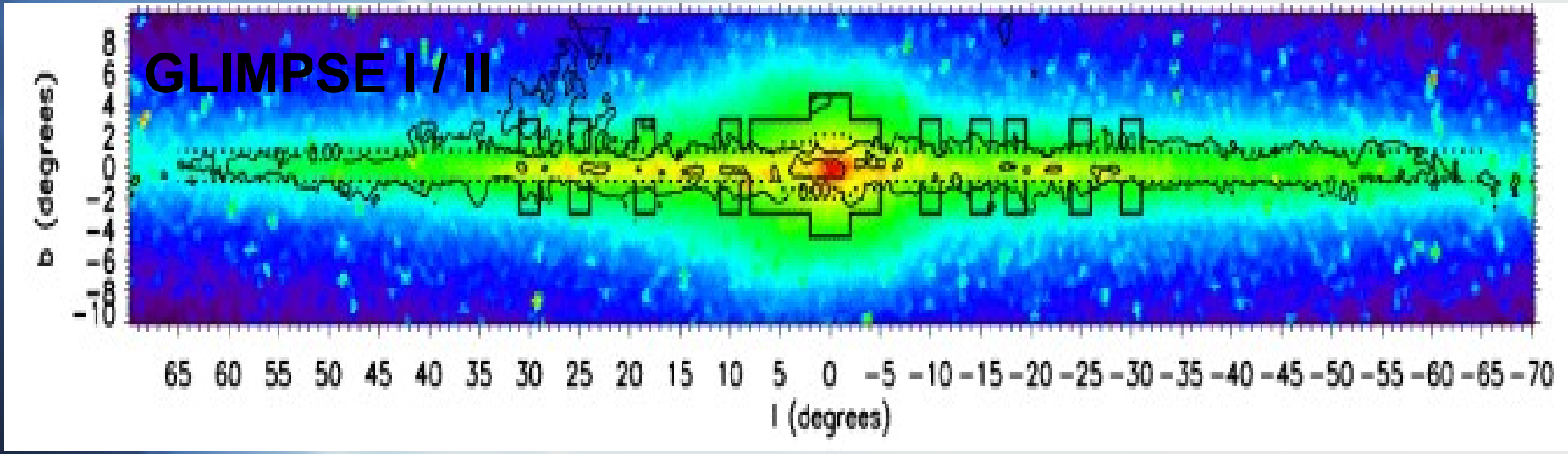
The GPS/GLIMPSE 360 search for red objects

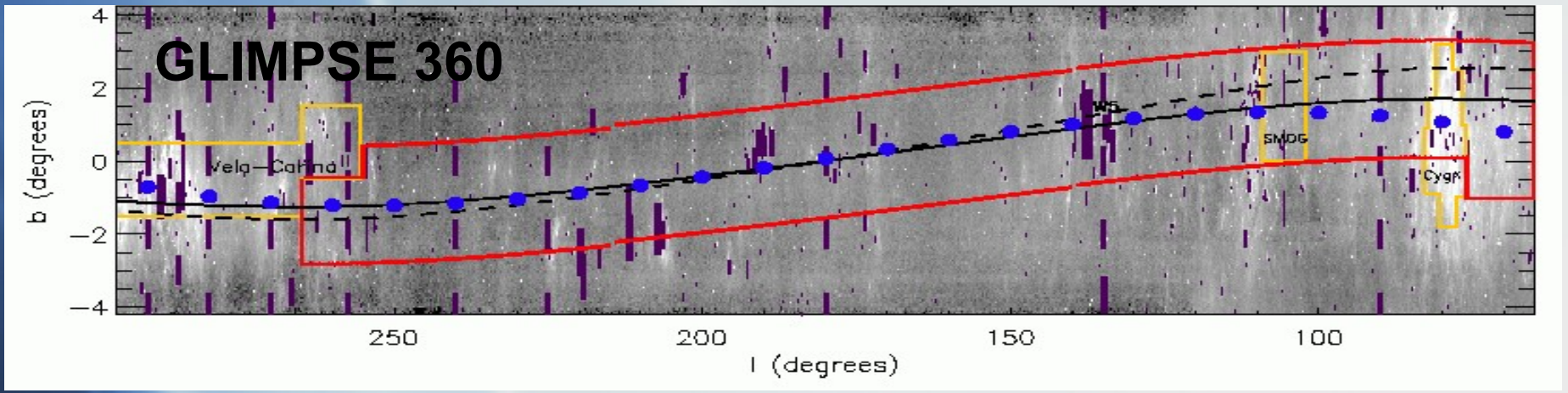
Basmah Riaz (UH), Phil Lucas (UH),
Thomas Robitaille (CfA), Barbara Whitney (UWisc)

GLIMPSE I/II Surveys



- GLIMPSE I (|l|=10-65deg, |b|<1.5deg)
- GLIMPSE II (|l|<10deg , |b|<1.5deg)
- All IRAC bands (3.6, 4.5, 5.8, 8mu), follow-up 24 & 70mu MIPSGAL I/II surveys
- vertical extensions for GLIMPSE 3D (|b|<3.1deg)

GLIMPSE 360 Survey

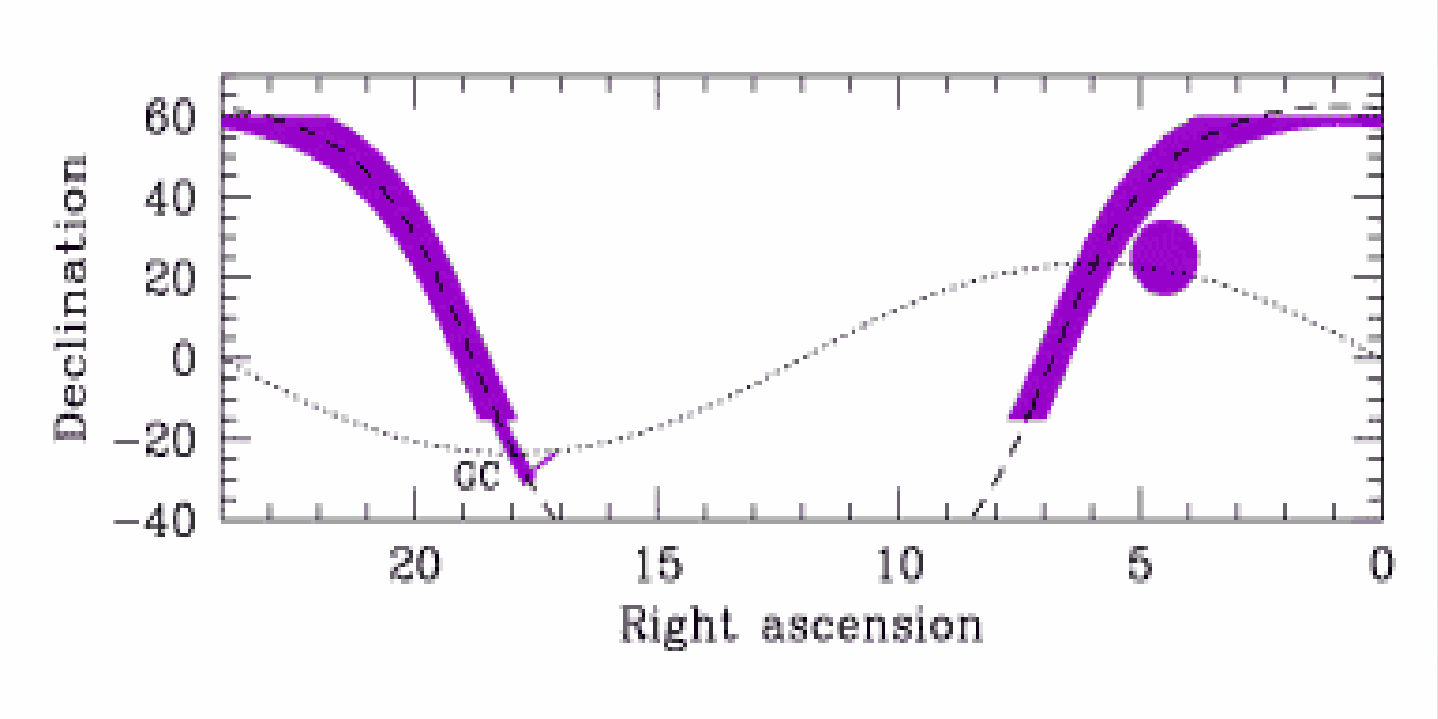


- **GLIMPSE 360 (65 < *l* < 102 and 109 < *l* < 265 , |b|<3.1deg)**
- **IRAC 3.6 & 4.5mu only**
- **deeper and brighter than GLIMPSE I/II**

Table 1. Sensitivity Limits in mJy (magnitudes in parentheses)

Project	3.6 μm Lower	3.6 μm Upper	4.5 μm Lower	4.5 μm Upper
GLIMPSE360[a]	0.015 (18.2)	1100 (6.0)	0.021 (17.3)	1100 (5.5)
WISE[b]	0.06 (16.8)	110 (8.6)	0.10 (15.6)	60 (8.6)
GLIMPSE	0.20 (15.4)	440 (7.0)	0.20 (14.9)	450 (6.5)

UKIDSS GPS Survey



- Mapping Galactic plane covering ~1800 sq. deg in JHK to a depth J=20.0, H=19.1, K=19.0
- 15<l<107 and 142<l<230 deg, |b|<5deg.

