

NCAC Annual Meeting 2026

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MOCCA Upgrades and Collaboration Projects

Last year, we continued to expand and further improve the MOCCA code, with a focus on

- a more realistic description of globular clusters (GCs) hosting **multiple stellar populations**, and
- stellar dynamics in extremely dense environments, including tidal disruption events involving IMBHs.

In parallel, this work resulted in **8** peer-reviewed publications, **5** papers under review, and **2** in preparation.

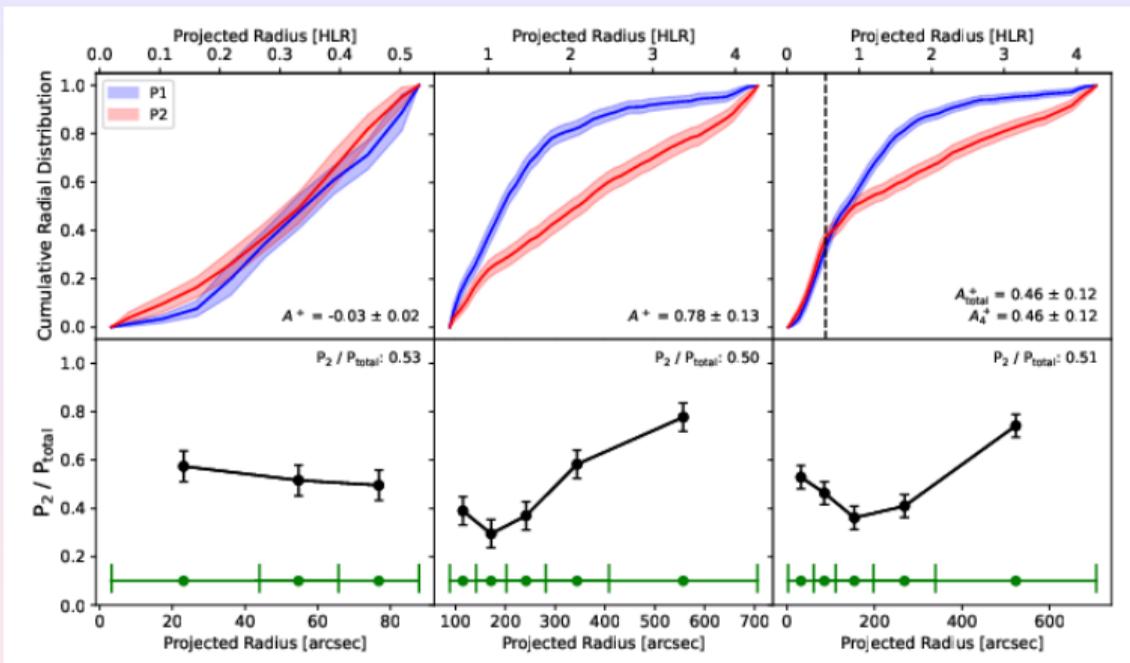
AGB pollution scenario and its extension:

Speculative scenario in which GC environment and early dynamical evolution shape observable MSP properties, including the correlation between cluster mass and the fraction of enriched stars.

Today I focus on one specific result of this scenario: an explanation for cases where the **pristine population appears more centrally concentrated** than the enriched population — an observational finding that is difficult to reconcile with proposed formation scenarios.



GCs with Centrally Concentrated Pristine Stars: NGC 3201

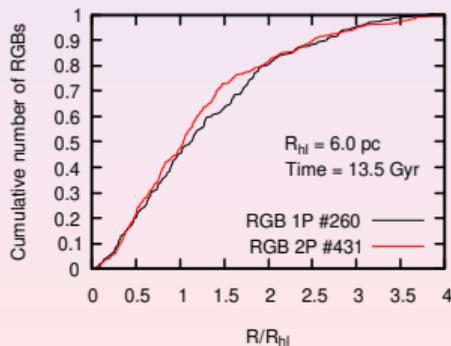
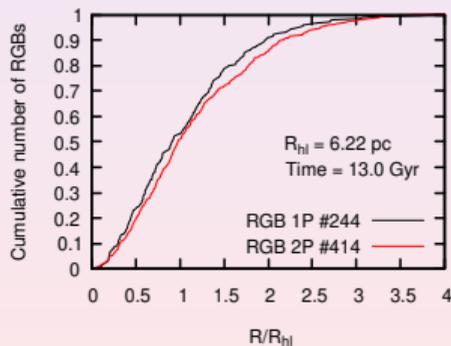
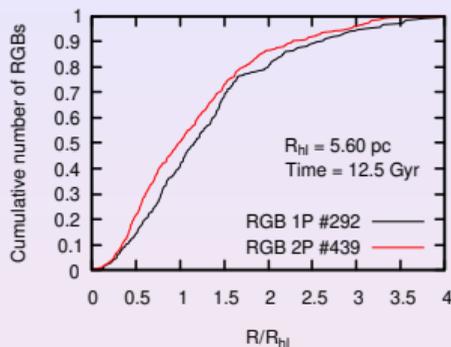
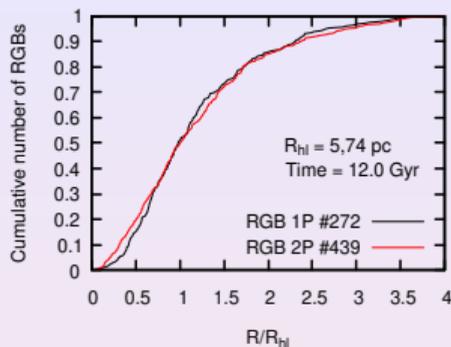


