

Unlocking the galactic Wolf–Rayet population with Gaia DR2

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Classical Wolf–Rayet (WR) stars

- ▶ He core burning stage of most massive stars
 - Initial mass $>25M_{\odot}$
- ▶ High mass loss rates
 - Reduced / negligible atmospheric H.
- ▶ Broad emission lines
 - He, N and C
- ▶ Tracer of massive star birth/evolution.



Image courtesy: ESA/Hubble & NASA

Birth and evolution

- ▶ Born close to galactic midplane
 - Scale height $\sim 50\text{pc}$
 - Can be ejected from birth location
 - Travel at $> 30\text{kms}^{-1}$ (runaways)
- ▶ Mostly in clusters and associations
 - Short lifetime, avoid cluster dissolution
- ▶ 50%–70% in binaries
 - Effect on evolution.
 - Secondary channel of WR formation.

WR and Gaia DR2

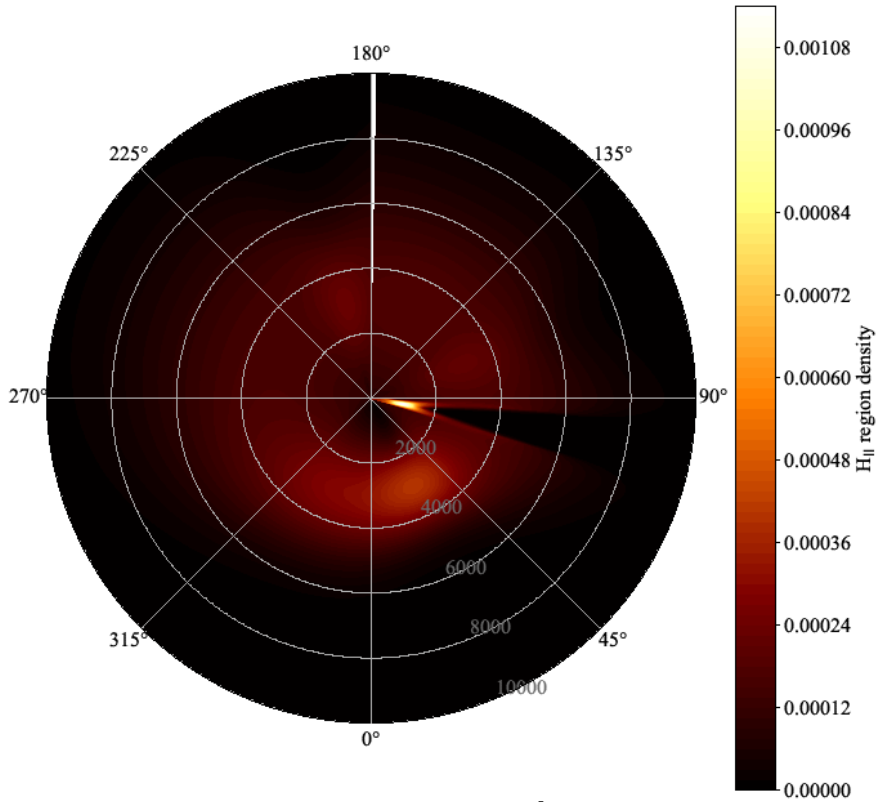
- ▶ Need distances!
 - Previous distances found using WR in clusters.
 - Generated absolute magnitude calibrations.
 - Large uncertainties.
- ▶ Gaia DR2: Survey of ~ 1.1 billion stars in the Milky Way
 - Gaia DR2 expands WR sample with parallaxes from 1 to ~ 400 .

