MULTIWAVELENGTH ANALYSIS OF AFGL 5157 STAR FORMING REGION

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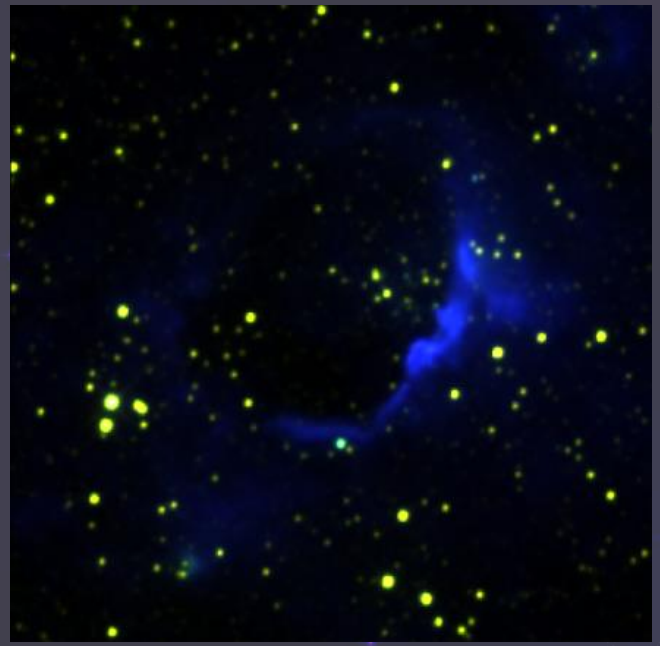
Image credit: ARIES

01 Introduction

Overview of AFGL 5157

- AFGL 5157 is an interesting star-forming region due to its high degree of fragmentation and presence of multiple YSOs, including massive YSOs.
- Massive stars are crucial in influencing the evolution of galaxies, making the understanding of the formation of massive YSOs essential for gaining insights into larger-scale processes.
- The molecular cloud that makes up AFGL 5157 is approximately 12 x 15 parsecs in size and has a mass of around $10^5 M_\odot$.
- Investigating AFGL 5157 can yield significant insights into the physical processes that shape the interstellar medium, as well as the formation and evolution of stars and galaxies.



AFGL 5157
star formation site

02

Objective of Research

The primary objective of this research study is to determine the physical conditions of Galactic H II region AFGL 5157 through multi-wavelength photometric analysis by using IRAF and DAOPHOT II softwares. These studies provide valuable insight into various modes of star formation and their evolution.

03

Research Methodology

Optical Photometric Data

The broadband UBV(RI)$_c$ optical observations of AFGL 5157 was obtained from 1.3m Devasthal Fast Optical Telescope having an aperture of f/4

Image Processing of Optical Photometric Data

imcombine – Combine all bias frames → master bias
imarith – to perform image arithmetic (subtraction of master bias from object frame)

Flat fielding – bias subtracted flat frames → create master flat for each filter separately

imstat – to perform normalization
imarith – *to generate normflat for each filter*

Flat correction of the bias subtracted object frames and alignment of images by *imalign* task

Data Reduction

Processed object frames of all bands are viewed under SAO DS9 software to note down FWHM, sky and standard deviation (SD) of 7 bright isolated stars and computing their Median value.

Write code to generate Harmonic series from FWHM and seven times it's value which is used while running *phot* task.

DAOPHOT subroutines (*find, phot, psf and allstar*) are used to fit stellar photometry on sky-subtracted and combined images

Calibration of data

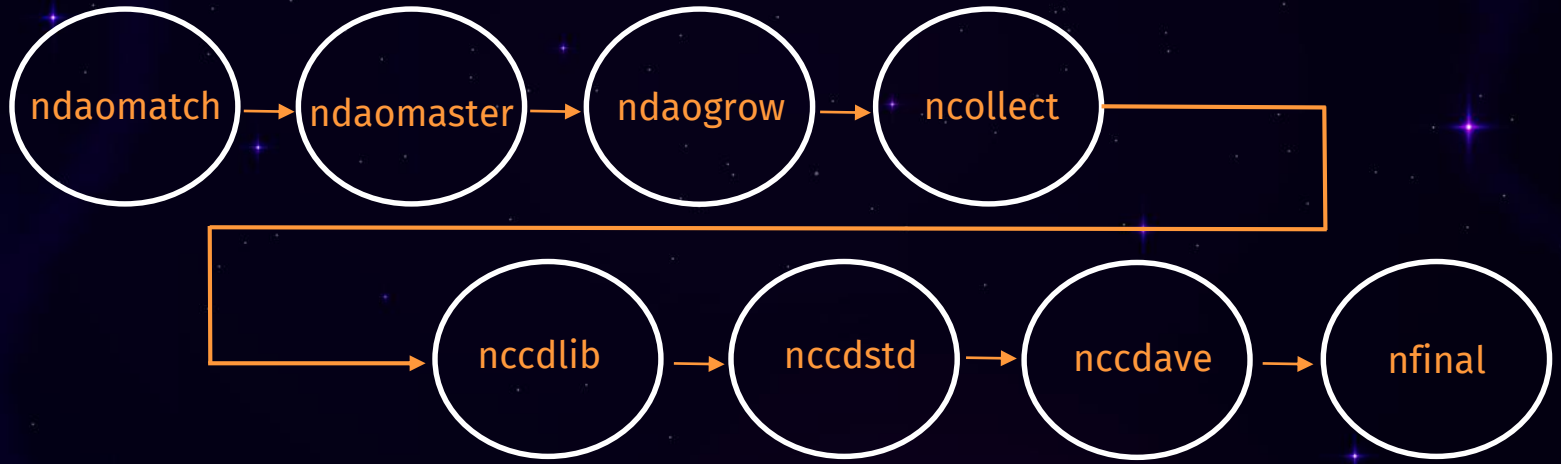
During the same night of observations, several bias and flat frames were also captured along with the object frames. The optical observations of AFGL 5157 were standardized by observing stars in the SA 95 field (α_{J2000}: $03^h53^m21^s$, δ_{J2000}: -00°00′01″) on the same night. The transformation equations are used to calibrate the photometry to the standard system:

$$v = V + A_0 + A_1(V - I_c) + A_2X_v$$
$$b = B + B_0 + B_1(B - V) + B_2X_b$$
$$i_c = I_c + C_0 + C_1(V - I_c) + C_2X_i$$
$$r_c = R_c + D_0 + D_1(V - R_c) + D_2X_r$$
$$u = U + E_0 + E_1(U - B) + E_2X_u$$

