

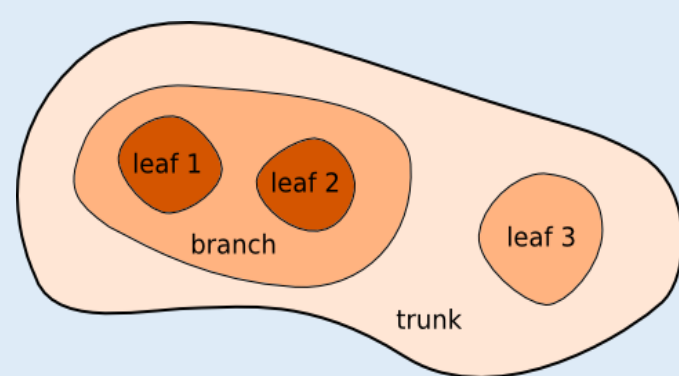
Identifying star-forming cores in ^{13}CO emission maps: Evolution stages of molecular clumps



Chung-Chen Chang, Raffaele Rani, Yueh-Ning Lee

Introduction

Multi-tracer surveys have revealed the hierarchical nature of molecular clouds, showing how high-density, small-scale features are always nested within more rarefied, larger envelopes. This structural hierarchy is, however, a non-trivial one: at any scale, there appear to be more high-density and compact clumps than larger and less dense structures. The densest clumps in a cloud's hierarchy are compact cores, the sites of star formation. This hierarchy can be encoded as a dendrogram representing the nested levels of the emission. We search the densest regions (the densest of the dendrogram) of the ^{13}CO emission maps of the CO Heterodyne Inner Milky Way Plane Survey (CHIMPS) to identify star forming clumps at different stages of their evolution.



Data

CHIMPS:

CO Heterodyne Inner Milky way Plane Survey
Frequency: $J = 3 - 2$ rotational transitions of ^{13}CO (330.587GHz) and C^{18}O (329.331GHz)
Region: Galactic plane
Longitude: $\ell = 27.5^\circ \sim 46.4^\circ$
Latitude: $|b| < 0.5^\circ$
Angular resolution: 15 arcsec.

ATLASGAL(AG):

The APEX Telescope Large Area Survey of the Galaxy
Frequency: 870 μm submillimeter survey
Region: Galactic plane
Longitude: $|\ell| < 60^\circ$
Latitude: $|b| < 0.5^\circ$
Angular resolution: 30 arcsec.

ATLASGAL provides a catalog of physical properties an evolutionary stages of clumps based on their emission bands.

Methods

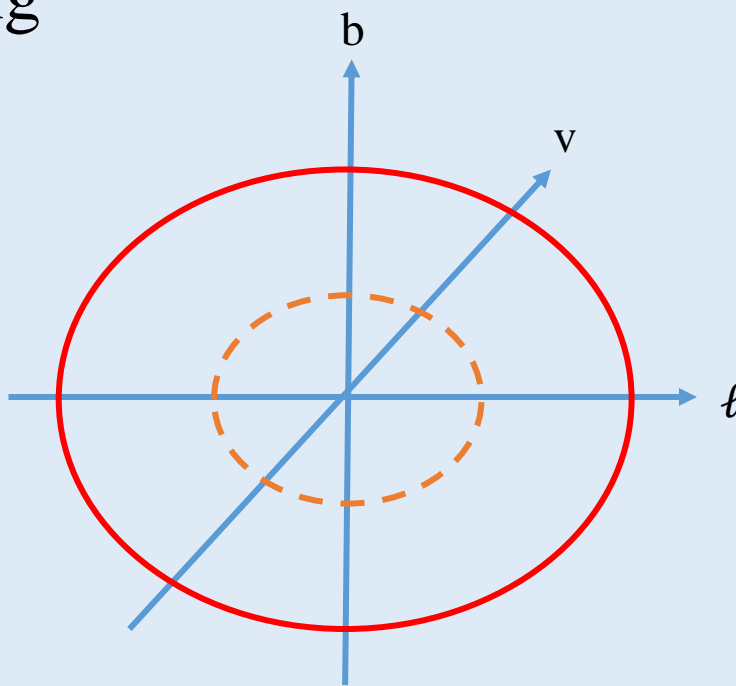
Leaf-ATLASGAL sources assignment

Direct matching:

By using the position(ℓ , b , v) of ATLASGAL sources to find if there are a matching leaf.