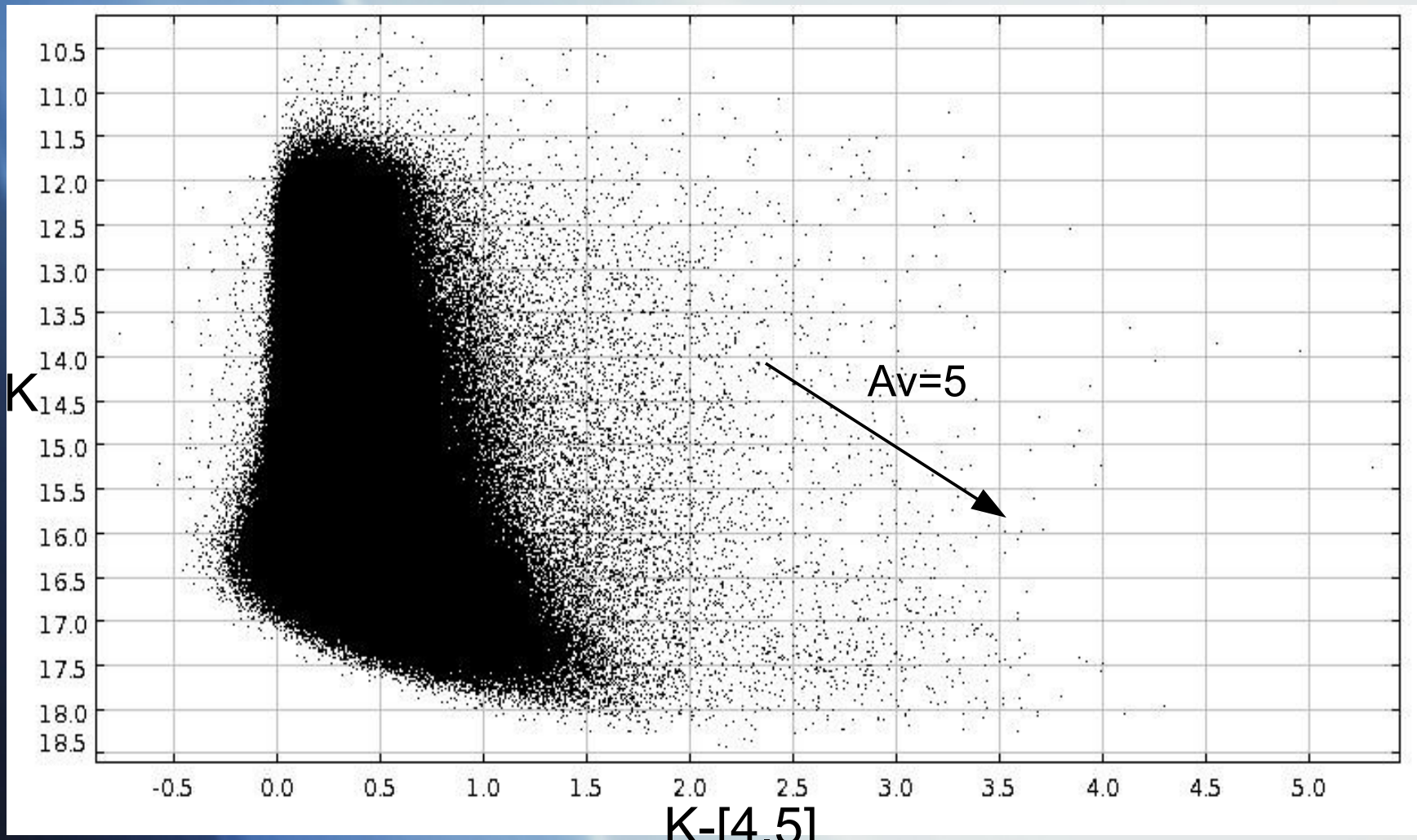
GLIMPSE 360+GPS

- GLIMPSE 360 depth well-matched to GPS near-IR **survey depth** (K=17.8, H=18.6, J=19.5)
- GPS covers a substantial portion of the GLIMPSE 360 region (**$65 < l < 102$ and $141 < l < 230$**)
- To create a **catalog of red sources** (YSOs, evolved stars (AGBs), PNe, T dwarfs), study star formation in the Outer Galaxy

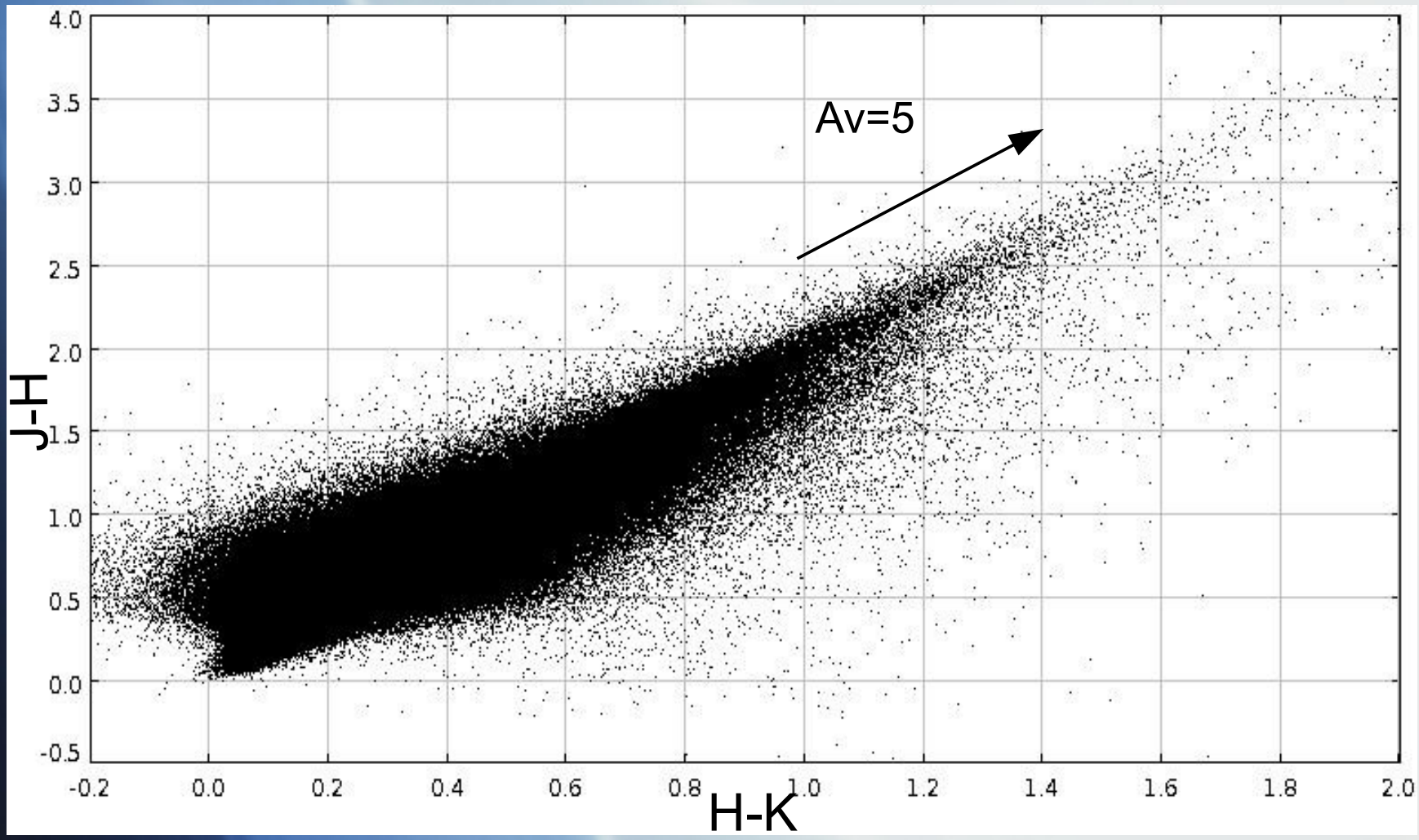
Matched Catalog Filters

- Applied GPS filters from Lucas et al. (2008) for reliable photometry
- mergedClass=0, Ell<0.3, pstar>0.99: minimum value for a source to be **classified as a star**, not a probable star or a galaxy, remove extended or unresolved stellar pairs
- ppErrbits<256: remove sources with less reliable photometry due to **deblending or bad pixels**
- For **reliable photometry**: selected sources with fractional flux errors below 15% ('Quality Criteria' from Robitaille et al. 2008)
- GLIMPSE360 Remove close stellar pairs: csf=0 (**no source within 3"**)
- GLIMPSE360 Remove spurious detections: selected sources detected at least **twice at 3.6 and 4.5mu**
- Merged catalog consists of **3,033,279 sources**

