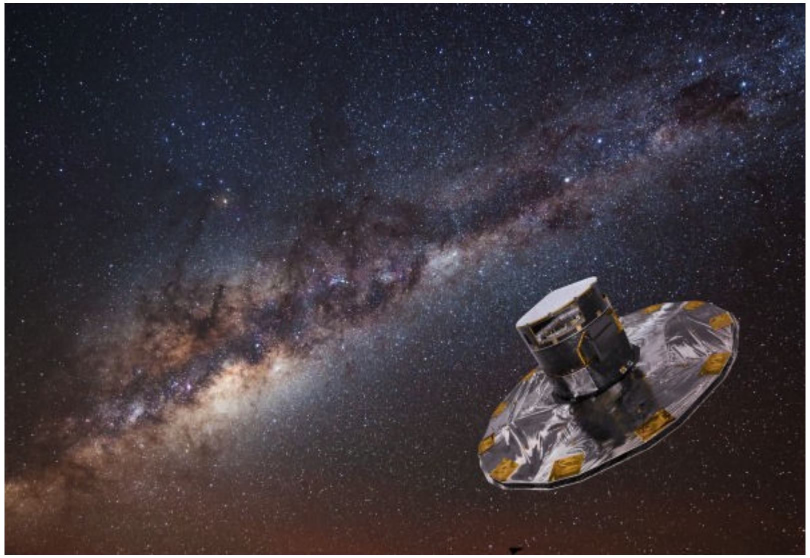
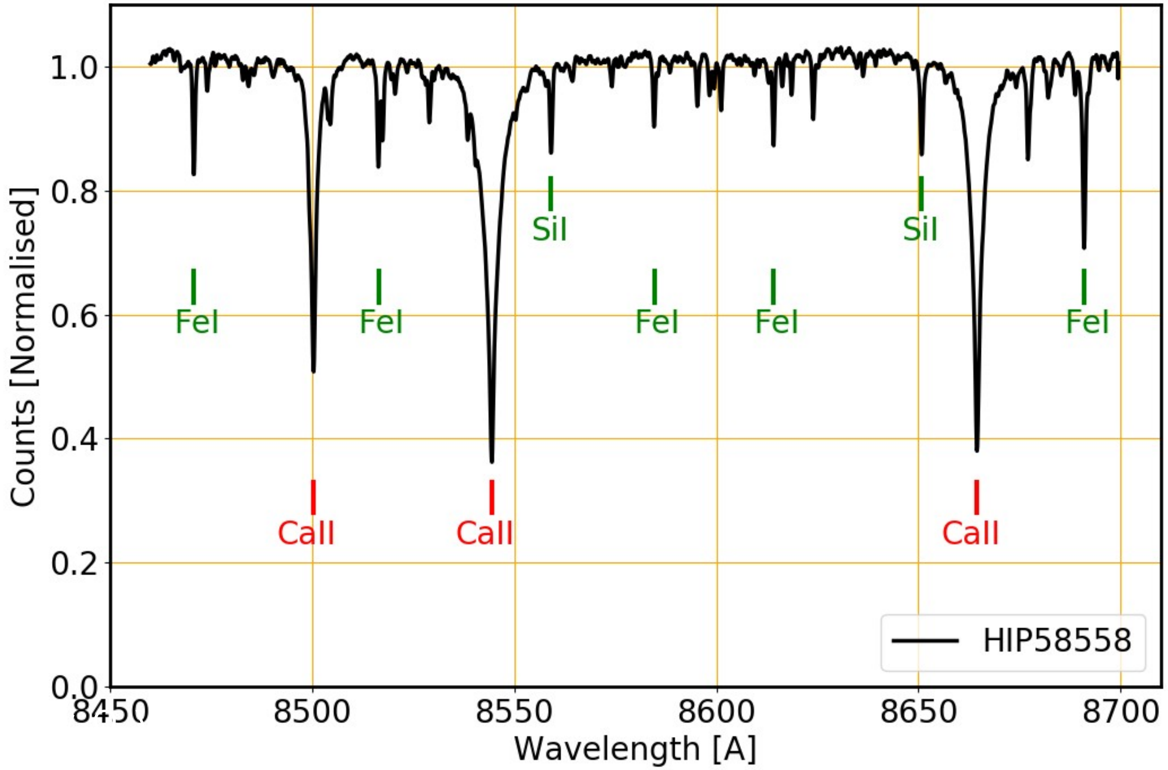
On your astrometric journey, don't forget your spectrograph ...





