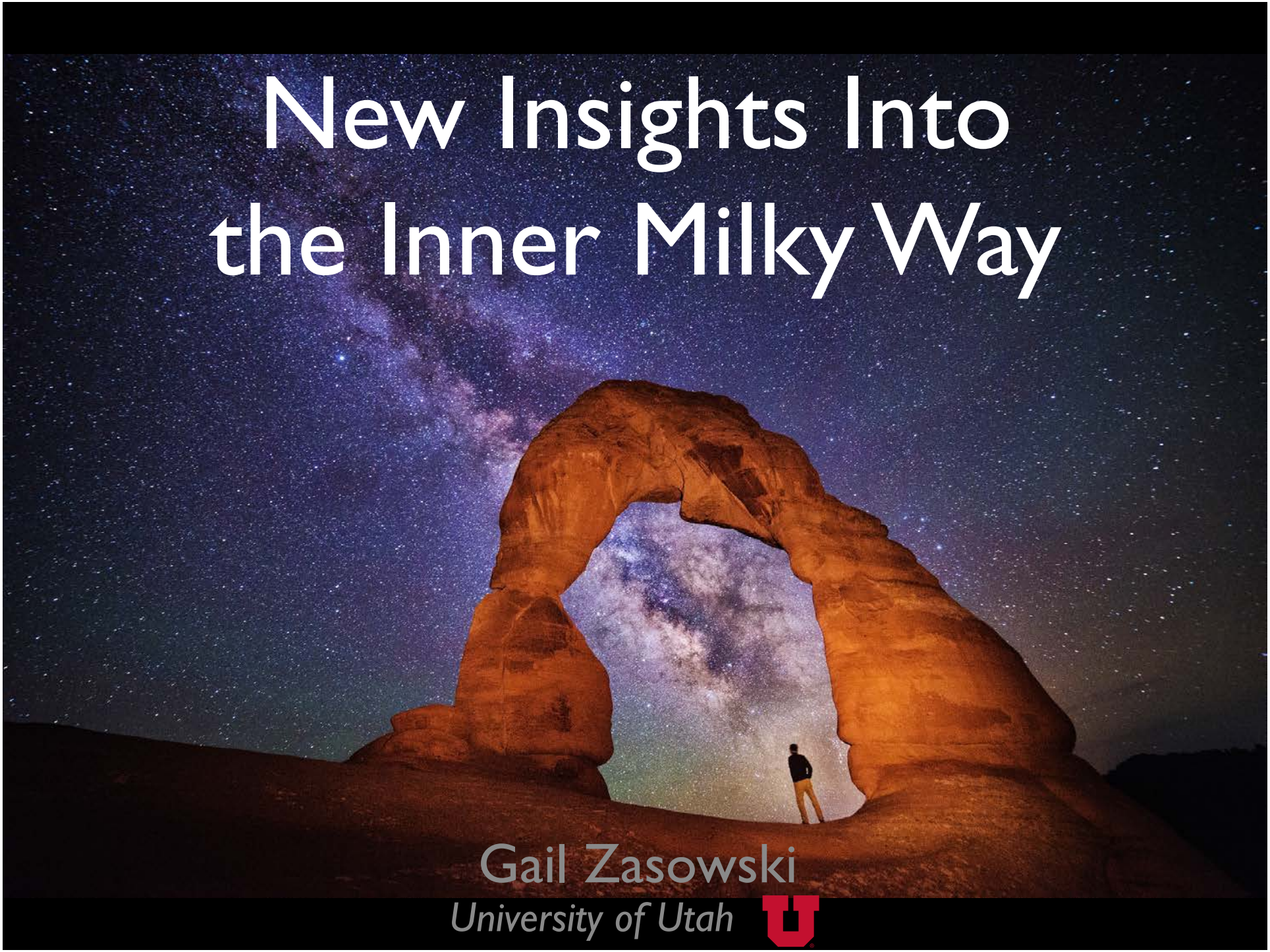
New Insights Into the Inner Milky Way

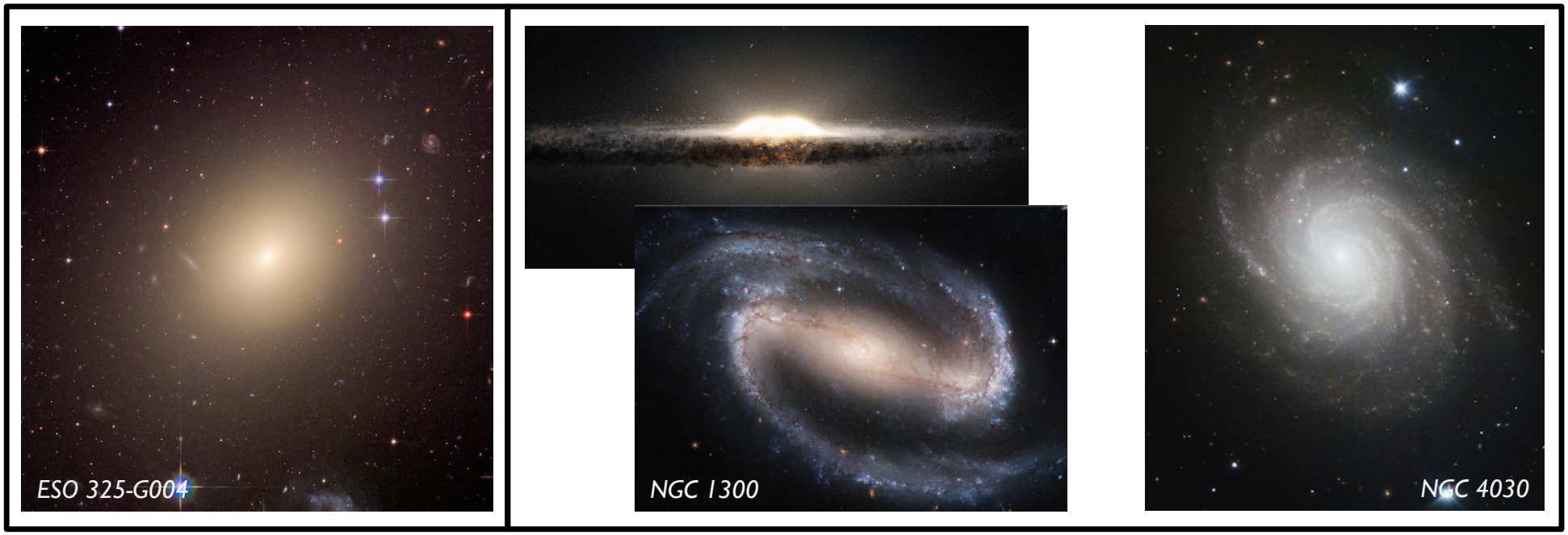


Gail Zasowski
University of Utah

Emu (various Australian peoples)

Galactic Protuberances

"Considerable confusion has been brought by...a mixture of the seemingly appropriate buzzwords..."
Athanassoula (2005)



"Classical"

