Internal Dynamics of Multiple Stellar Populations in Globular Clusters

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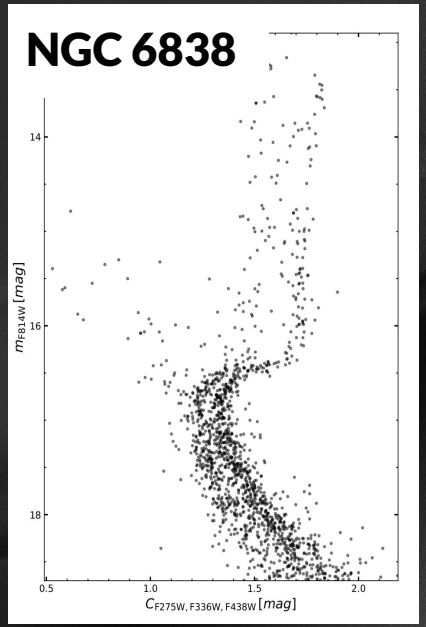
Multiple Stellar Populations

Complexity →



Multiple Stellar Populations

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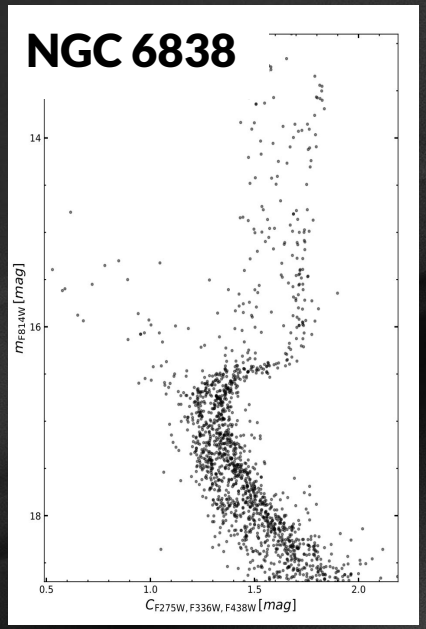
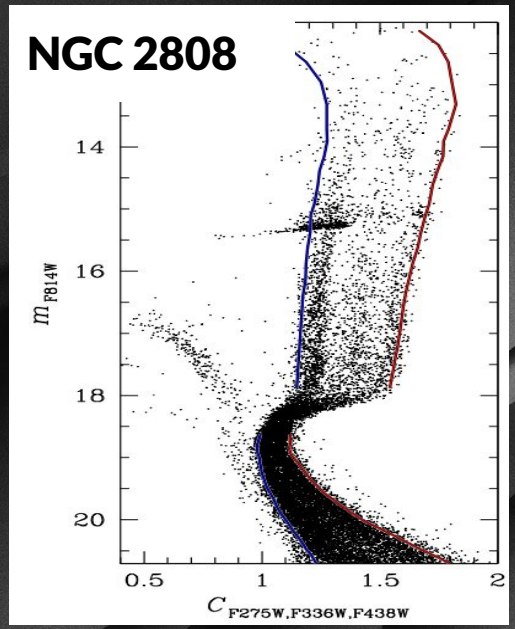
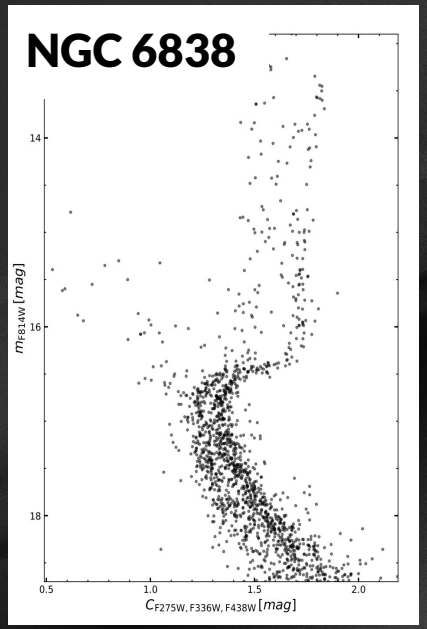
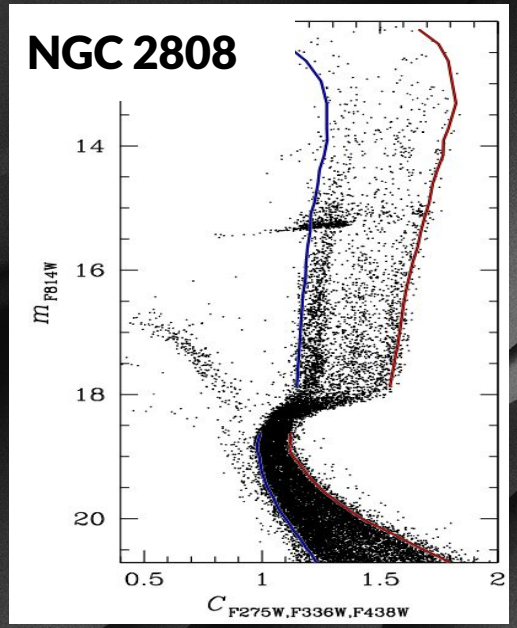


