The Perseus star forming region at 1 kpc distance:
what we can learn for the distant high mass star forming clouds

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Abstract. Typical distances of high-mass star forming regions (SFRs) are of the order of 1 kpc or more, so the mass distribution derived from the fluxes is artificially cut at the lower end for the limit in sensitivity, while the lack of adequate spatial resolution causes clumping of close sources. These effects must be considered when discussing the properties of a high-mass SFR: the cut in sensitivity turns into a cut in the mass, but the effects of the source confusion are not easy to model. Herschel data provide for the first time images in the 70-500 µm at high spatial resolution (~5" to 36"). We have now the possibility to image the closest low mass SFRs with a high level of detail. As part of the Herschel Gould Belt survey, the SFR in Perseus, forming stars of low- to intermediate mass has been observed by both the PACS and SPIRE Herschel instruments. Here we report the results of a photometric analysis of this SFR both at its native distance of 250 pc and at a scaled 1 kpc distance: we discuss how the lower linear resolution of the more distant cloud affects our understanding of its star-forming properties.

1. It is well known that low mass and high mass star formation can not be described within the same theoretical framework. High mass stars form and evolve faster, following different evolutionary paths, and obeying different physical laws: the two scenarios can not be obtained simply by a mass scaling.

Also observationally, high and low mass star forming regions (SFRs) form two distinct families: low mass SFRs are close to the Earth, at a distance of few 10^2 pc; on the other hand, with the exception of the complex in Orion, high mass SFRs are at distances ≥ 1 Kpc.

It it then not surprising that Herschel KP are targeted either to one or to the other kind of regions: for instance, the Herschel Gould Belt Survey (GBS, André et al. 2010) is aimed to characterize the early phases of low mass stars formation by deriving, eg, the core mass function of the prestellar objects, while HOBYS KP (Motte et al. 2010) has the goal to characterize the clump mass function, where one clump may contain more than one single core. In fact, due to the larger distance of the regions observed inside the HOBYS program, even the Herschel linear spatial resolution is not enough to separate the emission due to different close cores.

A big challenge in studying a high mass star forming regions is then to derive how the intrinsic core mass function is linked to the observed clump mass function. Aim of the present work is to provide some clues to this problem, exploiting the data that are obtained as part of the GBS at high spatial resolution. In particular we use the maps obtained for the Perseus region, that at ~250 pc hosts low- to intermediate mass forming stars, to see the effects of degrading the linear spatial resolution.

2. The Perseus molecular cloud hosts a number of star forming regions at a declination of about 31° and extending in RA from 3.5h (NGC 1333) to 3.8h (IC 348). On the average it is at a distance of about 250 pc. For this work we use a tile of 2°.25x2°.5 centred around NGC 1333 observed in phohometry with Herschel (Pilbrat et al. 2010) as part of the GBS, with PACS (Poglitchs et al. 2010) and SPIRE (Griffin et al. 2010) in parallel mode, at 70, 160, 250, 350 and 500 µm, and with a scanning speed of 60"/s.

Data reduction and map making are described in Traficante et al. (2011). The region will be fully described in an upcoming paper (Pezzuto et al., in preparation): Bressert et al. (in preparation) has derived the spatial correlation between prestellar cores and YSOs, while a small region close to NGC 1333 (B1-E) has been studied using Herschel data as well as ancillary ground based observations, by Sadavoy at al. (submitted to A&A).

To project the maps at 1Kpc we follow these steps: let us consider the map at 70 µm. The map has a pixel size of 3.2", this size has been changed to 0.8" (¼ of its true value) and convolved with a Gaussian beam of FWHM=8.55" and resampled to 3.2". In this way we have simulated the observation of this regione once at 1 Kpc, assuming that the map at 250 pc is the true sky.

Gaussian noise has been added to report its level to the value in the original maps: for the map at 70 µm the value is 13 Mjy/srad. Finally, because in parallel mode the fields of view of the two instruments do not overlap, the two sets of images have been astrometrically registered to a common origin.

