



# Deeply-embedded protostars driving outflows in the Outer Galaxy



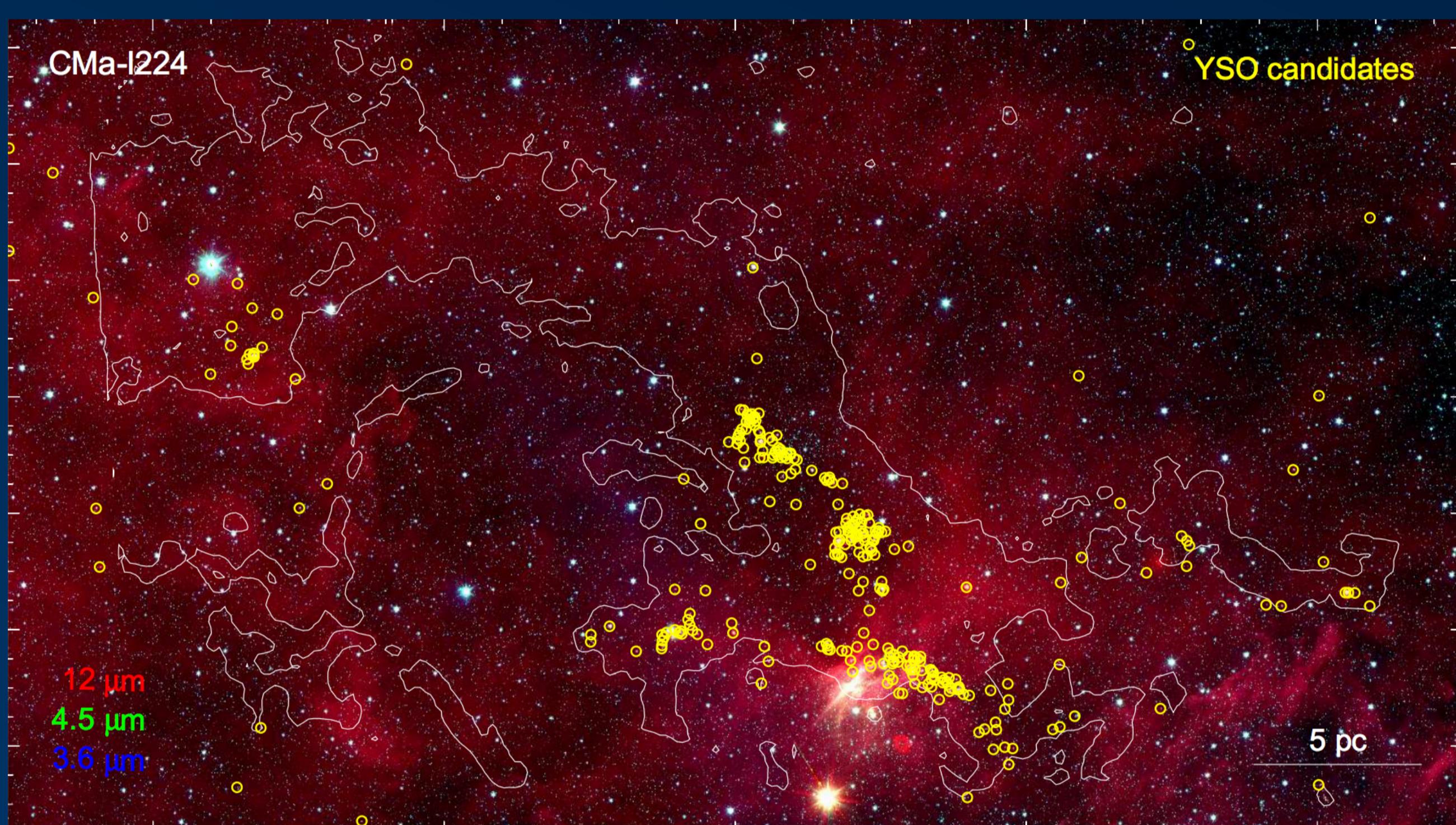
Agata Karska, M. Sewiło, B. A. Whitney, B. H. K. Yung, T. P. Robitaille, D. Elia, R. Indebetouw, E. Schisano, W. Fischer, B. Babler, M. Boyer, M. Meade, D. Padgett, N. Siódmiak, R. Szczerba, J. Wiseman

## Introduction

Recent large-scale photometric surveys in the infrared give the opportunity to identify new sites of star formation in our Galaxy and to study the impact of environment on star formation.

