CHARACTERISING THE GALACTIC WARP WITH GAIA. DIFFERENT APPROACHES

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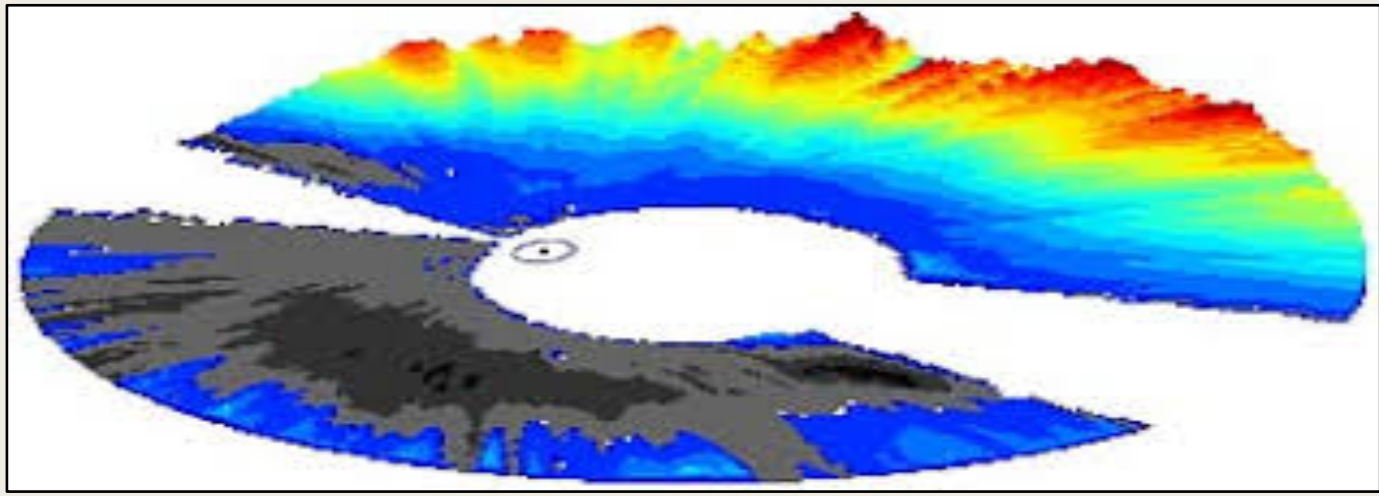
Expanding the Gaia legacy. The role of Spanish ground-based facilities

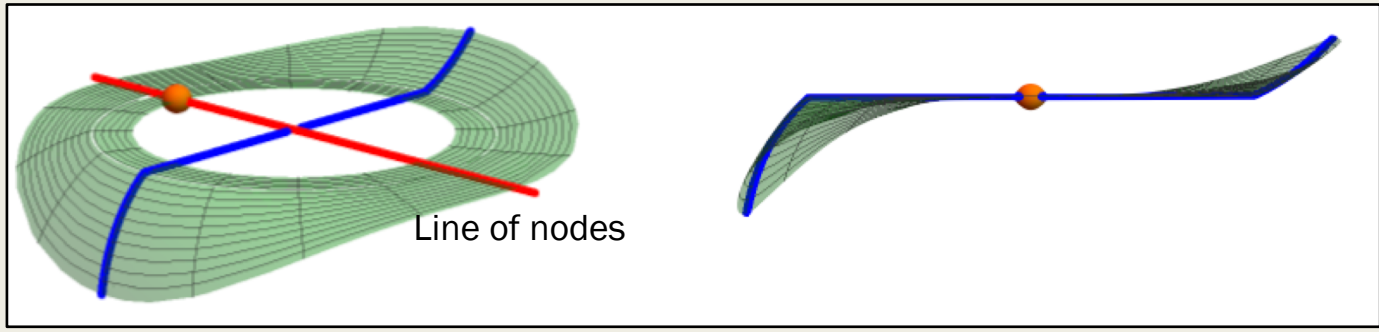
What is the Galactic warp?

- A deformation of the galactic disc that when seen edge-on it has a typical S-shape

An edge-on view of the ESO 510-G13 warped galaxy.
Credit: Courtesy of NASA, the Hubble Heritage Team, and C. Conselice



The warp in the Milky Way in HI gas, Levine et al (2006)



Schematic representation of a Lopsided warped disc (Romero-Gomez et al, 2019)

Mechanisms

- Bending modes
  - *Lynden-Bell (1965) suggested that warps could result from a misalignment between the spin axis and the disc normal, or the disc and the inner halo, though studies show that no long-lived warp is possible (e.g., Nelson & Tremaine, 1995; Dubinski & Kuijken, 1995)*
- Misaligned infall
  - *N-body simulations of a live halo accreting material whose angular momentum vector misaligned from the initial symmetry axis of the disc (Jiang & Binney, 1999; Shen & Sellwood, 2006)*
- Gravitational interaction with satellites
  - *The warp can be generated from the tidal interaction between galaxies: Sagittarius dwarf galaxy (Bailin, 2003), LMC (Weinberg & Blitz, 2006)*
- Precession of the Galactic bar
  - A small misalignment between the angular momentum of the bar and its angular velocity (Sanchez-Martin, Masdemont & MRG, 2016)

To understand the warp origin and mechanisms

- We need to understand the Galactic disc
  - *Structure: gas, dust, stars*
  - *Kinematics, dynamics (orbital analysis)*
  - *Evolution: dependency on age?*
- With GaiaDR2
  - *Stellar component up to large distance*
  - *Positions, parallaxes and proper motions*
  - *Stellar populations*

