High Resolution Imaging and Gratings in Concert

An abundance of cutting edge science that can only be done with Lynx

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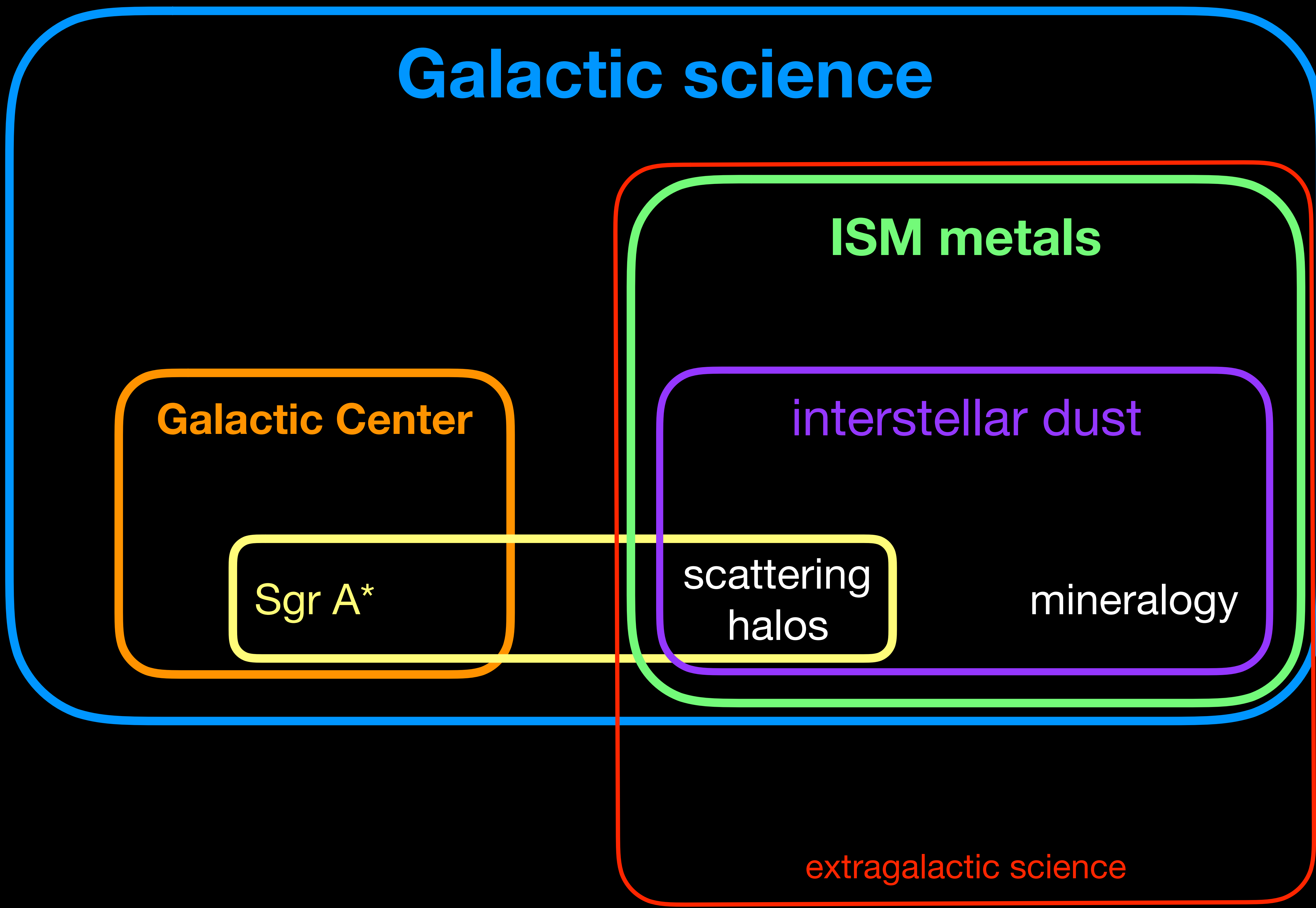
University of Wisconsin - Madison
Einstein Fellow

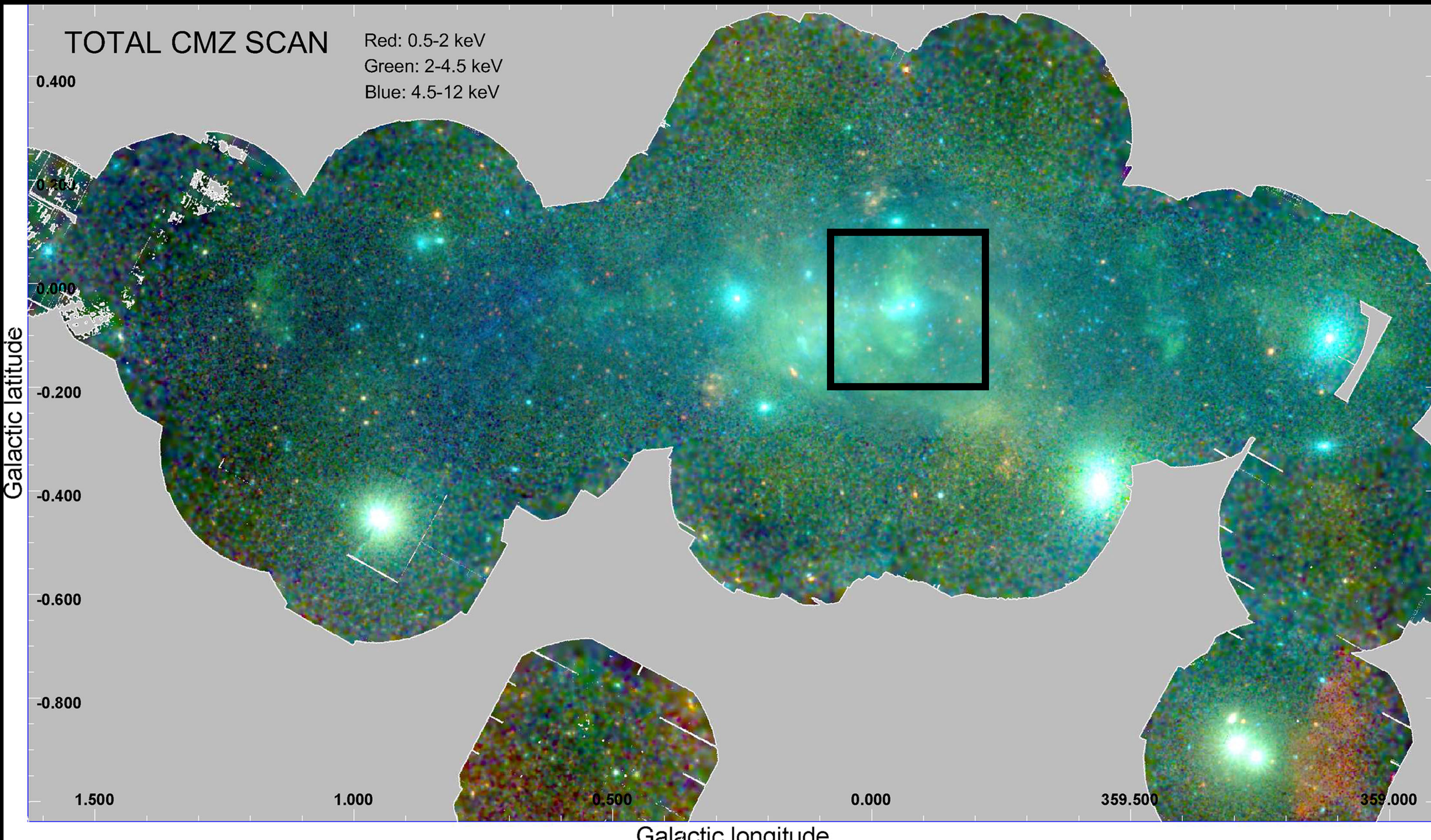
In collaboration with
Sebastian Heinz, University of Wisconsin - Madison
Fred Baganof, MIT Kavli Institute

High resolution imaging and **soft X-ray spectroscopy**, *together*



State of the field:
Why high resolution imaging matters

XMM view of the Galactic Center

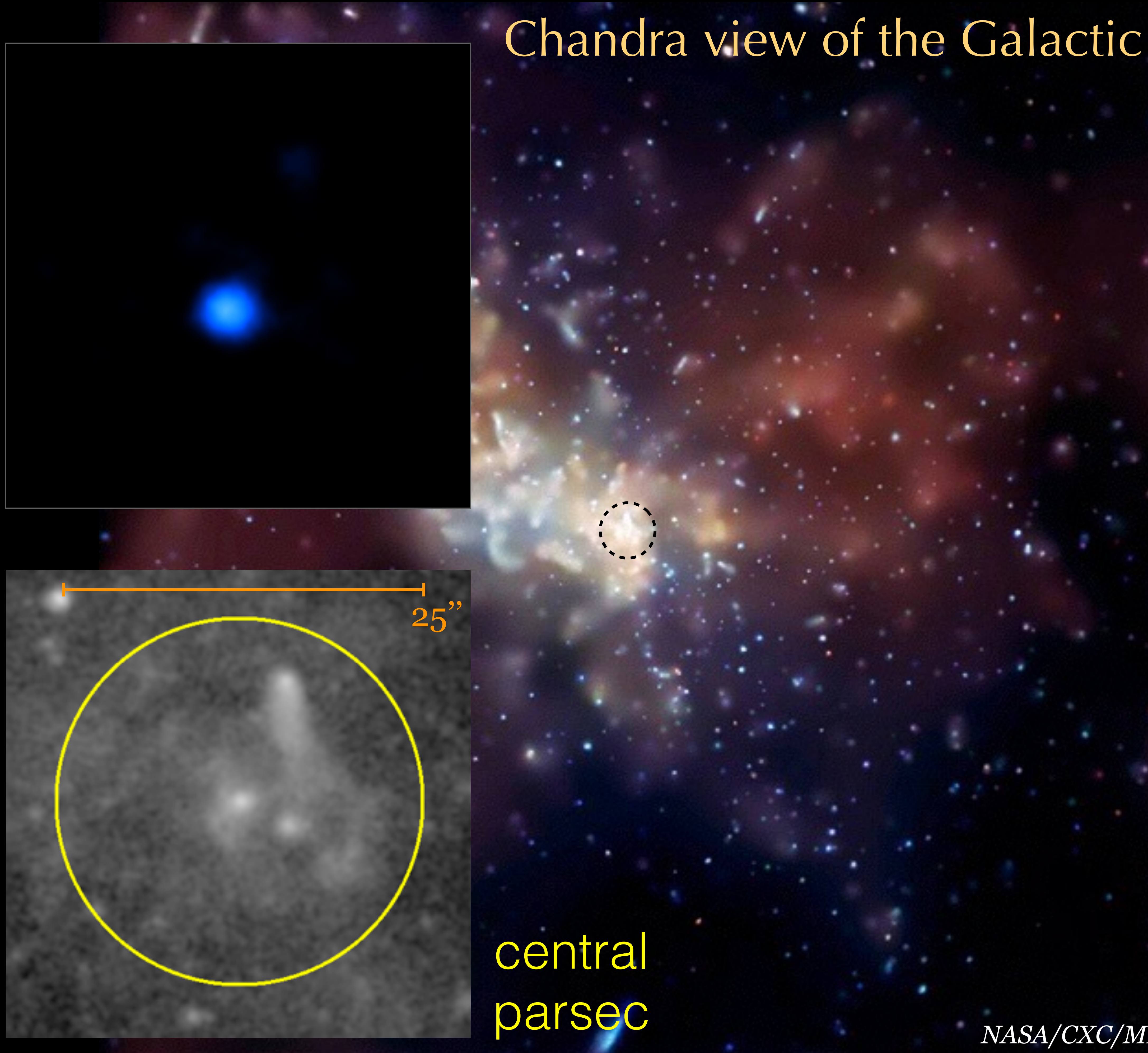


Ponti et al. (2015)

Chandra view of the Galactic Center

NASA/CXC/MIT/Baganoff

Chandra view of the Galactic Center



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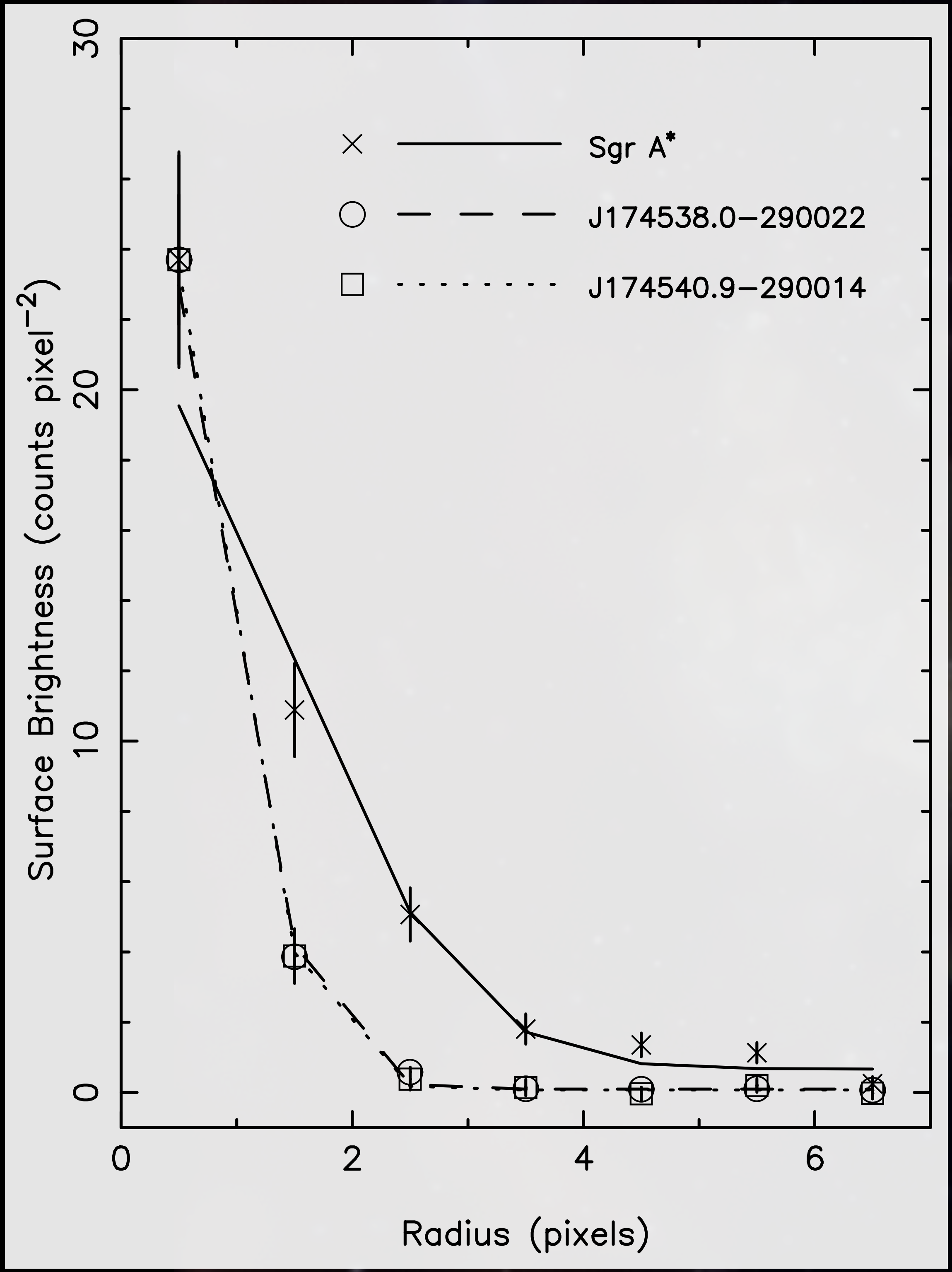
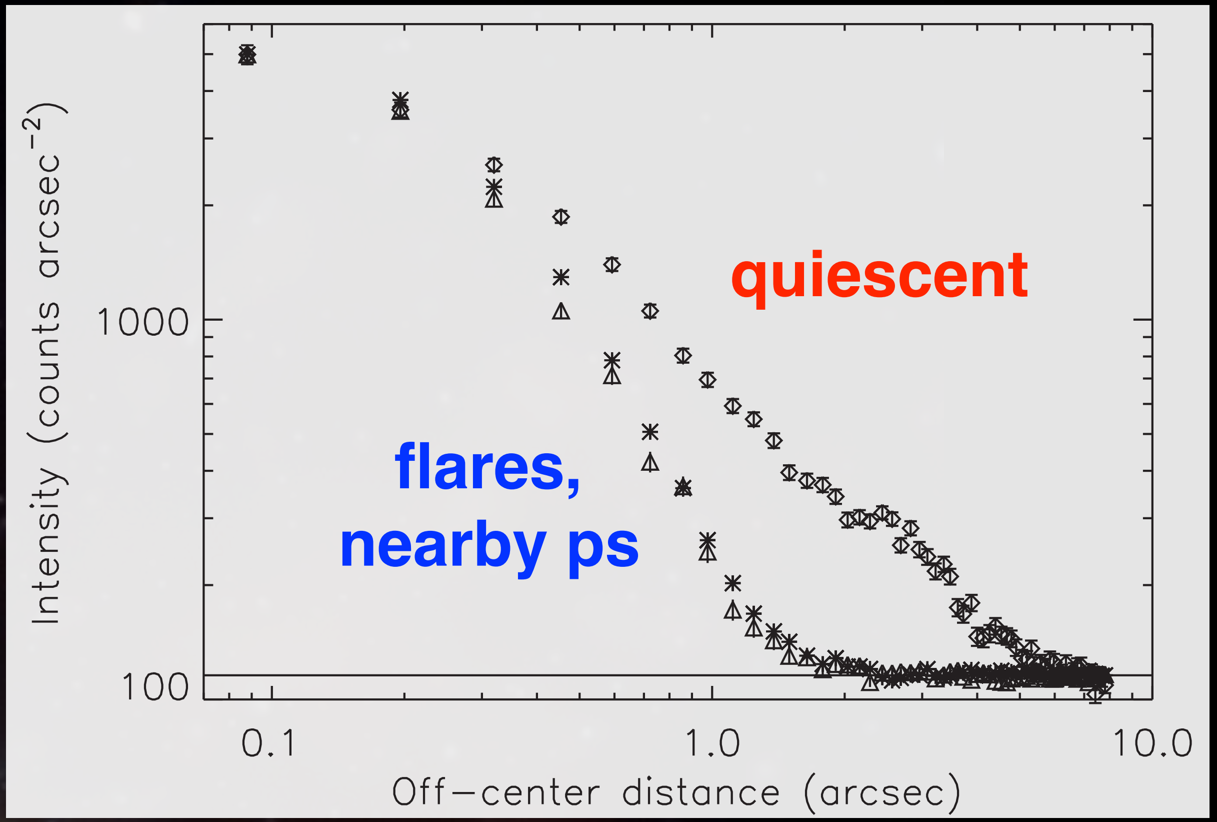
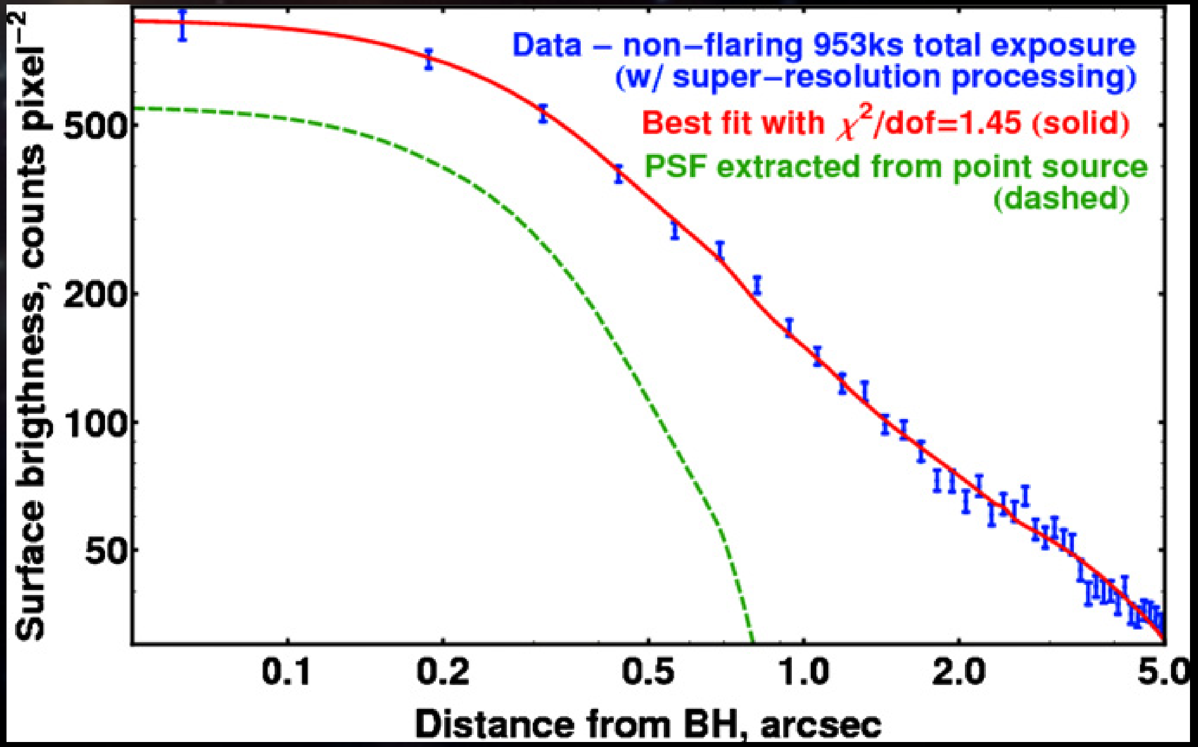


