Max-Planck-Institut für extraterrestrische Physik

Probing the Interstellar Dust towards the Galactic Center Using X-ray Dust Scattering Halos

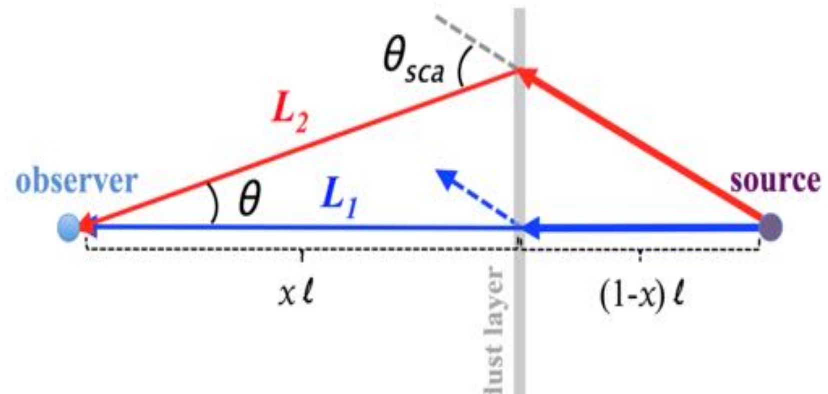
Chichuan Jin[1], Gabriele Ponti[1], Frank Haberl[1], Randall Smith[2]

[1]Max-Planck-Institut für extraterrestrische Physik, Garching, Germany, 85741

[2]Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138, USA

X-ray Dust Scattering

Interstellar dust grains can scatter X-ray photons along the line-of-sight (LOS) of X-ray sources, thereby reducing the source flux and producing a halo around it, i.e. the X-ray dust scattering halo.



$$I^{(1)}_{sca}(\theta) = F_X N_{H,sca} \int_{E_{min}}^{E_{max}} S(E) \int_0^1 \frac{f(x)}{(1-x)^2} \int_{a_{min}}^{a_{max}} n(a) \times \frac{d\sigma_{sca}(a,x,E,\theta)}{d\Omega}\, da\, dx\, dE$$

Galactic Centre Line-of-Sight

- ✧ Galactic Centre (GC) harbours many X-ray sources and is heavily extincted ($N_H \sim 10^{23} cm^{-2}$) => significant dust scattering opacity => potential spectral biases.
- ✧ Dust scattering was never studied in detail or properly considered for any GC X-ray sources.
- ✧ Interstellar Dust distribution and properties (e.g. grain size distribution & abundances) along the GC direction is unknown and difficult to determine.

AX J1745.6-2901

- ➢ An eclipsing neutron star X-ray binary at 1.45 arcmin away from Sgr A⋆, $N_H \sim 3\times10^{23} cm^{-2}$
- ➢ Being X-ray bright and transient: allowing a directly measurement of background diffuse emission.
- ➢ Well observed: within the FoV of hundreds of obs of Sgr A⋆ by *XMM-Newton* and *Chandra*.

