

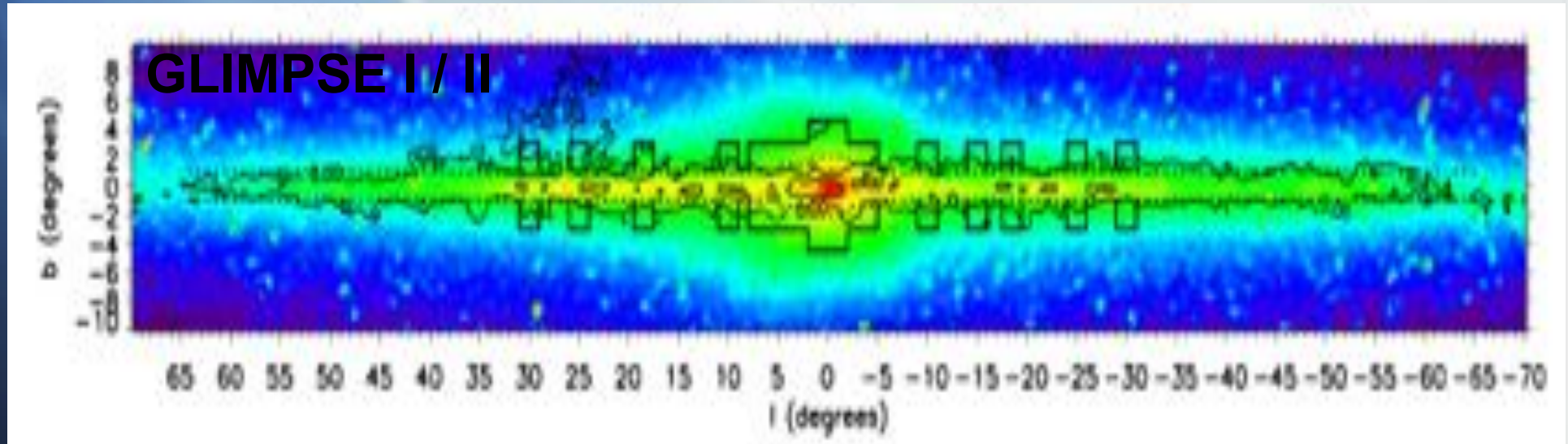
# The GPS/GLIMPSE 360 search for red objects

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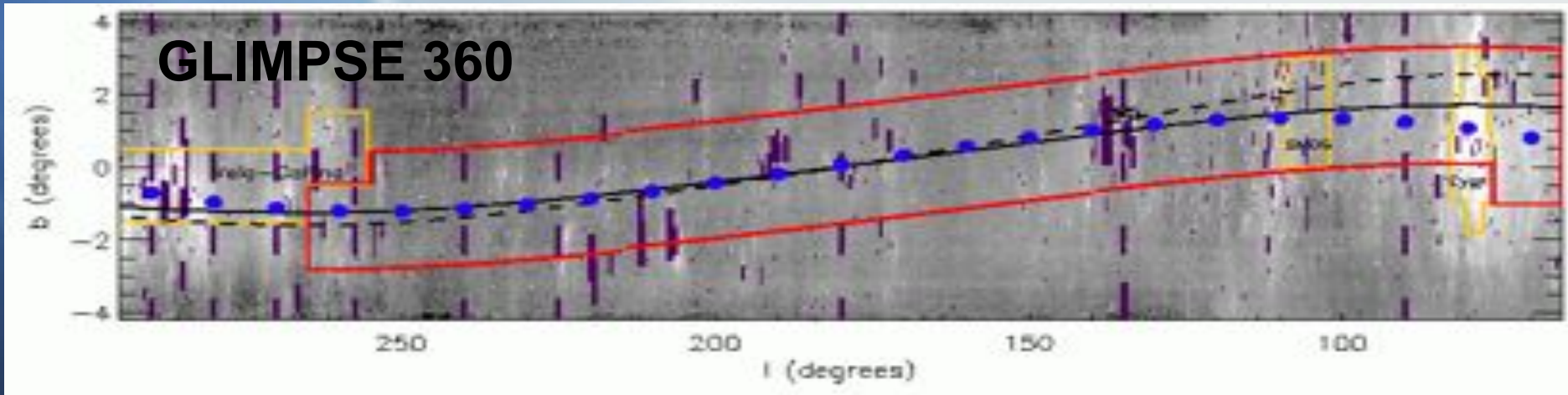


# GLIMPSE I/II Surveys



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

# GLIMPSE 360 Survey

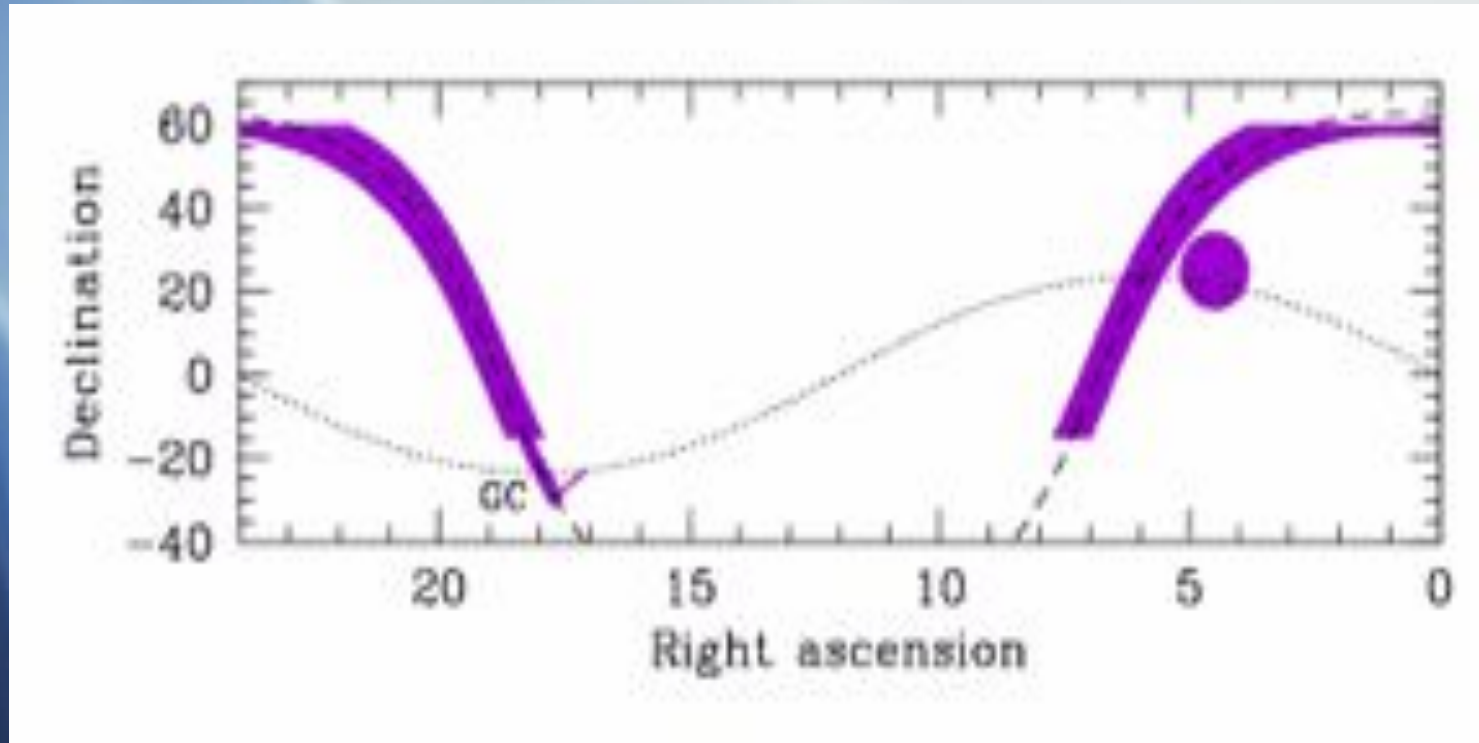


- **GLIMPSE 360 ( $65 < l < 102$  and  $109 < l < 265$ ,  $|b| < 3.1$ deg)**
- **IRAC 3.6 & 4.5 $\mu$  only**
- **deeper and brighter than GLIMPSE I/II**

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

Project	3.6 $\mu$ m	3.6 $\mu$ m	4.5 $\mu$ m	4.5 $\mu$ m
	Lower	Upper	Lower	Upper
GLIMPSE360 <sup>a</sup>	0.015 (18.2)	1100 (6.0)	0.021 (17.3)	1100 (5.5)
WISE <sup>b</sup>	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  $\sim 1800$  sq. deg in JHK to a depth  $J=20.0$ ,  $H=19.1$ ,  $K=19.0$
- $15 < l < 107$  and  $142 < l < 230$  deg,  $|b| < 5$  deg.

