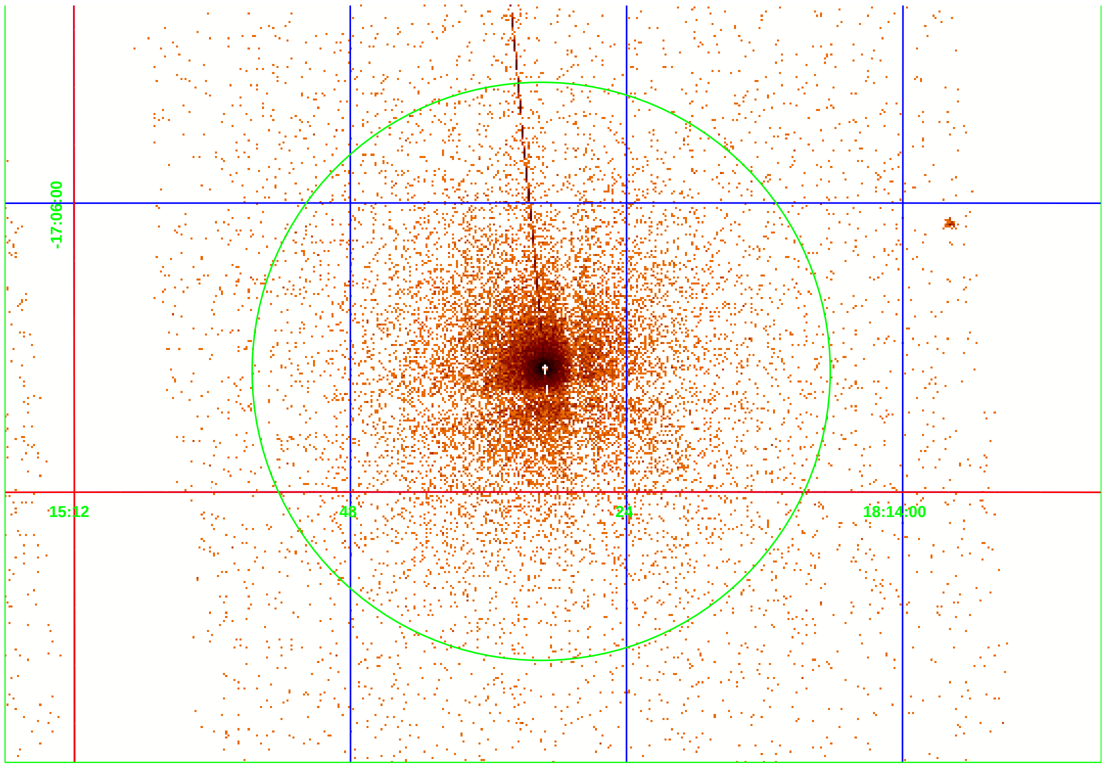
X-Ray Halos with Chandra and Con-X



The LMXB GX 13+1 with Chandra

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Con-X FST Meeting

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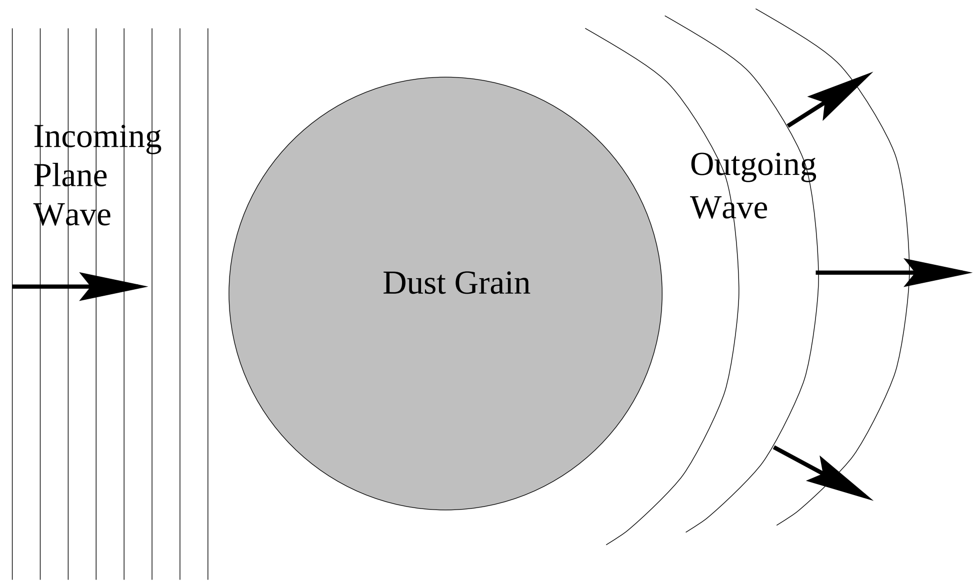
What causes the scattering?



