Age-dependent kinematics of Mira variables in the Galactic Centre

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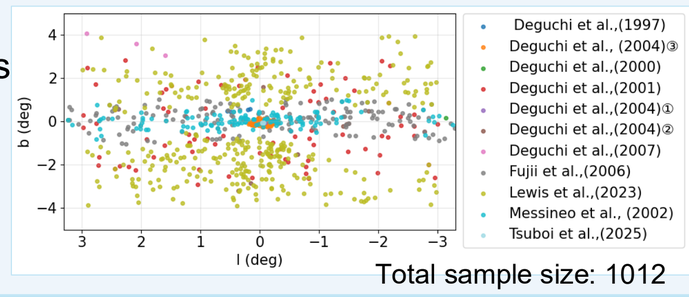
1. Introduction

- The Nuclear Stellar Cluster (NSC) and Nuclear Stellar Disk (NSD) retain information about their formation and dynamical evolution.
- **Mira variables** are infrared-bright AGB stars whose **ages** can be reasonably estimated from their pulsation periods.
- ➢ Their ages, combined with their kinematics, provide powerful constraints on **the formation and evolution** of the Nuclear Stellar Cluster(NSC) and Nuclear Stellar Disk(NSD) in the Galactic Center.

2. Data — Mira & SiO maser catalogues

- We focused on **Mira variables** in the Galactic Centre
- Took line-of-sight velocities from **Mira SiO maser catalogues** (e.g. Deguchi et al. 2004; Messineo et al. 2018; Tsuboi et al. 2025 / Observed at 43/86 GHz using Nobeyama, IRAM 30m, and ALMA),
- Took pulsation periods from previous monitoring surveys (e.g. Wood et al. 1998; Glass et al. 2001; Matsunaga et al. 2009)



