Angela Bragaglia
INAF-OAS Bologna

WEAVE:
STELLAR SURVEYS

Milano, Science with MOS spectrographs

WEAVE consortium

WEAVE = **W**HT **E**nhanced **A**rea **V**elocity **E**xplorer

Science & Technology Facilities Council

university of groningen

NWO

ASTRON

INAF ISTITUTO NAZIONALE DI ASTROFISICA

INSTITUTO DE ASTROFISICA DE CANARIAS IAC

l'Observatoire de Paris

NOVA

UNIVERSITY OF OXFORD

RAL Space

ISAAC NEWTON GROUP LA PALMA

liverpool JMU

UNIVERSITY OF CAMBRIDGE

INAOE

LUND UNIVERSITY

WEAVE Characteristics

Telescope, diameter	WHT, 4.2m
Field of view	2° ⌀
Number of fibers	960 (plate A)/940 (plate B)
Fiber size	1.3″
Number of small IFUs, size	20 x 11″x12″ (1.3″ spaxels)
LIFU size	1.3′x1.5′ (2.6″ spaxels)
Low-resolution mode resolution	5750 (3000–7500)
Low-resolution mode wavelength coverage (Å)	3660–9590
High-resolution mode resolution	21000 (13000–25000)
High-resolution mode wavelength coverage (Å)	4040–4650, 4730–5450 5950–6850

Fibre-to-fibre minimum distance: 1 arcmin (➔ problems with clusters)

WEAVE Characteristics

R~5000 (mostly) for RV to mag~21

R~20000 (mostly) for abundance to mag~16

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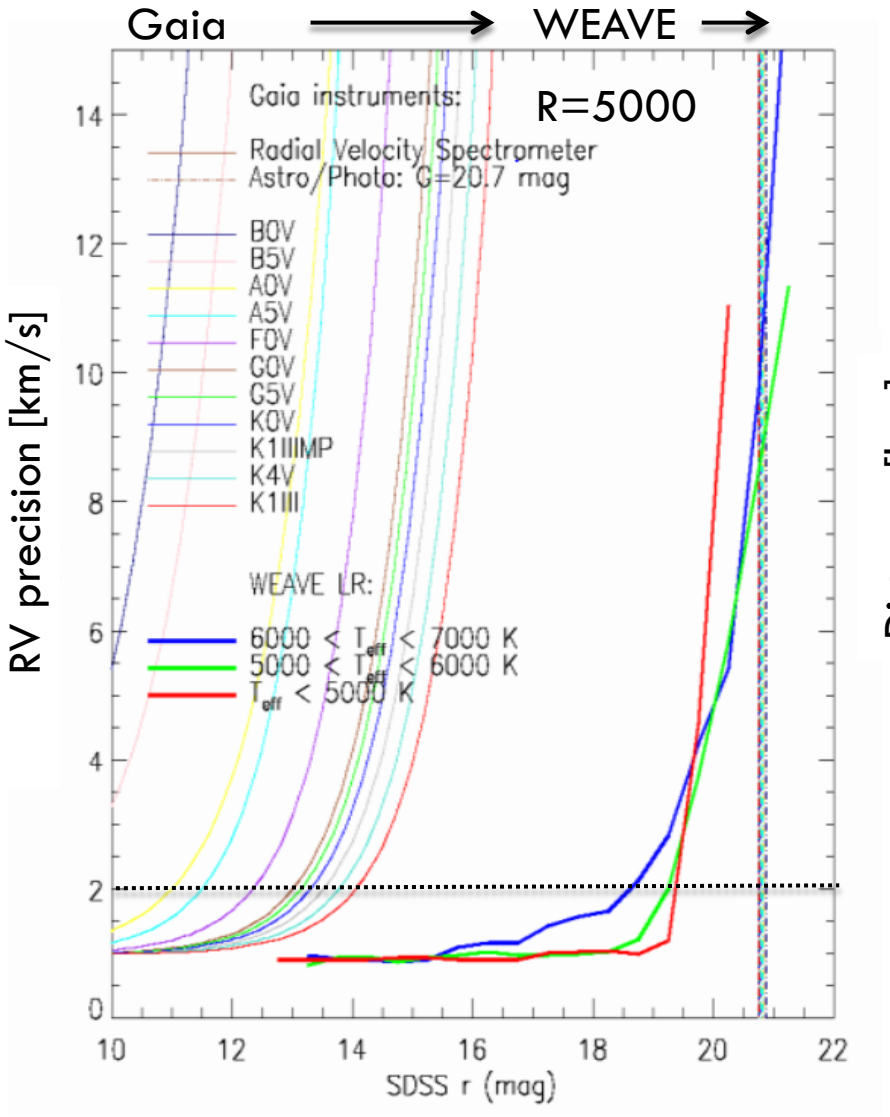
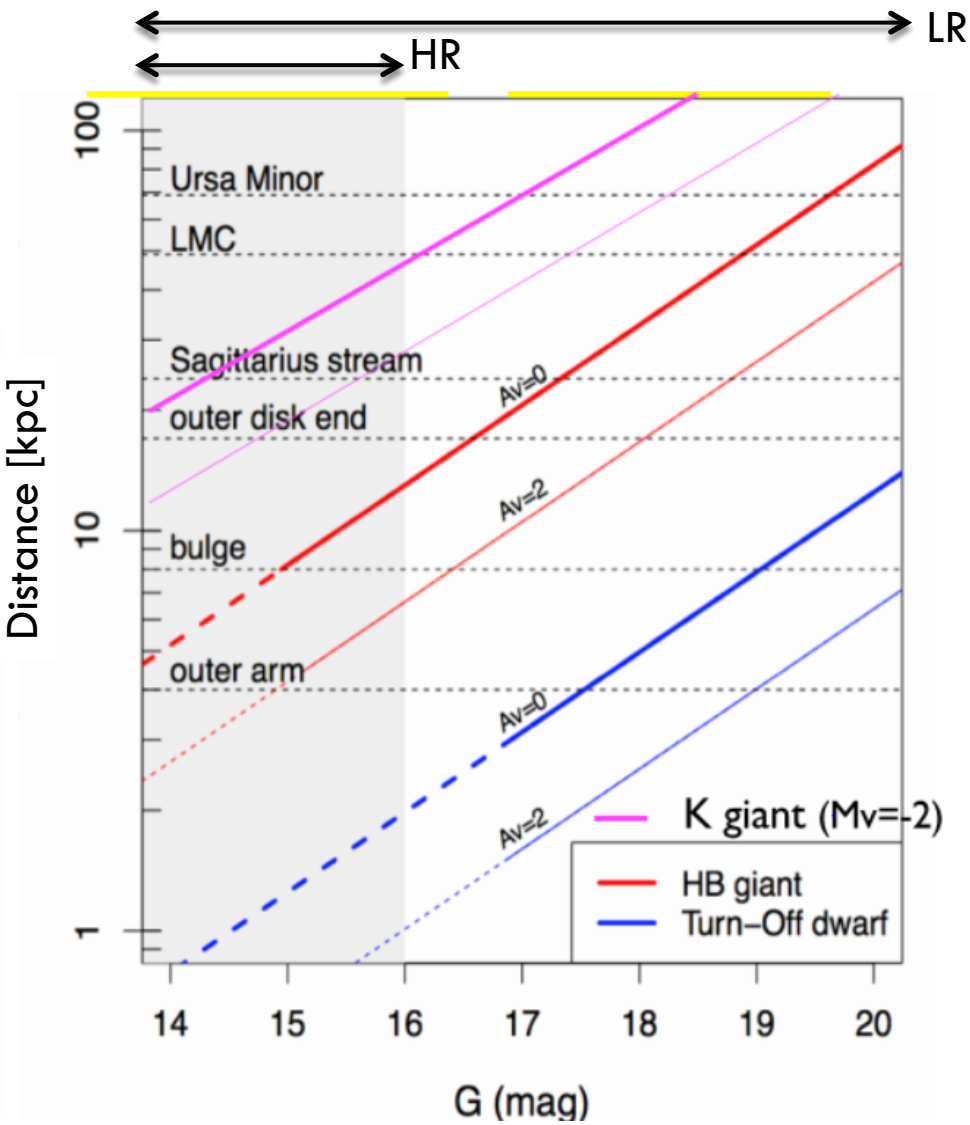
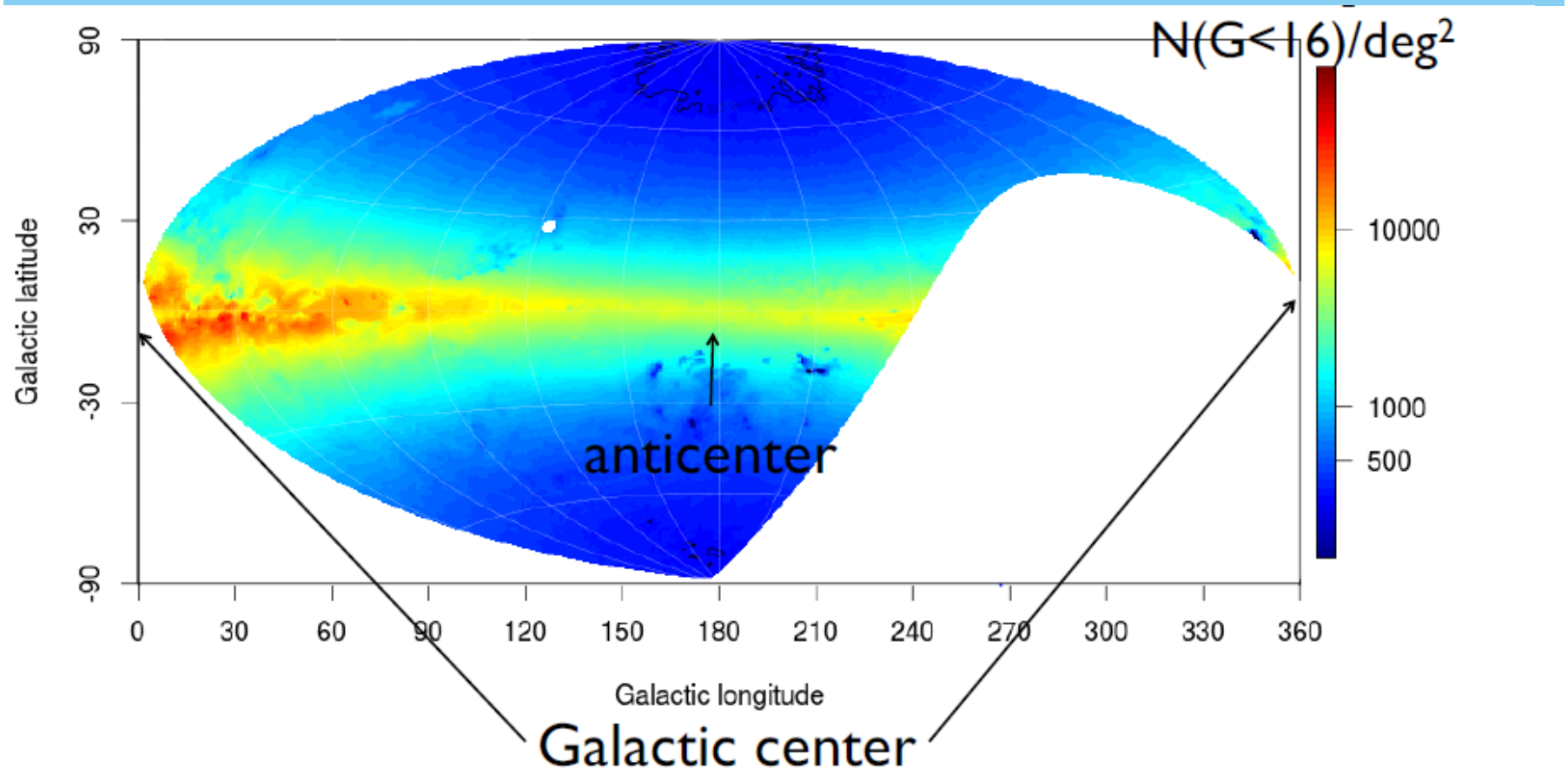
WEAVE performances