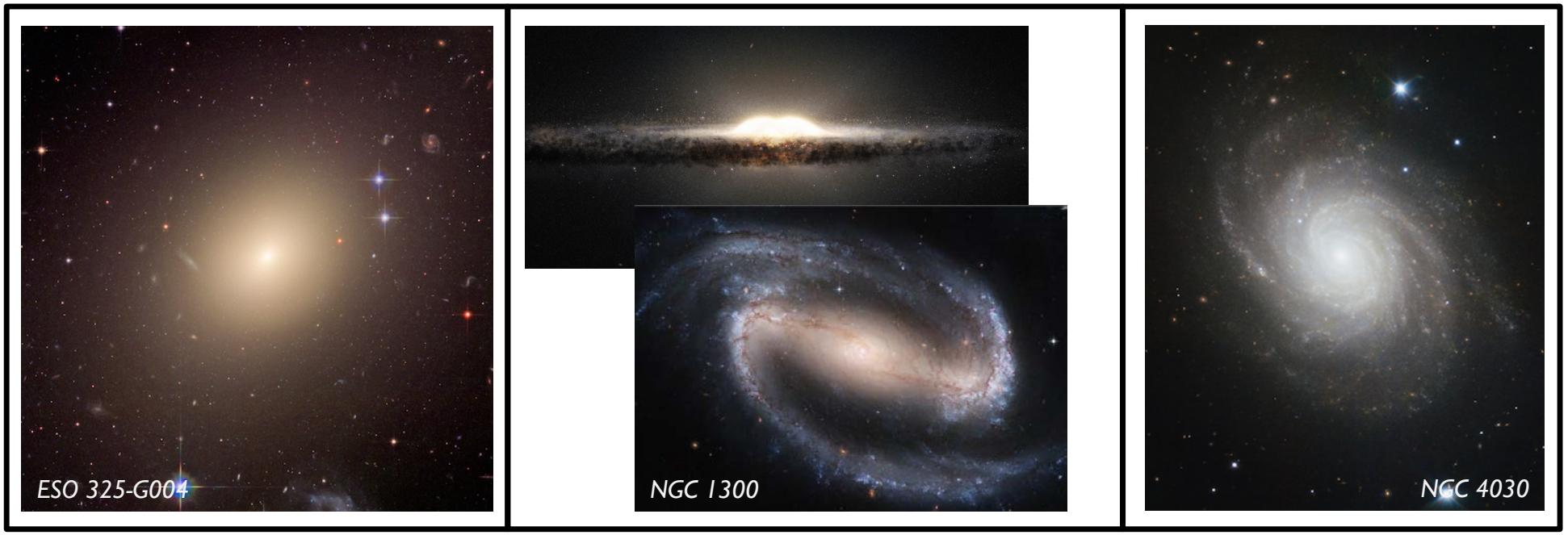
- *smooth isophotes*
- *low/zero SRF, dust*
- *dominated by random motions*
- *~elliptical galaxies, kinematically*
- *formed by hierarchical mergers or violent relaxation of disk*

"Pseudobulge"

- *asymmetric morphologies: bars, rings, spirals, &c.*
- *active/recent SF*
- *coherent rotation*
- *formed by secular, dissipative processes*

Galactic Protuberances

"Considerable confusion has been brought by...a mixture of the seemingly appropriate buzzwords..."
Athanassoula (2005)



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- *smooth isophotes*
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- *formed by hierarchical mergers or violent relaxation of disk*

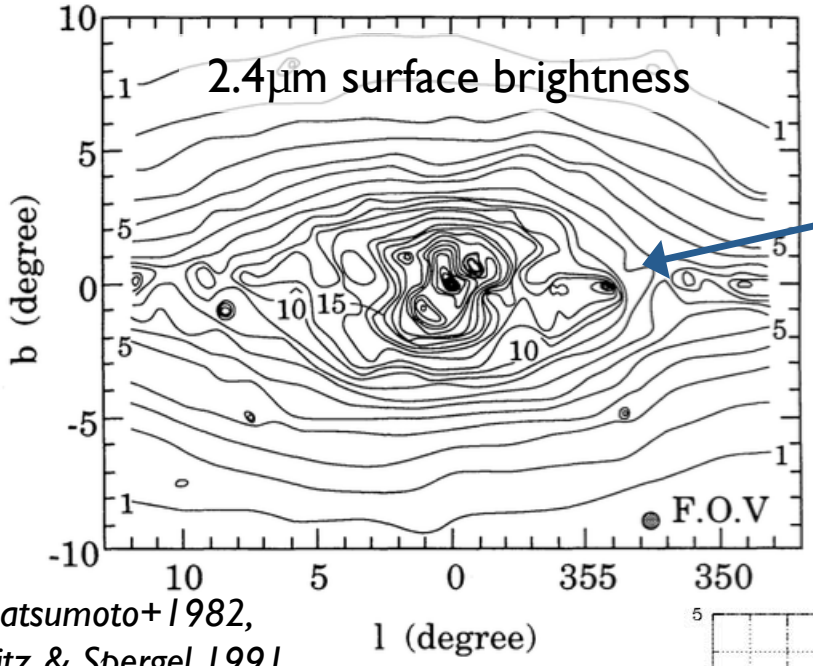
"Bar/Boxy/Peanut"

- *clear elongated/boxy/peanut isophotes*
- *some SF, but pattern is younger than stars*
- *can have rings, spiral arms at the ends*
- *formed by disk buckling*

"Disky/Pseudobulge"

- *rounder, disk-like isophotes*
- *recent/active SF*
- *can co-exist with bar and spirals*
- *formed by gas migrating inwards(?)*

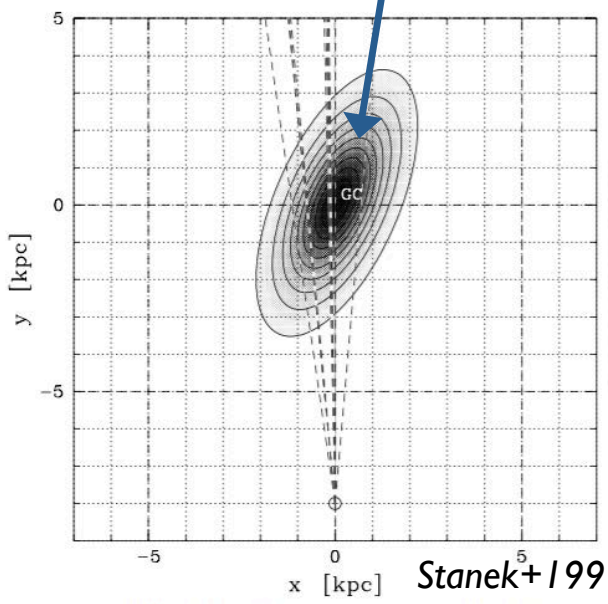
1990s: Milky Way has a bar!



