HIGH ENERGY STUDIES OF INTERSTELLAR DUST GRAINS

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NASA Earth and Space Science Fellow

with Frits Paerels
Columbia University

X-ray scattering as a diagnostic tool

Introduction to Cyg X-3

Interesting data products

Dust-to-gas mass ratio

Elemental constituents of dust

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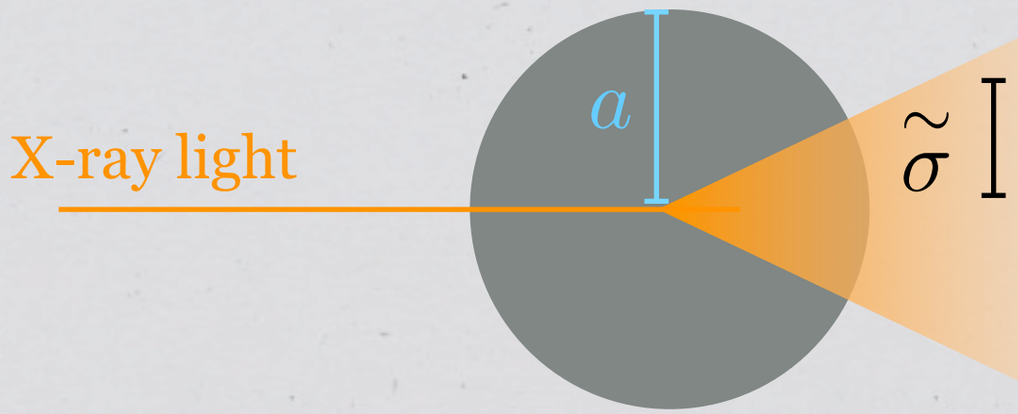

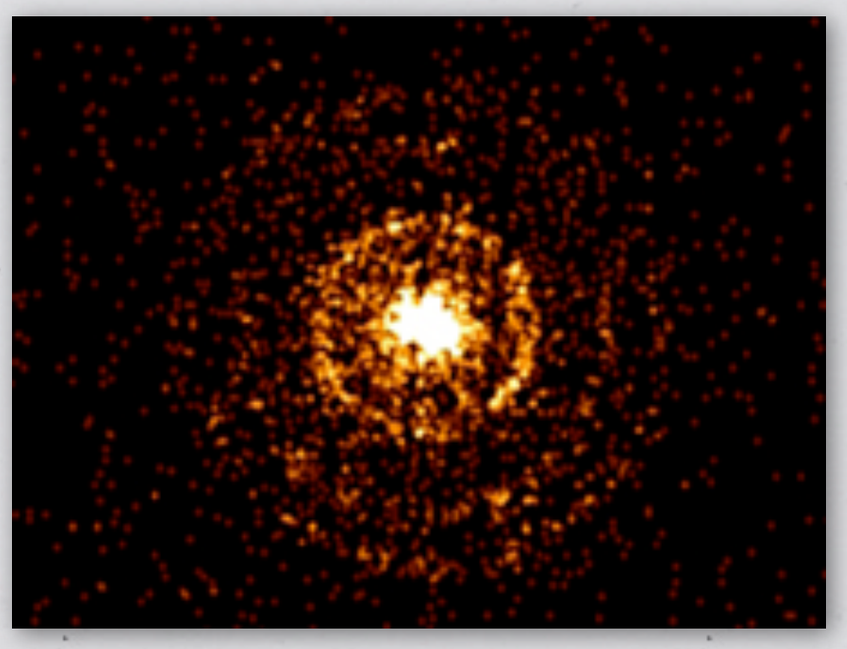

SGR J1550-5418
(NASA/Swift/Halpern)

1. Strongly forward (small angle) scattering $\longrightarrow$ $\tilde{\sigma} \sim \dfrac{1'}{a(\mu\mathrm{m})E(\mathrm{keV})}$

2. Strongly sensitive to grain size $\longrightarrow$ $\sigma_{\mathrm{sca}} \propto a^4 E^{-2}$

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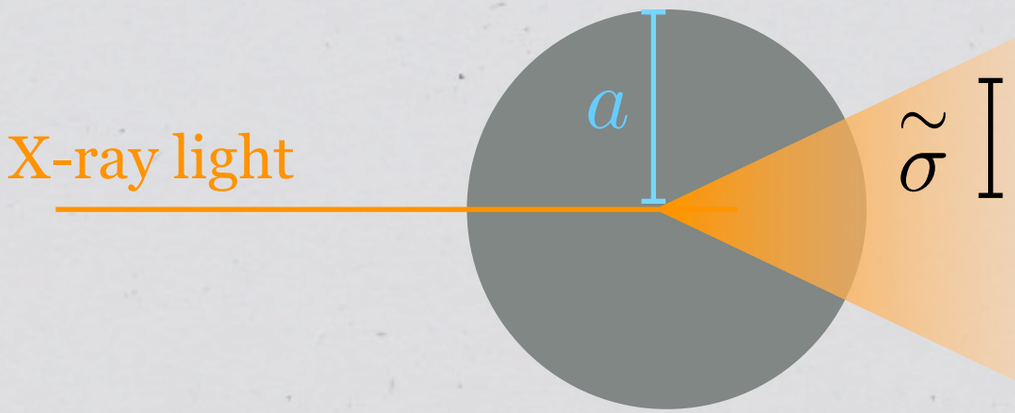

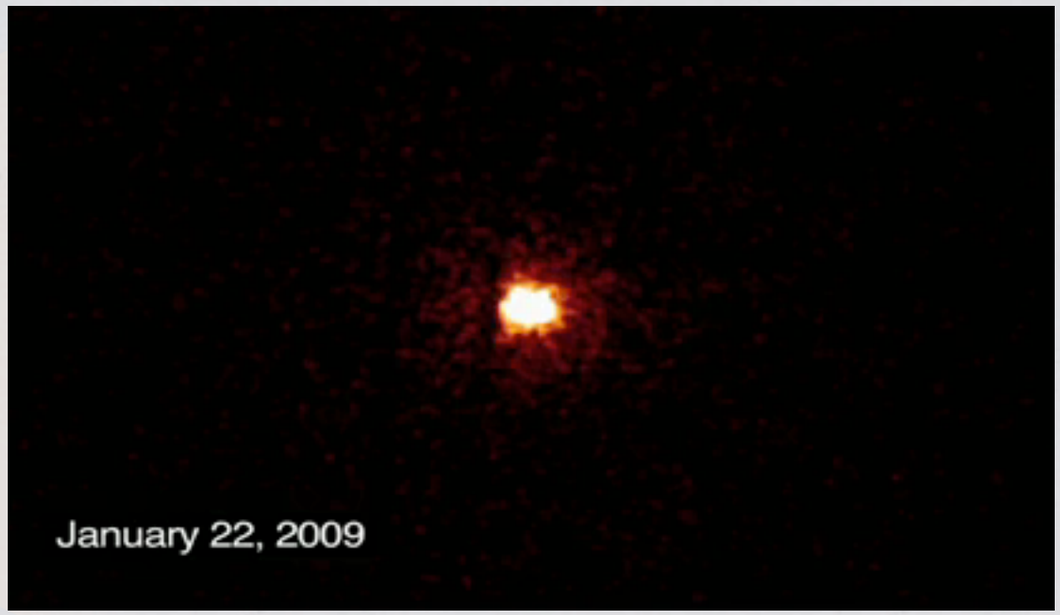

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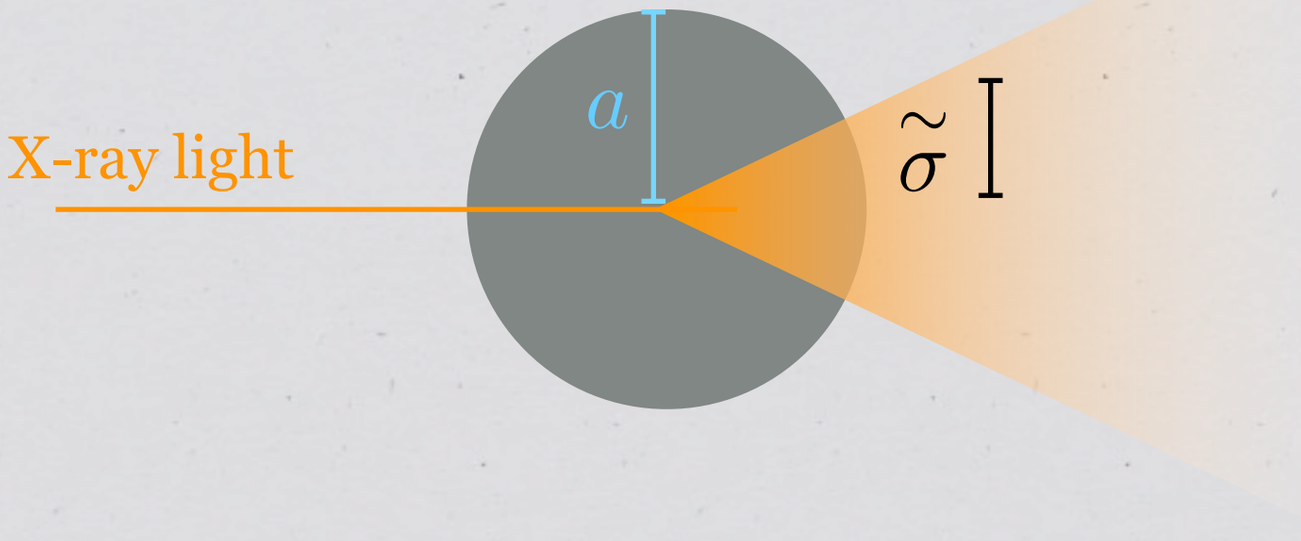

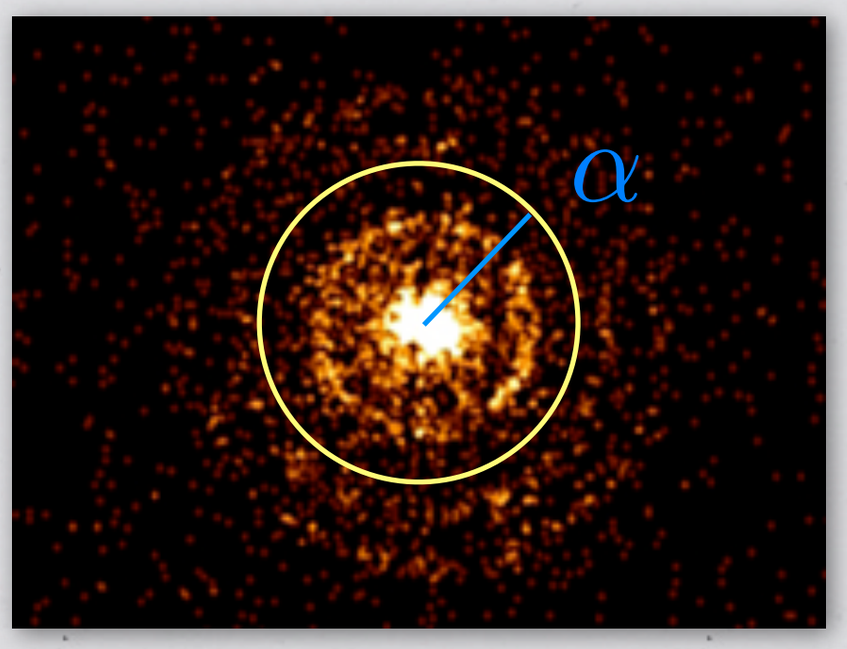

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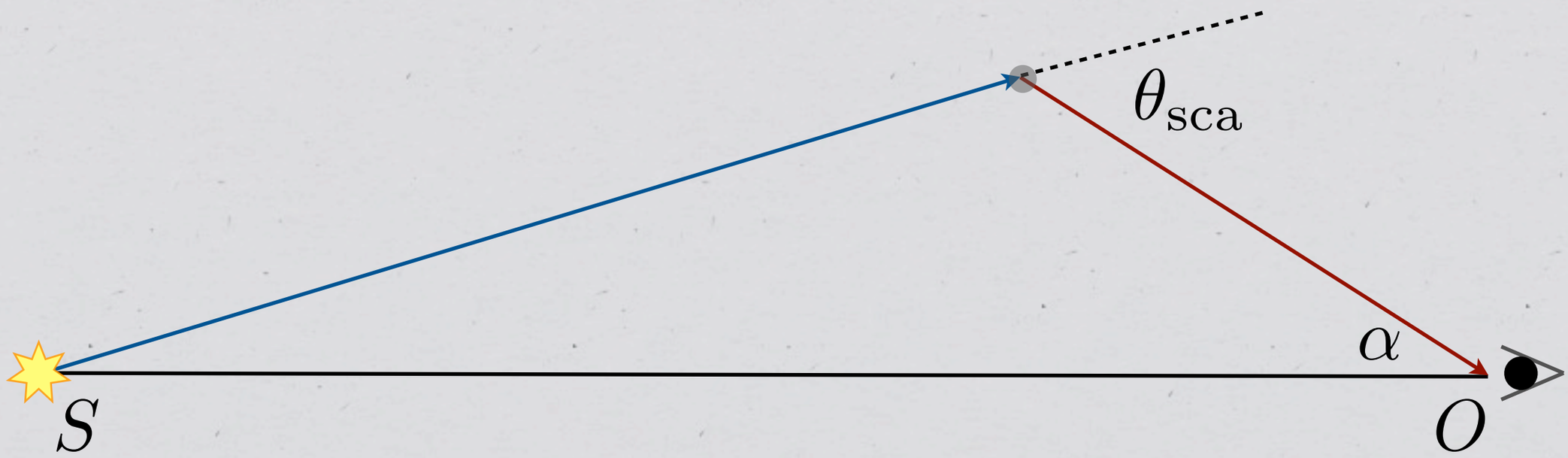

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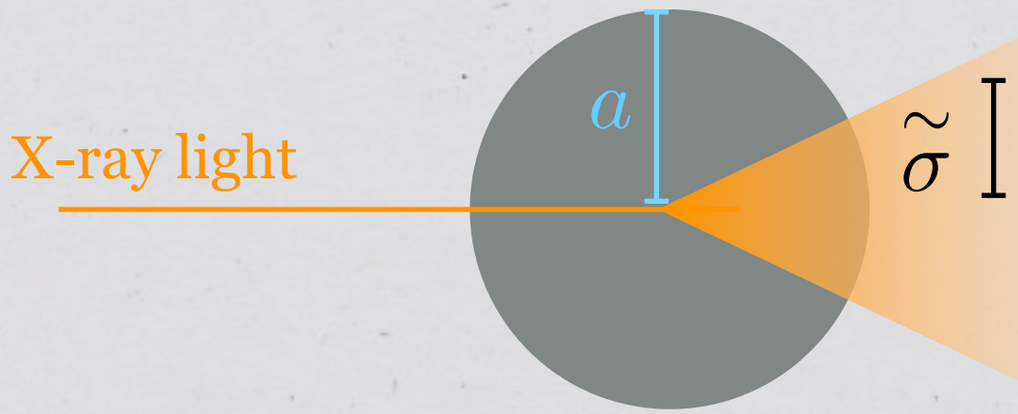