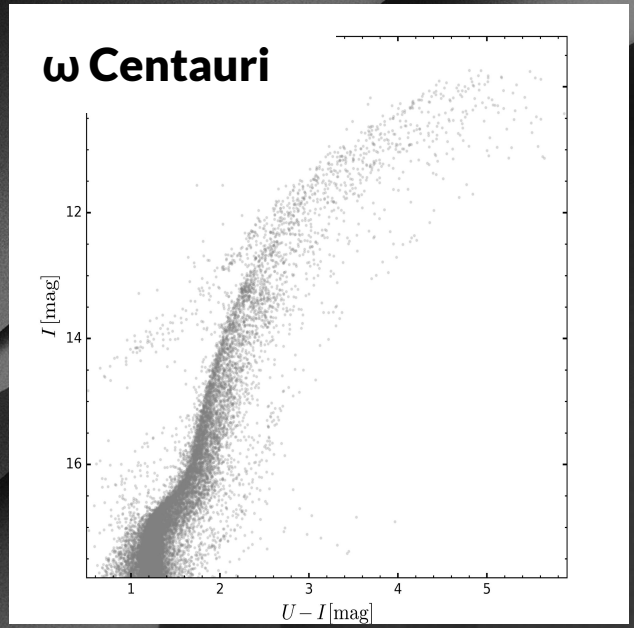


Multiple Stellar Populations

Complexity







Multiple Stellar Populations

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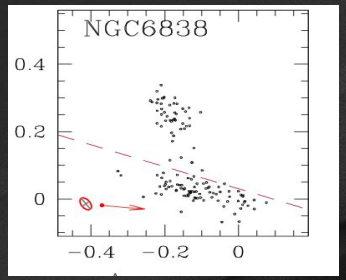
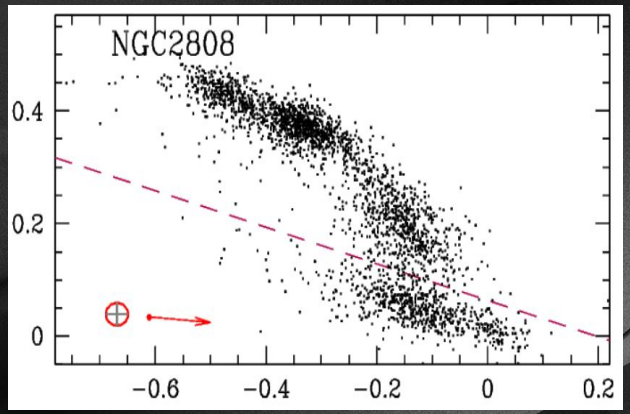
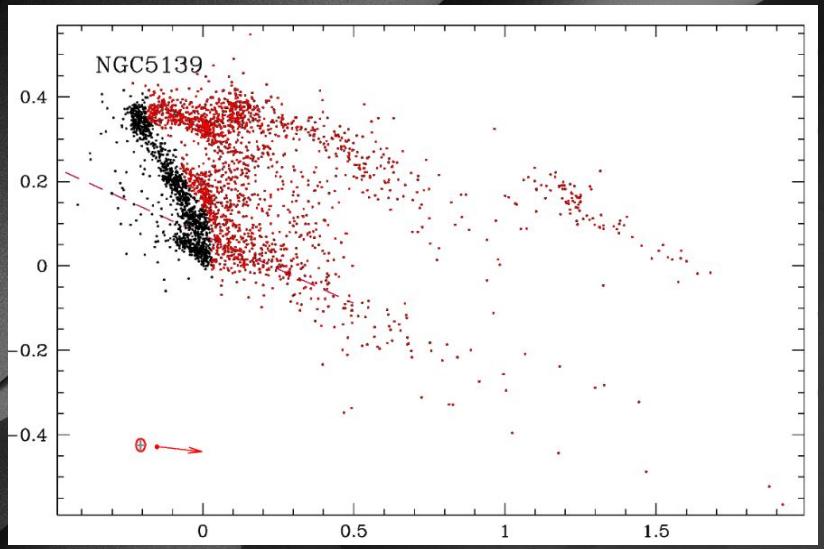
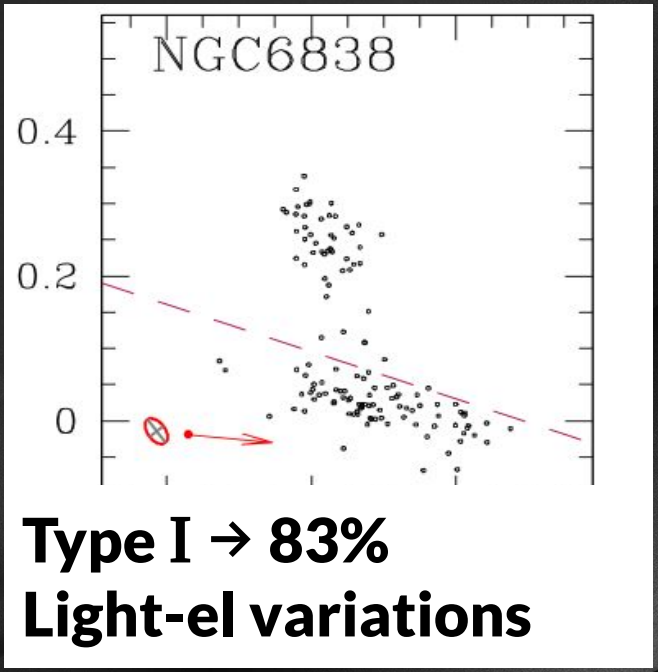


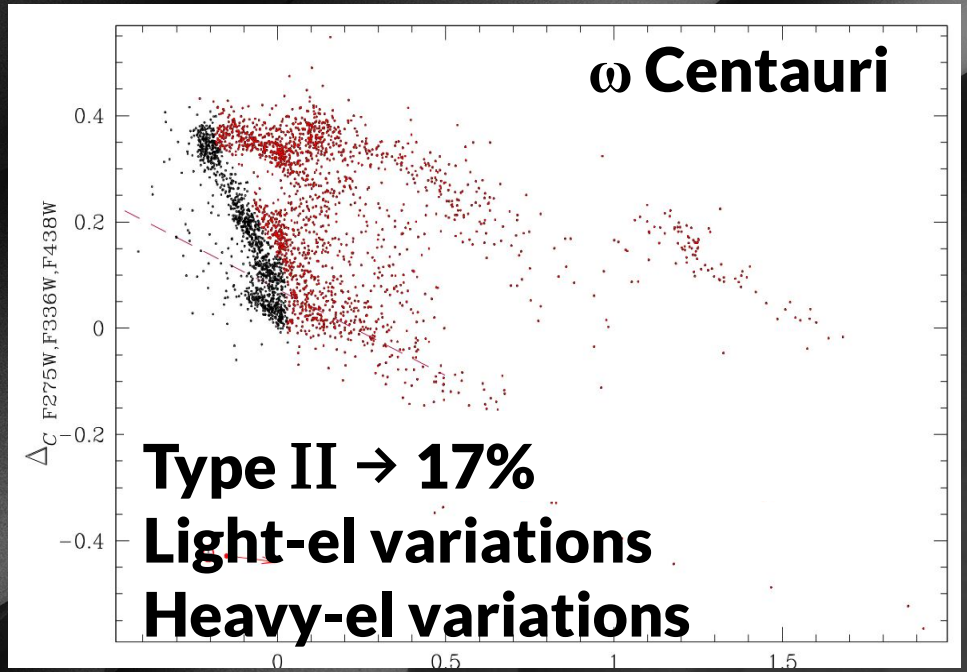




Type I/II Globular Clusters



Type I → 83%
Light-el variations



Type II → 17%
Light-el variations
Heavy-el variations

How did Multi-populations form?

Multi -Generations

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

Single Generation

- Single star-burst
- 2G changes chemical composition ‘on the fly’
  - Massive interacting binaries

State-of-the-art

Photometry

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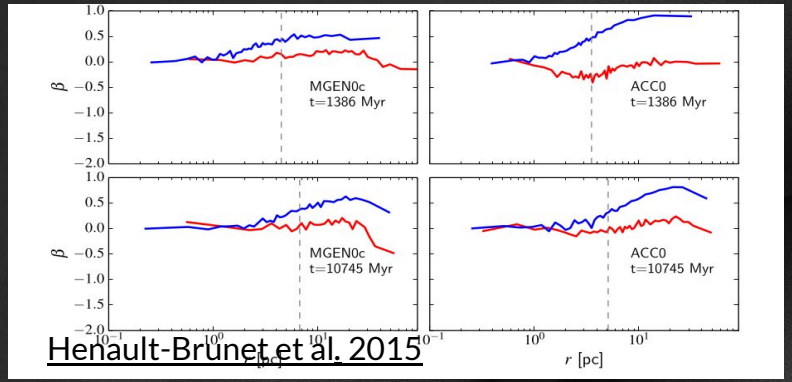
Spectroscopy

- *Detailed chemical composition*
- *Abundance patterns*
- *Population ratios*
- *MPs complexity*
- *Dependence on cluster parameters*
- *Radial distributions*

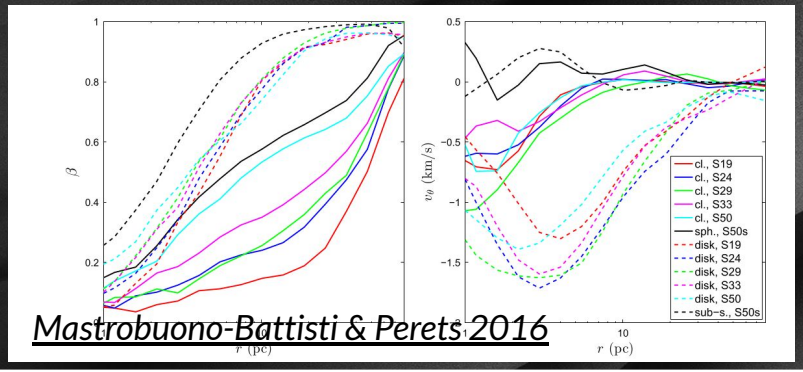
New approach: Internal dynamics

Present-day dynamics of multiple populations is linked to the initial configuration of different populations
(*Vesperini et al. 2013*, *Hénault-Brunet et al. 2015*, *Mastrobuono-Battisti & Perets 2016*, *Tiongco et al. 2019*)

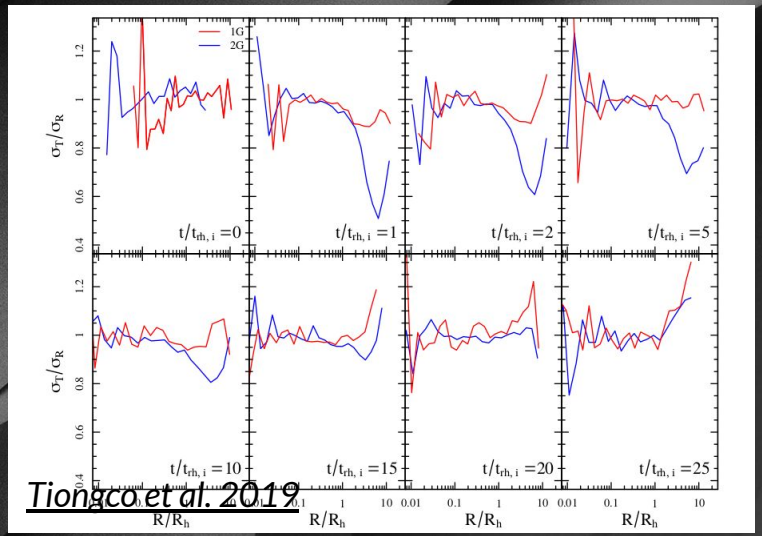
New approach: Internal dynamics



Henault-Brunet et al. 2015



Mastrobuono-Battisti & Perets 2016



Tiongco et al. 2019

Analysis

HST data
photometry and proper motions from 0 to ~0.5 R_h

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GAIA astrometry
proper motions from ~1 to ~4 R_h

