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The asymmetry in the GC population of NGC 4261

[Paolo Bonfini]

University of Crete

Foundation for Research and Technology-Hellas (FORTH)

A. Zezas (University of Crete,FORTH,CfA)
M. Birkinshaw (University of Bristol)
D. M. Worrall (University of Bristol)
G. Fabbiano (CfA)
E. O'Sullivan (University of Birmingham,CfA)
G. Trinchieri (INAF)
A.Wolter (INAF)

The case of NGC 4261

- Research prompted by the asymmetry discovered in the X-ray point sources *(Zezas et al. 2003)*

- NGC 4261: E galaxy (E2) in Virgo cluster (~29 Mpc) *(Jensen et al. 2003)*

- Elliptical galaxies are *spheroidal* systems

  → in general they are expected to show *uniform* starlight distribution

The case of NGC 4261

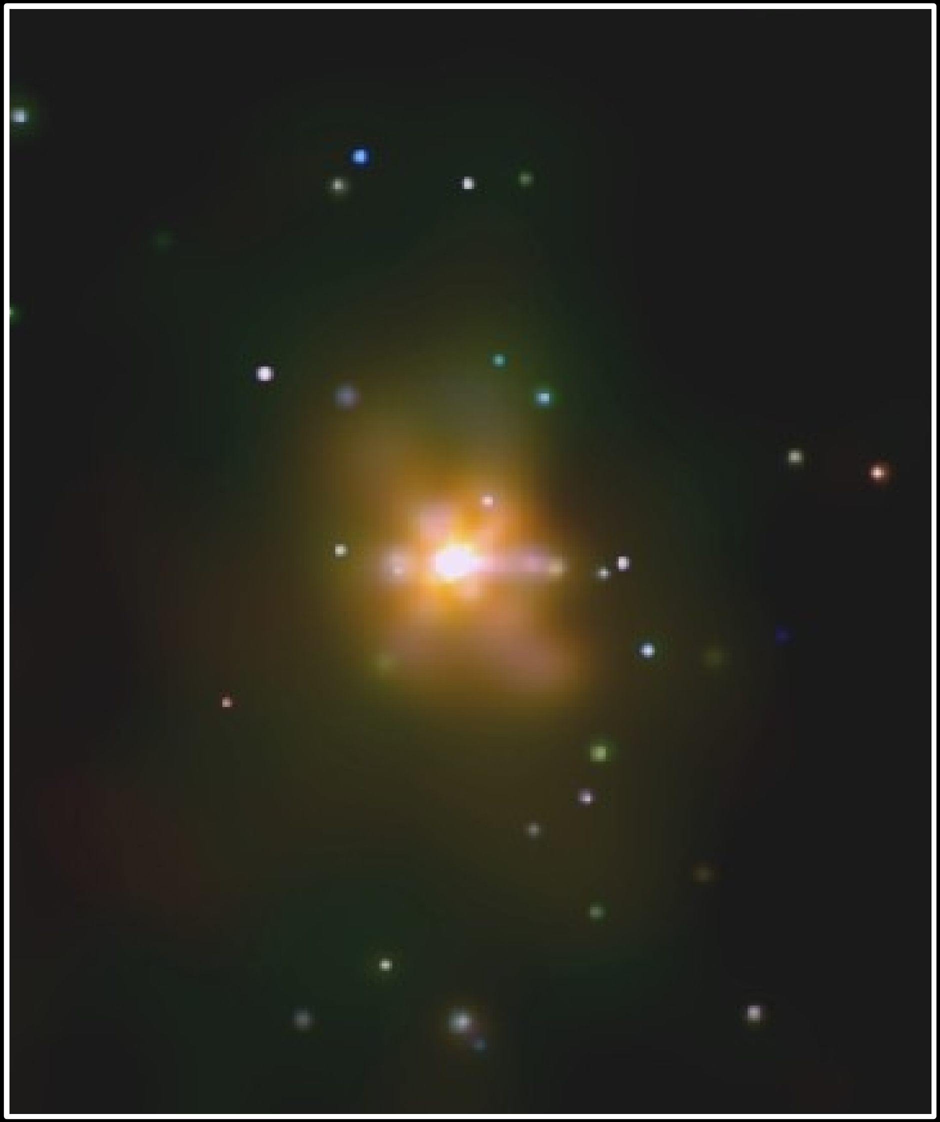
- Apart from the “boxy“ isophotes (e.g. *Nieto & Bender 1989*), does not show sign asymmetry *(Schweizer & Seitzer 1992)*

  → the same uniform distribution is expected for X-ray sources

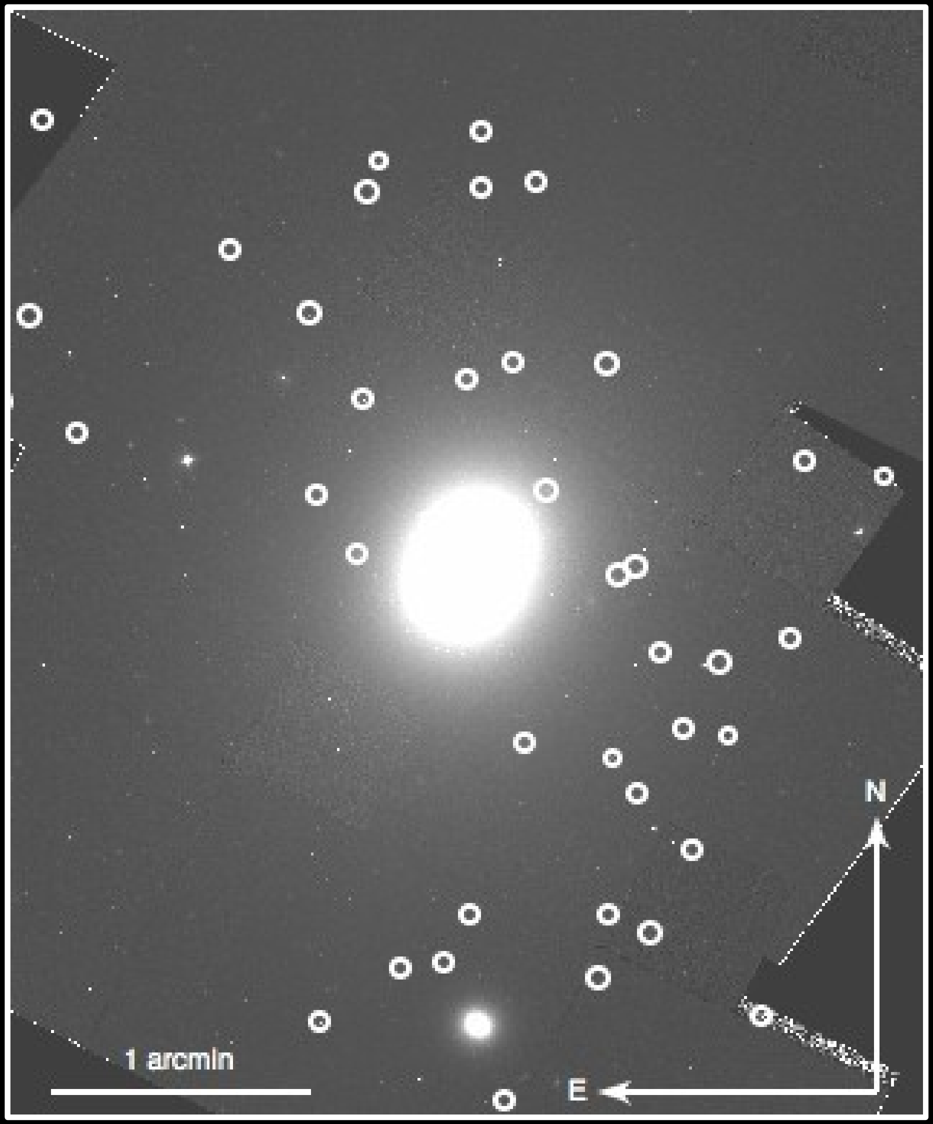
BUT ..