The X-ray photon sees the dust particle as a cloud of free electrons, each one a scattering site. Assuming each electron "sees" the wave (photon), it will oscillate like a dipole at the wave frequency–ie, Rayleigh scattering.

The differential scattering cross section is (using the Rayleigh-Gans approximation) :

$$(\frac{d\sigma}{d\Omega})(E,a,\phi) \approx 1.1(\frac{\rho}{3\,\mathrm{g\ cm^{-3}}})^2(\frac{F(E)}{Z})^2\frac{a_{\mu m}^6}{E_{keV}^2}\exp{(-\frac{\phi^2}{2\sigma^2})}\ \mathrm{cm^2\,sr^{-1}}$$

where $\sigma \approx 62.4''\, E_{keV}^{-1}\, a_{\mu m}^{-1}$.

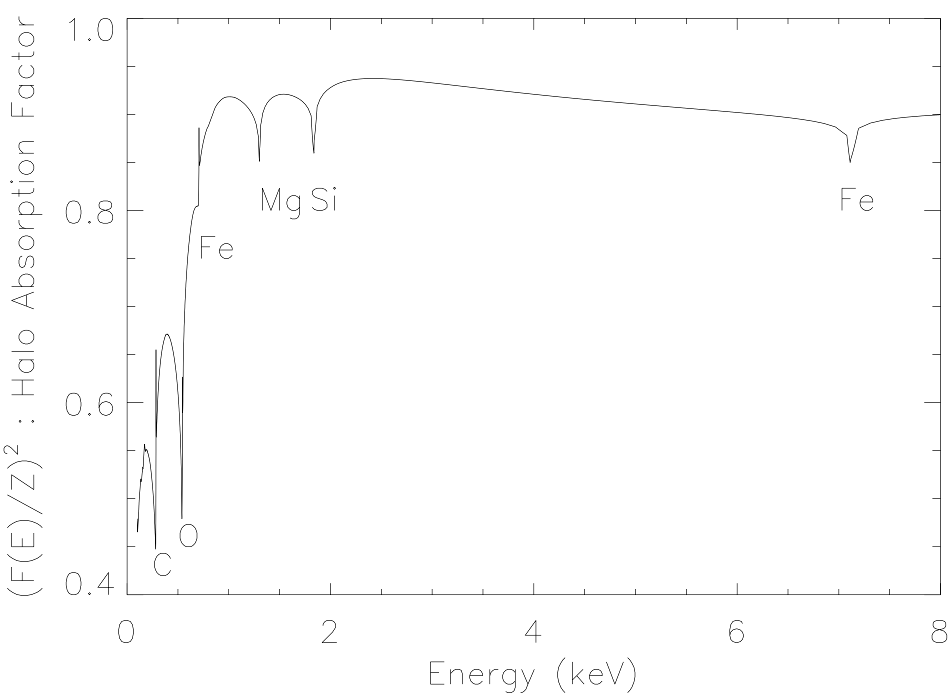
$F(E)$ is the Henke atomic scattering factor, and is $\approx Z$ except near edges.