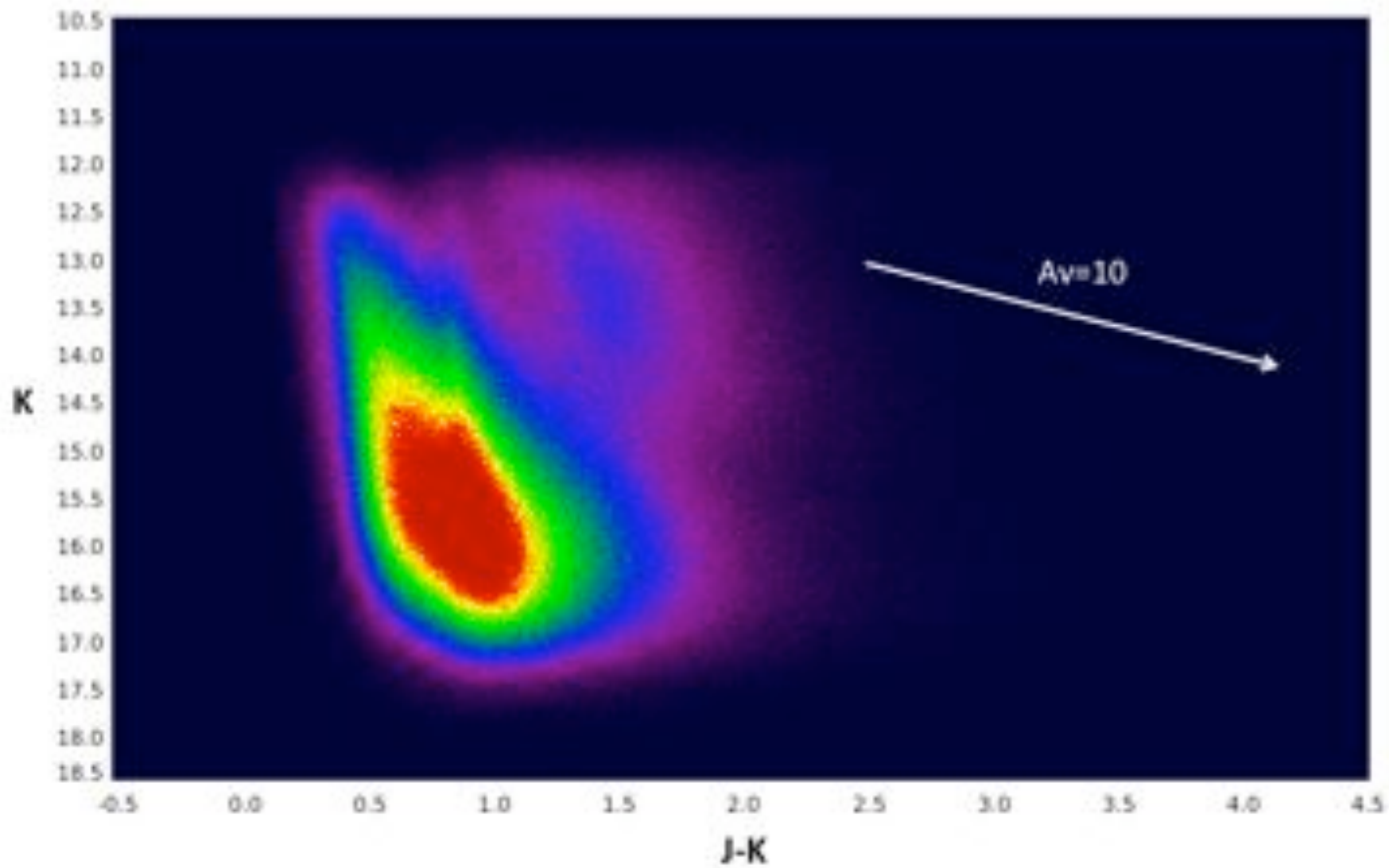
# GLIMPSE 360+GPS

- 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

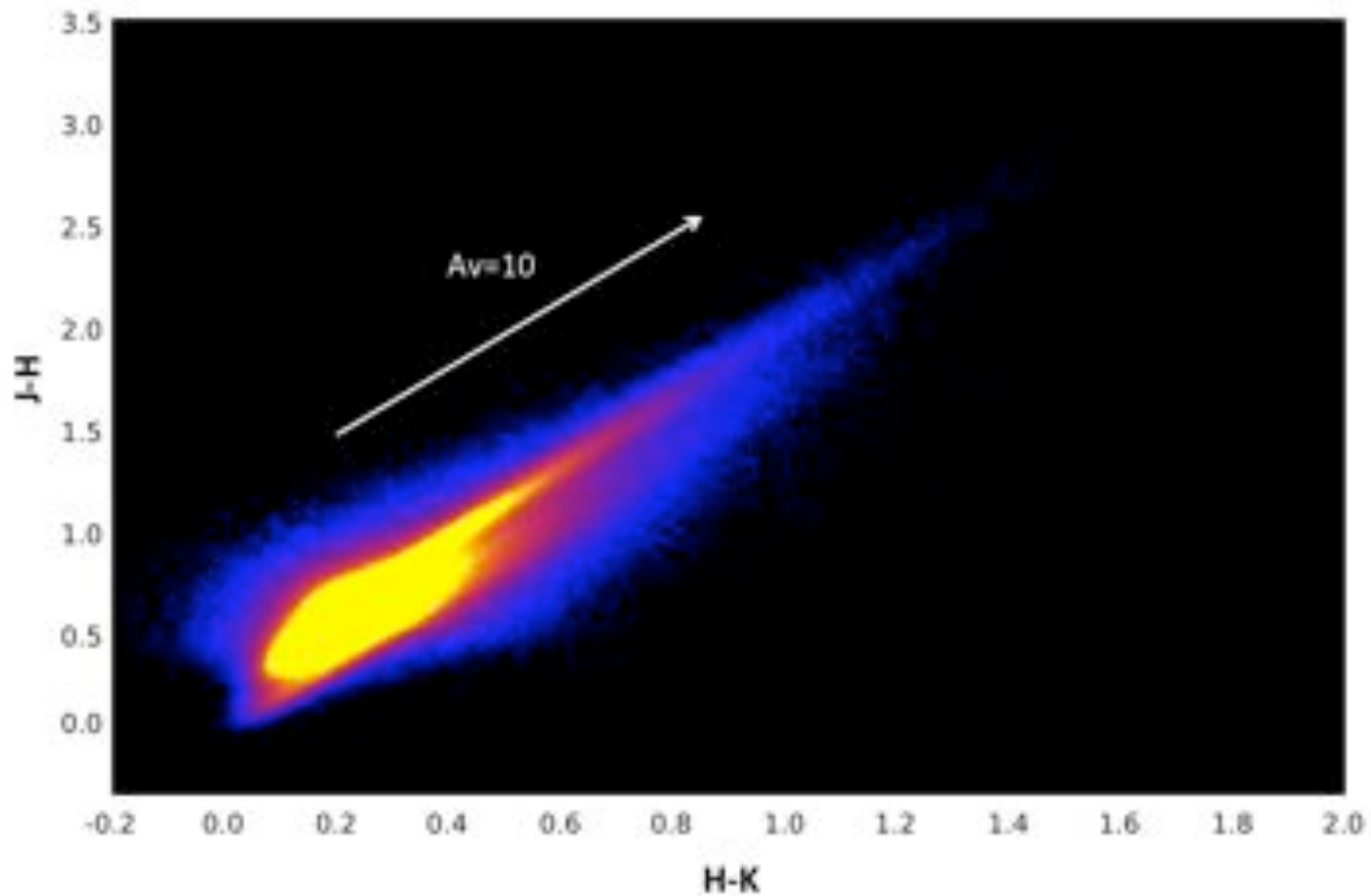
# Matched Catalog Filters

- Remove close stellar pairs:  $csf=0$  (**no source within 3"**)
- $mergedClass=0$ ,  $E11<0.3$ ,  $pstar>0.99$ : 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%