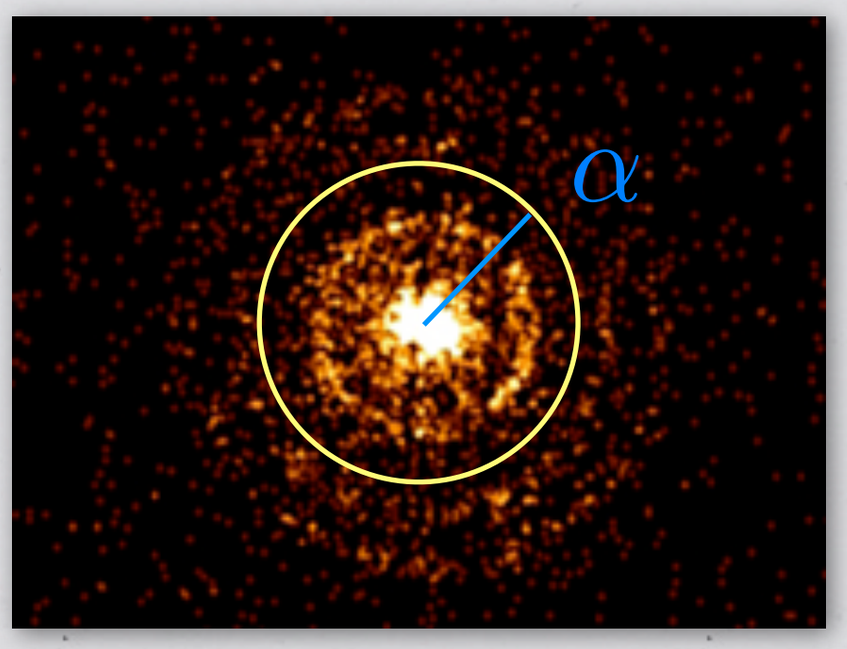

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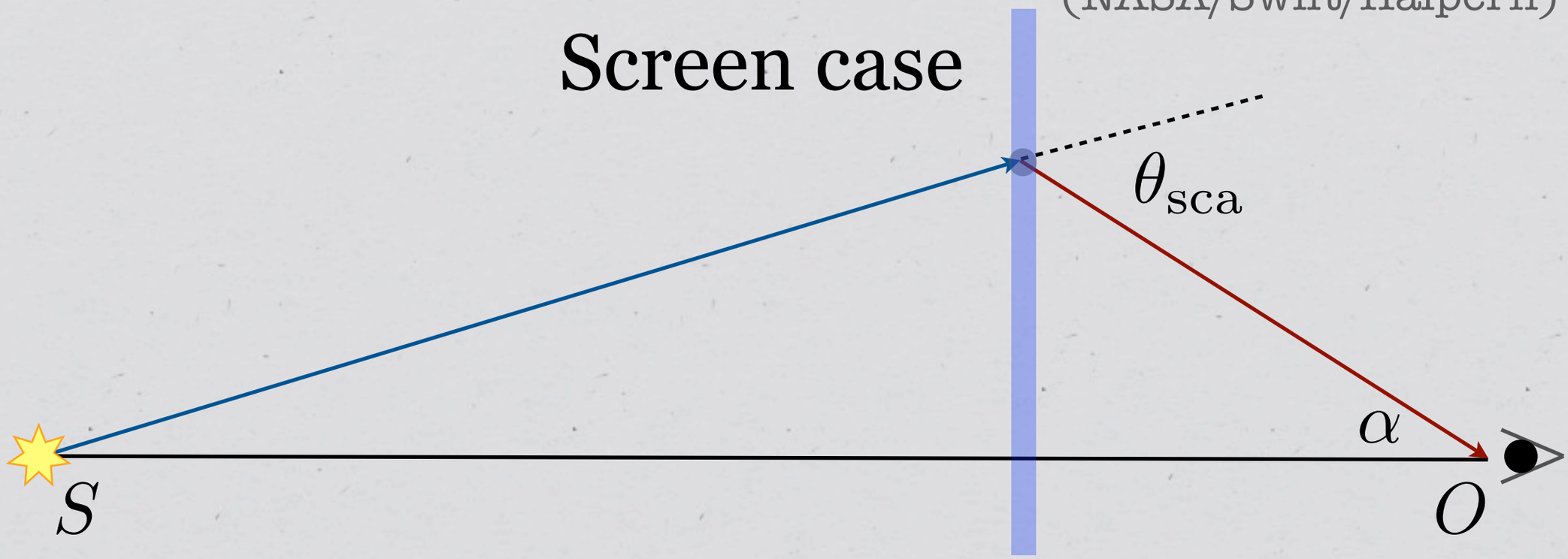

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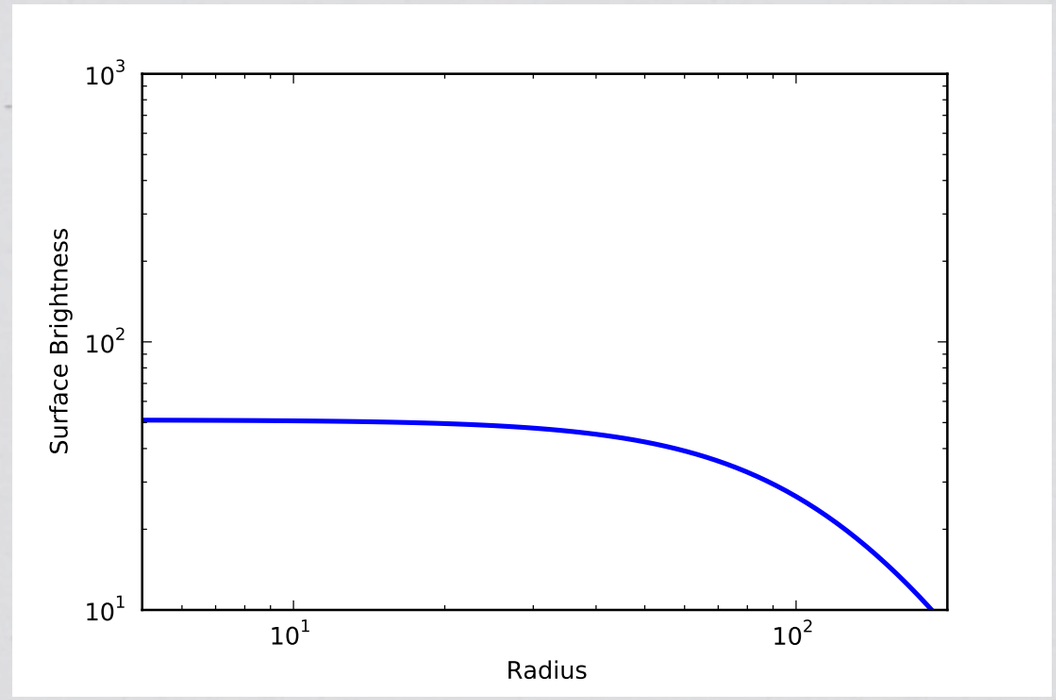

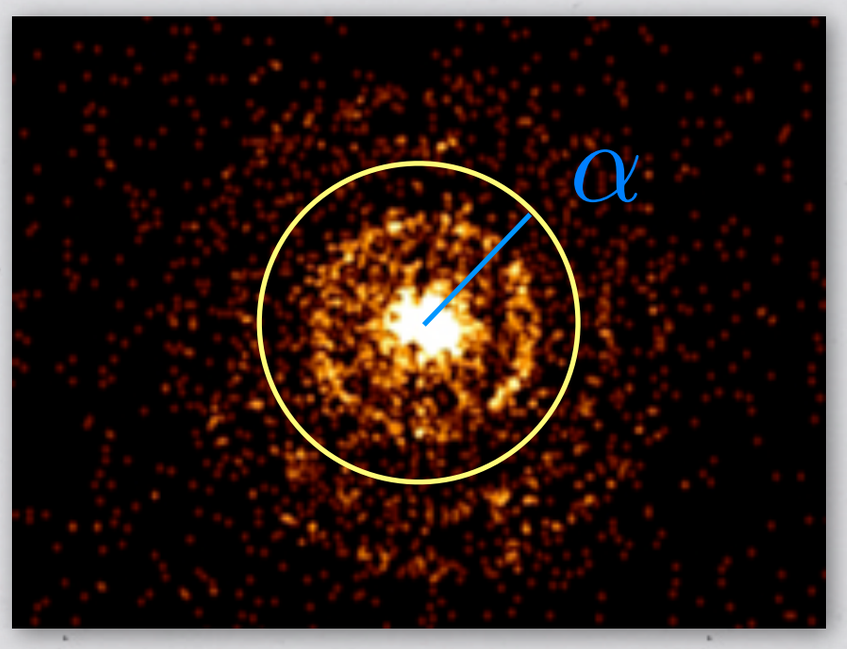

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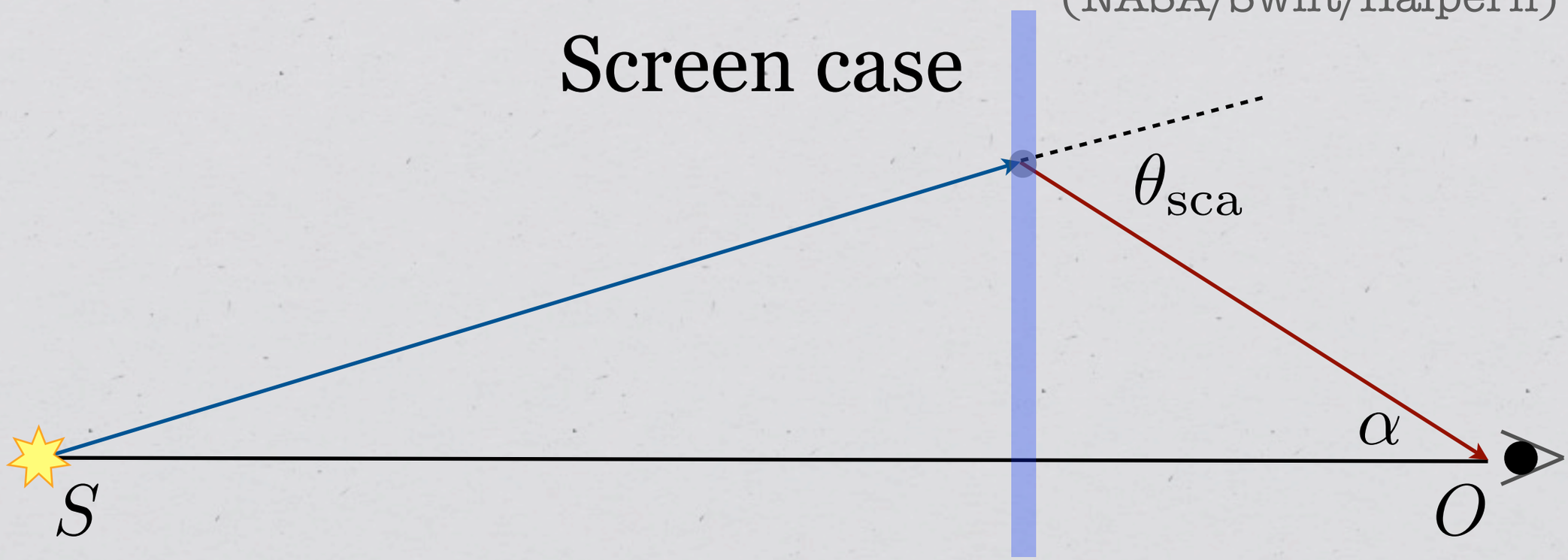

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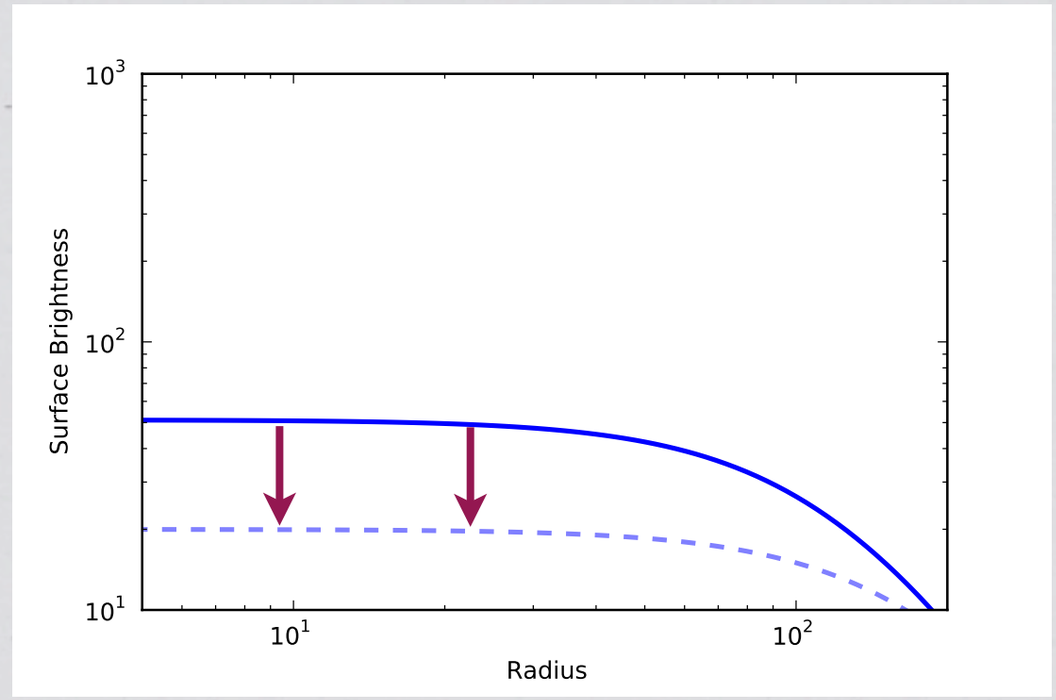

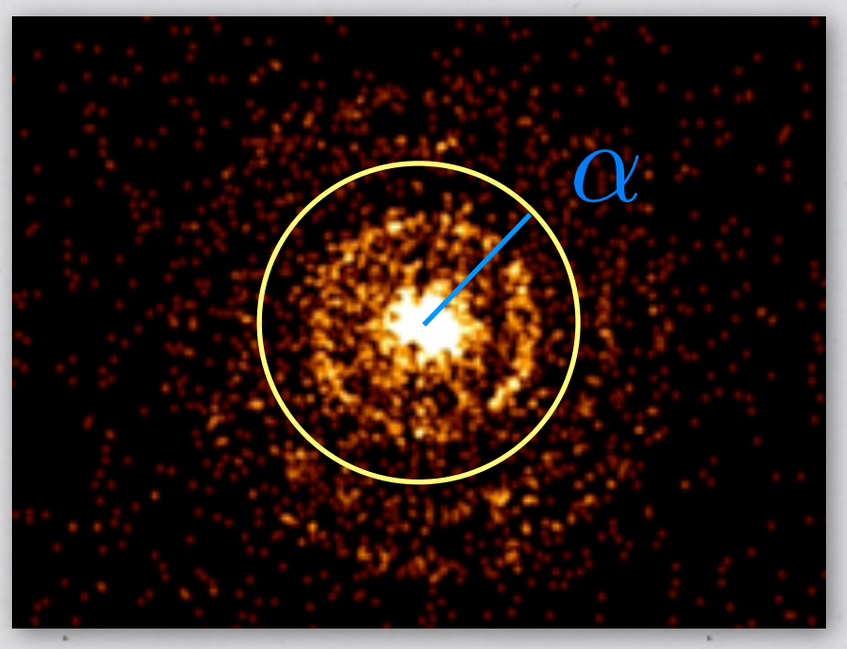

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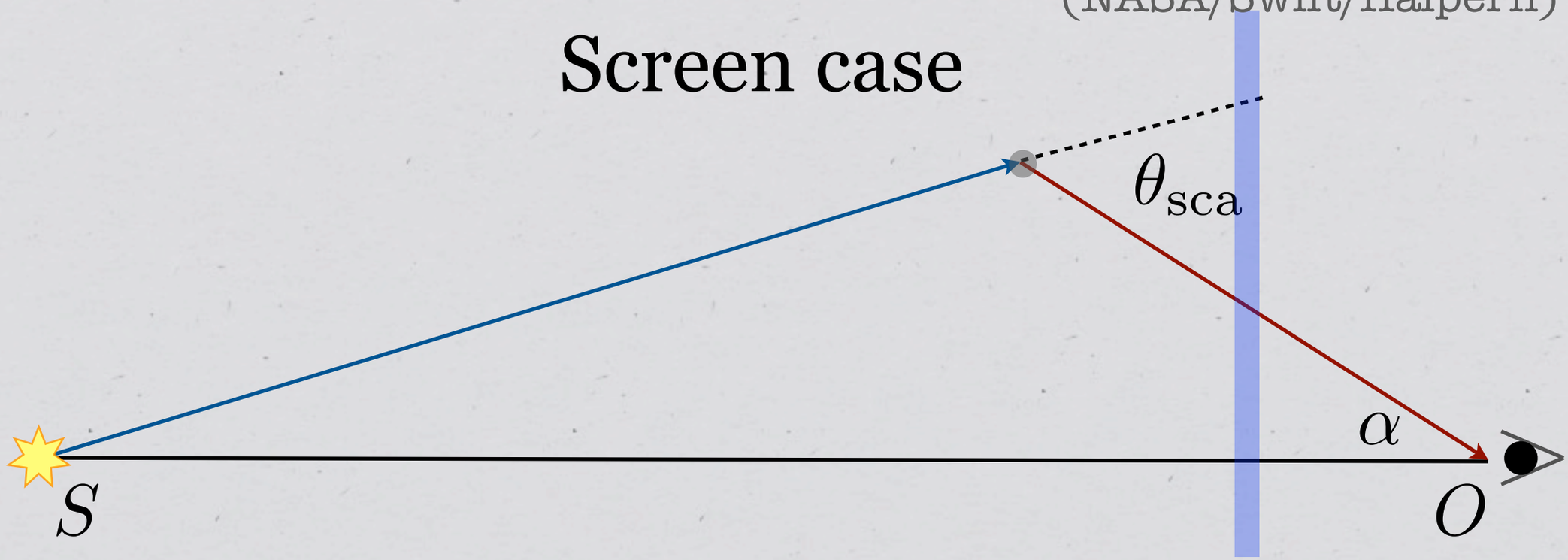

