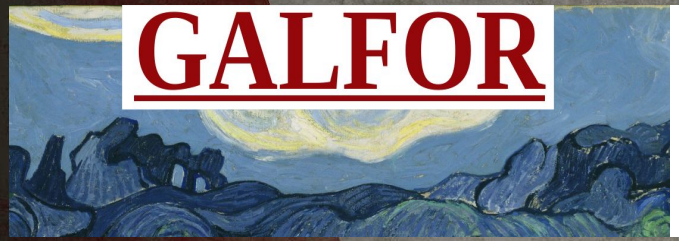
Università degli Studi di Padova

eWEASS Lyon 2019

Kinematics of Multiple Stellar Populations

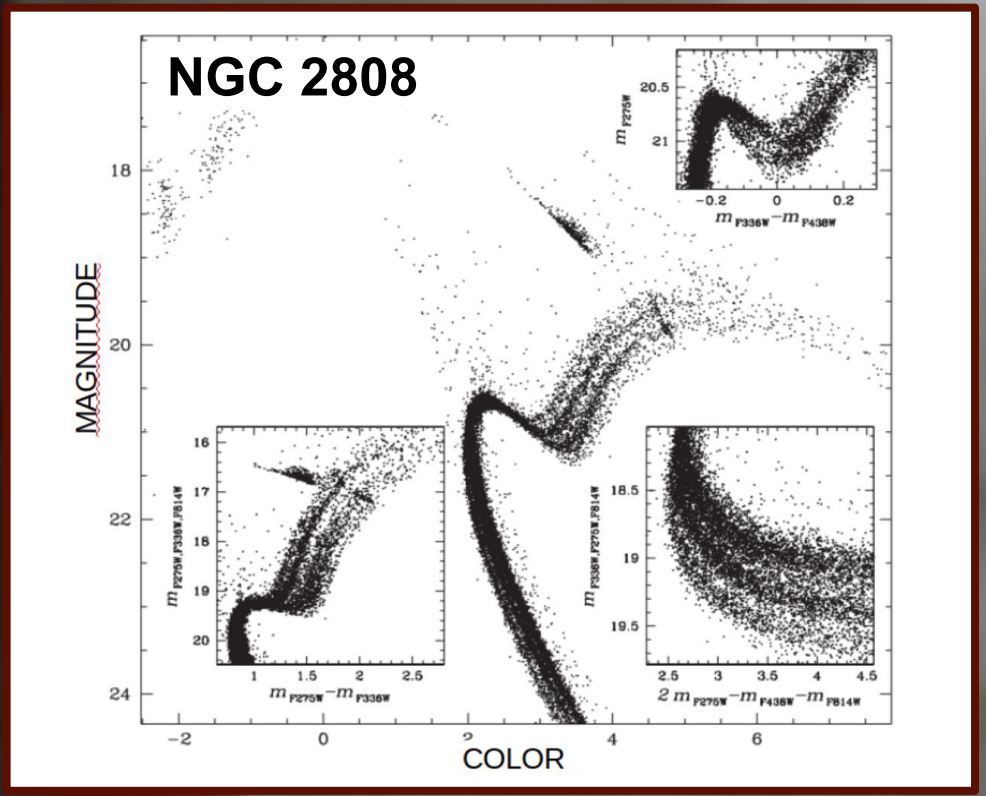


GALFOR

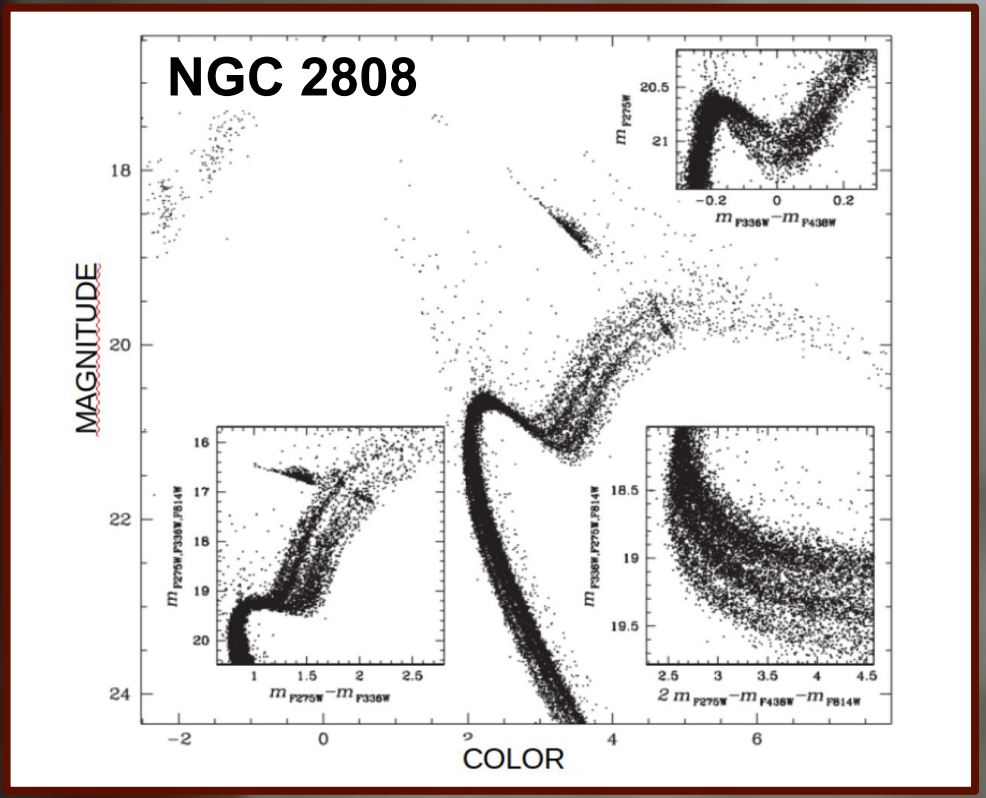
erc
European Research Council
Established by the European Commission