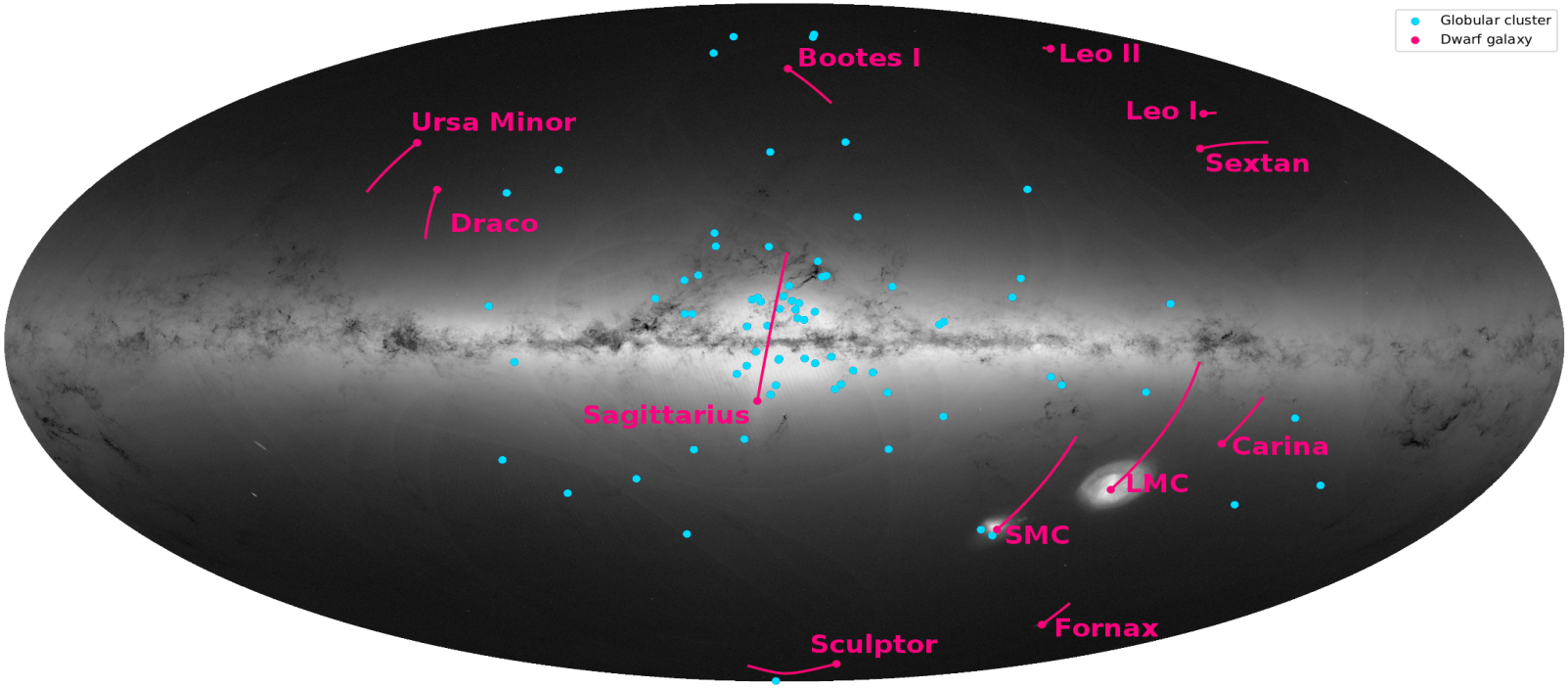


WEAVE: Nothern multiplex



only X-wide field & X-high multiplex optical high-resolution in *Northern Hemisphere* *(cf Maunakea Spectroscopic Explorer, 2025+)*

WEAVE-Gaia connection

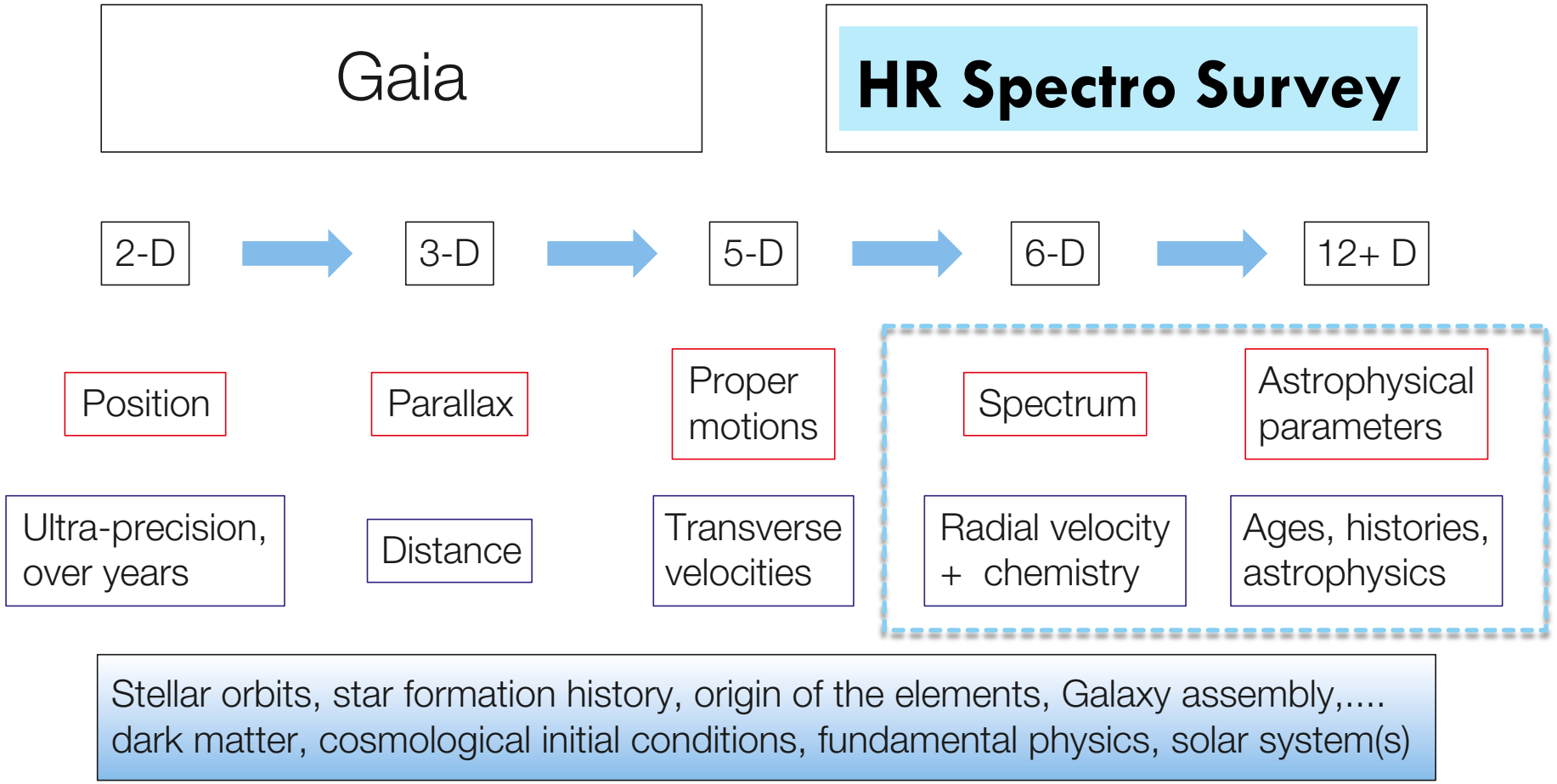


- WEAVE (stellar) is the first survey with target selection from **Gaia DR2+** and building on Gaia DR2+ results
- Gaia DR2 real catalog (real data quality, real target densities, etc) : evolution of target selection
- Gaia DR2 findings (e.g. Enceladus, new clusters) in target selection and footprint