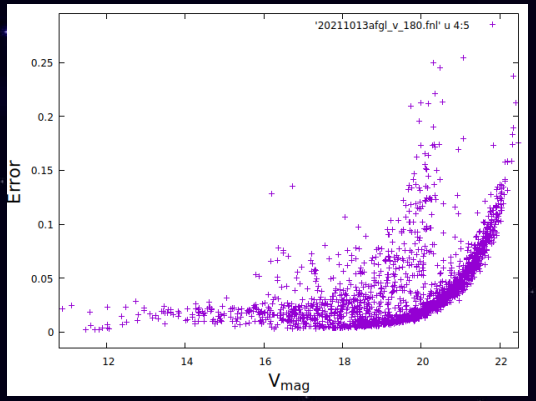
where, V, B, I_C, R_c, U are the Standard Magnitudes,
v, b, i_c, r_c, u are the instrumental magnitudes,
X'_s are the airmasses,
A_i, B_i, C_i, D_i, E_i $[i = 0,1,2]$ are the transformation coefficients,
such that for $i = 2$ yields extinction coefficients

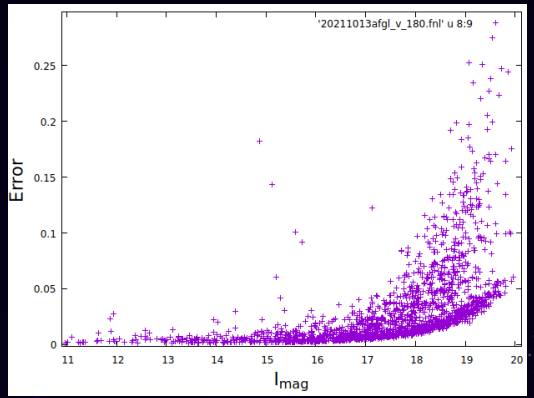
Estimating Parameters

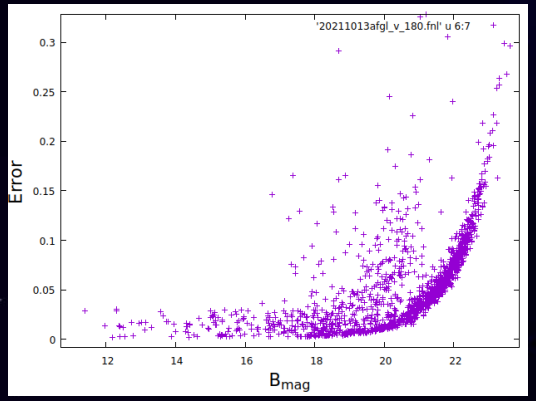
Obtained instrumental magnitudes, transformation coefficients and extinction coefficients using DAOPHOT II subroutines in sequential order