Baganoff+ 2003

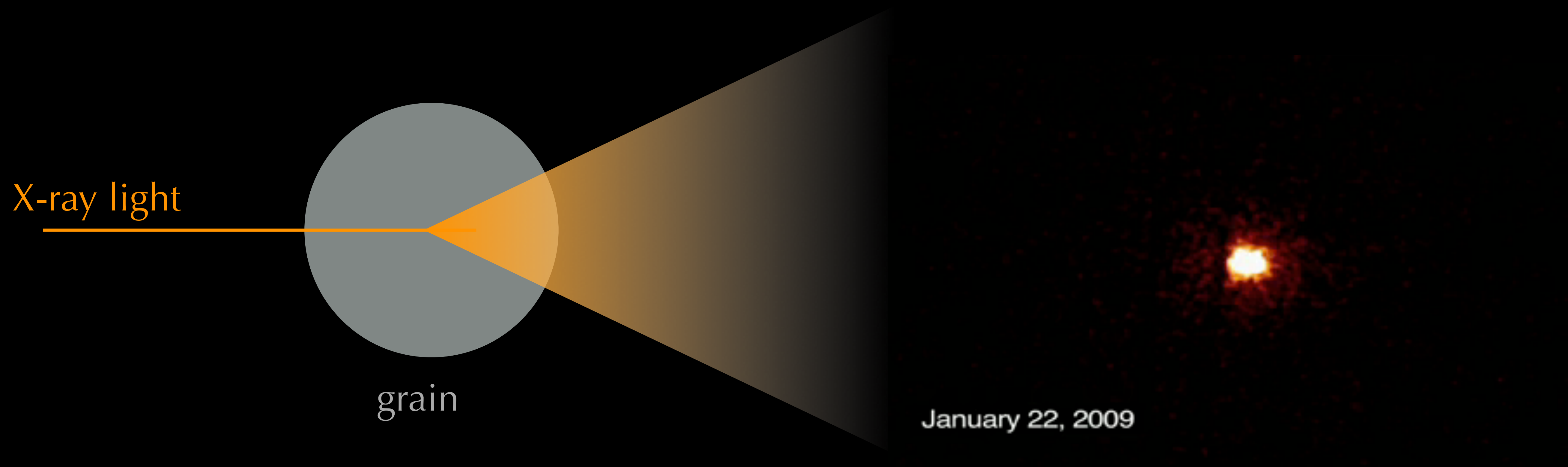


Wang+ 2013



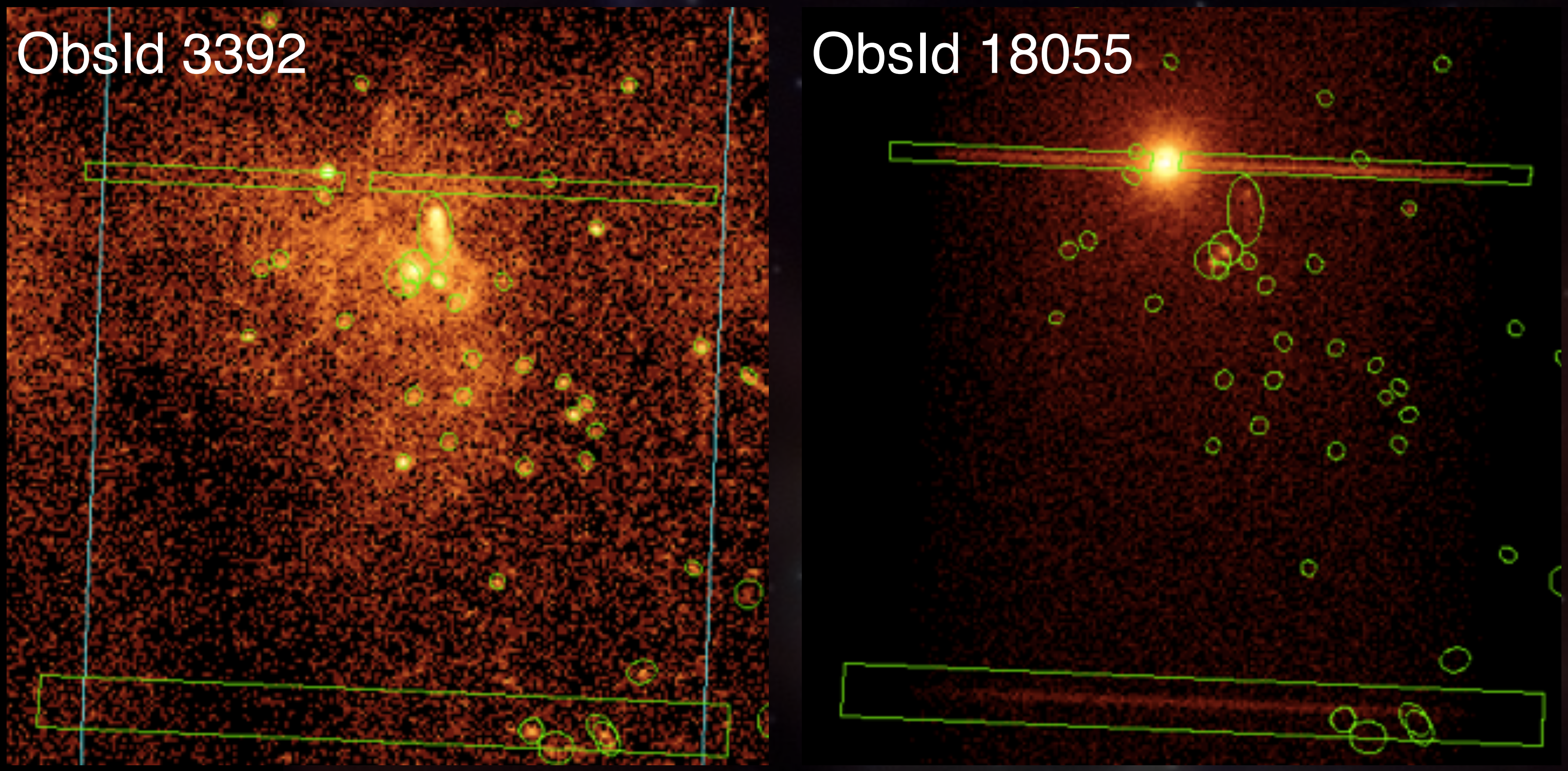
Shcherbakov+ 2005
see also Rozanska+ 2015, Roberts+ 2016

Small angle scattering by dust produces time-dependent image



SGR J1550-5418

Use **X-ray transients** in the Galactic Center
to **map foreground dust structure** affecting X-ray images
so we can **apply this knowledge to Sgr A***

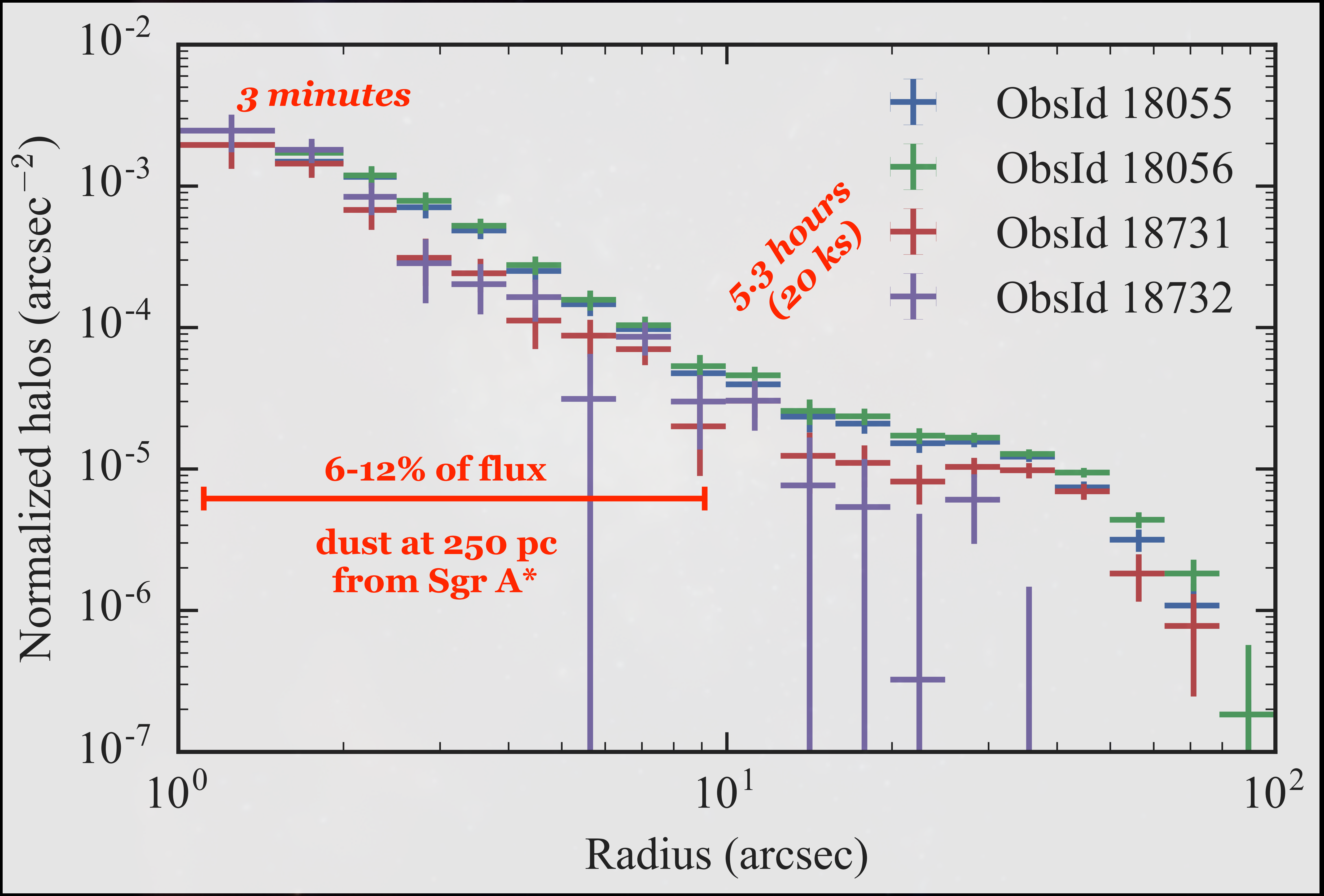


background

J174540.7-290015 profiles

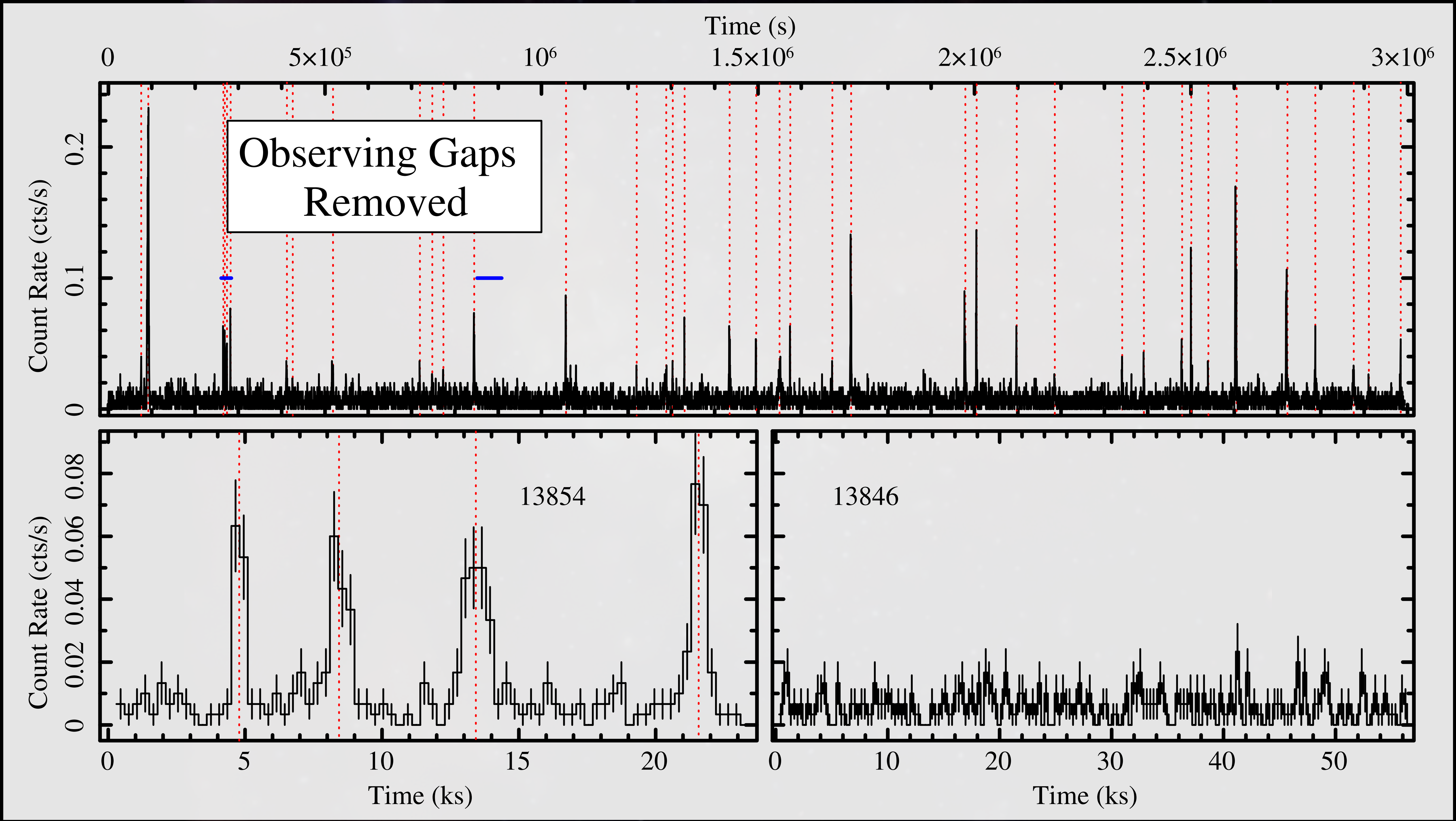
PSF constructed with
a low-NH source as template
(QSO B1028+511)

Corrales+ 2017



Corrales+ 2017

Sgr A* light curve from *Chandra* GC XVP



Neilsen+ 2013

State of the field:
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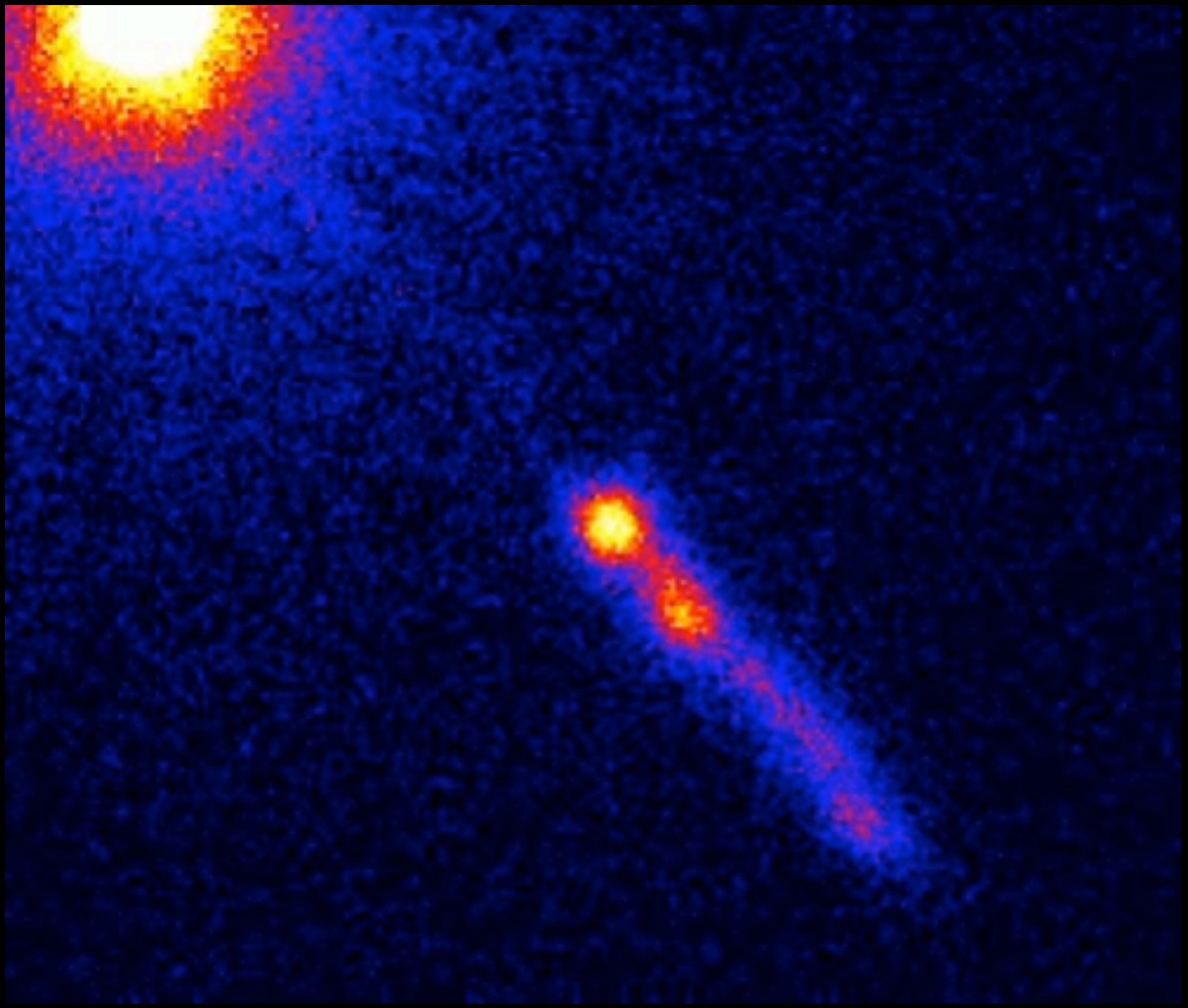
The future of X-ray astronomy: Assumptions