Matsumoto+1982, Blitz & Spergel 1991

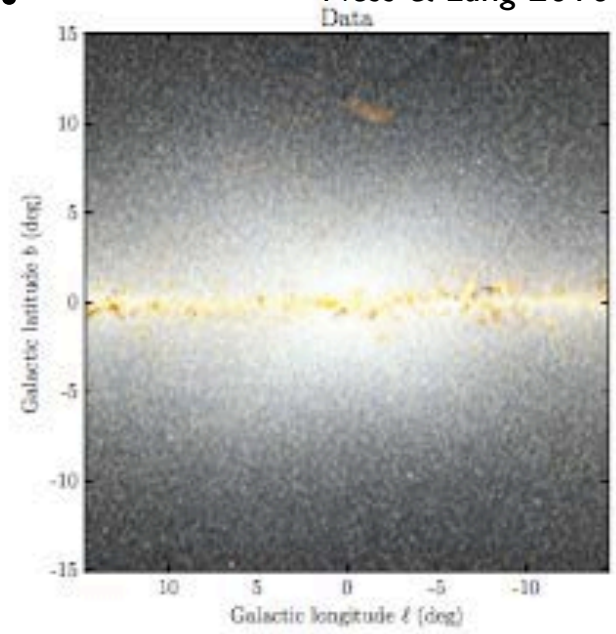
Asymmetric IR surface brightness

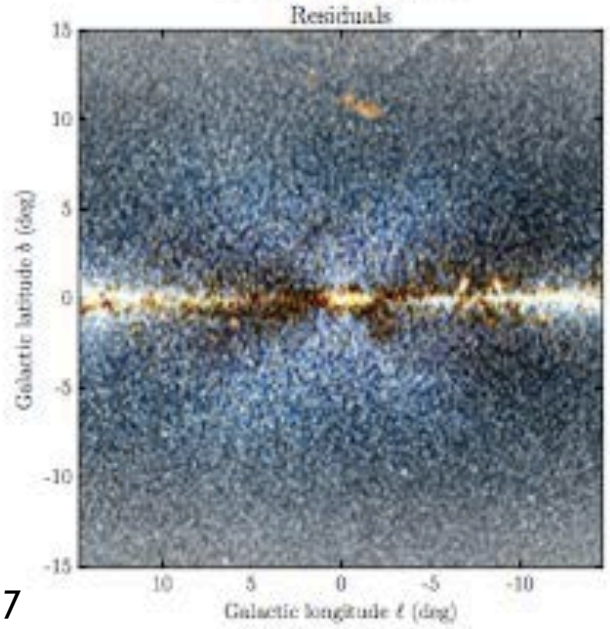
RC giant distribution



Stanek+1997

Ness & Lang 2016

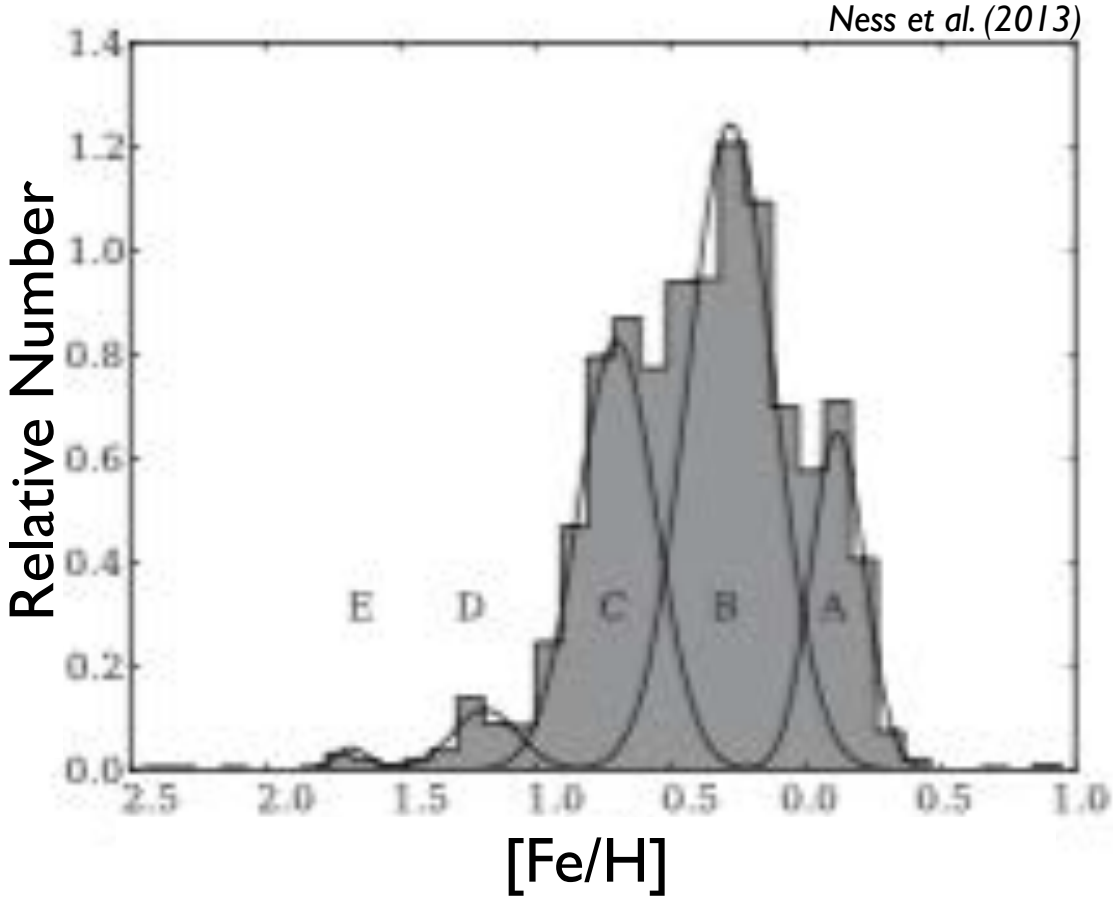




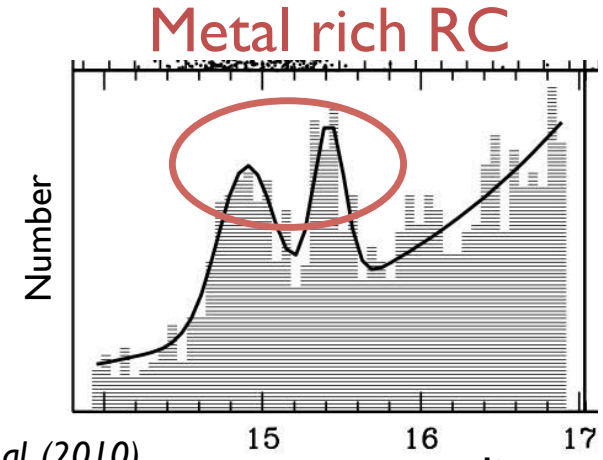
- Noncircular HI motions
- IR integrated starlight
- Asymmetric Mira variables
- Microlensing rate
- Asymmetric gamma ray emission
- Asymmetric RC stars

Highly Complex

- On *average*, bulge is old & metal-rich
- But it's significantly richer than just that!



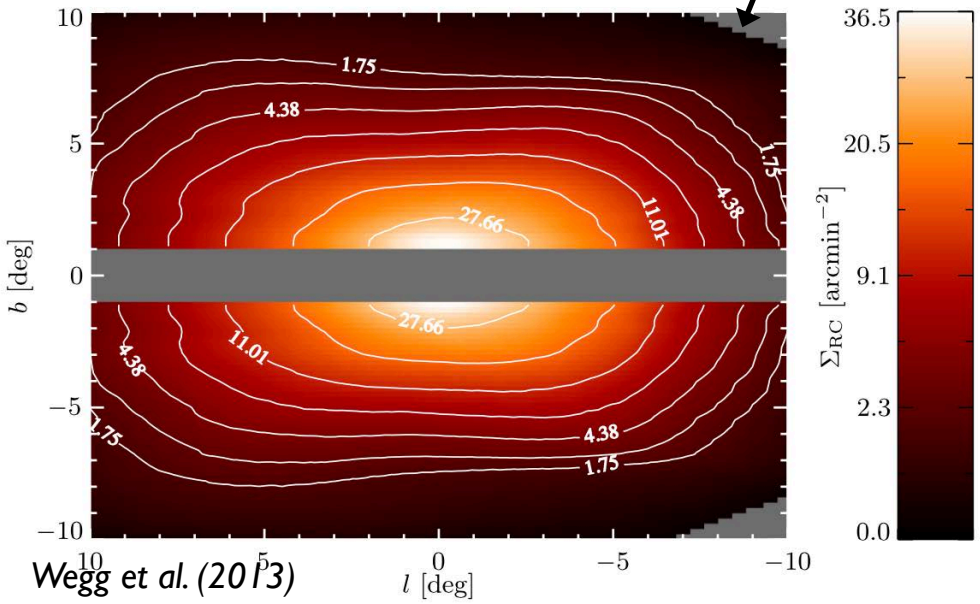
Shape



Nataf et al. (2010),
McWilliam et al. (2010)

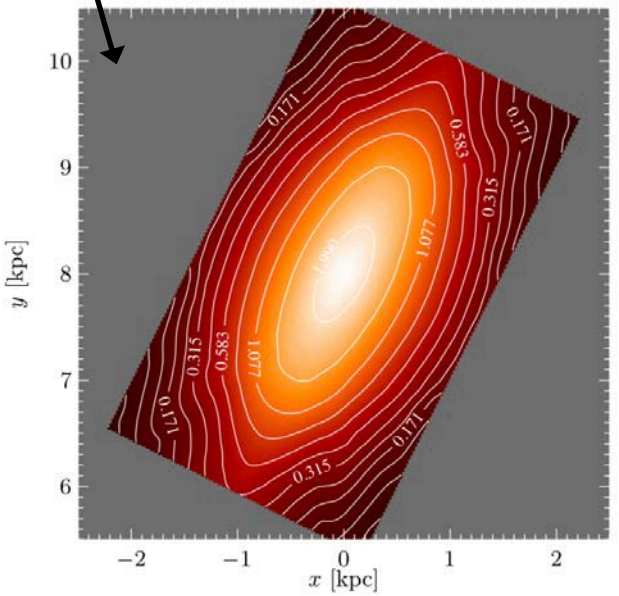
(Metal-rich) red clump giants

Seen from the Sun



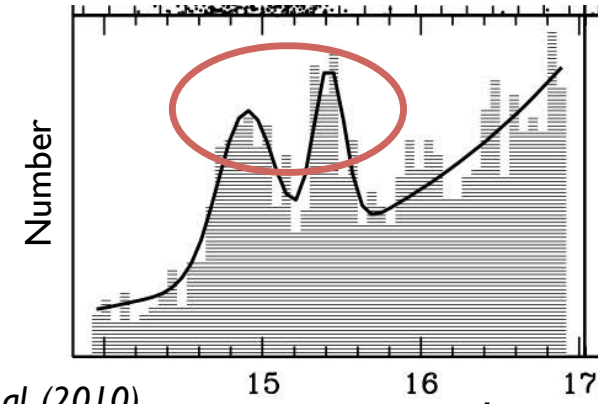
Wegg et al. (2013)