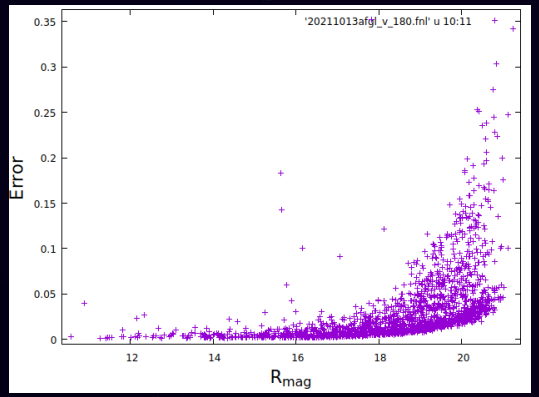


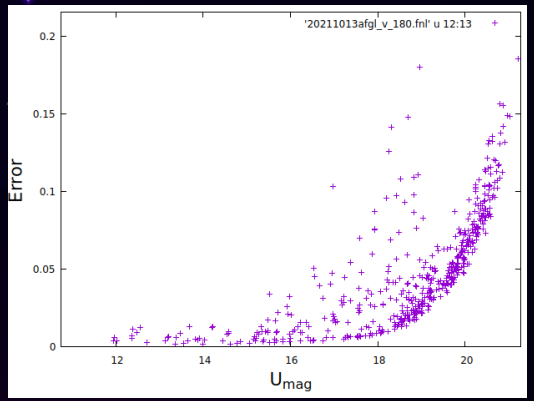
Plots of magnitudes versus Error



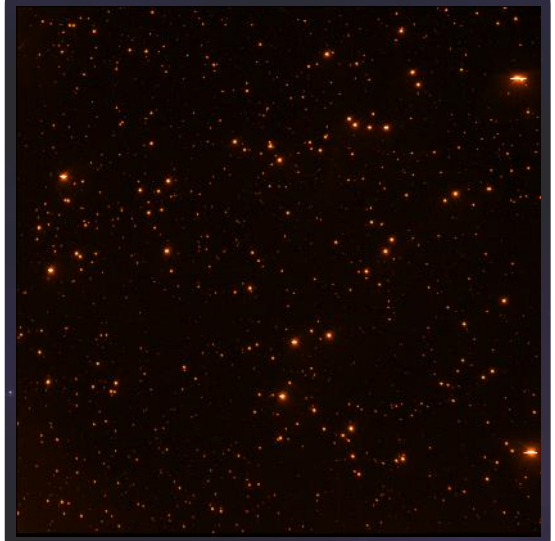








Astrometry

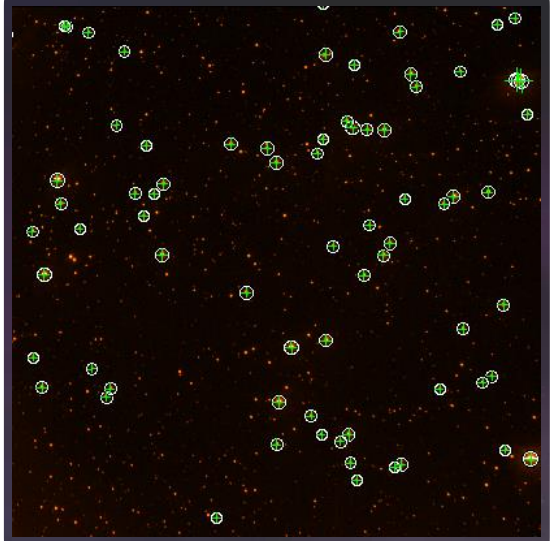


Before Astrometry

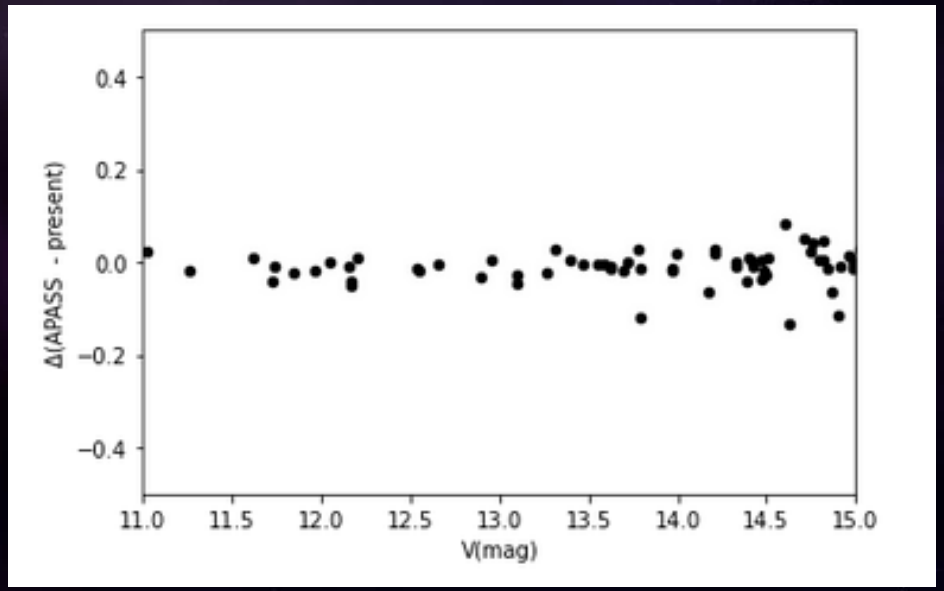
Astrometry → object frame using GAIA (Graphical Astronomy and Image Analysis)

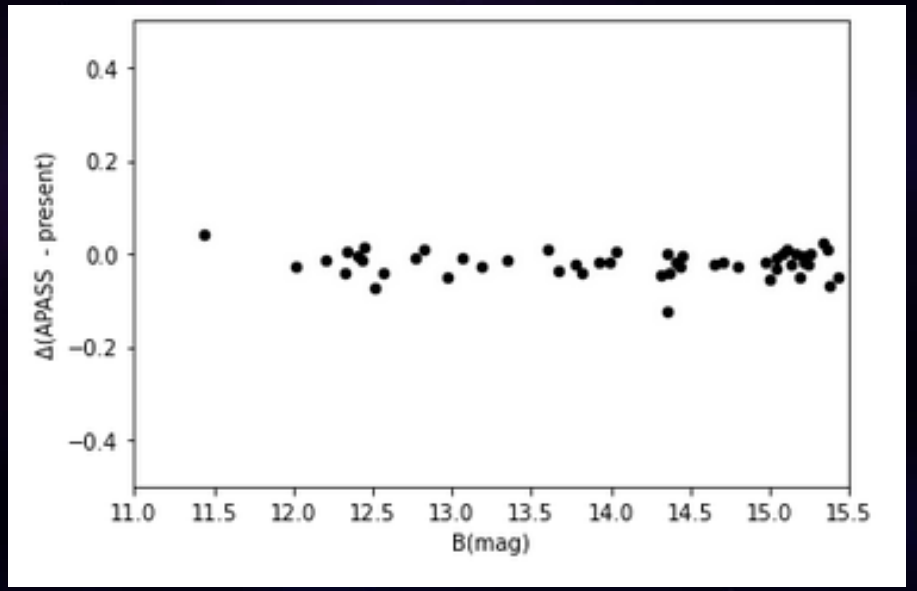
wcstools → to obtain the world coordinates of a set of image coordinates of fits file

