Massive Young Stellar Objects in Embedded Clusters in the W49, W43 and W51 GMCs

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From Stars to Massive Stars
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Goal

➢ Study the star formation process in Giant Molecular Clouds (GMCs) at different evolutionary stages by identifying Young Stellar Objects (YSOs), and massive protostars.

➢ Identify the groups and clusters of YSOs and examine the properties of these clusters.

➢ Moreover, we expect to increase our statistics of the very rare high-mass protostars by examining these most active star-forming regions in the Galaxy.
Source Catalog

2MASS/ UKIDSS
SPITZER/IRAC
MIPS

YSO Classification

used color-color criteria described in Gutermuth et al. 2009 and Koenig & Leisawitz 2014 to eliminate the contaminant sources (galaxies, AGB stars, background sources) and then classify the YSOs
YSO Groups & Clusters

Minimal Spanning Tree Method (MST) (Cartwright & Whitworth 2004)

The MST method defines clusters as a collection of stars that are connected to each other by branches smaller than a branch length with a minimum number of stars ($N$) in a group.

Koenig et al. 2008; Gutermuth et al. 2009; Beerer et al. 2010; Billot et al. 2011; Chavarria et al. 2014
W49 complex

previously identified star-forming regions

d = 11 kpc
YSO Groups & Clusters in W49

\[ d_c = 96'' \text{ (5.2 pc @ 11 kpc)} \]

\[ d_c = 40'' \text{ (2.2 pc)} \]

31 Class I, 57 Class II
Massive YSO Candidates \((M \geq 8 \, M_\odot)\)

SED Fitter by Robitaille et al. 2007
SED models from Robitaille et al. 2006

*** at least 6 data points to limit the fitting to the better-constrained objects
YSO candidates confirmed as MYSO type (Wu et al. 2016)

MYSOs $\rightarrow$ 7% (16/231)
YOUNG STELLAR OBJECTS IN THE MASSIVE STAR-FORMING REGION W49

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W51

IRAC
3.6 μm
4.5 μm
8.0 μm
YSO Groups & Clusters in W51

W51 A

9 clusters

d_c = 81" (2.1 pc @ 5.4 kpc)

W51 B

16 sub-clusters

d_c = 51" (1.3 pc)
MYSO candidates in W51
15% (130/895)

82% of them within the clusters and the rest is distributed around W51.
Galactic ministarburst region
~0.25 $M_{\odot}$/yr
(Motte et al. 2003)

two regions are connected
(Nguyen Luong+ 2011, Carlhoff+ 2013, Motte+2014)
extends over 140 pc at
$l=(29^\circ-32^\circ)$, $b=(-1^\circ-+1^\circ)$
YSO Groups & Clusters in W43

\[ d_c = 78'' \text{ (2.1 pc @ 5.6 kpc)} \]
\[ d_c = 59'' \text{ (1.6 pc)} \]

57 clusters

102 sub-clusters

MYSO candidates in W43 \(\rightarrow\) 19\% (1123/5873)

82\% of them within the clusters and the rest is distributed around the clusters
Thousands of YSO candidates according to color-color relations have been identified in W49, W43, and W51 regions.

Massive YSO candidates have been identified with SED models.

Groups and clusters of YSOs have been identified with statistical MST method.

What is next?

Use other clustering tools for comparison.

Look for any connection with massive star formation tracers (UCHIIs, masers, etc.)

Compare to other star-forming regions.

Go forward with spectroscopic study for interesting targets.