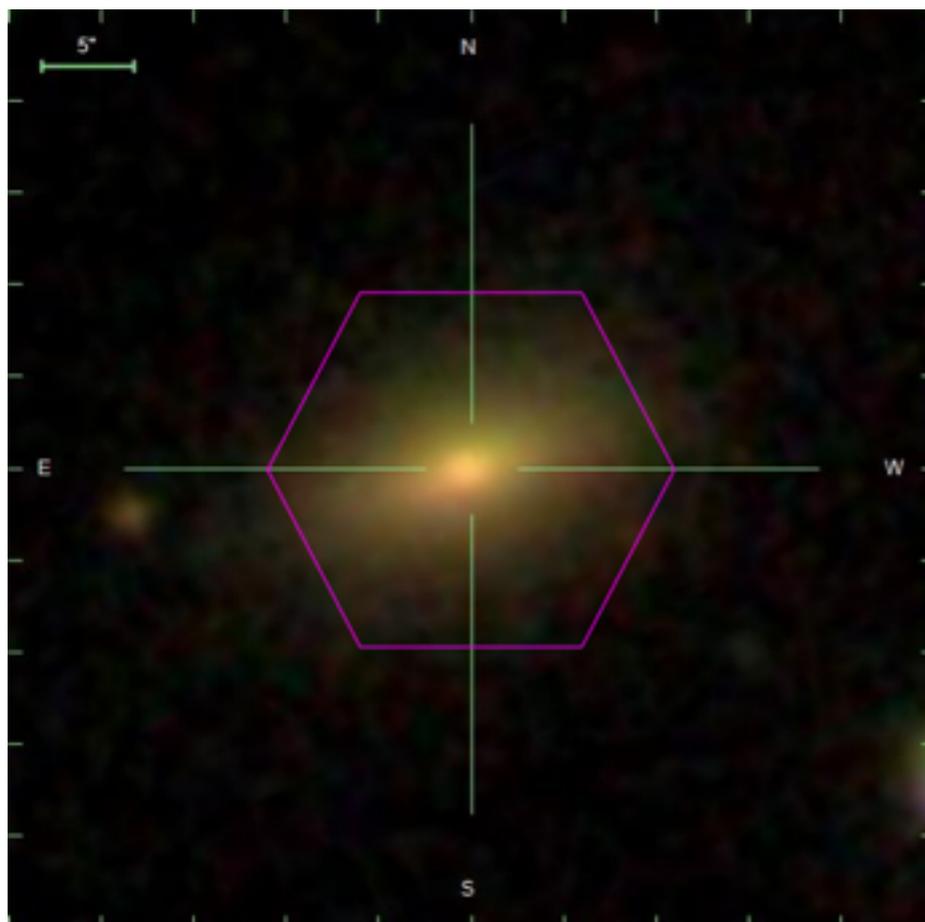


# Stellar populations in galaxy haloes with SDSS-IV/MaNGA

10,000 of these



Daniel Thomas  
University of Portsmouth

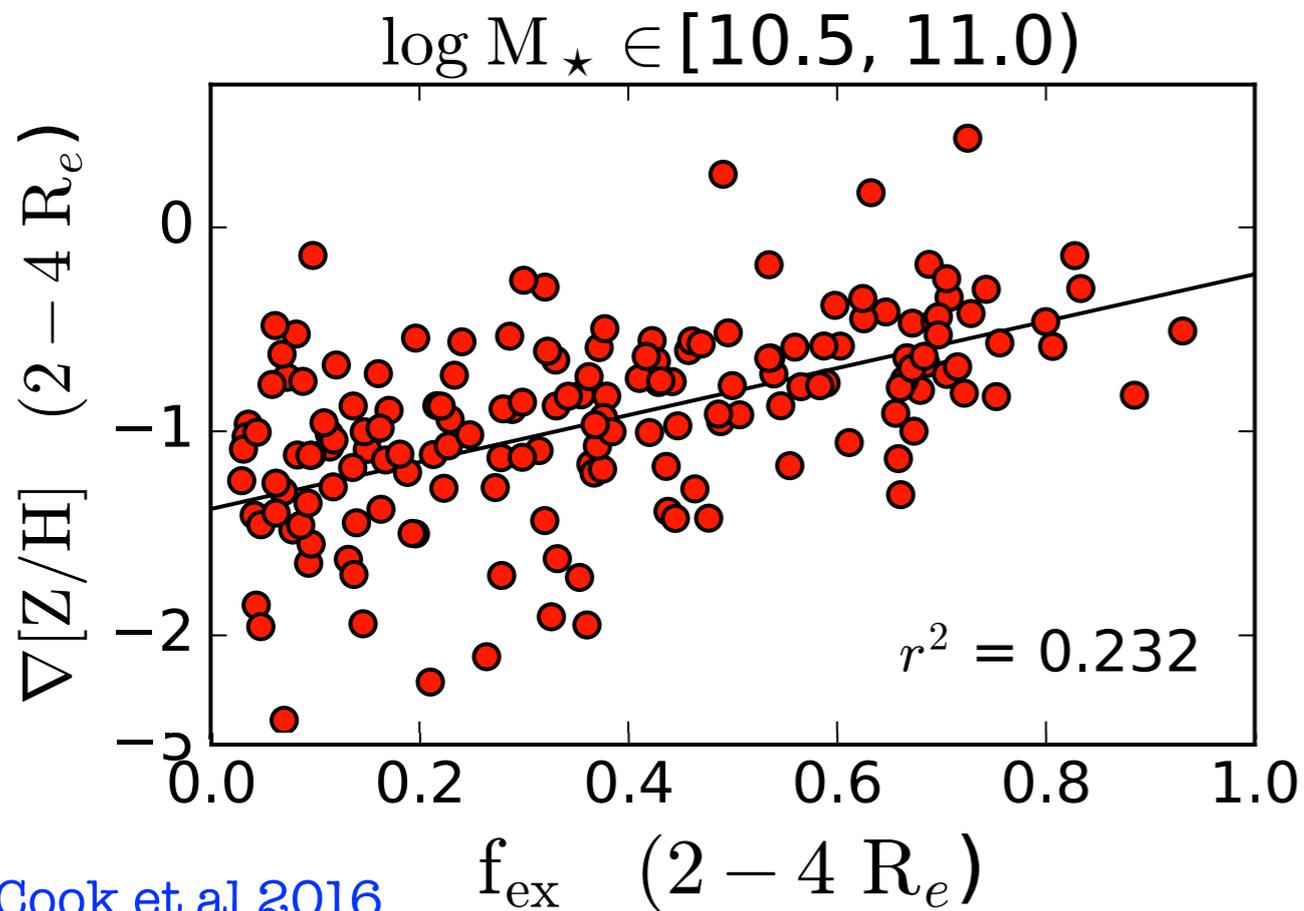
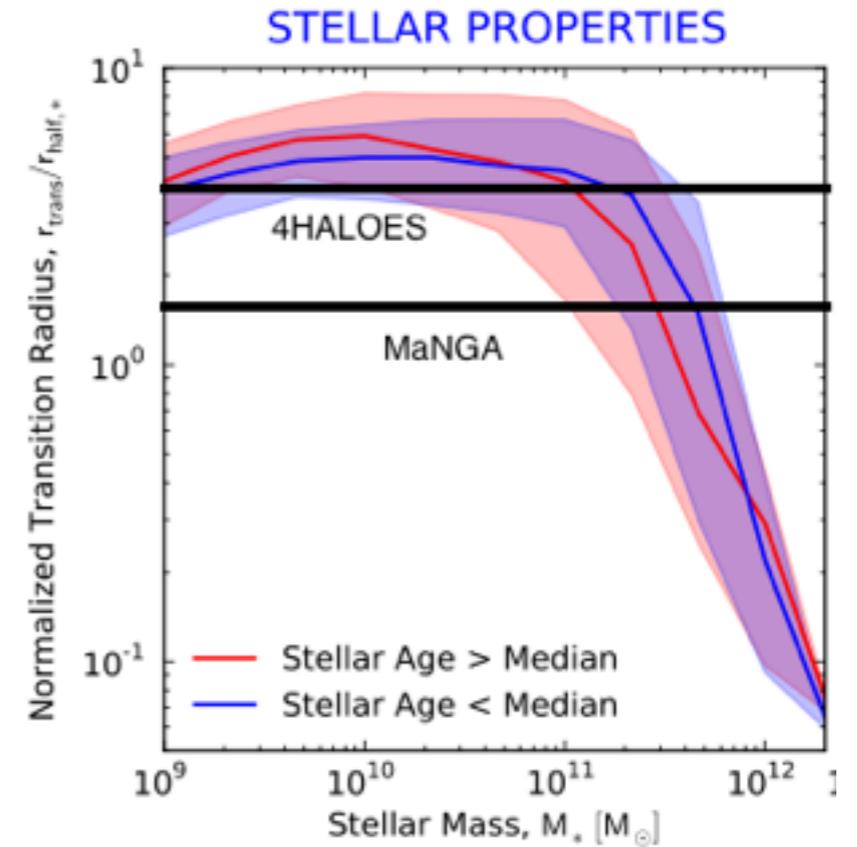
Daniel Goddard, Taniya Parikh, Jianhui Lian