Bayesian methods

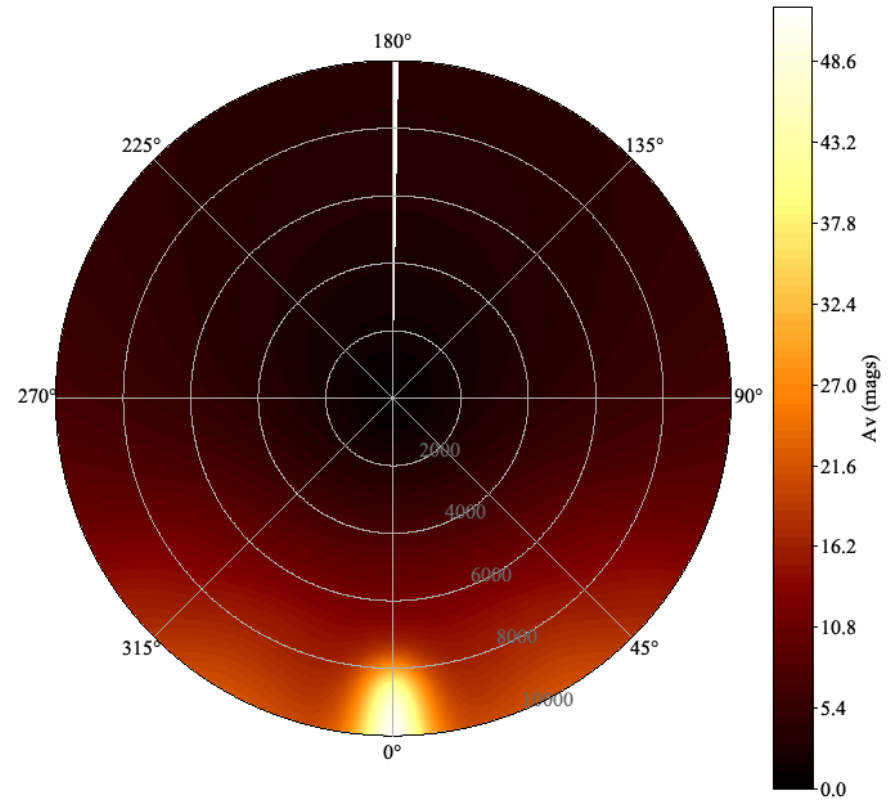
- ▶ Use Bayesian methods for distance calculation
- ▶ Can improve on distances from Bailer–Jones et al. (2018)¹.
- ▶ Differing distribution to other stars
- ▶ Need a different prior

1. Estimating Distance from Parallaxes. IV. Distances to 1.33 Billion Stars in Gaia Data Release 2, Bailer–Jones, C.A.L. et al. 2018. The Astronomical Journal, 156, 2, 58

