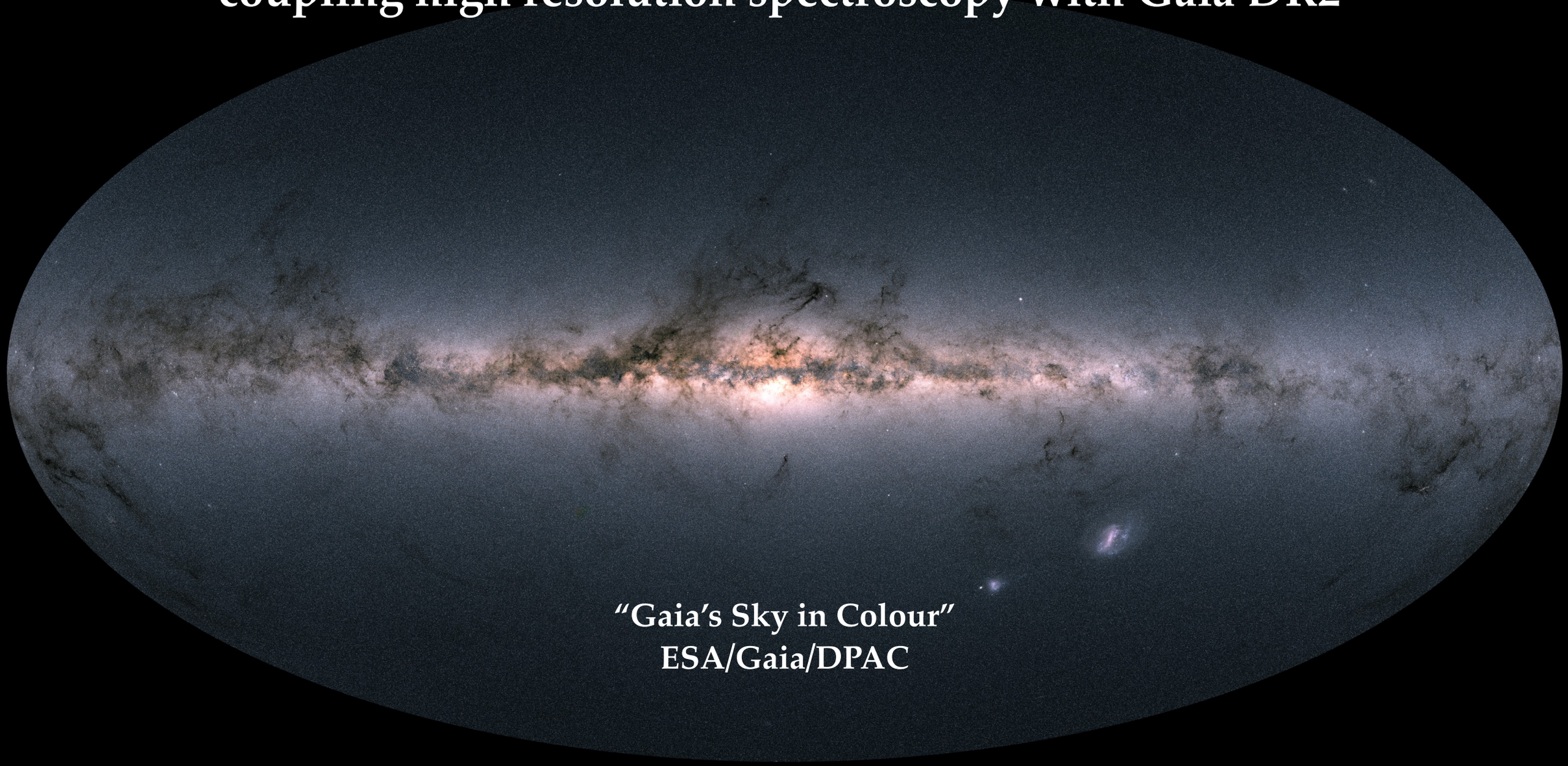
Probing the chemo-dynamic history of the Milky Way