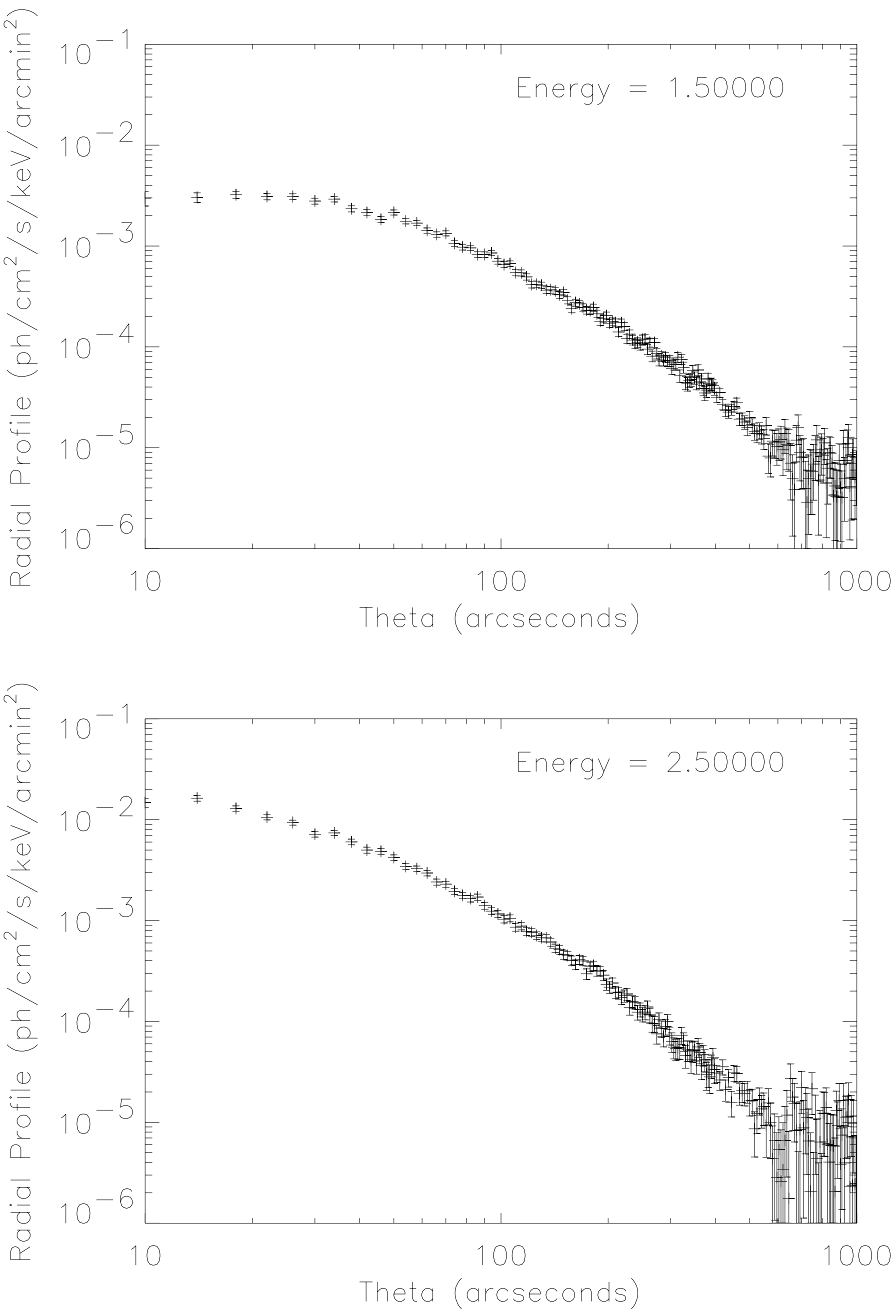
Integrating over the line of sight, the total scattering is

$$I_{sca}(\theta) = N_H F_X \int dE\, S(E) \int da\, n(a) \int \frac{f(z)}{(1-z)^2} \frac{d\sigma}{d\Omega}(E, a, \frac{\theta}{1-z}) dz$$

So the halo strength depends upon the following parameters:

- $S(E)$: Spectrum of the X-rays
- $n(a)$: Size distribution of the dust grains
- ρ : Density of the dust grains
- $f(z)$: Distribution of dust along the line of sight
- $F(E)$: Composition of the dust

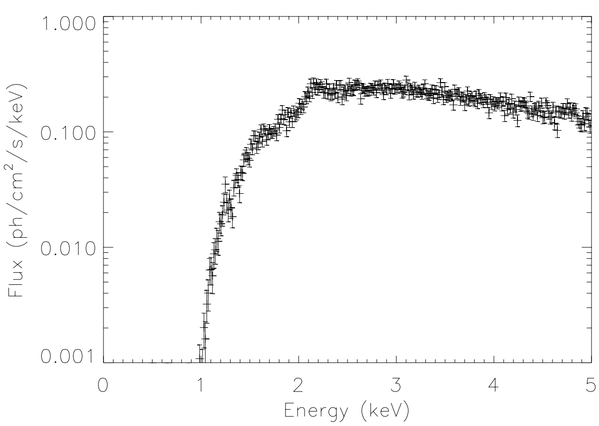


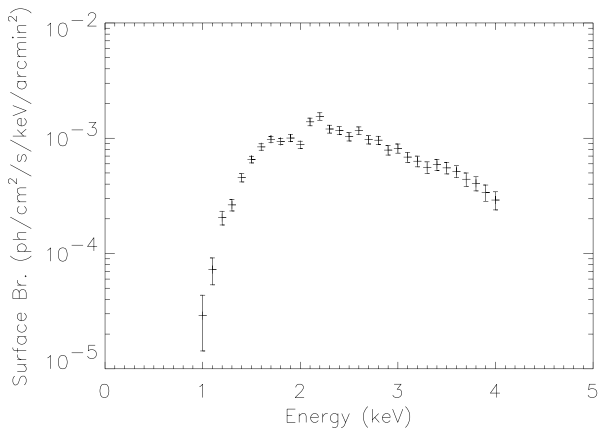


Radial profiles from the Chandra observation, at 1.5 and 2.5 keV. The Chandra PSF has been removed; data within 10″ is heavily piled-up and not plotted.

