M54: A key to the connection between globular and nuclear star clusters

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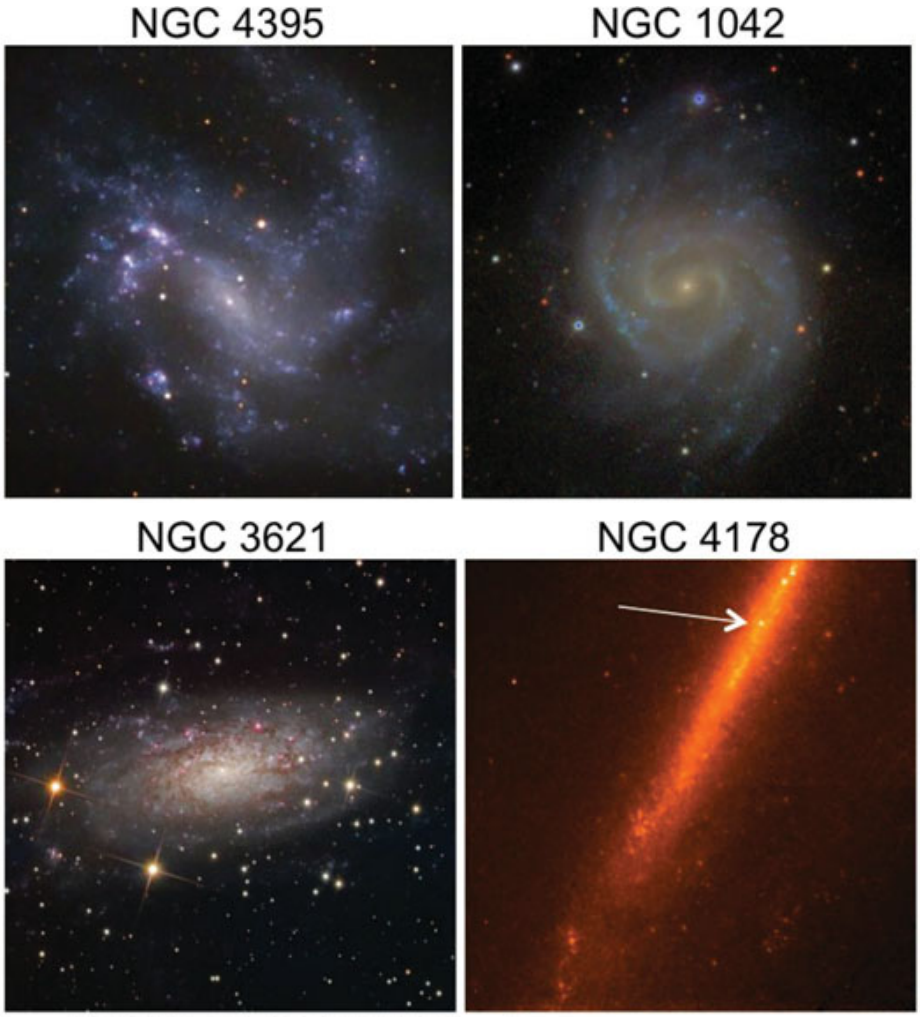
December 5th, 2016

Nuclear star clusters (NSCs)



Böker 2009

- 75% in late-type (Scd-Sm) spirals (Böker et al. 2002)
- 50% in earlier-type (Sa-Sc) spirals (Carollo et al. 1997)
- 70% in spheroidal (E & S0) galaxies (Cote et al. 2006)

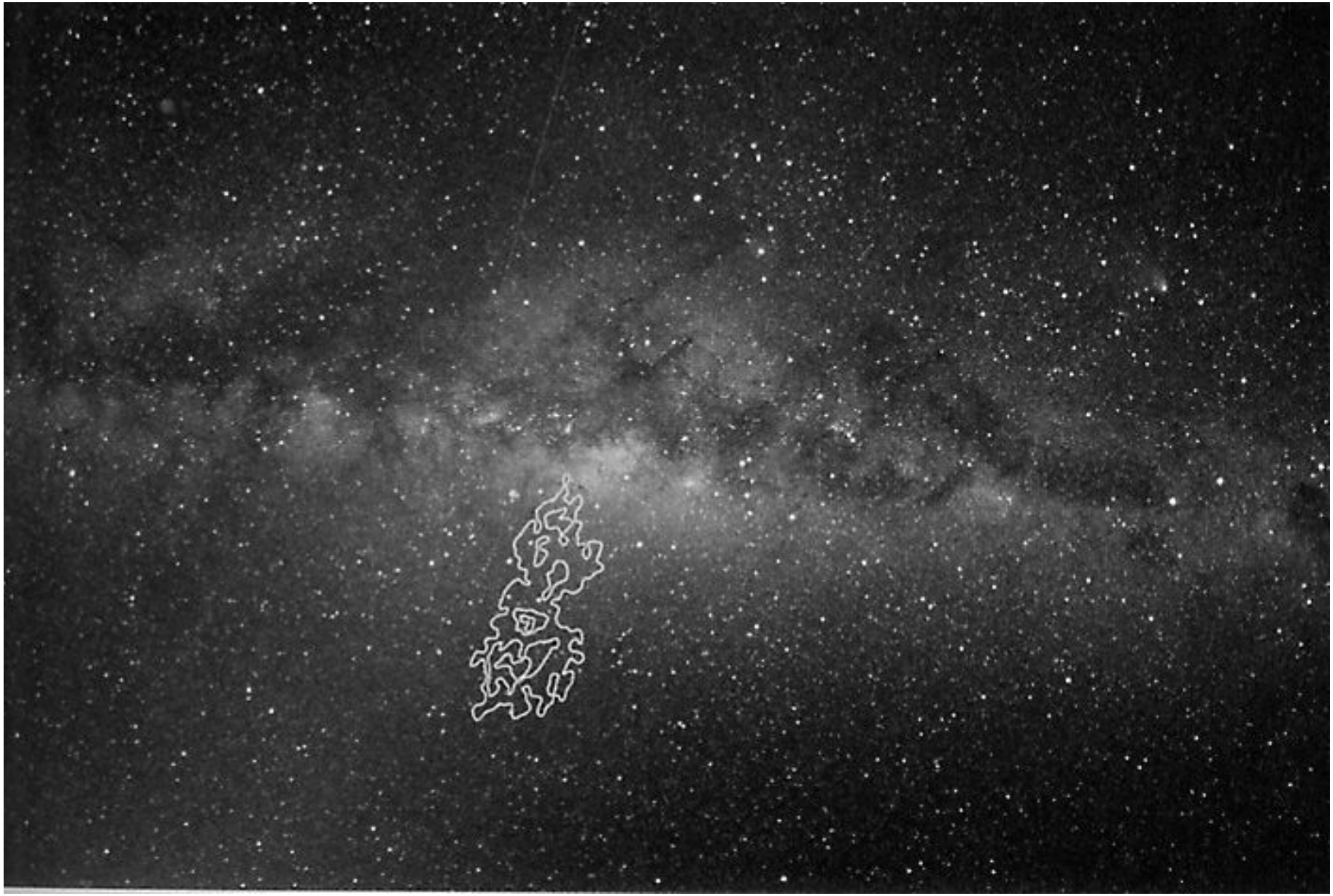
- Considerably more luminous than typical globular clusters (GCs).