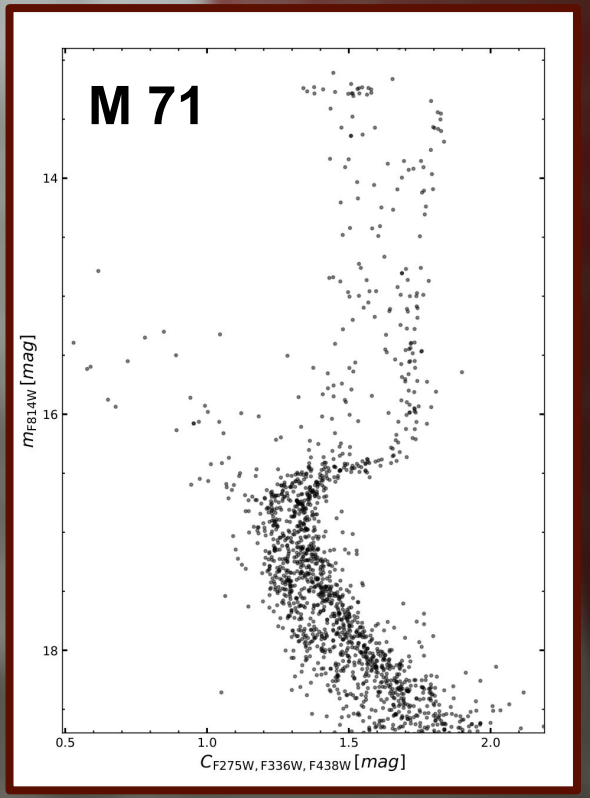
Giacomo Cordoni

Multiple Stellar Populations

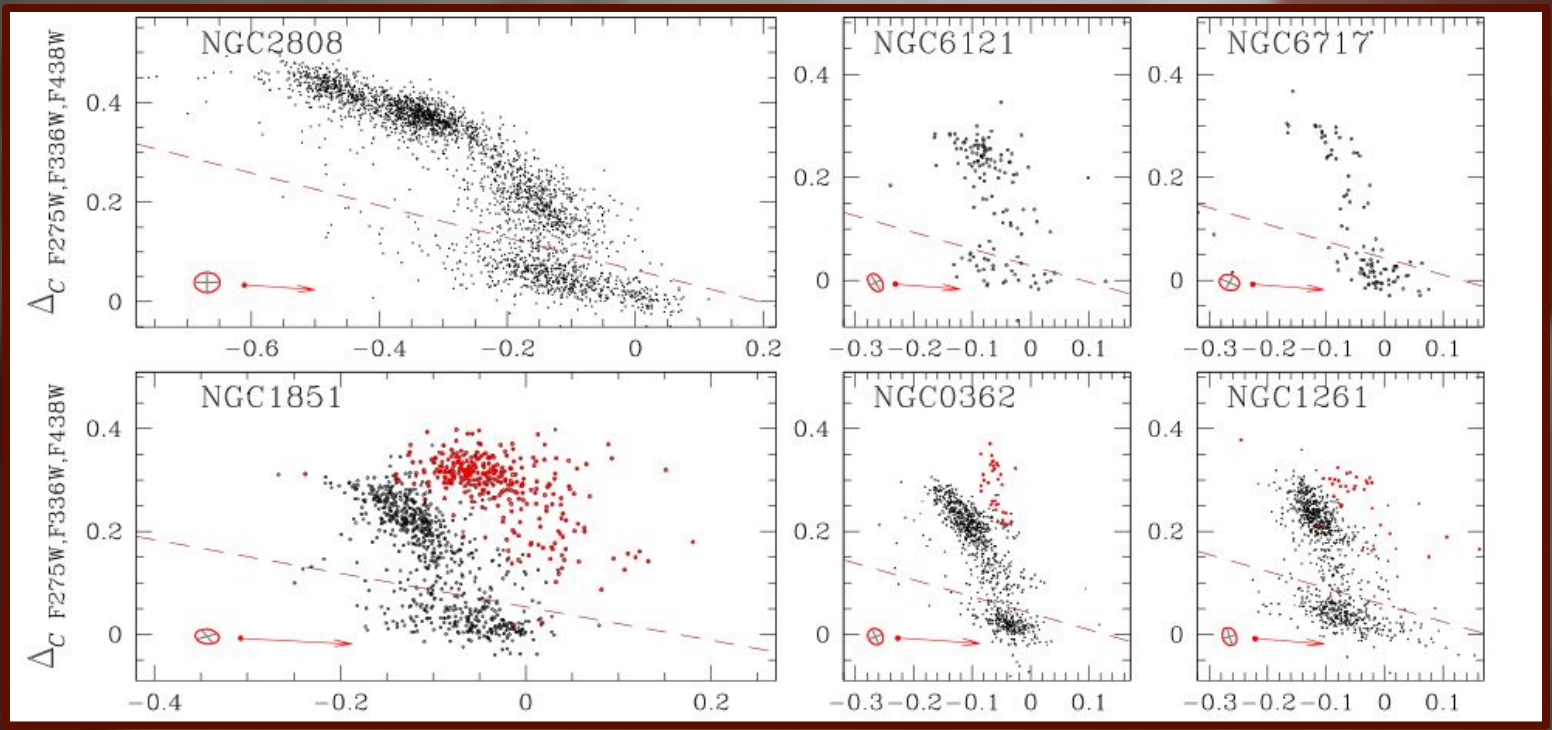


Multiple Stellar Populations



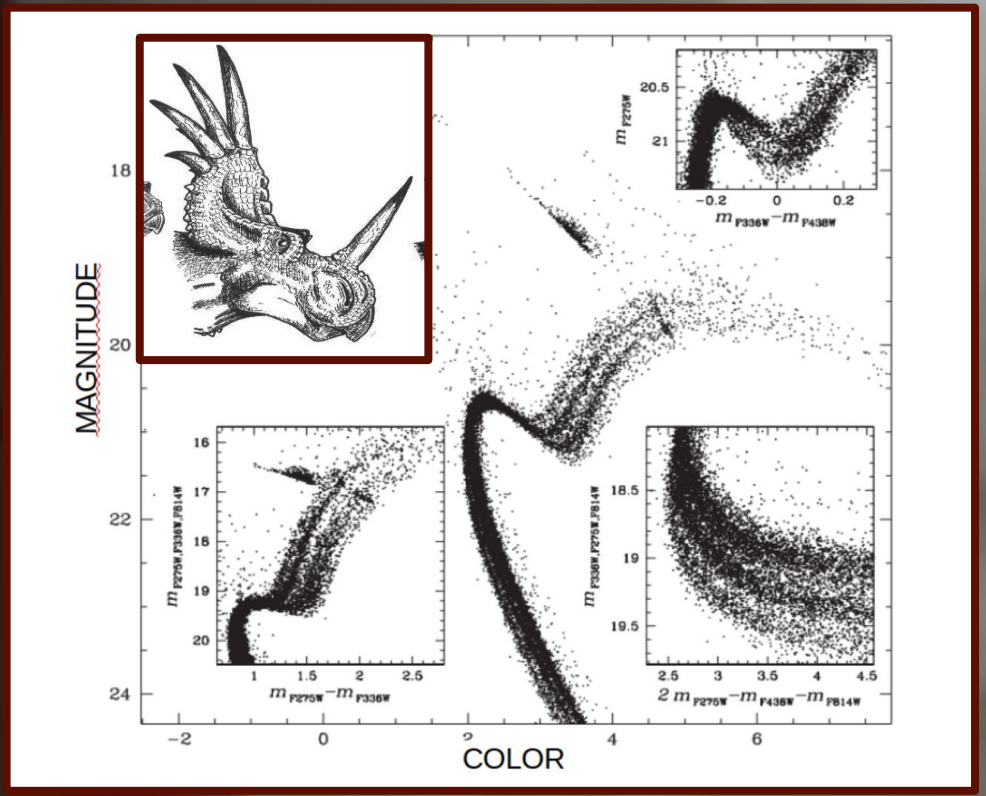


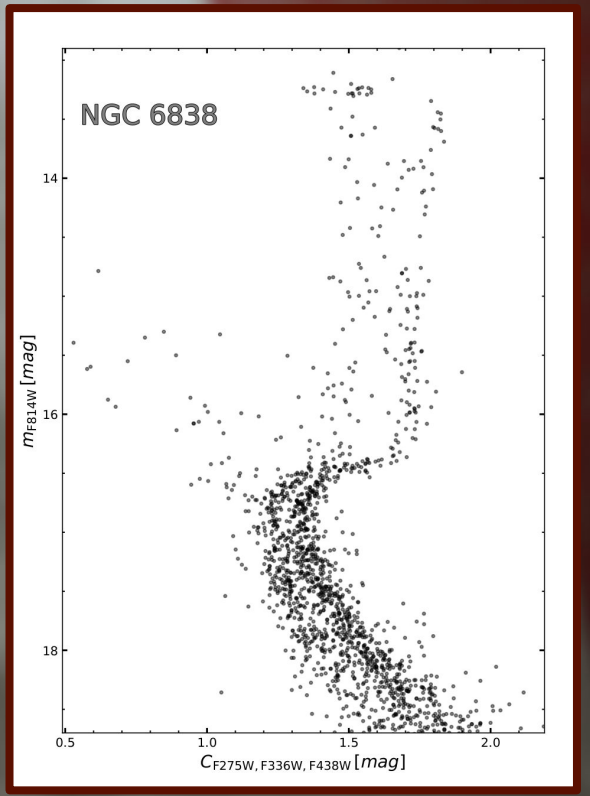
Multiple Stellar Populations



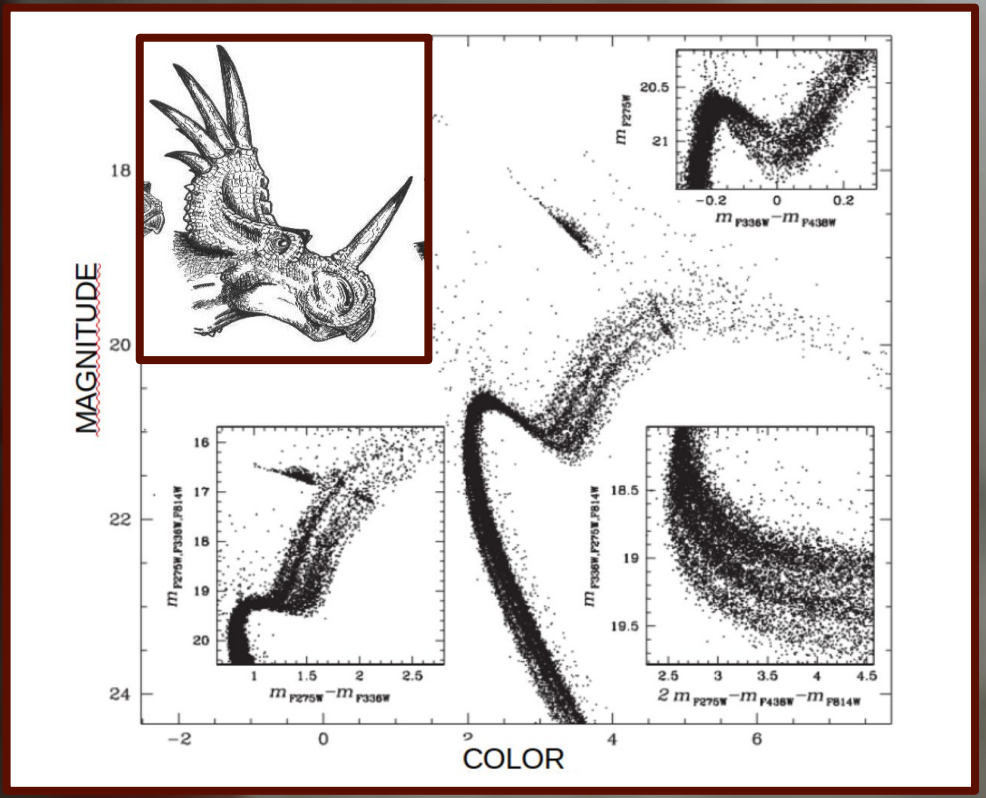
Milone et al. 2017

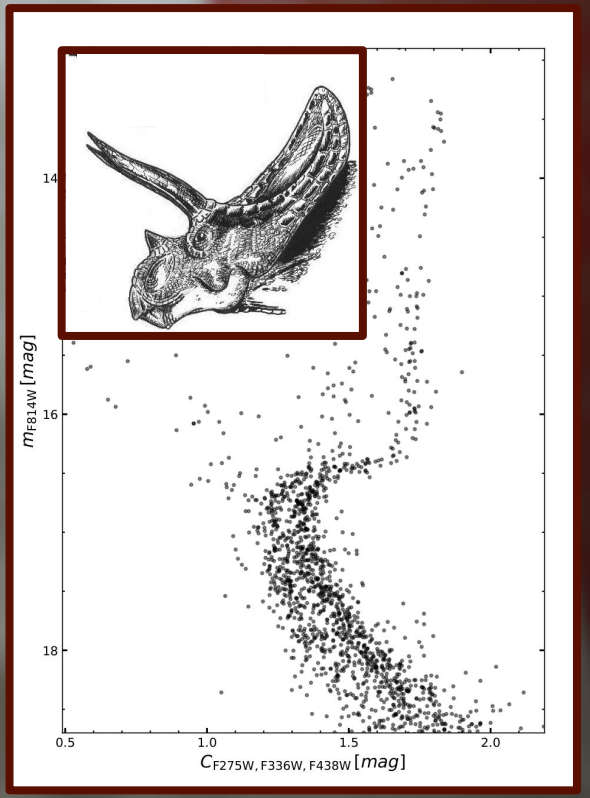
Multiple Stellar Populations



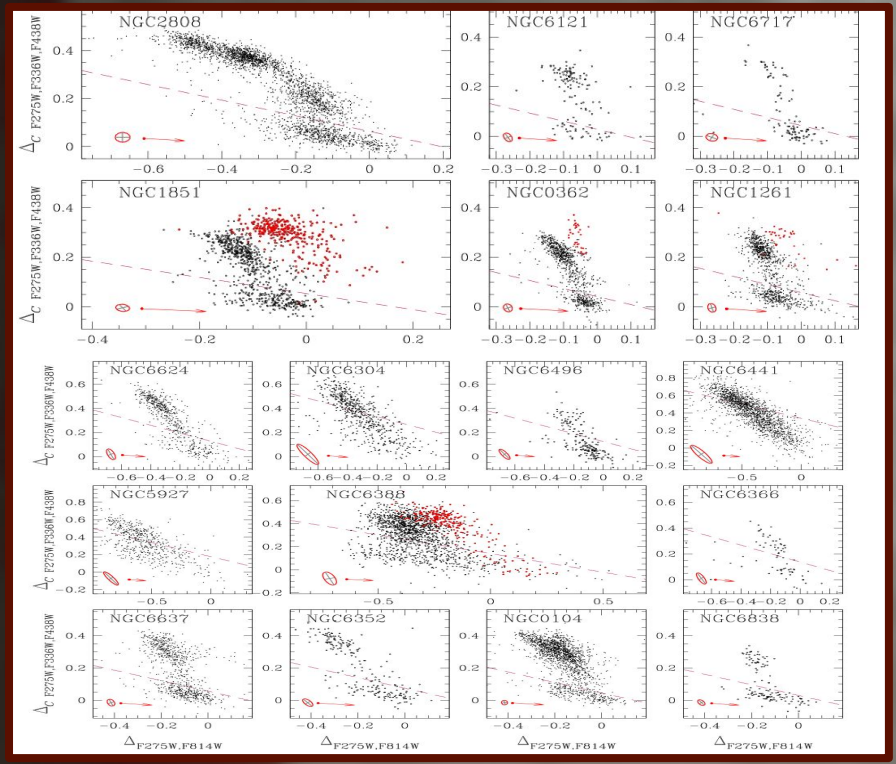


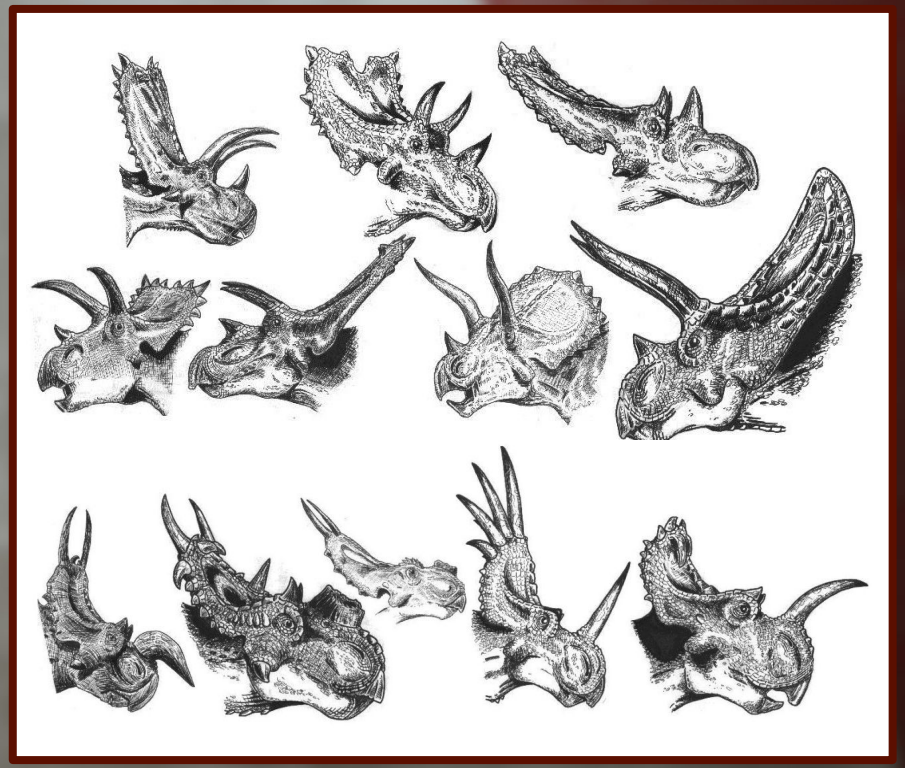
Multiple Stellar Populations





Multiple Stellar Populations





How did Multi-populations form ?

Multi-Generations

- Multiple star-bursts
- 2G born out of ejecta of 1G more massive stars
  - ➔ AGB stars
  - ➔ Fast rotating stars
  - ➔ Super massive stars

Single Generation

- Single star-bursts
- 2G change chemical composition “on the fly”
  - ➔ Massive interacting binaries

How did Multi-populations form ?

Multi-Generations

- Multiple star-bursts
- 2G born out of ejecta of 1G more massive stars
  - ➔ AGB stars
  - ➔ Fast rotating stars
  - ➔ Super massive stars

- Different polluters
- 2G more centrally concentrated ✓
- Non flat N_{1G}/N_{tot} radial profile ✓
