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Optical/IR follow-up of ISOGAL survey

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Abstract. The new infrared satellite ISO (Infrared Space Observatory) was launched by the European Space Agency (ESA) in November 1995. One of the most important programs scheduled on this satellite is the "ISOGAL" survey of the selected areas of the inner galactic disk at 15 and 7 microns. In combination with IJK data from the near-infrared southern sky survey DENIS, the ISOCAM (ISO camera) data allow the first detailed study of the infrared stellar populations in very obscured regions of the inner Galaxy. The dominant old stellar population is bright M giants with or without excess dust emission, which must be distinguished reliably from other compact sources, especially young stars. Additionally, ISOGAL detects many other types of stars, among them a large number of dusty young stars. Some open clusters are also observed. Although the ISO and DENIS multicolor observations may discriminate most of the stellar types, follow-up Optical/IR observations from ground-based telescopes would provide more deeper data at high spatial resolution and spectral studies would give the informations for modelling new stellar objects detected.

Keywords: galaxy: stellar content-interstellar medium: general - interstellar medium: dust, extinction - infrared: stars

1. Introduction

The central regions of the Milky Way provide unique and important informations. The inner disk and the bulge are that part of the Galaxy where most of the stars and interstellar medium, most star forming regions, the greatest number of products of late stages of stellar evolution, most rare and short-lived stages of stellar evolution, can be discovered and studied in critical details. In spite of this scientific potential, the central parts of the Galactic disk and bulge remain poorly studied. This is mainly due to extinction at short wavelengths and poor spatial resolution available in studies at longer wavelengths. From the ground most of these observations provide data that are of low sensitivity near infrared (caused by the earth's atmosphere). From space, only low sensitivity and/or low spatial resolution data exist thus far, which keeps our understanding of the inner Galaxy at superficial level.

The new infrared satellite ISO was launched by the ESA in November 1995, which have the capabilities to radically change this situation. One of the most important programs scheduled on this satellite is the "ISOGAL" survey at 15 and 7 microns with ISOCAM of the inner galactic disk. This project was proposed and is carried out by a European group led by A. Omont at IAP, France. The survey covers ~ 18 square degrees in selected areas of the central $l = \pm$ 30 degree of the Galactic plane, all complemented by 0.8-2.2 microns DENIS data (DENIS: "A DEep Near Infrared Southern Sky Survey", is a European project in progress, whose data are also processed at IAP, France). A survey (ISOGAL) of selected areas of the Galactic disk has been nearly completed with the ISO camera which will probably reach 200 hours of observations.

Combined with the near infrared (I,J,K) data of the DENIS survey ISOGAL is mainly aimed at the study of the cold stellar populations of the most obscured regions of the inner Galaxy and the corresponding Galactic structure. The dominant old stellar population detected by such surveys is bright M giants, with or without excess dust emission, which are detectable as far as the Galactic center by both surveys, probing the stellar mass distribution, the Galactic structure and the interstellar extinction.

2. Scientific results

The results from the first ISOGAL field in LW3 (12-18 microns) filter at $l \simeq -45°$ are shown in Perault et al. (1996) and Ojha et al. (1997). This field was observed with ISO in January 1996 as a part of commissioning of ISOCAM (Cesarsky et al. 1996). The analysis of the ISOGAL field was limited to a total area of 0.144 deg^2 after dropping the edges of the 0.25 deg^2 7 by 24 raster field, where the quality of the data is dubious because of the lack of several observations of the same sky point. The preliminary image reduction and source extraction for this field is reported in Perault et al. (1996). The completeness limiting flux achieved is ~8 mJy (m_{15}~8.5; m_7~10). This is two orders of magnitude more than IRAS, as expected with a sensitivity and a pixel surface (6"×6") almost 100 times better.

