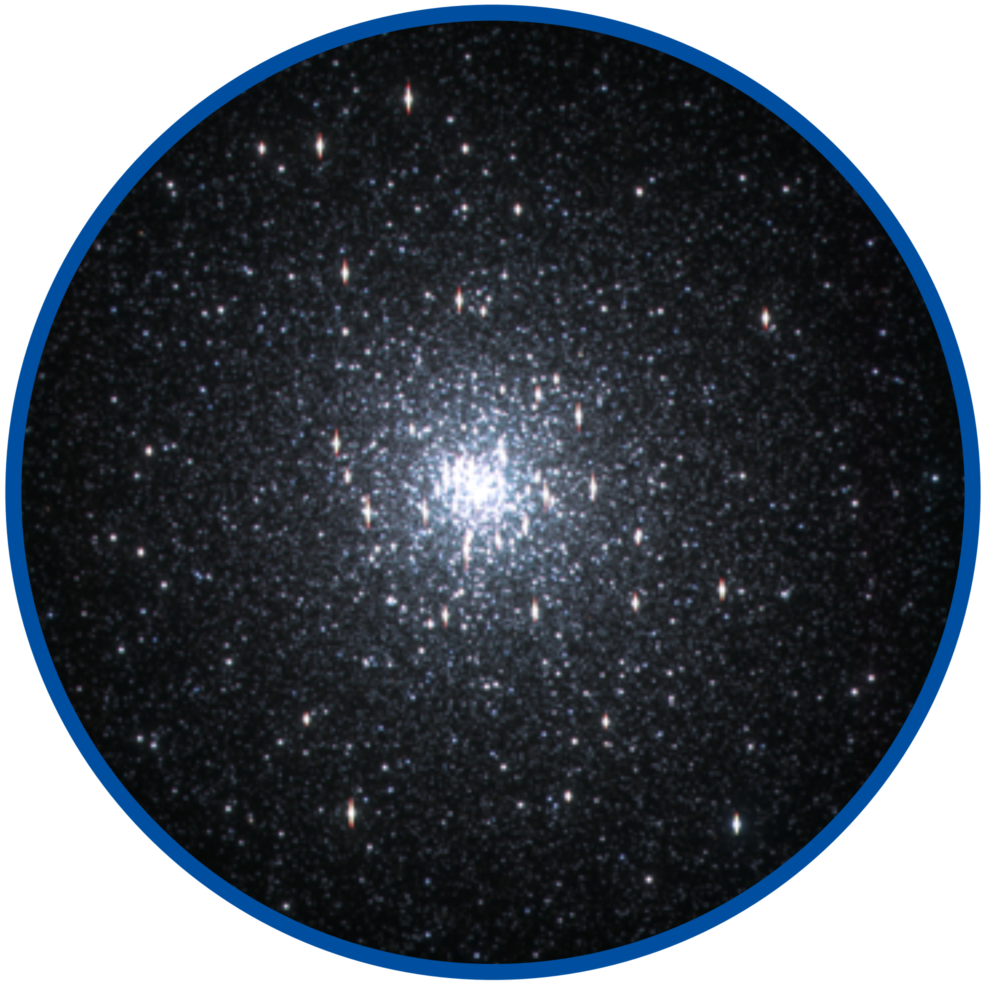
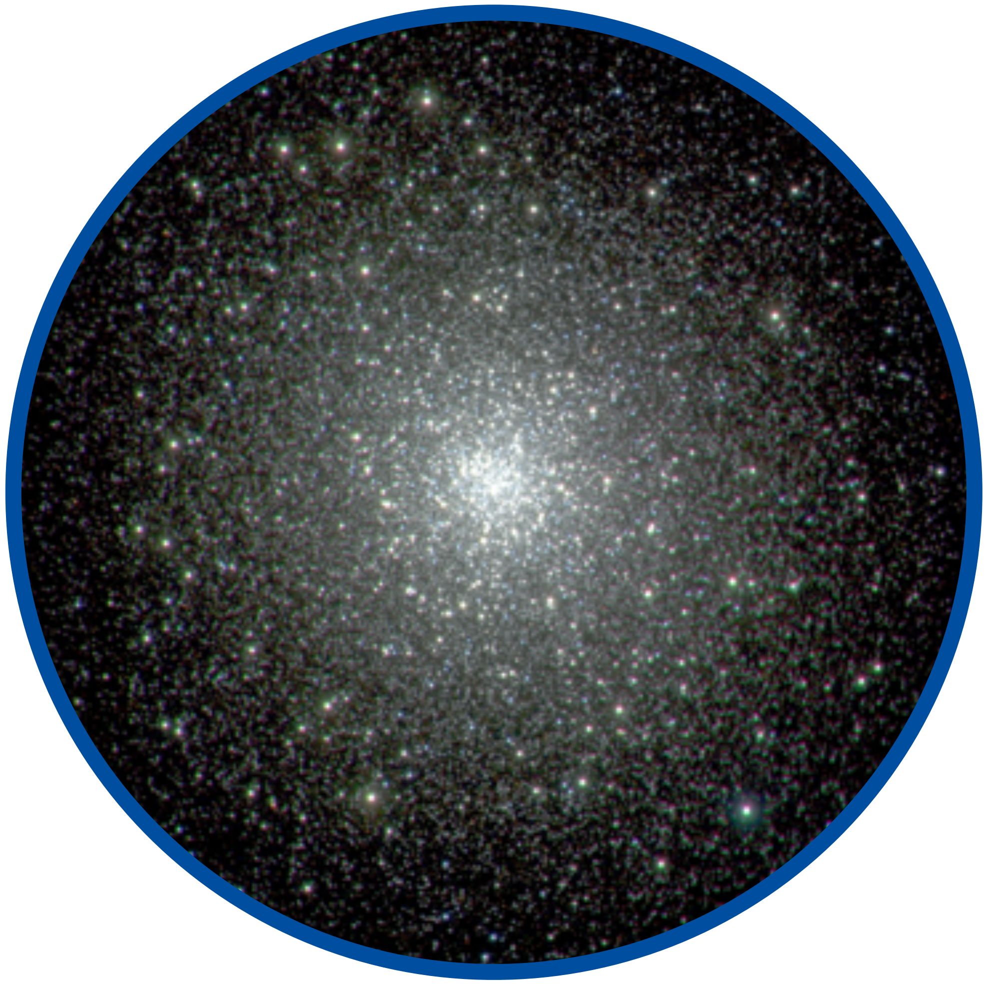
Uncovering Milky Way Globular Cluster Formation and Evolution with LBC+LUCI



LBC - V, R, and I



LUCI - J, H, and K_s

Mark A. Norris, Paolo Bianchini, Glenn van de Ven, Eva Schinnerer, Tom Herbst, Hans Walter-Rix (MPIA)

SPACE TELESCOPE SCIENCE INSTITUTE

HSTPROMO Collaboration (STScI), R. van der Marel, A. Bellini, J. Anderson, L. Watkins

Max-Planck-Institut für Astronomie Heidelberg
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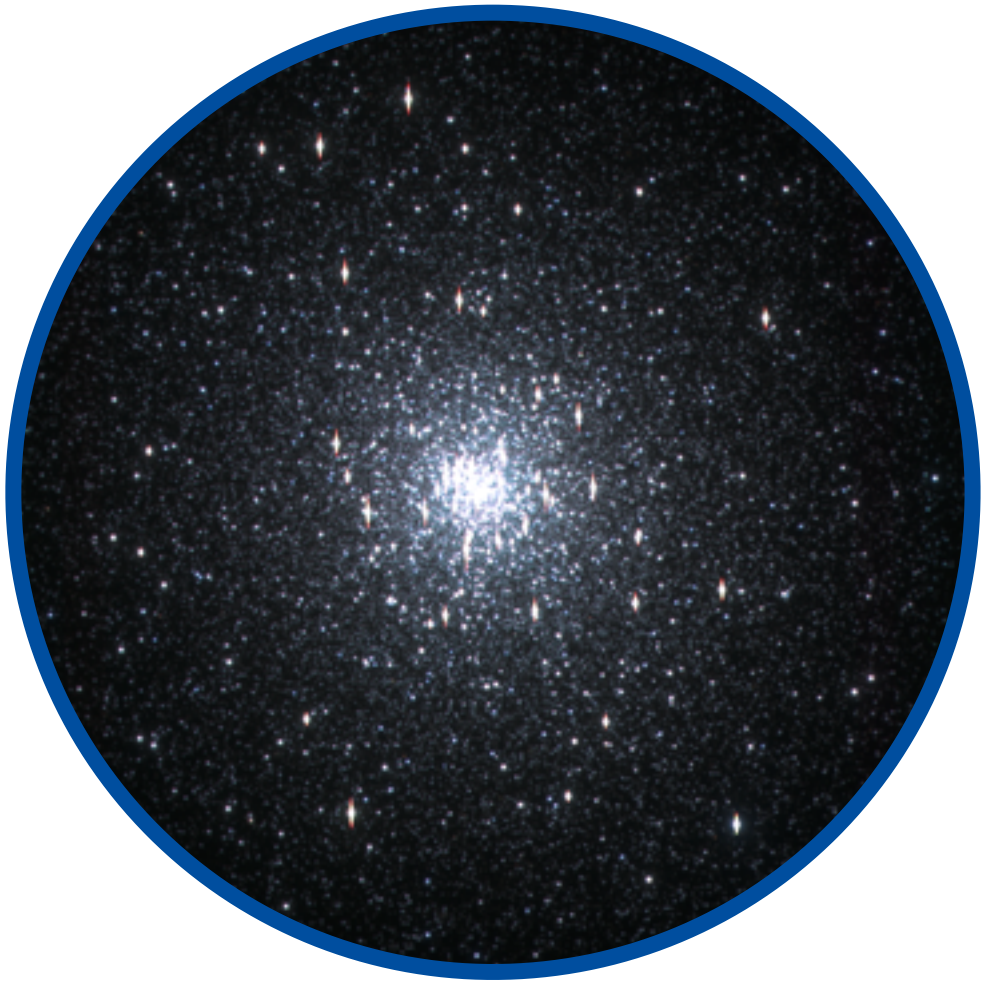
+ HST



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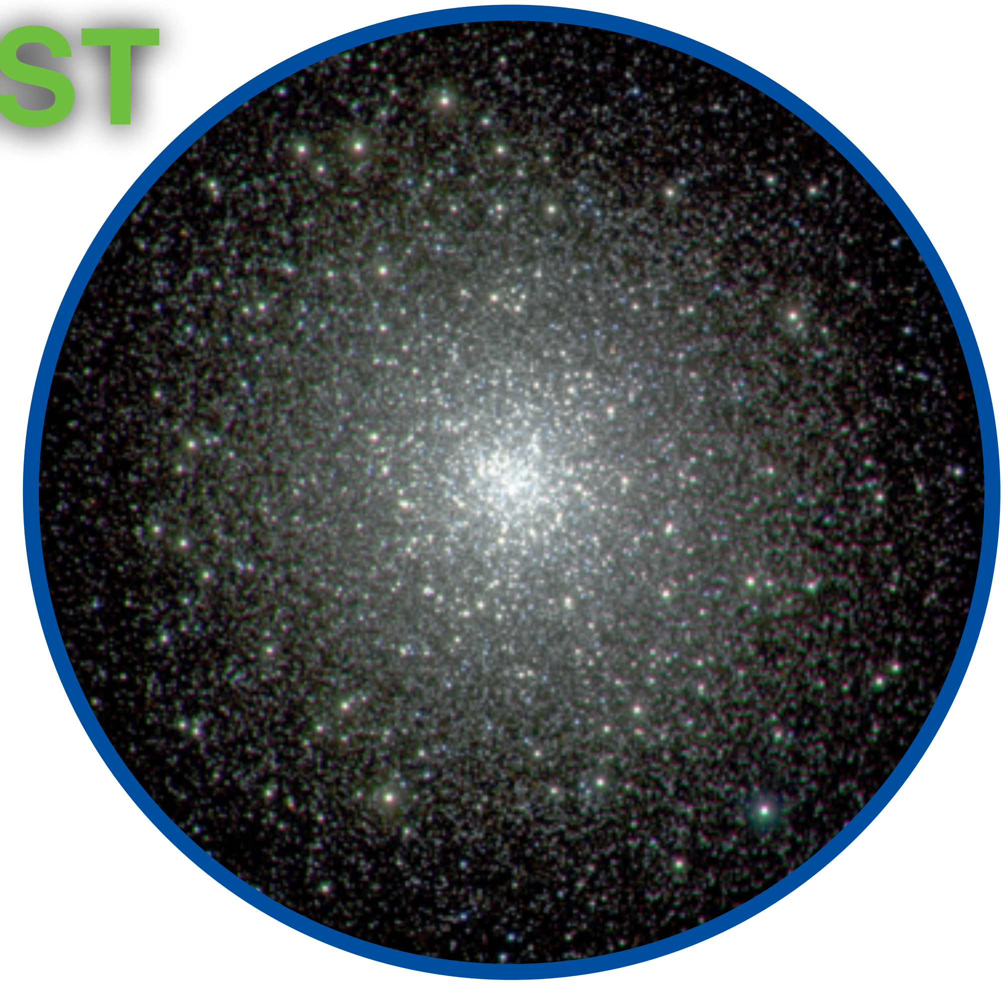

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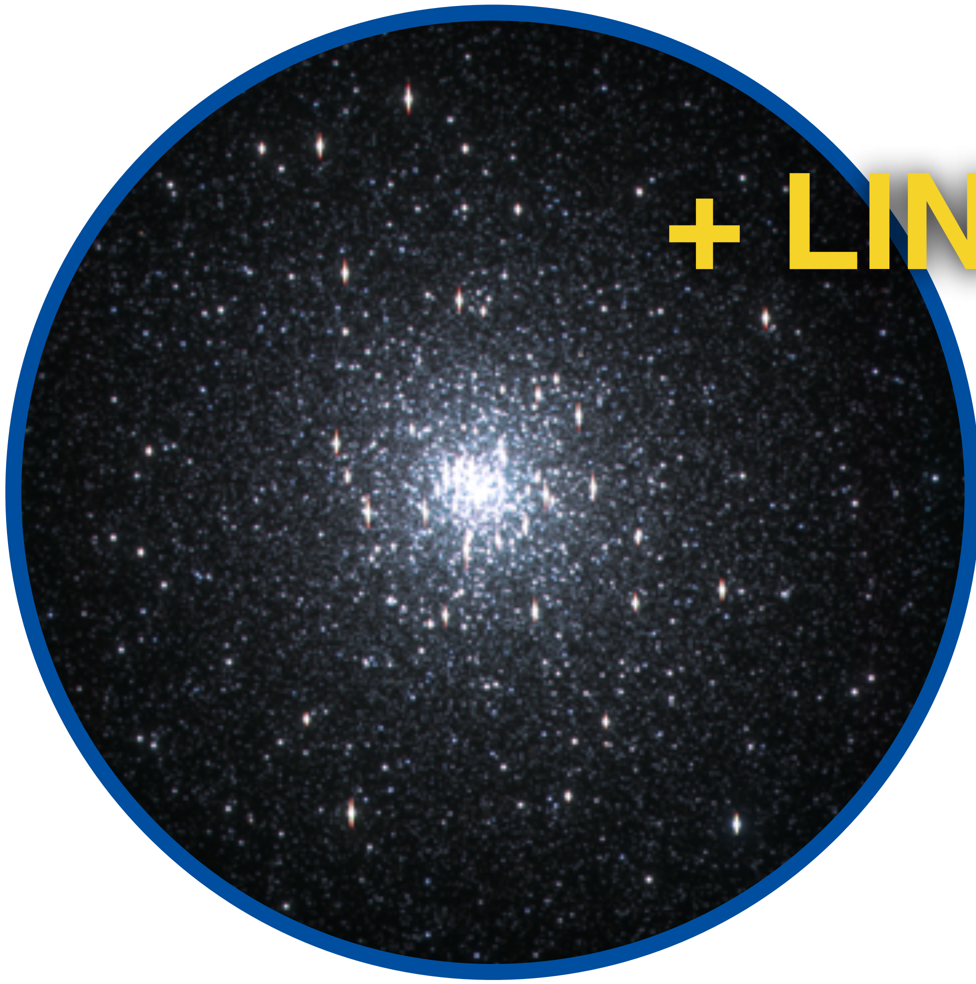
+ LINC-NIRVANA