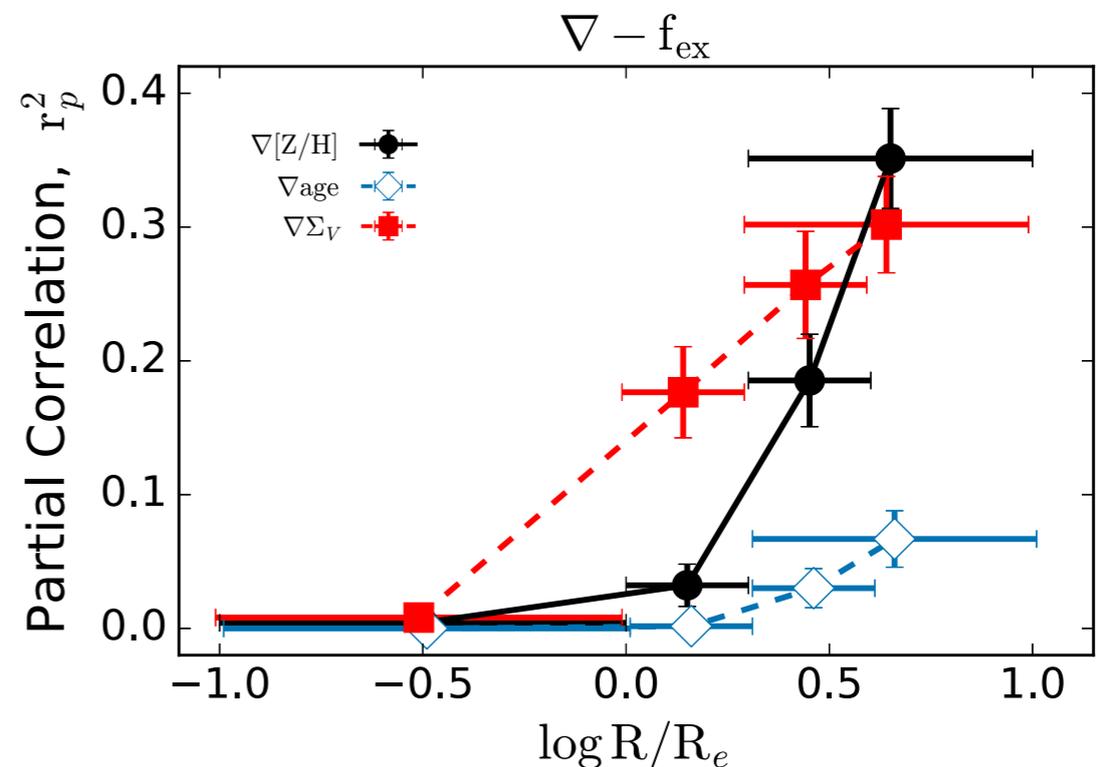
# Signatures of accretion

- Illustris simulations
- Transition radius to halo defined in simulations
- Link between metallicity gradient and ex-situ fraction
- Transition radius from Planetary Nebulae as low as  $1 R_e$  (Pulsoni et al 2018).