By volume search:

Search a volume centered at the peak of the emission and defined by spatial semi axes equal to the equivalent radius of the leaf plus 5 pixels and velocity semi-axis spanning 5 velocity channels.



Result

The number of matching data

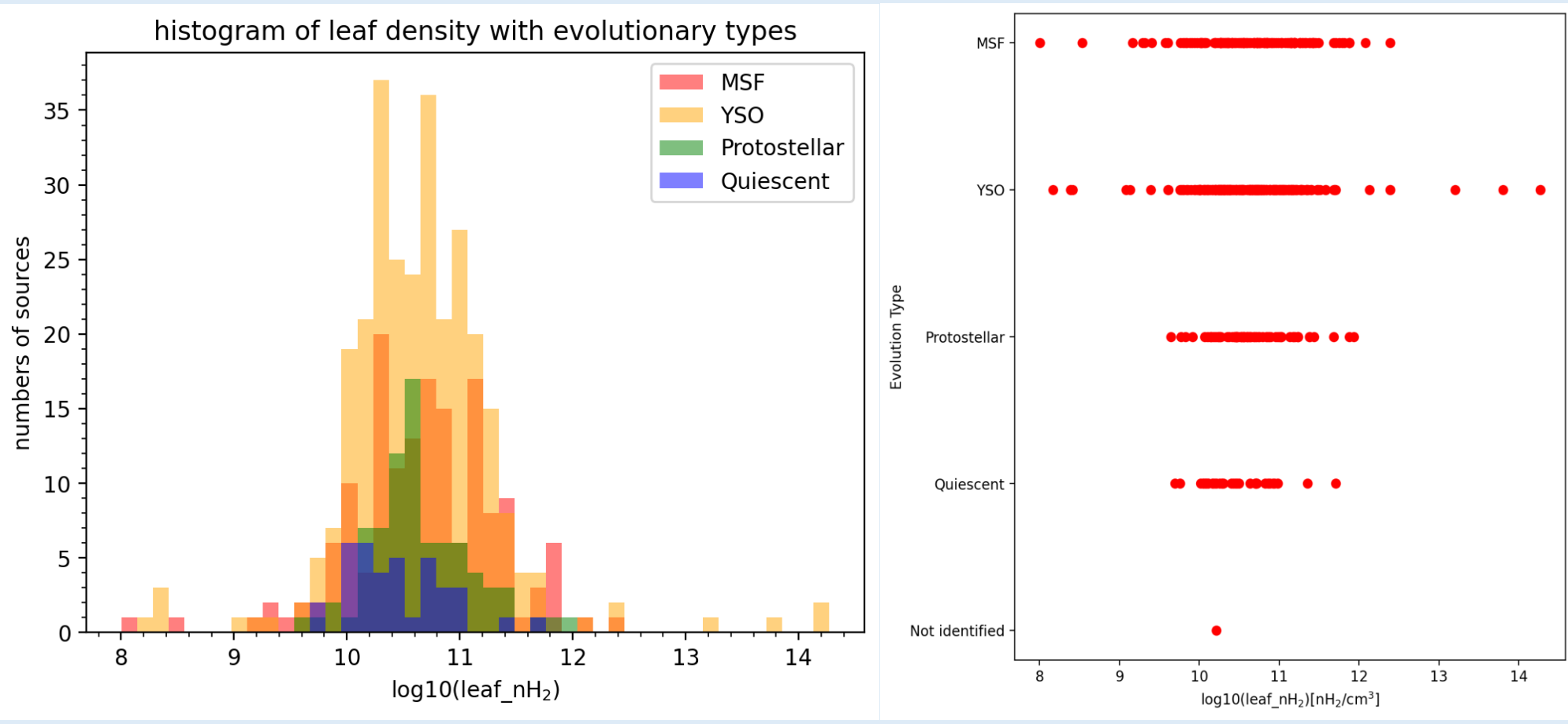
The original number of leaves in CHIMPS are 5025, ATLASGAL sources are 934 in the area covered by CHIMPS. There are 638 ATLASGAL sources can match a leaf in 525 leaves in total. Most of the ATLASGAL sources contain in leaves are YSO.

