The Universe after Gaia Data Release 2

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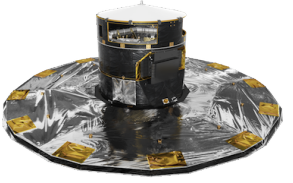
Synopsis

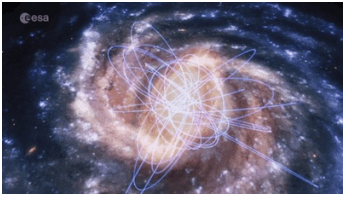
- Overview of the Gaia mission and DR2:

  scientific instruments, catalogue contents,
  measurement uncertainties, caveats and limitations.



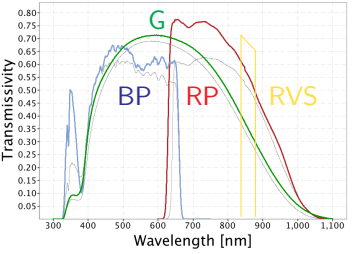
- Scientific highlights:

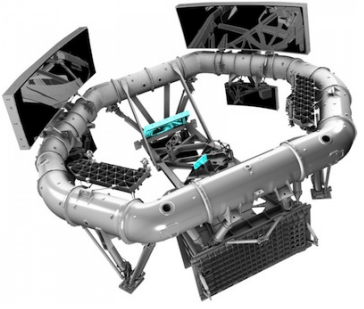
  Kinematic complexity of the disk
  Accretion history of the halo
  Search for new objects (streams, satellites)
  Measurement of gravitational potential
  Internal kinematics of stellar structures
  Hypervelocity stars

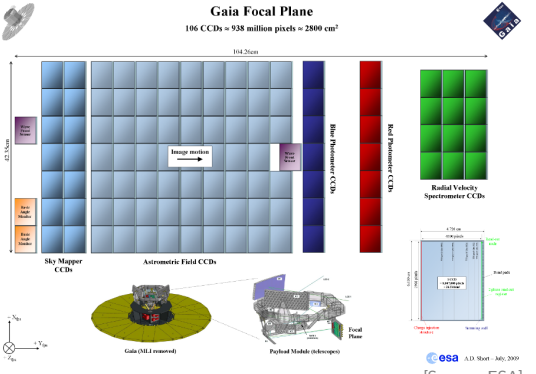


Overview of Gaia mission

- Scanning the entire sky every couple of weeks
- Astrometry for sources down to 21 mag
- Broad-band photometry/low-res spectra
- Radial velocity down to $\sim$ 15 mag (end-of-mission)



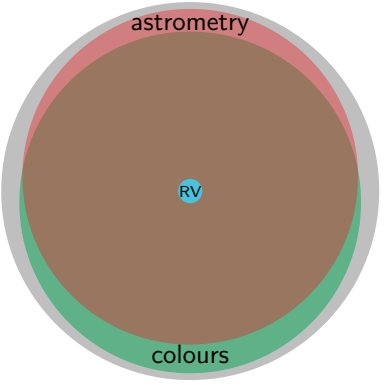


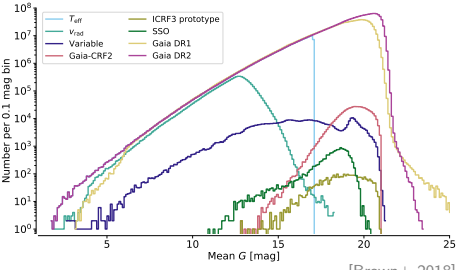


[Source: ESA]

Overview of Data Release 2

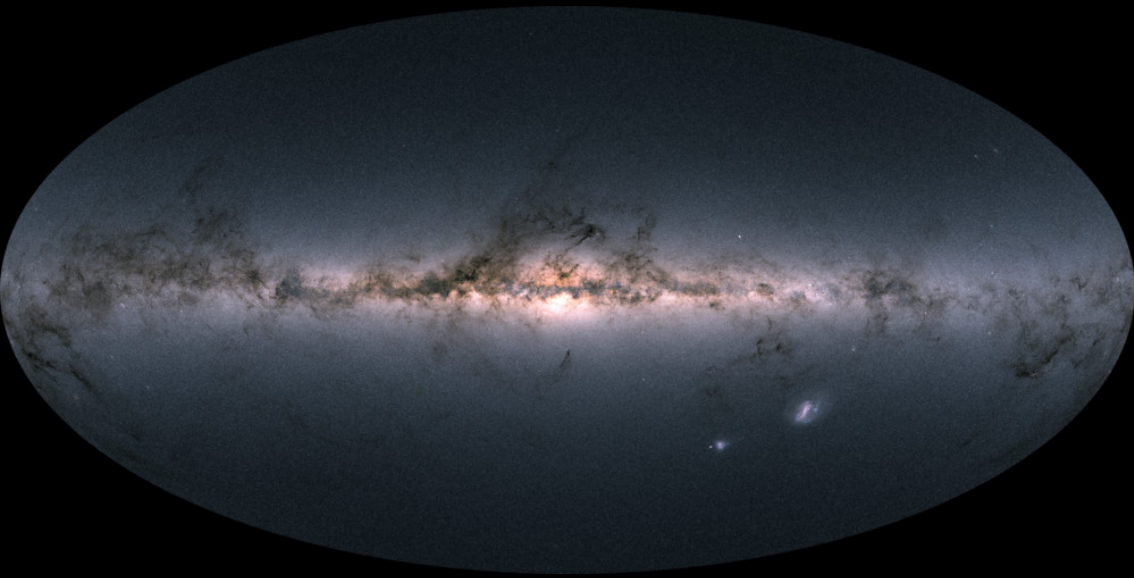
- Based on 22 months of data collection
- Total number of sources: 1.69×10^9
- Sources with full astrometry (parallax ϖ, proper motions $\mu_{\alpha*}, \mu_\delta$): 1.33×10^9
- Colours (G_{BP}, G_{RP}): 1.38×10^9
- Radial velocities: 7.2×10^6
- Effective temperature: 160×10^6
- Stellar parameters ($R_\odot, L_\odot$): 77×10^6
- Extinction and reddening: 88×10^6
- Variable sources: 0.55×10^6