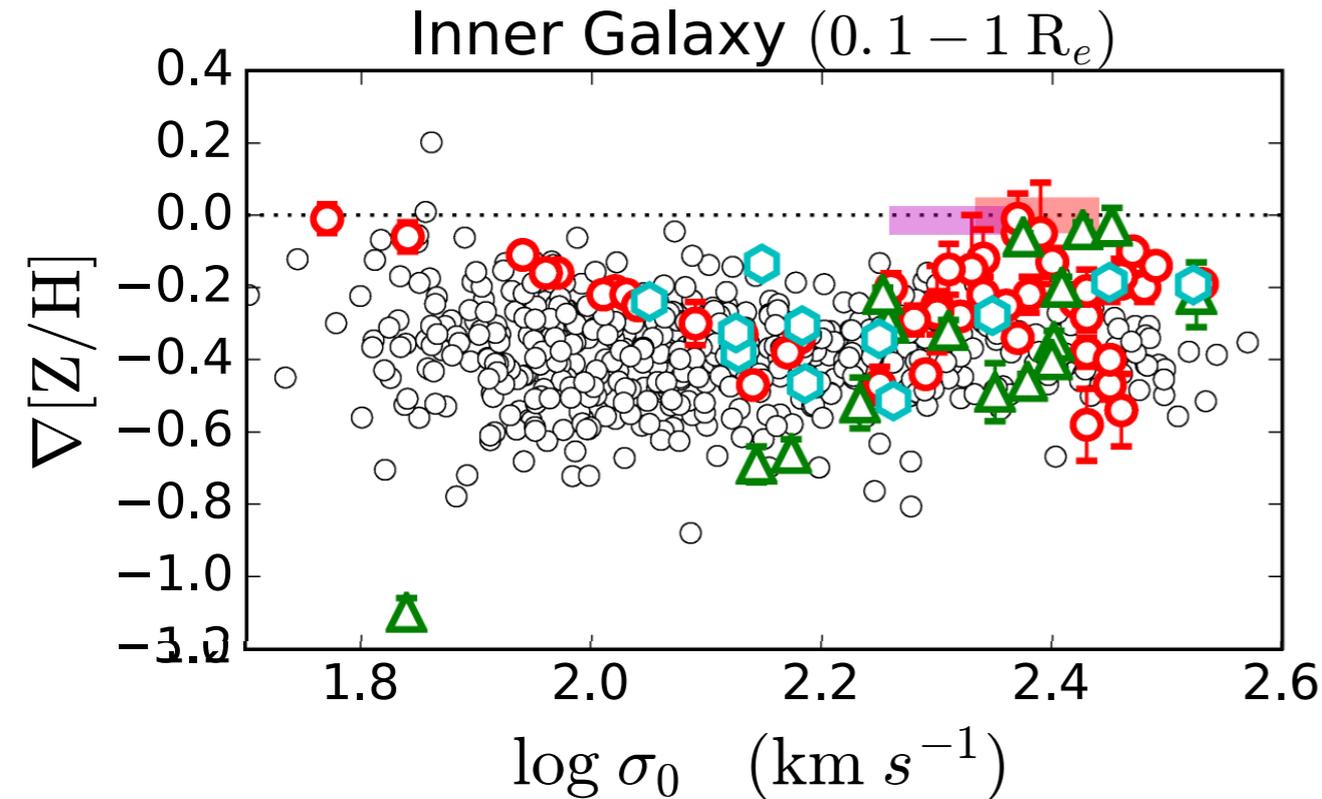
Rodriguez-Gomez et al 2016