WEAVE timeline

- Complete survey plans: mid Q2/2019
- Survey readiness review: Q2/2019
- Early science project definition (first year of observations)
- Construction complete: Q3/2019
- Assembly and integration at WHT complete: Q4/2019
- First engineering light: Q1/2020
- First science light: Q2/2020
- Science verification begins: mid Q3/2020
- **Surveys begin: begin Q3/2020**
- 2019-2024: **5 years of WEAVE surveys (70% of available time)**, plus TAC time (30%) which may also include using WEAVE
- Post-2024: not defined, but likely continued use of WEAVE instrument (not necessarily current surveys)

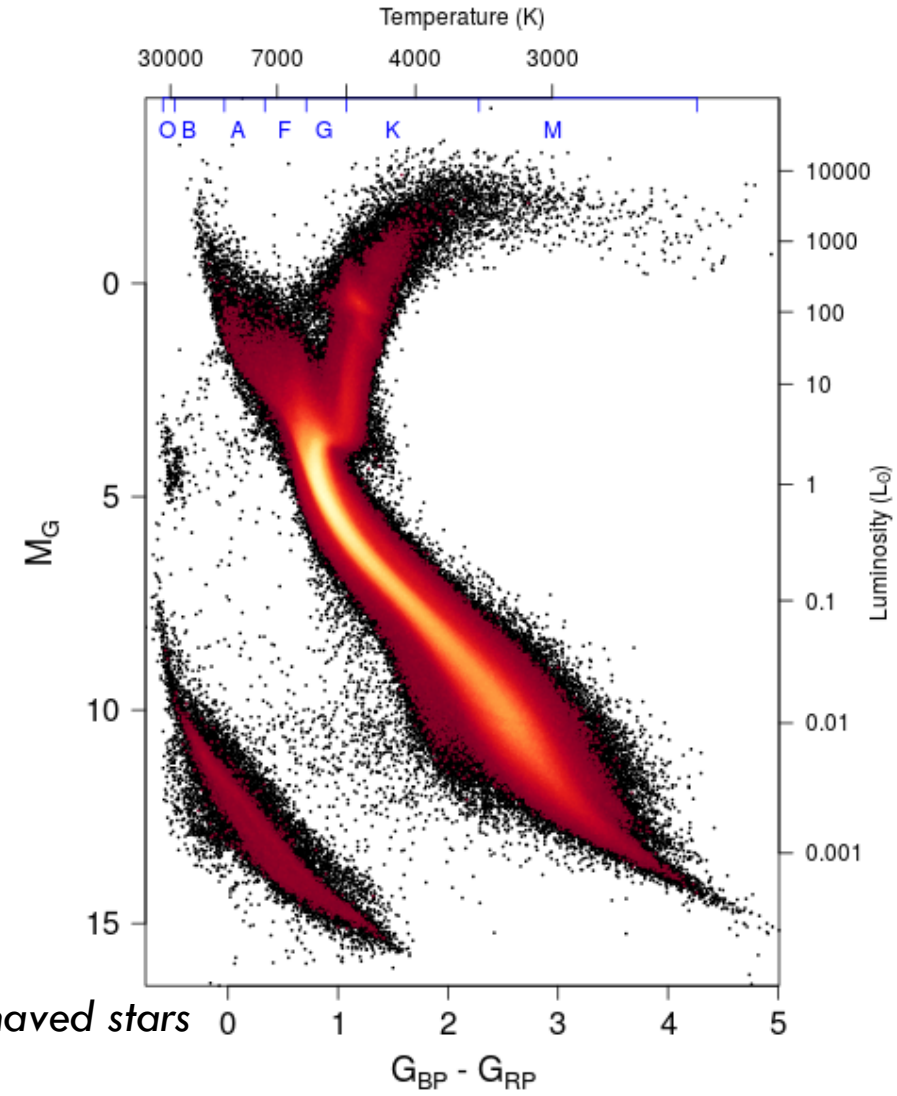
WEAVE mission for the Milky Way



(Figure for Gaia-ESO survey, see Gilmore, Randich et al. 2012, The Messenger, 147, 25)

WEAVE mission for the MW

- Combine (spectroscopic) stellar parameters plus RV with Gaia PLX, PM, photometry: get **ages**, e.g. to constrain the mass assembly of the MW disc(s) with time
- Derive **distances** where errors on Gaia parallax are killing
- **Chemo-dynamical labelling** (tagging) with all main nucleosynthetic channels, to deconstruct galactic stellar populations



Gaia DR2 HRD: ~4.2 million low-extinction, well-behaved stars (Gaia Collaboration, Babusiaux et al. 2018)

WEAVE stellar surveys

- **Galactic Archaelogy** *(lead V. Hill)*

  complement Gaia

  complement MOONS, 4MOST in North (& APOGEE)

  - LRhighlat ; HRhighlat
  - LRdisc ; HRdisc (also thick disc)
  - Open Clusters ***(lead A.Vallenari)***
  - (Globular Clusters)
  - (calibration)

- **SCIP** *(lead J. Drew)*

  Galactic plane Stellar, Circumstellar, and Interstellar Physics

  $|b| < 4°$; massive stars, ISM, YSO, SFRs

- **WD** *(lead B. Gaensicke)*

  10-20 per FoV at G=21 (LR) : flux/tellurics calibrators & science

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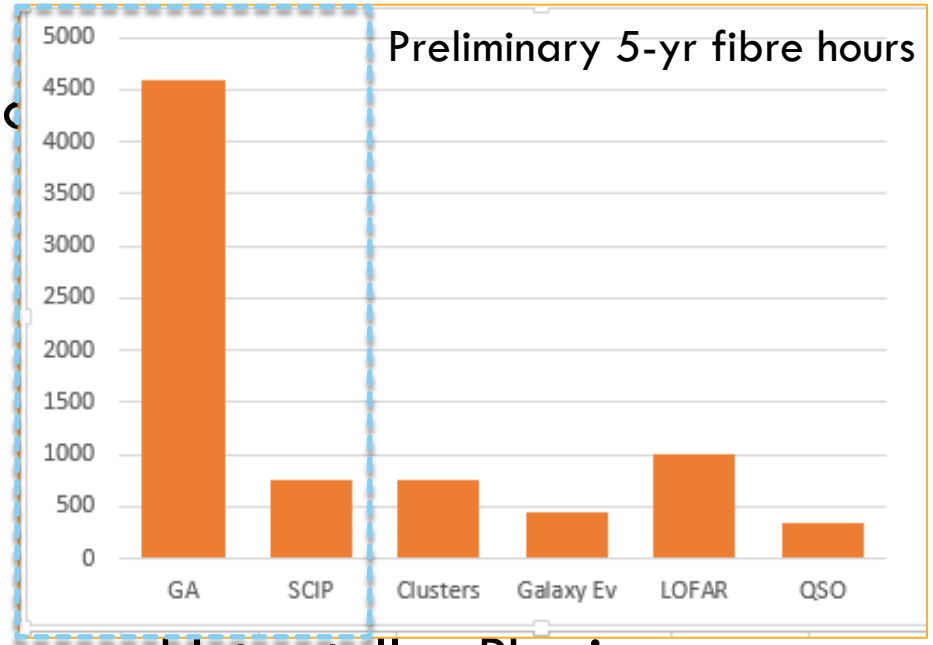

