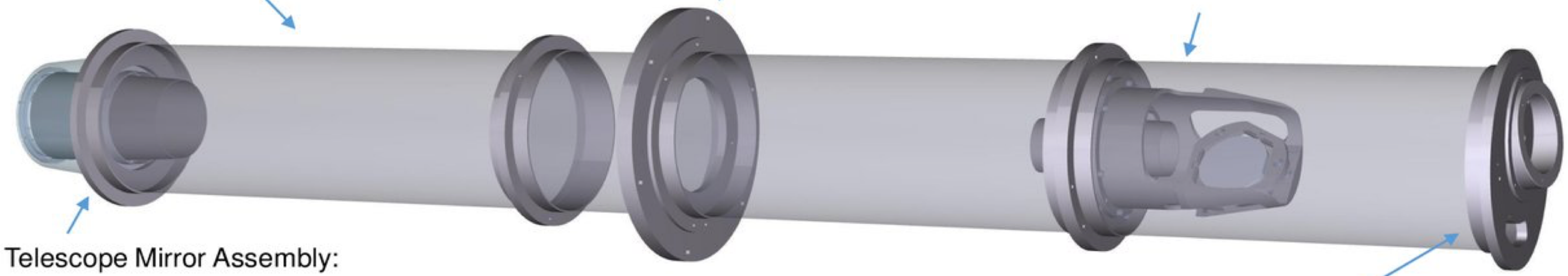
- Stainless steel thin-wall tubing (low cost, acceptable thermal expansion)

Central flange:

- Single interface to 22-inch rocket skins; telescope & spectrograph cantilevered from this flange
- Slit & slitjaw mount

Spectrograph Optics Assembly:

- Spectrograph mirror pair, aligned then bonded
- Grating mount (kinematic interface)
- Alignment features (centering reticle & reference flat)



Telescope Mirror Assembly:

- Sun sensor mount
- Prefilter (Al on mesh)
- Telescope mirror shell
- Alignment features (centering reticle & reference flat)

Camera mount & Camera

- Focal plane filter (Al on polyimide)
- MSFC custom design camera

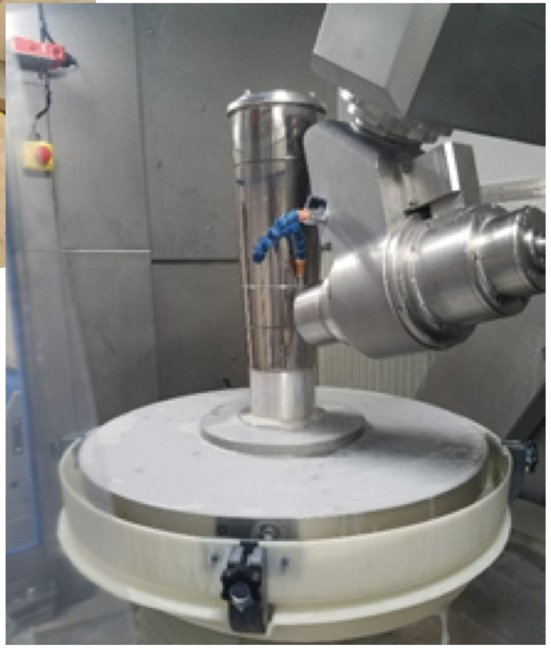
MaGIXS will also carry a slit-jaw imaging camera to get context image of the Sun during MaGIXS observation