3. Source extraction has been done with the CUTEX (Molinari et al. 2010) software that finds possible source based on the second derivative map obtained from the image. In this way 5 lists of sources are obtained, one per band.

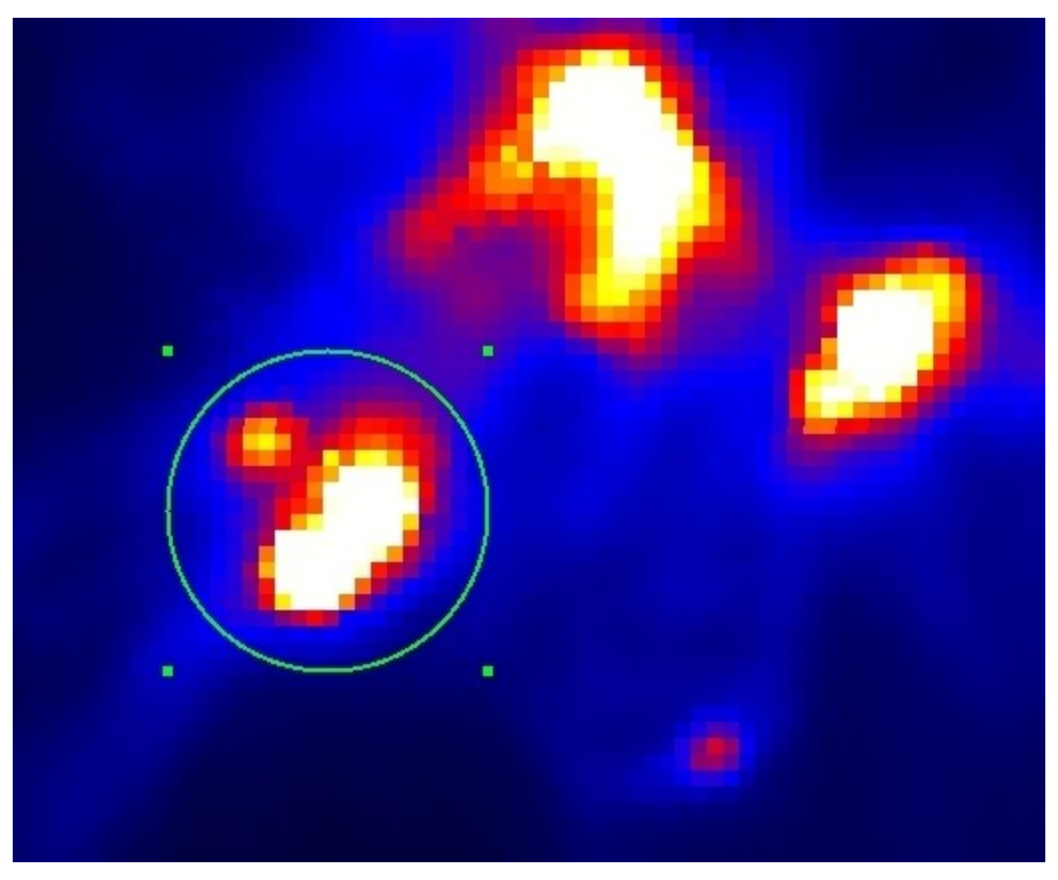
Afterwards, the lists are merged in one single catalog by associating sources that are closer that 1 PSF at the longest wavelength. For this preliminary work we considered all the sources detected in at least three consecutive bands: since any combination of three consecutive bands must contain the 250 µm flux, we took this band as reference.