- Remove spurious detections: selected sources detected at least **twice at 3.6 and 4.5mu**
- Merged catalog consists of **3,037,470 sources**

# Matched Catalog

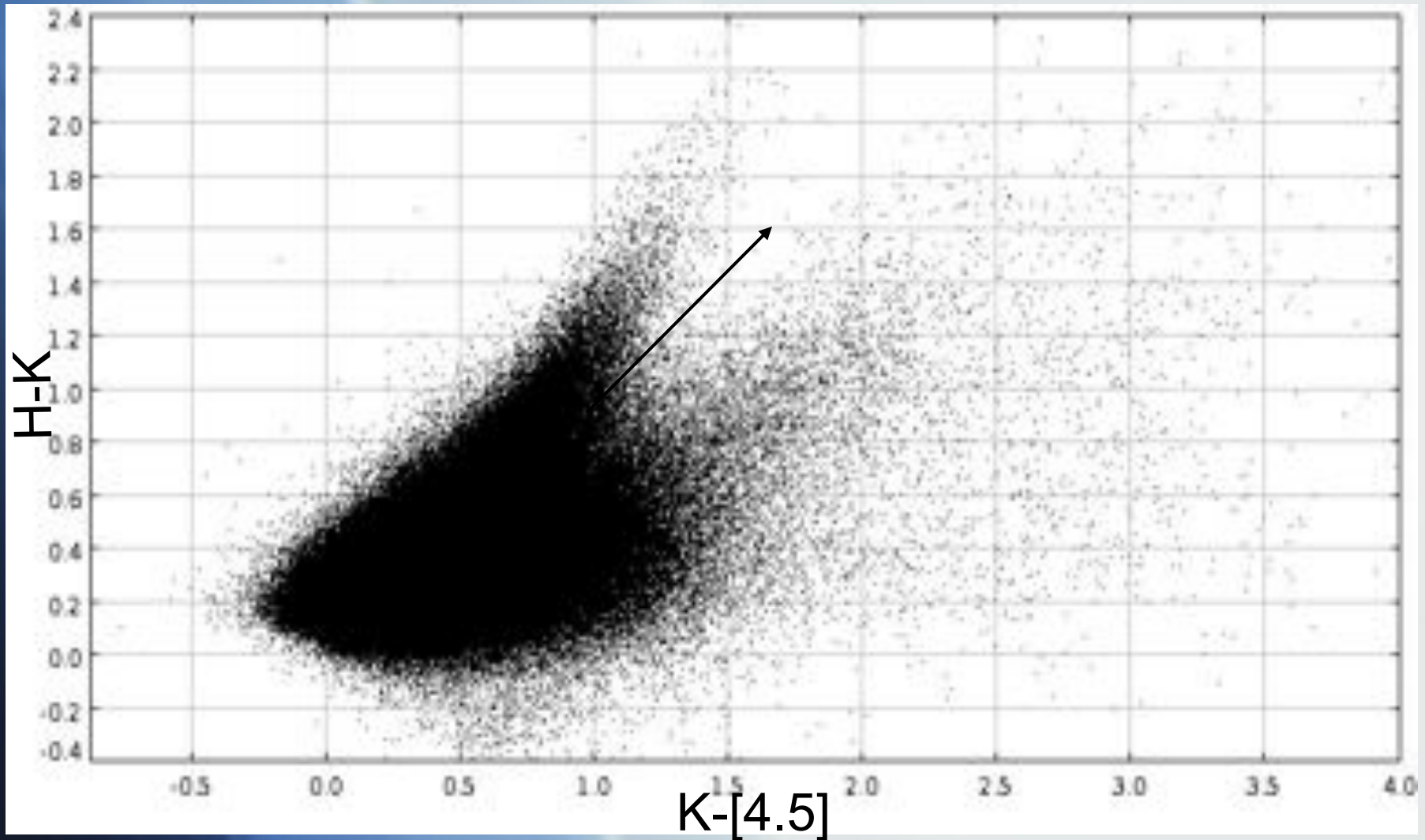


# Matched Catalog





# Matched Catalog



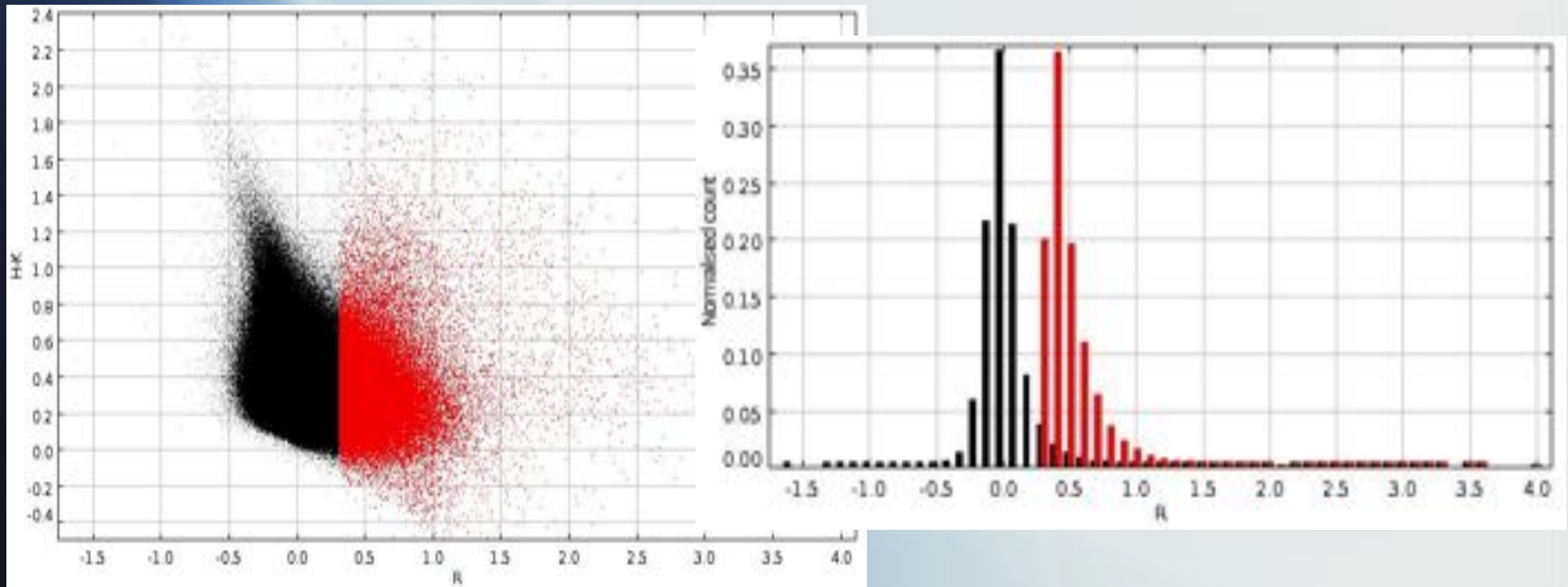
- $H-K$  vs  $K-[4.5]$  provides the best distinction between **extincted and 'red' sources**