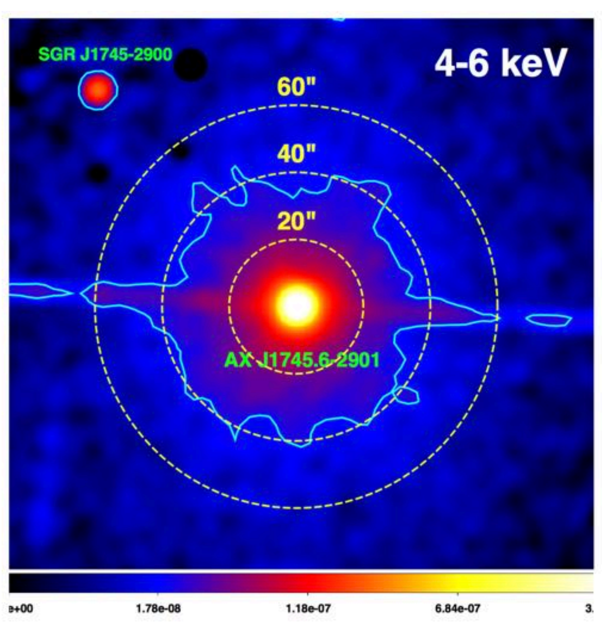


Fig. X-ray Dust Scattering Halo around AX J1745.6-2901

Halo Radial Profile Fitting

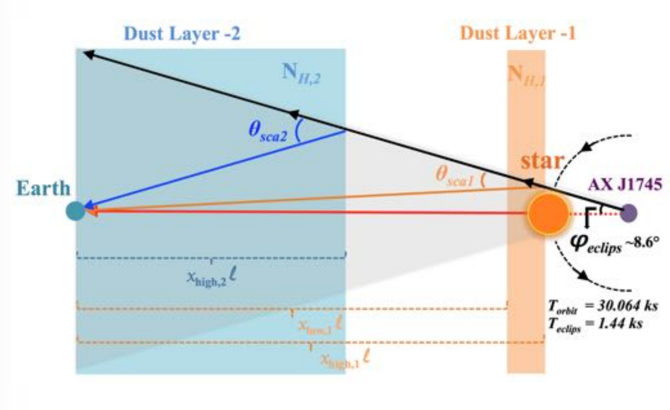


Fig. Schematic of the two-layer dust distribution and parameters

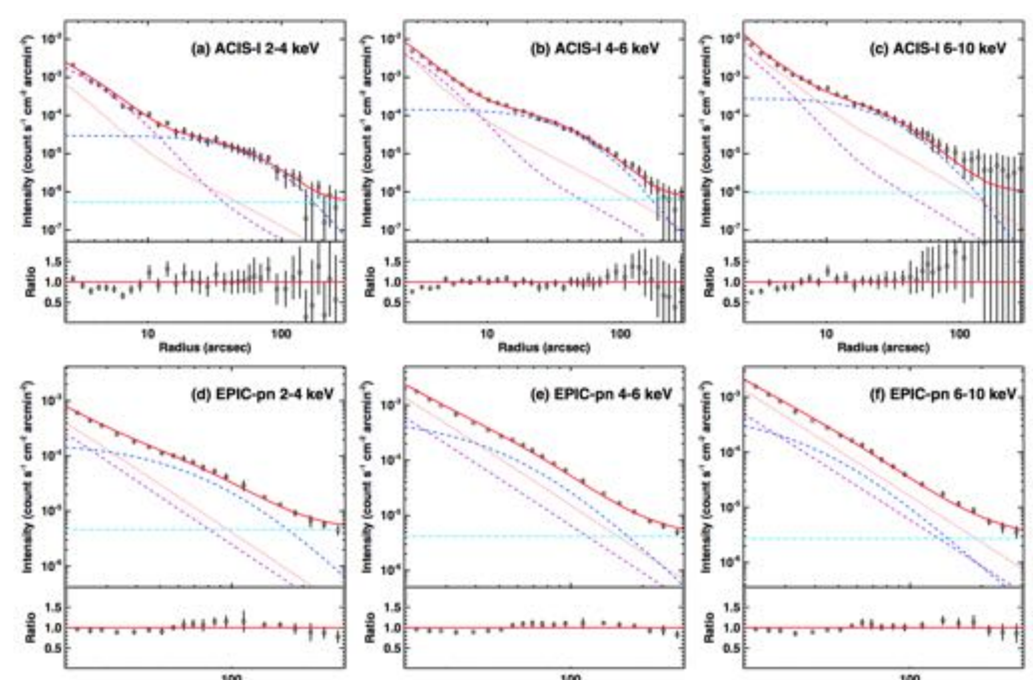
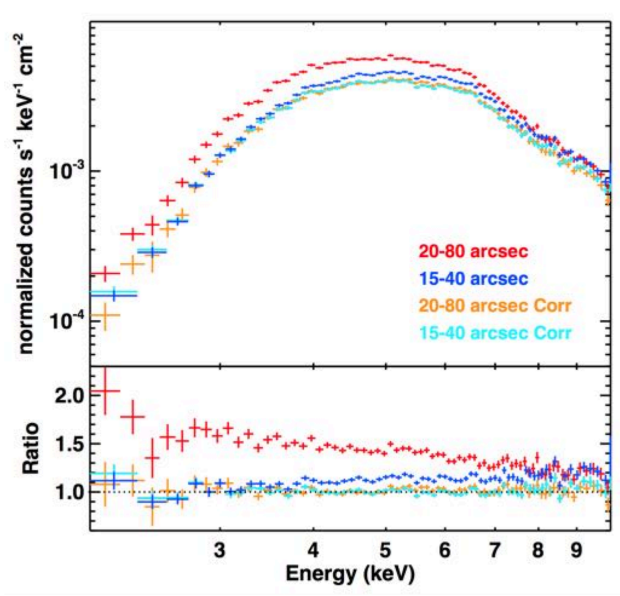