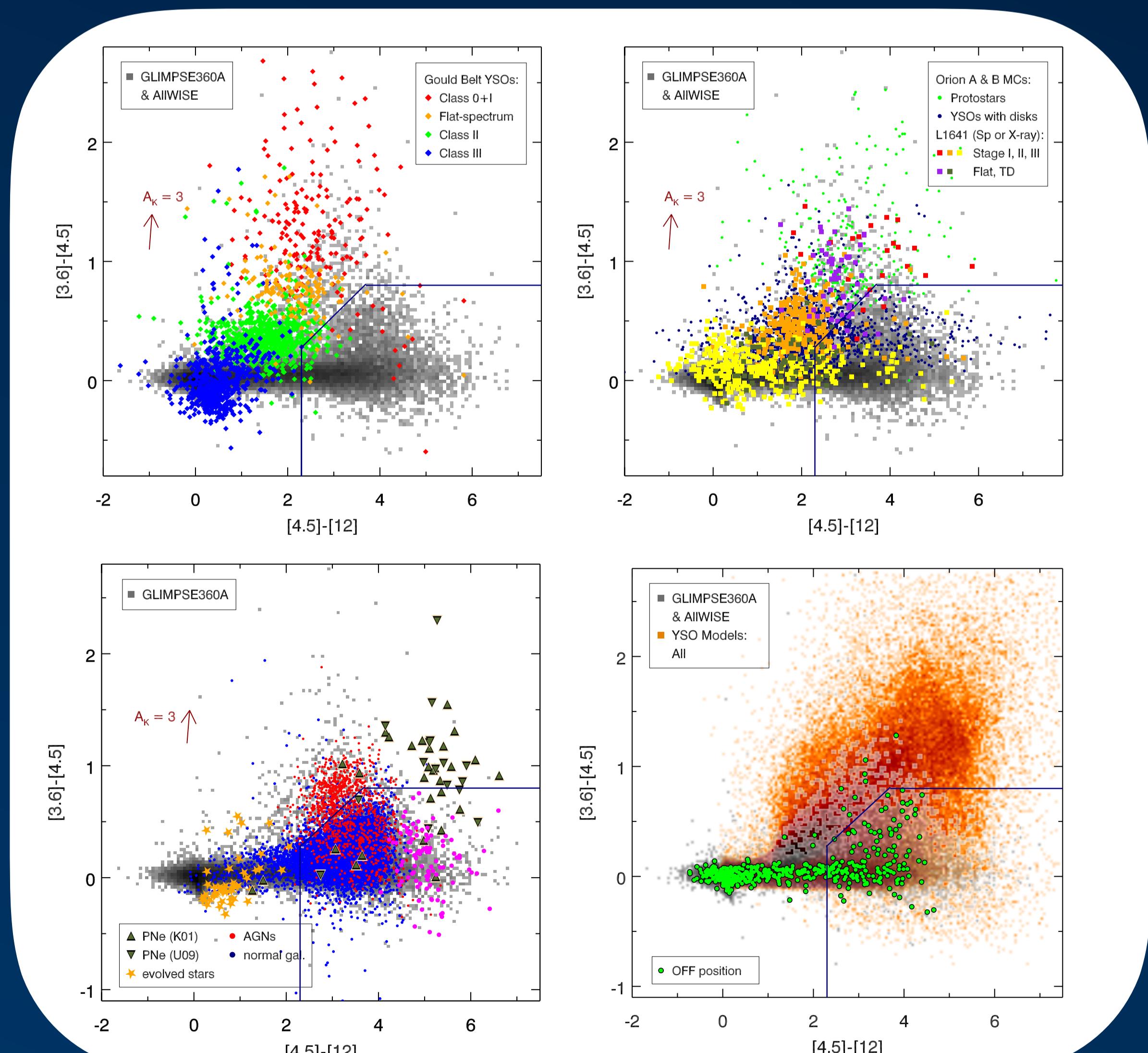
Here, we use results from Spitzer / GLIMPSE360 (PI: B. Whitney) and Herschel / Hi-GAL (PI: S. Molinari) to identify and classify young stellar objects (YSOs) in the  $\sim 34 \text{ deg}^2$  region in the Outer Galaxy with longitudes from  $l=215 \text{ deg}$  to  $l=227 \text{ deg}$  and latitude from  $-2.3 \text{ deg}$  to  $0.5 \text{ deg}$  in the Canis Major ("I220"). We focus on the part of I220 containing regions with bright, extended  $4.5 \mu\text{m}$  emission probing  $\text{H}_2$  jets - "the CMa-I224" - the home for the most deeply embedded YSOs (Sewiło et al., in prep.).