# Red Catalog Selection

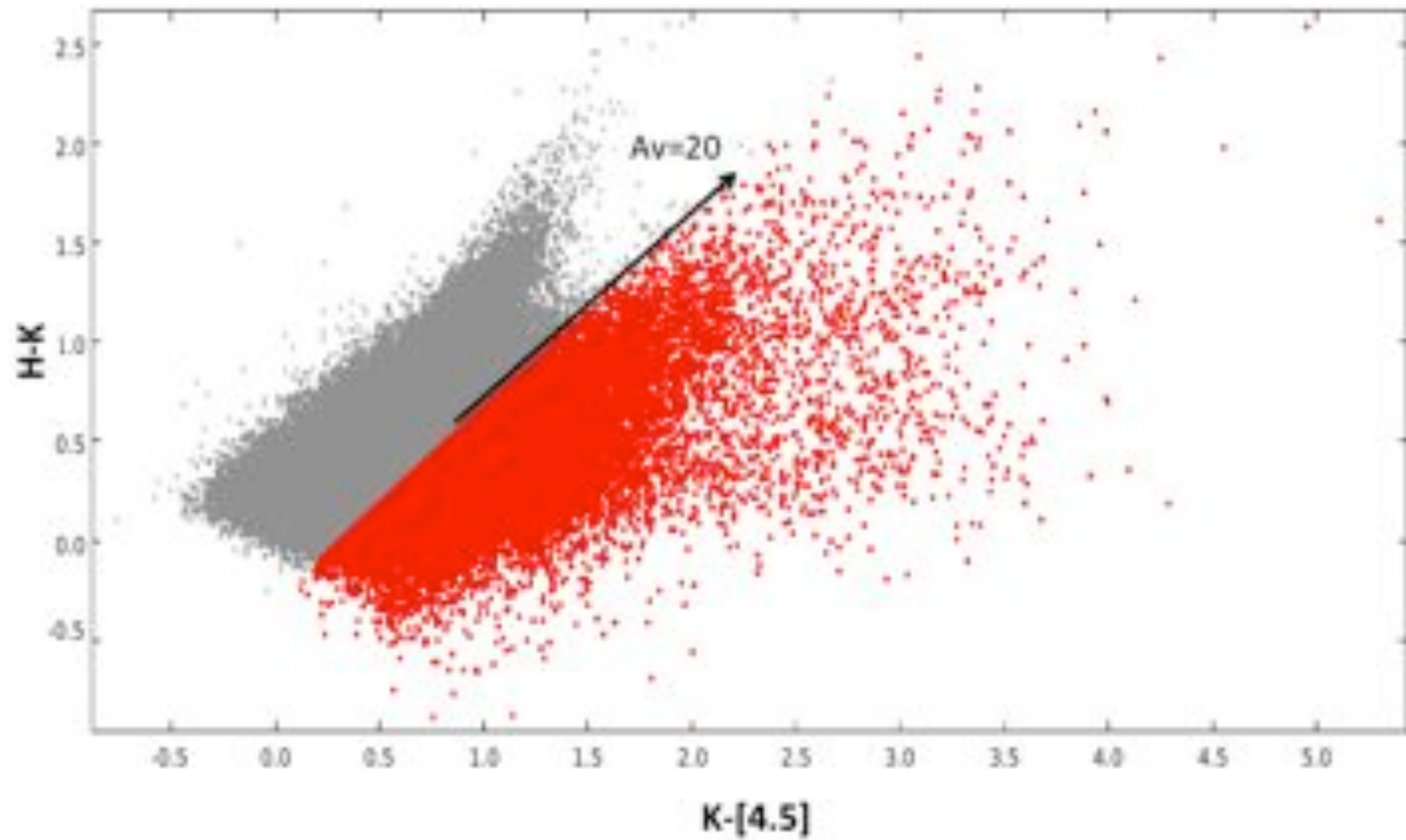
- Calculated the color index R:

$$R = (K-[4.5]) - [E(K-[4.5])/E(H-K)] * (H-K)$$

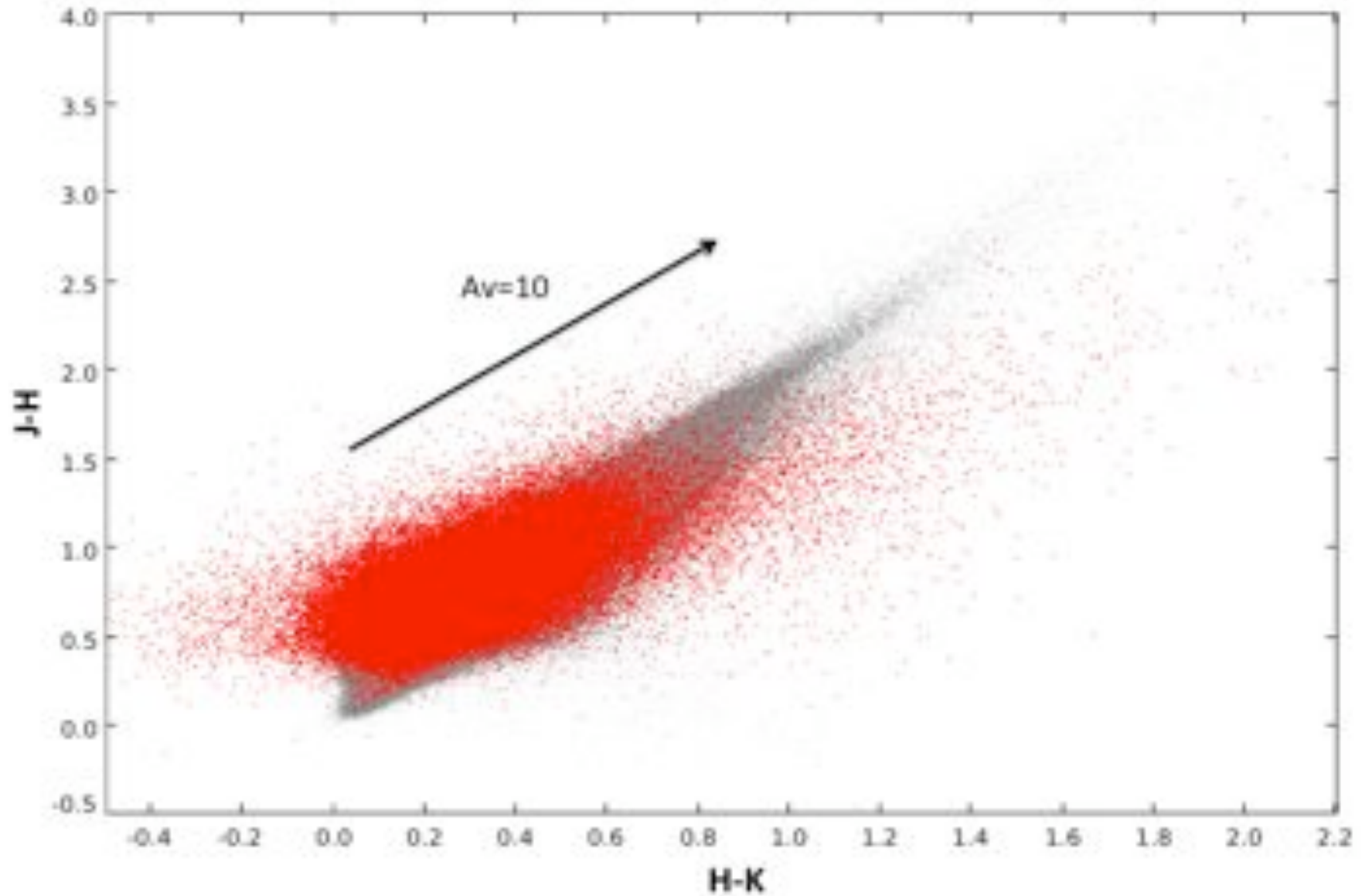
- Std. dev.  $\sigma$  of R = 0.18
- **Selected sources with  $R \geq 2\sigma$**
- **Red Catalog: 199,552 sources (~7%)**