[Brown+ 2018]

Gaia sky in color



Measurement uncertainties

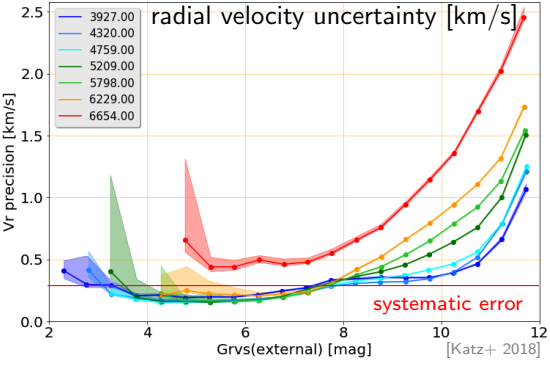
Parallax: $\epsilon_{\varpi} \gtrsim 0.05 - 0.1$ mas

Proper motion: $\epsilon_{\mu} \gtrsim 0.1 - 0.2$ mas/yr

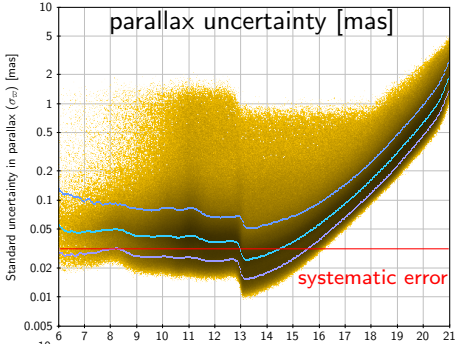
Line-of-sight velocity: $\epsilon_V \gtrsim 0.5$ km/s

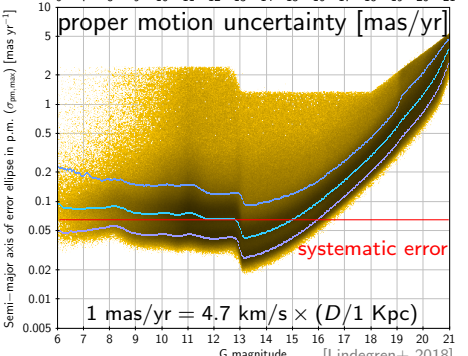
RV measurements only for stars with

$T_{\rm eff} \in [3500 \div 6900]$ K and $G_{\rm RVS} \leq 12$ ($G \lesssim 13$)



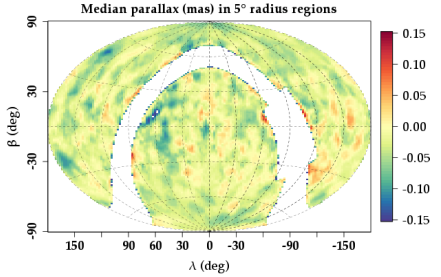
[Katz+ 2018]



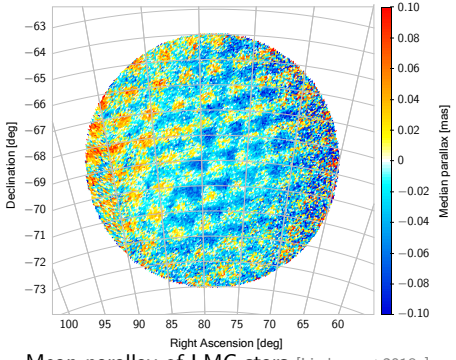


[Lindegren+ 2018]

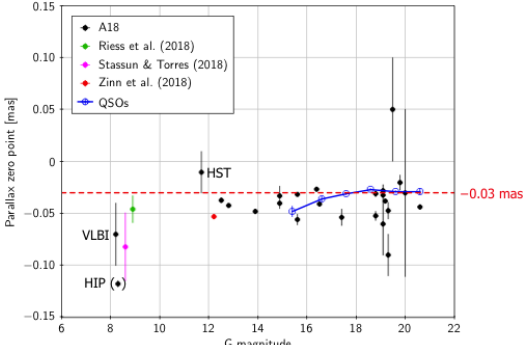
Gaia parallaxes and the absolute distance scale



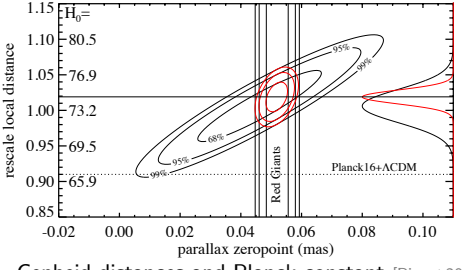
Mean parallax of 5×10^5 quasars [Arenou+2018]



Mean parallax of LMC stars [Lindegren+2018a]

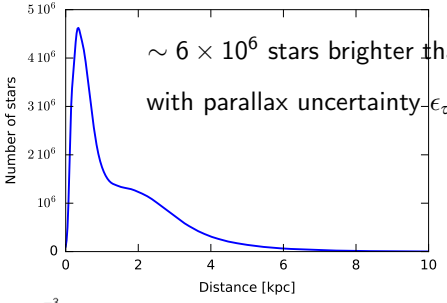


Compilation of parallax offset measurements [Lindegren+2018b]



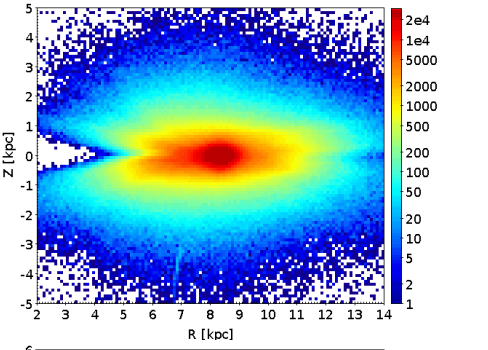
Cepheid distances and Planck constant [Riess+2018]