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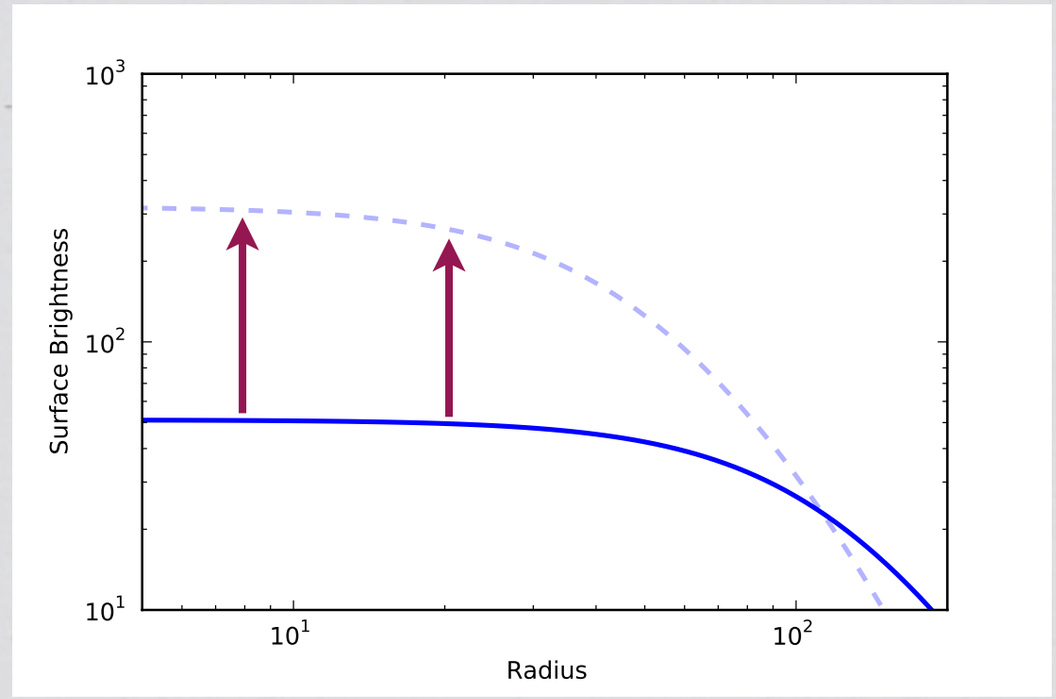

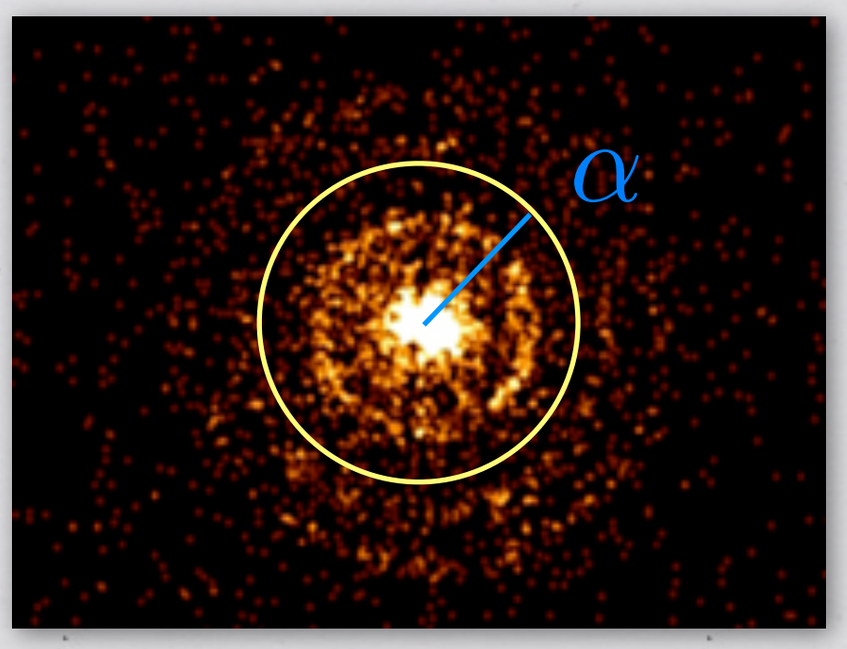

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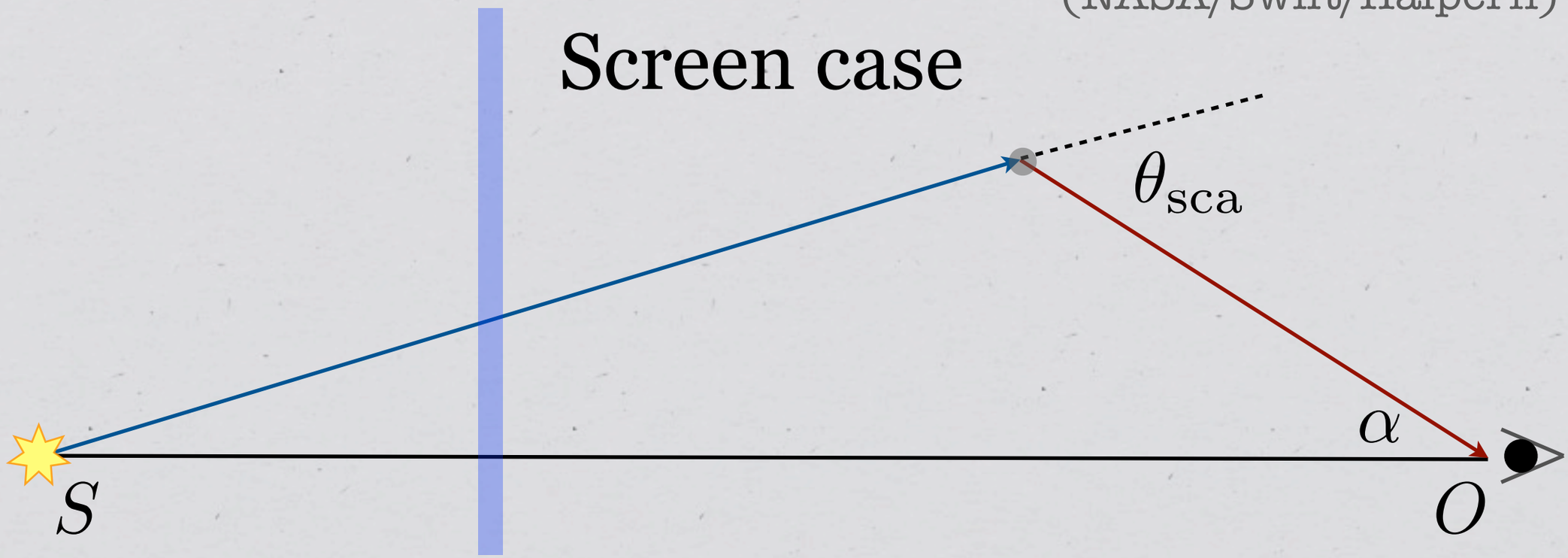

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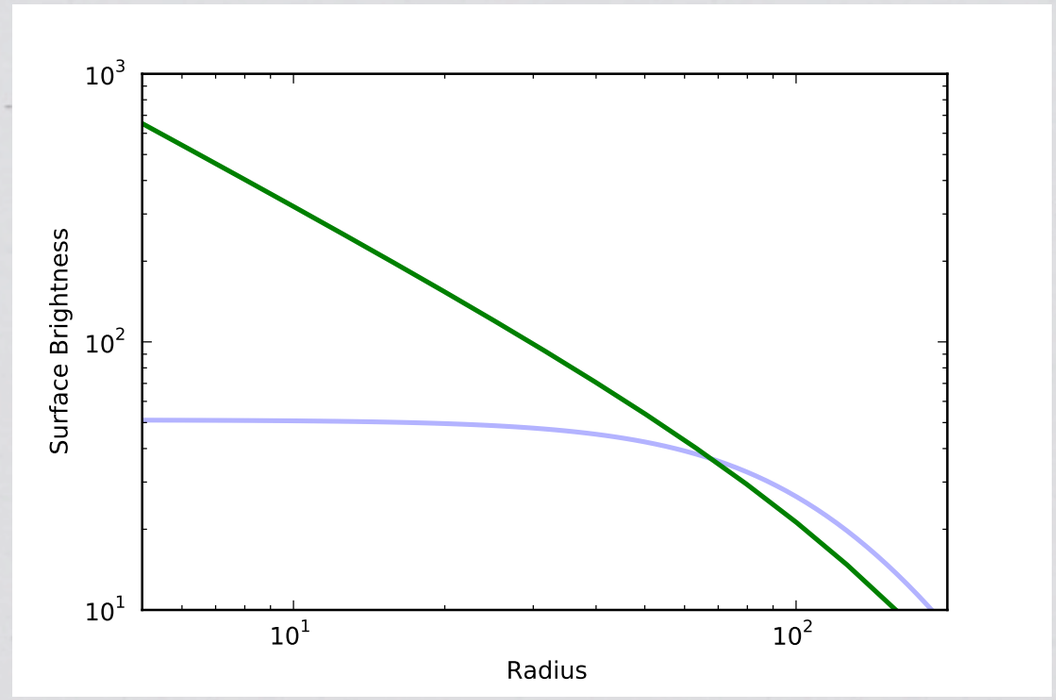

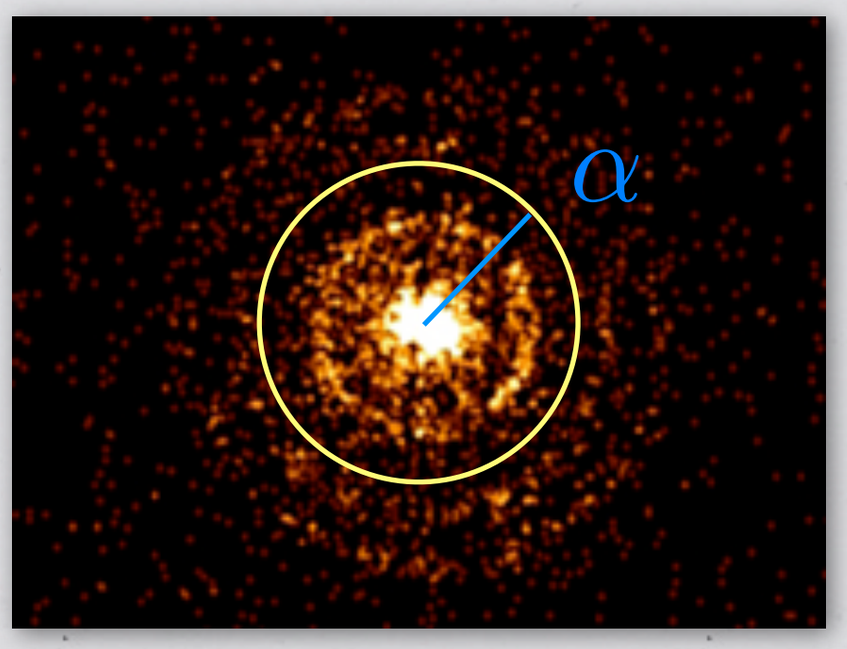

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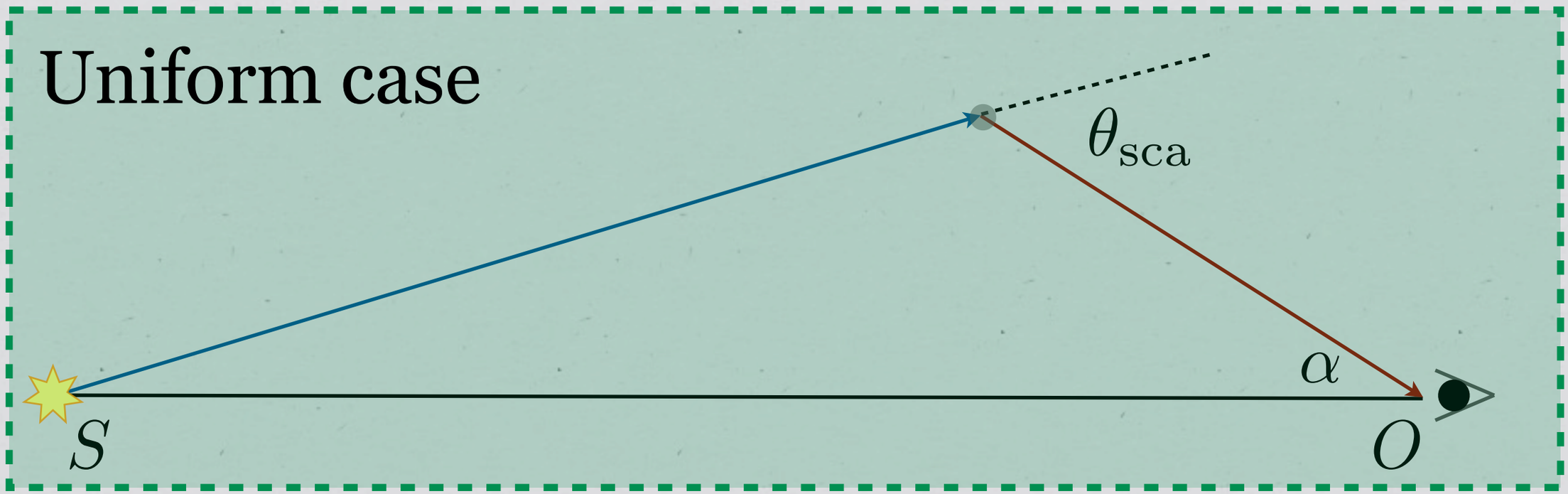