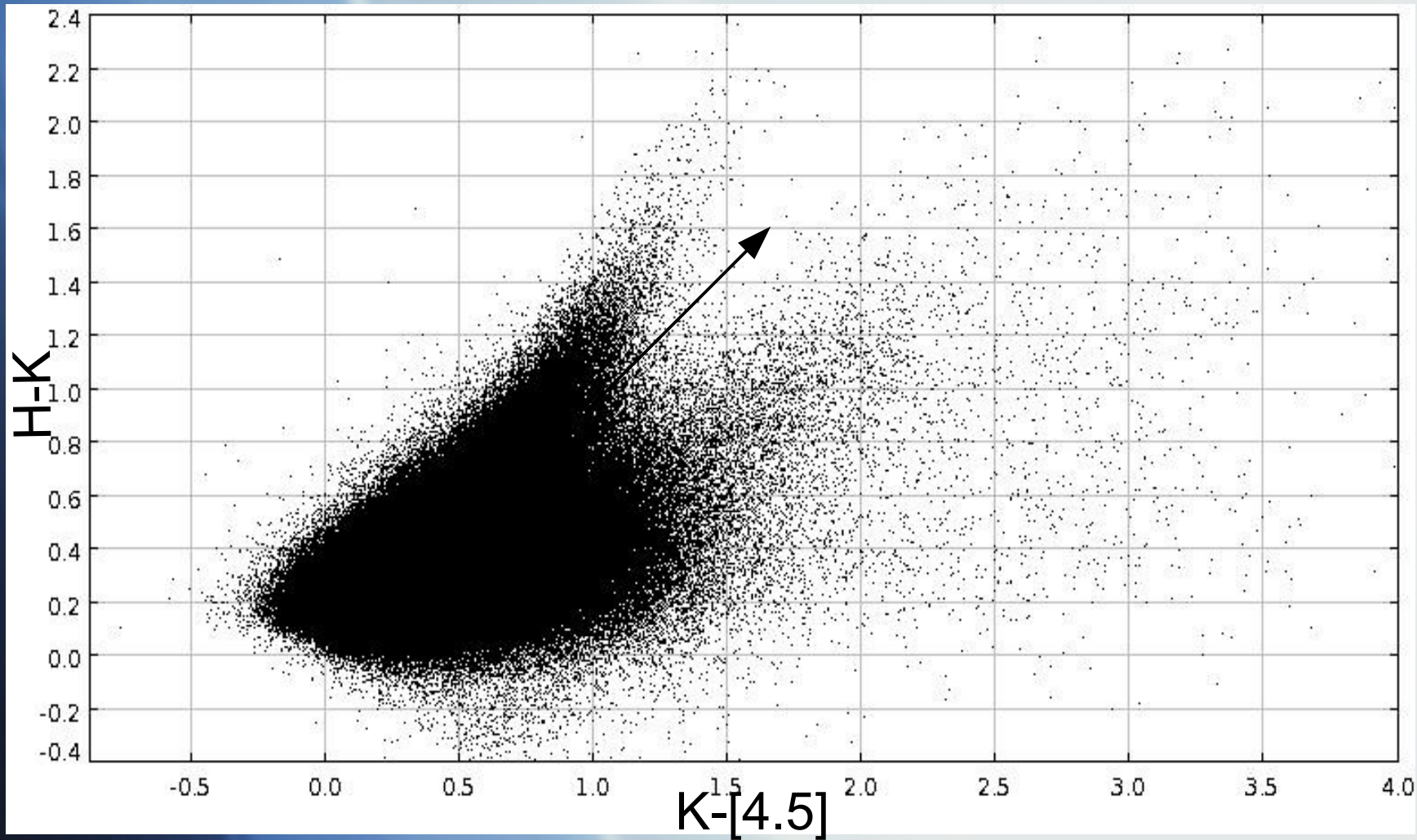
Matched Catalog



Matched Catalog



Matched Catalog

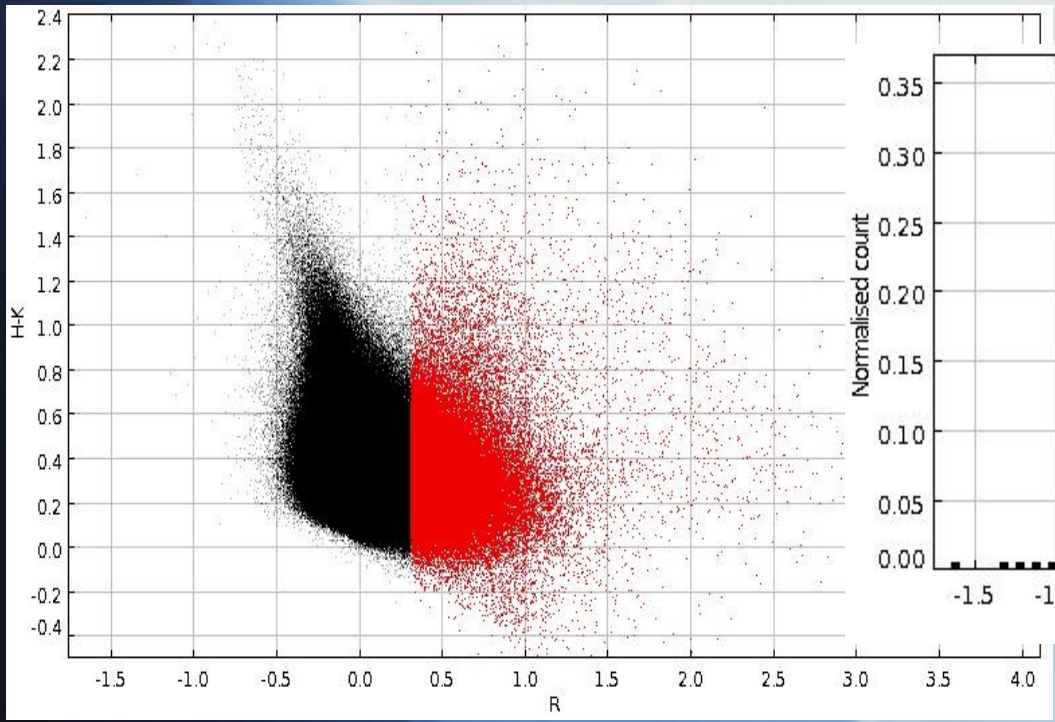


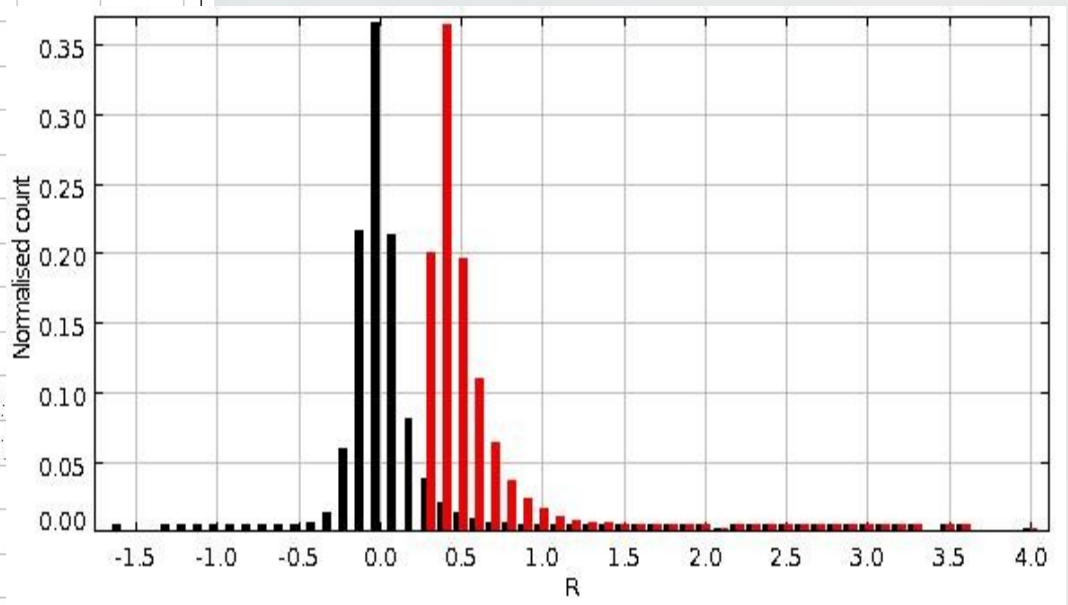
- H-K vs K-[4.5] provides the best distinction between **extincted and 'red' sources**