⊕

SUMO photometry
Ground-based photometry from ~0 to ~4 R_h

→

→ *Morphology*
- Ellipticity profile
- Semi-major axis

→ *Internal dynamics*
- Rotation
- Radial/tangential ν profile
- Dispersion profile
- Anisotropy

Internal dynamics

Cordoni et al. 2020a, *ApJ, 889, 18*

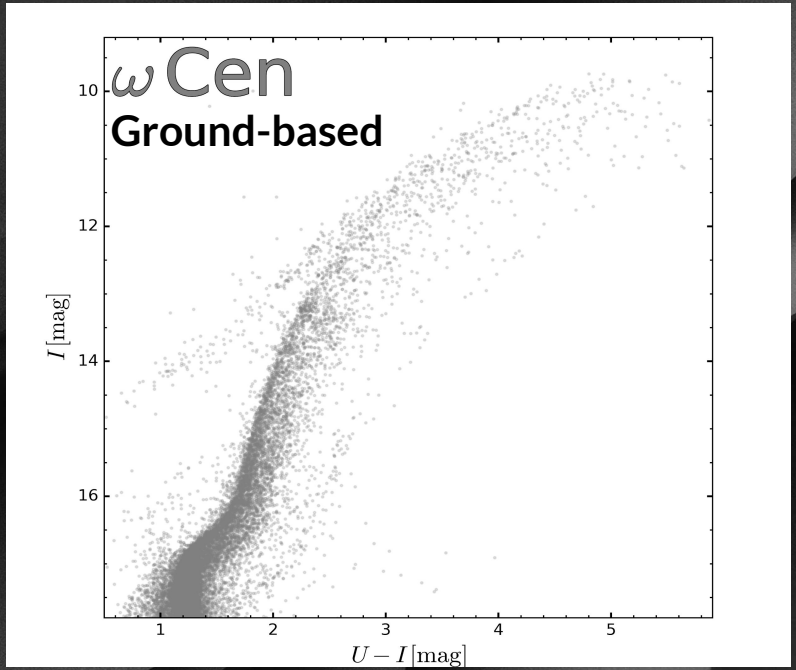
→ Internal dynamics of 7 type I Globular Clusters

Cordoni et al. 2020b, *ApJ, 898, 147*

→ Internal dynamics of 2 type II Globular Clusters

The case of ωCentauri

Iron



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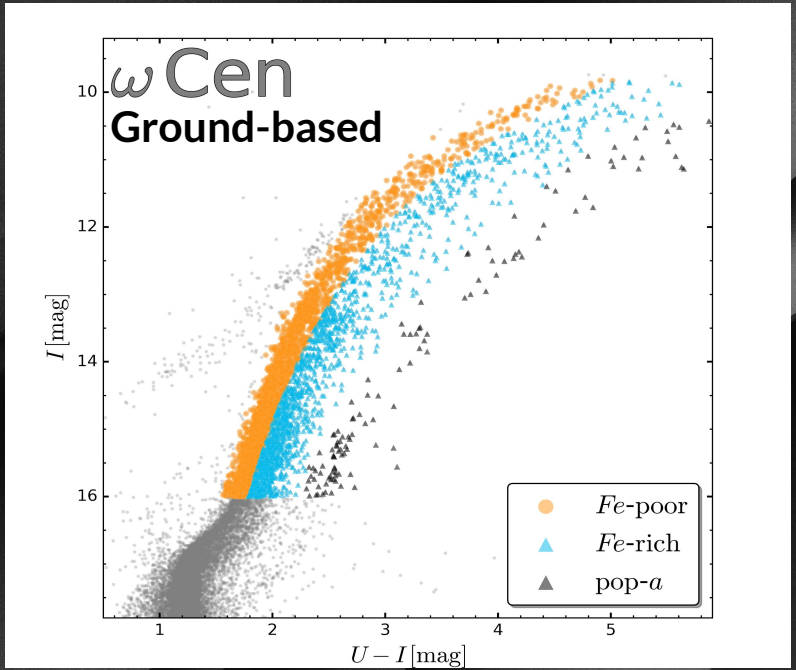
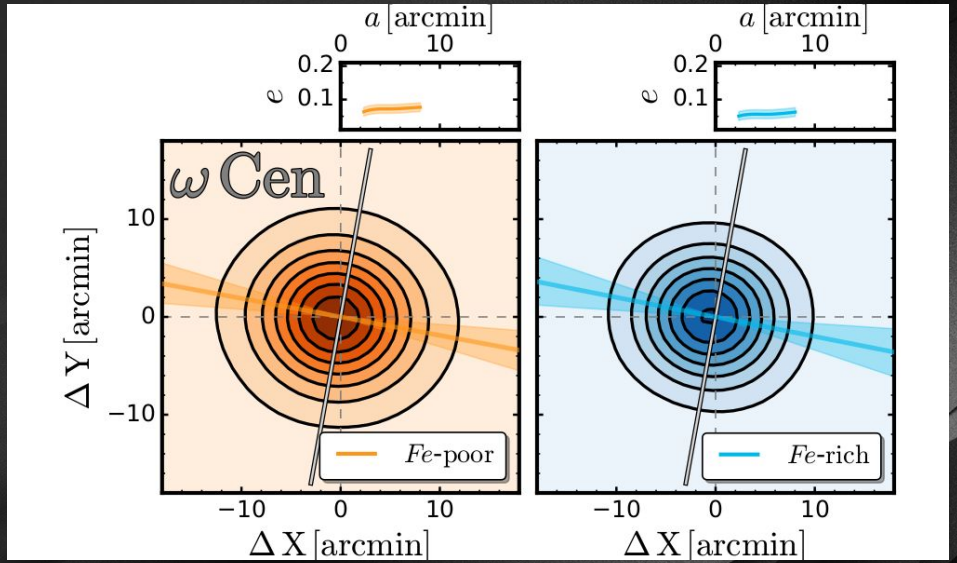


Results

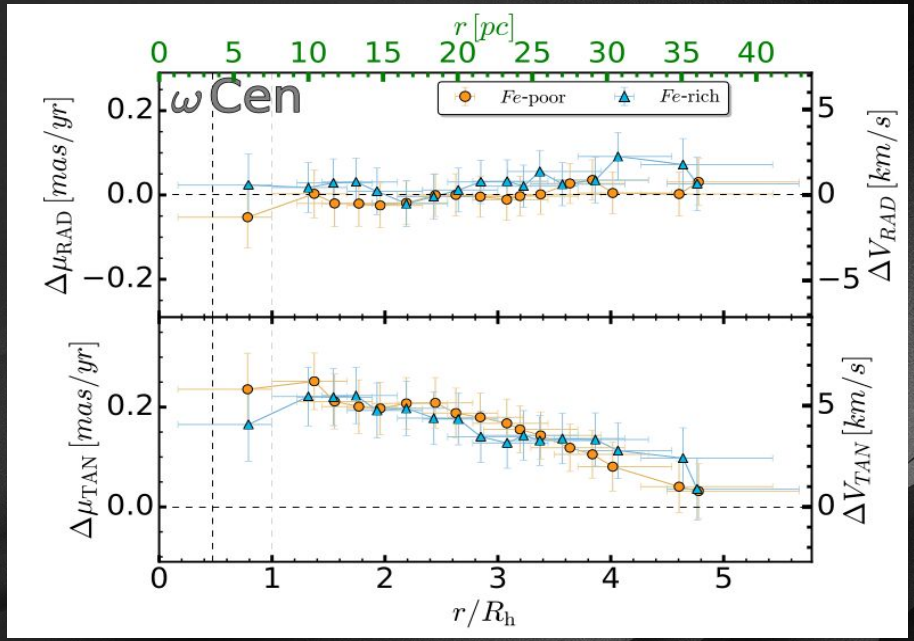
Morphology of populations with different Fe



