Young Stellar Objects in GAIA

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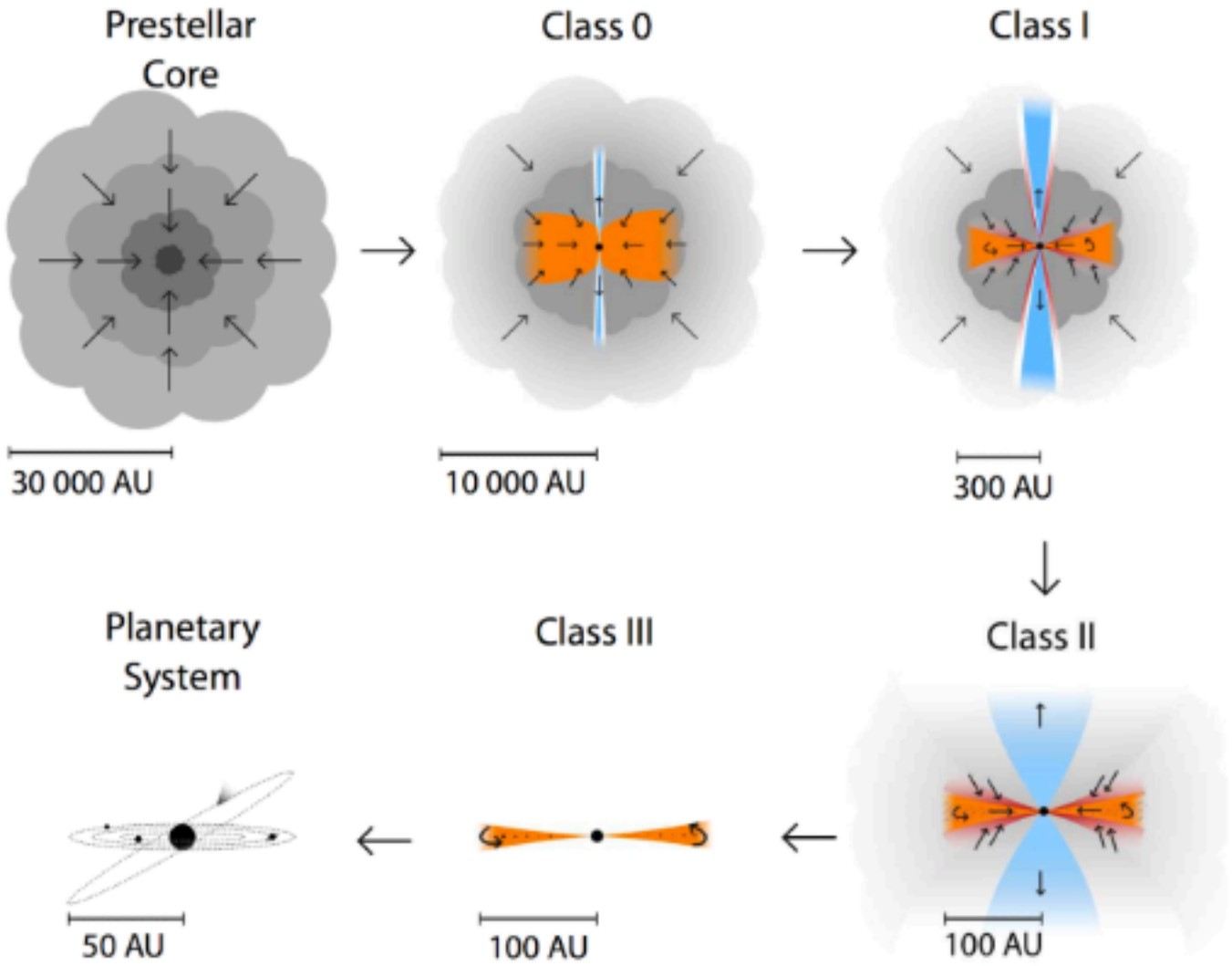
Young Stellar Objects are stars under construction!

Lada+ 99, Andree+ 99



PROTOSTARS

Class 0 and I

Pre-Main Sequence Stars

Class II and III

- Typically, very young embedded sources are visible only from the NIR to mm wavelengths.

- Relatively older (> Myr), revealed sources are visible at optical to NIR.

- Depending on their stellar masses and evolutionary stages, they show different characteristics.

Star formation (SF) throughout the Galaxy before Spitzer traced by radio and all sky survey at far-infrared wavelengths;

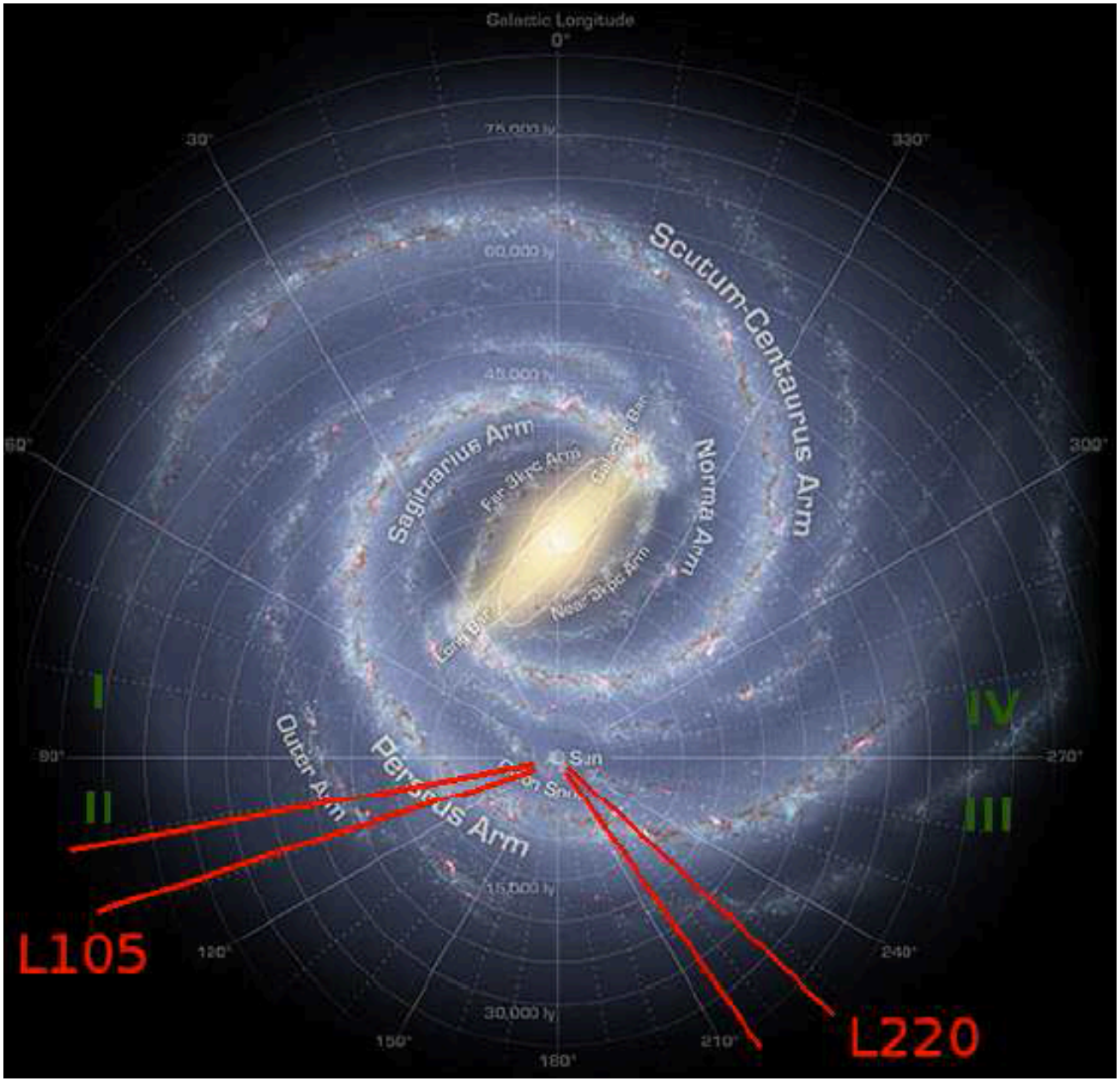
Follow-up surveys based on IRAS and radio catalogs biased toward high mass SF systems, or focused on Sun's neighborhood;

In between, leaving vast clouds of low- and intermediate-mass star formation at larger distance undiscovered.

In collaboration with:

- **Ryszard Szczerba** (NCAC, Toruń, Poland)
- **Marta Sewiło** (NASA/GSFC, Greenbelt, USA)
- **Aleksandra Solarz** (NCBJ, Warsaw, Poland)
- **Natasza Siódmiak** (NCAC, Toruń, Poland)
- **Agata Karska** (UMK, Toruń, Poland)
- **Davide Elia** (INAF, Rome, Italy)

We have initiated a systematic study of star formation in the Outer Galaxy!