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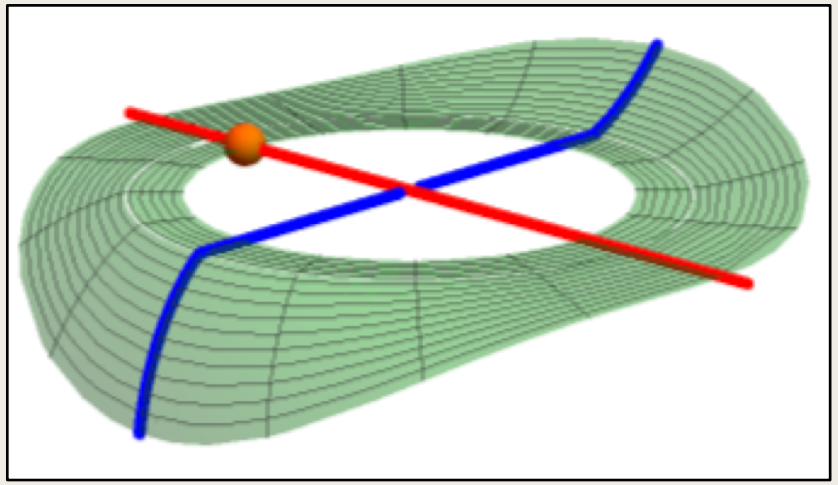
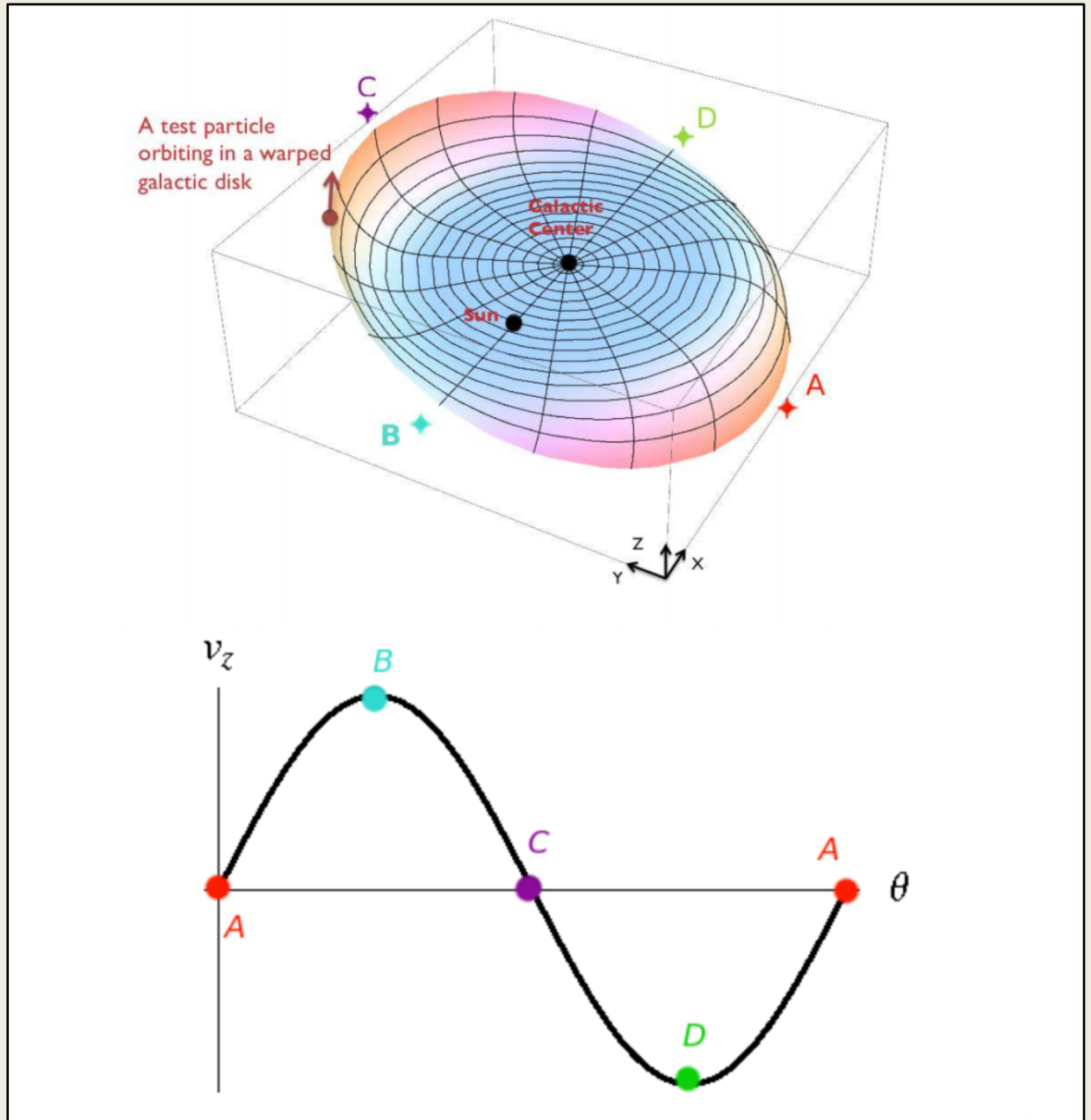
Simple warp models