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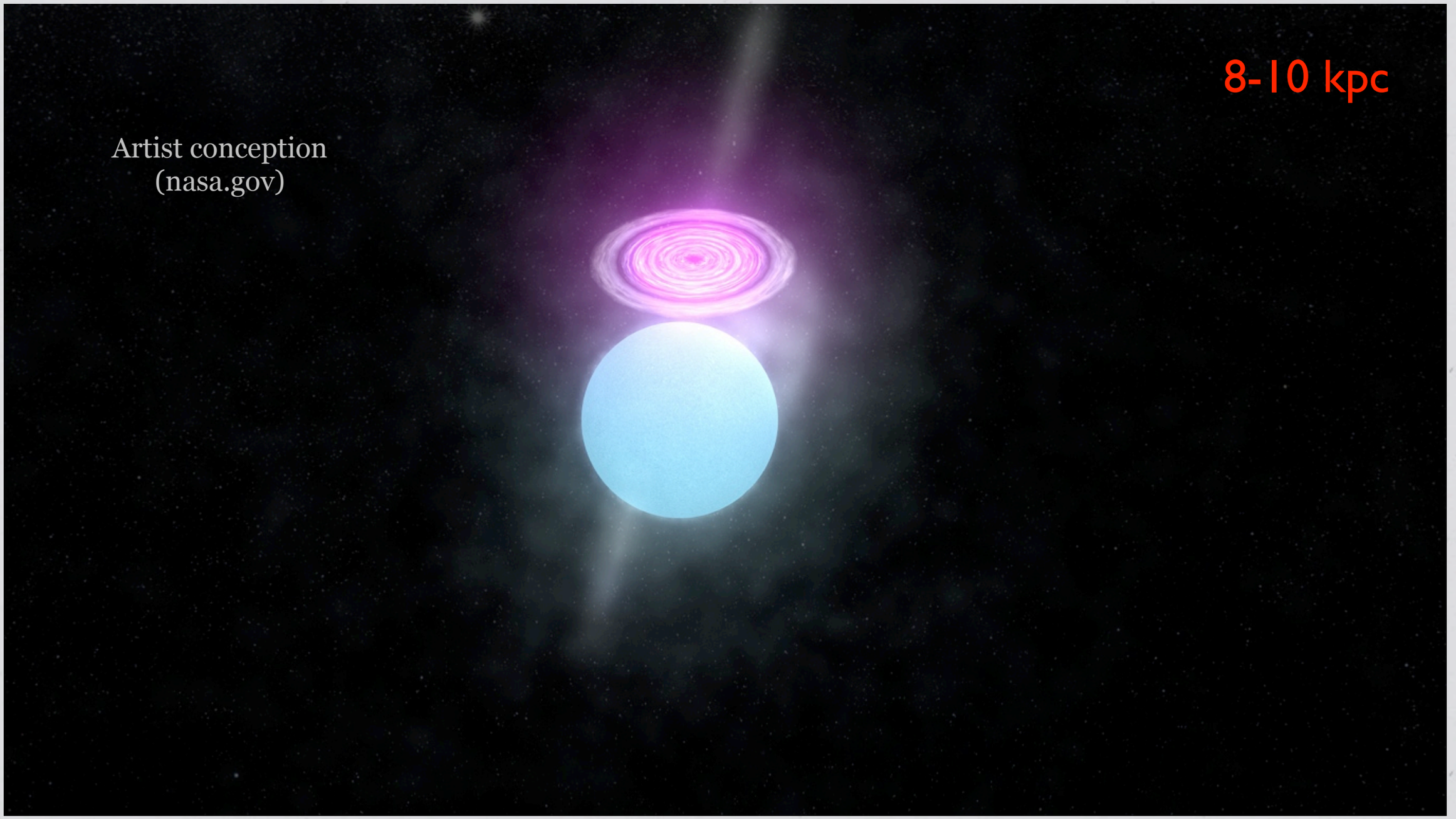
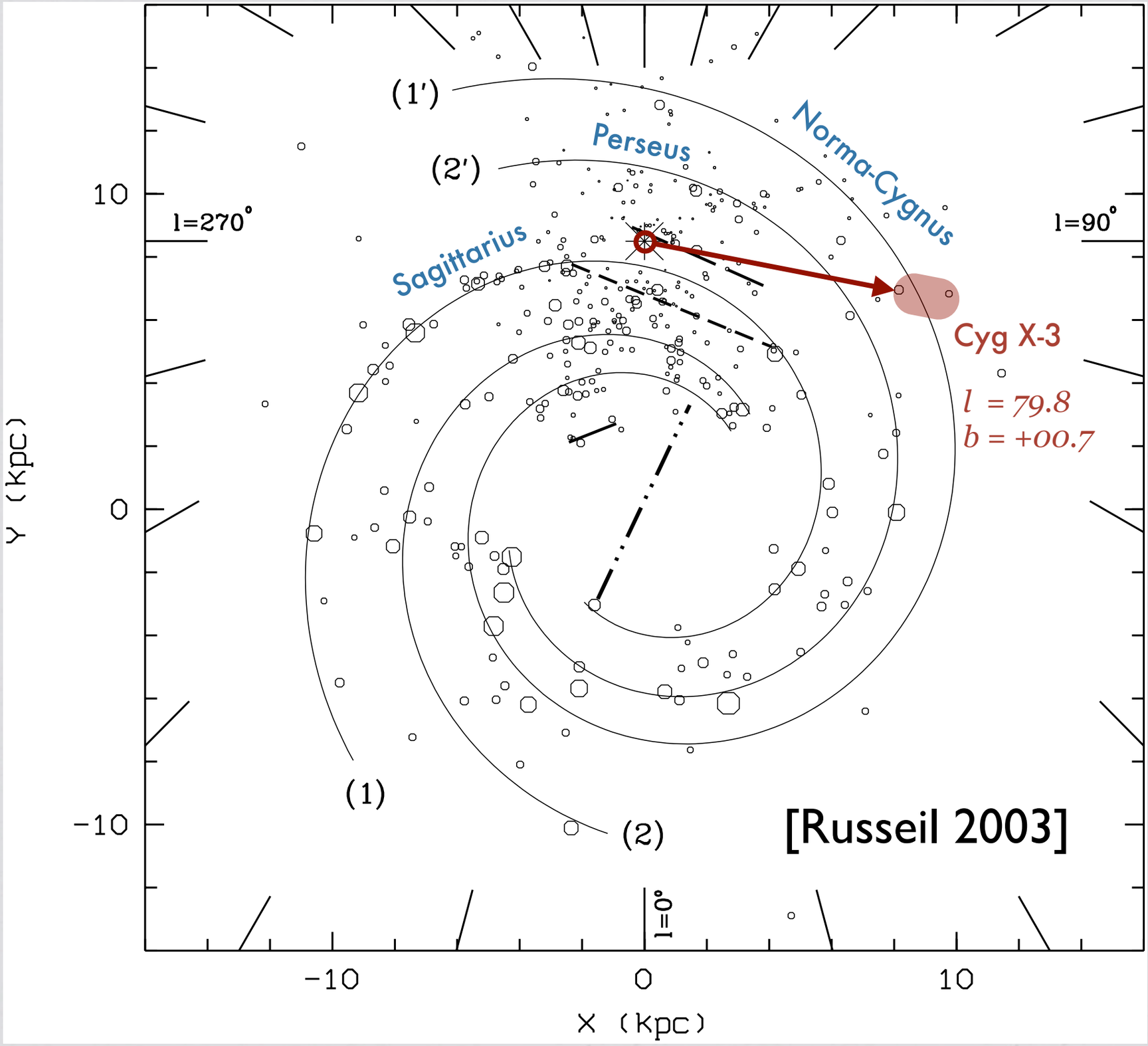
Elemental constituents of dust

Introduction to Cygnus X-3

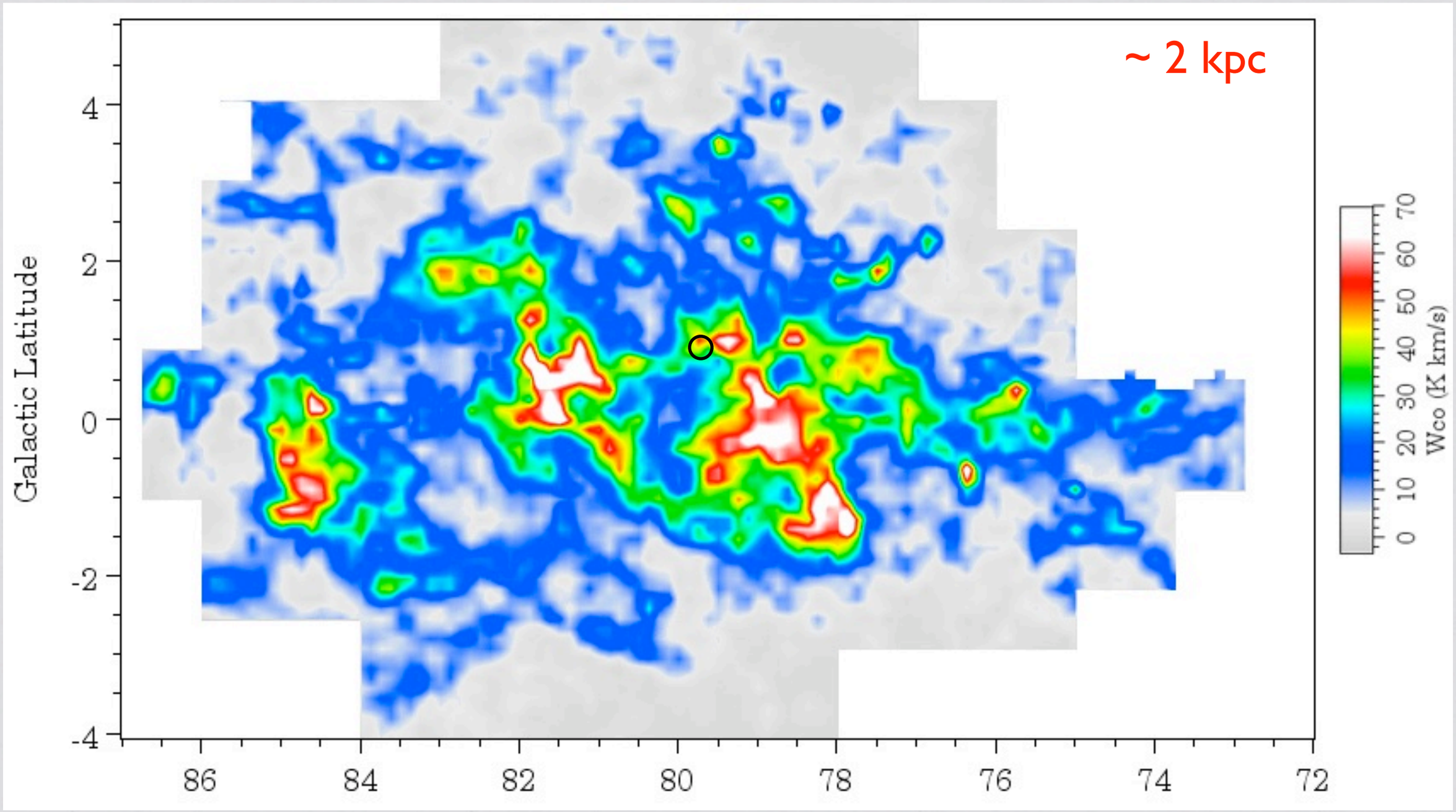
High Mass X-ray Binary with Wolf-Rayet star companion



Milky Way spiral structure as probed by star forming complexes

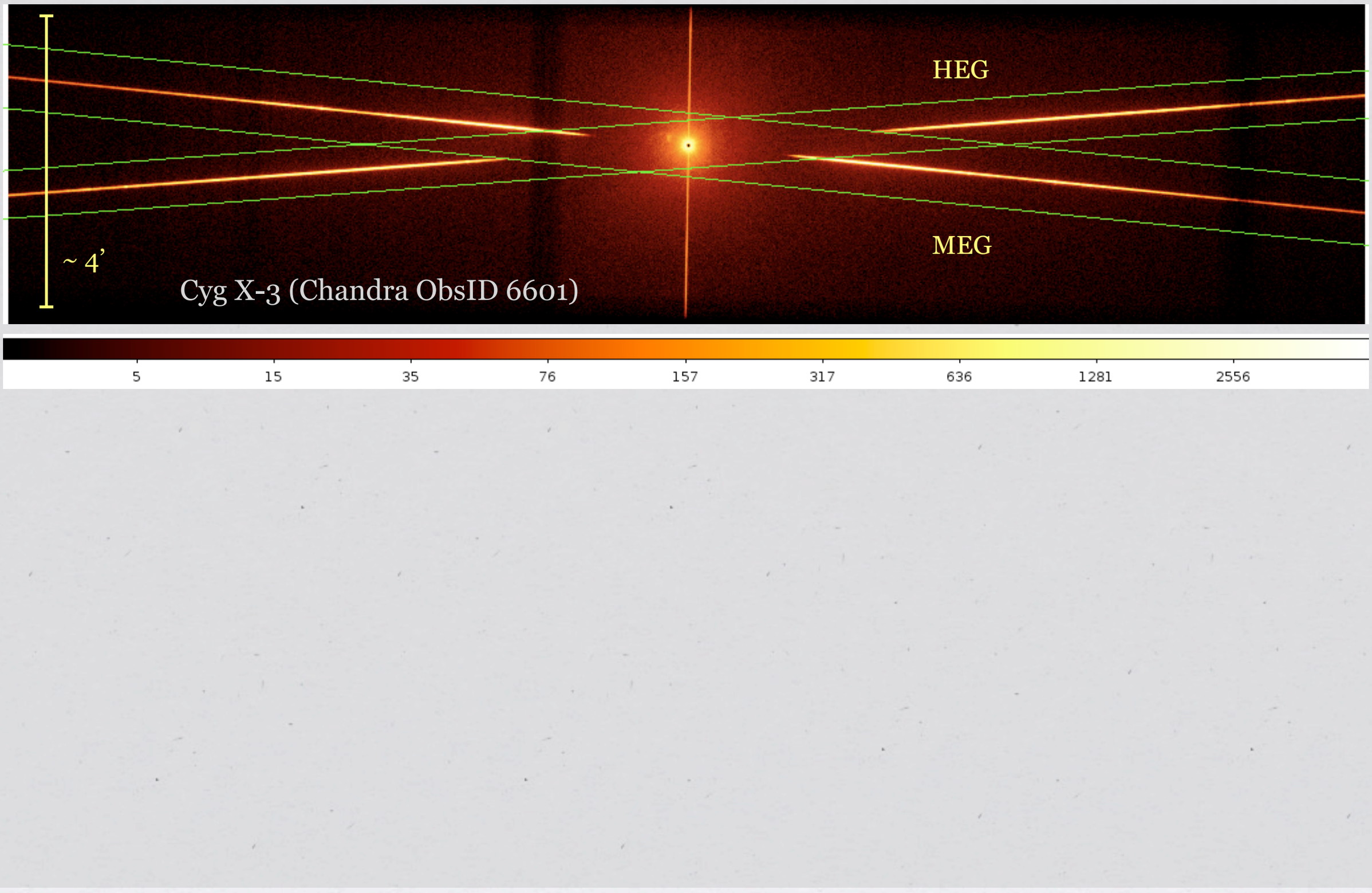


CO map of the Cygnus X-3 region



[Dame et al. 2001]

