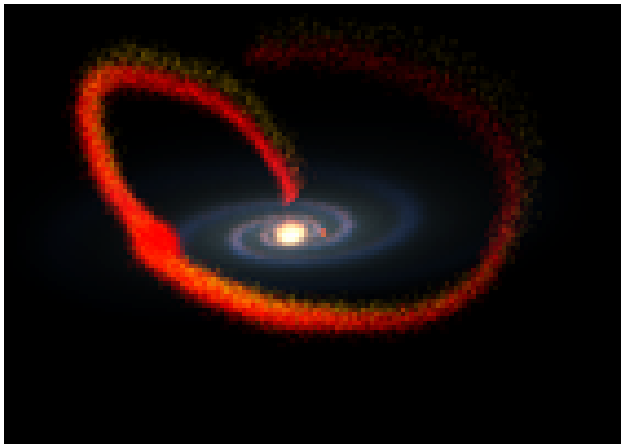
# Milky Way Halo in Action Space



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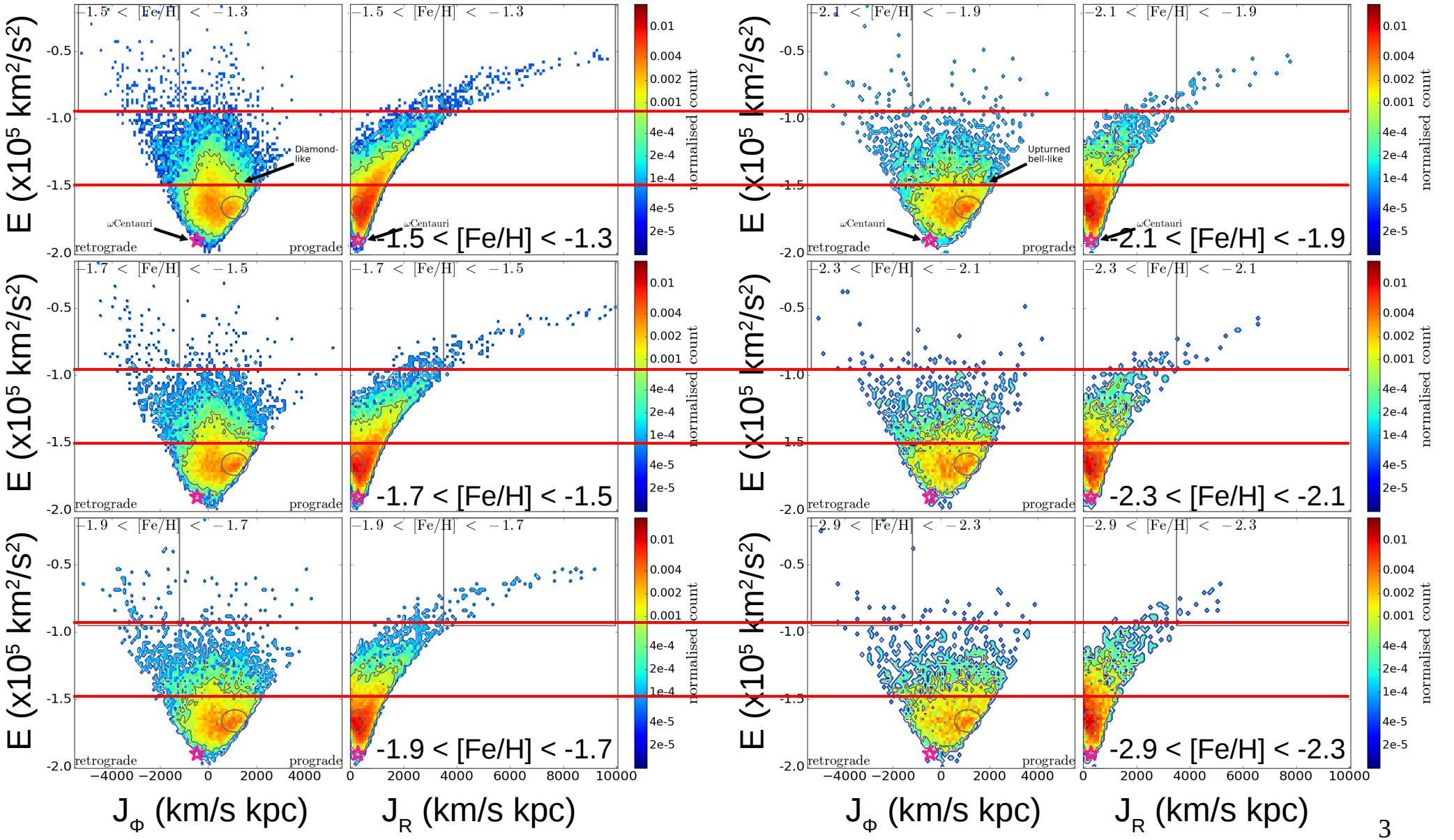
# Milky Way Halo in Action