The case of NGC 4261

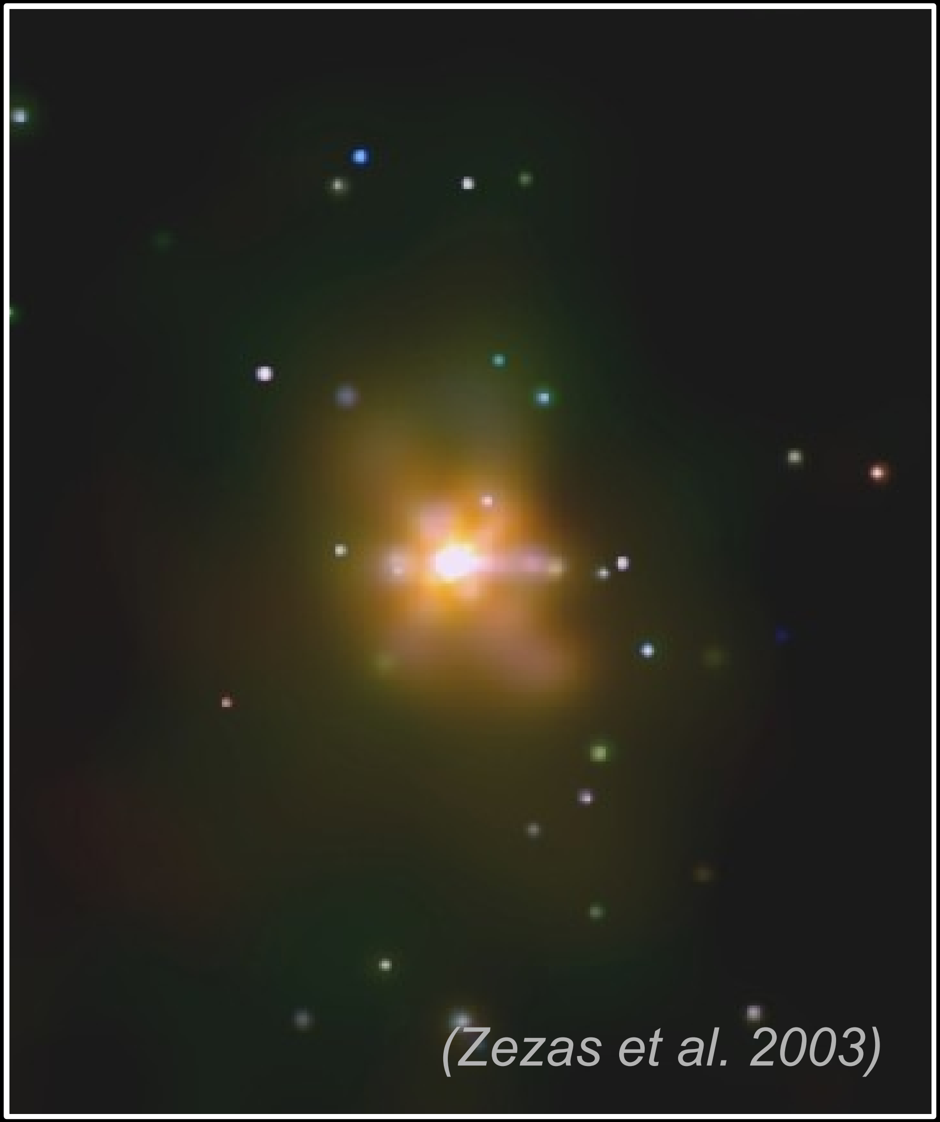
- *.. THEY ARE NOT UNIFORM !*
  (Zezas et al. 2003)



The case of NGC 4261



The case of NGC 4261



- Point like sources are indeed
  Low Mass X-ray Binaries (LMXBs)
  (Giordano et al. 2005)

- LMXBs are binary systems in which accretion produces X-ray emission

- LMXBs in E have > 50% or more probability to be found in GCs
  (e.g. Fabbiano 2006)

  → we want to check whether GCs show similar non uniform distribution

AIMS

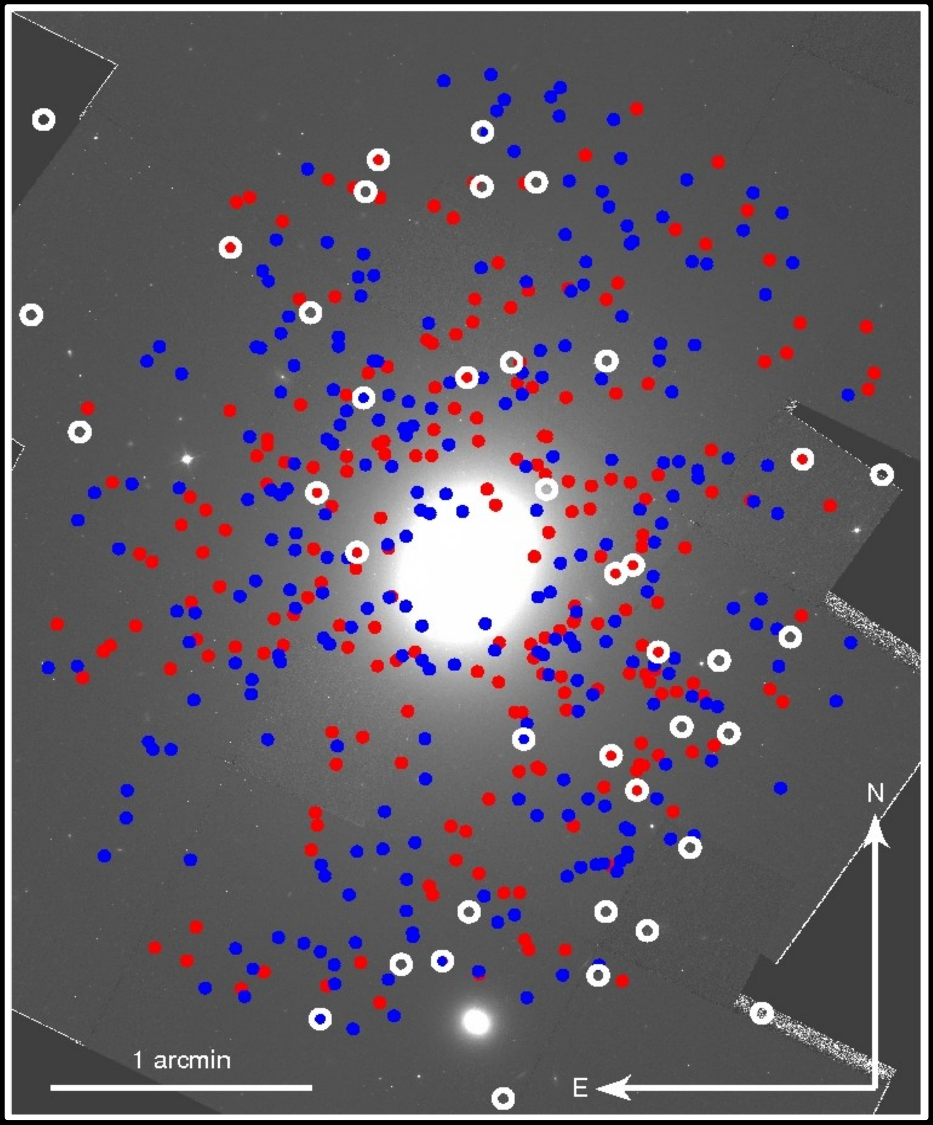
.. WE STUDIED THE 2D DISTRIBUTION OF THE GCs OF NGC4261

- Aims:

