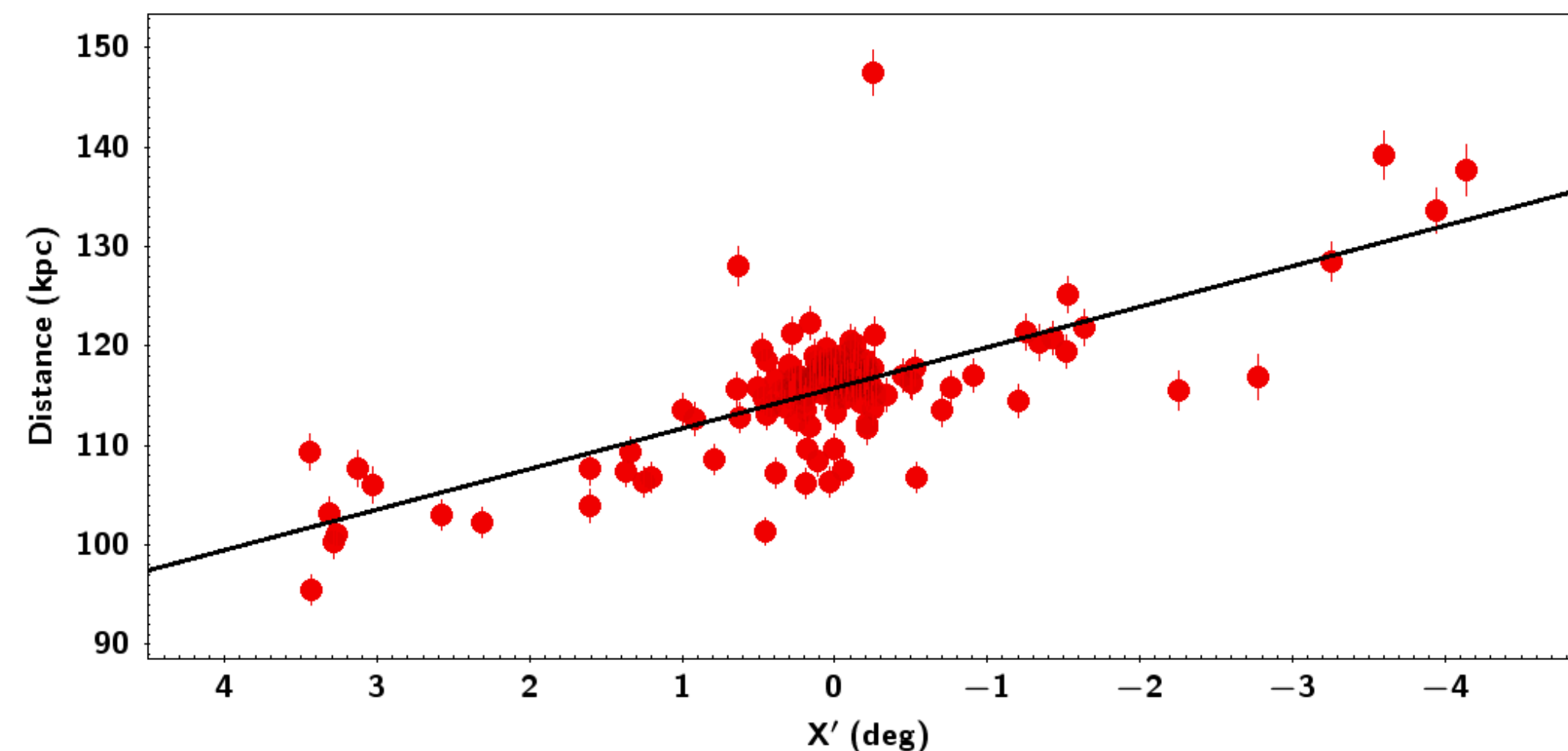


Is Crater II disrupting?

Kathy Vivas

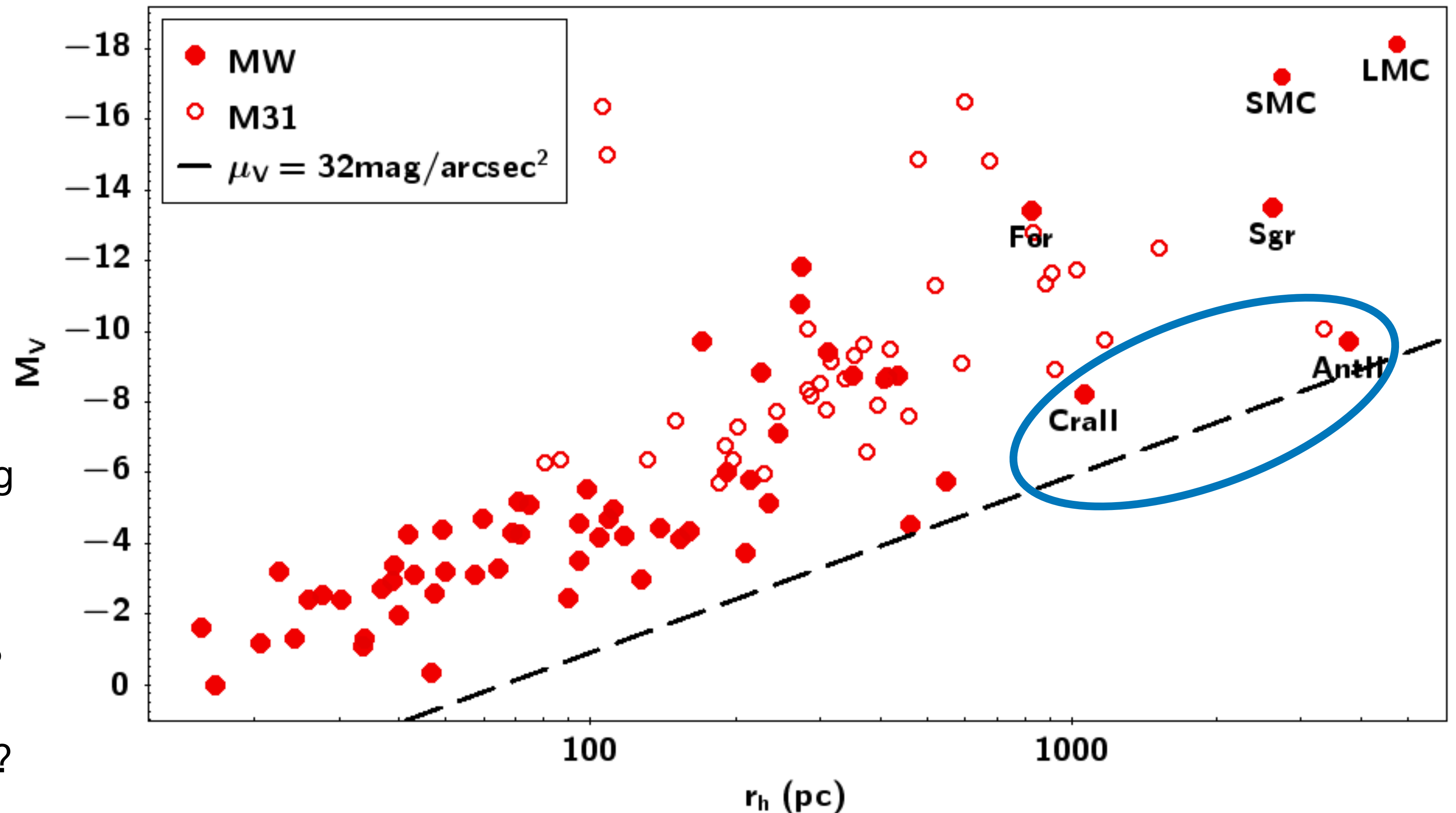
NSF NOIRLab / Cerro Tololo InterAmerican Observatory

with Clara Martínez-Vázquez, Alistair Walker, Matteo Monelli



Milky Way Satellites

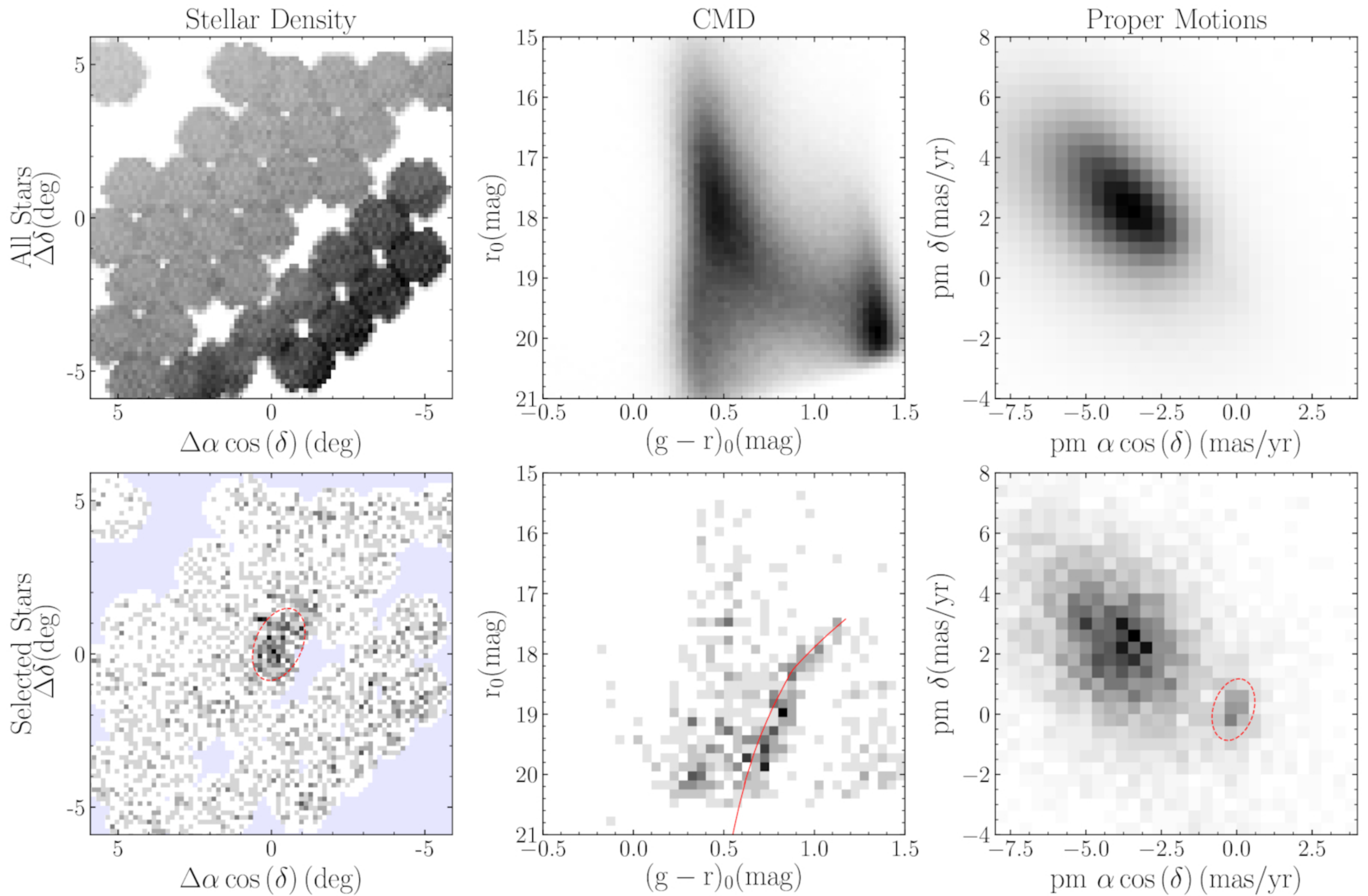
- Giants among the faint: Crater II and Antlia II
- Extreme low surface brightness (~100 times fainter than many UDGs!)
- Why are these galaxies so large: internal heating mechanisms? Tidal disruption? Mergers?
- How common are they? Are there more in the MW awaiting discovery?



Data from Andrew Pace's database

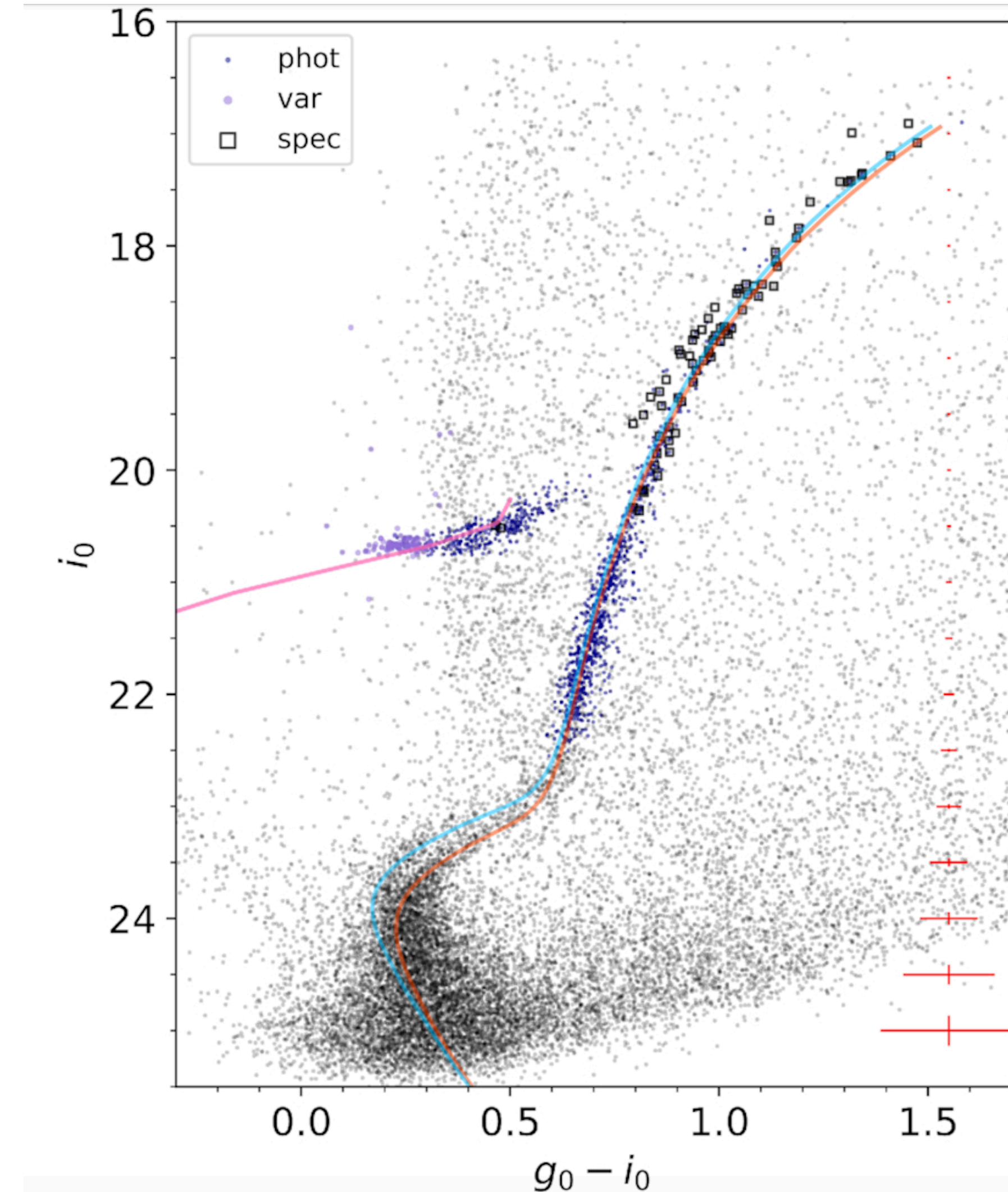
Observational challenges

- Contamination by foreground stars is huge!
- If galaxies are distant, faint background galaxies are also a challenge (MSTO $> \sim 24$ mag)