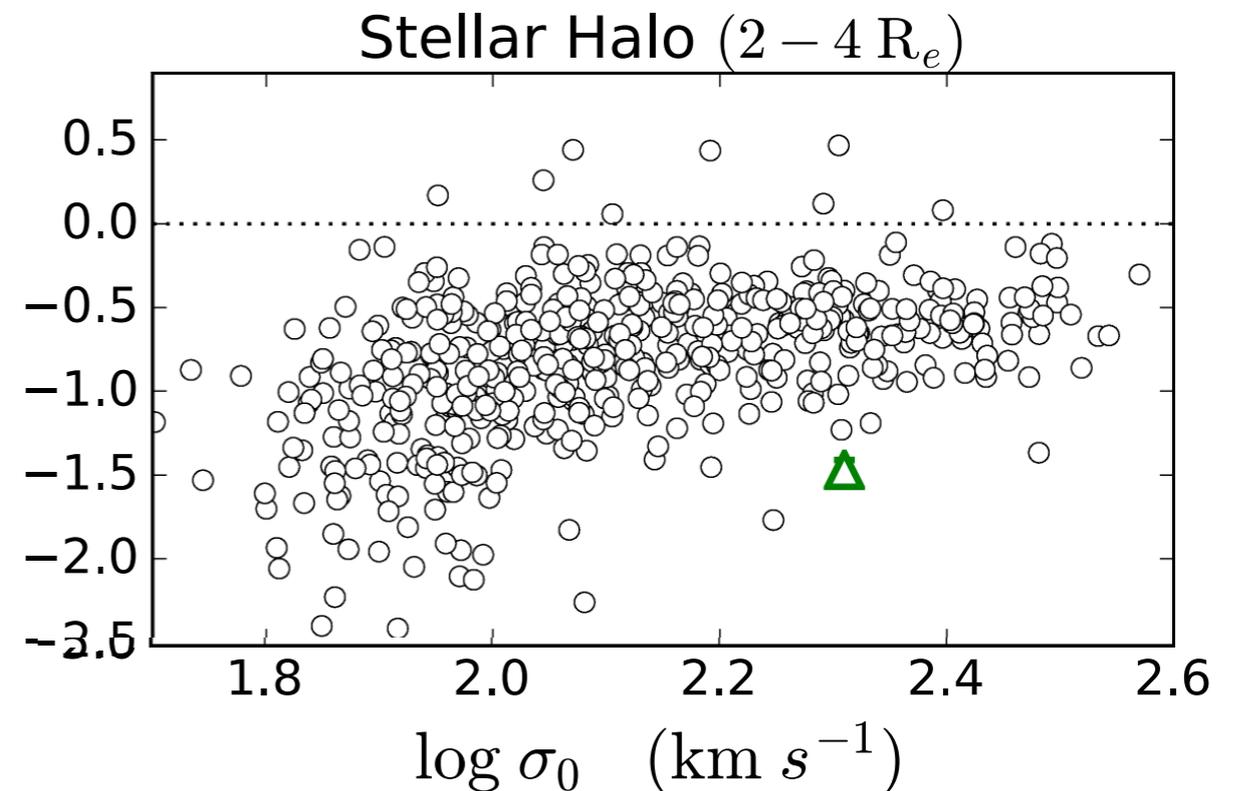
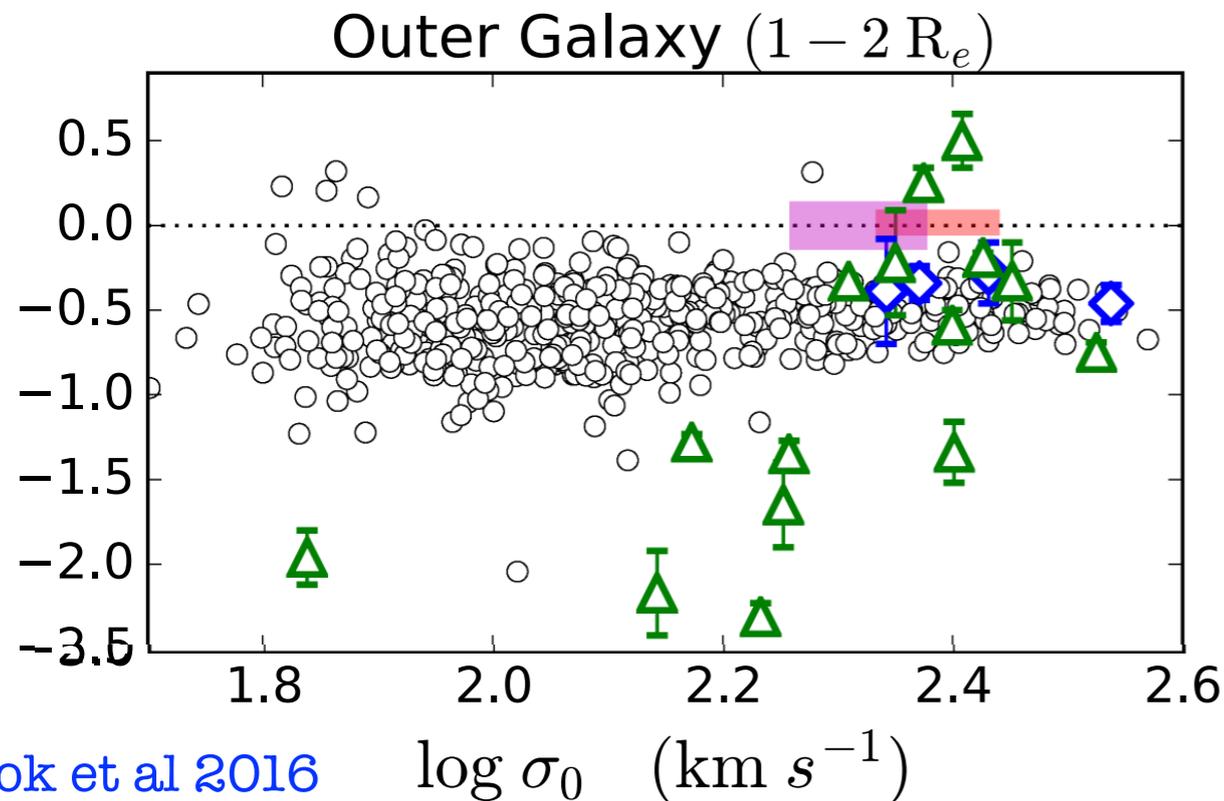
Cook et al 2016