  I. Study the galaxy history: past galaxy interactions may have displaced the LMXBs and GCs in a similar fashion

  II. Address the debate on the formation of LMXBs: establish whether they form in GCs or in the field

The data



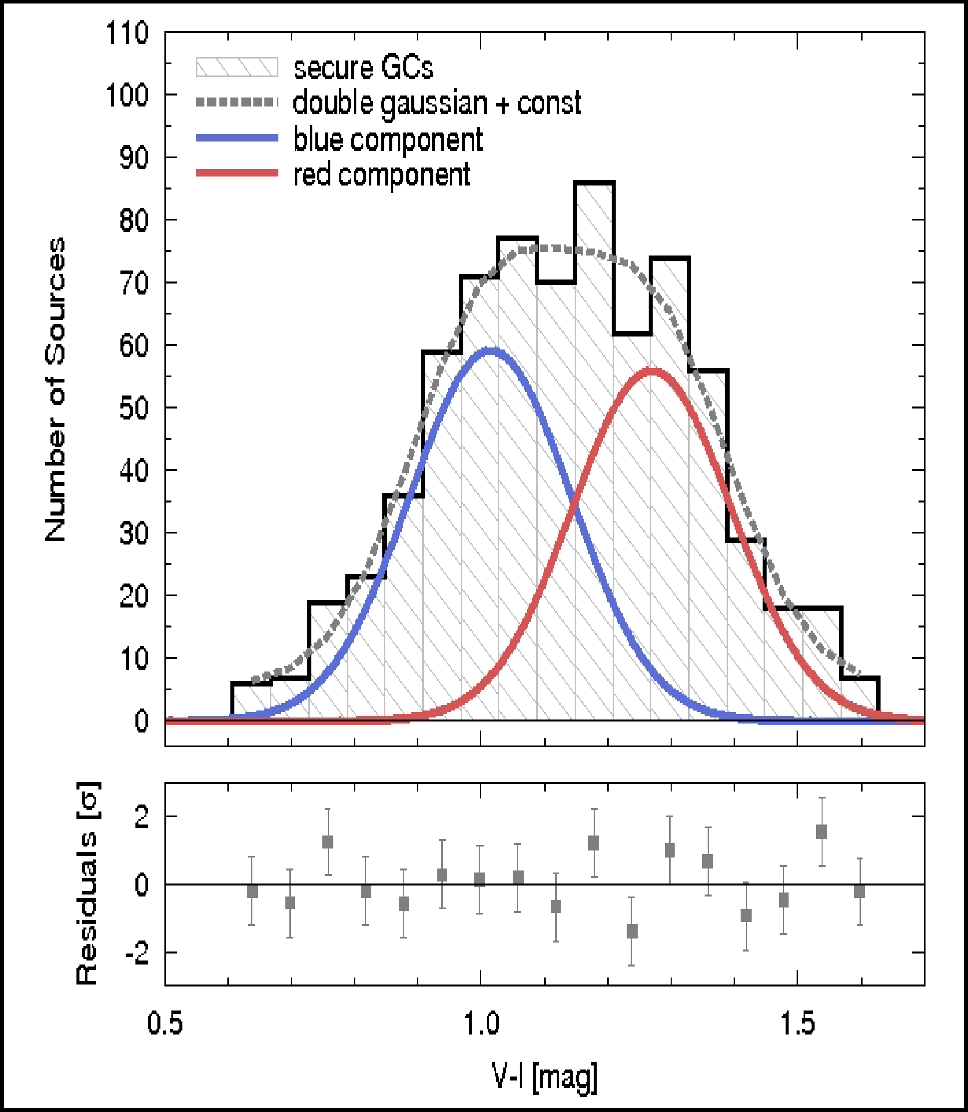
- HST WFPC2 data - filters:
  B, V, I (F450W, F606W, F814W)
  ← mosaic

- Source detection with SExtractor
  (Bertin & Arnouts 1996)

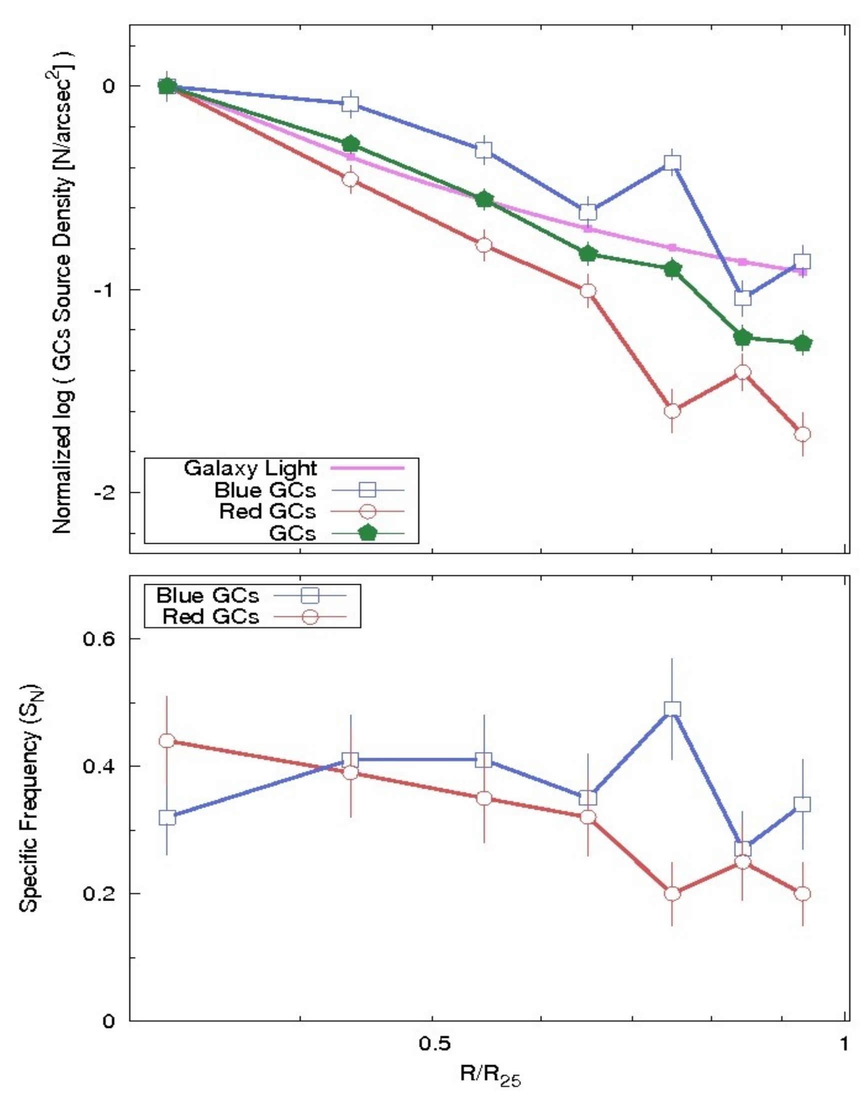
- *Secure* GC sample (718):
  > cross-correlation V and I
  > within D25 (D25 ~ 2')
  > S/N (> 20)
  > FWHM (1.5 < FWHM < 4 px)
  > V - I color (0.6 < V-I < 1.6 mag)
  > axial ratio (0.5 < ∈ < 2.0)

GCs population – Color Distribution

- GCs in E show color bimodality
- In the merging scenario:
  Blue ↔ “donated” by the mergers
  Red ↔ formed in the merging
  (*Ashman & Zepf 1992*)
- Blue ↔ metal poor
- Red ↔ metal rich
- Blue/Red: V – I = 1.15 mag