- Halo structure as a “collection of orbits”
  - Overall structure as a sum of individual stellar orbit
  - Actions provide a useful map of the local halo
- Various components:
  - Chemo-dynamical dichotomy

    (see also, Deason et al. 2011; Belokurov et al. 2018; Haywood et al. 2018; Helmi et al. 2018)
  - High energy, retrograde, and metal-rich component
  - Resonant component

# Slicing with metallicity



# The Rich

- Metal-rich ( -1.7 < [Fe/H] < -1.3 )
  - more distended toward high $J_R$, narrower in $J_z$

    → flattened, radial anisotropy
  - radially anisotropic velocity dispersion

    → $(\sigma_R, \sigma_\Phi, \sigma_z) = (155, 77, 88)$ km/s

    → axis ratio, q ~ 0.6 – 0.7
  - originated from the radial infall of a massive satellite?

    (see also, Belokurov et al. 2018; Myeong et al. 2018; Haywood et al. 2018; Helmi et al. 2018)

# The Poor

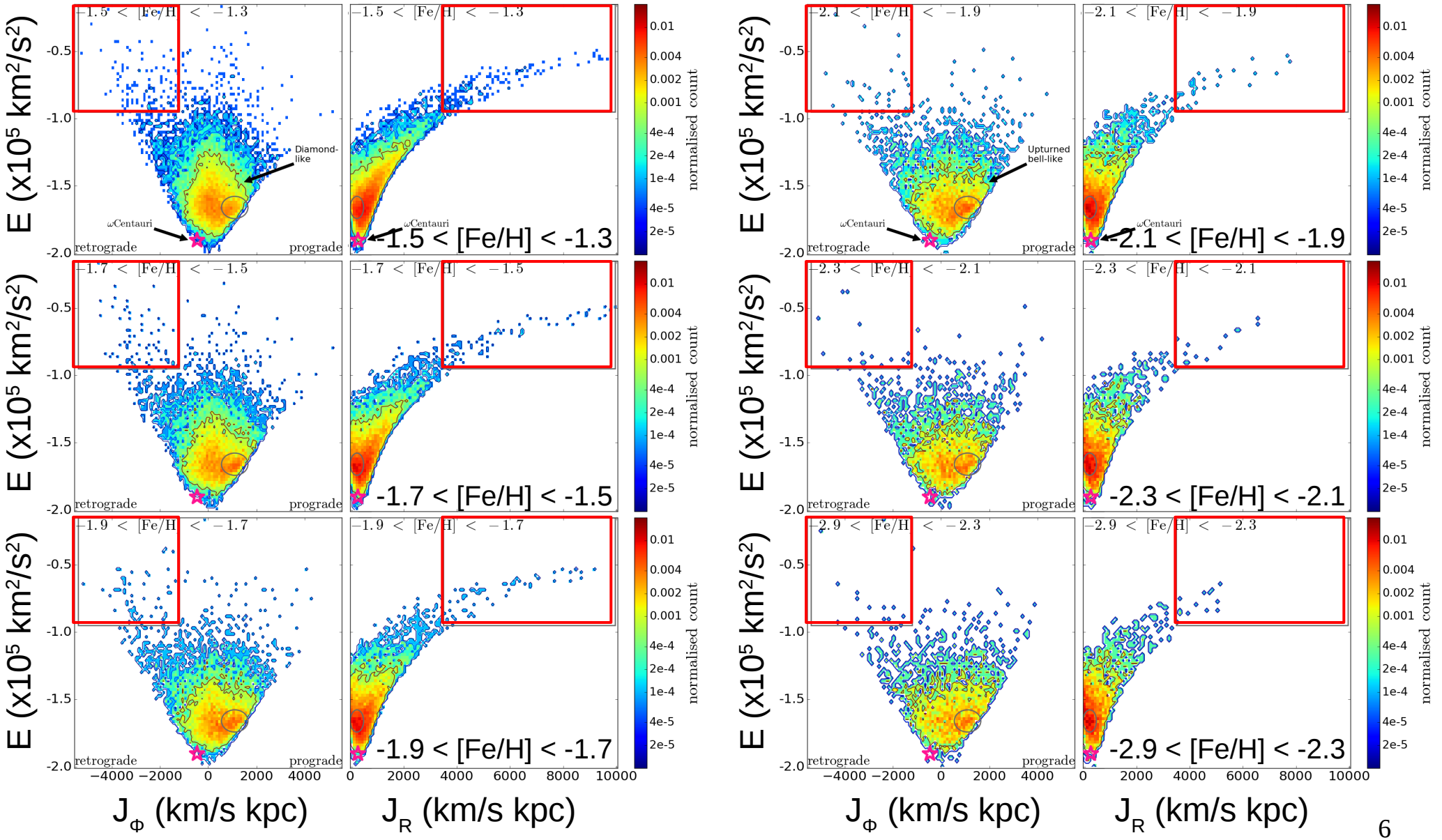
- Metal-poor ( -2.9 < [Fe/H] < -1.7 )
  - similar in all three actions → rounder isotropic morphology
  - excess at positive $J_\Phi$ → net prograde rotation ~ 49 km/s
  - close to isotropic velocity dispersion