Cyg X-3 as imaged by *Chandra*



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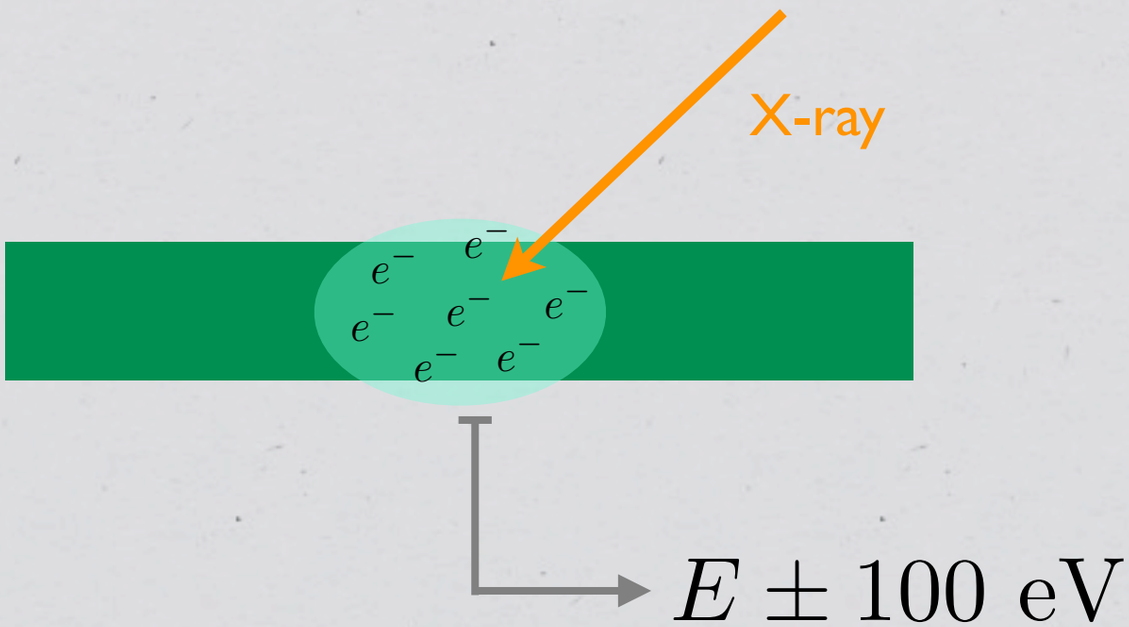
CCD Spectroscopy



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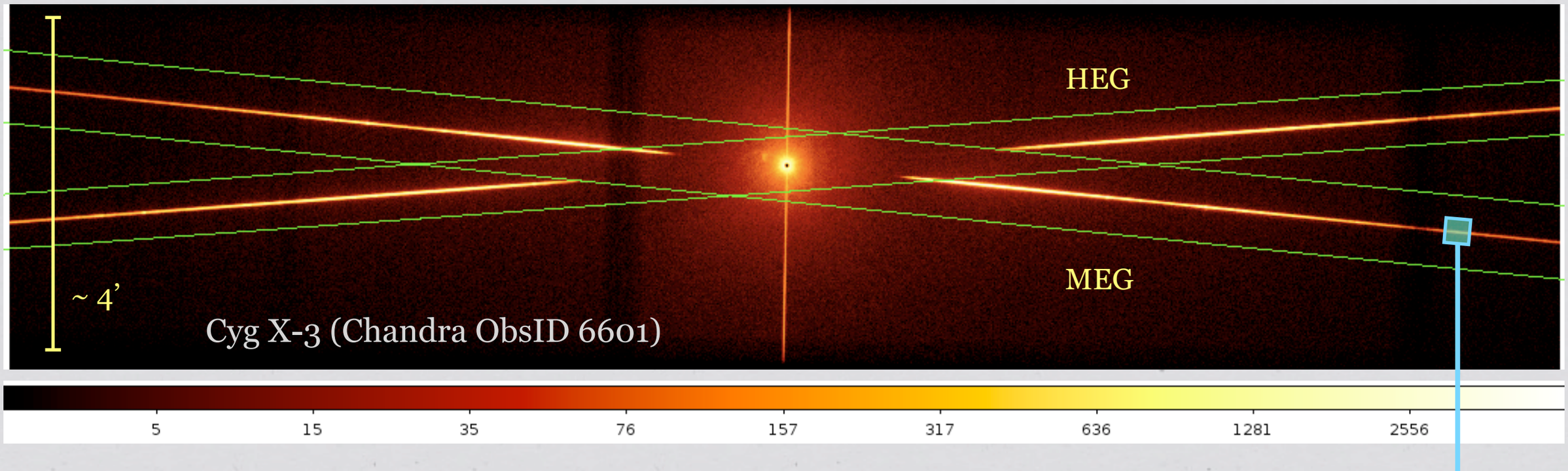

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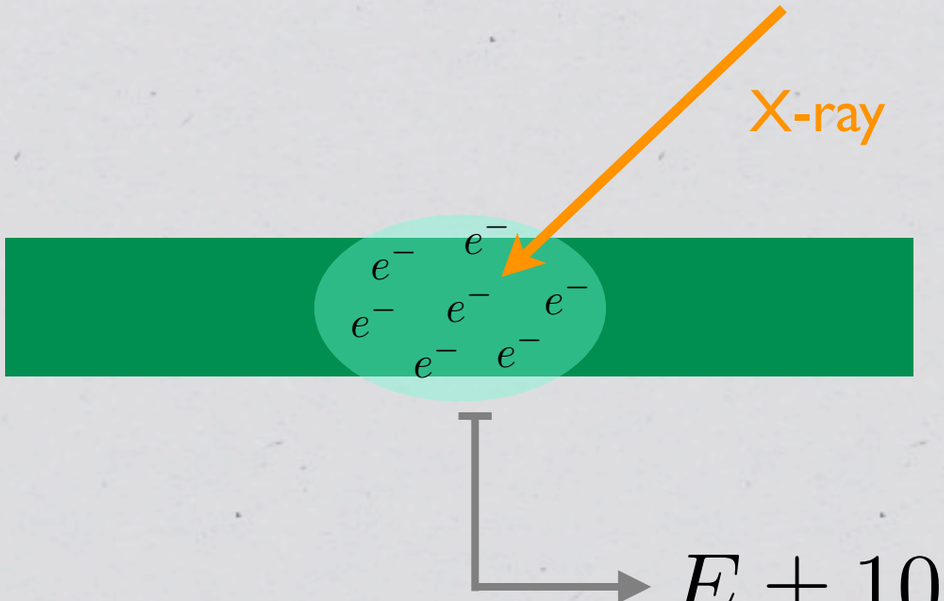


$E \pm 100$ eV

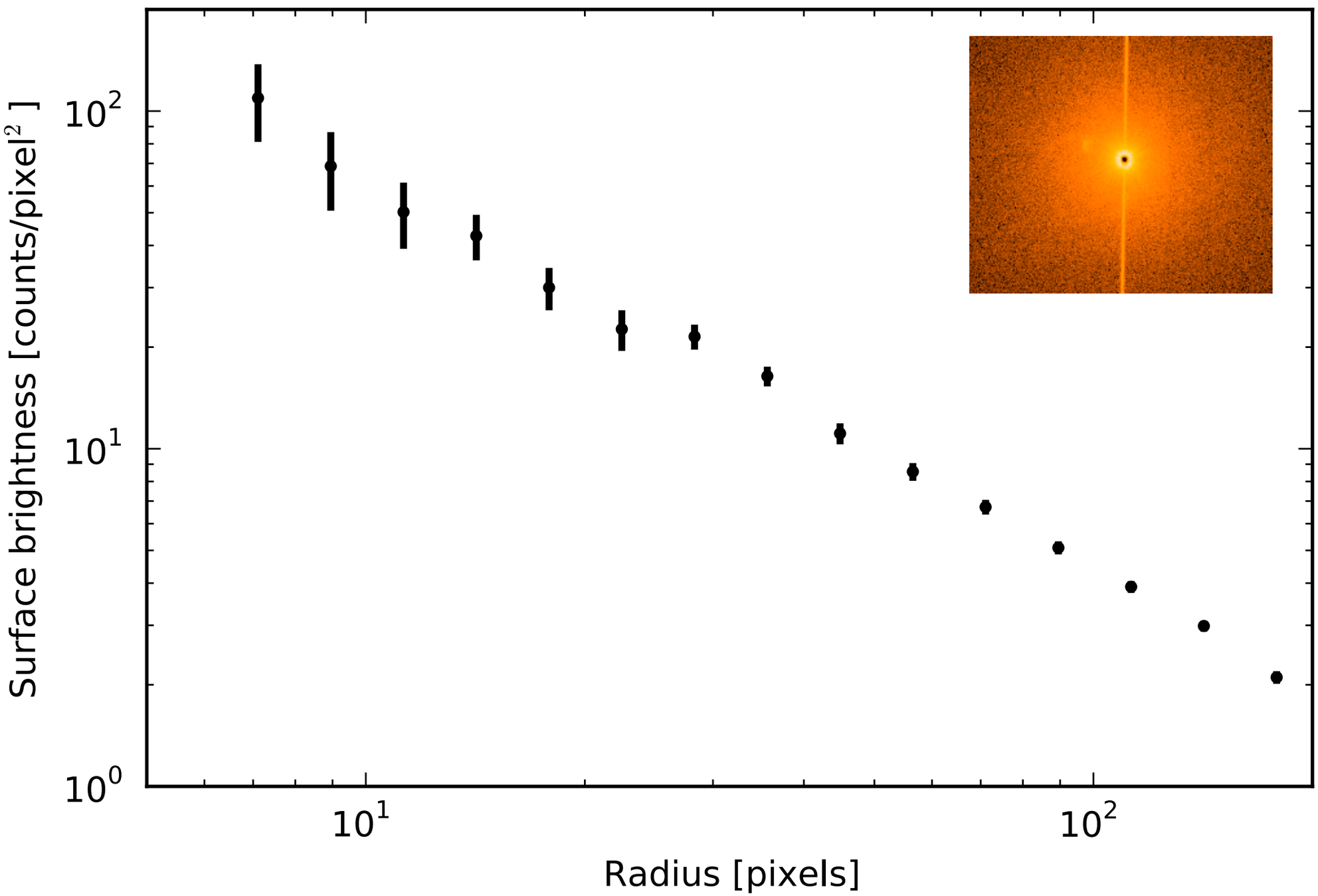
Grating Spectroscopy

$x,\ y,\ E_{\rm CCD}$

$E \pm 1 - 2$ eV

Corrales & Paerels (in prep) - July 30,2013

Observed Halo Surface Brightness



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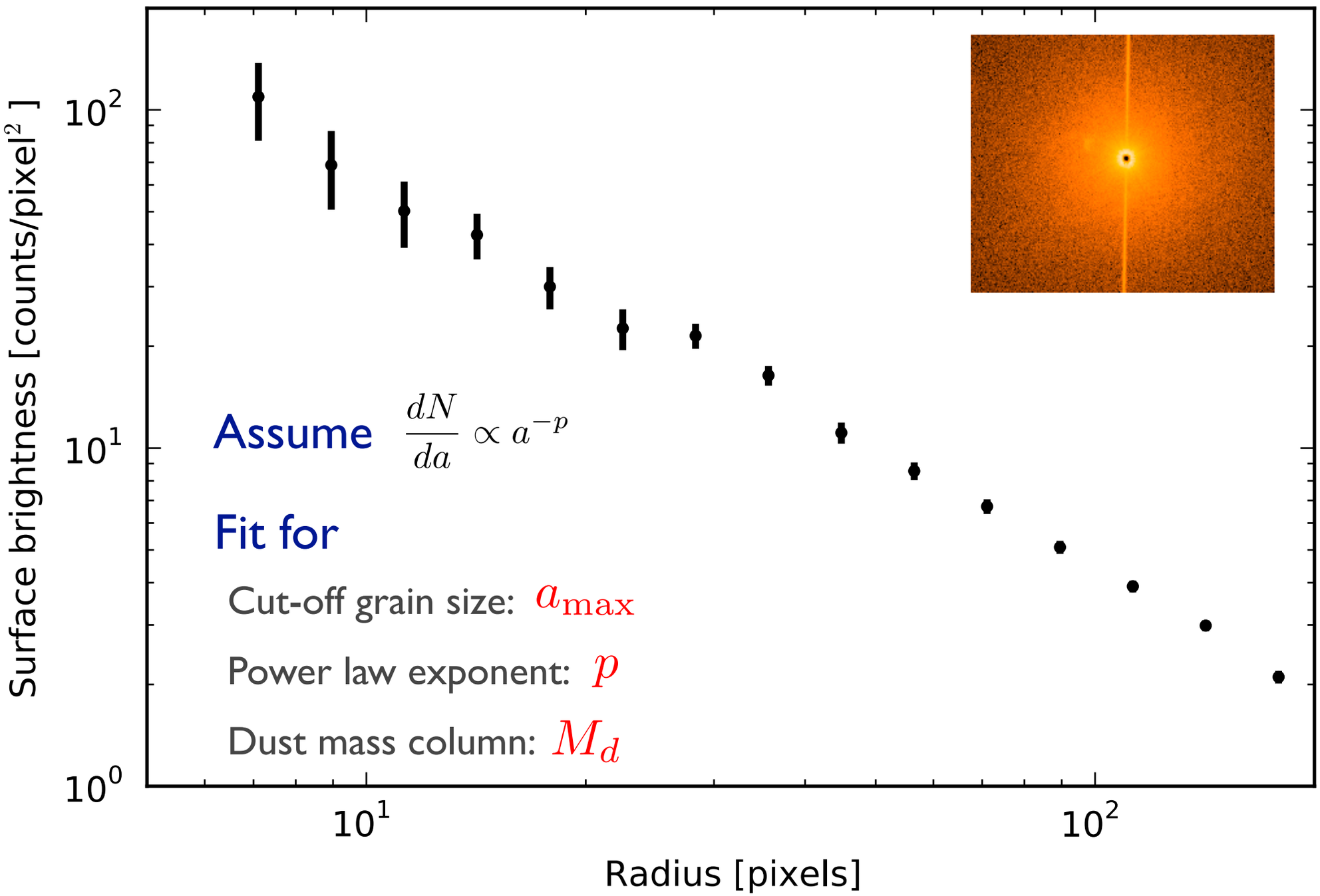
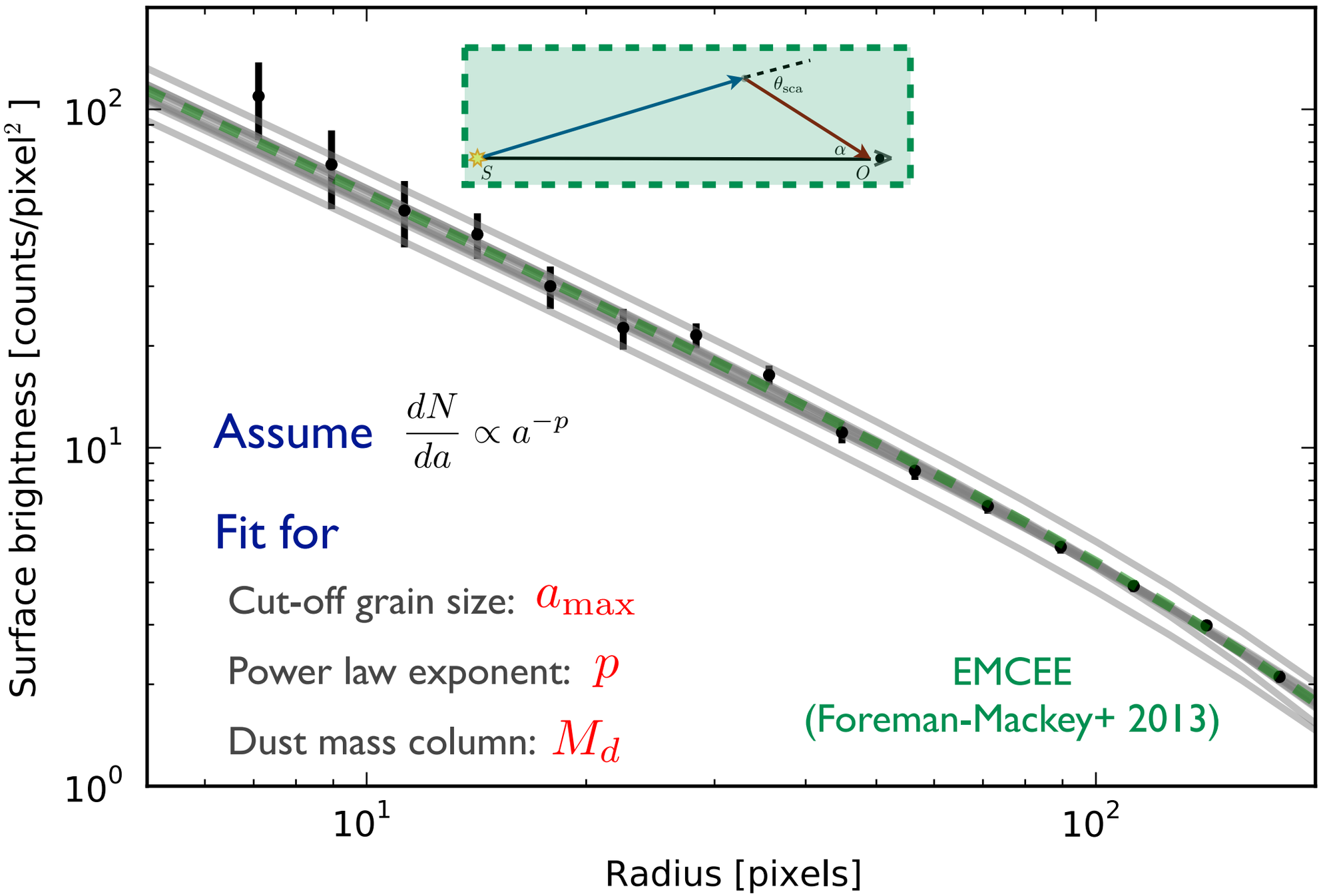