HII regions and extinction



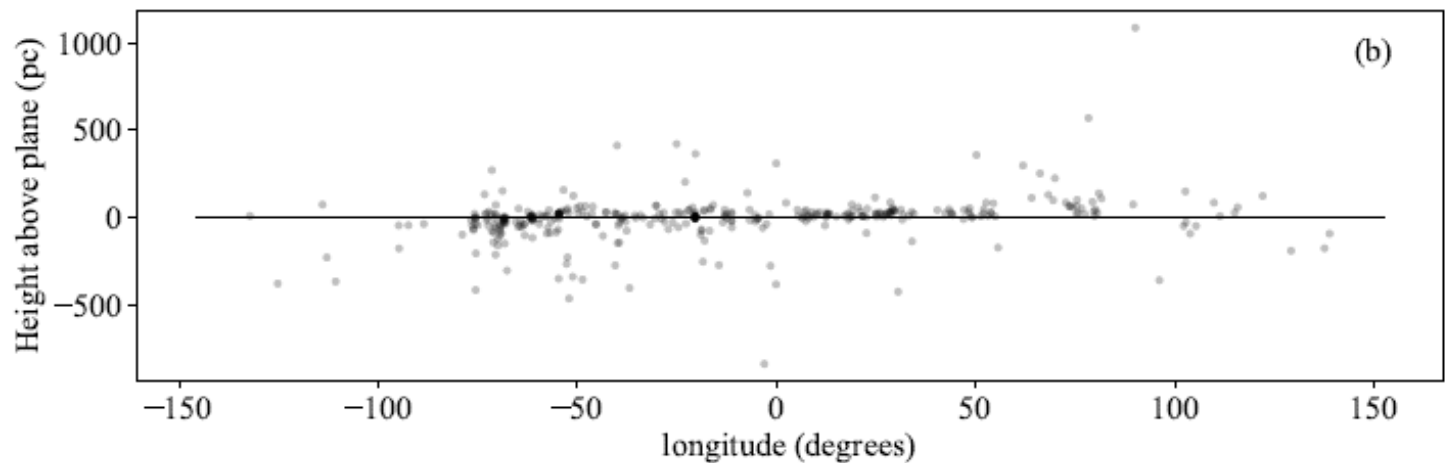
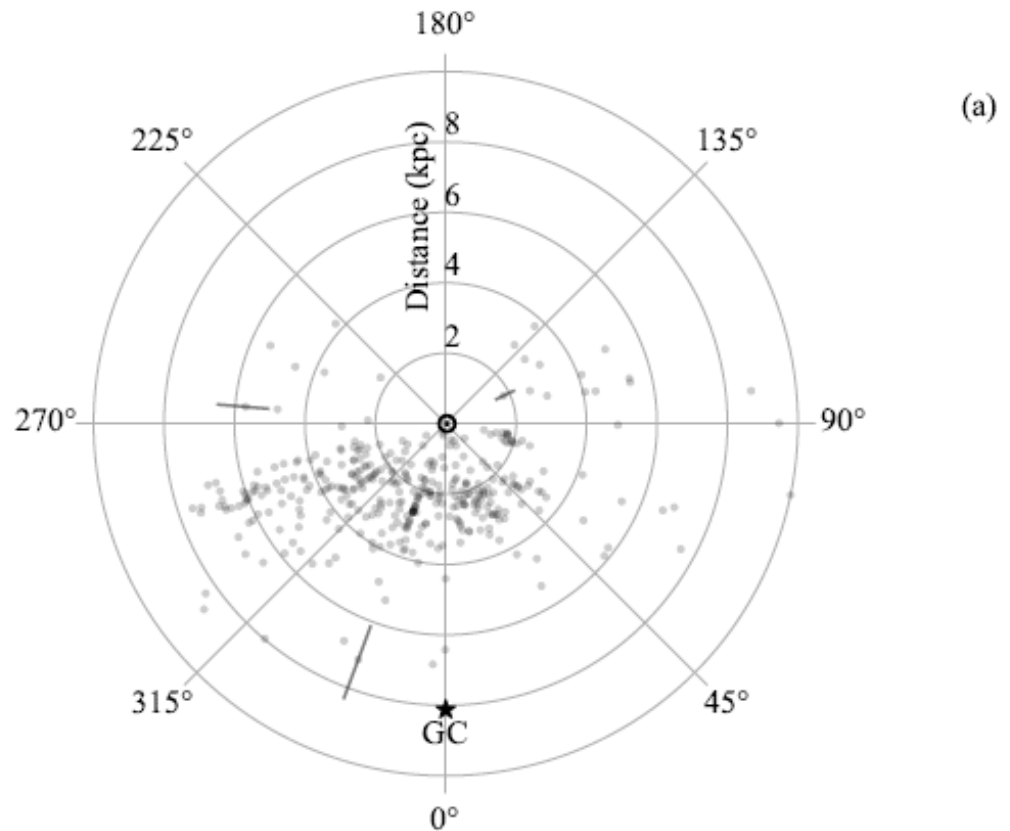
HII regions in radio