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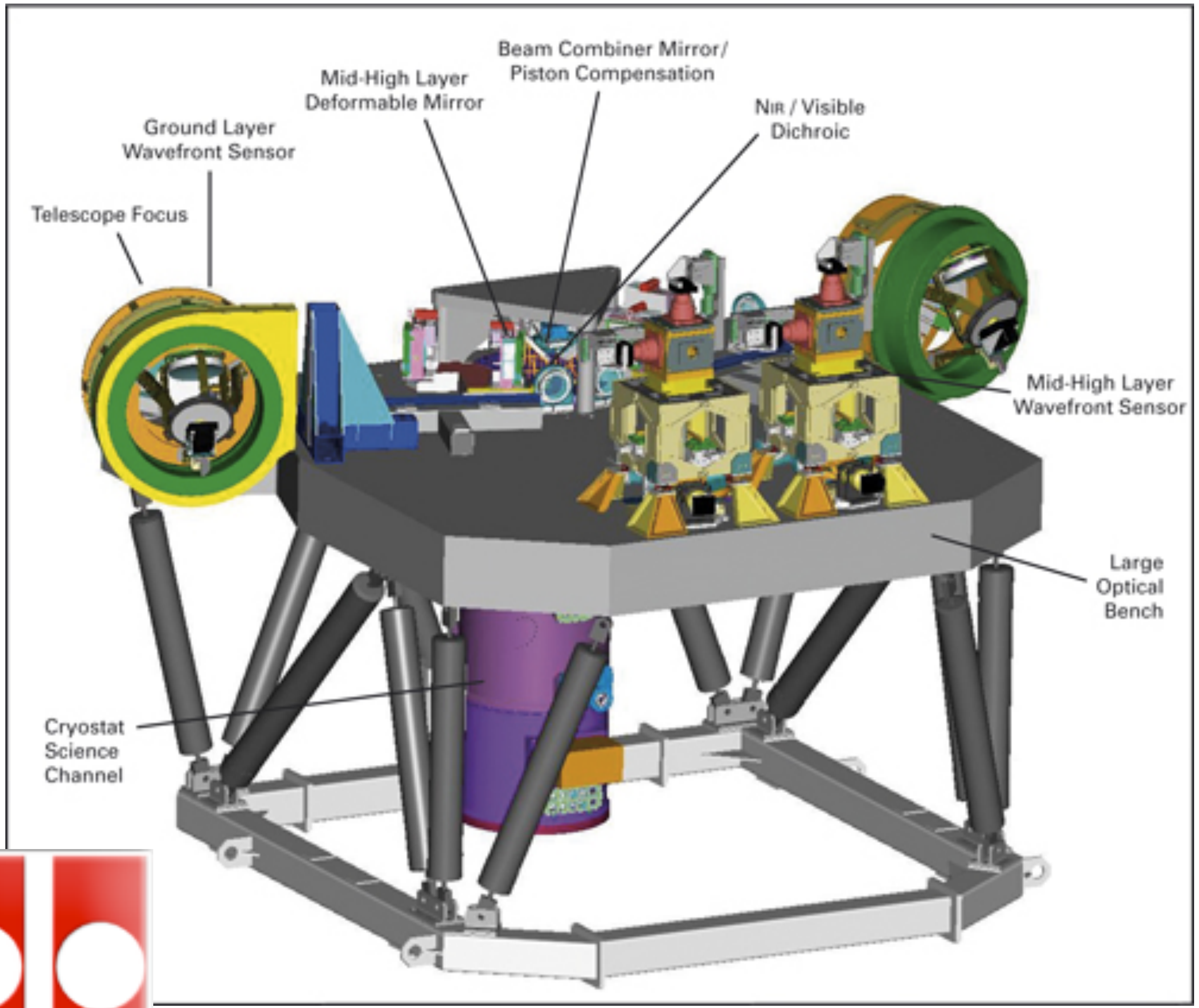
Background

Preparatory project to enable MPIA LINC-NIRVANA Key Science Project on Milky Way GCs



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Aims of the Key Science project:

To determine GC formation histories

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Did they form in-situ, or were they accreted?

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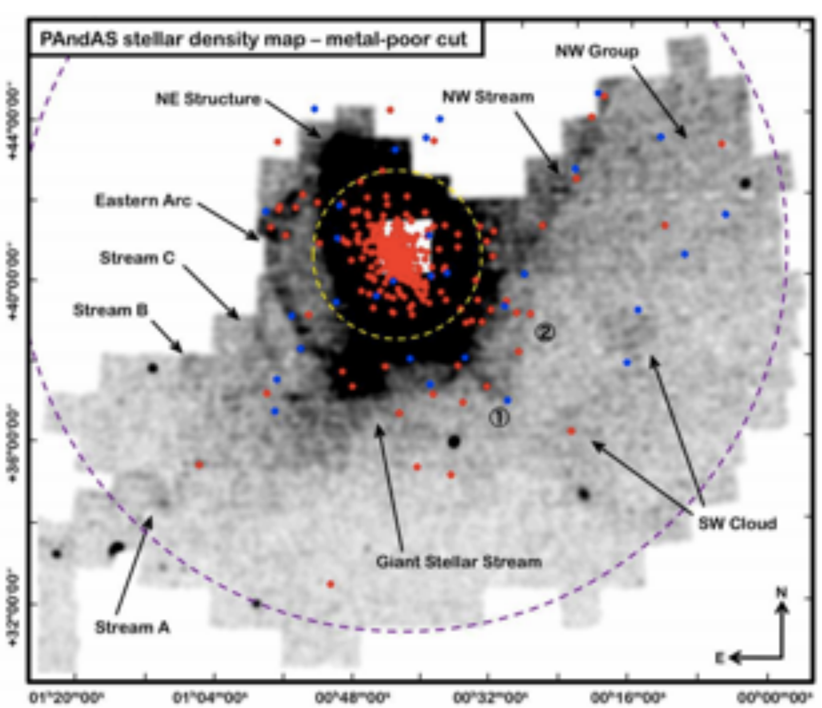
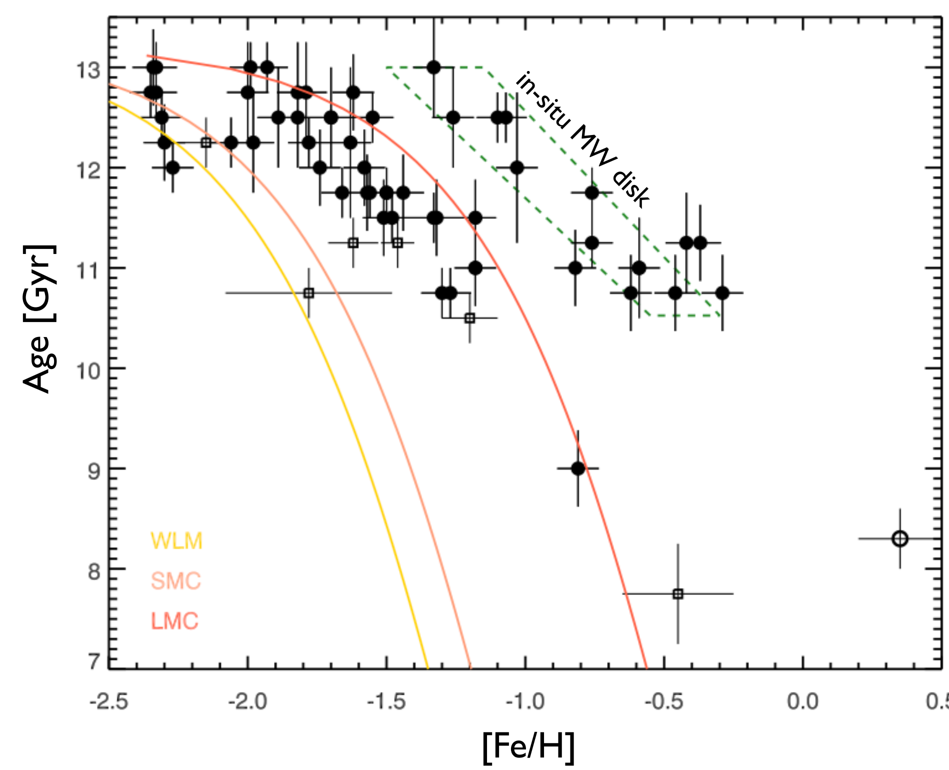


Mackey et al. 2010



Leaman, VandenBerg and Mendel 2013

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To determine GC formation histories

- Did they form in-situ, or were they accreted?
- How did the multiple stellar populations arise?

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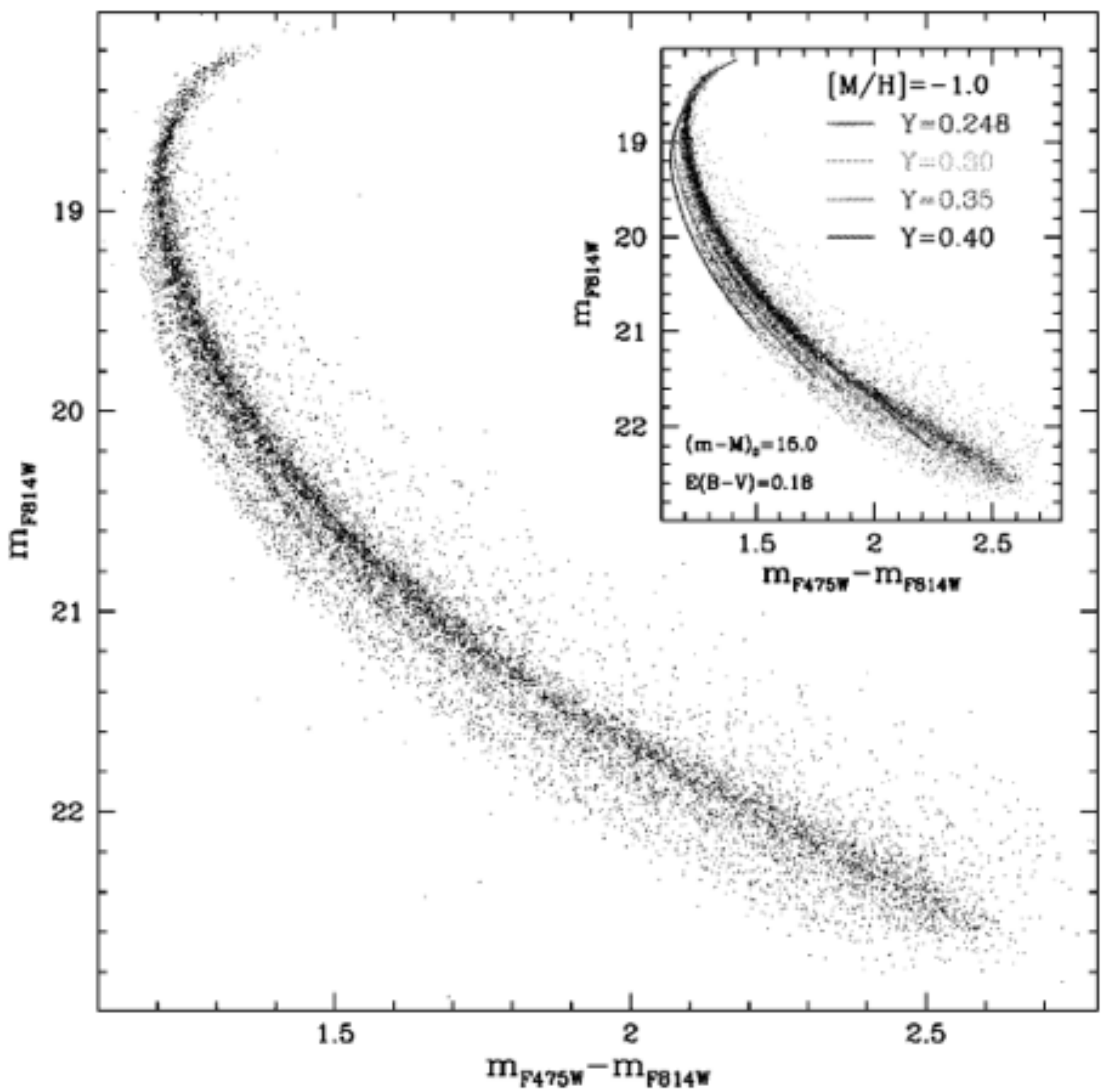
Did th   accreted?

How   tions arise?



Piotto et al. 2007

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Aims of the Key Science project:

To determine GC formation histories

- Did they form in-situ, or were they accreted?
- How did the multiple stellar populations arise?

To search for evidence of IMBHs

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Preparatory project to enable MPIA LINC-NIRVANA Key Science Project on Milky Way GCs

Aims of the Key Science project:

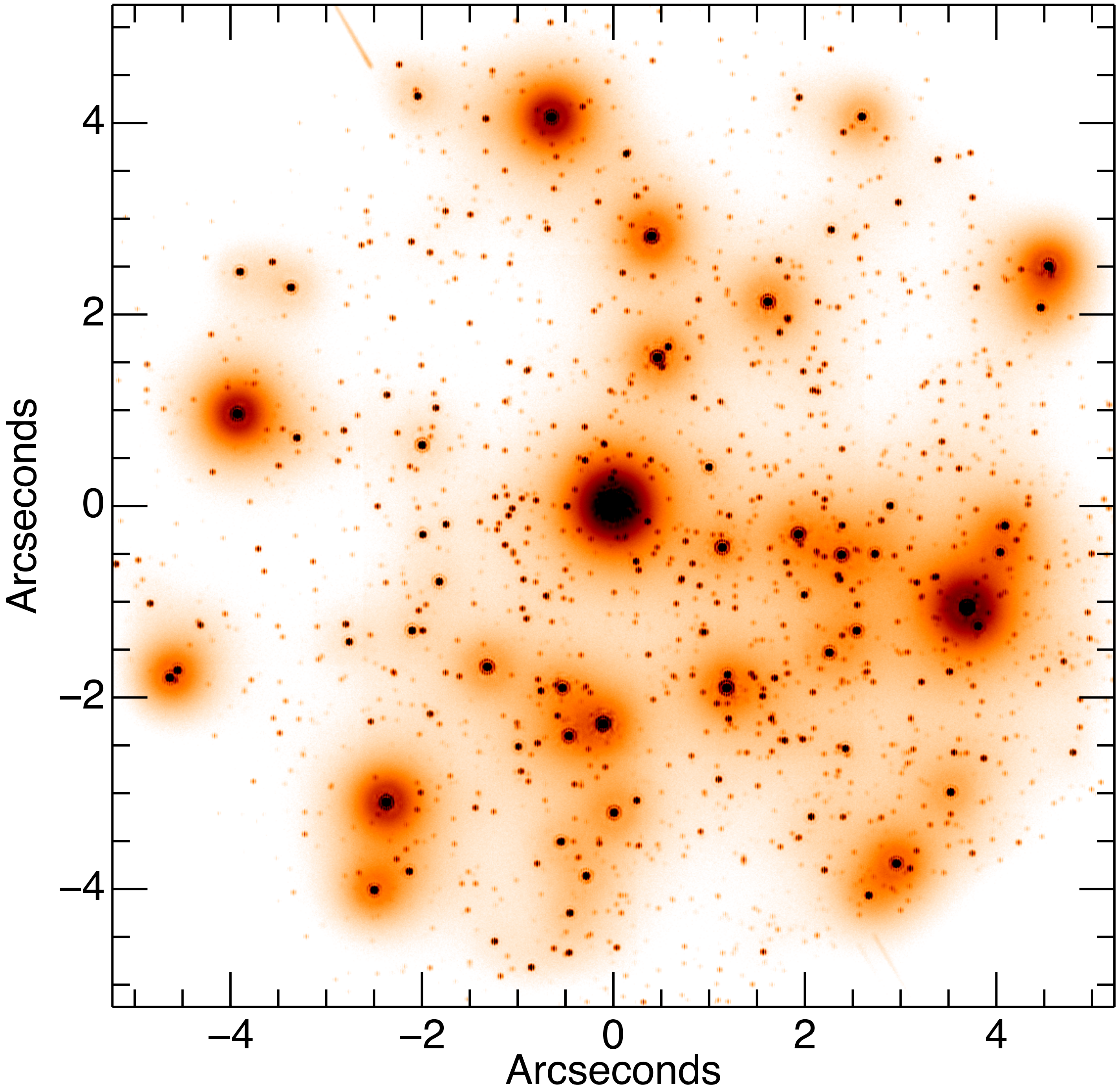
To determine GC formation histories
- Did they form in-situ, or were they accreted?
- How did the multiple stellar populations arise?

