

Star formation activity around NGC7538-IRS9 region

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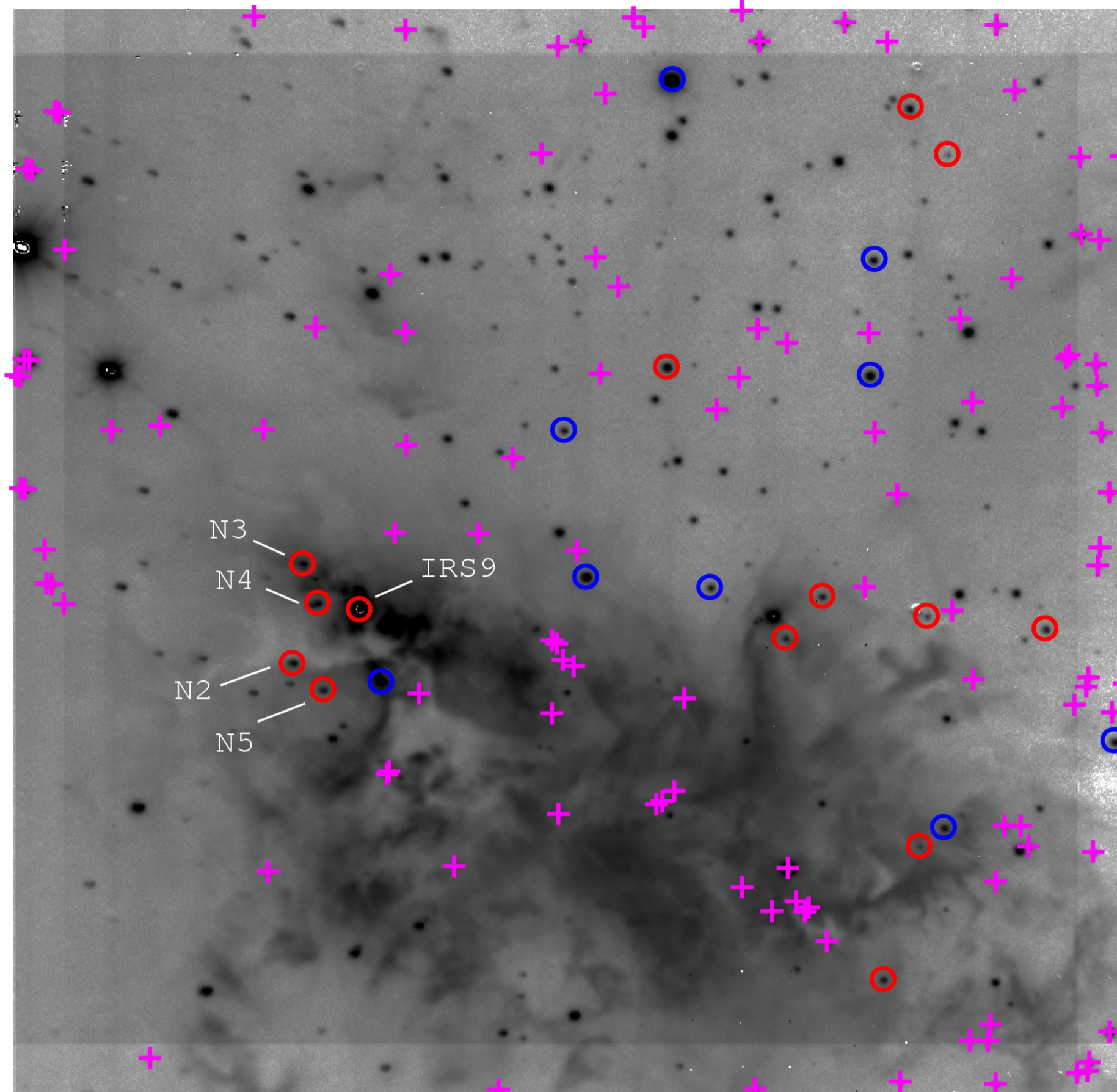
Introduction

- Location : Cassiopeia OB2 complex
- l : 111.57°
- b : $+0.75^\circ$
- Distance : 2.8 kpc
- Motivation :