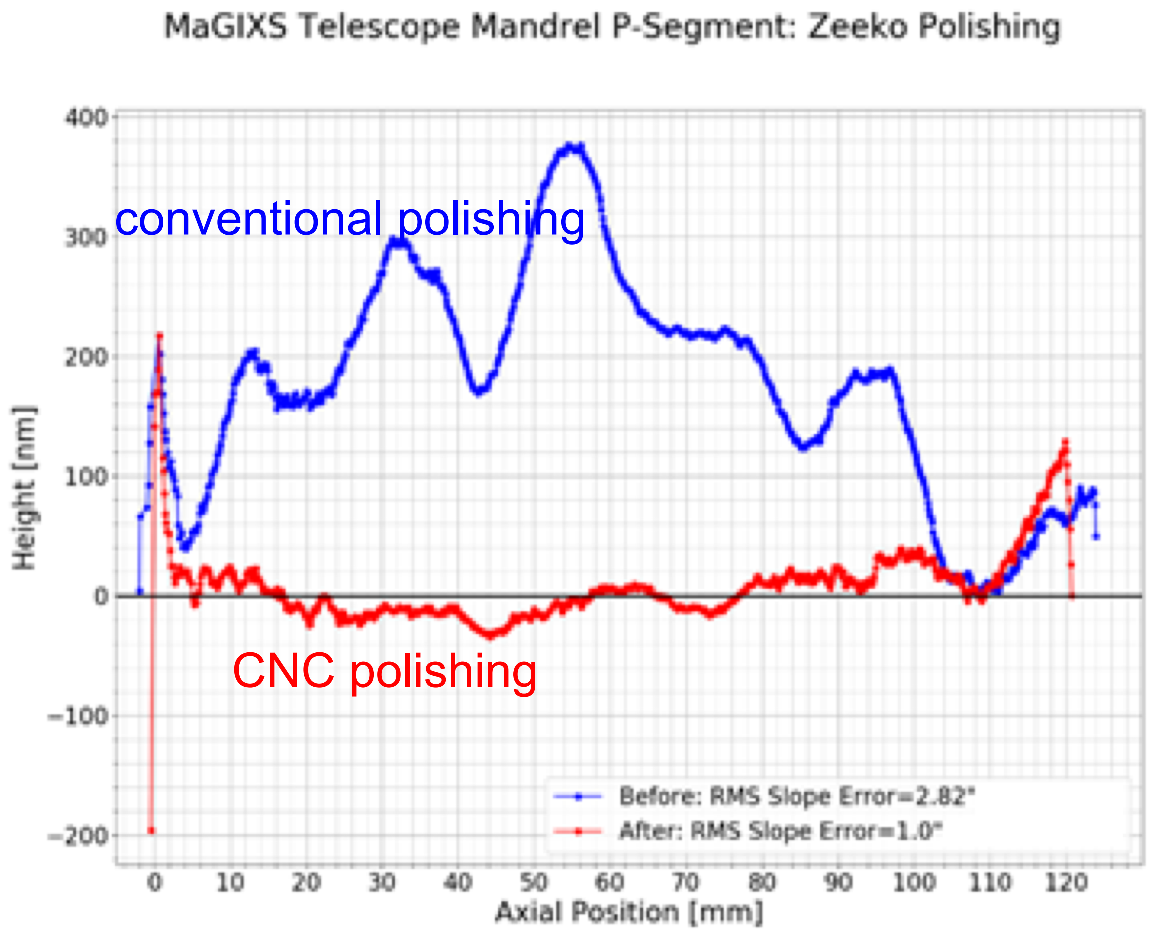
Challenges Associated with the Optics

Instrument	Energy [keV]	Focal Length [m]	HPD [arcsec]	# Reflections
HEROES	40-60	6	25-30	2
ARC-XC	6-30	2.7	60	2
FOXSI	5-15	2	25-30	2
IXPE	2-8	4.0	≤ 30	2
MaGIXS	0.5-2.0	1.09	6	5

- Short focal length requires steep curvatures - more challenging to polish
- Resolution is ~5 times less than nickel-replicated optics produced in the past
- Resolution balanced between 5 successive reflections - summed in quadrature
- Co-alignment of single shells in series
  - MSFC has a mature process for coaxial alignment of nested shells
  - SAO and MSFC co-developed method for aligning shells in series

CNC Deterministic polishing





Champey et al., private communication

MaGIXS Mirror Performances

- Performed X-ray tests on shells replicated from CNC polished mandrels at the Stray light facility.
  - On-axis PSF
  - Through focus PSF
  - De-focus annulus for shell irregularities, scattering

- Working toward establishing an image analysis technique to quantify the improvements achieved through deterministic polishing (Champey et al. in preparation)