→ *Similar* morphology

Results

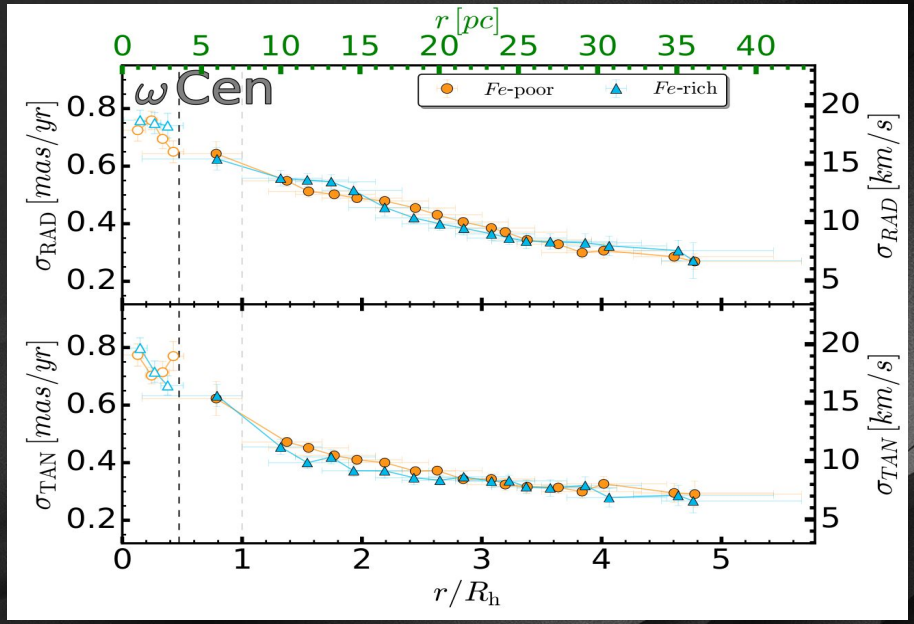
Internal dynamics of populations with different Fe



- → ***Similar*** **morphology**
- → ***Similar*** **velocity profiles**

Results

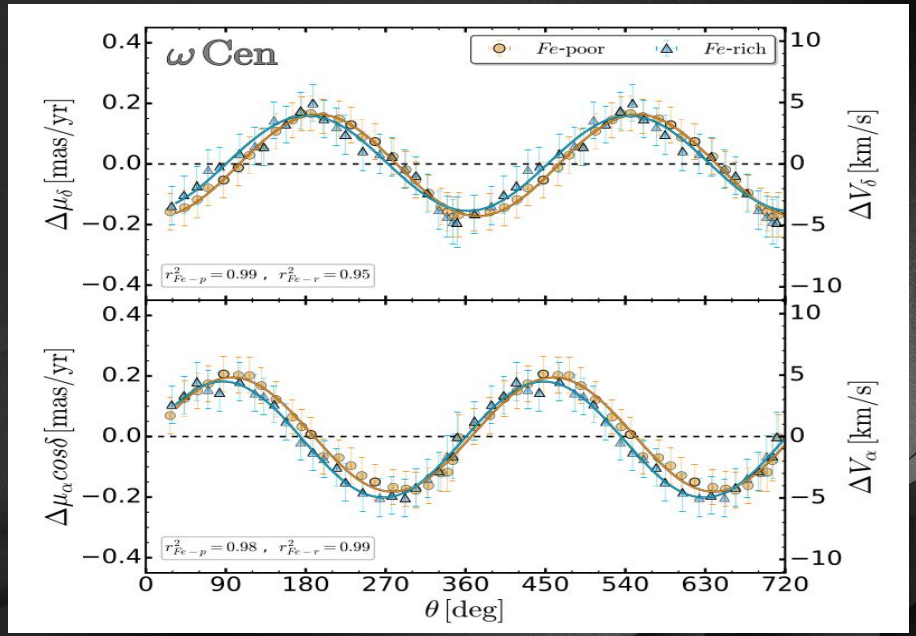
Internal dynamics of populations with different Fe



- → ***Similar*** **morphology**
- → ***Similar*** **velocity profiles**

Results

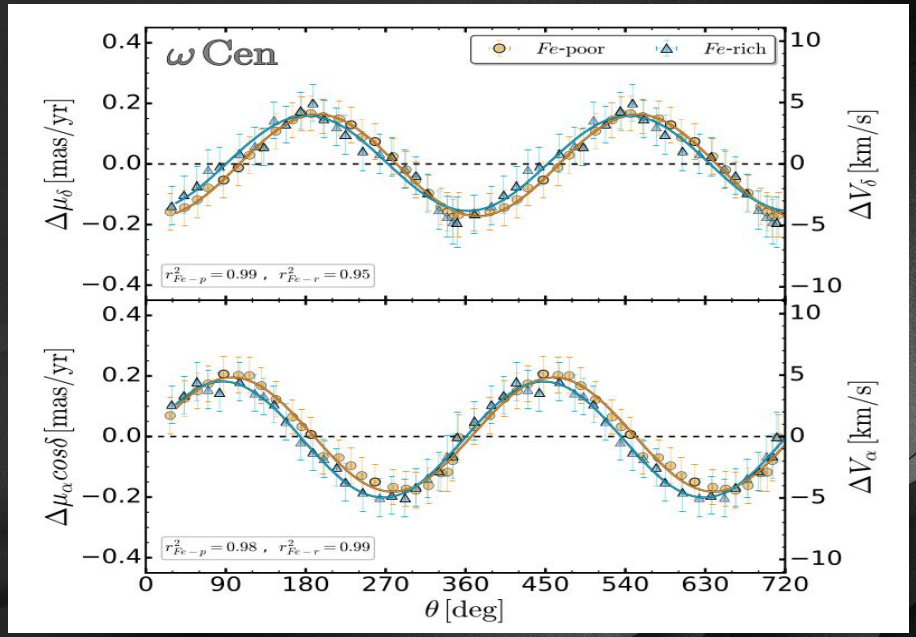
Internal dynamics of populations with different Fe



- → *Similar* morphology
- → *Similar* velocity profiles
- → *Similar* rotation

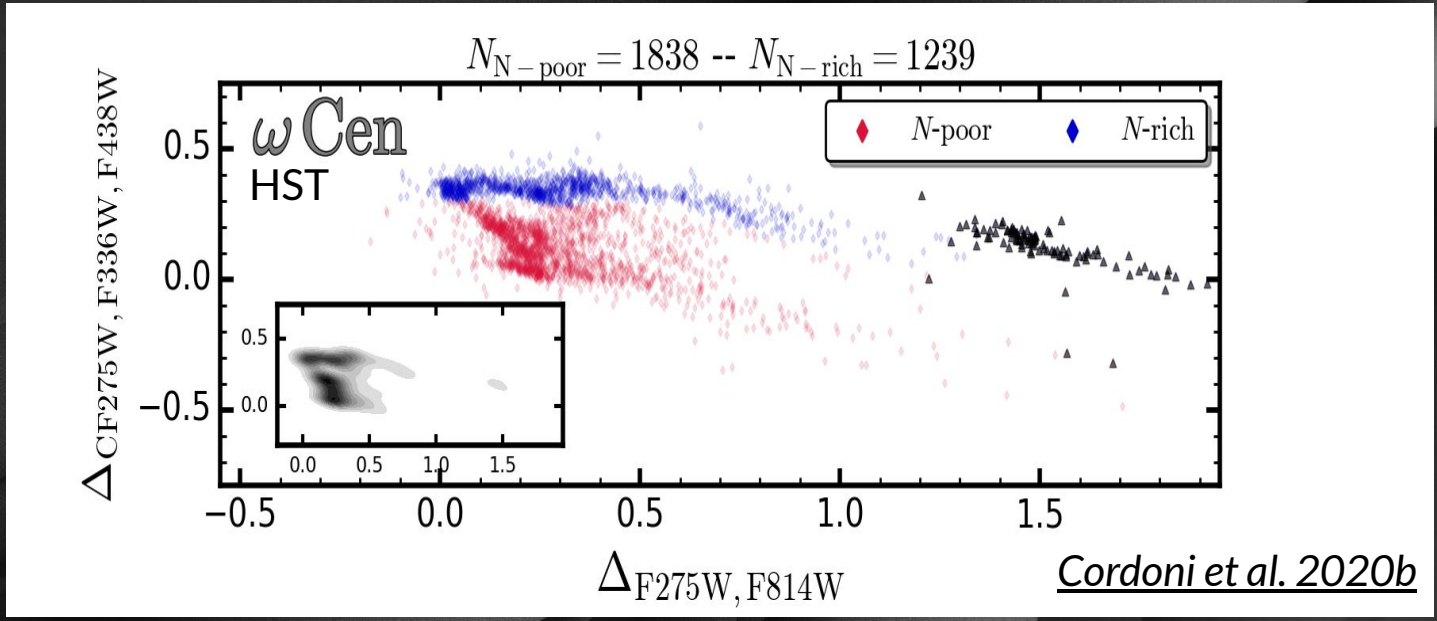
Results

Internal dynamics of populations with different Fe



- ➔ *Similar* morphology
- ➔ *Similar* velocity profiles
- ➔ *Similar* rotation
- ➔ ***Similar* dynamics**

