Protostellar clusters in the Rosette Molecular Cloud

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for the **HOBYS*** consortium and the **SPIRE** Specialist Astronomy Group Star formation in the Galaxy

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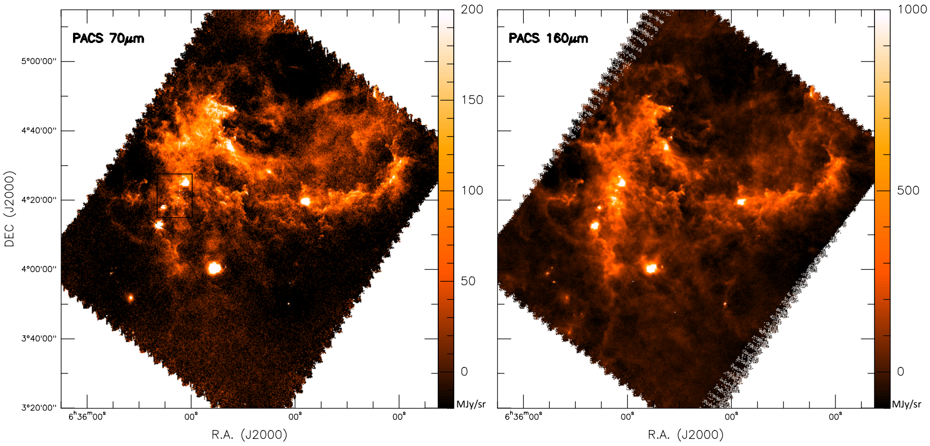
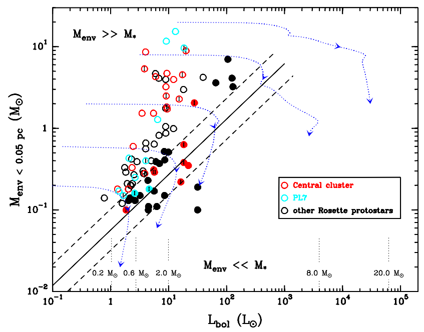
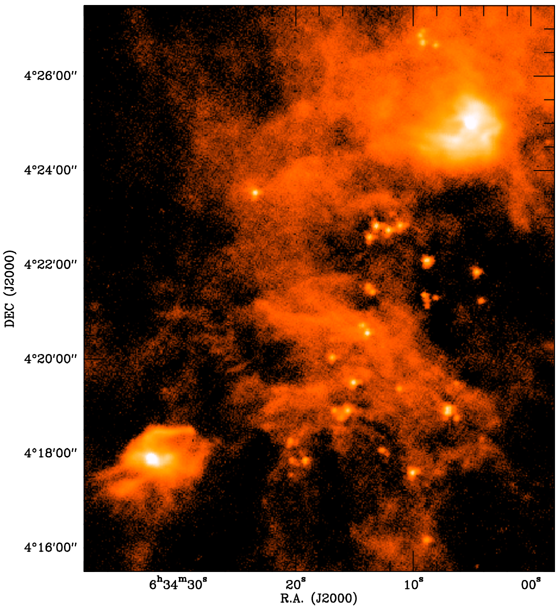
The *Herschel* **OB young stellar objects survey (HOBYS, Motte, Zavagno, Bontemps et al.)** has observed the Rosette molecular cloud providing an unprecedented view of its star formation activity. These new far-infrared data reveal a **population of compact young stellar objects** whose physical properties we aim to characterise. We compile a sample of protostars and constrain key properties in the protostellar evolution: Bolometric luminosity L_{bol} and envelope mass M_{env}. The M_{env} of the analysed protostellar population in Rosette ranges from **0.1 to about 15 $M_\odot$ with L_{bol} between 1 and 150 $L_\odot$** which extends the evolutionary diagram from low-mass protostars into the high-mass regime. Some sources lack counterparts at near- to mid-infrared wavelengths indicating extreme youth. The central cluster and the *Phelps & Lada* 7 cluster appear less evolved than the remainder of the population. We find indication that **about 25% of the protostars in the central cluster classified as Class I from near- to mid-infrared data are actually candidate Class 0 objects**. As a showcase for protostellar evolution, we analyse four protostars of low- to intermediate-mass in a single dense core which represent different evolutionary stages from Class 0 to Class I. Their mid- to far-infrared spectral slopes flatten towards the Class I stage, and the 160 to 70µm flux ratio is largest for the presumed Class 0 source. This exemplifies that the ***Herschel* observations characterise the earliest stages of protostellar evolution in detail**.