- Different dynamics ?

Why study internal kinematics ?

Present-day dinamics of multiple populations can retain information about the initial configuration of different populations

Mastrobuono-Battisti+16, Vesperini+15, Hénault-Brunet+15

HST

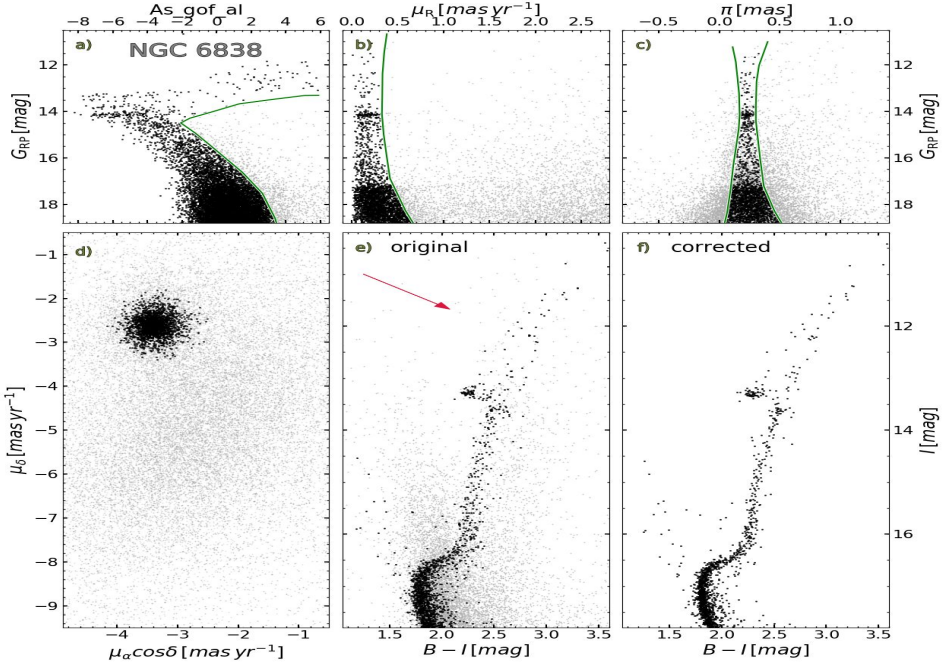
- Few studied clusters (ωCen, 47Tuc, NGC2808)
- High precision ✓
- Relative proper motions
- Small FoV ✗
- (Mostly) innermost regions ✗

Gaia

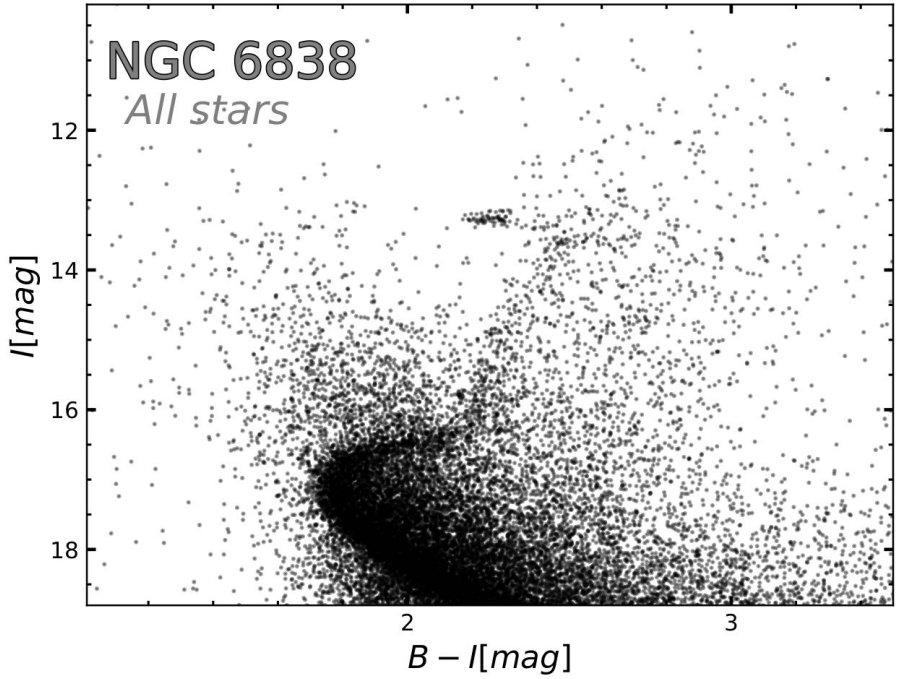
- Available for many clusters
- High precision ✓
- Absolute proper motions
- Wide FoV ✓
- Whole cluster field ✓

Let's start

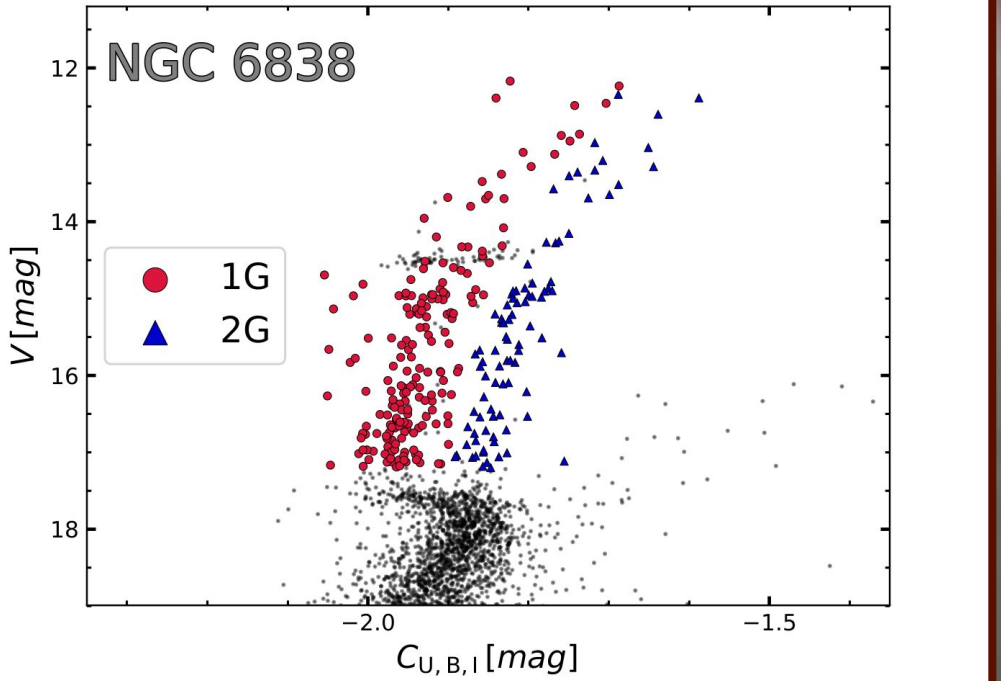
Cluster membership



Cluster membership



Ground-based photometry



Globular Clusters sample

ID	RA (J2000)[a]	DEC (J2000)[a]	d_{sun} [b] [pc]	R_c^b arcmin	R_h^b arcmin
NGC 0104	00 24 05.67	−72 04 52.6	4410	0.38	2.78
NGC 0288	00 52 45.24	−26 34 57.4	9800	1.67	2.45
NGC 5904	15 18 33.22	+02 04 51.7	7500	0.55	1.65
NGC 6121	16 23 35.22	−26 31 32.7	2140	1.06	4.53
NGC 6254	16 57 09.05	−04 06 01.1	4710	0.59	2.03
NGC 6752	19 10 52.11	−59 59 04.4	4300	0.15	1.92
NGC 6838	19 53 46.49	+18 46 45.1	3860	0.46	2.63