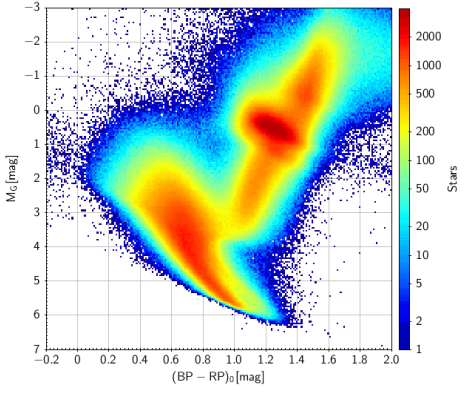
The “golden” 6D sample



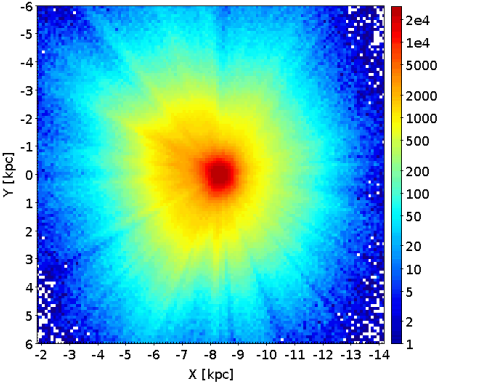
$\sim 6 \times 10^6$ stars brighter than $G \sim 13$

with parallax uncertainty $\epsilon_\varpi / \varpi \leq 0.2$



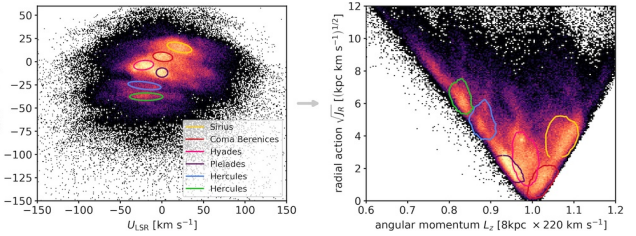


[Katz+ 2018]

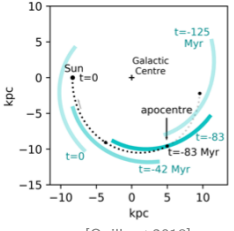


Kinematic complexity in the disk

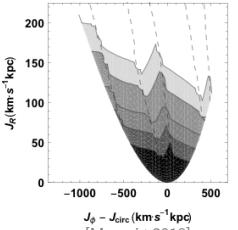
- Moving groups in velocity space
  [Gaia Collaboration: Katz+2018] $\Longrightarrow$ more clearly seen in action space.
- Bar pattern speed constraints
  [Monari+2018]
- Perturbations from spiral arms
  [Quillen+2018; Hunt+2018]
- Tests of spiral structure theories
  [Sellwood+2018]



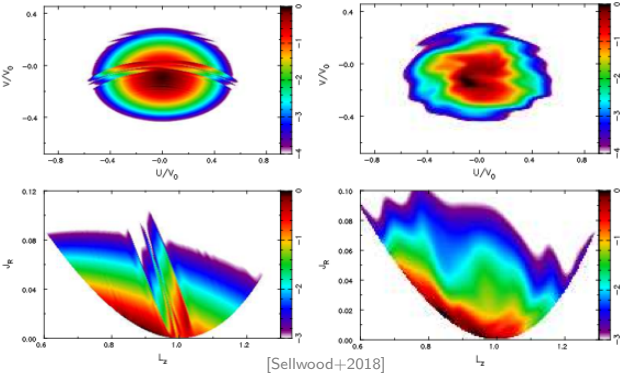
[Trick+2018]



[Quillen+2018]

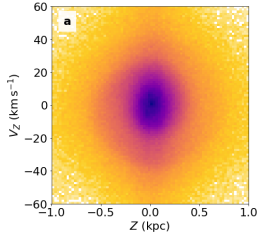


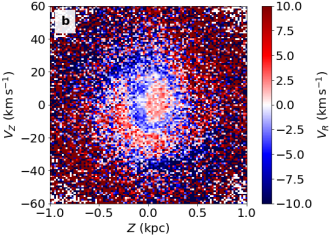
[Monari+2018]

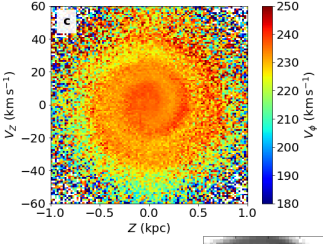


[Sellwood+2018]

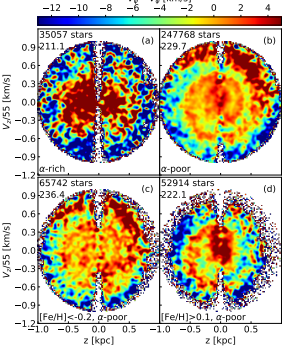
Vertical perturbations and the disk seismology





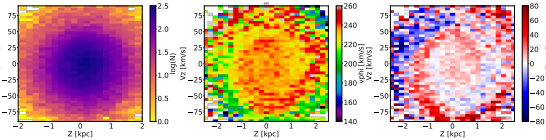


Phase-space spiral [Antoja+2018]

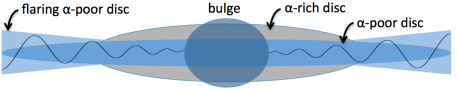


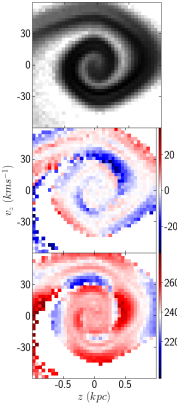
Gaia+GALAH [Bland-Hawthorn+2018]

perturbation from a $(2-10)\times10^{10}\,M_\odot$ satellite crossing the disk $200-400$ Myr ago (Sgr dSph?)