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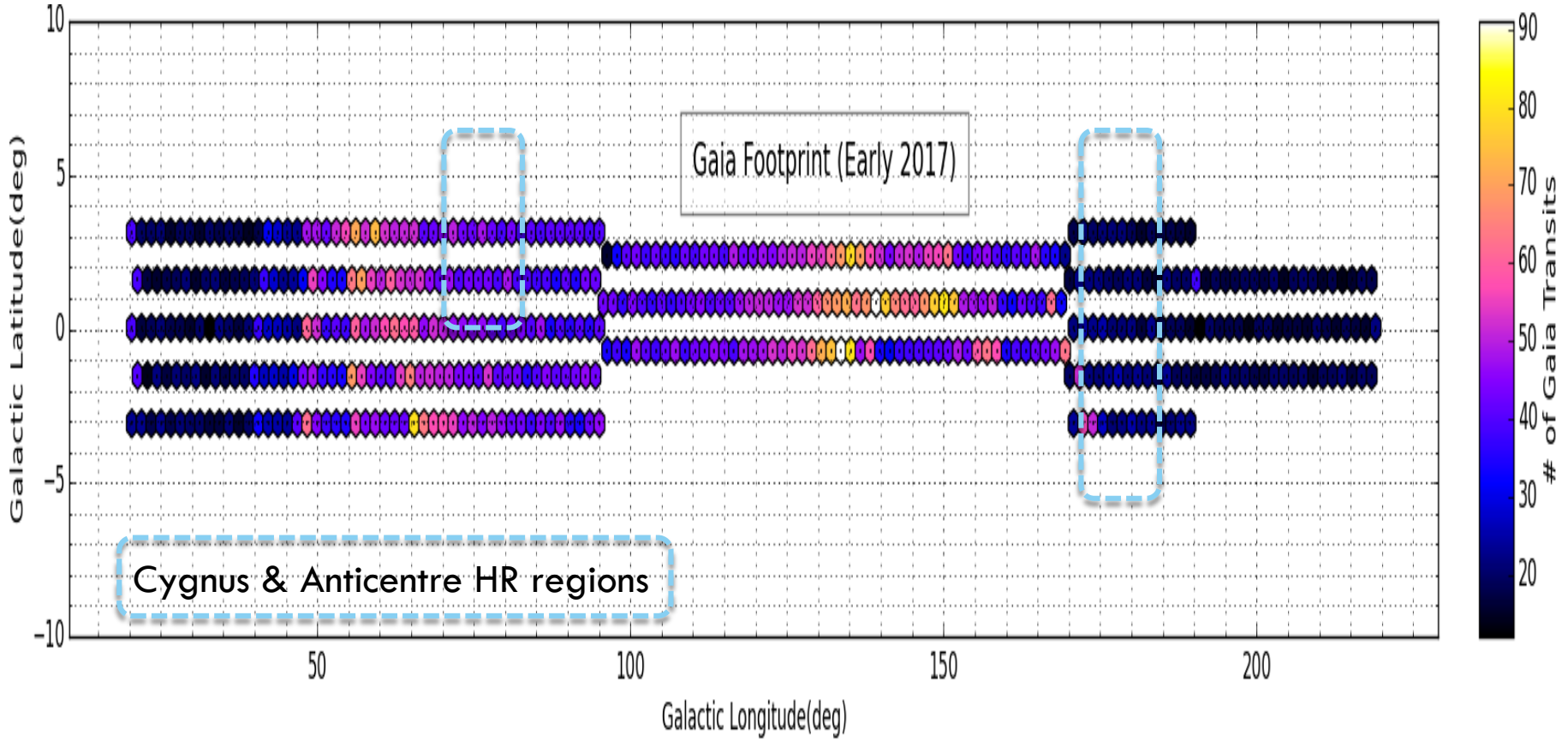
StellarCircumstellarInterstellarPhysics

- (mostly) LR Survey on Galactic Plane, in synergy with GP surveys:

  b<4°; ugri+Hα , 20th mag VPHAS+ ESO; UVEX (ugr, some Hel) & IPHAS (riHα) North



SCIP LR footprint, colored according to expected coverage in first Gaia release

StellarCircumstellarInterstellarPhysics goals

Only in MW we can access individually examples of the less well-described and short-lived phases in stellar evolution, even for sub-solar mass objects and study at maximum resolution the relationship between stars and the interstellar medium.
(LR) **spectroscopy** advantages over photometry alone: RVs (systemic, orbital); stellar parameters and metallicity, evidence of chemical peculiarity, IS absorption features, constraints on CS/nebular matter, mass transfer/loss, magnetic activity signature

- Study environmental effects on star formation
- Map extinction and ISM
- Study the life-cycles of massive stars
- Study mass-loss across HRD
- Determine consequences of binary interaction
- Study cooling WDs
- Study X-ray emitting binaries and gravitational wave sources

Targets: OBA stars (including emission line stars and RSGs), ionized nebulae and diffuse ISM, young stars, WDs and compact binaries, Cepheids

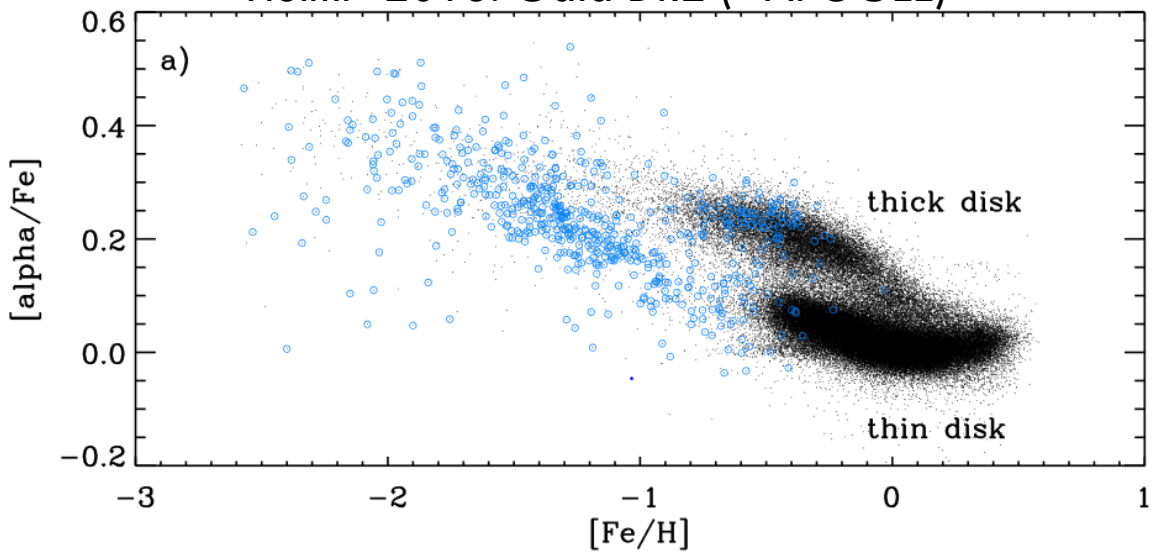
MW surveys: some key questions

Structure formation on sub-galactic scale

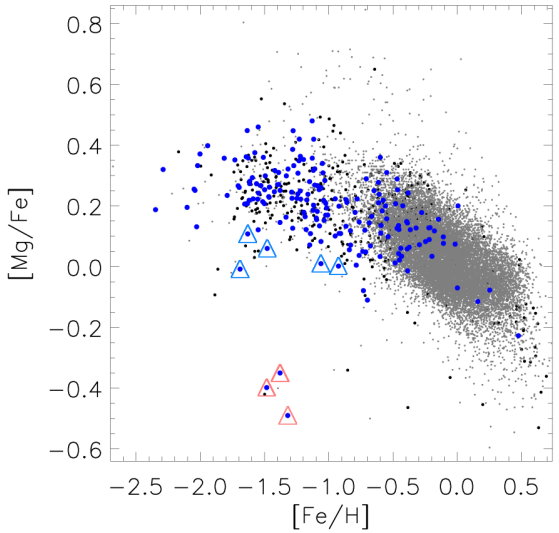
- **Halo:** in situ vs accreted
- What is the total mass of the Milky Way? What is the shape of the Galactic gravitational potential?
- Where are the most metal-poor stars in the Milky Way, what are their properties, and what do they tell us about the physics of the early Universe?
- dSph and UDFs : the role of disrupted dwarfs
- **Dark matter**
- How much substructure does the Galactic dark matter distribution have within 20–50 kpc? How do they interact with cold streams?
- **Discs:** respective roles of hierarchical formation and secular evolution in shaping the Galaxy
  - what are the roles of spirals (+ number of arms, pitch angle, pattern speed?) and the bar (length, pattern speed?)
  - **How do clusters form and dissolve, populating the MW ?**
  - **what is the chemical evolution traced by the open clusters?**

Gaia DR2 "surprises" - halo

Helmi+2018: Gaia DR2 (+APOGEE)