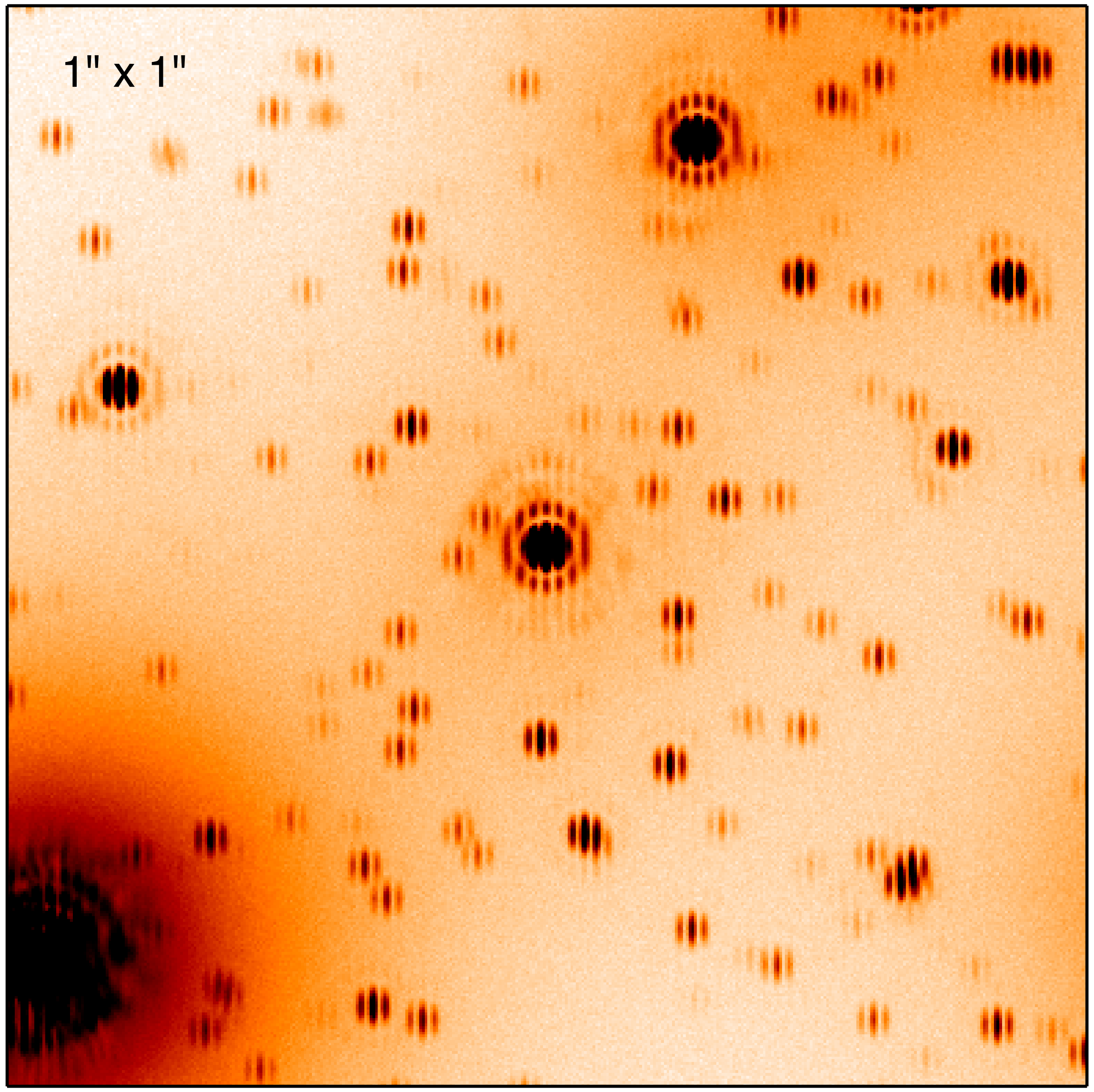
To search for evidence of IMBHs

To investigate dynamical and stellar evolution
- What is the primordial binary fraction?
- How did exotic star types (e.g. blue stragglers) arise?

LN Simulations

Simulation of a LINC-NIRVANA (in LINC interferometric mode) observation of a MW GC

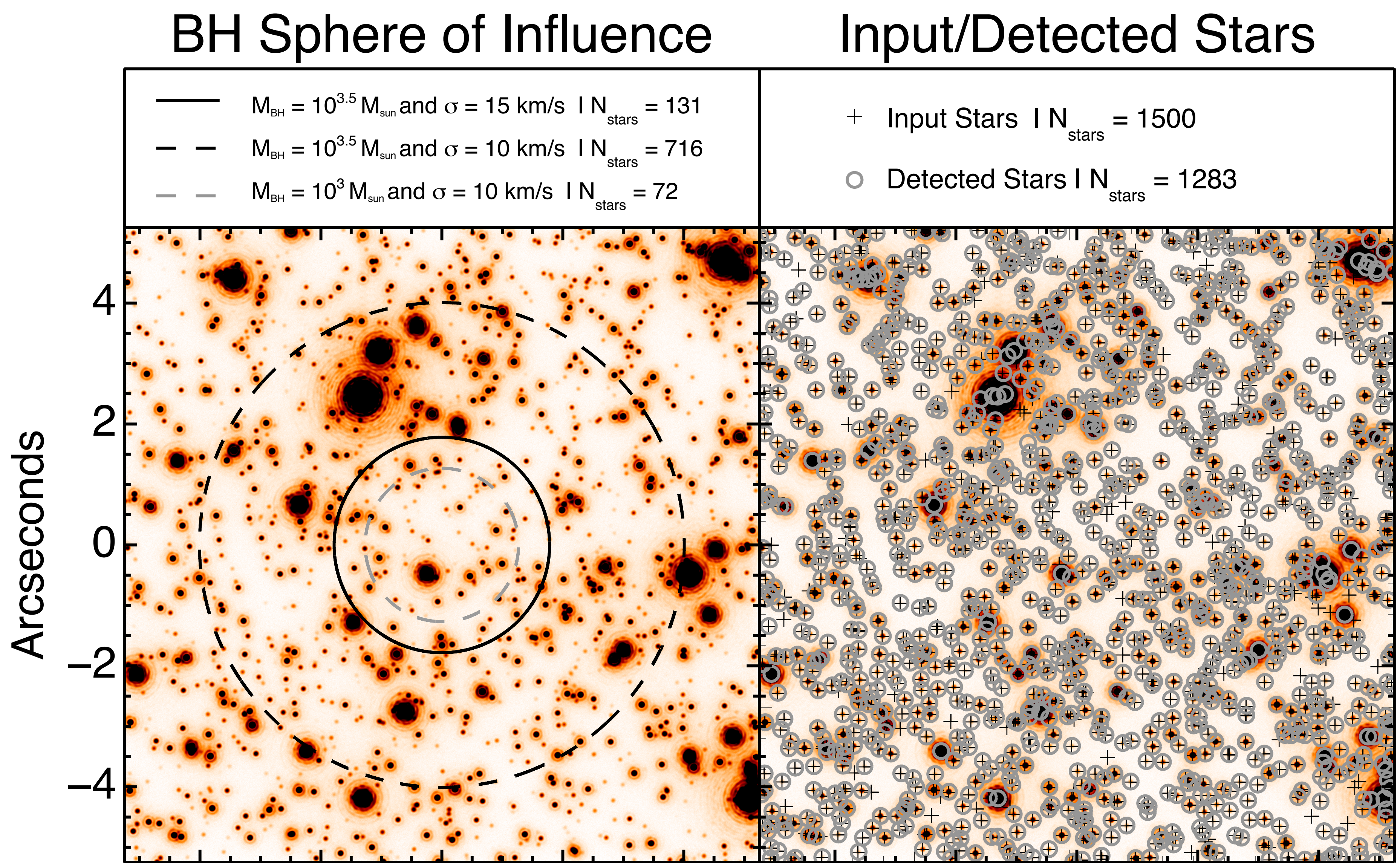




Exquisite resolution (~20mas @ K), but… spatially varying PSF… and low sky coverage

LN Simulations

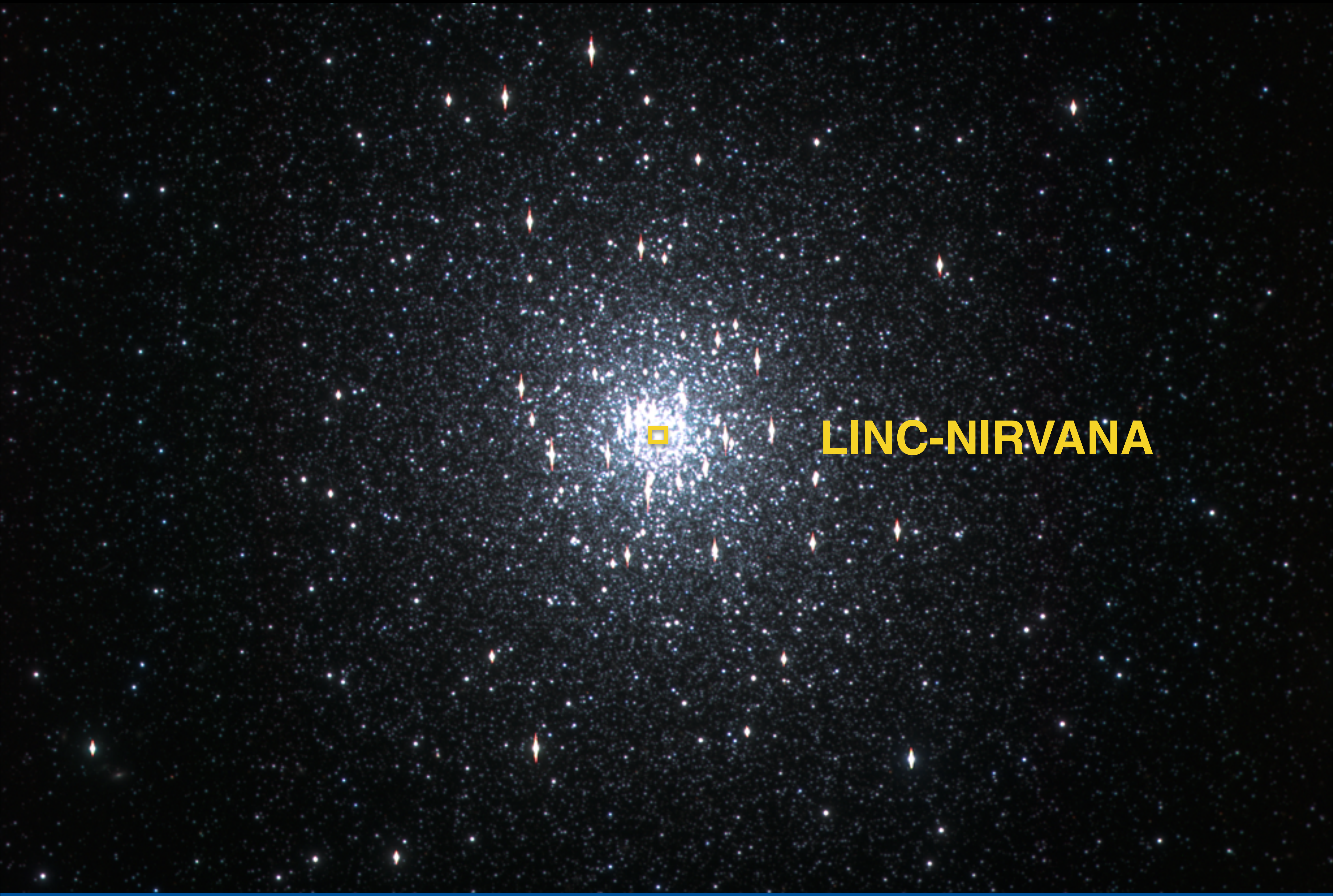
Simulation of a LINC-NIRVANA (in MCAO mode) observation of a MW GC



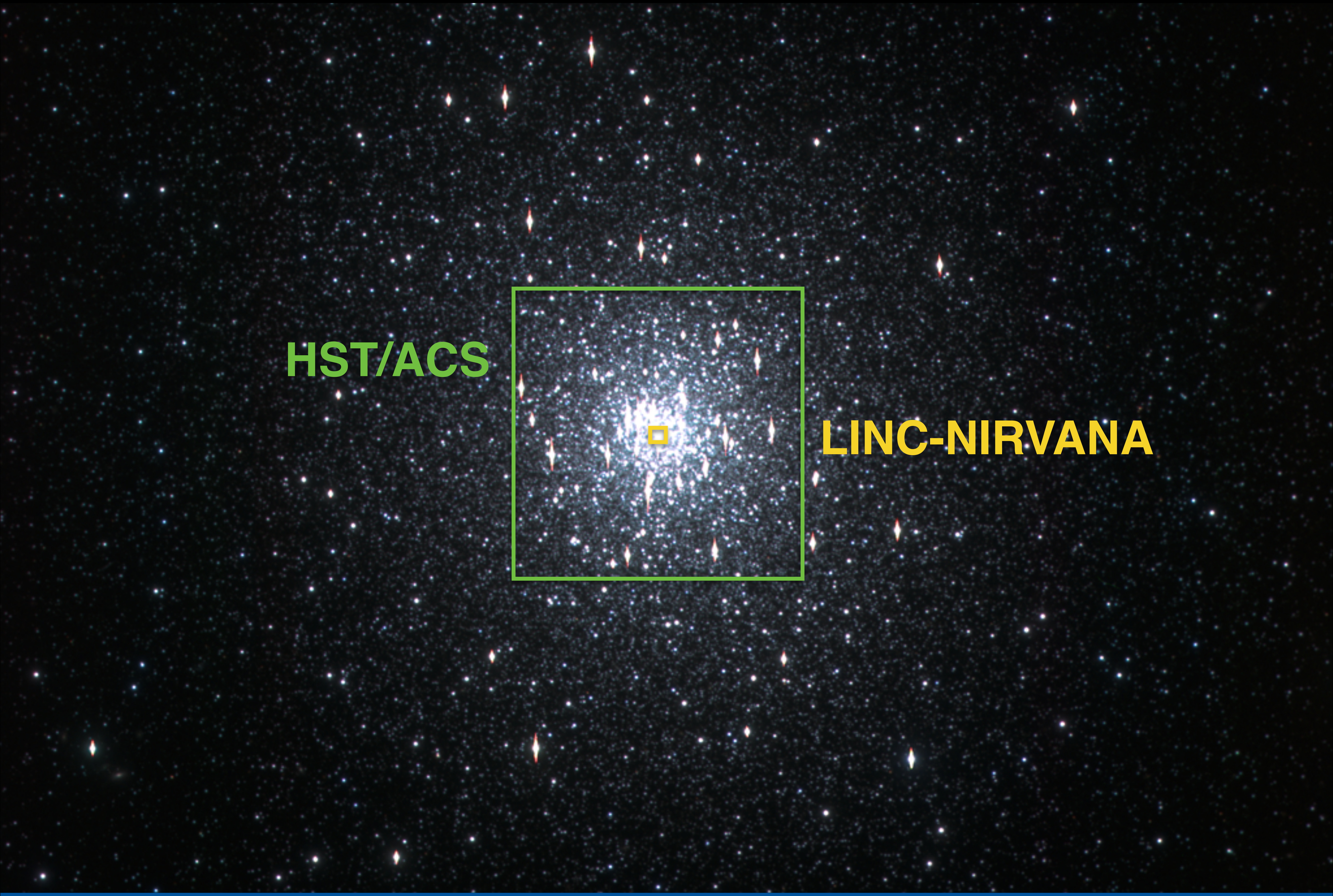
Lower resolution (~50mas @ K), but ~constant PSF and can detect all H burning stars in ~a few hours for nearby GCs - perfect for studies of spatial variation in stellar populations, also high sky coverage

Observations

Observations



Observations



Observations

Selected 6 MW GCs suitable for study with LN.