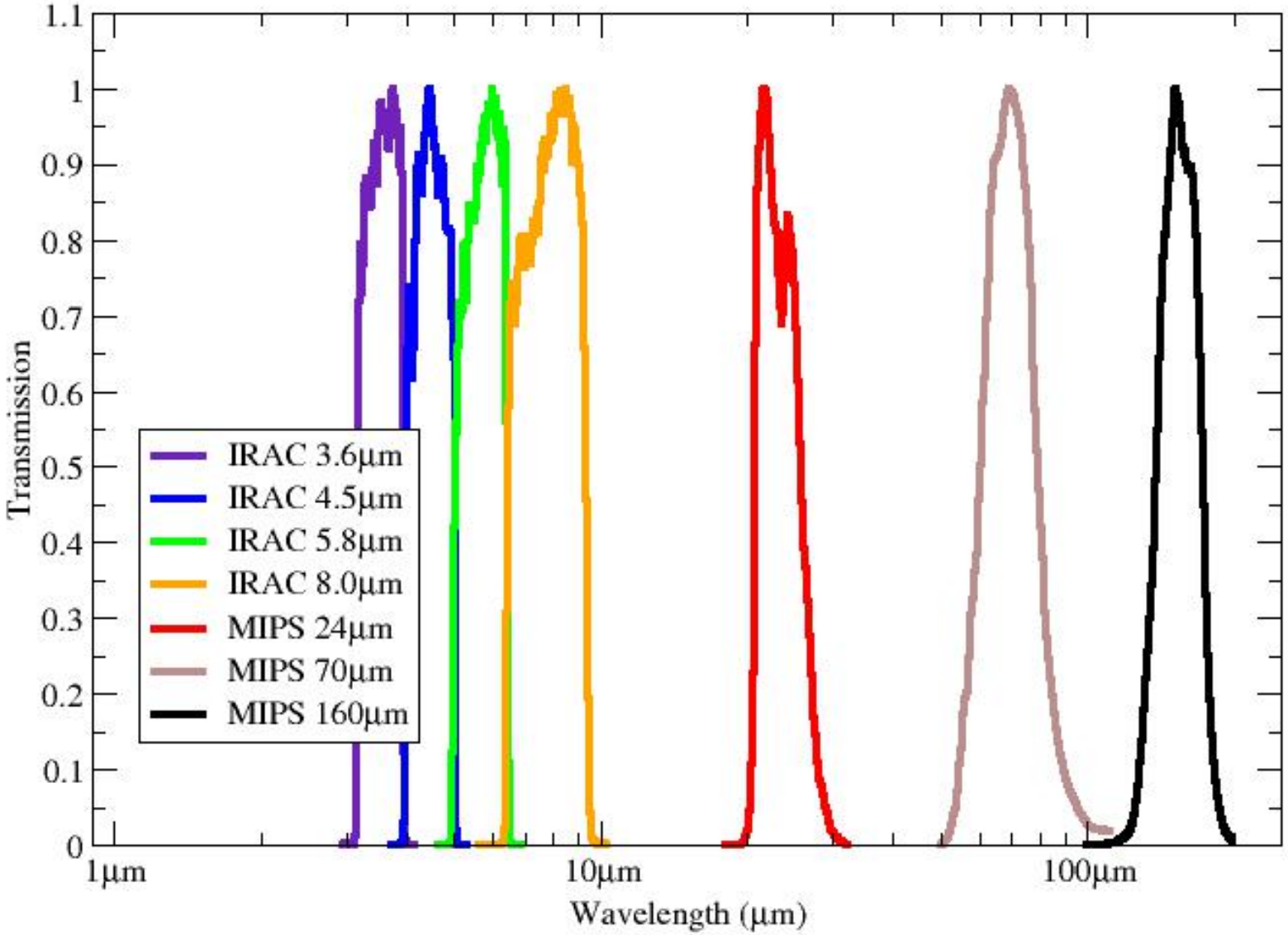


Credit:
NASA / JPL-Caltech / R. Hunt (SSC Caltech).

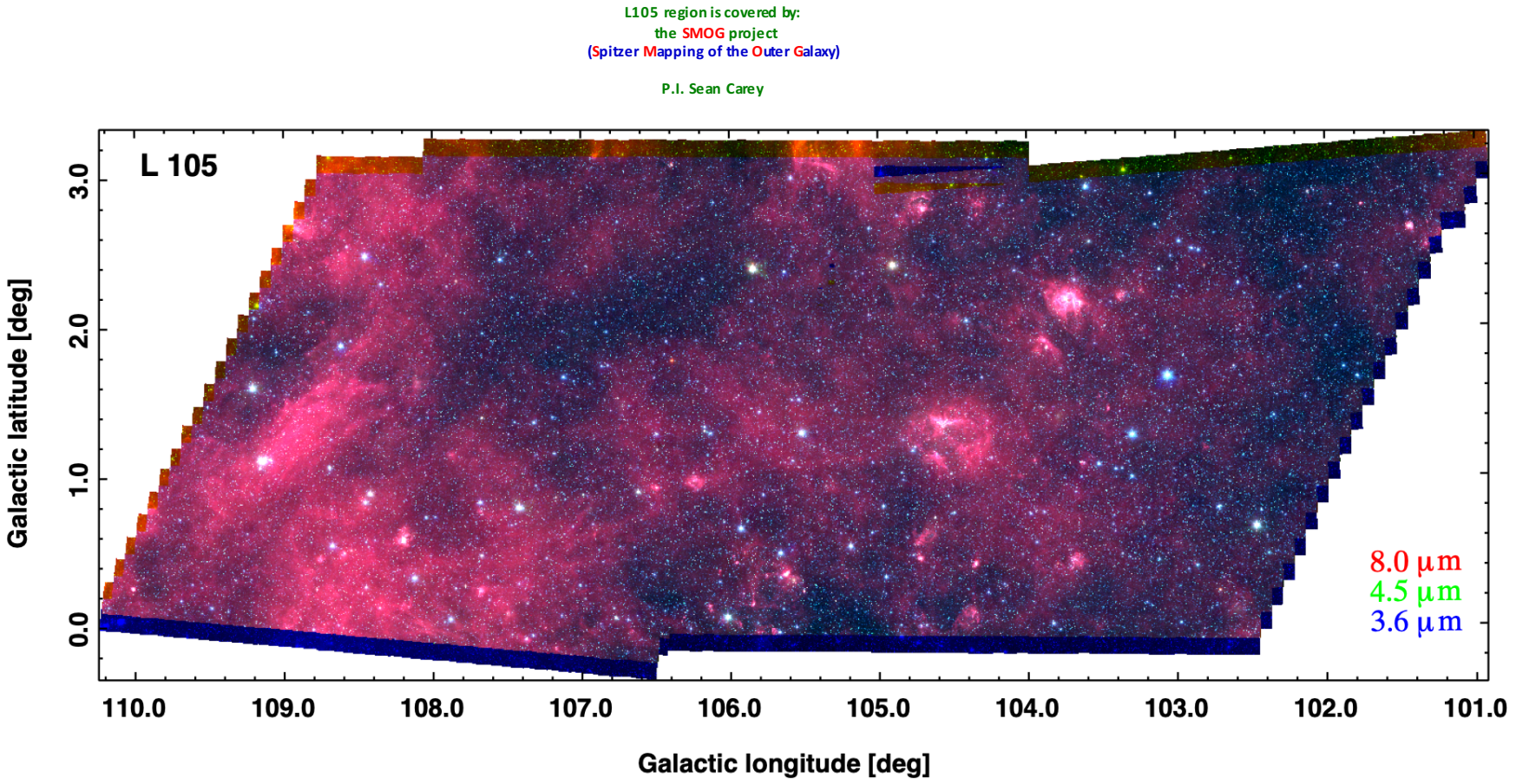
We study two large swaths (~20-30 square degrees each) in different regions of the Outer Galactic plane,
to uncover a completely unstudied population of intermediate- and low-mass YSOs,

using Spitzer data.
PI: Marta Sewiło

Spitzer Filters



L105: l=(102°-109°); b=(-0.2° - +3.2°)



The Spitzer Mapping of the Outer Galaxy (SMOG) project is a 24 square degree area mapping of a representative region of the outer Galaxy using Spitzer's IRAC and MIPS instruments (3.6; 4.5; 5.8; 8.0; 24 μm).