    → $(\sigma_R, \sigma_\Phi, \sigma_z) = (125, 114, 110)$ km/s

    → axis ratio, q ~ 0.9
  - reminiscent of the (kinematic) distribution of halo globular clusters

    → disintegrated stellar material?
  - accretion of low-mass dwarf satellites?

# The Retrograde stars



# The Retrograde stars

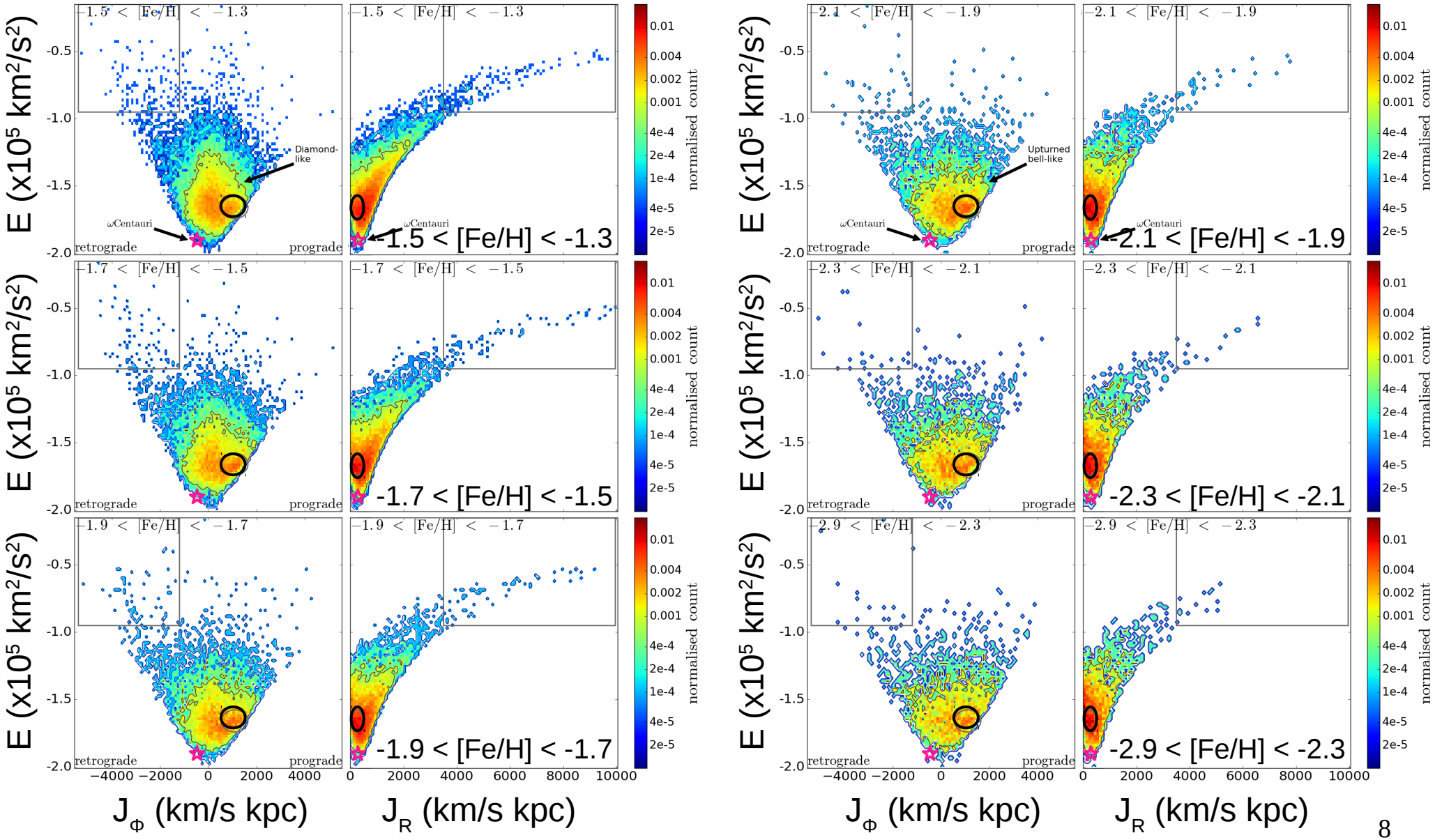
- Metal-rich (e.g., [Fe/H] > -1.9)
- High energy (e.g., $E > -1.1\times10^{5} km^{2} s^{-2}$ )
- Retrograde ($J_{\Phi} < 0$), large radial action, $J_R$