1. Lynx imaging resolution will at least be the same as Chandra
2. We will have X-ray IFUs (micro-calorimeters) in space

1. *Lynx* **imaging resolution** will at least as **good as *Chandra***

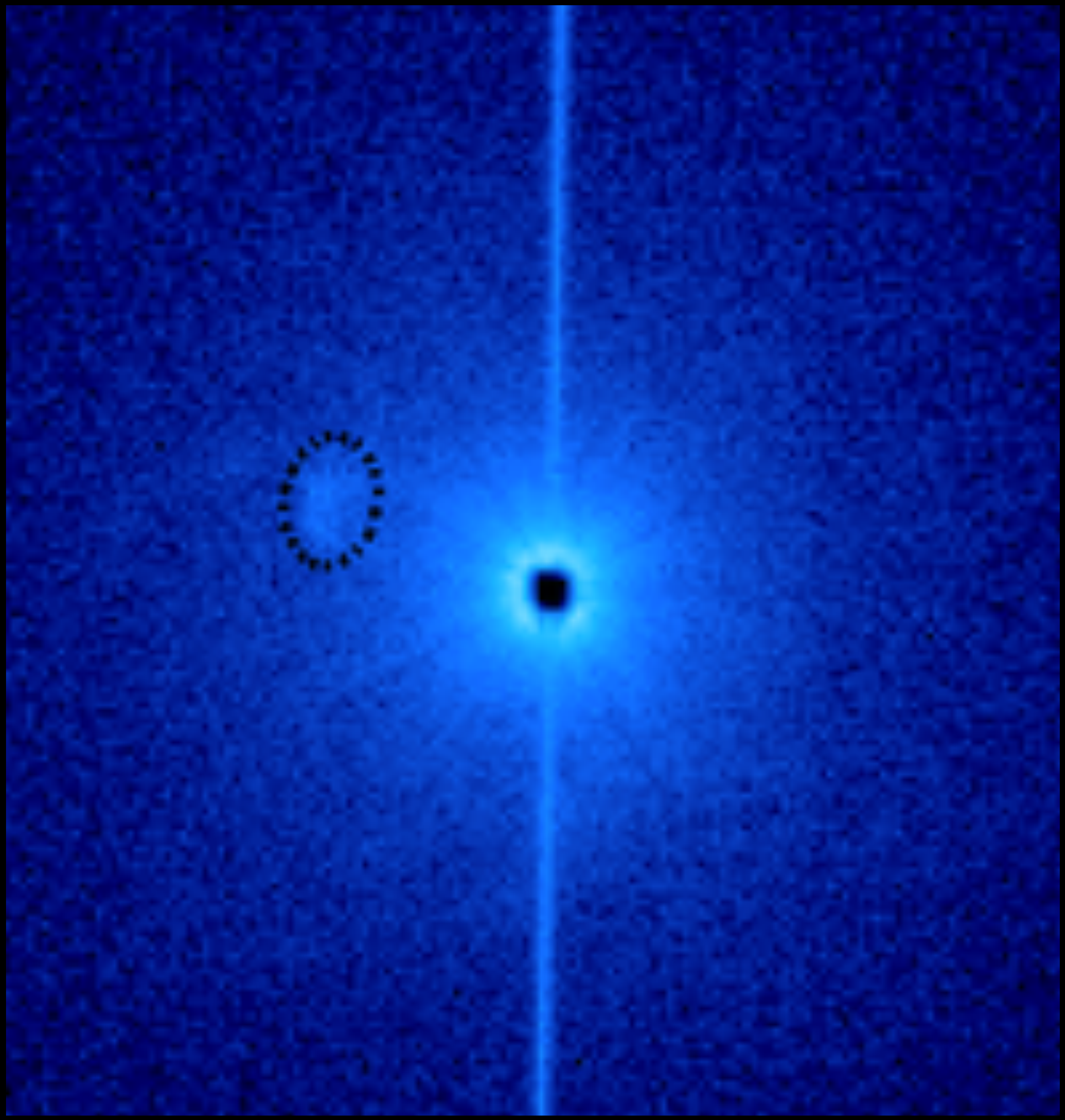
Chandra Deep Field South (NASA)



3C 273 as seen by Chandra

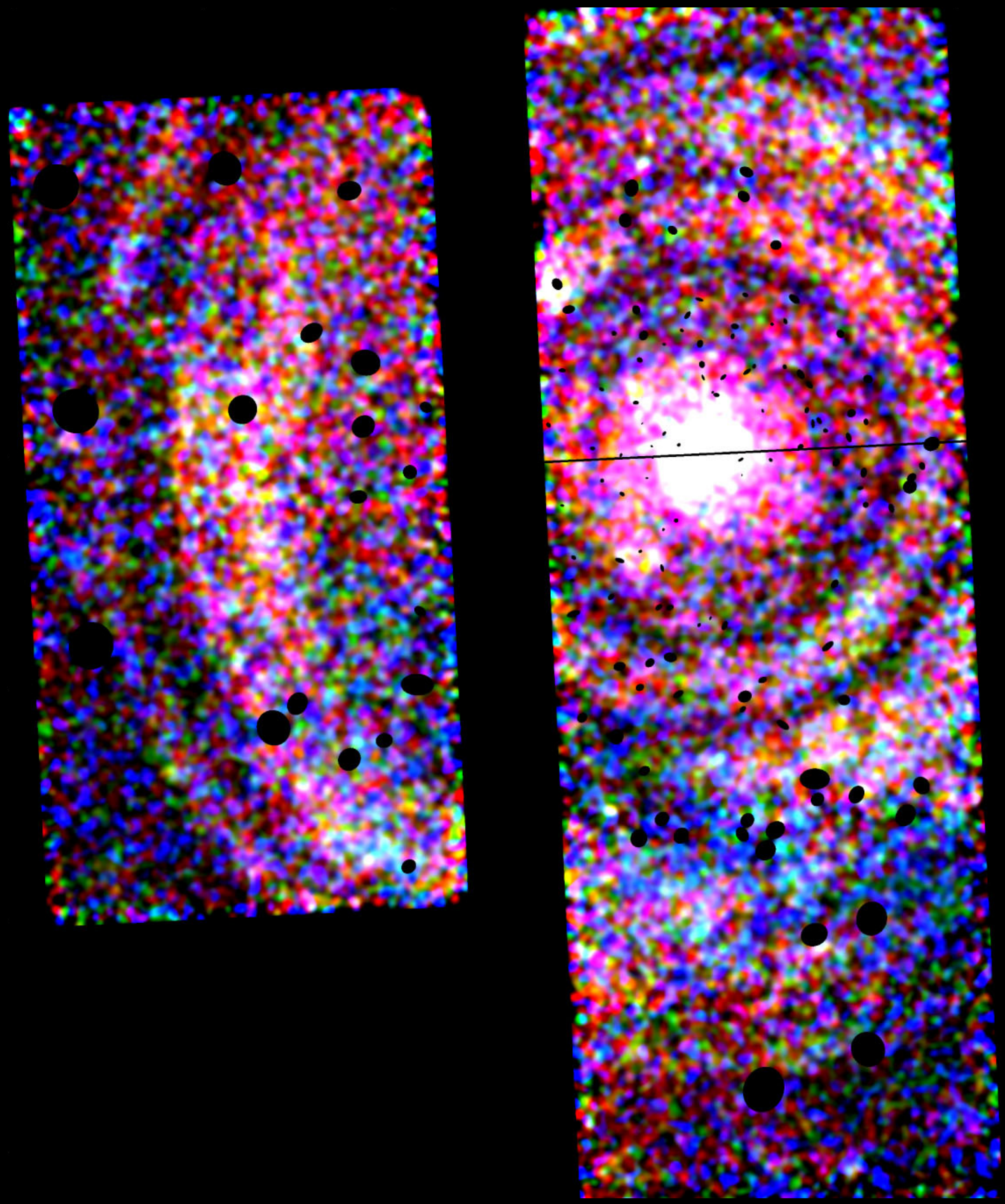
1. ***Lynx* imaging resolution** will at least as **good as *Chandra***

Cyg X-3's Little Friend



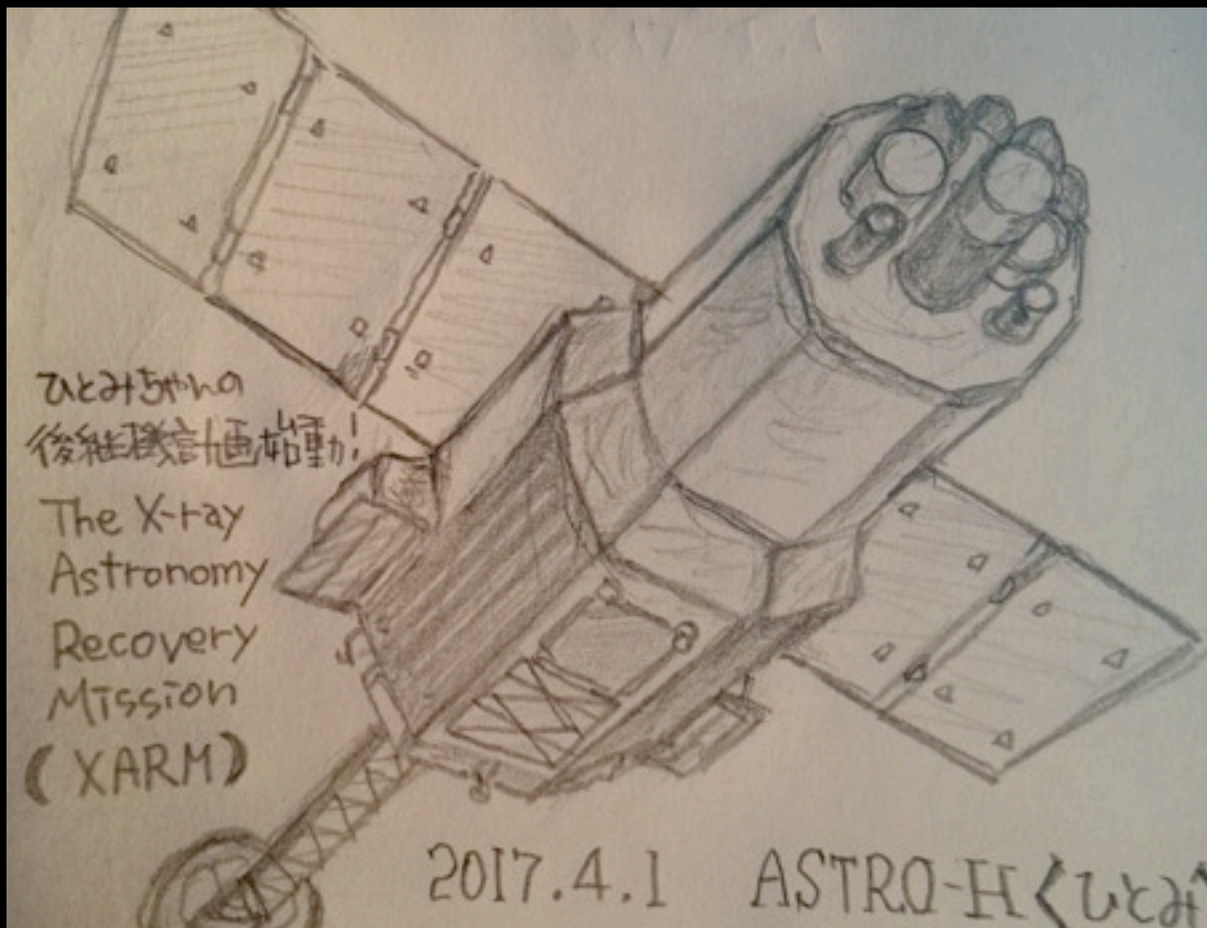
McCollough et al. (2013)
McCollough, Corrales, & Dunham (2016)

Cir X-1 dust scattering echoes



Heinz et al. (2015)

2. We will have **X-ray IFUs** (micro-calorimeters) **in space**



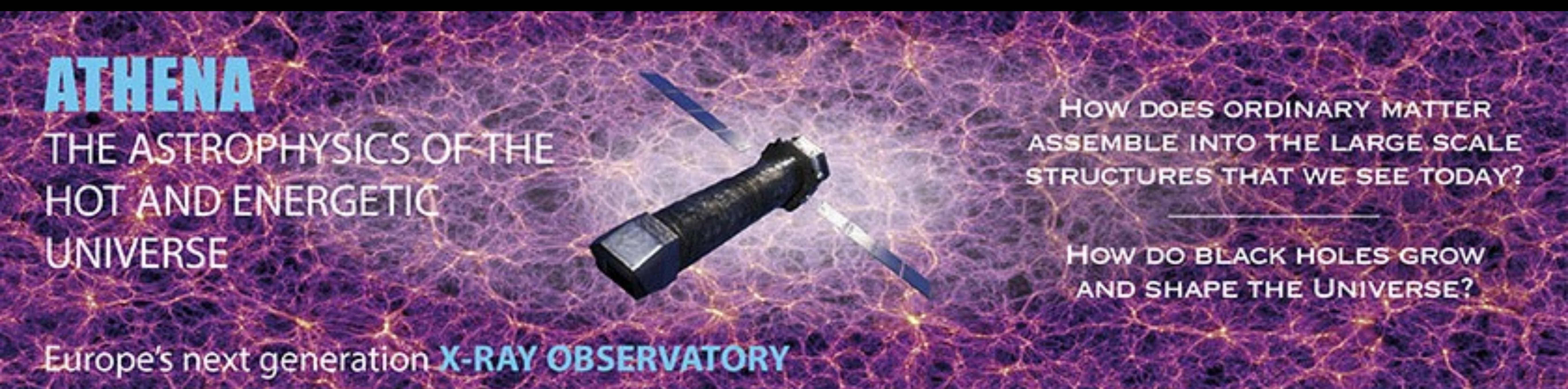
twitter: @kittenblue0706

XARM (based on Astro-H)

Resolution ~ 1.7 arcmin HPD
Effective Area ~ 200 sq cm

Athena

Resolution ~ 5-10” HEW
Effective Area ~ 200 sq cm



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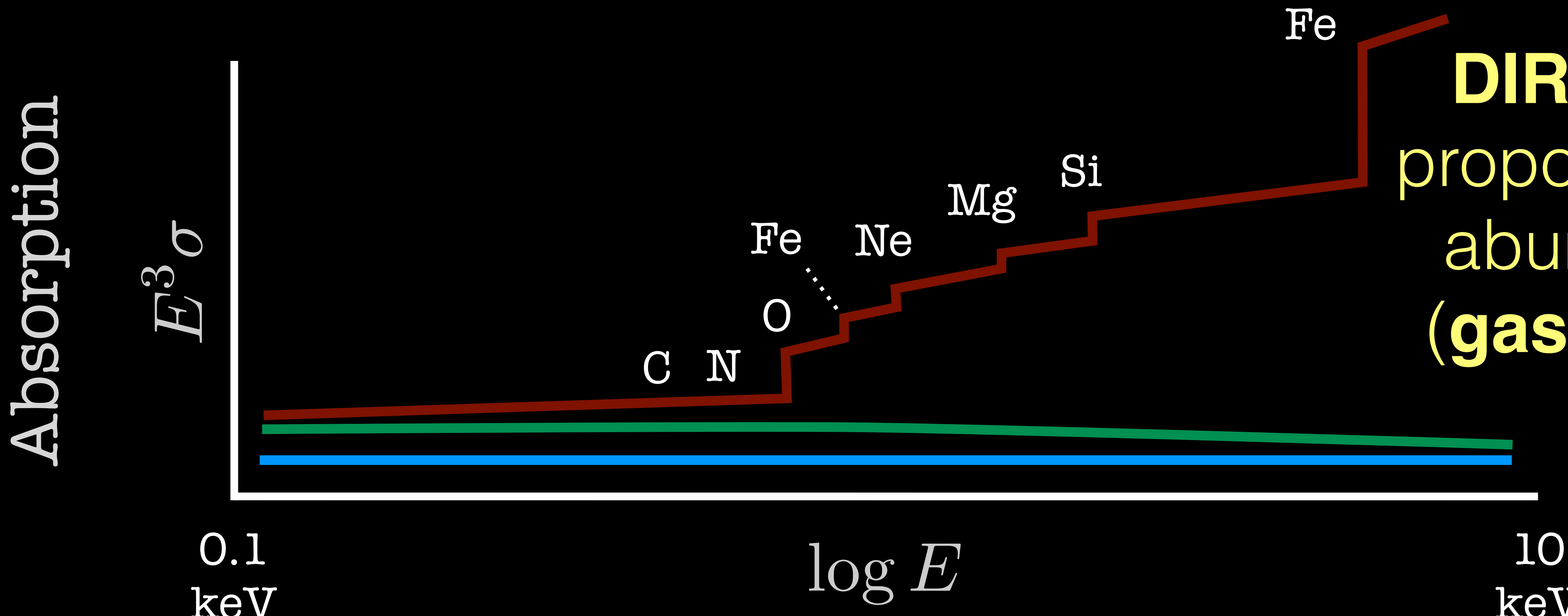
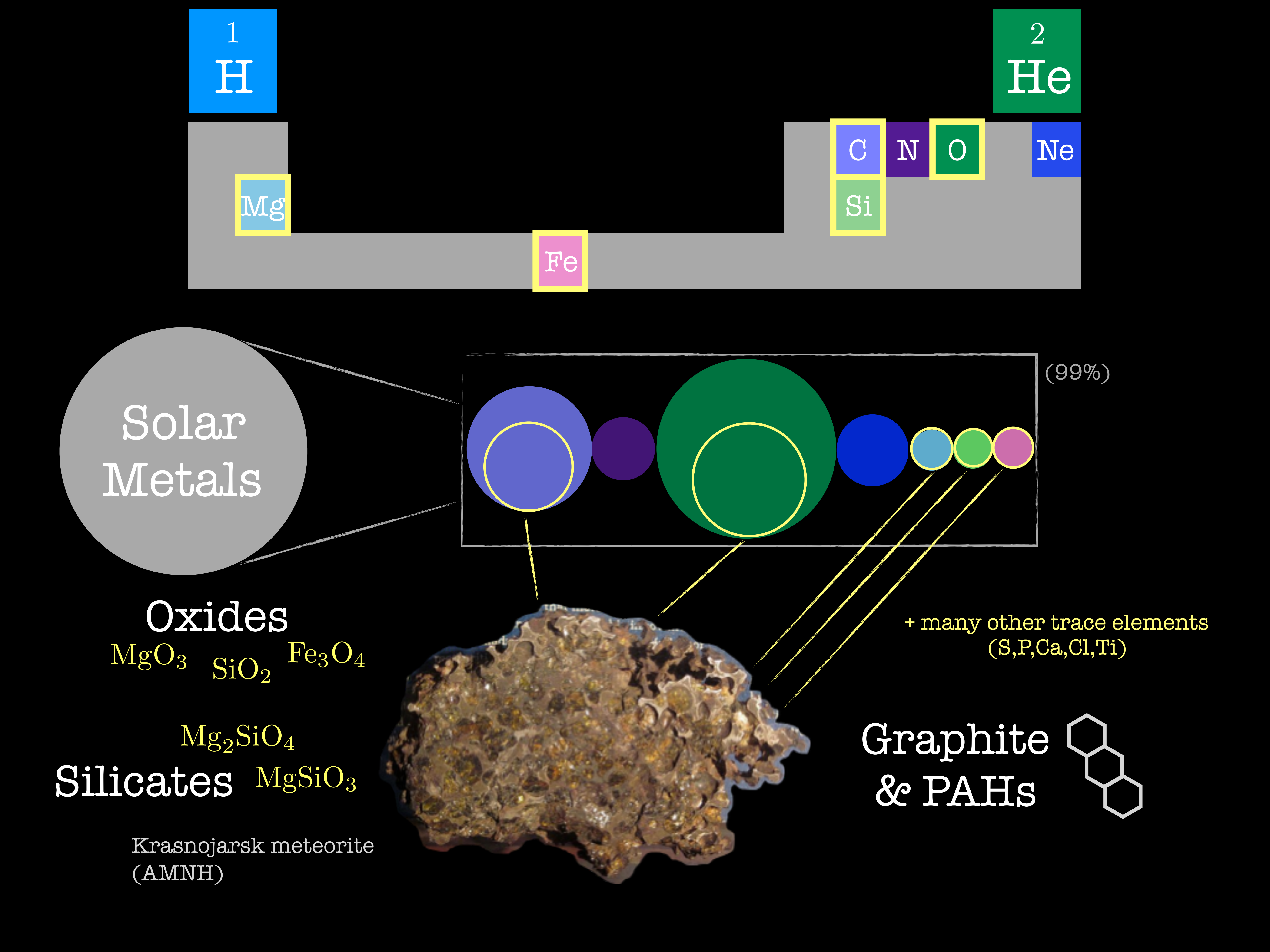
ISM and dust studies with an X-ray IFU