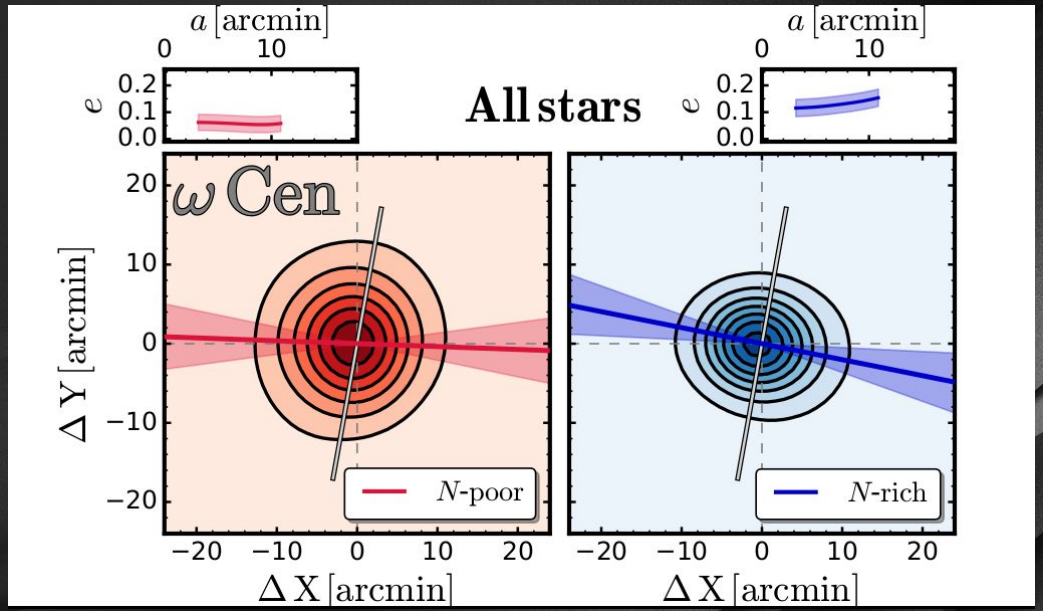
Multiple Populations: *Nitrogen*



Cordoni et al. 2020b

Results

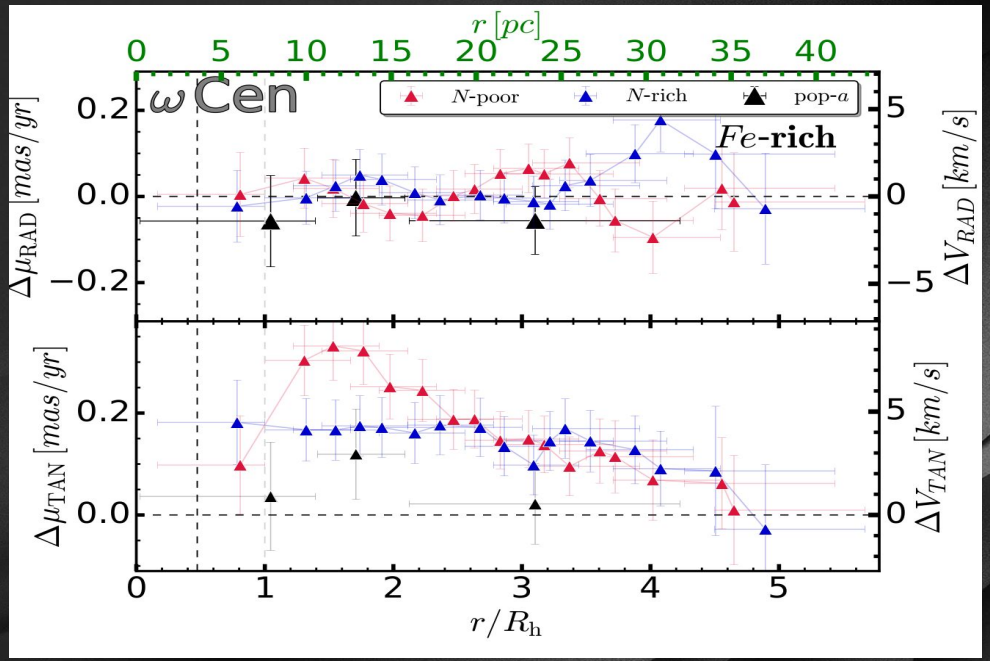
Morphology of populations with different N