$xy2sky$ → to obtain Right ascension and Declination



After Astrometry



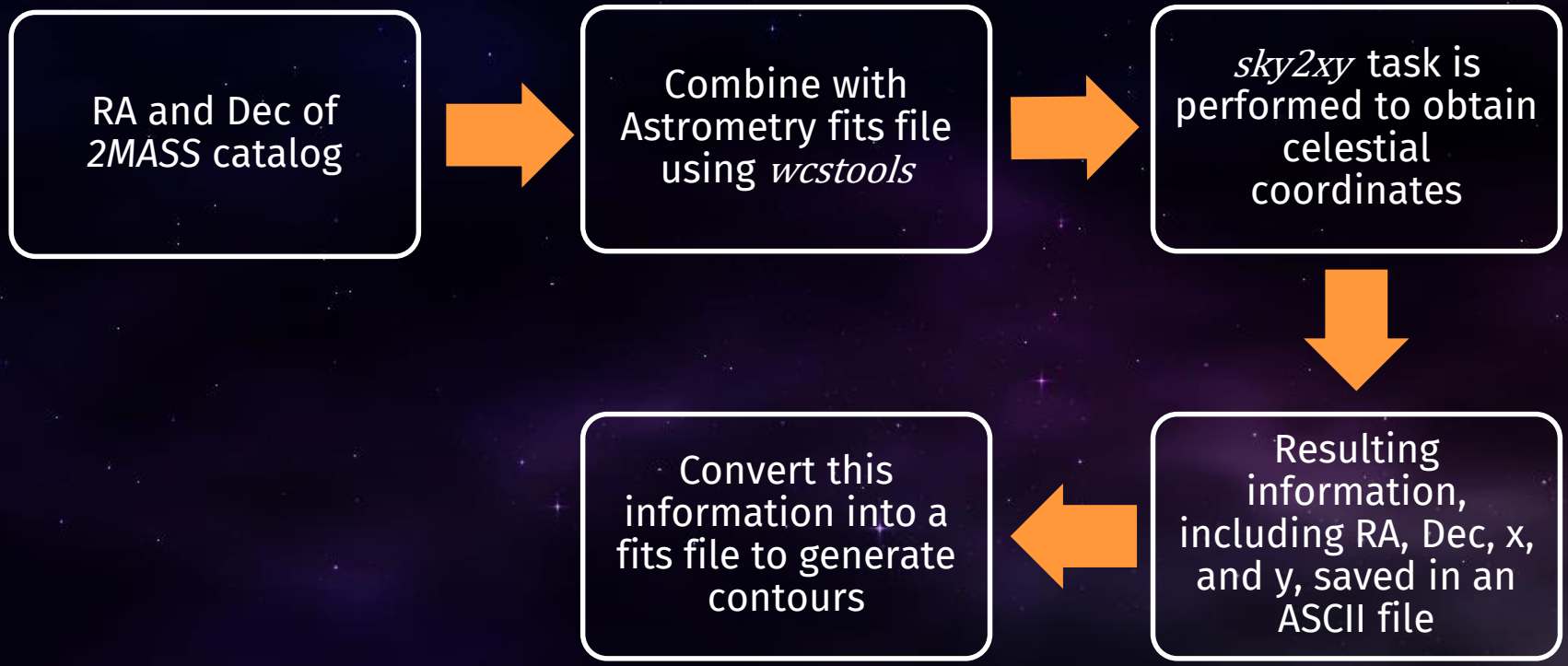


Comparison between the magnitudes from archive “APASS” and present photometry in V and B bands