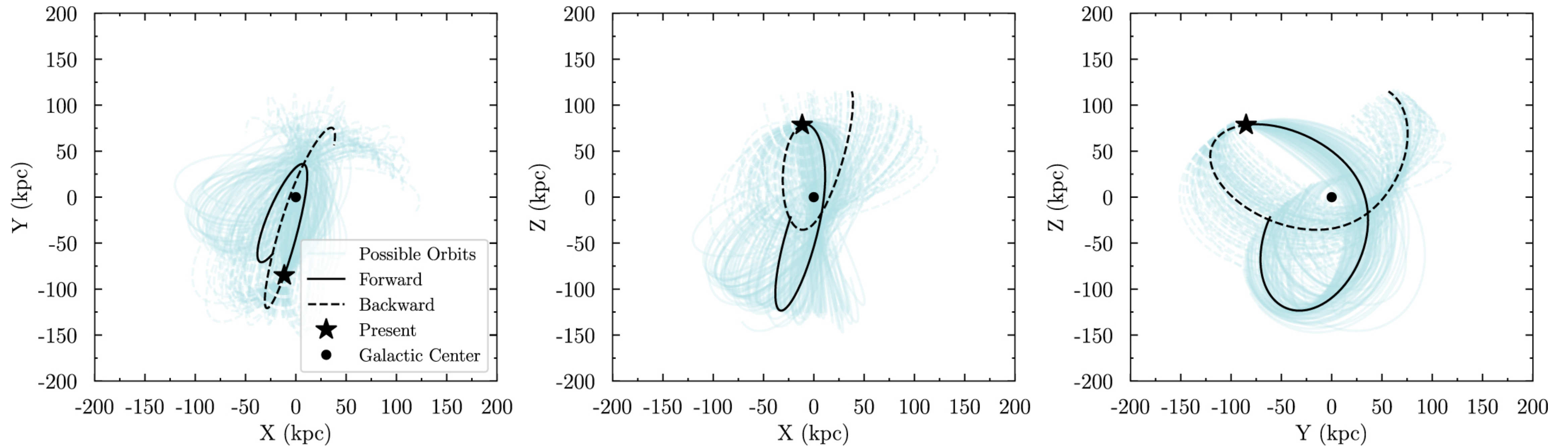
Crater II

- Discovered in ATLAS data in 2016 (Torrealba+16)
- At ~ 120 kpc from the Sun
- Two sub-giant branches seen in the CMD (10.5 and 12.5 Gyr). No young or intermediate age populations seem to be present. (Walker+20)
- $[\text{Fe}/\text{H}] \sim -2.0$ (Caldwell+17, Fu+19)
- Low velocity dispersion (2.7 km/s; Caldwell+17, Fu+19) \rightarrow **Heavy mass loss??**



Crater II with DECam (Walker+20)

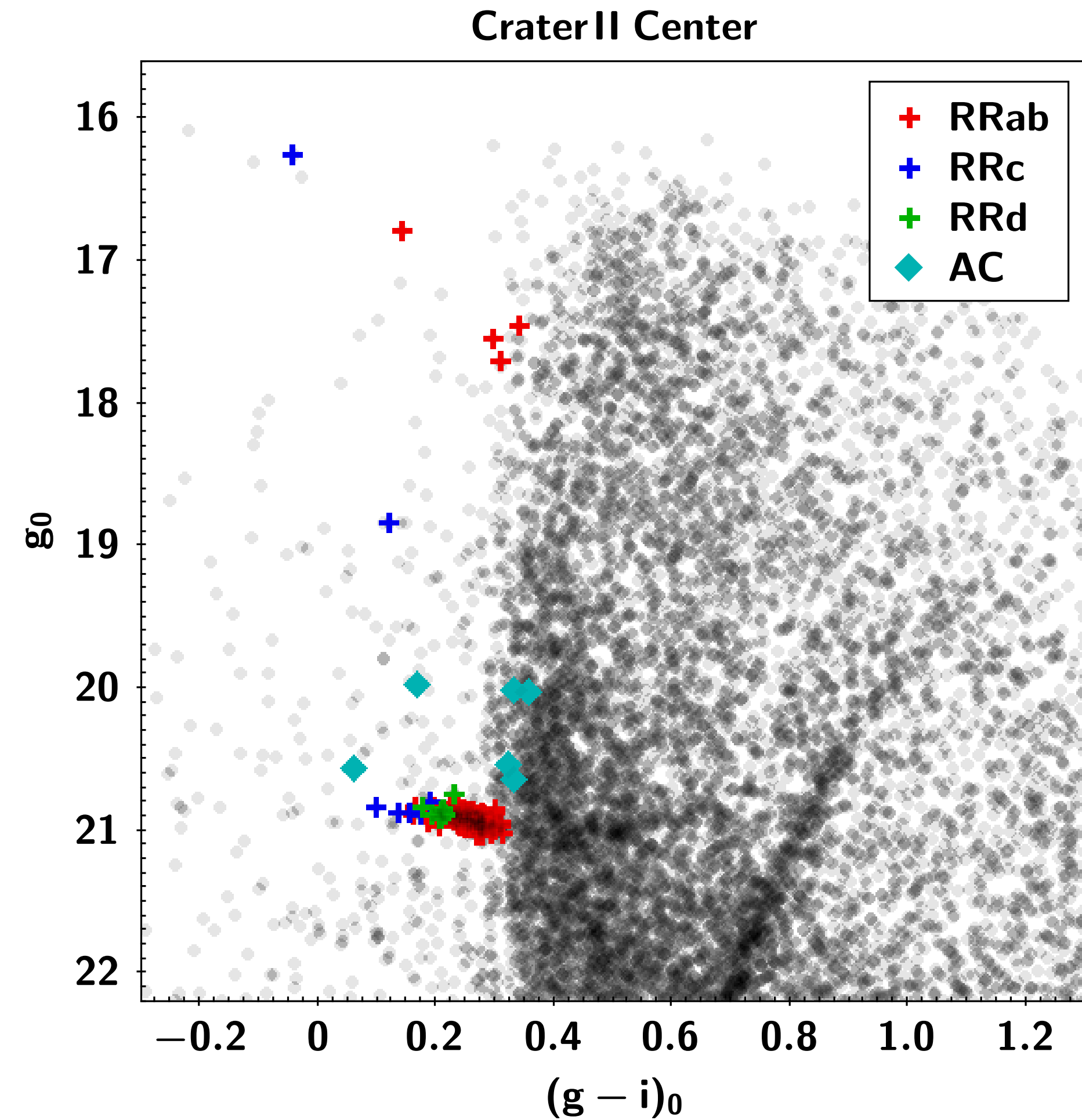
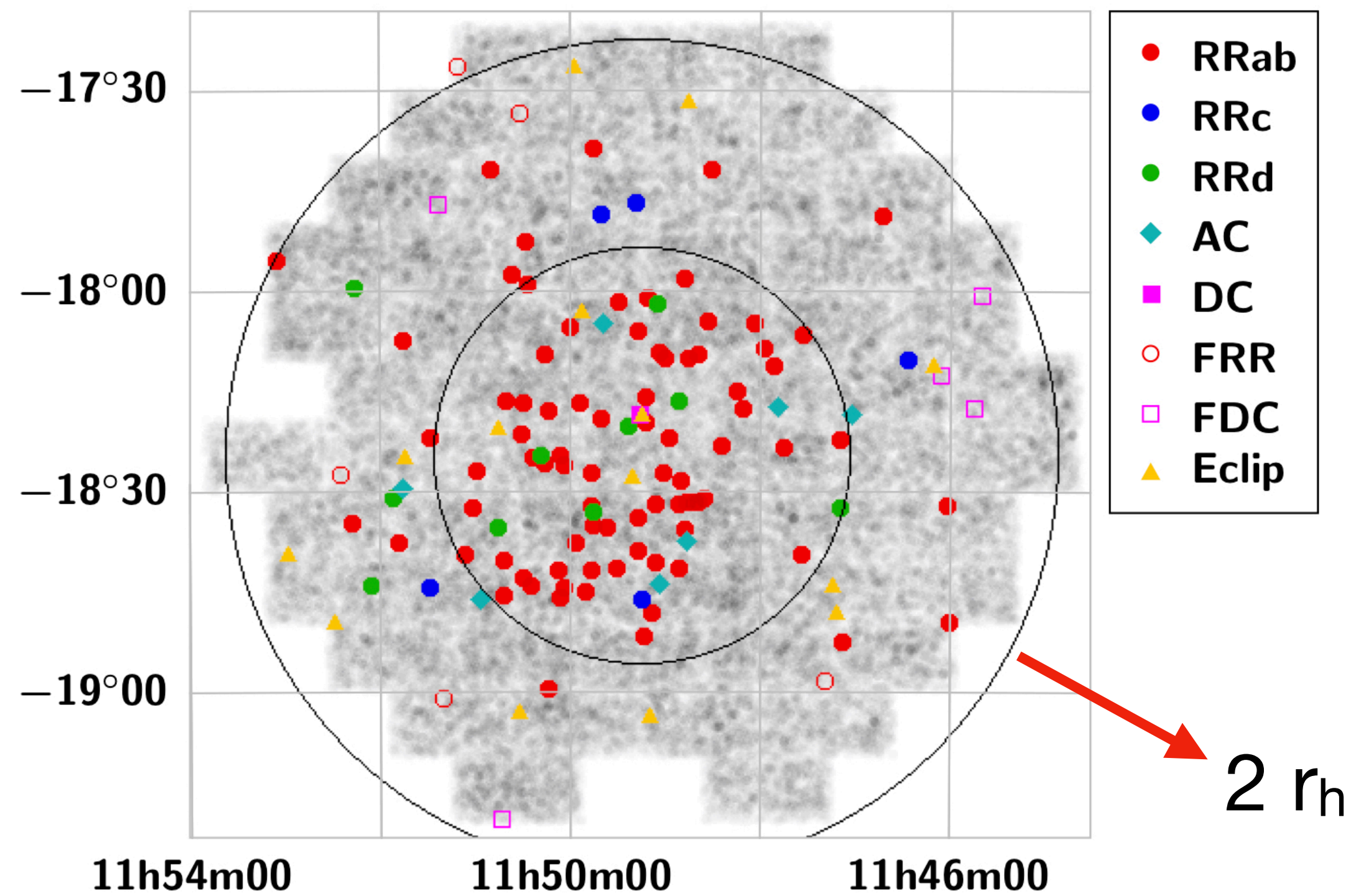
Tidal disruption scenario for Cra II



- Fu+2019: Crater II orbit indicates the galaxy passed as close as 33 kpc from the Galactic center ~1.5 Gyr ago. Likely disrupting!

Variable Stars in Crater II

- Rich in RR Lyrae stars (Monelli+18, Joo+18, Vivas+20): **99 stars**
- Anomalous Cepheids also present (**6 stars**)