➔ *Different* morphology

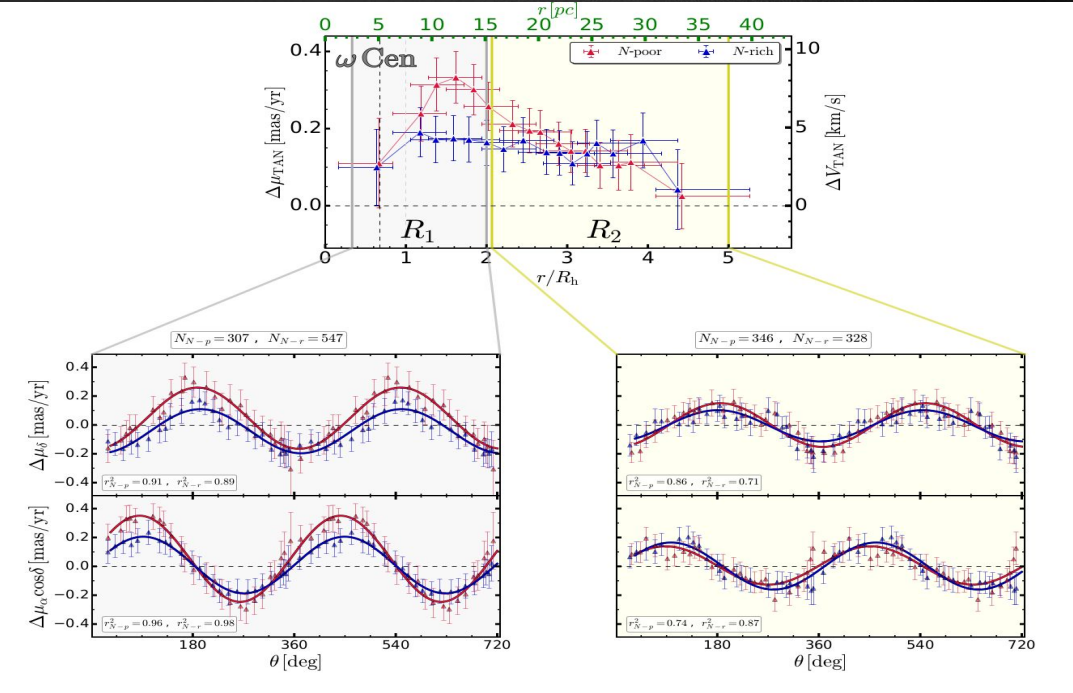
Results

Internal dynamics of populations with different N



- → *Different* morphology
- → *Different velocity profiles and rotation*

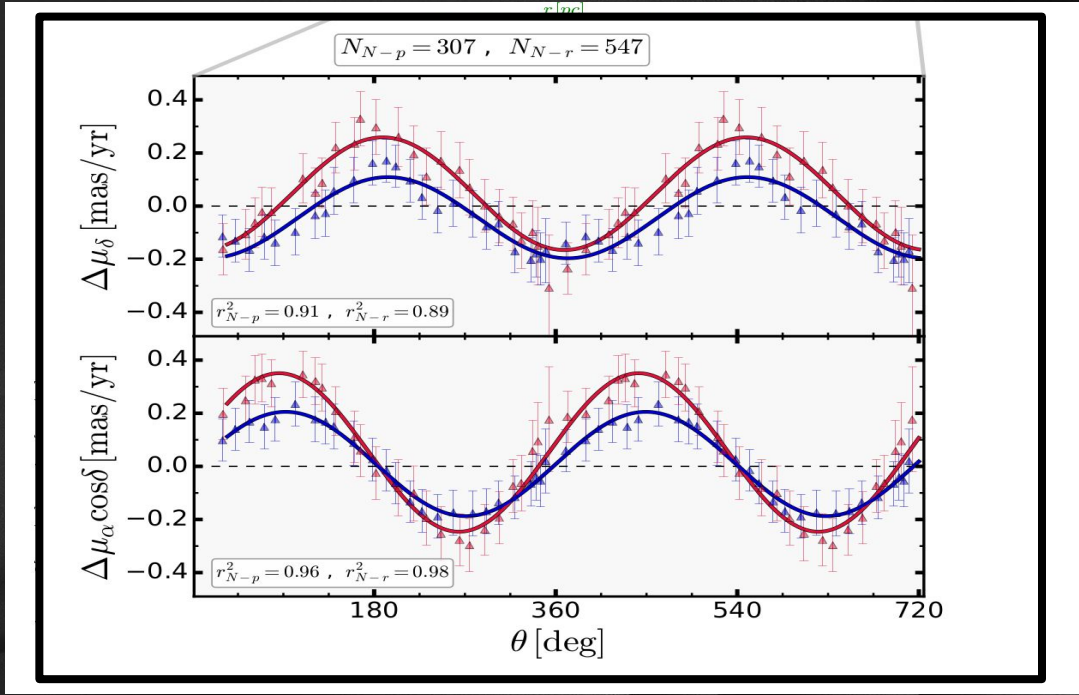
Results: different N



→ *Different* morphology
→ *Different velocity profiles and rotation*

Results

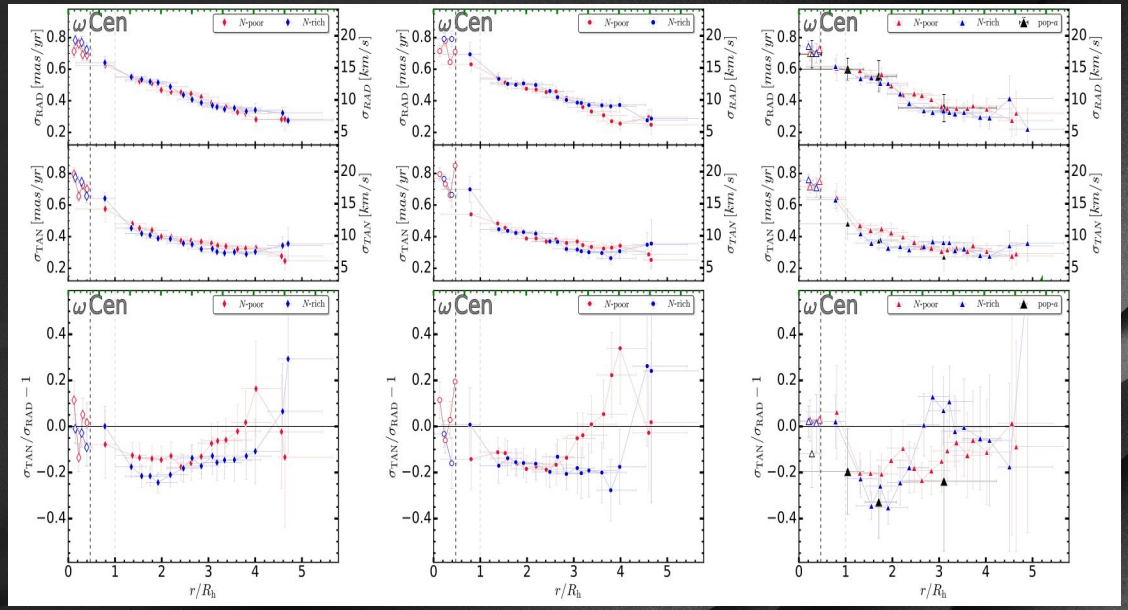
Internal dynamics of populations with different N



- → *Different* morphology
- → *Different velocity profiles and rotation*

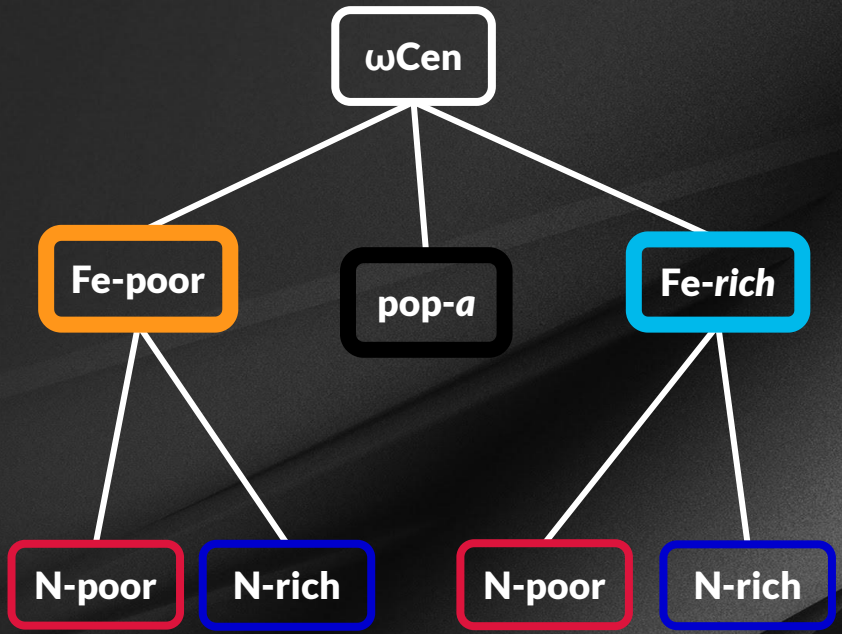
Results

Internal dynamics of populations with different N



- → *Different* morphology
- → *Different velocity profiles and rotation*
- → *Similar* dispersion and anisotropy profiles
- → *Different* dynamics

ωCentauri
Summary



- → Different Fe → Same morphology/dynamics
- → Different N → Different morphology/dynamics
- → Puzzling pop-*a*

Conclusions

Take Away

- ➔ *9 analyzed clusters*
- ➔ *Kinematical differences*
- ➔ *Morphological differences*
- ➔ *Cluster-to-cluster variations*

More details

- Cordoni et al. 2020a, ApJ, 889, 18
- Cordoni et al. 2020b, ApJ, 898, 147

- www.giacomocordoni.me
- http://progetti.dfa.unipd.it/GALFOR

Analyzed clusters

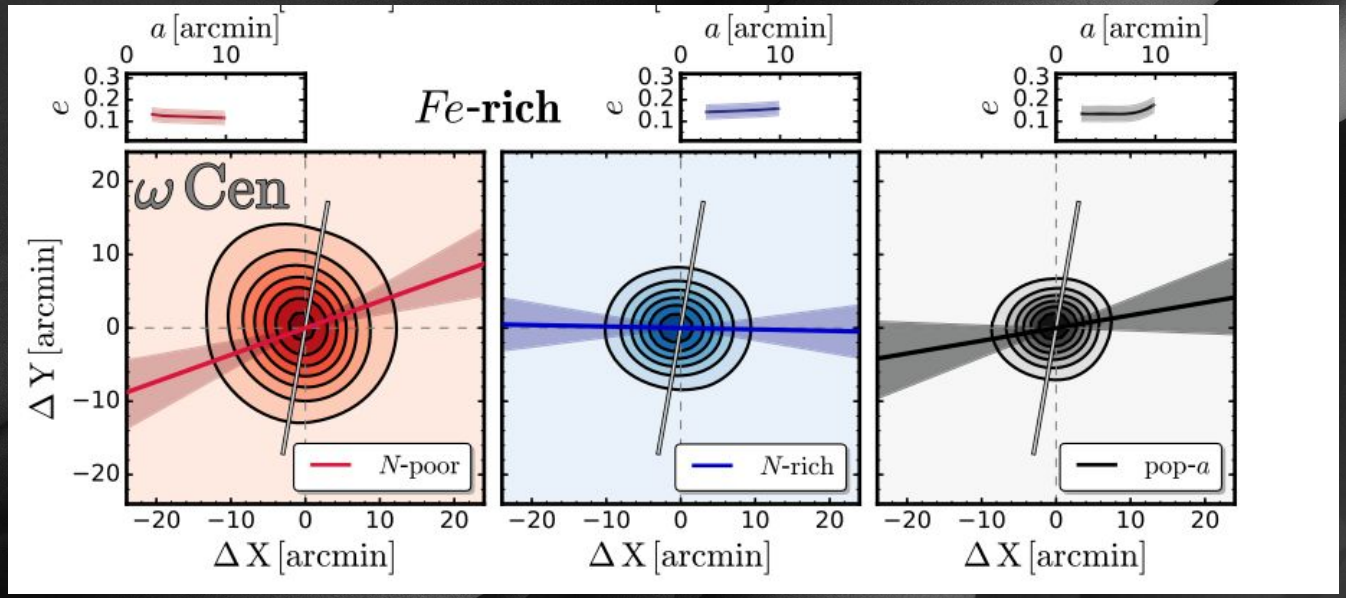
Type I GCs

- NGC 0104 (47 Tucanae)
- NGC 0288
- NGC 5904 (M 5)
- NGC 6121 (M4)
- NGC 6254 (M 10)
- NGC 6752
- NGC 6838 (M71)