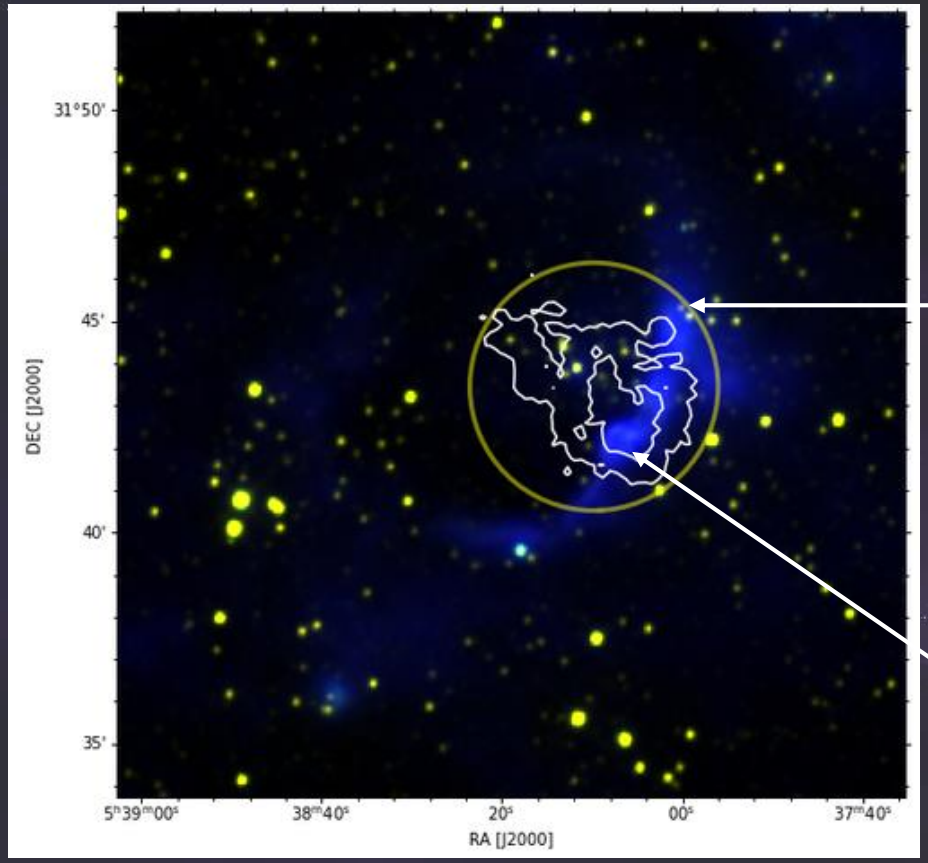
04

Data Analysis and Results

Multiwavelength Analysis using 2MASS catalog

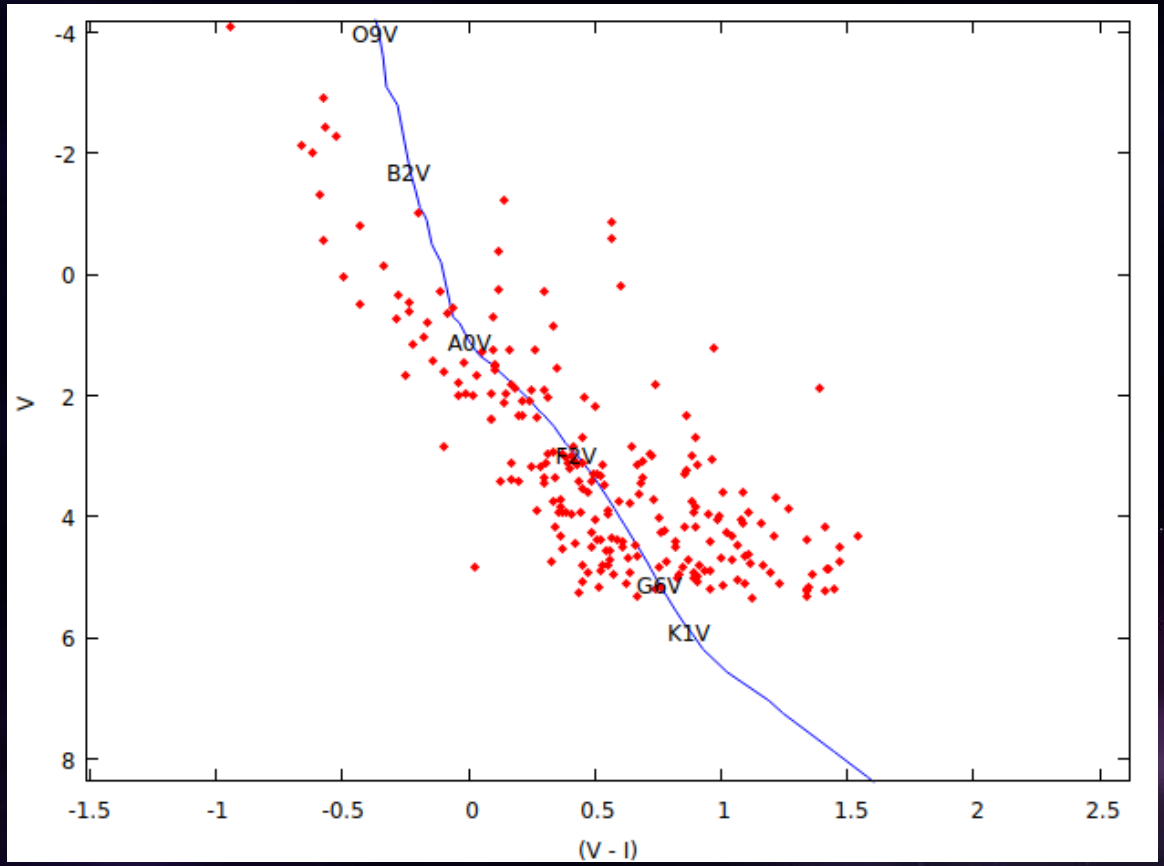


Multiwavelength Analysis using 2MASS catalog



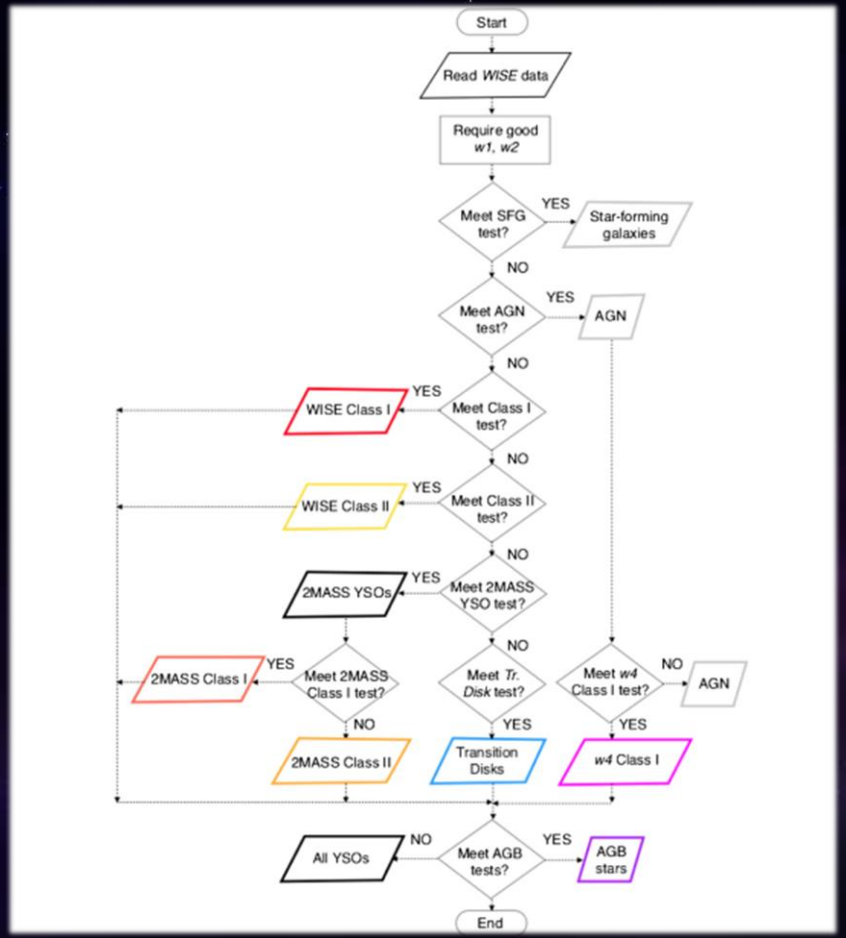
Represent clustering identified in the analysis

Density contours



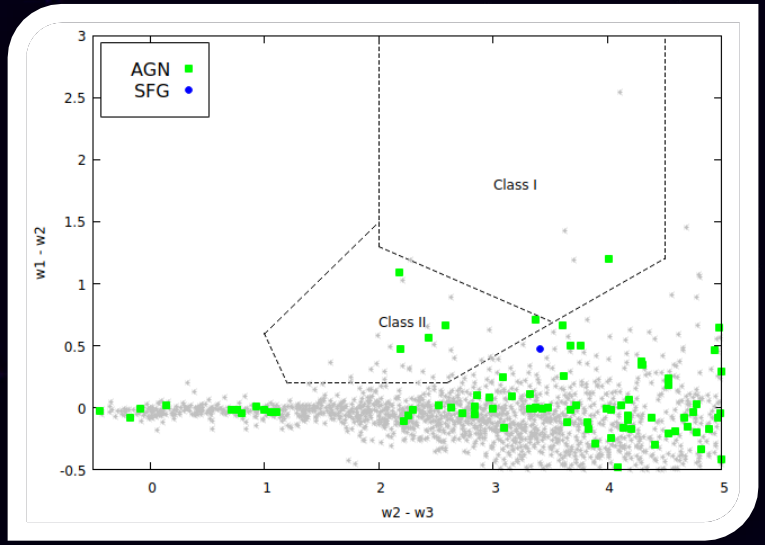
CMD plot of *V* vs *(V – I)* for the sources in AFGL 5157 cluster region