[Laporte+2018, see also Binney & Schönrich 2018]



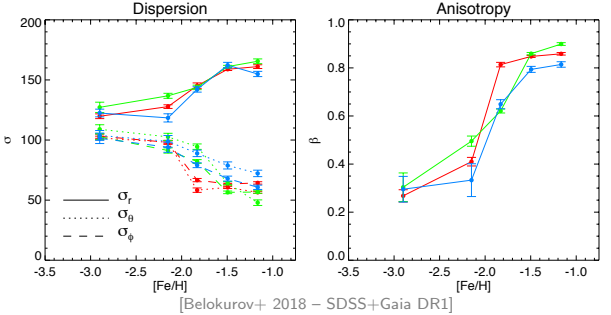


[Darling & Widrow 2018]

Radially-anisotropic population in the stellar halo

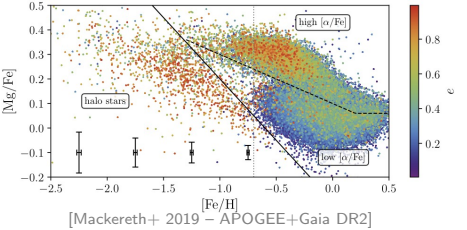
Evidence for a major merger with a $\gtrsim 10^9\, M_\odot$ satellite $\sim 8-10$ Gyr ago

(kinematics + metallicity)

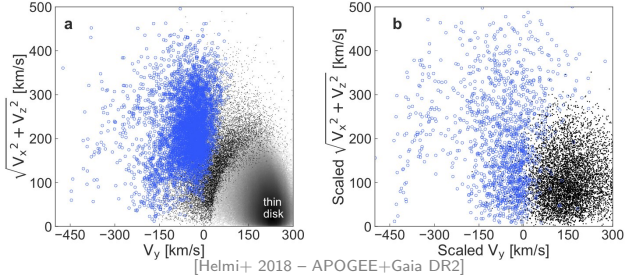


[Belokurov+ 2018 – SDSS+Gaia DR1]

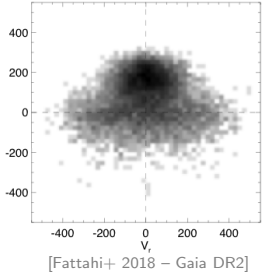
[see also Kruijssen+2018 for globular clusters]



[Mackereth+ 2019 – APOGEE+Gaia DR2]

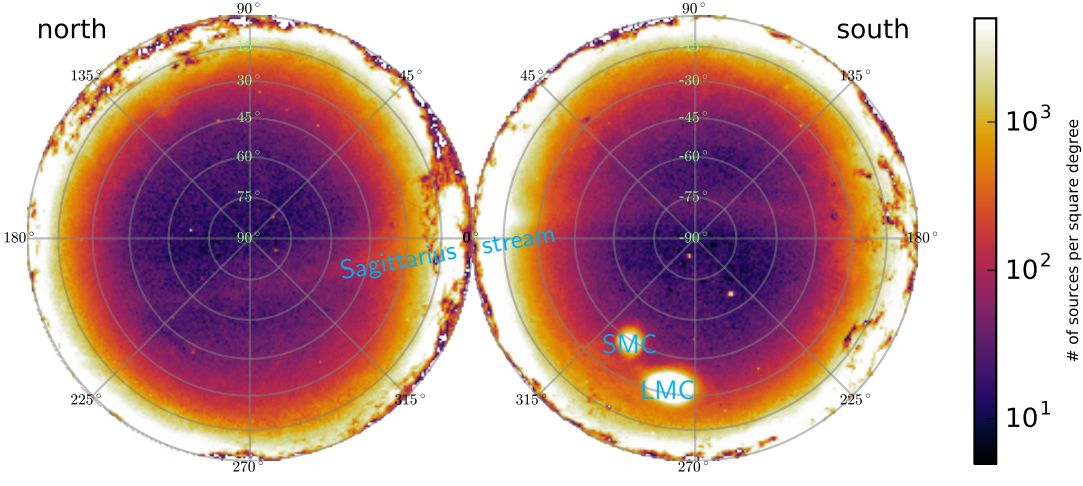


[Helmi+ 2018 – APOGEE+Gaia DR2]



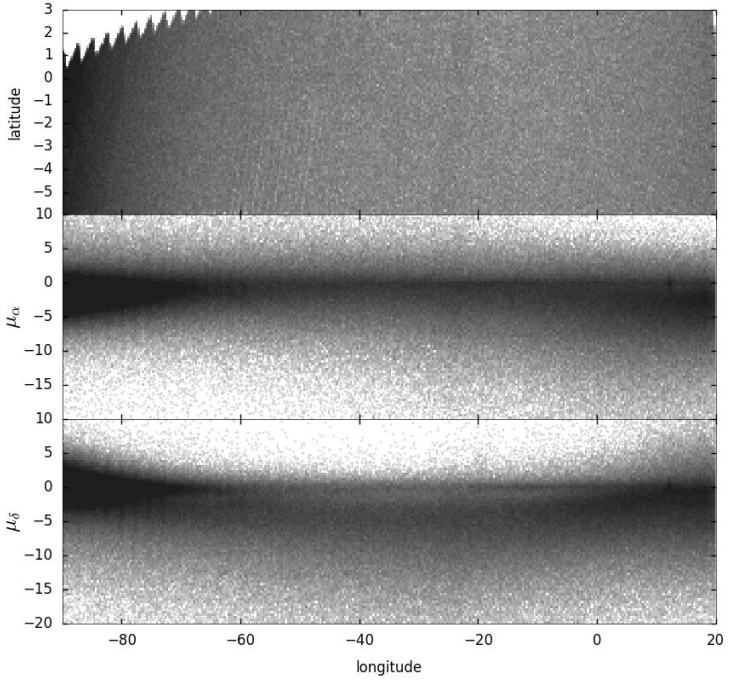
[Fattahi+ 2018 – Gaia DR2]