DIRECTLY proportional to abundance (**gas + dust**)

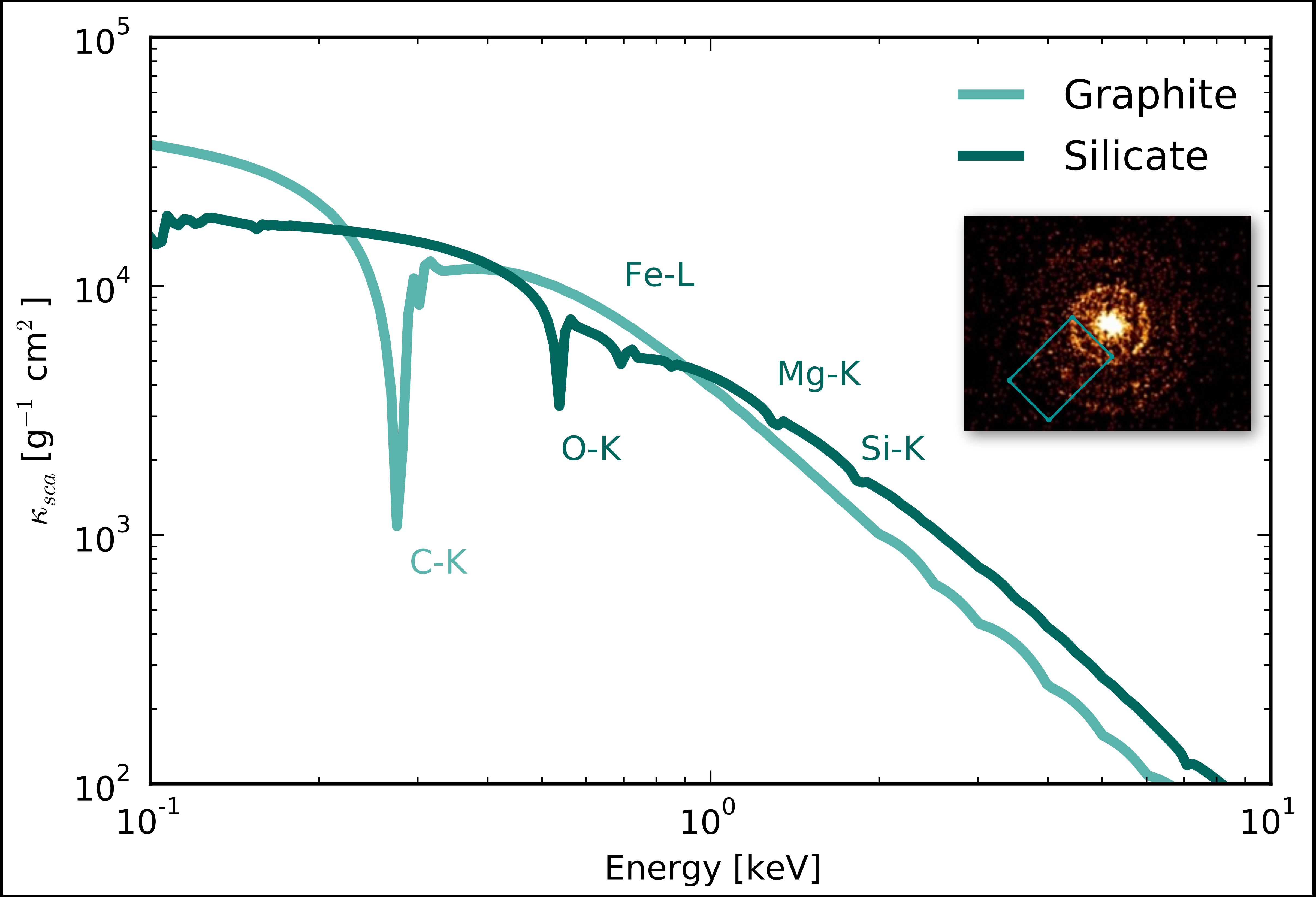
Wilms, Allen, & McCray (2000)

No curve-of-growth

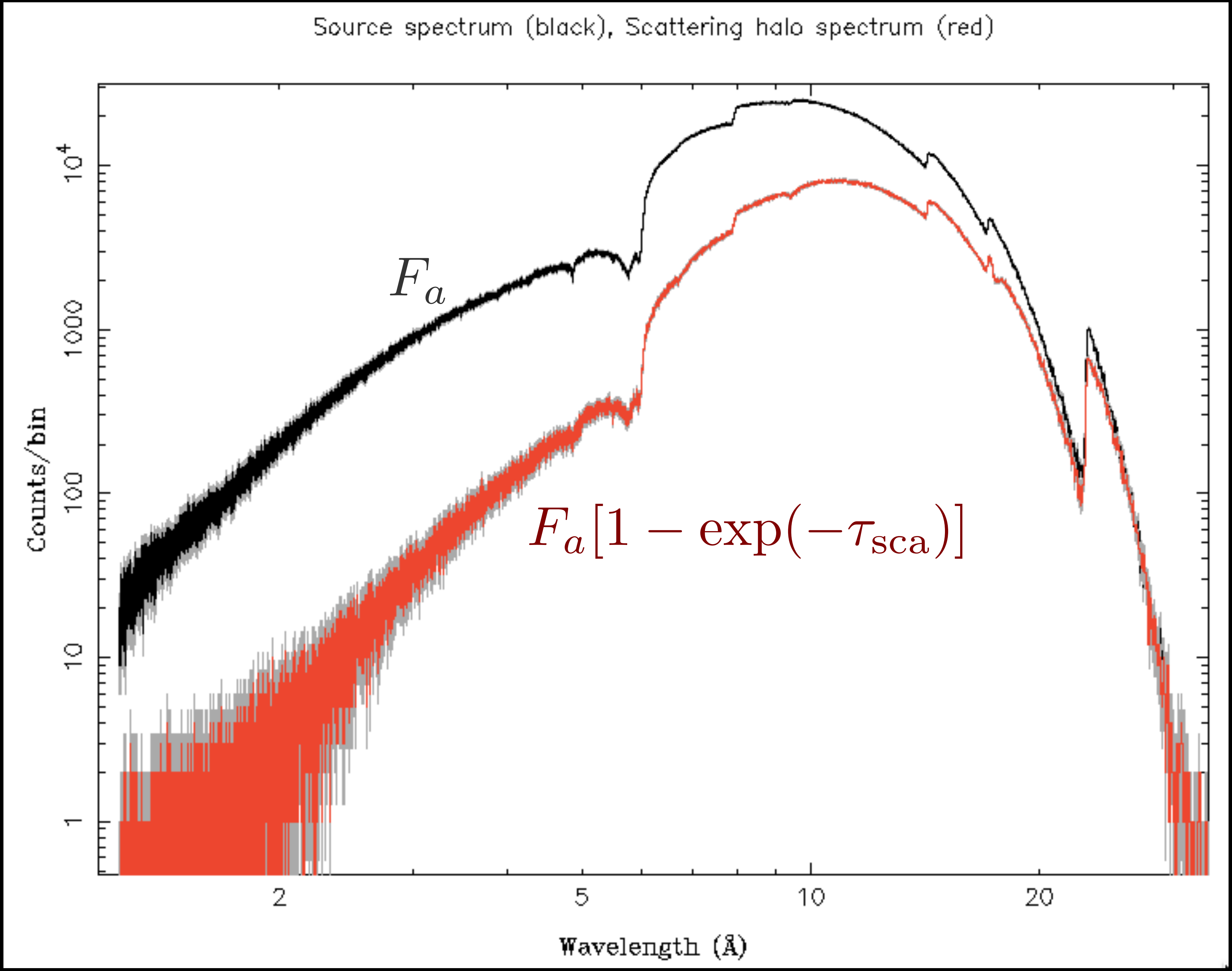


1
H
2
He
C
N
O
Ne
Mg
Si
Fe
Solar Metals
(99%)
Oxides
MgO3
SiO2
Fe3O4
Mg2SiO4
Silicates
MgSiO3
+ many other trace elements
(S,P,Ca,Cl,Ti)
Graphite & PAHs
Krasnojarsk meteorite
(AMNH)

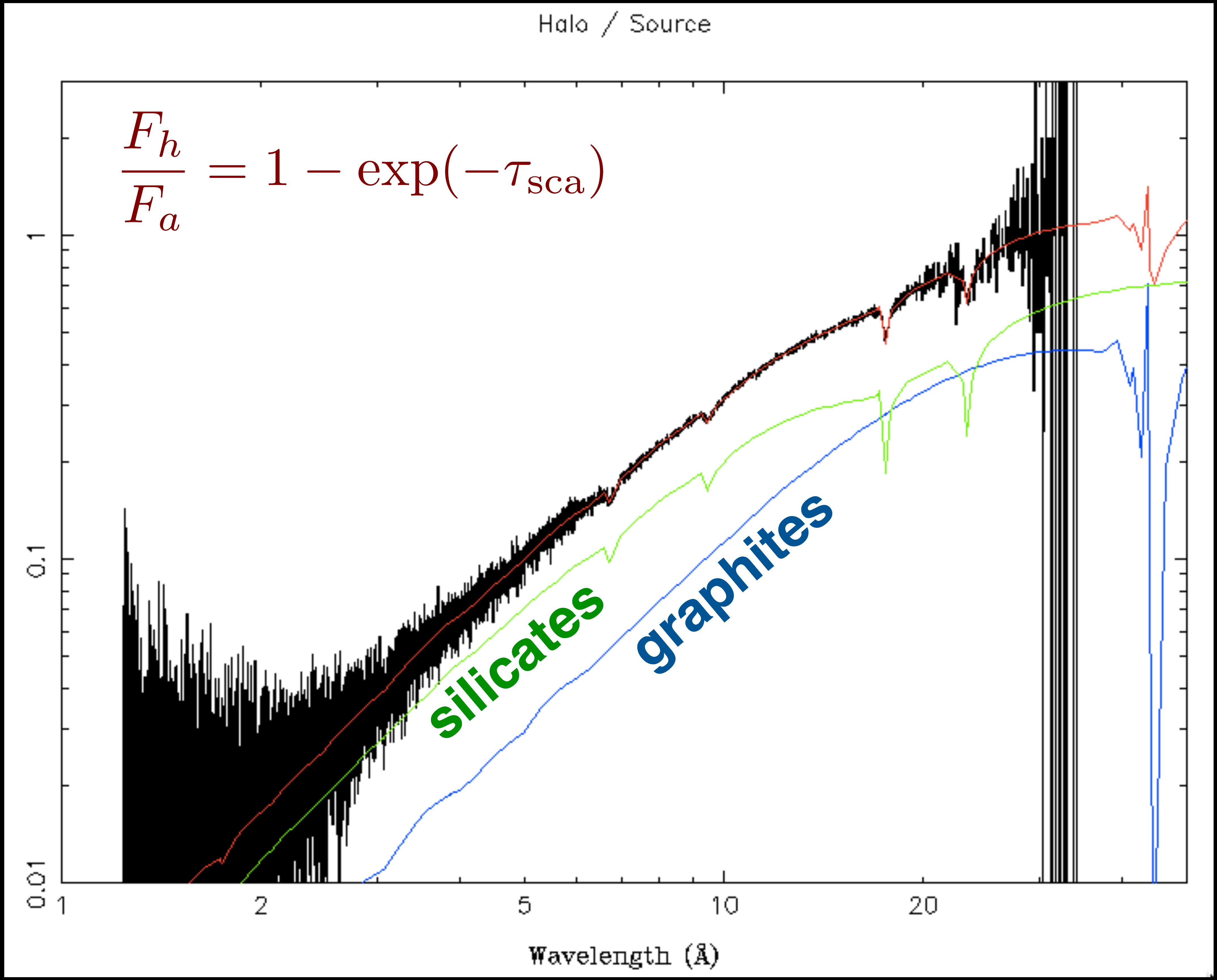
Spectrum of dust scattered light should have features coincident with **absorption edge structure** from **constituent elements**



Simulated micro-calorimeter spectrum



Ratio of halo to source reveals **dust spectral features**



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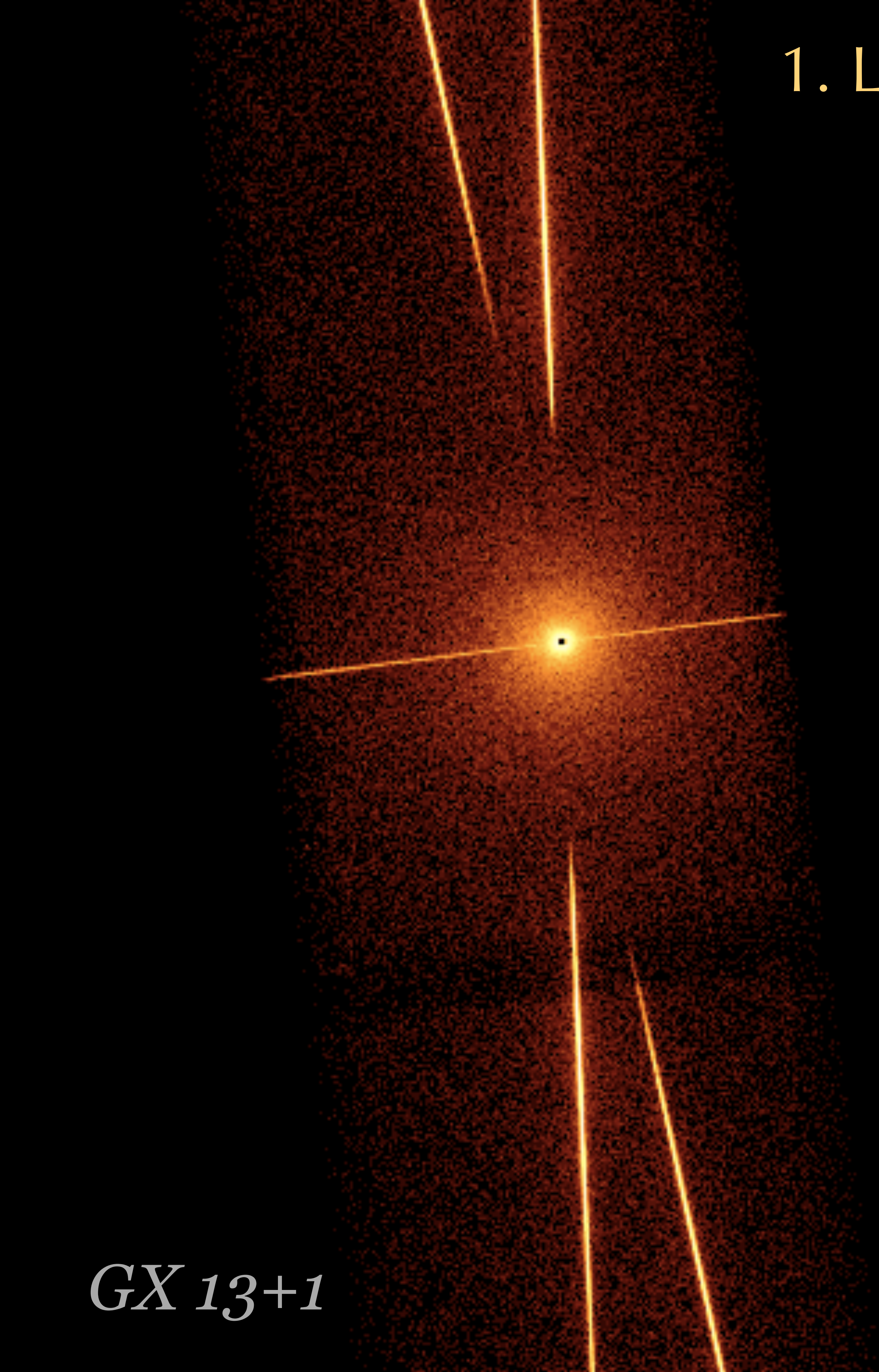
The future of X-ray astronomy: Limitations

1. Limits on observing bright sources

Instrument tolerance
Non-linear detector behavior
Telemetry saturation



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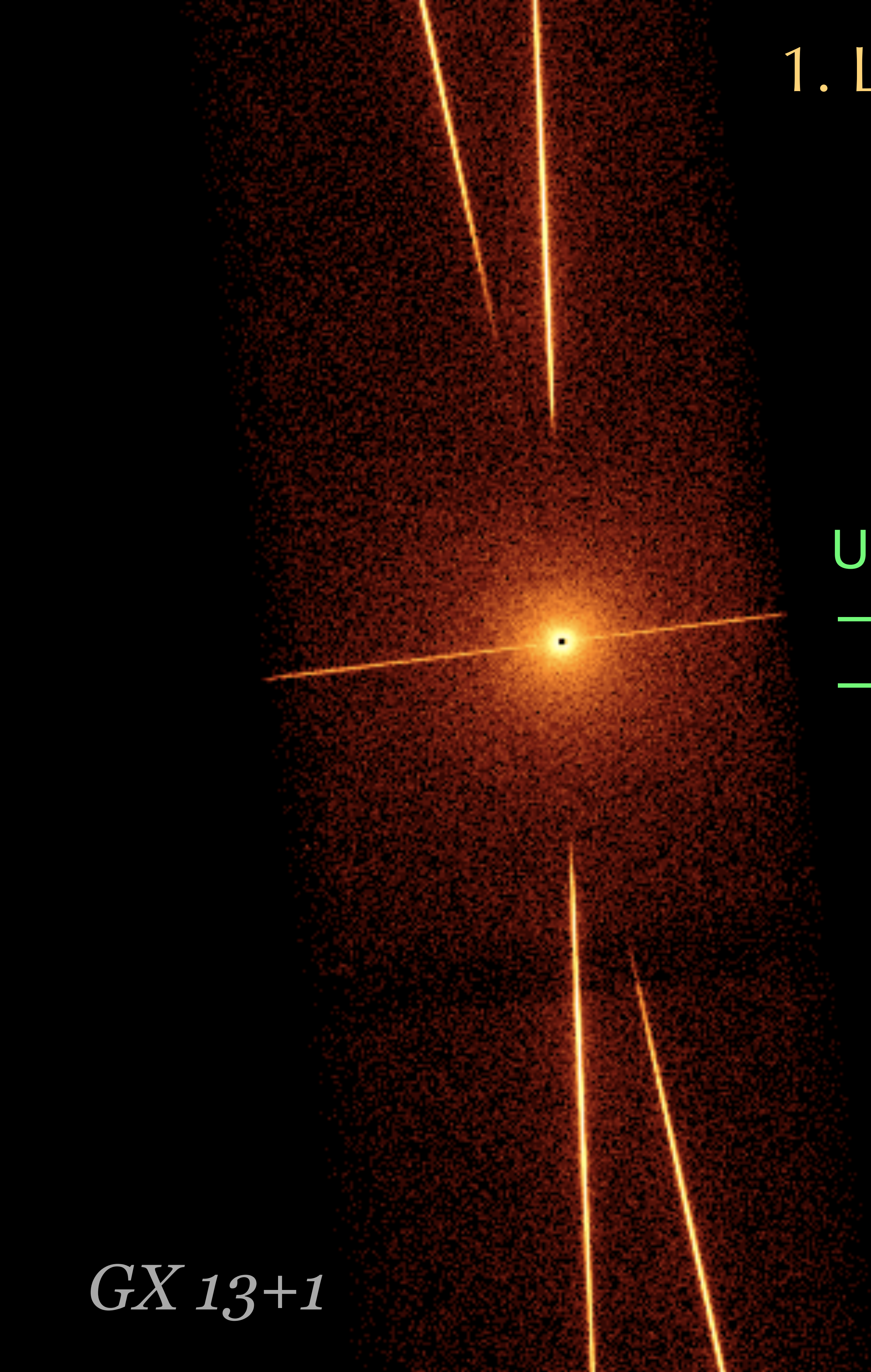


Use tricks!
— Readout streak [**calibration needed**]
— De-focus [**problematic**]