Some statistics:

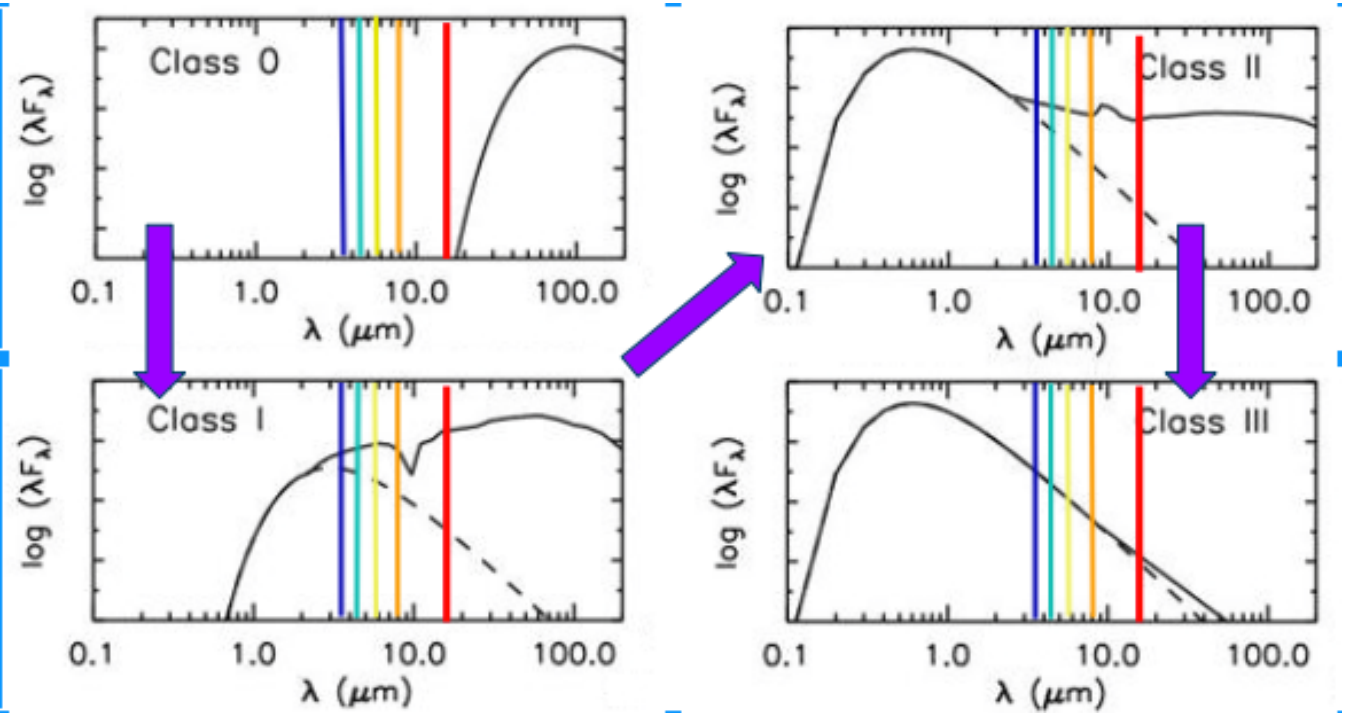
- **2 836 618 sources;**

- **254 849 sources have good photometry**

(σ < 0.2) at all bands: 3.6; 4.5; 5.8, and 8.0 μm.

For these sources we have used a source classification scheme developed by Gutermuth et al. (2008, 2009)

3.6μm 4.5μm 5.8μm 8.0μm 24μm



Spitzer IRAC bands can distinguish different types of YSOs

IRAC based C-C diagrams work well for class division

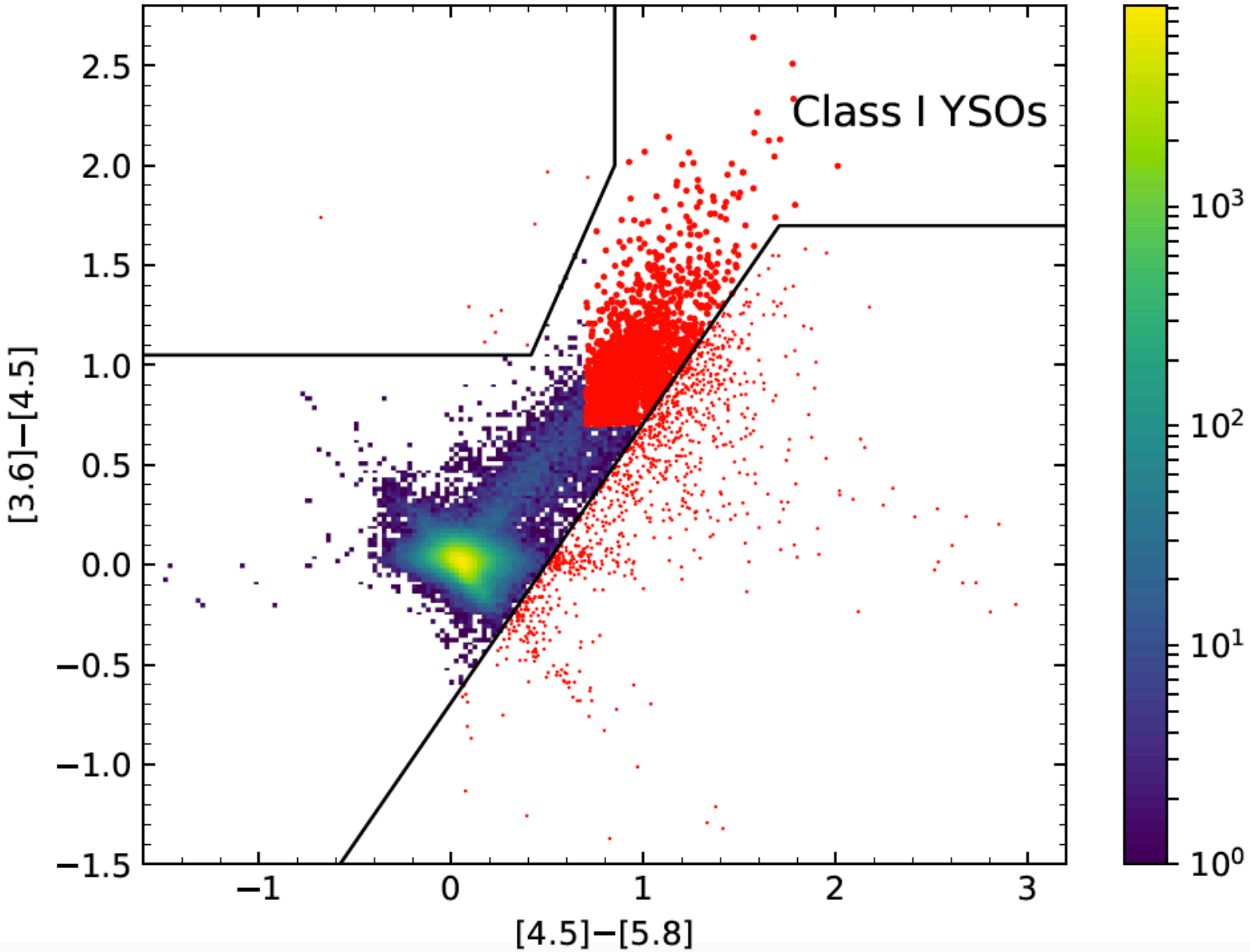
24 μm passband is crucial for distin-guishing different evolutionary phases

available for 11 % of objects in SMOG

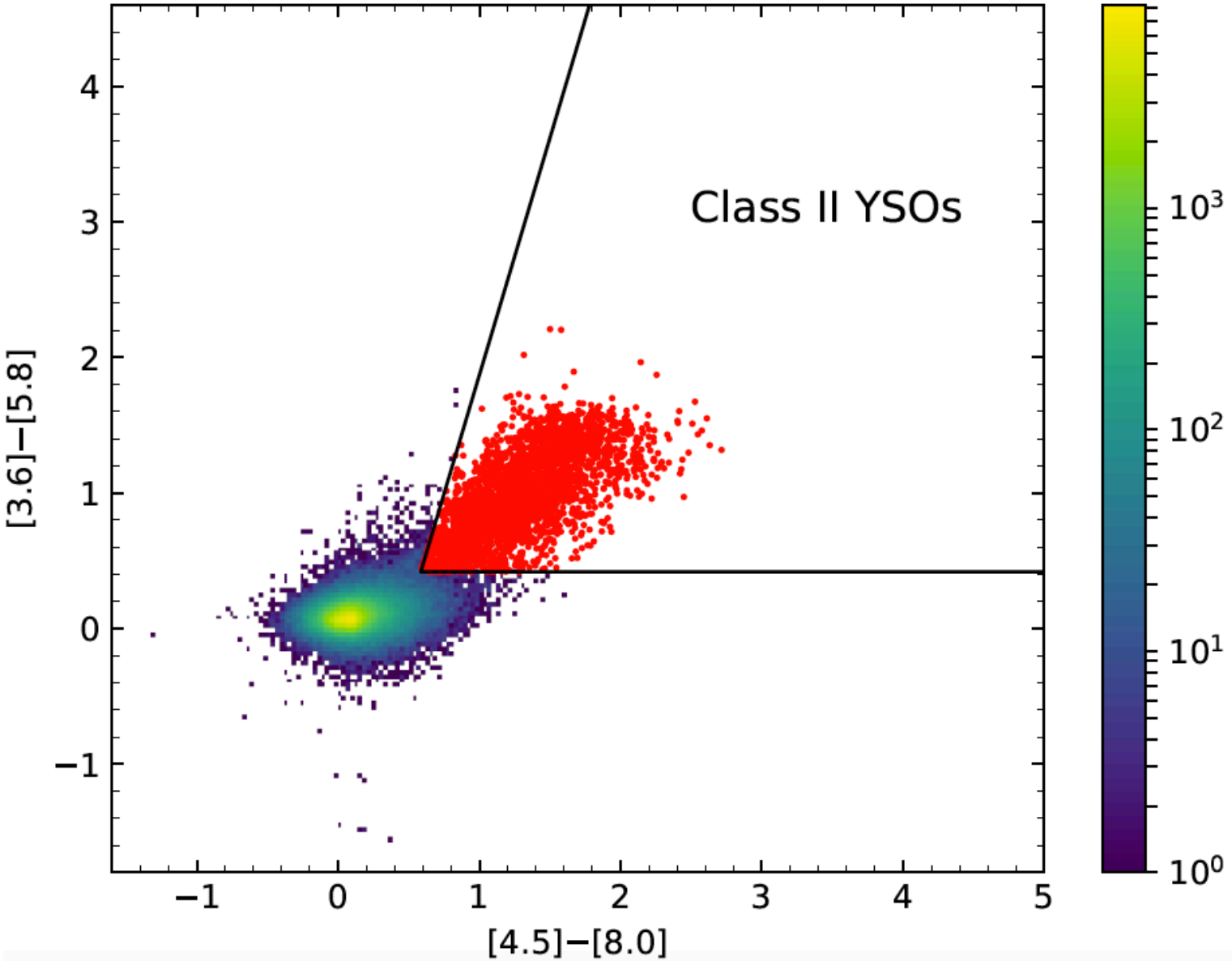
Good photometry ($\sigma < 0.2$) for 14!