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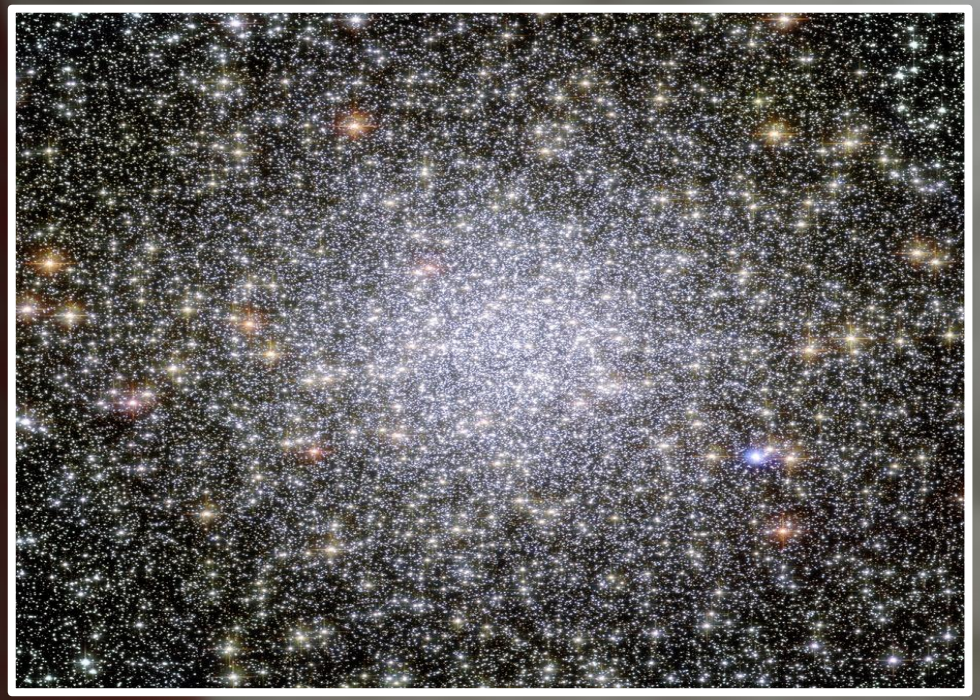
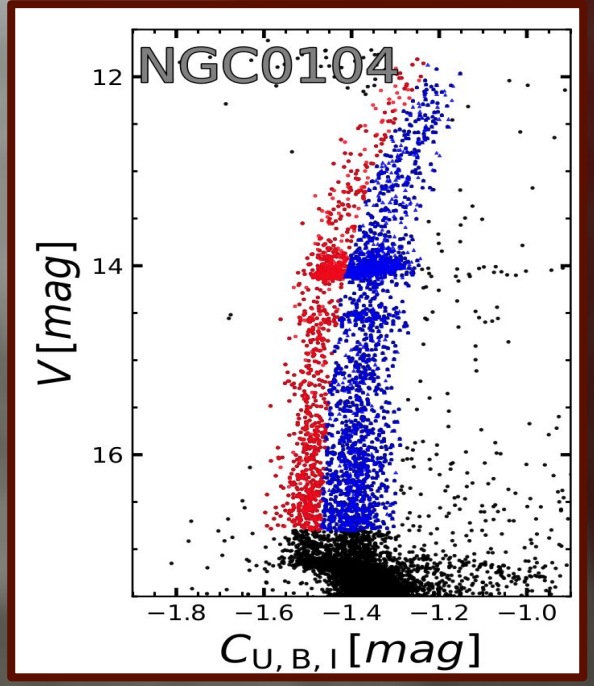
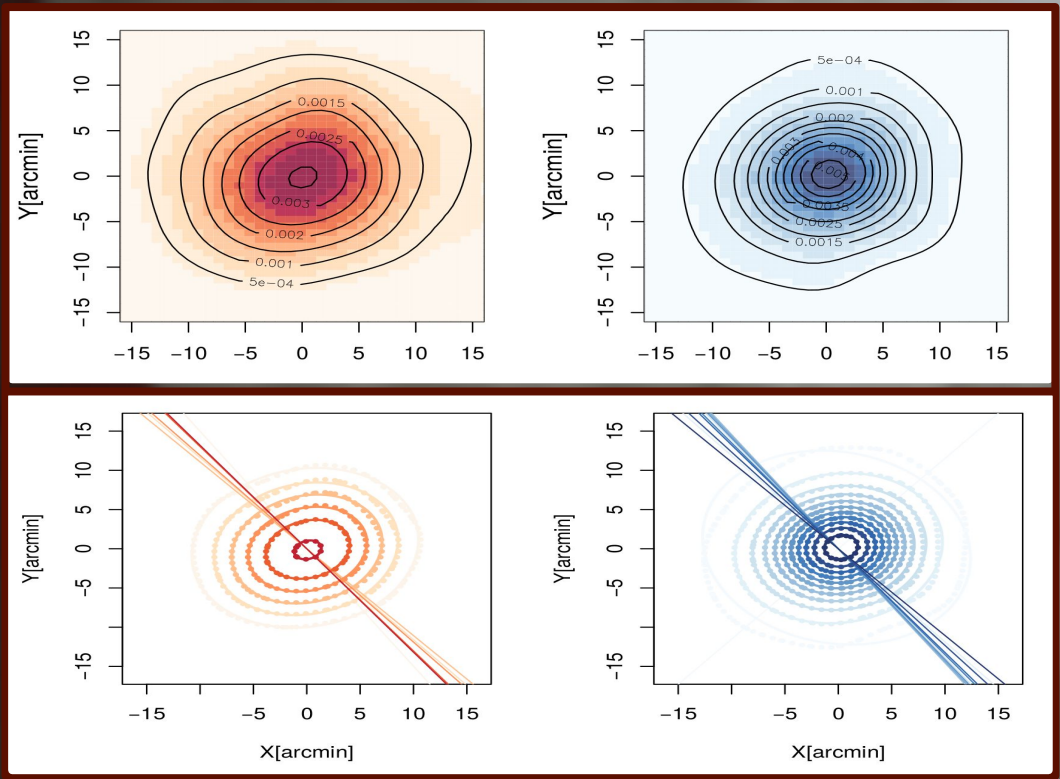
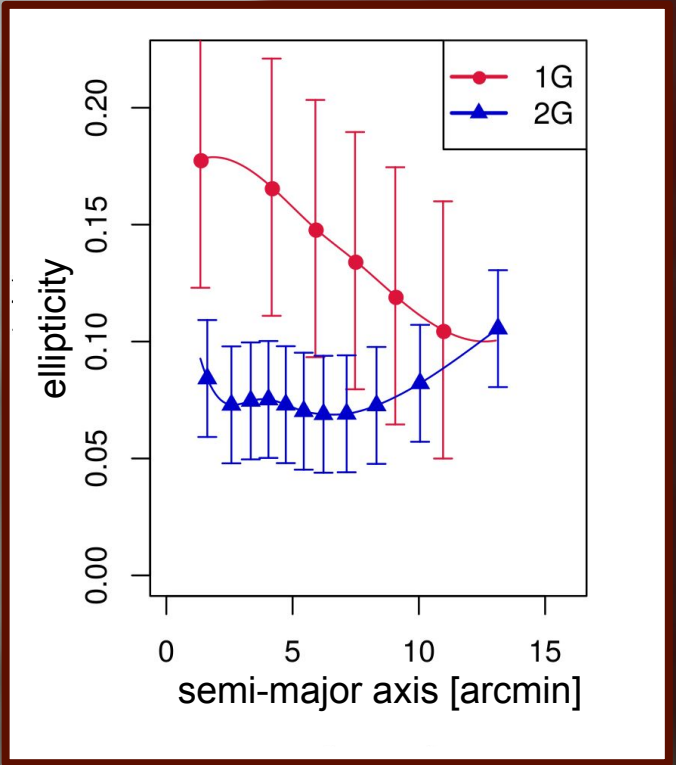
47 Tucanae (NGC 104)