Red Catalog Selection

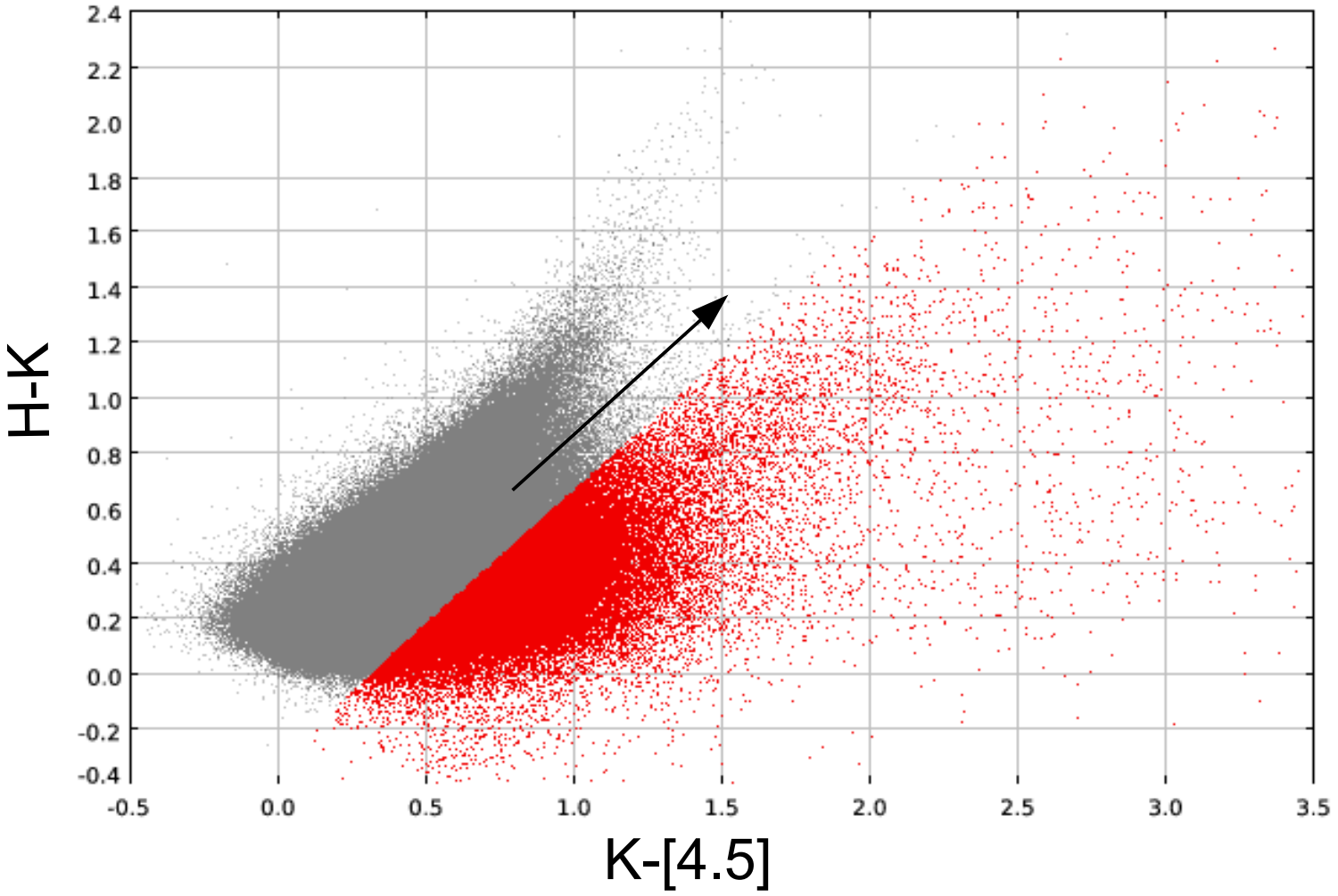
- Calculated the color index R:

  R = [E(H-K)/E(K-[4.5])] * (K-[4.5]) – (H-K)
- Std. dev. σ of R =0.16
- **Selected sources with R>2σ**
- **Red Catalog: 142,690 sources (5%)**