The NGC7538-IRS9 source lies at the apex of the complex reflection nebula towards the southeast of the NGC7538 star forming region (see figure below). It was identified as a protostellar source by Werner et al. (1979, MNRAS, 188, 463). IRS9 also has a powerful bipolar CO outflow which traces the shocked H_2 flow from it (Ojha et al., 2004, ApJ, 616, 1042). The extensive reflection nebula is a manifestation of this massive outflow. There is high-mass star formation, in its early stages, going on in this region. Hence, it presents a unique scenario to study the morphology, chemistry and the physical processes involved in such a situation. An interesting feature about this region is that it seems to be undergoing spontaneous star formation, even though it is located close to a triggered star-forming region.

Observations and Analysis

Near infra-red (NIR) observations :

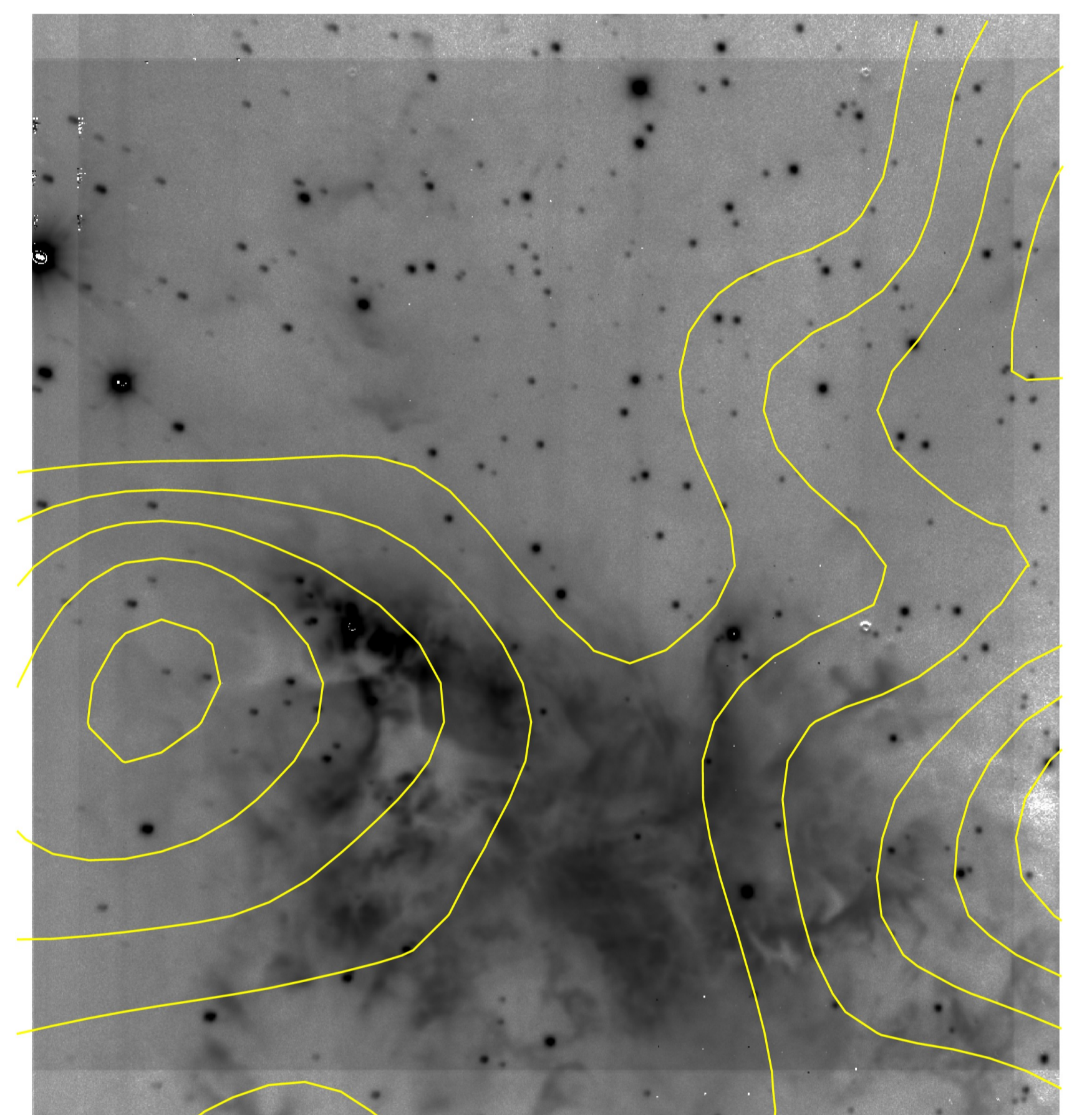
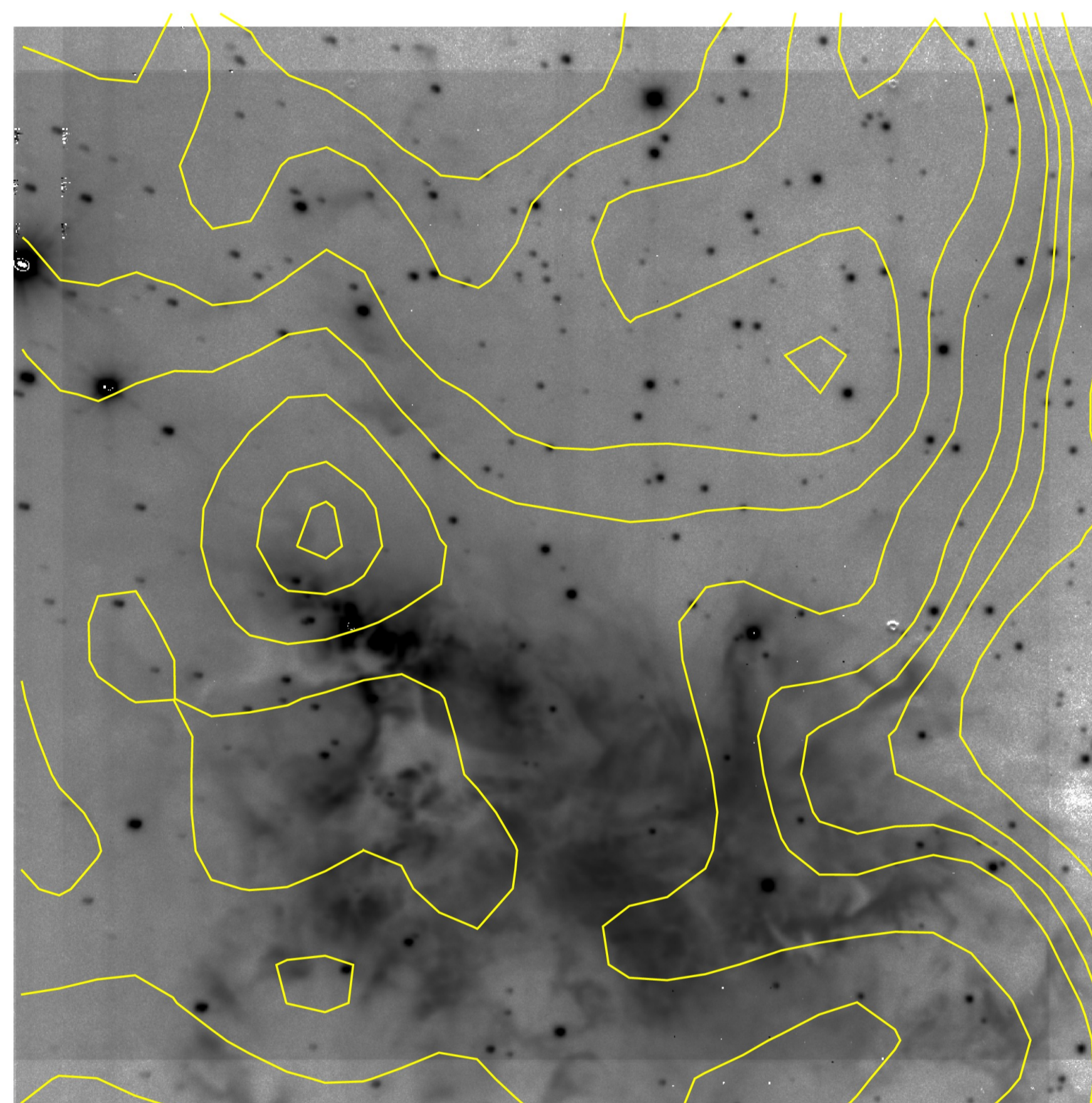


K_s band image of the IRS9 region, obtained with the Subaru telescope (CISCO camera). The field of view is $1.8' \times 1.8'$.