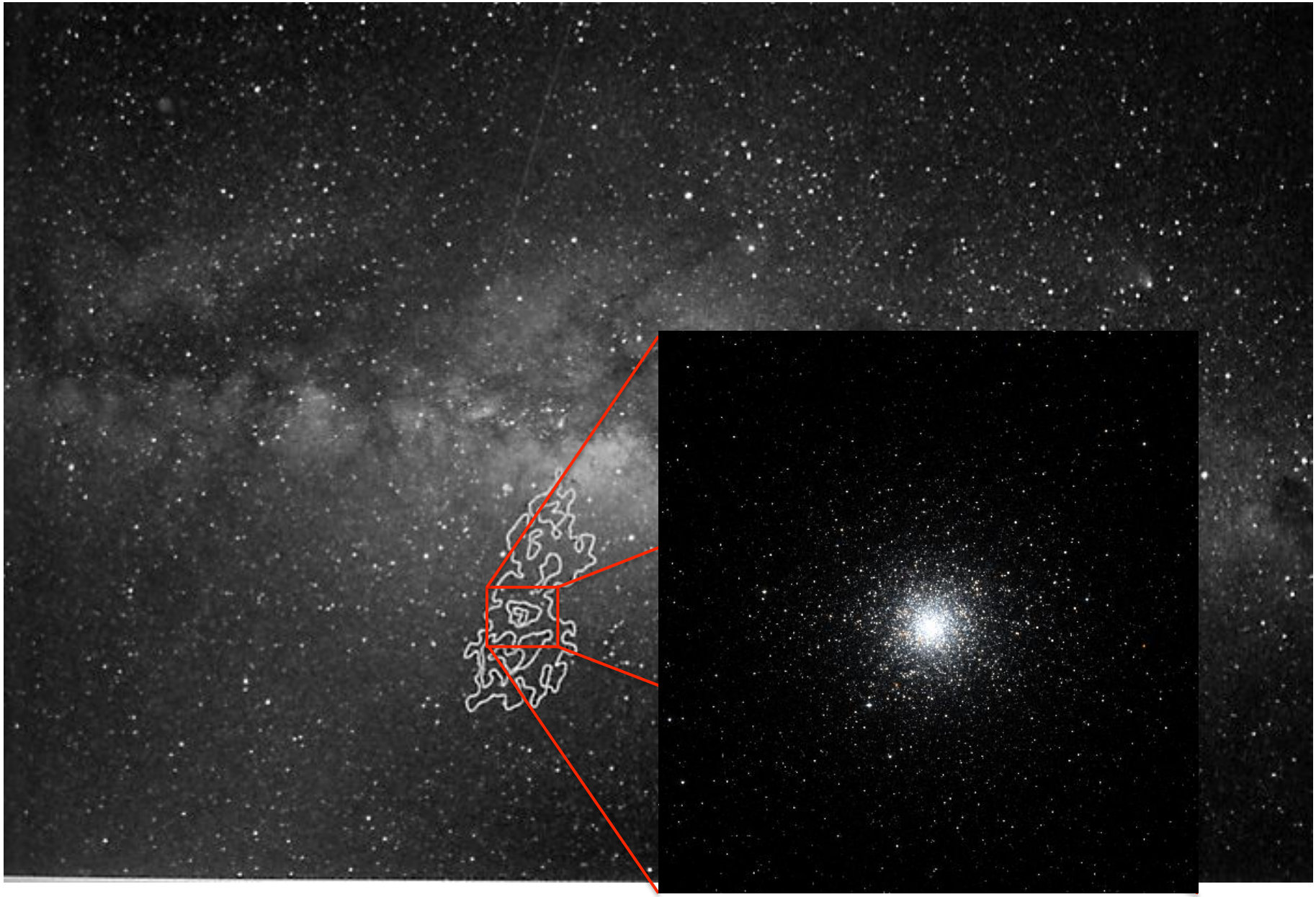
  M_I: between -14 and -10

  (Böker et al. 2002, Cote et al. 2006).

- Typical half-light radius of 2-5 pc (Böker et al. 2004, Cote et al. 2006).

- Mass ~ 10^6 - 10^7 $M_\odot$ (Walcher et al. 2005).





M54 (NGC 6715)

- Distance of 27.4 kpc (Layden & Sarajedini 2000).

HST ACS/WFC f814w+f606w

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- Stripped NSC in the Sagittarius dwarf spheroidal galaxy (Sgr).

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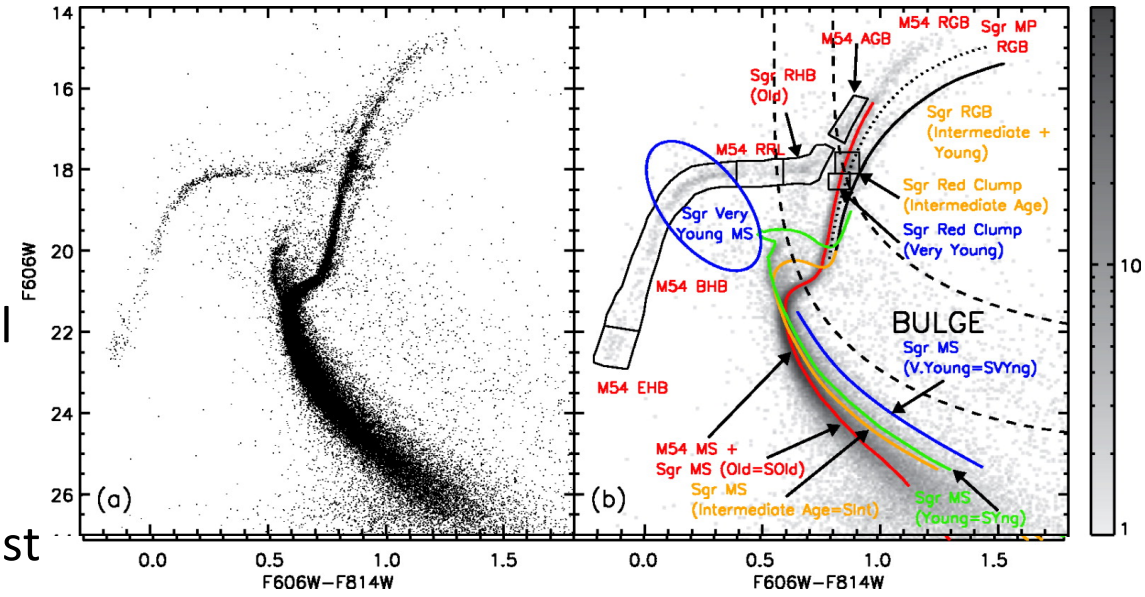
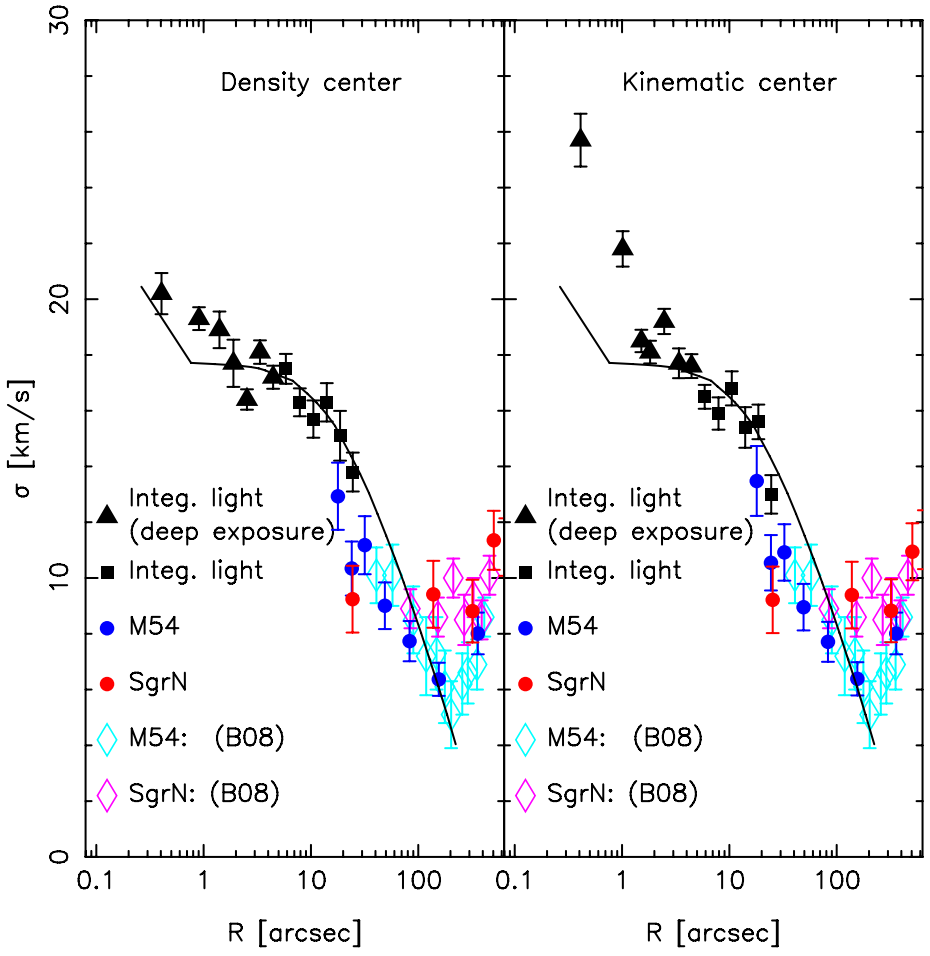
- CMD shows an Blue HB and multiple MS of the M54+Sgr system.