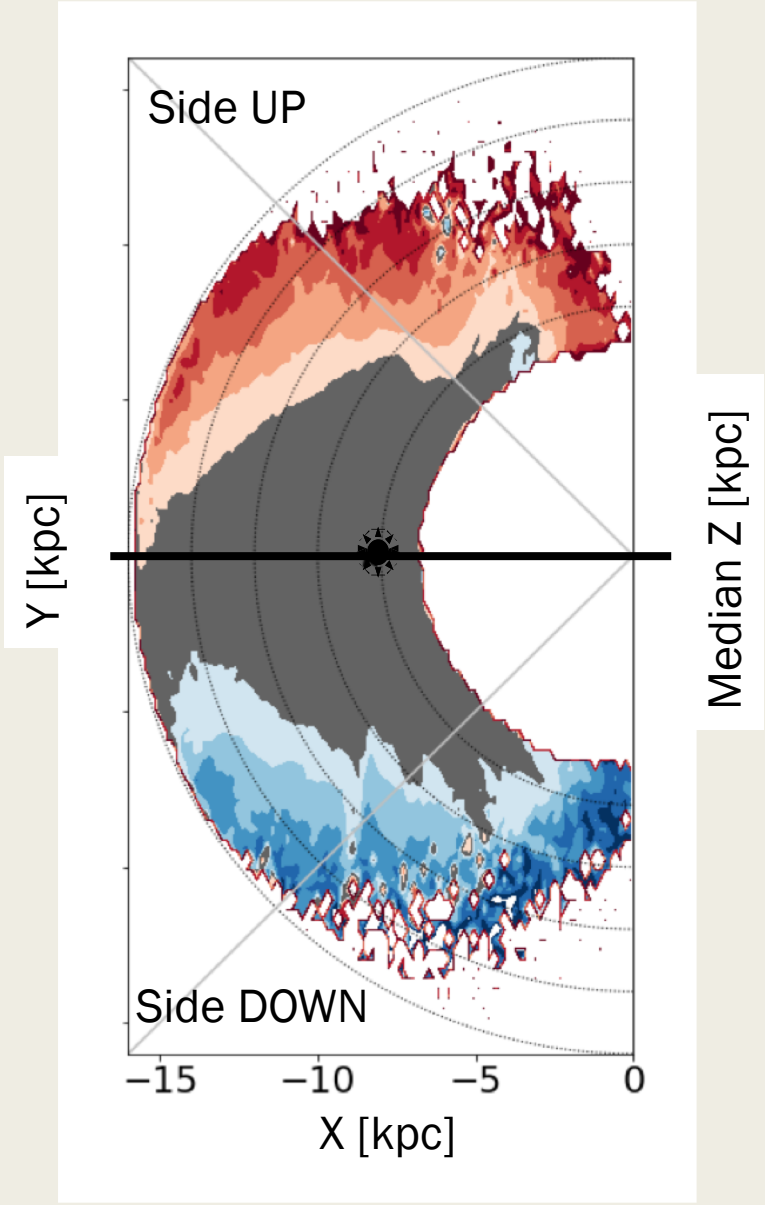




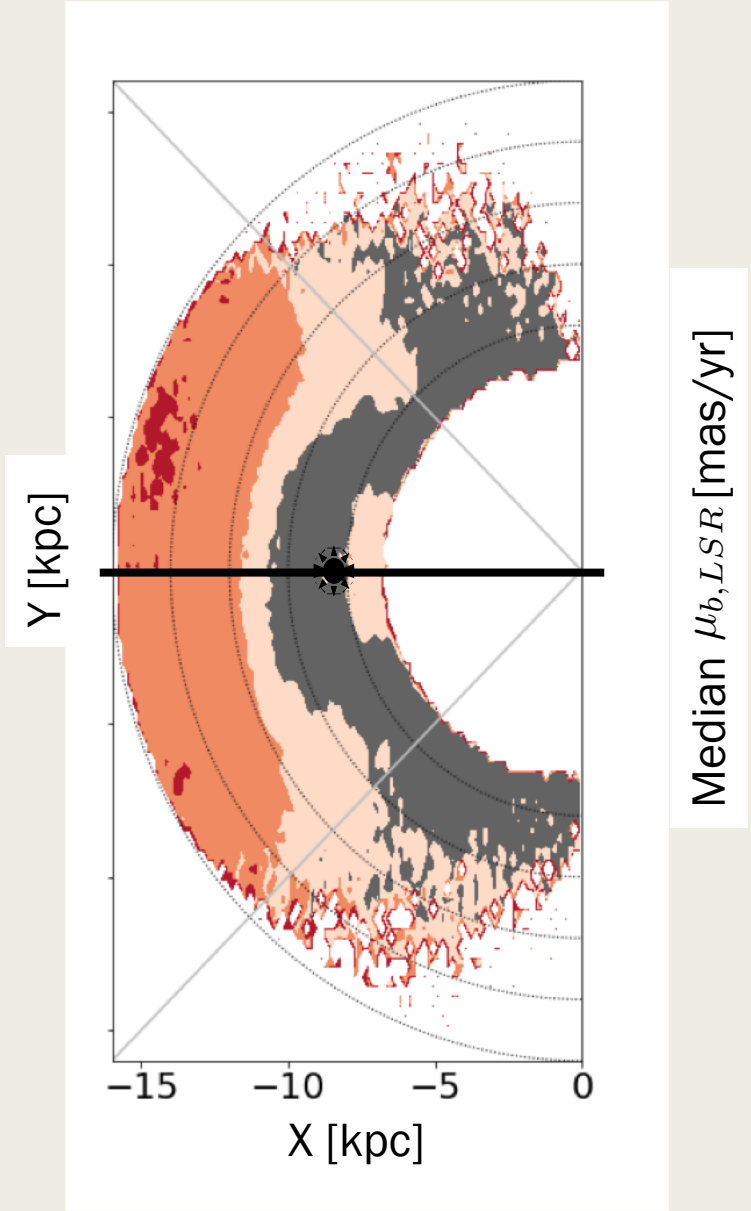
Romero-Gómez et al (2019)

Simple warp models

Gaia mock catalogue:
- RC disc population
- the extinction model,
- the Gaia selection function with DR2 errors