# Metallicity gradients in transition



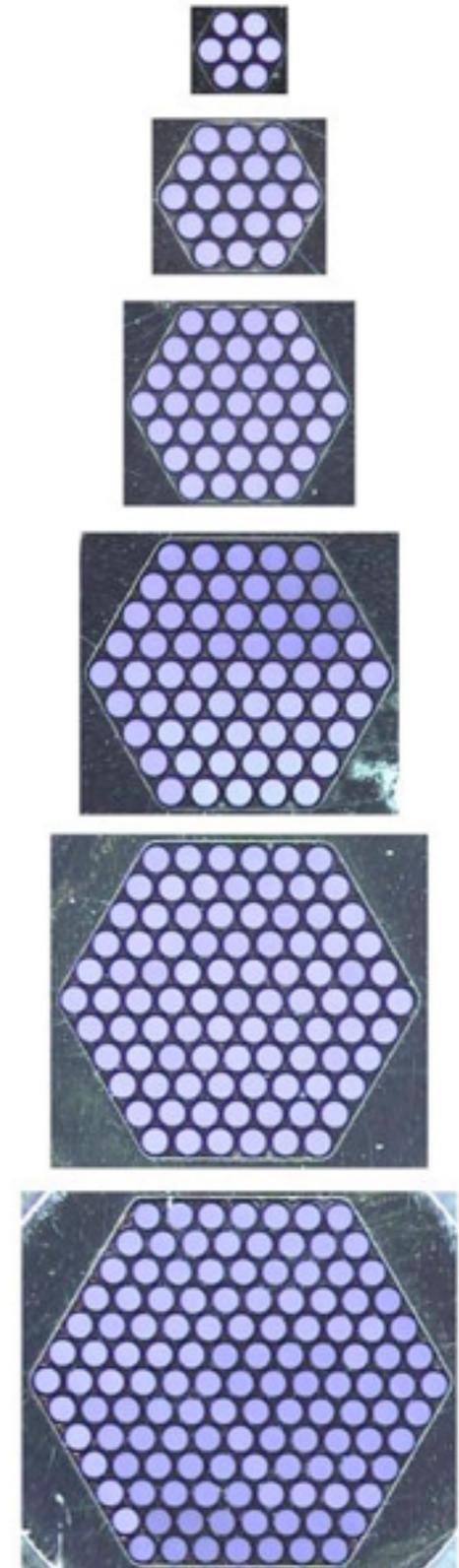
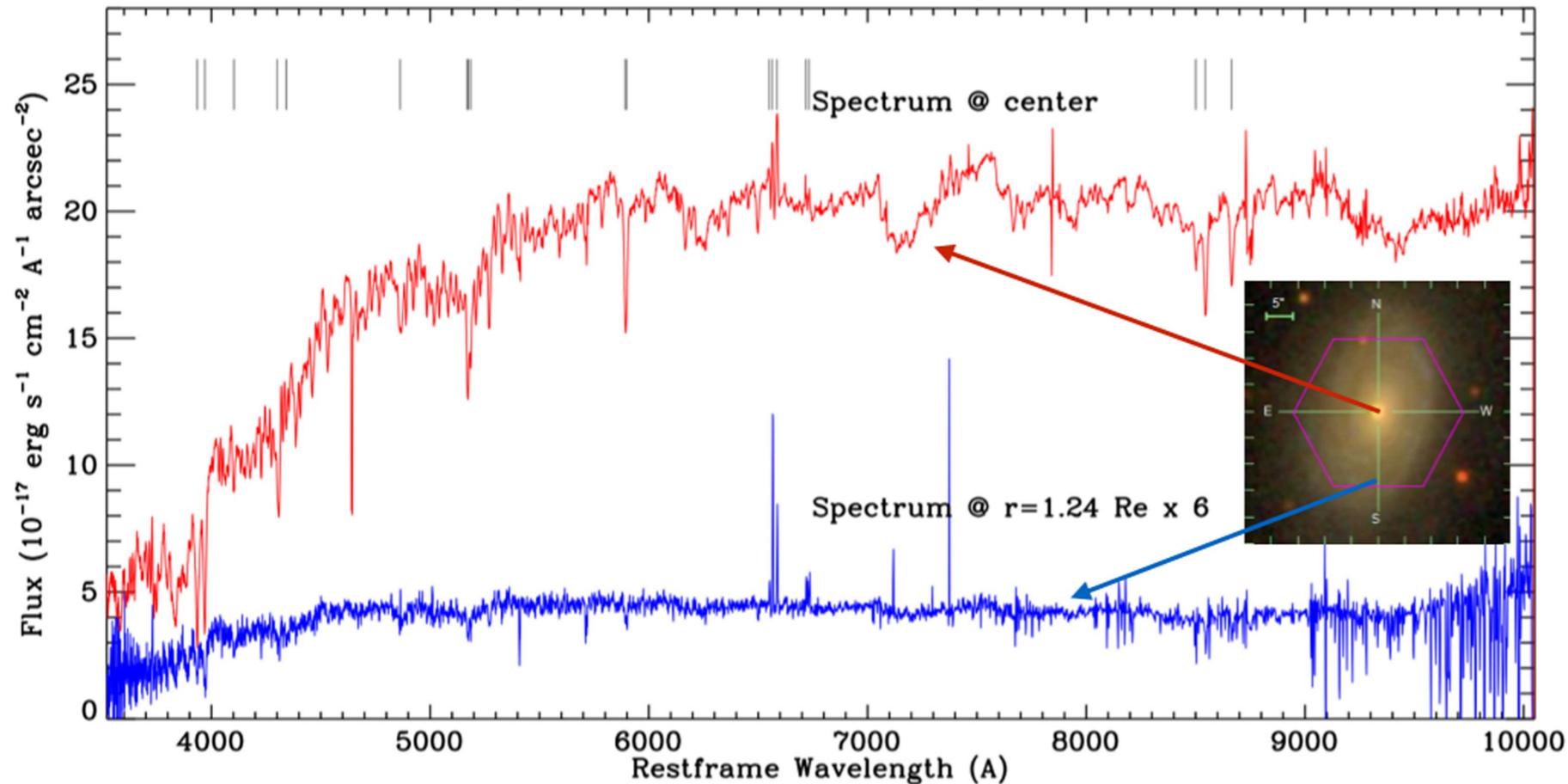
- Illustris simulations
- Transition radius to halo defined in simulations
- Link between metallicity gradient and ex-situ fraction



Cook et al 2016

## Mapping Galaxies at APO

- SDSS-IV collaboration, 2014-2020, PI Kevin Bundy
- 10,000 galaxies, mass-selected above  $10^9 M_{\text{sun}}$ ,  $z=0.005-0.15$  (30×ATLAS3D)



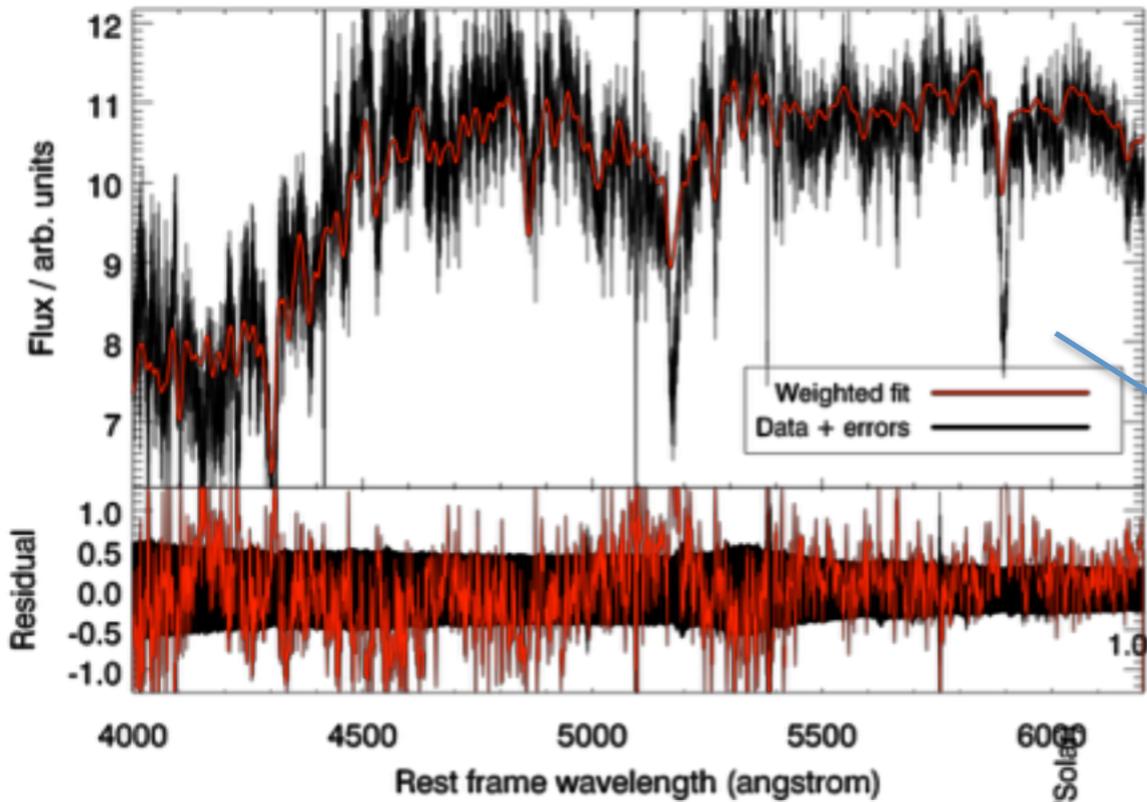
Bundy et al 2015; Drory et al 2015; Law et al 2016;  
Yan et al 2016; Wake et al 2017