  → eccentric, retrograde population
- Clear tail-like feature along the energy range

  → tracing the orbital decay process of the progenitor
- Potential evidence of a retrograde merger/accretion event in the past

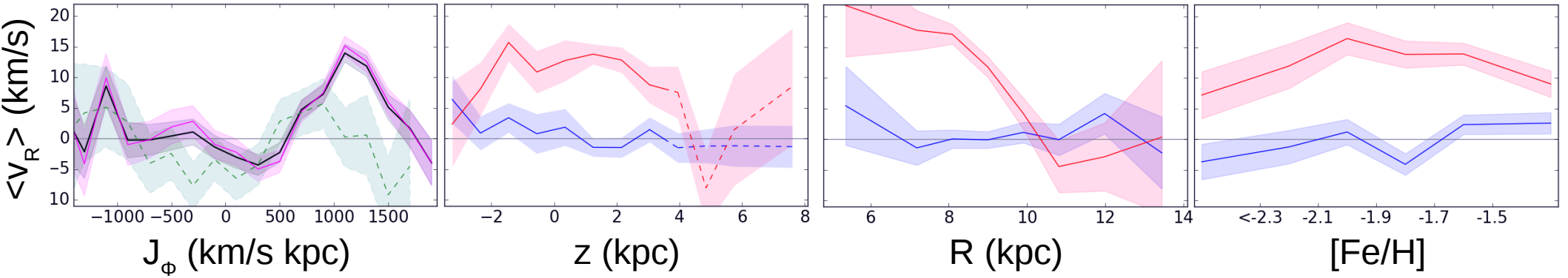
  → potential link with ω Centauri?

# The Resonant stars



# The Resonant stars

- Net outward motion, $\langle v_R \rangle$ ~ 12 km/s, prograde rotation, $\langle v_\phi \rangle$ ~ 140 km/s
- Dynamical origin
  - An overdensity present at all metallicity
    - around ($J_\Phi$, $J_R$) ~ (1100, 150) km/s kpc, and $E \sim -1.6 \times 10^5 \, km^2 \, s^{-2}$
  - low-latitude stars between |z| ≤ 3.5 kpc
  - inner to near Solar radius → Outer Lindblad Resonance of the bar?
- Association with the Hercules stream?
  - has not been seen from low metallicity population (i.e. halo) before



# References

In order of date reported:


- Deason et al. 2011, MNRAS, 416, 2903
- Deason et al. 2013, ApJ, 763, 113
- Myeong et al. 2018a, ApJL, 856, 26
- Belokurov et al. 2018, MNRAS, 478, 611
- Myeong et al. 2018b, MNRAS, 478, 5449
- Haywood et al. 2018, arXiv:1805.02617
- Helmi et al. 2018, arXiv:1806.06038


Also check:

- https://phys.org/news/2018-07-gaia-sausage-major-collision-milky.html
  and the references therein