Type II GCs

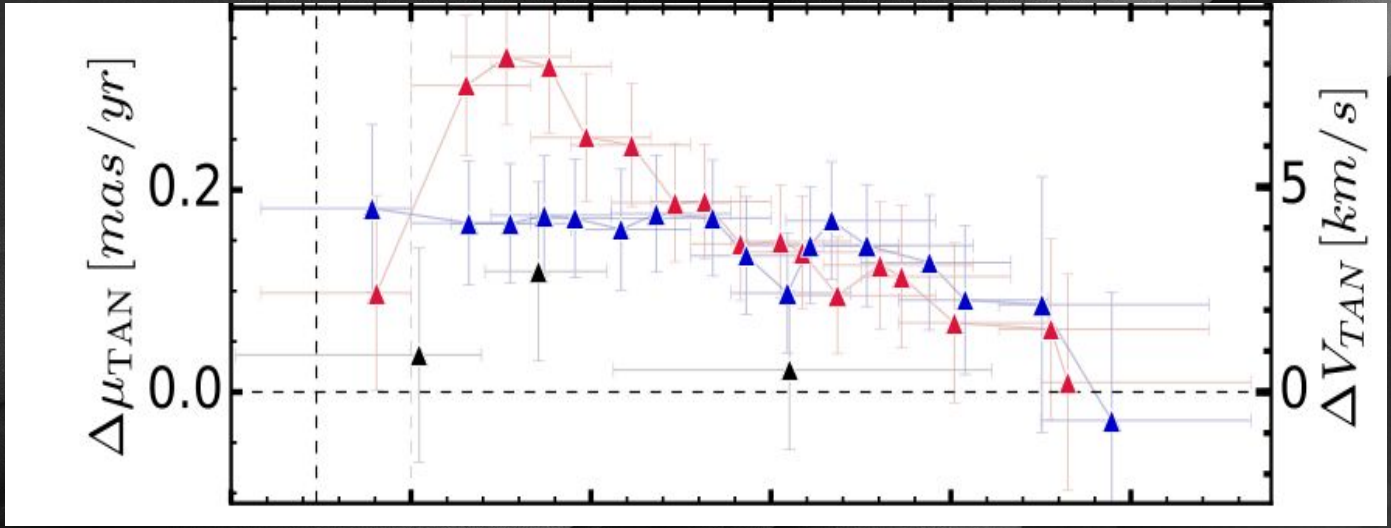
- NGC 5139 (ω Centauri)
- NGC 6656 (M 22)