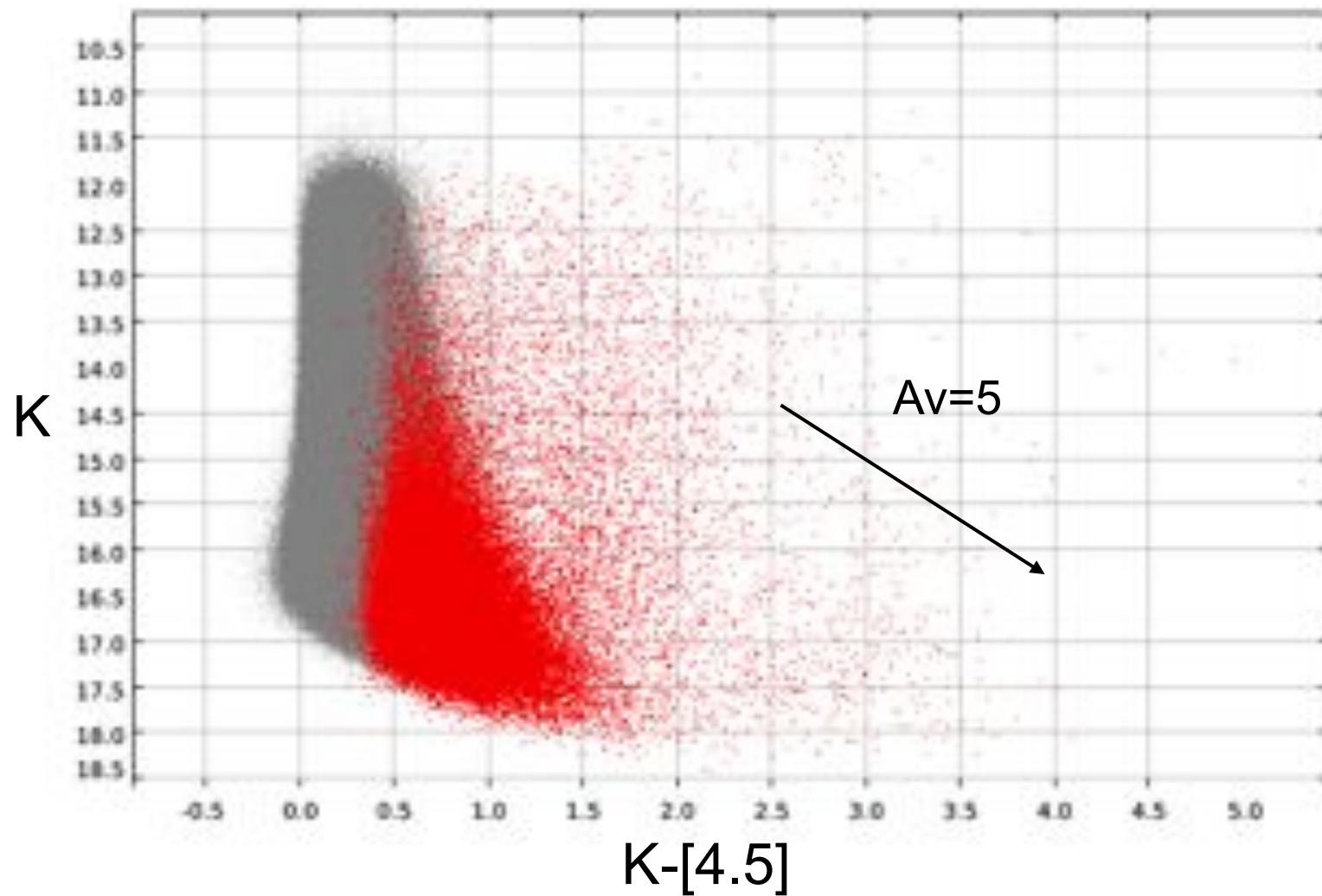
# Red Catalog



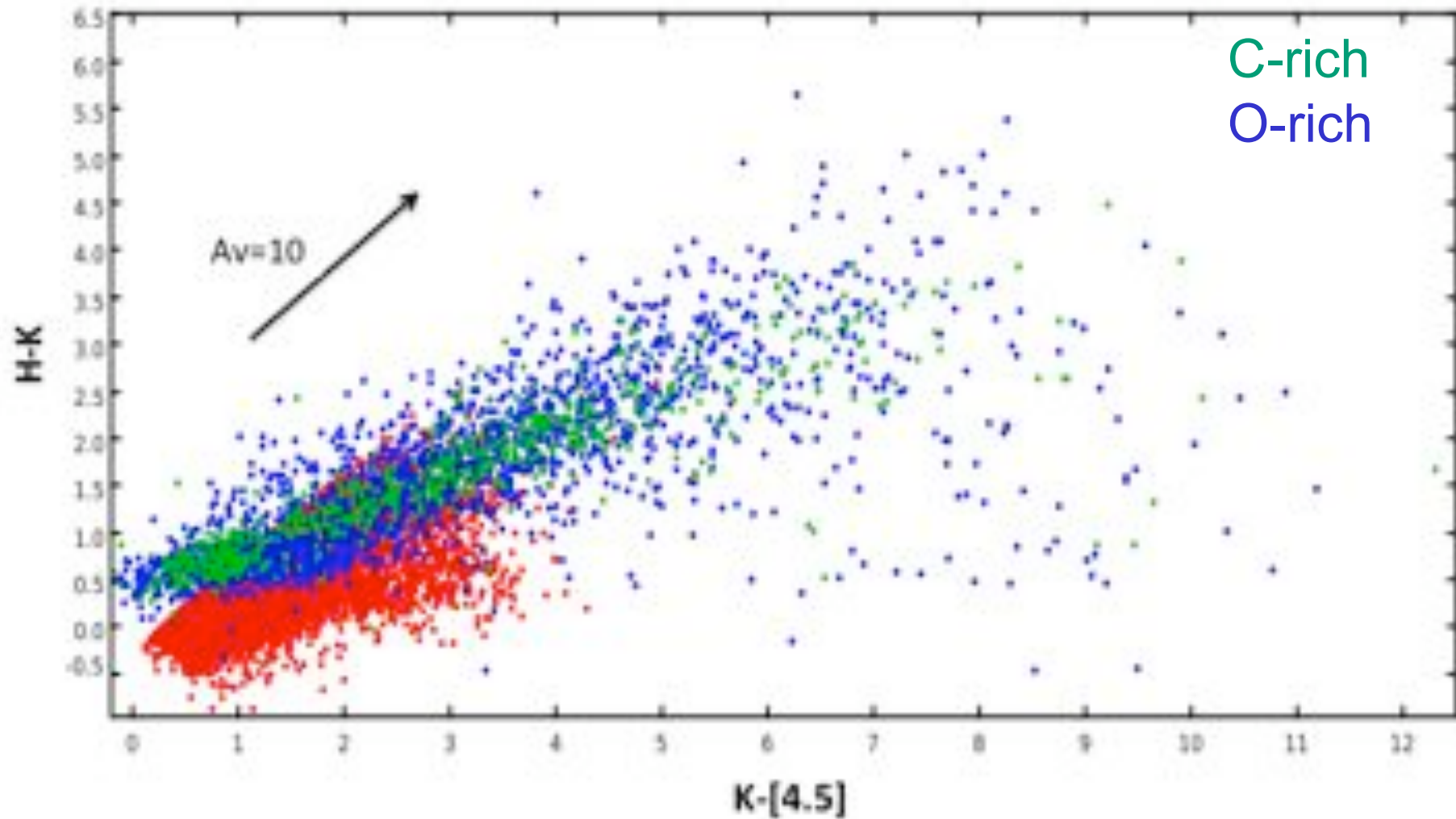
# Red Catalog



# Red Catalog