Siegel et al. 2007

M54 (NGC 6715)



- Possible $10^4 M_\odot$ BH host (Ibata et al. 2009).

Ibata et al. 2009

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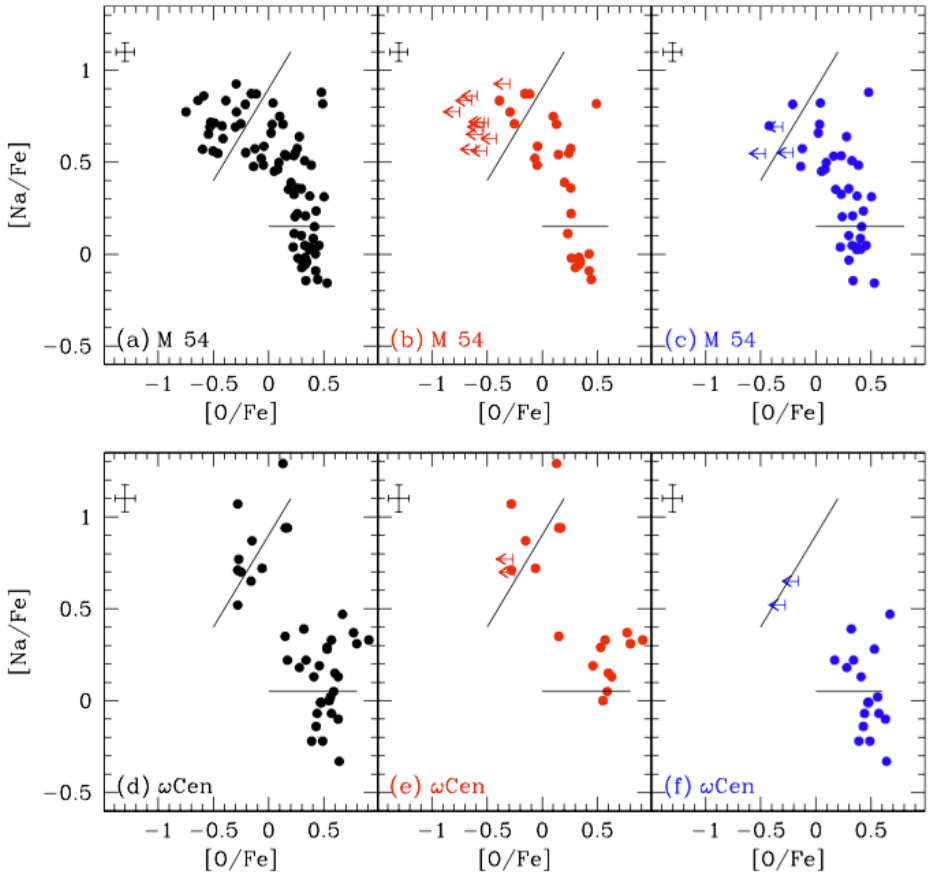

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- Large spread in O and Na abundances: strong Na-O anti-correlation (Carretta et al. 2010a)

Carretta et al. 2010a

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HST ACS/WFC f814w+f606w

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- An earlier phase of ωCen? (Carretta et al. 2010a)
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→ Remnant from the accreted Sgr and an excellent laboratory.

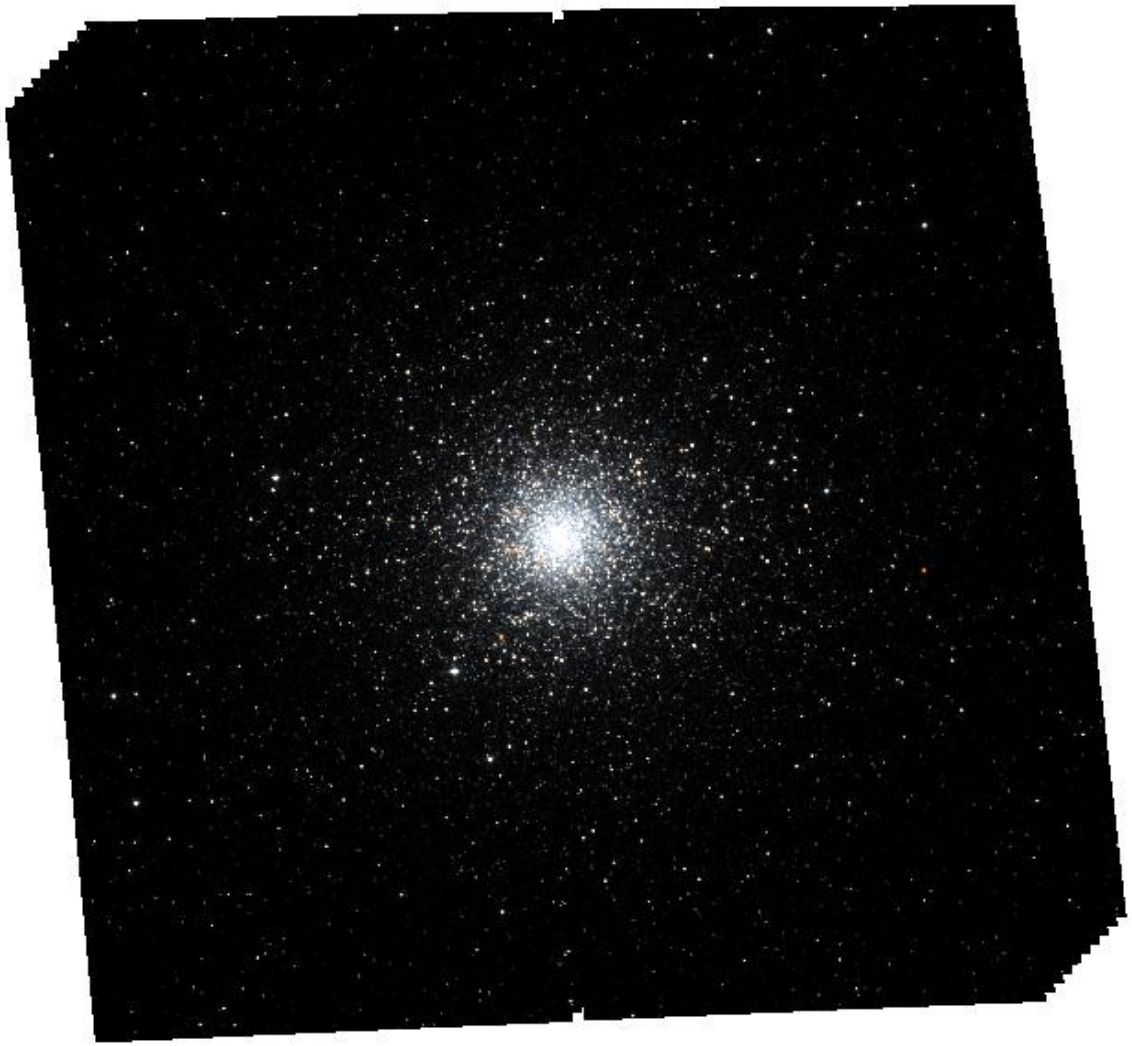
Main Goal

Revealing the formation history of M54

→ Constraining the dynamical properties and chemical enrichment.

→ Using comprehensive chemo-dynamical models.