Selection of YSO's using CCDs

Select Class I YSO: 1778 sources



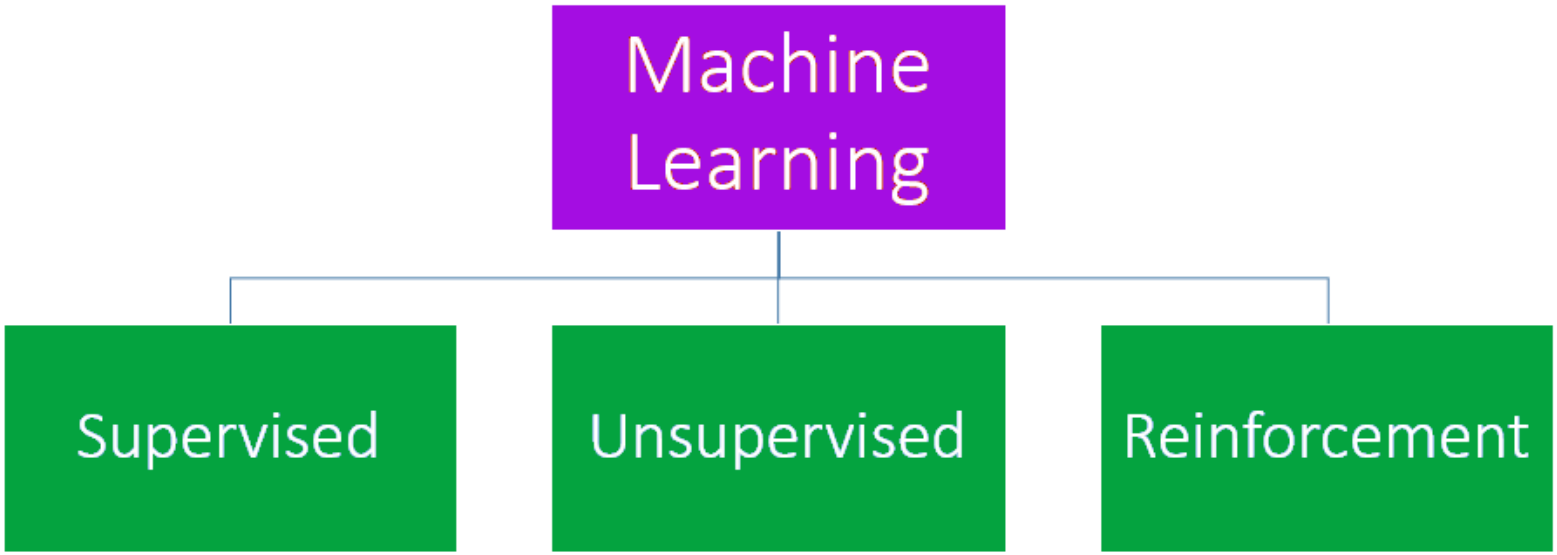
Select Class II YSO: 2962 sources



Selection of YSO's using "artificial inteligence"

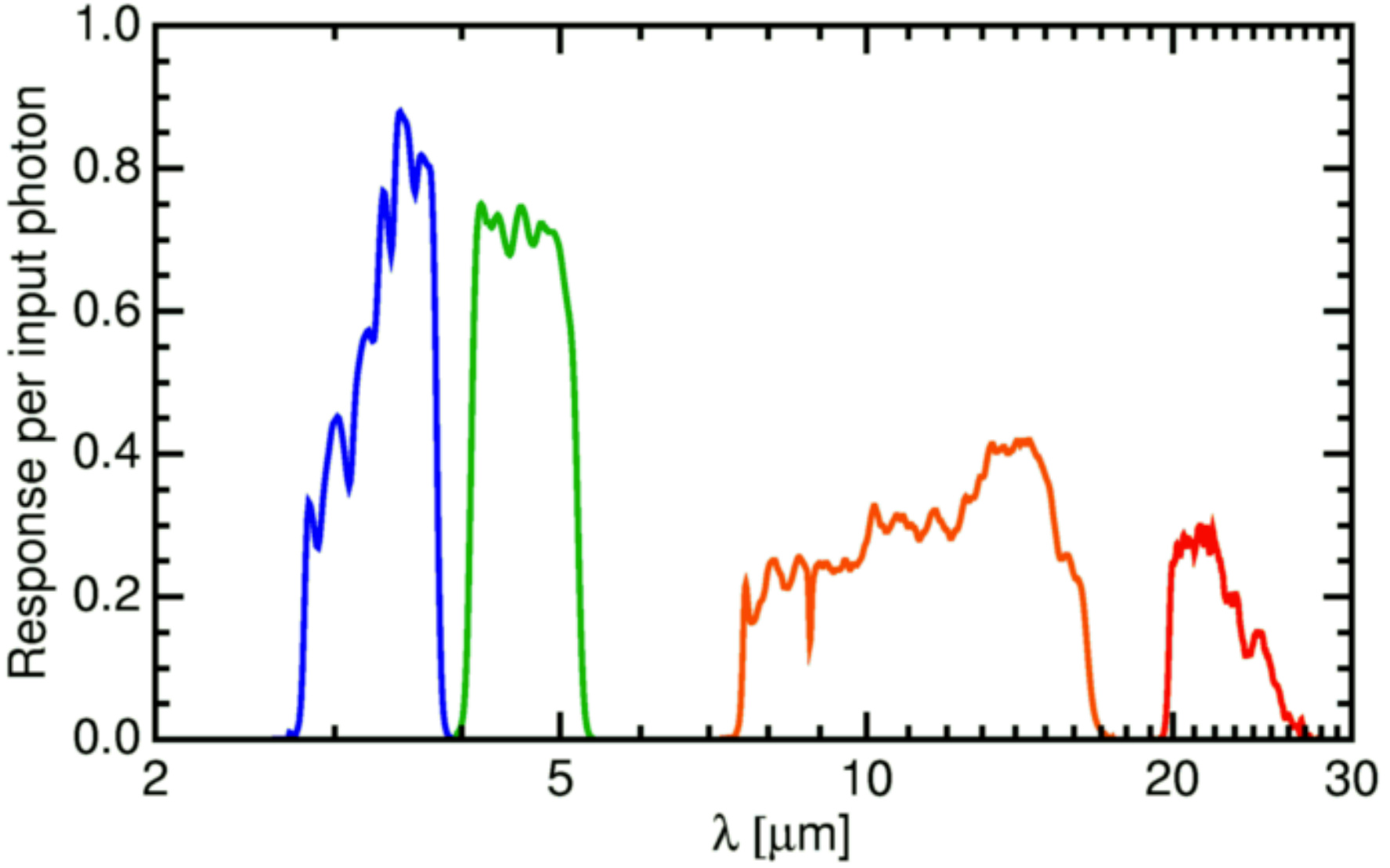
Machine learning in a nutshell

Machine Learning Algorithms (MLA): branch of artificial intelligence
Computer can "learn" from data, develop a model and make predictions



Application of “AI” to search for YSOs among WISE sources

WISE: **W1=3.4; W2=4.6; W3=12; W4=22 μm**



RESULTS

- There are 459 922 AllWISE counterparts for the SMOG sources. However, ONLY 12 185 of them have good quality data.

- This sample has been used to search for YSO sources.

- As a training sample YSO I and YSO II found from the Spitzer CCDs analysis have been used.

