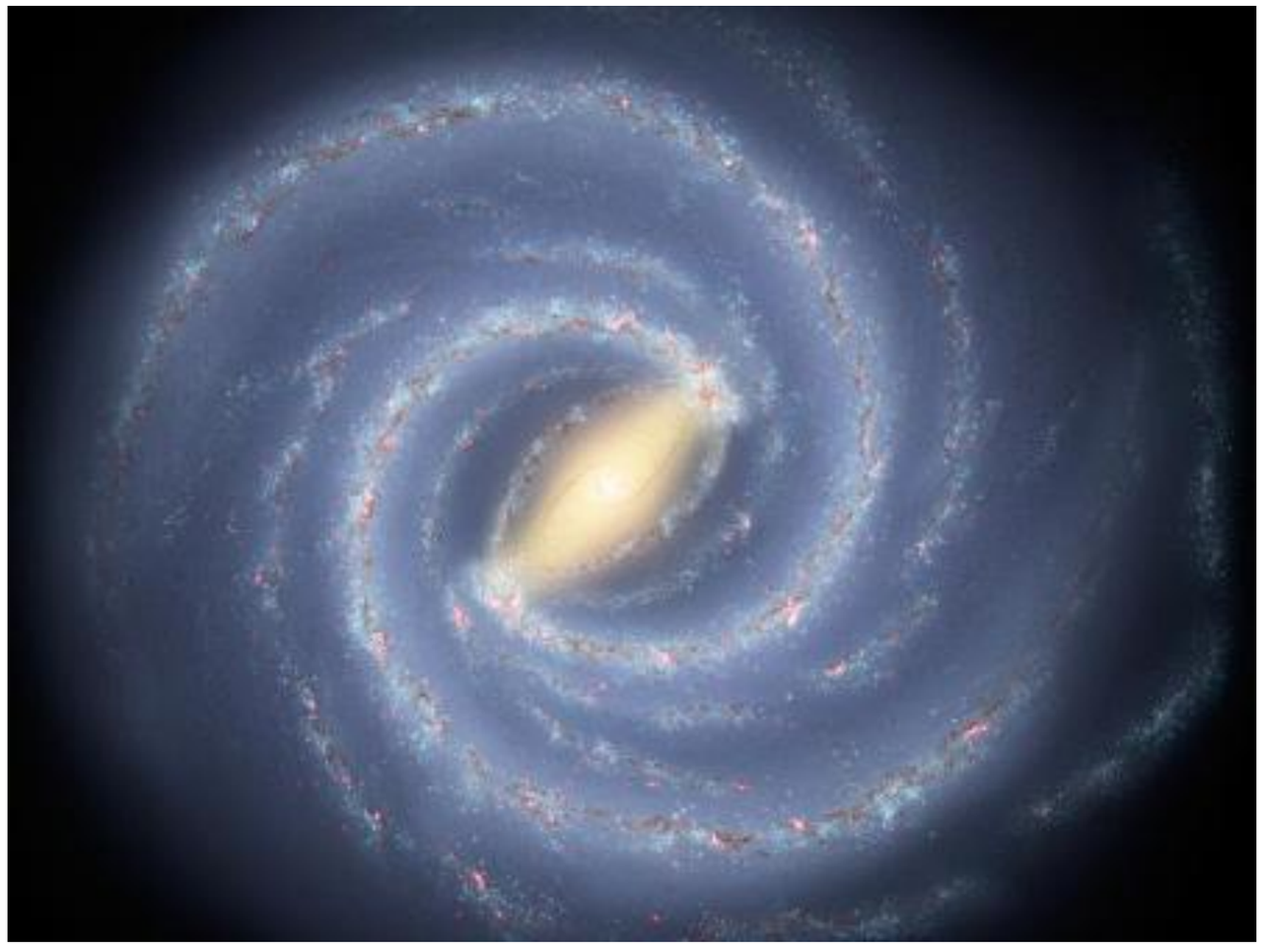
Fundamentals of the Milky Way

Why study the MW?