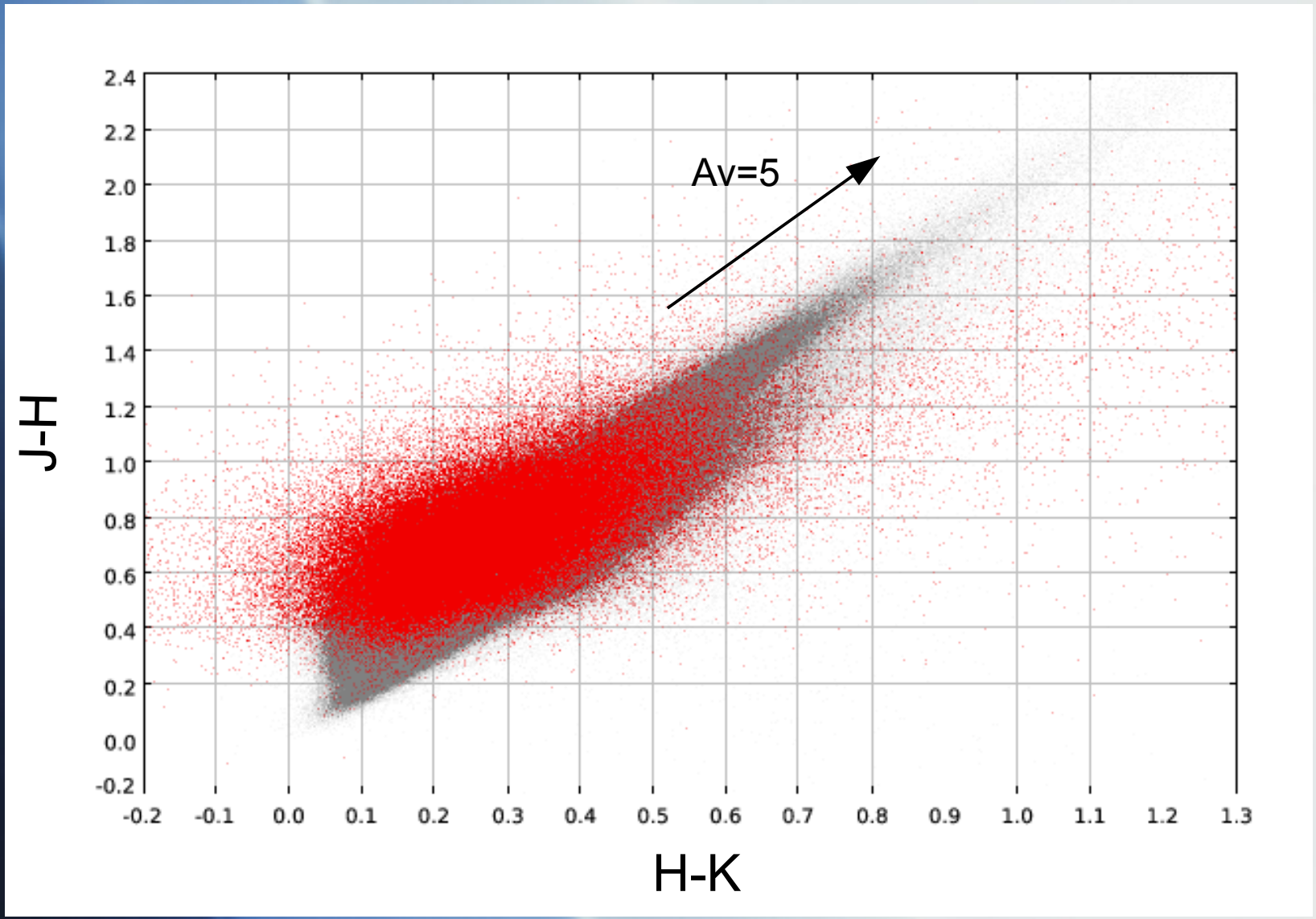




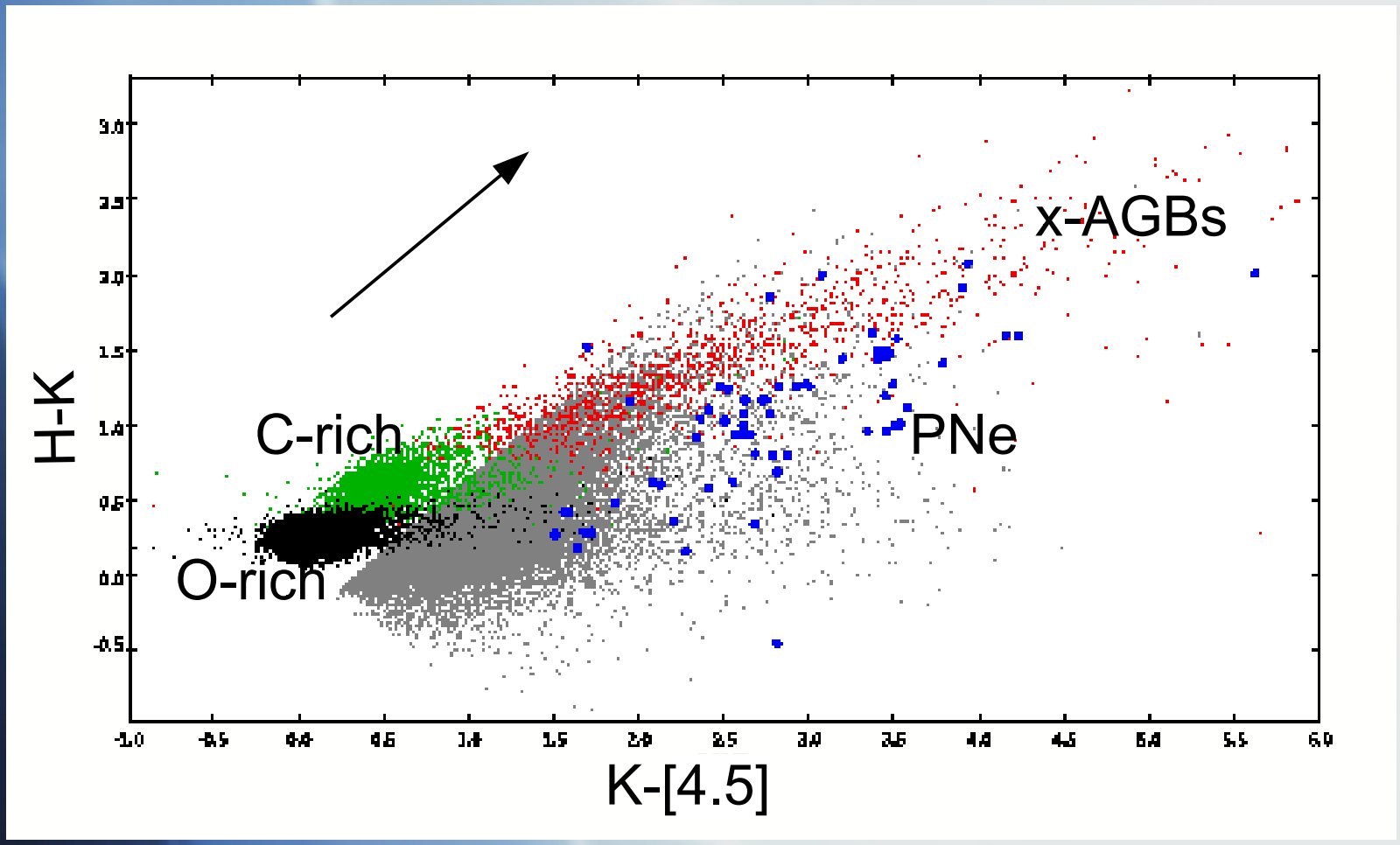
Red Catalog


H-K
K-[4.5]
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Red Catalog

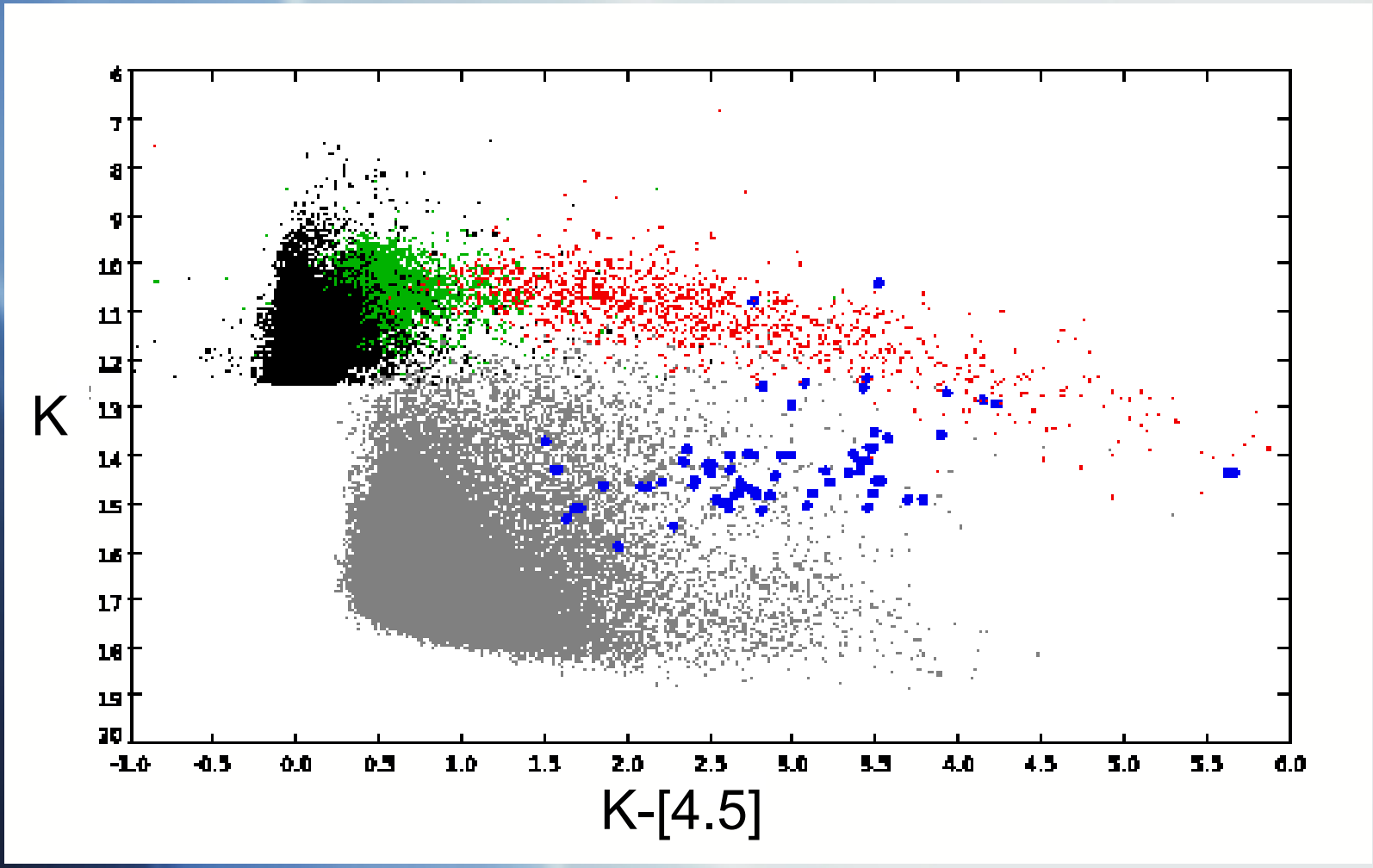

Av=5
J-H
H-K
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

Red Catalog: PNe, AGBs



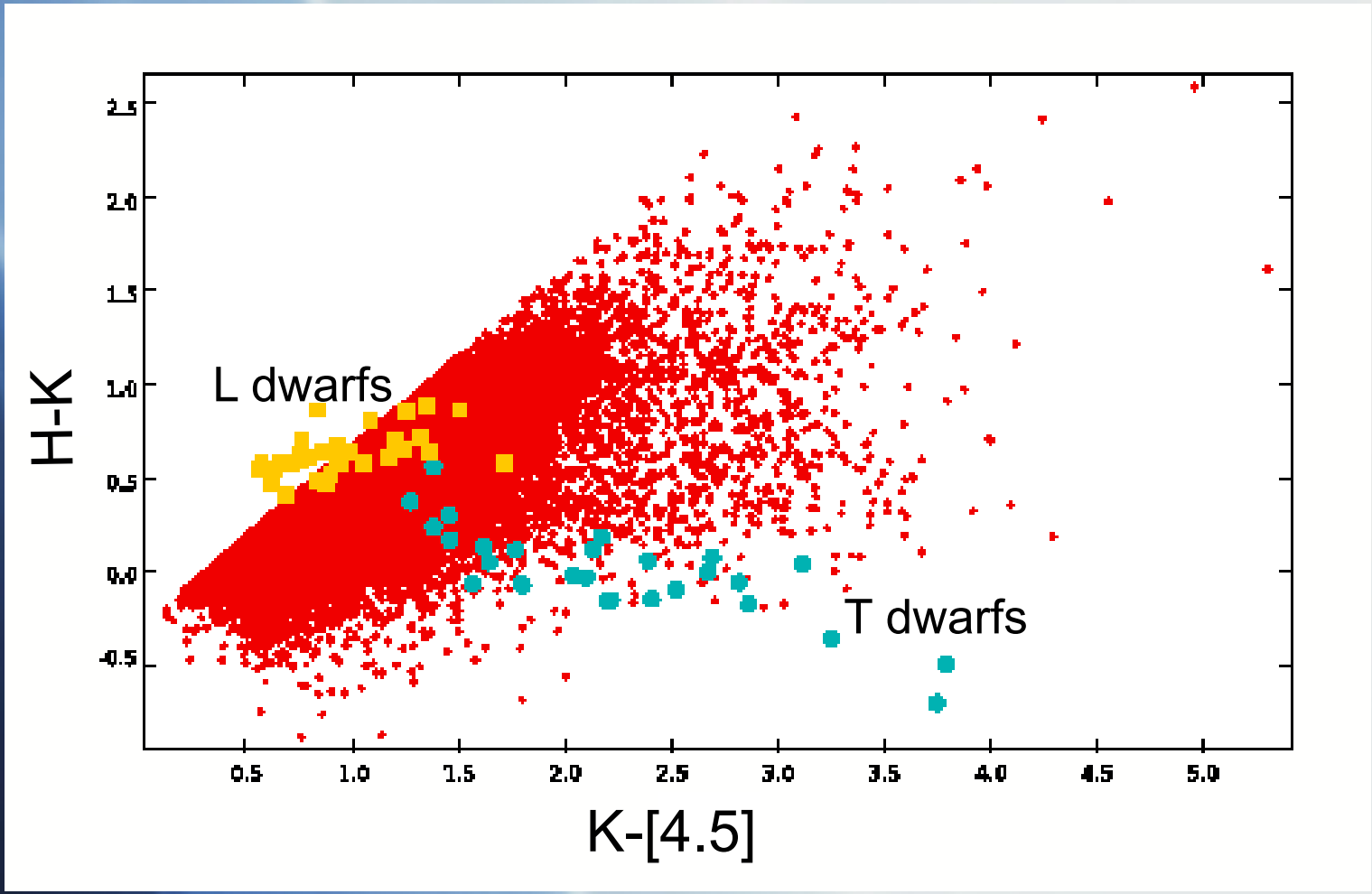
C-rich,O-rich,x-AGBs from SAGE surveys (Srinivasan et al. 2009)
PNe from Hora et al. (2004;2008), Whitney et al. (2008)

