The Dynamical Structure and Initial Mass Function of the Arches Cluster

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The Arches Cluster: A Young Massive Cluster Near the Galactic Center

Stolte et al. (2008)
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What impact does the GC environment have on the dynamical structure of massive star clusters?

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Hosek et al. (2015): Measure the Radial Profile to Large Radii

- Unknown tidal radius, profile only measured to $R = 0.4$ pc (Espinoza+09)
  - Extra-tidal stars?

HST WFC3IR image of the Arches Cluster
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- **Challenge:** Significant differential reddening
  - $\Delta A_V \sim 10-15$ mag (Habibi+13)
  - Cluster membership tricky!

HST WFC3IR image of the Arches Cluster

- High reddening
- Low reddening

1 pc
Solution: HST Astrometry

- HST WFC3IR: 3 epochs / 2 years in F153M, 1 epoch in F127M

Advantages:

1. Proper motions for improved cluster membership
2. Wide field of view: 120x120” (4.8 pc x 4.8 pc)
3. Deep: ~2.5 $M_\odot$

http://www.spacetelescope.org/
High-Precision Proper Motions

Hosek+15

Proper Motion Error (mas yr$^{-1}$)

0.65 mas/yr

24.7 km/s

~2.5 M$_\odot$
High-Precision Proper Motions

Stars passing error cut: 6023

Hosek+15

~2.5 \( M_\odot \)

0.65 mas/yr

24.7 km/s
Modeling Cluster and Field Kinematics: Gaussian Mixture Model

Vector Point Diagram

Hosek+15
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Vector Point Diagram

Observed CMD

ClusterMembers \( (P > 0.7) \)

Hosek+15
Modeling Cluster and Field Kinematics: Gaussian Mixture Model

Vector Point Diagram

Probable Cluster Members (P > 0.7)

2.5 Myr isochrone

Diff. De-reddened CMD

Hosek+15
The Extended Radial Profile of the Arches Cluster

Model:
Power-Law + Constant

$\mathcal{L}(r, \Gamma, b) = A_0 r_i^{-\Gamma} + b$

Best-Fit Params:
$\Gamma = 2.06 \pm 0.17$
$b = 2.52 \pm 1.32 \text{ stars/pc}^2$
$A_0 = 23.09 \pm 3.5 \text{ stars}$

Background subtracted profile:
$0.25 \text{ pc} \leq R \leq 3 \text{ pc}$

Stellar Density (stars pc$^{-2}$)
The Extended Radial Profile of the Arches Cluster

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3\(\sigma\) lower limit on tidal radius: 2.8 pc

Espinoza+09: \( R \leq 0.4 \text{ pc} \)

Background subtracted profile: \( 0.25 \text{ pc} \leq R \leq 3 \text{ pc} \)

Predicted Tidal Radius: 2.5 pc

Hosek+15
Mass Segregation Throughout Cluster

- KS test: not drawn from same parent population
  - Stolte+05, Espinoza+09, Habibi+13
No Evidence of Tidal Tails

- KS test: cannot discount same parent population
Unbroken Profile: Implications for Orbital History?

Peñarrubia+09, Lokas+13: Simulations of dwarf galaxies on elliptical orbits show break in profile after pericenter

- Position of break related to time since pericenter passage

Fig. 2 of Peñarrubia+09
If Applicable to Arches…

- No pericenter passage between ~0.2 – 1 Myr ago

Possible Arches Orbits
(Stolte+08)

Data courtesy of Andrea Stolte
If Applicable to Arches...

• No pericenter passage between ~0.2 – 1 Myr ago

Possible Arches Orbits (Stolte+08)

• Retrograde orbits excluded

• Arches located in front of GC sky plane

Data courtesy of Andrea Stolte
Next Step: Combine HST with AO Data

HST/WFC3IR
F153M
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HST/WFC3IR F153M

Keck/NIRC2 AO K’-band

Start of Keck/NIRC2 JHK’ observing campaign: 2006
Conclusions

• HST WFC3IR study of Arches cluster
  – Proper motions to identify cluster members
  – Large FOV to measure radial profile to 3 pc
  – Depth: 2.5 M☉

• Unbroken power-law profile
  – 3σ limit on King-like tidal radius: 2.8 pc
  – Constrains orbit to prograde solutions?

• No evidence for tidal tails

• Next step: Combine HST with AO imaging of cluster core