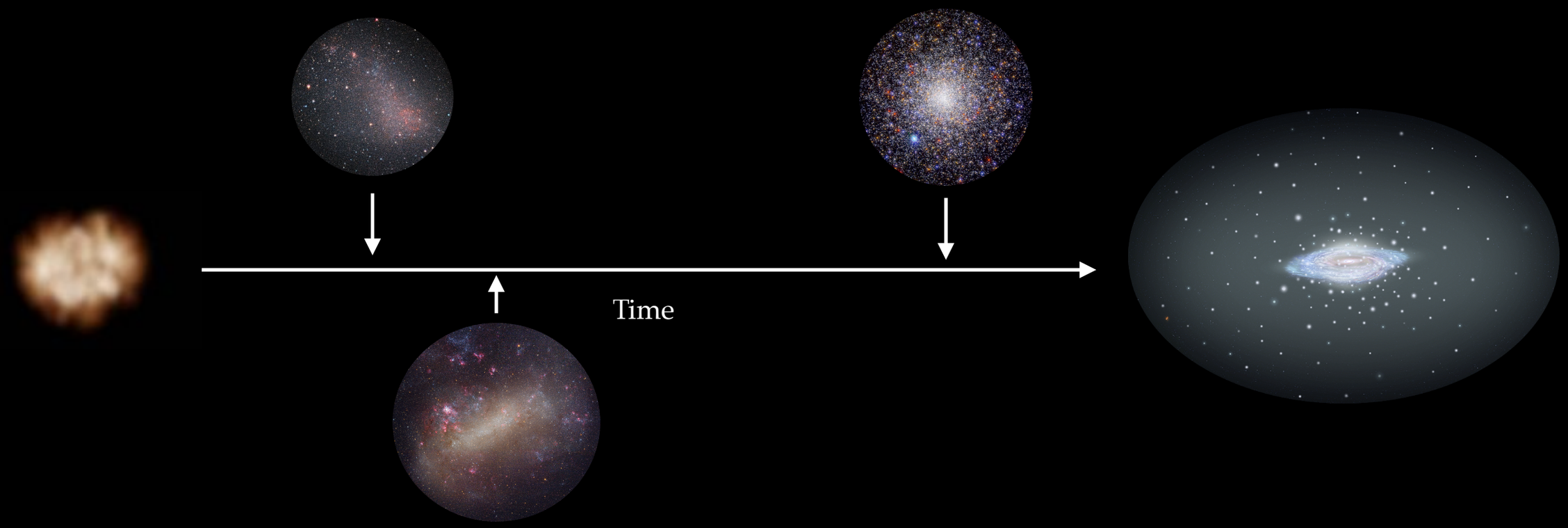
coupling high resolution spectroscopy with Gaia DR2



"Gaia's Sky in Colour"
ESA/Gaia/DPAC

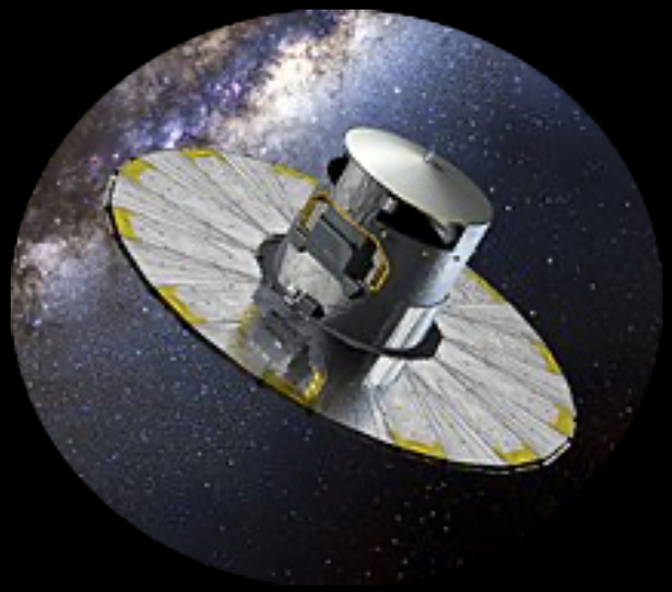
Stephanie Monty (Australian National University)
Kim Venn (University of Victoria, Canada)