- Provides unique opportunity to study on a star-by-star basis

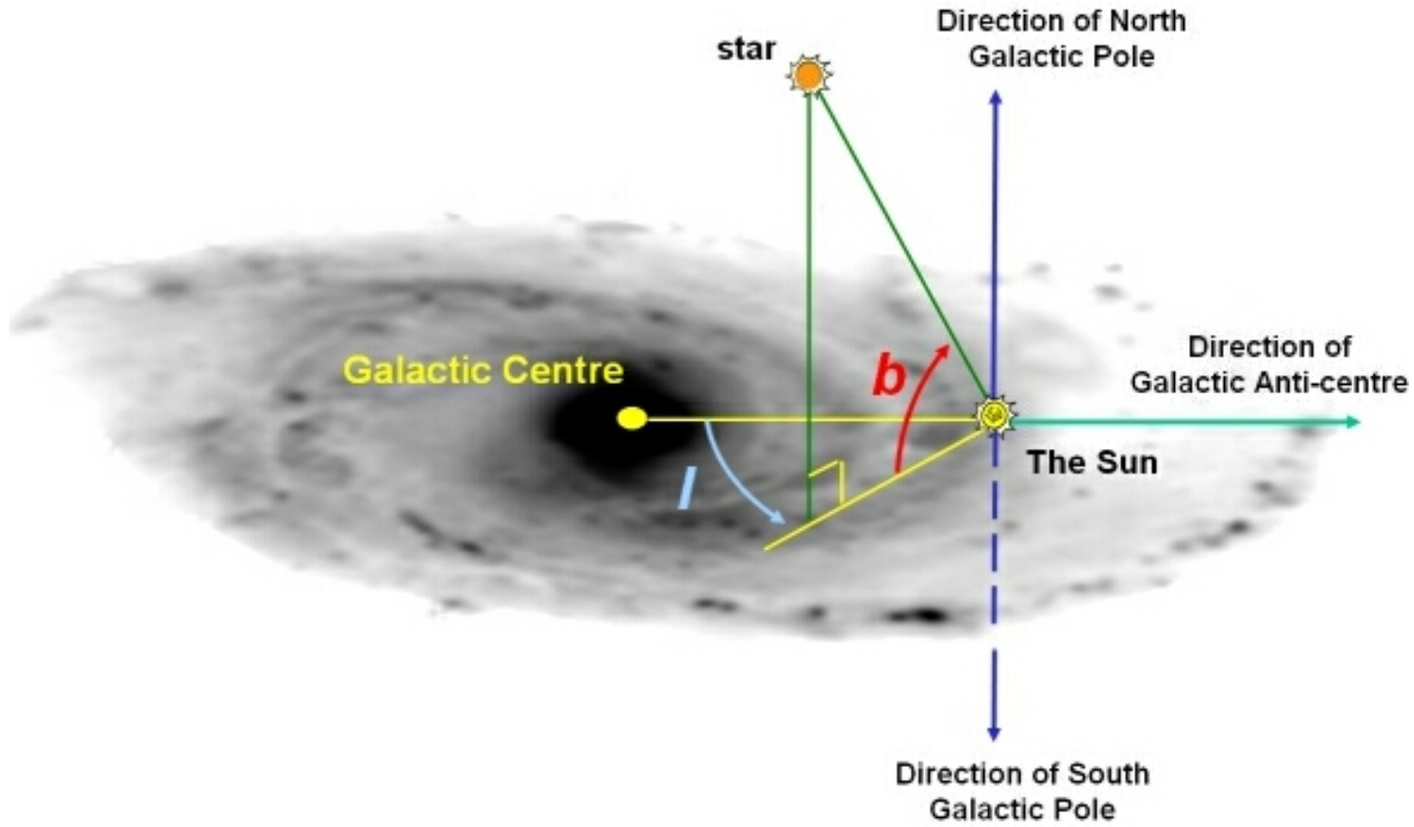
- Not possible for almost all other external galaxies



Standing questions about the MW

- Detailed properties (# of stars, mass, DM content), structural properties
- Evolutionary pathway over the cosmic time
- Galactic dynamics, dynamical effect of spirals, bar on the secular evolution

Galactic coordinates



- The galactic longitude (l) of a star is defined as the angle between the baseline of the center of the Galaxy and the Sun and the line between the star and the Sun. The galactic longitude l is measured in degrees (0° to 360).