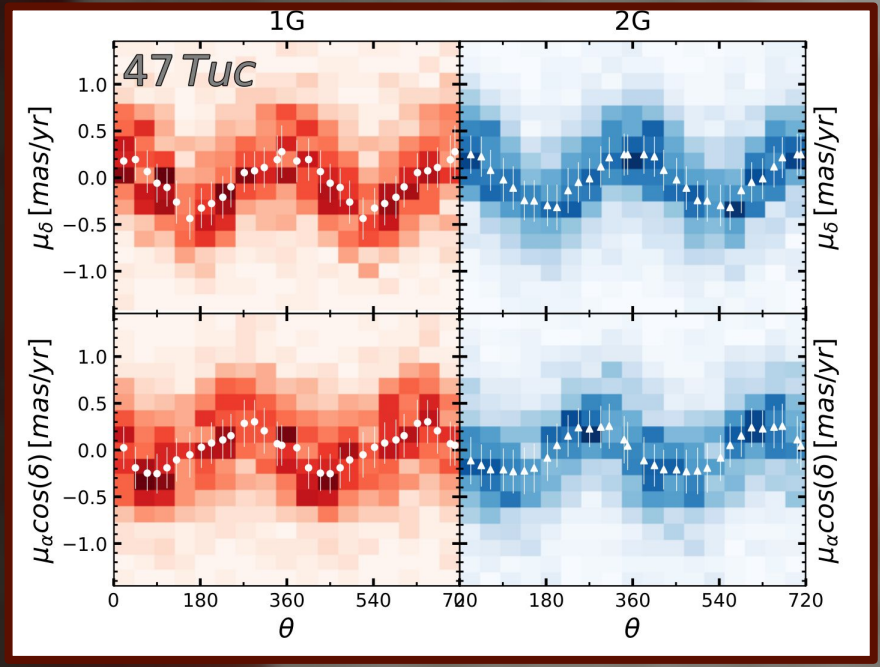


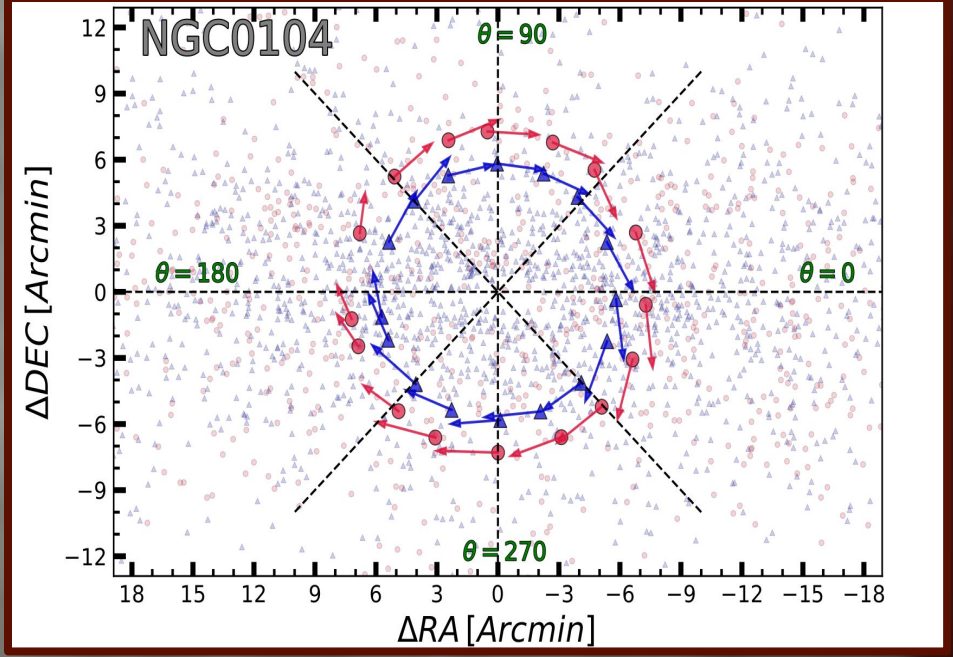
47 Tucanae : spatial distribution





47 Tucanae : rotation





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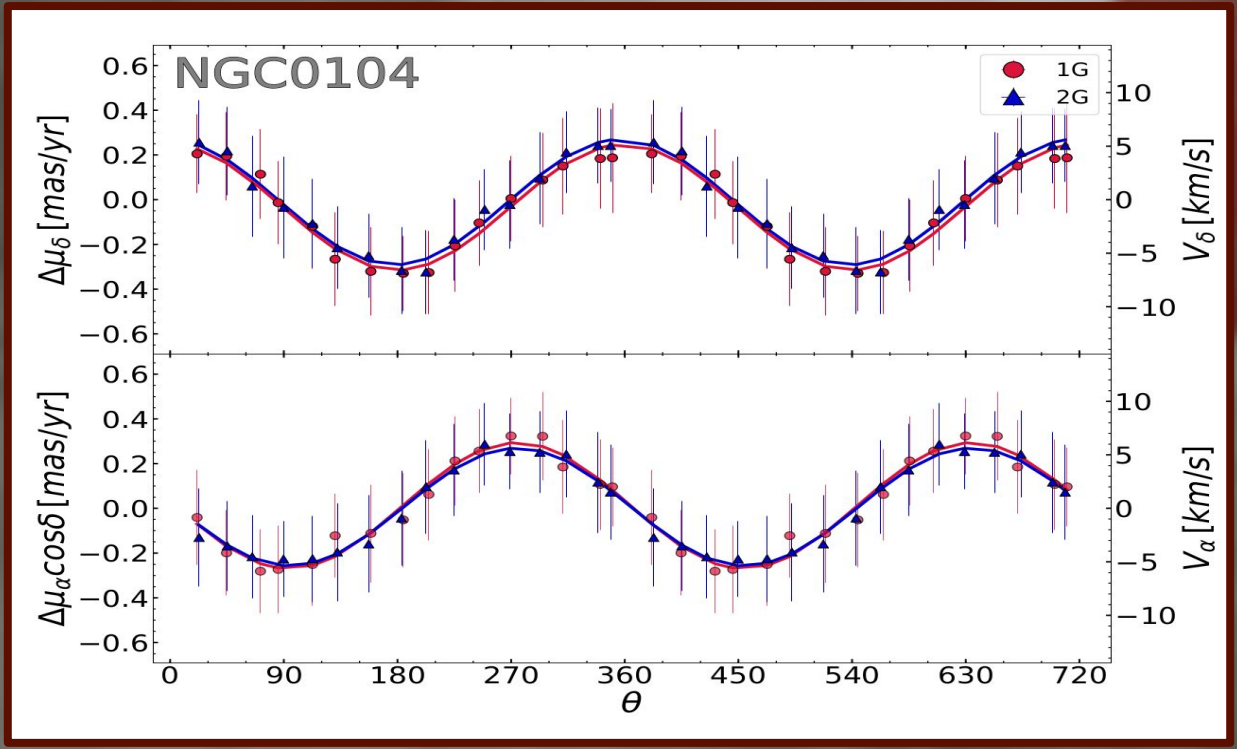
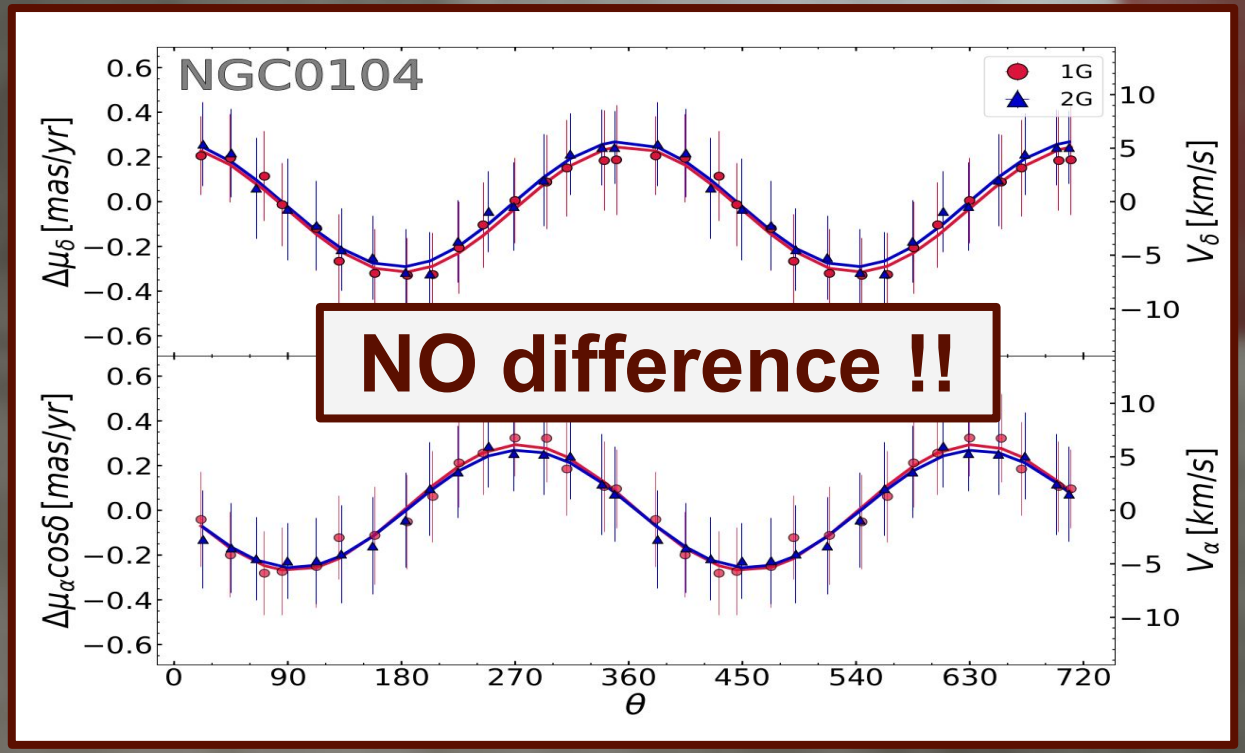
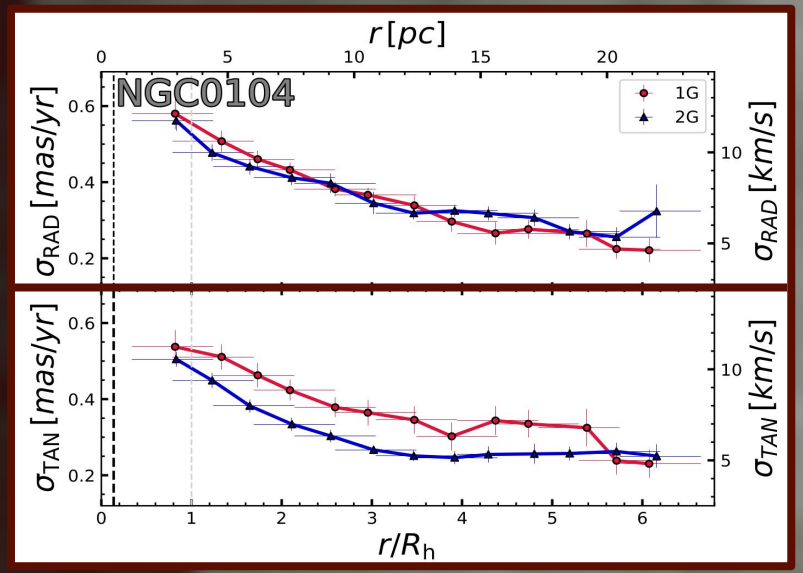