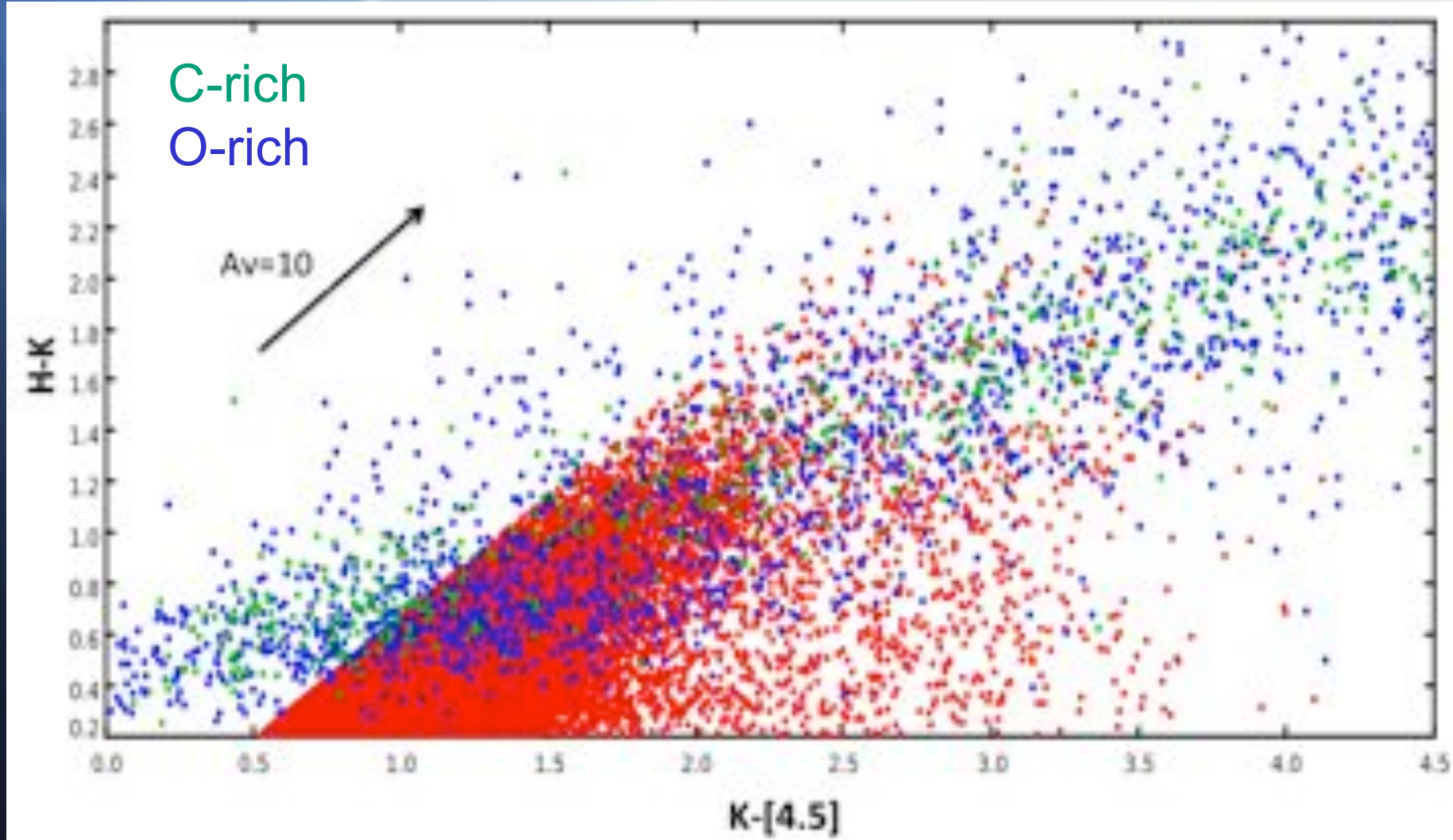


# Red Catalog: AGB contamination



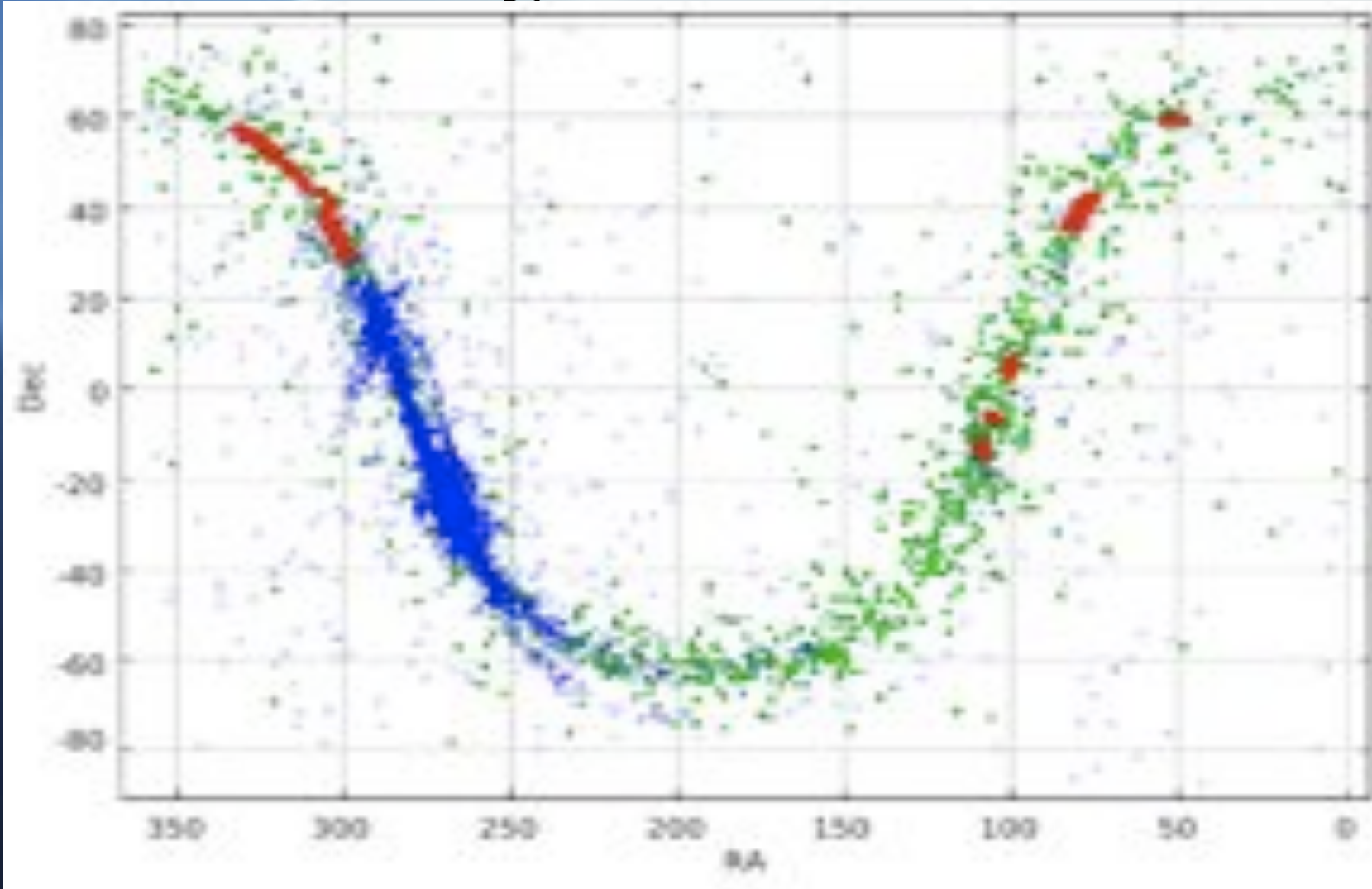
C-rich, O-rich AGBs from Kwon et al. (2011)