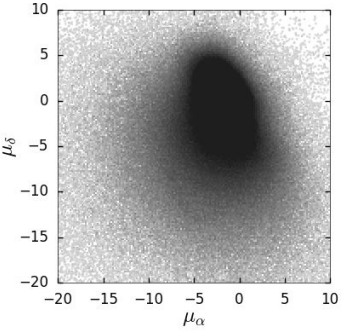
Finding substructures with Gaia

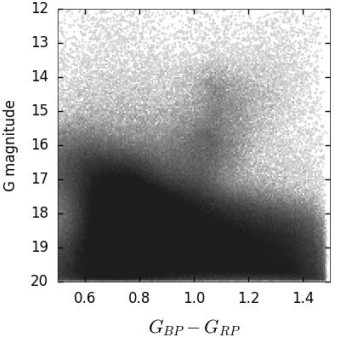


Stars with $\varpi < 0.3$, $1 < G_{\mathrm{BP}} - G_{\mathrm{RP}} < 1.5$, $|\mu_\alpha| < 3.5$, $|\mu_\delta| < 3.5$ (mainly distant halo)

Finding streams with Gaia







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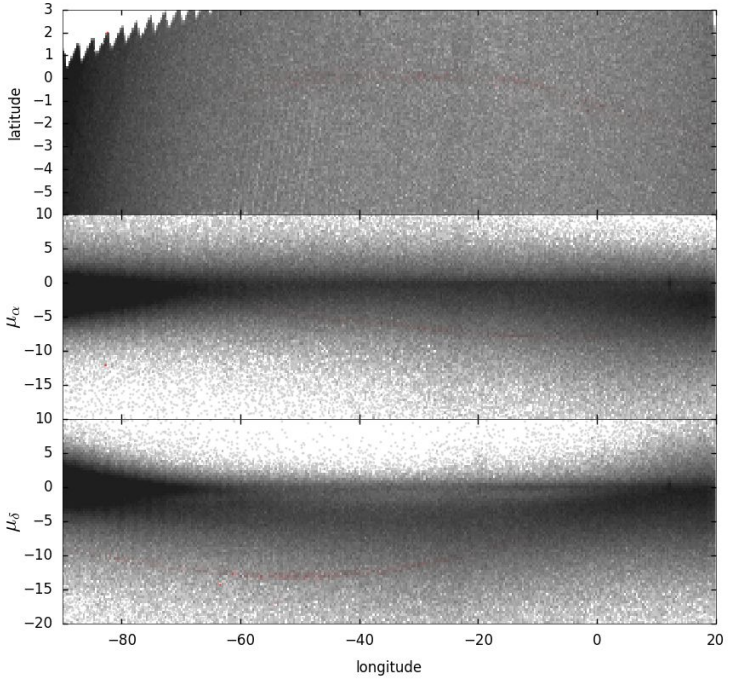
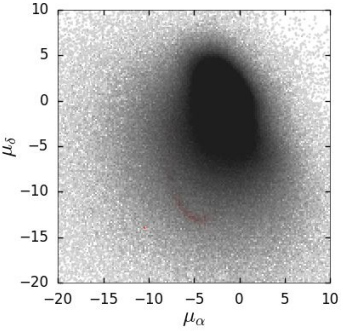
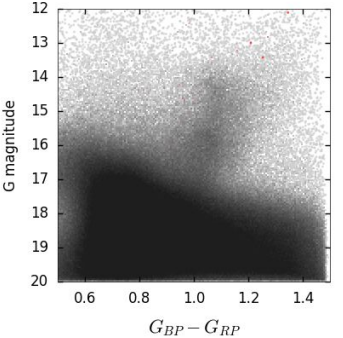
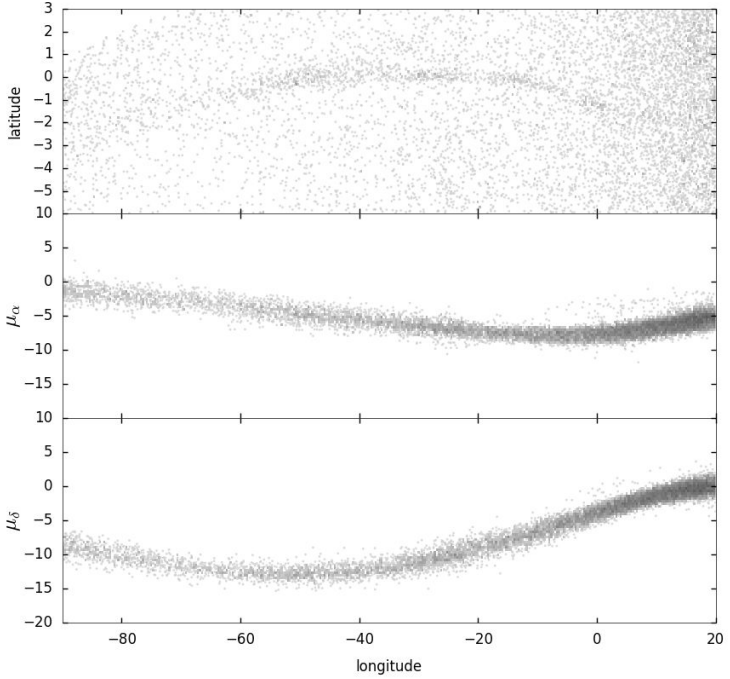
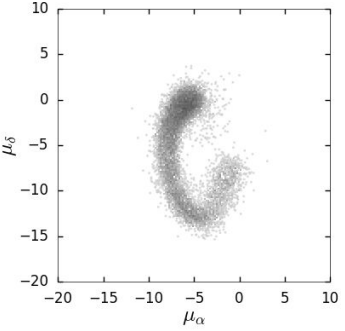