## CMa-I224: Young Stellar Objects



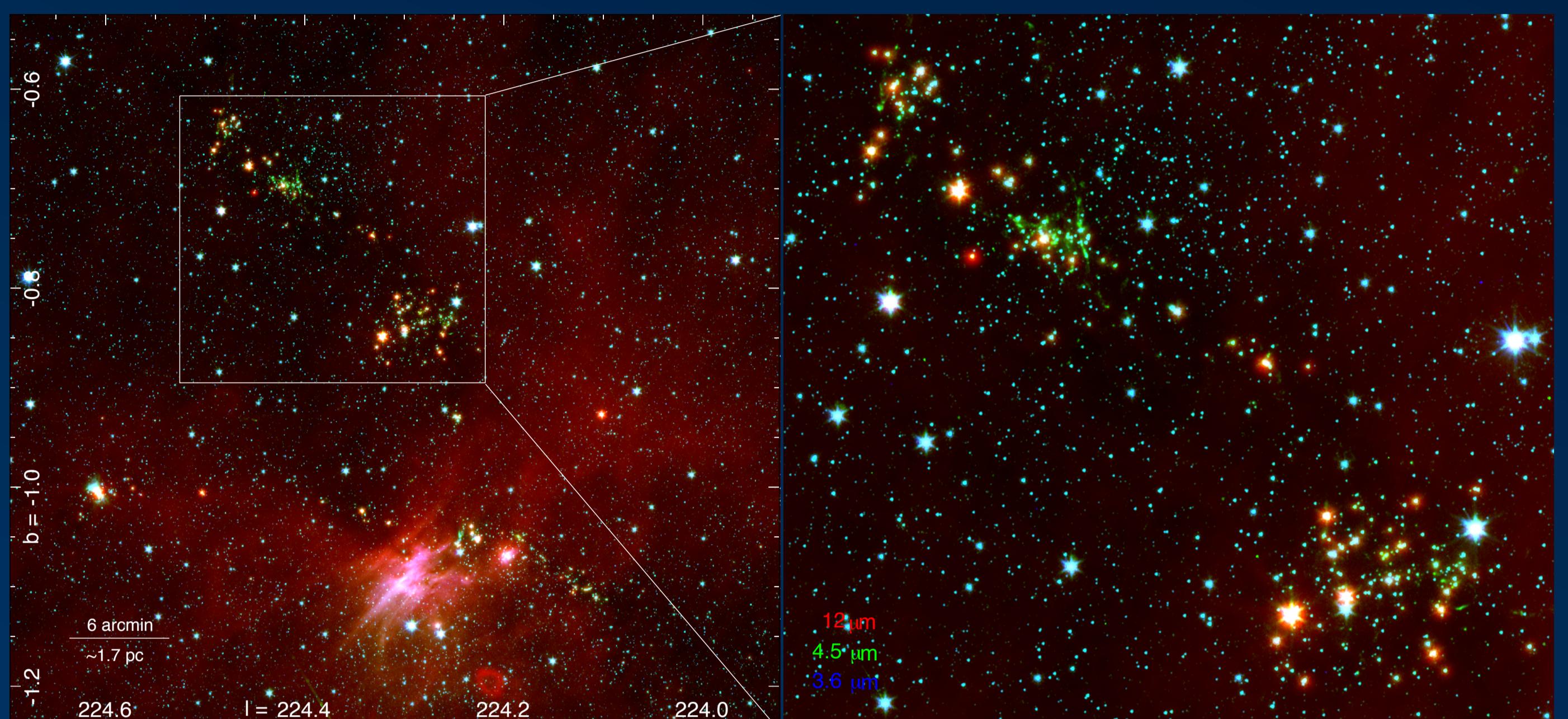
The CMa-I224 region in the Outer Galaxy at  $3.6$ ,  $4.5$  and  $12 \mu\text{m}$  with positions of the 293 identified YSO candidates. The white contour corresponds to the  $\text{H}_2$  column density of  $4 \times 10^{21} \text{ cm}^{-2}$ .

