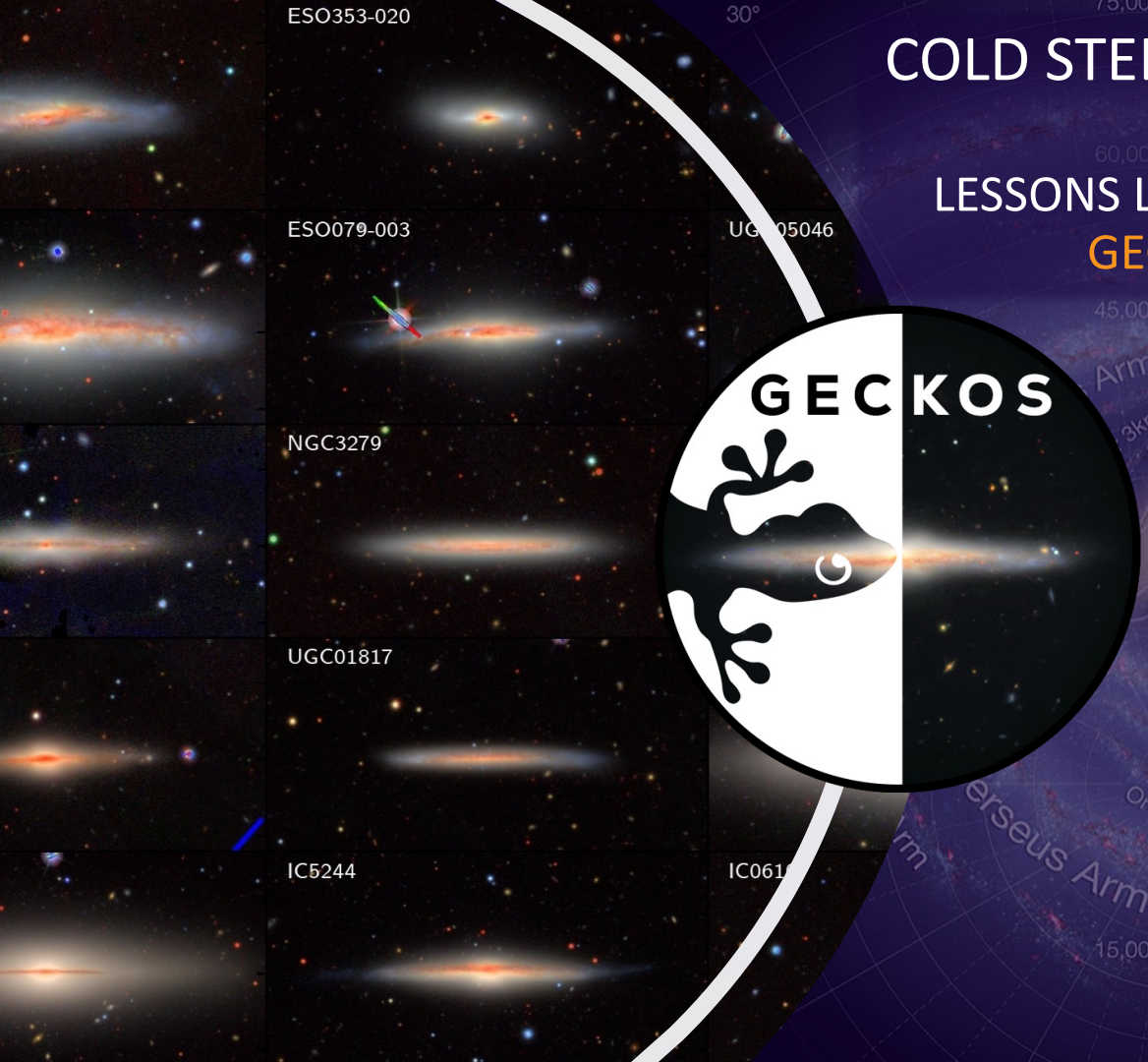


COLD STELLAR DISKS SEEN EDGE-ON

LESSONS LEARNED FROM THE VLT/MUSE GECKOS LARGE PROGRAM

Jesse van de Sande
& the GECKOS team

@GeckosSurvey

BlueMuse Science Meeting, April 2024

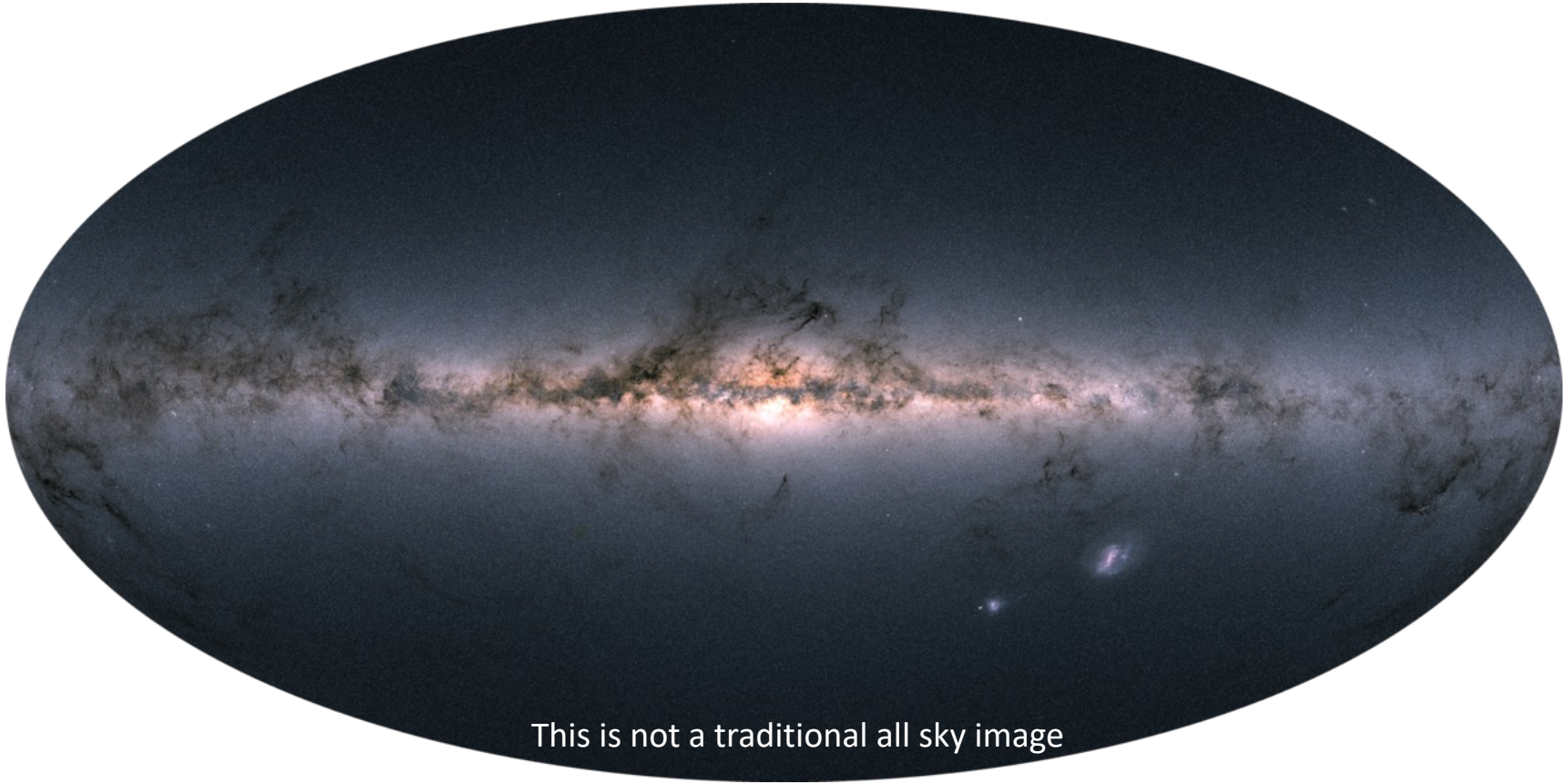
ASTRO 3D
ARC CENTRE OF EXCELLENCE FOR ALL SKY ASTROPHYSICS IN 3D

THE UNIVERSITY OF SYDNEY

UNSW SYDNEY

THE MILKY WAY

GAIA DR2 – ESA

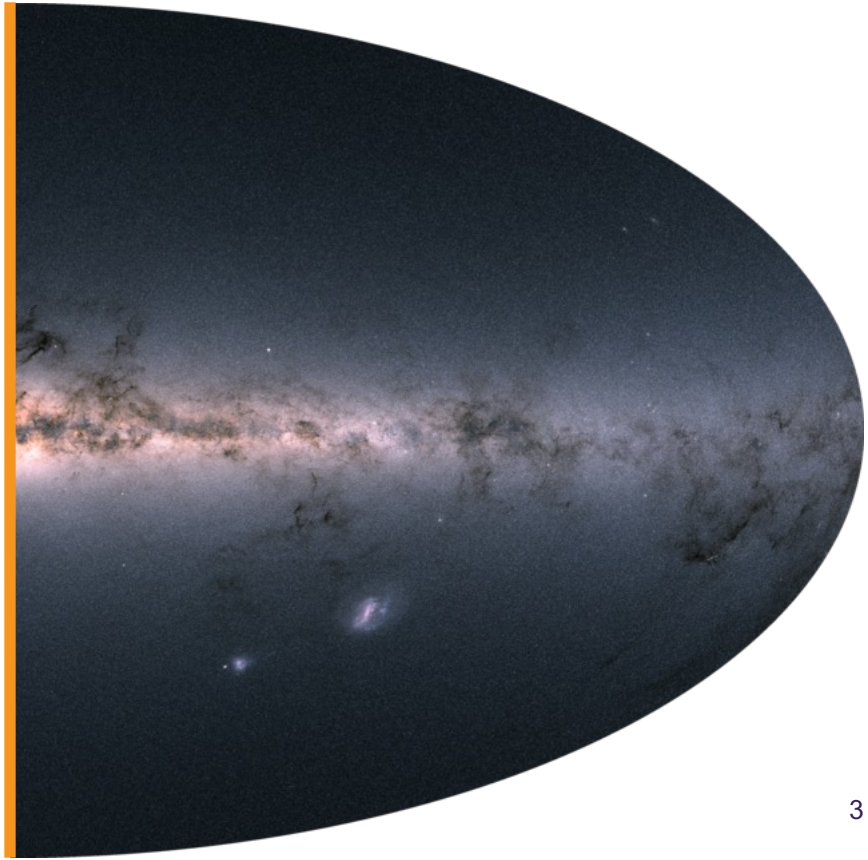


This is not a traditional all sky image

