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SDP *Herschel*/HiFi results from post-AGB sources

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The telescope and all telescopes sub-systems are performing as expected, and so the data are of very good quality. The high spectral resolution provided by the heterodyne detection technique allows the detection of spectra of high velocity resolution (always better than 1 km/s), in which the different dynamical components of the nebulae can be clearly separated and identified.

This data allows, for the first time, systematically study of the warm molecular component in these objects, including in particular the study of thermal lines of water vapor, which of course cannot be done from the ground.

In this poster we summarize the very first results on pPNe and PNe obtained with *Herschel*/HiFi. In particular we note the detection of intense emission from the bipolar fast flows in the C-rich pPNe CRL 618. A crude comparison with the existing models for the source, indicates that this emission comes from the base of the very fast shock-accelerated jets. Results on additional sources, like NGC 6302, the Red Rectangle, and others, are also discussed.

SDP Herschel*/HIFI** results from post-AGB sources

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ABSTRACT The first Herschel/HiFi data on pPNe and young PNe are being obtained, providing, for the first time, systematic observations of high-excitation molecular lines from these sources with high spectral resolution. The telescope and all telescope sub-systems are performing as expected, and so the data are of very good quality. The high spectral resolution provided by the heterodyne detection technique allows the registration of spectra of high velocity resolution (always better than 1 km s^{-1}), in which the different dynamical components of the nebulae can be clearly separated and identified. This data allows for the first time to systematically study the warm molecular component in these objects, including in particular the study of thermal lines of water vapor (H_2O), which of course can not be done from the ground. In this poster we summarize the very first results on pPNe and PNe obtained with Herschel/HiFi during the SDP. In particular we note the detection of intense emission from the bipolar fast flows in the C-rich pPNe CRL 618. A crude comparison with the existing models for the source, indicates that this emission comes from the base of the very fast shock-accelerated jets. Results on the O-rich pPN OH 231.8+4.2 and the C-rich PN NGC 7027 are also presented.

1: INTRODUCTION The Herschel Space Observatory was launch in 2009. This is a 3.5 m space telescope designed to work at sub-mm and far-IR wavelengths (de Graauw et al., 2010, A&A in press). Onboard the satellite there are three scientific instruments, PACS, SPIRE, and HIFI, the Heterodyne Instrument for the Far Infrared. HIFI, see Pilbratt et al. (2010, A&A in press) is a high resolution spectrometer (better than 0.15 km/s), which covers the frequency range between 480 and 1906 GHz (625 to 157 microns), that has been designed to study the warm (100 - 500 K) molecular gas in space.

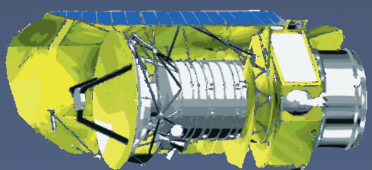
This instrument is the workhorse of the Guaranteed Time Key Program HIFIStars (P.I. V. Bujarrabal), which with a total allocated telescope time of ~ 200 hours, aims to study the warm molecular gas in the CSEs around evolved stars. HIFIStars will mainly observe several lines of CO and of H_2O (in different isotopomers) in CSEs around evolved stars, including C- and O-rich sources, regular and irregular variables, super- and hyper-giants, pPNe and molecular rich PNe. The post-AGB sources included in the HIFIStars sample are: Frosty Leo, The Red Rectangle, OH 231.8+4.2, CRL 618, CRL 2688, IRAS 17436+5003, The Boomerang Nebula, IRAS 22272+5435, NGC 7027, and NGC 6302.

The new Herschel/HIFI ^{12}CO and ^{13}CO observations, which include the rotational transitions J=16-15, 10-9, and 6-5, will probe the the warm molecular gas at in these sources. Thanks to the high spectral resolution of the instrument, the kinematics of this warm component can be studied in great detail, allowing a better understanding of the wind interaction responsible for the shape of pPNe and PNe. Here we present the first results of the HIFIStars program, obtained during the Science Demonstration Phase of the HIFI instrument, for pPNe and young PNe. These results are summarized in Figs. 1 and 2.

2: OBSERVATIONS HIFIStars observations are always performed in dual beam switch (DBS) mode, using the two orthogonal receivers available at each band. At frequencies below 1.2 THz (HIFI bands 1 to 5), the receivers provide an instantaneous IF bandwidth of 4 GHz in double side band mode, which results in a sky frequency coverage of 8 GHz at once. At frequencies above 1.5 THz (bands 6 and 7), the IF bandwidth is only 2.6 GHz, resulting in a total instantaneous sky frequency coverage of 5.2 GHz. As backend, we have used the Wide Band Spectrometer (WBS), an acusto-optical system which covers the full bandwidth provided by the receivers with a resolution of ~1.1 MHz (i.e. from 0.66 to 0.17 km s^{-1}).

The observations have been carefully designed so no strong lines, coming from the two side bands of the receivers, lie on top of each other, but trying to maximize the number of potentially detectable lines within the observed frequency range. This has lead to the detection of many molecular species while observing CO and H_2O (the main target molecules in the proposal), see Fig. 2. The data have been processed with the standard HIFI pipeline using HIPE*** (version 2.8). Later on, spectra have been exported to FITS format, for further processing in CLASS.

