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Rusty old stars: a source of the missing interstellar iron

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Iron is the most important missing element in interstellar space. It is depleted by 90–99% and is believed to occur mainly in a solid form. This solid remains undetected. Interstellar dust forms in the ejecta of evolved stars. Using the *Spitzer Space Telescope*, we present the first strong evidence that these stars produce metallic iron grains, and that in some stars metallic iron is the dominant dust product. We find some evidence that iron oxide also forms, suggesting that the primitive iron oxide discovered in the Solar System originates from such stars. Our results indicate that the missing iron is in metallic form, and this metallic iron is a major constituent of interstellar dust.

Rusty old stars

A source of the missing interstellar iron?

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Why is iron missing?

Iron is depleted from the gas phases of the interstellar medium, planetary nebulae and post-AGB stars (1,2,3). It must start condensing into some solid form before the star leaves the AGB. Silicate dust produced by AGB stars is iron-poor (4,5). Iron is therefore expected to condense as metallic grains (4).

Why is metallic iron so hard to find?

Unlike most circumstellar dust species, metallic iron does not create any infrared spectral features, producing only a modified blackbody. This means the only tracer of circumstellar iron is the excess emission it creates in the mid-infrared, compared to a 'naked' star (Fig. 1).

Can't other things produce a similar excess?

Yes, they can. Molecular shells and very large silicate grains can, but either don't produce a smooth continuum or the right amount of flux between 3-8 microns. (Fig. 2). A hot chromosphere would produce an excess too, but the densities and temperatures required to produce that much near-IR emission are implausible. The remaining possibility is amorphous carbon, but large quantities of carbon-rich dust can only be produced in oxygen-rich stars when CO dissociates, in which case you would expect both oxygen and carbon rich dust.

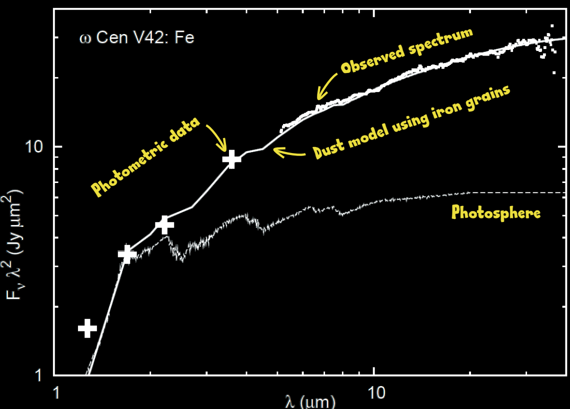

Fig. 1 - Infrared spectrum of the AGB star omega Centauri V42

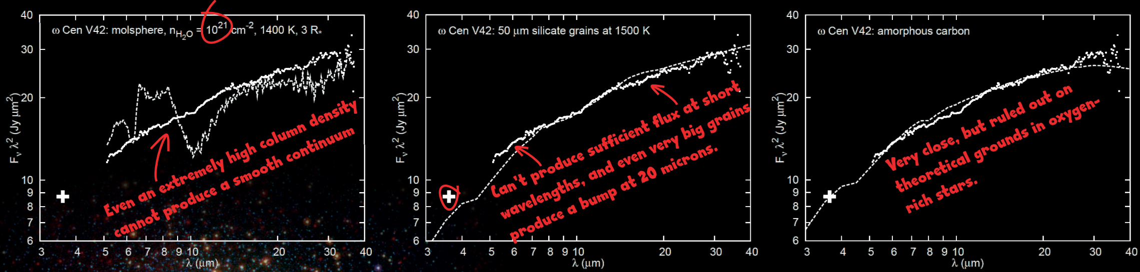

Fig. 2 - Alternative explanations for the mid-infrared excess

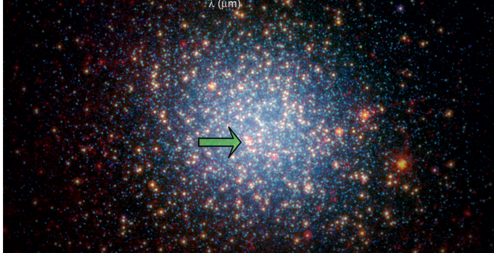

Fig. 3 - Spitzer's view of omega Centauri, V42 is highlighted. (Credit: NASA/JPL-Caltech/NOAO/AURA/NSF)

What's special about these observations?

Previous observations (5,6) showing evidence for circumstellar iron grains found other, oxygen-rich dust species there as well. The concern was that this could be due to other dust species, or combinations of the above effects which are then obscured by emission from the oxygen-rich dust. Our observations of 35 oxygen-rich AGB stars in 19 globular clusters (e.g. Fig. 3) show that many of these stars have no other significant dust species present. The lack of oxygen-rich dust means it cannot be amorphous carbon, and our clear view of its emission lets us rule out other possibilities.

Where does the rust fit in?

A 20-micron bump attributed to FeO is seen in several stars (Figs. 4,5; also (7,8)), but only in stars hosting silicate dust, and not in the most luminous objects. We theorise this is due to oxidised iron being ejected from otherwise magnesium-rich silicate grains.

Want to know more?

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arXiv/1005.3489

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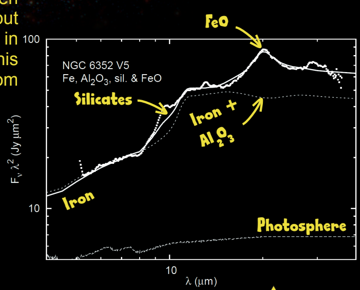

Fig. 4 - Star showing emission from FeO grains along with other oxygen-rich dust.

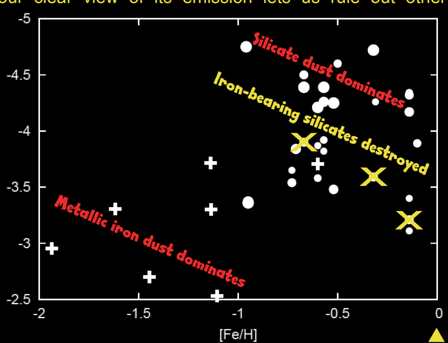

Fig. 5 - Dust production in various clusters. + = only iron dust; o = silicate and iron dust (size indicates silicate strength); x = FeO, Fe and silicates.