The Expanding Orion Nebula

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Overview

We have surveyed a one square degree area centered on the Orion Nebula in the [CII] 1.9 THz line using the heterodyne upGREAT instrument on the Stratospheric Observatory for Infrared Astronomy (SOFIA), resulting in two million spectra at a spatial resolution of 16". This is the first large-scale velocity-resolved map of the [CII] fine-structure emission of this region. These data allow us to study the detailed kinematics of the region. Velocity-resolved studies of the [CII] line are a powerful tool to study the interaction of massive stars with the environing gas. Here, we will focus on the large bubble associated with the Orion Veil, blown by the stellar wind from the central star, Θ^1 Ori C.

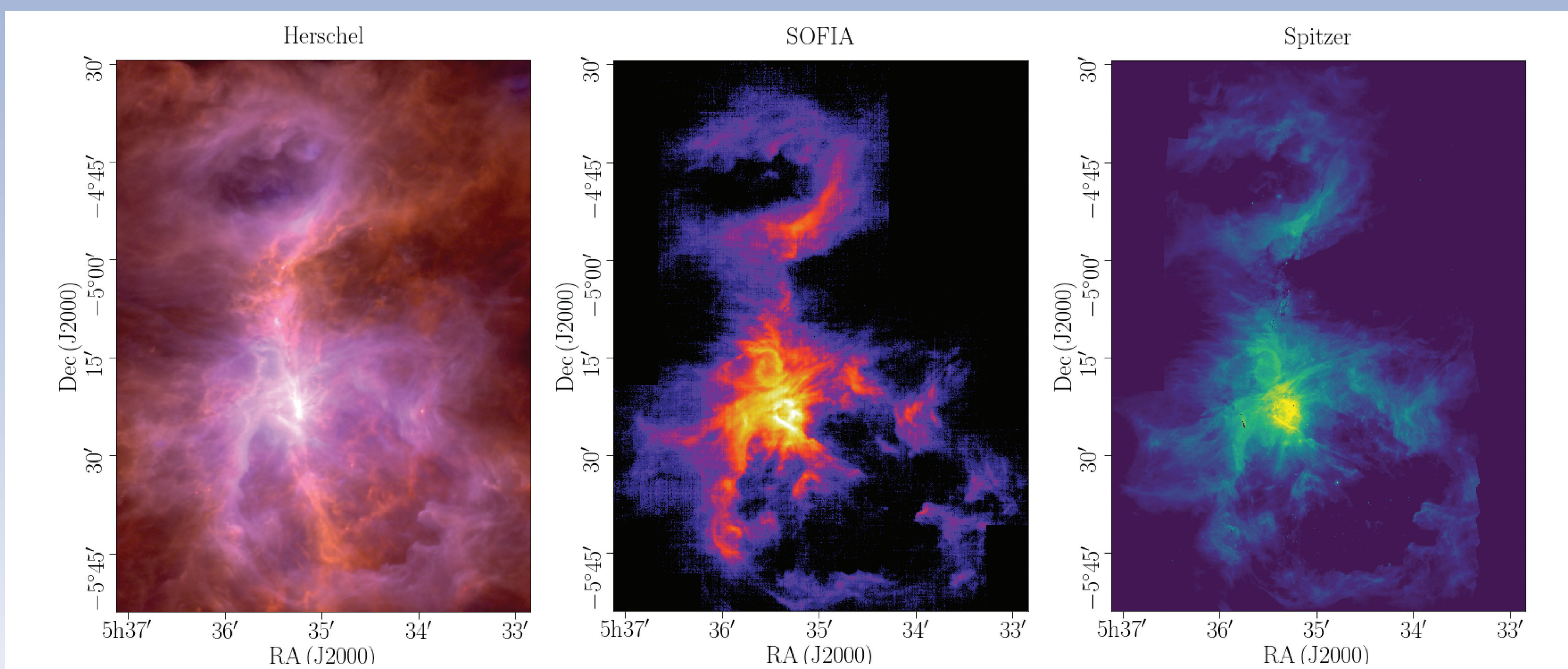

Figure 1: Three-observatory view of the Orion Nebula in the south with the central bright Huygens region, where the massive Trapezium stars with Θ^1 Ori C are located, and the northern bubble associated with NGC 1973, 1975, and 1977. The left-hand panel shows a three color image of the Herschel/PACS 70 µm (blue) and 160 µm bands (green), and the SPIRE 250 µm band (red). The PACS bands probe the UV-illuminated warm dust, whereas the SPIRE band probes colder and denser structures. The middle panel shows the SOFIA/upGREAT [CII] 158 µm emission tracing the warm neutral gas. [CII] probes the radiative and mechanical interaction of the massive stars with the molecular cloud. The right-hand panel shows the Spitzer/IRAC 8 µm emission tracing UV-irradiated PAHs.