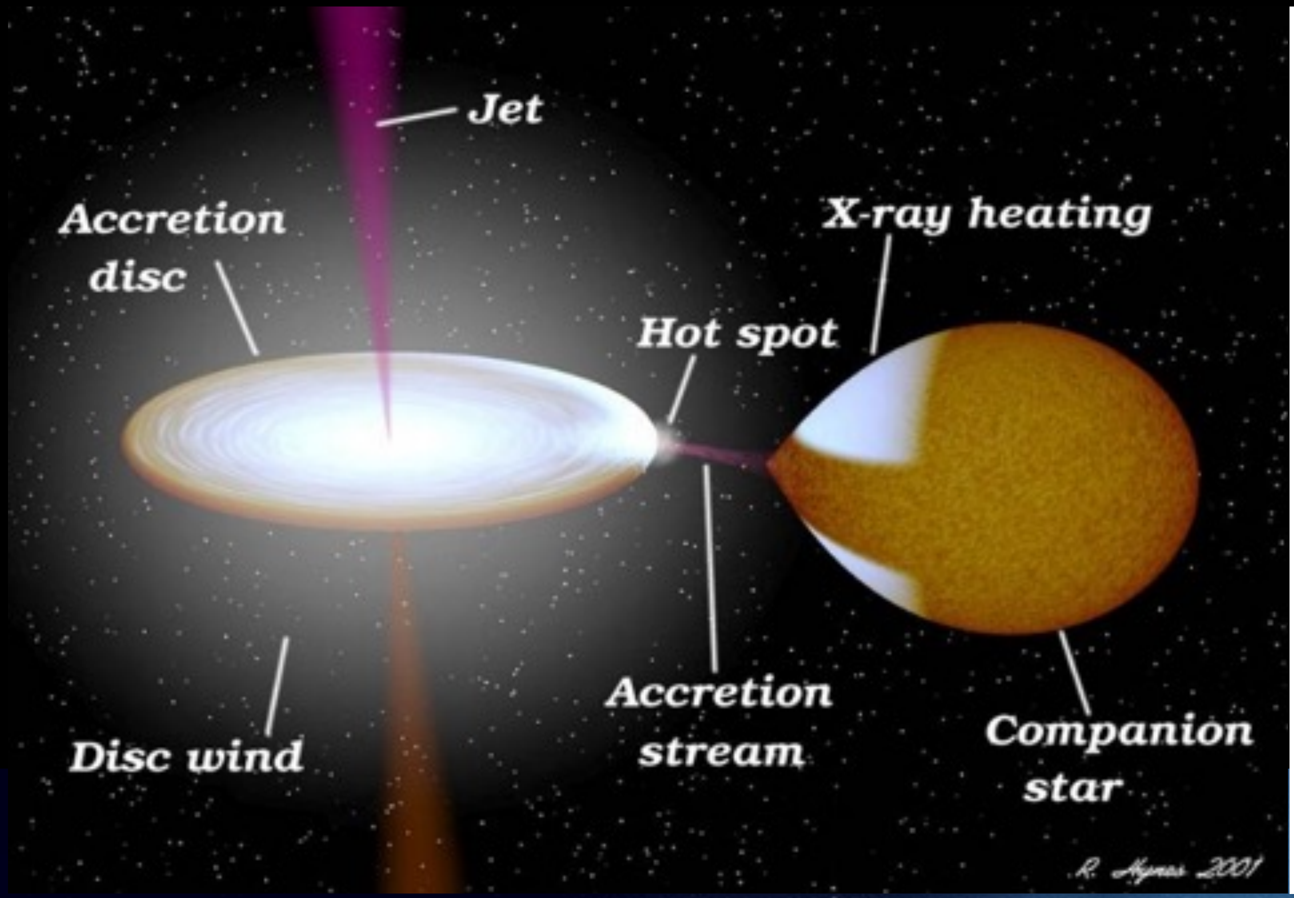
Faster readout time

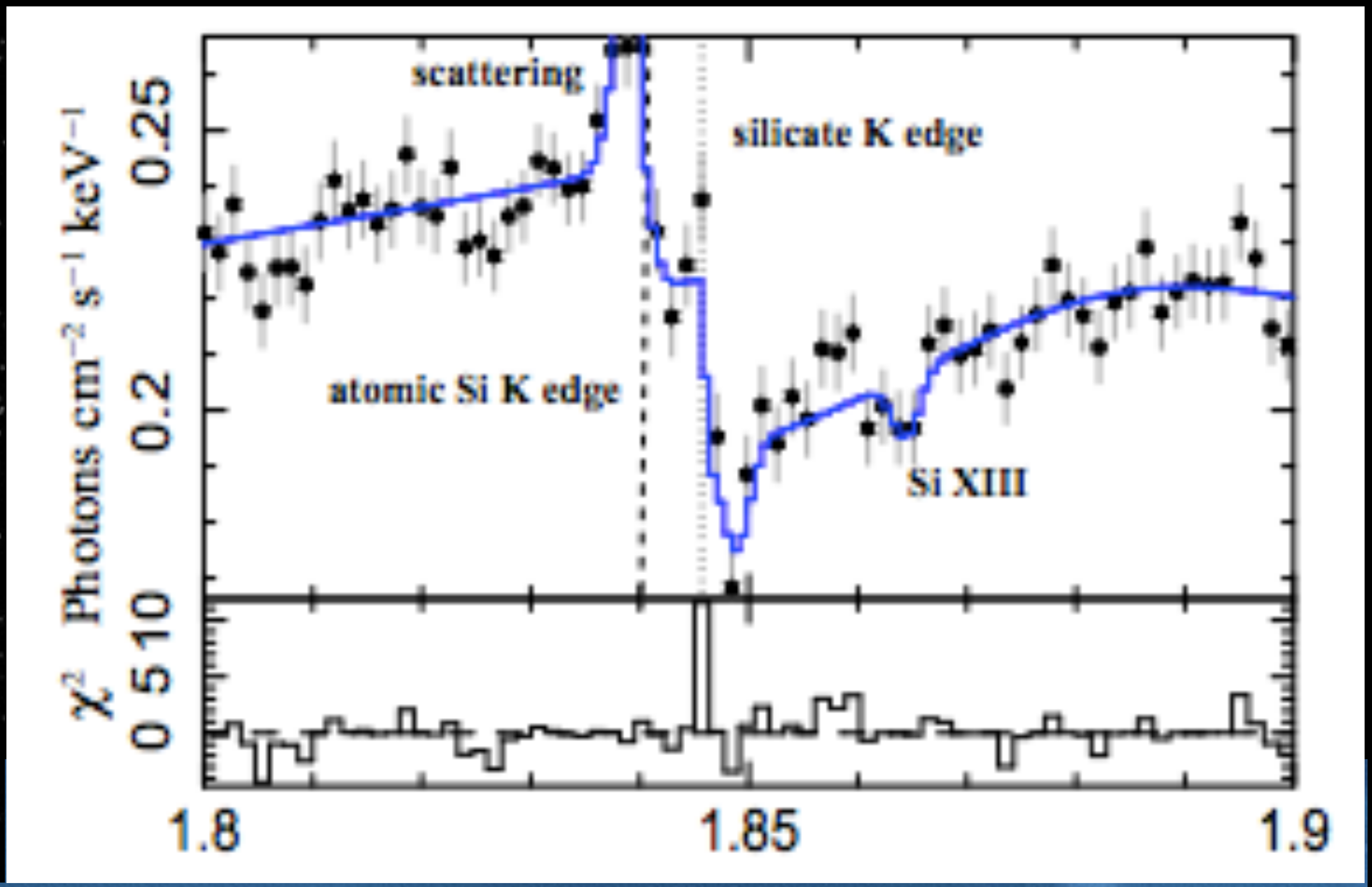
Gratings increase tolerance

Dispersing light prevents
non-linear effects (in most cases)

1. Limits on observing bright sources

Athena may **not** be capable of observing **brightest X-ray binaries**





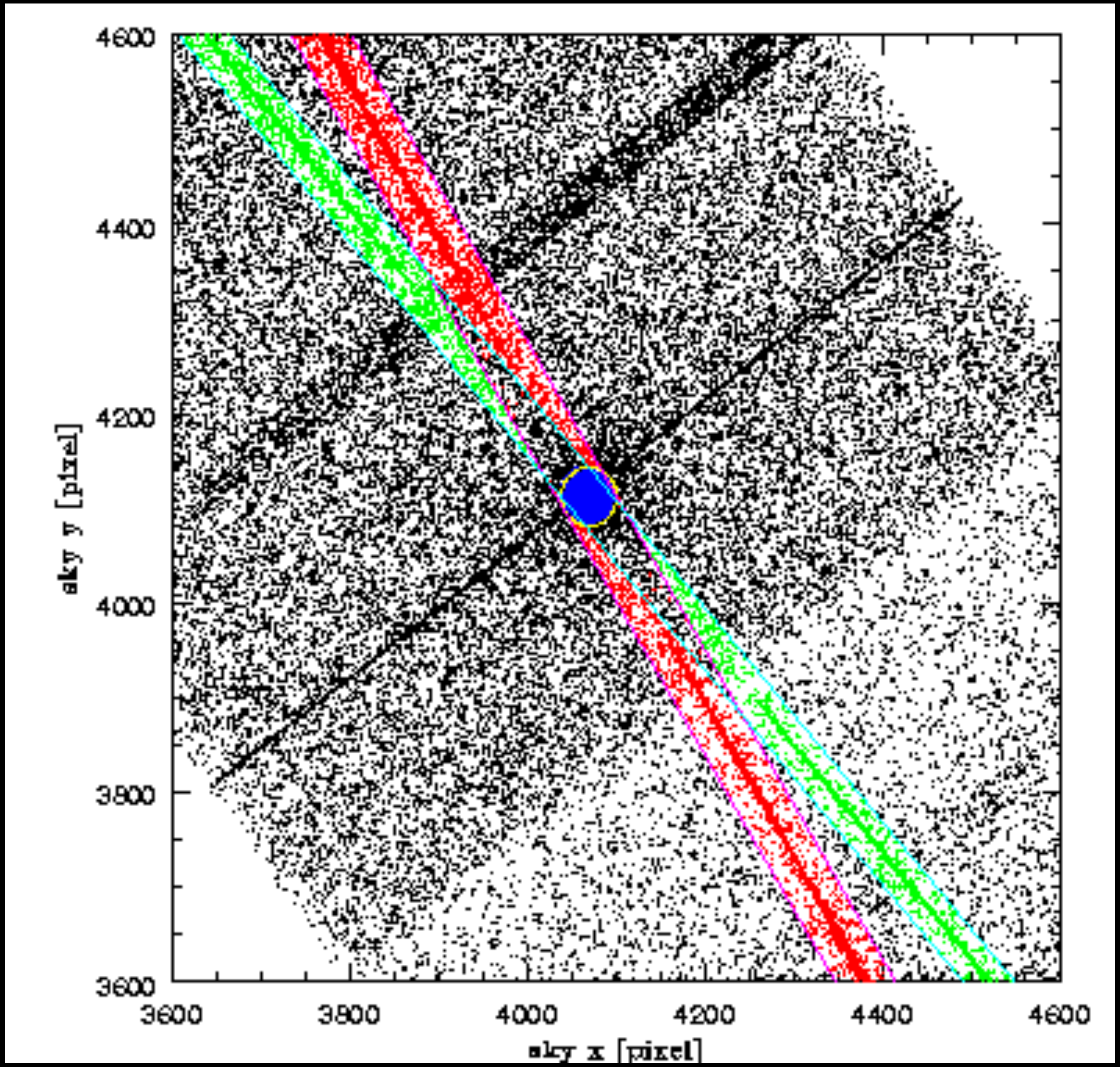
Will Lynx be different?

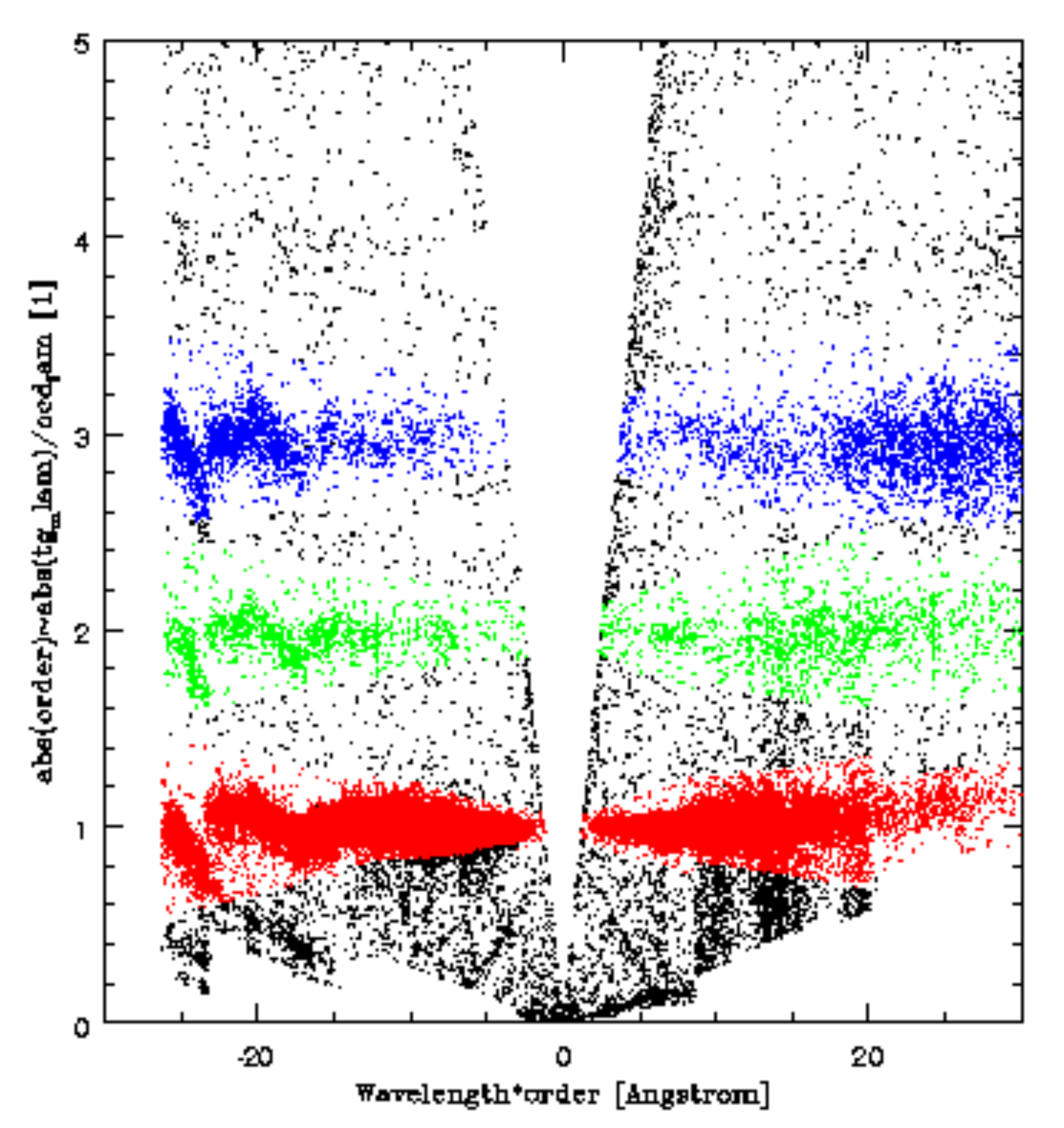
2. Limits from background

High resolution imaging helps resolve out background point sources (CXB)