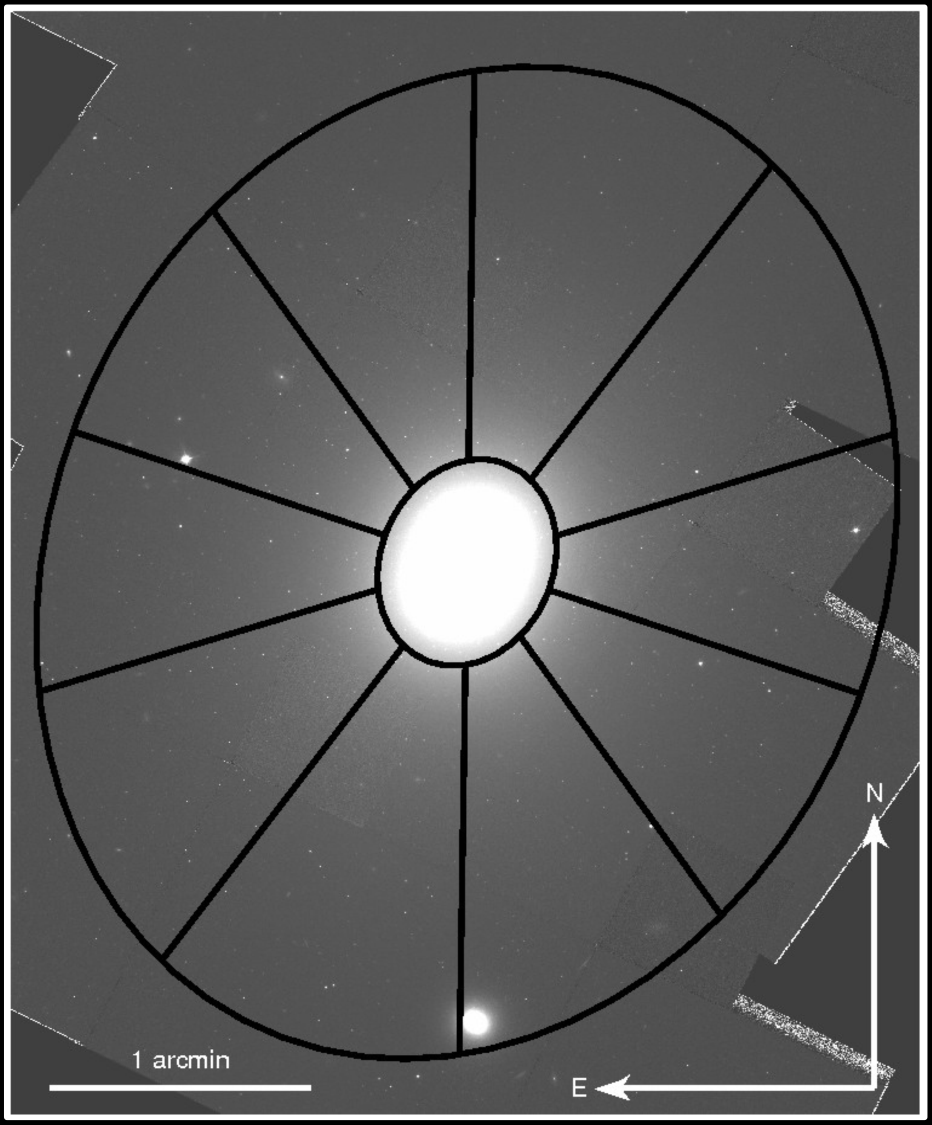


2D distribution – Radial Profile



- Radial profile:
  > Overall GC population is distributed as galaxy light (up to $R/R_{25} = 0.75$)
- S_N ($S_N = N_{GC} \times 10^{0.4(M_V + 15)}$) radial profile:
  > Red GCs consistently declining
  > Blue GCs constant
- In contrast with merging scenario (Red GCs should follow galaxy light)
- Possible confusion due to blending of colors

2D distribution – Azimuthal Profile



- Comparison of:

  GC density **vs** surface brightness within a set of *elliptical* wedges

- Ellipse parameters (P.A., $\in$, ..) determined from 2D fit (GALFIT, *Peng 2002*)

- Procedure:

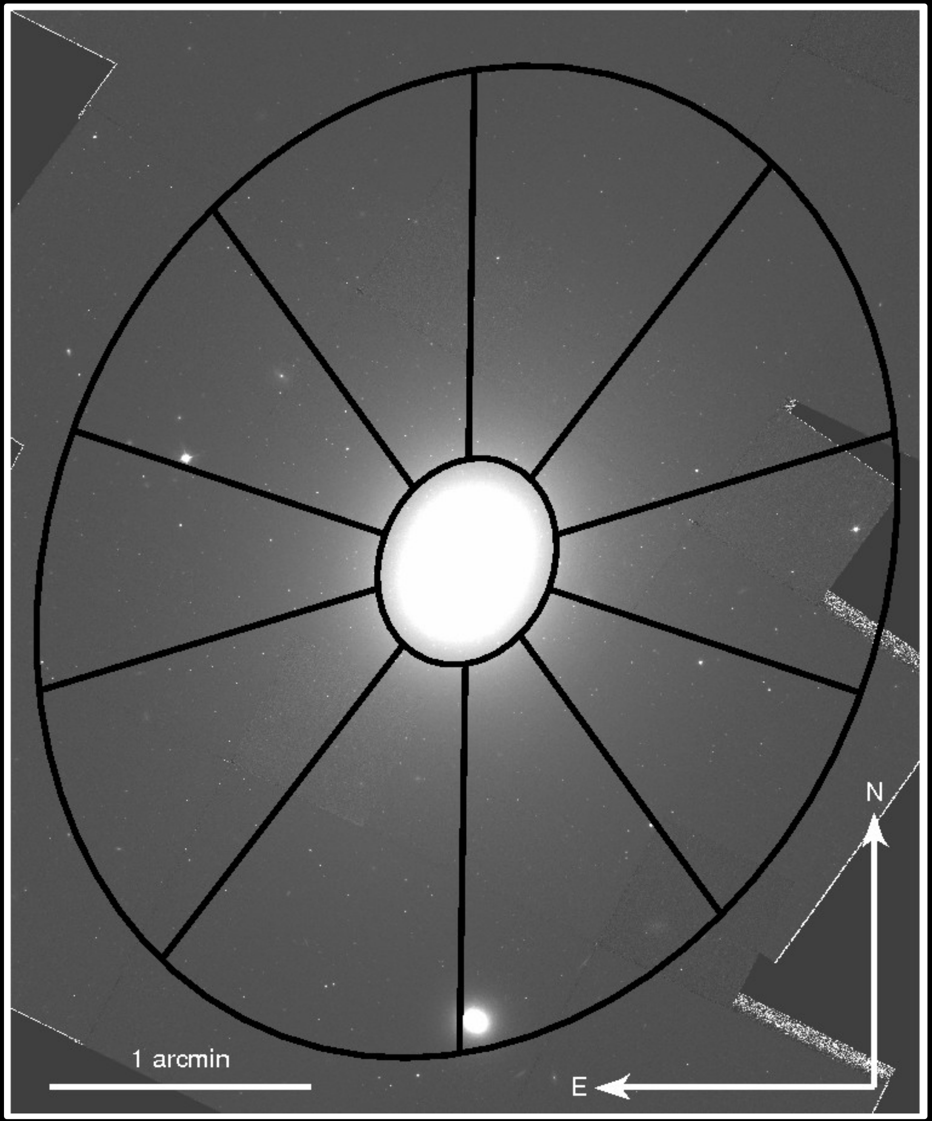
  > measure GC and light density (within each wedge) → profile

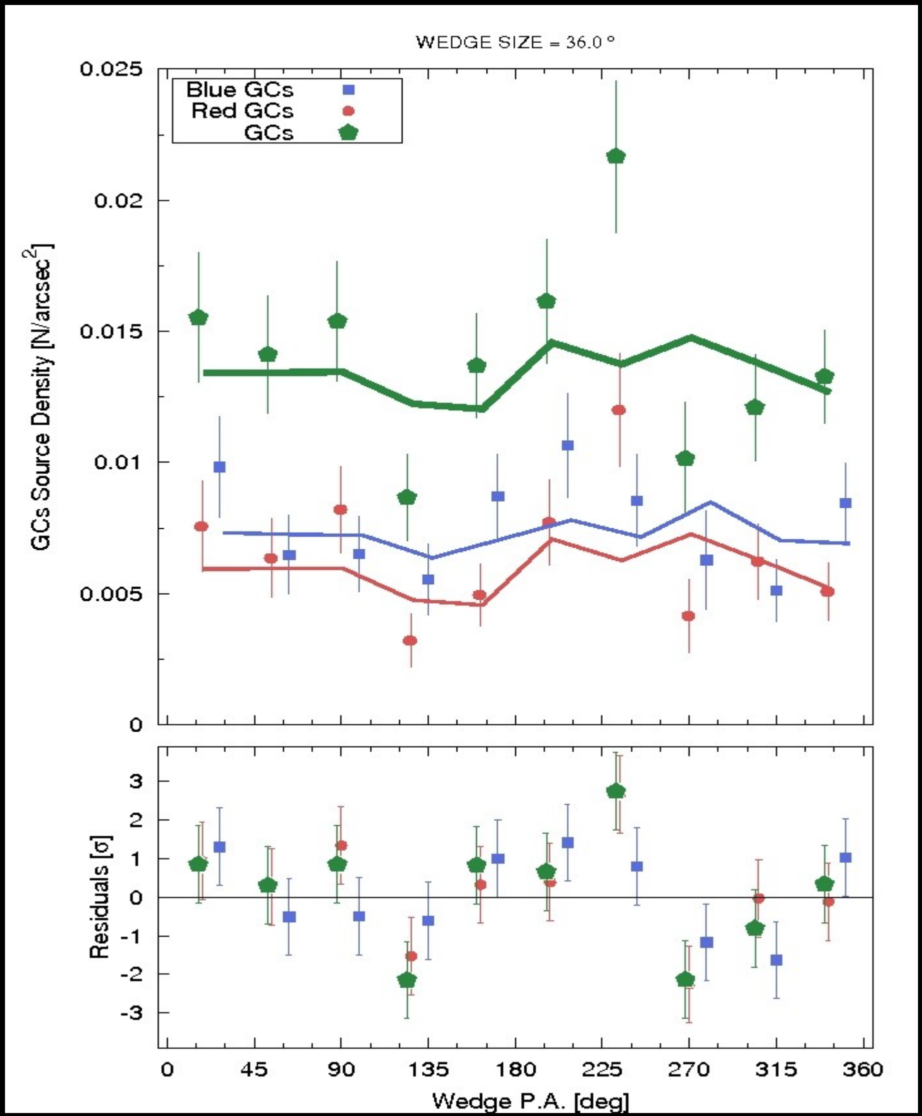
  > perform a χ^2 test (fit light to GC azimuthal distribution)