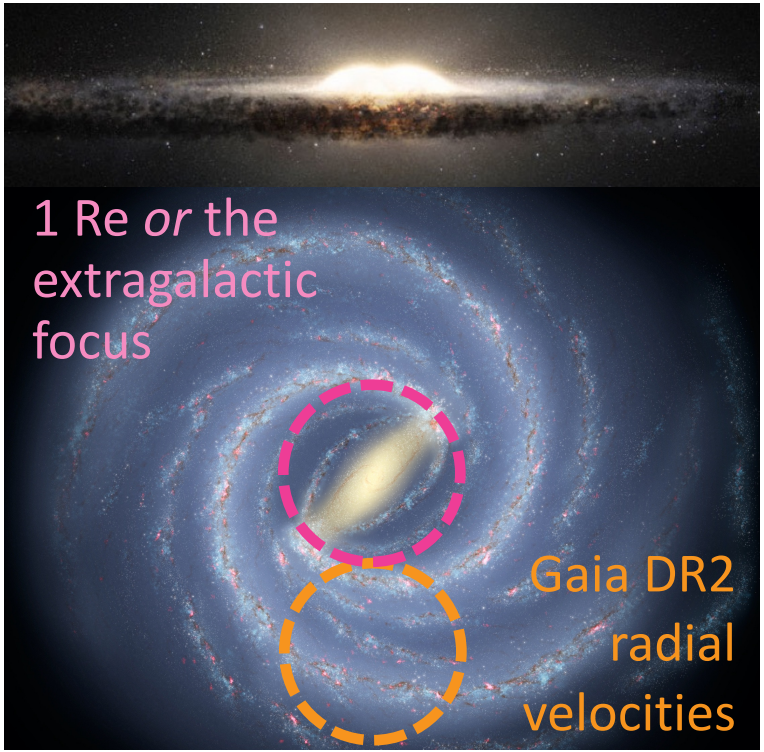
THE MILKY WAY

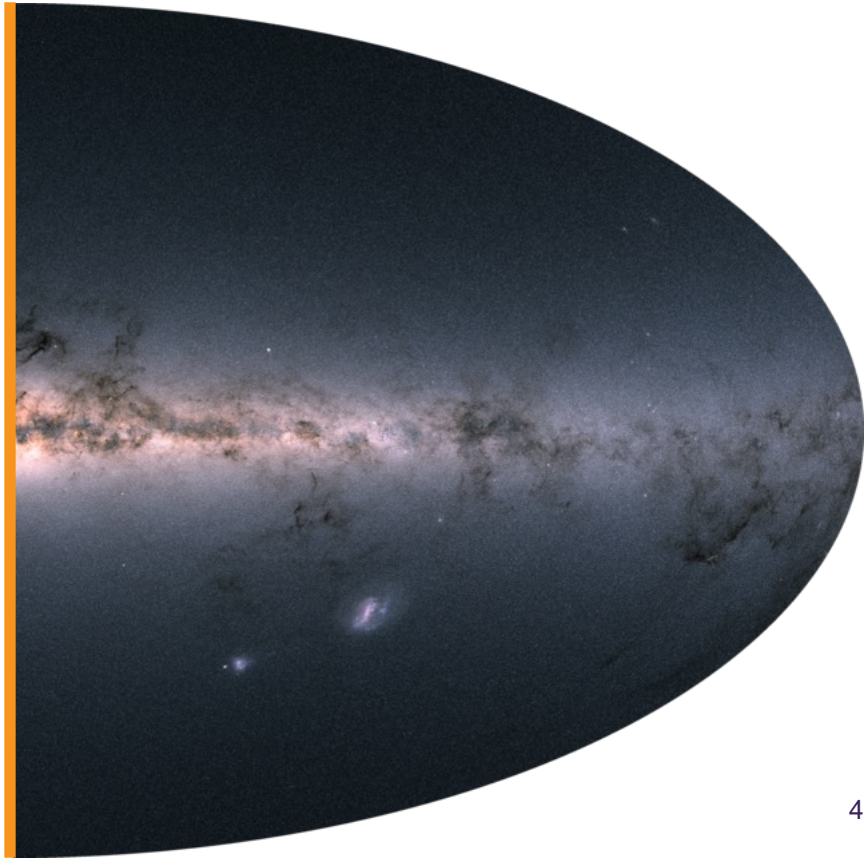
- **The ESA-Gaia mission has revolutionized our knowledge of stars in the Milky Way:**
  - 1.46 billion positions, parallaxes, and proper motions
  - 34 million sources with 6D phase space information (x,y,z,v_x,v_y,v_z)

- Gaia combined with Galactic archaeology surveys (GALAH, APOGEE, and LAMOST) are currently driving a paradigm shift in our understanding of the Milky Way.