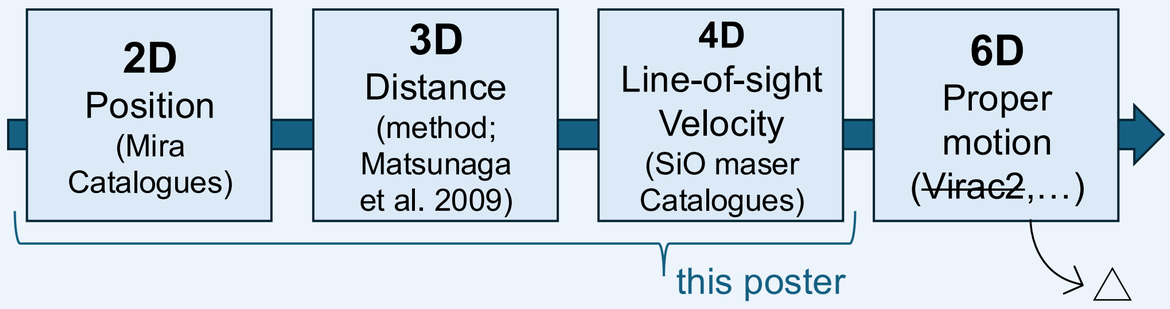
Mira Catalogues

Total sample size: 1012

3. Method

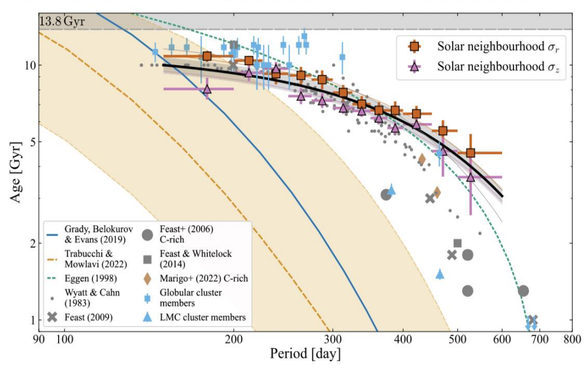
Sample construction

・Cross-matching the SiO maser catalogues with the Mira catalogues



Age estimation using PAR

Zhang & Sanders, 2023



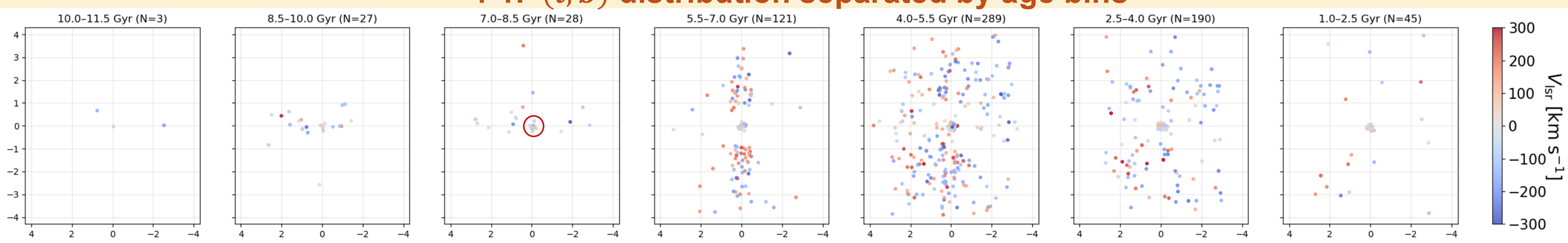
・Using the following PAR, we assigned ages to the sample, divided the data into several age bins, and investigated how their kinematics depend on age.

Period-**A**ge **R**elation (Zhang & Sanders. 2023)

$$\tau = \tau_0 \frac{1}{2}(1 + \tanh[\frac{330 - P}{P}])$$

4. Results & Discussion

4-1. (l, b) distribution separated by age bins



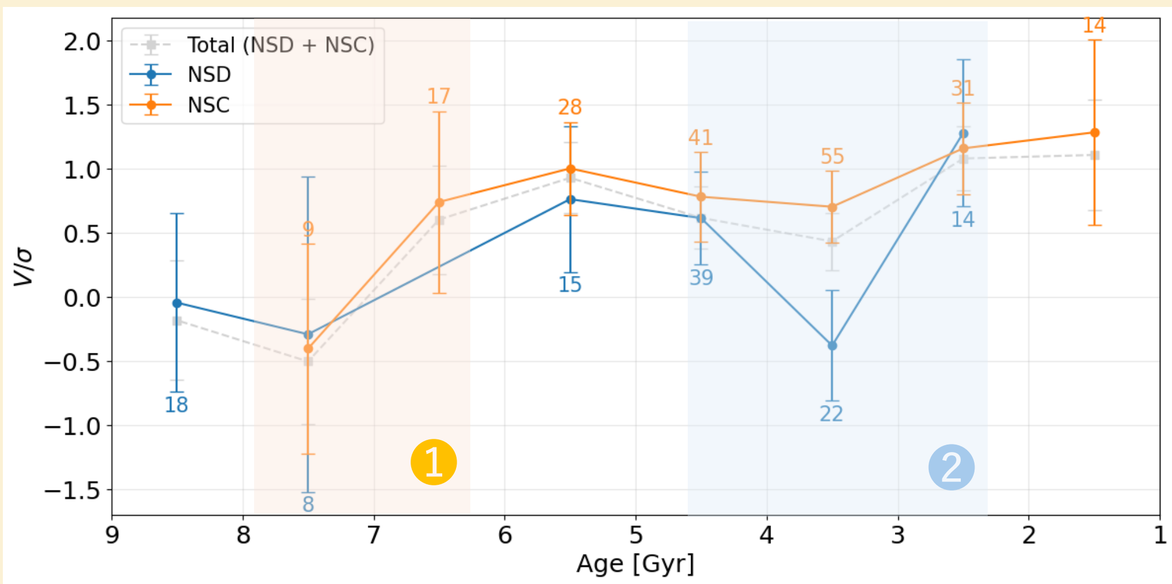
past → **present**

- In the |l|,|b| < 0.5 deg region, an NSC-like is clearly identified in the 7–8.5 Gyr bin (○). This is younger than the formation epoch of more than 10 Gyr ago proposed by Schödel et al. (2020), suggesting that our analysis gives a younger age for the NSC component
- By incorporating age information, we find that star formation is is still ongoing within the NSC in the central region defined above.
- Across the entire region, rotational motion becomes prominent in the age bins older than 8 Gyr. Motivated by this result, Section 4-2 discusses the temporal evolution of the NSD and NSC, whilst Section 4-3 examines the temporal evolution of their rotational velocities.

4-2. Estimating the timing of dynamical evolution of NSD & growth of NSC (Sample selection: $|l| < 3°$, $|b| < 1°$, N=340)

Temporal evolution of V/σ, calculated from the rotational velocity and velocity dispersion in each age bin.

