PANEL B1: STELLAR EVOLUTION

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Abstract

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1. Introduction

The Stellar Evolution Panel met twice during the conference, with twenty-one conference participants signing-in at these discussions. As a result of the discussions, two major programmes were identified as suitable for executing with FIRST: (a) Complete spectral scans, principally with HIFI, of a number of bright archetypal evolved stars having extensive molecular envelopes; (b) An imaging survey to seek fossil dust shells around evolved stars at many different evolutionary stages. The imaging survey should be initiated using SPIRE, followed by PACS observations of those targets having shells detected by SPIRE.

2. Spectral scans of archetype evolved stars

It was agreed that it was highly desirable to obtain complete spectral scans, at HIFI's maximum resolution, for a select number of archetypal oxygen-rich and carbon-rich objects which are known to have rich mm-wave molecular spectra. These observations would serve the following purposes:

- Provide comprehensive line lists and identifications, including those for complex organic molecules in the case of C-rich objects. These line lists and identifications should prove invaluable for a whole range of other science programmes that will be carried out by Herschel (FIRST).
- Probe the chemistry and excitation conditions in the outflows, and thus the evolutionary history of the objects.
- Probe the structure and dynamics of the outflows from these objects, from their inner to outer regions.

The panel estimated that complete spectral scans with HIFI would require about 50 hours per target. Six targets were initially identified, implying that 300 hours in total would be needed for this subprogramme. Complementary spectral scans at shorter wavelengths using PACS and SPIRE are also desirable, but the required observing times with these instruments are very much shorter than with HIFI. The targets, listed below, were chosen to cover a range of advanced evolutionary phases.

1. IRC+10°216: C-rich AGB star (carbon star)
2. IK Tau (=NML Tau): O-rich AGB star (OH/IR star)
3. AFGL 618: C-rich post-AGB object
4. OH231.8+4.2: O-rich post-AGB object
5. NGC 7027: C-rich planetary nebula
6. VY CMa: O-rich supergiant

3. An imaging survey for fossil dust shells

As in several other areas of astrophysics, there is a 'missing mass' problem in stellar evolution. In cases where both white dwarf masses and initial main sequence masses can be determined (e.g. for certain open clusters with known distances and well-determined main sequence turn-off masses), the sum of the white dwarf mass (0.6–0.9 $M_\odot$) and the planetary nebula ('superwind') mass (0.3–0.5 $M_\odot$) is usually significantly less than the lower limit to the initial main sequence mass implied by the cluster main sequence turn-off. This implies that at some point(s) during the evolution of the star, before it reached the tip of the AGB, significant mass loss took place. The challenge is to identify the stage(s) of evolution during which this mass loss took place.

Although ejected atomic material is rather hard to detect (unless it gets ionized, as during the PN phase), dust particles are much easier to detect and are likely to be be present in any material ejected after the main sequence phase of evolution. The detection of extended dust shells can therefore provide a powerful tracer of previous mass loss events. The IRAS all sky survey led to the detection at 60- and 100-μm of very extended dust shells around a number of evolved stars, e.g. around the N-type carbon star U Ant and the O-rich Mira variable R Hya. However, the dust in such shells had to be relatively warm in order to be detectable at these wavelengths. Herschel (FIRST) will be a much more powerful tool for the detection of extended dust shells, due to its its much longer wavelength coverage, high sensitivity and powerful imaging capabilities. In typical extended ejecta shells, the dust will be heated to temperatures of 10-30 K by the interstellar radiation field, corresponding to Planckian re-emission

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peaking at wavelengths between 100 and 300 μm.

It is proposed that the imaging photometers in SPIRE and PACS be used to map the environs of about 100 evolved stars, at six wavelengths between 90 and 500 μm. The targets should be chosen to cover a wide range of evolved stellar types across the HR diagram, with preference given to targets at high galactic latitudes in order to minimise contamination by Galactic cirrus emission. Since SPIRE can map larger areas more quickly than PACS, the first part of the survey should consist of simultaneous imaging at 250, 350 and 500 μm of 8$\times$8 arcmin fields around each target, requiring about 2.5 hours per target, i.e. 250 hours altogether. This is expected to deliver a 1σ sensitivity of 1 mJy/pixel. A further 250 hours should be allocated to follow-up photometric imaging with PACS, at 75, 110 and 170 μm, of those targets around which SPIRE mapping observations have detected extended dust shells. The overall wavelength coverage from 75-500 μm using 6 filters should lead to an excellent characterisation of the temperatures and masses of the detected dust shells. [A useful by-product of this programme should be the acquisition of some striking publicity images for Herschel (FIRST).]

4. Summary

Part (a) of the proposed programme, consisting of complete spectral scans with HIFI of approximately six archetypal evolved sources, is estimated to require about 300 hours of observing time. Part (b) of the proposed programme, the survey for fossil dust shells around a range of evolved stars, using SPIRE and PACS, is estimated to require about 500 hours of observing time. Our total observing time estimate for these two key programmes is therefore 800 hours.