Red Catalog: PNe, AGBs



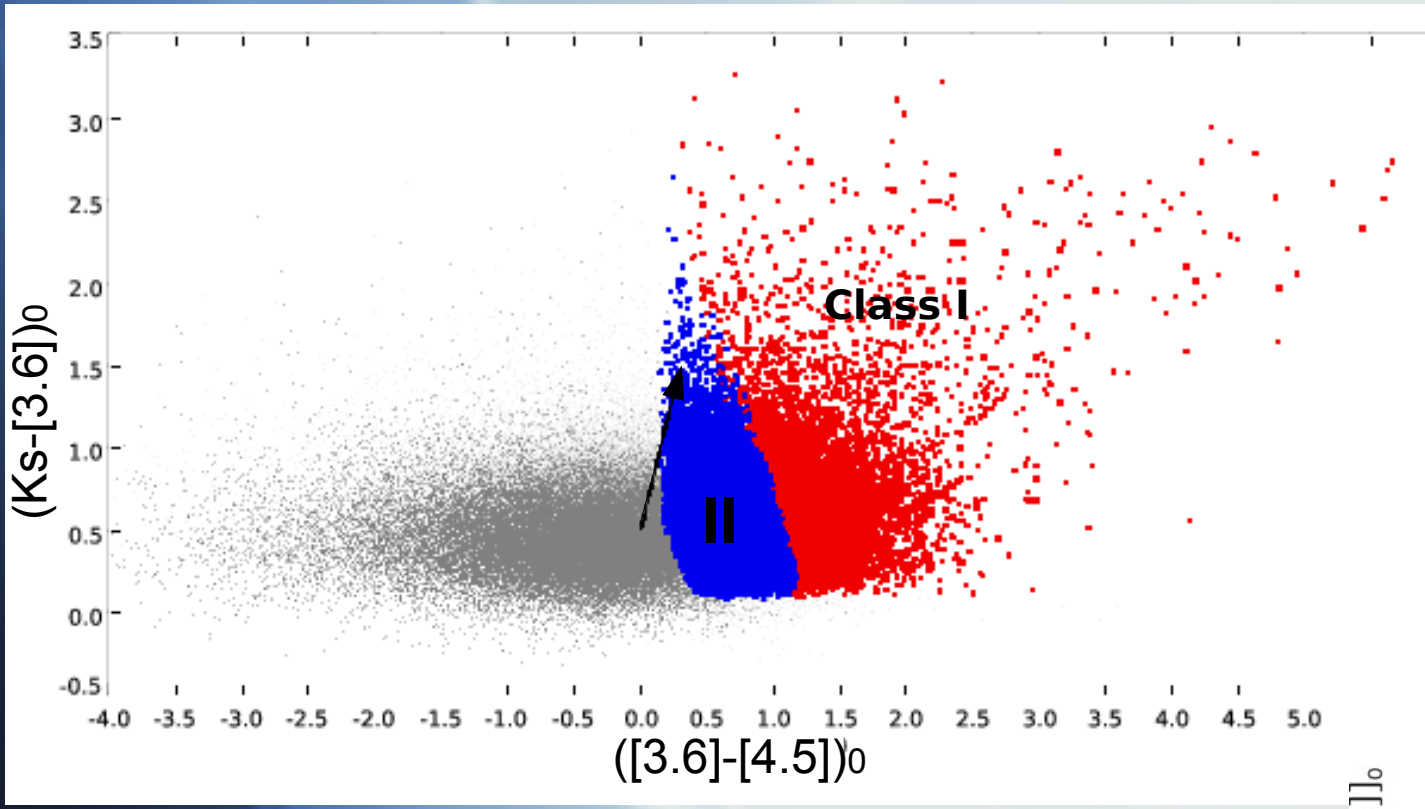
- Most AGBs brighter than the saturation limit of UKIDSS (Ks~12.5mag)
- Estimate ~5% of the red catalog to be contaminated by AGBs/PNe, mostly x-AGBs

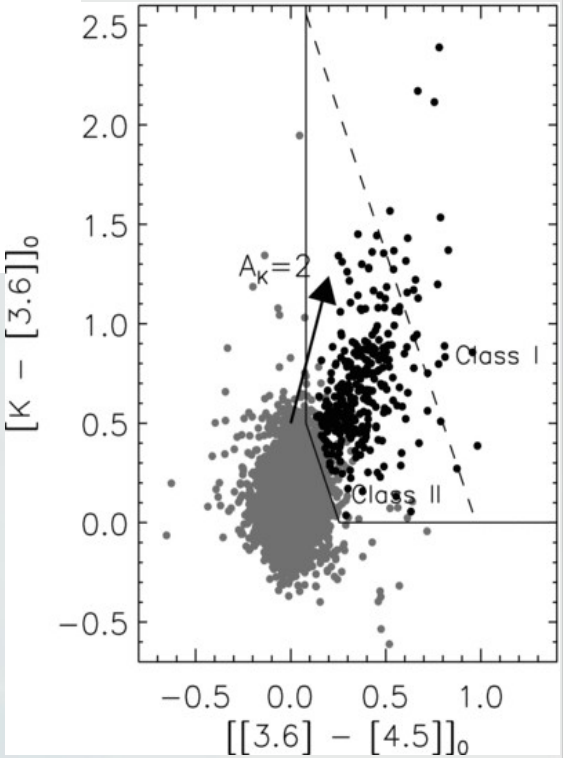
Red Catalog: L & T dwarfs



L and T dwarf colors from Patten et al. (2006)