D. Katz

Observatoire de Paris - LIRA

on behalf of the Meudon-Gaia spectroscopy group

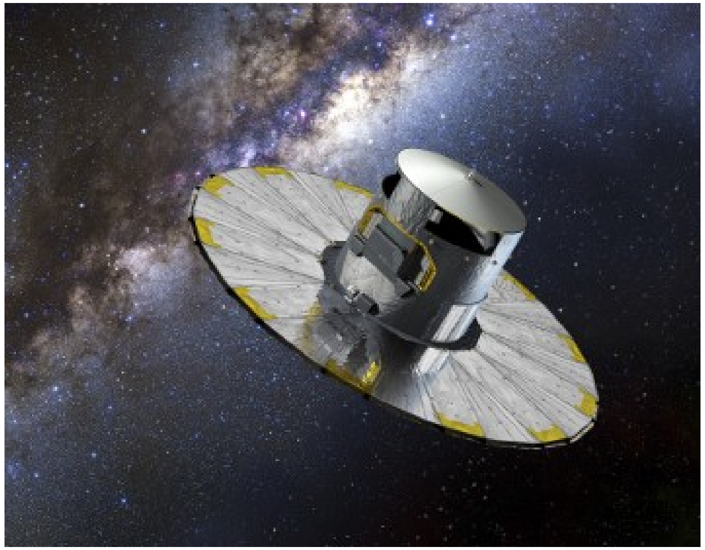
Hipparcos and Gaia

- Hipparcos (1989-1993) : 118 218 stars
  - no spectrograph on-board → vast ground-based observation effort with CORAVEL
  - catalogue + 10 years: ~15% stars observed

    (13 500 F-G dwarfs Nordström+04 ; 6 500 K-M giants Famaey+05)

- Gaia (2014-2025) : 1.5 billion stars
  - Radial Velocity Spectrometer (RVS)
  - Simultaneous publication of the radial velocities → ~10% end of mission

Was it a good idea to include a spectrograph on-board Gaia ?



Artist's view of a recent successful astrometric satellite with a spectrograph on-board