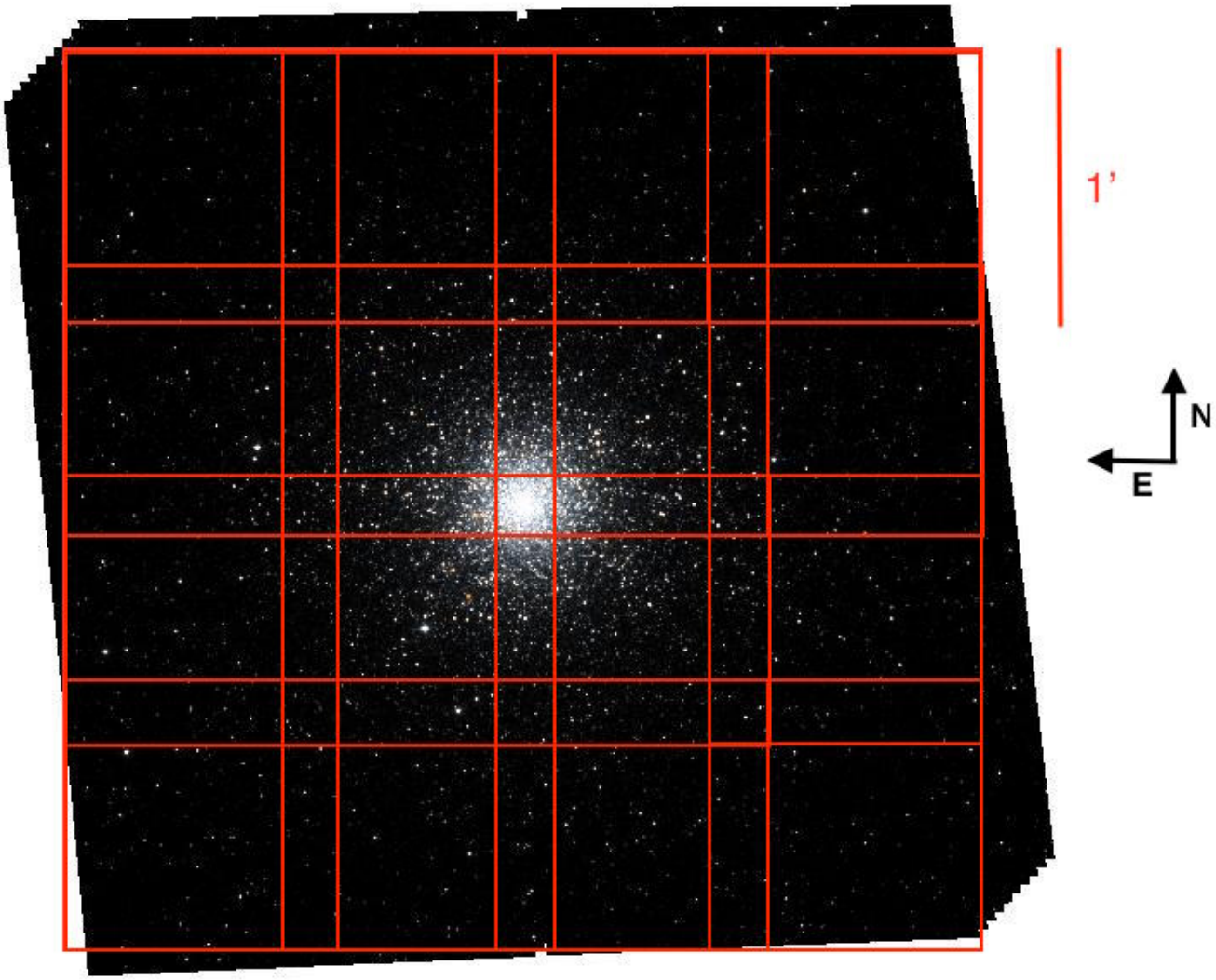
IFU MUSE Data



M54:

HST acs/wfc
f814w+f606w

IFU MUSE Data



R ~ 1500 -3500

16 pointings

~2.5 r_{eff}

(r_{eff} ~ 0.8', Monaco et al., 2005.)

FOV ~
3.25' x 3.25'

Seeing:
0.65 - 0.90 "

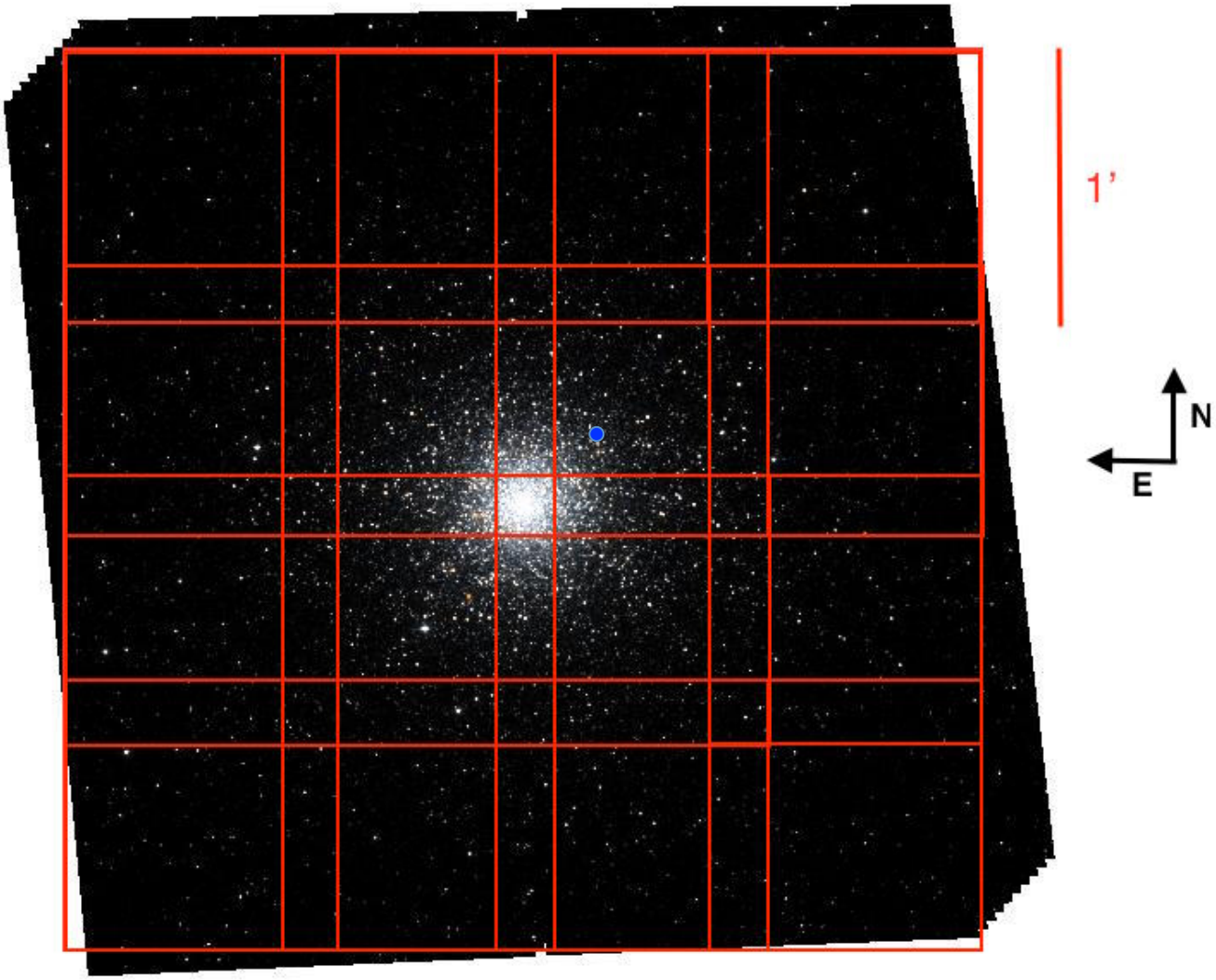
Stellar Kinematics of M54

Methods:

- **Spaxel by spaxel radial velocity estimation**

  → pPXF (Cappellari et al. 2012)