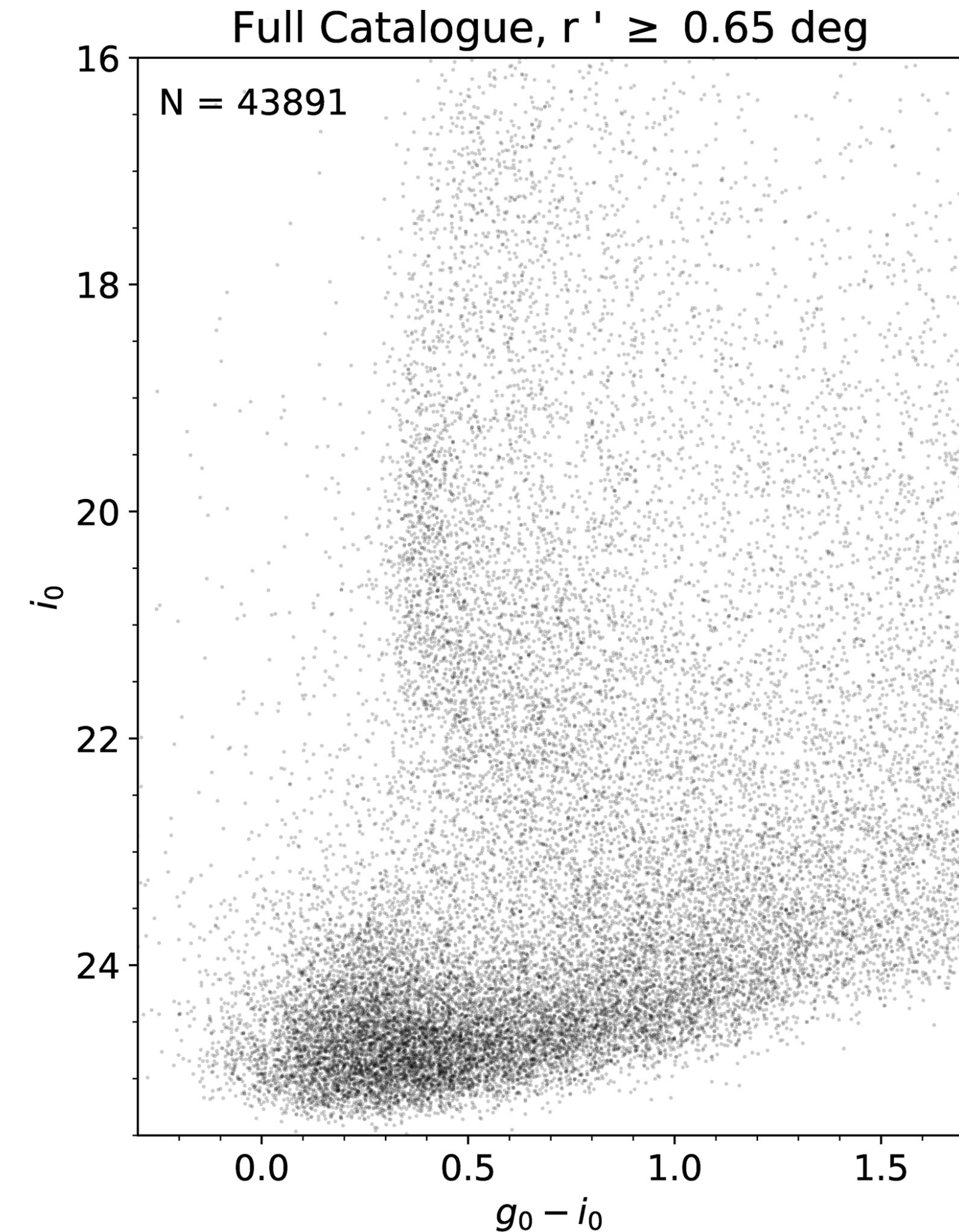
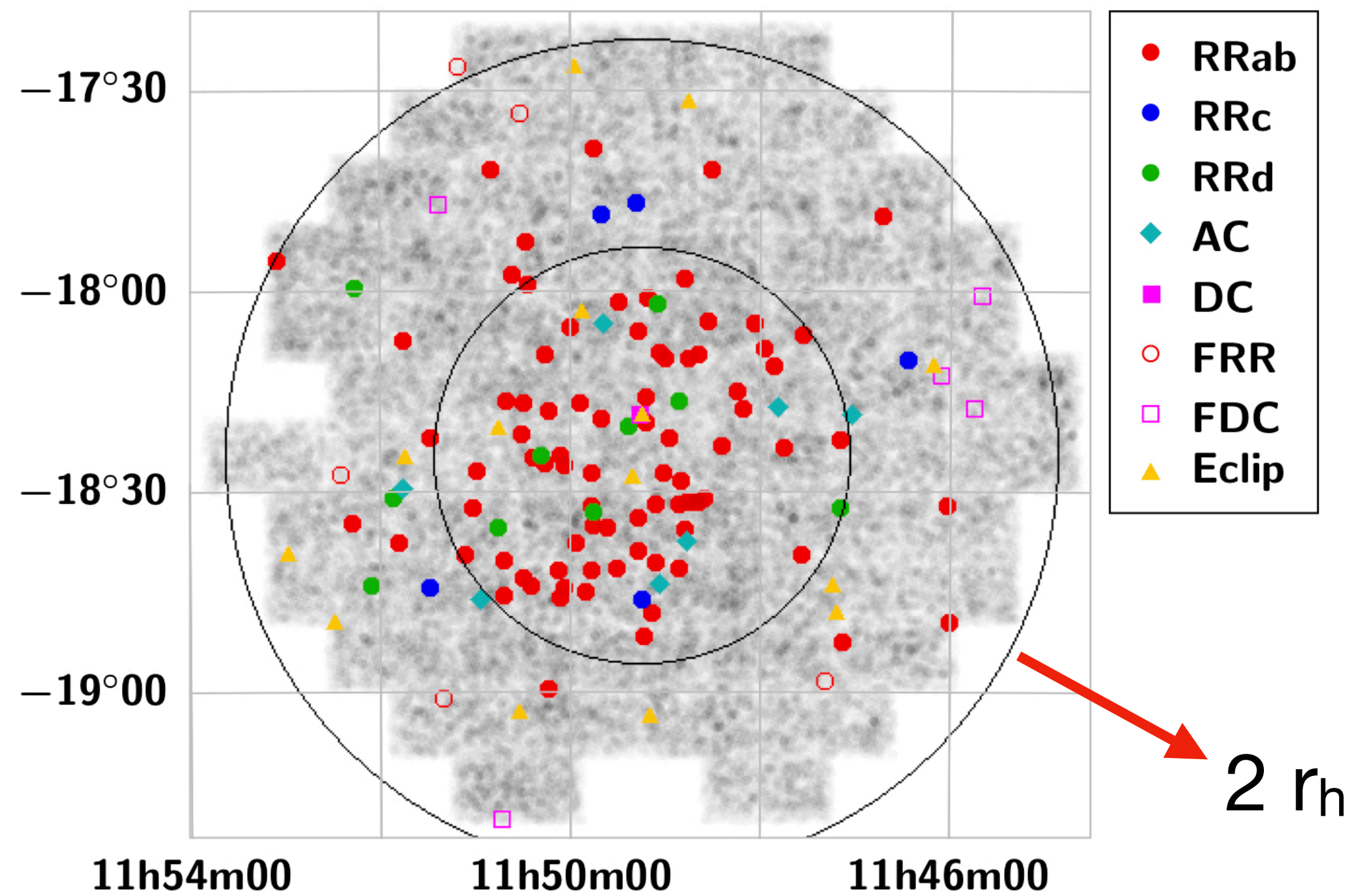


Variable stars in Crater II from a single DECam pointing (Vivas+20)

RR Lyrae stars are standard candles!!

Variable Stars in Crater II

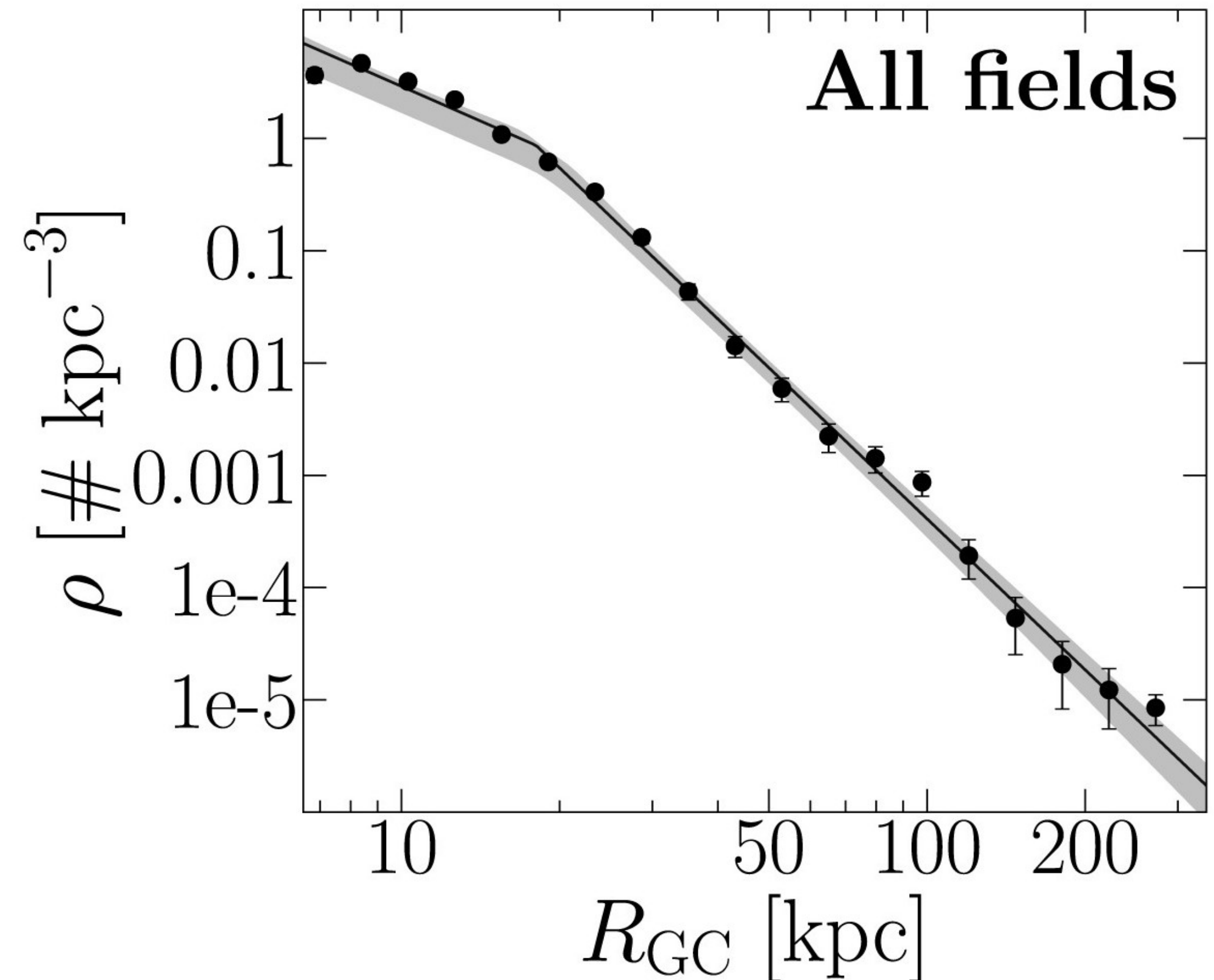
- Rich in RR Lyrae stars (Monelli+18, Joo+18, Vivas+20): **99 stars**
- Anomalous Cepheids also present (**6 stars**)



RR Lyrae stars are standard candles!!

RR Lyrae stars in the Outer Halo

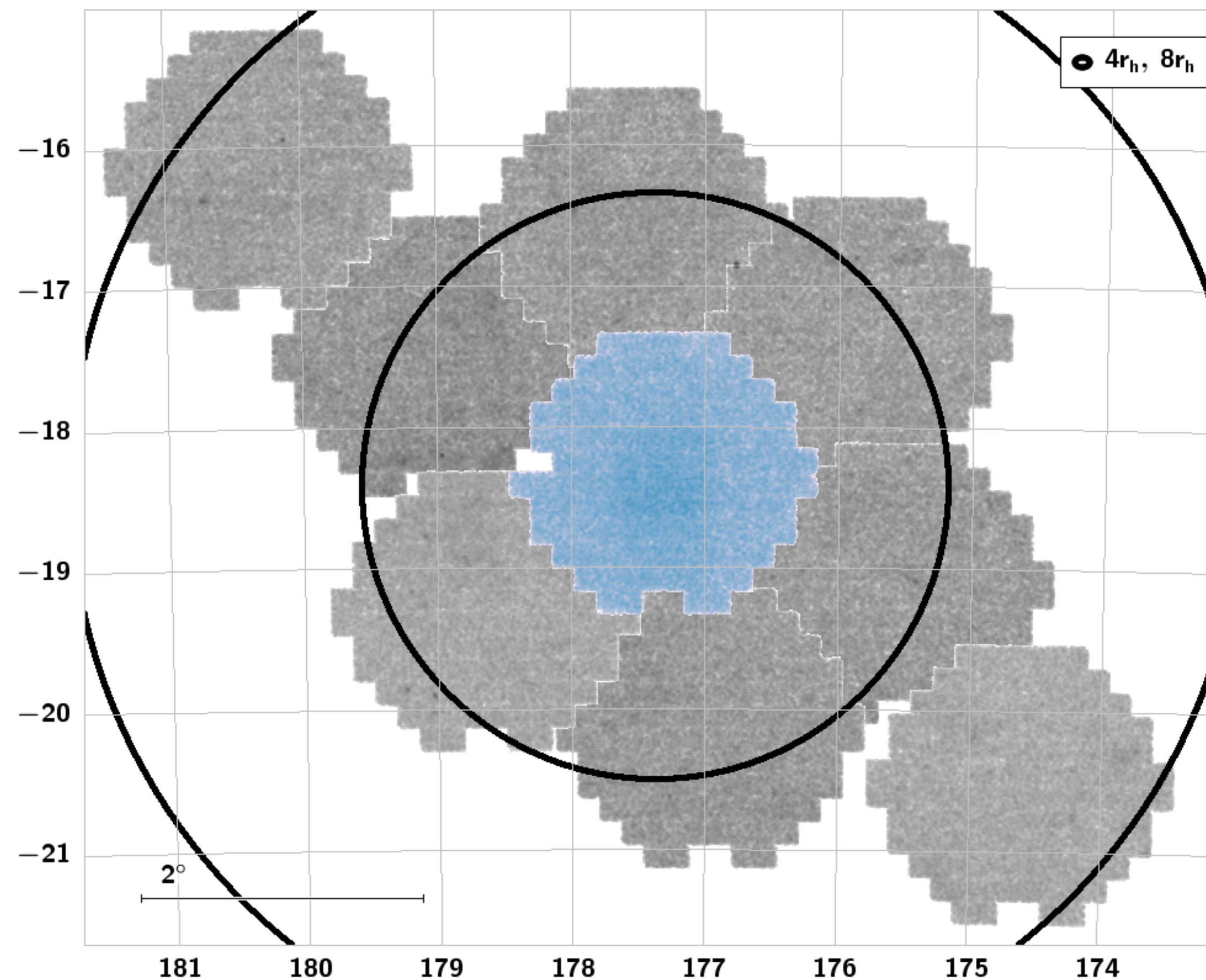
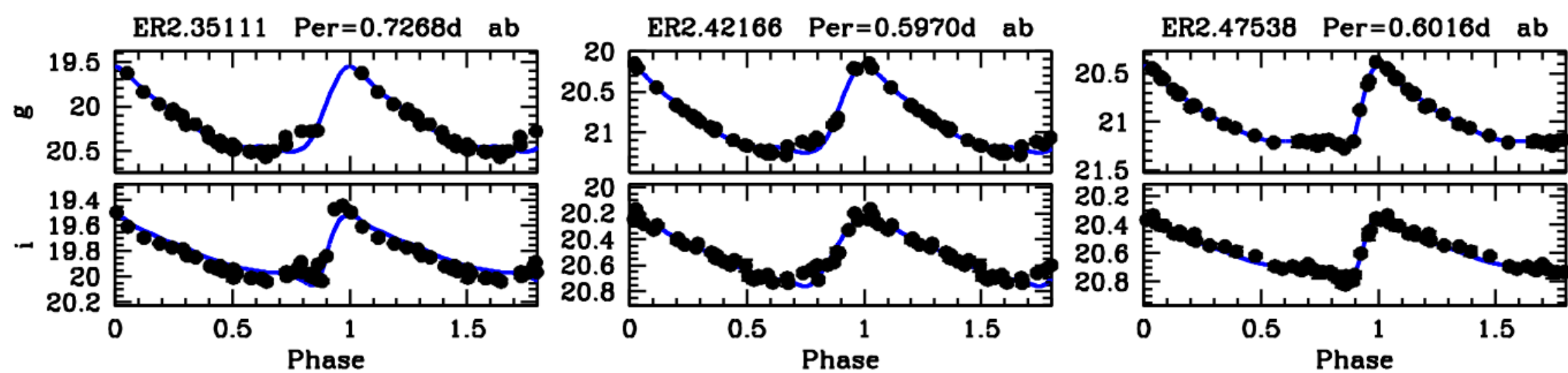
- Number density of RR Lyrae stars decreases as a power law with distance from the center of the Galaxy
- VERY rare at distances > 100 kpc
 - 1 every 30 sq deg between 80-100 kpc
 - 1 every 50 sq deg between 100-120 kpc
 - 1 every 75 sq deg between 120-140 kpc
- **Any external population in Crater II should be cleanly traced by RR Lyrae stars**