V/σ = 1~3 → Rotational motion dominates
V/σ < 1 → Random motion dominates



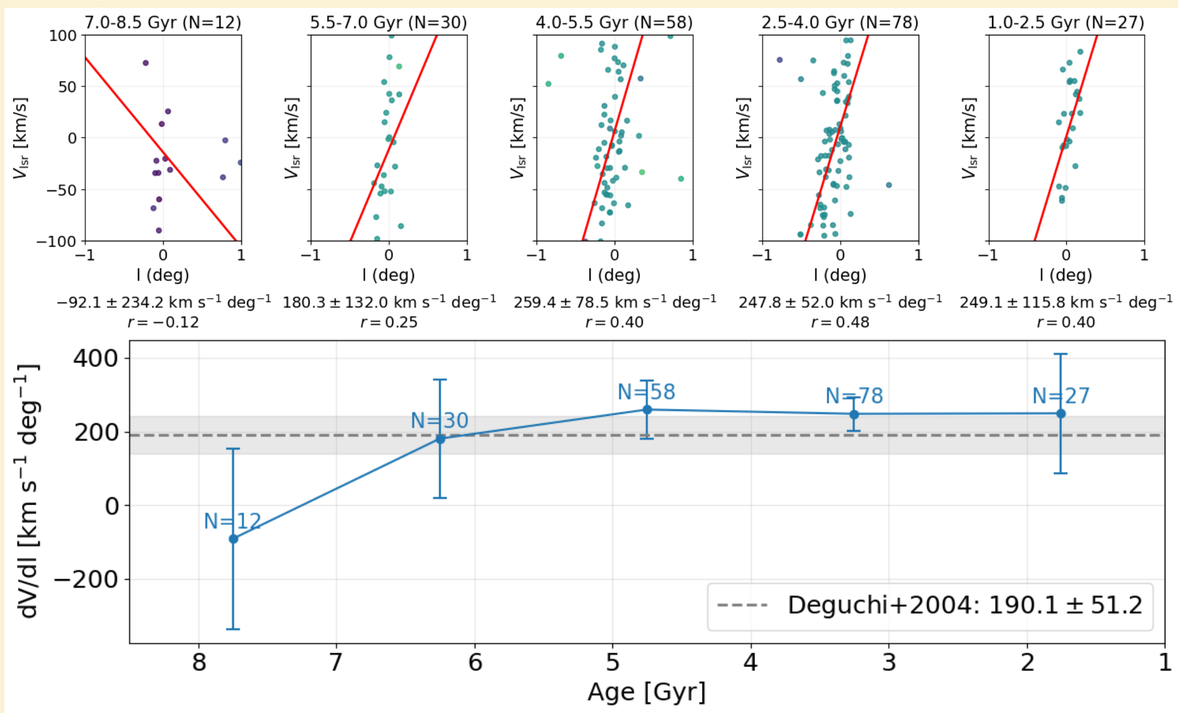
- During period ❶, a sharp jump in V/σ is observed
  → may be related to the formation and rapid growth of the NSD associated with bar evolution.
- During period ❷, whilst the V/σ of the NSD decreases sharply, no significant changes are observed in the NSC
  → may reflect an internal or external dynamical event affecting the NSD.

ex). Virgo Radial Merger, @3 Gyr ago (Donlon et al. 2019)
NSC growth @ 3-5Gyr ago (Chen et al. 2023)

4-3. Temporal evolution of rotational velocity

(Sample selection: $|l| < 0.3°$, $|V_{lsr}| < 150$ km/s, N=205)

The rotational velocity was derived for each age bin from a linear fit, and its temporal evolution is discussed below.



- A positive correlation between l and V_{lsr} was observed in the 1–7 Gyr range.
- No significant age dependence of the rotational velocity was found within the current uncertainties.
- The derived rotational velocities are broadly consistent with previous measurements by Shuji Deguchi et al. (2004).
- ➢ This analysis demonstrates the potential of Mira variables as age-tagged tracers of Galactic-centre kinematics.

▶Future work

- Add proper motions → Motion Analysis Using 6D+ Age Information
- Constraining NSD/NSC evolution using Mira age information
- More Advanced Separation of NSC, NSD and Bulge

References:
Matsunaga, N. et al. 2009, MNRAS, 399, 1709; Zhang, H. & Sanders, J. L. 2023, MNRAS, 521, 1462; Schödel, R. et al. 2020, A&A, 641, A102; Deguchi, S. et al. 2004, PASJ, 56, 261; Donlon, T. et al. 2019, ApJ, 886, 76; Chen, Z. et al. 2023, ApJ, 994, 79