YOUNG STELLAR CLUSTERS: FROM ISO TO HERSCHEL

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Abstract

The studies of young stellar clusters with ISO are introduced as a starting point for potential studies with the Herschel Space Observatory. The higher spatial resolution at longer wavelengths is identified as the major strength of Herschel for studies of star forming regions. The likely advances of the future SIRTF studies are outlined and emphasis is given to areas where Herschel is likely to make major advances after the SIRTF results.

In the interpretation of the luminosity function of young stellar clusters the most interesting targets are the very youngest star forming regions where the embedded population dominates the number counts. These studies allow addressing the issues of accretion processes in protostars. For somewhat older clusters with star formation ages of the order of a few million years, the most interesting aspect is to examine the disk dispersal time scales. The open issue for Herschel will be the question of cool disk dispersal in view of the very rapid inner disk dispersal observed in the near infrared. SIRTF will make a significant contribution to many other studies of star formation and disk dispersal processes. Therefore a Herschel key programme in these areas can only be fine tuned after the SIRTF results have been made available.

Key words: Stars: formation – Stars: circumstellar disks

1. Introduction

Young stellar clusters can be studied statistically to address various fundamental questions of astrophysics: initial mass function (IMF), star forming history and early stellar evolution. Significant amount of ISO time was dedicated for these purposes to map close by star forming regions: Chamaeleon I (Nordh et al. 1996; Persi et al. 2000), ρ Oph cluster (Bontemps et al. 1999), Serpens (Kaas et al. 2000), R CrA cluster (Olofsson et al. 1999), LDN 1641, NGC 1333, parts of the Taurus clouds etc. The results are consistent with a scenario where the high activity of star formation is only of short duration. This can be deduced from a feature in the luminosity function which is due to deuterium burning in the pre-main sequence stars The IMF is consistent with that of field stars with an extension toward brown dwarf mass domain with the same power law as for very low mass stars.

One of the interesting results of the ISO studies of young clusters is the clear separation of stars with and without infrared excess when observed at 6.7 and 14.3 μm (Fig. 2 in Nordh et al. 1996). The importance of this result is due to the fact that it is very difficult to disentangle infrared excess from extinction if only ground-based near-infrared JHK data is available. The reason for superiority of ISO data in this respect is due to the low and very similar extinction at 6.7 and 14.3 μm (Fig. 1). Therefore the observed ISO colour is very close to the intrinsic colour. The gap in the ISO [6.7]-[14.3] colour separates clearly stars with and without infrared excess. Furthermore, the lack of intermediate cases suggests that the disk dispersal, when started, is a very rapid process.

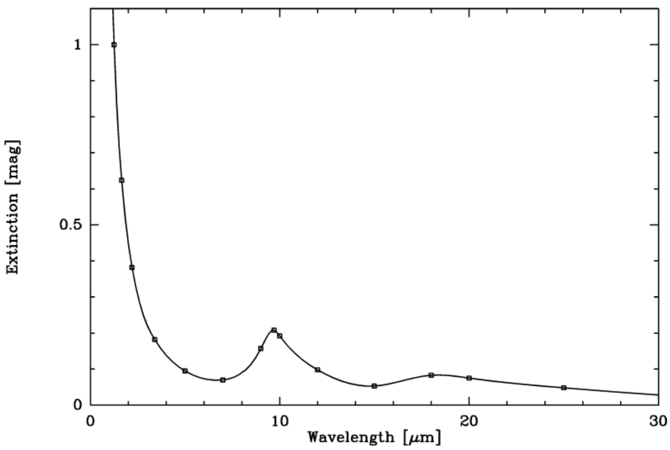

Figure 1. The normalized (A_J=1) infrared extinction according to tabulation by Mathis (1990) with a spline curve fitted through the points

2. The potential of Herschel

The strength of the Herschel Space Observatory will be the possibility to image star forming regions at 60 μm with the same spatial resolution as was done with ISO at 10 μm. This will open up research possibilities in studies of luminosity functions of young stellar clusters and in examin-

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inations of disk dispersal around stars. Both aspects will be addressed in the following sections.