Largest radial velocity catalogue

Gaia DR3

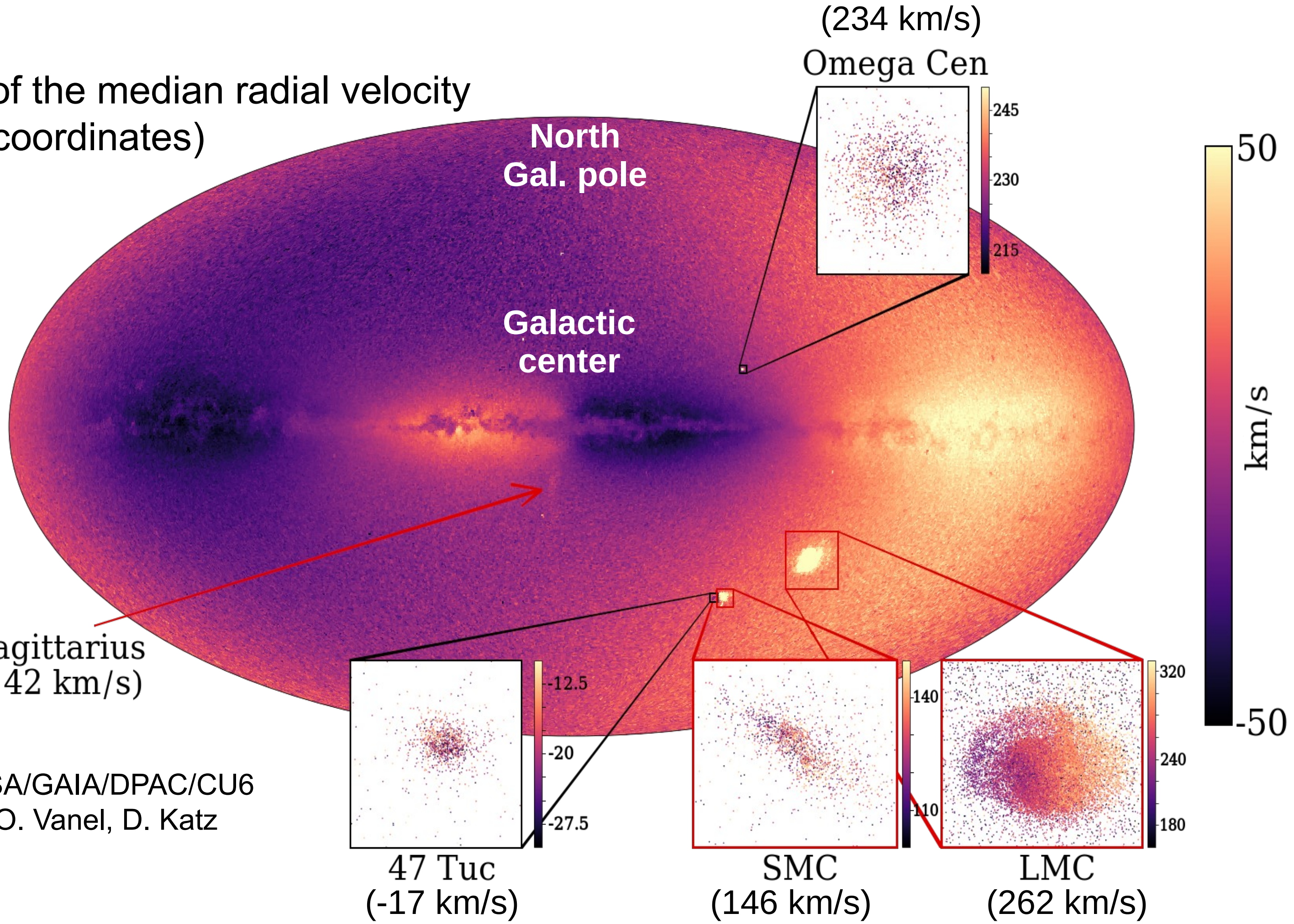
- 34 millions stars
- Full sky and “homogeneous” measures
- Multi-epochs