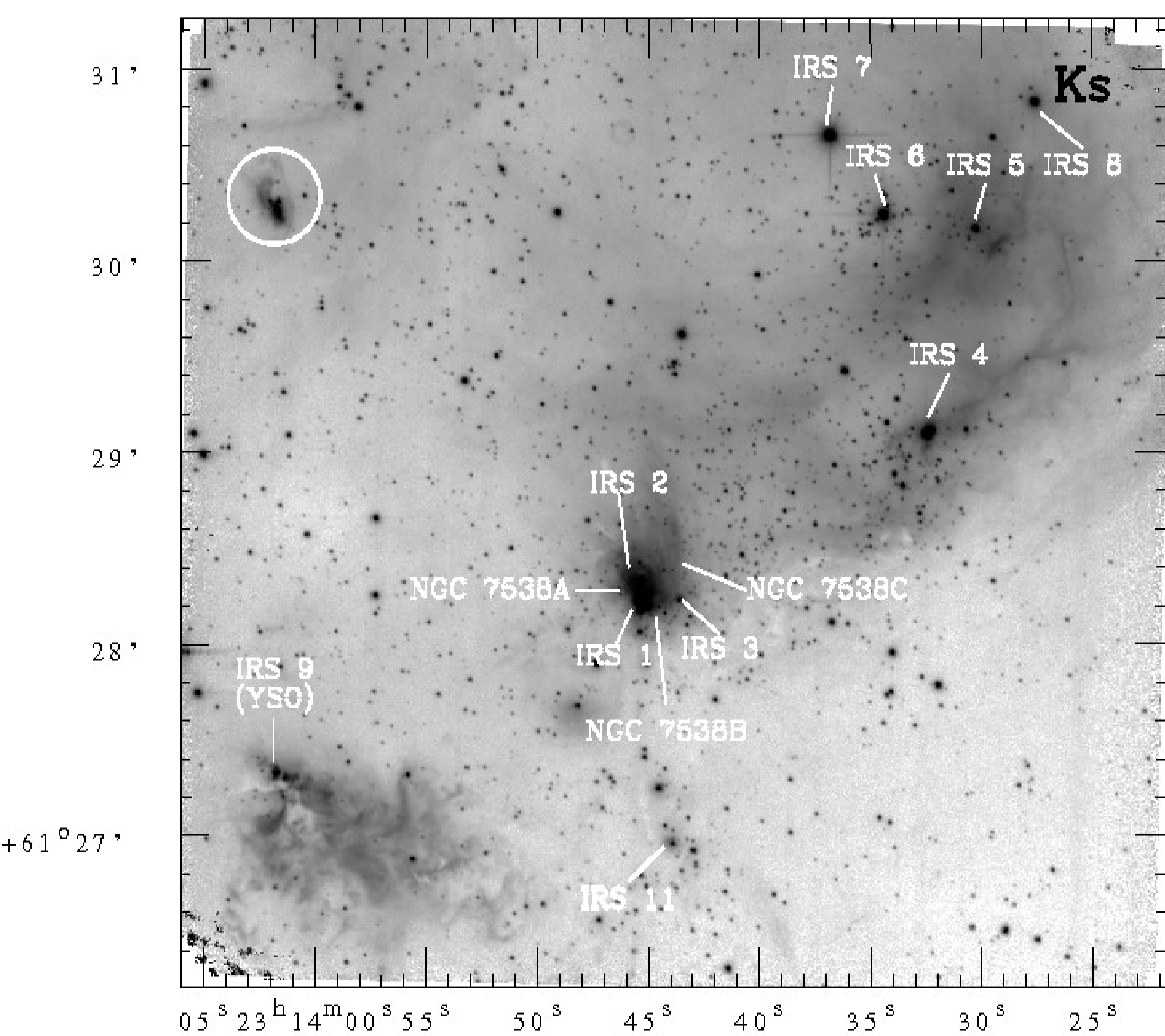
The infra-red excess sources are denoted by red circles. They were obtained with the help of colour-magnitude, H vs. $H - K$, diagram using the Subaru data. The criterion used was $H - K > 2$. The classical T-Tauri stars have been marked by blue circles. These were obtained with the help of colour-colour ($J - H$ vs. $H - K$) diagram using the IRSF data. The Magenta crosses denote the position of stars detected only in Subaru K_s band.

