A Herschel Study of the Helix nebula

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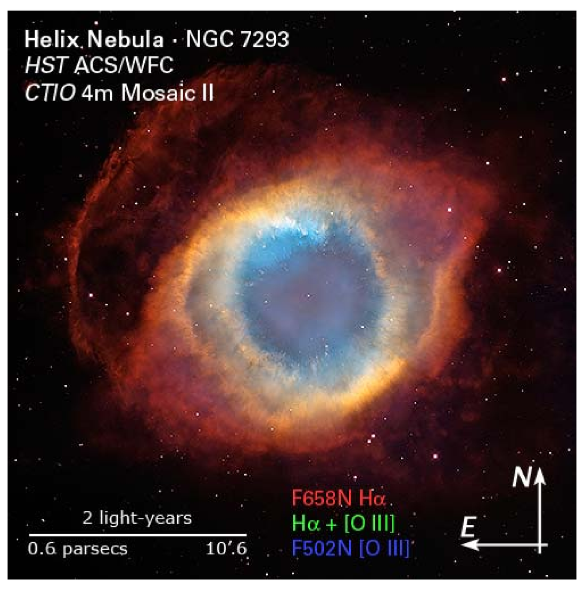
Abstract :

The Herschel Guaranteed Time Key Project MESS (Mass loss of Evolved StarS) aims to investigate mass loss from evolved stars (Groenewegen et al. 2011, A&A, 526, A162). The main goals of the project are three-fold: 1) to study the time dependence of the mass loss process and quantify the total amount of mass lost, 2) to study the dust and gas chemistry as a function of progenitor mass, and 3) to study the properties and asymmetries of the dust shell.
In this poster we present results of the Herschel PACS and SPIRE imaging of the dust shell around the planetary nebula NGC 7293.

The Helix Nebula NGC 7293

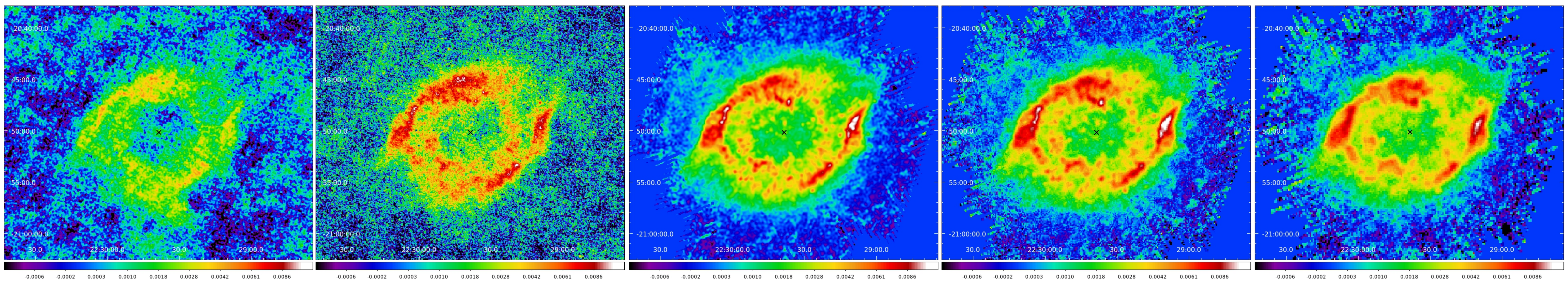
Although named for its resemblance to a coiling spiral seen face on, the Helix Nebula has a more complex three-dimensional structure. It is the closest planetary nebula to earth at a distance of 216 pc. Because the Helix is so close, we can see more details of its fine structure. The most striking feature of the Helix, first revealed by ground-based images, is its collection of thousands of distinct cometary knots. Spitzer IRAC images showed that the Helix is clumpy at very small scales.



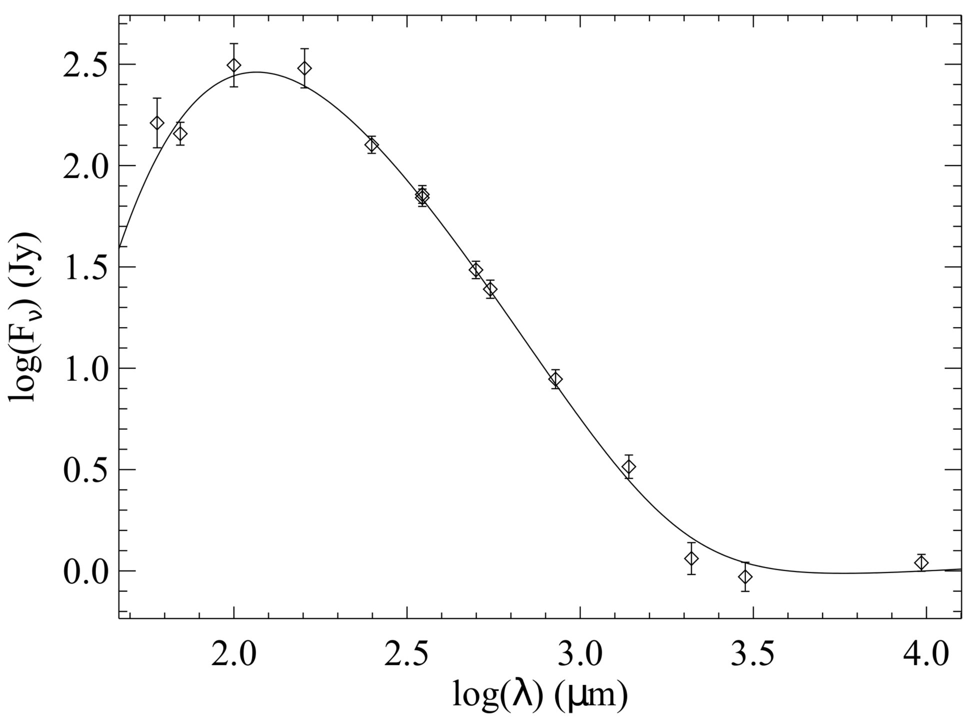
Data:

The Helix was observed at 70 μm and 160 μm with PACS and with SPIRE at 250, 350, and 500 μm in parallel mode. We also retrieved the MUST DO (MD) Spire images at 250, 350, and 500 μm. The latter have a smaller FOV, but are deeper than the images obtained in parallel mode. All data were reduced up to level 1 within the data processing package HIPE (Ott, S., 2010, ASP Conf. Series, 434, 139) . Subsequently the PACS and SPIRE images were made with the code Scanamorphos (Roussel H., 2013, PASP, 125, 1126).

Images (below): From left to right: PACS 70, 160 μm parallel mode and SPIRE 250, 350, and 500 μm MD images in Jy/pix. The PACS 70 image was convolved to the PACS 160 beam using the convolution kernels of Aniano et al. (2011, PASP, 213, 1218) with flux conservation. The central star is indicated with a black cross.



- We see a clumpy inner and outer dust ring. There is an intrusion from the northern part of the inner ring towards the center. The outer ring seems opened up in the NW. In the NNW and SSE are some brighter extensions.
- We detect the debris disk around the central star (Su et al. 2007, ApJ, 657, L41) only at 70 μm. Its flux is 239 ± 24 mJy. Based on Spitzer MIPS 24 μm flux and our upper limits at 160, 250, 350, 500 μm we determined a debris disk dust temperature of ~ 65 K and a dust mass of ~2E-7 $M_{\odot}$.



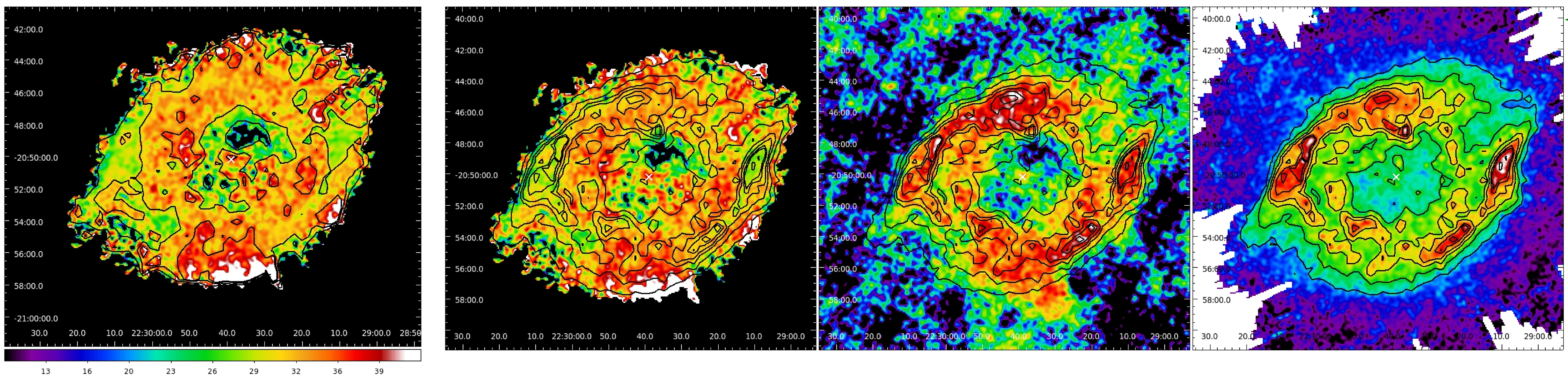
SED of the Helix nebula (left)

We determined the total flux in the Planck images and determined the flux value within the same contour in the PACS and SPIRE parallel mode images. We also determined the IRAS flux values at 60 and 100 μm and added the point at 31 GHz (Casassus et al. 2004, ApJ, 603, 599). The appropriate flux corrections were applied. The resulting SED is shown at the left. A modified black body with a component for free-free emission was fitted to the data. We got a satisfactory fit for:
T_{dust} = 30.8 ± 1.4 K and β = 0.99 ± 0.09.
The result could indicate that the dust in the Helix consists layered amorphous grains (Knapp et al., 1993, ApJS, 88, 173)