IFU MUSE Data



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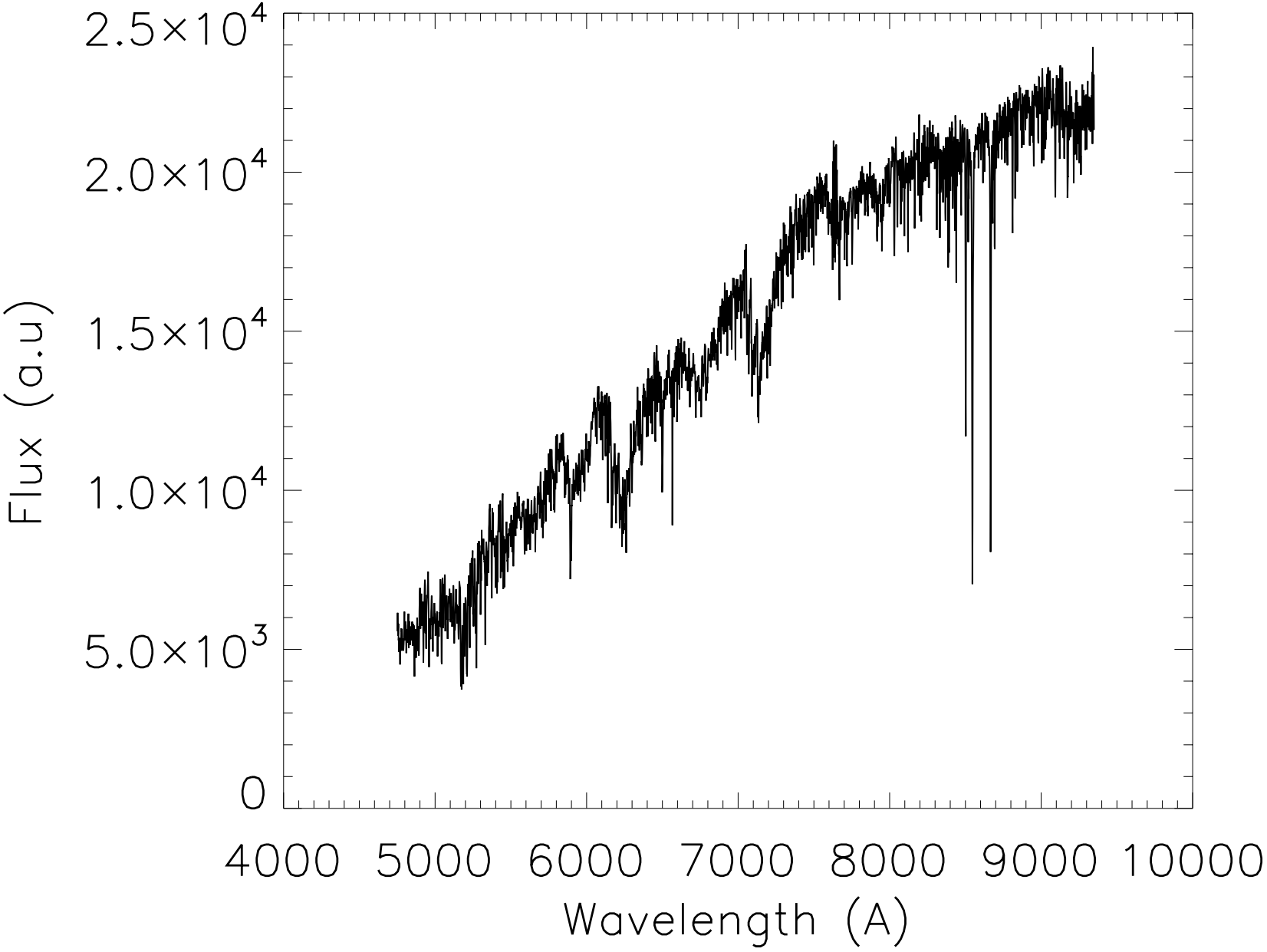
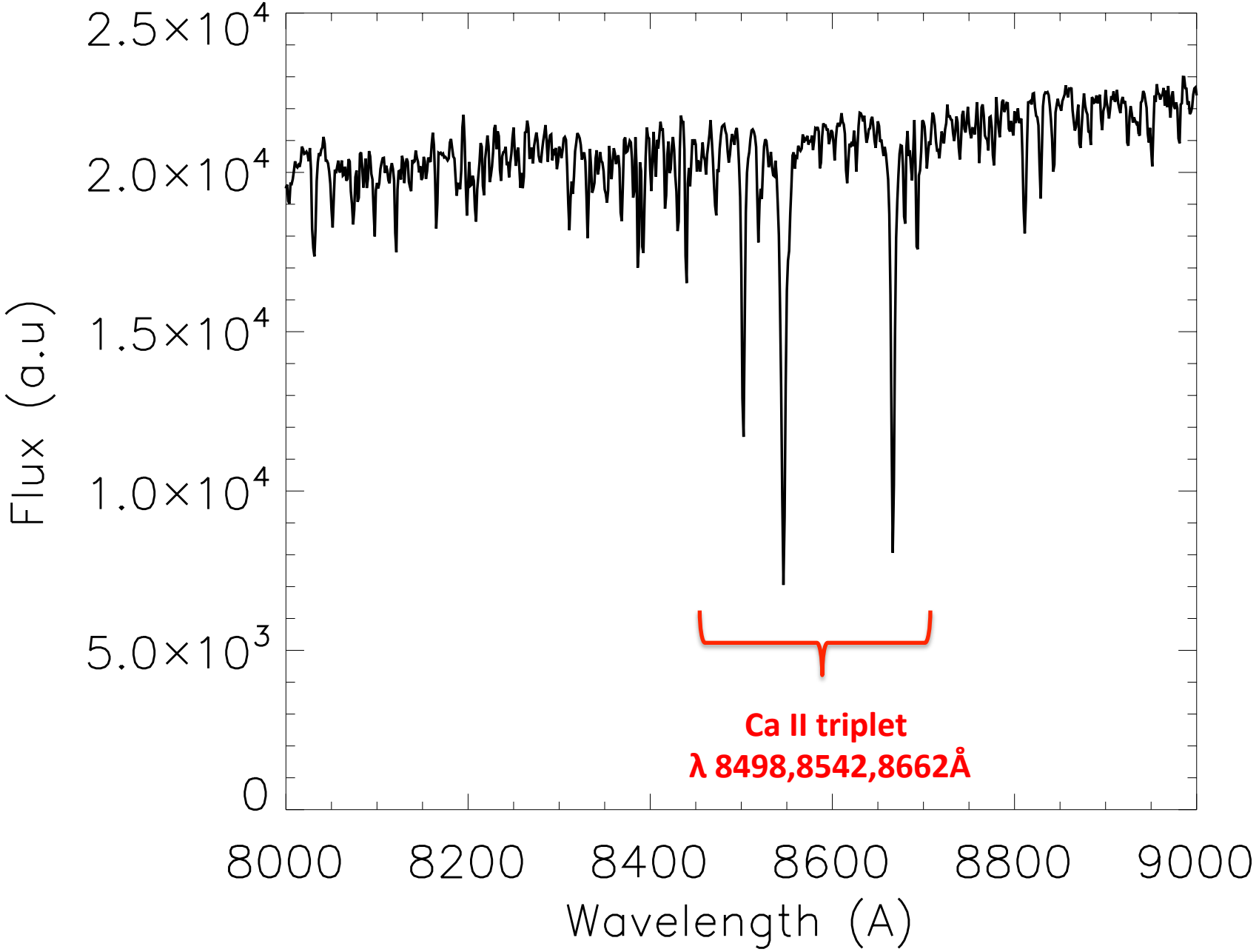
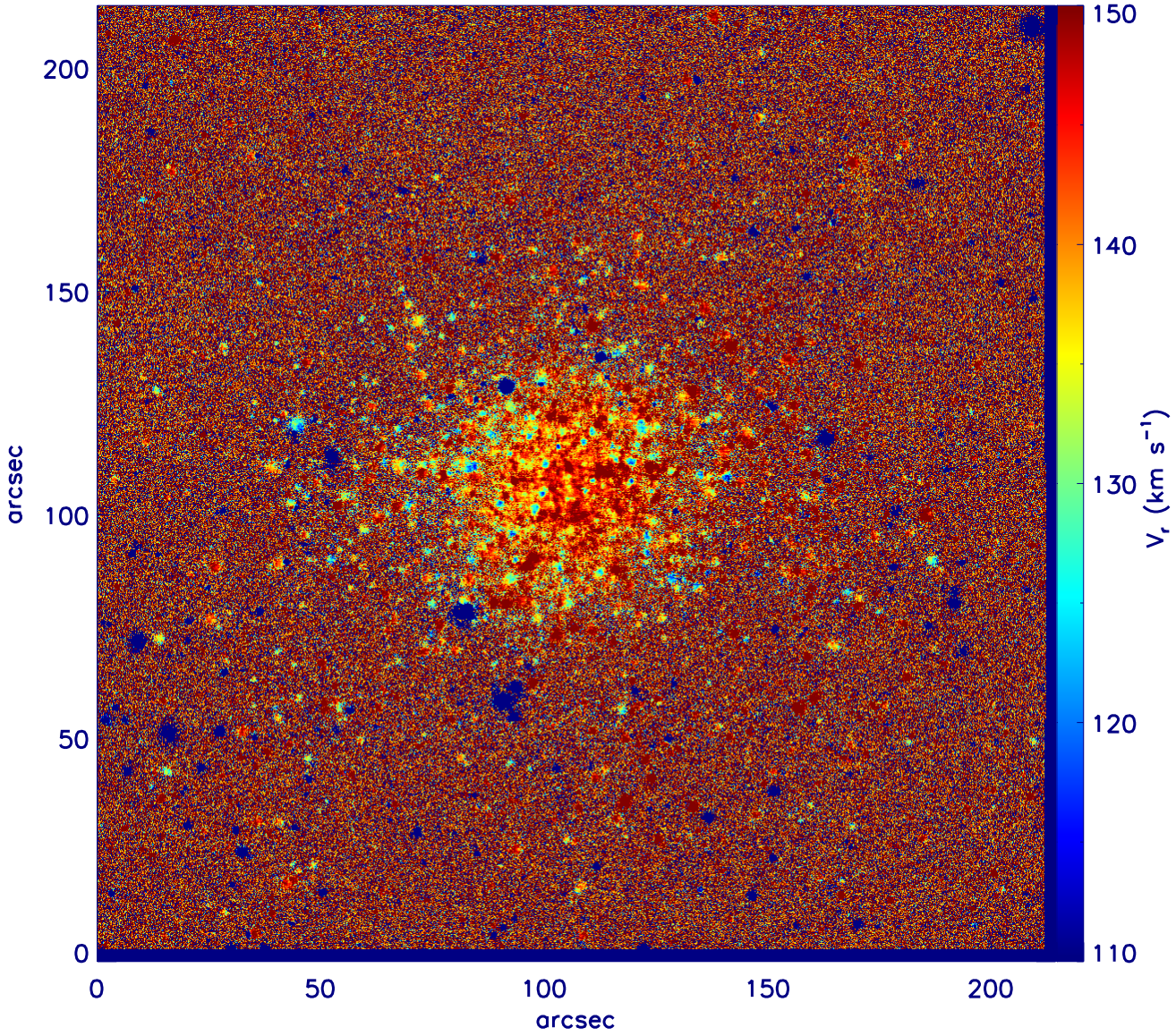

