The Phase Distribution Across the S140 PDR: New Insights from HIFI [CII] Observations

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Introduction:

We report the observation of [CII] emission in a cut through the S140 region together with single pointing observations of hydrides and water in several key regions of the photon-dominated region (PDR) and molecular cloud.

At a distance of 910 pc, the BOV star HD211880 ionizes the edge of the molecular cloud L1204, creating S140, a visible HII region and PDR (e.g. Crampton and Fisher, 1974). In addition, the dense molecular cloud hosts a cluster of embedded massive young stellar objects (YSOs) only 75" from the HII region (e.g. Beichmann et al., 1979; Minchin et al. 1993). We use HIFI on Herschel to observe [CII] in a strip following the direction of the impinging radiation across the ionisation front and through the cluster of embedded YSOs. With [CII], which Emery et al. (1996) report to be fairly extended in the S140 region, we can trace the ionizing radiation and try to disentangle influences of the external (ionizing B star) and internal (massive YSOs) contribution to the radiation.

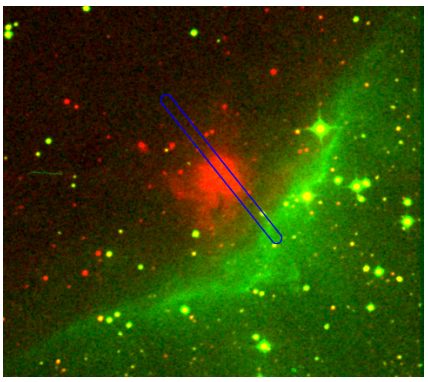


Fig. 1: 2MASS K band (red) and POSS2 red band (green) showing the S140 ionization front and the massive star forming region around IRS1. Overlayed in blue is the outline of the [CII] cut.

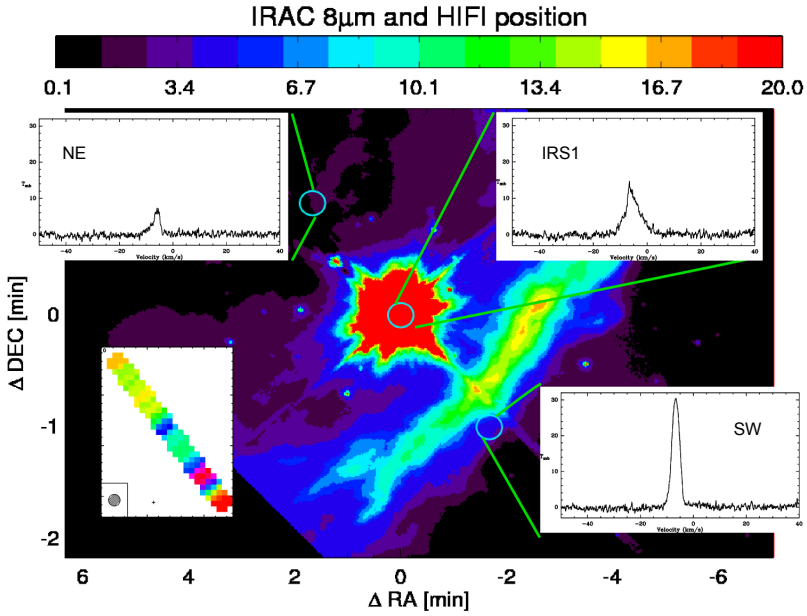


Fig. 3: [CII] emission over-plotted on Spitzer 8µm color-image. The circles correspond to the locations of the three HIFI single pointing positions. For this plot, the spectra from the cut where averaged in the respective locations to show the line profiles. NE is a quiet position deep in the molecular cloud, IRS1 is the center of massive star forming activity and SW corresponds to the ionization front of the PDR. The strip shows the integrated intensity along the cut.

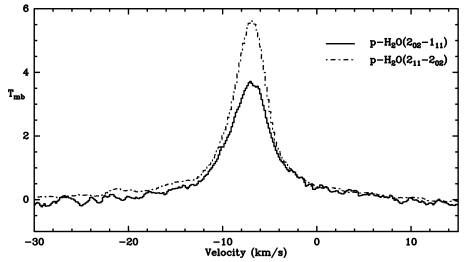
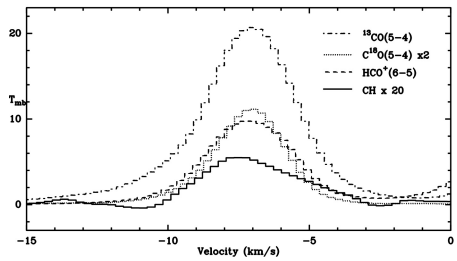


Fig. 2: Water emission lines at 752GHz and 987GHz towards the IRS1 position.

Discussion:

One can see that the [CII] emission is widespread throughout the cut. The strongest emission is as expected coming from the interface of the PDR. Comparison with the Spitzer 8µm emission shows that there might be a contribution from ionized gas at the SW position. There is another peak of [CII] emission at the position of IRS1.

It is noticeable how broad the line emission in IRS1 is, a trend which is also seen in the remaining molecular lines. Comparing the line profiles of several species in both IRS1 and the PDR, the lines in IRS1 show broad wings, which can also be seen in the two water transitions, indicating the presence of hot, and in the case of the water lines, shocked gas. While most of the species are 2-3 orders of magnitude weaker in the PDR, the light hydride CH is seen in similar strength both in IRS1 and in the PDR. CH is enhanced by FUV irradiation in the PDR. It has been predicted to be similarly enhanced by protostellar FUV in the outflow walls (Bruderer et al. 2010).



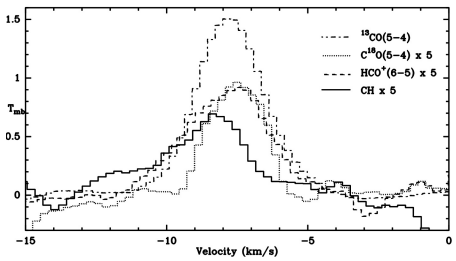


Fig. 4 (left): Line profiles in the IRS1 position in the molecular cloud. Fig. 5: (right): Line profiles in the PDR position. Note that some emission has been rescaled for better comparison.

Conclusions:

Preliminary analysis of the first Herschel-HIFI data has shed light on the spatial distribution of the [CII] emission across the S140 region. While the [CII] emission is strongest in the PDR interface, there are significant, and very broad, contributions from the molecular material. The stratification towards the PDR that can however be seen in the [CII] intensity supports the claim that the ionizing B star is illuminating the region from the side and not from above. The existence of a hot, shocked component in IRS1 is also hinted at in the broad wings of several molecular species.

After this first look, the line profiles will be analyzed to disentangle different components with HIFIs high spectral resolution and the chemical and physical conditions in the different regions will be modeled, giving particular emphasis to the light hydrides and their ions that are unique to the Herschel spectral range.

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