Evolutionary stage of *Herschel* protostars in Rosette



The envelope masses and bolometric luminosities are plotted in an evolutionary diagram shown above. Evolutionary tracks are displayed for stellar masses between 0.2 and 20 $M_\odot$. The diagonal lines indicate an approximate border zone between envelope-dominated Class 0 and star-dominated Class I objects based on the comparison of M_{env} to $M_\star$ (*André & Montmerle 1994*). **A surprisingly large fraction of our sample (≈⅔) falls into the candidate Class 0 regime** above these lines. A practical criterion inferred from this diagram is L_{smm}/L_{bol} > 1% for Class 0 (open plot symbols). The classification of objects lying near the border zone remains tentative. Nevertheless, it indicates that ***Herschel* allows us to significantly extend the sample of known Class 0 objects**. Both the central cluster and the PL7 cluster (*Phelps & Lada 1997*) appear younger compared to the remaining protostars.



PACS 70µm map of the Rosette molecular cloud centre. The region harbours the embedded clusters PL4 (north-west), PL5 (south-east), and a concentration of compact *Herschel* sources.

Classification of protostars in the Rosette central cluster[1]

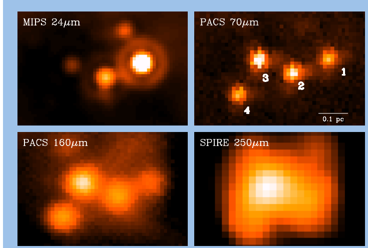
NIR/MIR classification	# total	# Class II	# Class I	# unclassified
Spitzer 24µm sources	83	39	26	18
Visible at 70µm	40 (±3)	10 (±1)	19 (±1)	11 (±1)
In analysed *Herschel* sample	22	1	12	9
Candidate Class 0: L_{smm}/L_{bol} > 1%	14	0	7	7

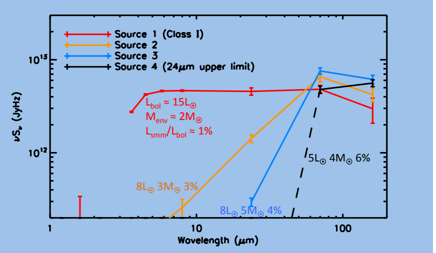
[1]Cluster area: 98.5° < R.A. < 98.6°, 4.25° < DEC < 4.4°

Visual inspection gives a 70 µm detection rate of about 50% for YSOs seen at 24µm. We expect more 70µm detections for Class I than for Class II, we find about ¾ compared to about ¼. Roughly, we include about half of the visible 70µm sources in the analysed *Herschel* sample. About ⅔ of these are Class 0 candidates. This applies to 7 out of 18 unclassified sources which indicates that many of the latter could be Class 0 protostars. **About 25% of 26 previously classified Class I sources are also Class 0 candidates, possibly more.**

Herschel resolves the early protostellar evolution

A particularly interesting large dense core is **resolved into several protostars at 70/160µm**. Four sources are clearly detected at 70µm (sources 1 to 4 from west to east). Based on the *Spitzer* data, source 1 is classified as Class I, the others remain unclassified due to non-detection in one or more of the IRAC bands (source 2 and 3) or non-detection in all near- to mid-infrared bands (source 4).





The SED slopes between 8 and 70µm for sources 1, 2, and 3 become increasingly steep. Beyond 70µm they are more shallow, and the 160 to 70µm flux ratio is the highest for source 4. Due to the assumption of a single dust temperature, the relative mass differences are not well constrained. Similar in mass, the sources represent **successive evolutionary stages from early Class 0 (source 4) to "flat-spectrum" Class I (source 1)**.

References

André & Montmerle, 1994, ApJ, 420, 837

Phelps & Lada, 1997, ApJ, 477, 176

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