Big picture: creating a timeline of the accretion history of the Milky Way



- Much of a galaxy's growth is through mergers (both major and minor)
- Gaia DR2 resulted in a flurry of discoveries of past merger events (~6 currently proposed accretion events + Sagittarius)
- This talk will focus on two proposed accretion events:
  - The "Sausage-Enceladus" event > $10^{10} M_{\odot}$ (Belokurov et al. 2018, Helmi et al. 2018, Koppelman et al. 2018, Haywood et al. 2018)
  - The "Sequoia" event ~ $10^{10} M_{\odot}$ (Myeong et al., 2019)

Chemodynamics: why couple Gaia and high resolution spectroscopy?



+

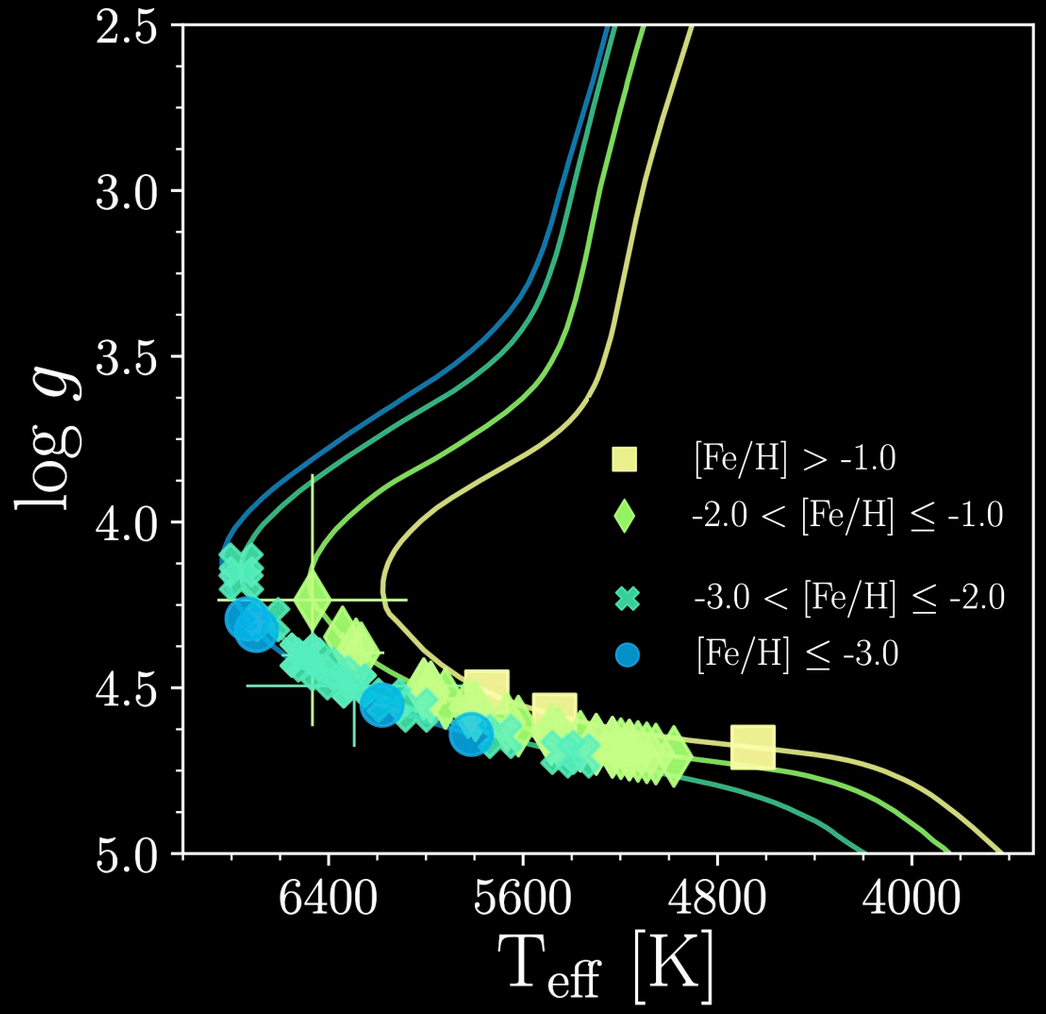
$(V_{rad}, \mu_\alpha, \mu_\delta) \longrightarrow (J_\phi, J_r, J_z)$