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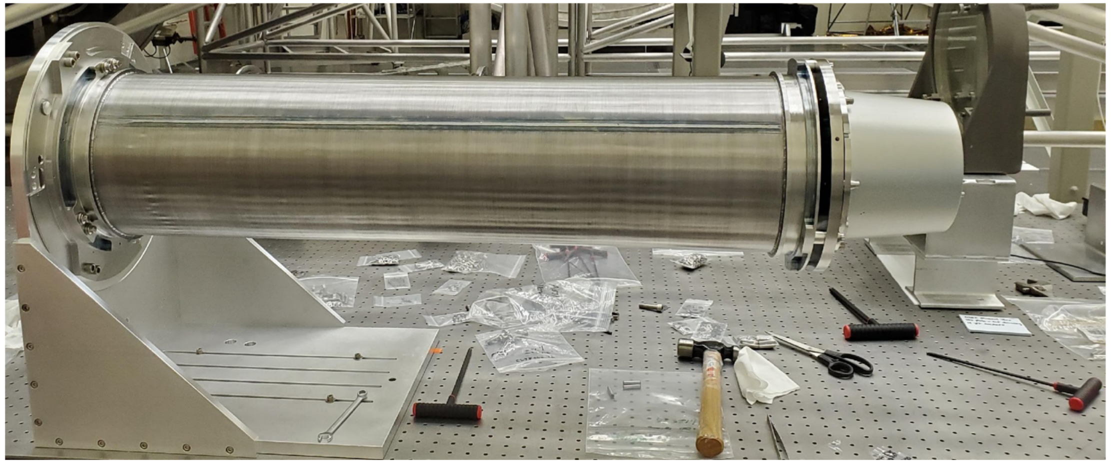
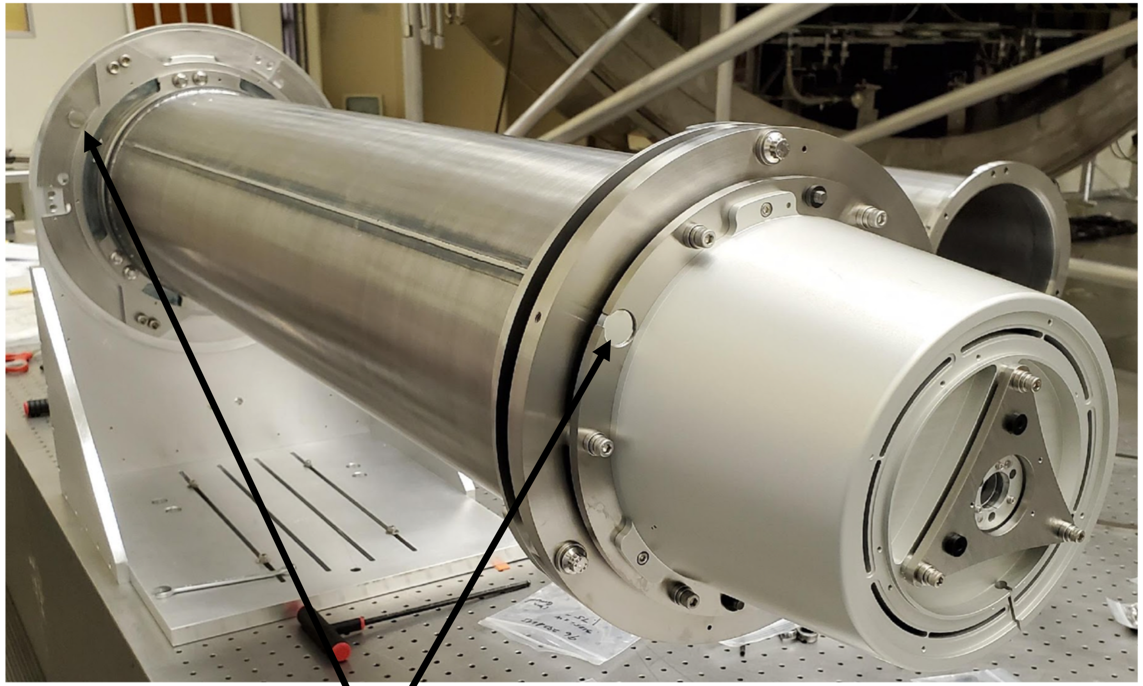
Instrument status