Seen from above the disk



Shape

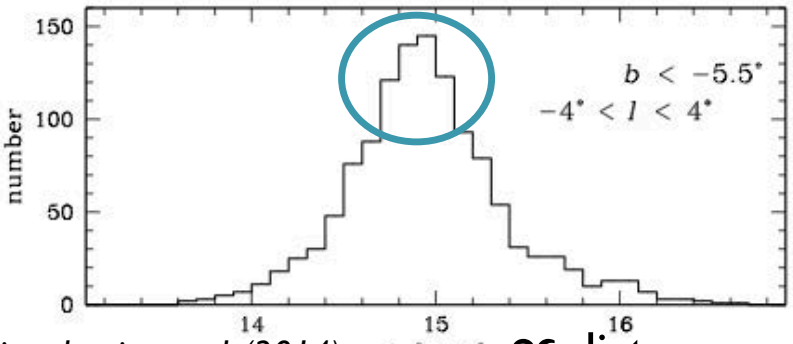
Metal rich RC



Nataf et al. (2010), McWilliam et al. (2010)

I_0 [mag] ∝ distance

Metal poor RRL



Pietrukowicz et al. (2014) I_0 [mag] ∝ distance

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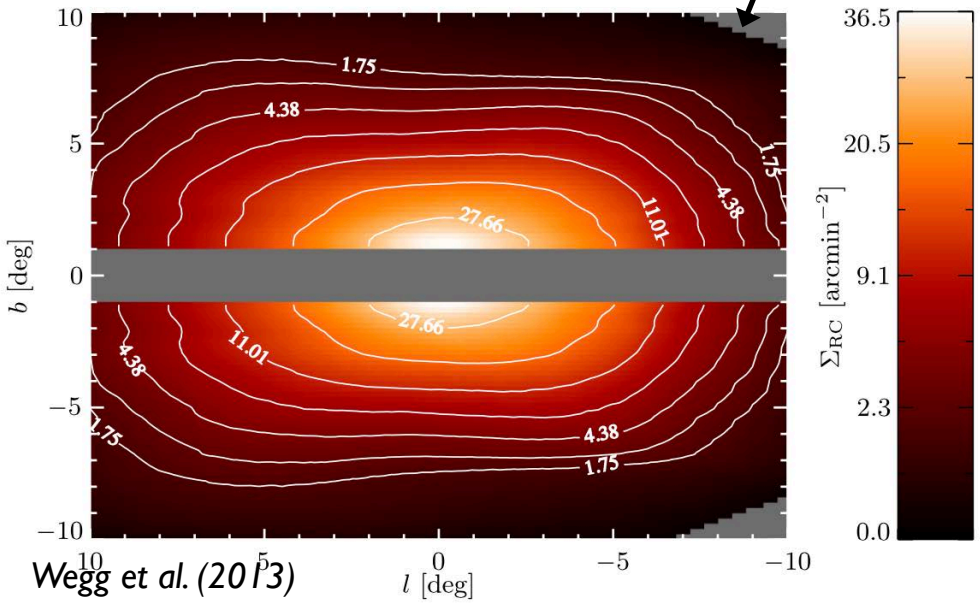
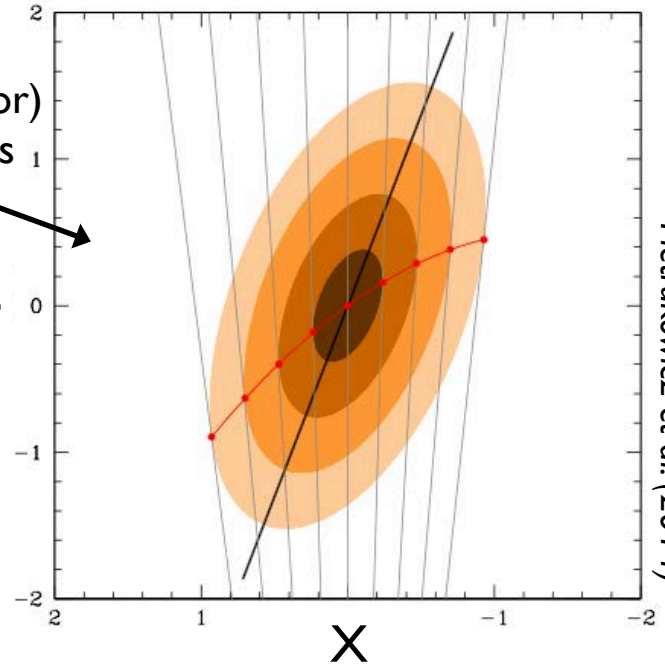
(Metal-rich) red clump giants



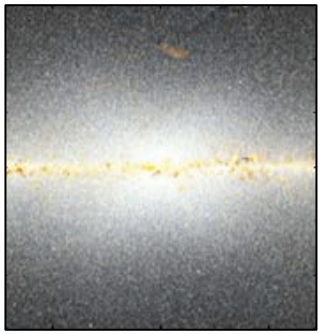
Wegg et al. (2013)

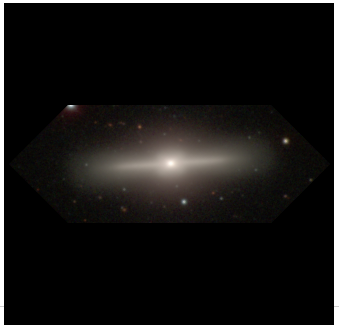
(Metal-poor) RRL stars

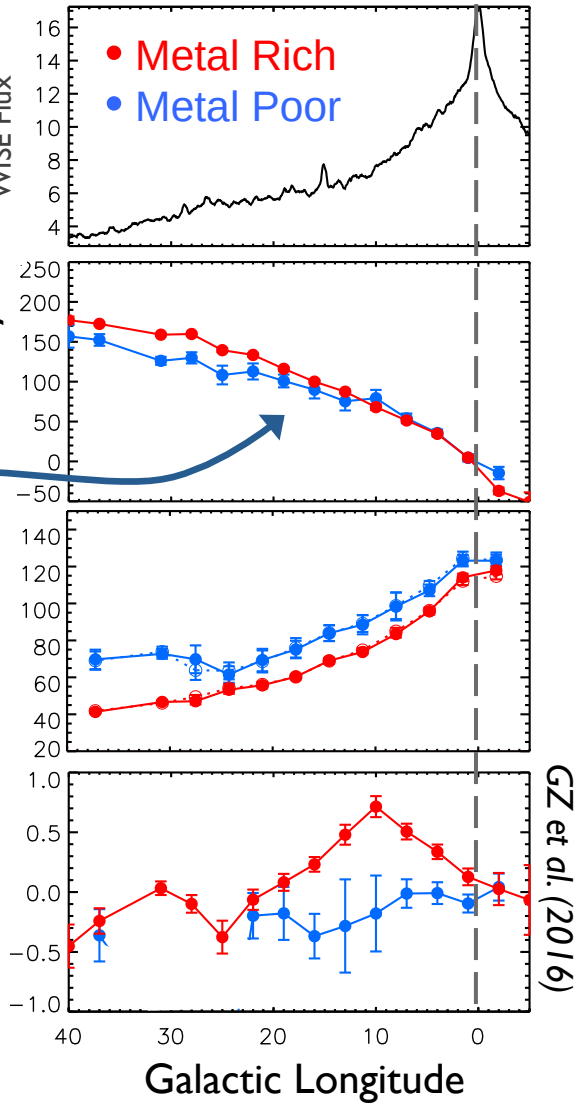


Pietrukowicz et al. (2014)