- *How* the star was brought in (eg. major vs. minor merger)
- *When* the star was accreted

$(T_{eff}, \log g, [Fe/H], EW) \longrightarrow [\alpha/Fe]$

- *What* the formation environment was like
- *Where* the star originated (eg. dwarf galaxy vs. globular cluster)

Spectroscopic dataset

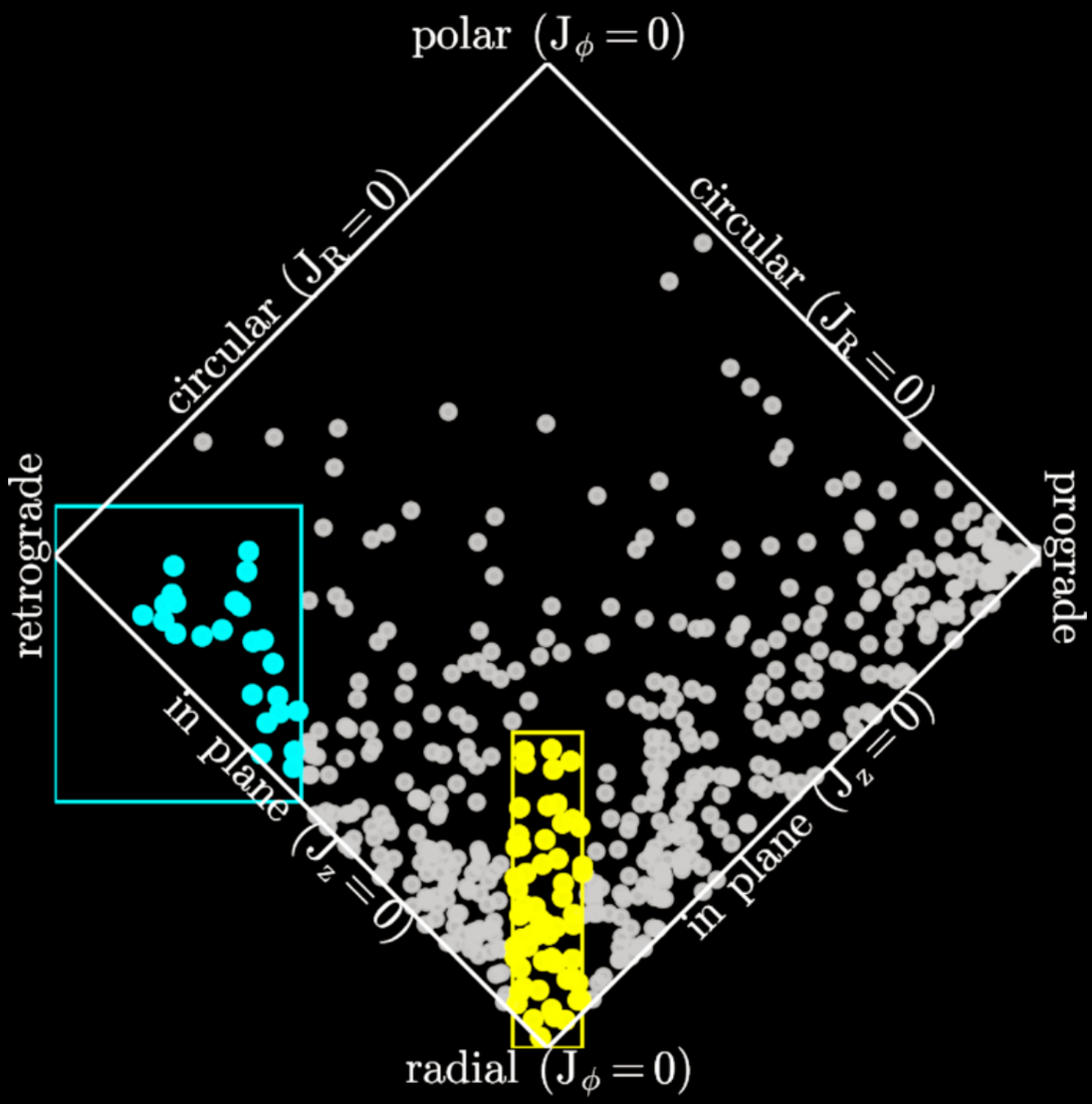


- Many wonderful spectroscopic datasets have been coupled to Gaia (see talks by A. Vallenari, A. Bragaglia yesterday)