  The method is described in Solarz et al. (2017)

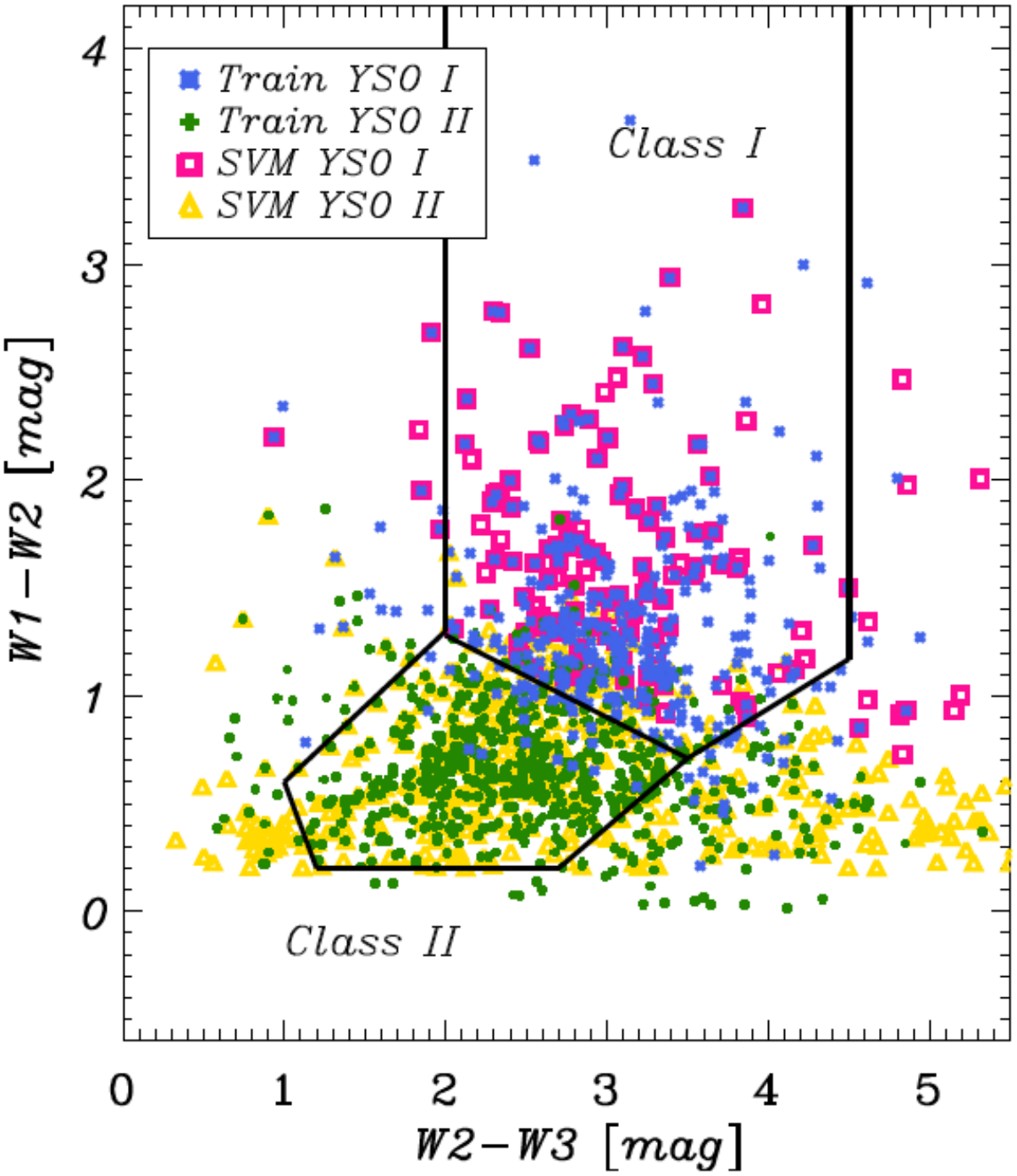
RESULTS

- We have 375 sources with good AllWISE data among 1778 YSO I objects, and 647 ones among 2962 YSO II objects.

88 % accuracy in recognizing the training objects has been achieved.

- We found 26 new YSO I and 549 new YSO II objects.

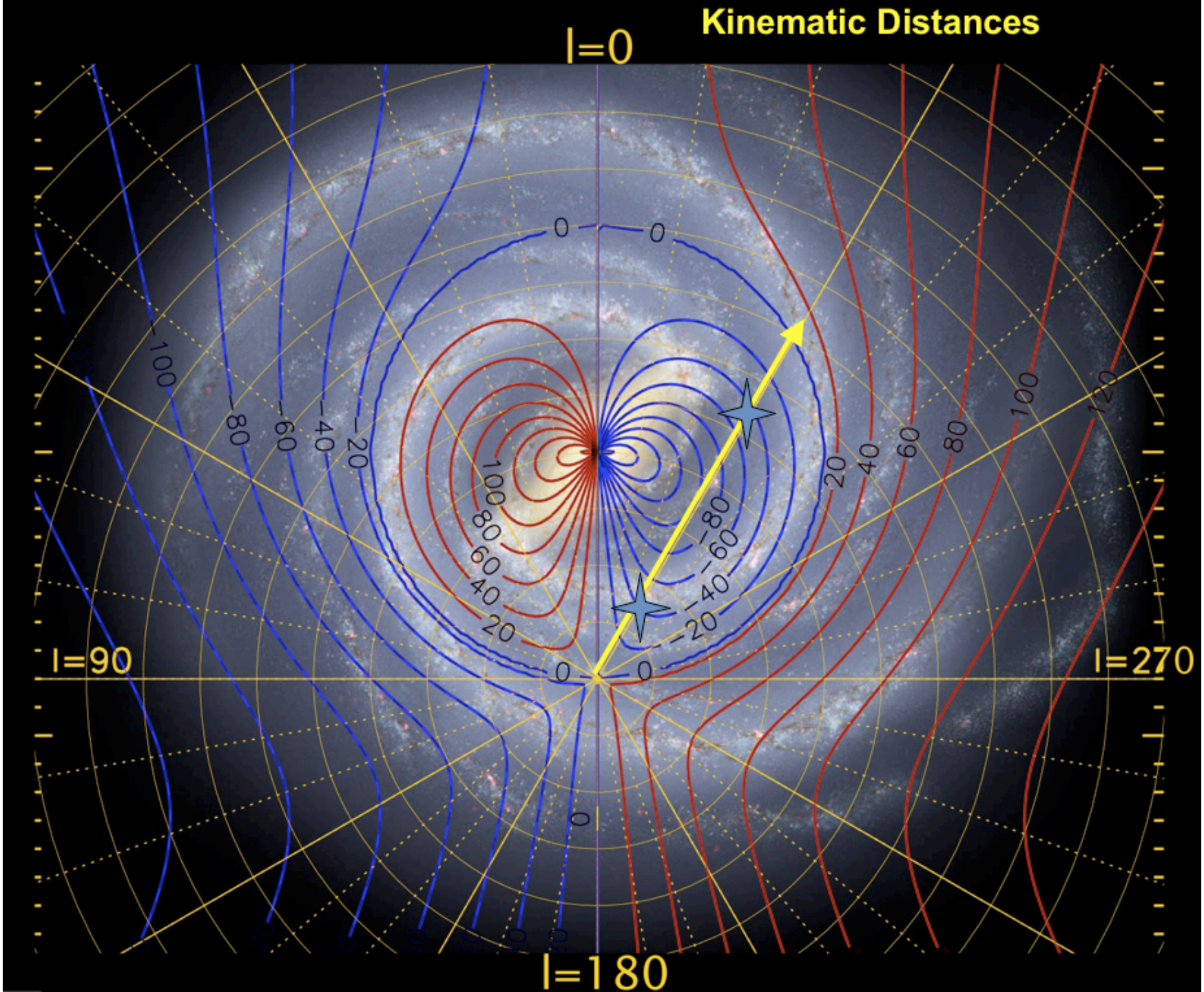
RESULTS of AI



The method can be used to search for YSOs in the whole Galactic plane using WISE data!!!

Distance determination

- CO (1-0) cubes from the Canadian Galactic Plane Survey (CGPS) have been exploited;
- Cloud decomposition algorithm CLUMPFIND (see e.g. Elia et al. 2013) has been applied;
- The Galactic rotation curve of Brunthaler et al. (2011) has been used.