Medina+24 (also Feng+24, Stringer+21)

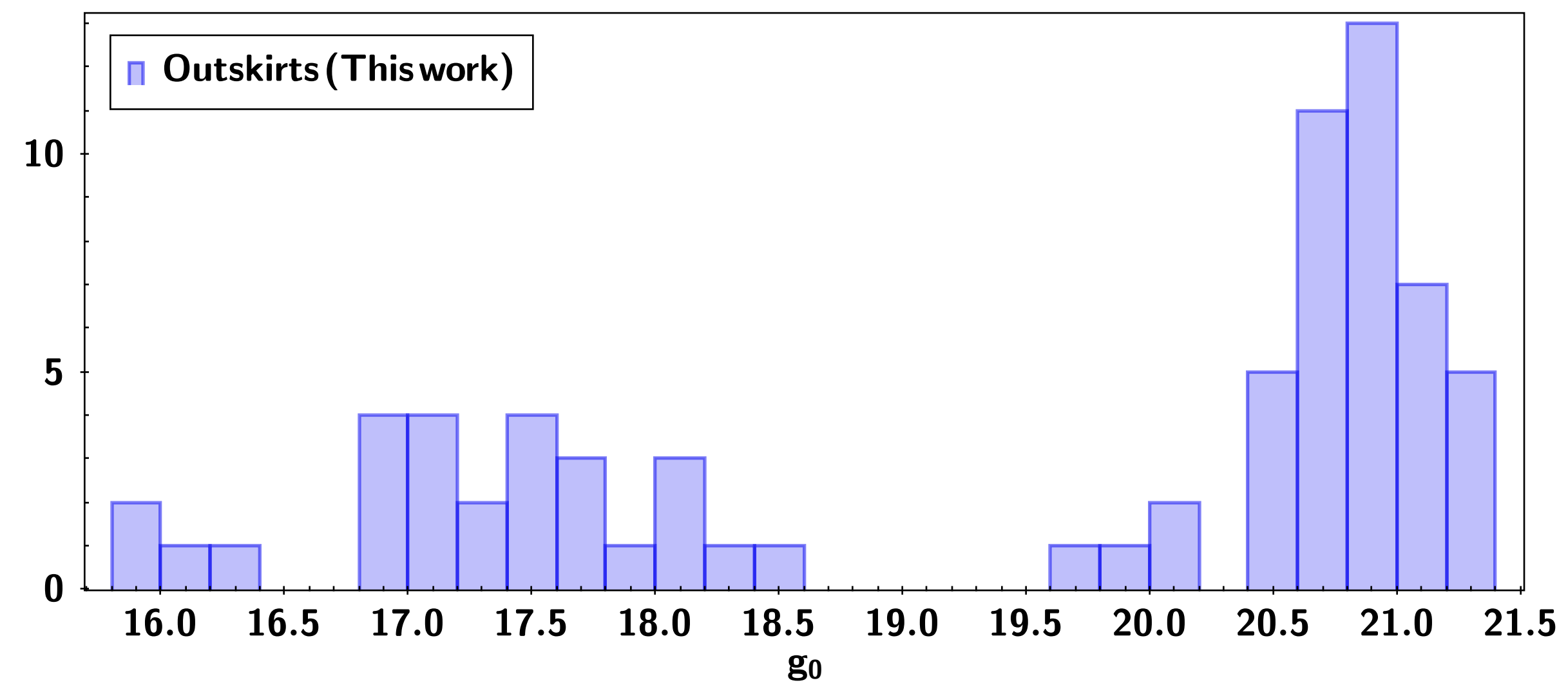
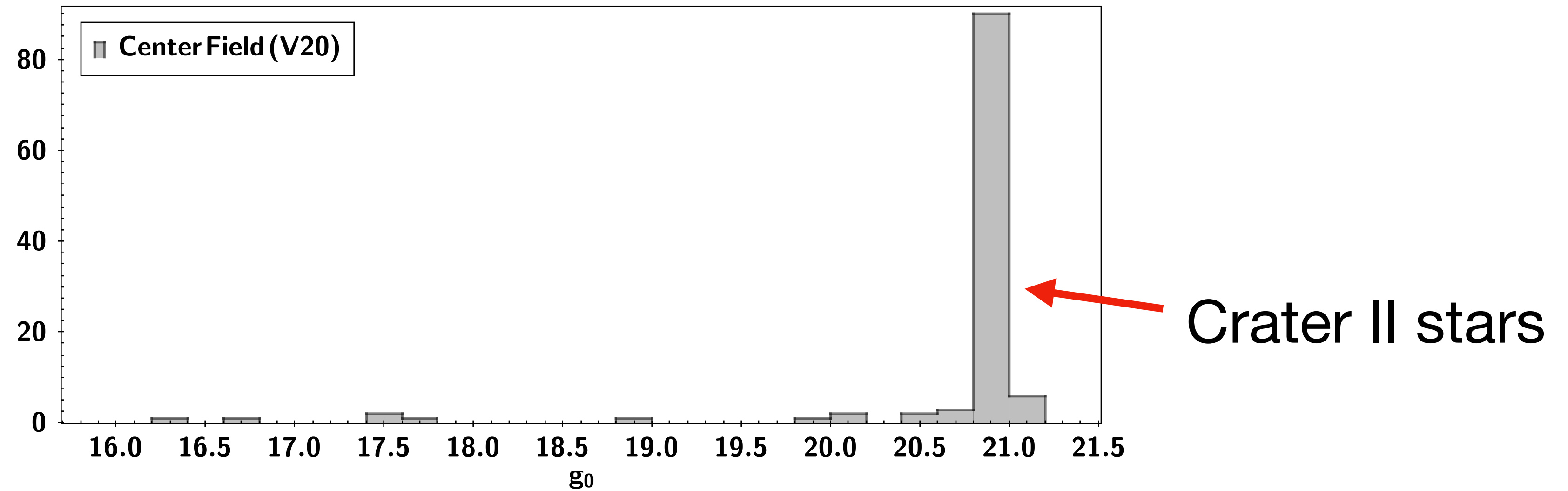
DECam Observations

- Time series in g, i in 8 fields around Cra II
- ~ 30 epochs/band
- Two fields along the proper motion direction
- ~27 sq deg

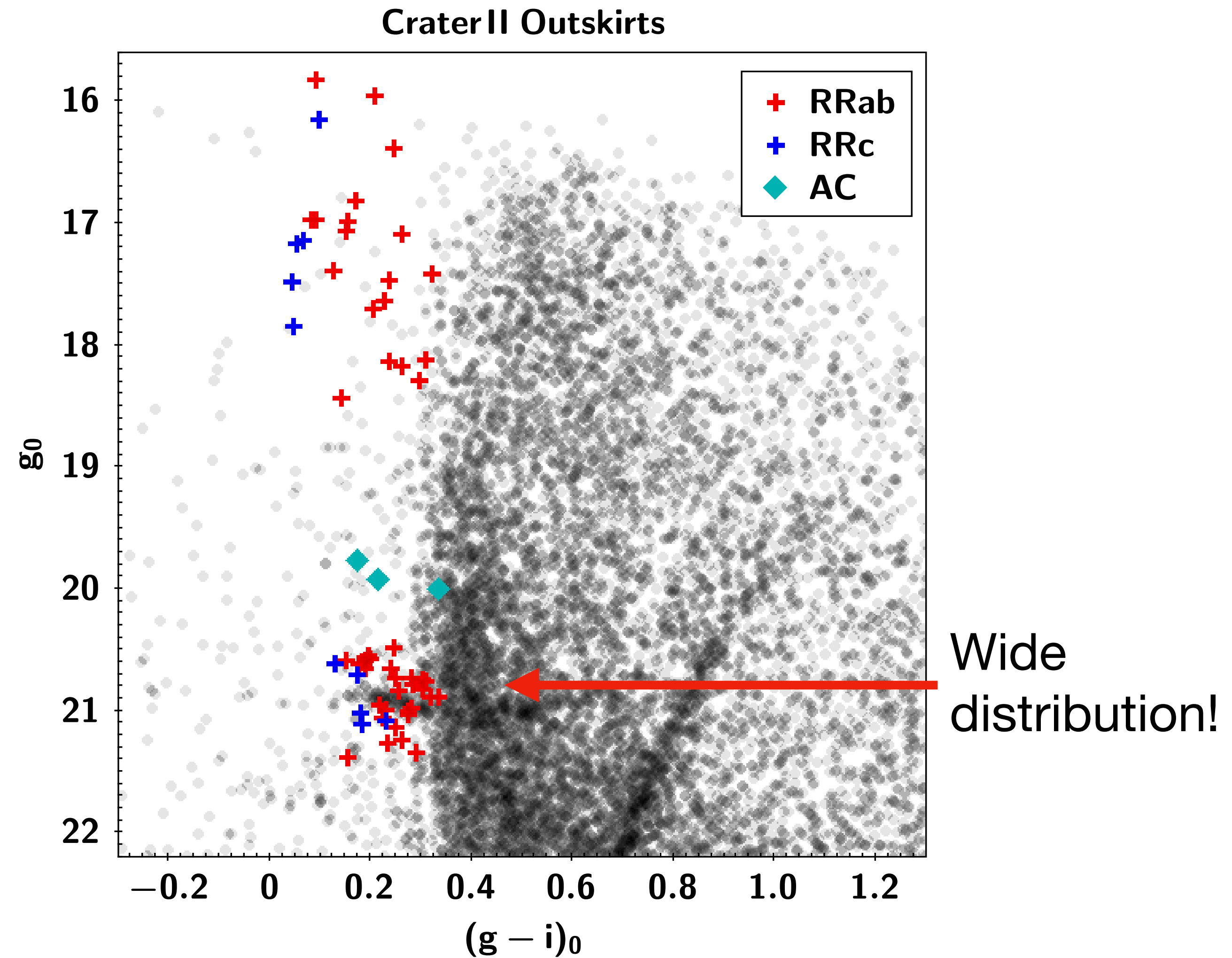
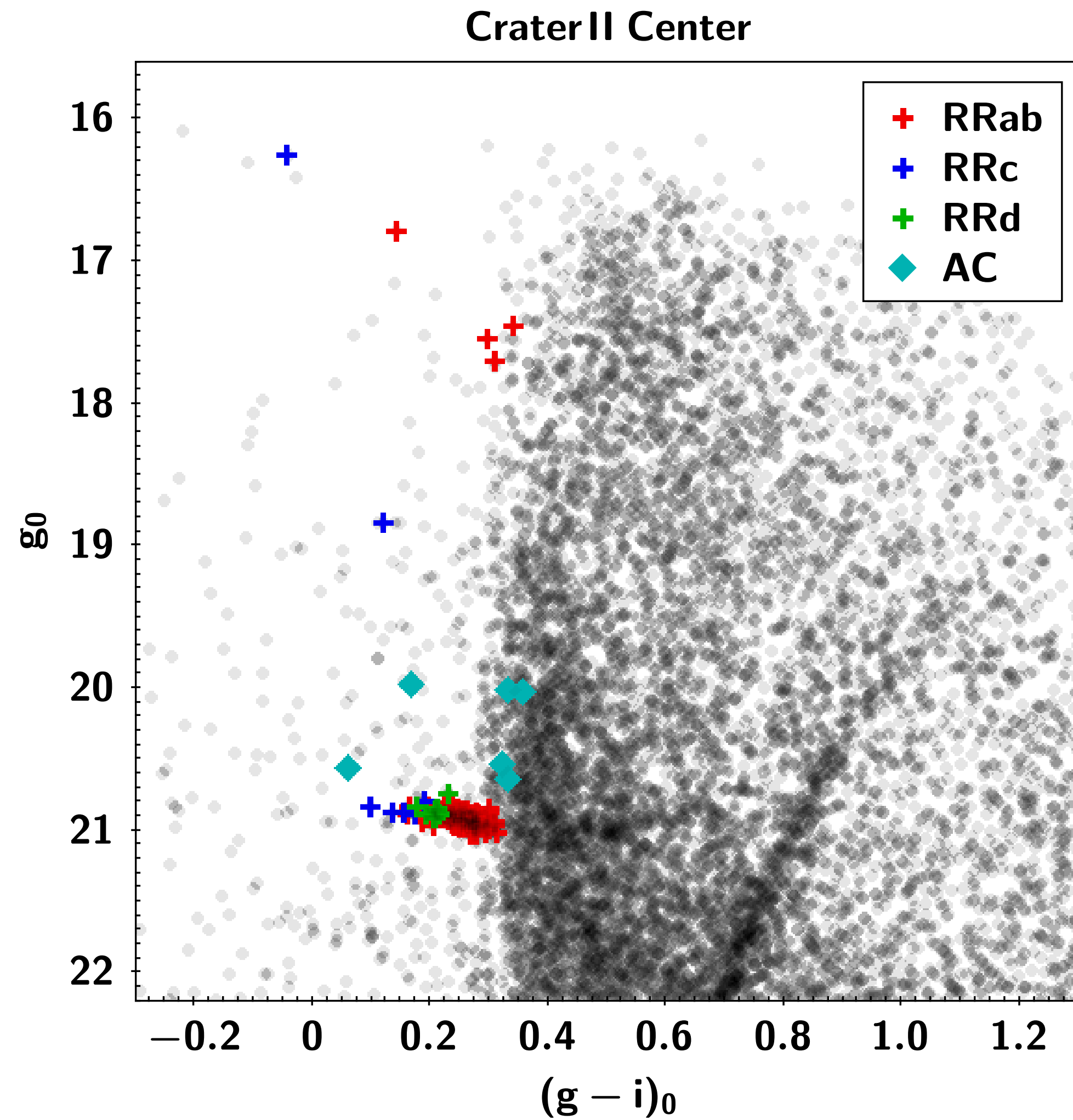