- The galactic latitude b (0° to +-90°) represents the angle between the line of sight from the Sun to the star and the galactic plane.

- The Sun revolves about the Center of the Galaxy in clockwise direction given the Galactic North Pole as a viewpoint.

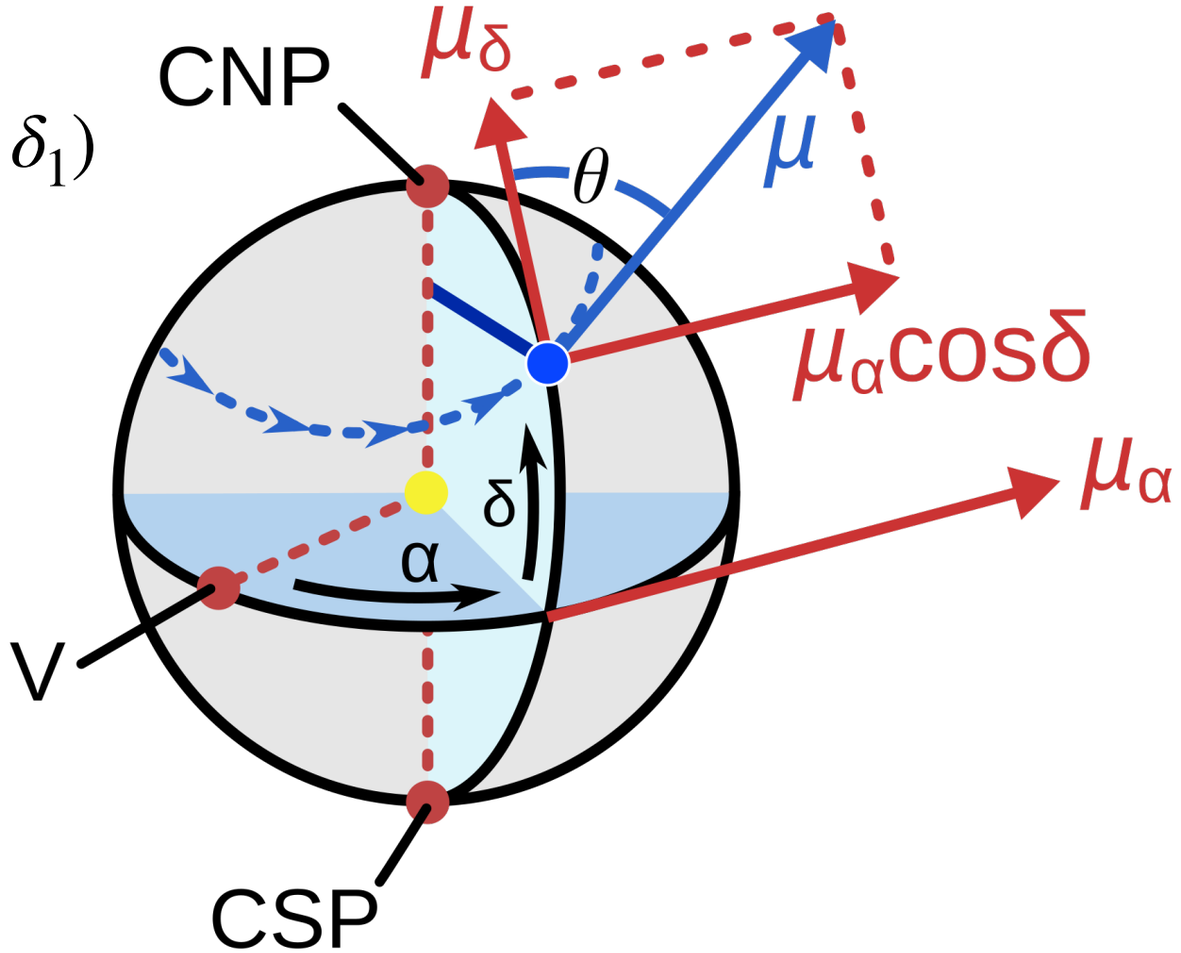
Proper motion

- **Suppose, a star moves from position (α_1, δ_1)**

to another position (α_2, δ_2) in time Δt

$$\mu_\alpha = \frac{\alpha_2 - \alpha_1}{\Delta t} \qquad \mu_\delta = \frac{\delta_2 - \delta_1}{\Delta t}$$

$$\mu^2 = \mu_\delta^2 + \mu_\alpha^2 \cos\delta$$



The angular changes per year in the star's right ascension (μ_α) and declination (μ_δ) with respect to a constant epoch.