Fig. halo Radial Profile Fitting of AX J1745.6-2901

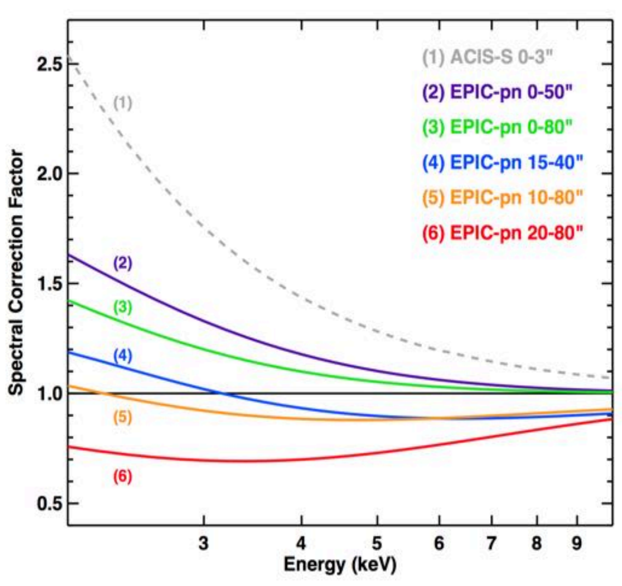
A simultaneous fit to the radial profile of AX J1745.6-2901 as derived from *XMM-Newton* and *Chandra* obs in the past 20 years in the 2-4, 4-6 and 6-10 keV bands, using two major foreground dust layers plus a halo wing component.

Spectral Bias & Correction



X-ray spectra will depend on the source extraction region due to the X-ray dust scattering halo.

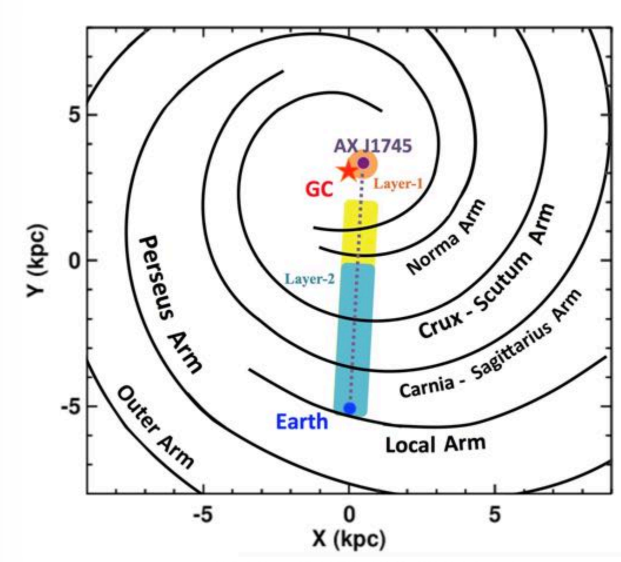
The correction factor calculated from the best-fit halo profile model.