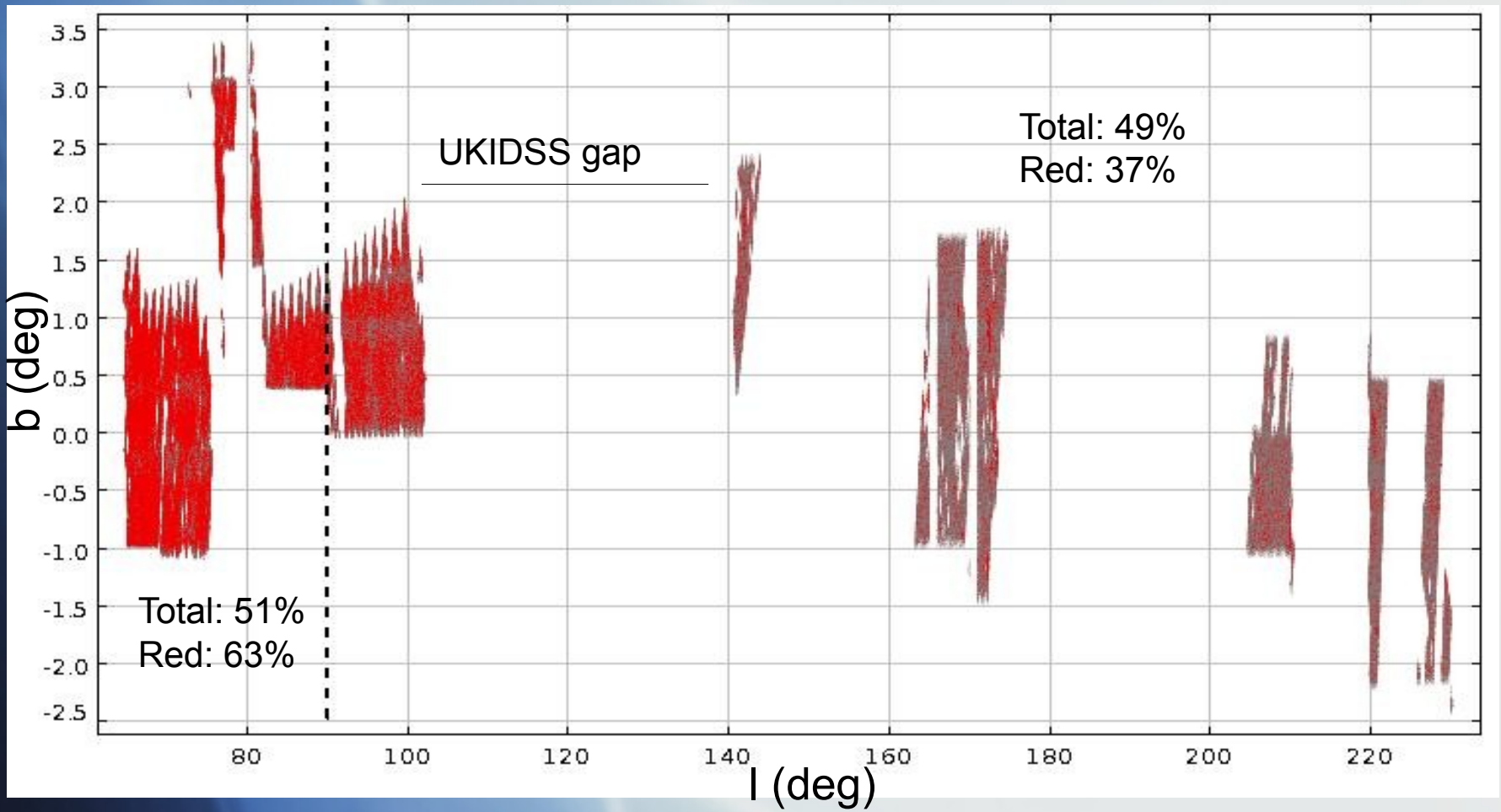
YSOs in Red Catalog





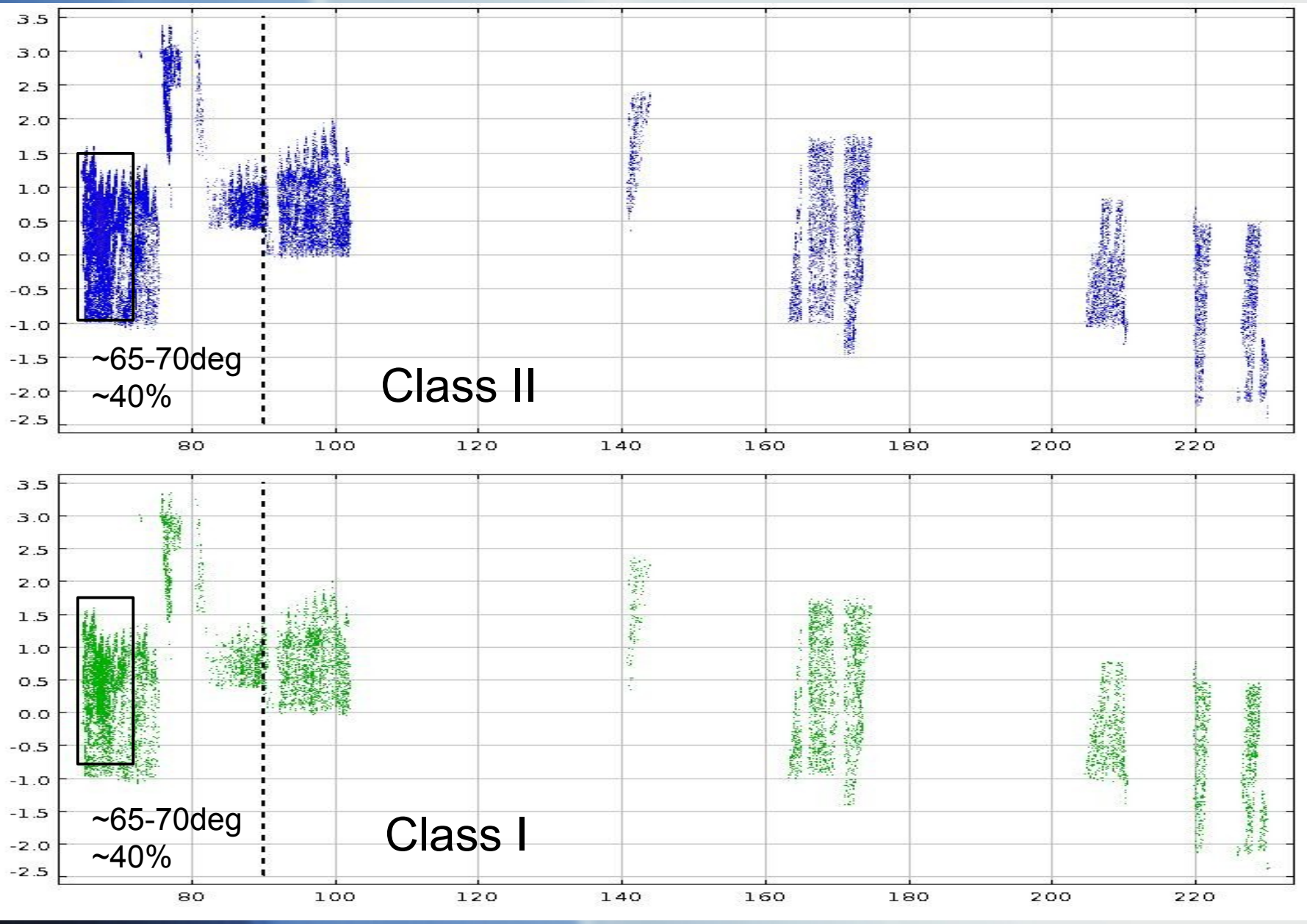
- Applied Gutermuth et al. (2008) SED classification scheme based on JHK[3.6][4.5] photometry
- **~8% - Class I, ~25% Class II**, rest Class III
- Includes x-AGBs and PNe

Inner vs. Outer Galaxy

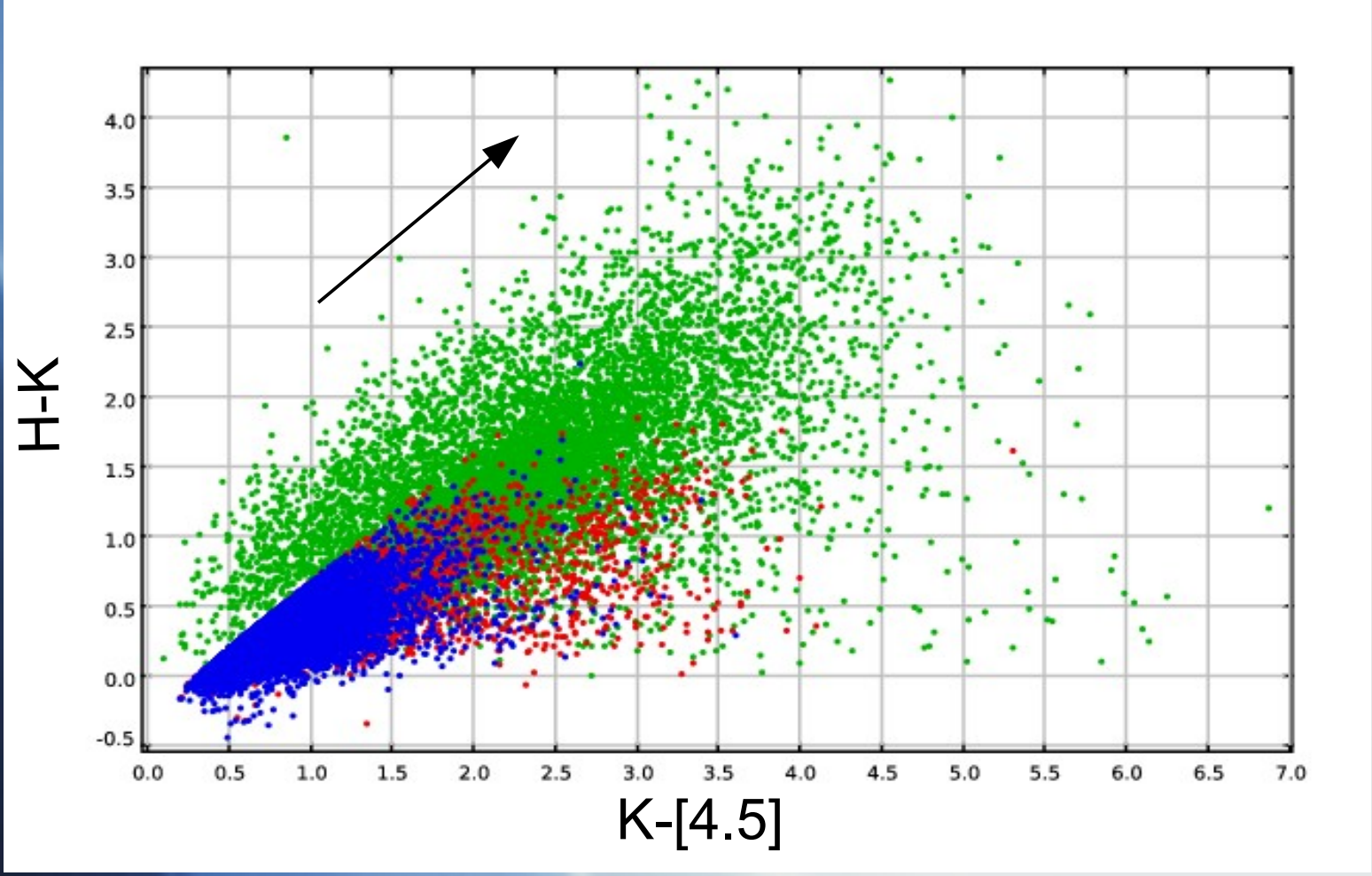


- Lower star formation rate in Outer Galaxy
- GLIMPSE360 observations for $142 < l < 230$ to be taken, census of YSOs in Outer Galaxy not complete