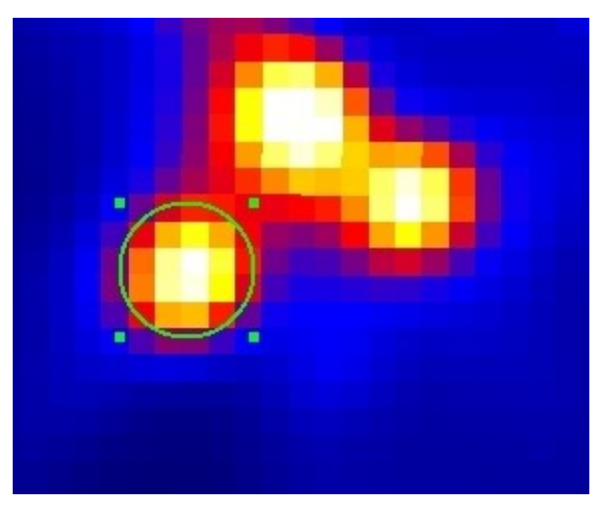
In this way we derived in the original map a sample of 263 sources with fluxes in the reference band between 126 mJy and 179 Jy.

With the same set of input parameters, we performed source extraction also on the map projected at 1 Kpc and again prepared a catalog of sources detected in at least three bands. We got 82 sources, two of which were rejected by eye inspection. The final set of 80 sources spans the flux interval between 390 mJy and 34 Jy.

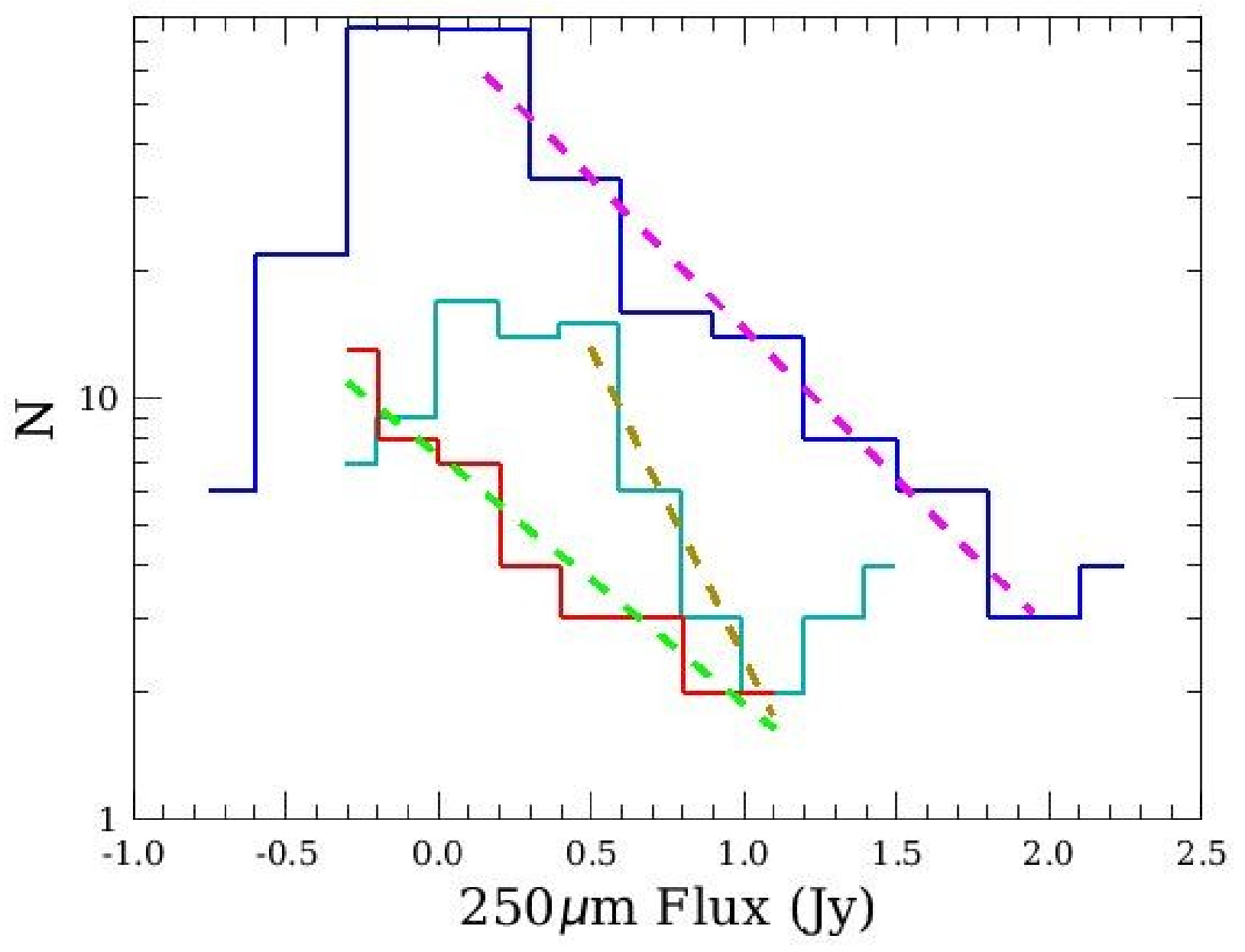
The instrinsic flux distribution at 1 Kpc derived from the distribution at 250 pc is simply the latter scaled by 16.