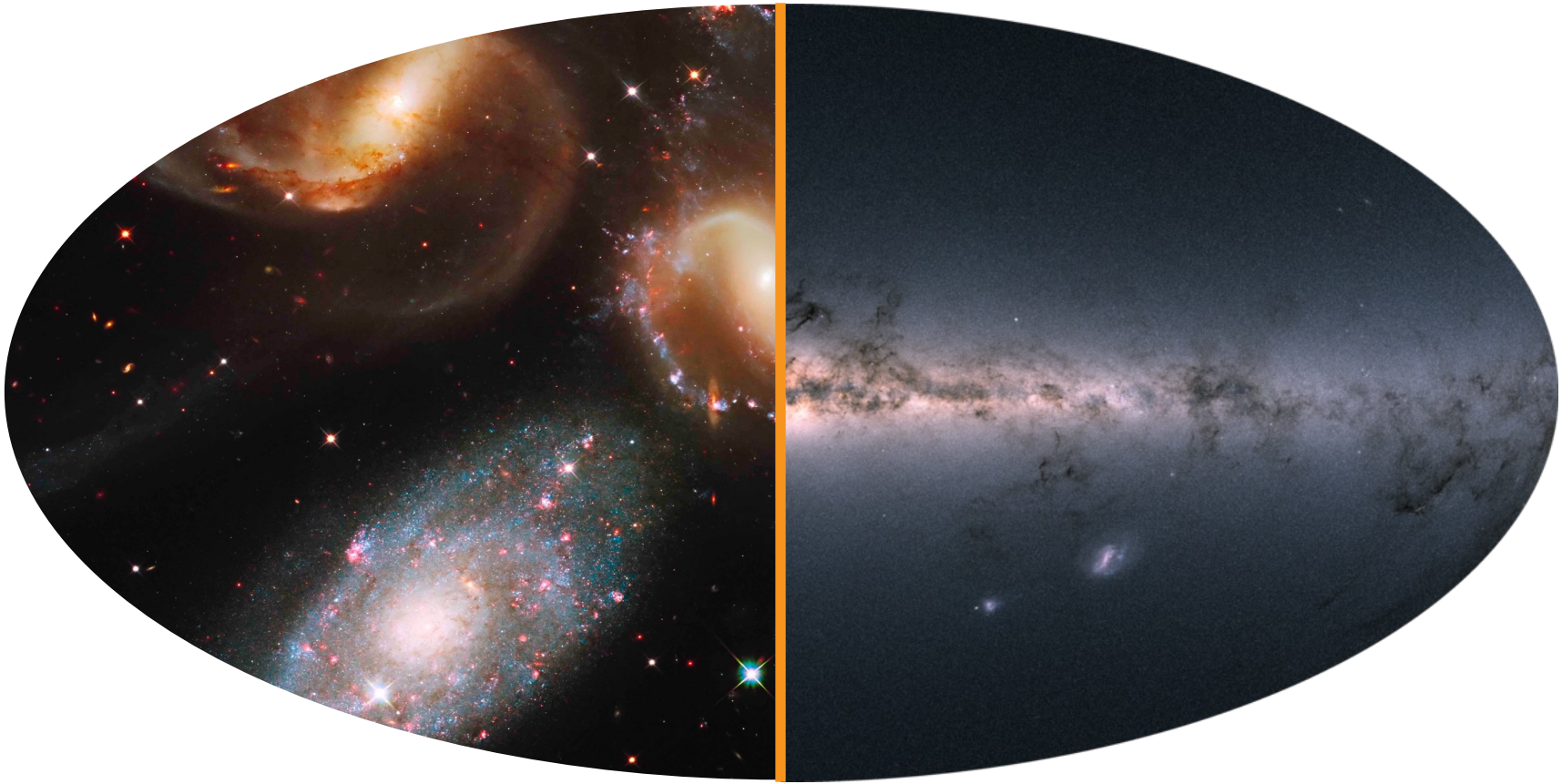


WE ARE STILL ONLY SCRATCHING THE GALACTIC SURFACE

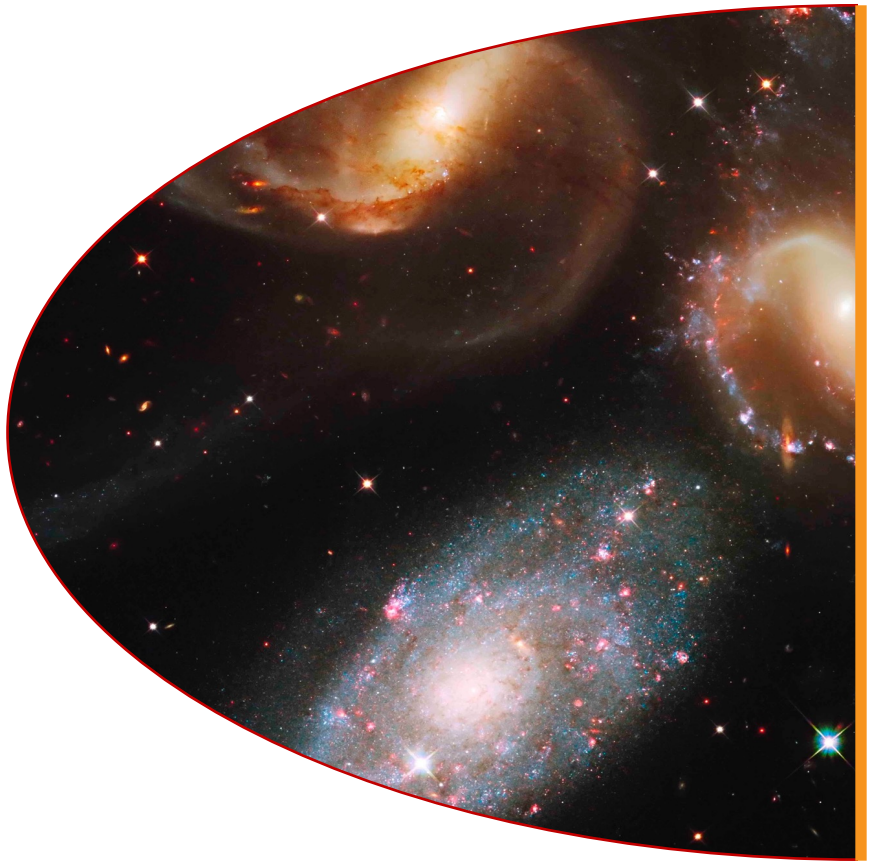




LINKING THE GALACTIC & EXTRAGALACTIC



THE EXTRAGALACTIC

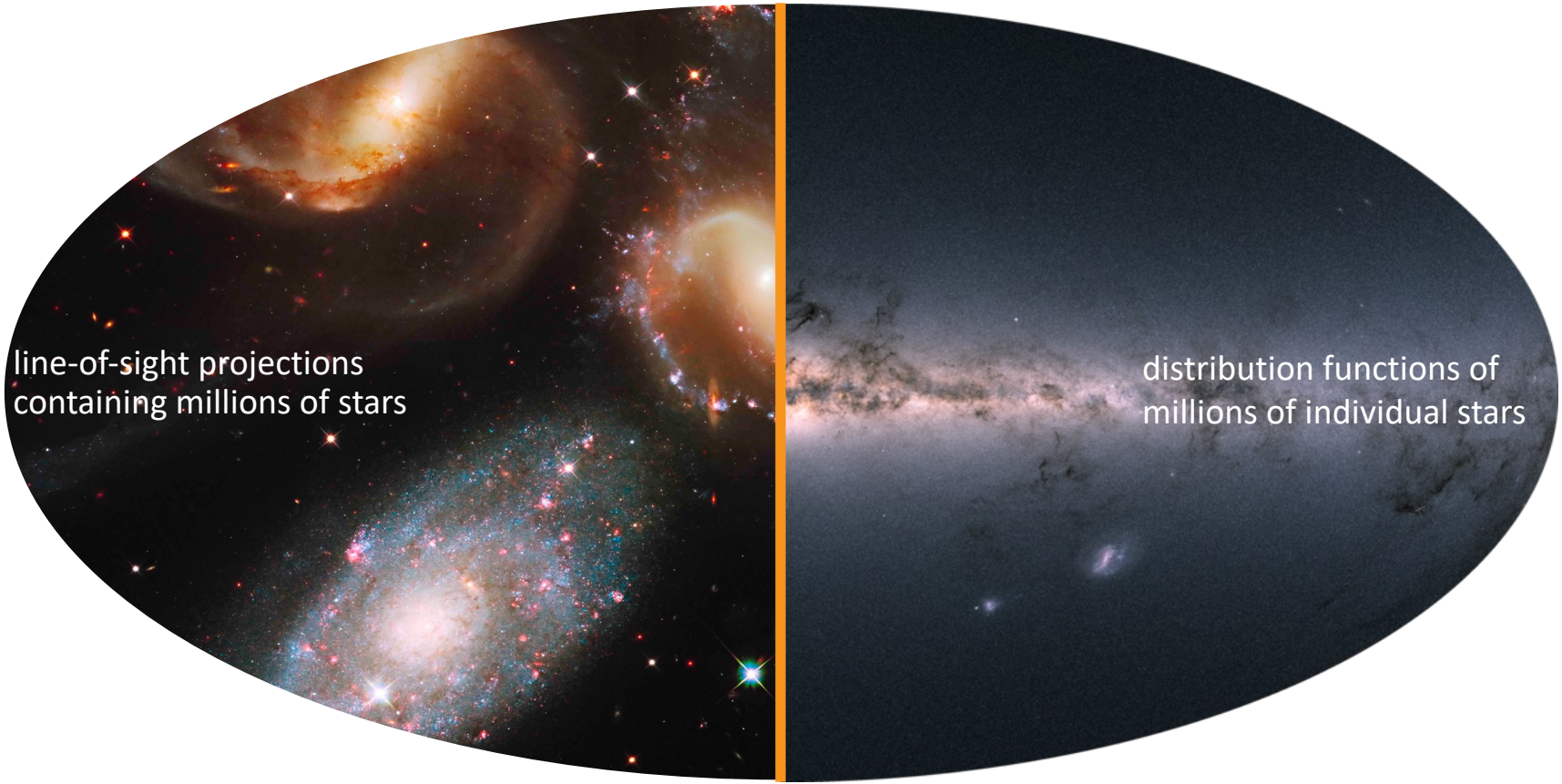


2D projections where each line-of-sight contains millions or billions of stars