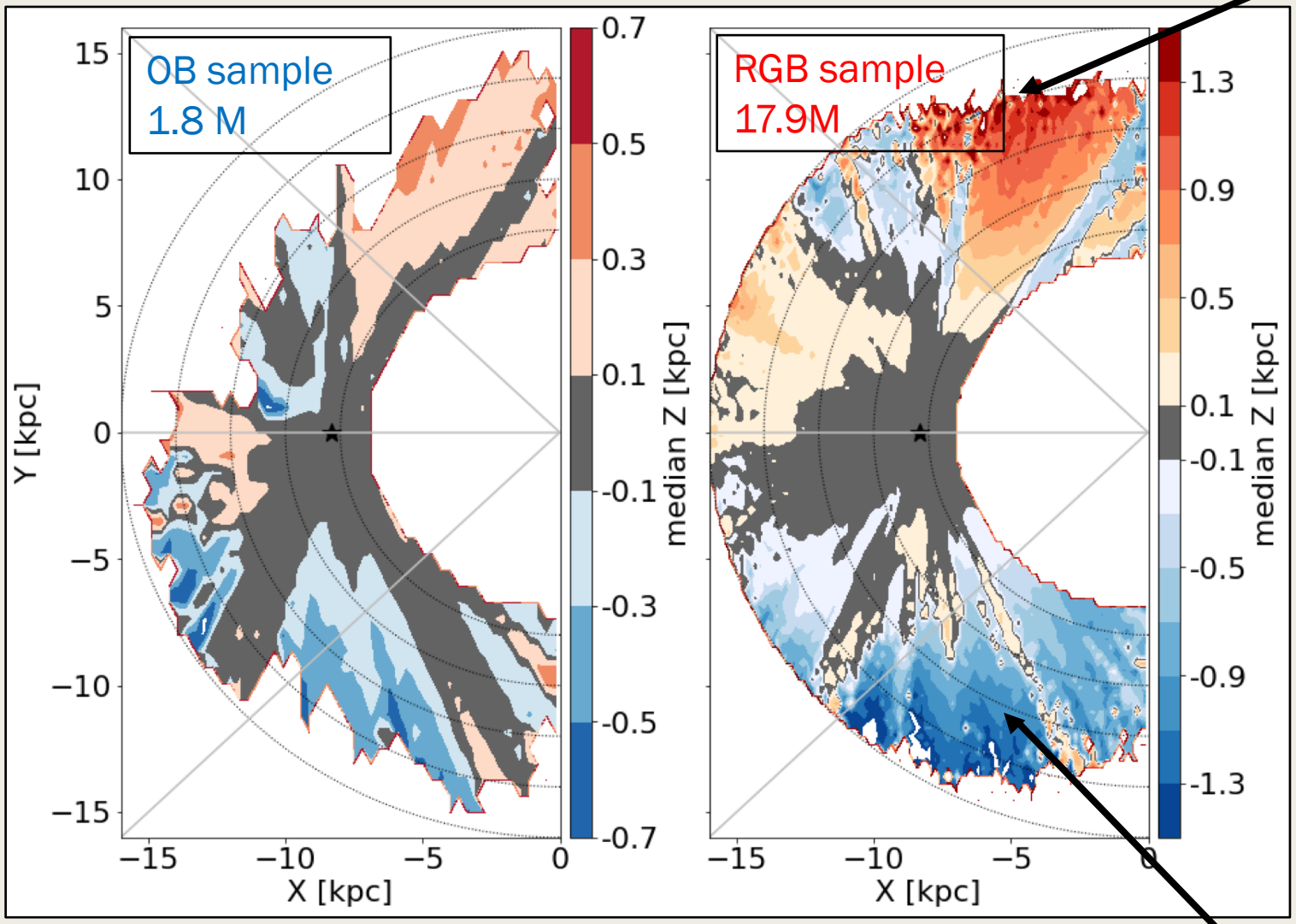


RC test particle simulation
Lopsided warp



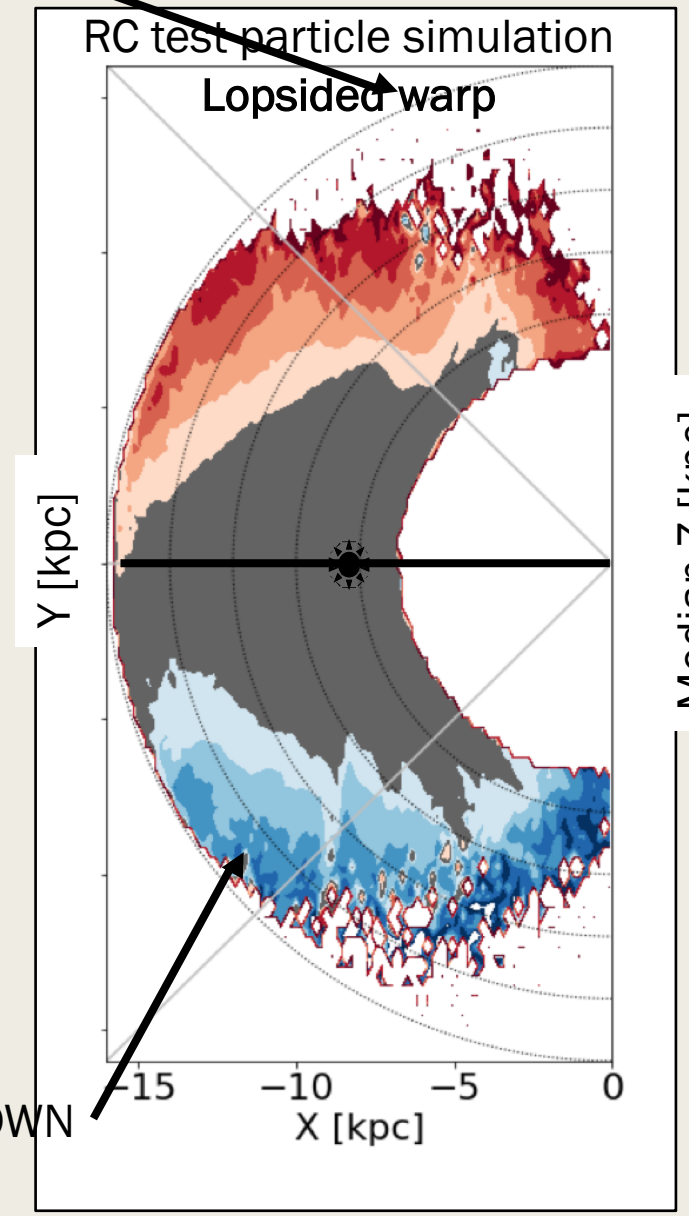
Romero-Gómez et al (2019)