Inner vs. Outer Galaxy



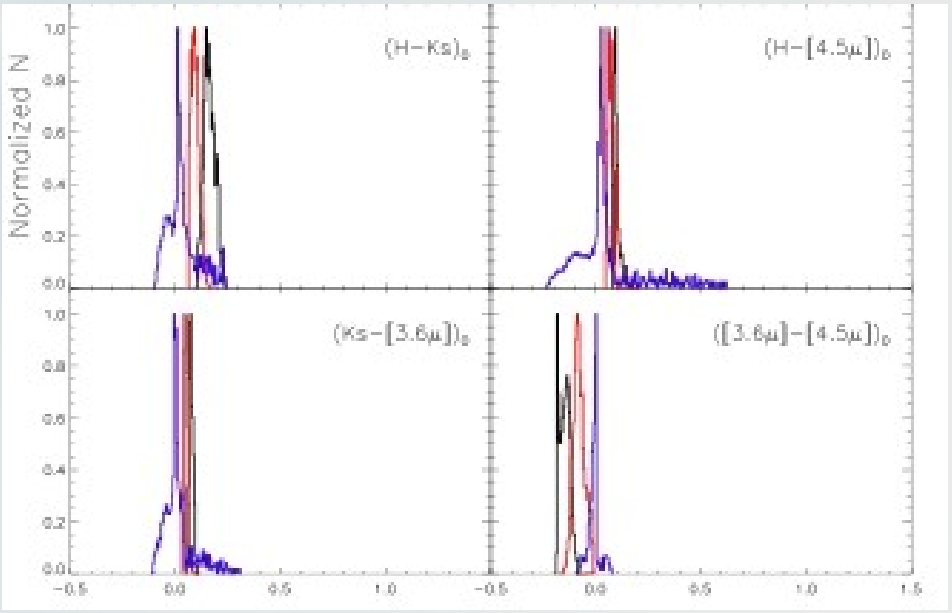
Comparison with GLIMPSE I/II

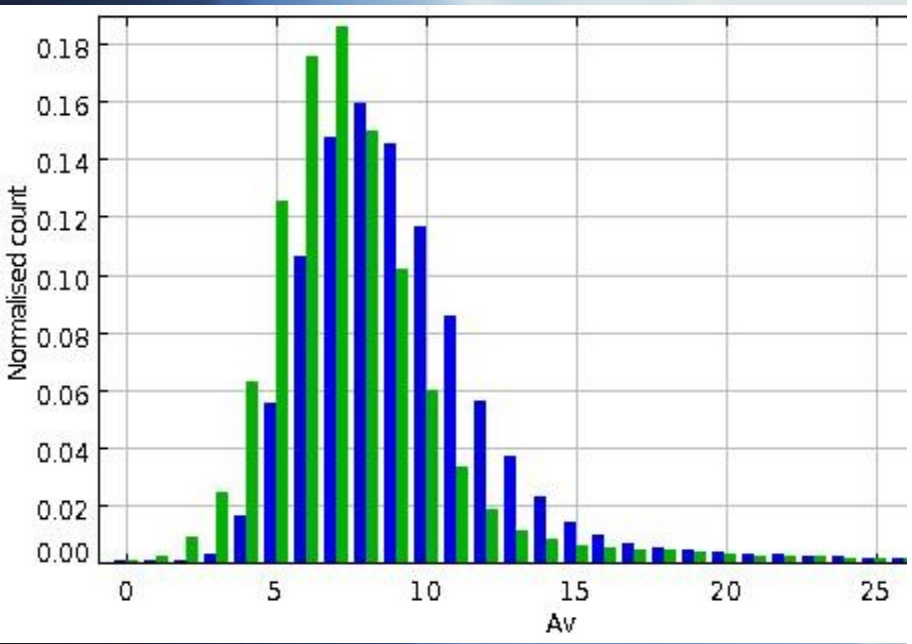


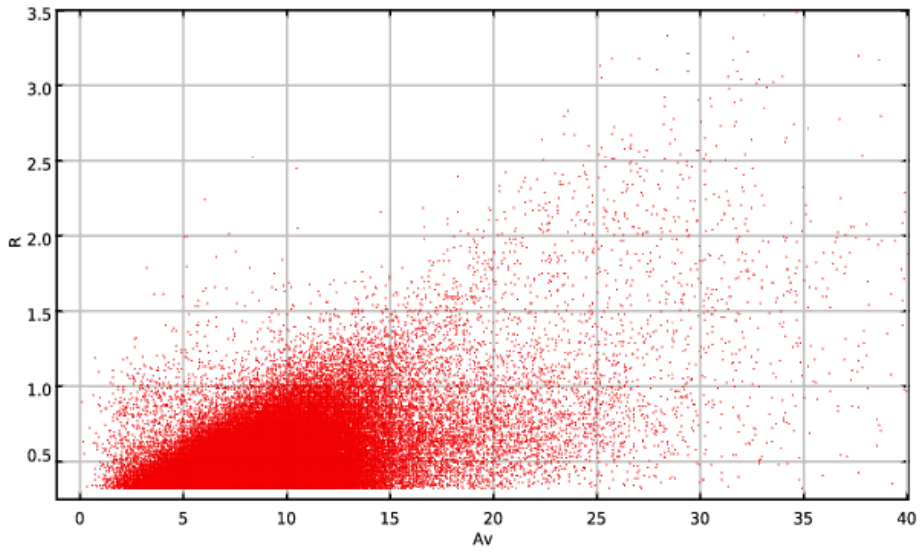
GLIMPSE I/II YSOs Robitaille et al. (2008)--> higher fraction of redder sources
GLIMPSE I/II (|l|=10-65deg); GLIMPSE360 (65 < *l* < 102, 109 < *l* < 265)

Extinction

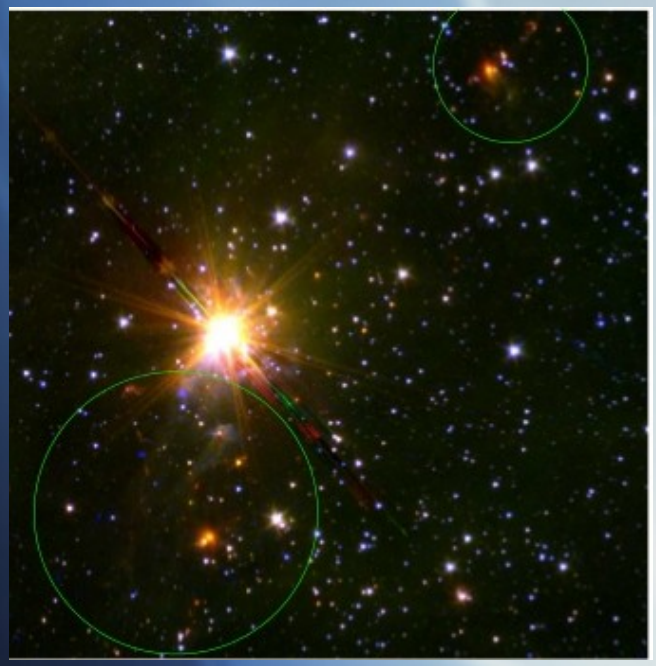
- Rayleigh Jeans Color Excess Majewski et al. (2011)
- Small spread in intrinsic colors for (H-[4.5]) and (Ks-[3.6])
- A(Ks)=0.918 (H-[4.5]-0.08)
- Peak in Av~7mag

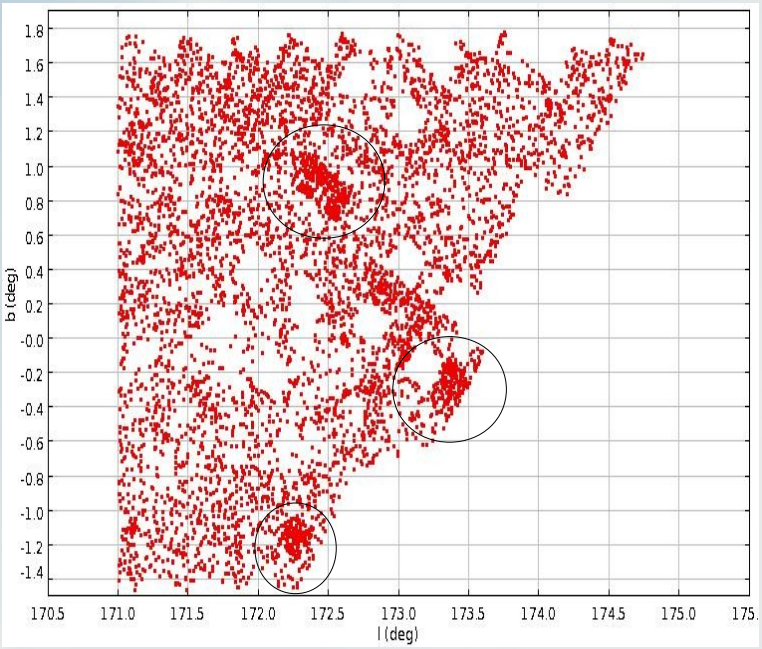






Work in progress





Identify possible **clusters** in the Outer Galaxy

"Extended Red Objects"- probable outflows

Ks(blue), 3.6mu (green), 4.5mu (red) composite img

Cyganowski et al. (2008) detected bright extended sources at 4.5mu, confirmed as outflows from massive YSOs from submm obs

PAH bubbles

bright at 3.6mu

Sites of massive star formation

Thank you!