# Full Spectral Fitting Code FIREFLY

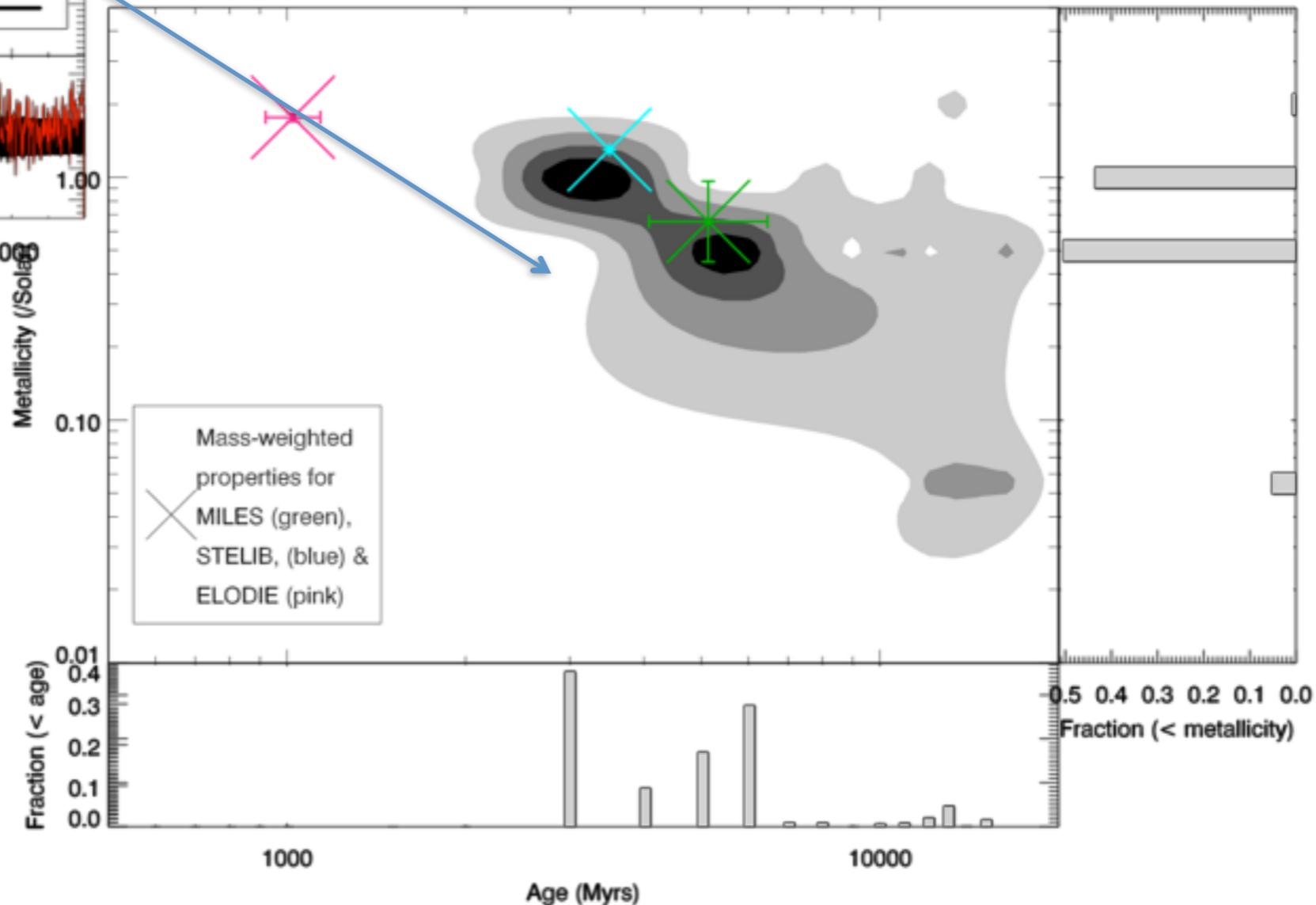


MILES : 0483-51902-532



Gives an array of fits, each as a combination of single-burst modes (SSPs), to get SFH, metallicity, age distribution, etc.

MILES : 0483-51902-532



Fast computation of likelihood surfaces of properties

Ability to change and compare input stellar population model ingredients

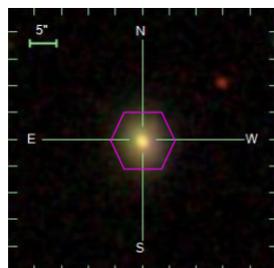
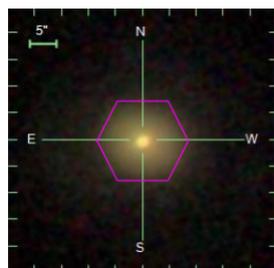
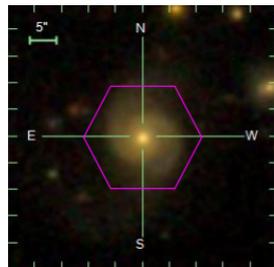
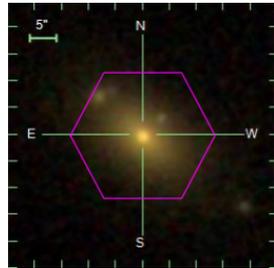
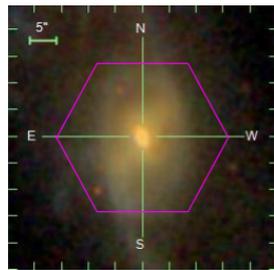
Reconstructs SFHs from combinations of bursts

[Wilkinson et al 2015, 2017;](#)  
[Goddard et al 2017b](#)