Evolutionary type	Number of sources	Fraction of total	Notes
MSF	182	0.285	} 0.93 Star forming
YSO	325	0.509	
Protostellar	90	0.141	
Quiescent	40	<0.065	} Non-star forming

- MSF: Massive star-forming
- YSO: Young stellar object

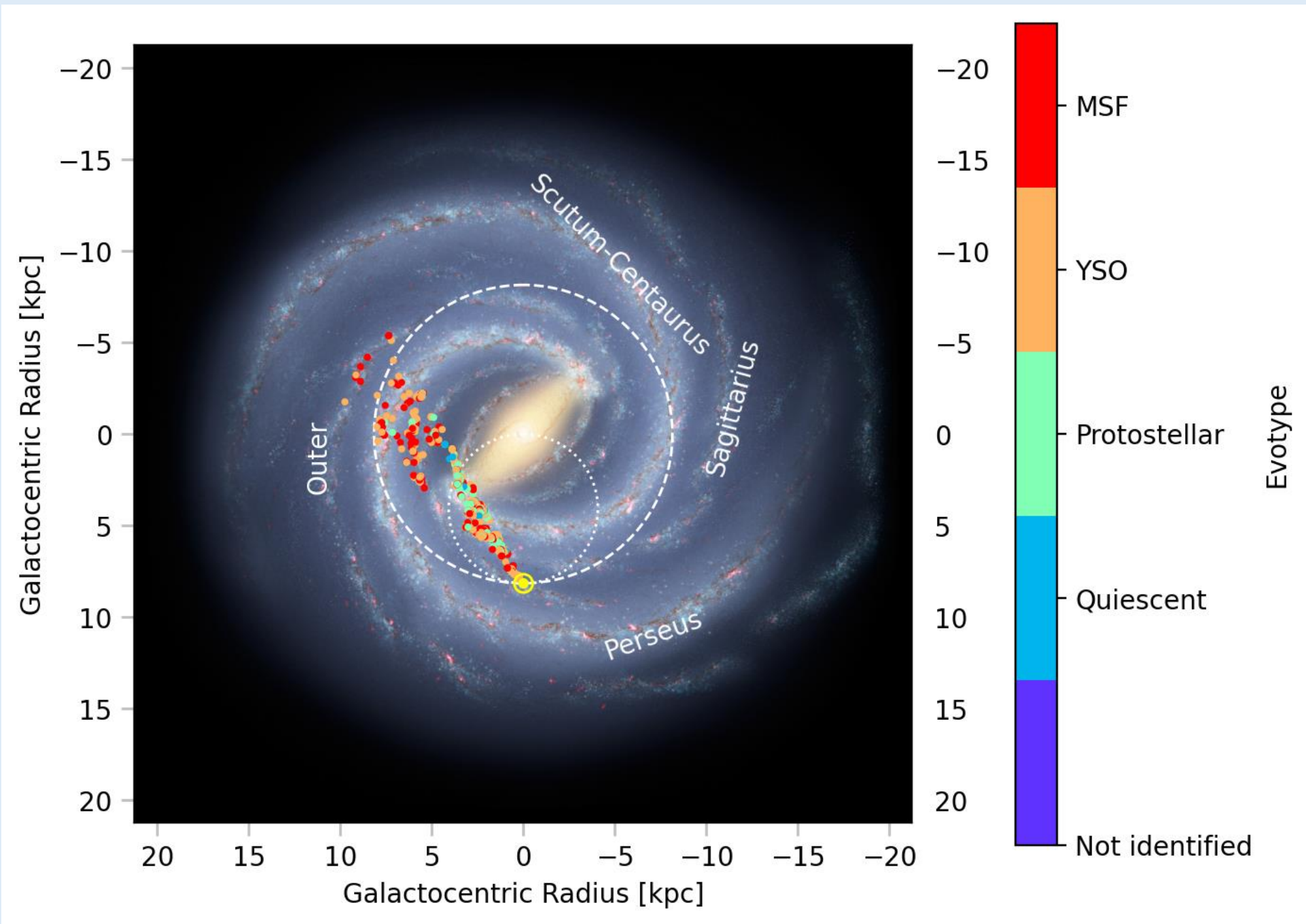
Evolutionary type and leaf nH_2

The right panels suggests that the star forming leaves span lower number densities. It might be caused by the stellar feedback. The stellar winds blow out the gas and reduce the density of the leaf.



Face on distribution of AG source contain in leaf

The sources covers different environments in the Milky way. Most of the sources are located at the spiral arms, Most of the of quiescent and protostellar sources are located near to the edge of the Inner Galaxy.