Fit to Halo Surface Brightness



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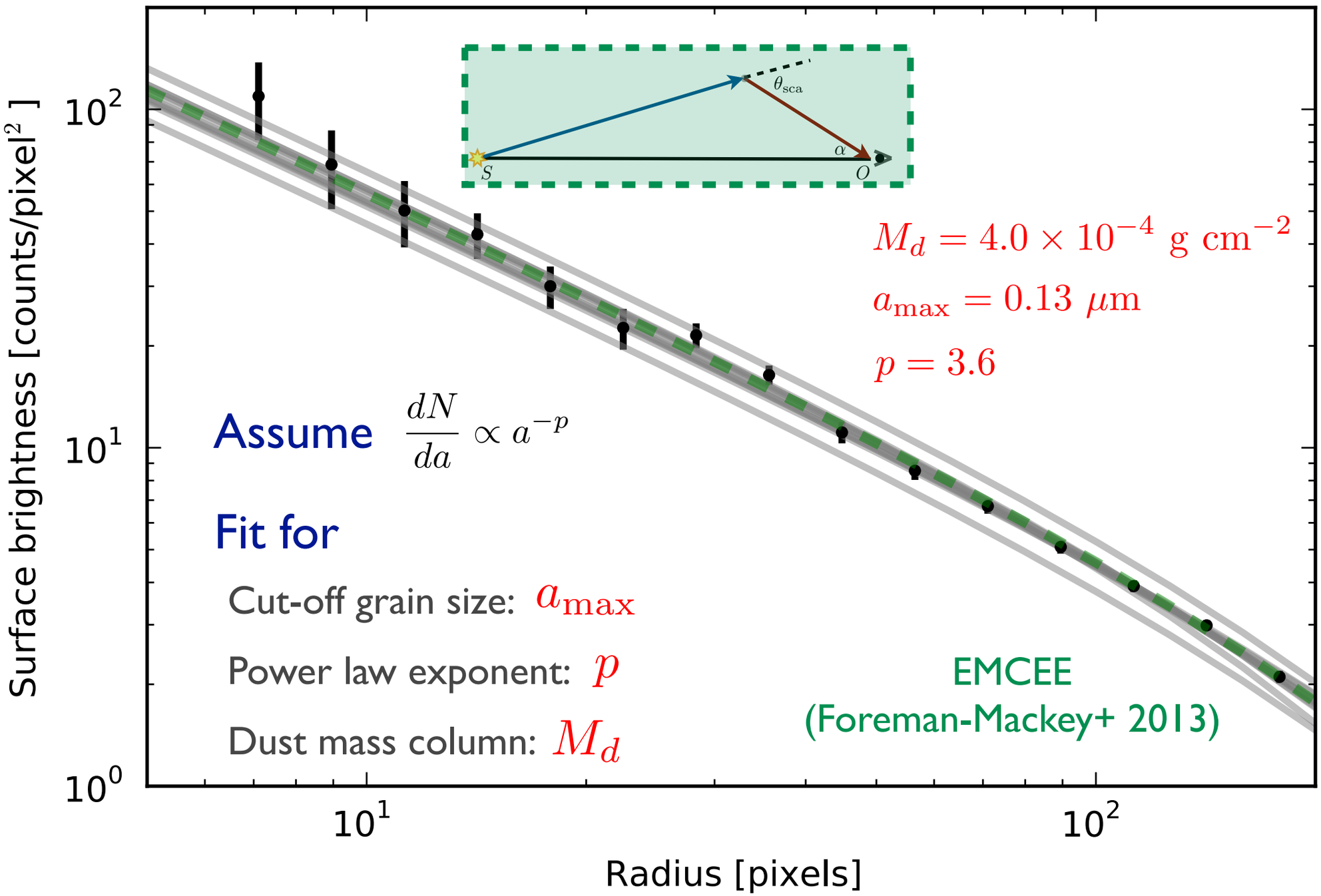

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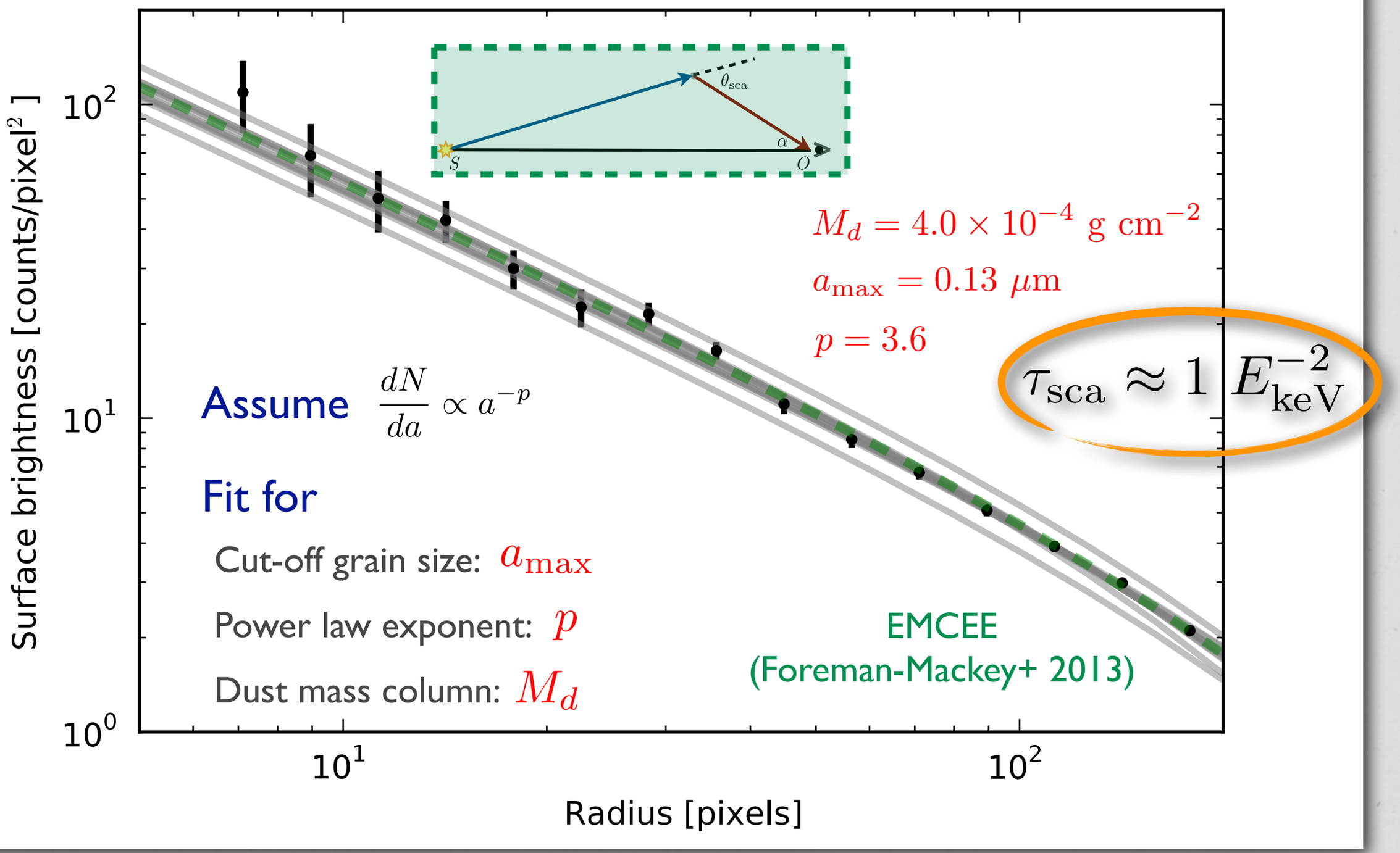
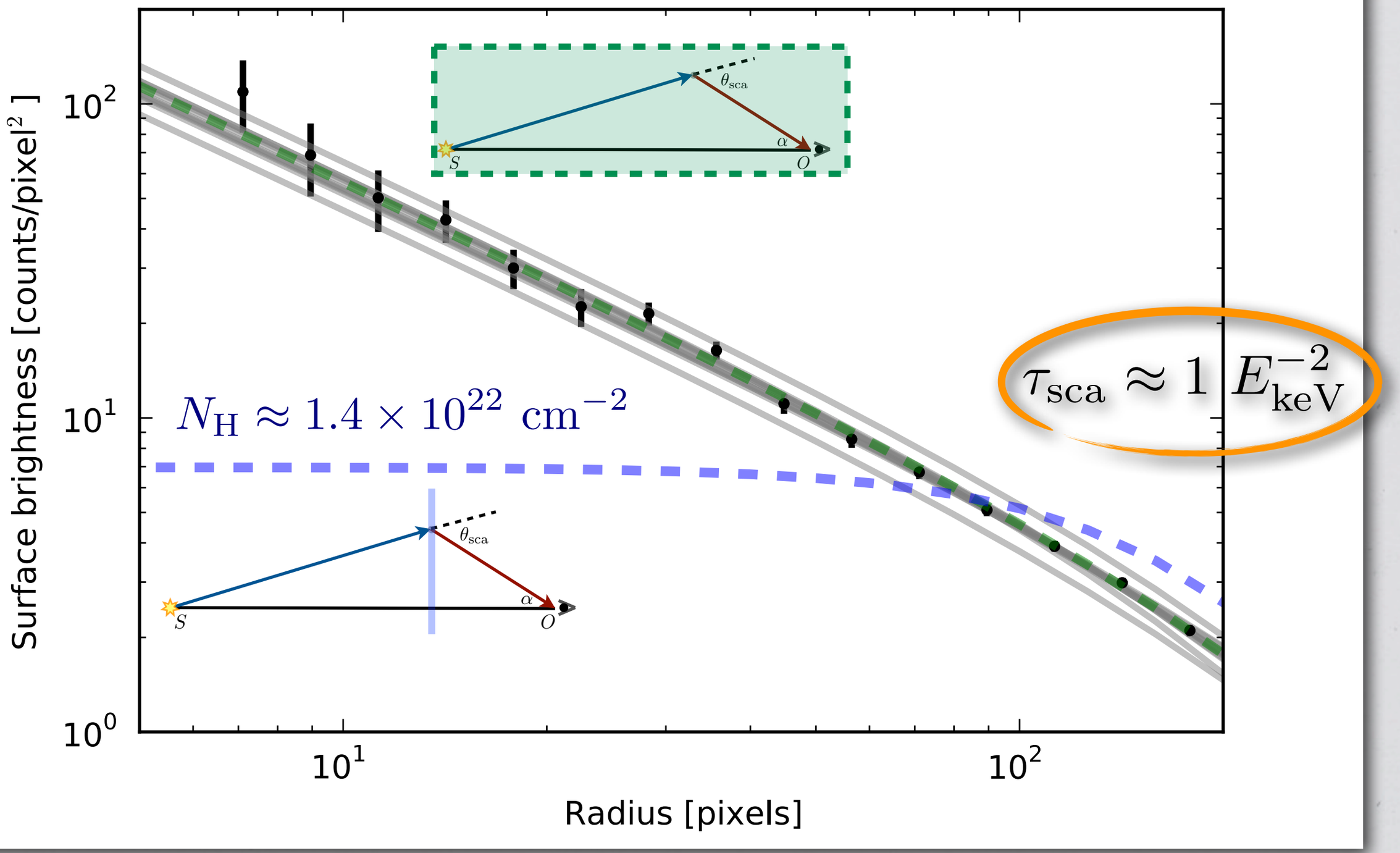


Where is the Cyg OB 2 dust?



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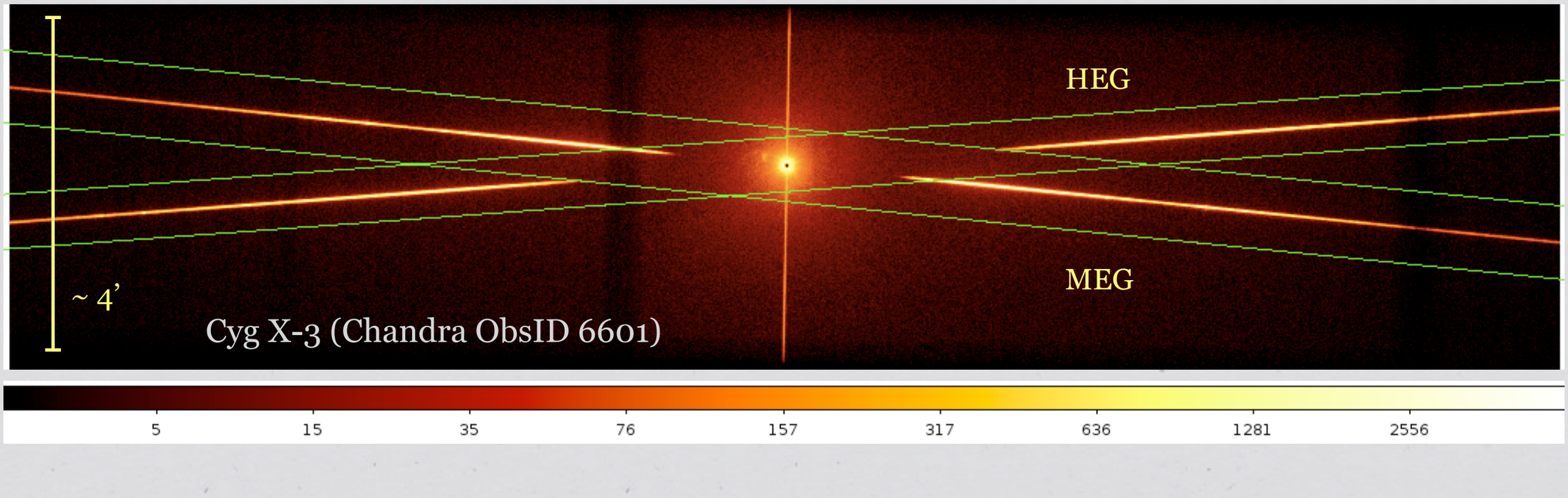

What's the hydrogen column?