# Red Catalog: AGB contamination



- Main overlap  $(H-K) \geq 0.4$ ,  $(K-[4.5]) \sim 0.7-3.0$ . Densest overlap  $(K-[4.5]) \sim 1-1.5$
- Most AGBs brighter than the saturation limit of UKIDSS ( $K_s \sim 12.5$  mag)
- Estimate  $\sim 5\%$  of the red catalog to be contaminated by AGBs, mostly O-rich

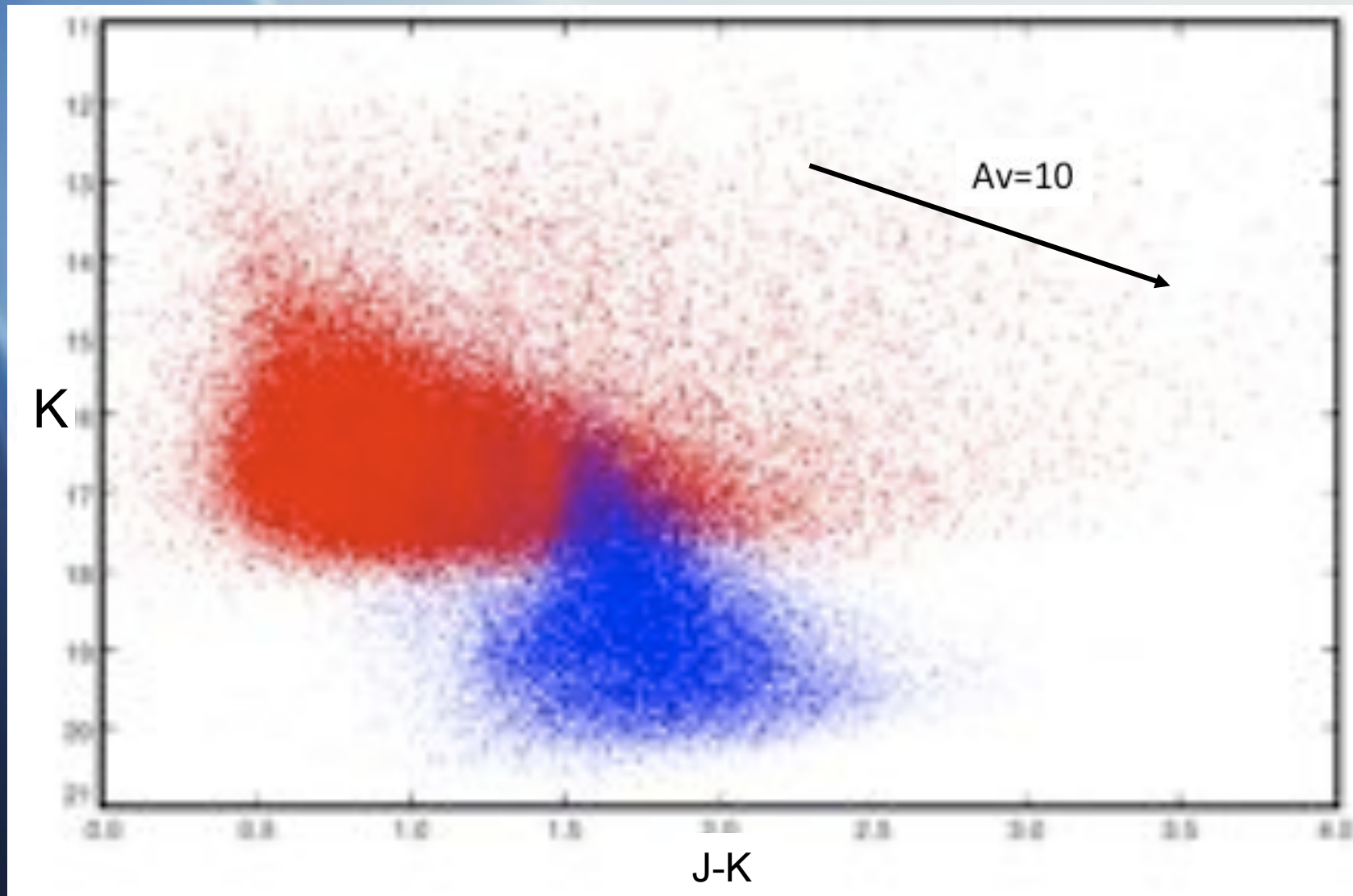
# Red Catalog: AGB contamination



- O-rich surface density  $3/\text{deg}^2$  Galactic center,  $<0.5/\text{deg}^2$  Outer Galaxy; C-rich uniform  $0.2\text{-}0.4/\text{deg}^2$  across Galactic plane (Ishihara et al. 2011)
- From the overlapping regions, AGB contamination  $\sim 3/\text{deg}^2$  inner Gal ( $|l| < 90\text{deg}$ ) and  $\sim 0.1/\text{deg}^2$  outer Gal.