- Gaia-ESO will be the highest resolution coupled dataset, prior to this only dedicated studies with R>45,000 completed to probe accreted star chemistry to *high precision* (e.g. Aguado et al. 2021)

- Re-examined accreted stars from the sample of halo *dwarf stars* from Stephens & Boesgaard, 2002 using Keck/HIRES and Gemini/GRACES

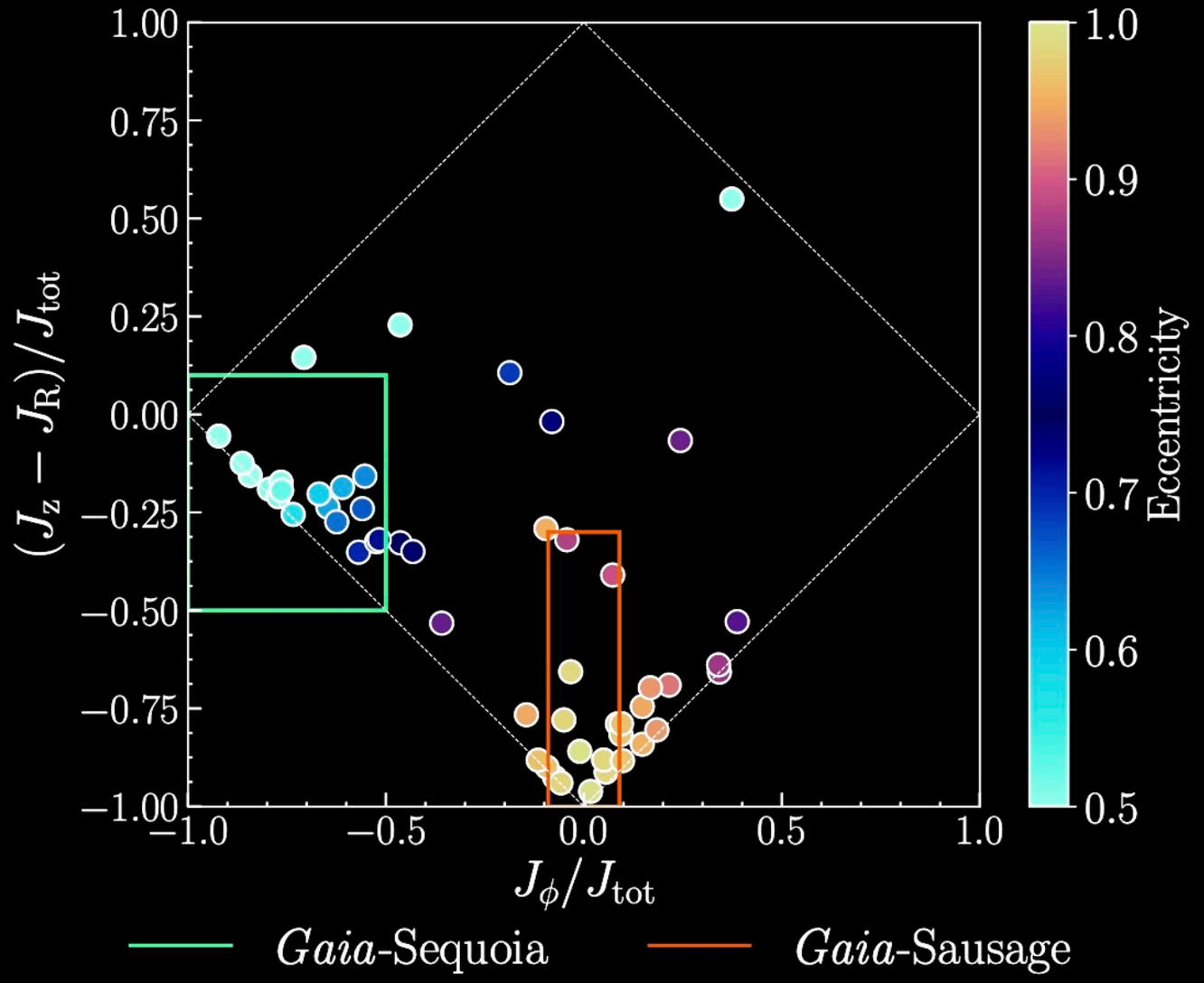
Dynamical dataset: Gaia in action space



- (J_ϕ, J_r, J_z) are orbital actions, adiabatic invariants that remain the same even if orbits don't
- Each action represents the "exploration" of a star in each cylindrical coordinate