Typically expressed in arcseconds per year (arcsec/yr) or in mas/yr

Hipparcos mission

First dedicated, systematic astrometric mission

Prime scientific goal : precise astrometric measurement of stars in the Solar neighbourhood

Launched in : August, 1989 (ESA)

Charted ~ 118,218 stars in the MW

For more details : https://www.cosmos.esa.int/web/hipparcos/home

Gaia mission

- Ambitious mission to chart a 3-D map of our galaxy, the Milky Way

  (Successor of Hipparcos mission)

- Aiming to provide largest, most precise astrometry for ~ 1 billion stars

  (~ 1 percent of total Galactic stellar population)

- Launched on December 19, 2013 by ESA

- Payload
  - The astrometric instrument (Astro)

    1. Star position 2. Proper motion 3. Parallax

  - The photometric instrument

    Continuous stellar spectra in the band 320-1000 nm (BP-RP spectra)

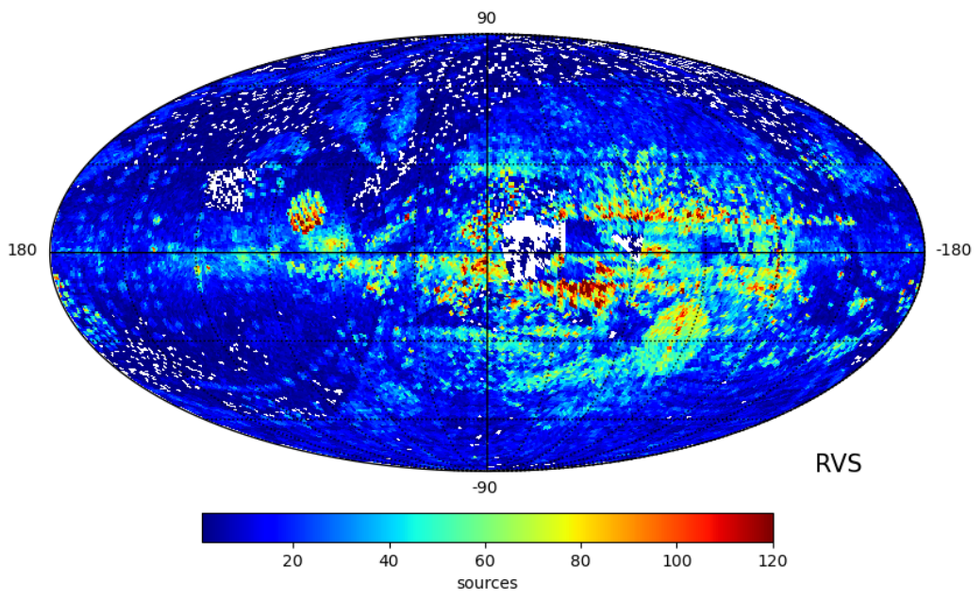
  - The radial velocity spectrometer (RVS)

    Radial velocity & medium-res spectral data (847-874 nm)

Gaia timeline

Data release 2 (DR 2)