- Northern Hemisphere.
- Massive - so IMBH detectable if present
- Suspected accreted and in-situ GCs
- Range of dynamical properties - w/wo core collapse

Observations

Observations:

LBC optical imaging to study large scale distribution of exotic types, and binary fraction.

Observations

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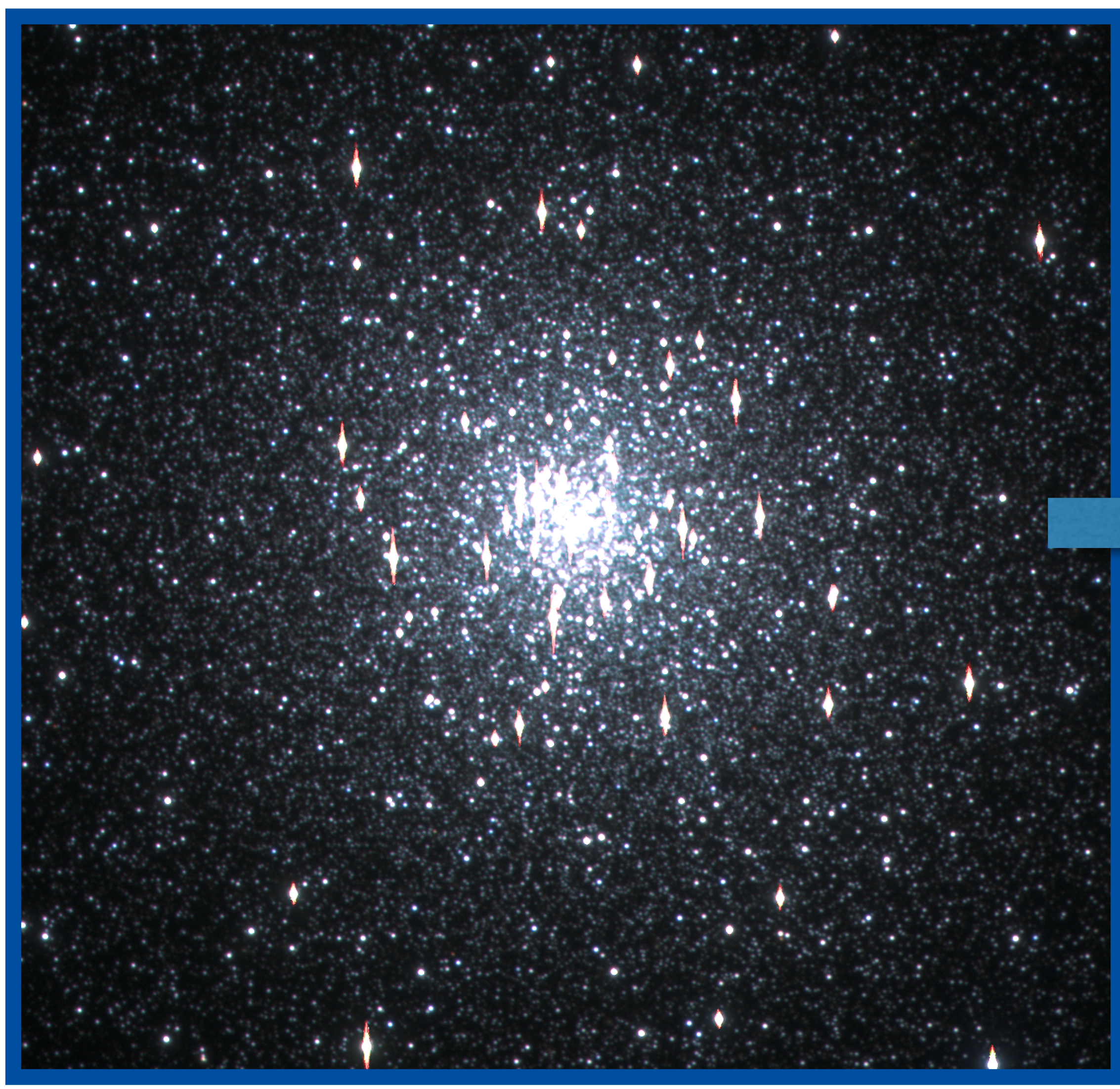

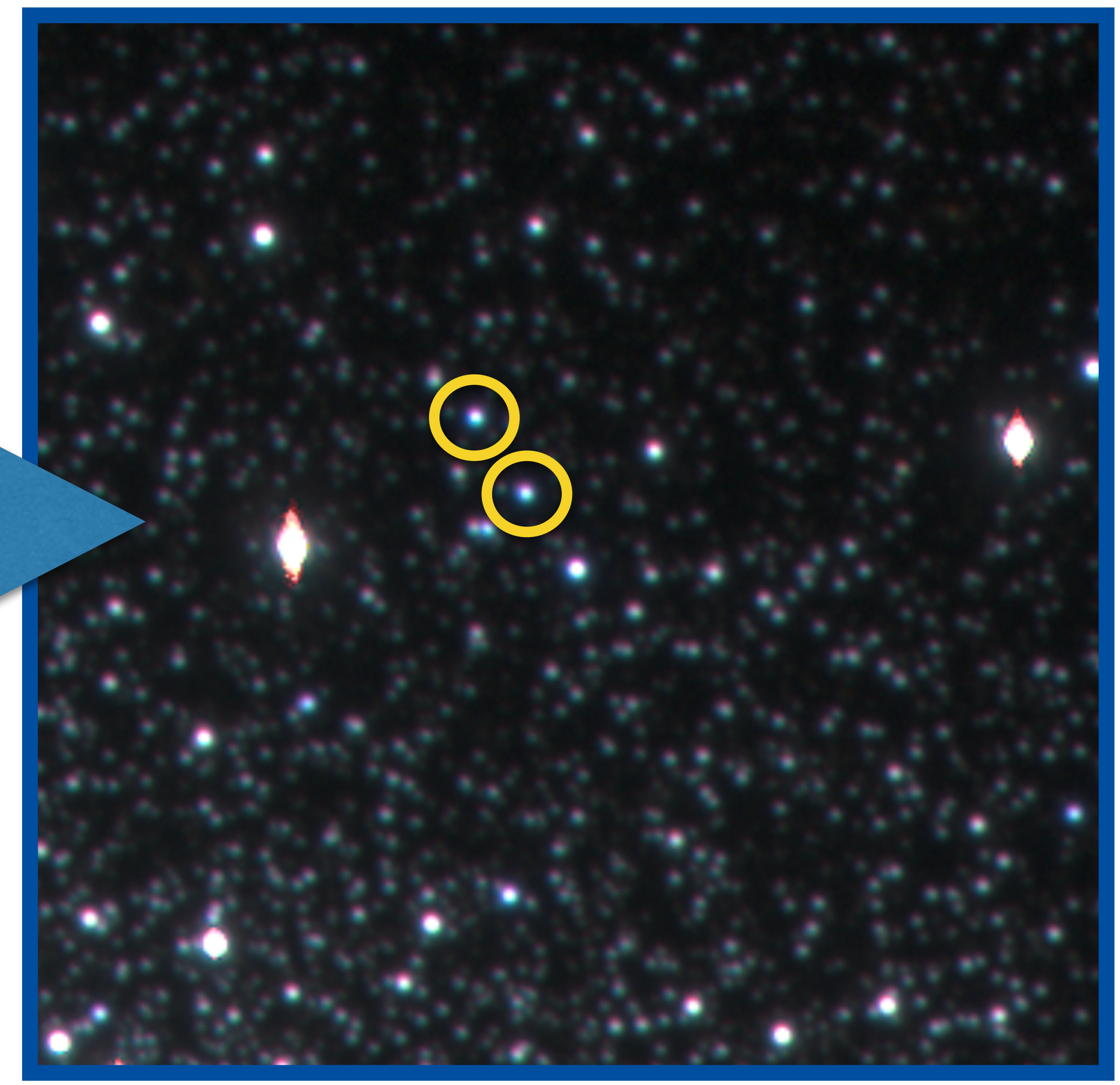

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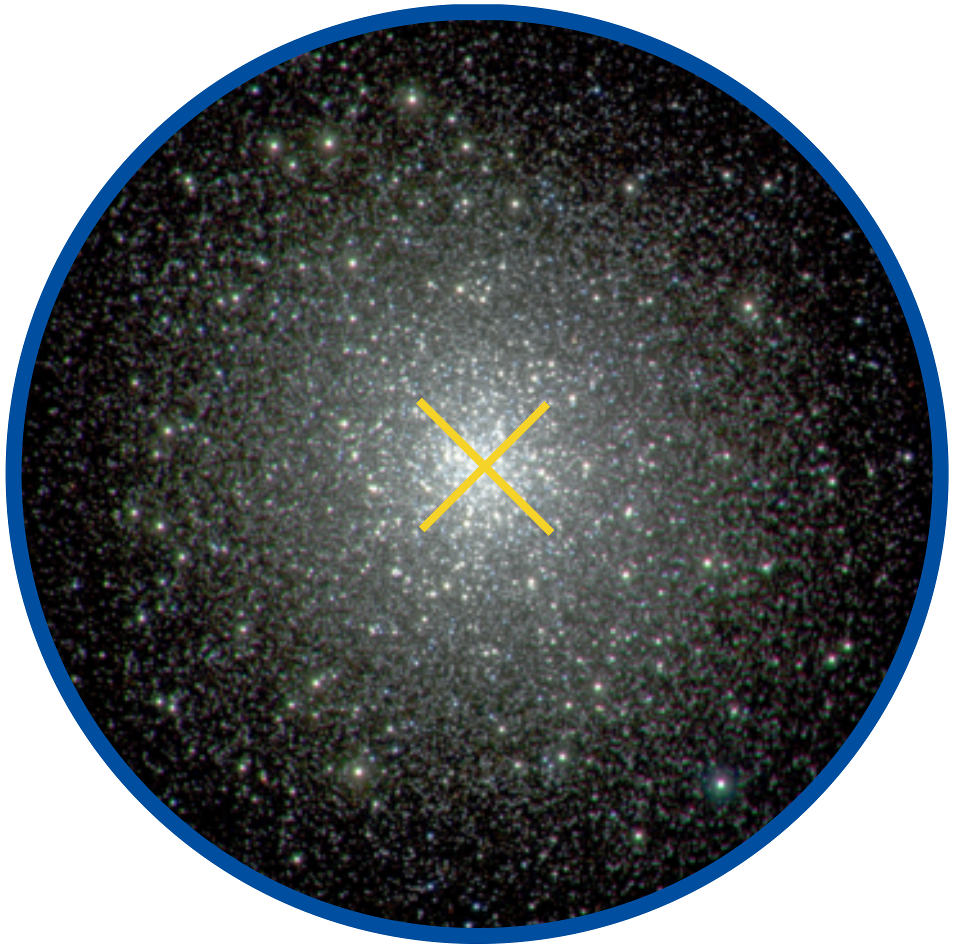
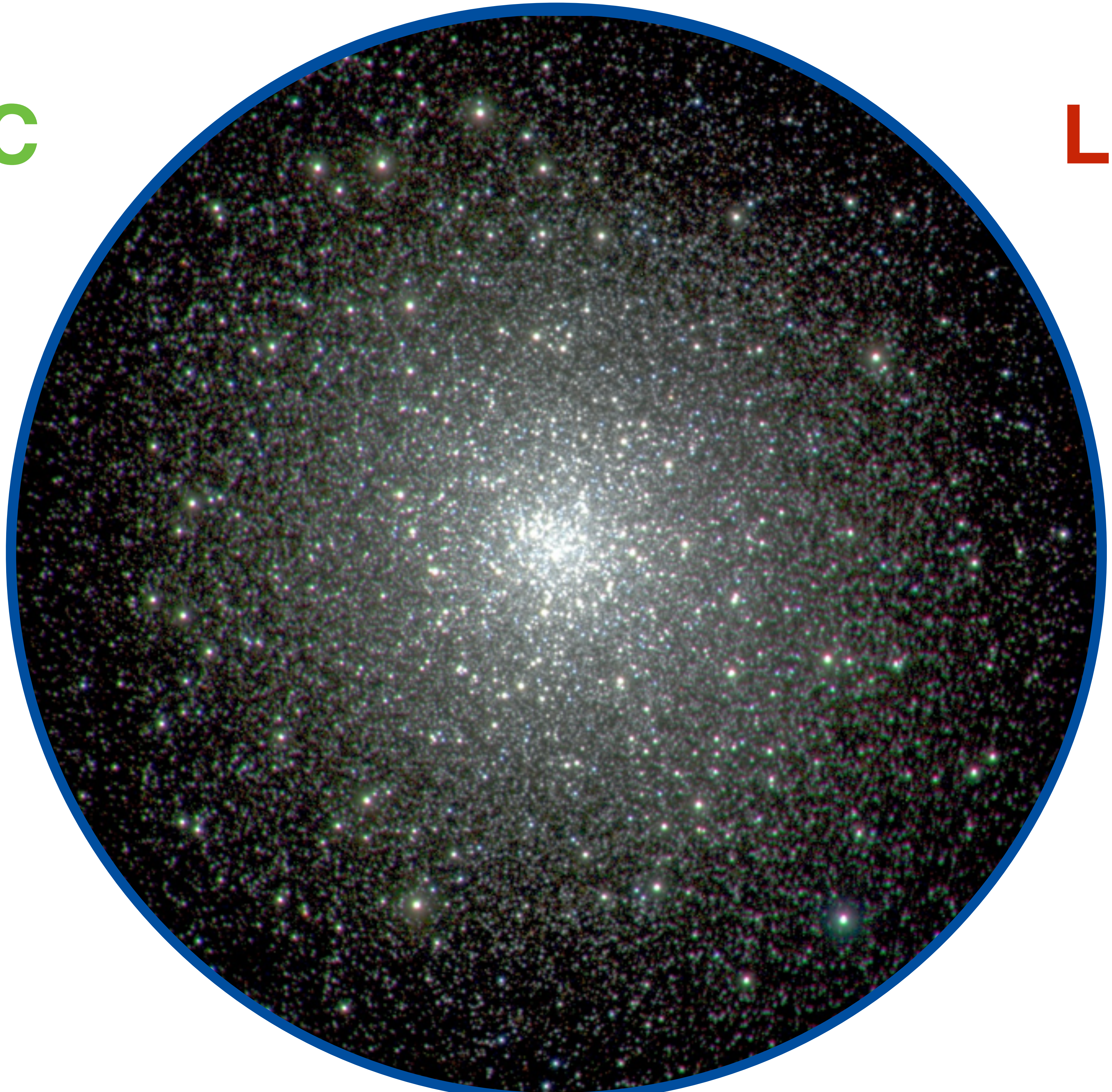
LUCI imaging to accurately determine structural properties - i.e. exact centre