YSOs Identification using *WISE* catalog

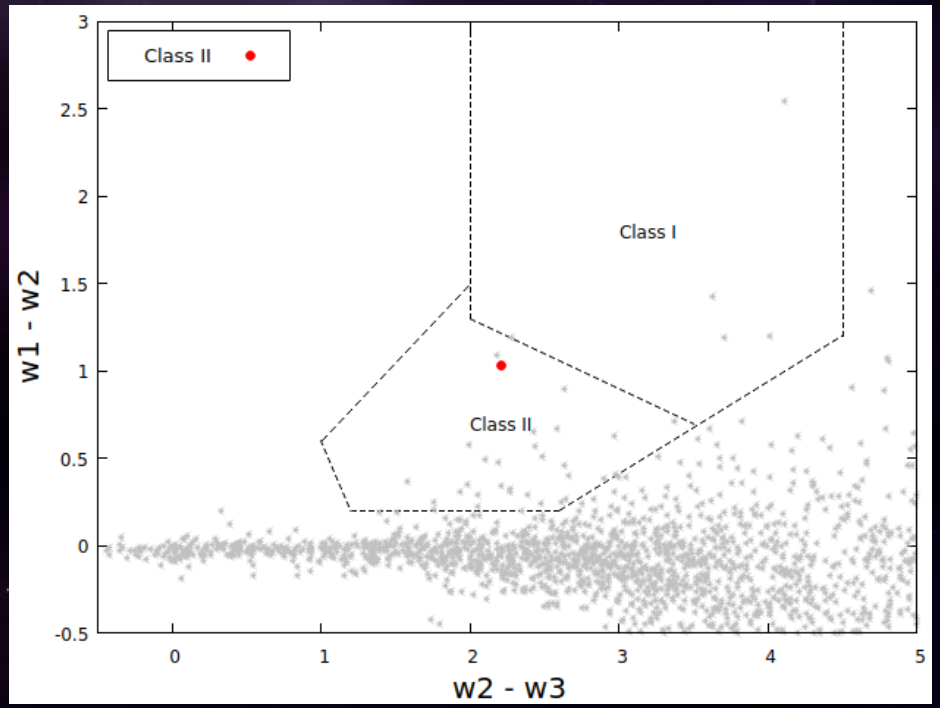


Extragalactic Contaminants

- Applying selection cuts to remove catalog objects that satisfy certain conditions, which are probably Star-forming Galaxies (SFG)
- After a color-magnitude cut, probable broad-line AGNs are eliminated.