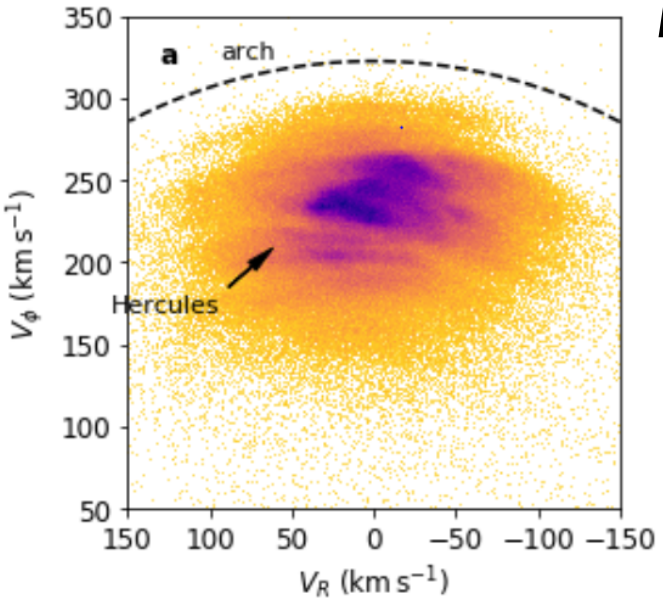


Gaia-ESO



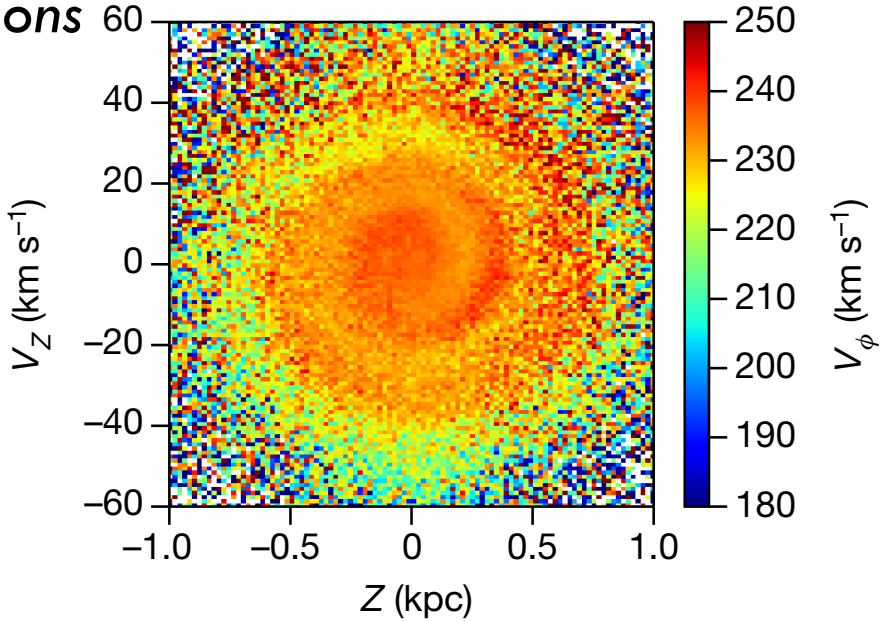
- Gaia+SDSS data: "Gaia Sausage" contributing to 50% mass of the halo within 25 kpc (Belokurov+2018, Lancaster+2018, Kruijssen+2018)
- Gaia-Enceladus retrograde stars are on the blue sequence (Helmi+2018)
- **Inner 30 kpc the stellar halo could be largely dominated by a single, ancient, extremely radial merger 10 Gyr ago, of high mass (10 $^{9\text{-}10}$ $M_\odot$)**
- [α/Fe] vs [Fe/H] different from thick disk: long lasting SF
- High e stars with abundances of dwarf satellites (Mackereth+2018, using APOGEE)

Gaia DR2 “surprises” - disk



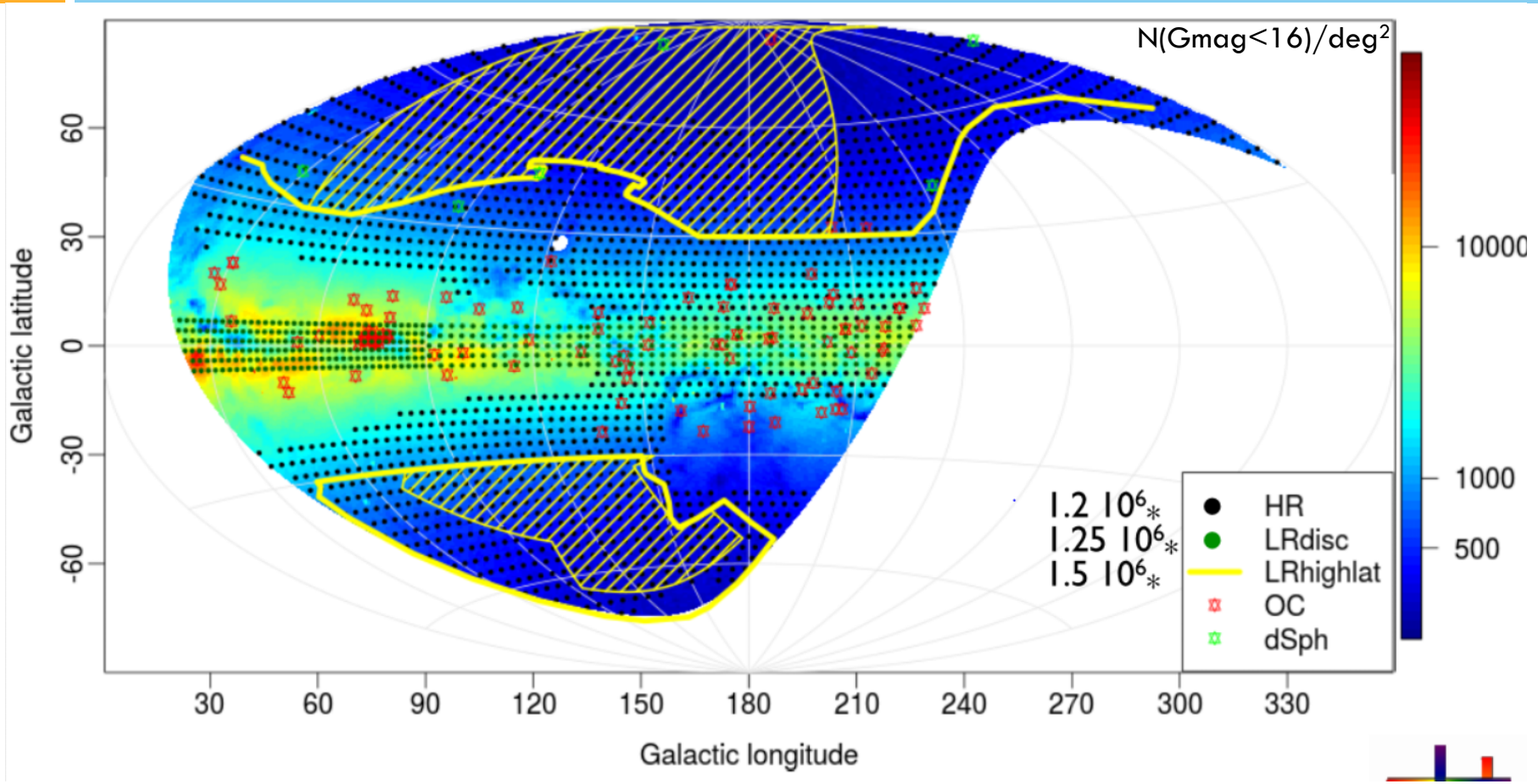
Disk perturbations

Antoja+ 2018



- **The disk is out of equilibrium state** (Antoja+ 2018; Kawata+ 2018; Trick+ 2018)
- Bending modes excited by dark matter halo ? (Chesquers 2018)
- Vertical waves from a perturbing satellite (Sagittarius ?) ? (Binney & Schoenrich 2018, Bland-Hawthorn+ 2018)
- Perturbations created by spiral arms ? (Hunt+ 2018, Quillen+ 2018)
- Bar perturbations ? (Gaia Collaoration+ 2018)

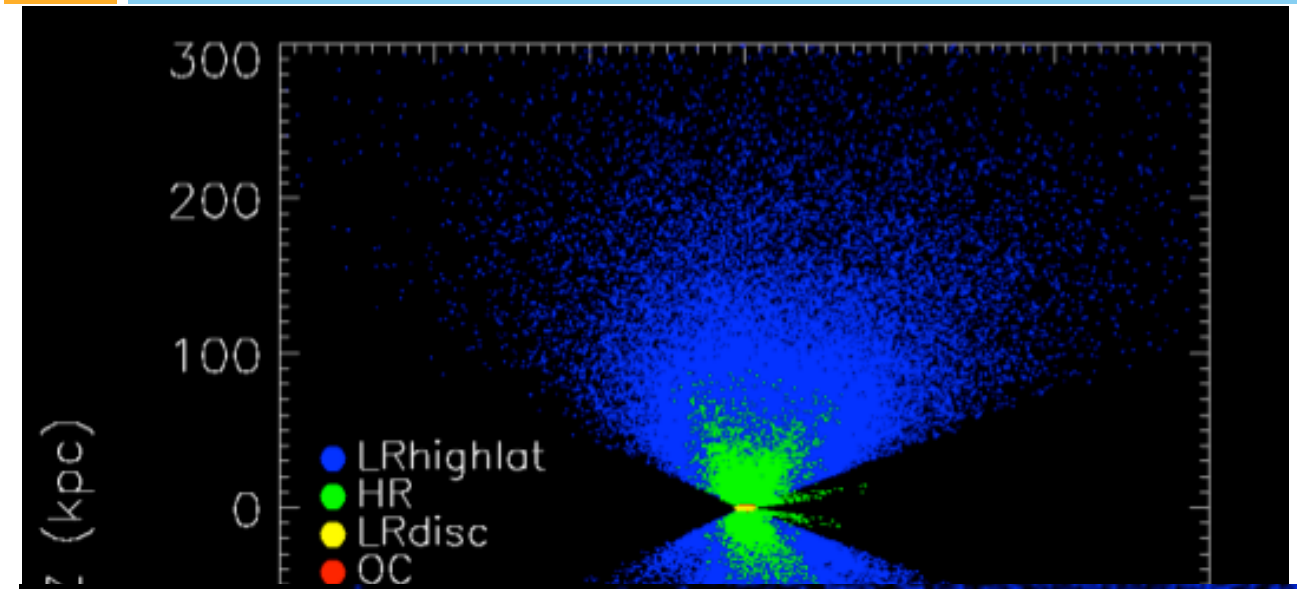
A few million stars to unravel MW history