2.1. Luminosity function

The possibilities and limitations of using luminosity function (LF) of young stellar clusters to study IMF, star formation history and pre-main sequence evolution have been reviewed by Prusti (1999). The Herschel strength of high resolution at longer wavelengths will not be of high importance to LF studies of most near by regions. This is due to the fact many regions have star forming histories extending a few million years back in time. This is enough to make T Tauri stars the dominating population. Given the intrinsic spectral energy distribution of T Tauri stars and typical extinction in these clouds, the optimal wavelengths for LF studies are below 30 μm. This makes SIRTF an ideal facility to address the questions convolved in an LF of a young cluster and the expectation is that SIRTF will provide estimates of IMF well into the brown dwarf mass domain.

The high spatial resolution of Herschel at long wavelengths is of great importance in regions where star formation is very recent. In the youngest regions the majority of the objects are in an earlier, embedded phase of evolution. The embedded stars have their peak emission beyond 50 μm and long wavelength observations are essential for estimations of their bolometric luminosity. These observations were not possible with ISO simply because of confusion. For the same reason SIRTF is not expected to help much. Based on ISO studies it looks like the Serpens star forming region is a cloud at such an early phase of evolution that the stellar population is dominated by embedded objects (Kaas et al. 2000). While IMF is often the most wanted entity convolved in an LF, one should not ignore the potential of using the Serpens LF to probe early stellar evolution. One of the open issues in the earliest phases of stellar evolution is the accretion rate as a function of time. The accretion rate leaves its fingerprints in the LF of Serpens because of accretion luminosity. Therefore Herschel Space Observatory studies of the Serpens LF will have much more important significance than simply completing a region which couldn't be done with SIRTF: they will allow a statistical examination of the proto-stellar evolution.

2.2. Disk dispersal

The disk dispersal time is going to be one of the key issues to be addressed by Herschel. Young stellar clusters provide an excellent target to probe this process. Ground-based and ISO results indicate that circumstellar disks disappear before stars reach an age of 10^7 years (Alves et al. 2000). However, this may be true only for the inner parts of the disk. The dispersal of the cooler parts can only be addressed at wavelengths longward of 60 μm, but at these wavelengths IRAS, ISO and SIRTF all hit the problem of confusion in star forming regions. It is the resolving power of the Herschel Space Observatory which will be crucial in addressing the dispersal time scale of the cooler parts of the circumstellar disks in young clusters. This information is needed to see if the inner disk dispersal seen in young clusters has any relation to the debris disks in field stars which have dispersal time scale of the order of 400 million years (Habing et al. 1999).

The first question to be answered is whether the cool disk disappers in concert with the hot inner disk in short time scales. This check can in principle be made very easily by simply observing all the members without hot disks in the study by Alves et al. (2000). In practice confusion is such a problem that we have to wait till Herschel Space Observatory to address the question properly.

If we assume that cool disks disperse slower than hot disks, then the prime targets will be clusters with ages around 10^7 years. Luckily the recent discoveries based on X-ray data have provided suitable target clusters. Both η Cha (100 pc) and TW Hya (50 pc) clusters are close and young enough that complete census of cool disks is feasible. As these clusters are already spatially more dispersed and have lost most of their parental clouds, the confusion problem is less severe. Depending on the quantity of the 60 μm excess, if existing at all, it may be possible that this study is already completed with SIRTF. This will naturally move the Herschel study to older objects in order to examine the connection to the debris disks, but the problem will be the availability of clusters at suitable distances to achieve completeness down to the photospheric emission levels.

3. Conclusions

The higher spatial resolution at longer wavelengths is the strength of the Herschel Space Observatory with respect to past (ISO) and future (SIRTF) facilities. In studies of young clusters where confusion is a very serious problem this strength can be directly utilised. In the youngest known star forming region a census of members and reliable luminosity function can only be constructed after Herschel has flown. This is essential in assessing statistically the issue of accretion luminosity which is one of the mysteries waiting to be solved.

In studies of disk dispersal time scales the higher spatial resolution can be used to assess the dispersal process of the cooler parts of the disk. While SIRTF may already give answers to the dispersal of cold disks in intermediate age clusters (10^7 years), it seems that the examination of cool disk dispersal in time scales typical to hot disk dispersal needs to wait for the spatial resolution provided by Herschel. Star formation in general and disk dispersal in particular are key issues of the guaranteed time and legacy programmes of SIRTF. Therefore it seems likely that the years before the launch of Herschel will bring us many advances in these research areas. While the higher spatial resolution of Herschel makes it possible to identify already now the key elements of an observing programme of young clusters, it is clear that fine tuning will be needed to account for the coming SIRTF work in these areas.

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