Gaia DR4 ~ 80 millions stars

Gaia DR5 ~ 100 - 150 millions stars

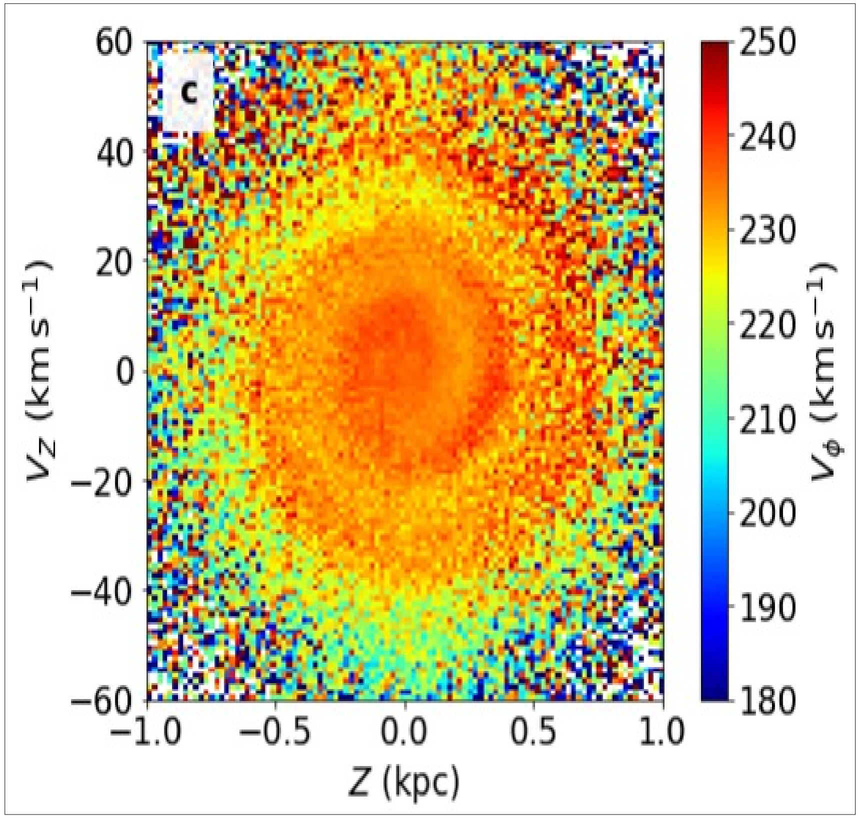
LAMOST DR9 LR ~ 10 millions stars

Sky map of the median radial velocity
(Galactic coordinates)



Credits: ESA/GAIA/DPAC/CU6
C. Hottier, O. Vanel, D. Katz

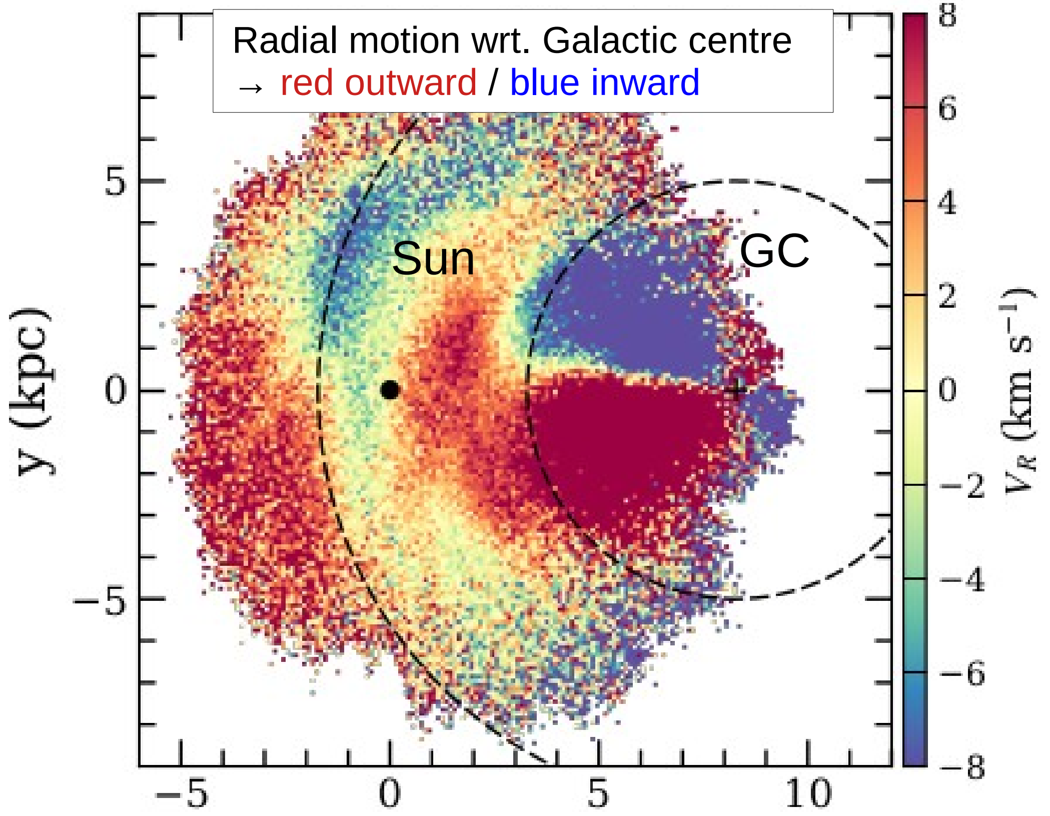
Disc perturbation



Antoja, Helmi, Romero-Gomez et al., 2018, Nature, 561, 360

Large number of stars in the solar neighbourhood
→ enhance the pattern visibility