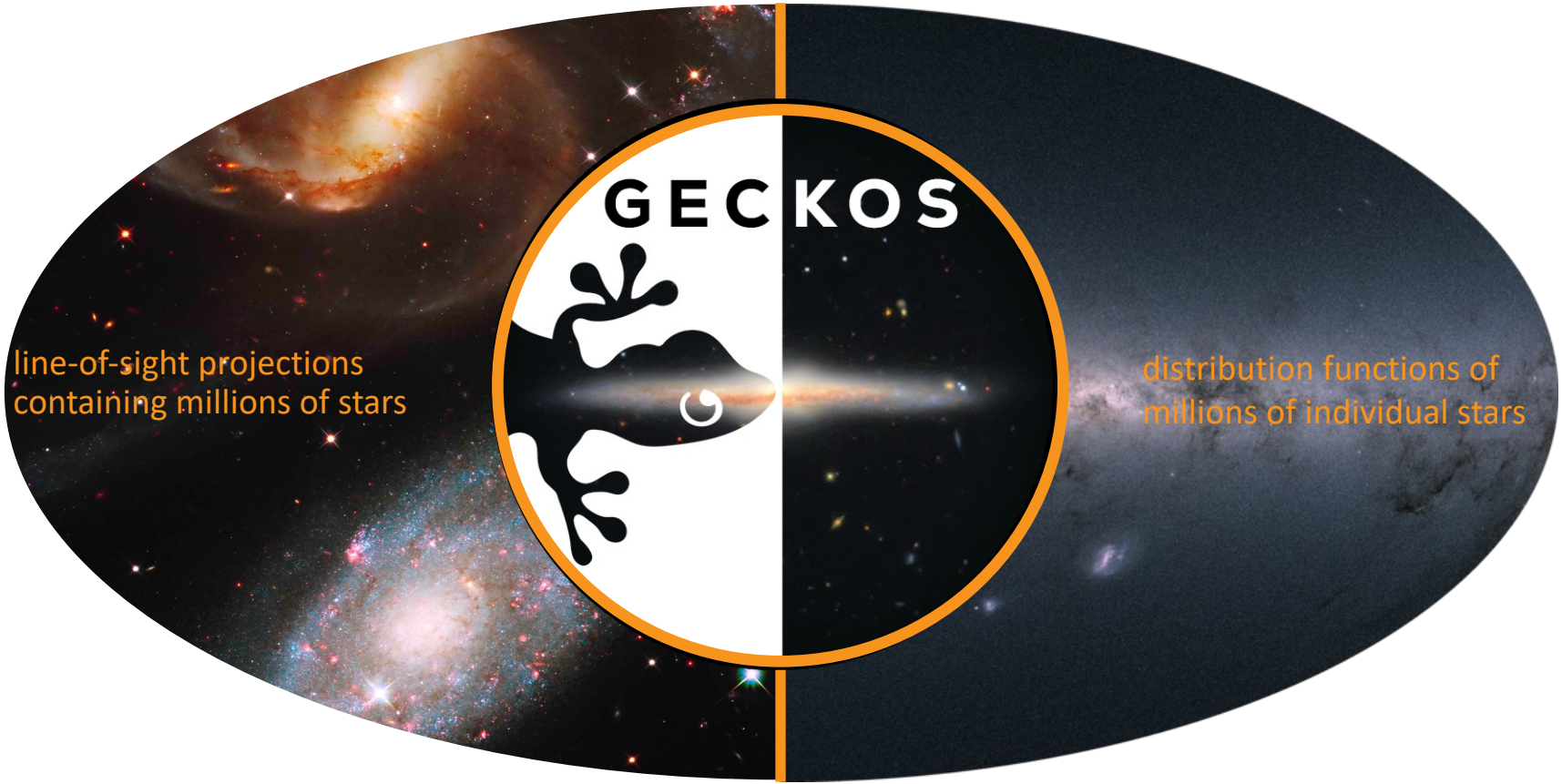
- **face-on**: high spatial & radial resolution, but light dominated by thin disk stars.
- **edge-on**: able to detect stellar populations in thick disks but dust extinction challenge;
  → ideal for direct Milky Way comparisons.