2.5×10^4
2.0×10^4
1.5×10^4
1.0×10^4
5.0×10^3
0
Flux (a.u)
4000
5000
6000
7000
8000
9000
10000
Wavelength (A)


2.5×10^4
2.0×10^4
1.5×10^4
1.0×10^4
5.0×10^3
0
Flux (a.u)
8000
8200
8400
8600
8800
9000
Wavelength (A)
Ca II triplet
λ 8498,8542,8662Å

Spaxel by spaxel radial velocity map



V_r = 140.9 ± 0.4 km/s
(Bellazzini et al. 2008)

Alfaro-Cuello et al. in prep

Stellar Kinematics of M54

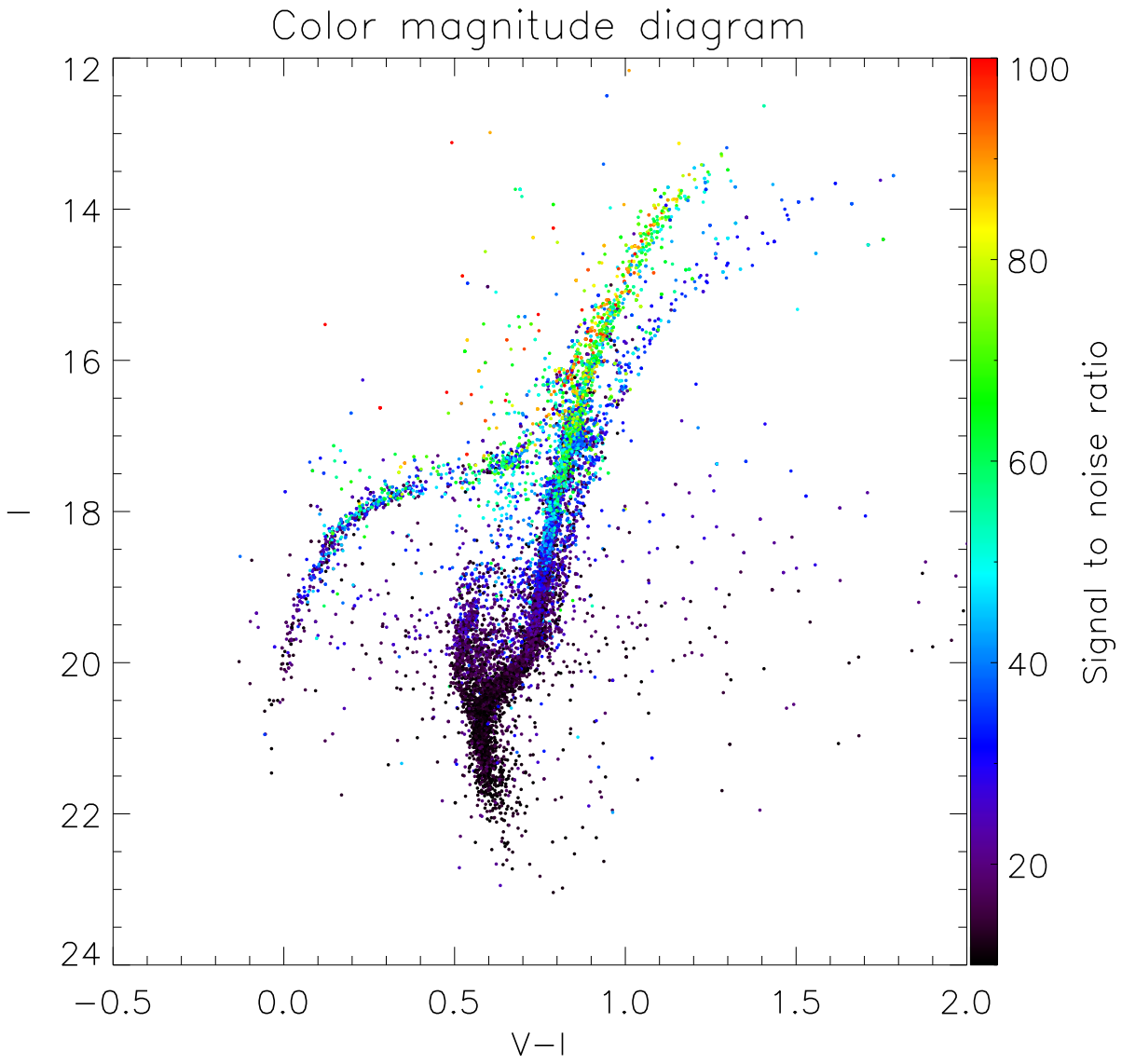
Methods:

- Spaxel by spaxel radial velocity estimation

  → pPXF (Cappellari et al. 2012)