47 Tucanae : rotation

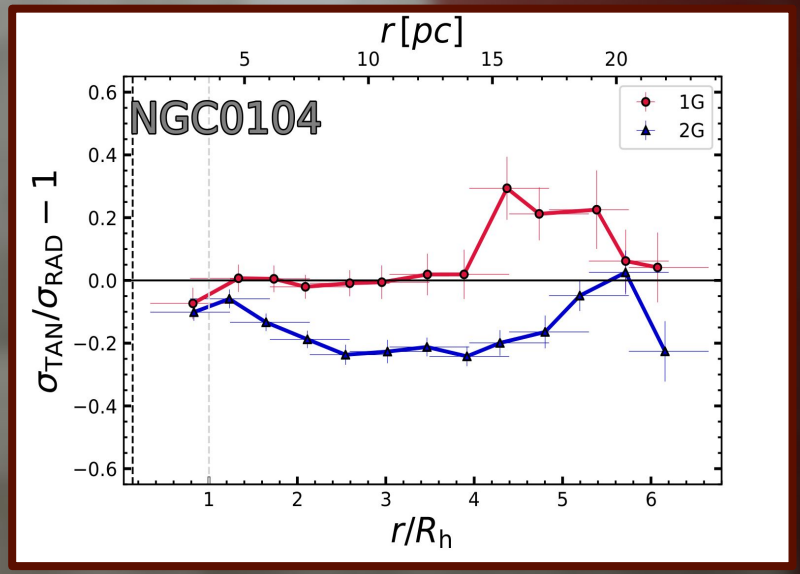


47 Tucanae : radial profiles



Dispersion

Anisotropy



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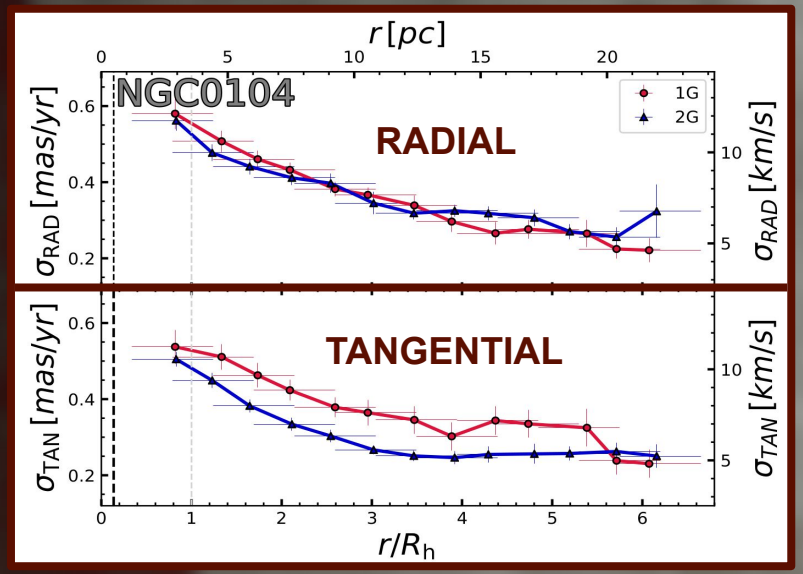
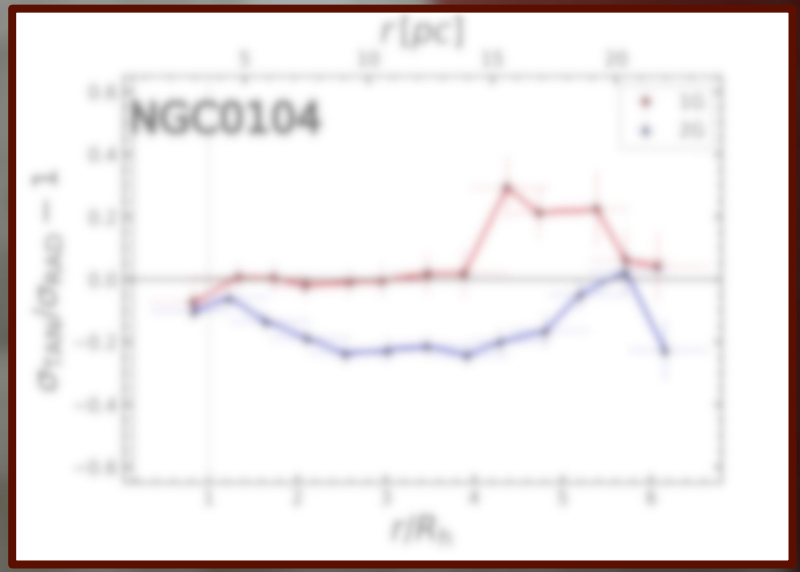
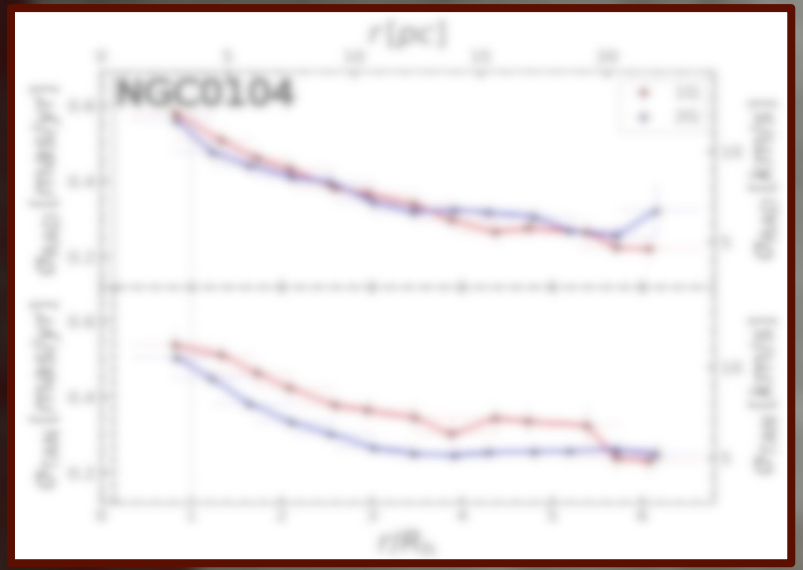


Dispersion

Anisotropy

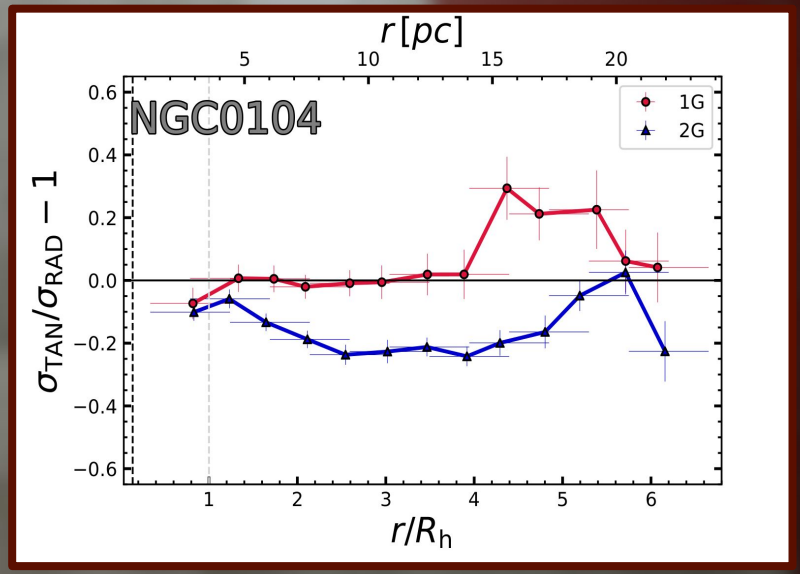


47 Tucanae : radial profiles



Dispersion

Anisotropy

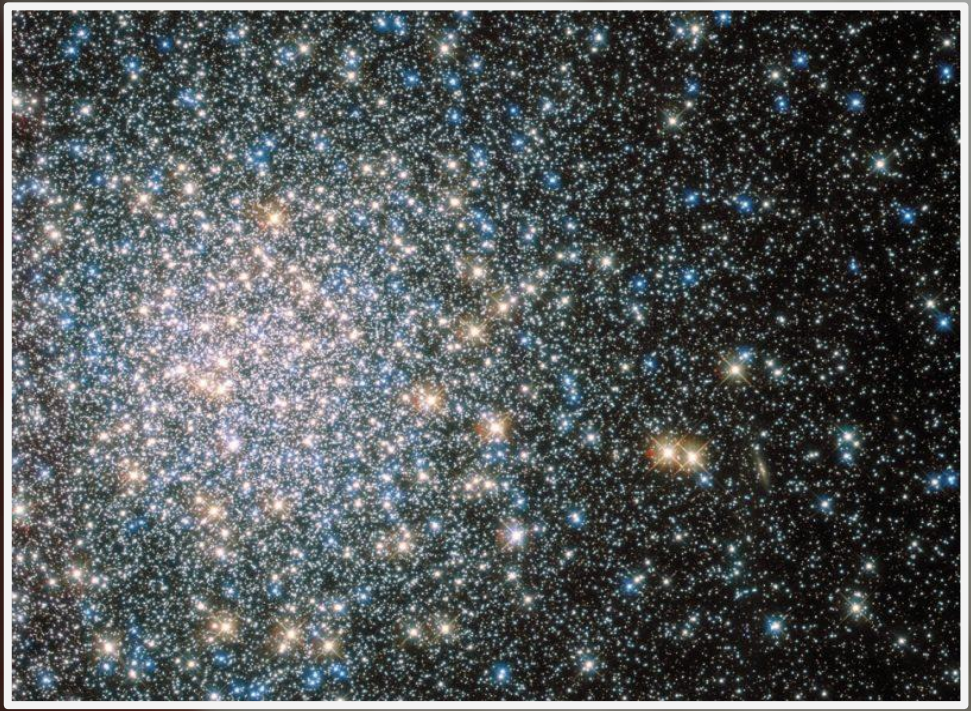


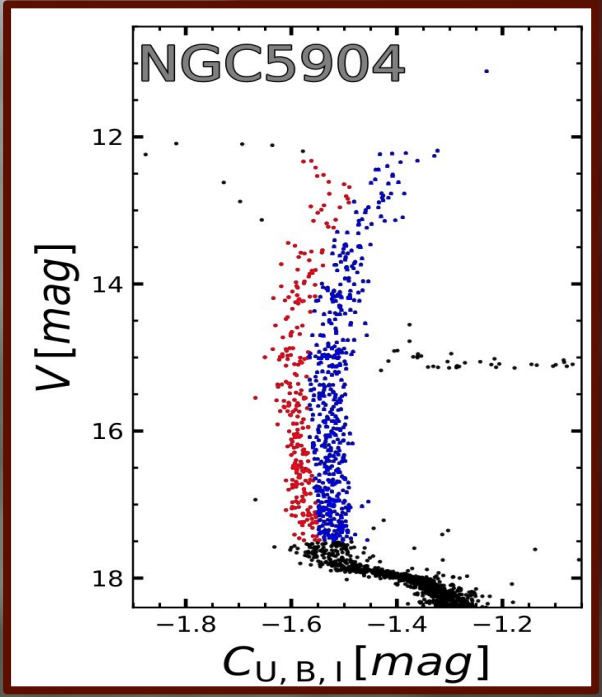
47 Tucanae : conclusions

- ➔ *Same* rotation
- ➔ *Different* tangential dispersion
- ➔ *Different* anisotropy
- ➔ *Different* concentration Milone+12
- ➔ Consistent with simulations