- Integral field spectroscopy (IFS) or Hyperspectral Imaging (HSI) gives us 3D information about stars and gas

THE CHALLENGE: LINKING THE GALACTIC AND EXTRAGALACTIC



THE SOLUTION: LINKING THE GALACTIC AND EXTRAGALACTIC



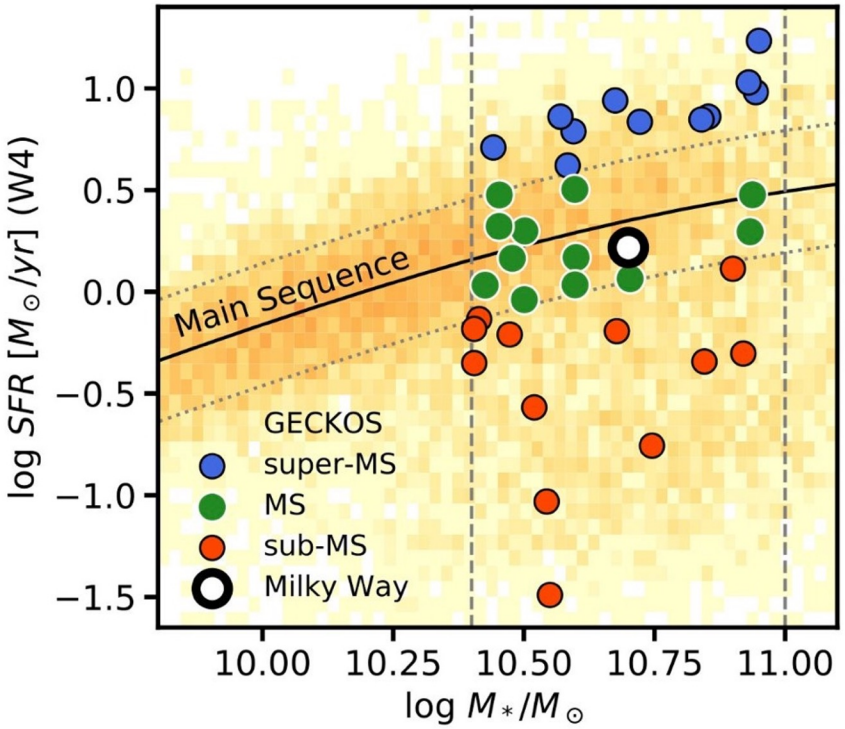
An ESO VLT/MUSE Large Program

Generalising Edge-on galaxies and their Chemical bimodalities, Kinematics, and Outflows out to Solar environments

@GeckosSurvey

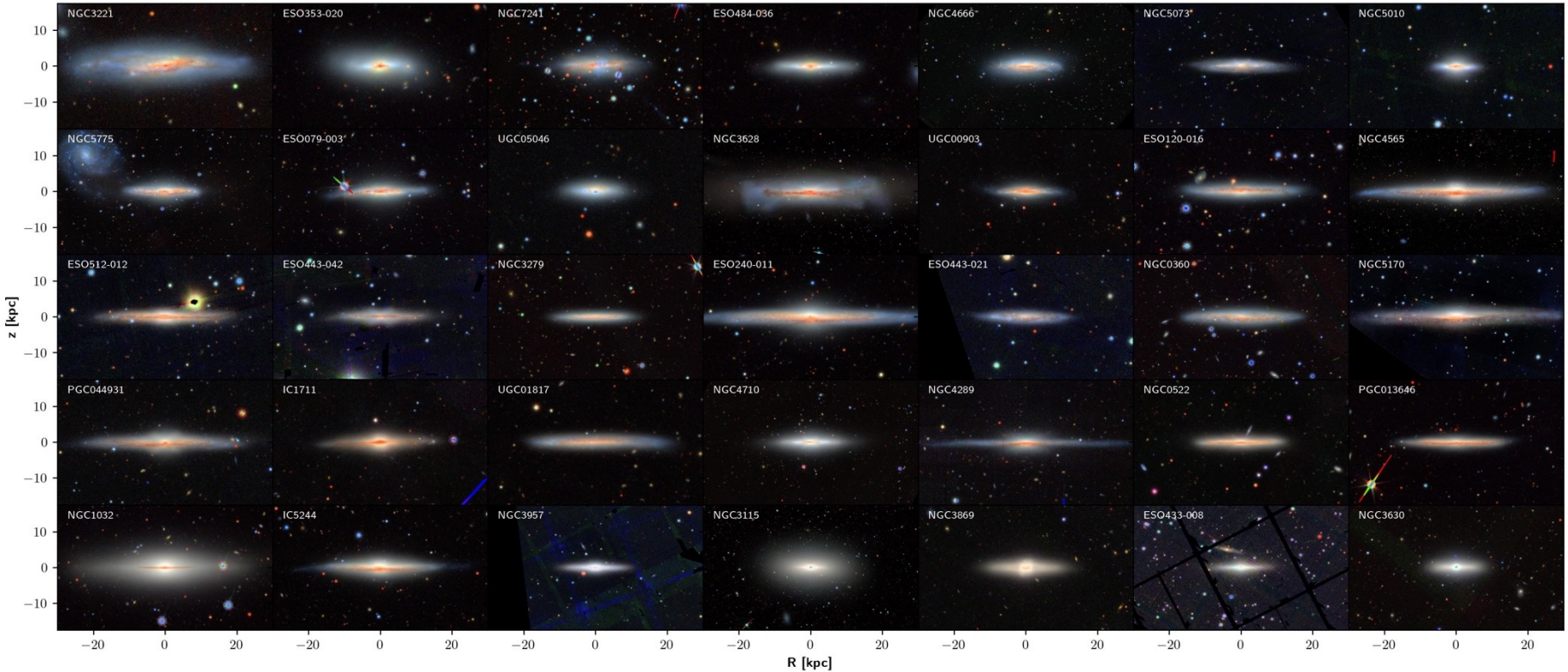
Sample: 35 edge-on galaxies at D < 70 Mpc with a variety of central components

key science goal: determine the interplay between internal and external processes that shape disk galaxies with similar mass as the Milky Way



THE GECKOS SURVEY: OBSERVATIONS

- 317 hours of VLT/MUSE in various seeing conditions
- S/N = 40 at surface brightness 23.5 mag/arcsec^2
- Better than 200pc spatial resolution out to solar environments