Disc/Bulge/Bar dynamics



Gaia collaboration, Drimmel et al., 2023, A&A, 674, 37

Gaia DR3

2 x 10^6 stars R < 4 kpc / 27 x 10^6 R > 4 kpc

→ detailed 3D view: radial, azimuthal and vertical

Scientific return (2)

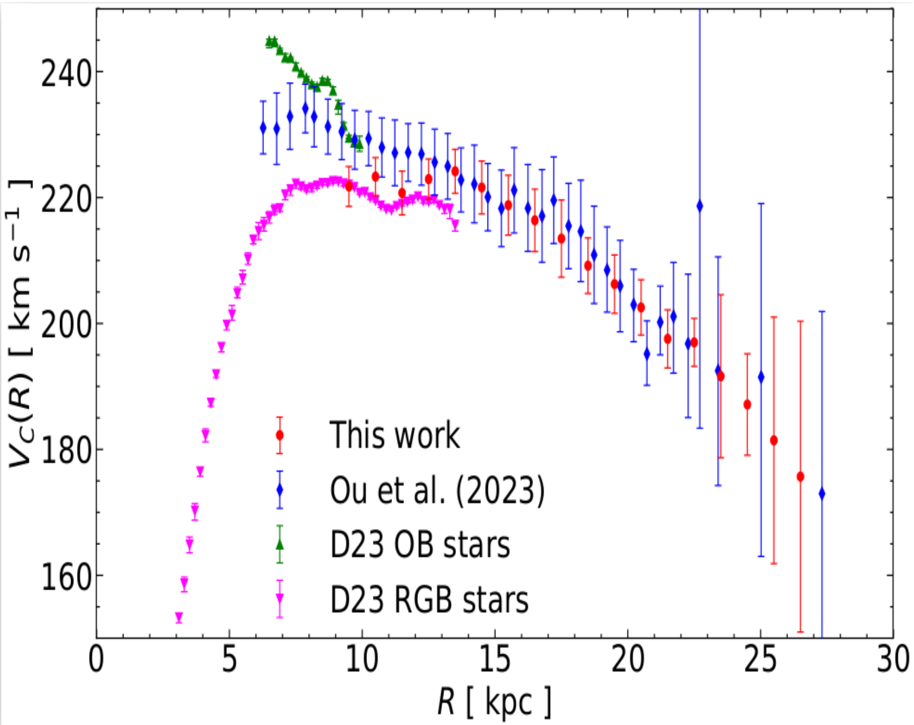
Disc rotation curve, MW mass and Dark Matter content