The Galactic warp in structure



Side UP

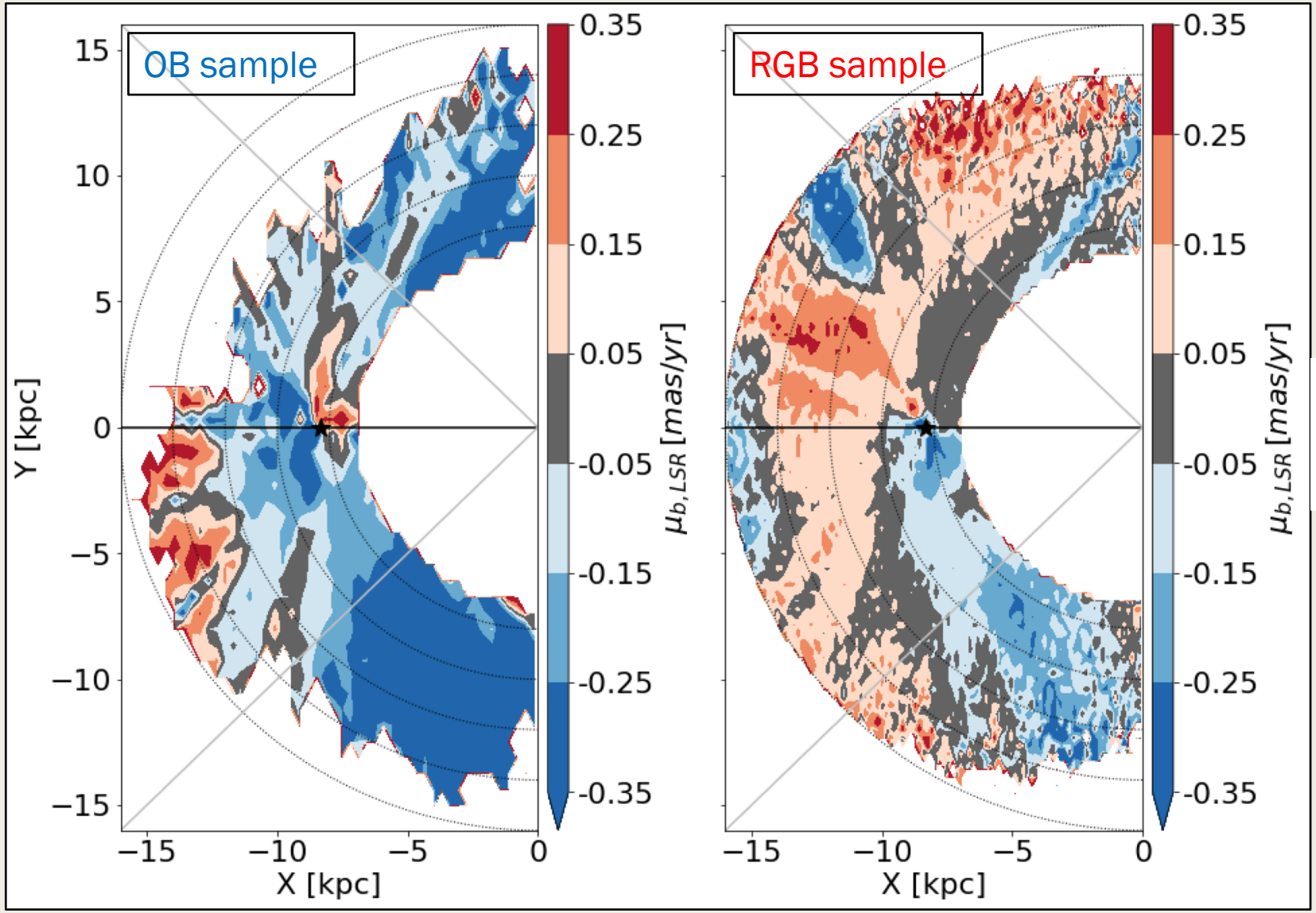
Side DOWN

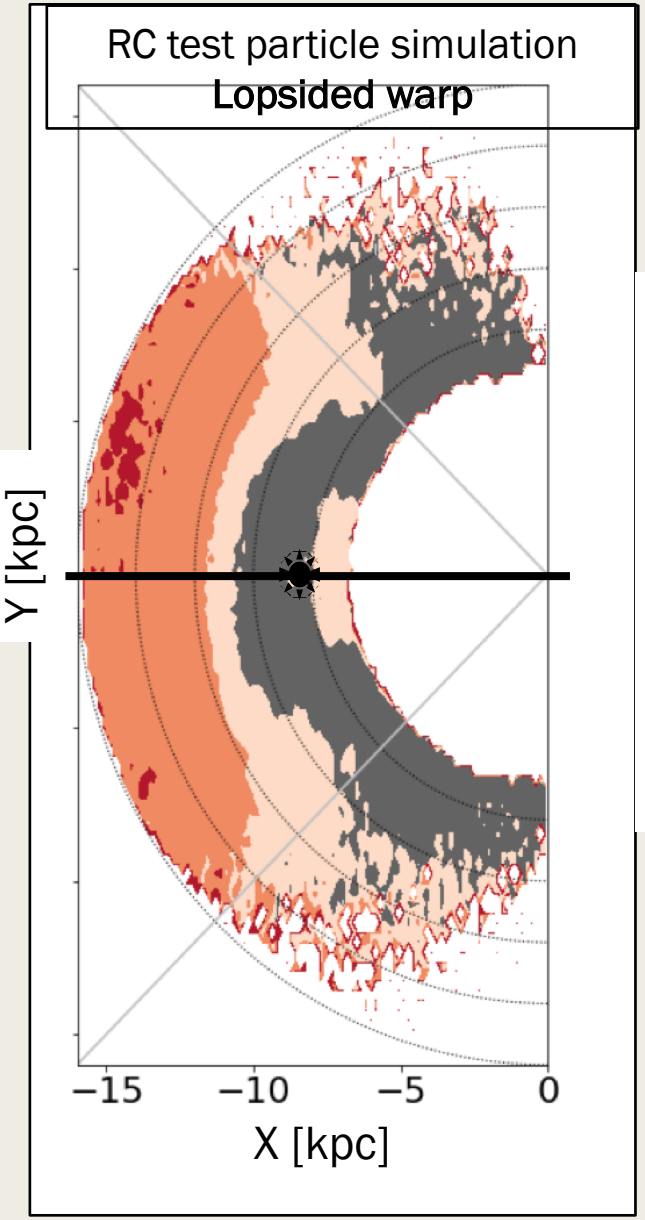


Using bayesian distances and an appropriate prior to minimise bias.