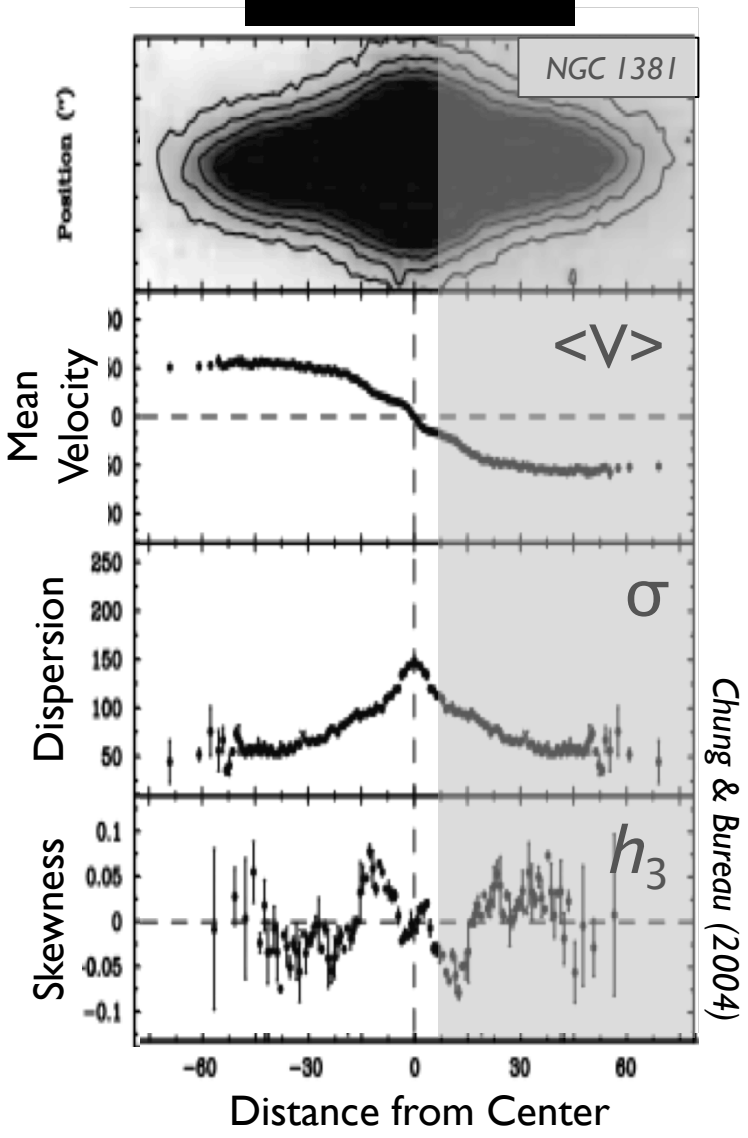
Dynamics



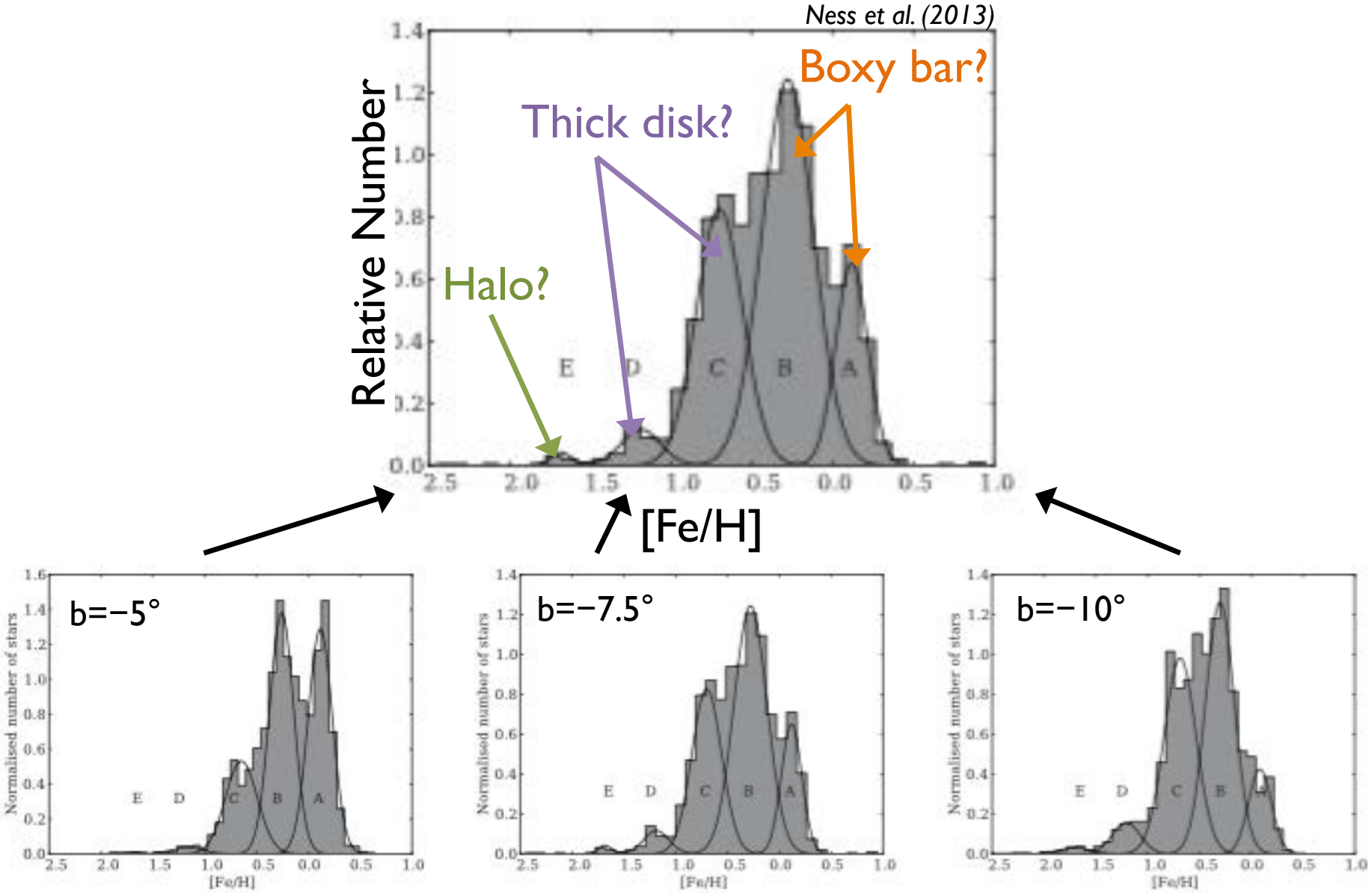




Only galaxy in which we can make this separation

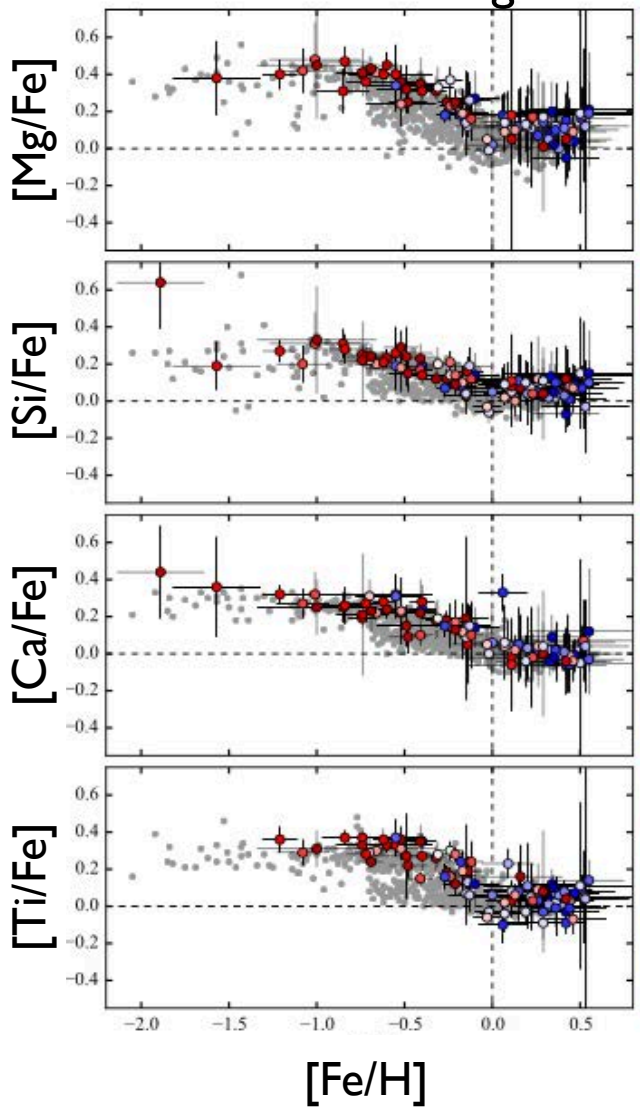


Metallicity & α-enhancement



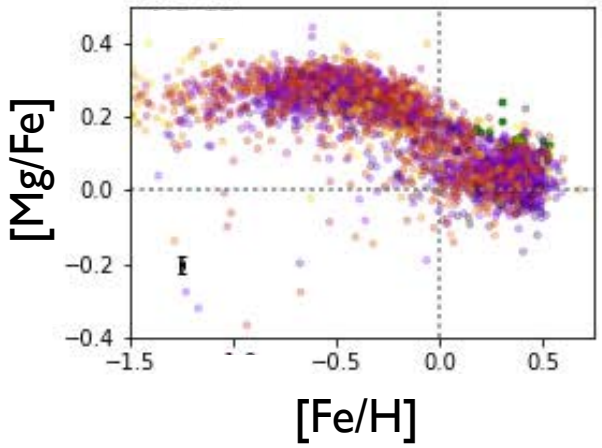
Metallicity & α-enhancement

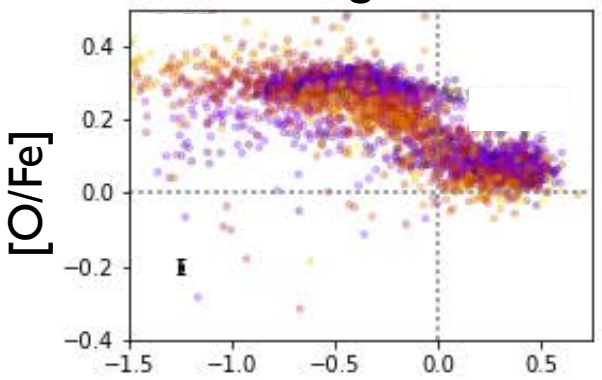
F/G dwarfs & subgiants

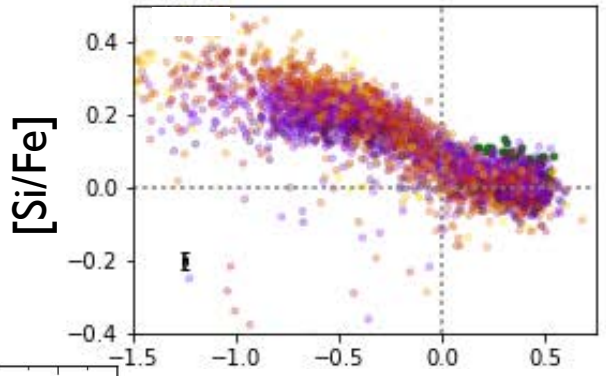


Bensby et al. (2017)