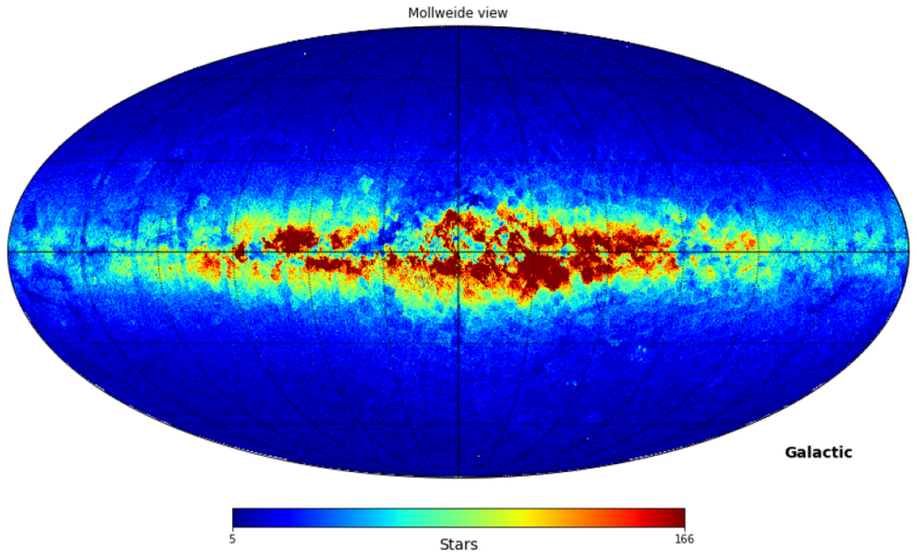
April 25, 2018



~ 7 million stars with 6-D information (RVS sample)

Data release 3 (DR 3)