Romero-Gómez et al (2019)

The Galactic warp in kinematics

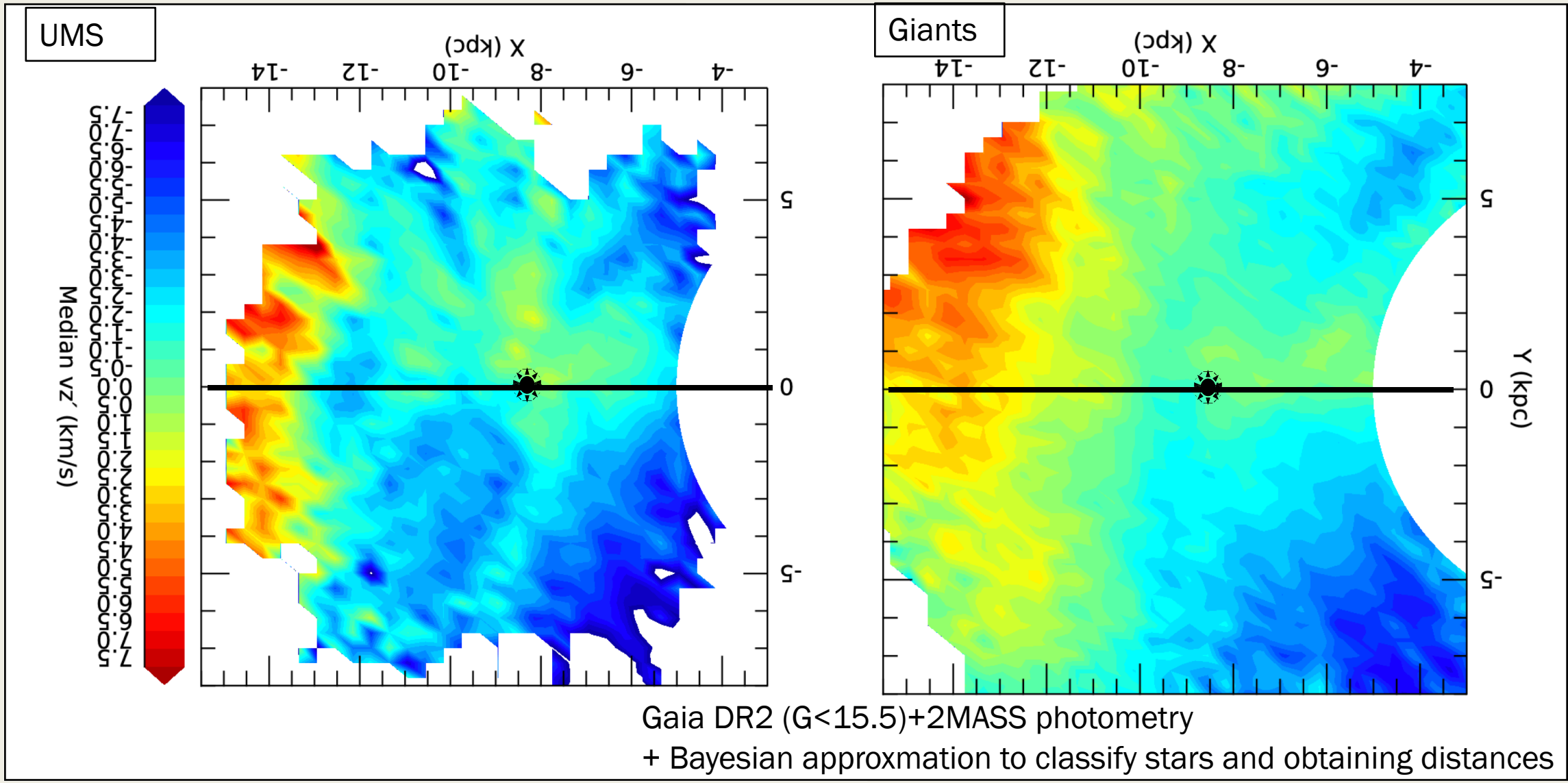




Romero-Gómez et al (2019)