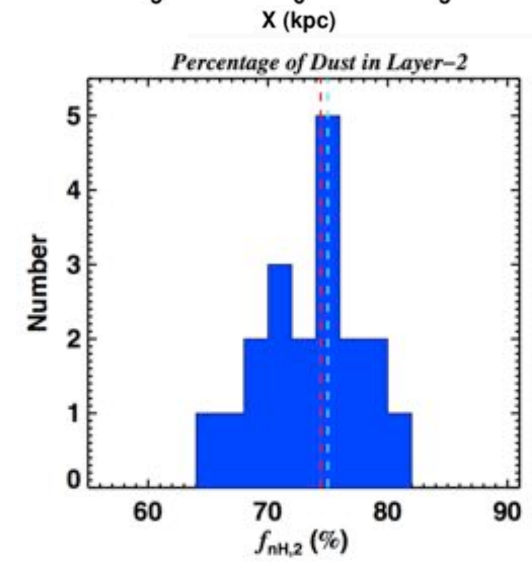


X-ray dust scattering halo can introduce severe spectral biases, which can be corrected by our new Xspec models.

Spectrum	$N_{H,abs}$ (10^{22} cm^{-2})	$\Gamma_{2\text{-}10\,keV}$	$F_{2\text{-}4\,keV}$	$F_{4\text{-}6\,keV}$ (10^{-12} erg cm^{-2} s^{-1})	$F_{6\text{-}10\,keV}$
Spec (15-40")	40.9 ± 0.6	3.06 ± 0.04	15.2 ± 0.1	68.4 ± 0.4	97.8 ± 0.5
Spec (20-80")	40.5 ± 0.4	3.38 ± 0.04	21.8 ± 0.1	86.3 ± 0.5	107.3 ± 0.6
Spec_cor (15-40")	38.8 ± 0.6	3.01 ± 0.04	14.1 ± 0.1	60.7 ± 0.3	88.6 ± 0.5
Spec_cor (20-80")	39.1 ± 0.6	3.06 ± 0.04	14.5 ± 0.1	62.3 ± 0.3	89.5 ± 0.5

GC Foreground Dust Distribution





- ● Dust Layer-1: local to AX J1745.6-2901 and contains 26% of the total LOS dust.
- ● Dust Layer-2: most likely in the Galactic disk and contains 74% LOS dust, associated with MCs distributed along the spiral arms.
- ● Halo Wing: an extra small dust grain population (λ < 600Å).
- ● Uncertainties: variation of dust grain size distribution and abundances along one GC LOS, and between different GC LOSs.

Conclusions

- ◆ For the first time, the X-ray dust scattering halo around a GC X-ray point-like source was accurately measured and modelled, using *XMM-Newton* and *Chandra* obs.
- ◆ We find most of the GC foreground dust and gas is located in the Galactic disk rather than in the GC CMZ.
- ◆ X-ray dust scattering halo can severely bias the source spectra. We create Xspec models to correct for this bias.

References

[1] Jin C., Ponti G., Haberl F., Smith R., 2017, MNRAS, 468, 2532; [2] Smith R., Valencic L. A., Corrales L., 2016, ApJ, 818, 143; [3] Valencic L. A., Smith R. K., 2015, ApJ, 809, 66; [4] Ponti G., Bianchi S., Muñoz-Darias T., et al., 2015, MNRAS, 446, 1536; [5] Predehl P., Schmitt J. H. M. M., 1995, A& A, 293, 889; [6] Mathis J. S., Rumpl W., Nordsieck K. H., 1977, ApJ, 217, 42

For Further Information, Please Contact C. Jin at chichuan@mpe.mpg.de