NGC 3201 – Credits: Letinger et al. 2023

- Cumulative radial **number distributions** of 1P/2P are derived using **RGB stars**.
- The degree of spatial segregation is quantified using the **difference in the areas** between the cumulative radial distributions (A^+).
- a few GCs (e.g., NGC 3201 and NGC 6101) shows an apparent central concentration of the **pristine (1P)** population.
- Confirmed by Cadelano et al. (2024).
- Challenged by Mehta et al. (2024).



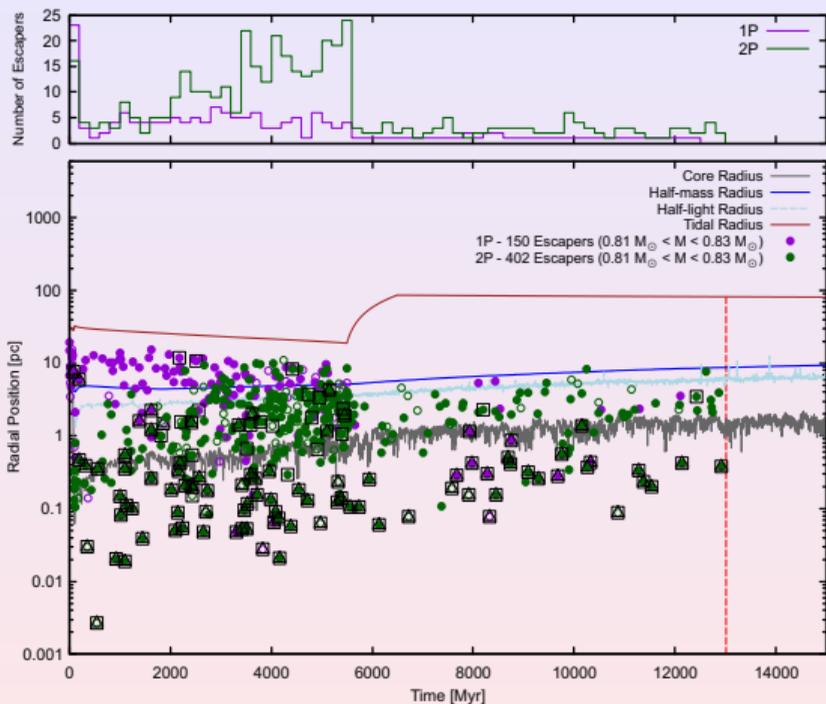
MOCCA Simulations with Centrally Concentrated Pristine Stars



- This model is a **MOCCA analogue** of clusters such as NGC 3201, showing an apparent central concentration of the pristine (1P) population.
- The effect appears **only when MSPs are studied using RGB stars**.
- **When main-sequence stars are used instead, the inversion disappears.**
- The behaviour is found mainly in relatively **low-mass, ex-situ** cluster models, e.g. NGC 3201 and NGC 6101.
- MOCCA results have been independently confirmed by direct *N*-body simulations performed in collaboration with **Peter Berczik's group** (with Francesco Flammini-Dotti; in preparation).



Physical Mechanism: Ejection of Enriched RGB Progenitor Stars



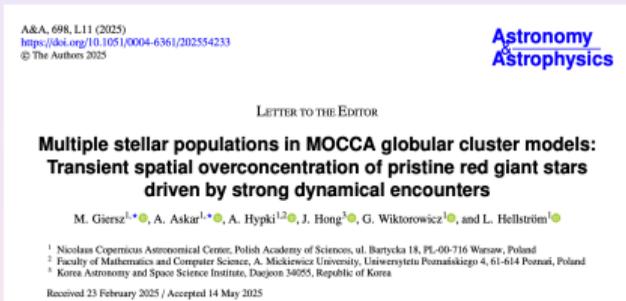
- Strong dynamical encounters (binary–single and binary–binary interactions) preferentially **eject progenitors of present-day enriched (2P) RGB stars**, which are initially more centrally concentrated.
- Many of these encounters involve stellar-mass black holes that form a subsystem in the cluster core.
- The strength of the effect can be quantified by

$$R = \frac{N_{\text{RGB, in cluster}}}{N_{\text{RGB, progenitor dyn escapers}}},$$

with small R implying a strong bias in **present-day** RGB radial distributions.

- The apparent over-concentration of **present-day** pristine (1P) RGB stars is therefore a **transient feature**.





The results presented in Giersz et al. (2025) make a **clear, testable prediction**:

- The apparent inversion seen among **RGB stars** should **not** be present when multiple populations are traced using **main-sequence stars**.
- This provides a decisive way to distinguish a **transient dynamical effect** from a distinct formation scenario.

Motivated by this prediction, a **JWST/NIRCam Cycle 5 GO proposal** has been submitted to study multiple populations among **low-mass main-sequence stars** in NGC 3201.

The proposal involves **leading observers of multiple populations in GCs**, together with **Mirek Giersz** and **Abbas Askar** from CAMK.

