The Tidal Radius of the Arches Cluster

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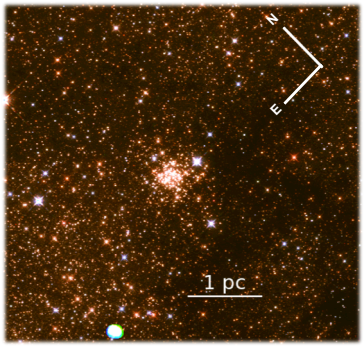
We present a comprehensive astrometric and photometric study of the Arches Cluster in order to constrain its tidal radius and orbit. Using proper motions derived with *HST* WFC3IR observations we separate cluster members from field stars down to F153M = 20 mag (~2.0 $M_\odot$) over a 120''x120'' field of view, an area over 140 times larger than those covered in previous proper motions studies. We create an extinction map of the region using the Red Clump stars in the field, producing a de-reddened CMD for the cluster. Using the extinction map, cluster membership probabilities, and extensive completeness simulations, **we measure the radial profile of the Arches Cluster out to 3 pc for the first time. We do not find evidence of the tidal radius out to 2.5 pc, constraining the cluster's closest approach to the galactic center to larger than 120 pc.** This suggests that the Arches Cluster was formed in the outer region of the central molecular zone, perhaps in a less extreme galactic center environment than previously thought.

Star Formation at the Galactic Center

The **Arches Cluster:** At a projected distance of just ~26 pc from the center of the Milky Way, this massive young cluster allows us to examine star formation in the dense high-radiation environment of the Galactic center (GC). Despite its importance, the cluster's orbit and birth environment are not well constrained and the nature of its initial mass function (IMF) remains highly debated in the literature.

Why the Tidal Radius?

- *Constraint on orbit and birth location*: Given the cluster's young age (~2.5 Myr), its tidal radius is set by the cluster's closest approach to the GC. This puts a strong limit on the possible orbits for the cluster.
- *Toward a more accurate IMF:* The full extent of the cluster out to the tidal radius must be considered in IMF measurements in order to mitigate possible biases introduced by mass segregation.



Observations with HST WFC3IR:

- F153M (1.53 μm): Three epochs over two years are used to derive proper motions
- F127M (1.27 μm), F139M (1.39 μm): Used to obtain color information

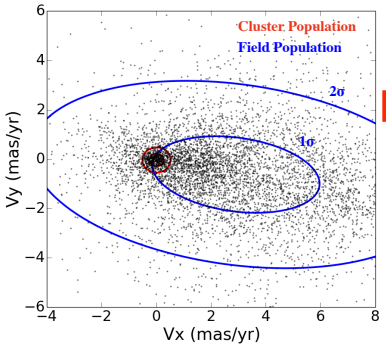
A color image of the Arches Cluster. F127M is used for blue, F139M for green, and F153M for red.

Membership Probabilities via Proper Motion

Cluster members can be distinguished from field stars by the cluster's bulk proper motion. This is advantageous over photometric membership methods due to the large degree of differential reddening across the field.

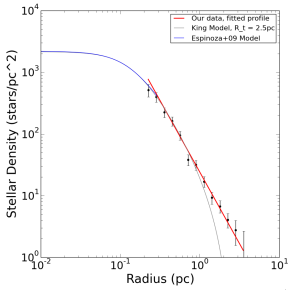
Bayesian Analysis

- 6000 stars with proper motions measured to better than 0.65 mas/yr (24 km/s at 8 kpc) are considered
- Simultaneous fitting of cluster (red circular gaussian) and field (blue elliptical gaussian)
- Membership probabilities calculated for each star
- **518 stars identified with $P_{membership} > 0.85$**



A vector-point diagram of the proper motions measured in our field.

Radial Profile and Consequences for Orbit



No Tidal Radius Observed out to at least 2.5 pc

- Completeness correction applied based on artificial star injection/recovery tests
- Red line: power-law Bayesian fit
- Blue line: Inner cluster profile from Espinoza et al. (2009)
- Gray line: A King profile with a tidal radius at 2.5 pc does not fit

Minimum Distance of GC Closest Approach: 120 pc

- Significant restriction on possible cluster orbits calculated by Stolte et al. (2008), shown as solid black lines
- Red circles at r=120 pc from GC, blue lines trace innermost allowed prograde and retrograde orbits
- **Indicates the Arches formed in the outer region of the central molecular zone (R < ~200 pc)**

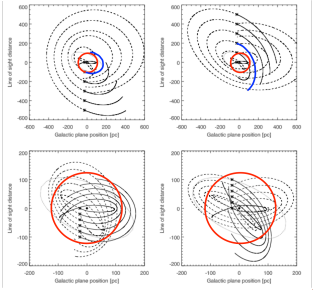
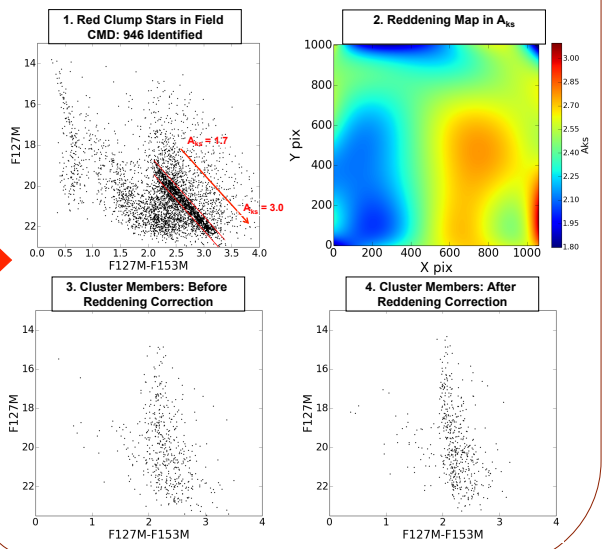


Figure modified from Stolte et al. (2008)

Reddening Map Using Red Clump Stars

Red clump (RC) stars have well understood luminosities and colors. We derive reddening values by comparing the observed colors to model colors and adopting a Nishiyama et al. (2009) extinction law.



References

1. Clarkson et al., 2012, ApJ, 753, 92
2. Espinoza et al., 2009, A&A, 501, 563
3. Figer et al., 1999, ApJ, 525, 750
4. Habibi et al., 2013, A&A, 556, A26
5. Kim et al., 2006, ApJL, 653, L113
6. King 1962, ApJ, 67, 471
7. Launhardt et al., 2002, A&A, 384, 112
8. Stolte et al., 2008, ApJ, 675, 1278

Bio

Matt Hosek is a third year graduate student at the Institute for Astronomy/University of Hawaii.