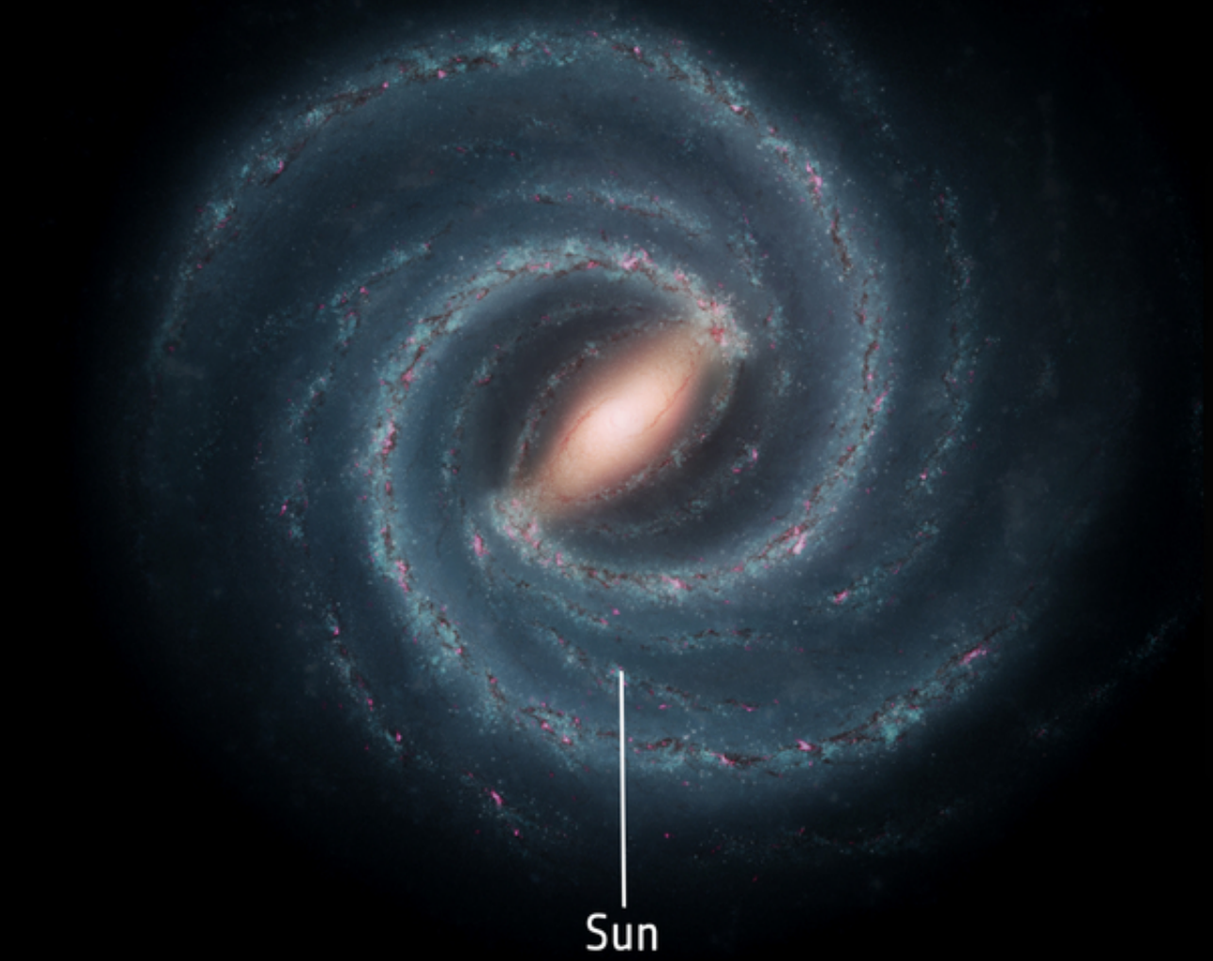
June 13, 2022

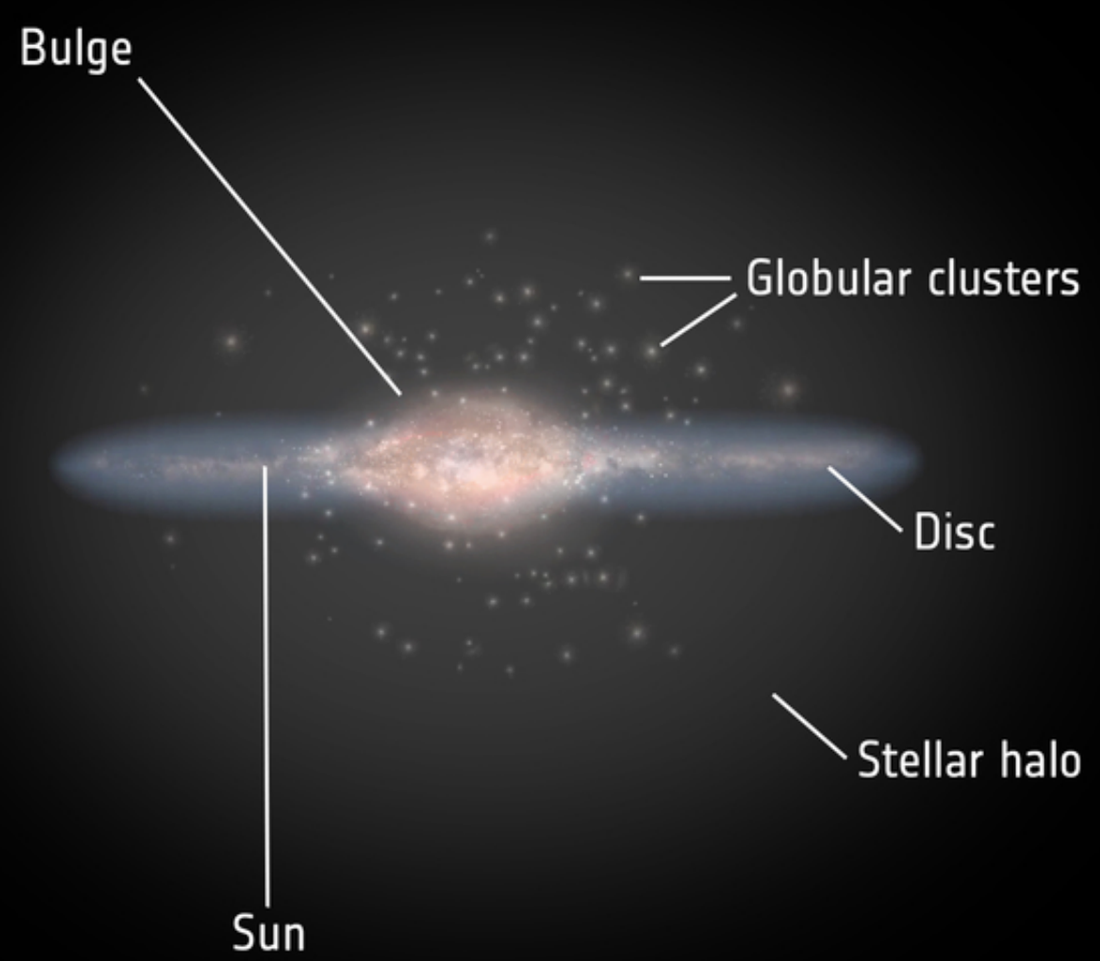


~ 33 million stars with 6-D information (RVS sample)