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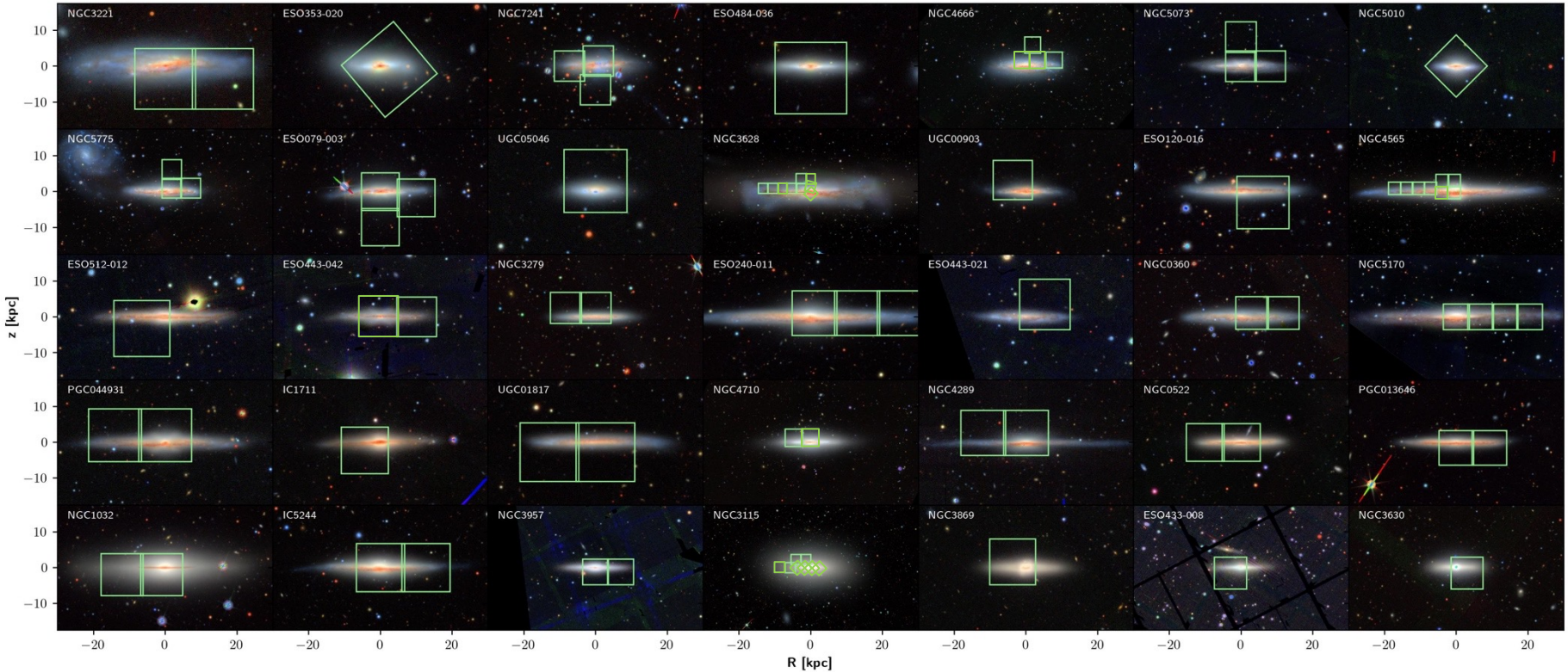
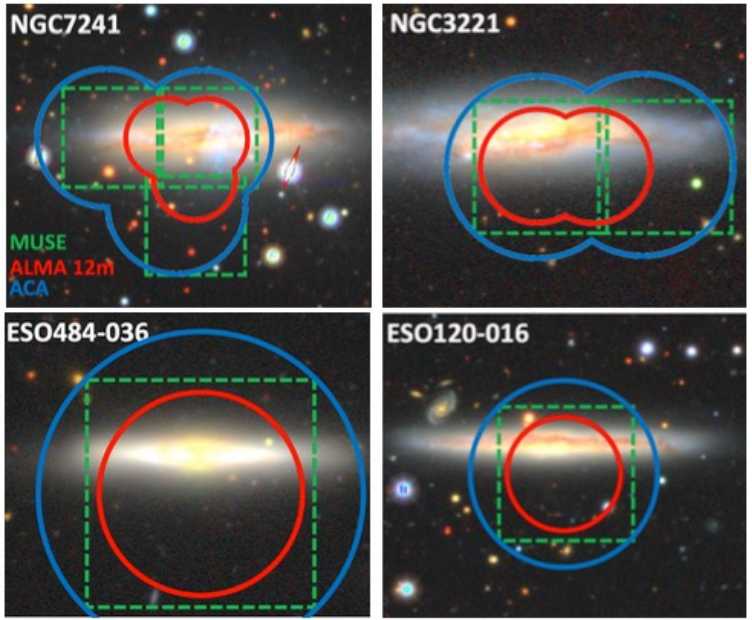


GECKOS: A MULTIWAVELENGTH SURVEY

GECKOS has grown much beyond "just" VLT/MUSE.
New observational campaigns to connect stellar measurements to all gas phases (ionized, molecular, HI)

Multi-Wavelength Follow-up:

- NOEMA observations of several super-MS targets
- ALMA + ACA Observations of 15 MS and super-MS
- ASKAP + MEERKAT Deep imaging follow-up
- JWST MIRI & NIRCAM on several galaxies



… BUT WAIT A SECOND

If everything looks amazing, then why do we need BlueMUSE?

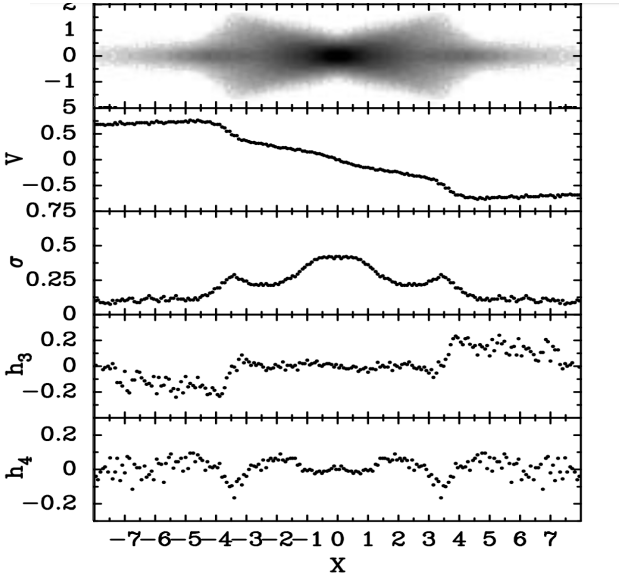
- Better Spectral Resolution needed for
  - Measuring non-Gaussian LOSVDs (requires $\sigma_{instr} < \sigma_{stars}$ *and* an accurate characterisation of the LSF, e.g. Cappellari+2017, Bryant+2016)
  - Measuring the various components of the emission lines tracing the outflows
  - Characterising the processes of gas-funnelling into the centre in galaxies with a bar.
- Bluer wavelength range
  - Covering the Balmer break is essential for getting accurate ages & α-enhancement
  - [OII] 3727A line essential for understanding star forming regions

HIGH-ORDER KINEMATICS

High-order kinematic moments (i.e. skewness and kurtosis) of the line-of-sight velocity distribution (LOSVD) reveal complex stellar orbital structures that go undetected when measuring *V* and *σ* alone *(e.g. van der Marel & Franx 1993; Gerhard 1993)*

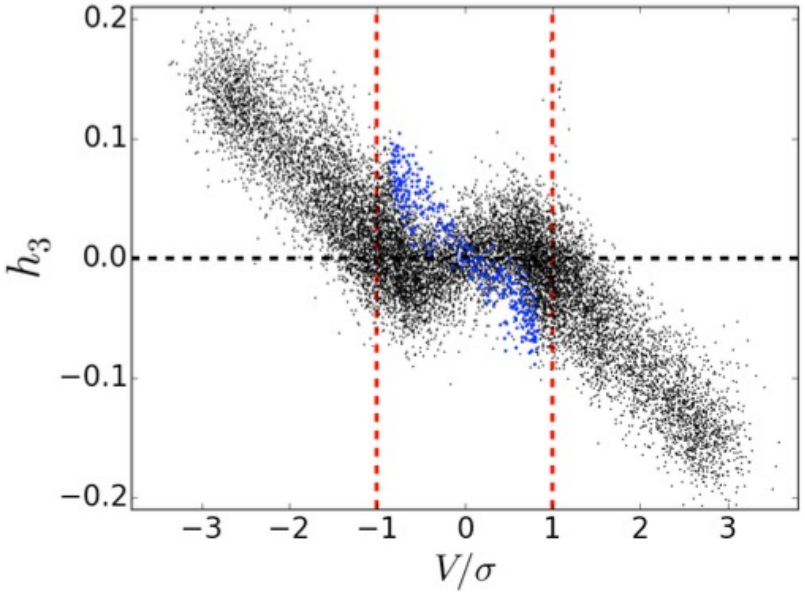
Prediction from simulations

(Bureau & Athanassoula – 2005)