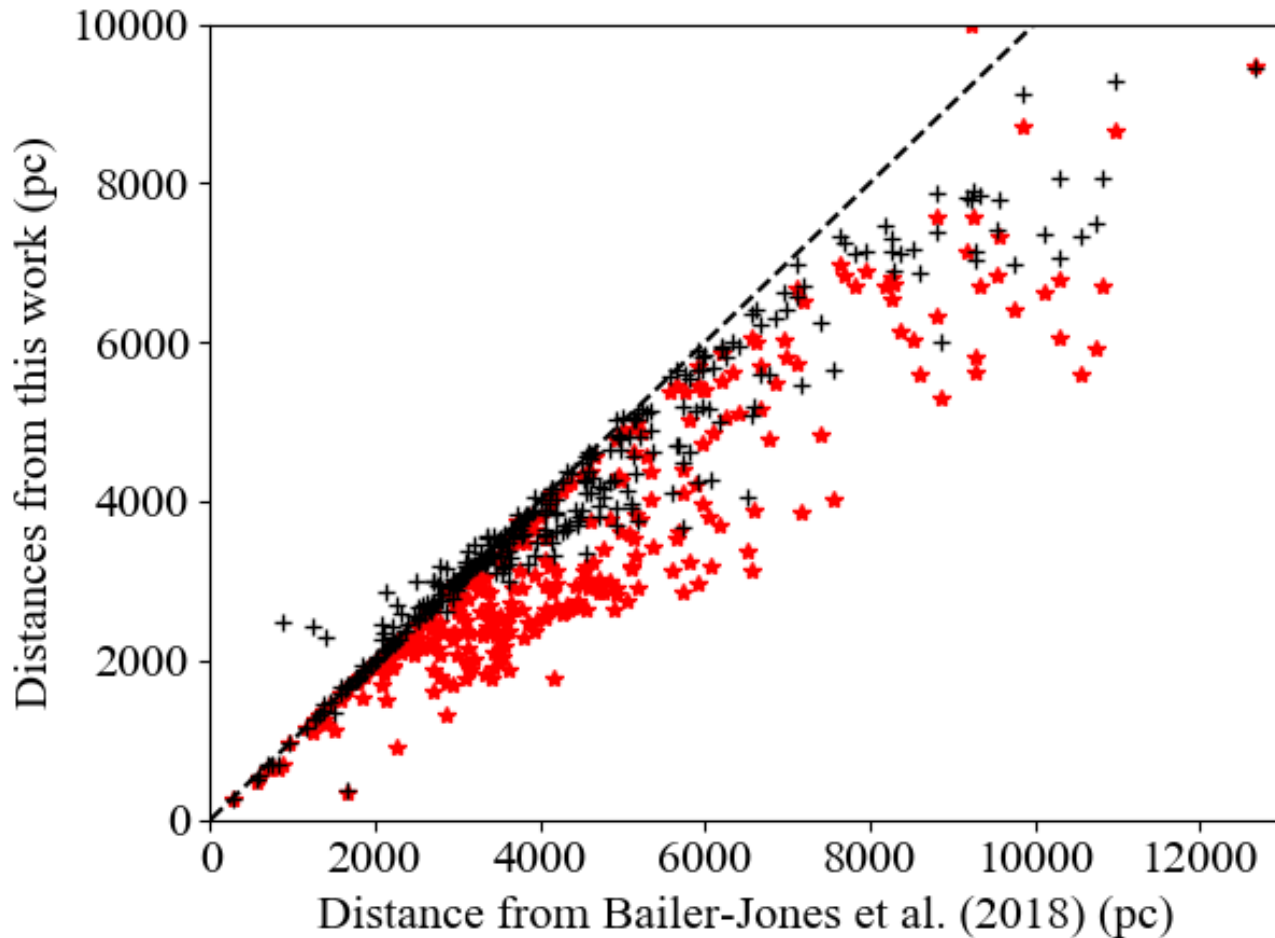
Extinction

WR map

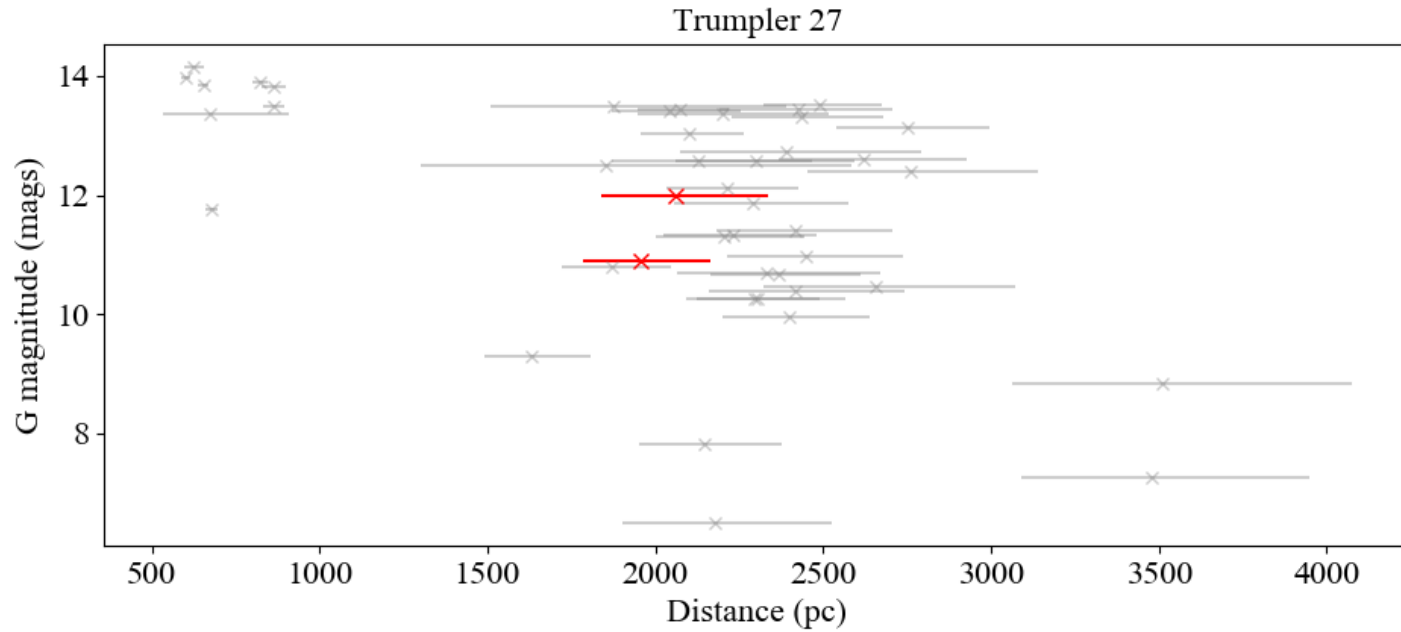
- ▶ 656 known WR
- ▶ 381 with distances



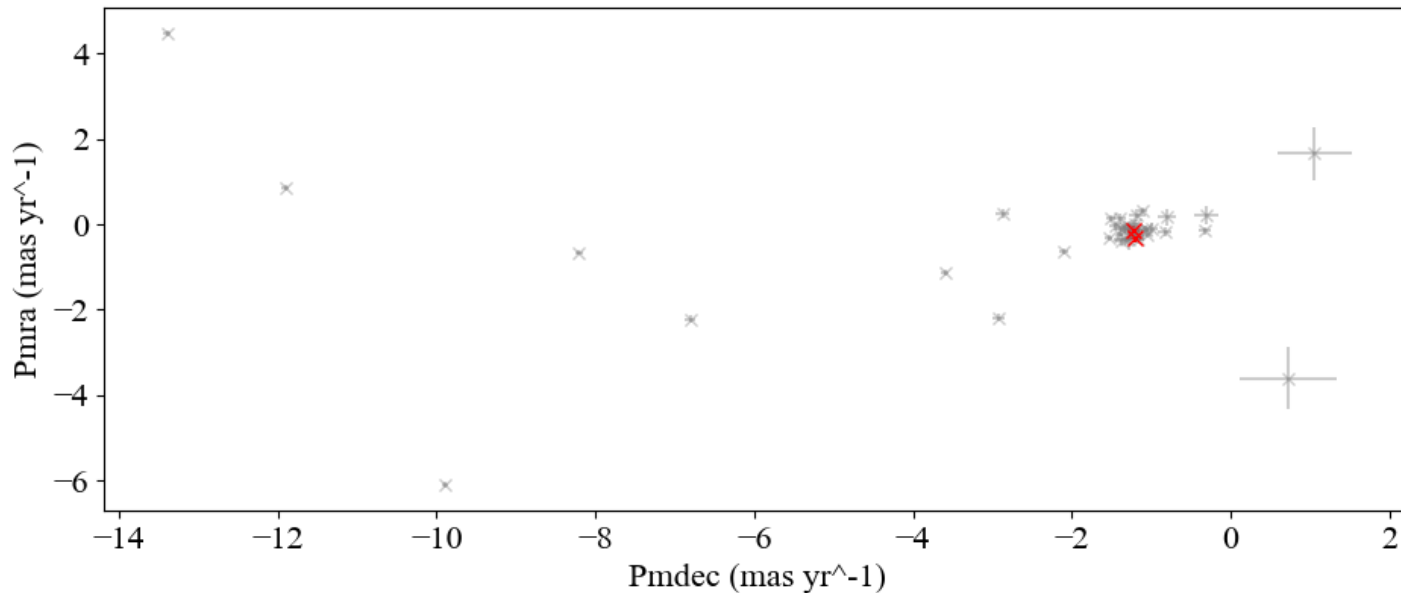
Bailer-Jones et al. comparison