Red giants

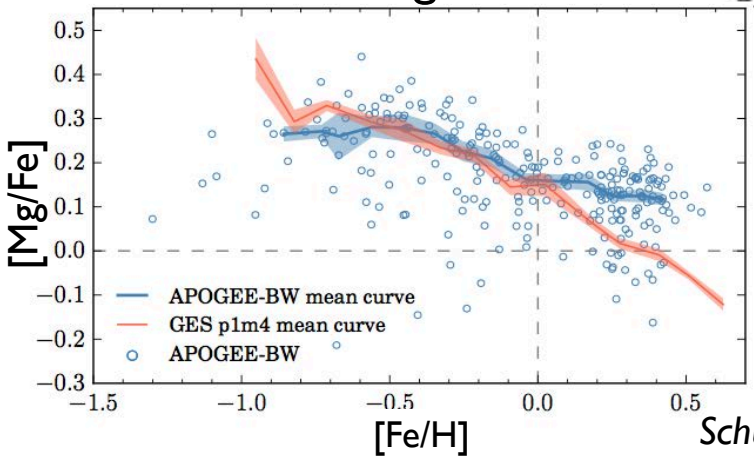




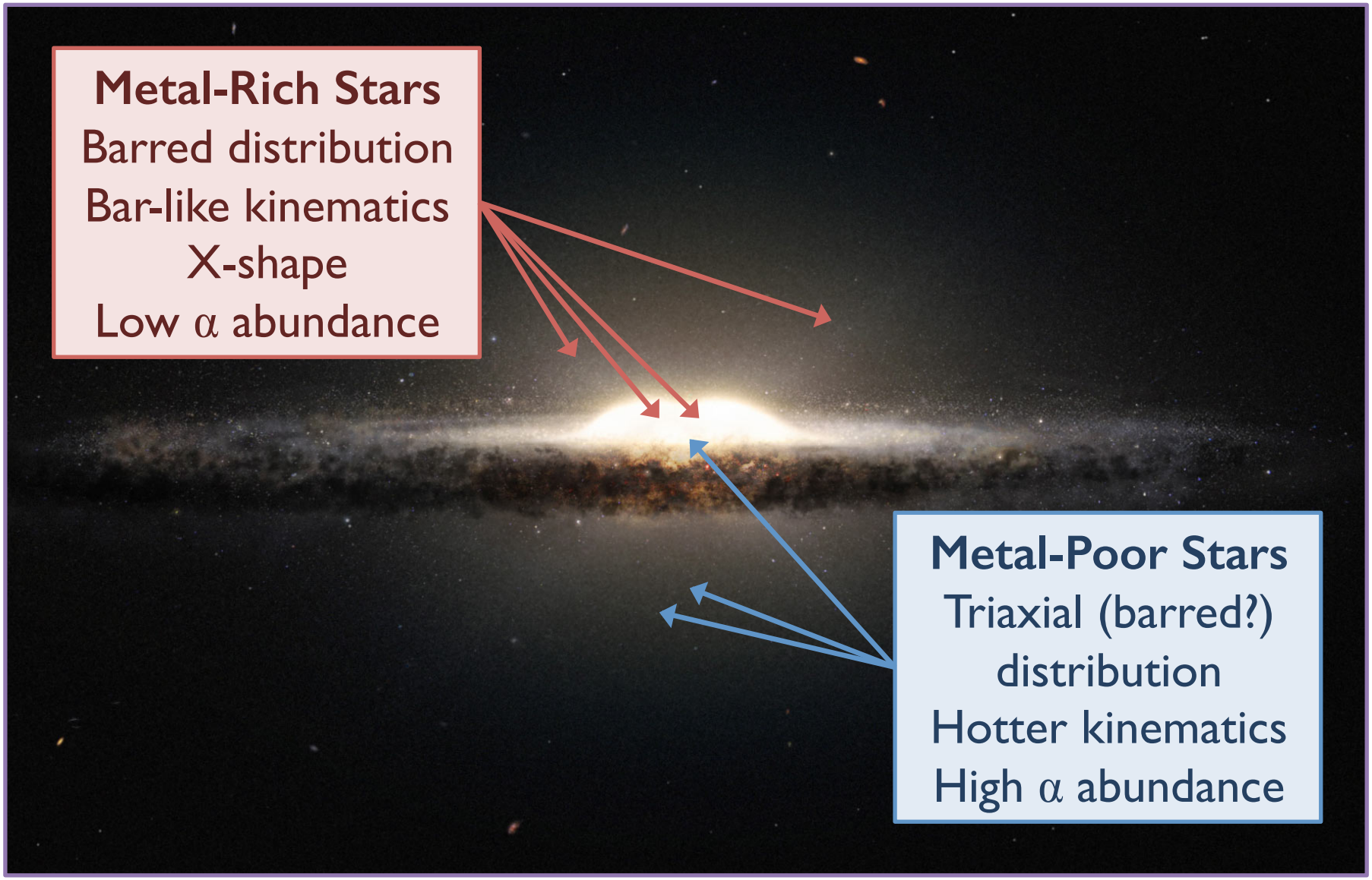


GZ et al. in prep

Red giants



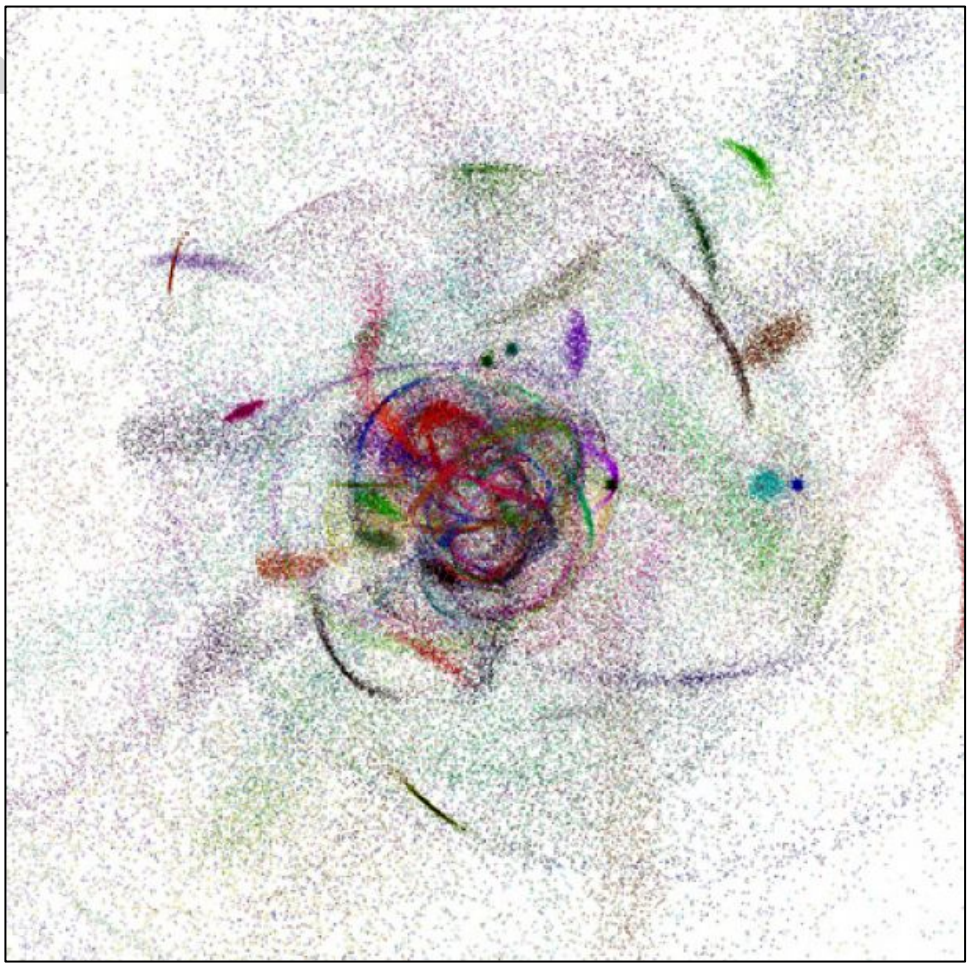
Schultheis et al. (2017)


Metal-Rich Stars
Barred distribution
Bar-like kinematics
X-shape
Low α abundance
Metal-Poor Stars
Triaxial (barred?) distribution
Hotter kinematics
High α abundance

How did the bulge form?

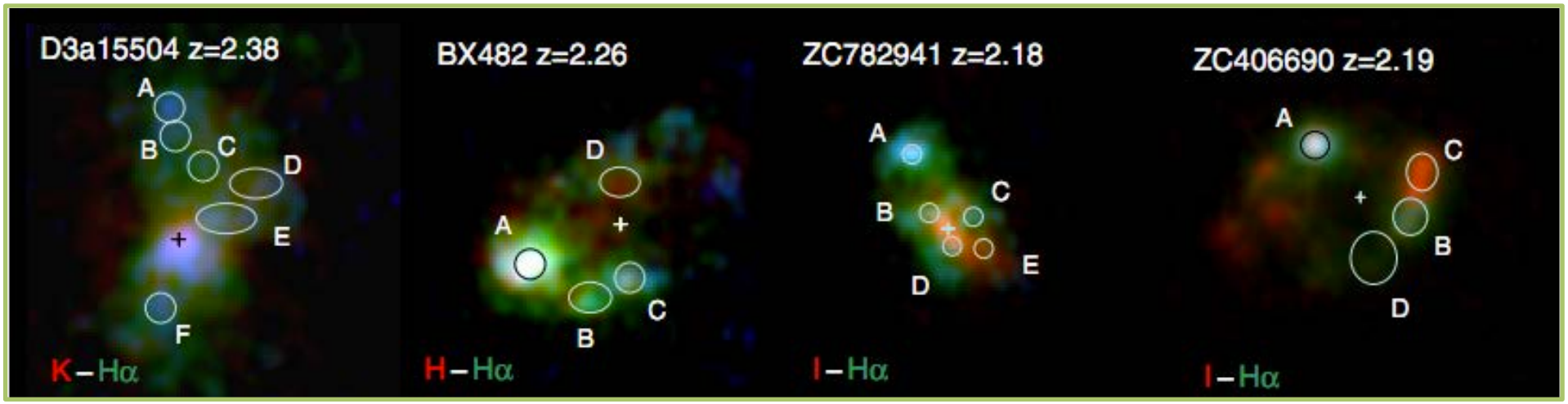