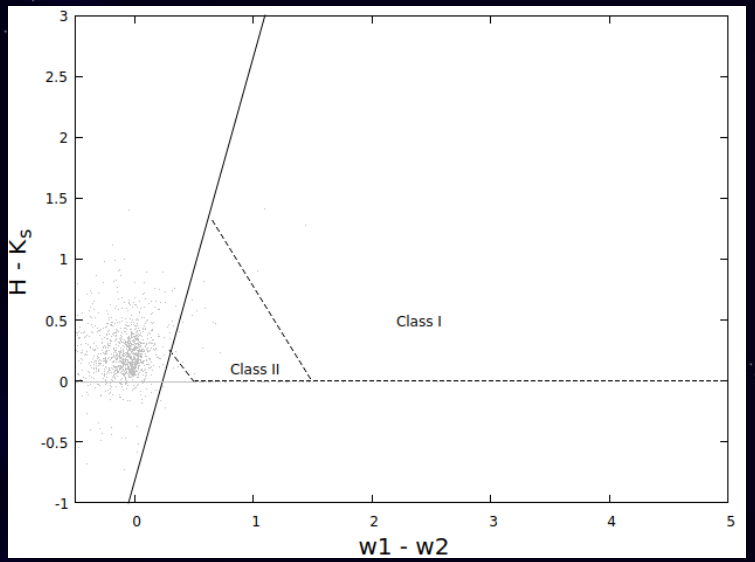


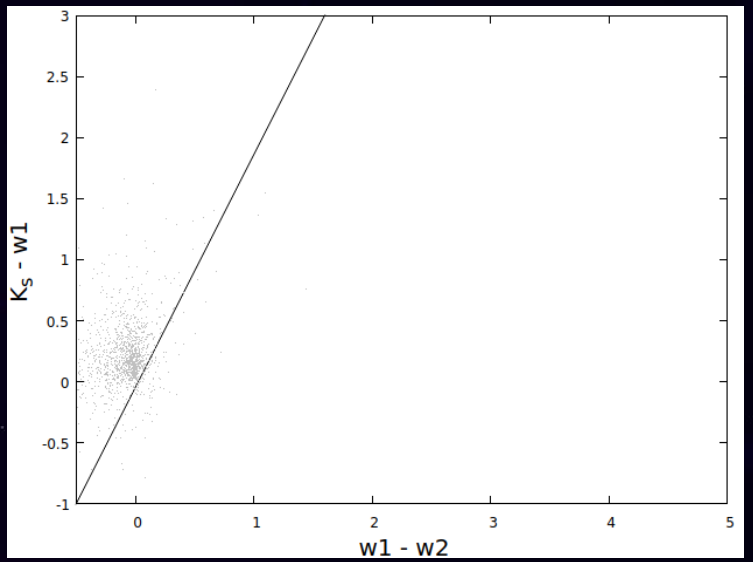
Young Stellar Objects



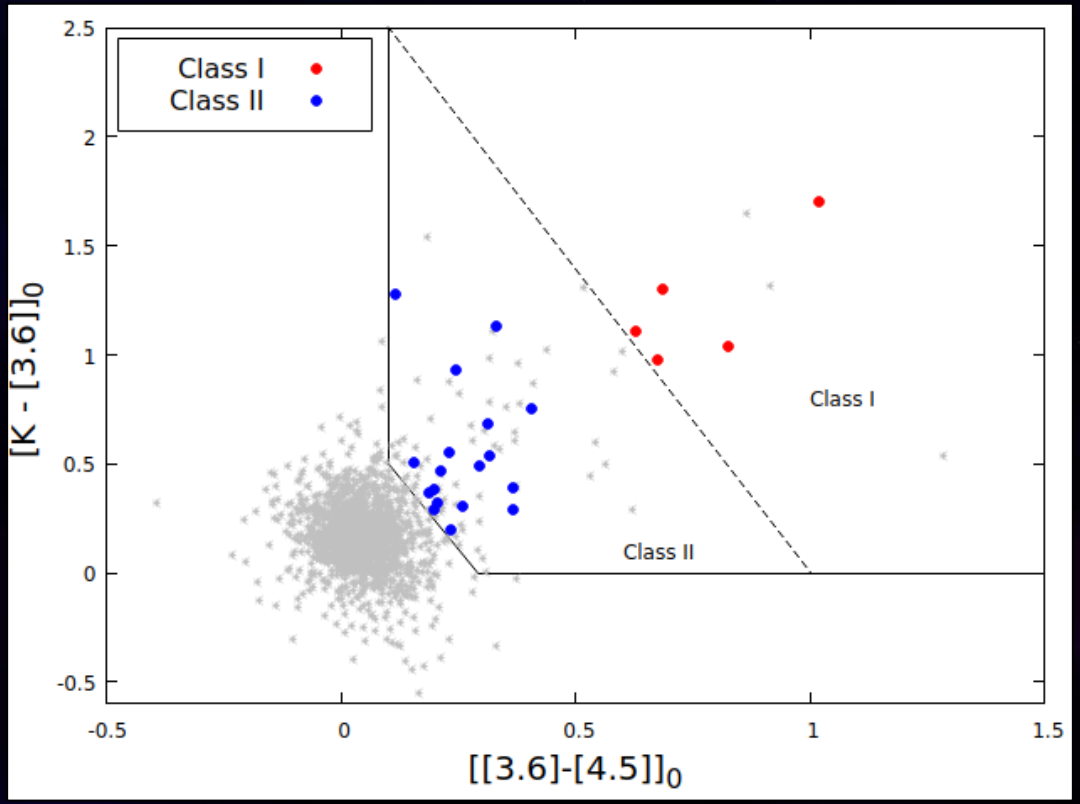
After removing the previously defined contaminants, objects are classified as Class I and Class II YSO based on color criteria conditions

Identifying YSOs using *2MASS-WISE* Color-Color Diagrams





YSOs Identification using *Spitzer* catalog



The color-color diagram to distinguish between Class I and Class II YSOs.

Results and Discussion

The AFGL 5157 cluster region is known to host a diverse range of stars, including O, B, A, F, G, and K type stars.

Spectral Type	Surface Temperature (K)	Luminosity ($L_\odot$)	Mass ($M_\odot$)	Radius ($R_\odot$)
O	30,000-52,000	30,000-1,000,000	16-90	6.6-20
B	10,000-30,000	25-30,000	2.1-16	1.8-6.6
A	7,500-10,000	5-25	0.9-1.1	1.4-1.8
F	6,000-7,500	1.5-5	1.2-1.4	1.15-1.4
G	5,200-6,000	0.6-1.5	0.8-1.2	0.9-1.1
K	3,500-5,200	0.01-0.08	1.15-1.4	0.1-0.7

Properties of different types of stars

New Insights into Star Formation through YSO Detection

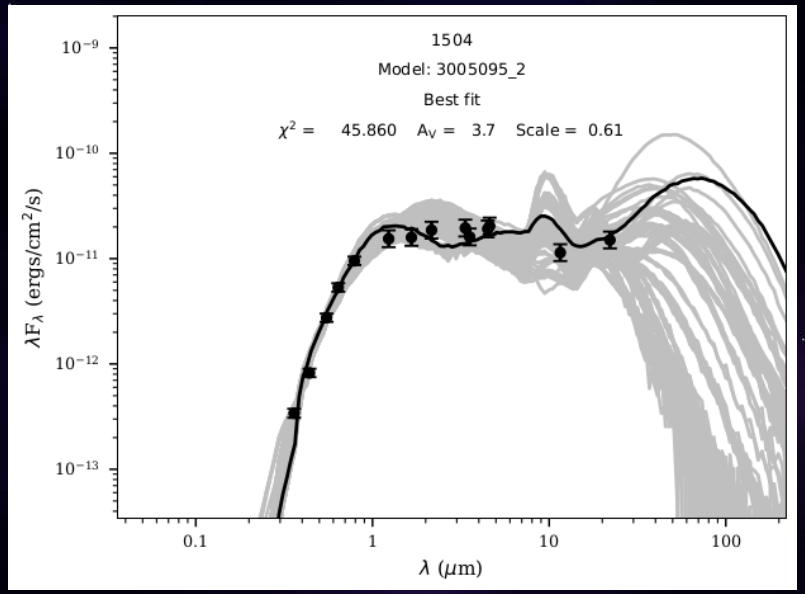
Catalog	YSO Detection Results
WISE	One Class II YSO detected
Spitzer	Higher number of YSOs detected, including Class I and Class II
2MASS + WISE	No YSOs detected

YSO Class	Characteristics
Class I	High luminosity, strong outflows, lack of a well-defined disk, typically found in dense molecular clouds
Class II	Strong infrared excess due to circumstellar disks, lack of strong outflows, typically found in less dense regions than Class I YSOs

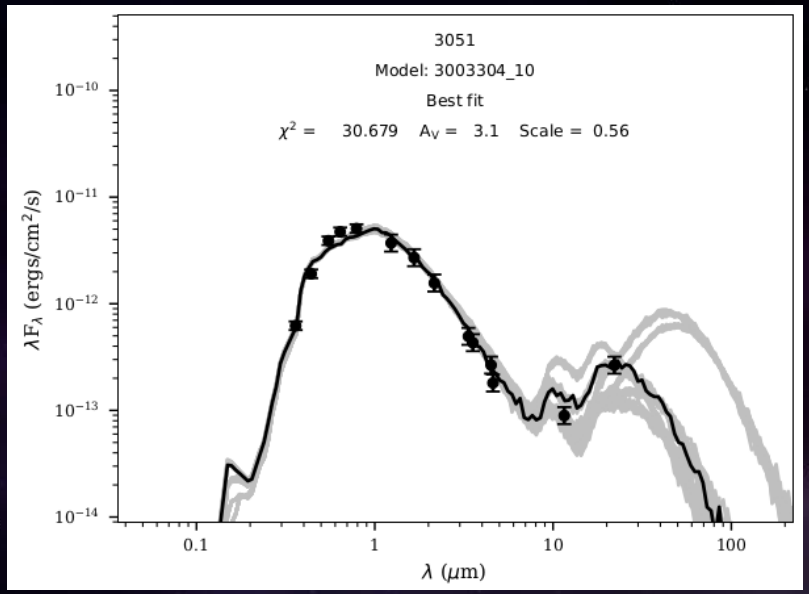
Characteristics of Class I and Class II YSOs for comparison

Spectral Energy Distribution (SED) fitting

The models were considered “well-fit” if their goodness-of fit parameter χ^2_{min} satisfied the condition $\chi^2 - \chi^2_{min} \leq 2N_{data}$, where N_{data} is the number of input data points.