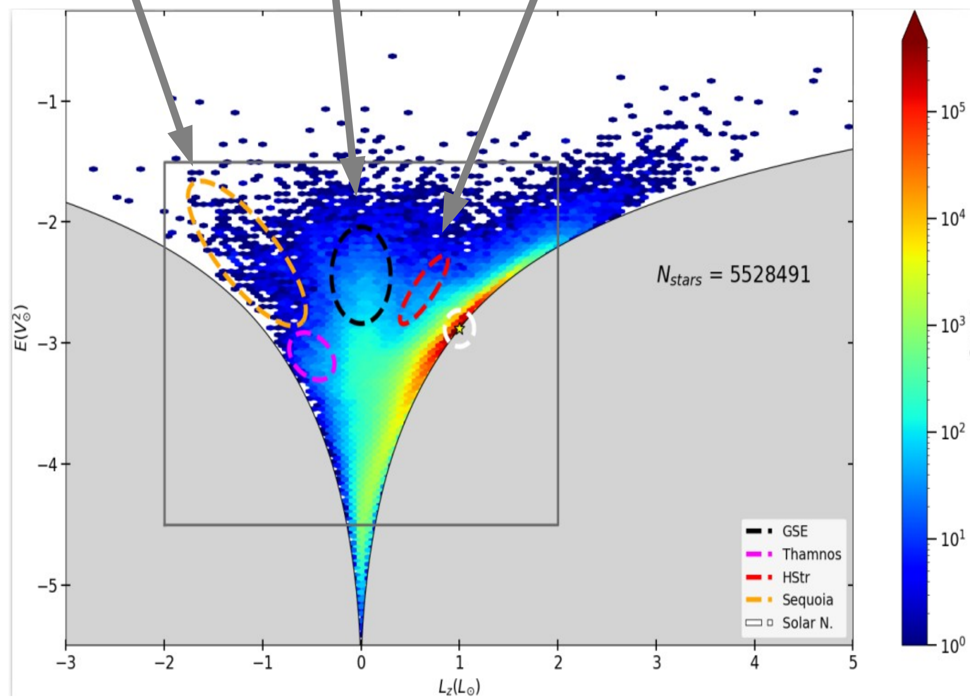
Accretion history of the MW inner halo

GSE

Sequoia

Helmi stream





Jiao, Hammer, Wang et al., 2023, A&A, 678, 208
showing also
Ou, Eilers, Necib & Frebel, 2024, MNRAS, 528, 693
Gaia collaboration, Drimmel et al., 2023, A&A, 674, 37

Gaia collaboration, Recio-Blanco et al., 2023, A&A, 674, 38

Significant number of stars at large distances

Full sky “magnitude limited” probe of the inner halo

Gaia-RVS Galactic science return → large sample / full sky magnitude limited sample

What about the next mission ?

No universal answer → depending on the science case

- On-board spectrograph

  → Large number of sources / large sky area

  → Gaia-RVS: 14 millions spectra/day - no comparable ground-based facility (in 2045 ? → explore new designs / technologies ?)

  → Synergy with ground-based spectrographs → e.g., abundances, fainter targets

  → Gaia-NIR

- Multi-object ground-based spectrographs

  → List of targets / moderate sky area (list of Dwarfs gal. / Globular Clusters)

  → Theia

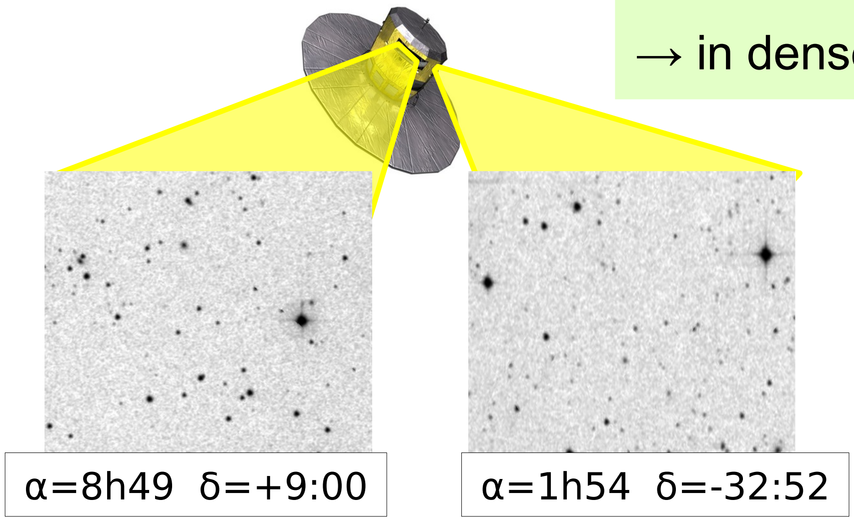
Potential gain of an on-board spectrograph for a Gaia-NIR-like mission

- Larger sample (full sky/homogeneous) → less extinction and/or fainter magnitude
- Longer time baseline → long period variability (for stars in common with Gaia)
- Different wavelength range → new/complementary spectral information
- (Possibly) more precise measures