DECam FoV = 3 sq deg

Selecting RR Lyrae Stars associated with Crater II

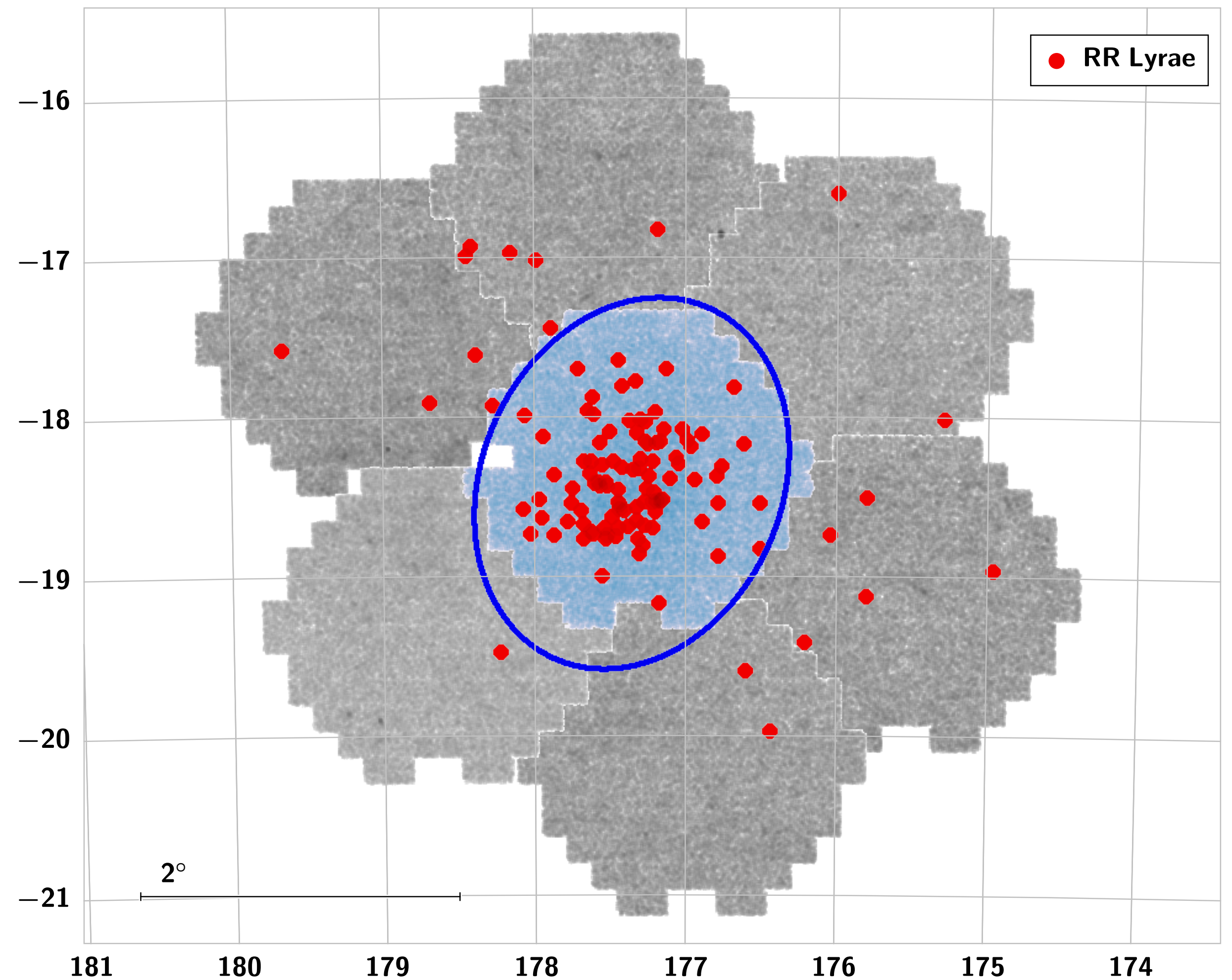


Color-Magnitude Diagram

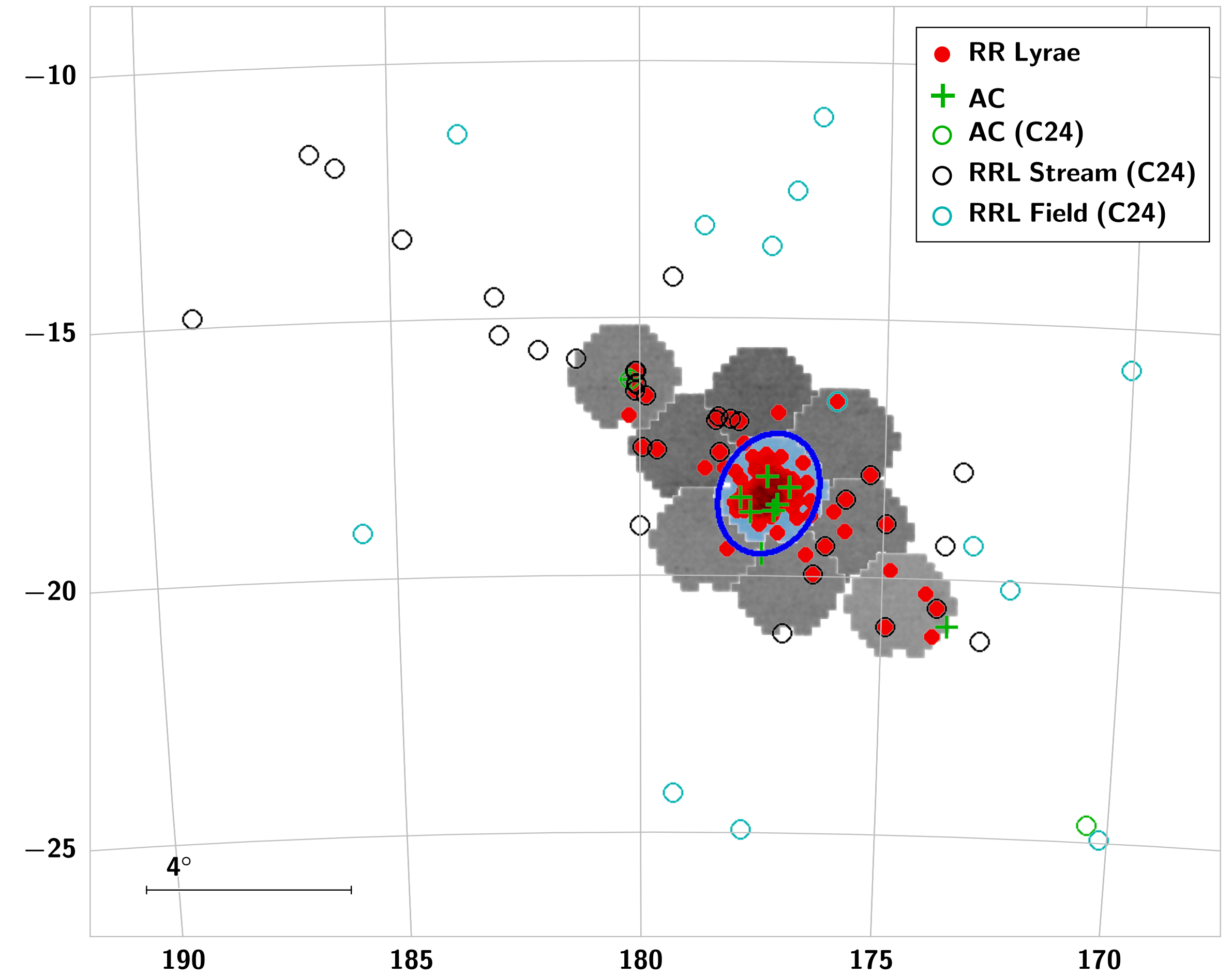
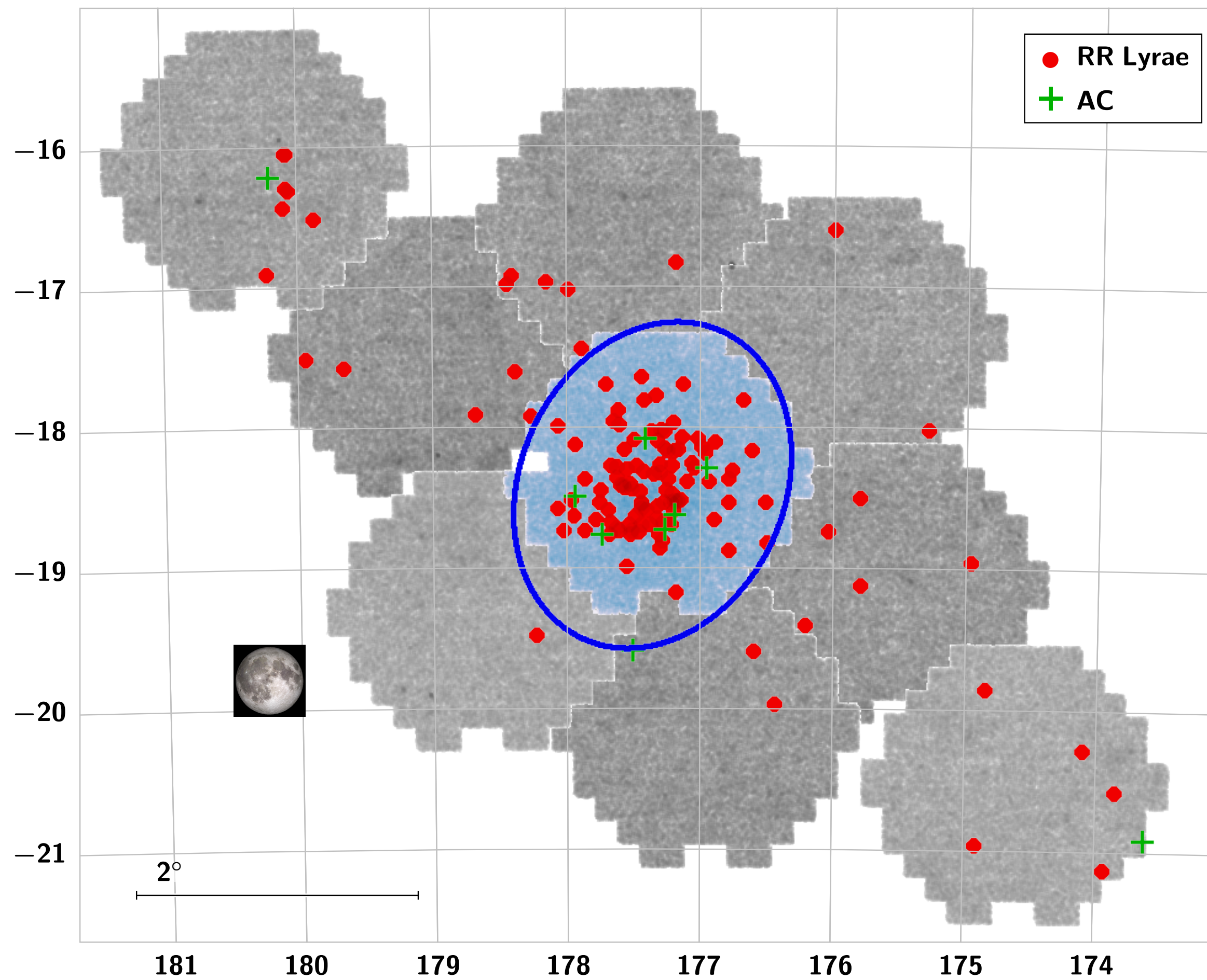


Morphology

- Most RR Lyrae stars are centrally concentrated
- Figure shows 3σ bi-variate Gaussian best fit
- Ellipticity = 0.21