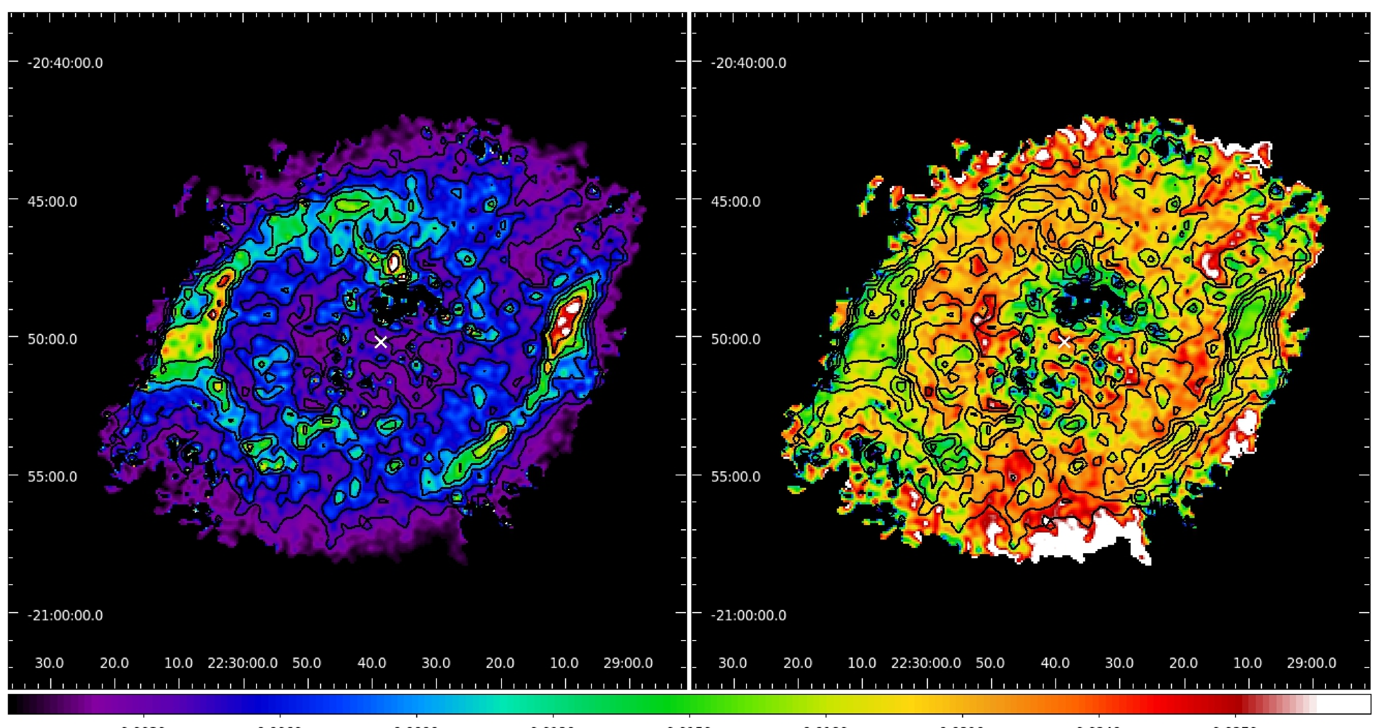
Temperature map of the Helix nebula (below)

The temperature map based on the PACS 70 μm image obtained in parallel mode and the SPIRE 250 μm image obtained in MD time are shown below. These images were convolved to the SPIRE 250 μm beam using the convolution kernels of Aniano et al. (2011, PASP, 213, 1218) with flux conservation. For the conversion of their ratio to the temperature image we used a β-law with β=1.0 as the SED fit indicated.

- The dust temperature is generally between about 22 and 42 K.
- We notice a warmer ring-like structure. This ring-like structure encompasses the fainter inner and brighter outer ring seen in the SPIRE 250 μm image, without the brighter extensions to the SE and NW.
- The temperature in the ring is not at all uniform but reflects the clumpiness of the ring.
- Where the outer ring is broken towards the NW in the SP250 image are clumps of higher temperature as well.
- We notice that the extension in the SE and NW are cooler than the ring. These high opacity regions are further away from the central star and are significantly shielded from direct starlight by this ring.



- The image of the temperature map to the left has the temperature scale below.
- The three images to the right are the temperature map, the convolved PACS 70 μm, and SPIRE 250 μm MD images with the SPIRE 250 μm contours overplotted.
- The white cross marks the position of the central star.



Comparison between dust temperature and dust mass

We calculated the dust mass column density for each pixel based on the temperature map and the SPIRE 250 MD image using the formula of Gledhill et al. (2002, MNRAS, 332, 55). The resulting map in $M_{\odot}$/pc² is presented in the image on the left, the mass column density scale is shown below. The dust temperature map is shown on the right with contours of the dust mass column density map overlaid. The central star is indicated by a white cross.

- The dust mass density image is not at all uniform, but reflects the clumpiness of the Helix nebula.
- At a distance of 216 pc (Benedict et al. 2009, AJ, 138, 1969) the total dust mass of the Helix is 5.2E-3 $M_{\odot}$.
- The dust is warmest in low density regions irradiated directly by the central star, and is cooler in dense regions and regions further away from the central star and/or shielded from direct starlight.

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