NGC 3115 (massive S0)

(Guérou et al. – 2016)



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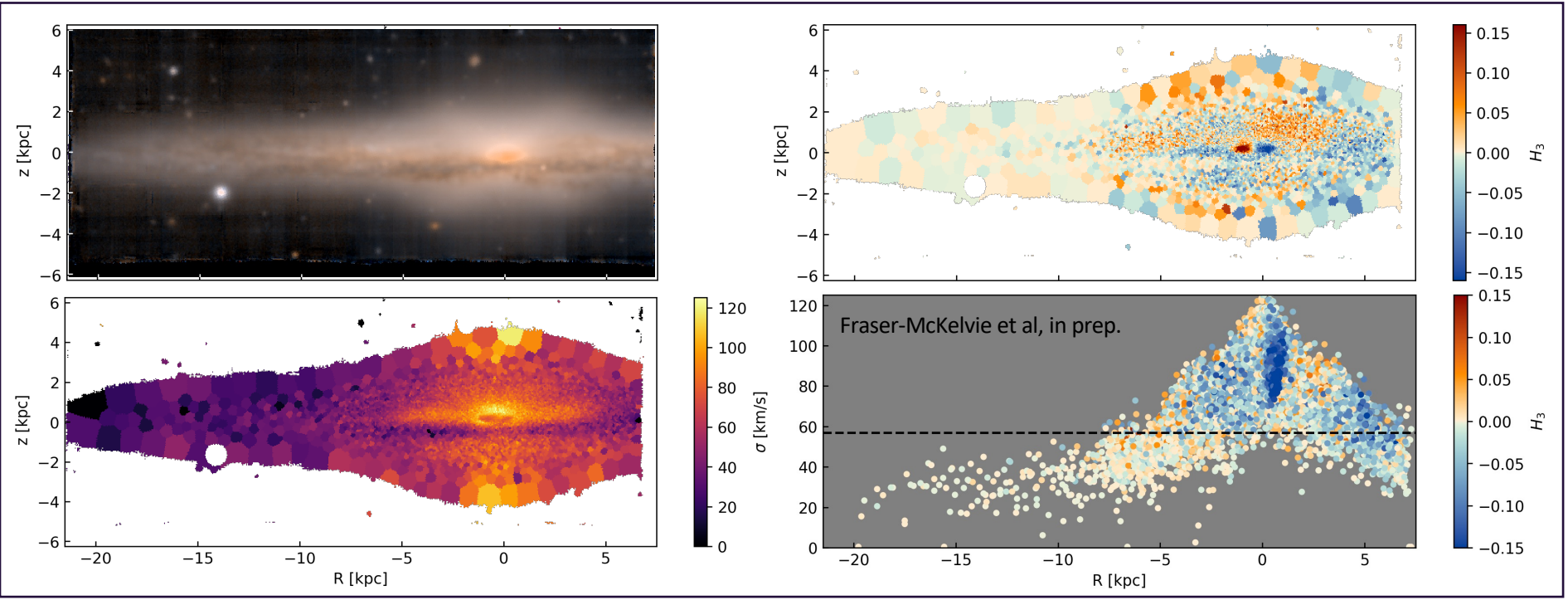
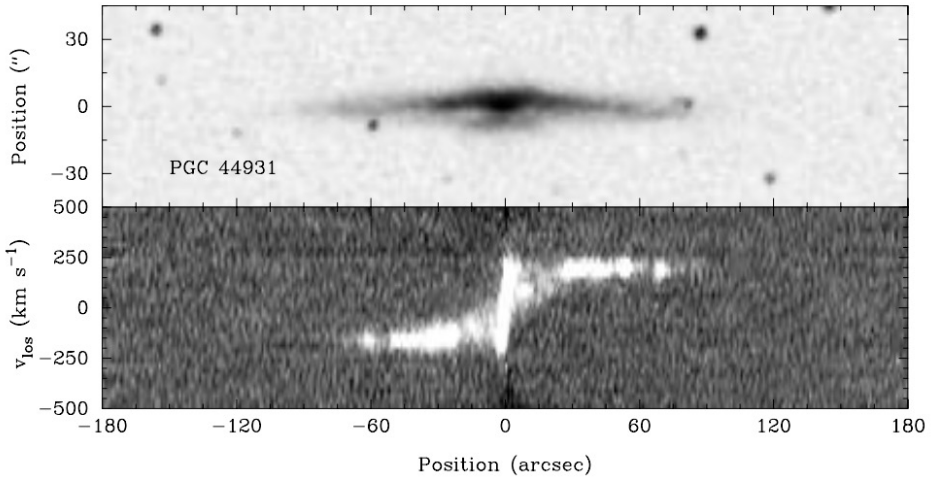


GAS-FUNNELLING IN BARS

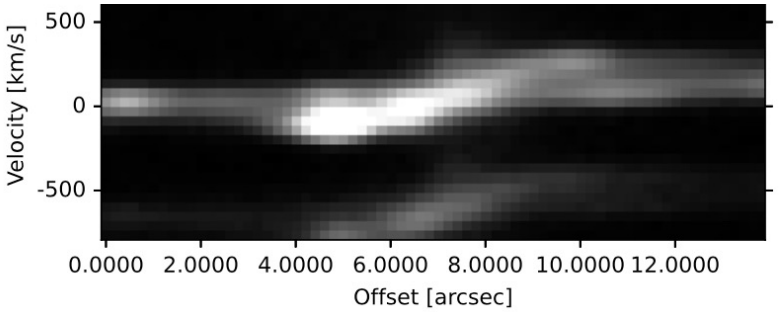
Barred potentials produce a strong ionised gas kinematic signature in the form of double-peaked LOSVDs (Bureau & Freeman 1999)

This signature is only visible if the line-of-sight circular motions of gas within a galaxy disk can be separated from inflow motions along a bar: requires $\sigma_{inst} < 25$ km s^{-1}



R~4000 DBS – 2.3m SSO
(Bureau & Freeman 1999)

R~2000 - MUSE
(Fraser-McKelvie et al., in prep.)