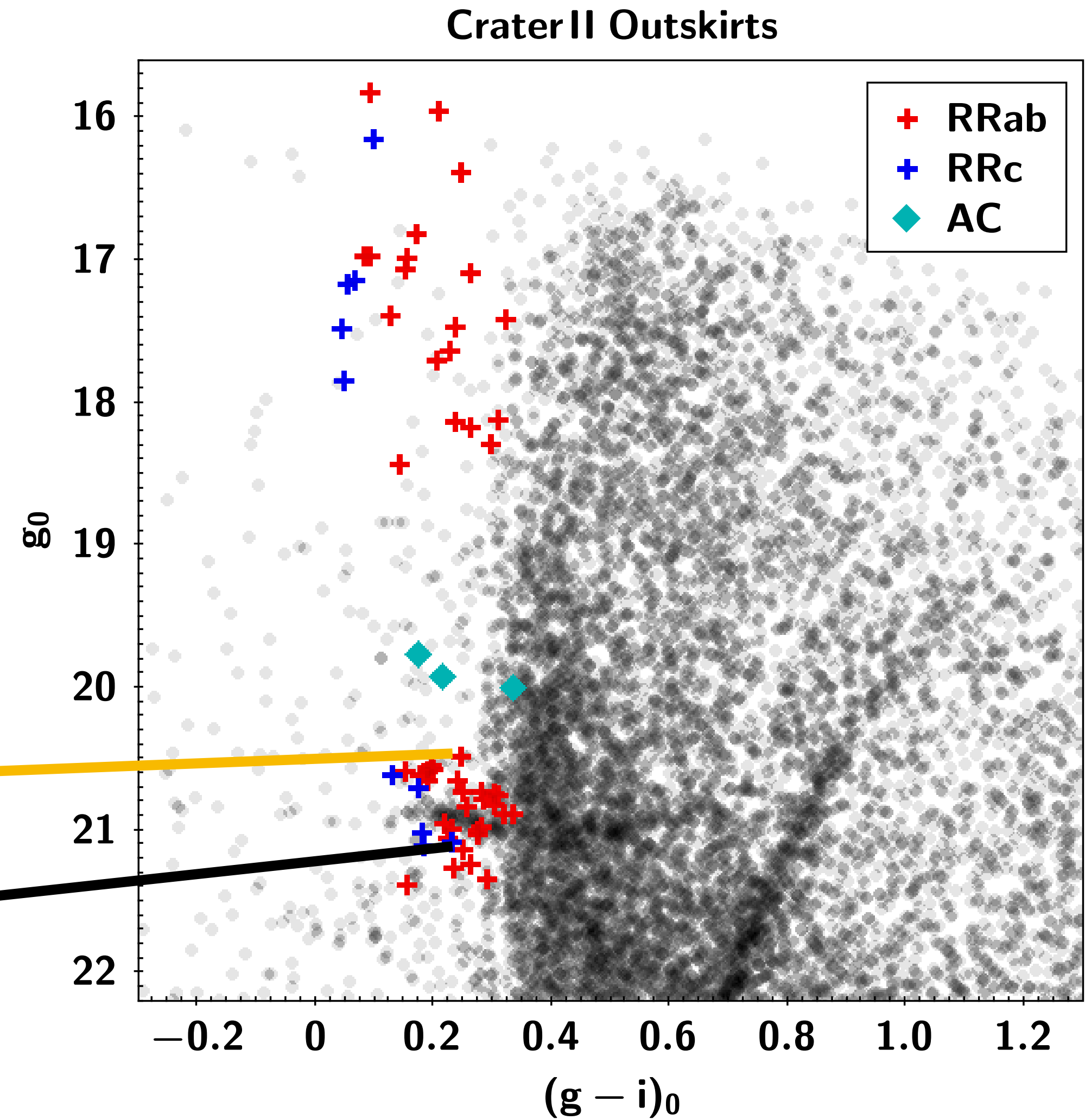
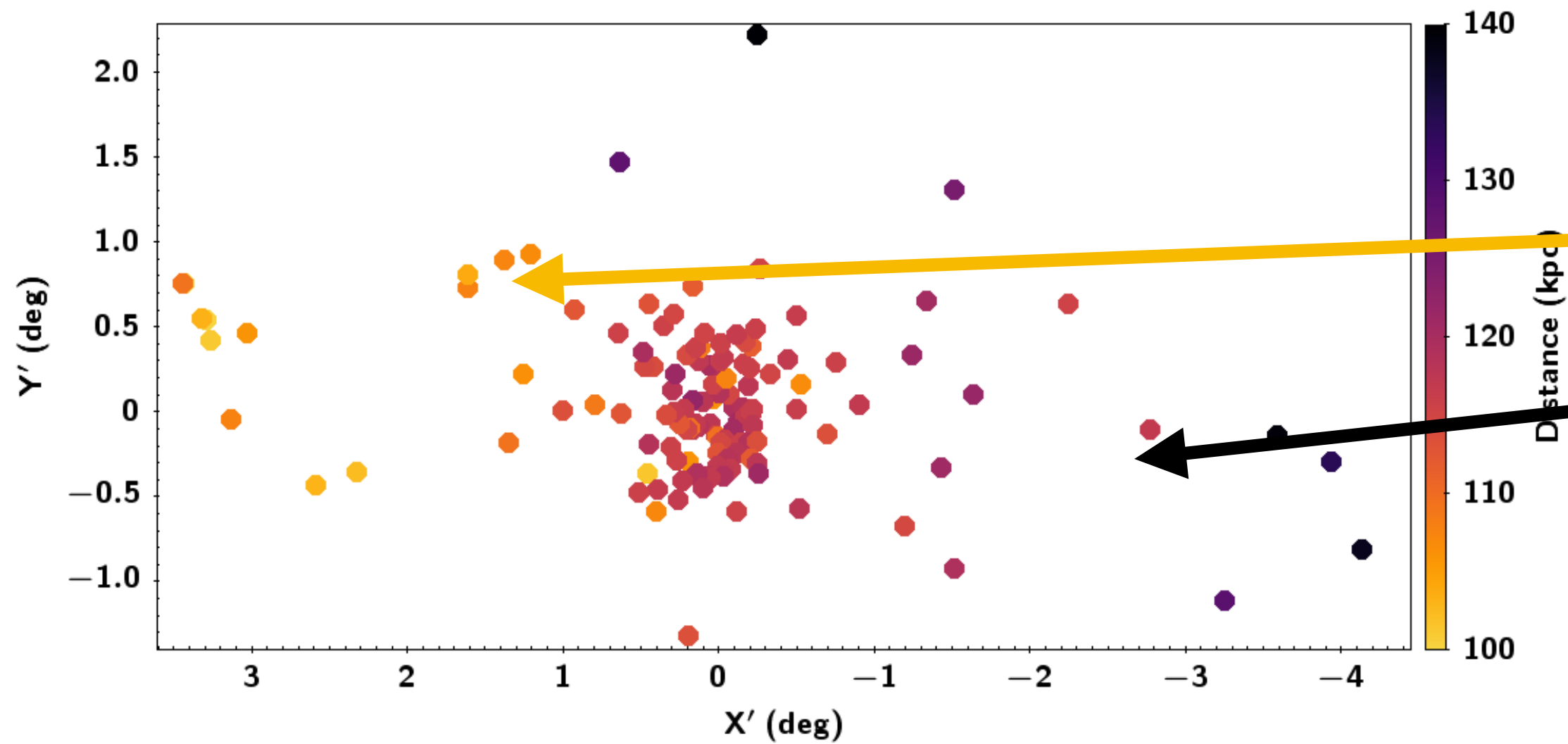
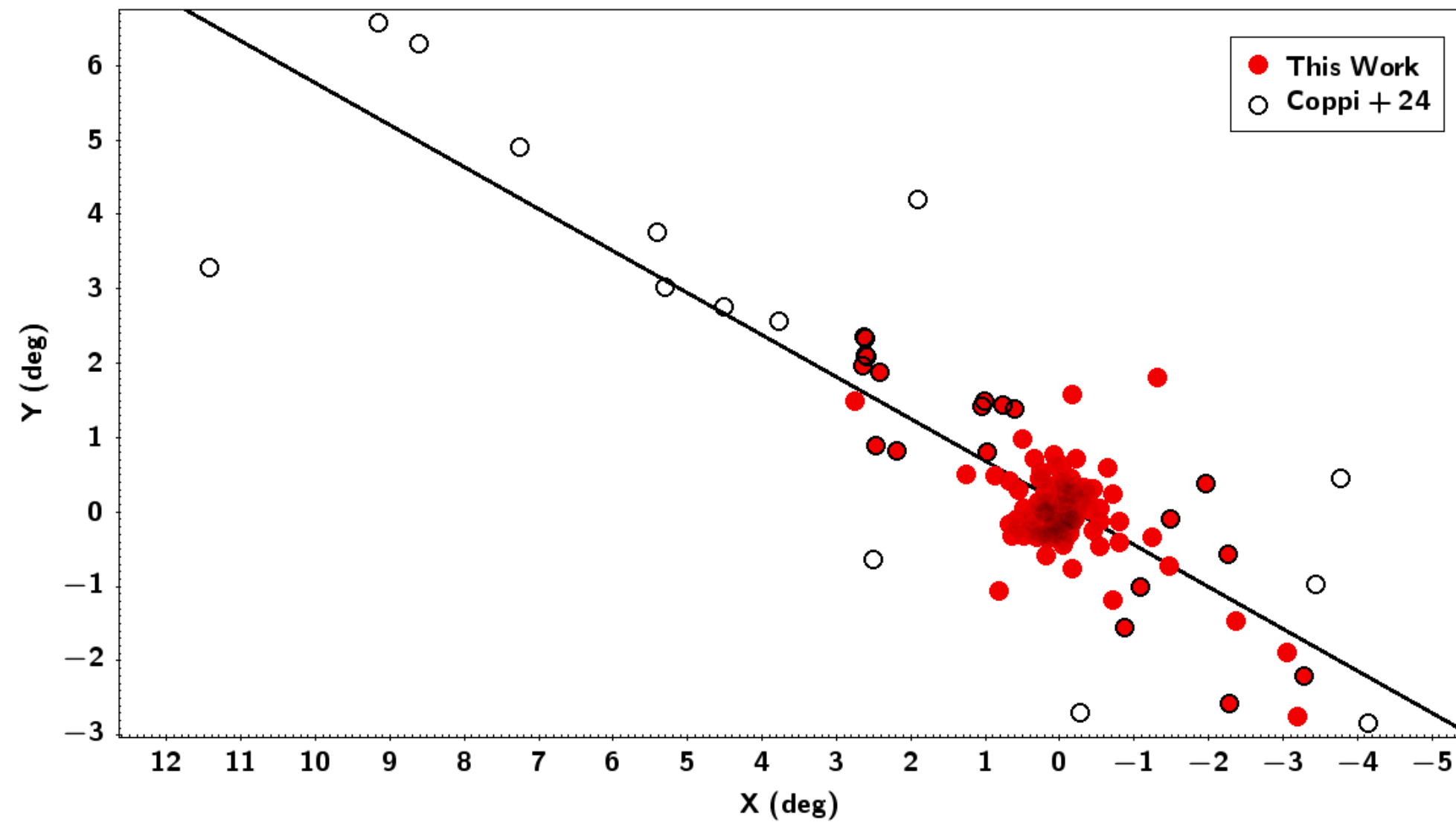


Tails!