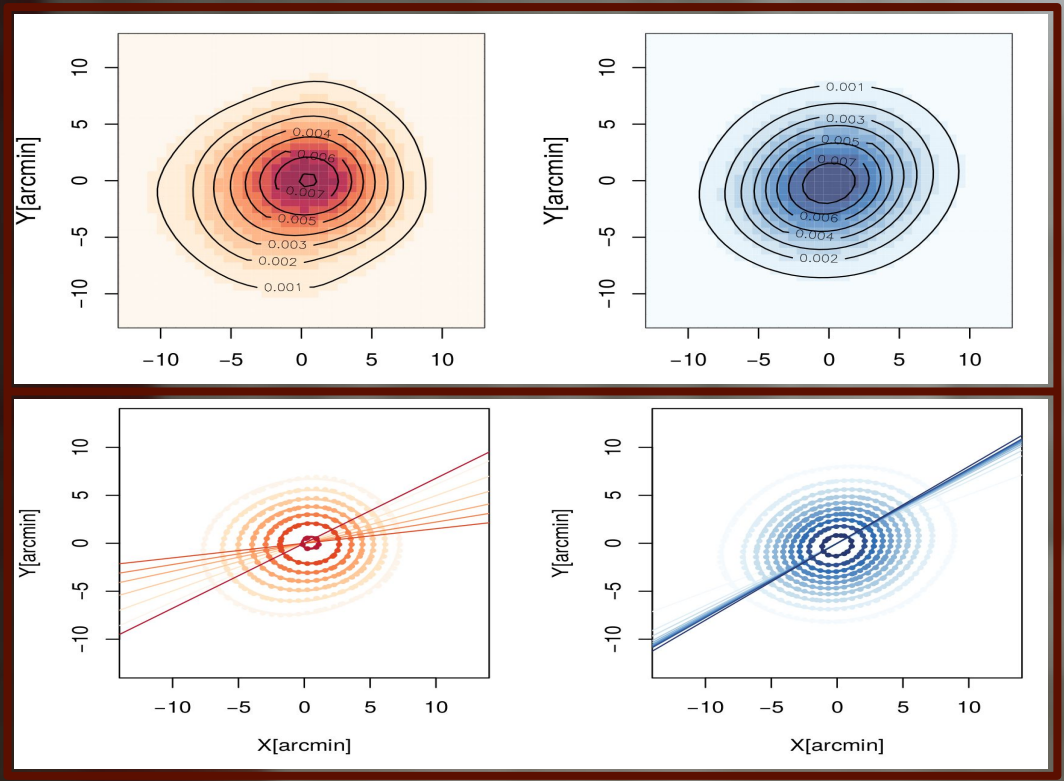
  Mastrobuono-battisti+16, Vesperini+15

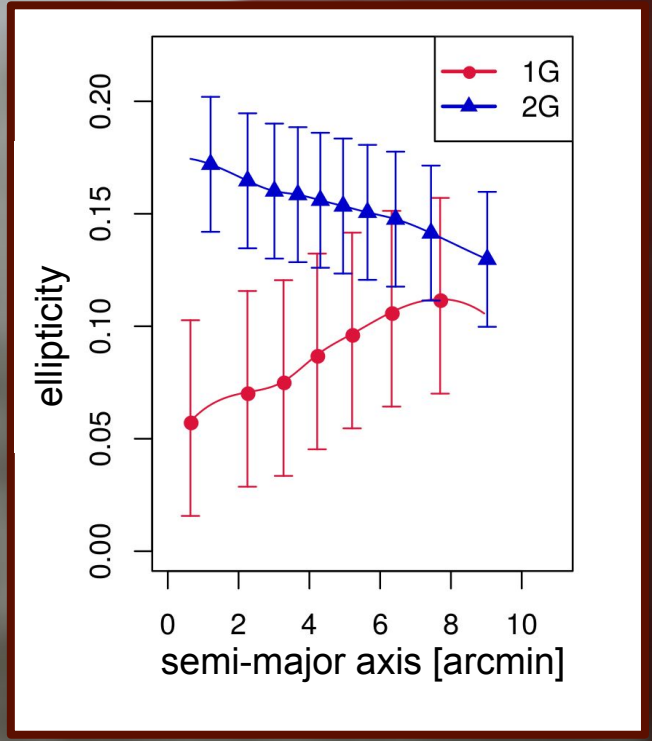
M5 (NGC 5904)



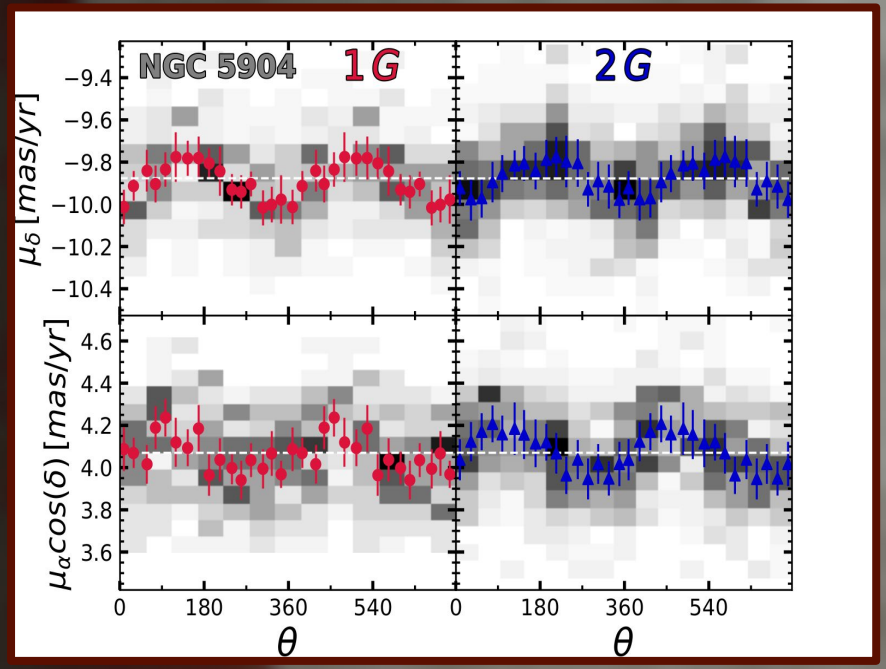


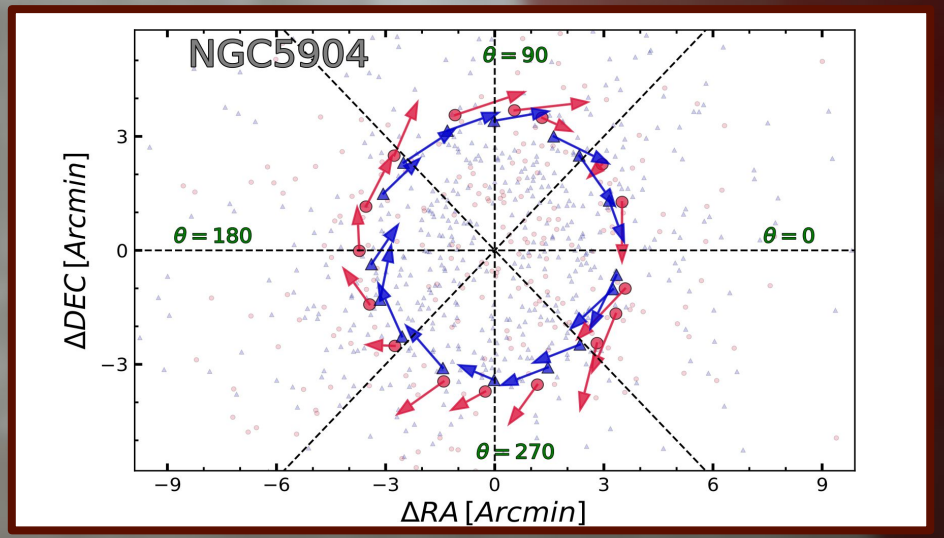
M5 : spatial distribution



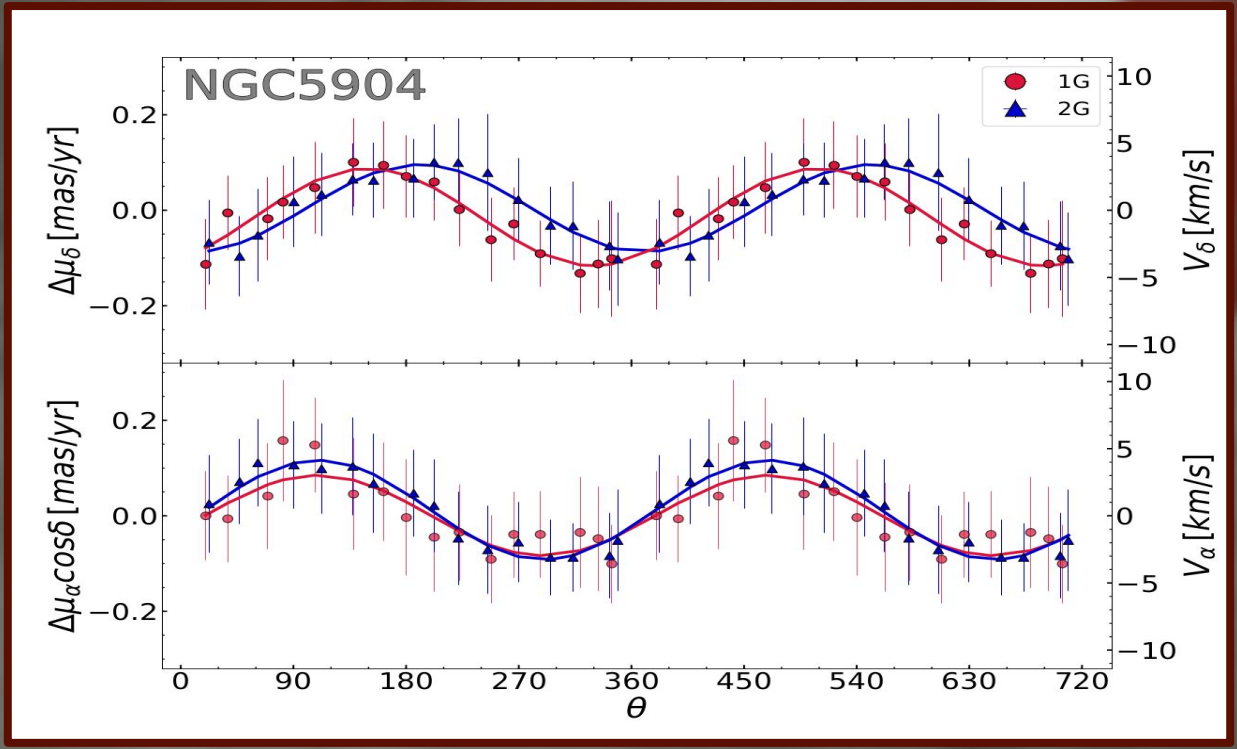


M5 : rotation

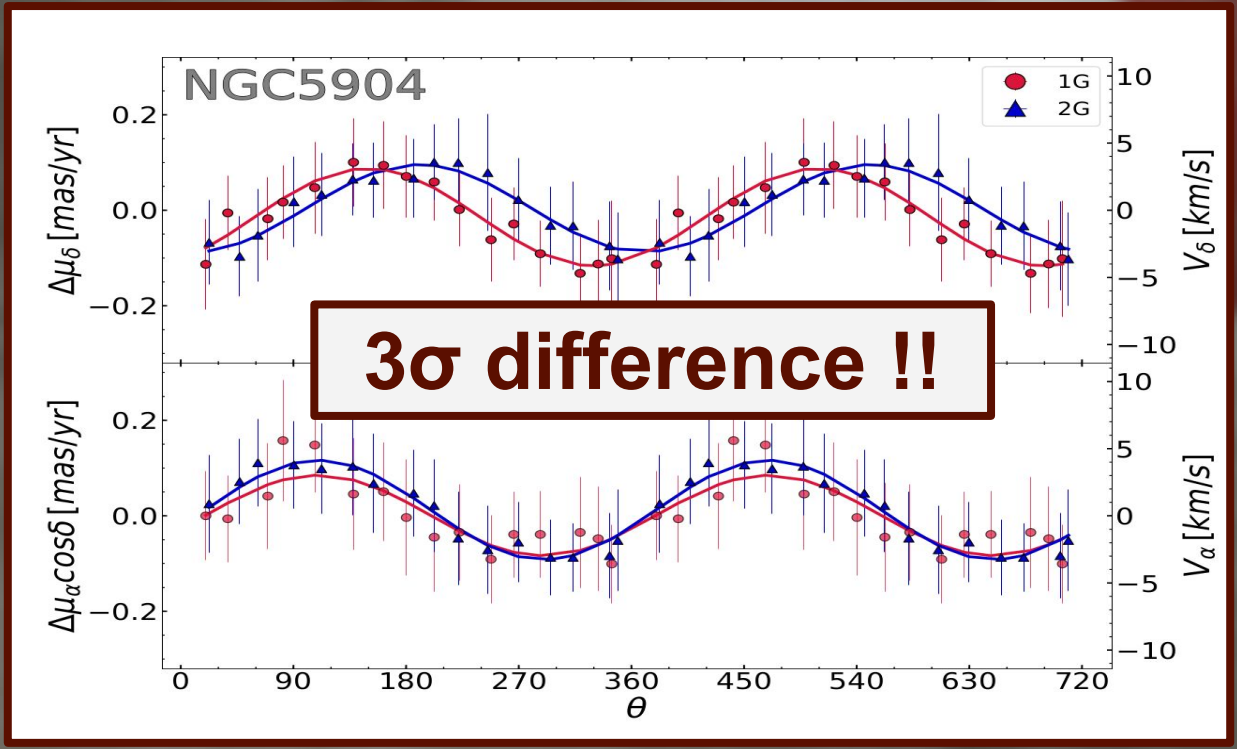

NGC 5904
1G
2G
μ_δ [mas/yr]
$\mu_\alpha cos(\delta)$ [mas/yr]
θ


NGC5904
θ = 90
θ = 180
θ = 0
θ = 270
ΔDEC [Arcmin]
ΔRA [Arcmin]