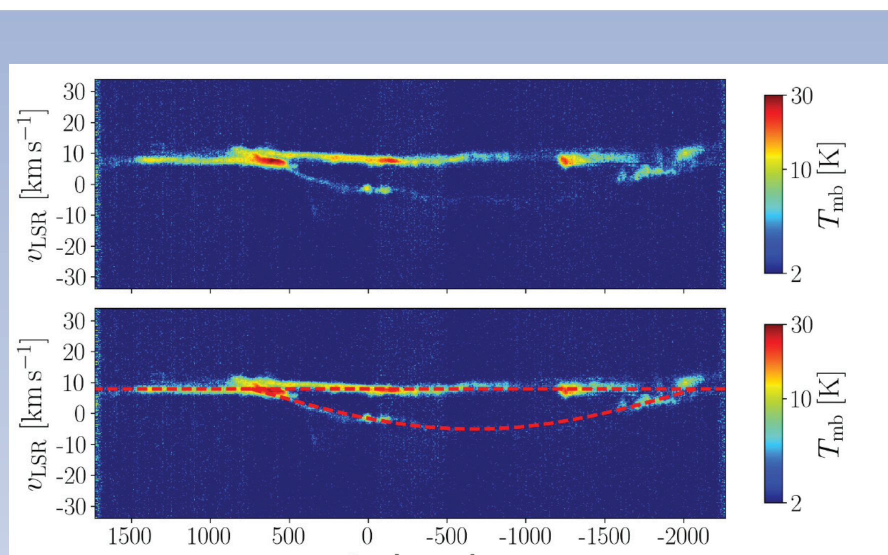

Figure 2: A typical [CII] position-velocity diagram through the center of the Orion Nebula. The expansion of the ~ 2 pc-sized bubble of the Veil can be observed in [CII] as an arc structure. In the lower panel the expected arc structure of an expanding shell with expansion velocity 13 km s^{-1} on a background velocity of 8 km s^{-1} is indicated with red dashed lines. From simple models of wind-blown bubbles (Weaver et al. 1977) we estimate an age of the expanding Veil of 0.2 Myr (Pabst et al., submitted)

Component	Mass M	Thermal Energy	Kinetic Energy	Reference
OMC1 molecular gas	3000	0.6	20	Buckle et al. (2012)
Veil	2600	3	400	Pabst et al. (submitted)
Stellar cluster	1800			Hillenbrand (1997)
Ionized gas	20	3	20	Wilson et al. (1997)
Huygens region	2	0.3	2	Wilson et al. (1997)
Hot gas	0.07	10		Güdel et al. (2008)
Stellar wind	3		500	Howarth et al. (1989), Stahl et al. (1996)

Table 1: Mass and energy budget of the ISM in the Orion Nebula. The kinetic energy of the stellar wind is calculated over the lifetime of the bubble. The mass of the swept up shell is comparable to that of OMC1 and of the newly formed stars, while it much exceeds the mass of ionized gas. The stellar wind mechanical energy is coupled very efficiently to the molecular core and plays a major role in the disruption of OMC1.

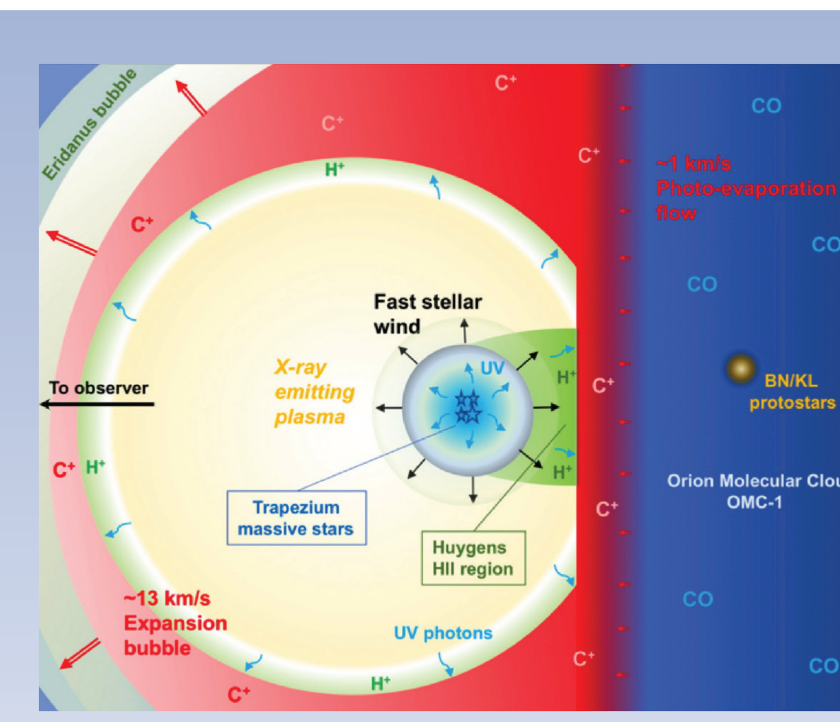

Figure 3: Schematic view of the Orion Nebula region. The central massive Trapezium heat and ionize the surrounding gas. Stellar winds create an X-ray emitting plasma (Güdel et al. 2008) that is surrounded by a [CII] emitting shell. Eventually, the bubble content will be released into the large-scale Eridanus bubble.

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