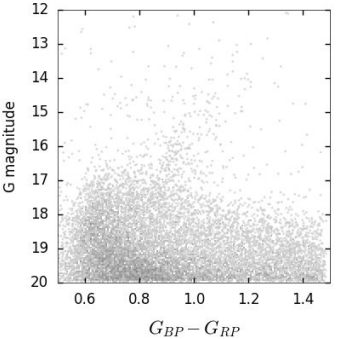




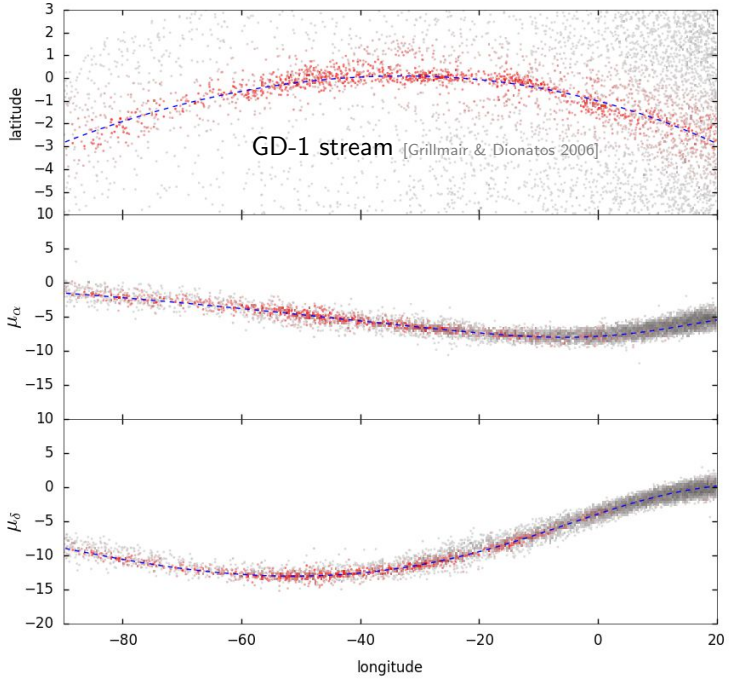
Finding streams with Gaia

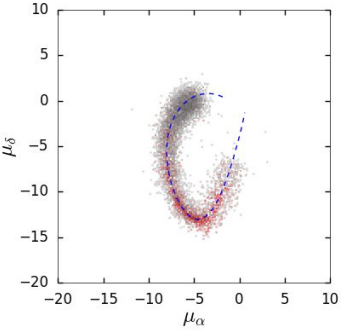


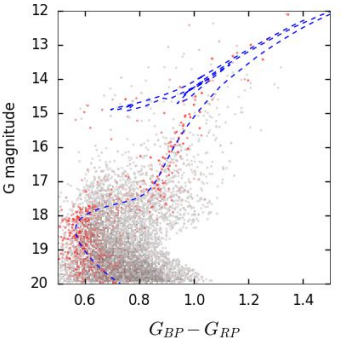




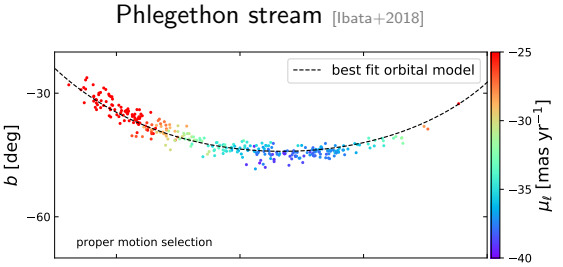
Finding streams with Gaia

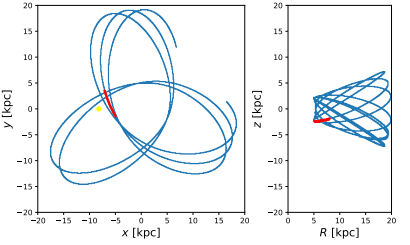


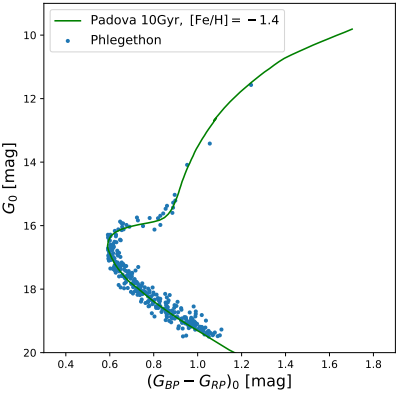




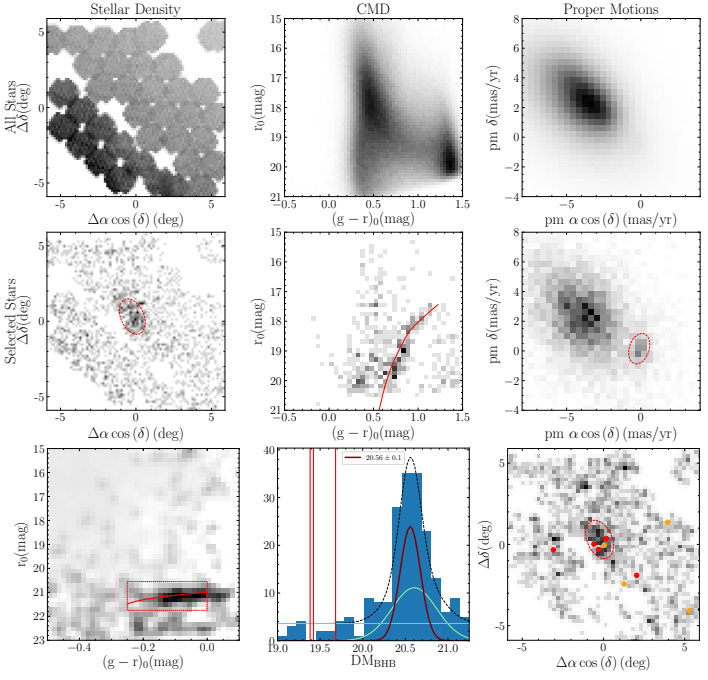
Finding new streams with Gaia

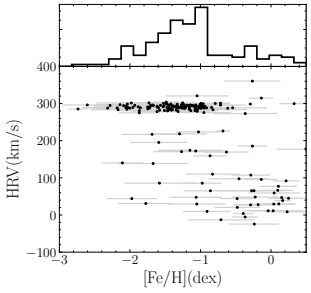


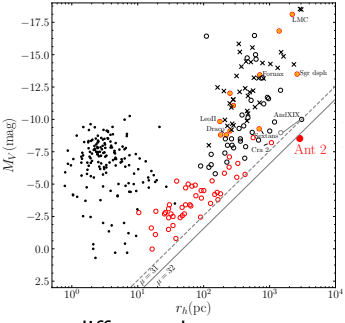




Finding new satellite galaxies with Gaia: Antlia 2