Orbit choice — intensity and stability

Background from gratings instruments is inherently lower

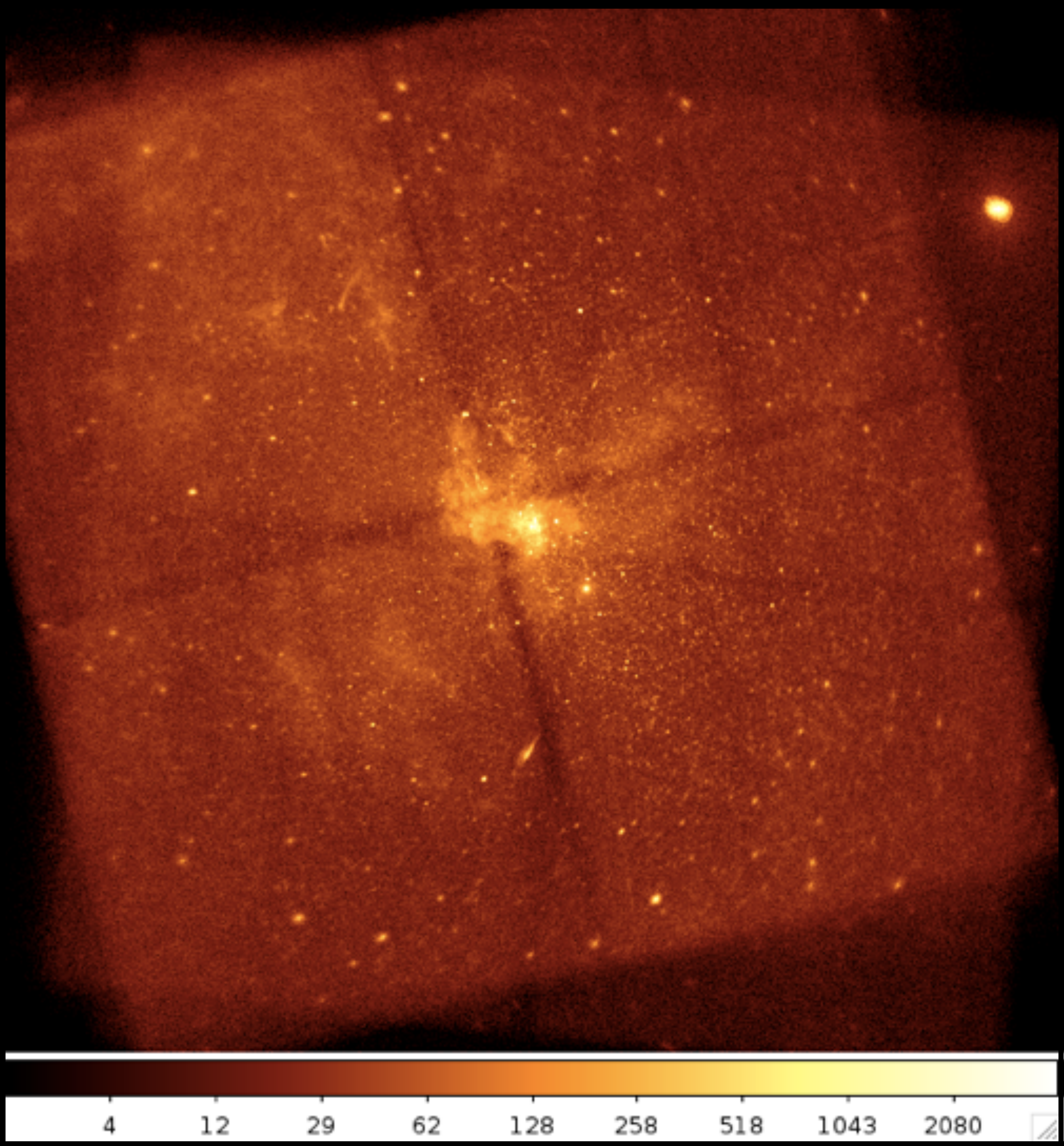




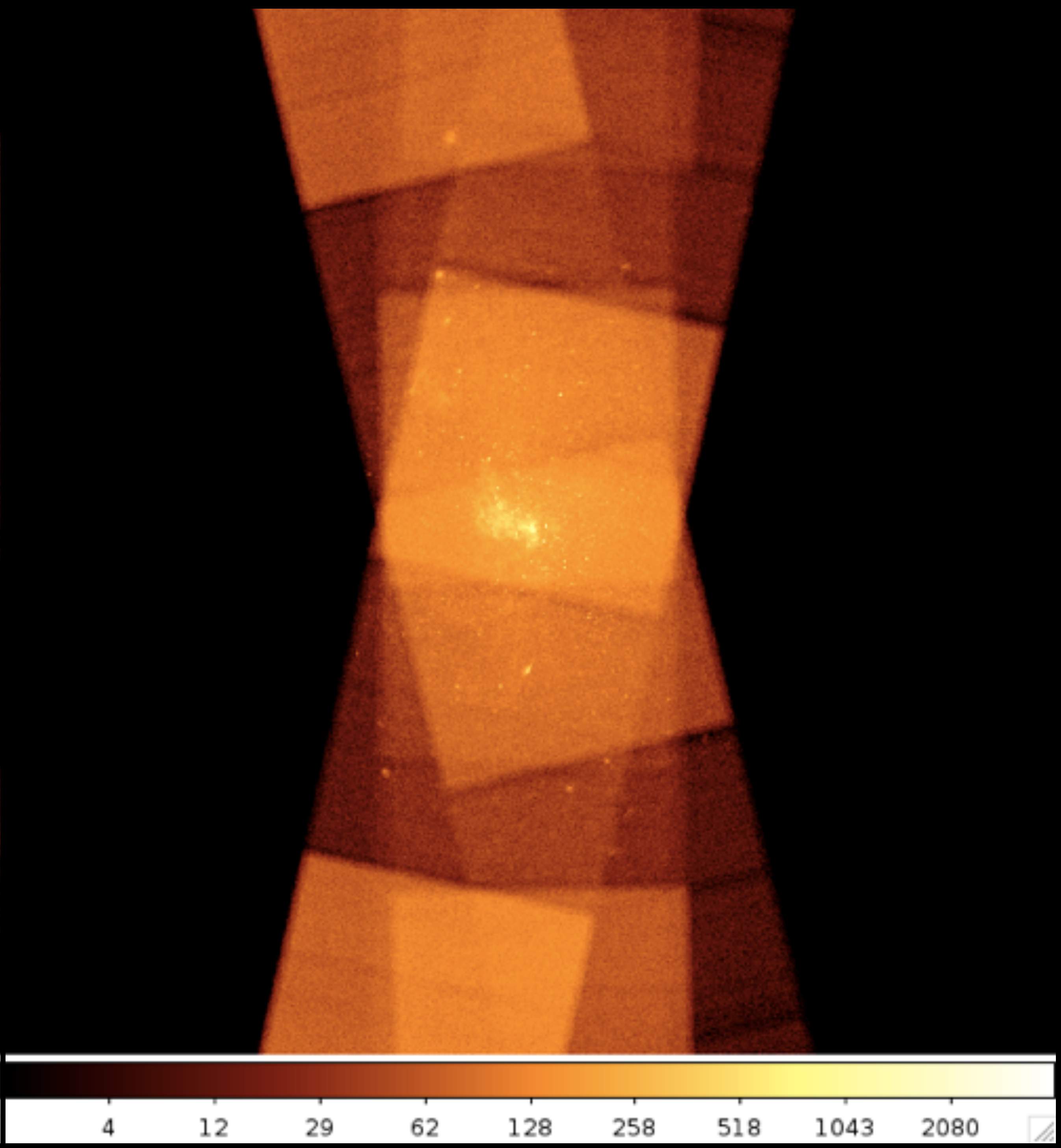
MIT HETG group

2. Limits from background

~1 Ms ACIS-I



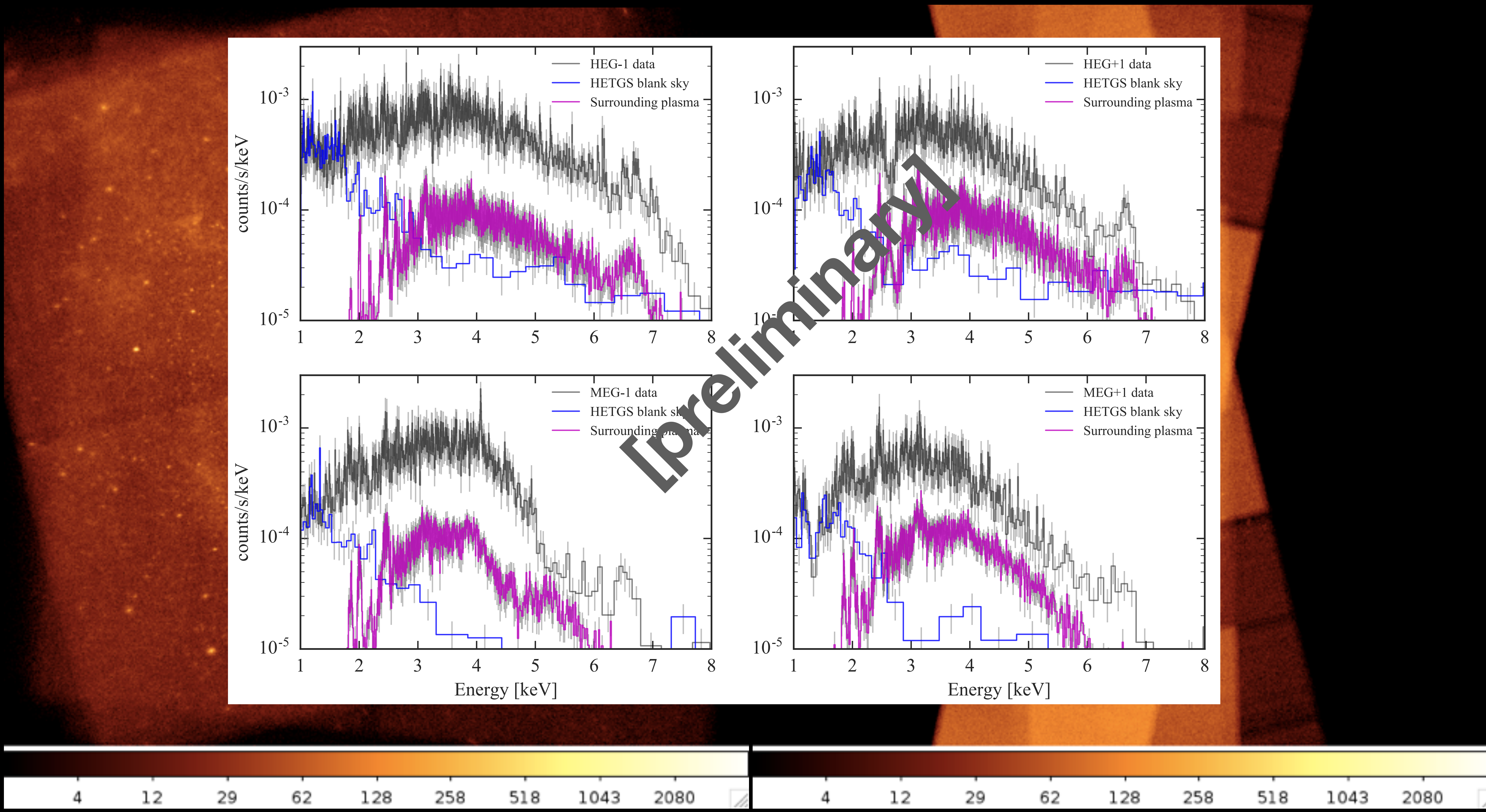
~3 Ms HETG (ACIS-S)



2. Limits from background

~1 Ms ACIS-I

~3 Ms HETG (ACIS-S)

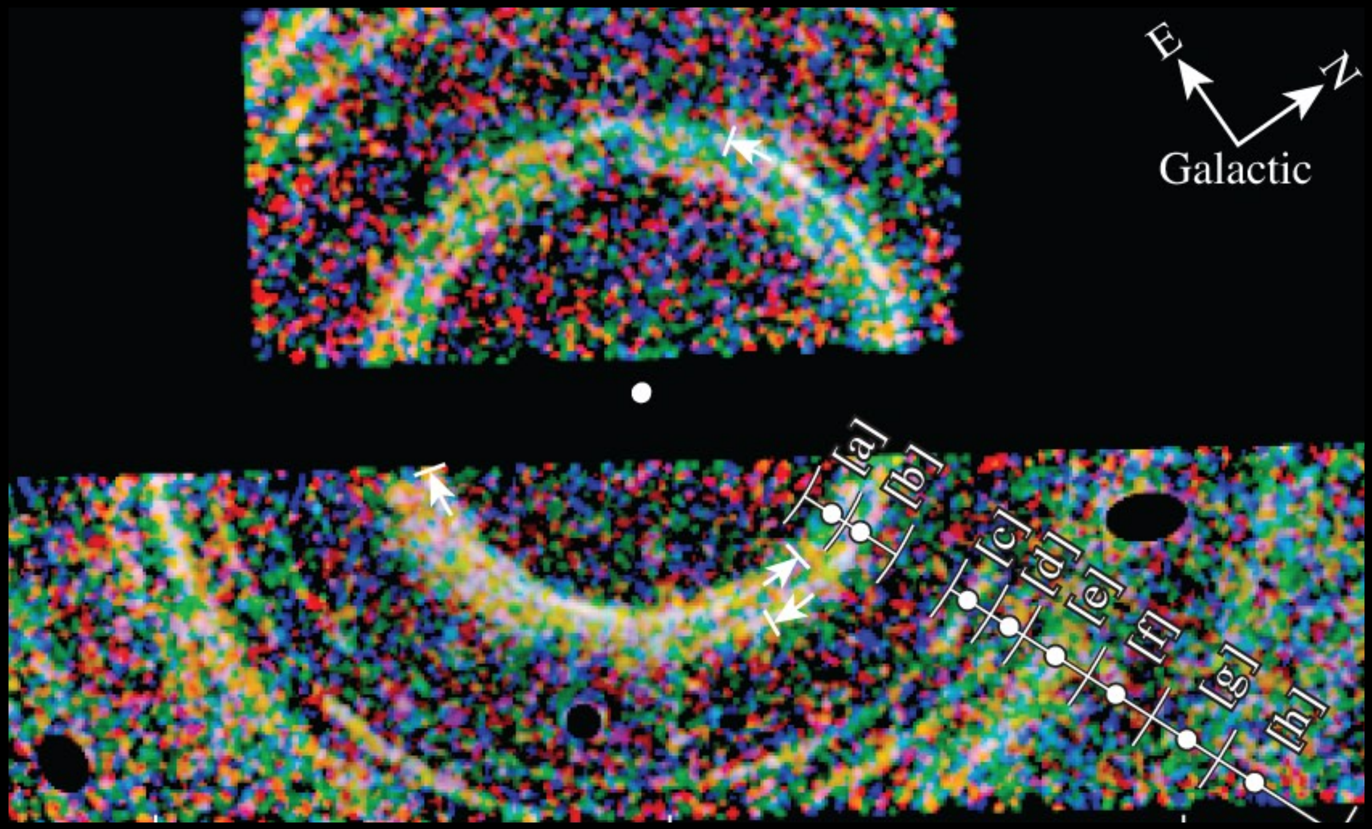


You can't ignore background

2. Limits from background

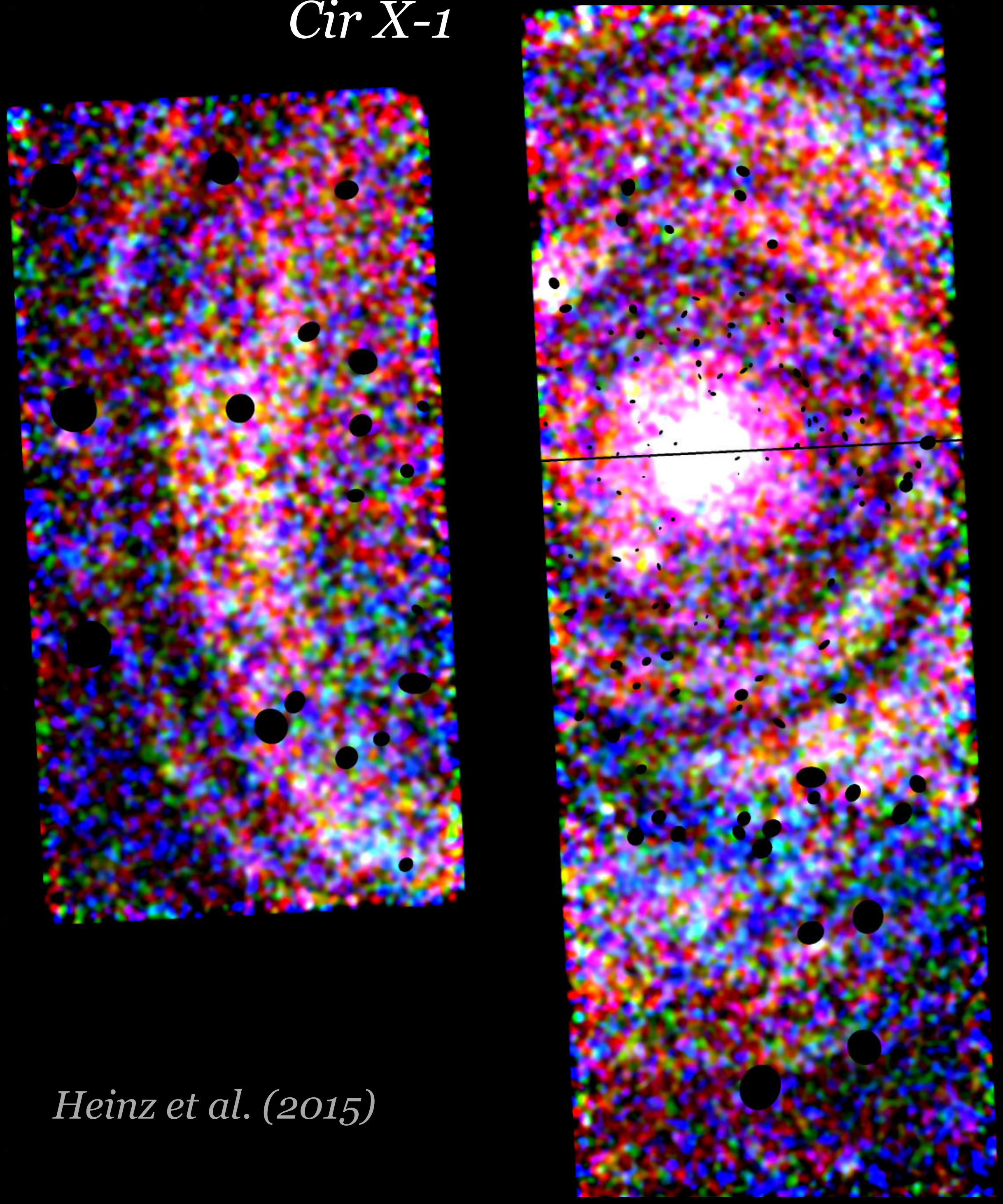
Deeper stellar and AGN **surveys**
Study **structure** of diffuse hot gas **in more detail**
Dust scattering halos and echoes

V404 Cygni



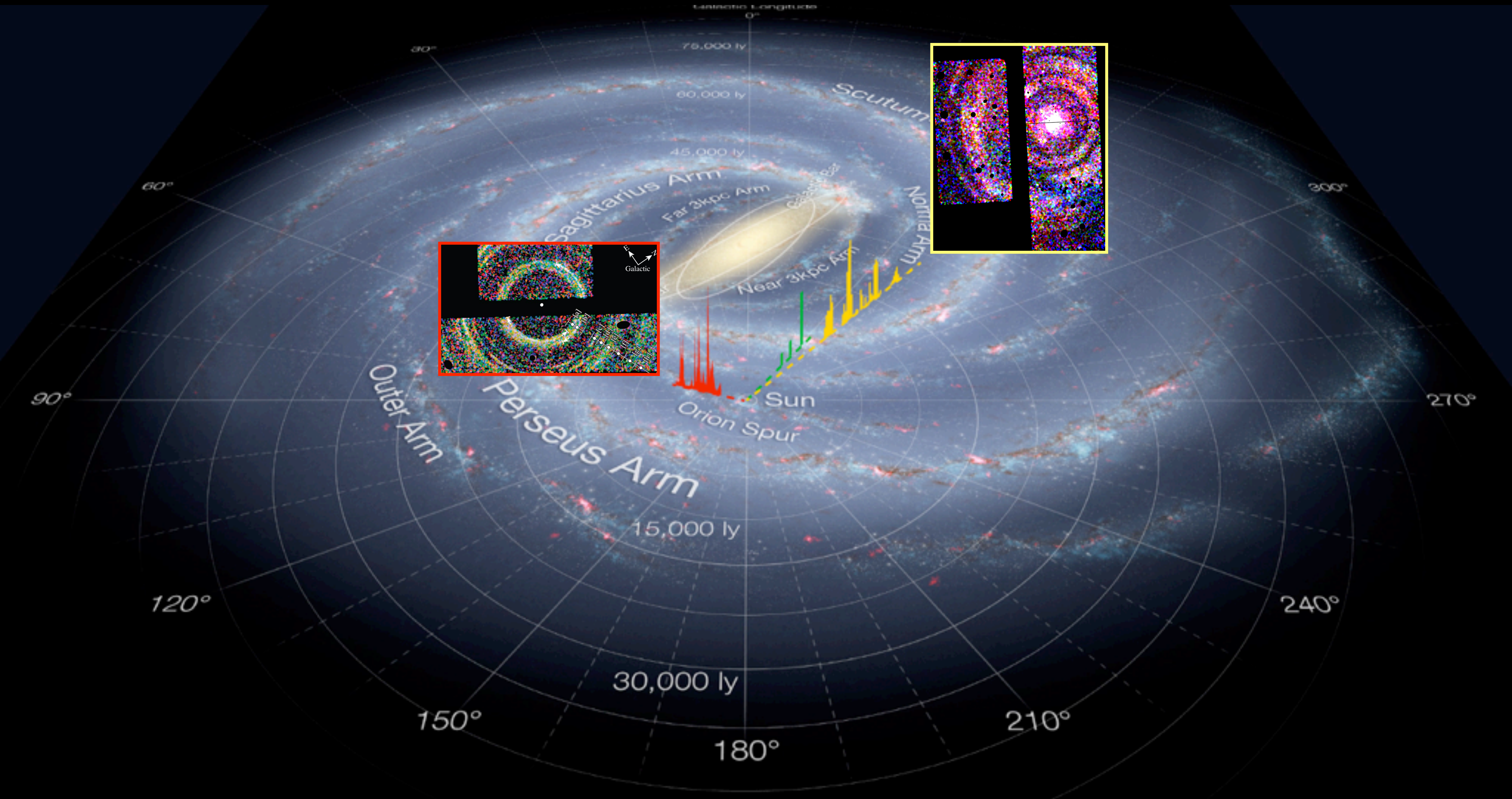
Heinz, Corrales, et al. (2016)

Cir X-1



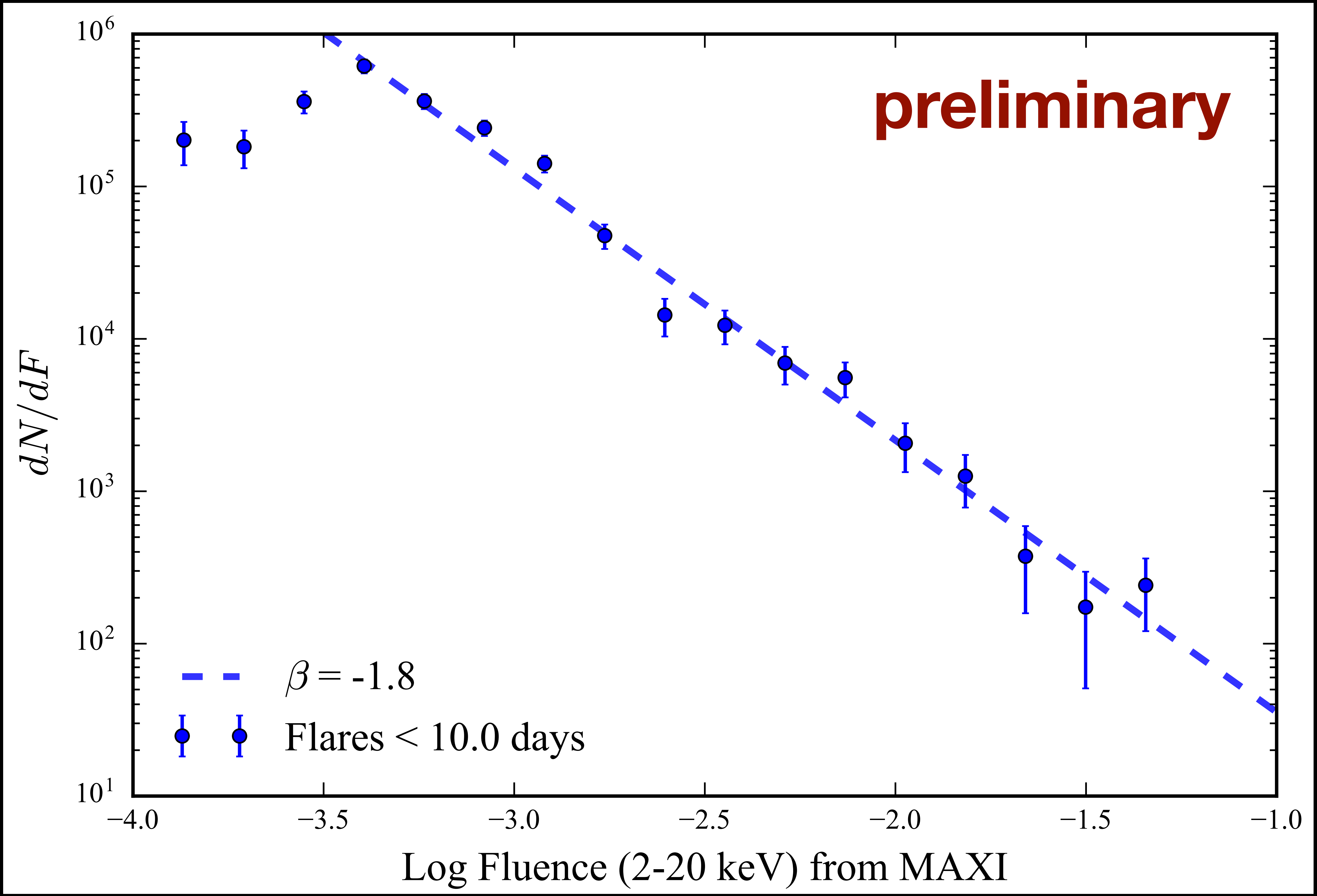
Heinz et al. (2015)