Observations

LBC



LUCI

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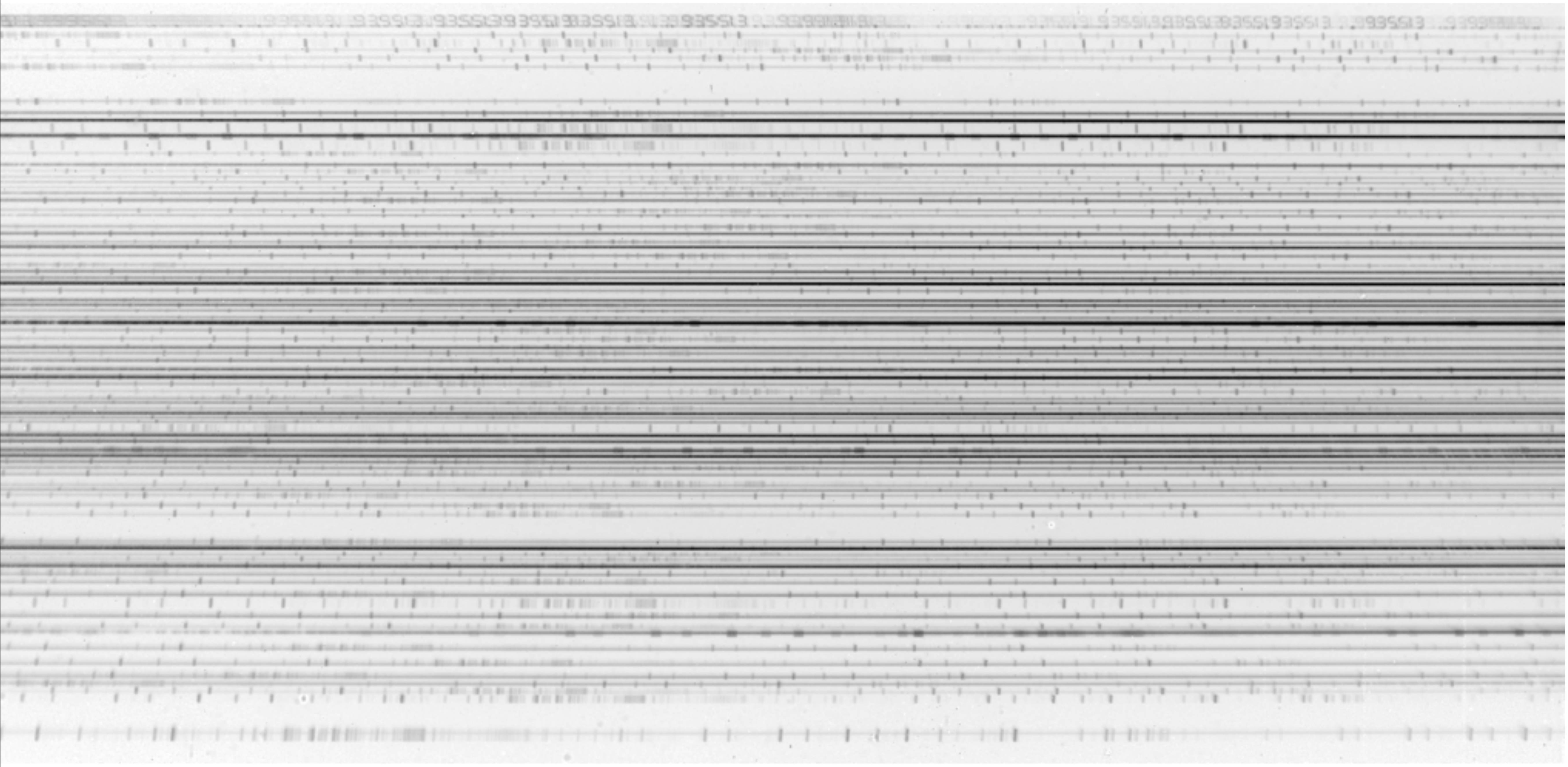
LUCI spectroscopy to obtain LOS velocities

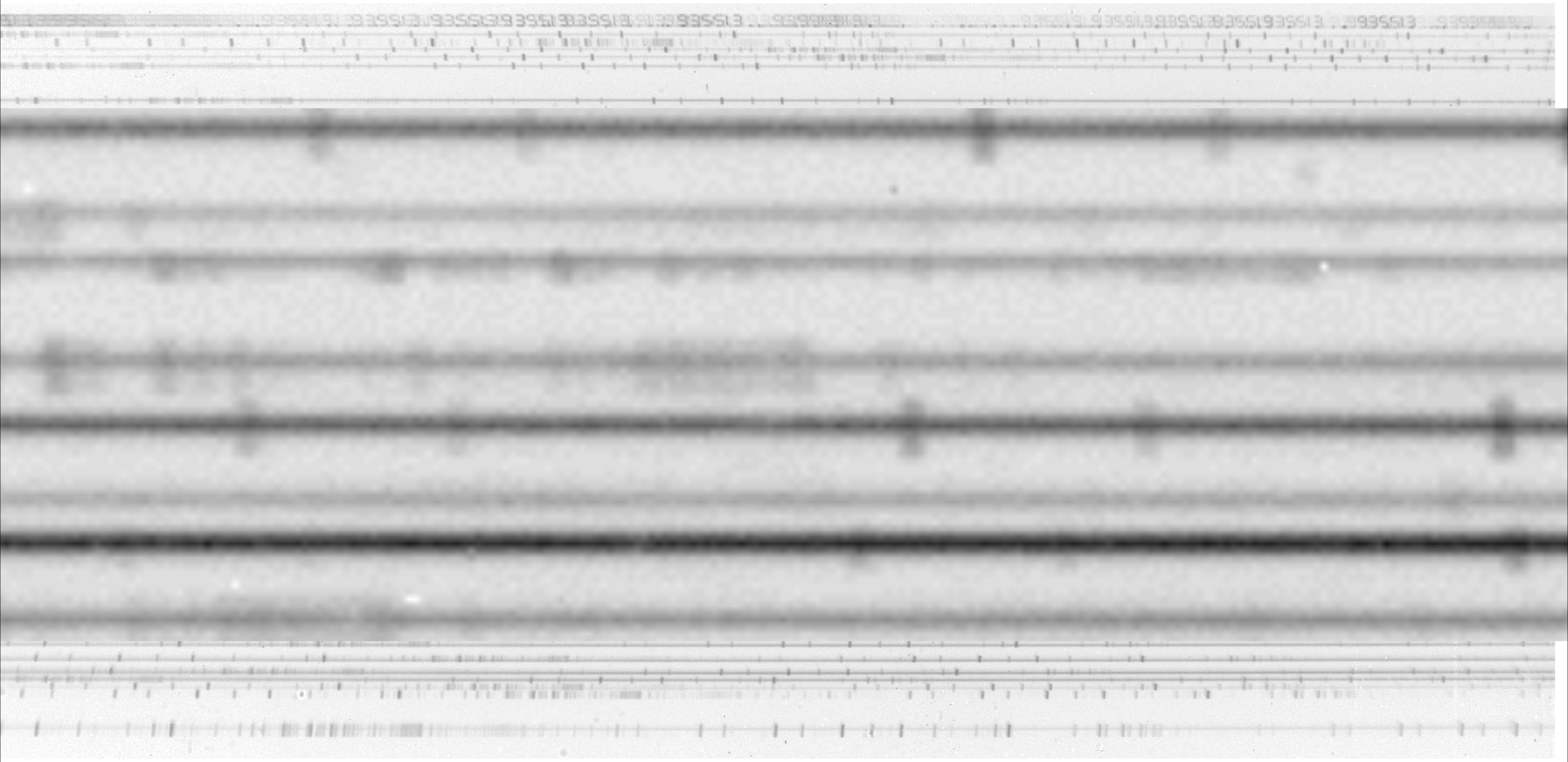
Preparatory Observations



LUCI J band spectroscopy of NGC 6341 red giants.

> 90 slitlets per mask, R > 8500

Preparatory Observations



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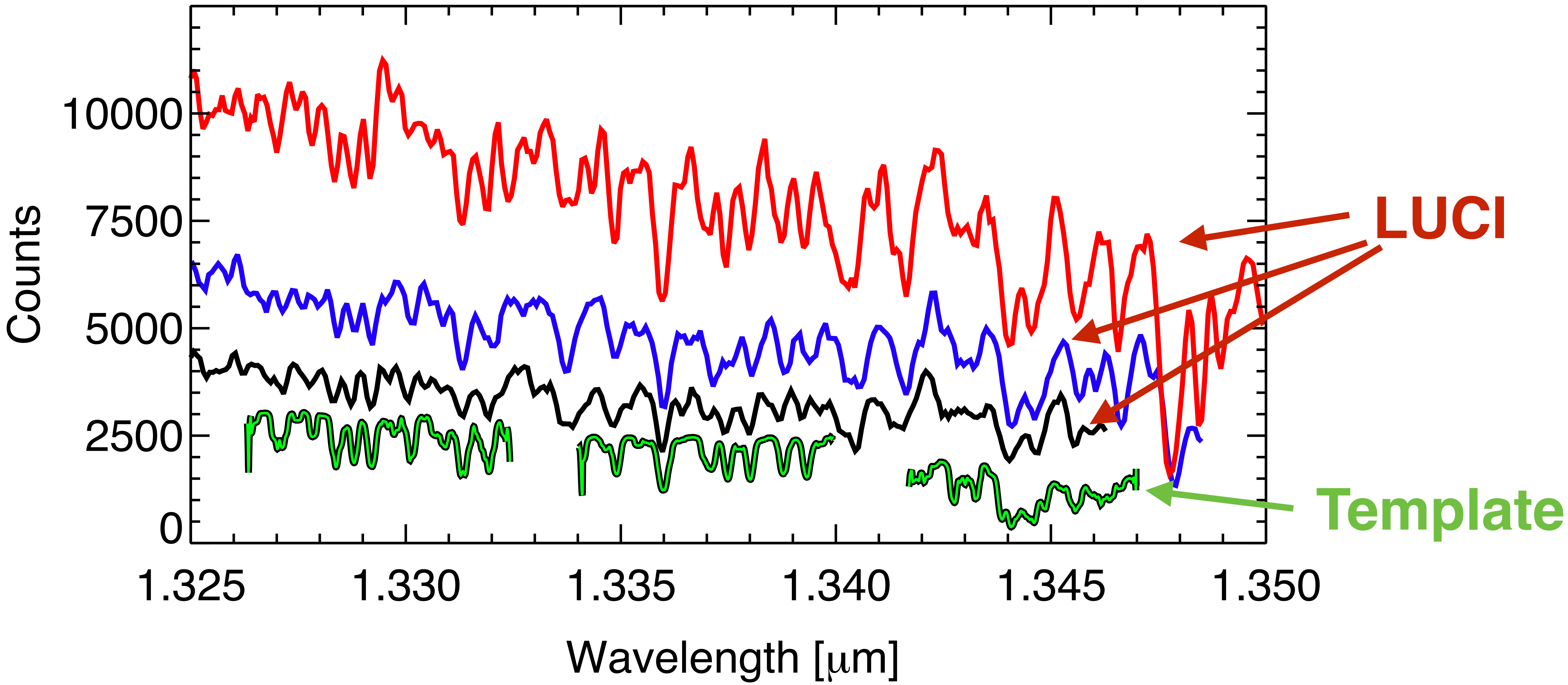

Confirmed velocity accuracy <~ 1.5 km/s

Observations

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HST Proper motions

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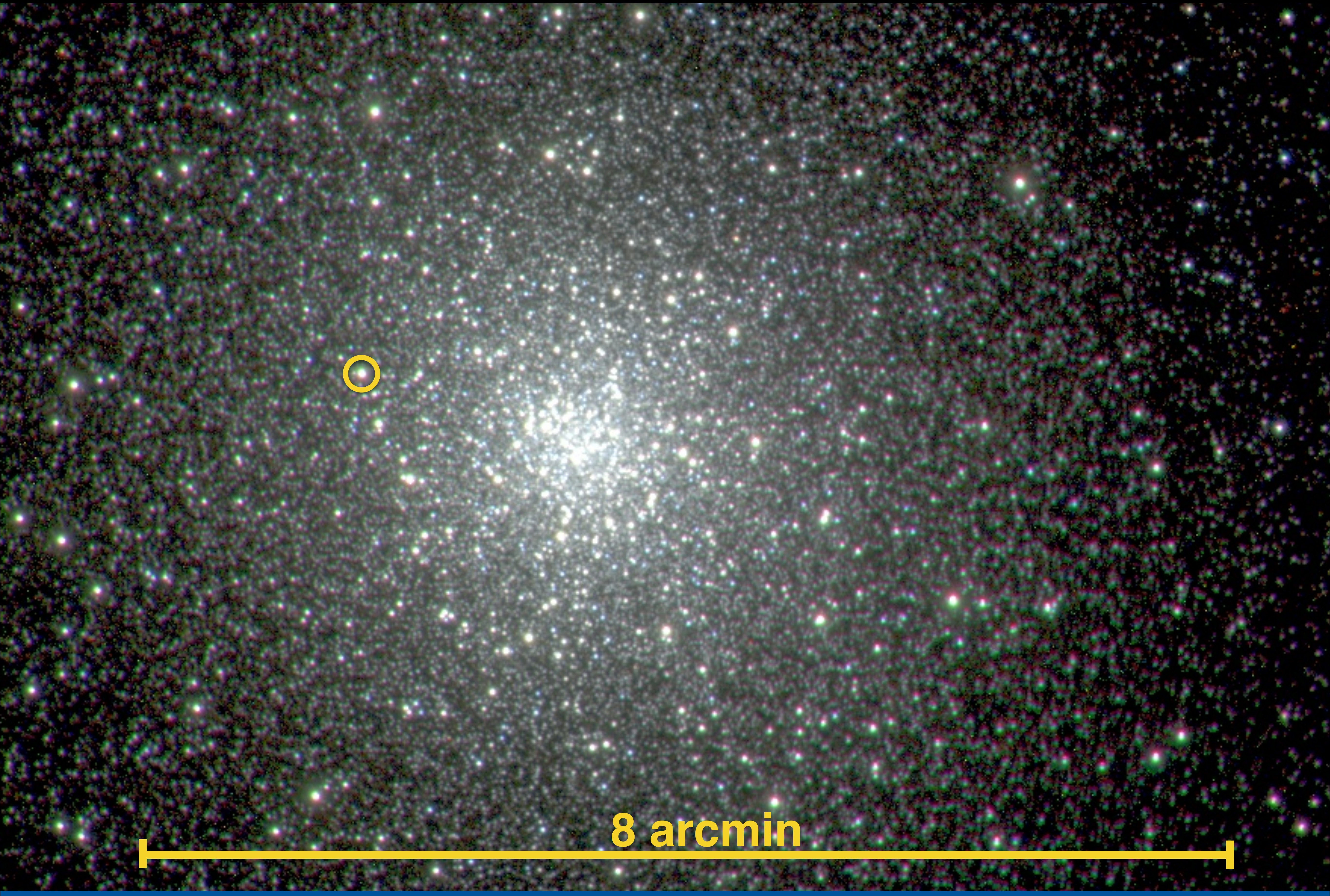