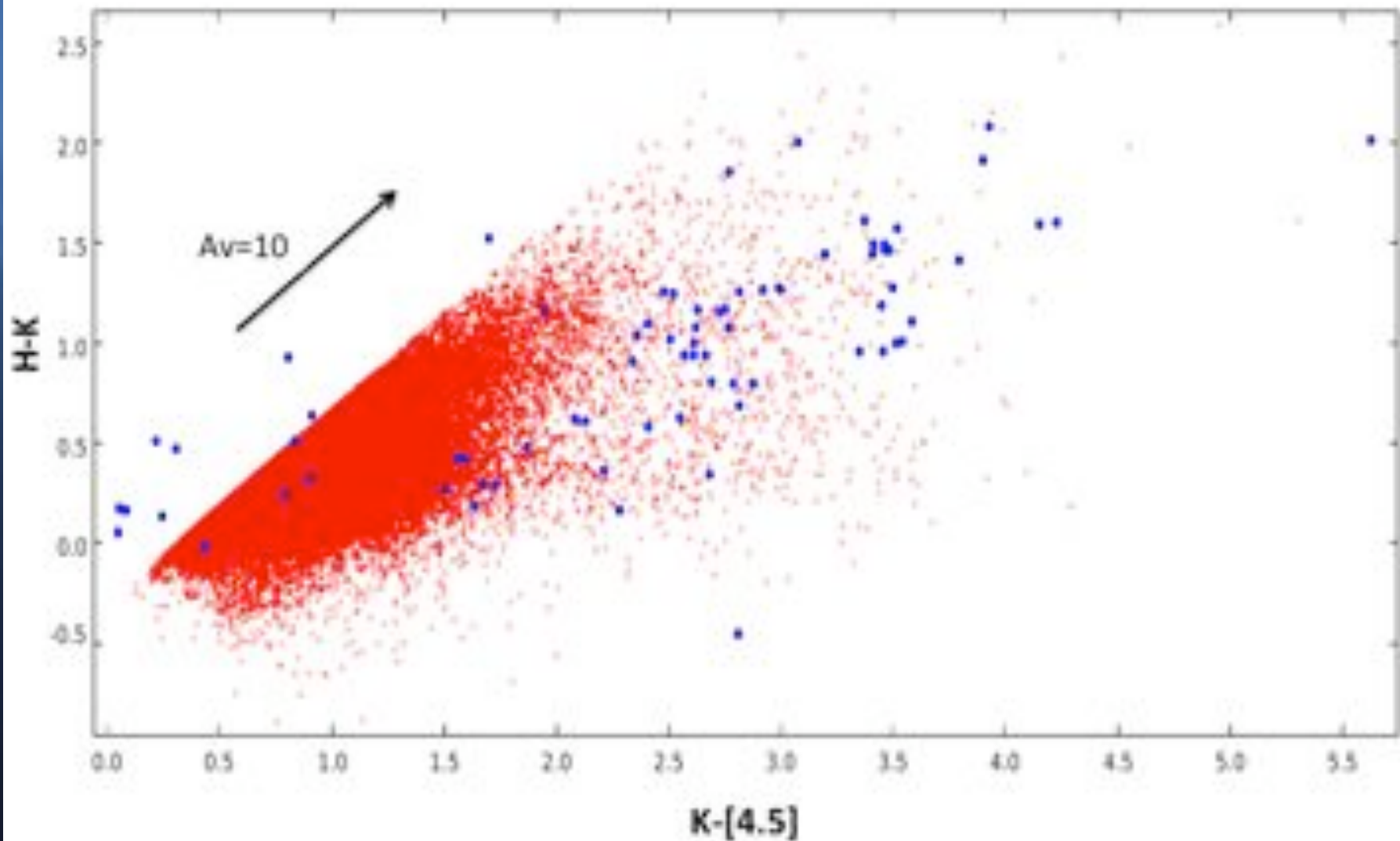


# Red Catalog: extragalactic contamination



- UKIDSS DXS survey, applied same constraints as for GPS
- Blue points classified as galaxies (mergedClass=+1)
- Main overlap at faint red end,  $K \sim 16-18$ ,  $(J-K) > 1.5 \Rightarrow$  estimate  $\sim 2\%$  contamination

# Red Catalog: PNe contamination



- PNe from Hora et al. (2004; 2008), Whitney et al. (2008)
- PNe have double-peaked SEDs--optical+IR
- Two groups: one photospheric colors ( $H-K$ ) $\sim$ 0.5, ( $K-[4.5]$ ) $\sim$ 0.5; 2nd with redder colors ( $H-K$ ) $\sim$ 1.0, ( $K-[4.5]$ ) $\sim$ 2.5
- Main contamination to very red sources in catalog => estimate  $\sim$ 0.5-1%

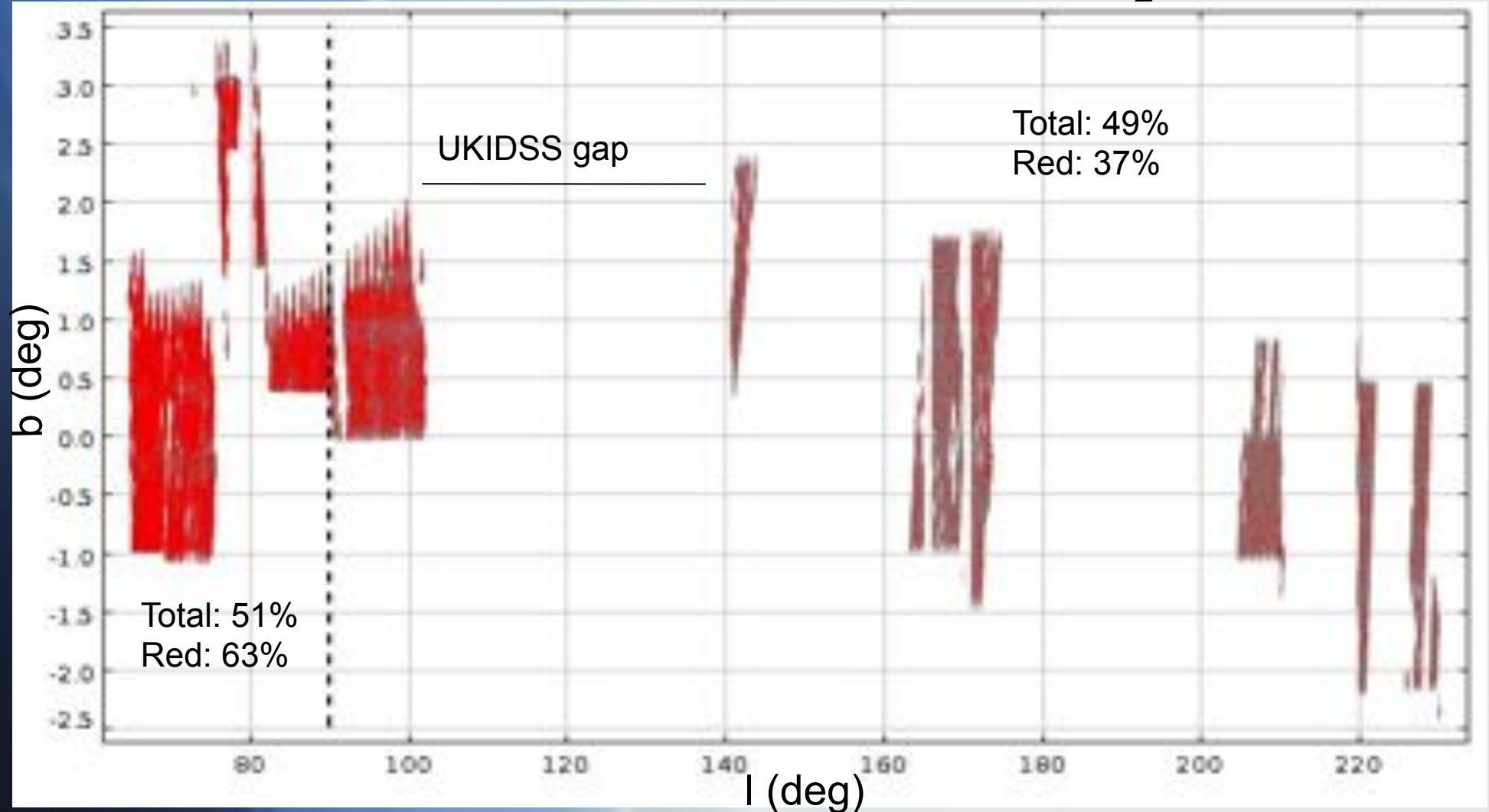
# Candidate YSOs

- estimate ~5% fraction of the red catalog could be composed of sources other than candidate YSOs.
- Searched matches within 10 arcsecond radius in the SIMBAD database for red catalog objects, -- 437 matches found
- A 17% fraction have a SIMBAD object type of YSO (“Y\*O”), 11% are classified as stars (30 objects are A-B type), 15% are infrared sources, 33% are radio sources (“Rad”), 3% are X-ray sources and 2% are emission line stars.
- only 7 objects have a known classification of PNe, 2 sources are classified as galaxies and 1 source as a carbon star (“C\*” or a C-rich AGB) ==> ~2% fraction of the total matches

## Star-forming regions

- Correlated red catalog with the Avedisova catalog of SFR -- found 752 SFR matches
- A few of these are well-known open clusters such as, Stock 8, NGC 1907, NGC 1960, NGC 2359 and NGC 6846, all part of the outer Galaxy  
(l ~172–270 deg)
- There are also several NH<sub>3</sub>, HCN and HCO<sup>+</sup> regions.

# Inner vs. Outer Galaxy



- red source density of  $3100\text{--}3700/\text{deg}^2$  and  $500\text{--}700/\text{deg}^2$  in the inner and the outer Galaxy, respectively
- a factor of  $\sim 5$  higher number density of candidate YSOs in the inner regions.
- census of YSOs in Outer Galaxy not complete



**Thank you!**