  > repeat for different wedge rotations

  > identify rotation which maximizes χ^2

2D distribution – Azimuthal Profile





2D distribution – Azimuthal Profile

- The *MAX* χ_ν^2 for the whole GCs sample was:

  $$\chi_\nu^2 = 2.5 \text{ (9 d.o.f.)}$$

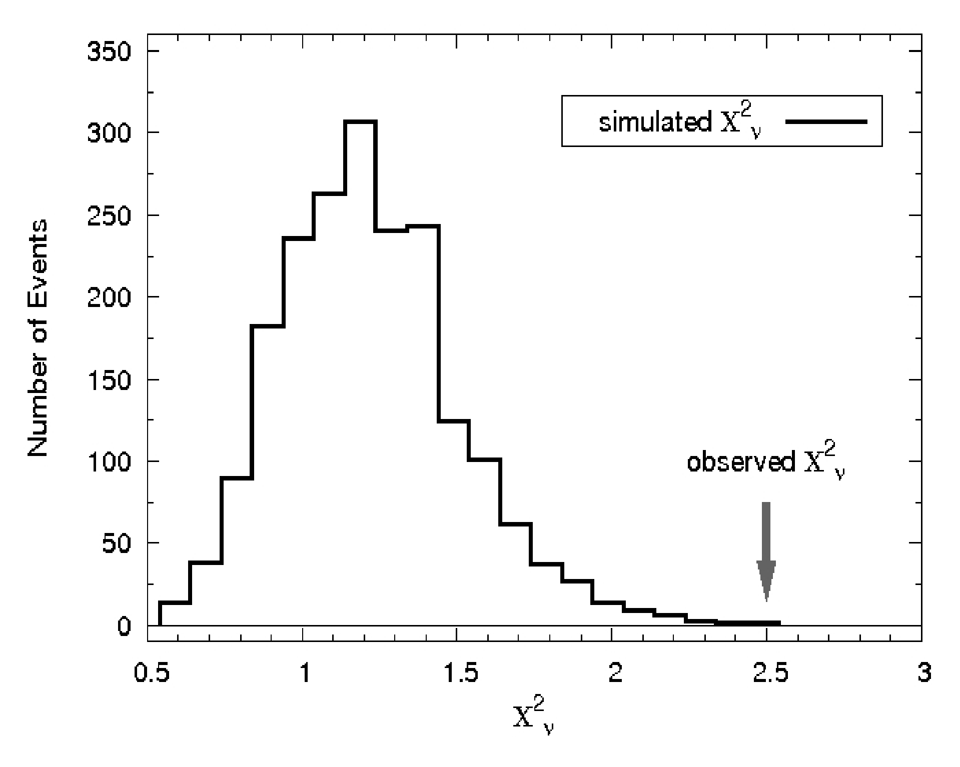
- We *chose* the maximum χ^2 → *can't* use the standard χ_ν^2 density function to get confidence level

- We simulated a uniform distribution within each wedge and fit with constant

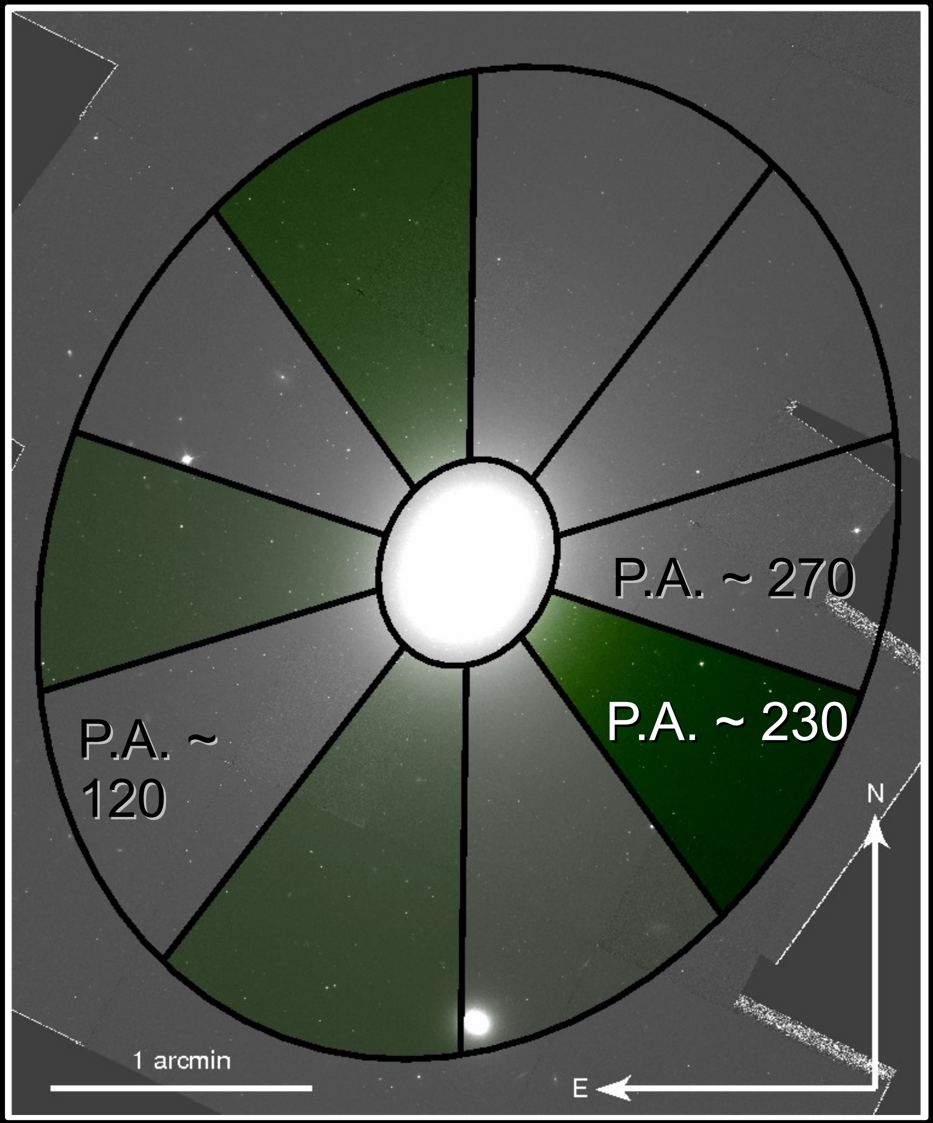
- We produced the χ_ν^2 distribution:

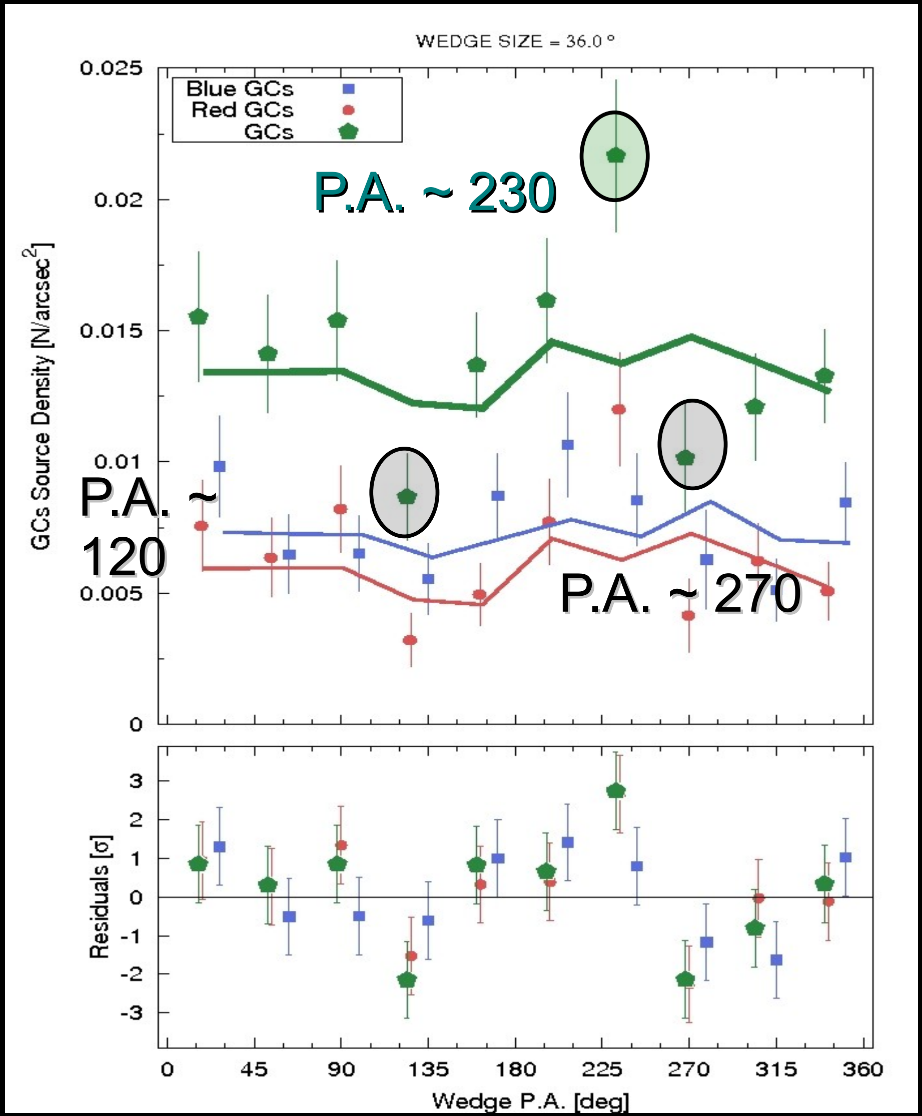
  $$P(\chi_\nu^2 > \chi_\nu^2 \text{obs}) < 0.1\%$$

  → *asymmetry is statistically significant*



2D distribution – Azimuthal Profile





On the origin of asymmetry

I. Major Merging

> Is the best candidate to explain such significant asymmetry

.. *BUT*

NGC 4261 does not show strong sign of interaction in the past 1 Gyr
→ stellar system is relaxed, GC system not
→ different relaxation timescale for the GCs - no evidence for such difference

On the origin of asymmetry

II. *Minor Merging*

> Little mass involved
→ easily explain displacement of GCs, but not donation or creation of GCs

e.g. NGC 1052 underwent a recent (1 Gyr) merging event with a gas rich dwarf
(van Gorkom et al. 1986)
its galaxy light showing almost no disturbance
(Schweizer & Seitzer 1992)
no young GCs associated with merger
(Pierce et al. 2005)

On the origin of asymmetry

III. Galaxy interaction

> Known to provoke displacements of the GCs systems
e.g. NGC 1399 - NGC 1404
(Napolitano et al. 2002, Bekki et al. 2003, Bassino et al. 2006)

> GCs may have been shifted from NW and SE “poles” towards NE-SW plane (with the galaxy nucleus masking the center)
The GC systems extend much further than galaxy light
→ the displacement affected mostly the outermost GCs and not the light

.. BUT

several companions 1 to 2 Gyr off NGC 4261 (using group *v* dispersion)
→ can not uniquely identify the responsible

Summary

- We studied the radial and azimuthal distribution, finding evidences for an *asymmetry* in the azimuthal distribution

- We explored the origin of the asymmetry in the context of galaxy interaction:
  > ruled out the possibility of minor merging
  > favored the hypothesis of fly-by encounter displacing the outermost GCs
  > stressed the importance of relaxation time in case of major merger

→ SUGGESTIONS ON THE ORIGIN OF ASIMMETRY ARE WELCOME !

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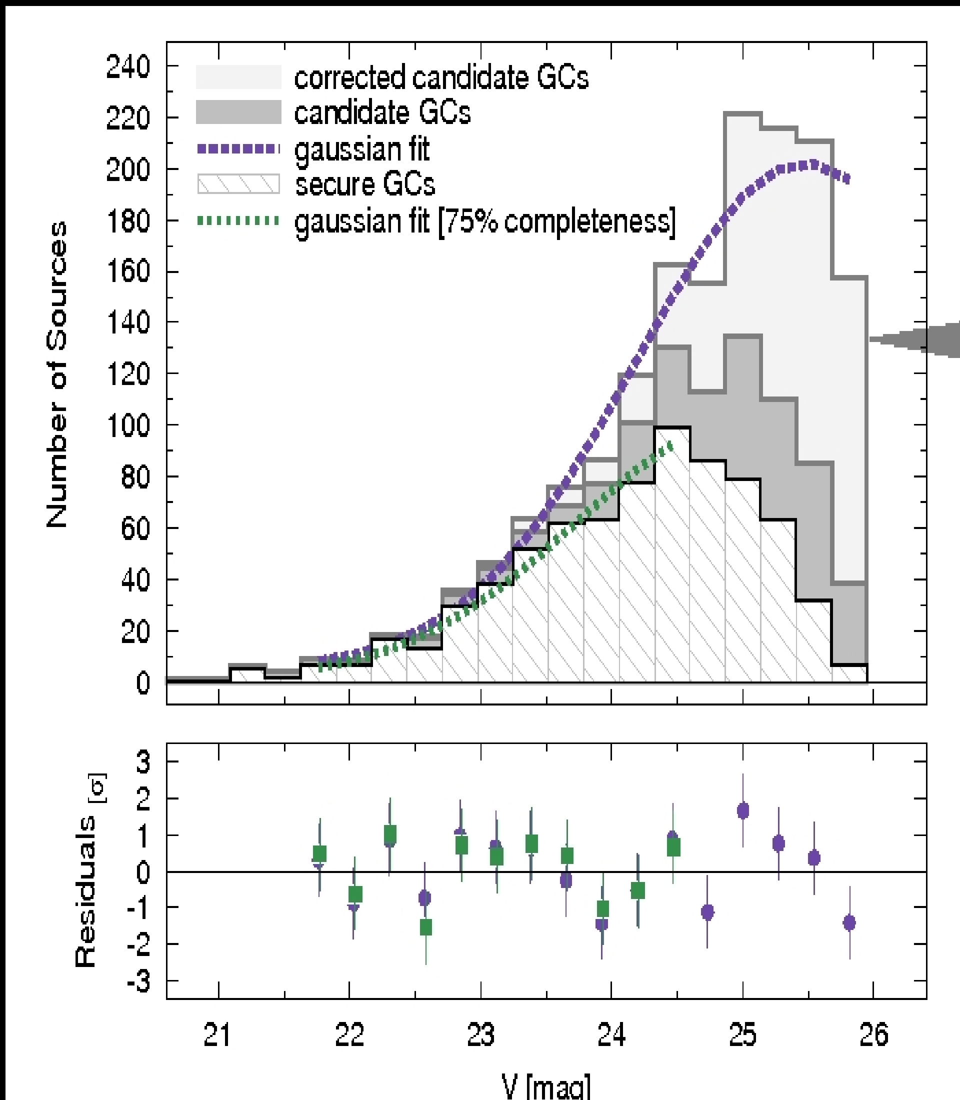
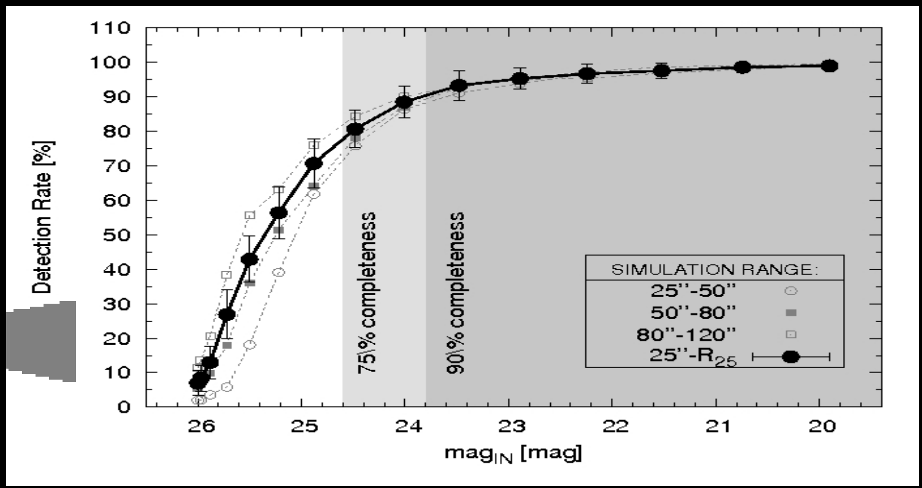
GCs population - Luminosity Function