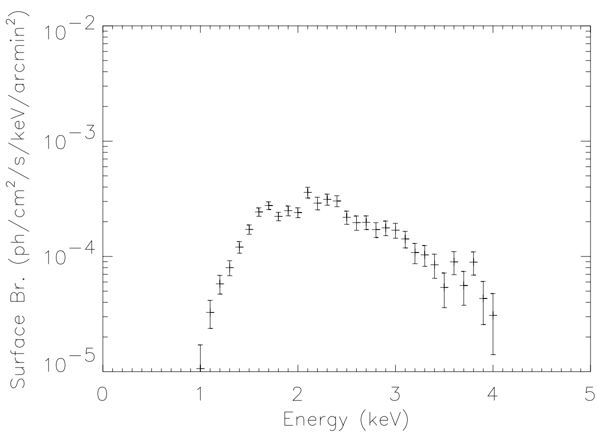
Initial Halo Results with Chandra

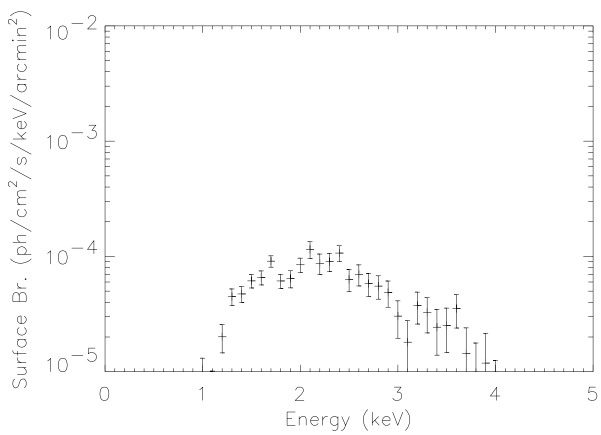
Source spectrum and halo surface brightness versus energy:





[Left] GX13+1 spectrum, from Chandra.
[Right] X-ray halo from GX13+1 with PSF subtracted, at 100″.





[Left] Same, at 200″

[Right] Same, at 300″.

The relevant baseline mission characteristics are:

Characteristic	$\sim 1\,\mathrm{keV}$	$\sim 6\,\mathrm{keV}$
Min. effective area	15,000 cm^2	6,000 cm^2
Min. angular resolution	$15''$ HPD	$15''$ HPD
Min. resolving power ($E/\Delta E$)	300	3000
Field of View (diameter)	$150''$	$150''$
Max. count rate/pixel	10^4 counts/sec	10^4 counts/sec

The halo absorption features can be modeled (poorly) as gaussians:

Atom	I_0	E (keV)	FWHM (eV)
Fe	5%	7.115	114.2
Si	7%	1.832	95.1
Mg	7%	1.300	53.2
O	20%	0.536	26.6

where I_0 is the peak absorption percentage, relative to the "continuum".

Halo intensity (1-2 keV, $100''$): $\sim 10^{-4}\,\mathrm{ph/cm^2/s/keV/arcmin^2}$
Extraction Region: $15'' \times 100''$ arc

$\rightarrow \sim 2.1\,\mathrm{cts/s/keV}$

Assume 10 ksec exposure, 5 eV bins
$\rightarrow \sim 200\,\mathrm{cts}/5$ eV bin

Total source flux: $\sim 0.9\,\mathrm{ph/cm^2/s}$ (just at count rate limit)

From Mauche & Gorenstein (1986):

Future imaging observations of X-ray halos offer promising refinements of the grain parameters derived in this paper, particularly in light of the potential reduction in the amount of mirror scattering offered by the next generation of X-ray mirrors. The enhanced energy resolution of the latest imaging detectors will as well allow a detailed investigation of the elemental composition of interstellar grains, which relies on a comparison of the intensity of a source's halo on either side of an absorption edge.

- Con-X will easily measure absorption features in the X-ray halos of bright sources.
- ISM gas- and dust-phase abundances are poorly understood, due to discrepancies between dust models of extinction and absorption measurements.
- Chandra and XMM observations can be used to model other grain parameters (size distribution, position)
- Observation relies on Con-X's non-dispersive energy resolution and effective area at 0.5-2 keV.
- Very bright sources would be usable if a filter were available, either movable or covering a portion of the detectors
- Off-detector bright sources require *excellent* baffles.
- Possibly a rectangular (16x64?) array instead of a square 32x32?