~ From the radio, $N_{\rm HI} \geq 10^{22}\ {\rm cm}^{-2}$
[LAB survey]

~ CO survey indicates $N_{\rm H} \sim 1.4 \times 10^{22}\ {\rm cm}^{-2}$
in the form of molecular clouds [Dame et al. 2001]

~ From X-ray absorption, $N_H \sim 3 - 4 \times 10^{22}\ {\rm cm}^{-2}$
depending on spectral model [Predehl & Schmitt 1995]

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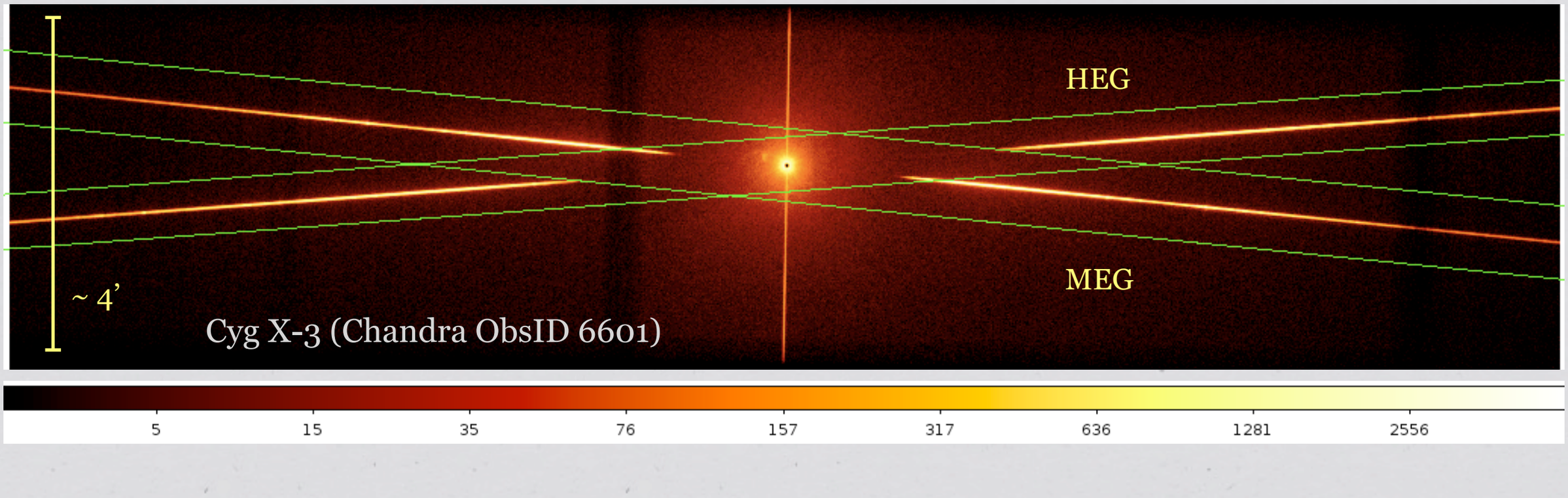

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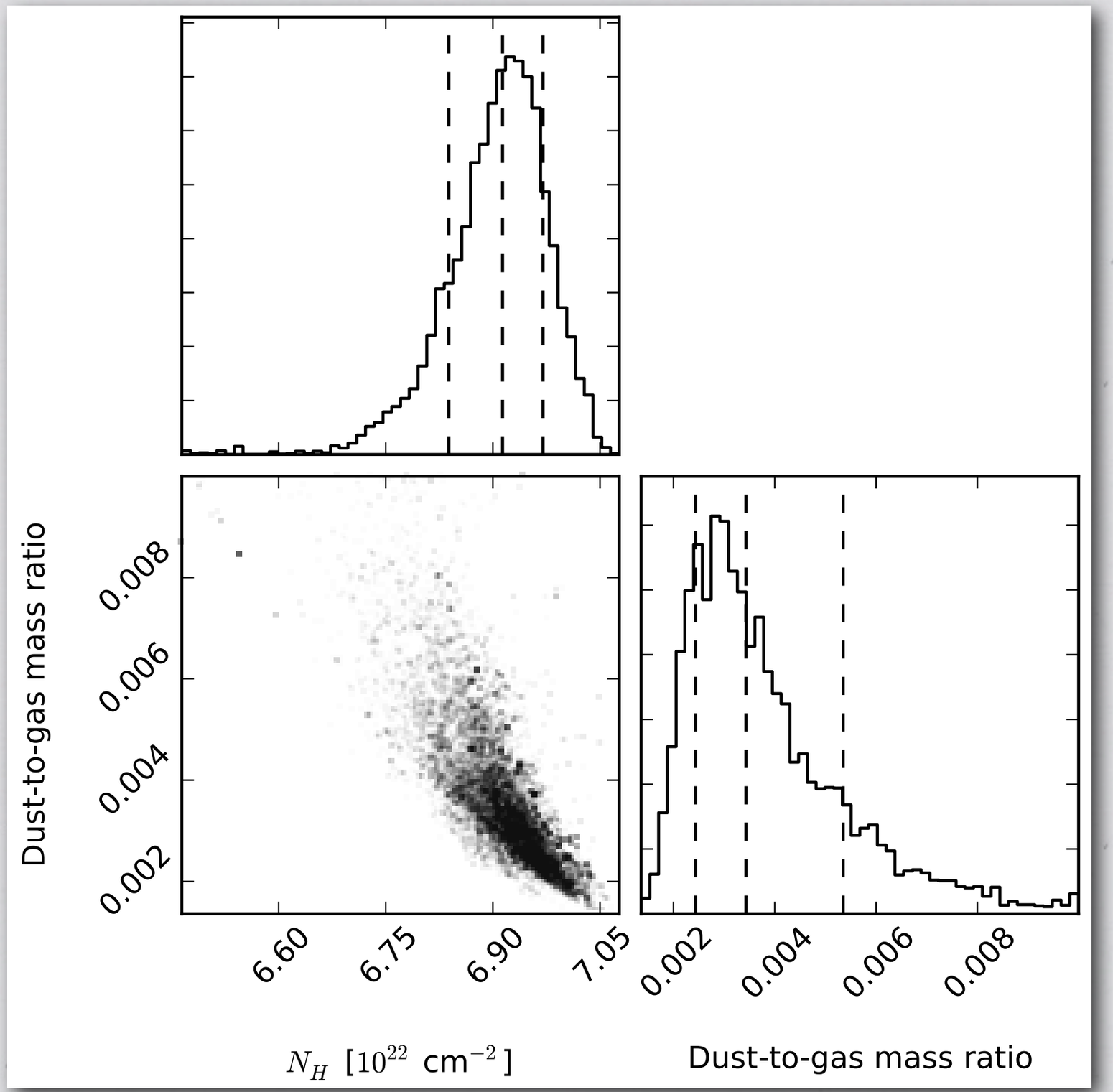
ROSAT: 0.3-2.4 keV

Chandra: 0.3-10 keV

X-ray Spectral Fitting yields a Gas-to-Dust Mass Ratio



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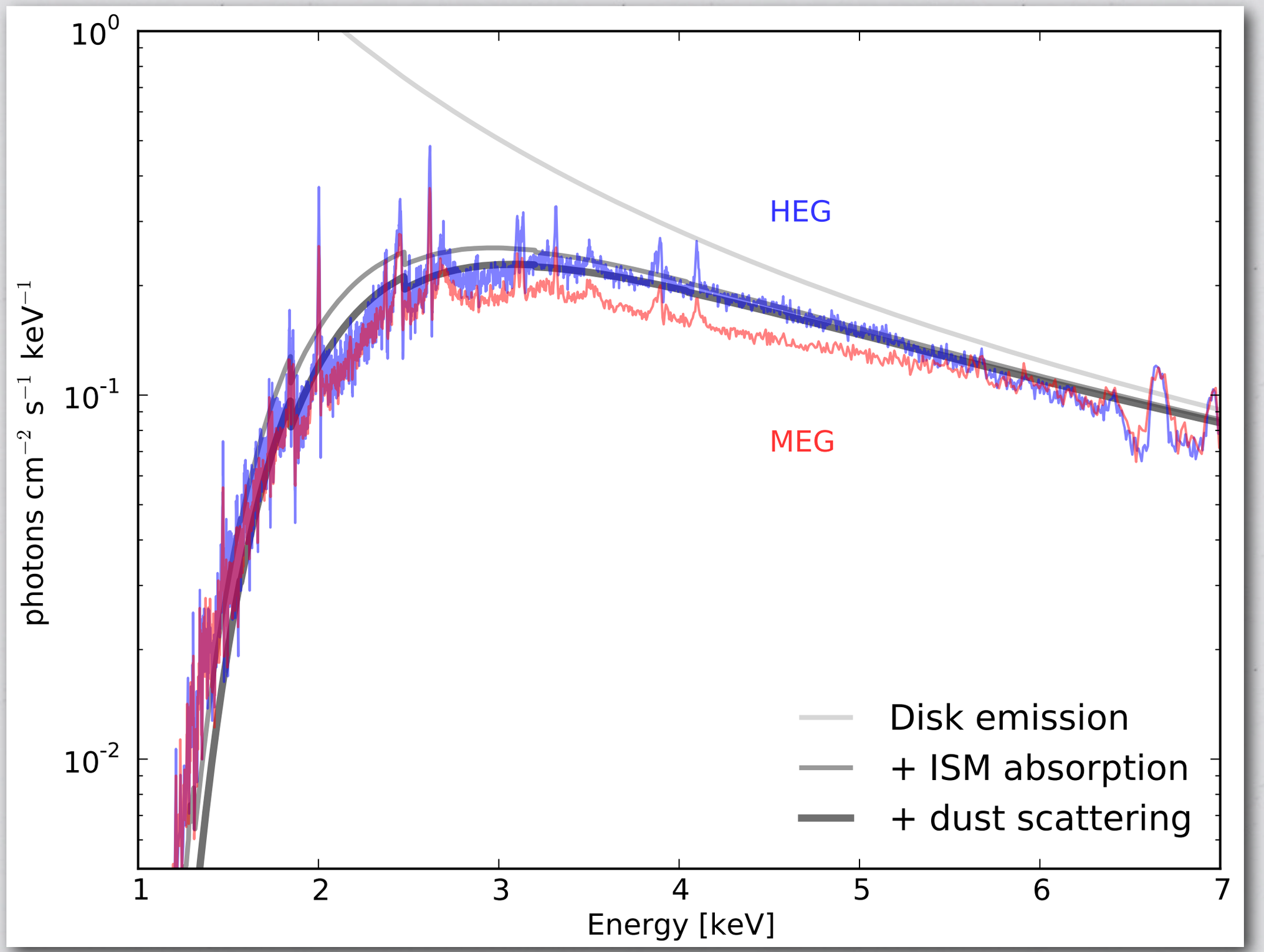

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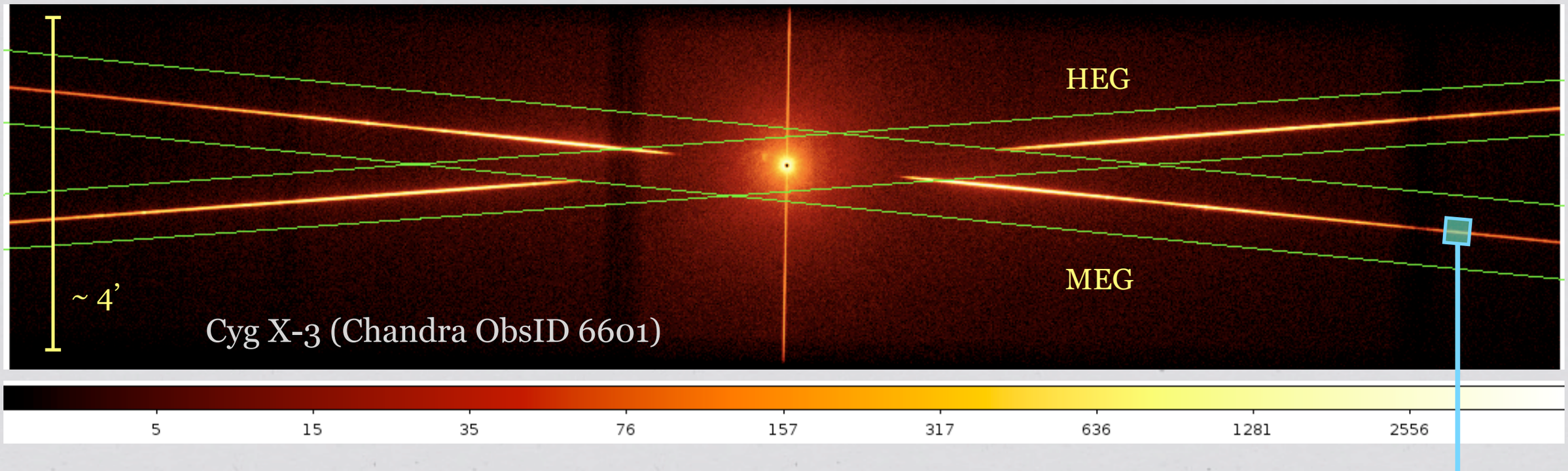

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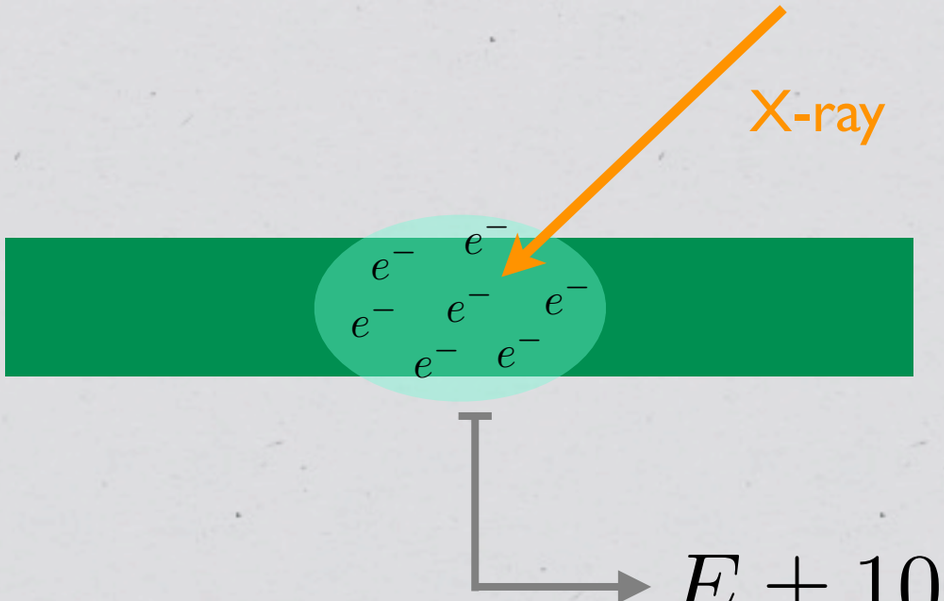

$E \pm 100$ eV

Grating Spectroscopy

$x,\ y,\ E_{\rm CCD}$

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Corrales & Paerels (in prep) - July 30,2013