Cluster and association membership



- ▶ Use:
- ▶ Proper motions
- ▶ Distances



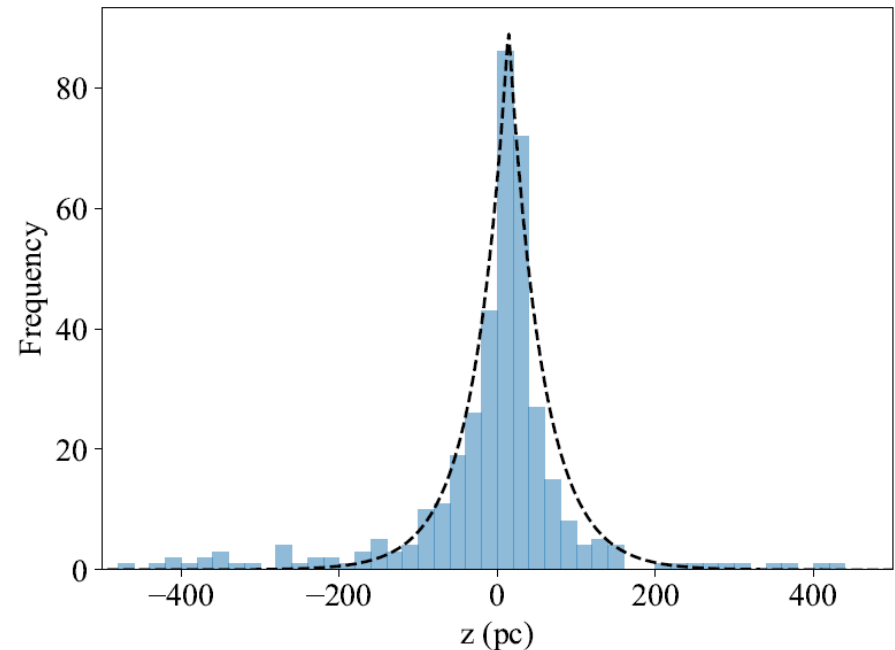
Cluster members identified in: Massey, DeGioia–Eastwood and Waterhouse, 2001, *The Astronomical Journal*, 121, 2, 150

Cluster and association membership

- ▶ 10% of 381 detected WR confirmed as cluster members
- ▶ 3% confirmed as association members
- ▶ Hampered by
 - Large scatter
 - Few members
- ▶ WR in more isolated environments than expected
 - E.g Gamma Velorum.