(a)

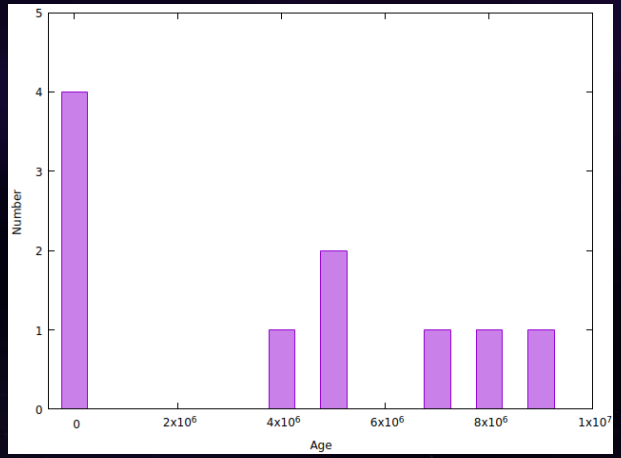


(b)

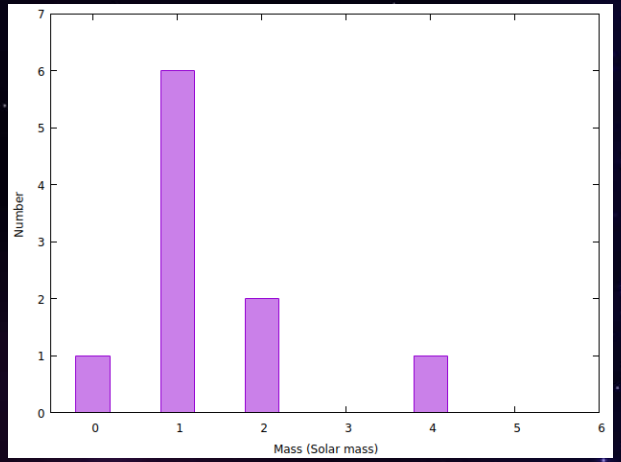
Sample SEDs for Class I [(a)] and Class II [(b)] sources created by the SED fitting tools

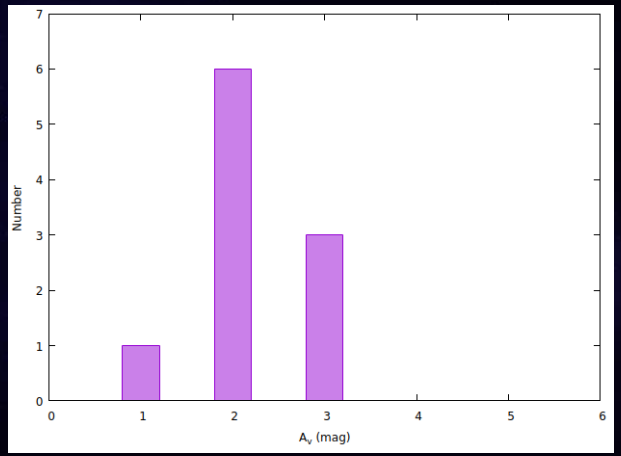
Estimation of stellar parameters based on SED Analysis

ID	N_{data}	χ^2_{min}	A_V (mag)	Age (Myr)	Mass ($M_\odot$)
1	14	30.679	3.065	5.909e	2.552
2	14	17.351	3.302	5.909	2.552
3	14	45.860	3.689	0.668	4.648
4	14	16.882	2.000	7.089	1.736
5	14	6.814	1.886	4.747	1.820
6	13	4.172	2.356	0.380	1.215
7	14	5.776	2.408	9.508	1.592
8	13	22.004	2.016	8.484	1.576
9	12	7.859	2.441	0.4049	1.038
10	12	9.898	2.008	0.5679	0.7864



The average age, mass, and extinction (A_v) of the YSOs in the sample are found to be 4.36 Myr, 1.95 $M_\odot$, and 2.517 mag, respectively





Histograms showing the distribution of the Ages , Masses, and Extinction values (A_V) of the YSOs in AFGL 5157 as derived from the SED fitting analysis

05
Conclusions

Key Findings

01

Bias subtraction helps in removal zero time integration noise and flat fielding is done for removing pixel to pixel non uniformity.

02

It is evident from plots of Magnitude versus Error that short exposure frames are responsible for some scattering in all bands.

03

The values of Extinction Coefficients A_2 ,B_2 ,C_2 ,D_2 and E_2 are 0.2, 0.24, -0.002, -0.009 and 0.5 respectively.

04

There were **1815** stars identified in the ~18′.5 × 18′.5 of AFGL 5157 having detection limits of 21.88 mag and 19.01 mag in the V and I_c bands, respectively.

05

It is evident that there is very small difference between magnitudes from archive ”APASS” and final standard magnitudes from standardization process.

06

From the plot of $w2-w3$ versus $w1-w2$ two-color diagram, only one probable Class II source YSO is detected.

07

There is no evidence of transition disks, AGB stars, or CBe stars. Additionally, there are no YSOs detected using *2MASS* and *WISE catalog.*

08

The classification scheme based on Spitzer data shows a greater number of YSOs in Class I and Class II compared to that from *WISE* data.

09

The WISE data shows a lower number of YSO detections in Class I and Class II, which suggests that it is less sensitive to the detection of YSOs in these classes.

10

Using Histogram, ages ranging from 3 to 10 Myrs, ~ 60% of the sources.
The mass of the YSOs is between 0.7 and 4.6 $M_{\odot}$, ~ 80% lying between 1.0 and 2.5 $M_{\odot}$.
The average age, mass, and extinction (AV) of the YSOs in the sample are found to be 4.36 Myr, 1.95 $M_{\odot}$, and 2.517 mag, respectively.

STAR

Don't let the insecurities of others dull your sparkle.
Shine like the star you are born to be.

- Karen Civil

THANK YOU