As can be seen from the distribution of the Young Stellar Objects (YSOs), there is no particular age sequence of star formation in the region. Also, going by the stellar population, which shows a large and almost ubiquitous presence of sources detected only in K_s band, the region seems to be extremely young. It also appears that a clustered star formation is ongoing around the IRS9 source.

Molecular line observations :

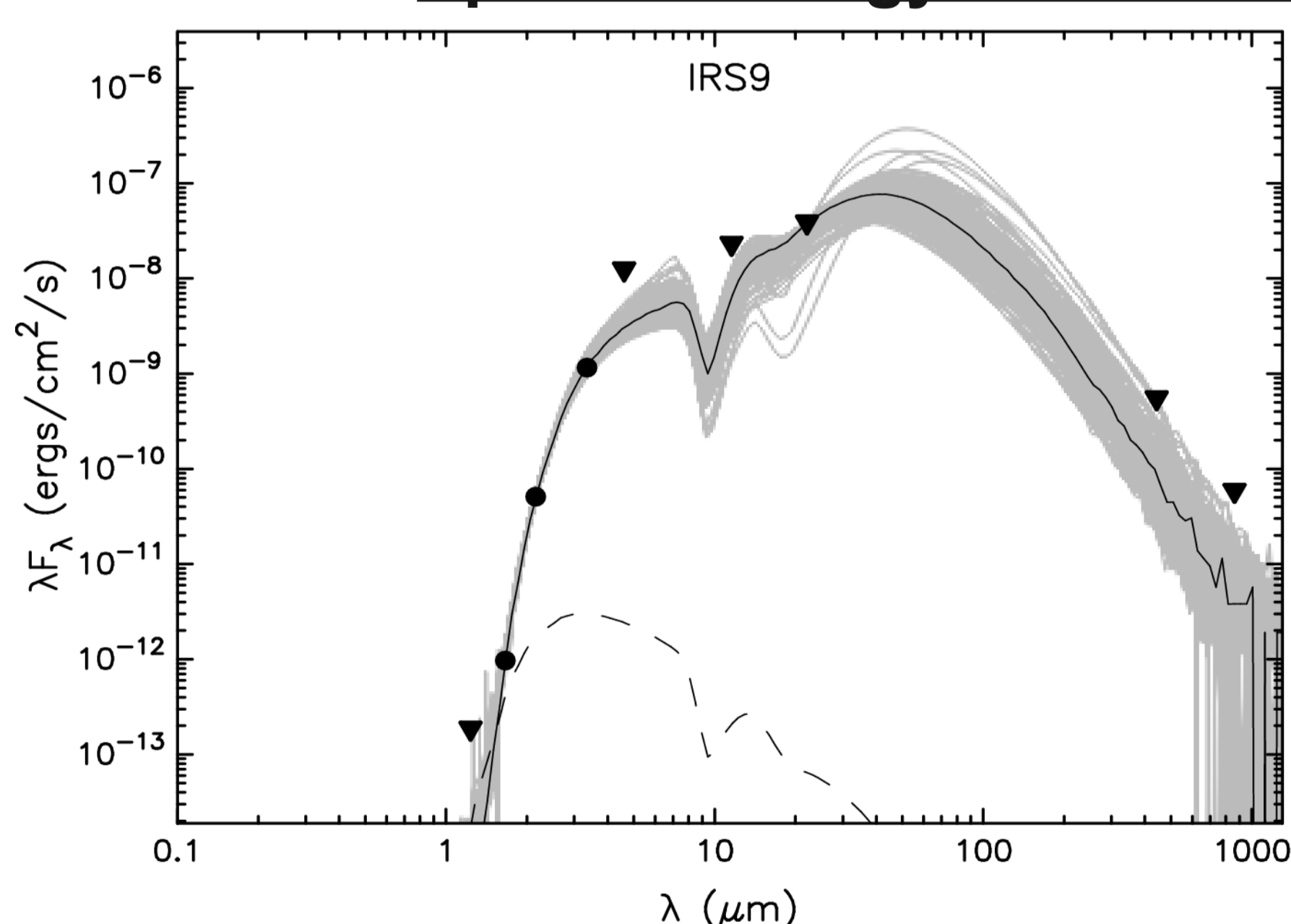


(left) The $C^{18}O$ ($J=1-0$) contour lines and (right) $H^{13}CO^+$ ($J=1-0$) contour lines superimposed on the Subaru K_s band image. These molecular line data were obtained using the 45 m Nobeyama telescope. $C^{18}O$ as well as $H^{13}CO^+$ are tracers of high density regions. We can see that the peak of the formylmolecule lies to the east of the IRS9 source, a region which hardly contains any YSOs. This indicates the presence of highly dense and cold (due to the near-absence of $C^{18}O$) gas in the neighbourhood of the IRS9 source, and hence that the region is extremely young. The peaks of both the molecules are well separated, which suggests that there are chemical variations going on in the region.



K_s band image of the NGC7538 region, obtained with the Infra-Red Survey Facility (IRSF) telescope. To the south-east lies our region of interest, IRS9. It can be seen that, though a part of the NGC7538 region, it is distinctly separated from the central high-mass (triggered) star-forming cluster. It probably is a high mass star-forming region in a very early stage.

Spectral Energy Distributions (SEDs) of the embedded YSOs



SED modelling was carried out for the infrared excess sources located around the IRS9 source (Robitaille et al., 2007, ApJS, 169, 328). In addition to the Subaru data, archival IR data from Spitzer, MSX, WISE, and sub-mm data from SCUBA were also used, as available.

This diagram shows the SED curve for the IRS9 source.

The following table shows the relevant parameters of the YSOs around IRS9 :