Prospects for dust echoes



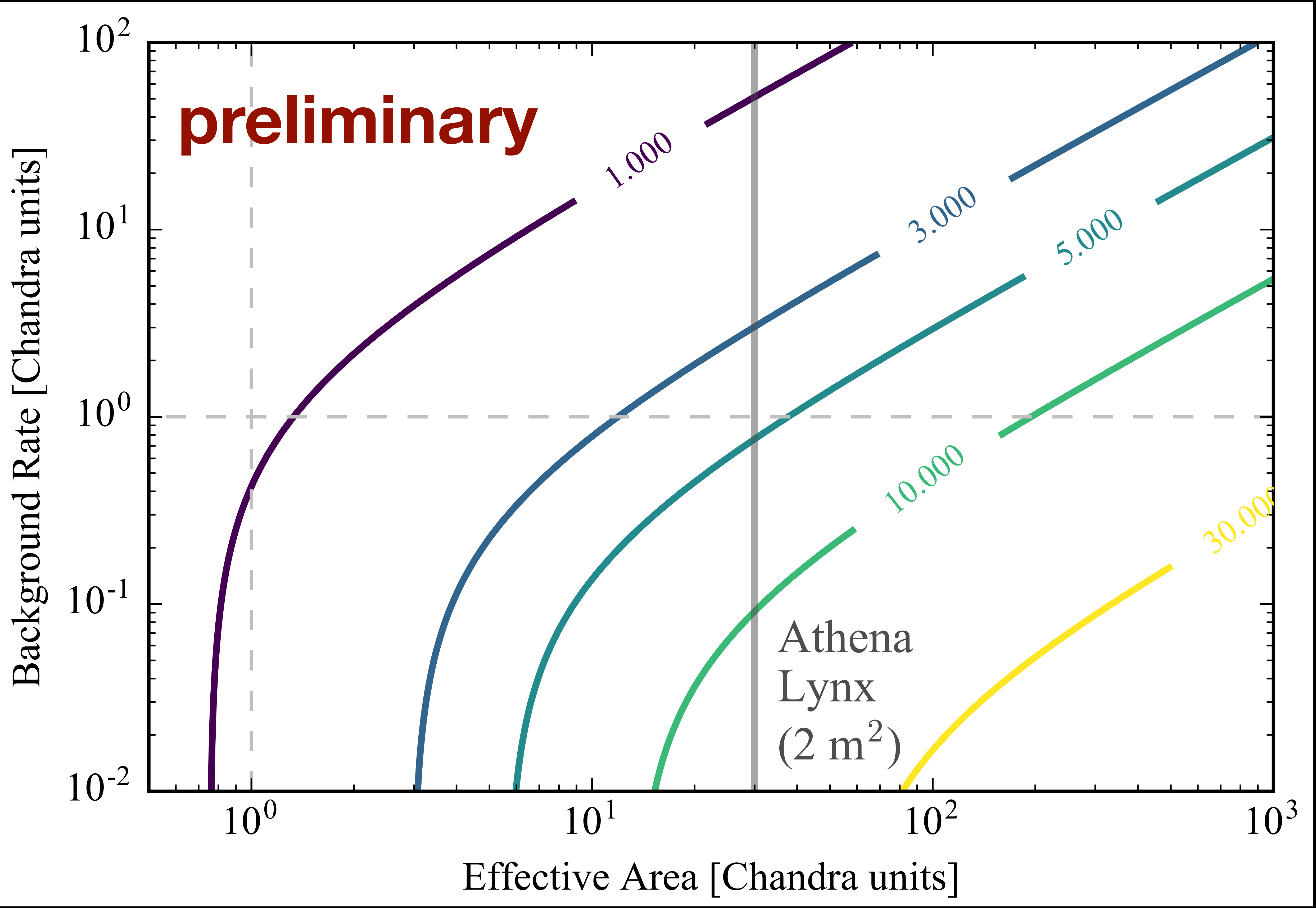
Dust echo brightness is directly proportional to **fluence** (time integrated flux)

Distribution of X-ray flares from all MAXI light curves



Brianna Mills (REU student), Heinz, & Corrales (in prep)

Echo discovery space compared to *Chandra*



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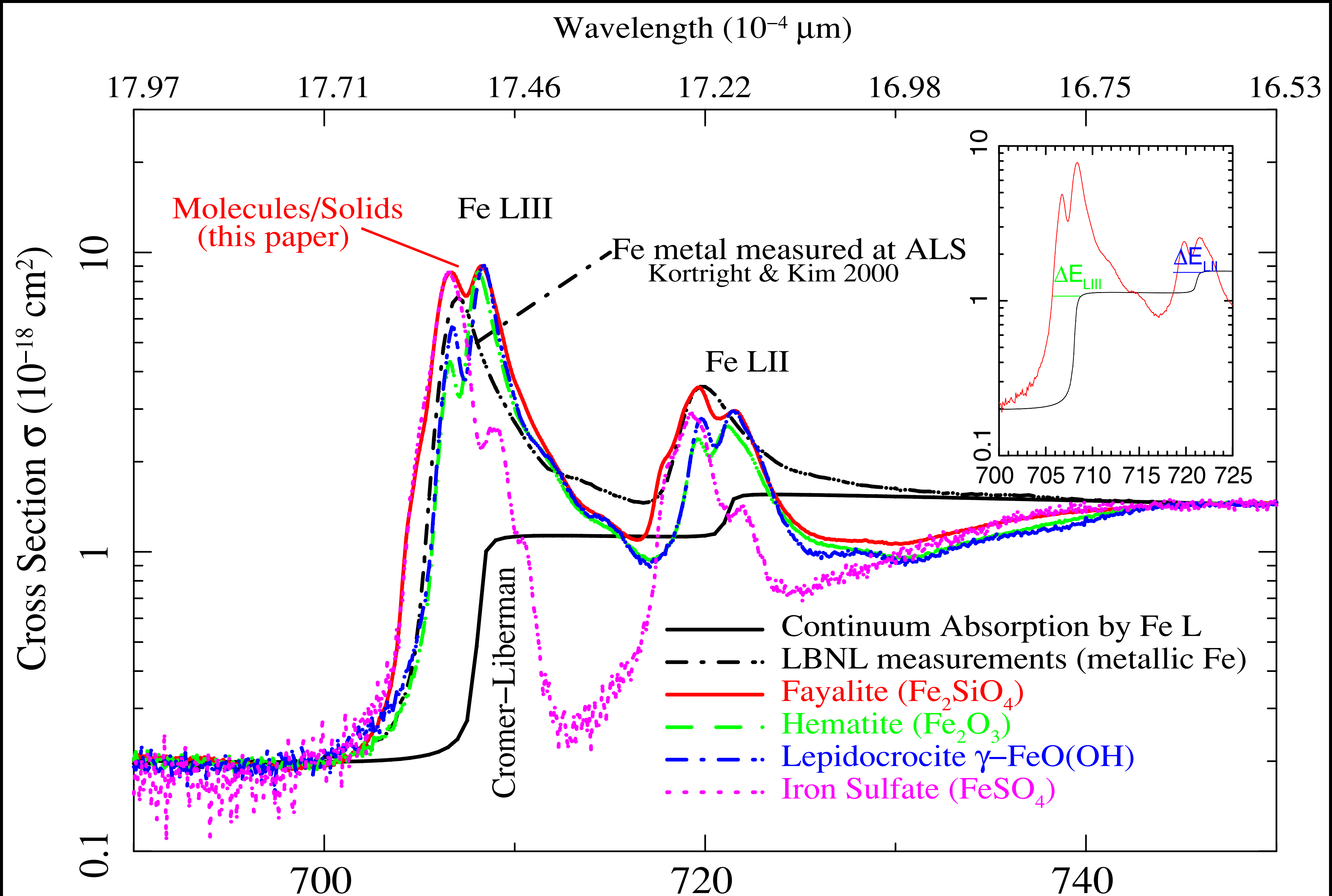
3. Soft X-ray Sensitivity

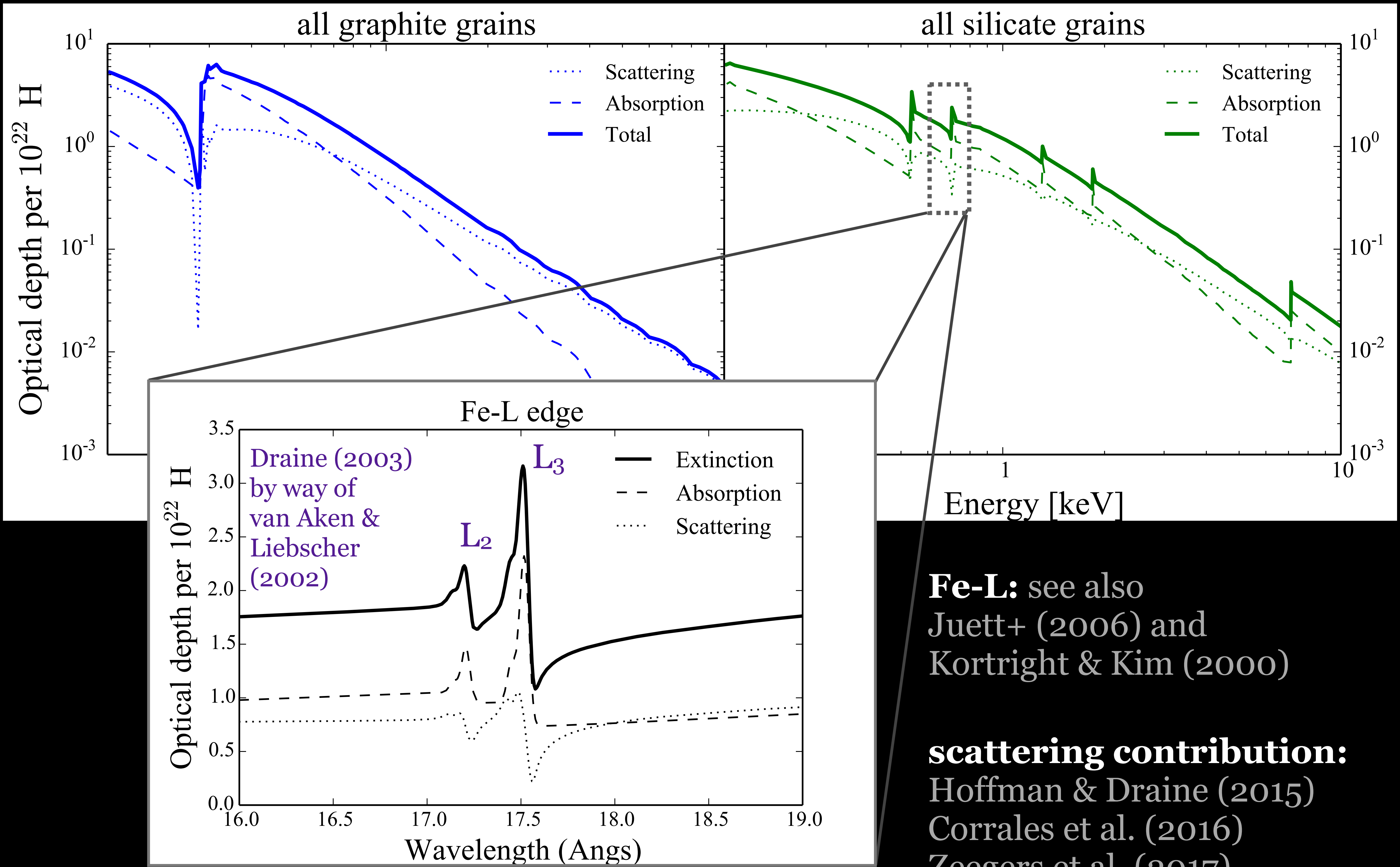
A lot of **dust science** can be done **without** an X-IFU



Lee et al (2009)

3. Soft X-ray Sensitivity

ISM extinction: **High resolution imaging and gratings in concert**



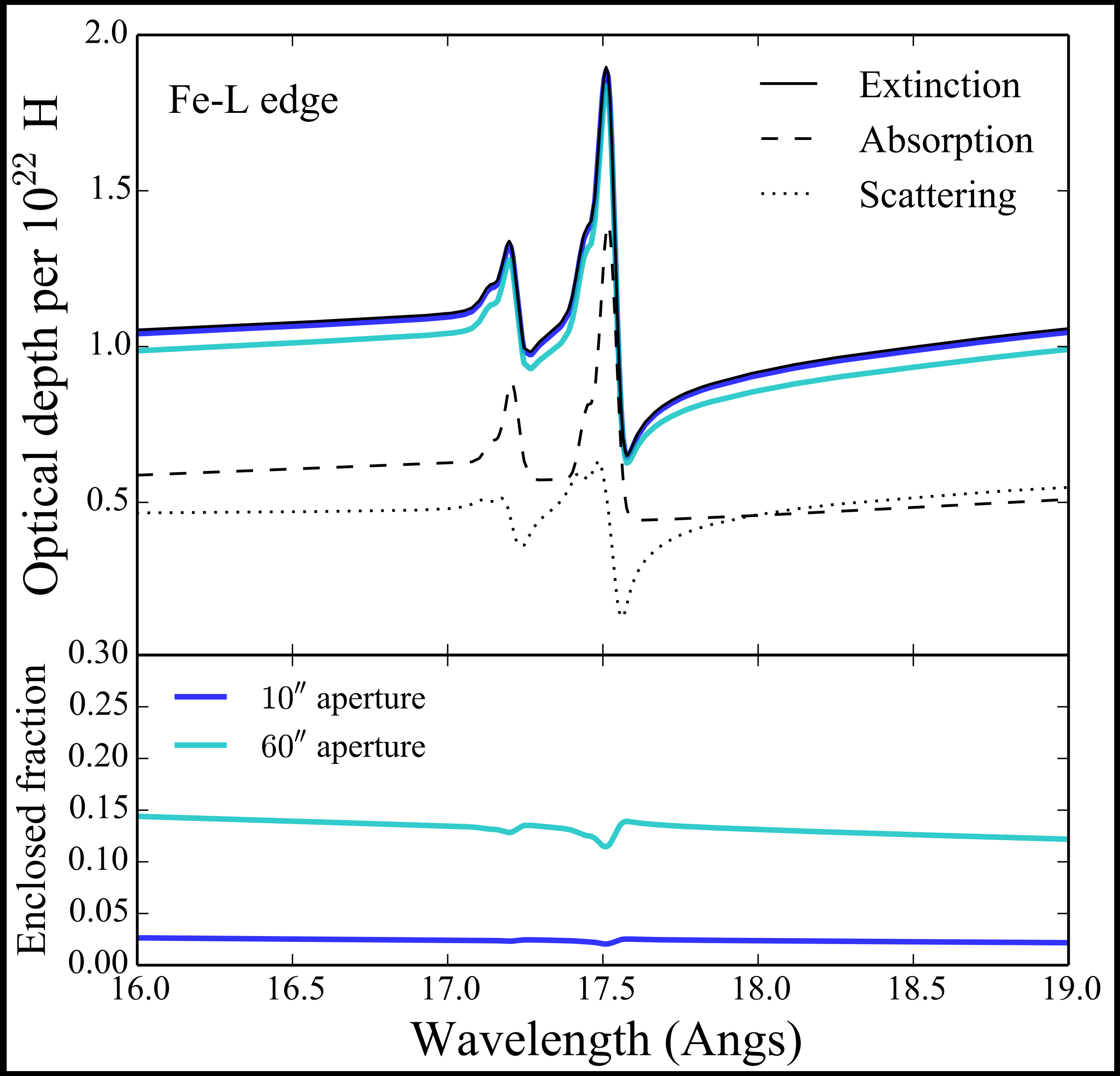
Fe-L: see also
Juett+ (2006) and
Kortright & Kim (2000)

scattering contribution:
Hoffman & Draine (2015)
Corrales et al. (2016)
Zeegers et al. (2017)

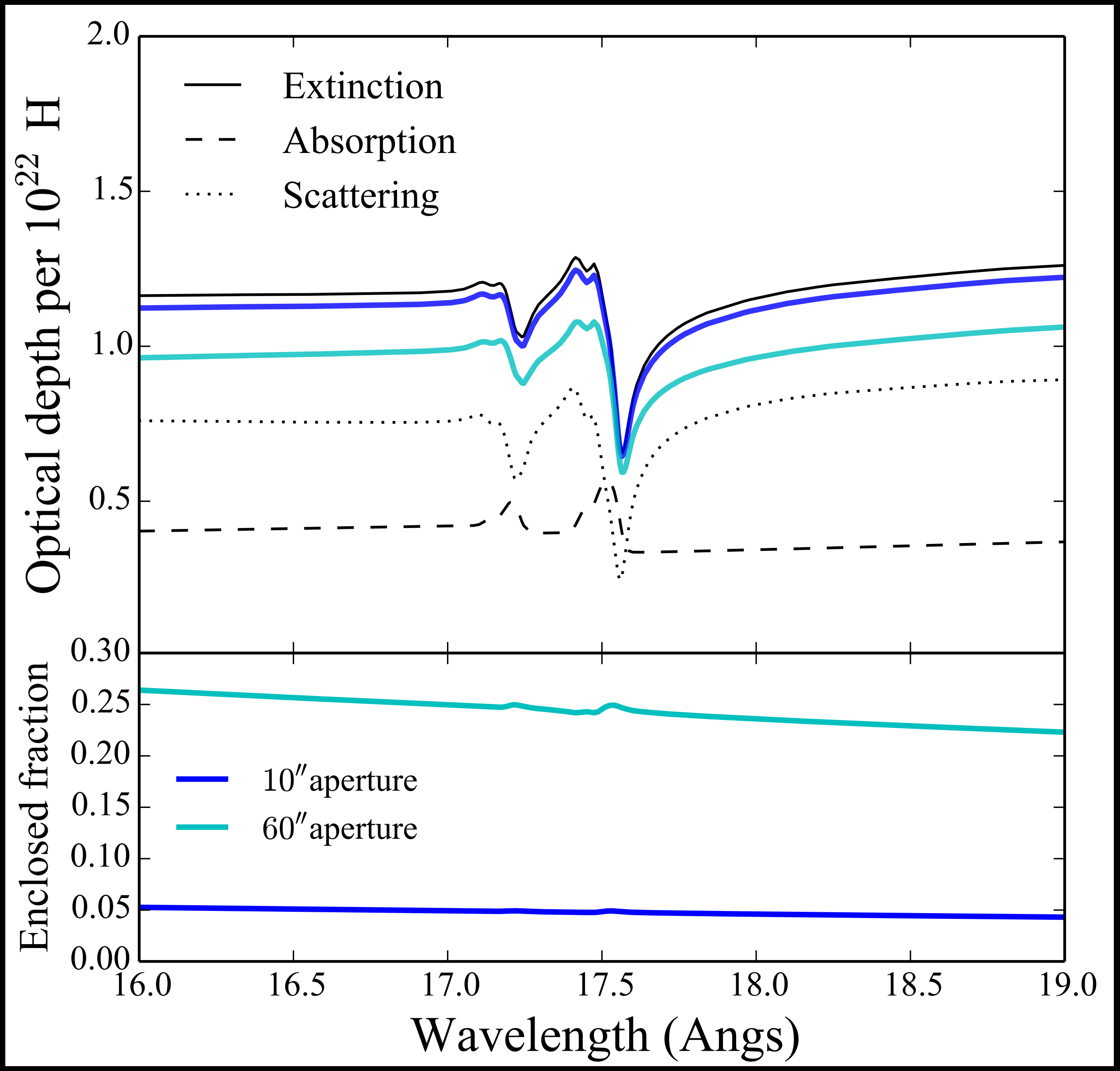
3. Soft X-ray Sensitivity

Absorption edge fine structure is dependent on **imaging resolution**, **grain size**, & **dust location**