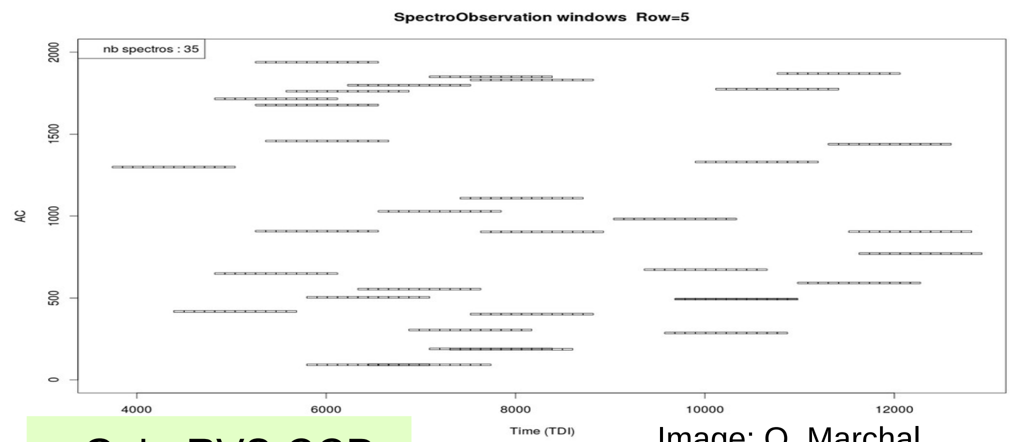
Anticipated complexity : crowding

Gaia-RVS : integral field spectrograph

→ in dense area spectra overlap



Gaia field of views



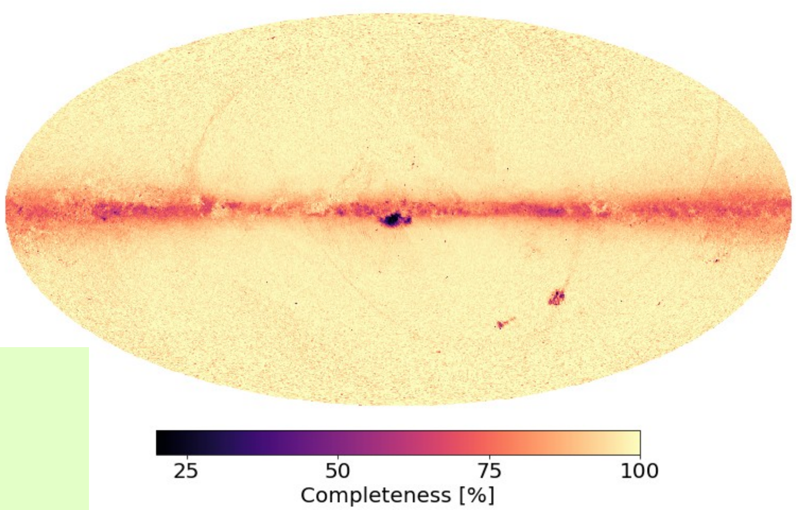
a Gaia-RVS CCD

Image: O. Marchal

Gaia DR3 V_R completeness map (Gal. coord)

→ Global 90 % / disc 70-80% / bulge densest areas < 30%

→ upgrade of deblending algorithm planned for DR5



- Crowding will increase with number of sources
- Preparatory studies

  → hardware / on-board software (windowing-sampling strategy)

  → software (ground segment)

Other preparatory studies

Define a strategy to obtain the stellar atmospheric parameters (APs)

- Required to select the template to derive the V_R
- Gaia : large fraction of APs provided by Bp / Rp spectra
- Future : on-board (spectro-)photometry

Other classical caracteristics

- resolving power
- wavelength range
- limiting magnitude
- filter properties
- throughput
- noise budget
- sampling
- windowing strategy
- ...

→

- V_R performance
- crowding
- SNR, other parameters
- telemetry
- ...

Conclusion

- A spectrograph would enhance the science return of a deep full sky astrometric mission
- Some specific complexities may require preparatory studies