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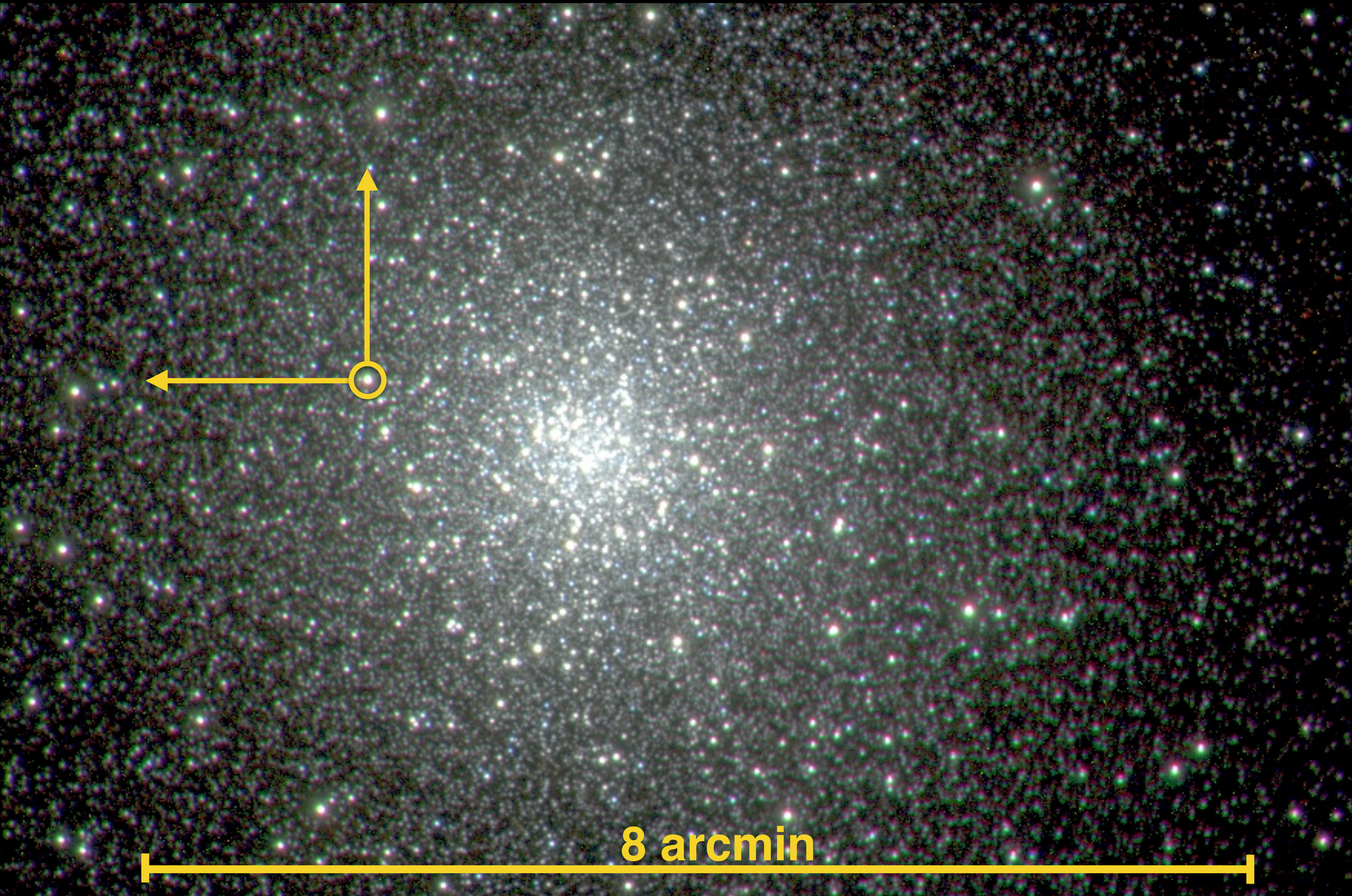

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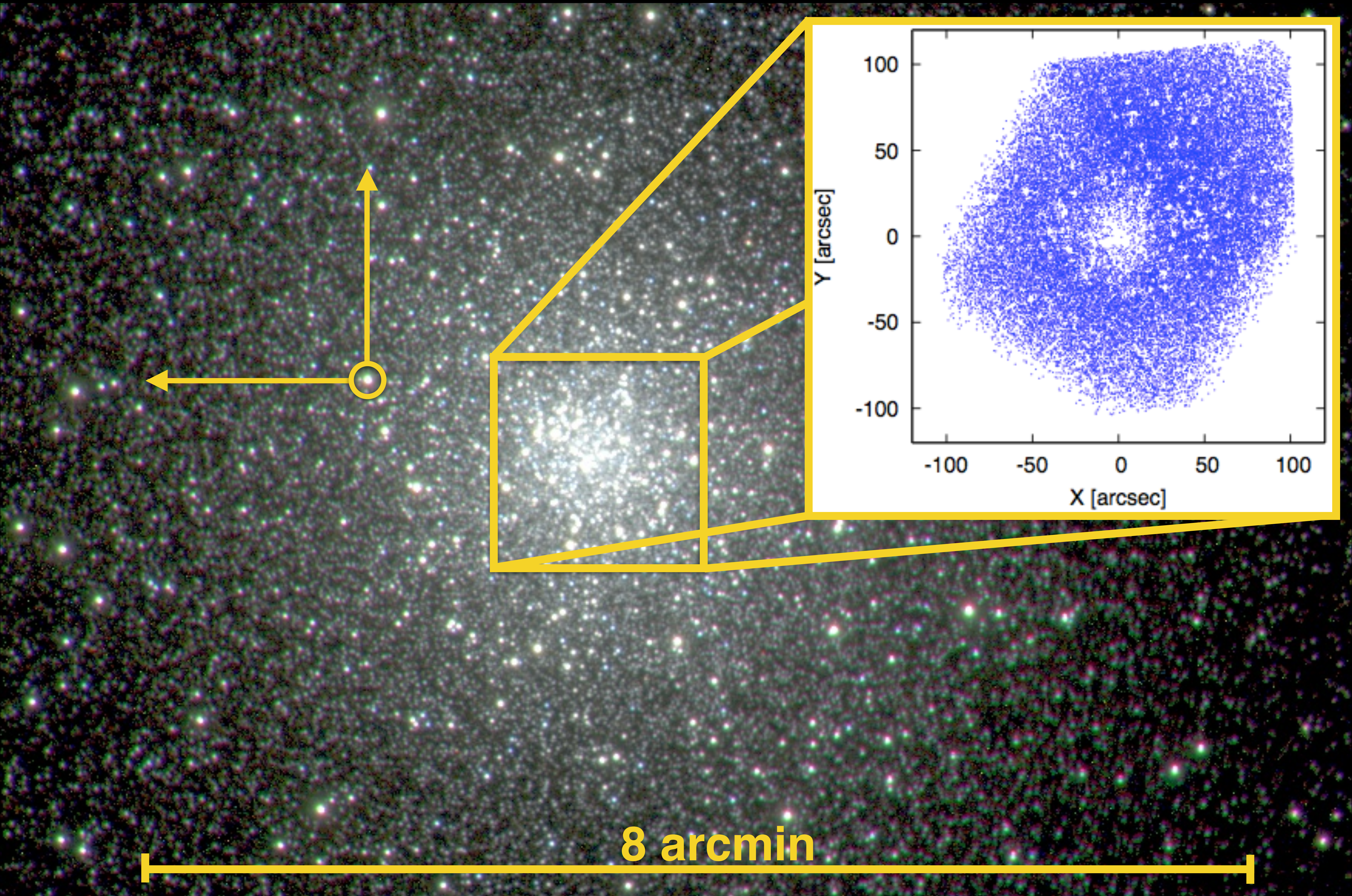

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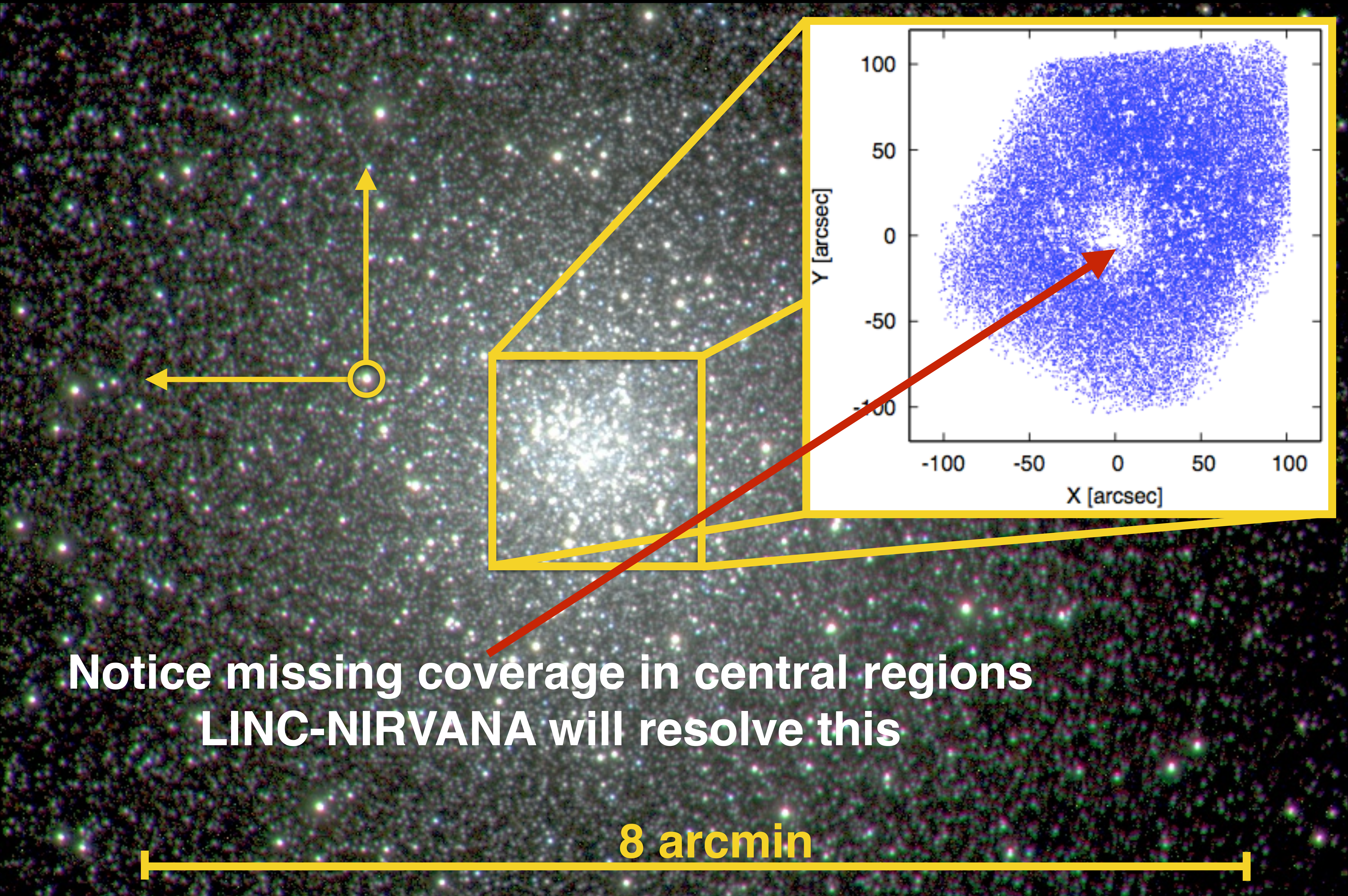


Notice missing coverage in central regions
LINC-NIRVANA will resolve this

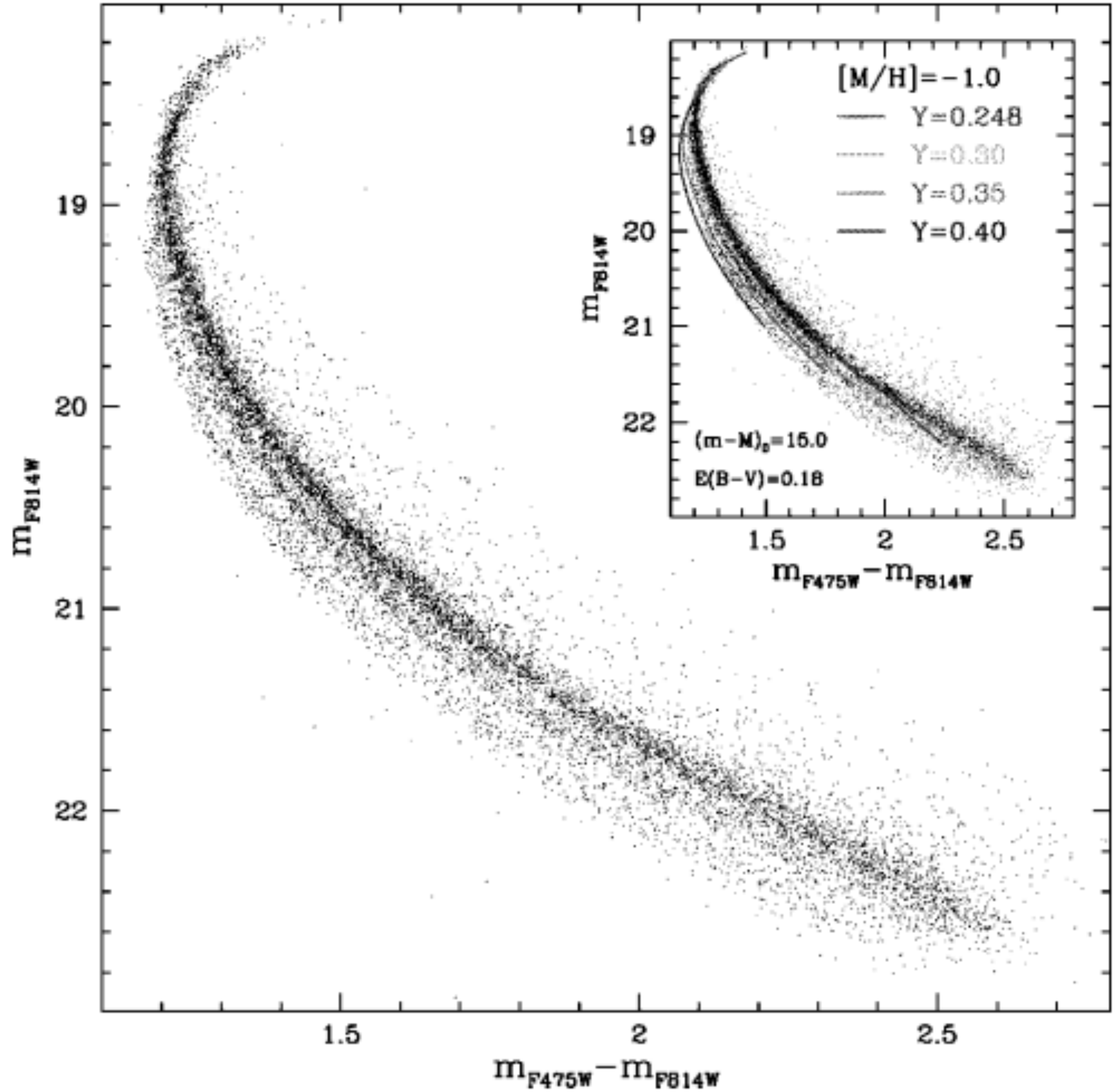
HST Proper Motions

Two competing theories for how multiple stellar populations in GCs arise:

1. Multiple periods of star formation

2. Enrichment of lower mass protostars without new star formation.

They predict different kinematic behaviours



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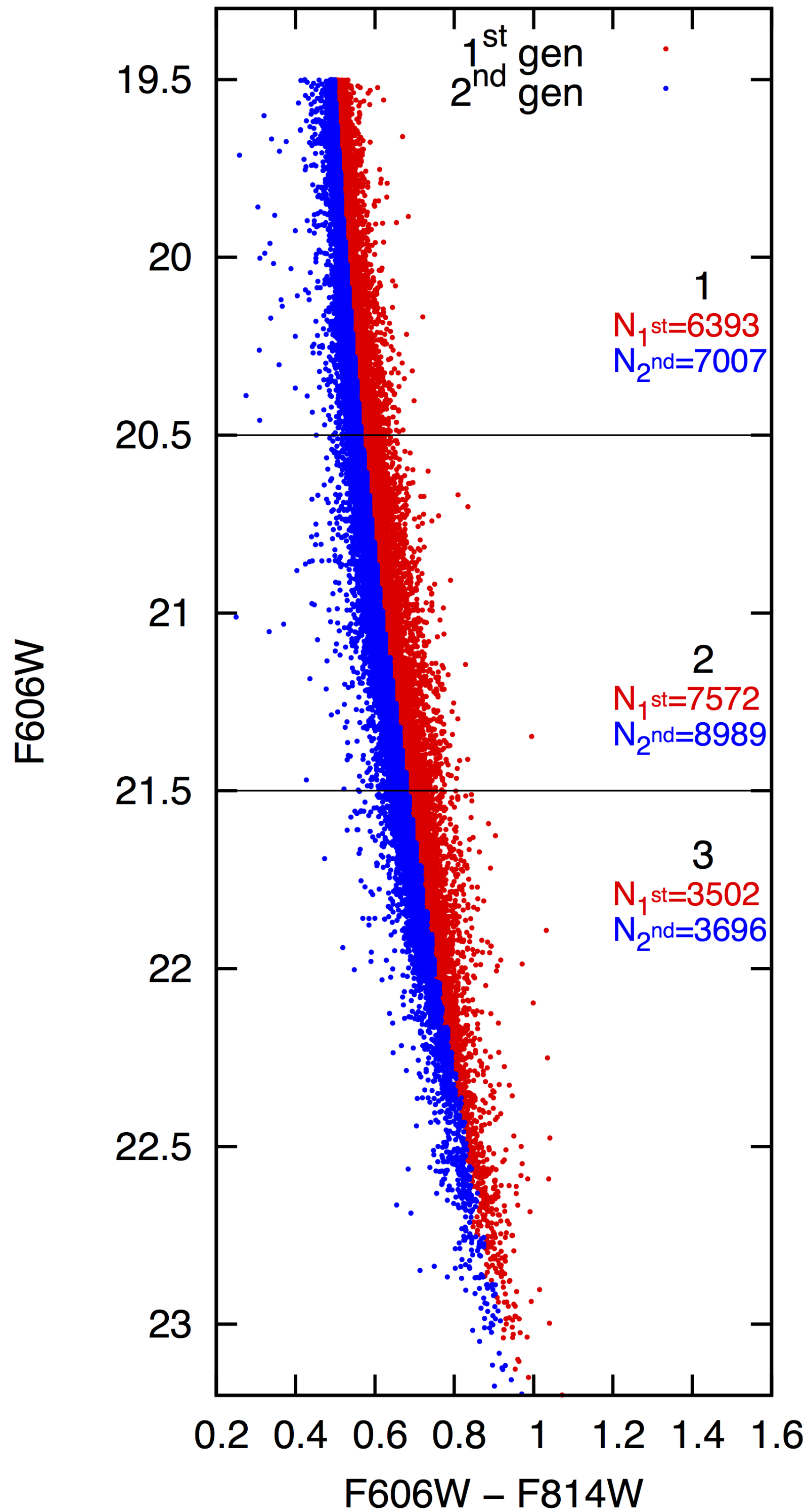

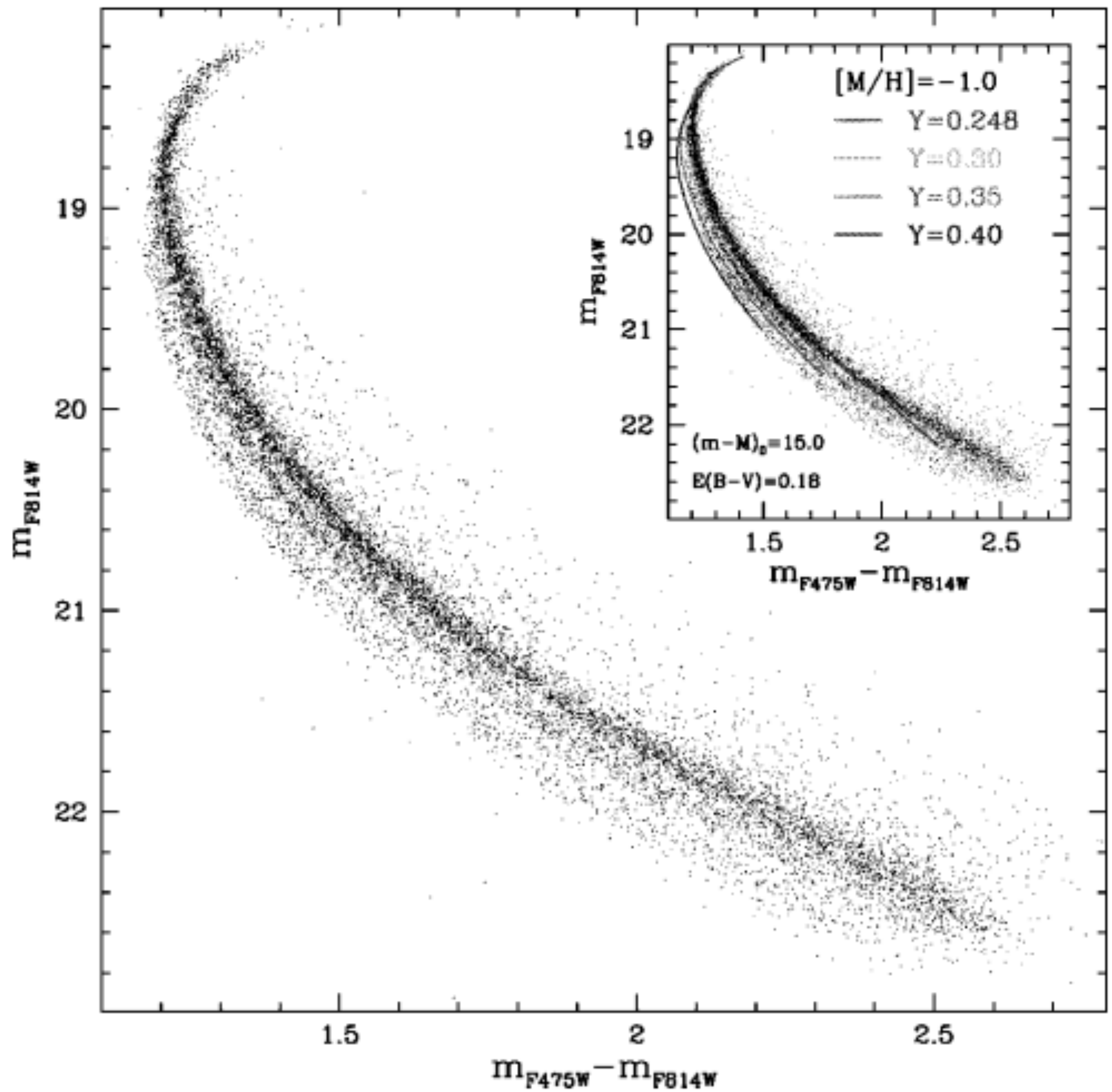

Bianchini, Bellini, Norris, et al. (in prep)

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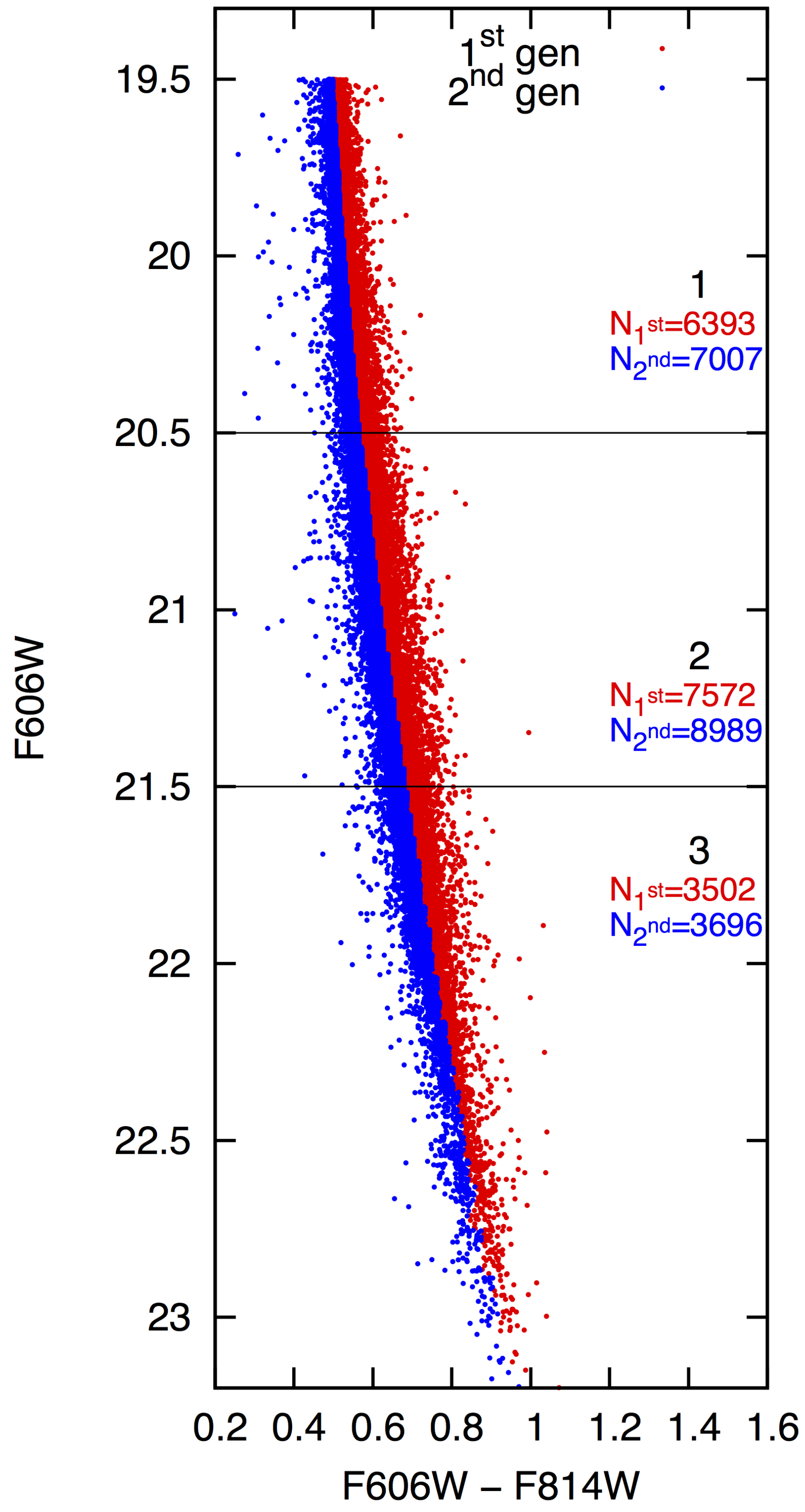

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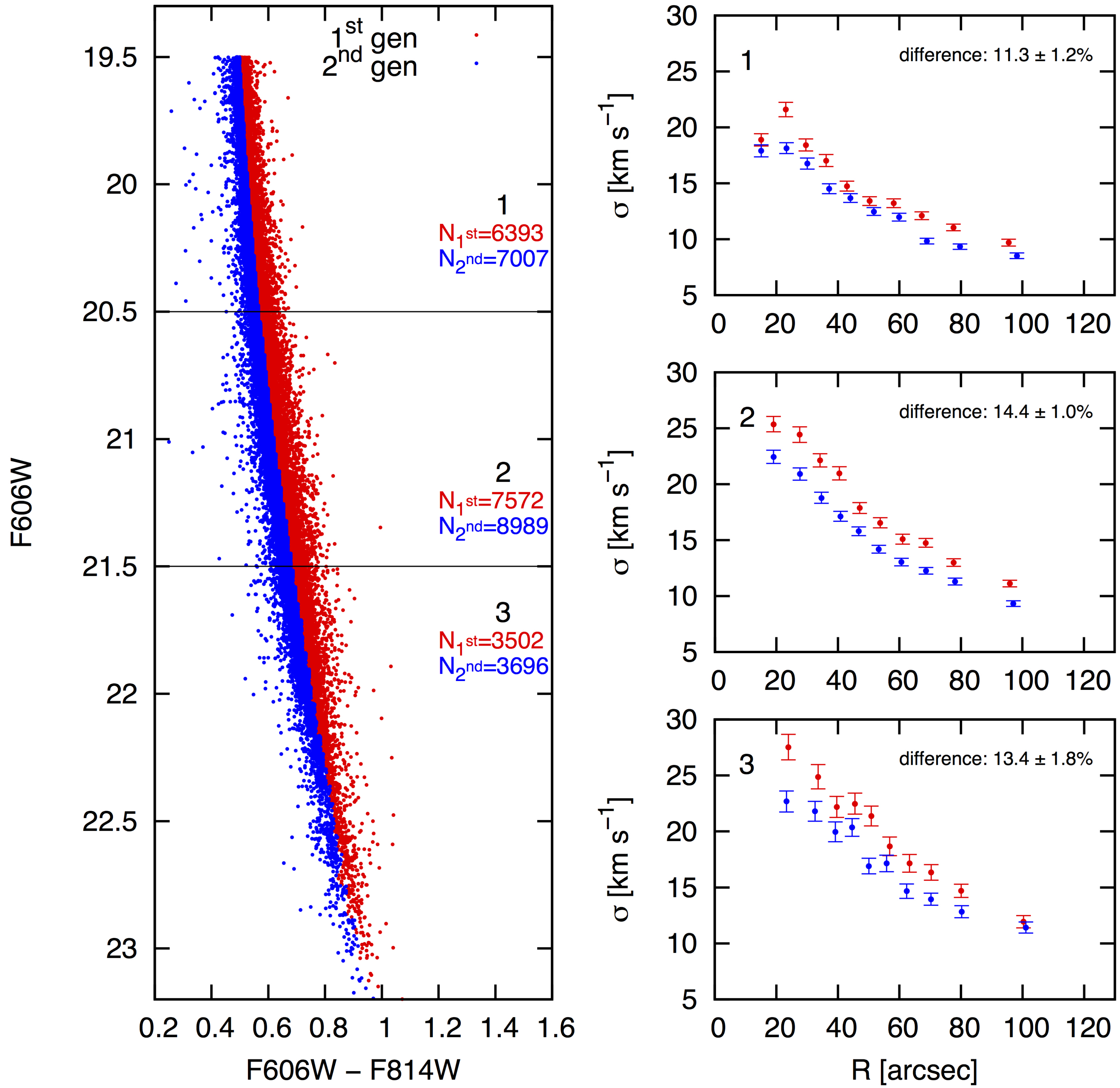

1st generation sample has dispersion ~13% higher than the 2nd generation

2nd generation is more compact

Bianchini, Bellini, Norris, et al. (in prep)

