Dust in the wind: the mineralogy of newly formed dust in Active Galactic Nuclei

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Active galactic nuclei
The nucleus of active galaxies consists of a supermassive black hole surrounded by an accretion disk and a dusty torus, with different viewing angles giving rise to different phenomenological descriptions (Figure below from Torres & Anchordoqui 2004). It is believed that the torus is a dynamical structure, comprising continuous formation of dust in the disk wind (Elitzur & Shlosman 2006).

Silicates in the dusty torus
The main dust constituent in the torus is believed to be silicate, which exhibit strong resonances at 9.7 and 18 μm. Radiative transfer calculations of the dusty torus have shown that, depending on the viewing angle, the silicates should appear in either emission or absorption (Pier & Krolik, 1992). The detection of silicate emission features (Siebenmorgen et al. 2005, Hao et al. 2005, Sturm et al. 2005) is considered evidence for the unified model.

Sample selection and mineralogical modelling
While silicate emission features are common in the mid-infrared spectra in galaxies, as indicated by the objects with positive silicate strength in the plot directly left (from Shi et al. 2006), the mineralogy of these silicates has not been studied in detail. It is clear that the silicates seen towards quasars differ from the interstellar silicate observed towards the Galactic Center. Elvis et al. (2002) have first explored the idea of dust formation in the quasar wind, and we developed a dust mineralogy model (Markwick-Kemper et al. 2007), that we are currently further improving, to fit the composition of the dust. We select a sample of quasars by requiring them to have IRS spectroscopy available, showing silicate features in emission. Most of these sources have by now been reported by Shi et al. (2006) and Hatziminaoglou et al. (2015). In addition, a good 60 or 70 μm photometric measurement from Herschel-PACS (Petric et al. 2015) is required to estimate the continuum emission longwards of the 18 μm feature.

We have constructed an initial sample of 38 sources and applied our improved fitting method, which, unlike the method by Markwick-Kemper et al. (2007), fits the continuum emission and the dust features at the same time. Below are three sample results with amorphous olivine (pink dashed); alumina (pink); MgO (blue); crystalline forsterite (green dashed) and amorphous forsterite (green). The total fit is shown in red.

The fit results over our sample of 38 PG quasars with silicate emission features are shown below. The boxes indicate the extent of the second and third quartiles in the data, with the thick horizontal line marking the median value. The diamond marks the mean value. The whiskers on either side of the box indicate the full spread of the measurement with a maximum of 1.5 the box length. Further outliers are shown as open circles. The majority of the dust is in the form of olivine or alumina, with slightly less MgO. Mg-rich olivine is relatively rare, and only a small fraction of the silicates (forsterite) are crystalline. The average crystallinity of silicates in our sample is 2.5%, and a significant fraction of quasars are more crystalline than the <2% reported for the local ISM (Kemper et al. 2004).

Comparison with other results
While we have been able to fit the IRS spectra of quasars with silicate emission features using mixed grain compositions, other groups have included grain porosity to achieve good fits (Li et al. 2008; Smith et al. 2010) for a handful of objects (see figure bottom left), while Nikutta et al. (2009) argue that the shift in the 9.7 μm feature may be a radiative transfer effect, and demonstrated this for one object (bottom right).

The mineralogy of PG quasars
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References

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