The Galactic warp in kinematics

Median Vz

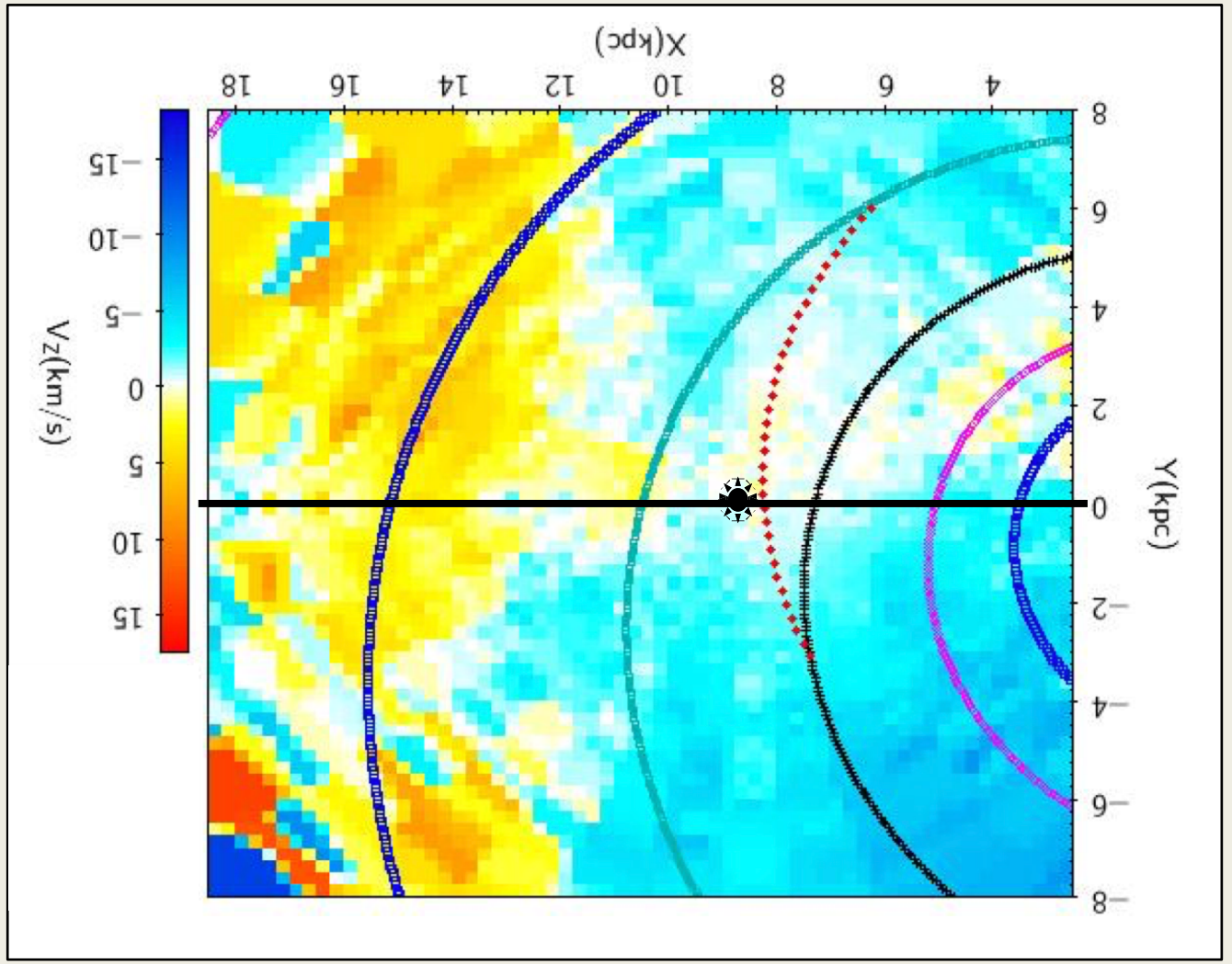


Gaia DR2 (G<15.5)+2MASS photometry
+ Bayesian approxmation to classify stars and obtaining distances

Poggio et al (2019)

The Galactic warp in kinematics

Median Vz

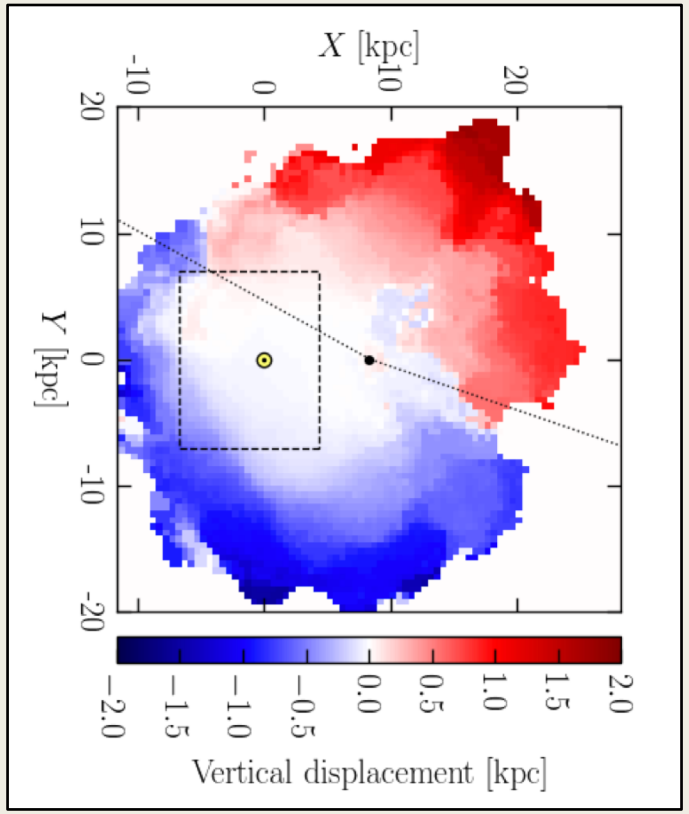


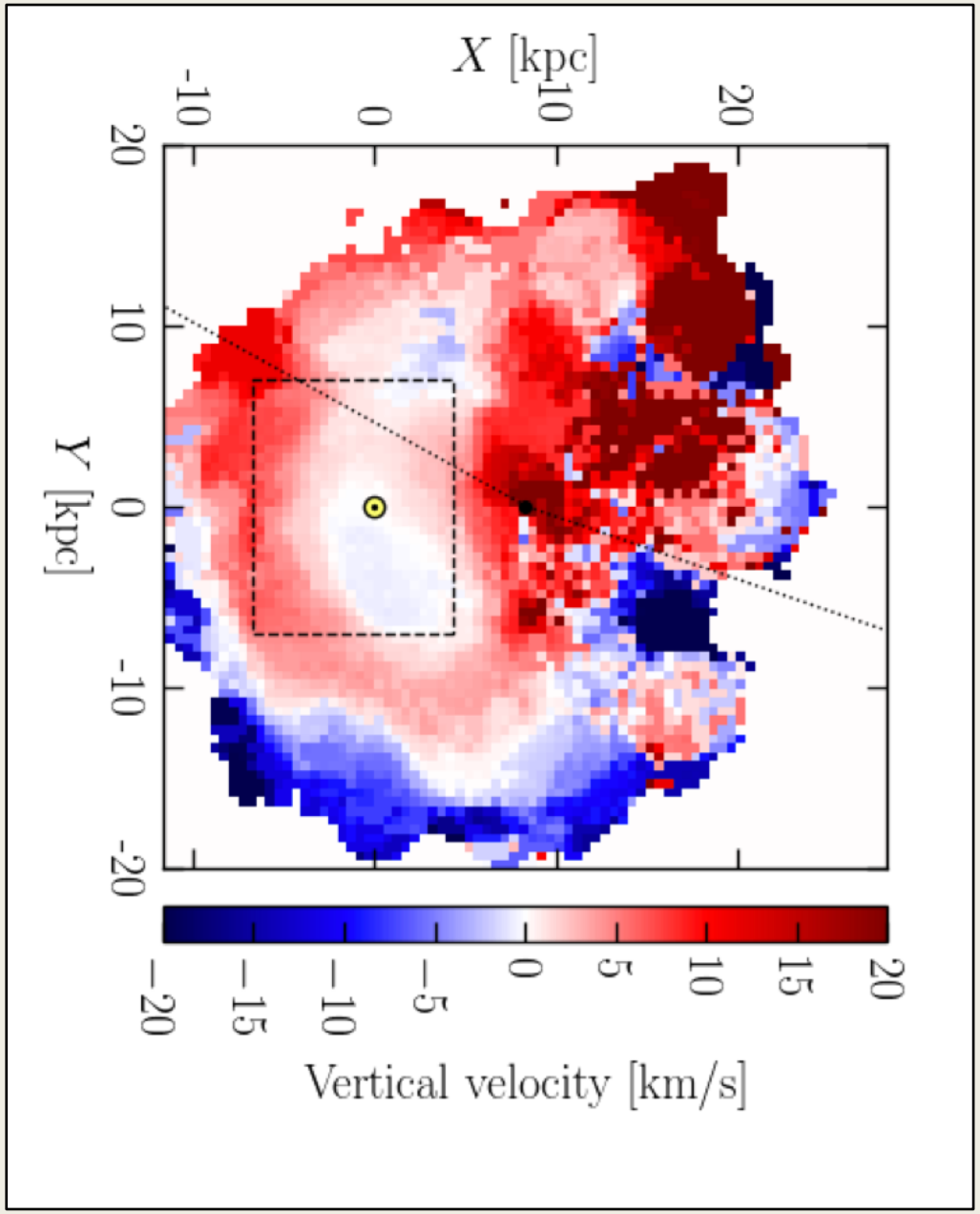
RVS sample as in Gaia Collaboration (2018)
+
applying a statistical deconvolution of the parallax errors based on the Lucy's inversion method of the Fredholm integral equations of the first kind.