M5 : rotation

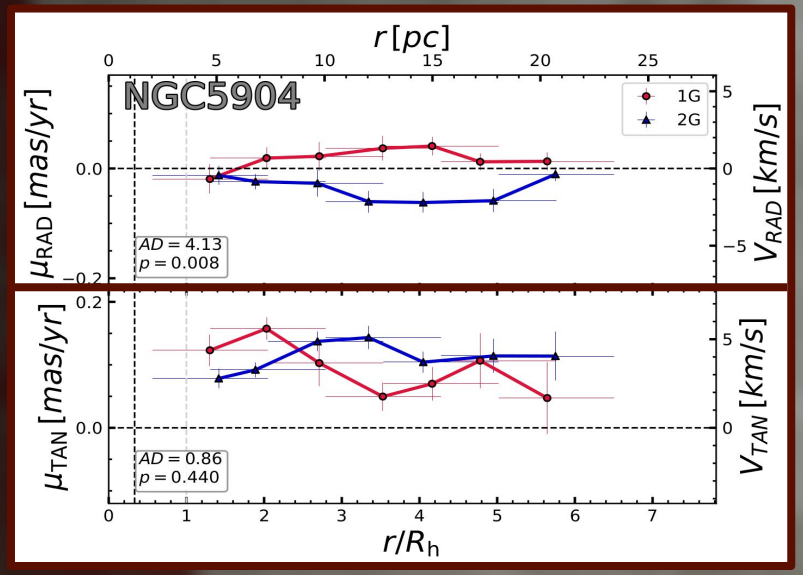

NGC5904
1G
2G
$\Delta\mu_\delta$ [mas/yr]
$\Delta\mu_\alpha cos\delta$ [mas/yr]
V_δ [km/s]
V_α [km/s]
0.2
0.0
−0.2
10
5
0
−5
−10
0
90
180
270
360
450
540
630
720
θ

M5 : rotation



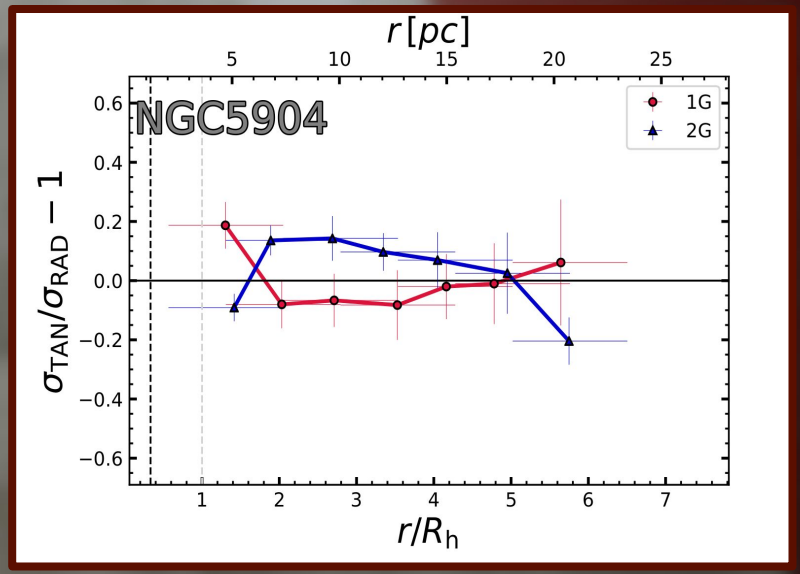
3σ difference !!

M5 : radial profiles

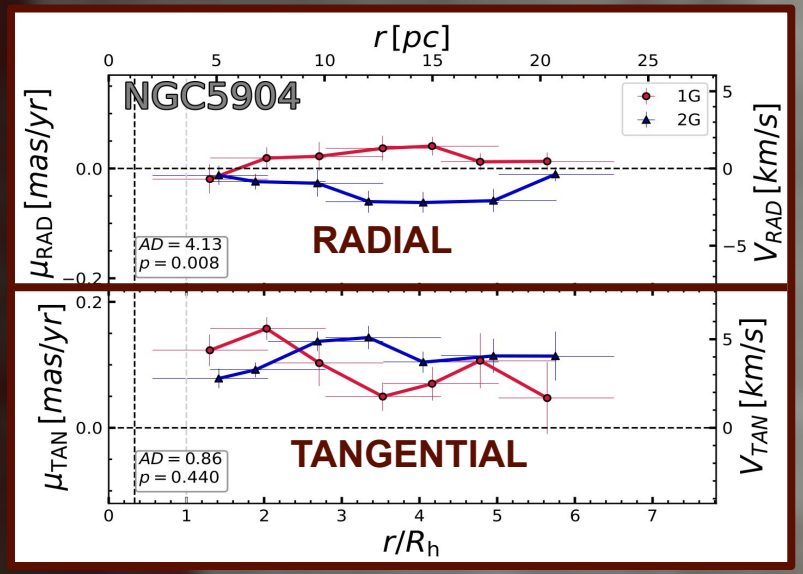


Median

Anisotropy

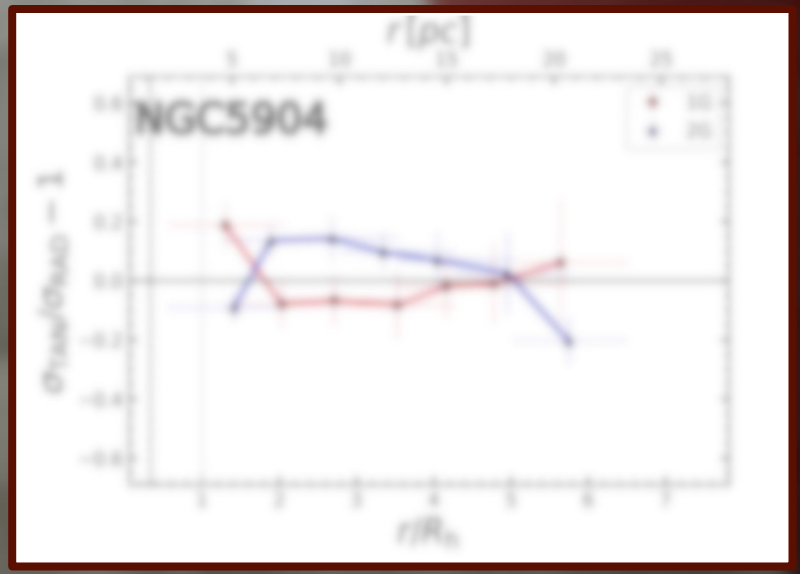


M5 : radial profiles

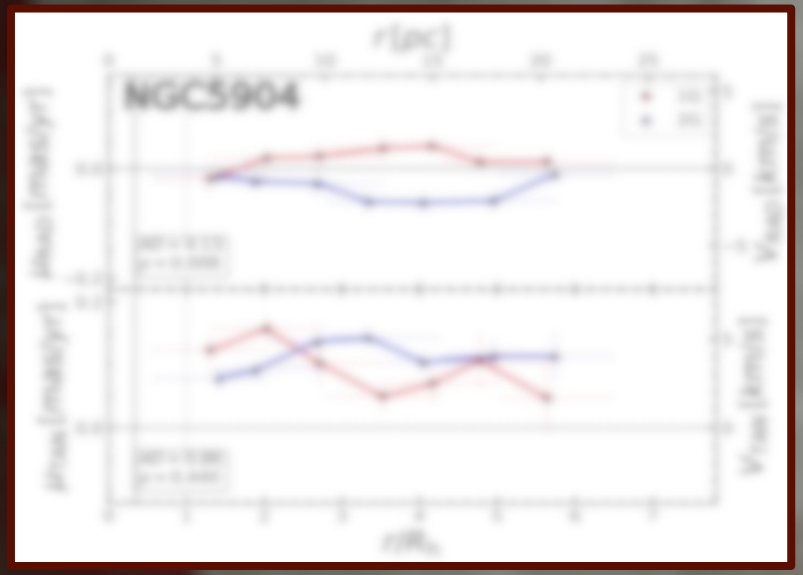


Median

Anisotropy

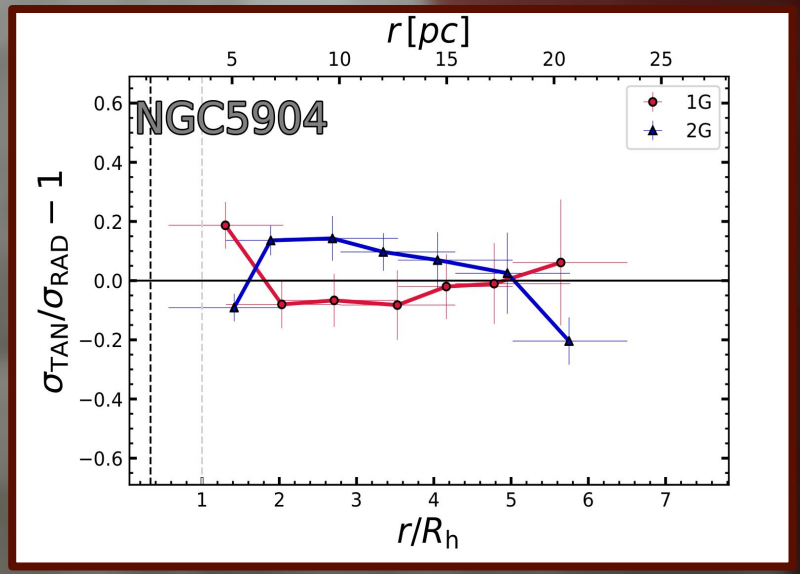


M5 : radial profiles



Median

Anisotropy



M5 : conclusions

- ➔ *Different* rotation
- ➔ *Different* radial profile
- ➔ *Different* anisotropy profile
- ➔ *Same* concentration Lee 15

Take away

- ➔ Clear kinematical difference in 47 Tuc and M5
- ➔ No significant differences in other clusters (NGC 288, M4, NGC 6254, NGC 6752, M71)
- ➔ Variety, as in spectroscopy and photometry
- ➔ Need of the comparison with detailed theoretical models
- ➔ More in Cordoni+19 in ArXiv 1905.09908

The GALFOR group

From left to right

- E. P. Lagioia
- A. F. Marino
- A. P. Milone
- G. Cordoni
- M. Zennaro
- M. Tailo

WEB: http://progetti.dfa.unipd.it/GALFOR/

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