3: RESULTS During the Science Demonstration Phase of Herschel/HIFI we have observed the O-rich pPN OH 231.8+4.2, the C-rich pPN CRL 618, and the C-rich young PN NGC 7027. For each source we obtained 4 different spectra targeting the J=6-5, 10-9 and 16-15 lines of ^{12}CO and the J=10-9 line of ^{13}CO (see Fig. 2). These data have been complemented with ^{12}CO data for the J=1-0, 2-1, 4-3 and 7-6 lines, obtained with ground based telescopes (see Fig. 1).



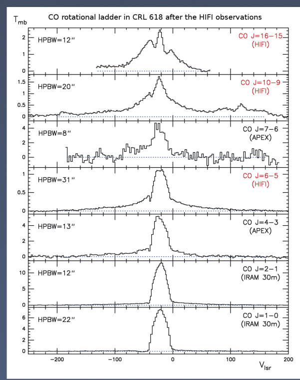


FIGURE 1: Herschel/HIFI data for ^{12}CO in CRL_618. For comparison we also show other rotational lines observed from ground based telescopes (IRAM 30m-MRT, J=1-0 and 2-1; and APEX J=4-3 and 7-6). HPBW sizes for each telescope and transition are annotated in the upper-left corner of each panel. Note how the cool fossil AGB envelope dominates the spectra at low energy transitions (up to J=6-5), while the line wings, due to relatively warm gas, progressively take over as the energy of the levels increases. The J=16-15 is mostly due to the warm gas in the bipolar outflow, plus some contribution from the central shells of the AGB envelope expanding a very low velocity.

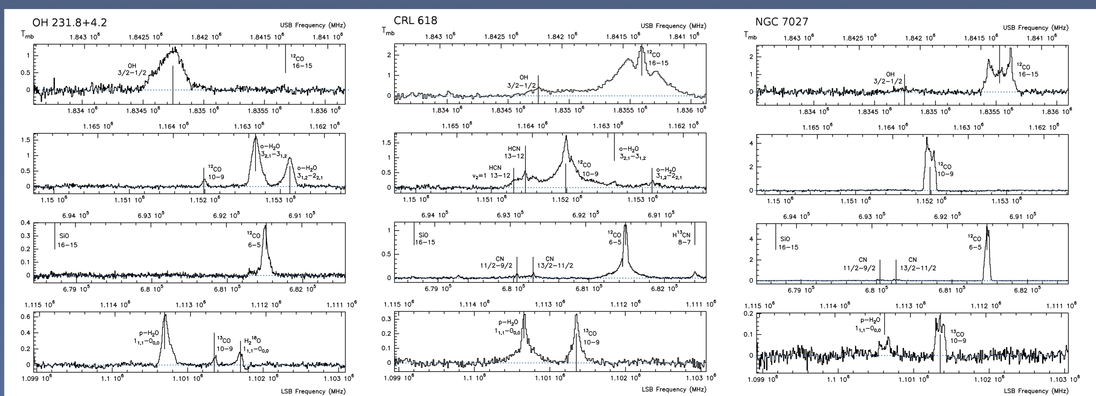


FIGURE 2: The spectra obtained by the HIFIStars project in post-AGB sources during the Science Demonstration Phase of Herschel/HIFI. From left to right, OH 231.8+4.2, CRL 618 and NGC 7027. From top to bottom, the spectra of the observations of ^{12}CO J=16-15, ^{12}CO J=10-9, ^{12}CO J=6-5 and ^{13}CO J=10-9. Due to the large instantaneous bandwidth, other species such as OH, HCN, $H^{13}CN$, H_2O, $H_2{}^{18}O$, CN and SiO are also detected. LSB/USB sky frequencies, w.r.t. the systemic velocity, are indicated in the lower/upper x-axis scale. Lines coming from the LSB/USB are marked in the corresponding x-axis. Note the lack of warm gas in OH 231.8+4.2, as the ^{12}CO J=16-15 (at E_{upp} ~750 K) is not detected, proving that there are not shocks running into the dense molecular envelope in this source, and the strong H_2O and OH lines, as it corresponds to a O-rich target. In spite that they are C-rich sources, both H_2O and OH are also detected in CRL 618 and NGC 7027, as well as ^{12}CO J=16-15 from their warm molecular gas.

*Herschel is an ESA space observatory with science instruments provided by European-led Principal Investigator consortia and with important participation from NASA.

**HIFI has been designed and built by a consortium of institutes and university departments from across Europe, Canada and the United States under the leadership of SRON Netherlands Institute for Space Research, Groningen, The Netherlands and with major contributions from Germany, France and the US. Consortium members are: Canada: CSA, Univ. Waterloo; France: CESR, LAB, LERMA, IRAM; Germany: KOSMA, MPIfR, MPS; Ireland, NUI Maynooth; Italy: ASI, IFSI-INAF, Osservatorio Astrofisico di Arcetri- INAF; Netherlands: SRON, TUD; Poland: CAMK, CBK; Spain: Observatorio Astronómico Nacional (IGN), Centro de Astrobiología (CSIC-INTA). Sweden: Chalmers Univ. of Technology - MC2, RSS & GARD; Onsala Space Observatory; Swedish National Space Board, Stockholm Univ. - Stockholm Observ.; Switzerland: ETH Zurich, FHNW; USA: Caltech, JPL, NHSC.

From left to right, HST archive images of OH 231.8+4.2, CRL 618 and NGC 7027.

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