In the two figures below we show a part of NGC 1333 at 250 µm, at the original size (left) and after the projection at 1 Kpc (right). The two circles (with radii 10 and 2.5 pixels respectively) mark the region of the "source" discussed in the next panel





4. The following figure shows the histograms of the fluxes distributions at 250 µm: solid blue line corresponds to the fluxes measured on the original map, the magenta dashed line is a linear fit with slope -0.711 ± 0.055;



the red solid line shows the distribution derived from the previous one, with the fluxes scaled at 1 Kpc, the linear fit, green dashed line, has a slope -0.591 ± 0.056: the two slopes agree each other at ~2σ level;
finally, the solid cyan line gives the distribution of the fluxes derived from the map projected at 1 Kpc, this is the distribution that the observer would get from an hypothetical observation. The slope of the linear fit, brown dashed line, is -1.46 ± 0.18.

The observed flux distribution is completely different from what should be, taking into account only the scaling of the flux. The detected sources are 80 (cyan line) instead of 43 (red line), there is an excess of sources between 1 and 3 Jy, and bright sources appear with F>10 Jy.

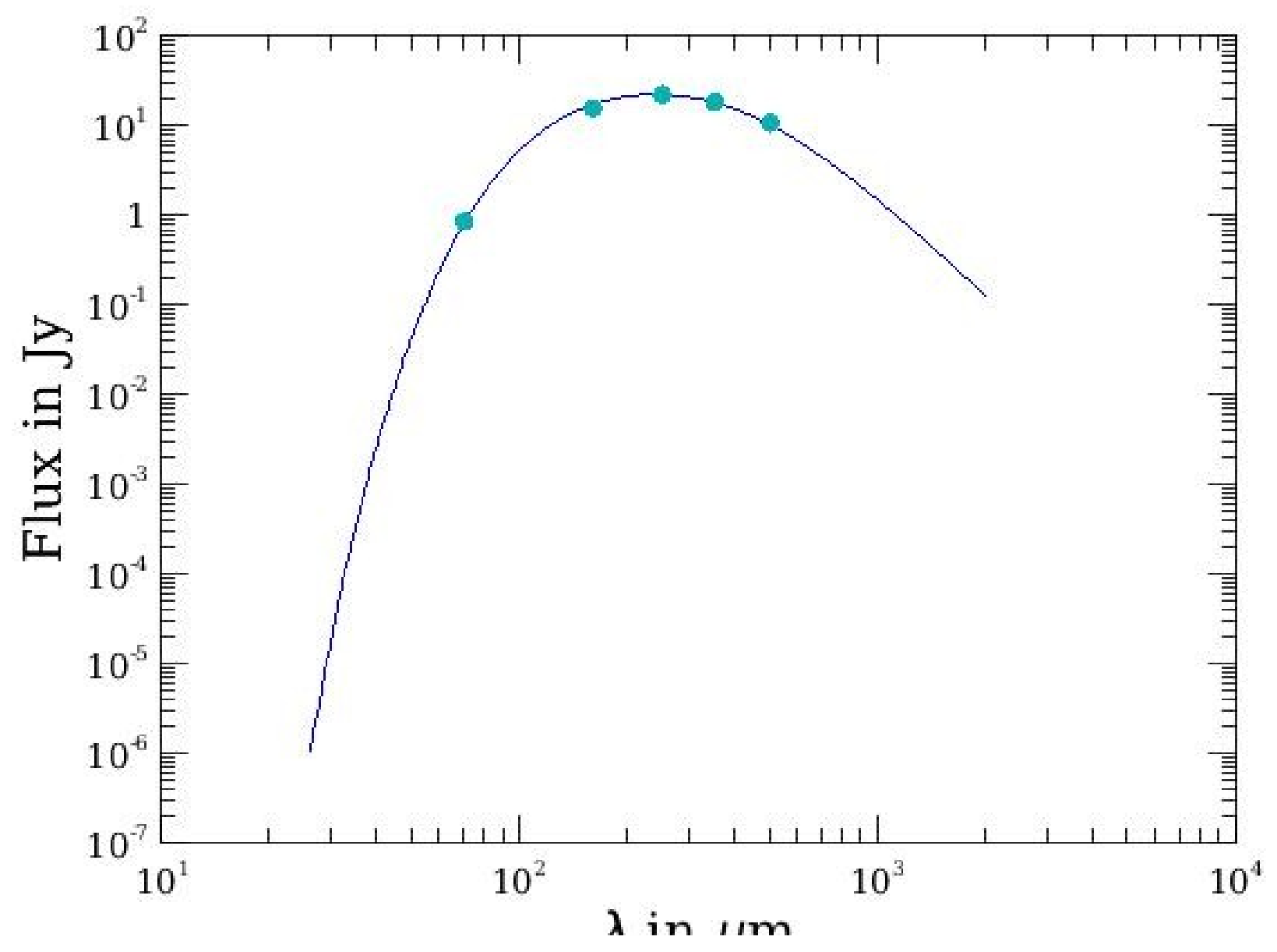
The source confusion completely changes the intrinsic flux distributions!

It is not easy to turn this flux distribution into a mass distribution, but just as an example we made a greybody fit to the second brigthest source (F_{250}=23.4Jy), shown in the two small maps on the left.

The mass of a greybody is (Pezzuto et al., in preparation)