- **Extraction of single stellar spectra**

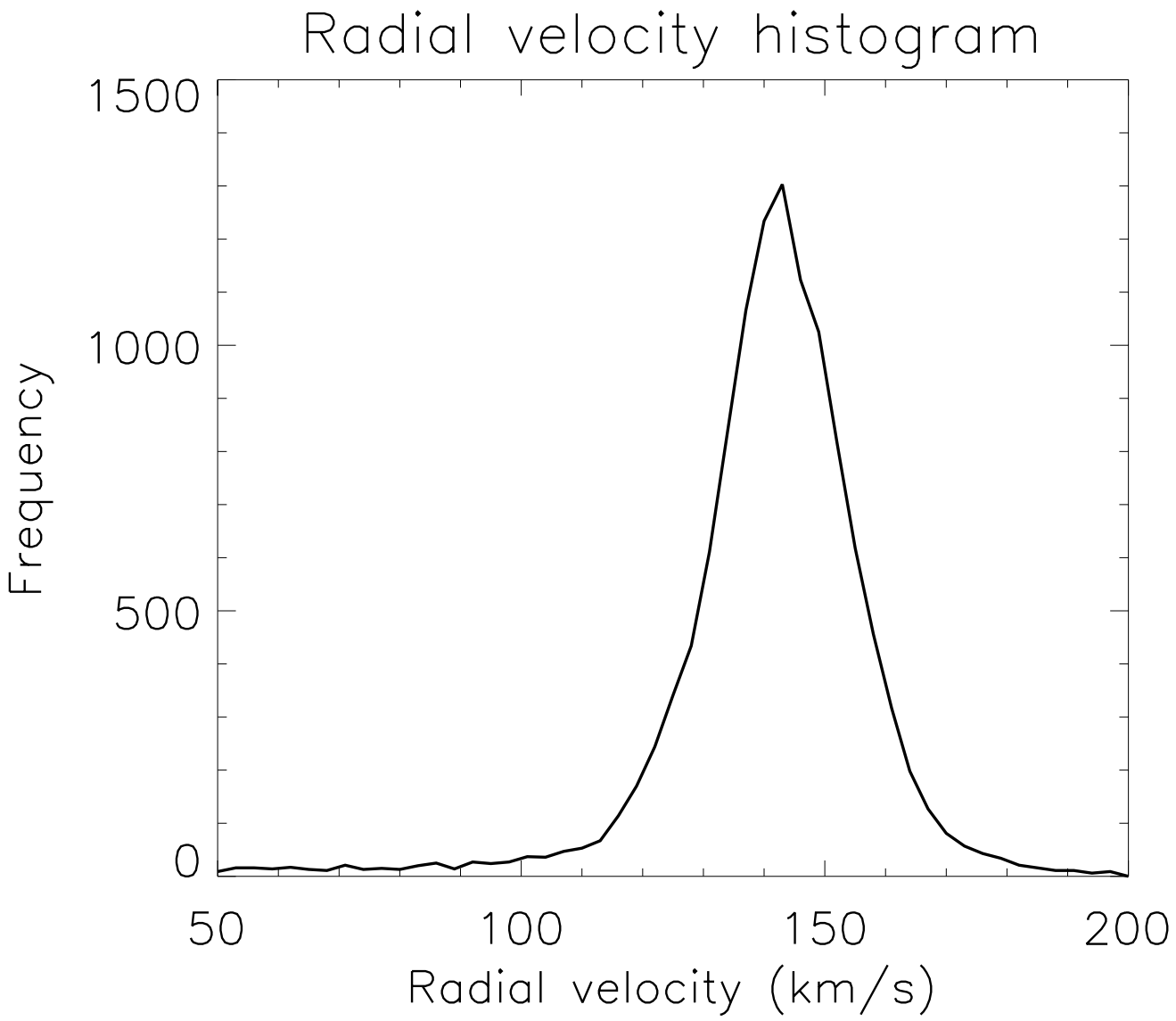
  → PampelMuse (Kamann et al. 2013) based on HST photometry.



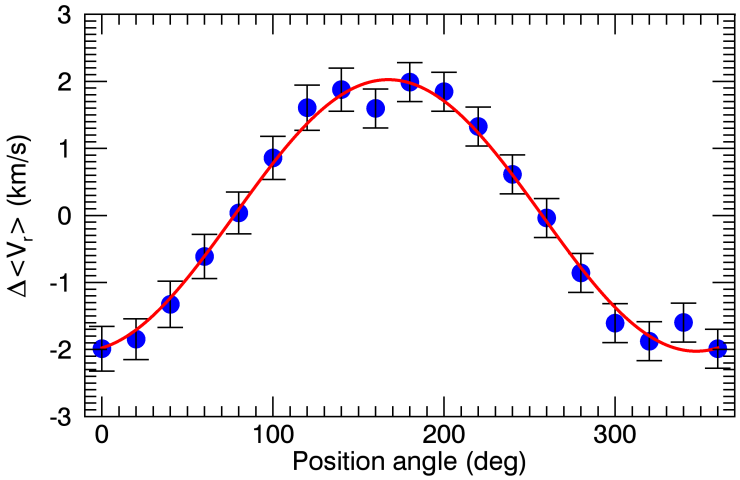
~ 10000 Single stellar spectra

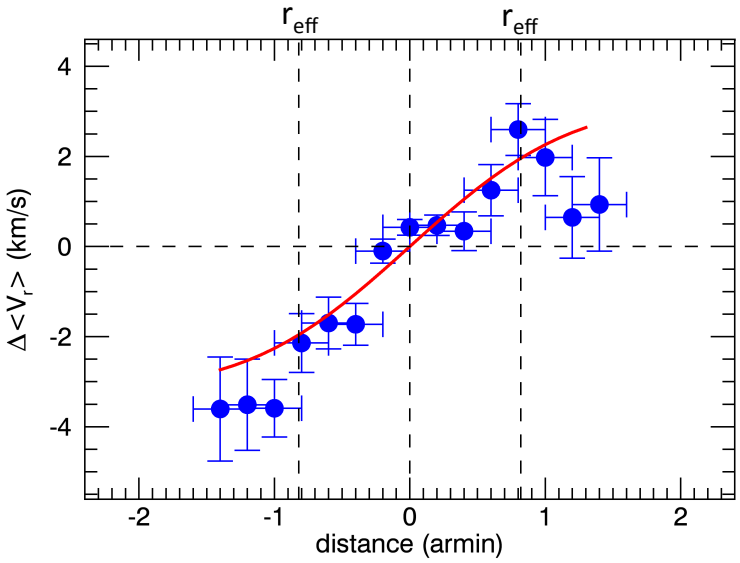
→ S/N > 10

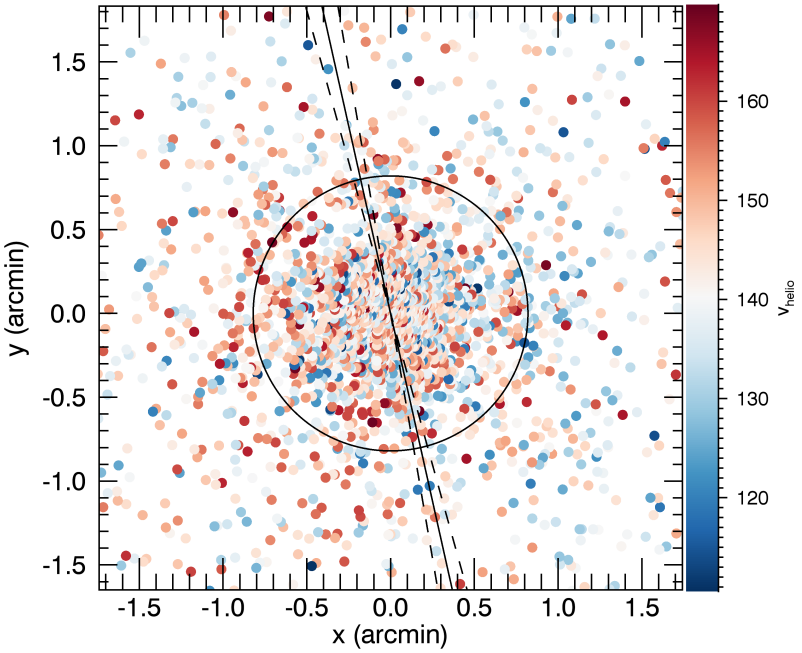
Alfaro-Cuello et al. in prep


Radial velocity histogram
1500
1000
500
0
Frequency
50
100
150
200
Radial velocity (km/s)