AGE-VELOCITY DISPERSION RELATION

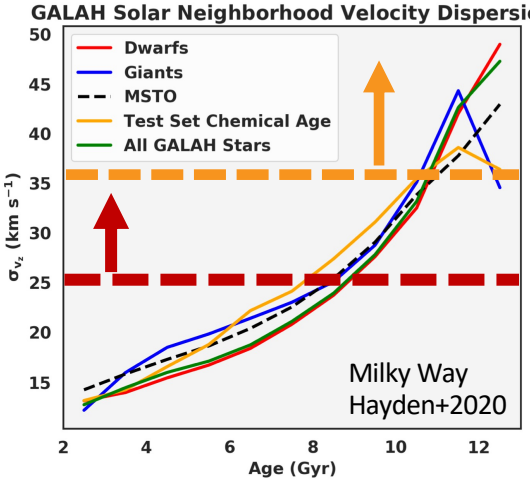
Age-Velocity Dispersion relation

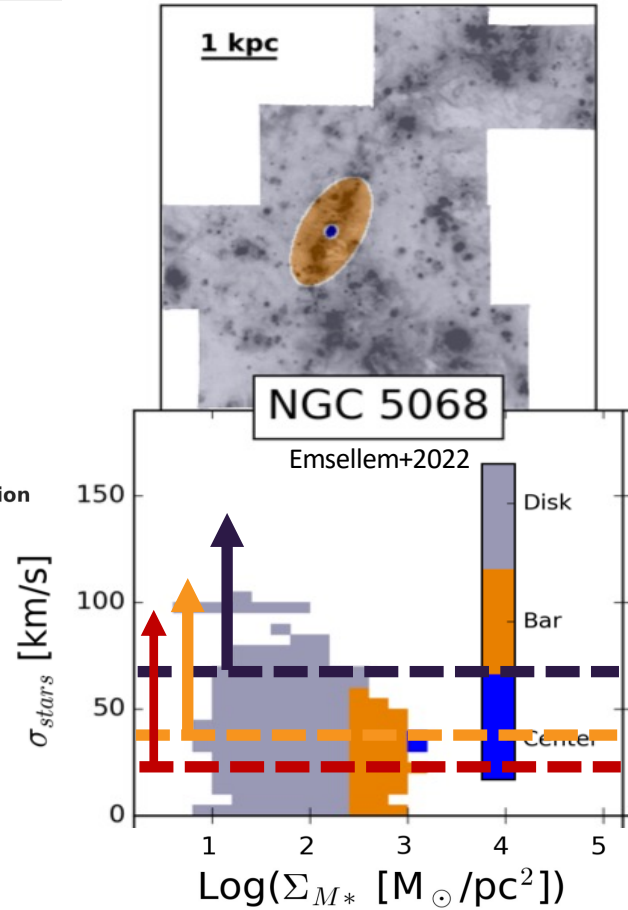
By comparing the stellar velocity dispersion of different age populations to the gas dispersion at different lookback times, we can quantify vertical disk heating, highlighting the contribution of mergers to the evolution of galactic disks.

$R_{4500Å}$ = 2000 (2.25Å) → σ_{instr} = 64 km s^{-1}

$R_{4500Å}$ = 3500 (1.30Å) → σ_{instr} = 36 km s^{-1}

$R_{4500Å}$ = 5000 (0.90Å) → σ_{instr} = 25 km s^{-1}

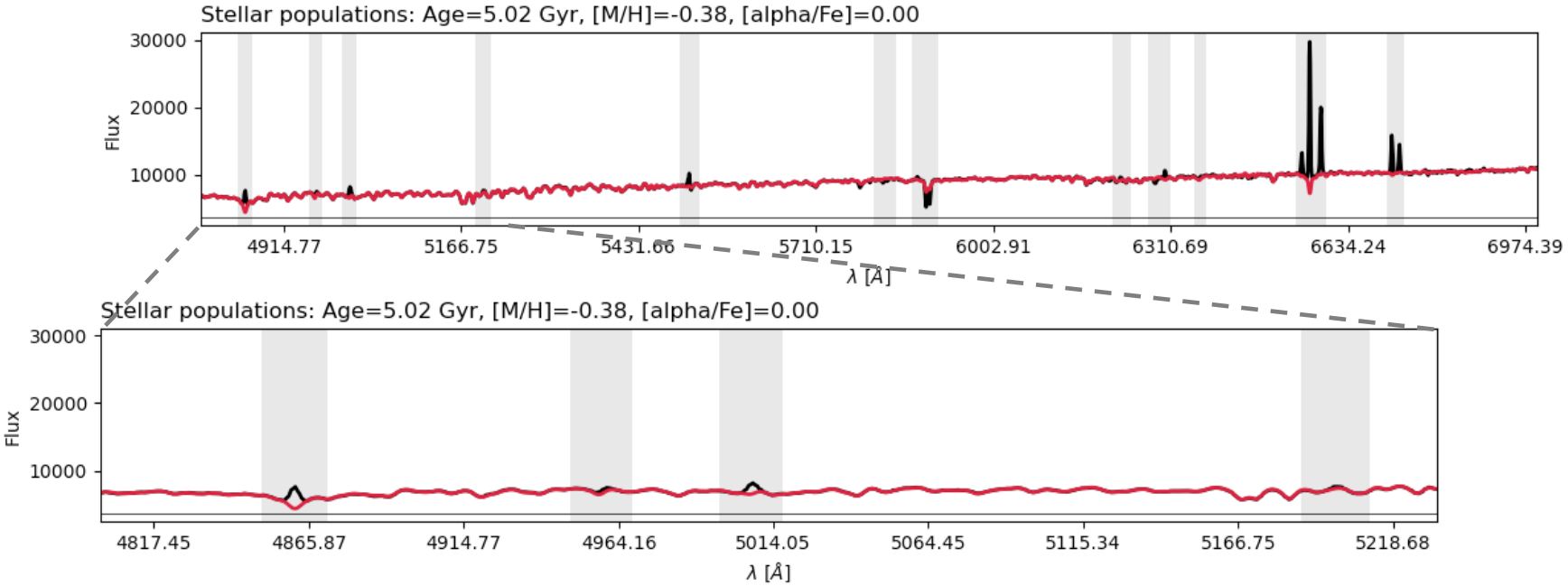




AGE MEASUREMENTS

Accuracy of age measurements drastically improves towards the blue

When Hβ is filled with emission, measuring age becomes highly reliant on accurate flux calibration



AGE MEASUREMENTS

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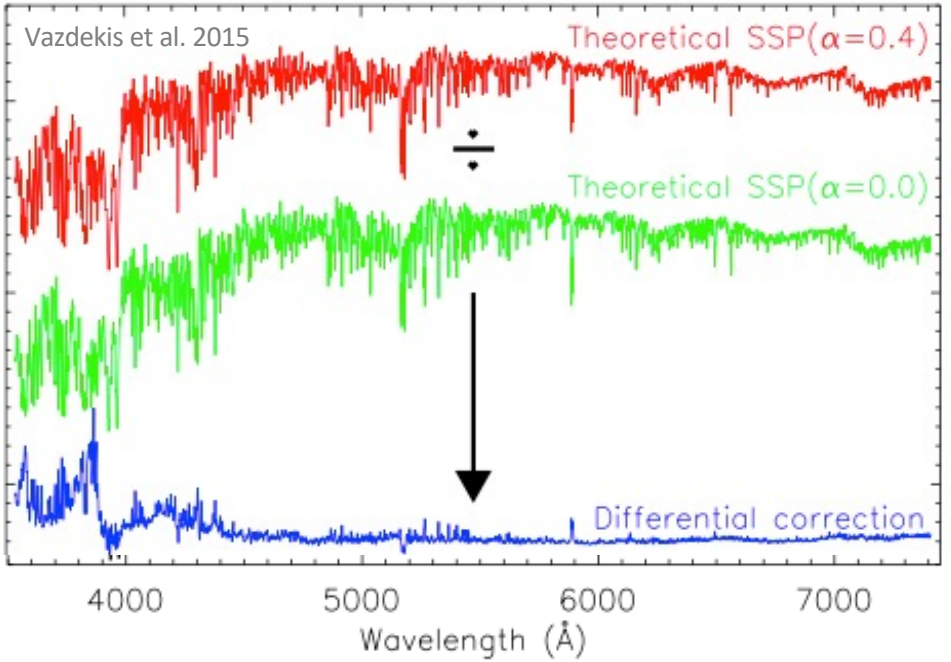
The blue region also contains several excellent α-element sensitive lines



TAKE HOME MESSAGE

- Edge-on Milky Way-like galaxies offer a unique insight into the chemical enrichment of galaxies (*e.g. Pinna+2019, Scott+2021, Martig+2021)*
- GECKOS aims determine the interplay between internal and external processes that shape disk galaxies like the Milky Way *(van de Sande et al. 2023)*
- Preliminary results from GECKOS show exciting prospects for understanding the chemical evolution of galaxies
- Both *Higher Spectral Resolution* and *Bluer Wavelength Range* (as compared to MUSE) are essential for understanding cold disks