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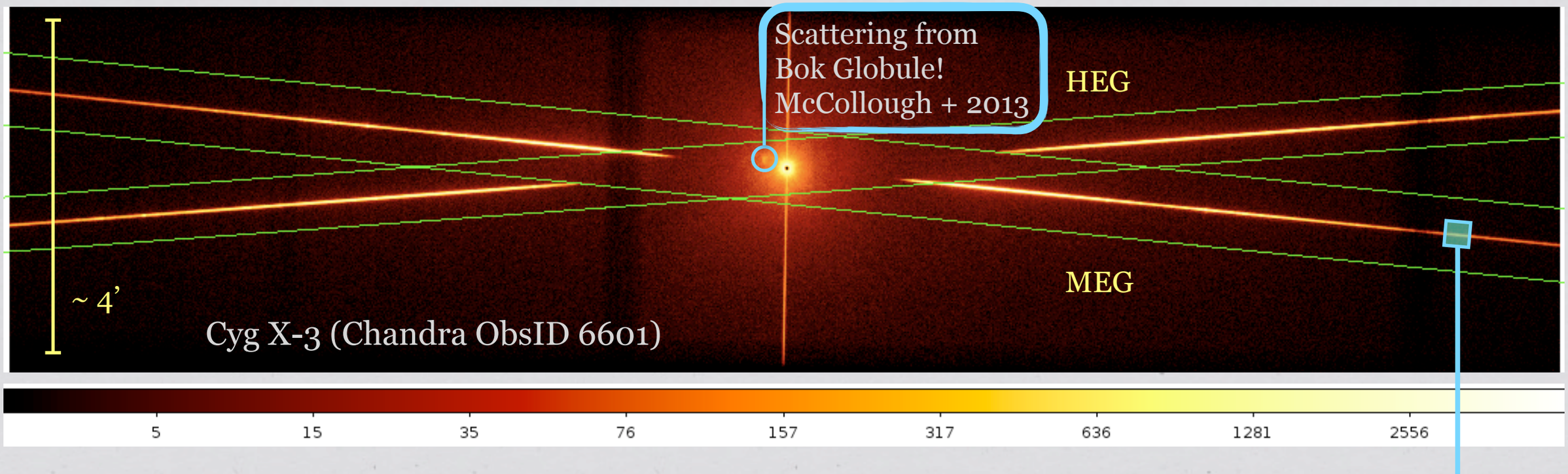

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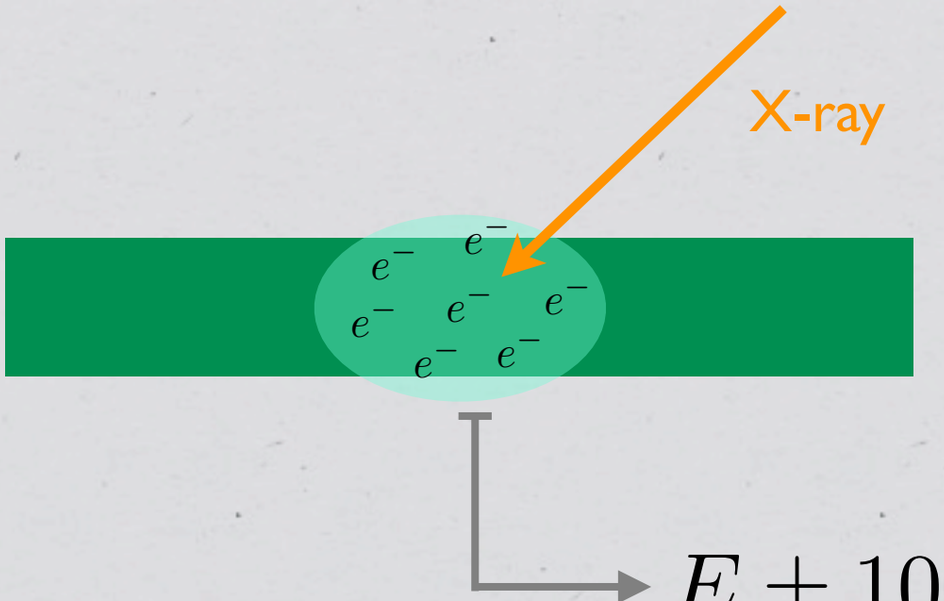


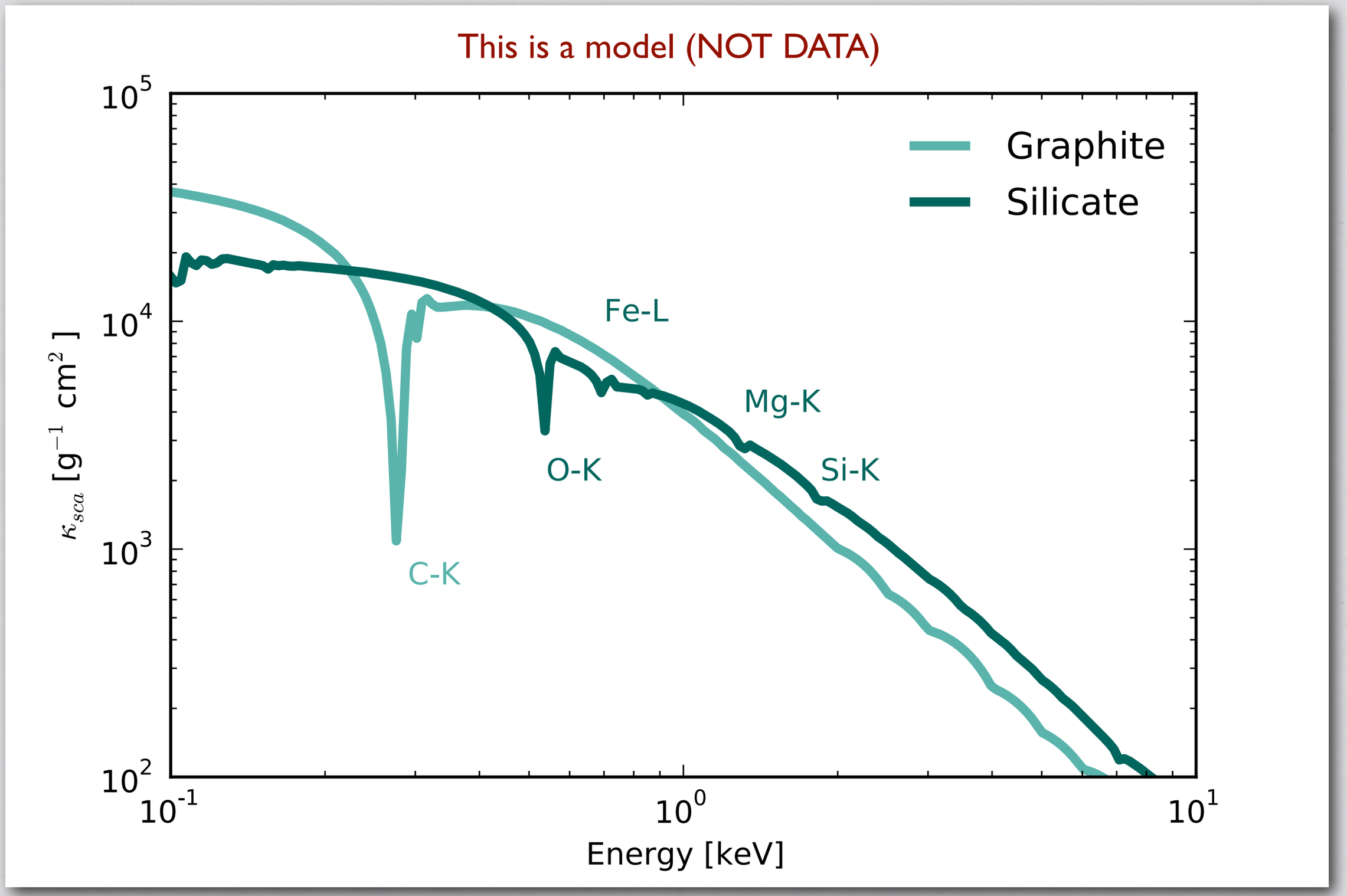
$$E \pm 100 \text{ eV}$$

Grating Spectroscopy

$$x,\ y,\ E_{\text{CCD}}$$

$$E \pm 1 - 2 \text{ eV}$$

Scattering Opacity and Absorption Edge Structure



Conclusions

Motivations

X-ray scattering probes the abundance and spatial distribution of large ('grey') dust

Spectroscopy can directly measure dust elemental constituents

Cyg X-3

The bright scattering halo and interesting line-of-sight is good for studying dust grain size and spatial distribution in the diffuse ISM

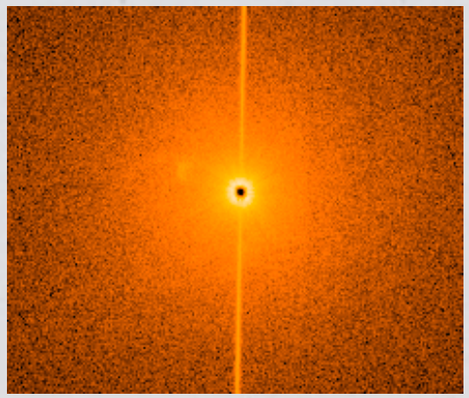
Uniformly distributed dust fits the halo profile well

X-ray spectrum can be fit with ISM absorption + dust scattering to get an independent measure of dust-to-gas mass ratio

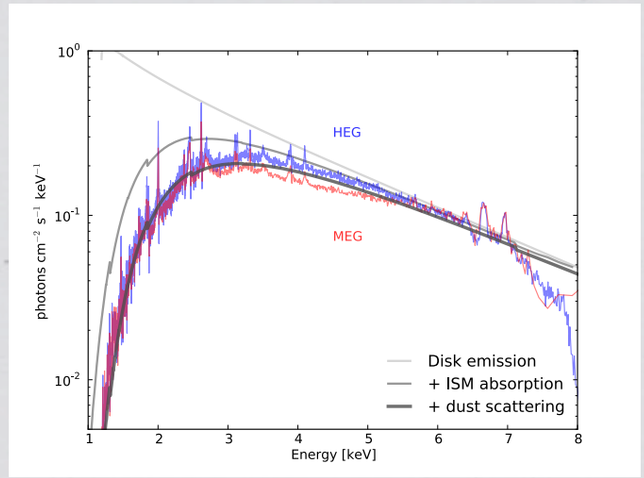
Future : Extract a high resolution spectra of scattered light

Ratio of scattered light to point source

$$f \equiv$$



$$\div$$



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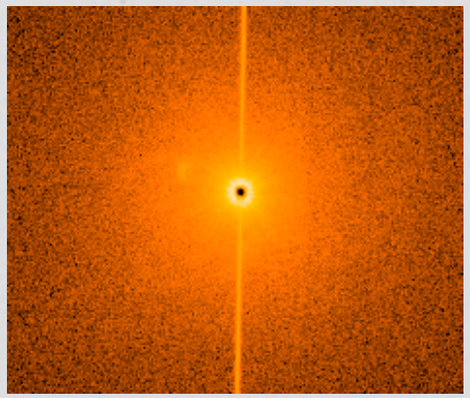

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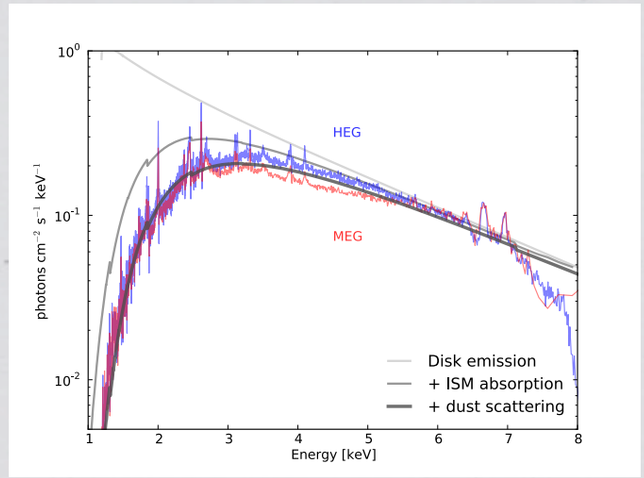
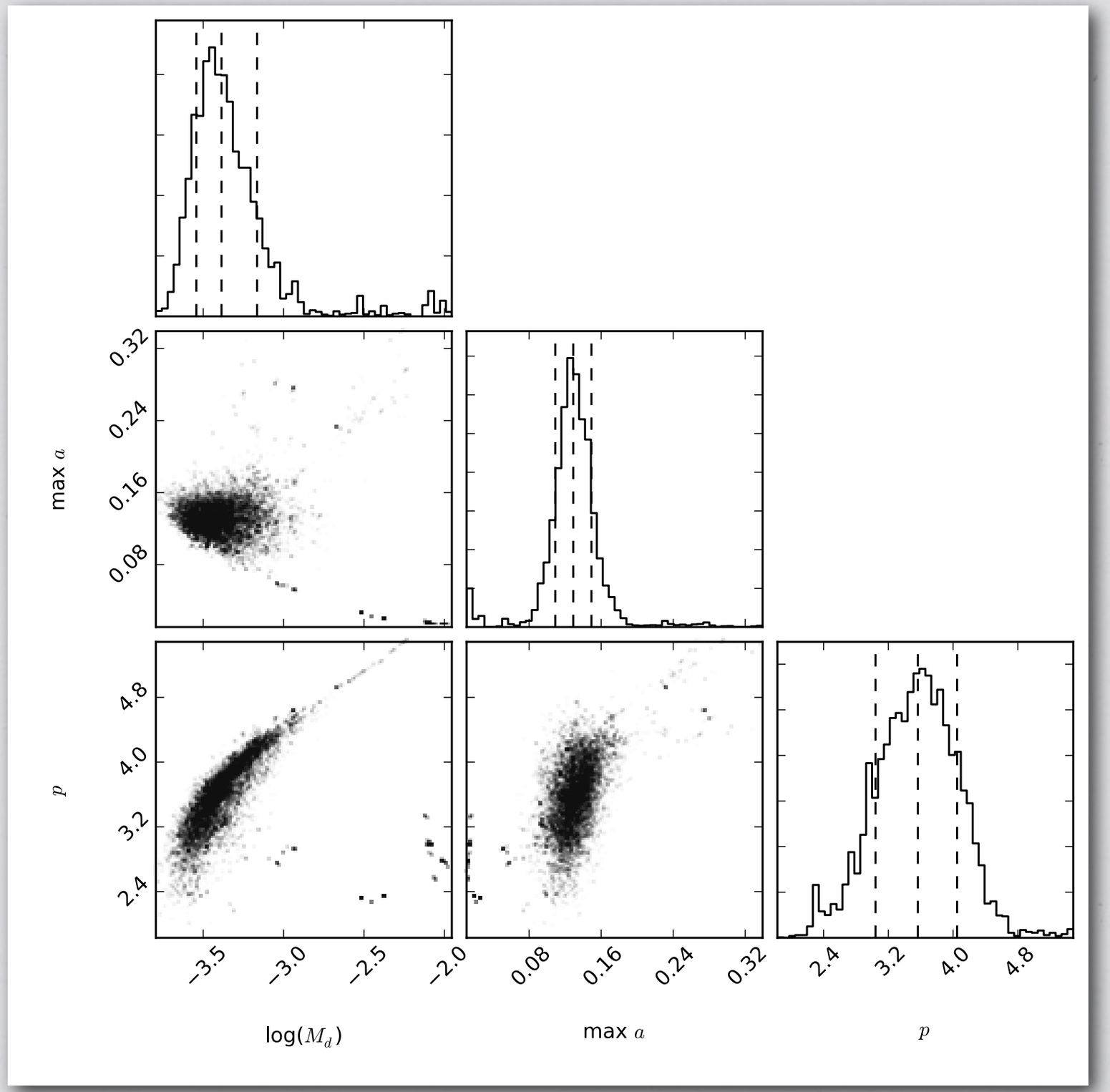


$$f = \frac{F_a(1 - e^{-\tau_{\rm sca}})}{F_a e^{-\tau_{\rm sca}}} = e^{\tau_{\rm sca}} - 1$$

Apparent flux

Fit to Halo Surface Brightness



$M_d = 4.0 \times 10^{-4}$ g cm^{-2}

$a_{\max} = 0.13$ μm

$p = 3.6$