- Hierarchical mergers ("classical" bulge)
- Clump migration
- Secular disk evolution

Simulated galaxy/halo and merger remnants



How did the bulge form?

- Hierarchical mergers ("classical" bulge)
- Clump migration
- Secular disk evolution ("bar")



z~2 galaxies with multiple large, off-center, star-forming clumps

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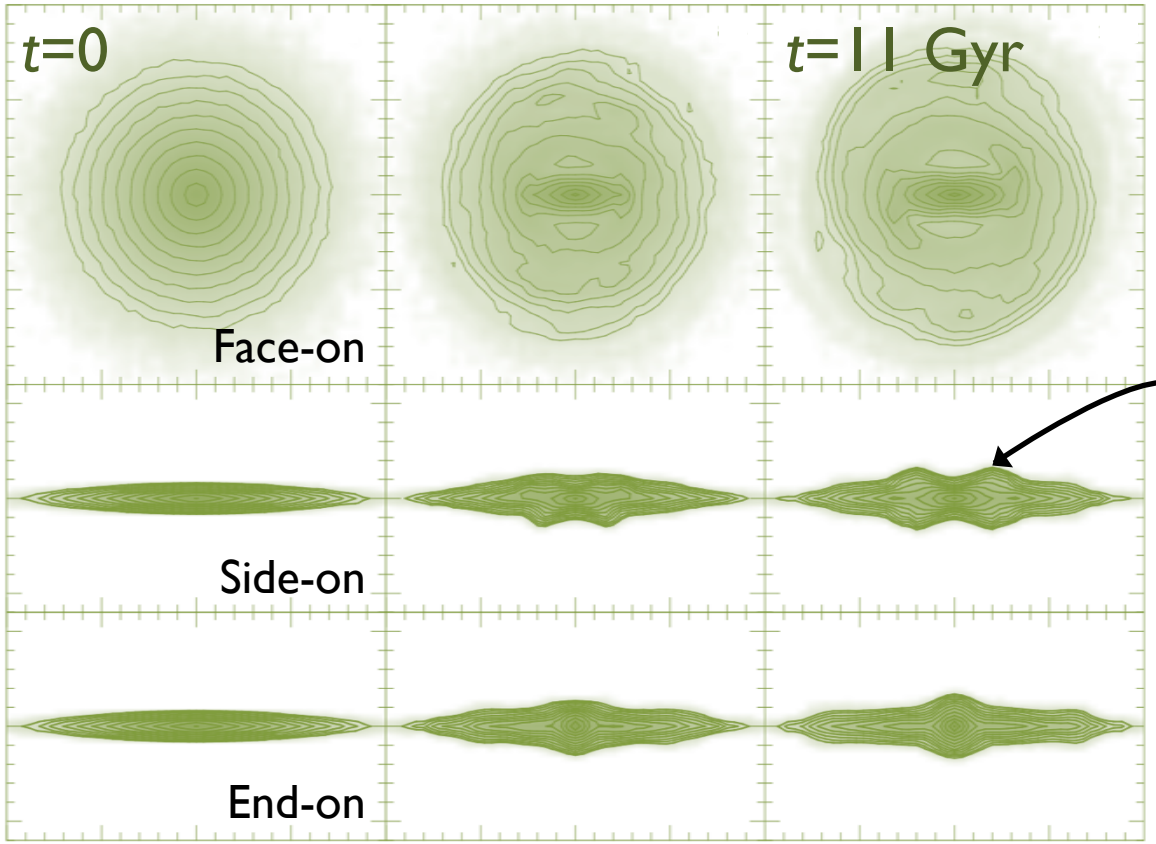
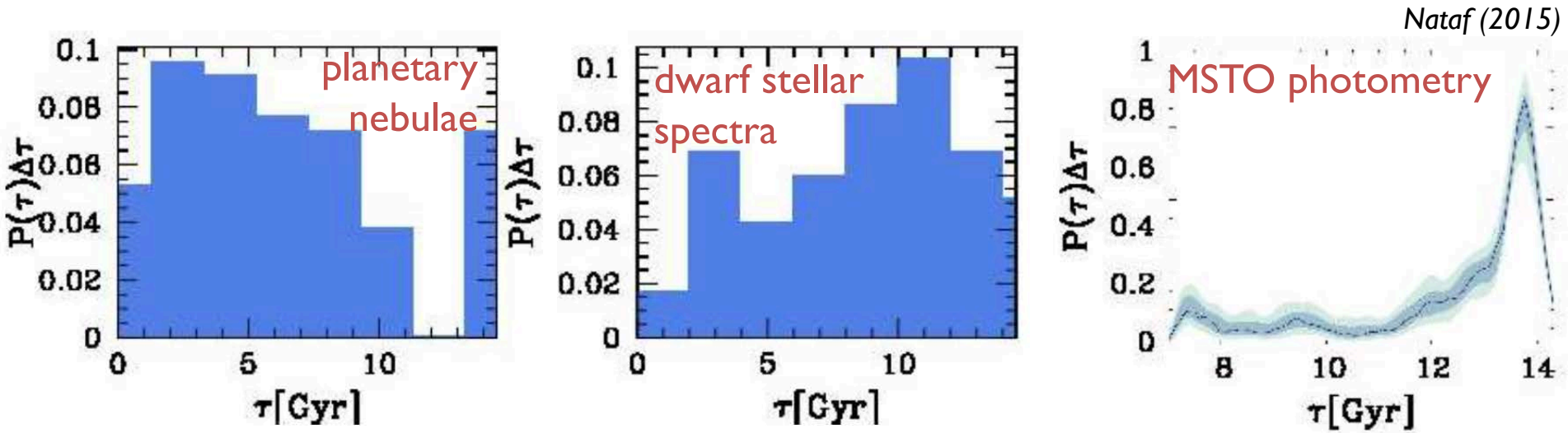


