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November 28, 2007

Astronomy and Astrophysics
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Comment on
“The shape and composition of interstellar silicate grains”

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In the paper entitled “The shape and composition of interstellar silicate grains” (A & A, 462, 667-676 (2007)), Min et al. explore non-spherical grain shape and composition in modeling the interstellar 10 and 20 µm extinction features. This progression towards more realistic models is vitally important to enabling valid comparisons between dust observations and laboratory measurements. Min et al. proceed to compare their model results with GEMS (glass with embedded metals and sulfides) from IDPs (interplanetary dust particles) and to discuss the nature and origin of GEMS. Specifically, they evaluate the hypothesis of Bradley (1994) that GEMS are interstellar (IS) amorphous silicates. From a comparison of the mineralogy, chemical compositions, and infrared (IR) spectral properties of GEMS with their modeling results, Min et al. conclude: “GEMS are, in general, not unprocessed leftovers from the diffuse ISM.” This conclusion is based, however, on erroneous and incomplete GEMS data.

It is important to clarify first that Bradley (1994) never proposed that GEMS are unprocessed leftovers from the diffuse ISM, nor did he suggest that individual sub-nanogram mass GEMS are a representative sampling of the enormous mass of silicates in the diffuse ISM. Bradley (1994) simply showed that GEMS properties are consistent with those of IS amorphous silicates. It is widely accepted that circumstellar outflows are important sources of IS silicates, and whether GEMS are processed or not, the circumstellar heritage of some has been rigorously confirmed through measurements of non-solar oxygen (O) isotope abundances (Messenger et al., 2003; Floss et al., 2006). Keller et al. (2000) assert that even GEMS without detectable O isotope anomalies are probably also extrasolar IS silicates because they are embedded in carbonaceous material with non-solar D/H isotopic composition. (Much of the silicate dust in the ISM may be isotopically homogenized (Zhukovska et al., 2007)). Recent measurements show that the elemental compositions of GEMS with non-solar isotopic compositions are “remarkably similar” to those with solar isotopic compositions (Keller & Messenger, 2007). About 80% of all isotopically anomalous IS silicates identified to date are GEMS with detectable and variable O isotopic memories of a circumstellar ancestry (Messenger, 2007).

Bradley (1999) proposed that GEMS are IS silicates from “a presolar interstellar molecular cloud, presumably the local molecular cloud from which the solar system formed.” Although based on incorrect data (detailed below), Min et al. propose that most GEMS actually formed in the presolar molecular cloud, and they further propose that none of them are IS silicates. IS silicate sources include molecular clouds, circumstellar outflows, supernovae, and even recently discovered black hole winds (Molster & Waters;
2003; Jones, 2005; Zhukovska et al. 2007; Markwick-Kemper et al. 2007). The average IS 10 µm extinction feature observed along lines of sight towards the galactic center (modeled by Min et al.) presumably provides a good average for IS silicates, but it cannot distinguish amorphous silicates originating in the presolar molecular cloud from amorphous silicates originating in other interstellar molecular clouds or indeed other sources of amorphous IS silicates. Even if most GEMS accreted in the presolar molecular cloud, then they must also be representatives of some portion of the IS amorphous silicate population. Laboratory heating experiments indicate it is highly unlikely that GEMS were modified in a protoplanetary accretion disk environment (Brownlee et al. 2005).

In claiming that the properties of GEMS are inconsistent with their IS grain modeling results, Min et al. make the following mischaracterizations of the bulk properties of GEMS:

(1) “Preliminary observations indicate that iron sulfide inclusions are located preferentially at the edge of grains (Keller et al., 2005).” Min et al. cite this experimental evidence to link GEMS formation to the presolar molecular cloud environment of the solar nebula. However, the supporting reference they cite (Keller et al., 2005) does not show that sulfides are located at the outer edges of GEMS. While there may be examples of GEMS with sulfides located preferentially at the edges, published data on GEMS show sulfides uniformly dispersed throughout their interiors (e.g. Dai & Bradley, 2005), as well as sulfides located preferentially within their interiors (e.g. Bradley, 1994; Bradley et al., 1997; Westphal & Bradley, 2004). Sulfides are not located preferentially at the outer edges of GEMS.

(2) “The average GEMS silicate has (Mg+Fe)/Si ~ 0.7 (Keller and Messenger, 2004), much lower than we derive....” Keller and Messenger, 2004 did not report on the compositions of the amorphous (glassy) silicate matrices in GEMS.

(3) “This gives O/Si ~ 2.7 in the GEMS silicates.” Min et al. did not measure the O/Si ratio in GEMS, and neither did Keller & Messenger (2004). Instead they estimated this ratio by assuming a crystalline silicate (pyroxene) O/Si stoichiometry. However, stoichiometry cannot be assumed in glasses and instead must be measured directly (Keller & MacKay, 1997). Measured average bulk O/Si ratios reported in the literature for GEMS, where O and Si are entirely in the glass, range from 3.6 to 4.0 (Bradley, 1994; Bradley & Ireland, 1996). These values are consistent with O/Si ~3.5 calculated for IS silicates by Min et al. They fail to cite references that measured the O/Si ratio.

(4) “the spectral position of the maximum absorption reported for GEMS is around 9.3 µm (Bradley et al., 1999a), while it is around 9.7 µm in the ISM.” In fact, Bradley et al. 1999a report absorption maxima ranging from 9.2 to 9.8 µm. Bradley et al. 1999b (also referenced in Min et al.) report absorption maxima in GEMS-rich specimens ranging from 9.3 to 10.4 µm, and more importantly, an absorption maximum in a rare “pure” GEMS specimen at 9.7 µm, again consistent with the 9.7 µm feature of IS silicates reported by Min et al.
In summary, Min et al. conclude from their modeling of the shape and composition of IS silicates that the properties of GEMS are generally inconsistent with those of IS silicates. First, it has been rigorously confirmed via ion microprobe measurements that some GEMS are indeed presolar IS silicates. Second, regardless of whether GEMS, or components of GEMS, originated in presolar circumstellar outflows or a presolar molecular cloud they are all IS silicates. Third, key GEMS data reported in Min et al. are inaccurate. Had complete isotopic, chemical, mineralogical and infrared (IR) spectral properties of GEMS been considered, Min et al. may have concluded that the properties of GEMS, although not an exact match, are generally consistent with those of amorphous silicates in the ISM.

References:


This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory in part under Contract W-7405-Eng-48 and in part under Contract DE-AC52-07NA27344.