Multiple objects in one leaf

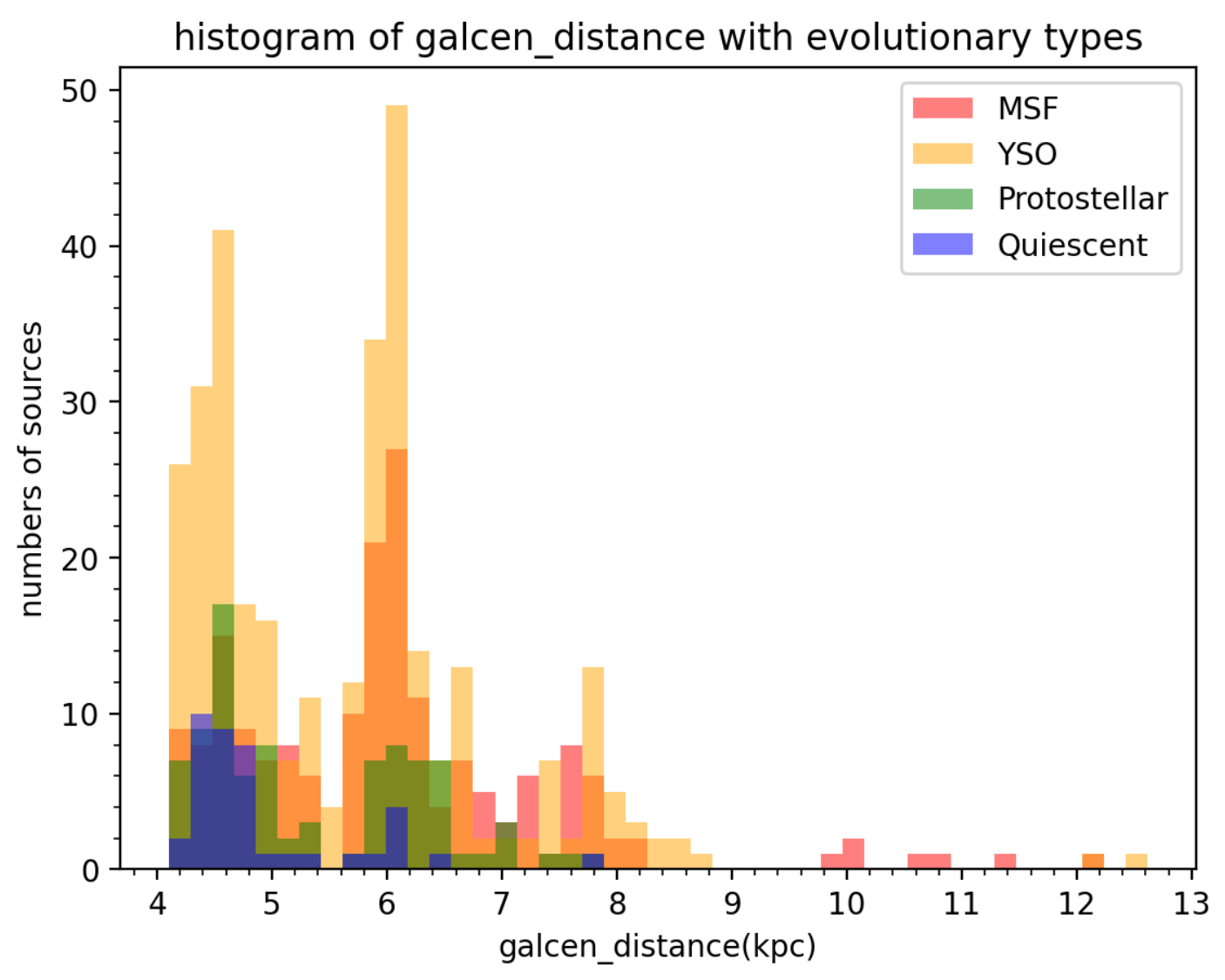
Several of the leaves contain two or more ATLASGAL sources inside. The maximum numbers of the sources in one leaf is 4. The most common of evolutionary type found in multiple-source leaves is YSO, followed by MSF with YSO.