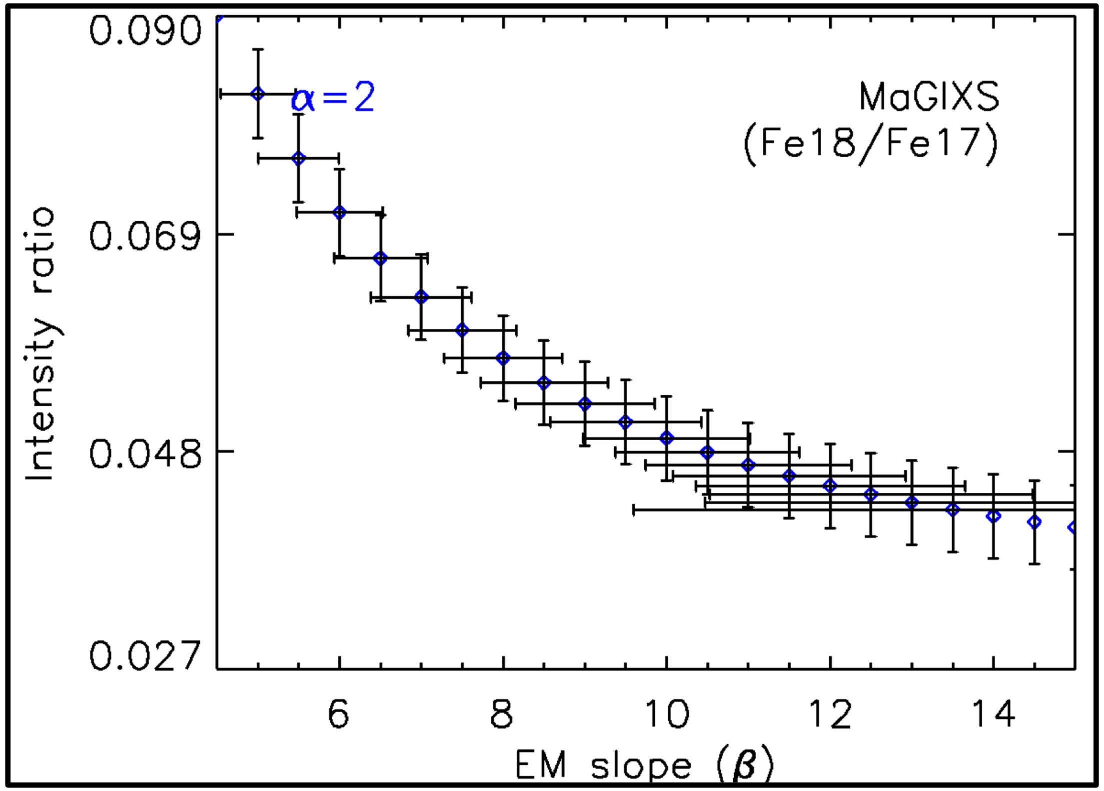


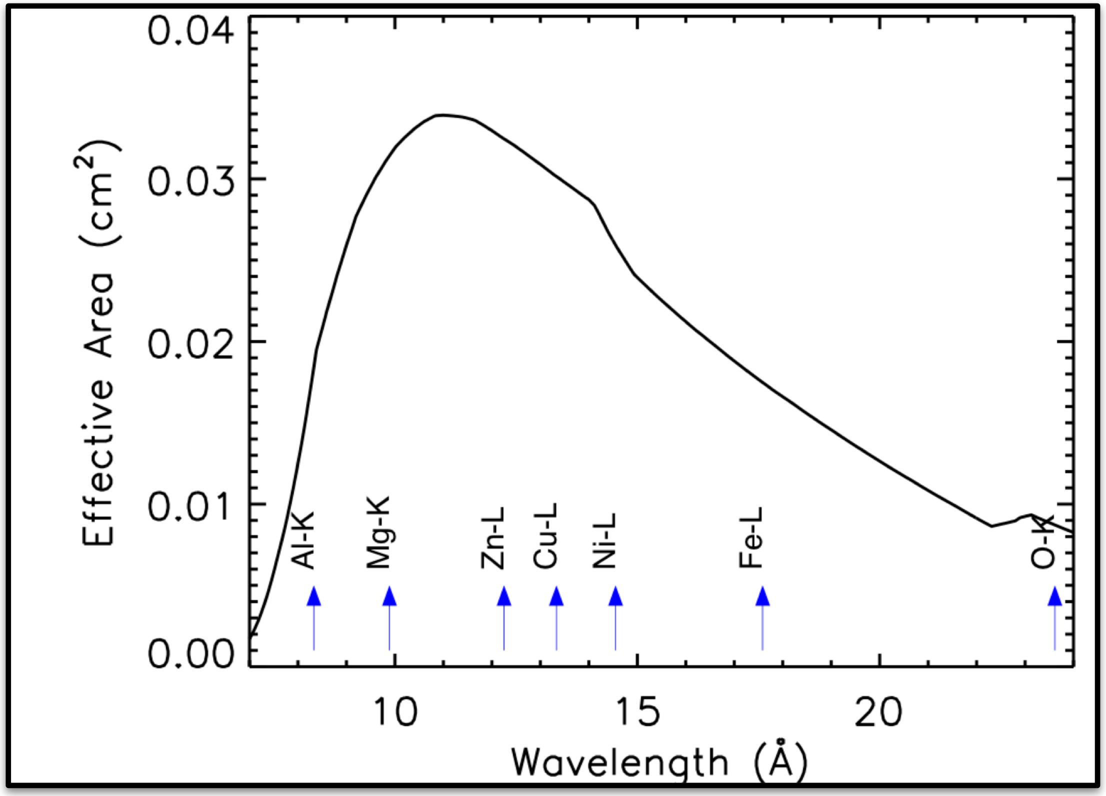


Reference mirrors

- Internal alignment of Telescope Mirror Assembly - completed by SAO
- Internal alignment of Spectrometer Optics Assembly – completed at SAO
- Instrument assembly and co-alignment started at MSFC
- Final alignment and calibration in X-ray at the X-ray Cryogenic Facility (XRCF)

Calibration requirements





1. We require relative uncertainty in MaGIXS response function to contribute < 10% to the uncertainty of β
2. Calibration will take place at MSFC using XRCF facility

Summary

- MaGIXS lines are sensitive to β
- Ratio between two MaGIXS line intensity can be used as a proxy for β, which is the “smoking gun” to constrain frequency of heating in ARs
- Technological challenges in MaGIXS is profound and are far-reaching
  - CNC polished optics
  - Alignment and calibration
- Instrument alignment and calibration are in progress for launch in Spring 2020.

Thank you