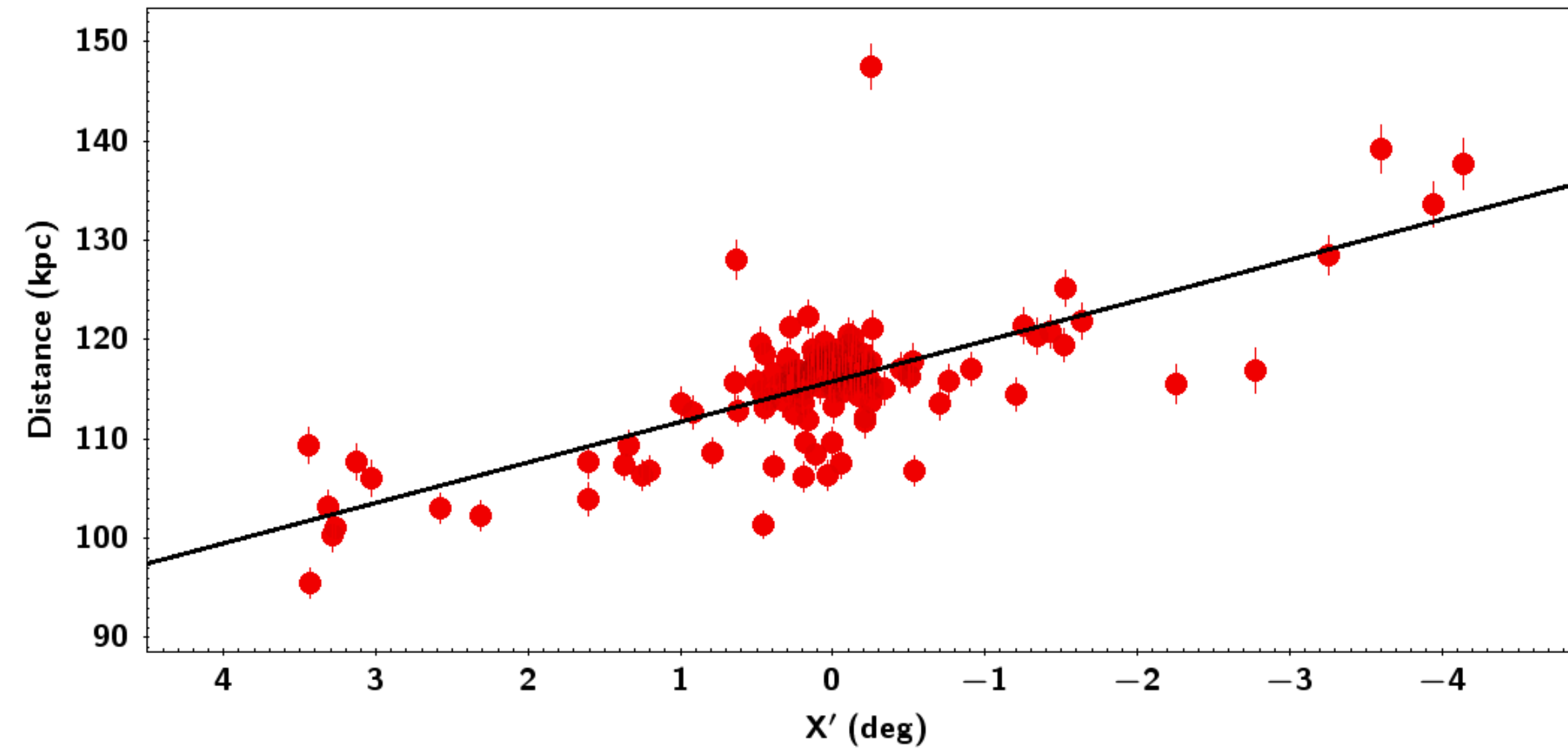


Also seen in Coppi, Zinn+24 in La Silla-QUEST Survey

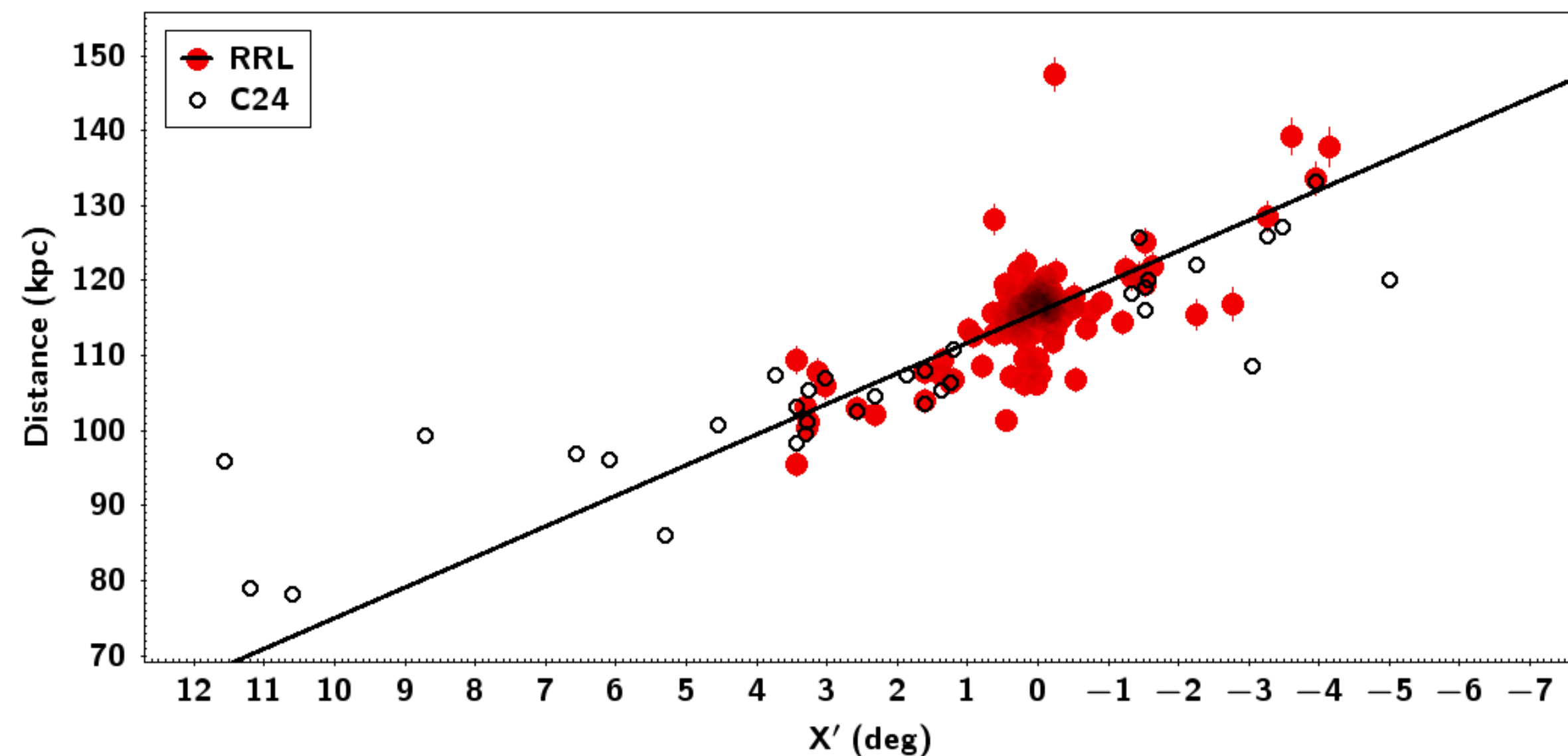
Distance Gradient



Distance Gradient



Gradient: 4 kpc/deg

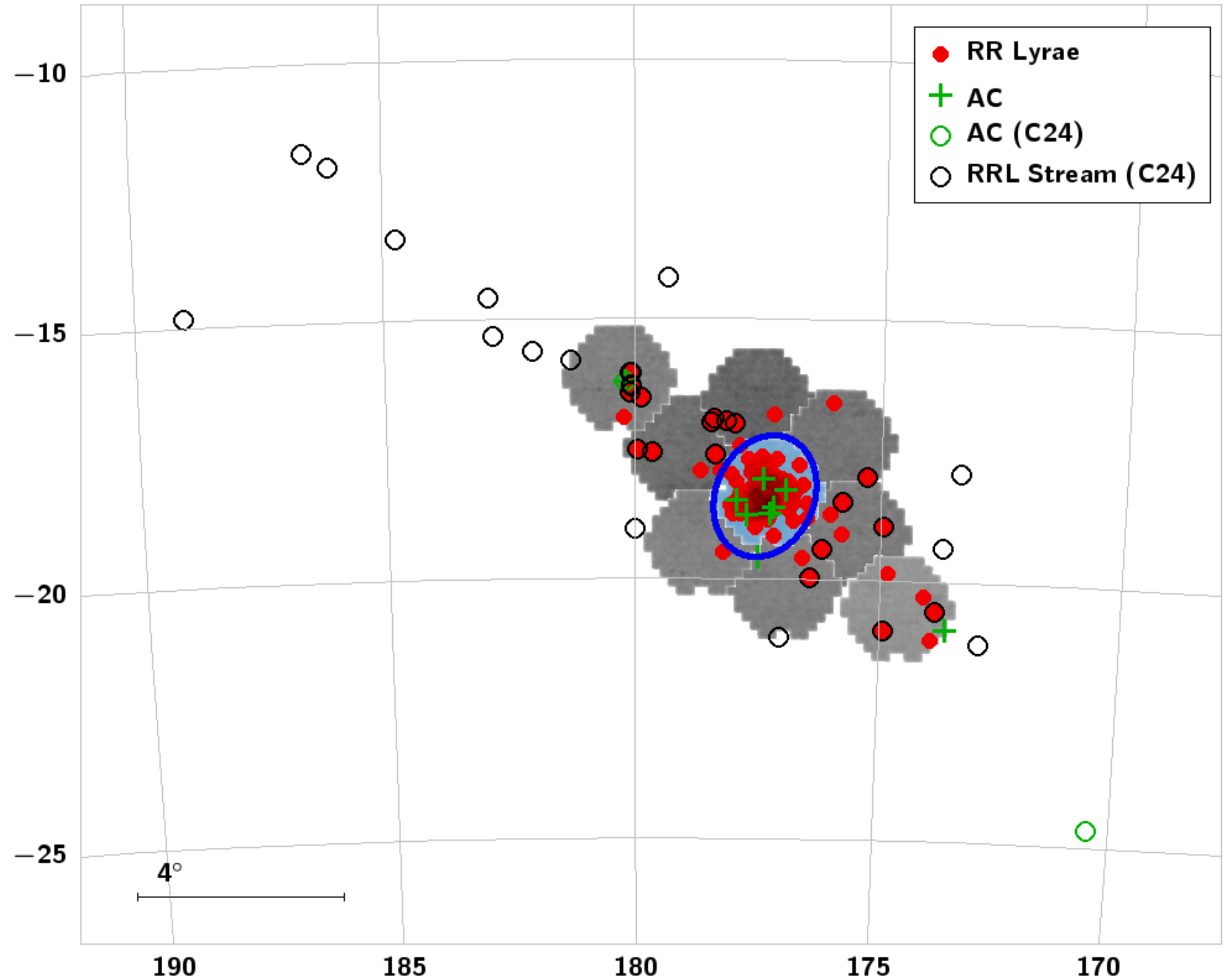


Few stars on the far-side tail

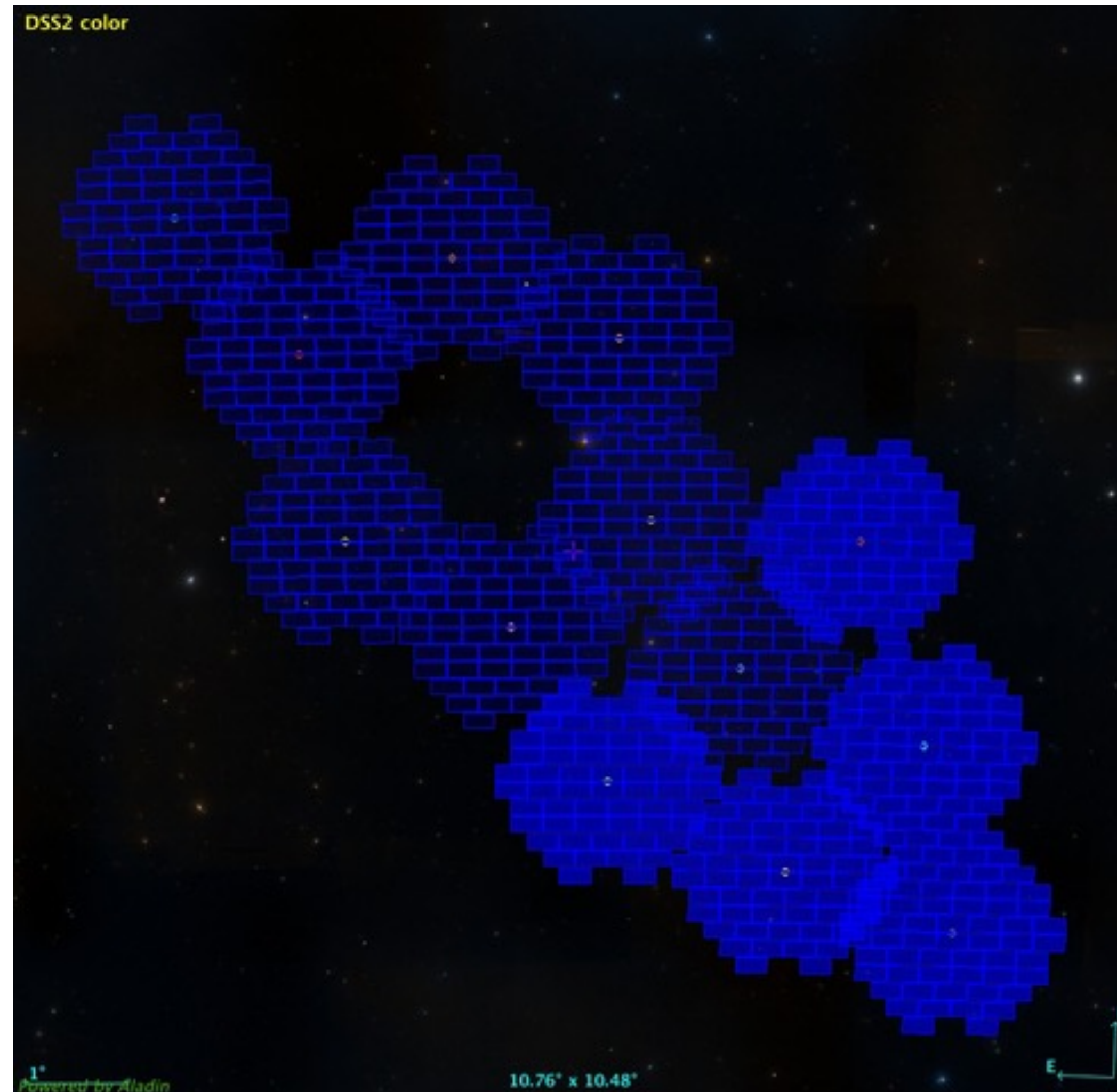
Likely an observational bias

Mass Loss in Crater II

- Coppi+24 estimated 30% mass loss
- We are finding ~50% more RR Lyrae stars in the outskirts of Crater II
- Combining both works, there are (at least) 47 RR Lyrae stars in the outskirts ==> **The tails have at least 47% of the current mass in the core**