Simulated evolution of an isolated disk

Athanassoula et al. (2013)

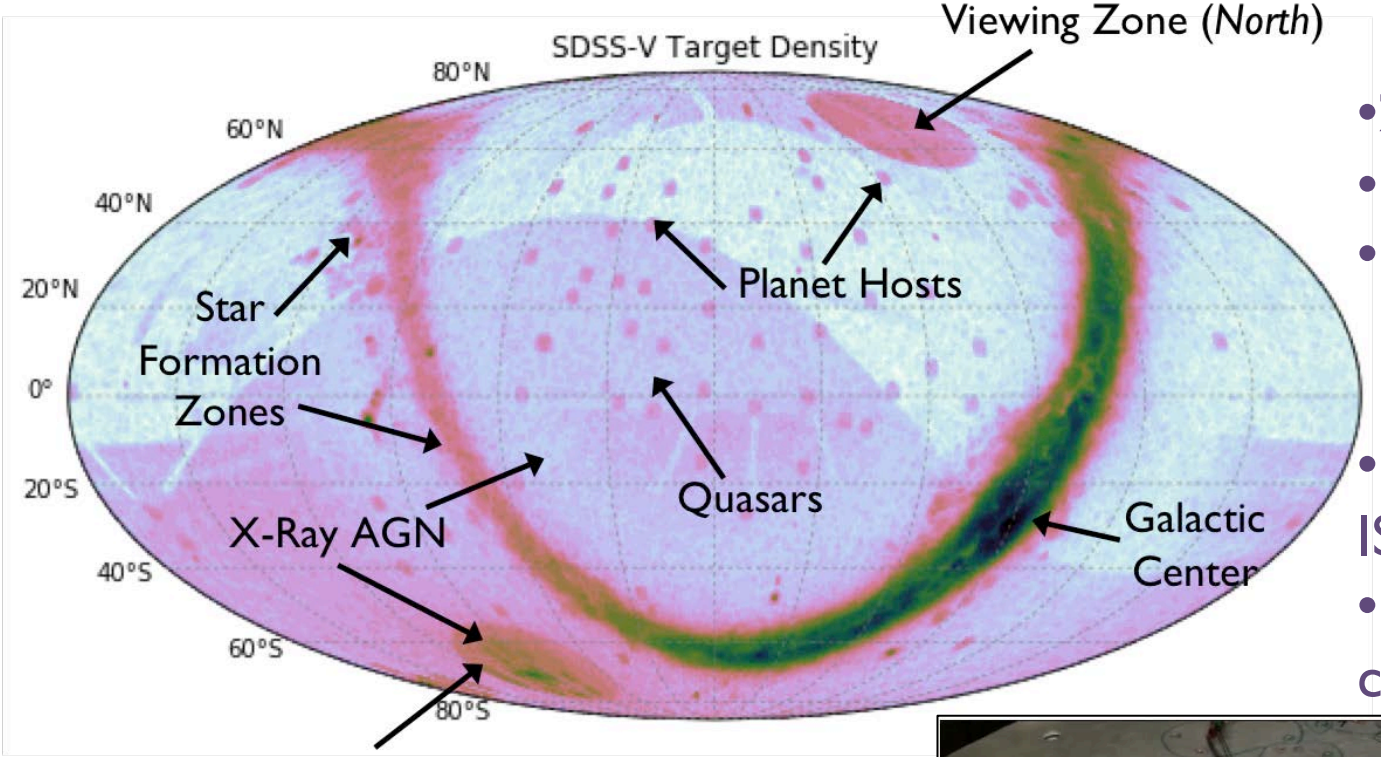
Next Questions

- What is the connection with the thick disk?
- Where did the metal poorest stars come from?
- What is the connection with the halo?
- What is the stellar age distribution?



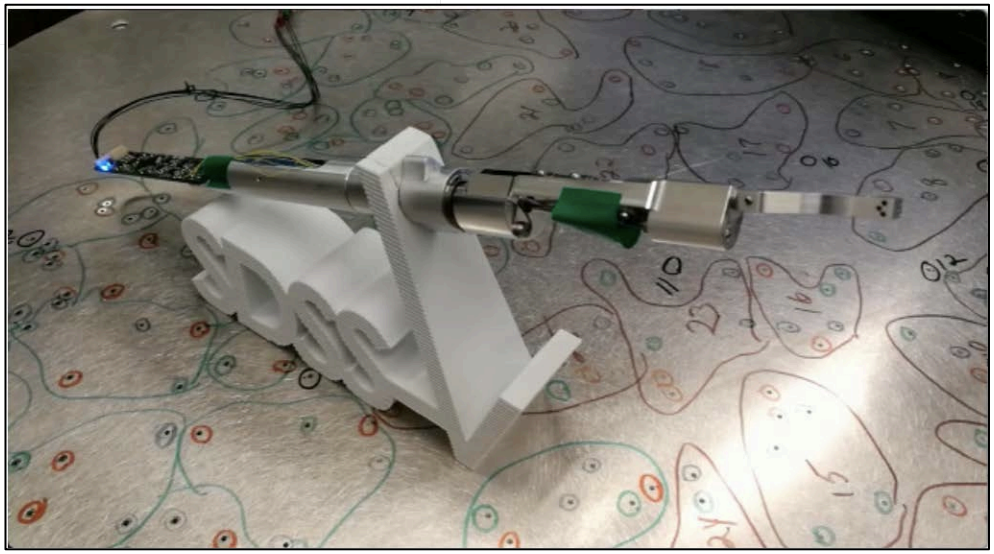
Nataf (2015)

The Future: SDSS-V



SDSS-V

- 2020-2025
- All-sky O/IR spectra
- 5-6 million stars
  - 3D kinematics, 20+ abundances
- Also 3000 deg^2 of ISM mapping
- Also BHs and galaxy clusters



Prototype of robotic fiber positioner, atop a fiber plugplate

Kollmeier, GZ et al. (2017)