→ ANATOMY OF THE MILKY WAY

esa



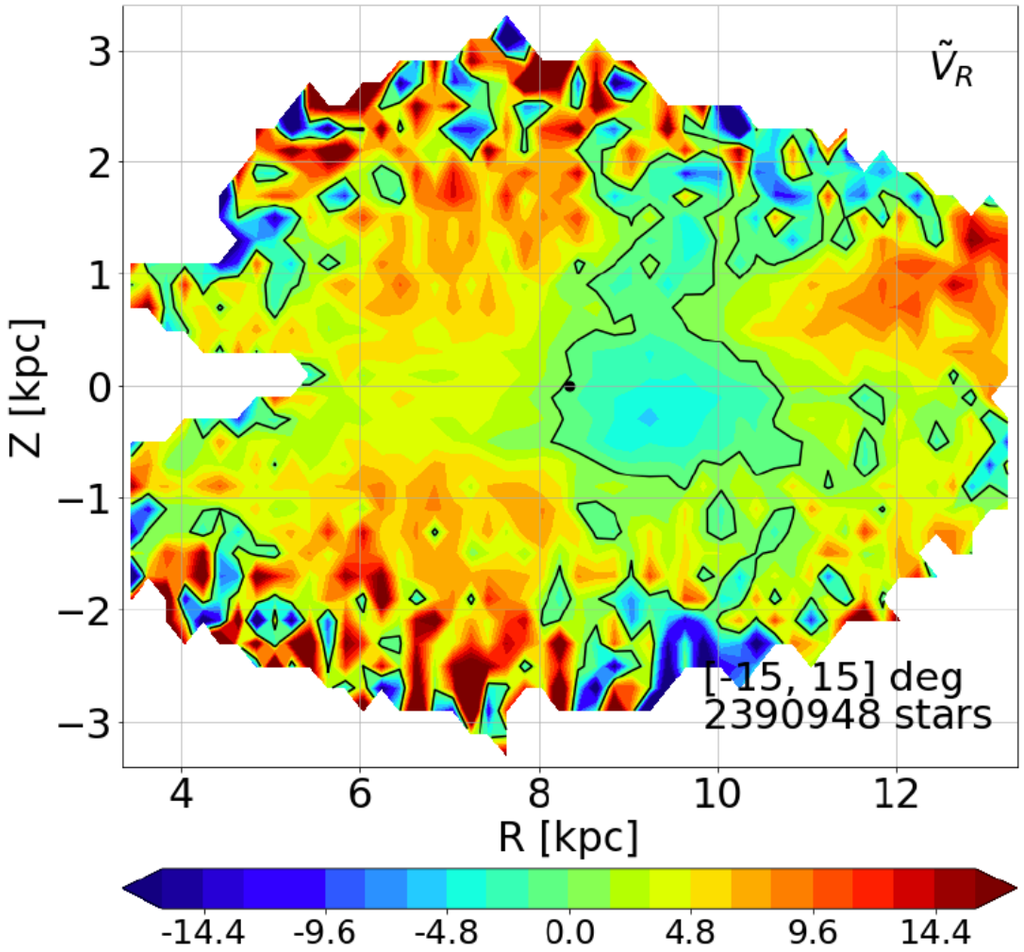


www.esa.int

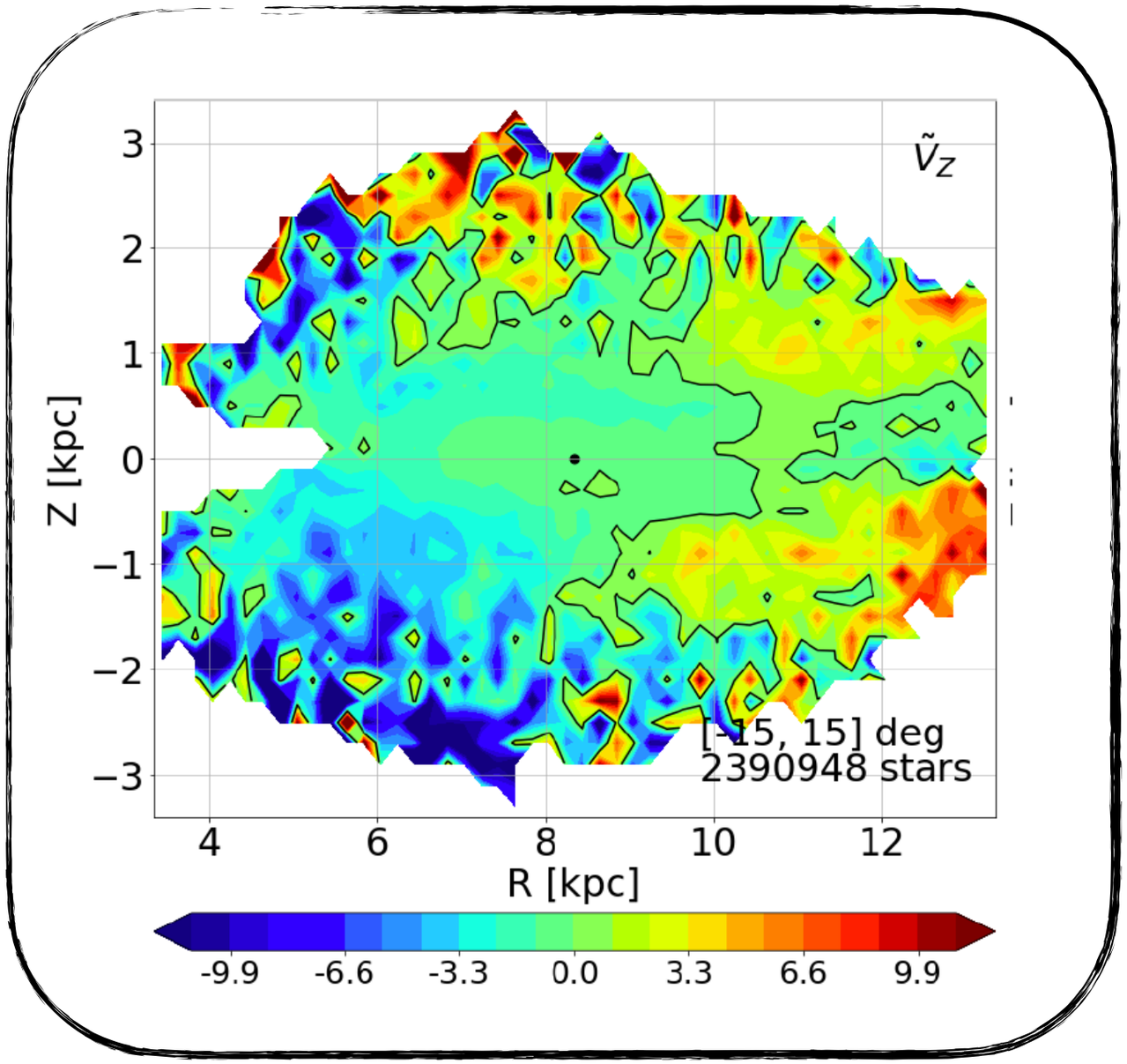
European Space Agency

Bulk motions in the MW from the Gaia DR 2

(Gaia collaboration: Katz+2018)



Bulk radial motions



Bulk vertical motions

Stars in the MW —> collisionless system

$$\frac{\partial f}{\partial t} + \vec{v} \cdot \frac{\partial f}{\partial \vec{x}} - \nabla \Phi \cdot \frac{\partial f}{\partial \vec{v}} = 0$$

(CBE)

Solution in steady state

[Jean's Theorem]

For an axisymmetric potenial —> $f(E, L_z)$

$$< v_R > = \int v_R \; f(E, L_z) \; d^3\vec{v} = 0$$

$$< v_z > = \int v_z \; f(E, L_z) \; d^3\vec{v} = 0$$

(Binney & Tremaine 2008)

Existence of Bulk motion → **External/internal driving mechanism**