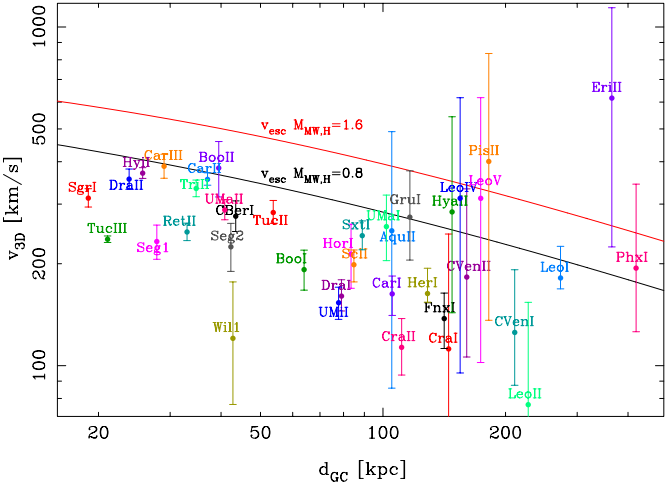




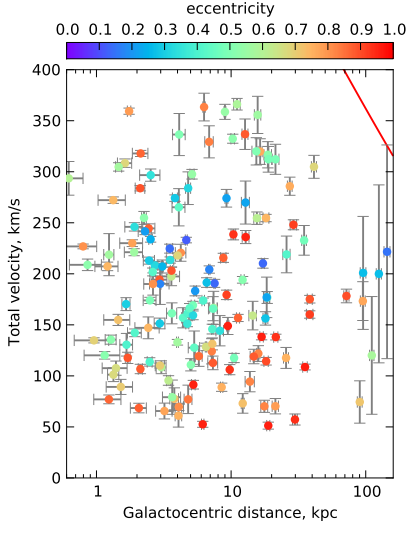
The most diffuse galaxy [Torrealba+2018]

Measuring 6d phase-space coordinates and orbits of

Satellite galaxies

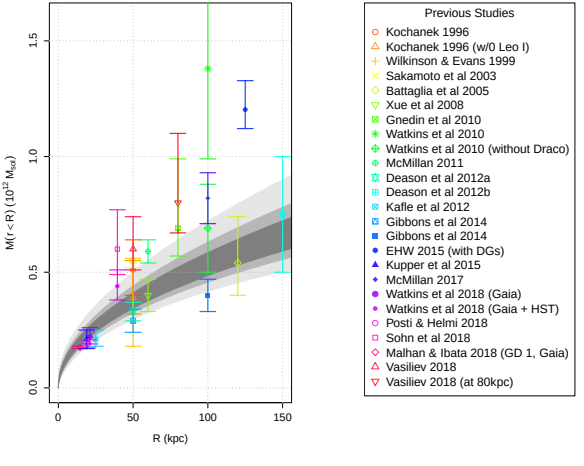


Globular clusters



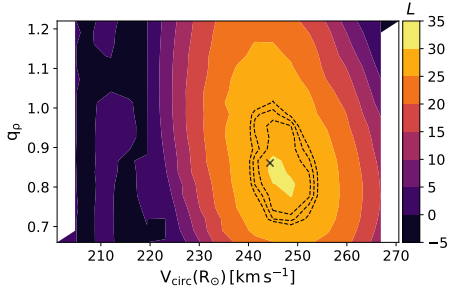
[Fritz+2018, see also Simon 2018; Pace & Li 2018; Massari & Helmi 2018]

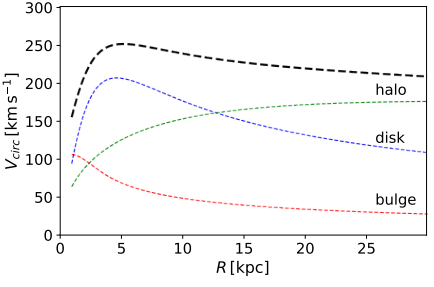
Constraining the Milky Way potential



Globular cluster dynamics

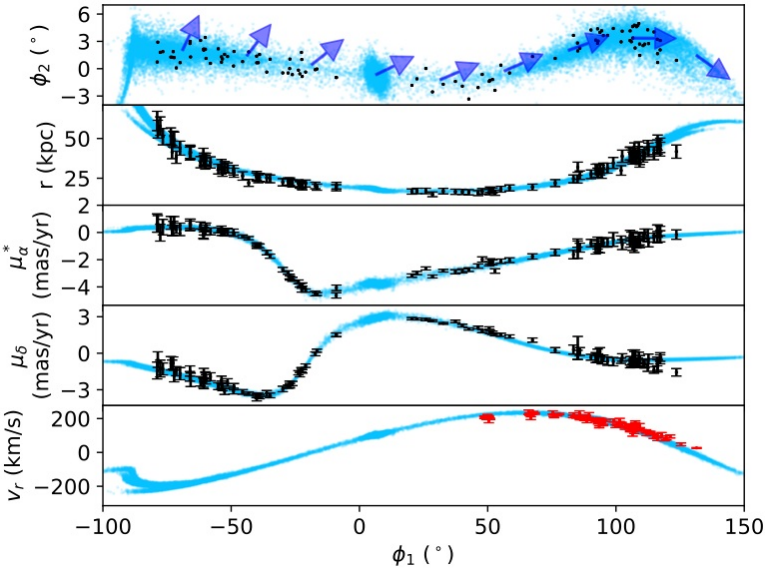
[Eadie & Juric 2018; see also Watkins+2018; Posti & Helmi 2018]