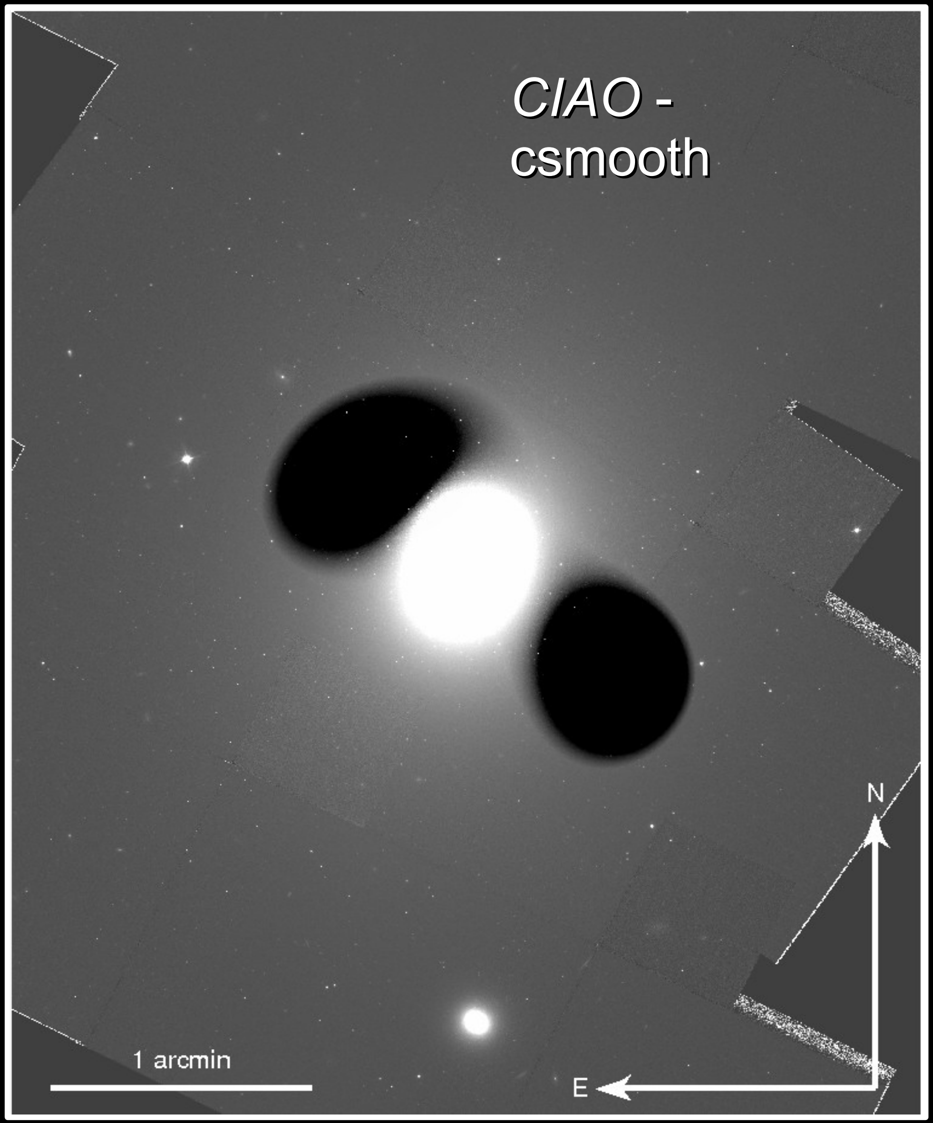
- Completeness simulation
- Gaussian fit (*secure* GCs truncated at V = 24.6 mag - 75% comp.)
- *Secure*:

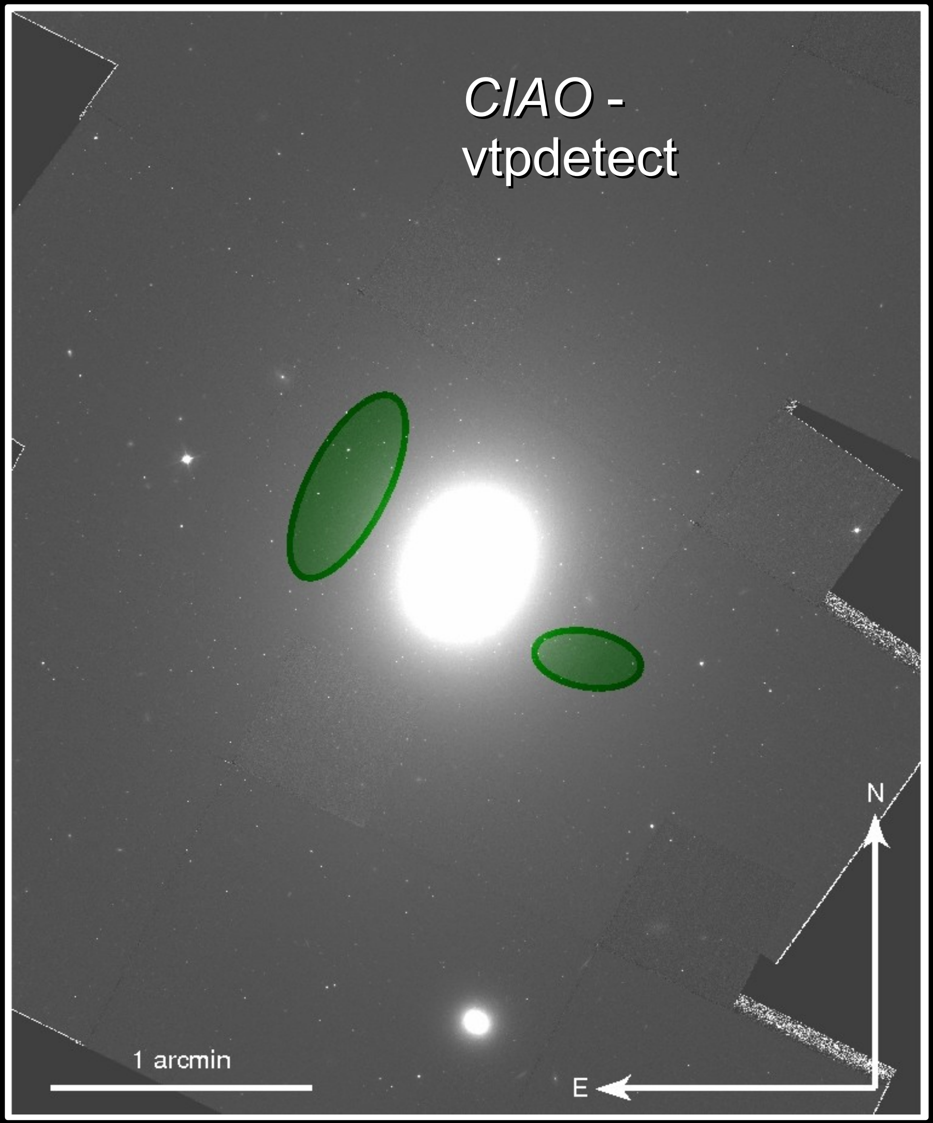
  > V_{peak} = 25.1 ± 0.8 mag

  → D = 31.6 ± 12 Mpc
- *Candidate*:

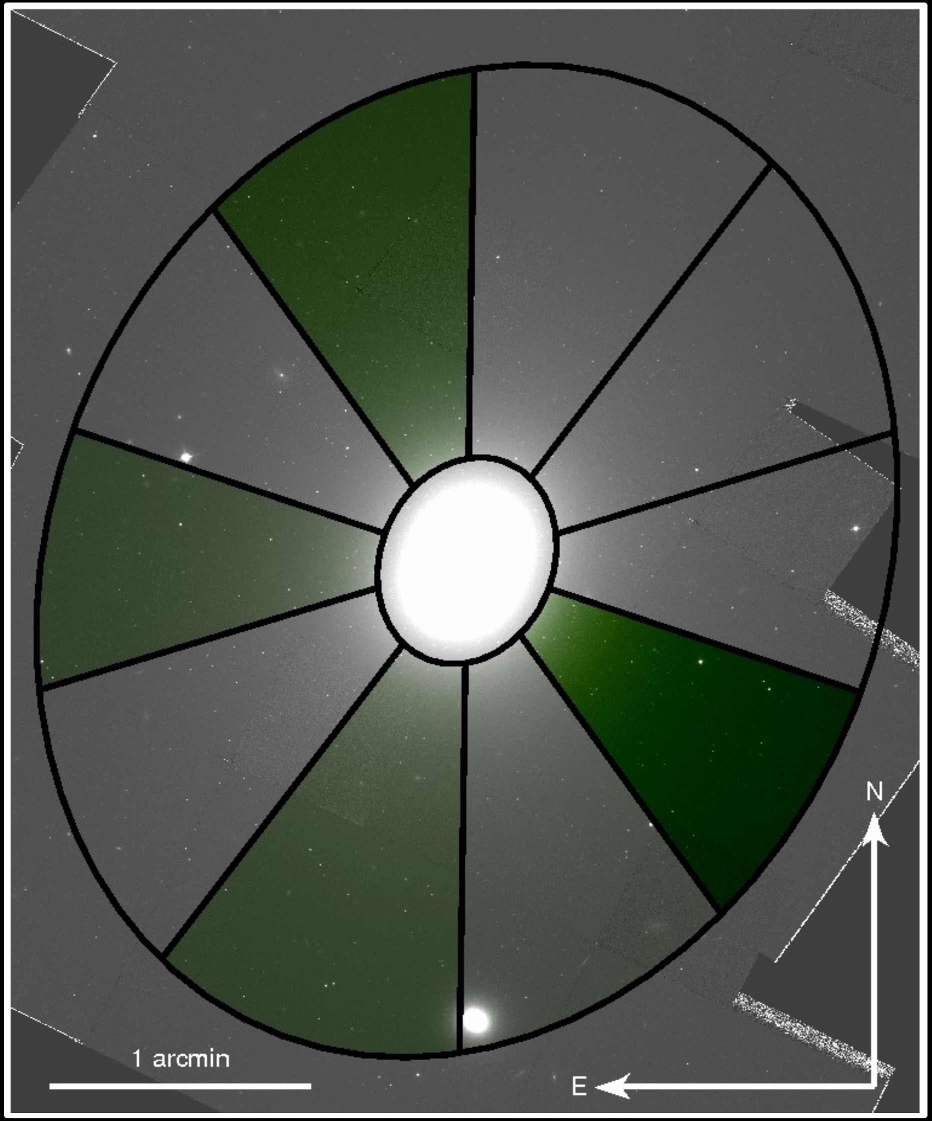
  > $S_N = N_{GC} \times 10^{0.4(M_V + 15)} = 2.8 \pm 0.5$

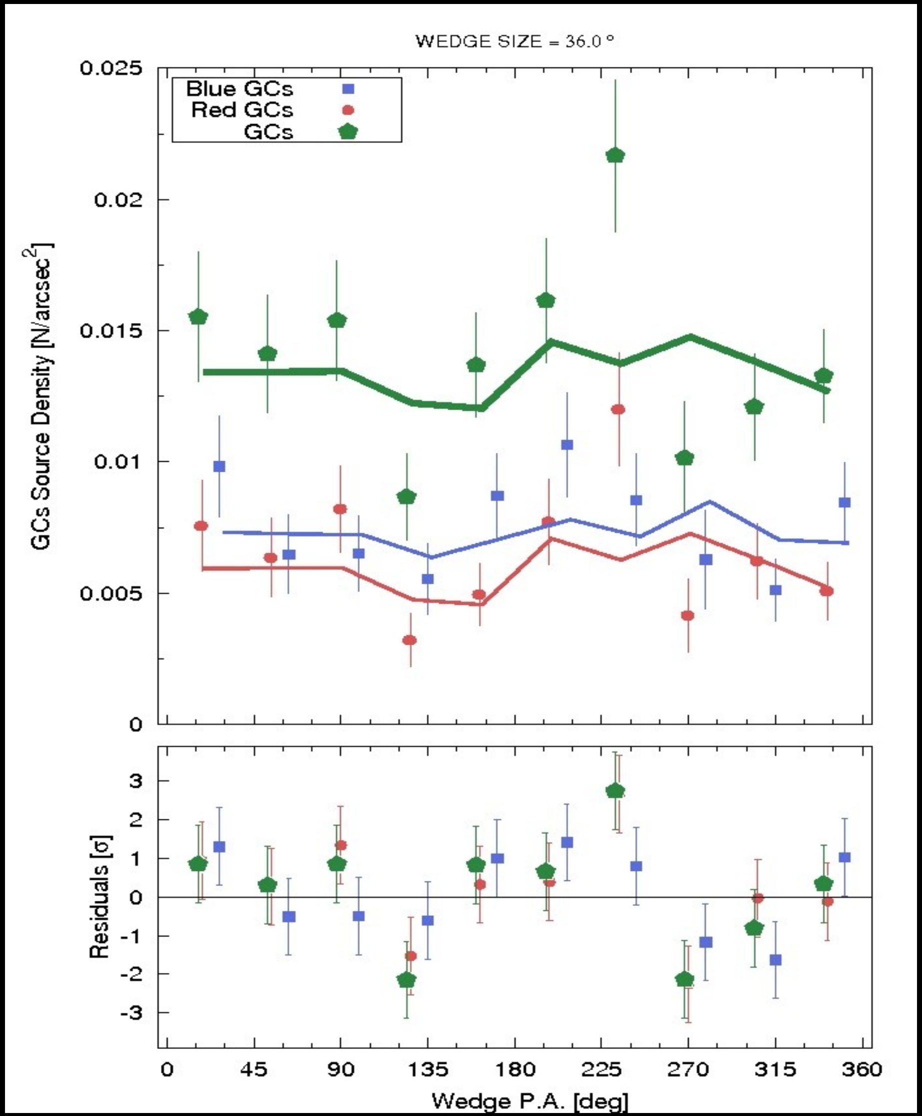
2D distribution – Source clustering





2D distribution – Azimuthal Profile





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> GCs could have been formed along a line-of-sight tail

.. *BUT*

Numerical simulations suggest that massive *boxy* ellipticals are the result of dry mergers between spirals of similar size
(e.g. Khochfar & Burkert 2005; Naab, Khochfar & Burkert 2006)
→ no significant GCs creation