ωCentauri
pop-*a*

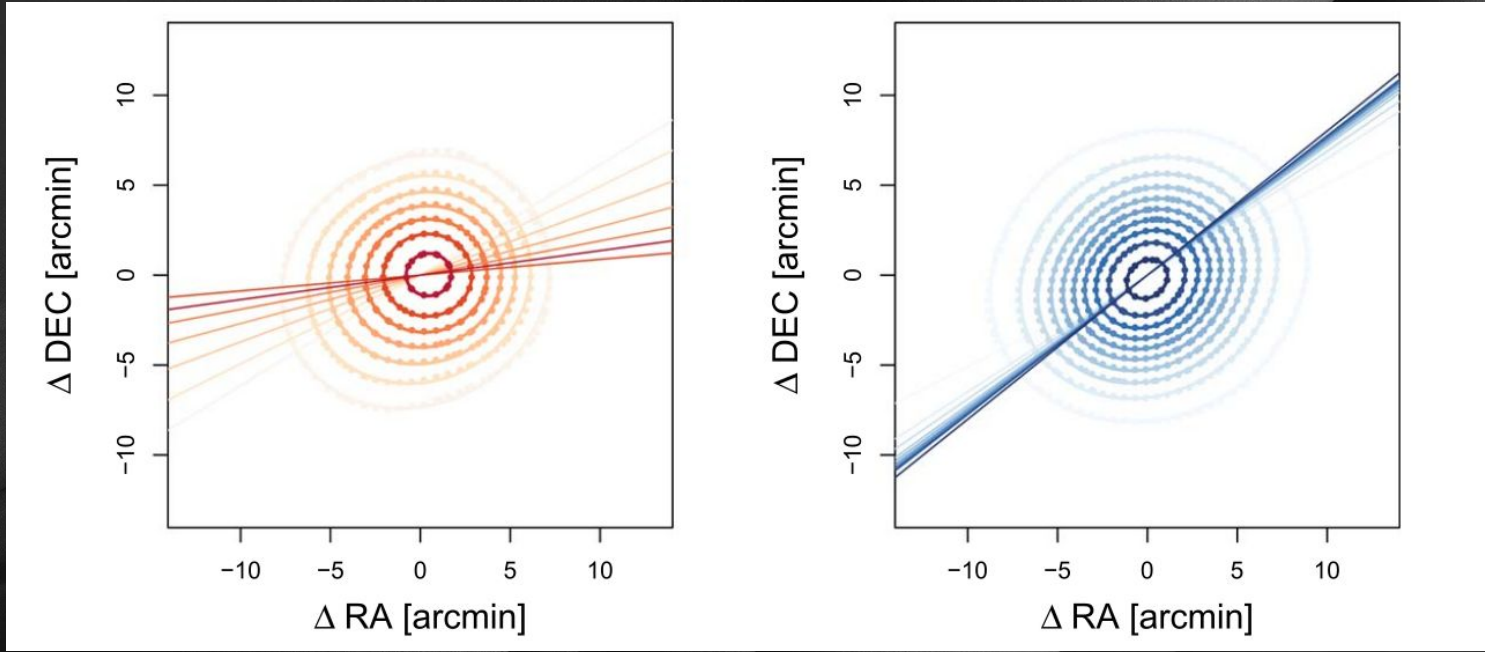


ωCentauri

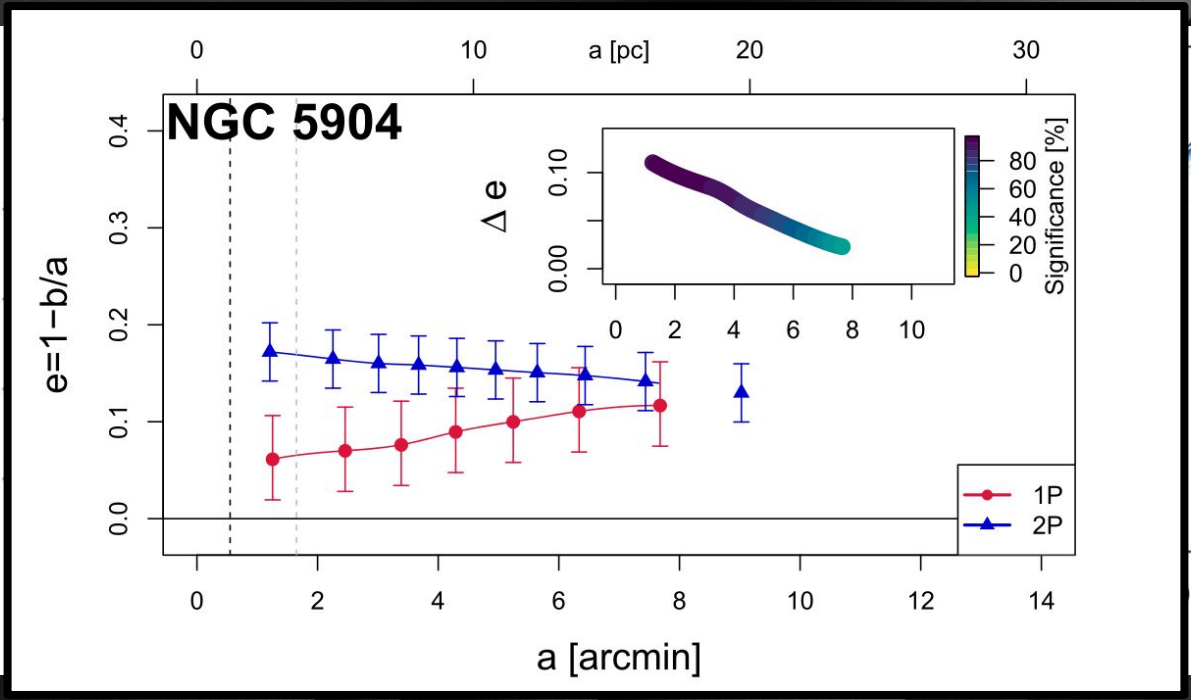
pop-*a*



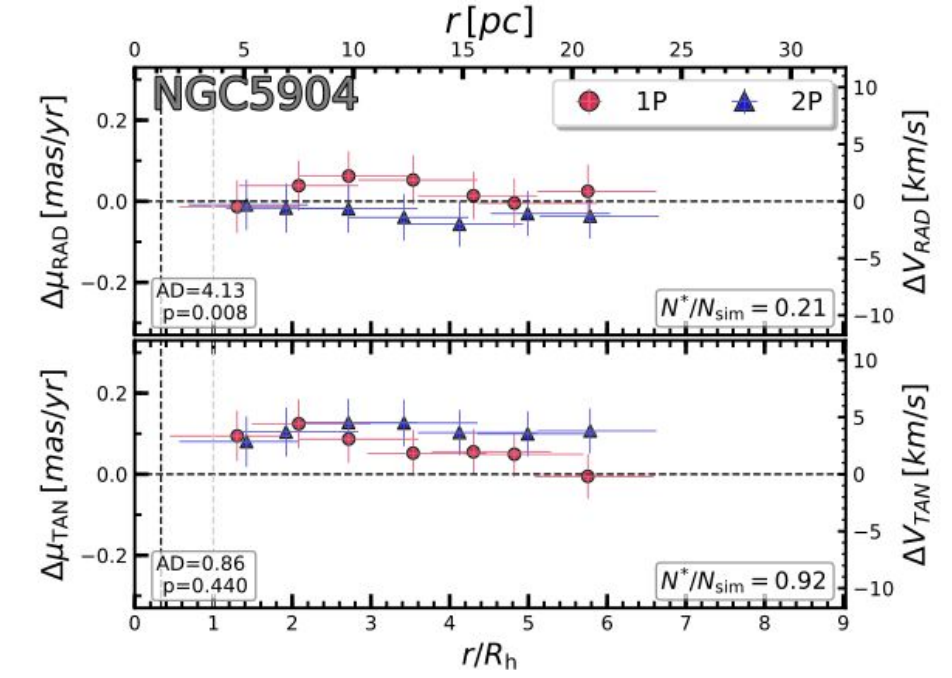
The *'simple' case: M5*
Morphology



The '*simple*' case: M5
Morphology

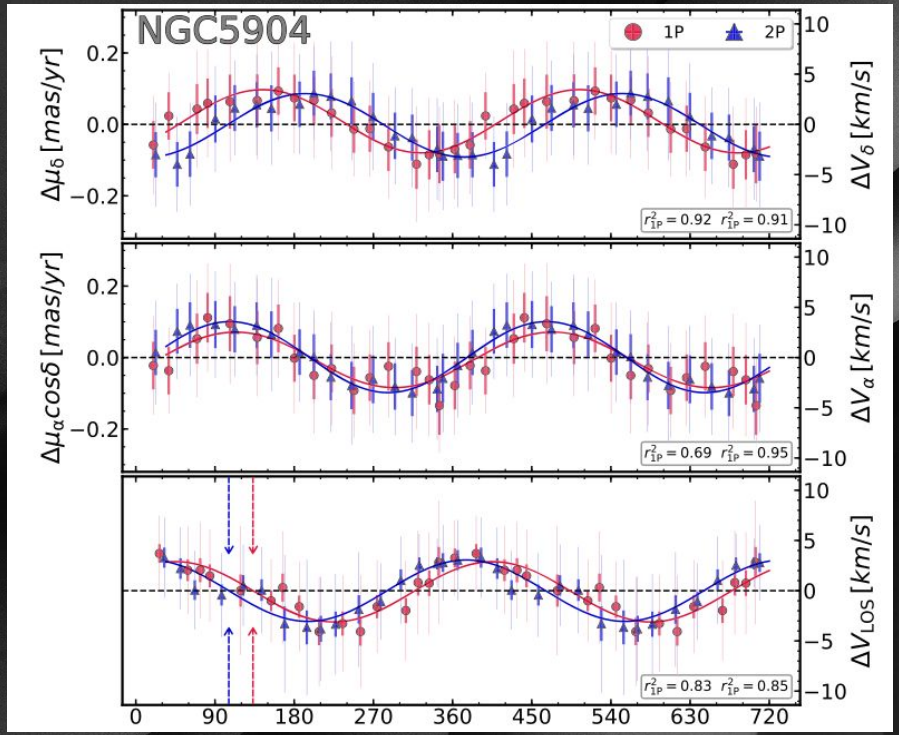


The *'simple' case: M5*
Internal dynamics

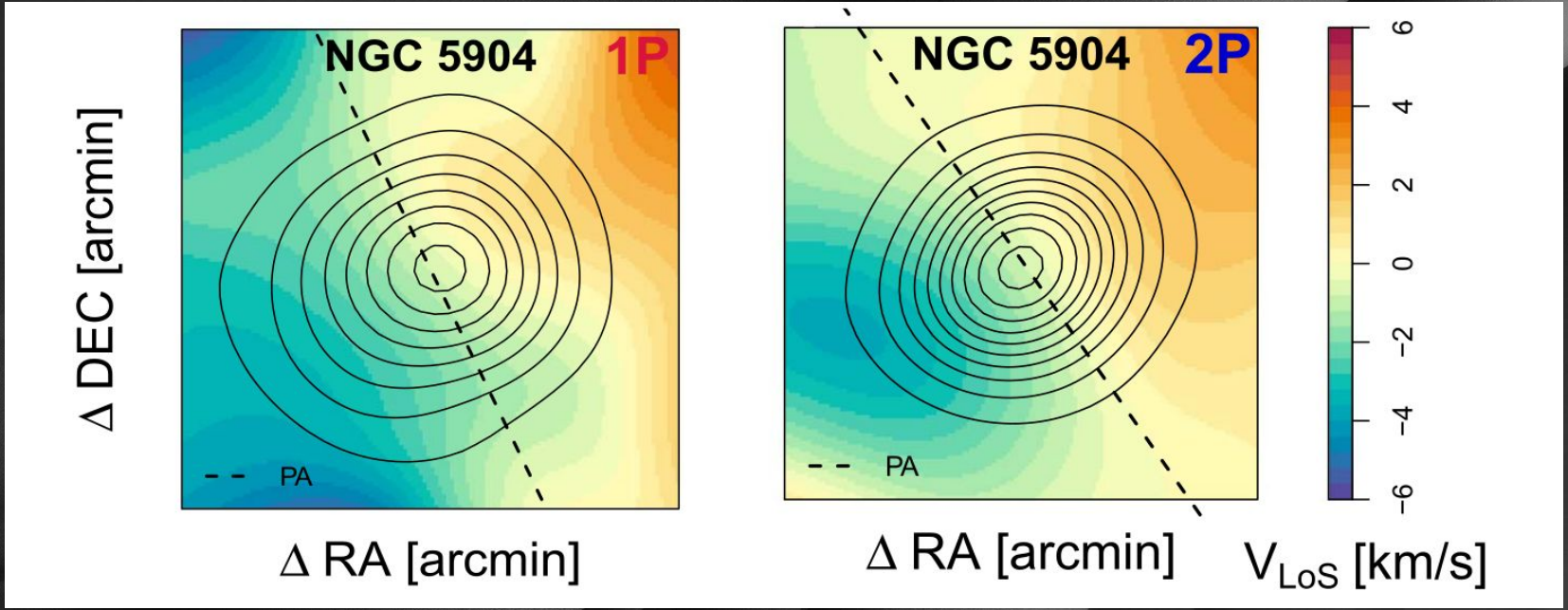


The '*simple*' case: M5

Rotation



The *'simple' case: M5*
Rotation



The *'simple' case: M5*
Summary

- → Different Morphology
- → Different rotation
- → Same dispersion profile

Different overall dynamics