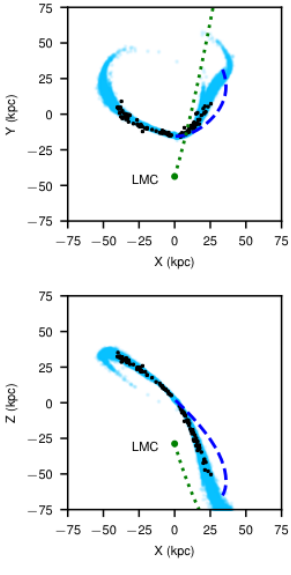




GD-1 stream [Malhan & Ibata 2018]

Constraining the mass of the Large Magellanic Cloud





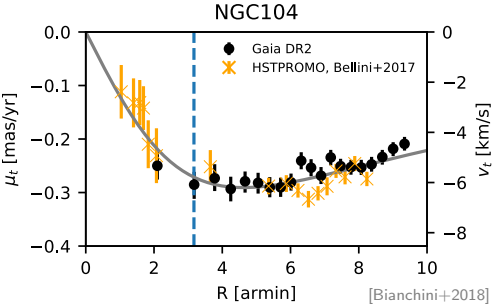
5d kinematics of the Orphan stream deflected by LMC flyby [Erkal+2018]

Internal kinematics of globular clusters

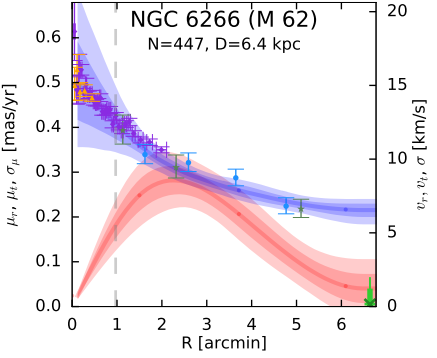
Rotation found in $\sim 10 - 20$ clusters,

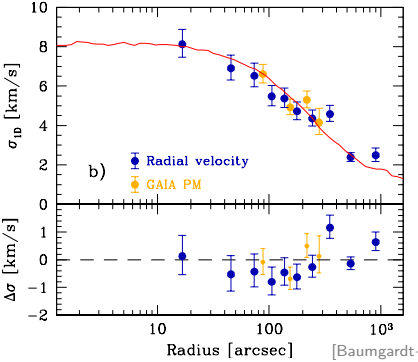
transverse velocity dispersion measured

in $\sim 60 - 100$ clusters (outer regions)



[Bianchini+2018]

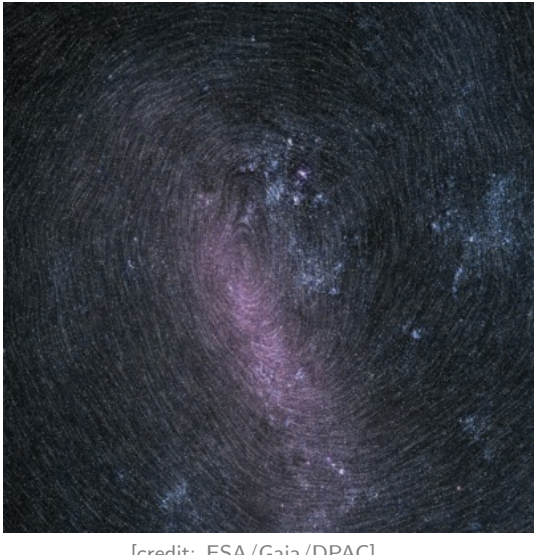




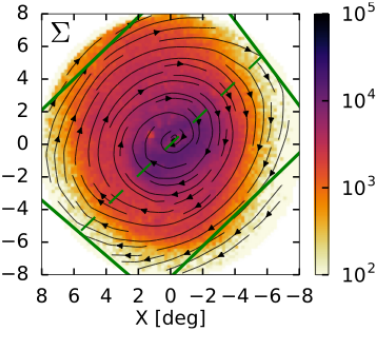
[Baumgardt+2019]

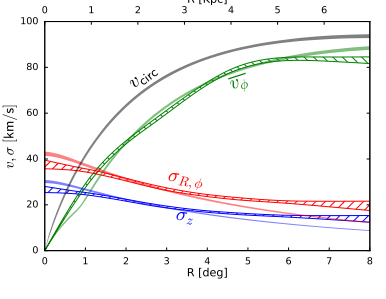
Internal kinematics of the Large Magellanic Cloud

rotation, velocity dispersion from $\sim 10^6$ stars at 50 kpc



[credit: ESA/Gaia/DPAC]

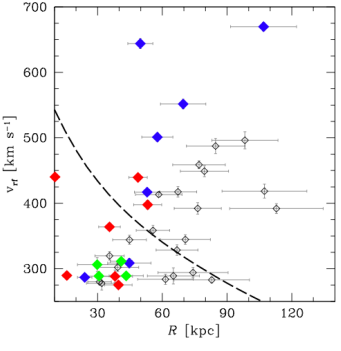




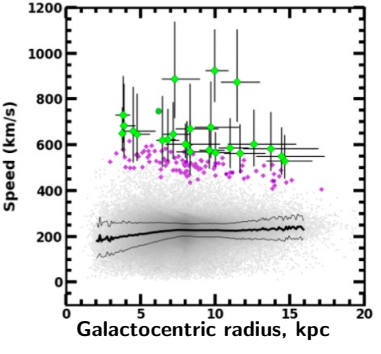
Hypervelocity stars

Stars ejected from the Galaxy with $v > v_{\text{escape}}$ by:

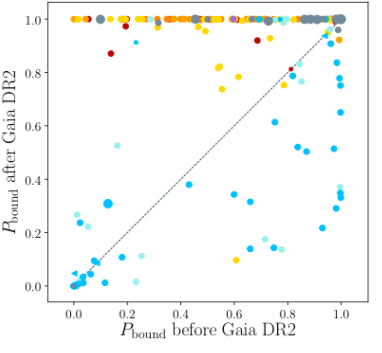
- tidal disruption of a binary star by the central supermassive black hole [Hills 1988]
- dissolution of a binary after SN explosion



[Brown+2018]



[Bromley+2018]



[Boubert+2018]

Summary

Gaia is awesome! (if used wisely)