## Color-color diagrams: YSO identification



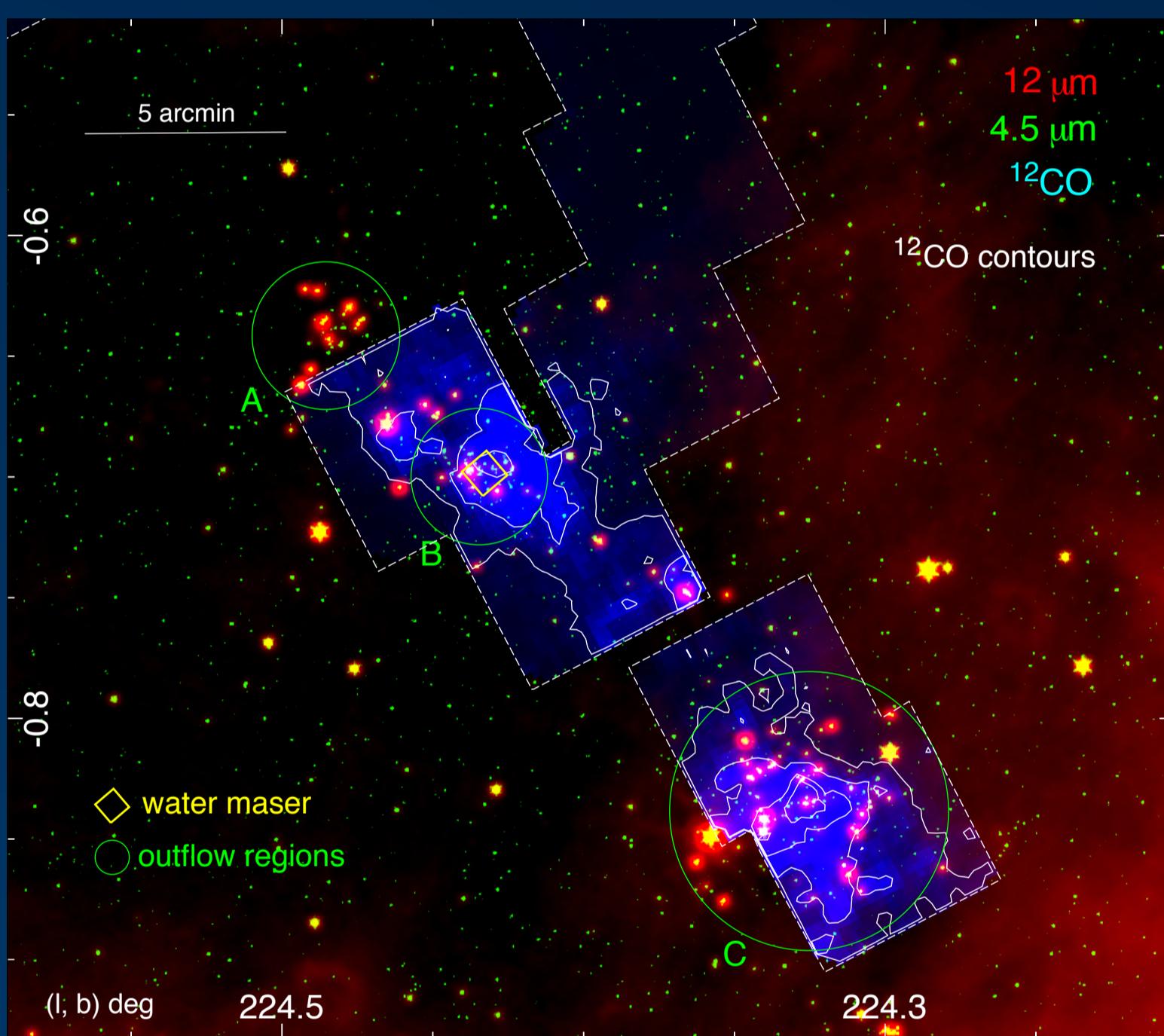
Color-color diagrams are a useful tool to isolate candidates for YSOs from the rest of "red" populations (e.g. evolved stars, galaxies). In addition to the Spitzer and 2MASS data, we use AllWISE filters to improve detections of the youngest YSOs.

## CMa-I224 region: $\text{H}_2$ jets



The Extended Green Objects (EGOs) from the GLIMPSE survey have been confirmed as YSOs with active outflows (Cyganowski et al. 2009). The CMa-I224 region in the Outer Galaxy shows clusters of YSOs with bright  $4.5 \mu\text{m}$  emission likely dominated by  $\text{H}_2$ , characteristic of embedded YSOs.