This analysis has proved that the combination of ISOGAL and DENIS data is quite powerful to identify the nature of the ISOGAL sources even in regions of high extinction (A_v up to 20-30). Most of the ISOGAL sources are associated with relatively bright DENIS sources (K≤11), although an important fraction (~30%) have no K association and are expected to be cold dusty young stars. The number of ISOGAL sources without K counterpart is also consistent with the expectation for dusty young stars inferred from the study of IRAS sources in Lynds 1641 dark cloud by Strom et al. (1989). A comparision with the infrared colours of the YSOs detected by IRAS in L1641 (Strom et al. 1989) shows that the group of "type II" YSOs, i.e. those identified in the visible with a relatively thin dust disk (T Tauri, Herbig Ae-Be stars, etc), has K/15μm colours such that 4.5<K-[12]<7. Such red colors well explain that very few of these 15μm sources are detected by DENIS (because the sensitivity of DENIS in the near infrared is relatively limited, mainly by confusion limit K = 12). However, deeper near IR imaging with a limit K=15, should detect most of these "type II" sources, i.e. perhaps 50 percent of the 15μm ISOGAL YSOs.

Omont et al. (1997) illustrated the scientific capabilities of ISOGAL with an analysis of the stellar sources in the fields of the inner Galactic bulge ($l,b = 0, \pm 1$). They showed that perhaps one third of the AGB (Asymptotic Giant Branch) stars above the RGB (Red Giant Branch) tip are losing mass, from their very red ISO colors. This high proportion of mass-losing AGBs above the RGB tip, if confirmed, is much larger than in the solar neighbourhood.

3. Scientific prospectives

When the ISOCAM infrared data are combined with photometric data in the same lines of sight from ground-based near-infrared surveys, one may determine the distribution of interstellar extinction on small angular scales, and hence deduce intrinsic stellar colors and spatial distributions, thereby allowing a broad range of analyses of Galactic structure. Additionally, from the reddening-corrected photometric data, one may search for and indentify any remarkable stars: The dominant old stellar population detected by ISOCAM is bright M giants, with and without excess dust emission, which are detectable as far as the Galactic center. The other most numerous class of sources detected by ISOGAL are intermediate mass dusty young stars. Other distinct, but rarer, sources which are visible throughout the Galaxy with ISOCAM include Planetary Nebulae, super giants which are especially valuable for identifying regions of recent star formation. Less intrinsically bright objects, which will be detectable only locally, include T-Tauri stars and OB stars.

It is essential to reobserve at least a substantial fraction of the ISOGAL fields with a sensitivity in the K band of K = 15, to identify and characterise "type II" YSOs in various galactic environments. Indeed, such a sensitivity is easily achievable with small telescopes equipped with current NICMOS arrays with small pixels. This has already been demonstrated by the preliminary analysis of the K band observations of one of the ISOGAL fields by the TIRGO telescope (see Testi et al. 1996) which provides the expected number of K detections of 15μm ISOGAL sources with K-15 colors characteristic of "type II" YSOs. Such a sensitivity (K=15) can be achieved with the PRL NICMOS camera at Mount Abu and we can carry out a systematic follow up observations of a few square degrees of the galactic disk observed by ISOGAL.

There are a number of known heavily reddened open clusters within the ISOGAL and DENIS fields, however, it is clear that detailed studies of the crowded cluster fields are quite limited by the lack of spatial resolution of the DENIS-ISOGAL surveys. A systematic program to study the peculiar brighter stars (H~10 mag) can be carried out at UPSO, Nainital using 1-meter telescope along with 2K×2K CCD camera and JHK photometer.

4. Conclusion

The ultimate goal will be to use all the data together to set constraints on the large-scale distributions of the Galactic stars in the inner parts of the Galaxy. An ISOGAL survey of a large area of the central Galactic plane, complemented by the shorter wavelength deep ground-based survey data, is expected to revolutionize our understanding of the basic structural components of our Galaxy, and of the earliest and latest stages of stellar evolution.

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