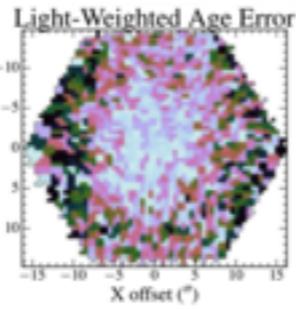
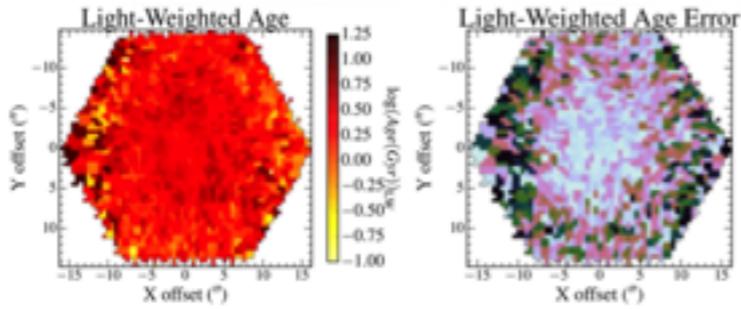


# Maps of stellar population parameters

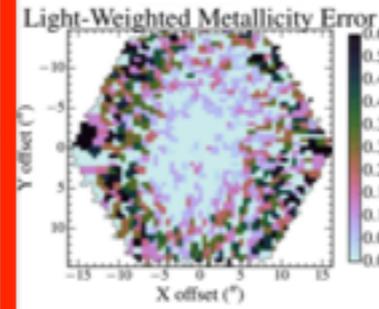
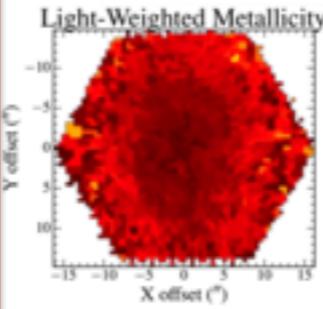
UNIVERSITY OF PORTSMOUTH



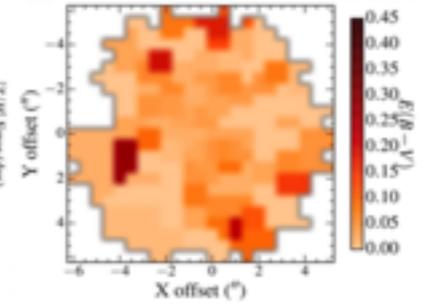
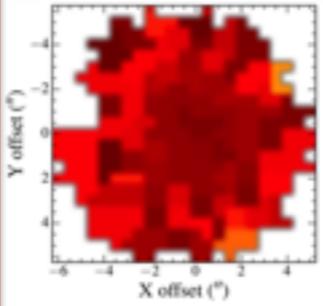
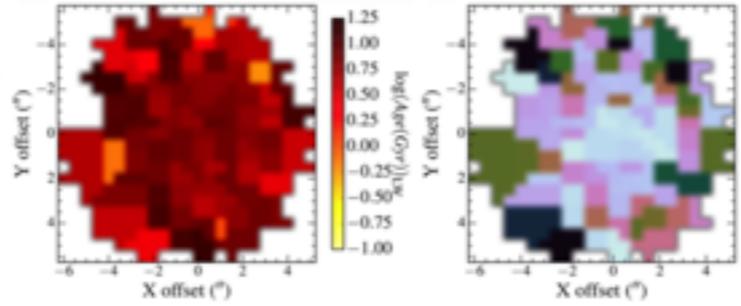
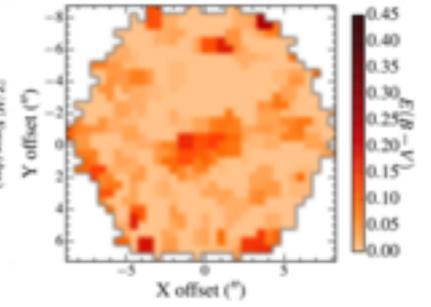
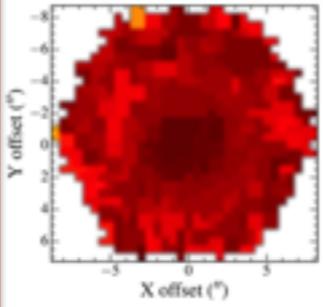
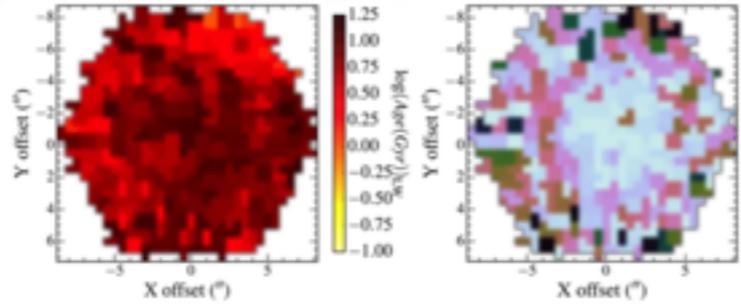
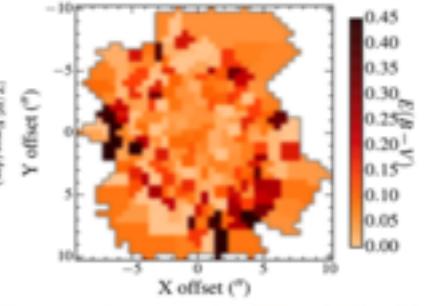
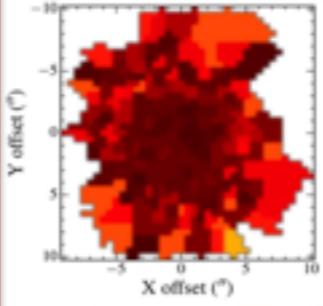
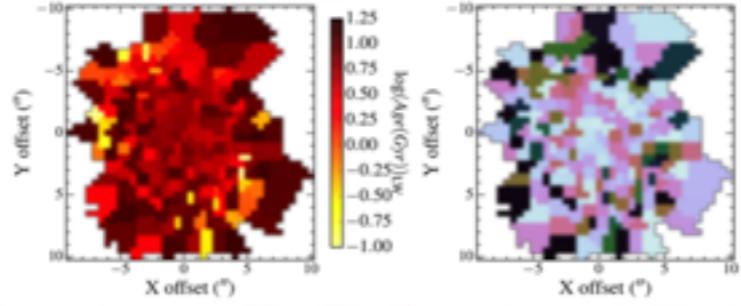
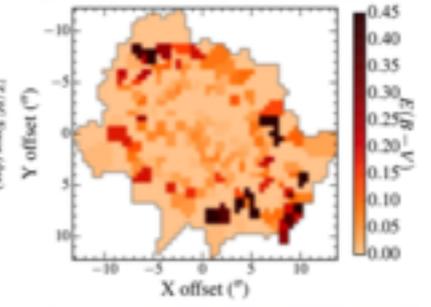
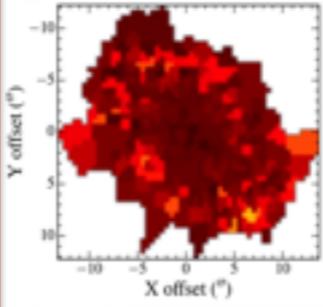
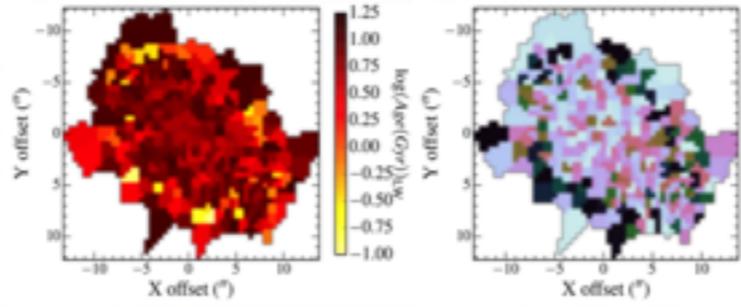
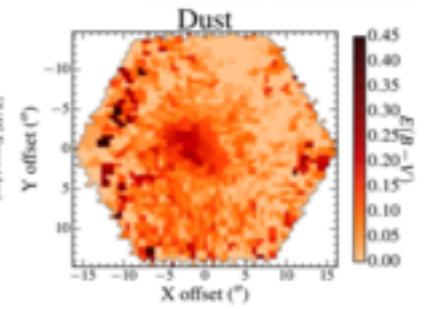
age