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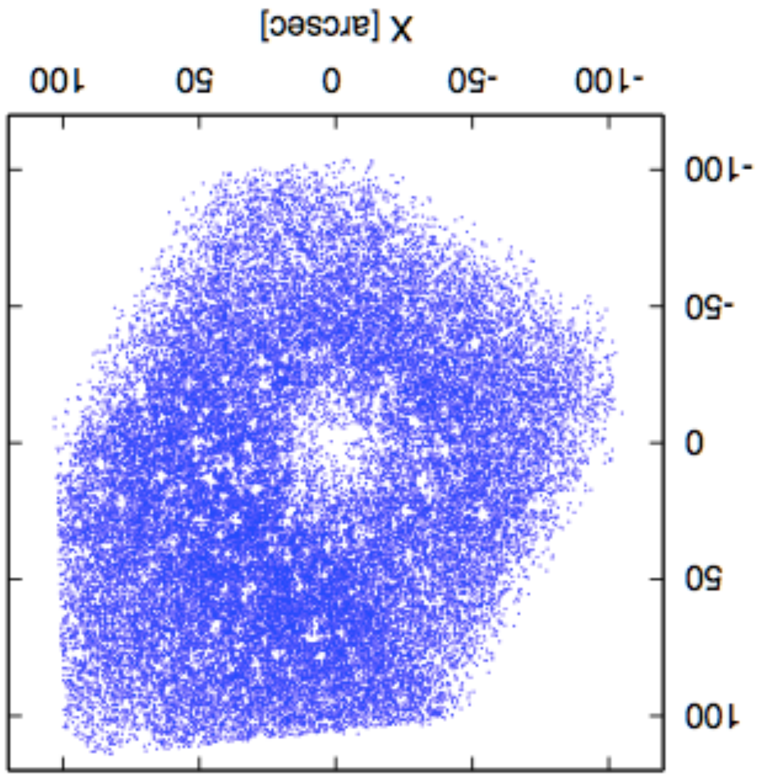

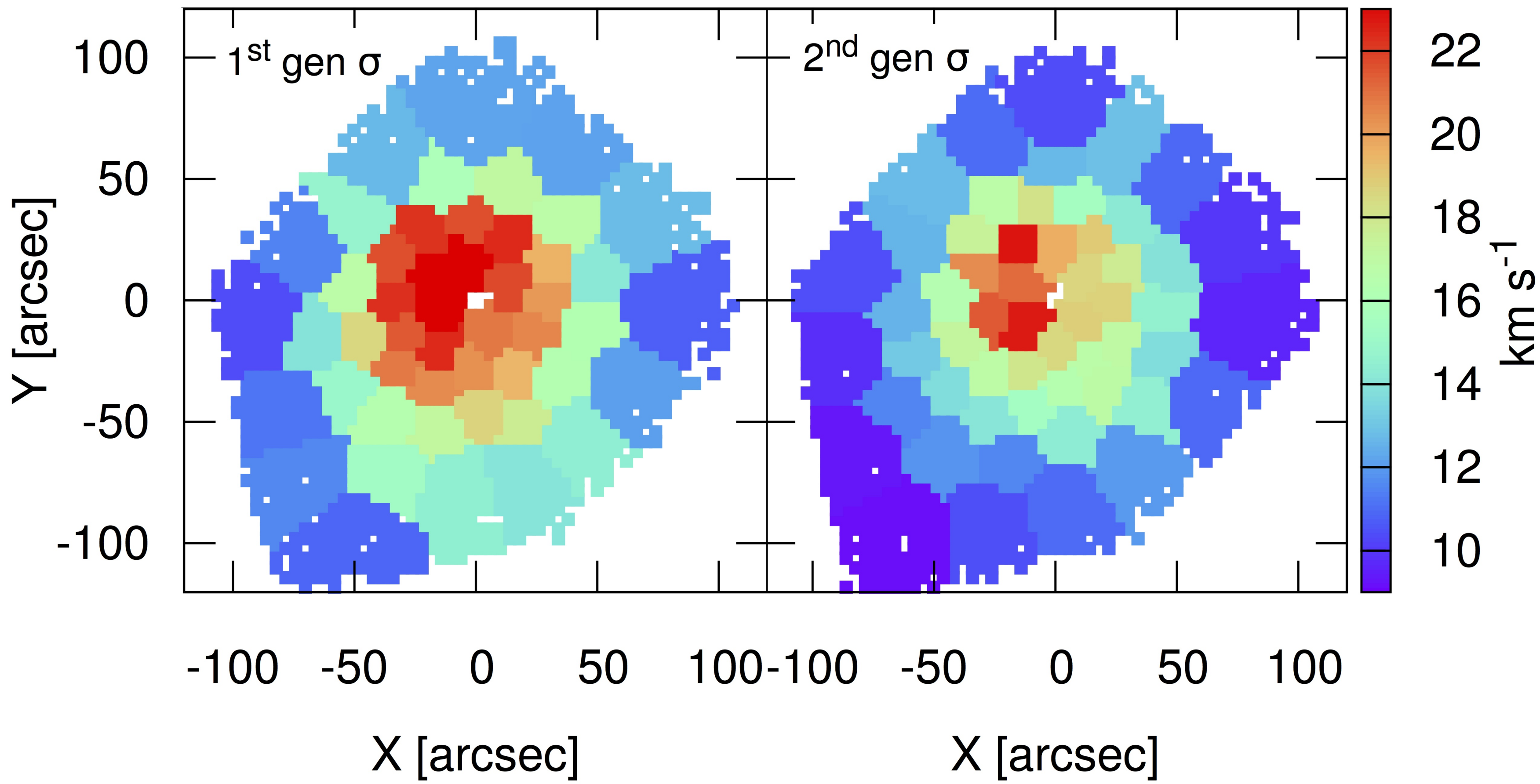

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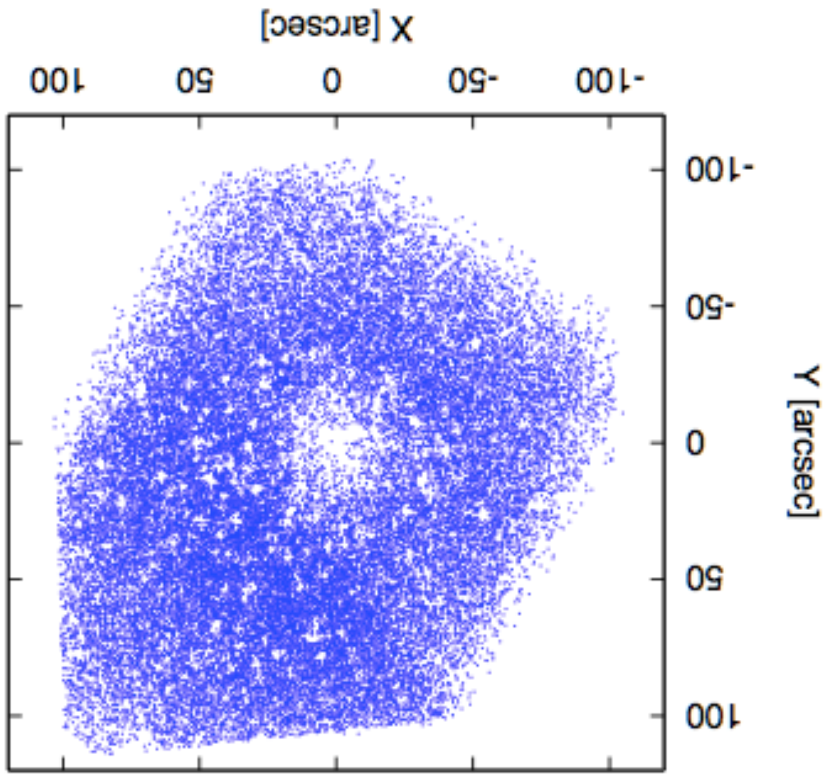

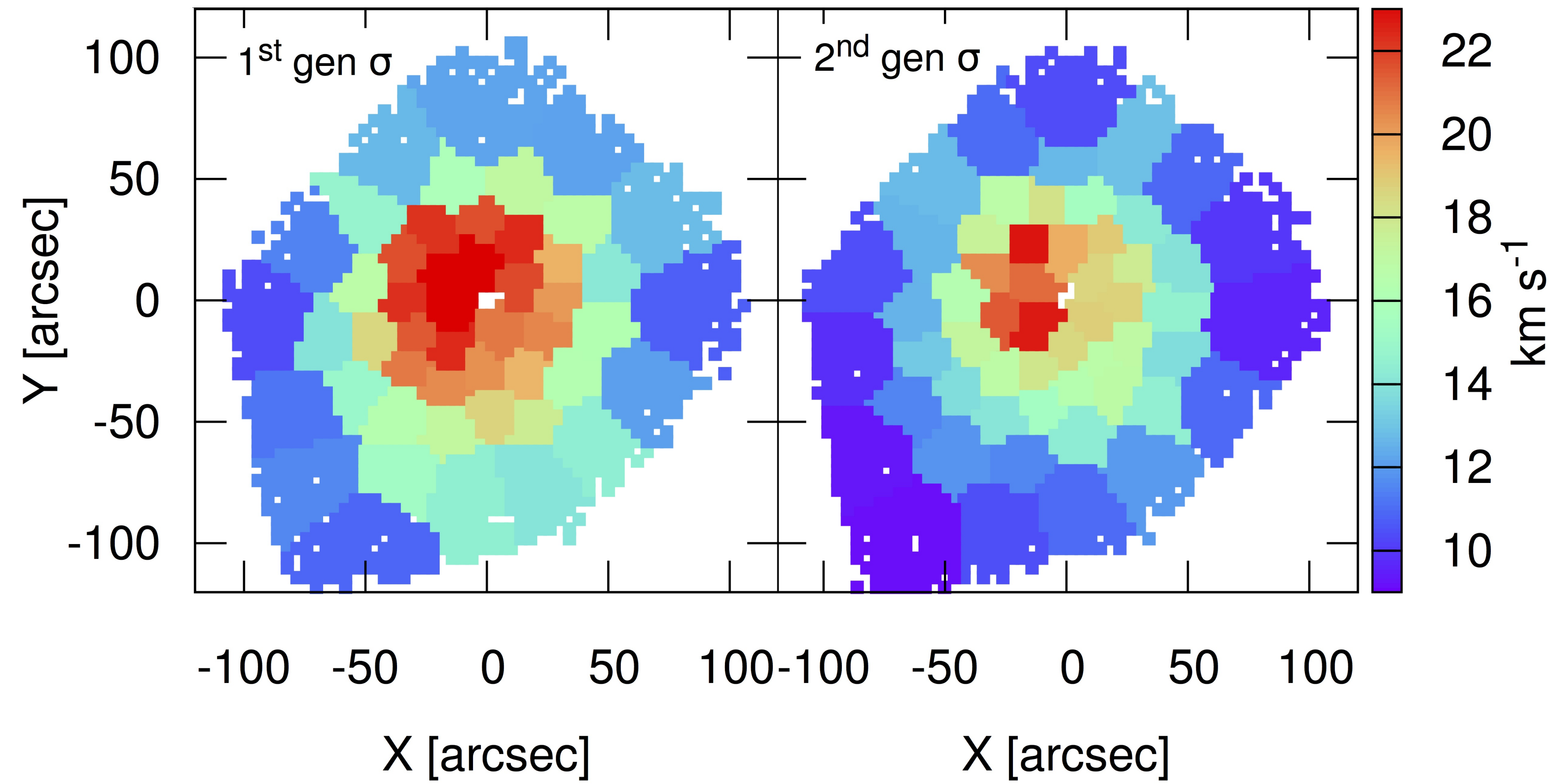

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$$\left(\frac{V}{\sigma}\right)_{2^{\mathrm{nd}}} \approx 3 \left(\frac{V}{\sigma}\right)_{1^{\mathrm{st}}}$$

Supports the idea that GCs had multiple star forming periods - likely formed within dwarf galaxies

Observations

Observations:

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+

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LUCI spectroscopy to obtain LOS velocities

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HST Proper motions

=

Exquisitely detailed large scale dynamical and stellar population picture of each GC

Conclusions

Started preparatory and science observations with LBC and LUCI.

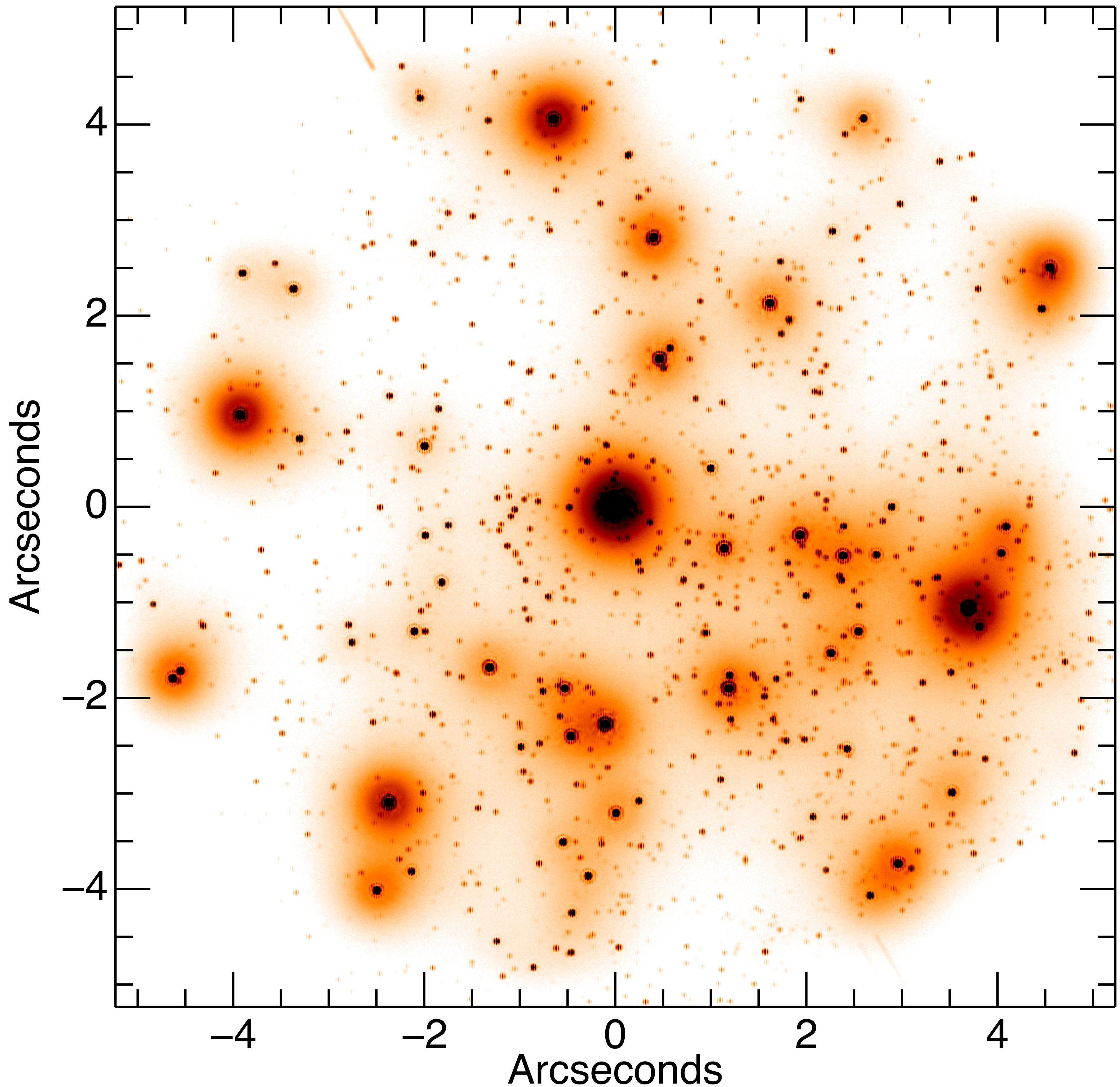
HST proper motions reveal the presence of kinematically distinct sub-populations

- Supports the formation of GCs in dwarf galaxies

LN-MCAO will significantly improve the study of the inner regions of GCs

Full LINC-NIRVANA will revolutionise the study of the inner regions of GCs

NIRVANA



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