Rotation detection





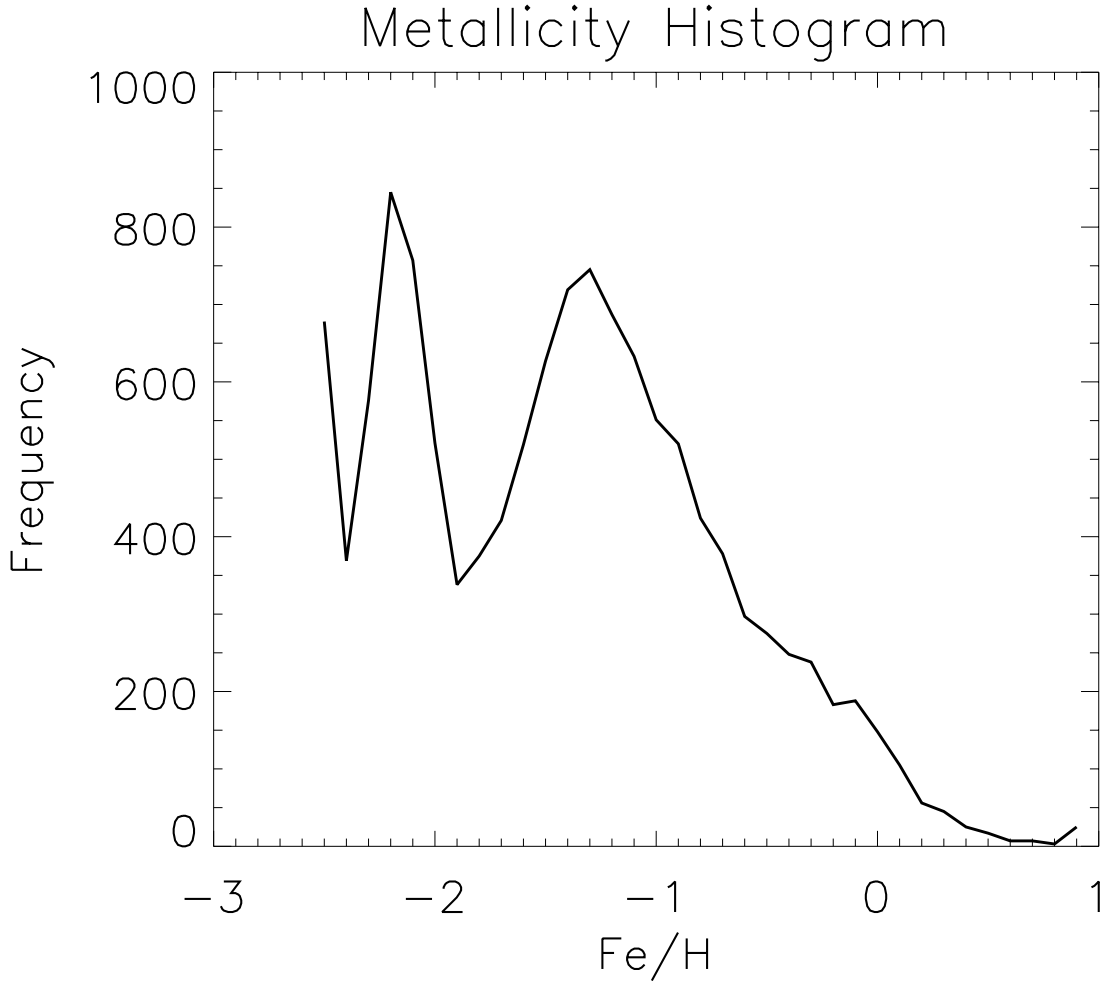


M54 (NGC 6715) = 4334 stars.
Rotation Axis = 167.40 +/- 2.88 degrees
Rotation Amplitude = 1.01 +/- 0.09 km/s
Mean radial velocity = 142.54 +/- 0.16 km/s

V_r = 140.9 ± 0.4 km/s (Bellazzini et al. 2008)

Alfaro-Cuello et al. in prep

Star properties results (preliminary)



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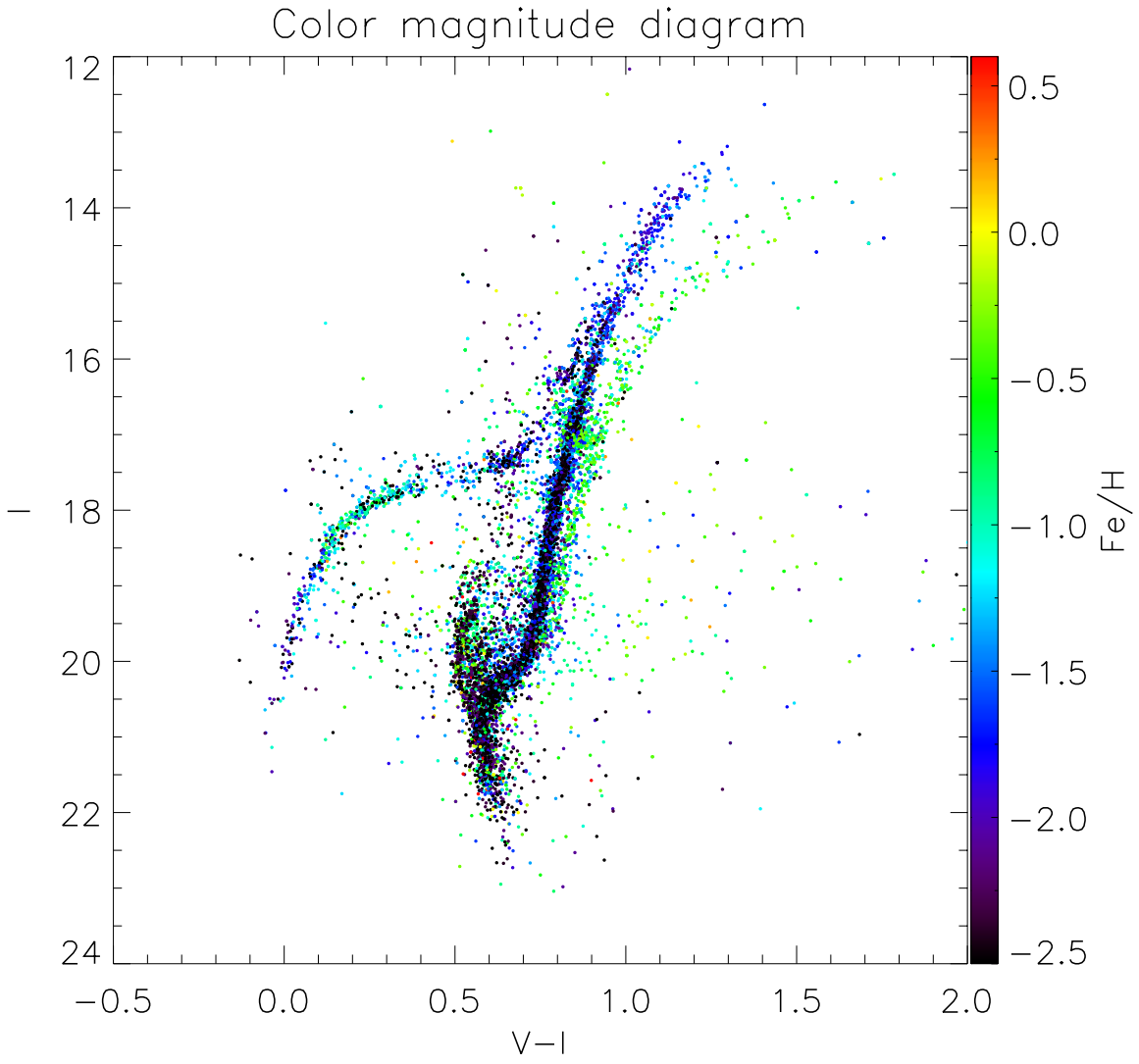
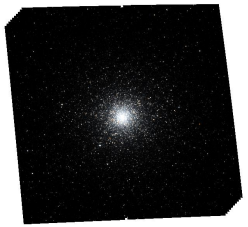
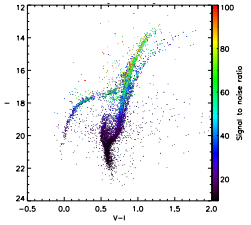


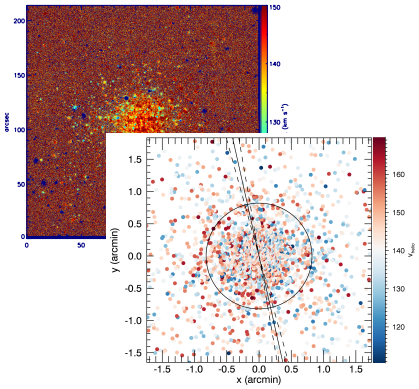
Summary

M54 is an excellent laboratory to look for the connection between GCs and NSCs through its formation history study.

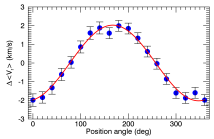


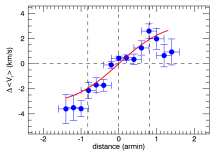


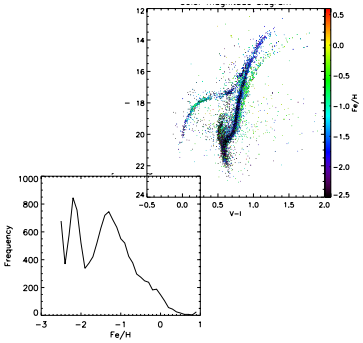
M54 presents a very complex formation history.



Kinematic extraction: 10^4 single stellar spectra in M54.





Detection of slow rotation, what can tell us about the origin of this object.

Firsts steps to constrain the dynamical properties and chemical enrichment of M54 in unprecedented detail.