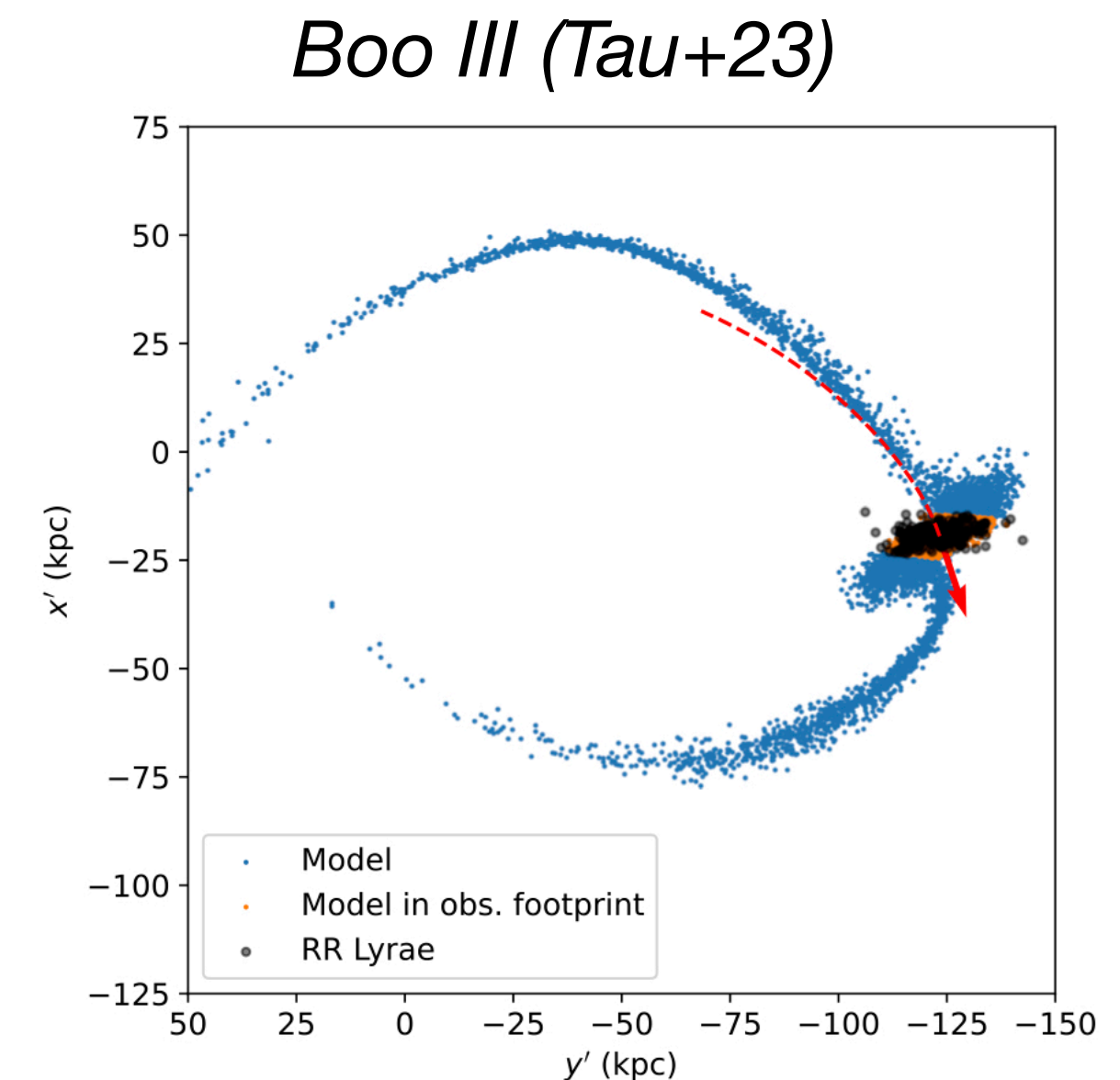
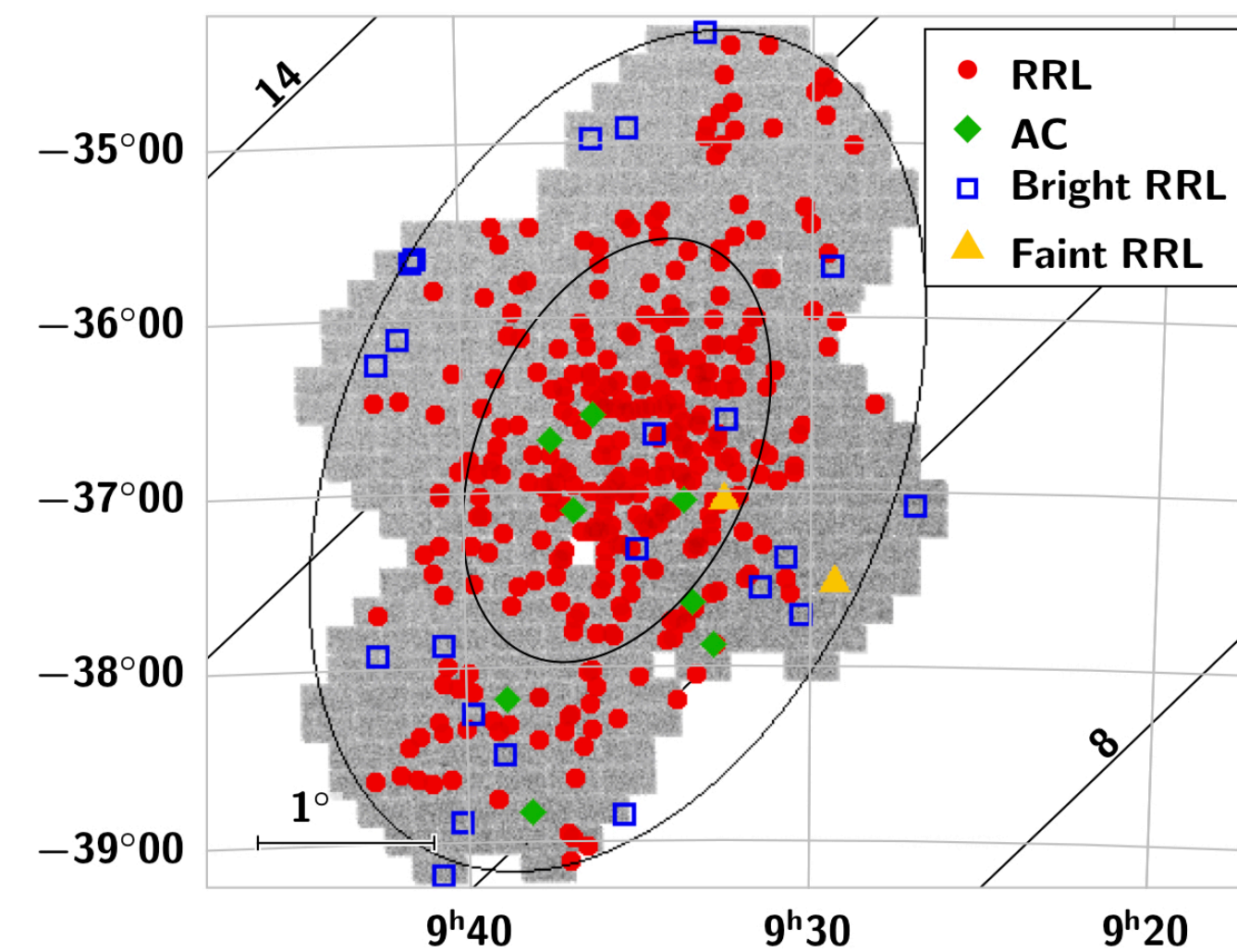
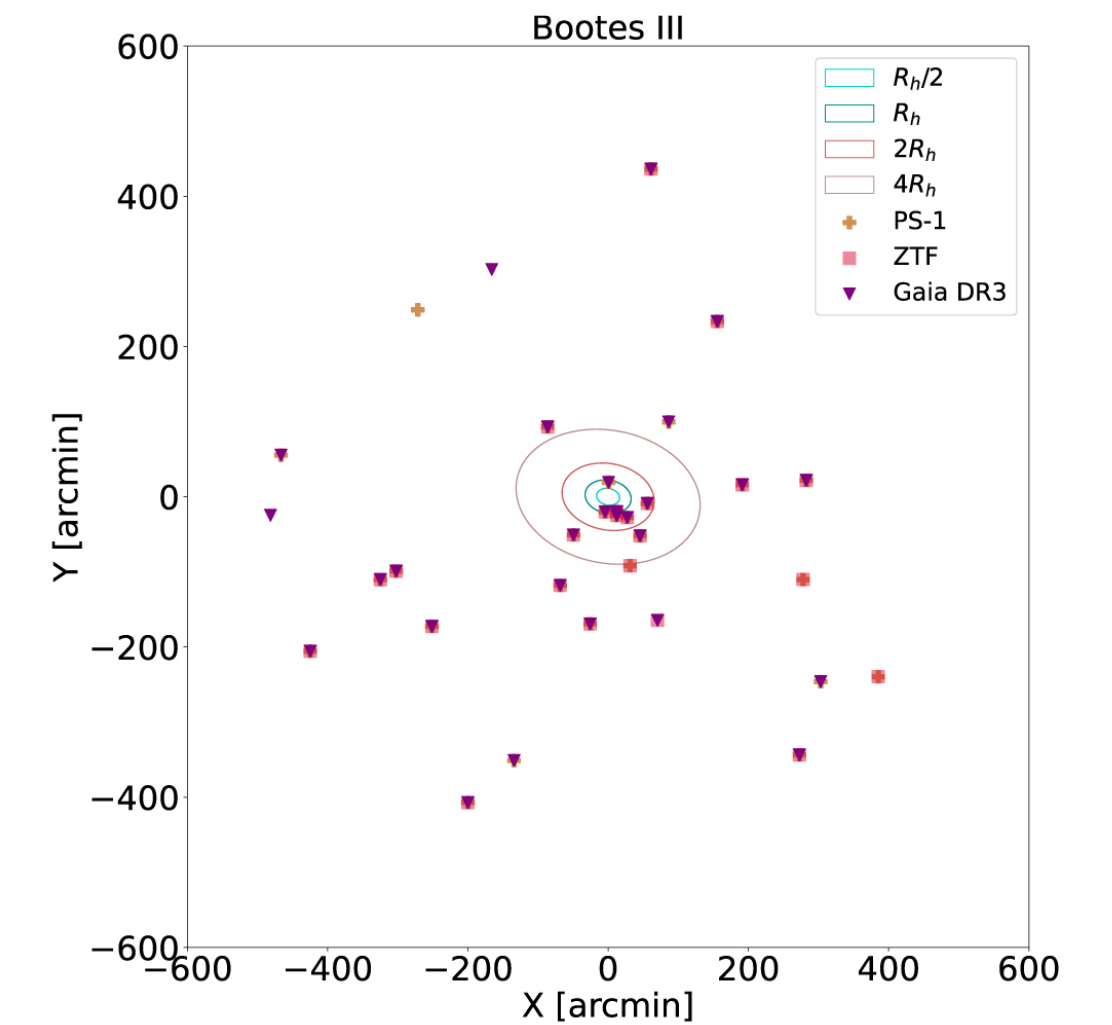
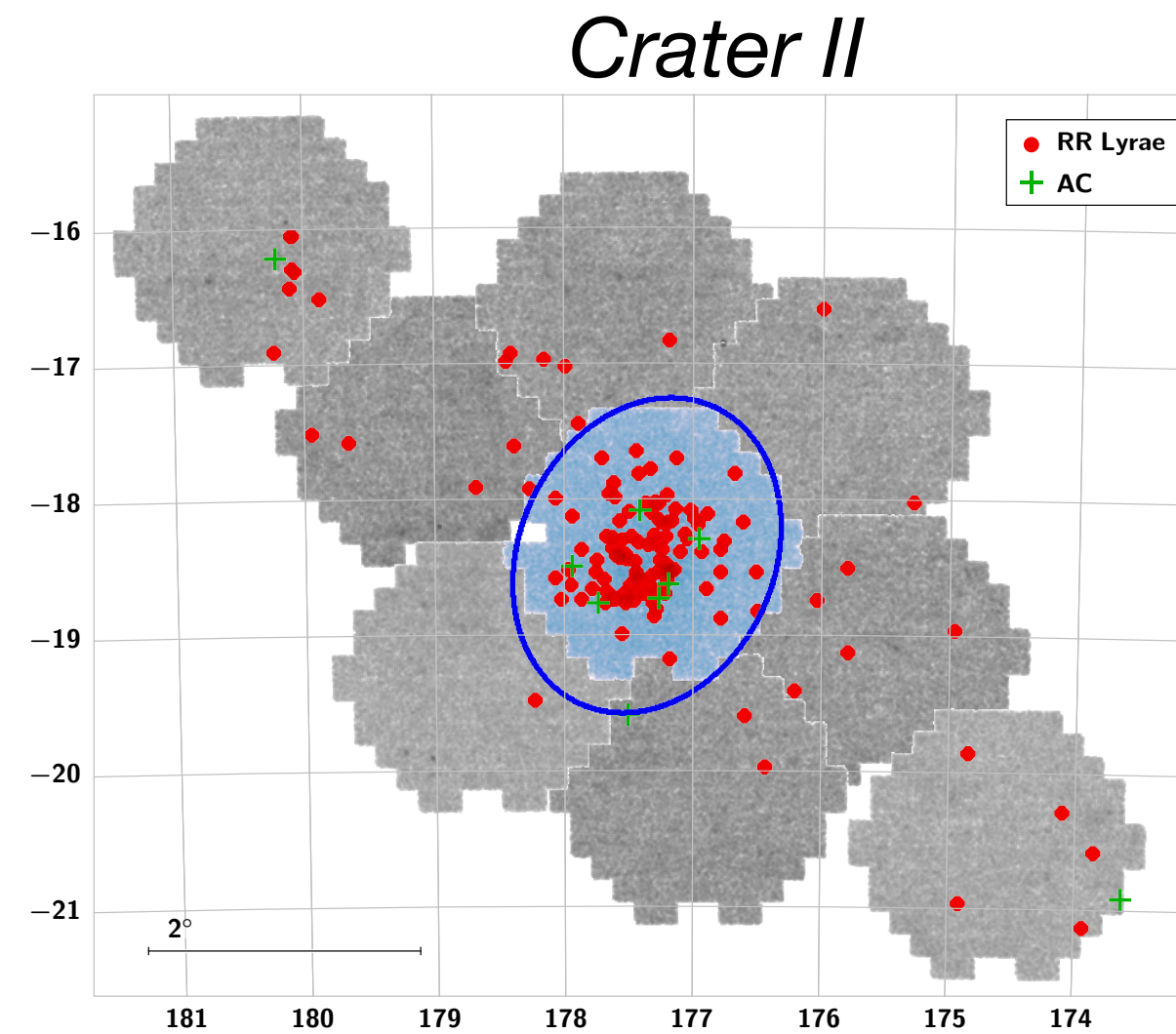


Ongoing Work

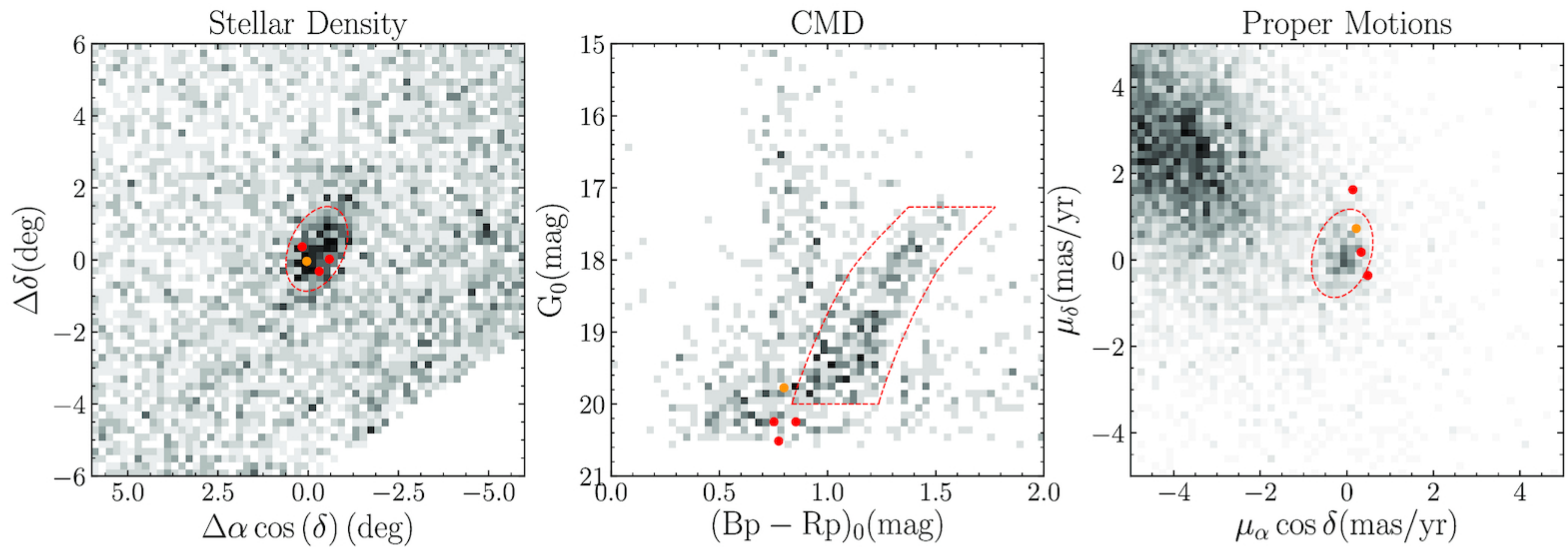


LSST: Finding the missing population of UDG

- Newton+22 estimates there is a missing population of UDG in the Local Group (from hydrodynamic simulations)
- If those missing galaxies resemble Antlia II or Crater II, they will have a sizable population of RR Lyrae stars
- LSST single observation limit of $g \sim 24.5$, corresponds to RR Lyrae stars up to distances of **600 kpc**
- **RR Lyrae stars will be a very efficient way to identify UDG and their tidal debris**



Antlia II (Vivas+20)



Discovery of Antlia II: Torrealba+19