Number of ATLASGAL source in leaf	amount
4	3
3	17
2	70
1	435

Type	amount	Fraction of total
MSF only	14	0.16
YSO only	30	0.33
Protostellar only	4	0.04
Quiescent only	2	0.02
MSF + YSO	19	0.21
MSF + Protostellar	4	0.04
MSF + Quiescent	3	0.03
YSO + Protostellar	3	0.03
YSO + Quiescent	4	0.04
Protostellar + Quiescent	4	0.04
YSO + MSF + Protostellar	2	0.02
YSO + Quiescent + Protostellar	1	0.01

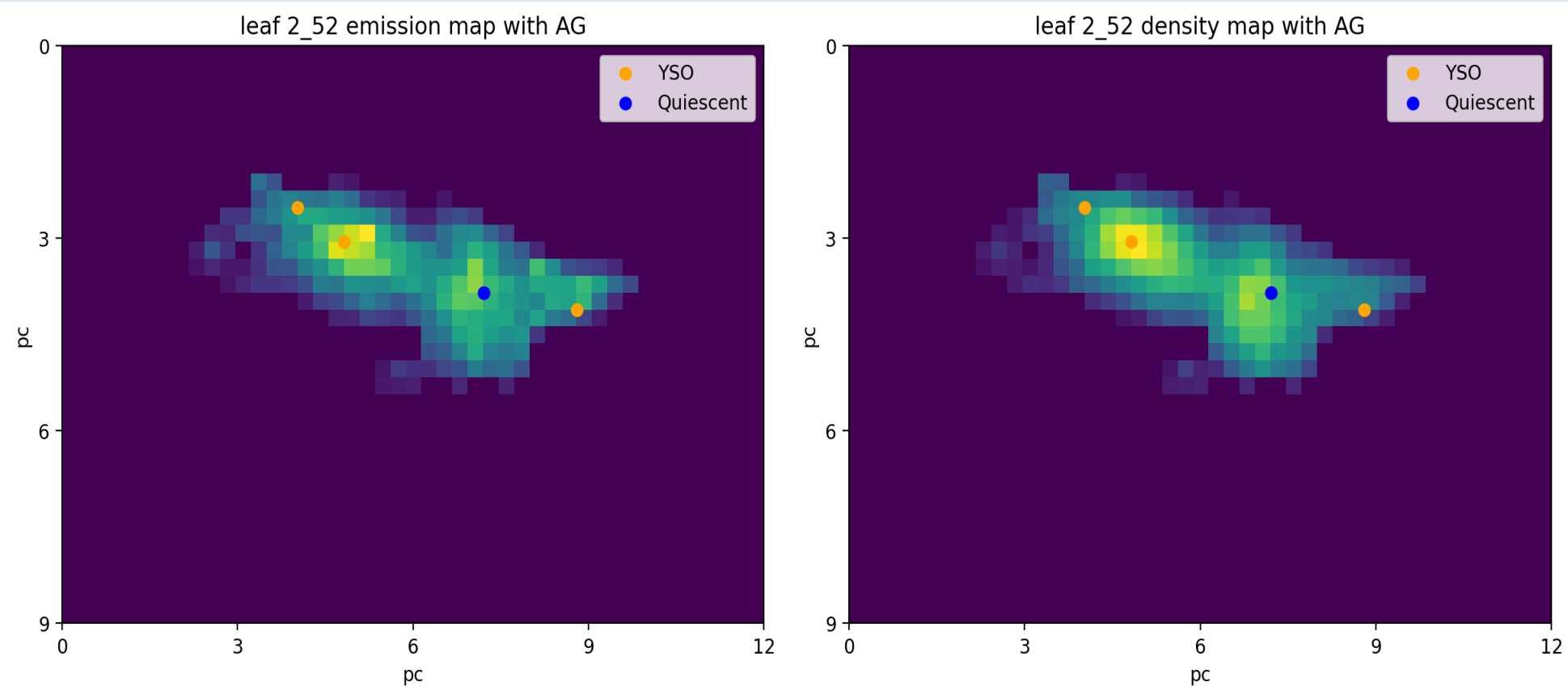
The Galactocentric distance and evolutionary types

The histogram of the Galactic center distance* of the different evolutionary types. Most of the quiescent clumps are located within 5 kpc of the Galactic center.. This may be a consequence of the rotation of the bar suppressing star formation.. *the leaves inherit their distances from their clouds(CHIMPS-SCIMES catalog)



Group of multiple source in the same leaf

Emission and density maps of a large leaf that contains 4 ATLASGAL sources, 3 YSO, 1 quiescent clumps. The quiescent may be the product of the stellar feedback of the star forming region next to it.



Discussion

Although in general, the different Galactic environments do not seem to impact clump evolution, we find that most of the non-star-forming sources are collected within 5 kpc of the Galactic center. Further investigation is required to exclude observational biases.

References

1. ATLASGAL, J. S. Urquhart et al. , 2017 MNRAS
2. CHIMPS SCIMES catalog, Rani et al. 2023, MNRAS
3. CHIMPS, Rigby et al. ,2016 MNRAS ,2019 MNRAS