ORIGIN OF GEMS: COMPARISON OF FE L-EDGE EXTINCTION IN THE ISM WITH SYNCHROTRON X-RAY ABSORPTION

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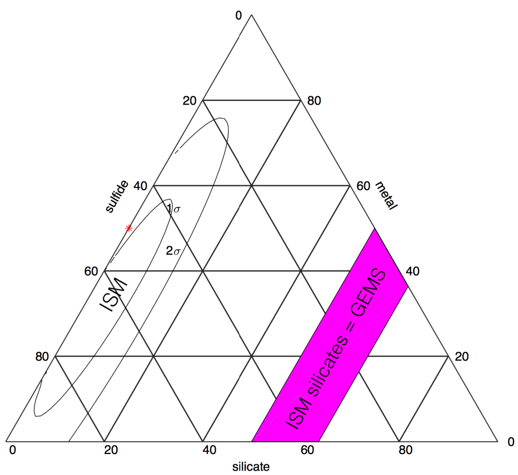
Introduction: Chondritic-porous Interplanetary Dust Particles contain abundant, enigmatic amorphous silicates called GEMS (Glass with Embedded Metals and Sulfides). GEMS have variously been proposed to have an interstellar [1,2] or solar system origin [3], based largely on transmission electron microscopy studies and comparison to the inferred properties of interstellar silicates. Here we directly compare the Fe L-edge extinction spectra of the ISM, measured by *Chandra*, with the extinction spectra derived from absorption spectra of GEMS measured by scanning transmission x-ray microscopy (STXM).

ISM observations: We used data from a 51-ksec *Chandra* High Energy Transmission Grating exposure of an outburst of the X-ray binary XTE J1817–330. We combined the first-order Medium Energy Grating MEG+1 and MEG-1 spectra, focusing on energy range at 0.6 – 0.9 keV.

Synchrotron observations: We acquired Fe L-edge absorption spectra (700-740 eV) at the Advanced Light Source Beamline 11.0.2 (STXM). Samples included previously characterized Fe metal, troilite, and several GEMS from chondritic-porous IDP RB-12A31-2. GEMS were verified by TEM and matched with the STXM Fe stacks (absorption images with 50nm spatial and ~100meV energy resolution).

Analysis and synthesis: Extinction features in astronomical data include both absorption and scattering [4]. Overabsorption in optically thick ISM dust can lead to suppression of spectral resonance features. To calculate expected extinction profiles of ISM dust, we first derived optical constants f_1 and f_2 of metal, sulfide and GEMS from our synchrotron measurements using the Kramers-Kronig dispersion relation [5]. We then calculated scattering and absorption cross sections from the optical constants using Mie scattering theory [6], and integrated cross-sections over the WD01 interstellar dust size distribution for silicates [7] to calculate an extinction profile. The calculations assumed that any metals and sulfides consisted of optically thin decorations or inclusions on or within silicates. Overabsorption of ISM dust is accounted for in the Mie scattering calculation. We then used the extinction profiles for metal, sulfide and GEMS, along with a Gaussian model of the continuum, to find a least-squares fit across the fractional metal-sulfide-GEMS parameter space. We also varied upper cutoffs in the size distribution to explore the effects of scattering and overabsorption.



Results: We found that the best fit to the *Chandra* data (χ^2=372 for 304 d.o.f.) corresponded to comparable fractions of Fe in metal and sulfide, with <15% of Fe in GEMS. This corresponded to a dust distribution with 40nm-radius cutoff at the upper end of the size range. Removing the cutoff entirely gave a significantly worse fit to the data, but was still inconsistent with a major fraction of Fe in GEMS.

Discussion: We consider the hypothesis that interstellar silicates are similar in composition and mineralogy to GEMS. Assuming that the average Fe/Si ratio in GEMS is 0.44-0.56 [3], and the cosmic Fe/Si=0.88, the remaining Fe would then be in metal or sulfide; the fraction of Fe in GEMS would then be ≥0.50. We find that the Fe GEMS fraction is <0.15 (2σ), so we reject the hypothesis that interstellar silicates consist of GEMS-like objects, and, therefore, that GEMS in CP-IDPs consist principally of unaltered interstellar silicates. This is similar to the conclusion reached by Keller and Messenger [3].

Pre-edge features in the x-ray extinction spectra are sensitive to the fraction of the largest particles (radius >100nm). The lack of features in the Chandra extinction spectra that are indicators of overabsorption and scattering by large particles may allow constraints to be placed on the structure of IS dust, and may be more consistent with fluffy aggregates in the ISM [8,9] rather than compact particles.

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