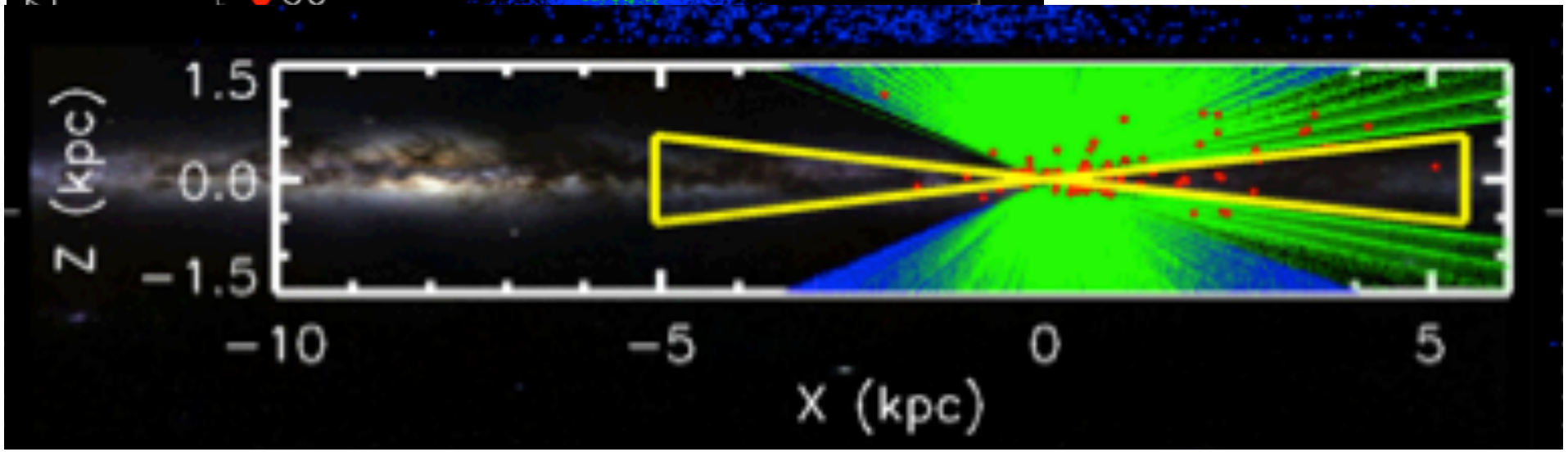
LR disk: |b|<6
1.5x10^6 stars – on 210+405 LoS

HR disk: 1,800 deg^2 with 15<|b|<30 to ensure coverage of discs

WEAVE Galactic Archaelogy plan



WEAVE reaches farther & with denser coverage than Gaia-ESO, APOGEE, GALAH



GA : LR high latitude

- **Goal 1.** Formation scenarios for the Galactic stellar halo: in-situ or accreted? Dist=10-35 kpc to trace the break of the halo
- **Goal 2**. Outer halo survey with RGB stars
- **Goal 3.** Total mass of the Milky Way out to 200 kpc through Jeans analysis
- **Goal 4.** The shape of the Galactic gravitational potential within 50–100 kpc from tidal streams. Dist > 50 Kpc
- **Goal 5.** Chemo-dynamics of Milky Way dwarf satellite galaxies
- **Goal 6.** Halo sub-structure. Dist < 30 Kpc
- **Goal 7**. Metal-poor stars and the earliest phases of metal-enrichment.
- **Goal 8.** Large scale mass assembly of the thick disc

$|b|>30°$, $V<20$ + color cuts, $\sim 1–2\times10^6$ stars (number of streams > 30)

Tracers : old MSTO (D<30 kpc) ; RGB (100 kpc) ; BHB & RRLyr ; EMPS (MoU with PRISTINE)

Pointed survey :

dwarf galaxies + streams + UDFs to V<21

(also repeated observations to get binaries with $|dRV| > 2$ km/s)

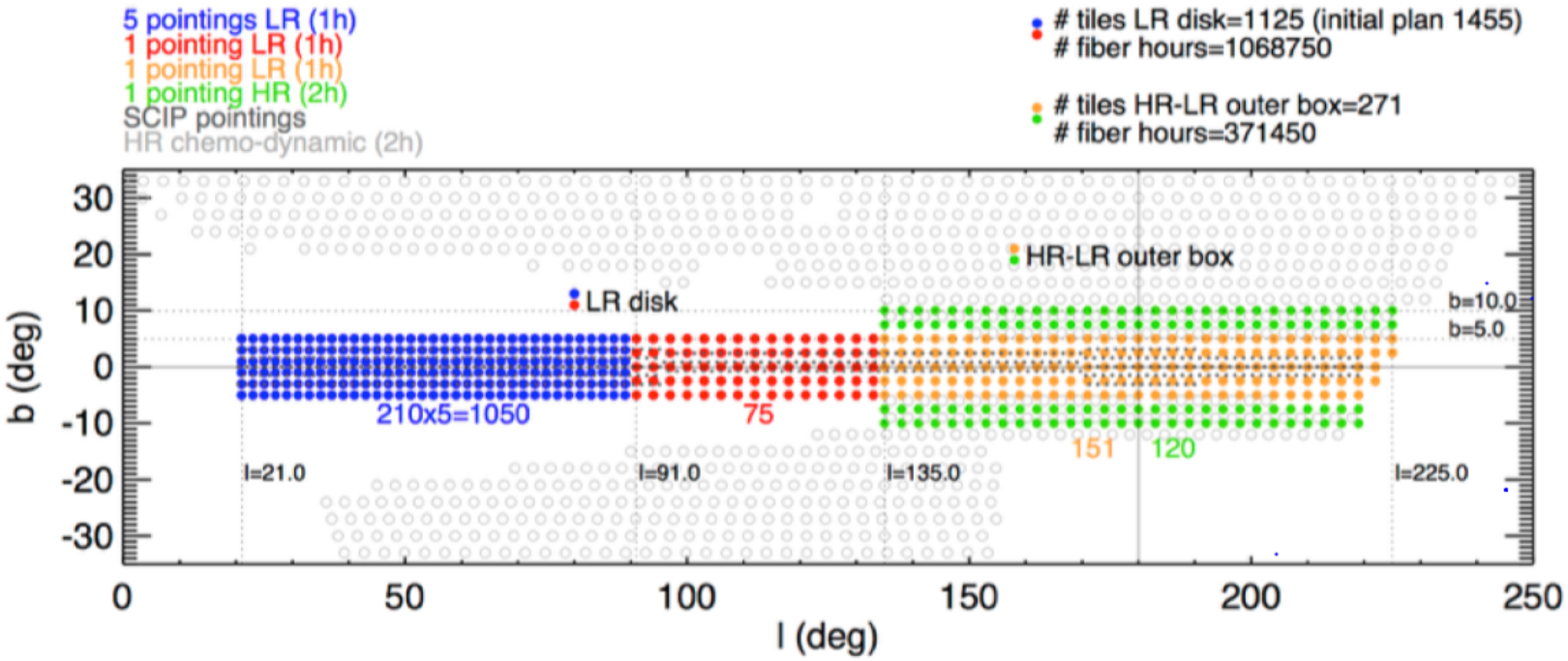
GA : LR disc

A galactic plane experiment to constrain the disc potential, including departures from axisymetry (spiral arms, bar, …), moving groups, study of accretion events, study of radial migration, etc

|b|< 6º, 550 LOS, RV to 2 km/s to discriminate streams with 5-10 km/s

WEAVE Privileged access to outer disc (clearly not in equilibrium): also HR, |b|< 10˚

Tracers: RGB and red clump stars



WEAVE HR surveys

- **Goal 1.** Probing the assembly of the Galactic discs with chemical labelling and ages
- **Goal 2.** Chemical labelling of streams, groups and substructures in the Galactic halo
- **Goal 3.** History of the chemical enrichment in the Galactic disc
- **Goal 4.** Stellar clusters (*GA-OC sub-survey already organized*)

WEAVE HR surveys : halo & disc(s)

- **Goal: Chemical tagging**

- High latitude Halo: searching for streams + first stars

  Assuming 500 streams cross the solar neighbourhood & 100 members each needed to characterize them

  → 5x10 ^{4} halo star → target 5 x10 ^{5} stars

  Given the density of halo stars at magnitudes 12<V<16 (~10 /deg^{2})

  → high-latitude survey 5000 deg^{2} (at |b|>30-40)