Lopez-Corredoira et al (2020)

The Galactic warp in kinematics

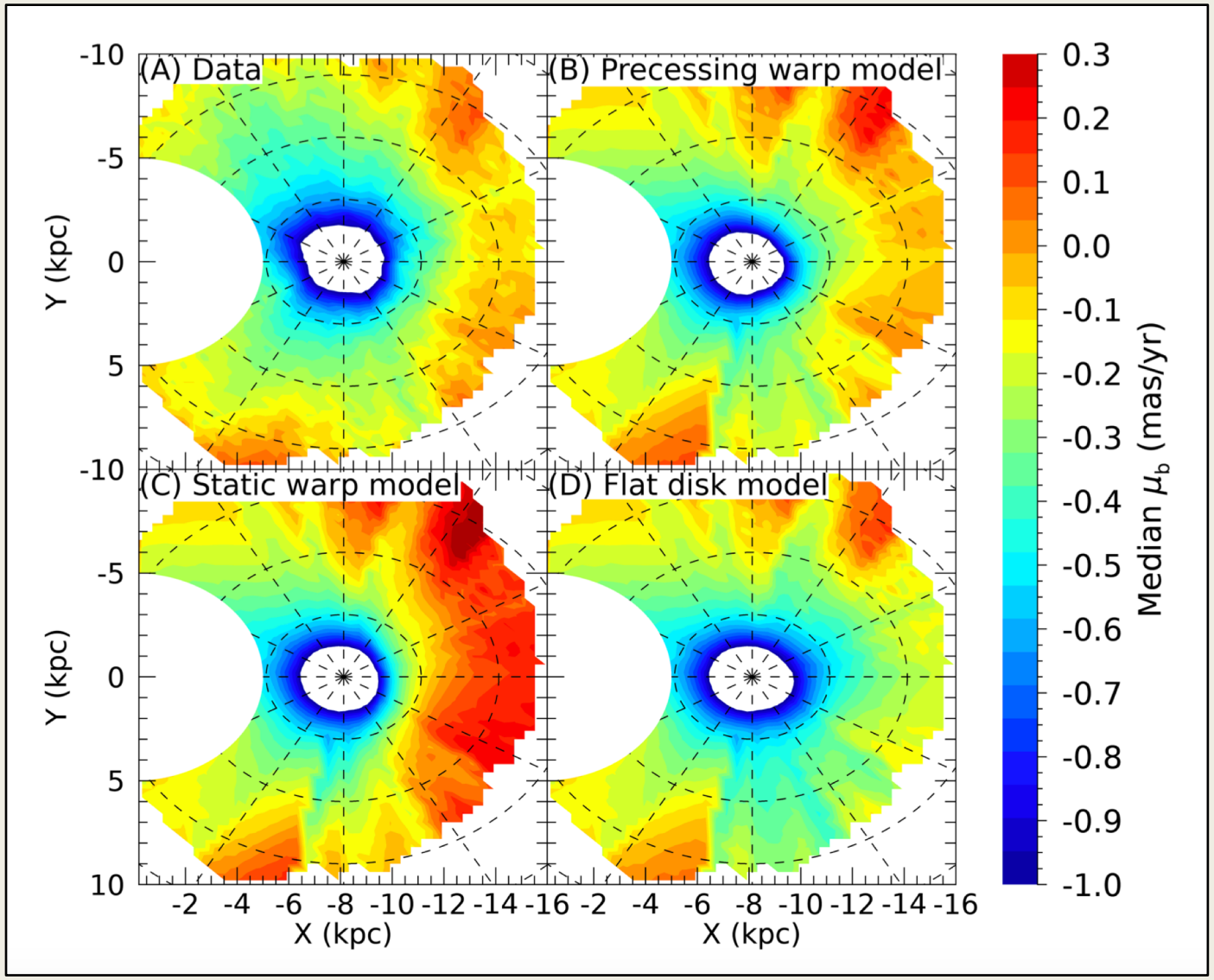
Using 2431 **classical Cepheids** (mainly from OGLE), individual distances





Skowron et al (2019)

The Galactic warp in kinematics



Giant sample as in Poggio et al (2018): Gaia DR2 (G<15.5)+2MASS photometry

Precessing line-of-nodes at $10.46 \pm 0.03_{stat} \pm 2.72_{syst}$ km s^{-1} kpc^{-1}

Poggio et al (2020)

Take away message

- Complex kinematics different from the expected from a flat relaxed disc
- GaiaDR2 reveals complex vertical motion: we need more complex models. It seems a precessing line-of-nodes makes the job.
- Clear differences between the young and evolved populations: confirmed age dependency
  - *The amplitude in the RGB sample is larger than in the OB, not clear using Cepheids*
- Maximum proper motion not aligned with the anticentre, which may imply a Lopsided warp or a misaligned line-of-nodes