## CO emission along the main filament

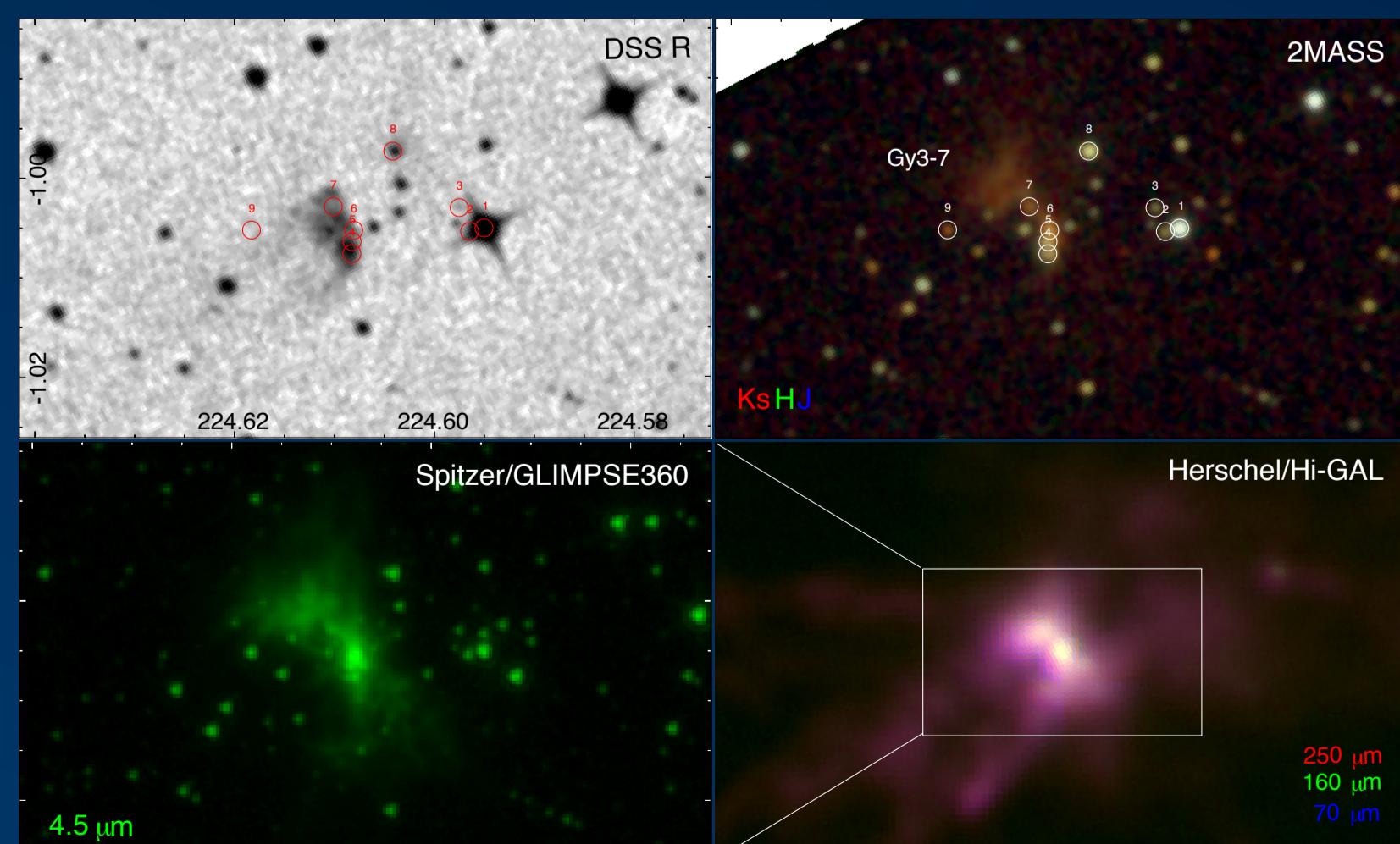


Clusters of protostars located in the main filament of CMa-I224 are associated with bright CO emission likely from the outflows driven by embedded YSOs (MOPRA, 38" beam, Olmi et al. 2016). Higher resolution observations are needed to associate the emission with individual sources.

## Summary

- We found  $\sim 2000$  sources by matching GLIMPSE360 and AllWISE catalogs and applied a series of filters to identify YSOs and remove various populations of contaminating sources
- We found and classified 293 YSO candidates at different evolutionary stages, most of them located along the main filament and concentrated in clusters associated with CO and  $\text{H}_2$  emission from the outflows / jets

## Embedded cluster Gy 3-7



One of the most striking subregions of CMa-I224 in the GLIMPSE360 survey is a reflection nebula Gy 3-7, extended and bright in  $4.5 \mu\text{m}$ . The 1 arc min in size nebula resembles a large outflow and is associated with an embedded cluster of protostars (Tapia et al. 1997).