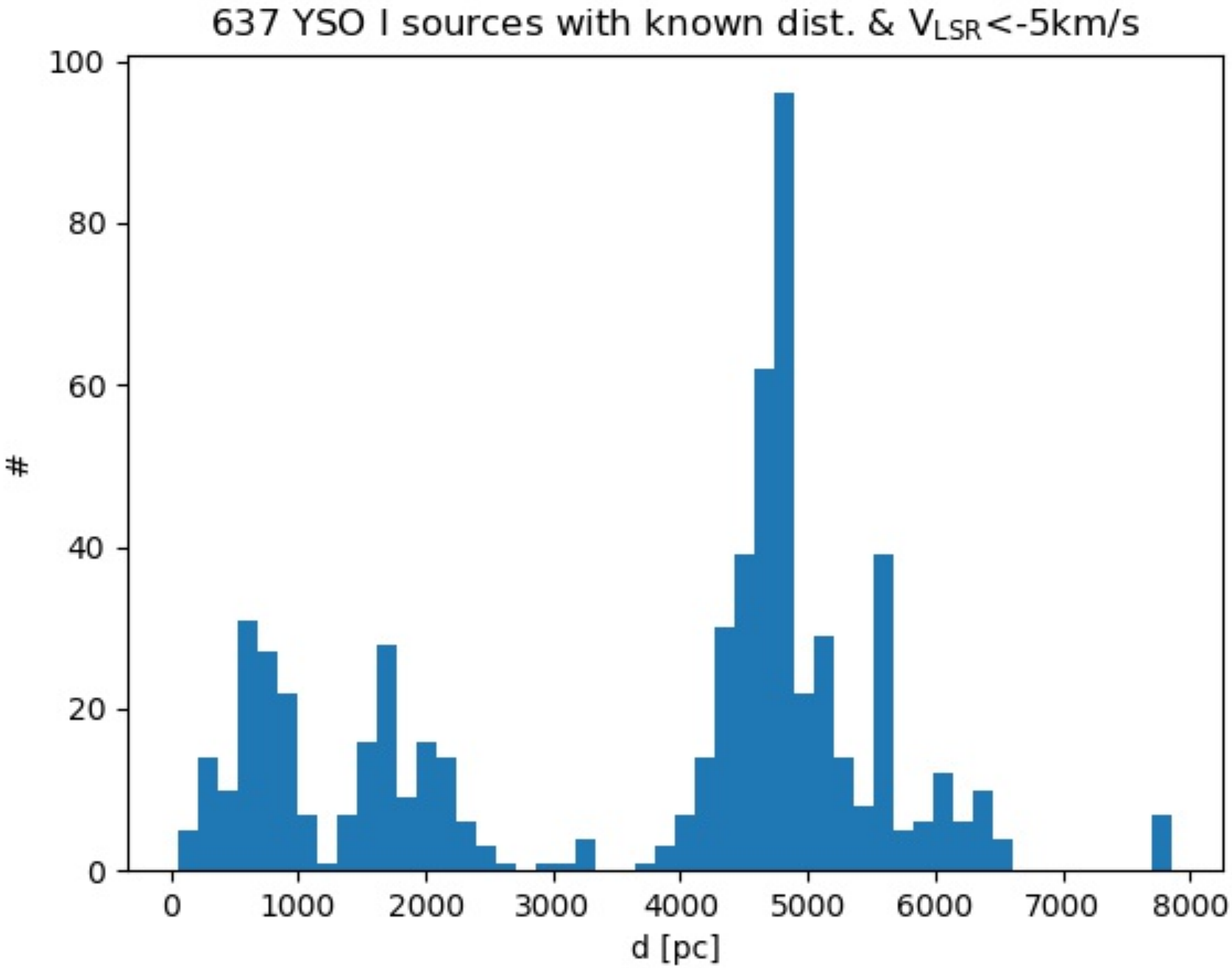

Kinematic Distances
l=0
l=90
l=270
l=180
0
20
40
60
80
100
120

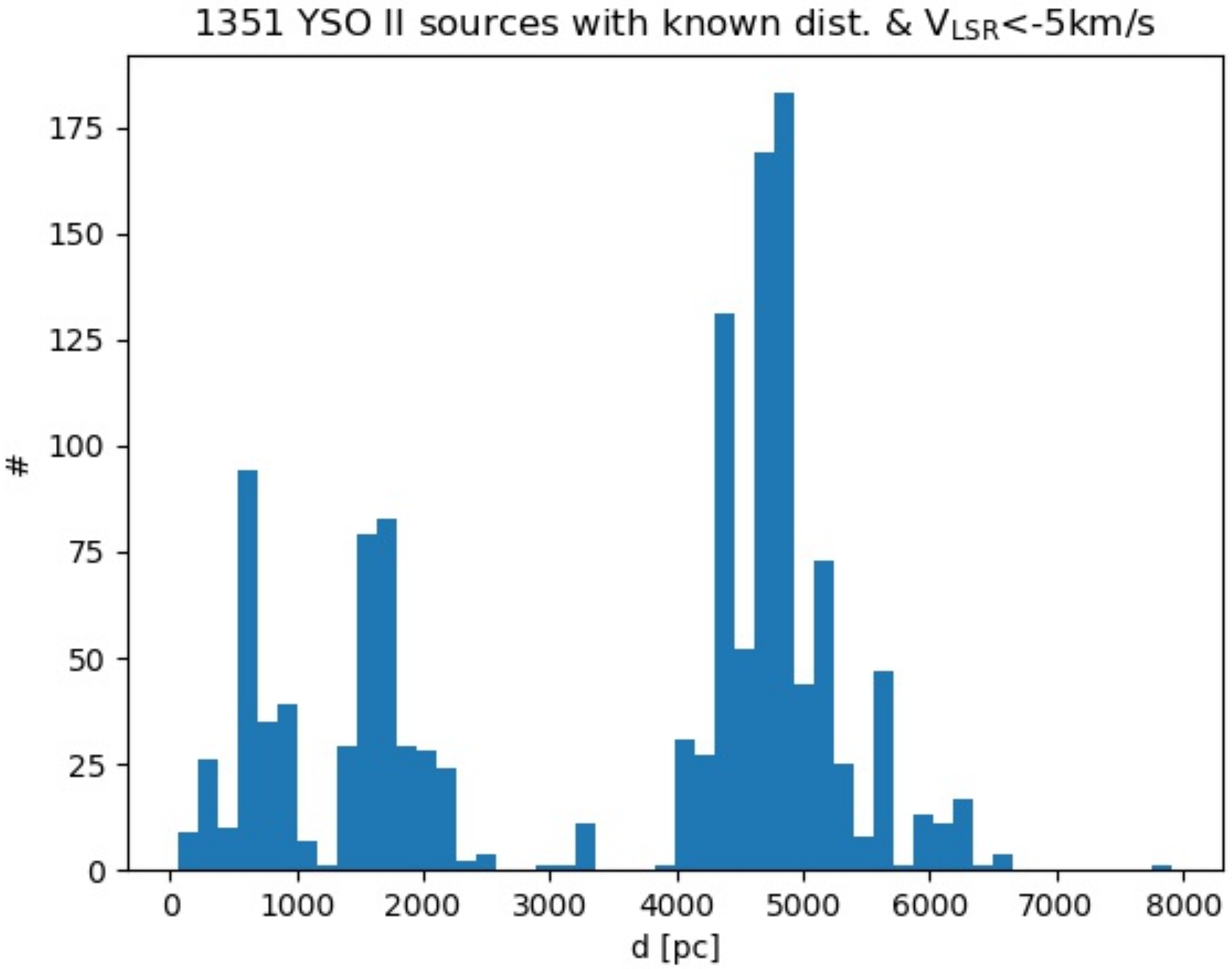
Some statistics:

- Distance have been estimated for 434 634 sources (15%) among total of 2 836 618 ones;

- 637 out of 1778 YSO I sources (i.e. about 36%) have known distance;

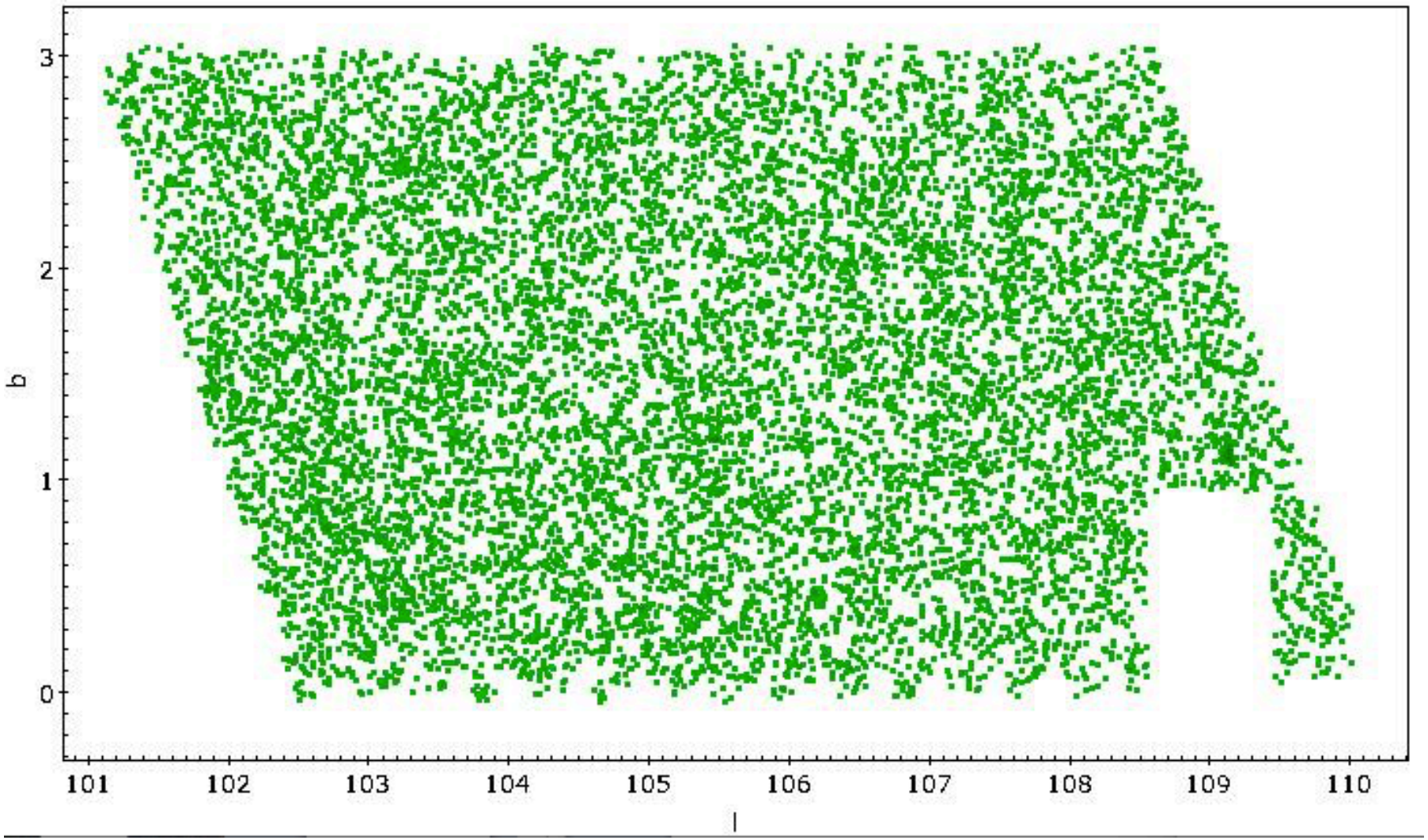
- 1351 out of 2962 YSO II sources (i.e. about 46%) have known distance.