Distance from plane

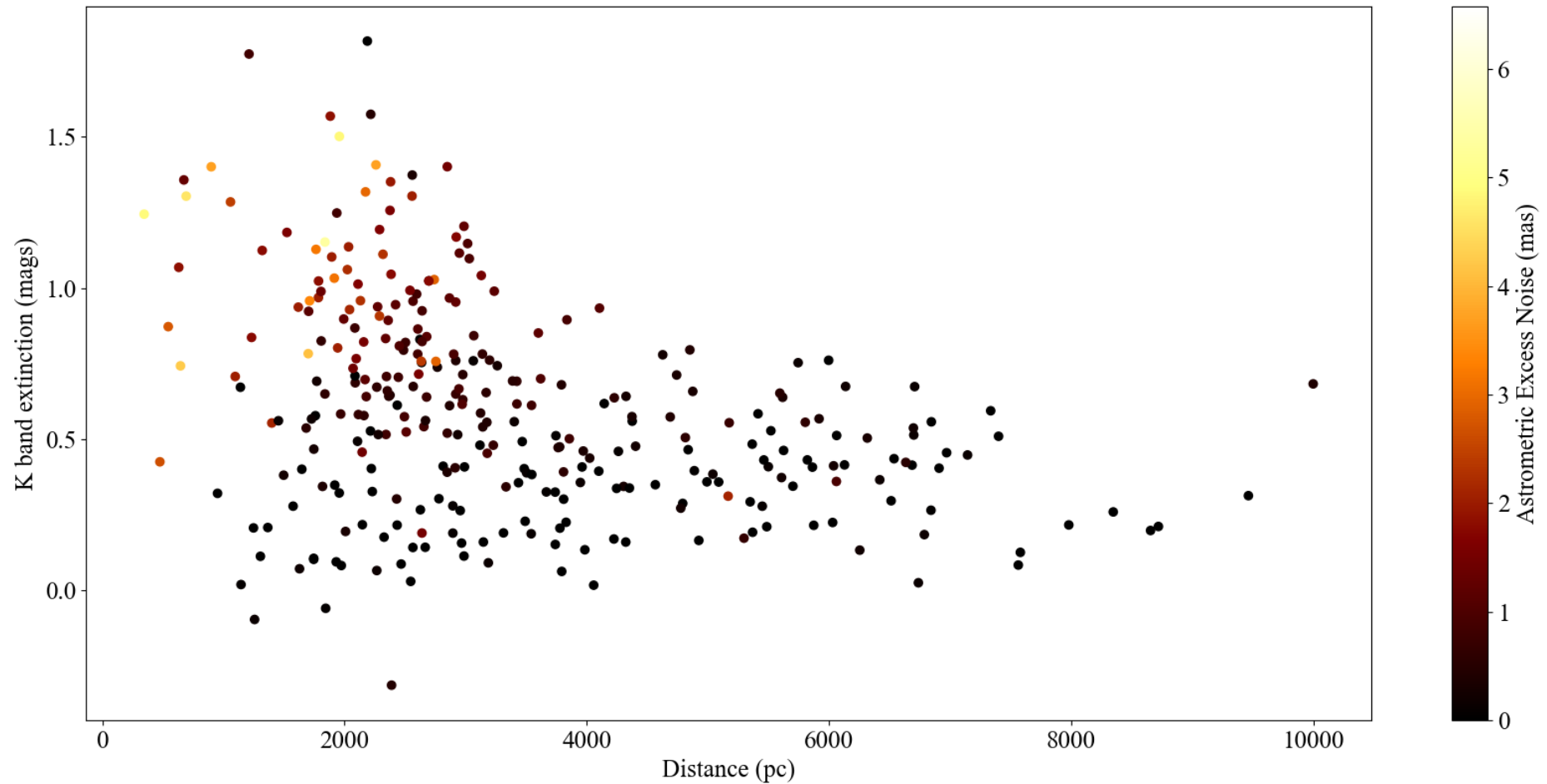
- ▶ WR formed near plane.
- ▶ Greater than ~ 150 pc is indication of runaway status.
 - WR with 5Myr lifetime travelling at 30km/s
- ▶ 2 key mechanisms to produce runaways
 - ▶ Disrupted by supernova
 - Single WR or WR+compact
 - ▶ Ejected from clusters
 - Single WR or WR+OB



Distance from plane

- ▶ ~10% WR above ~150pc
- ▶ 13 known runaways
 - 3 have OB companions
 - 37 are likely single
- ▶ Both methods may contribute
 - But few WR in clusters!
 - Supernovae therefore likely dominate
- ▶ Minimum estimate

Distance vs Extinction



Summary and next steps

- ▶ Distances to 381 WR
- ▶ Cluster and association membership is lower than expected
 - Only 10% and 3% confirmed.
- ▶ At least 10% WR are potential runaways
 - Most likely binaries disrupted by supernovae
- ▶ Verify distances with extinctions and absolute magnitudes