MRN dust



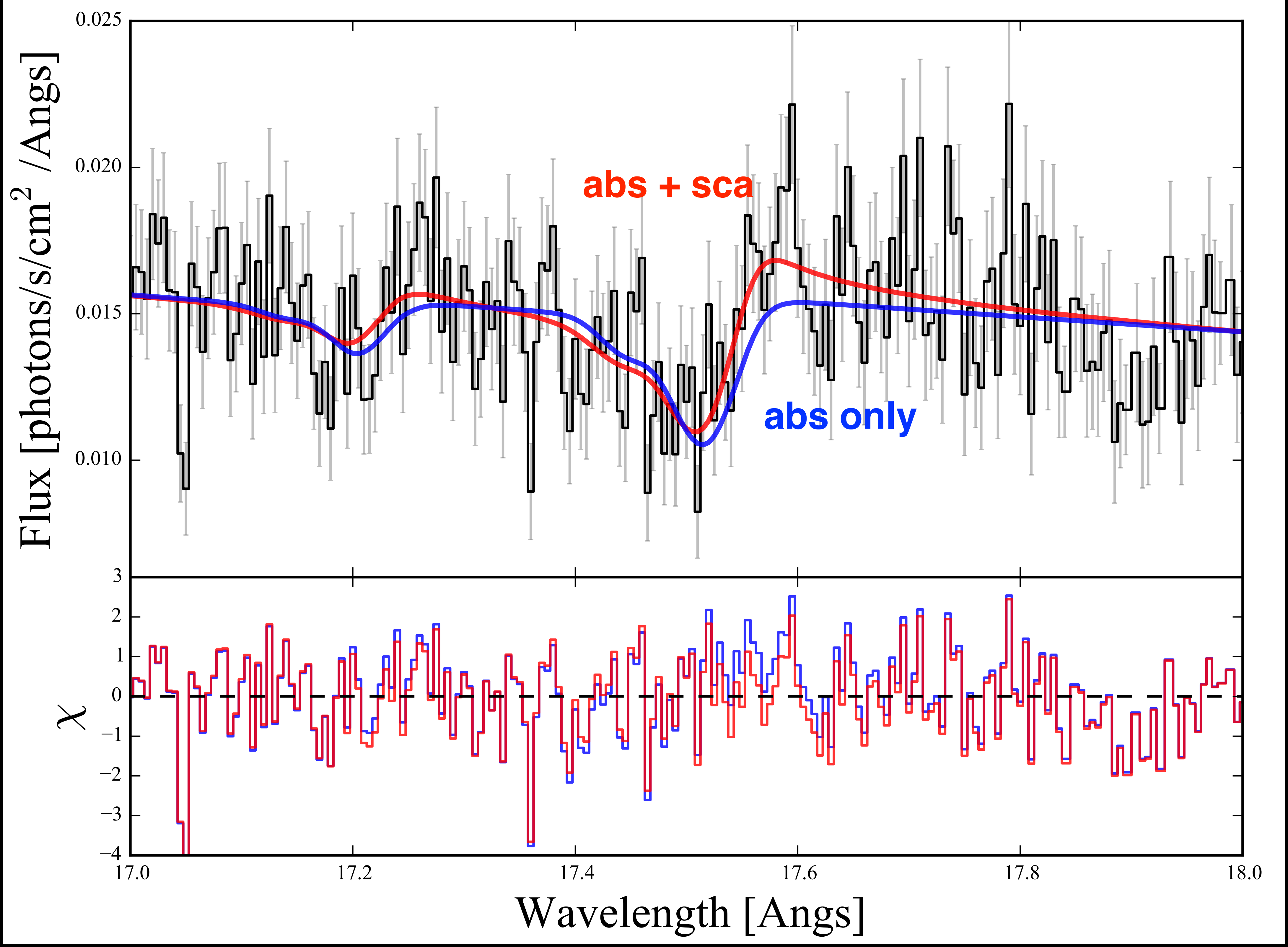
0.3 micron grains



Corrales et al. (2016)

3. Soft X-ray Sensitivity

LMXB GX 9+9 (96 ks)



Corrales et al. (2016)

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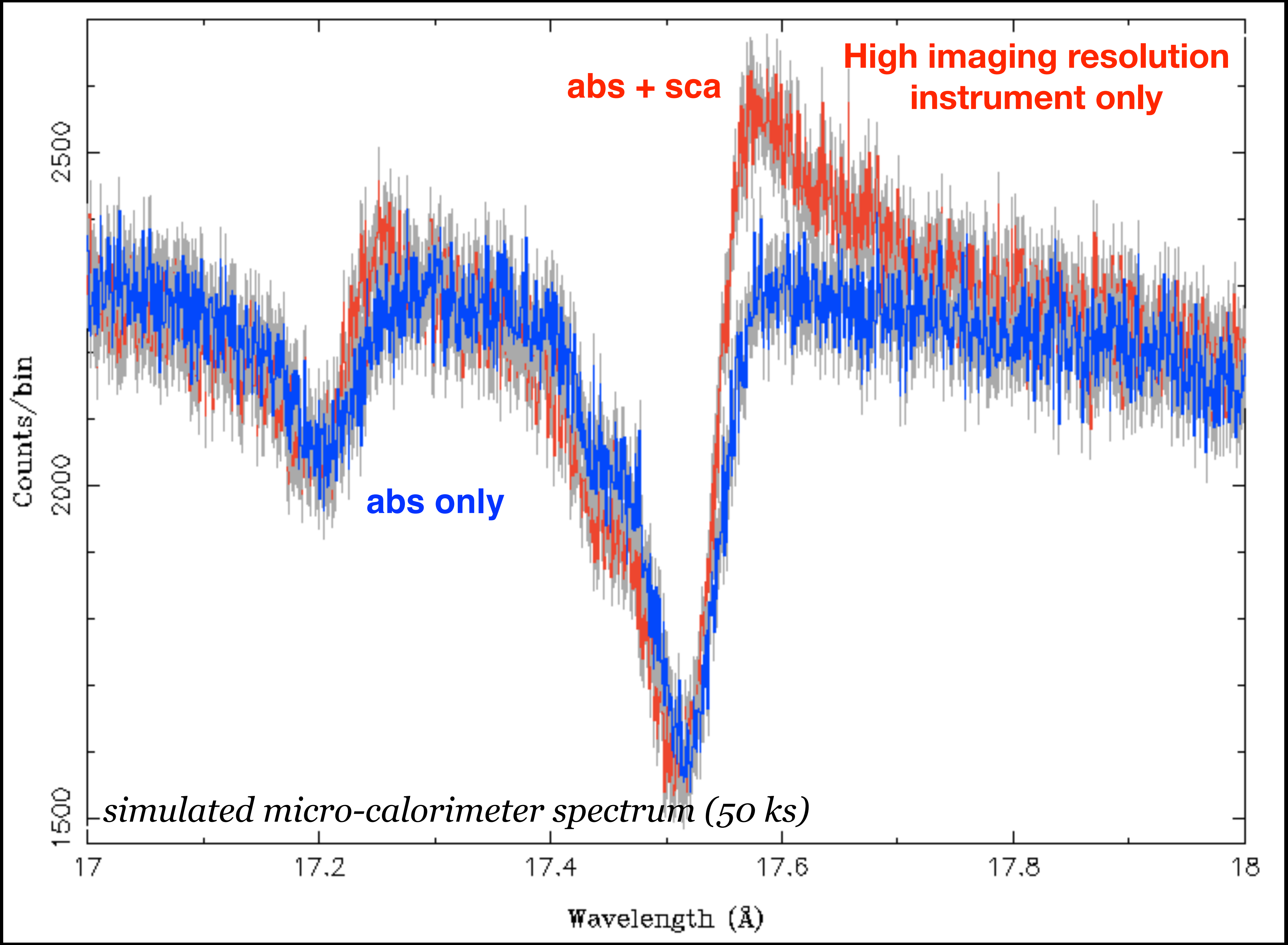

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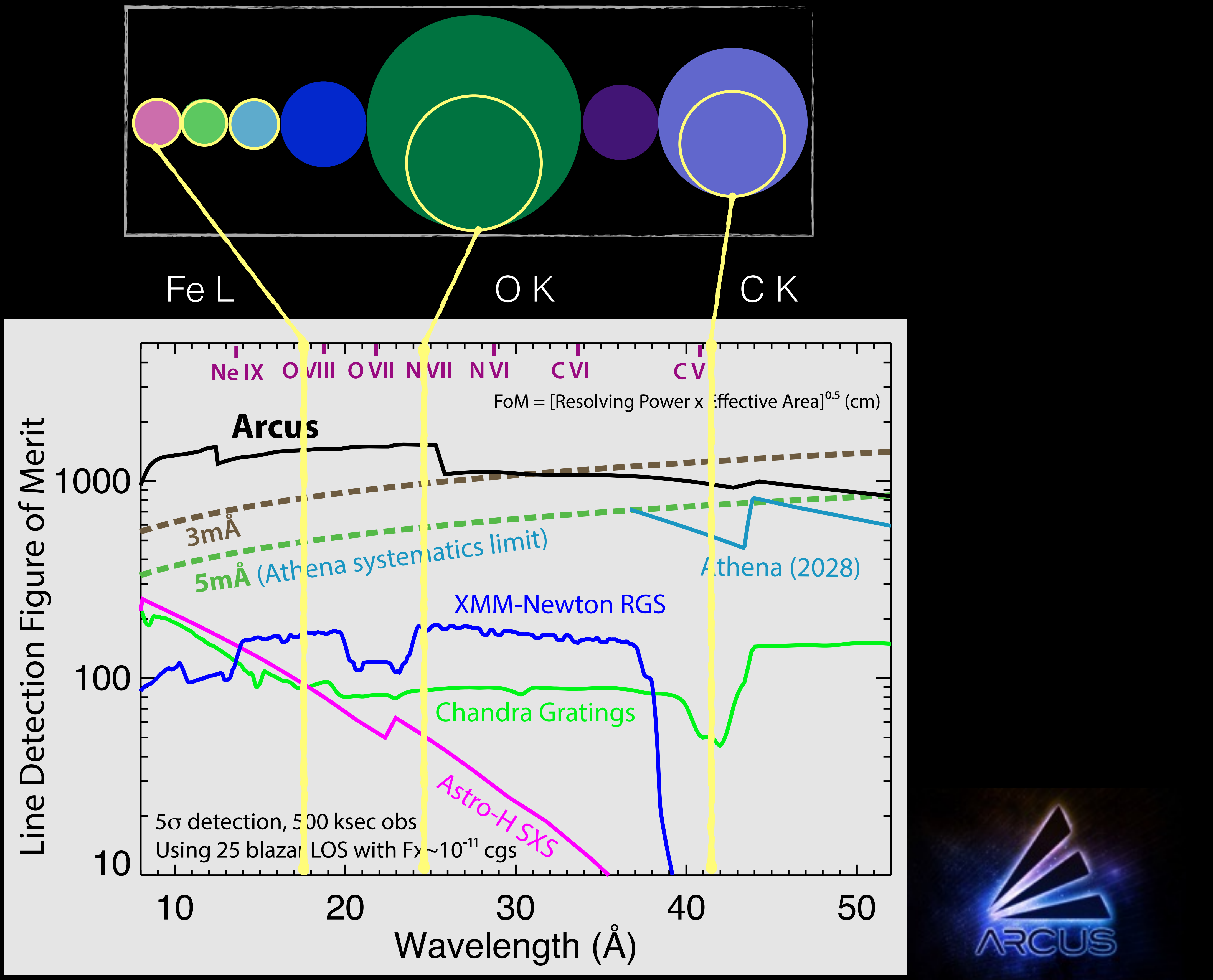
1. Limits on observing bright sources
2. Limits from background
3. Soft X-ray Sensitivity

Gratings are more ideal for soft X-ray spectroscopy

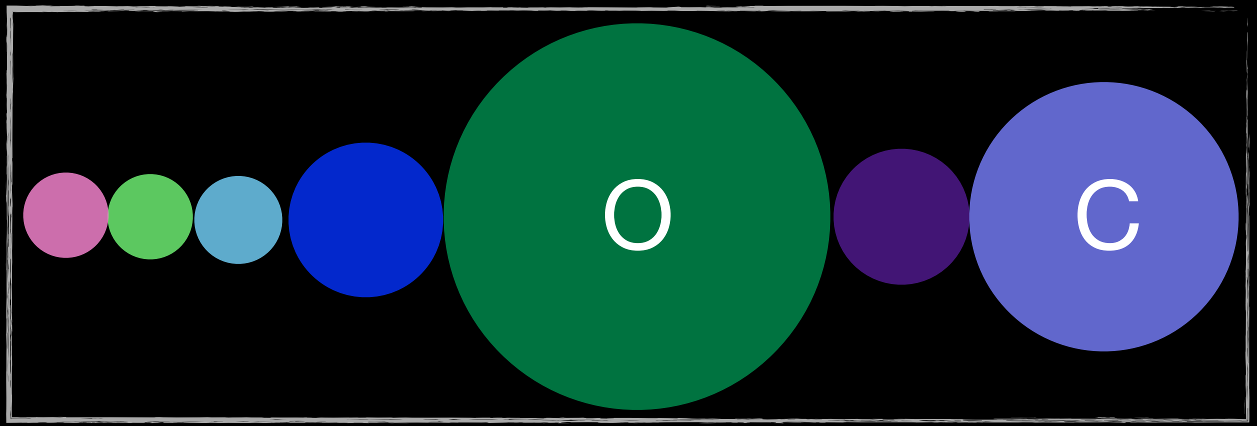
Gratings are more ideal for spectroscopy of neutral metals



$10 - 50$ Å

$R \equiv (\lambda/\Delta\lambda) \sim 3000$

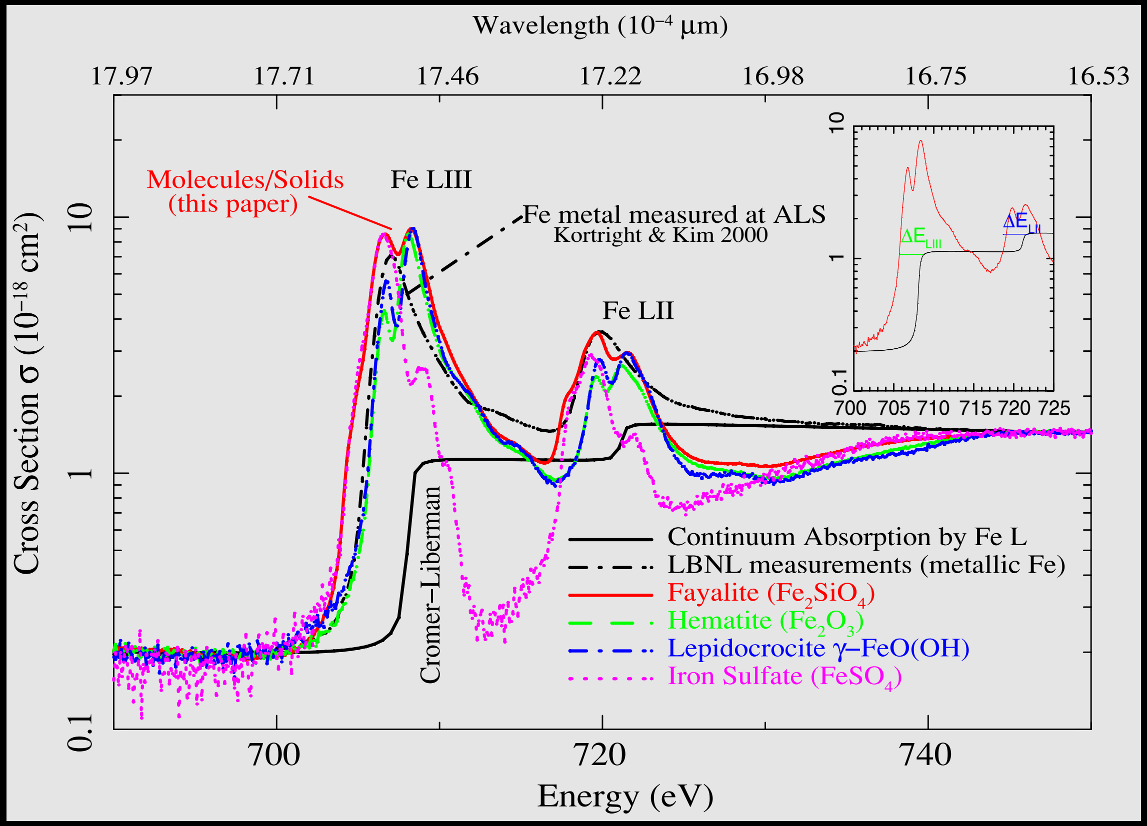
ISM science from soft X-ray spectroscopy

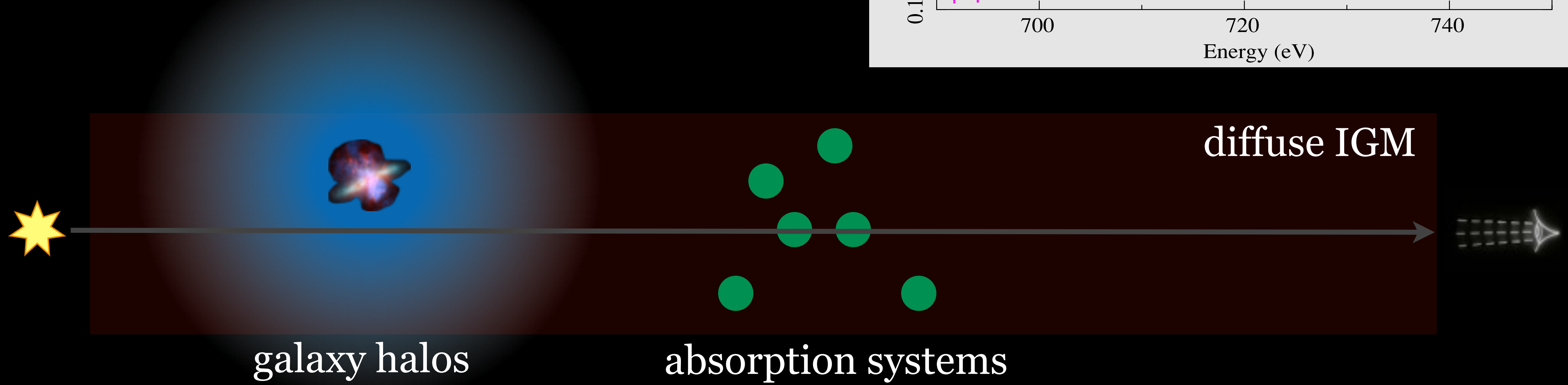


Neutral and near-neutral phases of the two **most abundant** metals

Astromineralogy, study **PAHs**

Study **absorption line systems** at moderate redshift





High resolution imaging:
Crowded star fields
Galactic Center science
Dust scattering edge structure

Reducing background:
Deeper surveys (point sources and diffuse)
Dust scattering echoes
Increasing spectroscopic S/N

Ability to study bright sources:
Accretion disk and stellar physics from bright X-ray binaries
Study multi-phase ISM in extinction

Soft X-ray sensitivity:
Study the most abundant metals in the Universe
Astromineralogy and multi-phase ISM
Access to higher redshift Universe

High resolution imaging:

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