$$M = \frac{D^2\,\Omega}{\kappa_{ref}}\left(\frac{\lambda_0}{\lambda_{ref}}\right)^{\beta}$$

with D distance to the source, Ω the solid angle, λ_0 the wavelength at which the dust optical depth is 1, β is the exponent of the dust emissivity, κ_{ref} the dust opacity at λ_{ref}. With only Herschel data the parameters of the fit are not well constrained, but we derived a set of models that have $\chi^2<1.61$ (90% confidence level for 5 points) and among these we selected the one which has the smallest mass (figure on the left): this model has T=21 K, β=2.0, λ_0=580 µm, from which the mass is 24 Mo. The deconvolved and circularized size at 500 µm, as derived from the map, is 23" (FWHM): assuming that the mass distribution of the source is a Gaussian, and taking the radius as twice 3σ, the average density is 2.3×10^3cm^{-3} (or 4.1×10^4cm^{-3} if the radius is taken as the FWHM).



For comparison, in the Rosette high mass SFR (Schneider et al. 2010), the masses of the clumps are found in the range between 19 and 161 Mo, with an average density of 1.1×10^4cm^{-3}: our hypothetical source would be indubitably classified as a high mass clump.

Conclusion

We have shown how the spatial resolution can alter the derived properties of a star forming region when seen at a distance of 1 Kpc.

The quantitative conclusions are preliminary and should be object of a more deep analysis, but it seems that a region like Perseus, which at 250 pc shows low- to intermediate mass, once projected at 1 Kpc shows, at the Herschel resolution, clumps with characteristics typical of those observed in the high mass star forming regions.

References

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