	Mass M_\odot	Age (in log units) years	Disk Accretion Rate (in log units) $M_\odot \text{ yr}^{-1}$	Envelope Accretion Rate (in log units) $M_\odot \text{ yr}^{-1}$	Luminosity (in log units) L_\odot
IRS9	19.67	4.99	-5.67	-3.15	4.65
IRS9N2	9.04	5.45	-7.02	-4.75	3.63
IRS9N3	8.02	4.58	-7.33	-3.93	3.06
IRS9N4	24.21	4.50	-6.38	-3.12	4.89
IRS9N5	9.85	4.38	-6.88	-3.86	3.35

The preliminary SED analysis for all the infrared excess sources around the NGC7538-IRS9 source shows that most of them have their ages in the range 10^4 - 10^6 years. The mass range varies from 8 to 24 solar masses. This opens up a vista for studying high-mass star formation in the region.

Results and Discussion

Preliminary results from our data analysis indicate that the region around NGC7538-IRS9 is an extremely young one, and possibly undergoing a spontaneous star-formation due to the collapse of the molecular cloud fragments. The presence of cold molecular gas is also borne out by the fact that there is no radio emission in this region, which otherwise is abundant in other regions of NGC7538.

For the IRS9 source, from the SED modelling, we obtain the envelope accretion rate as $1.4 \times 10^{-3} M_\odot \text{ yr}^{-1}$ and the luminosity as $4.5 \times 10^4 L_\odot$. The envelope accretion rate matches well with the mass entrainment rate given in literature (Davis et al. 1998, AJ, 115, 1118). Also, the morphology around the source (the massive collimated bipolar CO outflow jets associated with shocked H_2 , and the absence of any radio continuum radiation), coupled with the high luminosity and the mass entrainment value makes it a likely candidate for High Mass Protostellar Object (HMPO).

Further studies of this region to investigate other physical properties and to understand the star formation scenario are underway. Since, the process of high-mass star formation is not well understood, the study shall also be helpful in shedding some light on the little understood processes involved in such scenarios.