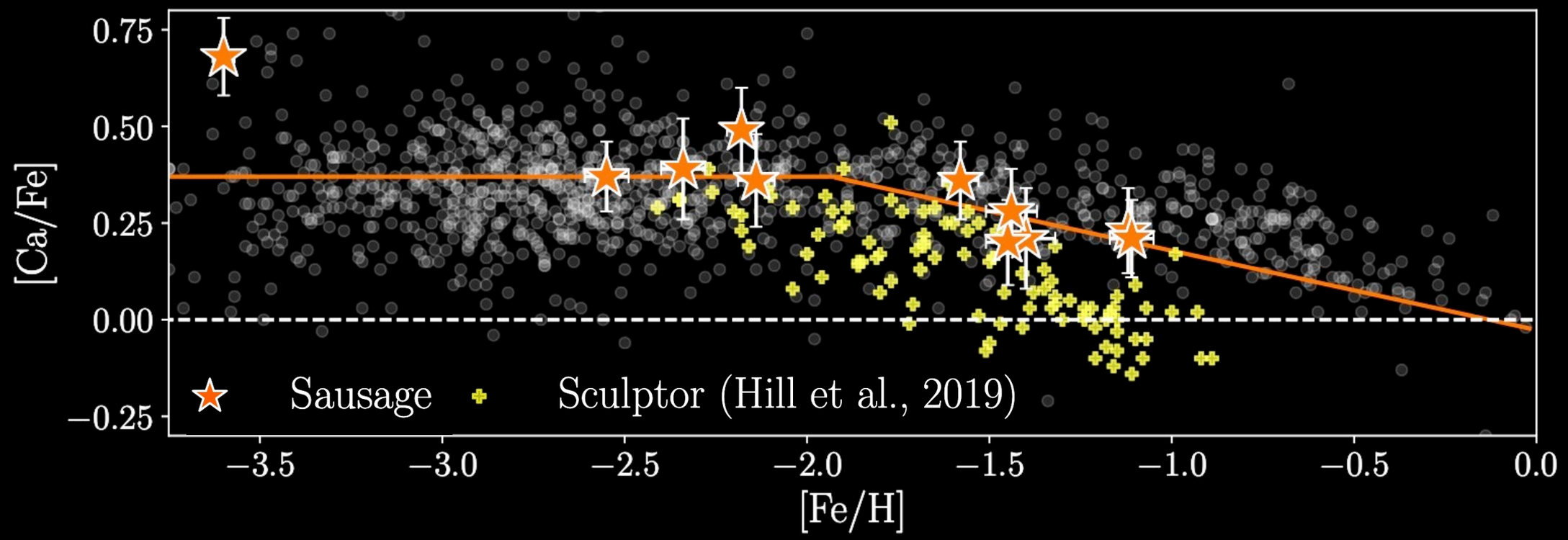
Myeong et al. 2019

Dynamical dataset: Gaia in action space



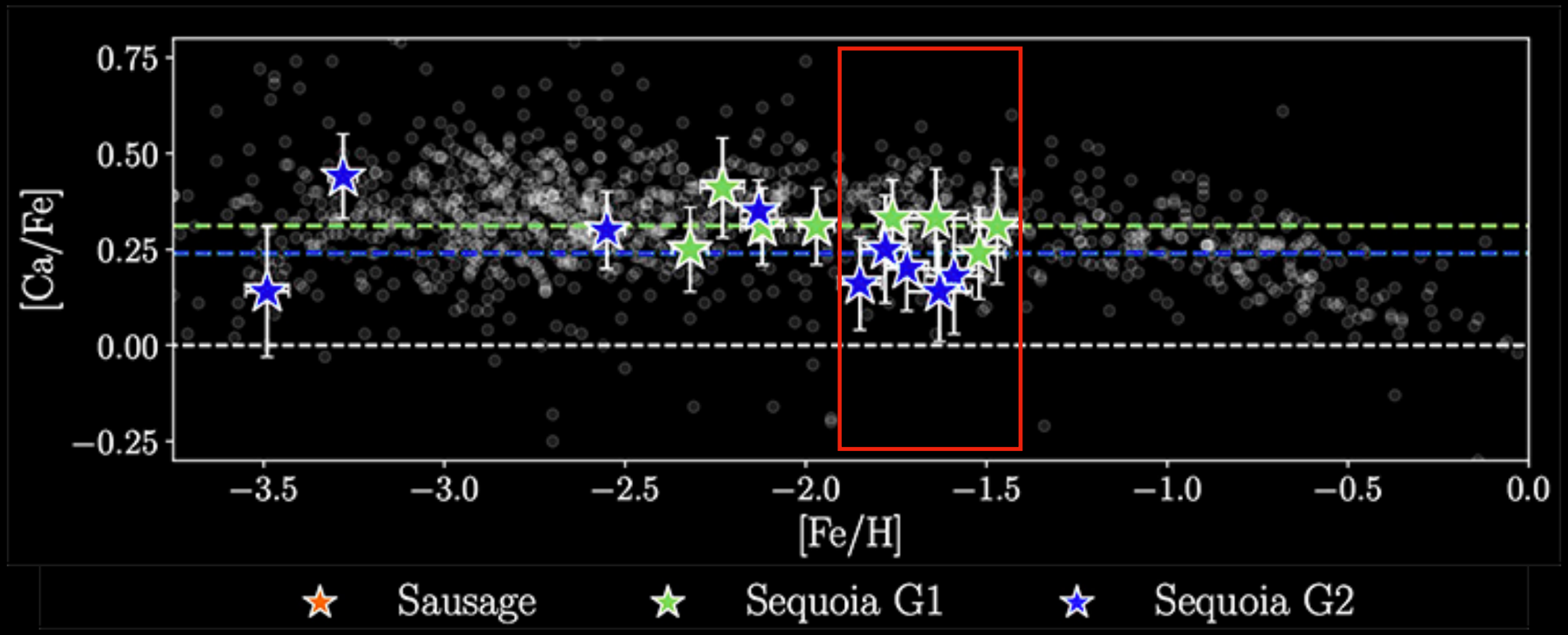
- Discovered 11 stars coincident with the Sausage event and 17 with Sequoia
- Note that Sausage and Enceladus do not occupy identical regions in action space
- The "Action Diamond" has been shown to be the most efficient dynamical method to seperate events (Lane & Bovy, 2021)

Chemical distinction agrees with dynamical distinction



- 11 Sausage stars show a distinct star formation history, different from the Milky Way
- Location of “alpha-knee” ~ [Fe/H] = -2, similar to a “textbook dwarf galaxy” like Sculptor (Hill et al. 2019)

Further distinctions: two groups within Sequoia



- Sequoia can further be split into two groups in energy space, low energy group may be “Thamnos” proposed by Koppelman et al. 2019
- Two groups show distinctly different alpha abundances at the same metallicity -> separation becomes more obvious with decreasing σ

Summary

- From a sample of 54 stars we recovered 11 Sausage members and 17 Sequoia members
- Sequoia stars could further be split into two groups with different energies, suggesting different origins
- Sausage stars displayed an alpha-knee around [Fe/H]~-2, supporting a unique star formation history compared to the Milky Way
- Coupling spectroscopy with dynamics is the most promising method to tag individual MW accretion events - common now (e.g. Naidu et al. 2020, Buder et al. 2021)

See Monty et al. 2020 for more details: arXiv:1909.11969