637 YSO I sources with known dist. & V_{LSR}<-5km/s
100
80
60
40
20
0
#
0
1000
2000
3000
4000
5000
6000
7000
8000
d [pc]


1351 YSO II sources with known dist. & V_{LSR}<-5km/s
#
d [pc]
0
25
50
75
100
125
150
175
0
1000
2000
3000
4000
5000
6000
7000
8000

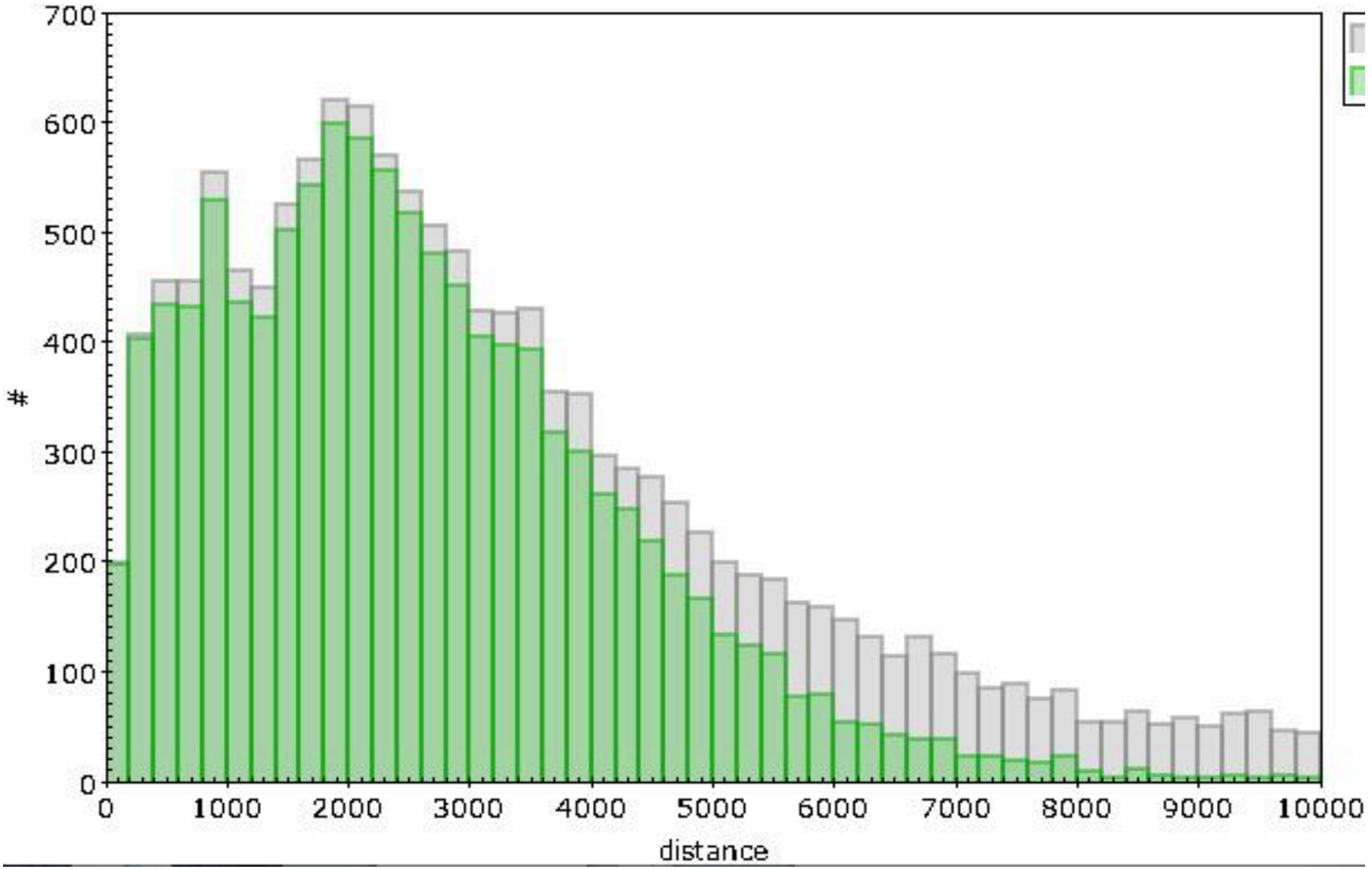
Distances with Gaia DR2

Gaia for L105: among **254 849** sources Gaia provides parallaxes for **15 114 (~5.9%)** objects. Among them **14 427** objects have parallaxes > 0; and only **10 880 (~4.3%)** have errors < 33%.



10 880 Gaia objects within 1" around **SMOG** sources with a good distance

Gaia for L105: histogram of distances for 14 427 sources with parallaxes > 0 (grey); and 10 880 ones with a good distance (green).



NO parallaxes for YSO I or YSOII objects !

Work in progress

Work to do:

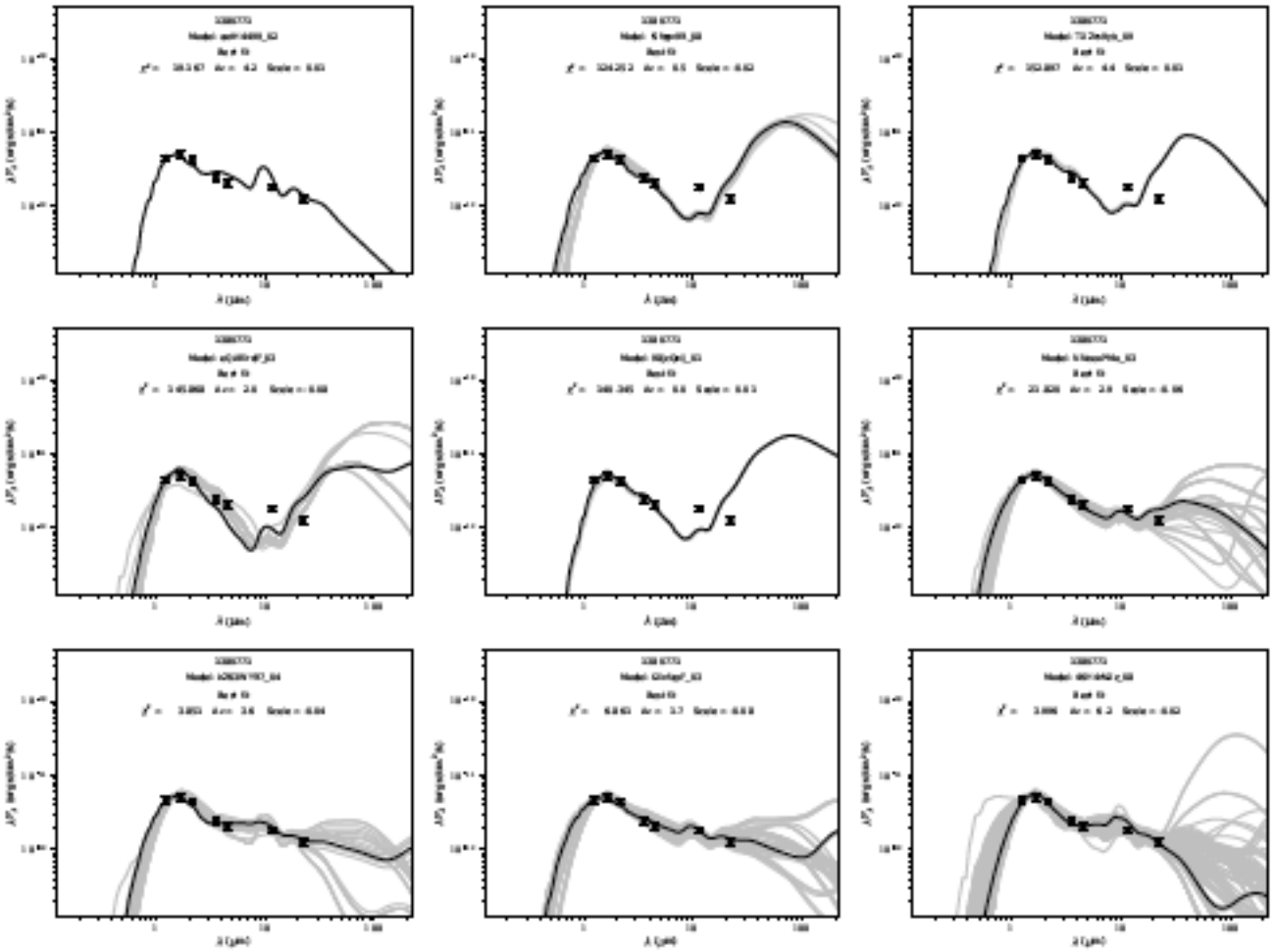
SED fitting

to find: stellar parameters and

class of models.