- Intermediate latitude survey mapping the thick disk

  MSTO stars selected from Gaia

  Assuming 0.1 dex thin/disk separation, an error on [α/Fe] abundances of 0.05 dex

  Nmin=3,000 stars per (R_{GC}, [Fe/H], Z) box

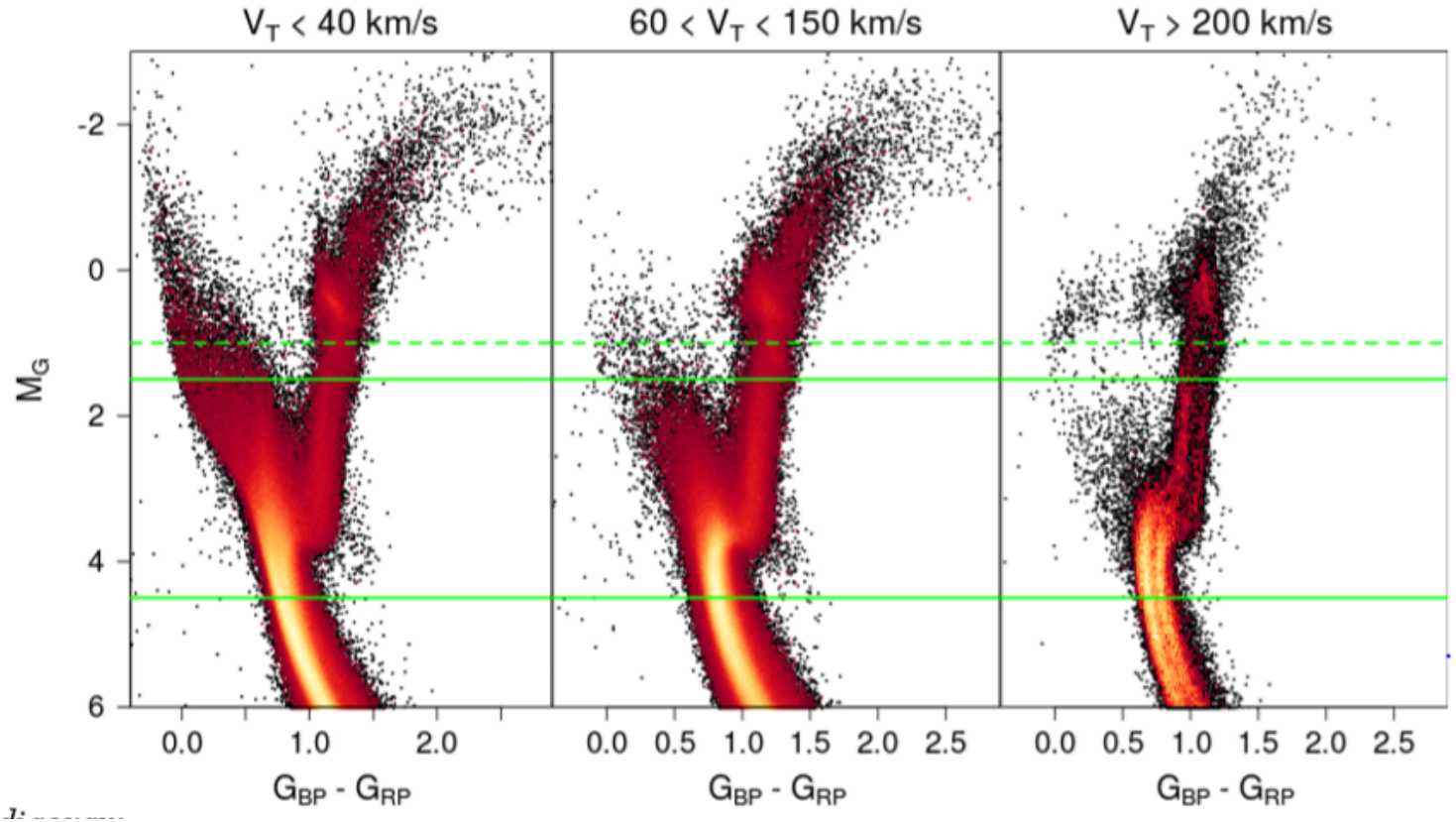
  → 1800 deg^{2} with 15<|b|<30° to insure R_{GC},Z coverage

  → 6x10^{6} thick disc stars

- HR (+LR) Globulars

WEAVE HR surveys : halo & disc(s)

- 90% of the HR survey is within the GDR2 5-D sample
- Target selection: G<16 including Gaia parallaxes (G<17 anticenter)
- Giants: all stars with $M_G < 1.5$
- MS: all stars $1.5<M_G<4.5$



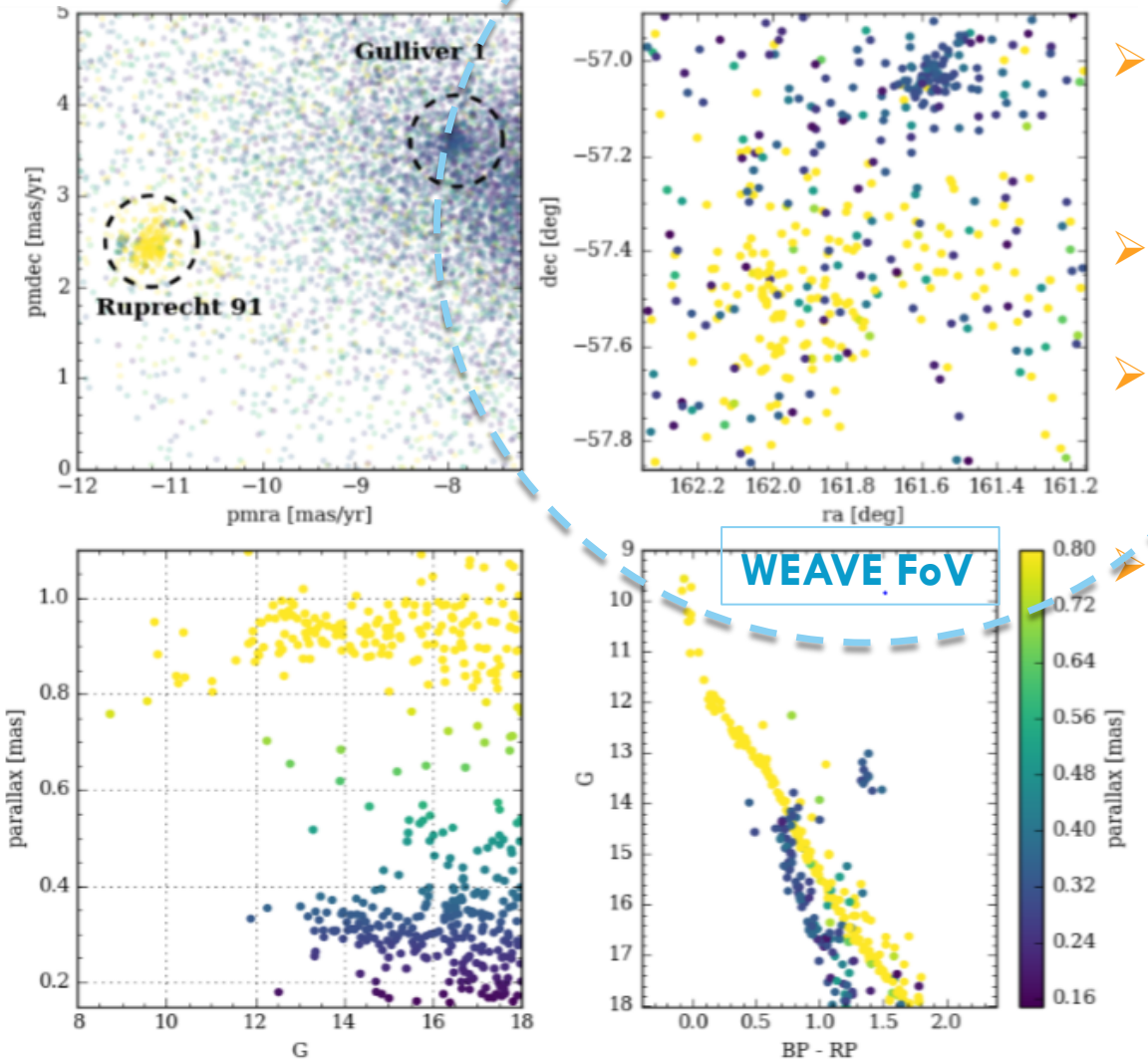
GA - Open Clusters

- **Goal 1.** Formation of open clusters and associations → FGK stars in Cygnus
- **Goal 2.** Disruption of open clusters
  - chemical tagging of young clusters in the field
  - Chemical tagging of the halo of open clusters
- **Goal 3.** OCs as tracers of the Galactic disc and of its chemical evolution → old OCs (age >500 Myr)
- As tracers of disk perturbations
- **Goal 4.** Early stellar evolution → nearby OCs
  - lithium (nuclear ages, mixing, etc)
  - accretion, activity: evolution and effect of environment
  - Expansion vs contraction
- **Goal 5.** Stellar evolution at later stages
  - Stellar population, binary confirmation, PMS

In red : science case/target selection revision based on Gaia DR2 data

Italy : INAF Padova, Bologna, Catania, Arcetri (+ Barcelona, Bordeaux)

Updates in the Open Clusters census



- Revised census for 1200+ OCs based on Gaia DR2 (see Cantat-Gaudin+ 2018a)
- 60 new OCs (and 32 of those have $D_{\odot}$< 2 kpc)
- More new OCs by Koposov + 2017; Castro-Ginard+ 2018; Dias+ 2018; Cantat-Gaudin+ 2018b
- Are we really complete inside 2 kpc?

New OC : Gulliver 1 (in blue), seen close to Ruprecht 91 (in yellow)

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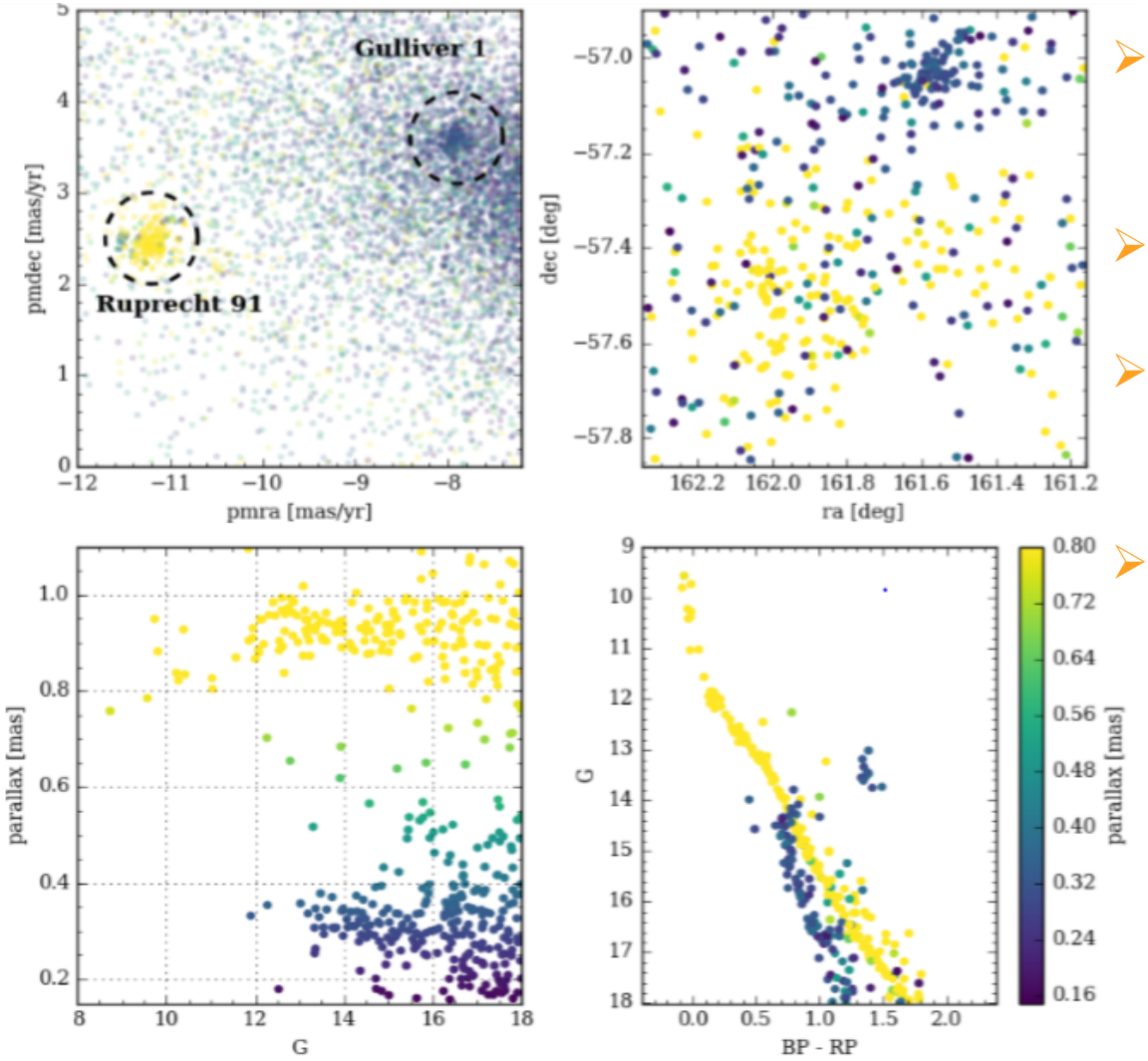

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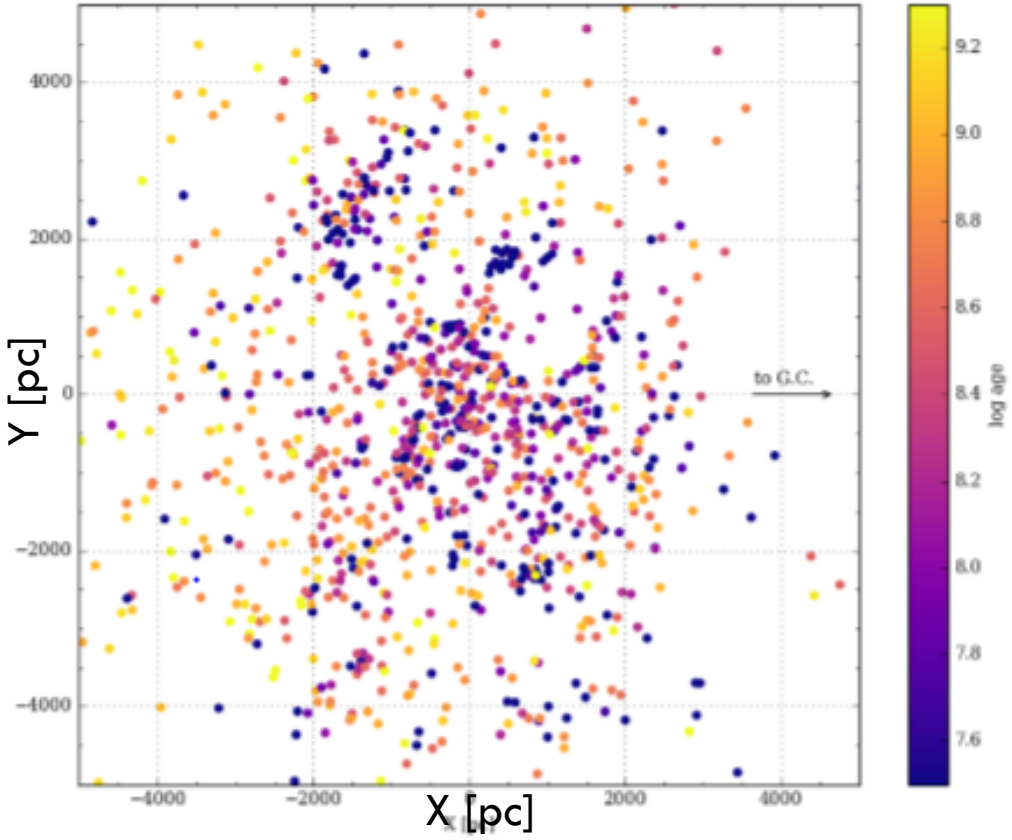
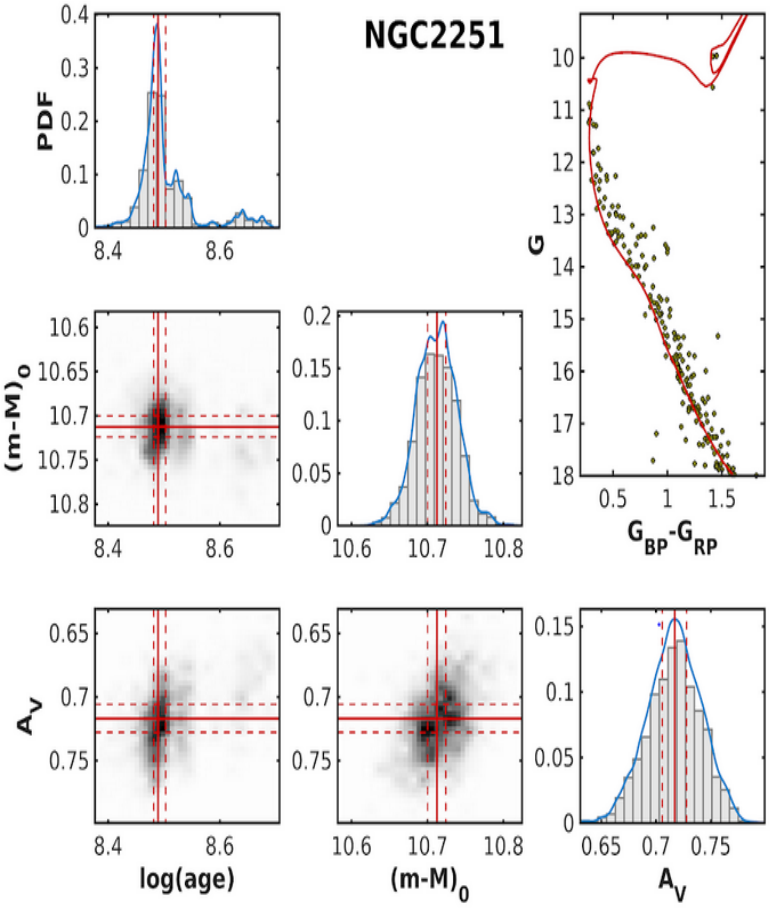
Updates in Open Clusters parameters



Cantat-Gaudin+2018a:
Gaia DR2 PLX, PM revision for 1200 Ocs
PLX uncertainty: 84% <5% ; 94% <10%



Bossini+2018:
Bayesian age determination (BASE9) for 270 OCs

Data policy

- Open data access inside the Consortium for all “nominal” products
- Proprietary period of 1 year for additional data products (CDPs)
- **First public data release after 2 years from survey beginning**
- Then every year
- PI-projects with WEAVE are analysed by the WEAVE pipeline

THANK YOU