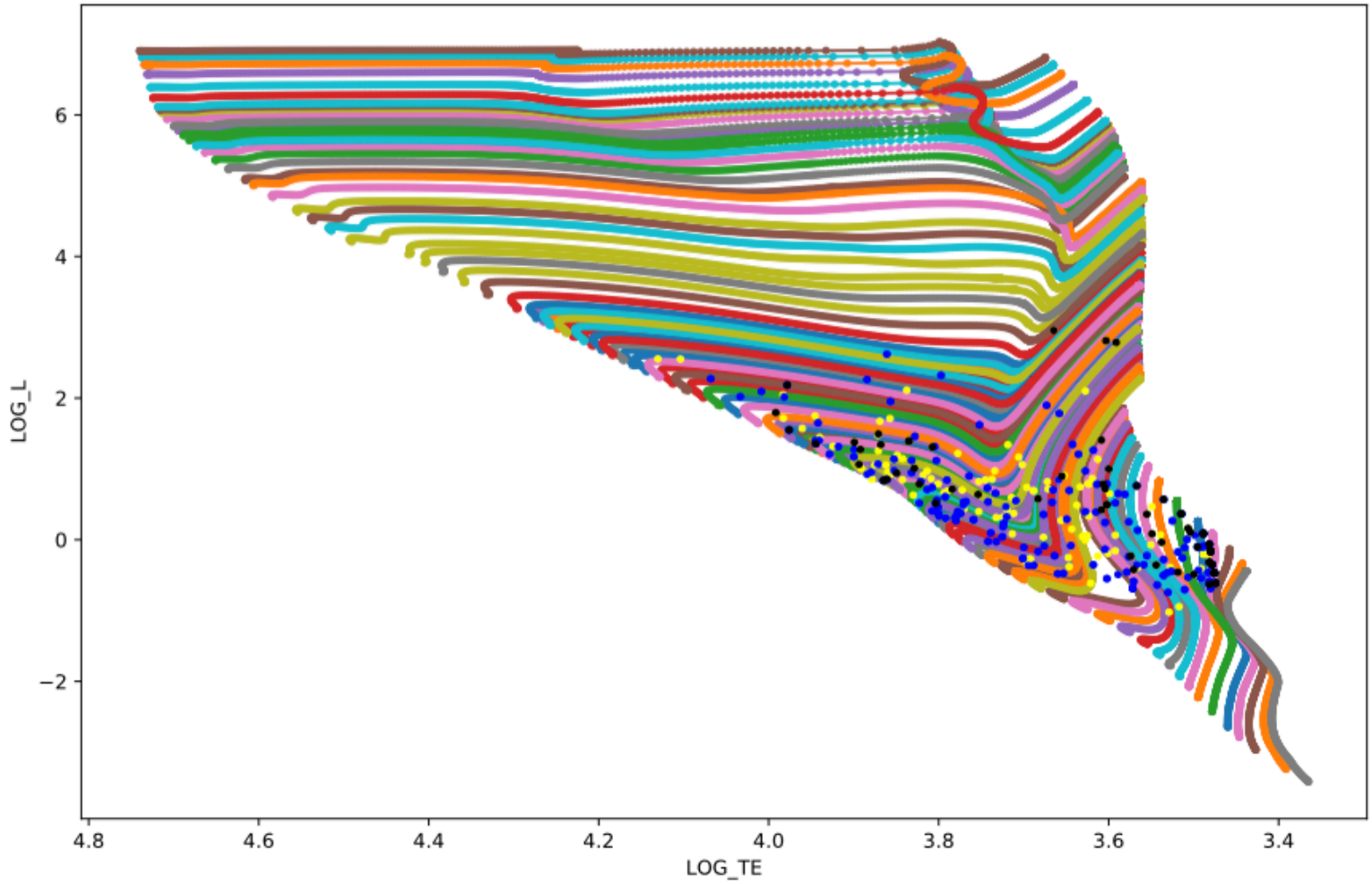
This has been already done for L220 region using models of

Robitaille (2017)



Work to do:

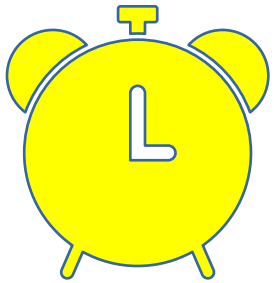
Determine masses and ages, as already done for L220 region.



- **YSOs are stars under construction**

- **They are active with dynamic circumstellar material such as; disk, outflows, and infalling clouds core**

YSOs in Gaia Alerts



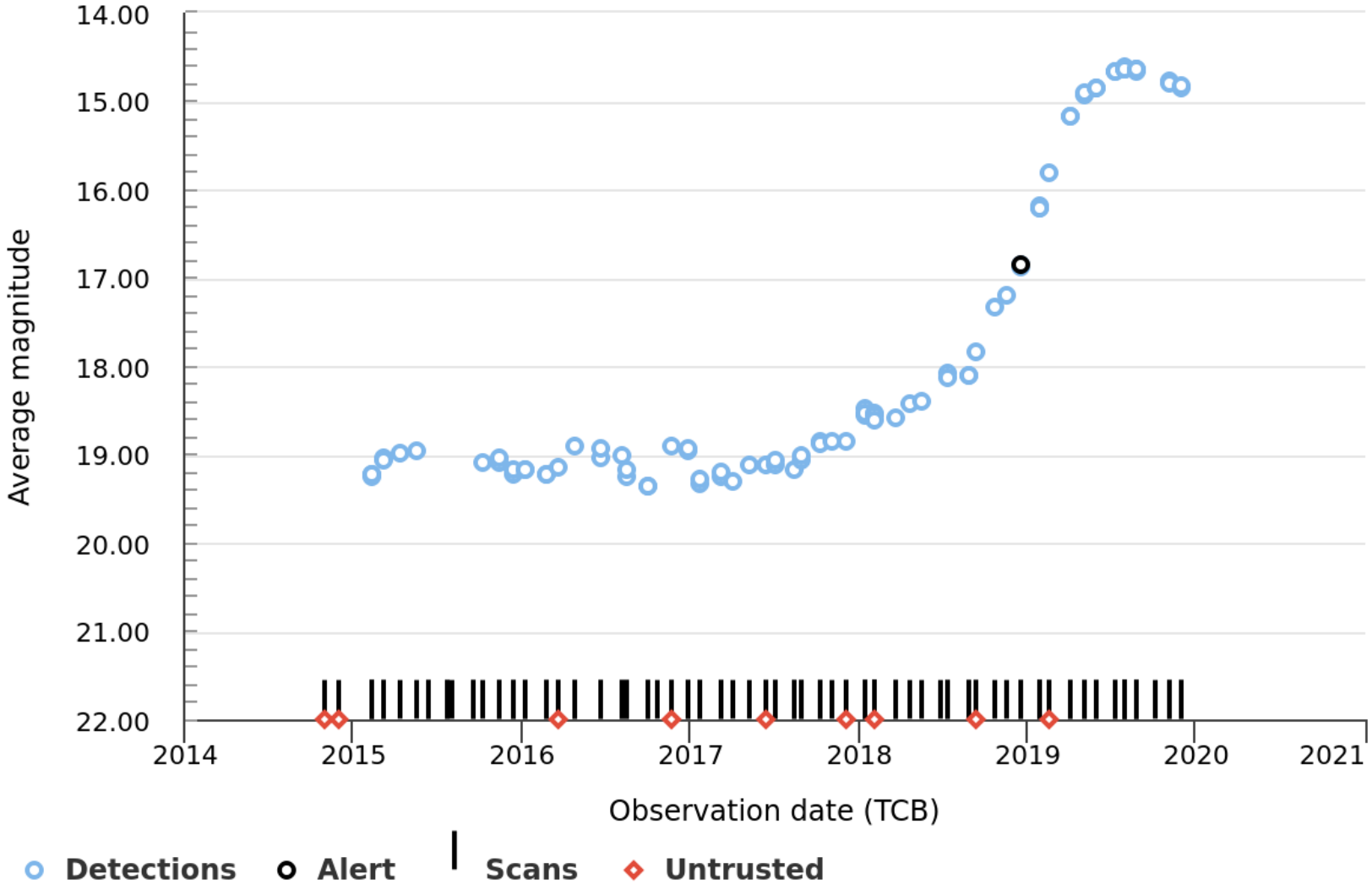
T Tauri stars ——> low mass (<3 Msun)

pre-main sequence stars, YSO Class II

- **H alpha emission line**
- **Ca II H and K emission lines**
- **Lithium absorption line at 6708 A**
- **Infrared excess**
- **Photometric variability**

Herbig Ae/Be stars——> massive counterparts of T Tauri stars (3-10 Msun) (Nuclear fusion has already started in the core!!!)

- **Spectral type A or B with emission lines**
- **Infrared excess**
- **Luminosity class III to V**
- **Photometric variability**


14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
Average magnitude
2014
2015
2016
2017
2018
2019
2020
2021
Observation date (TCB)
Detections
Alert
Scans
Untrusted

Thank You!