metallicity



dust



Goddard et al 2017b

Daniel Thomas - Galaxy haloes with MaNGA

Stellar haloes across the cosmos - Heidelberg - July 2018

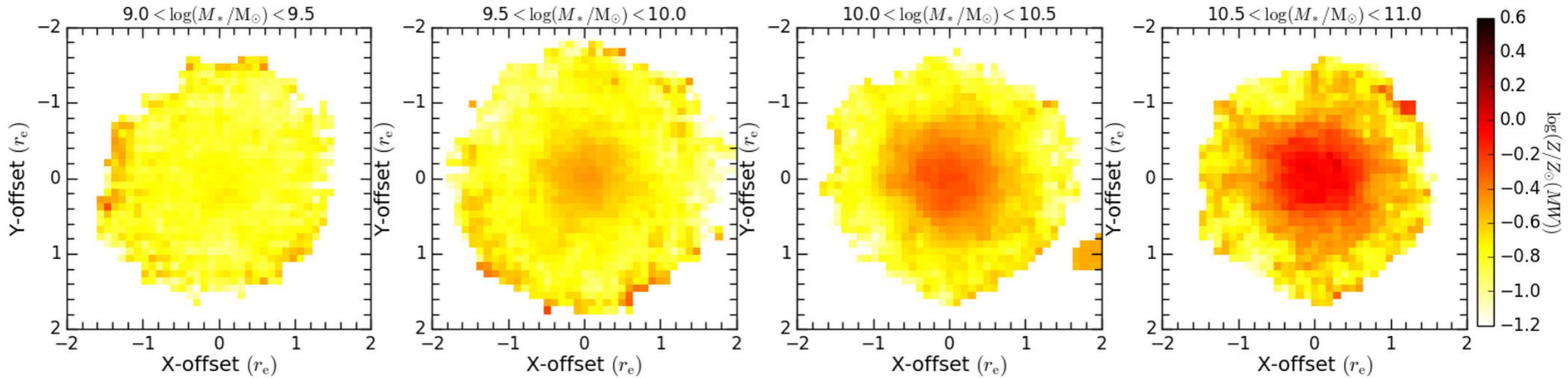
# Metallicity gradients with MaNGA

Stacked maps of 3,000 MaNGA galaxies

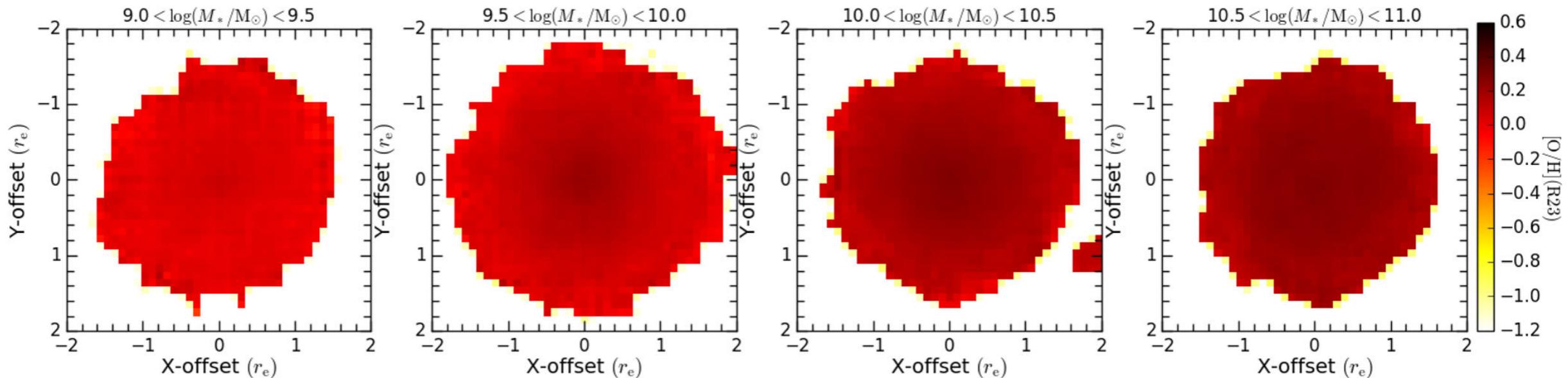
low mass

high mass

stars

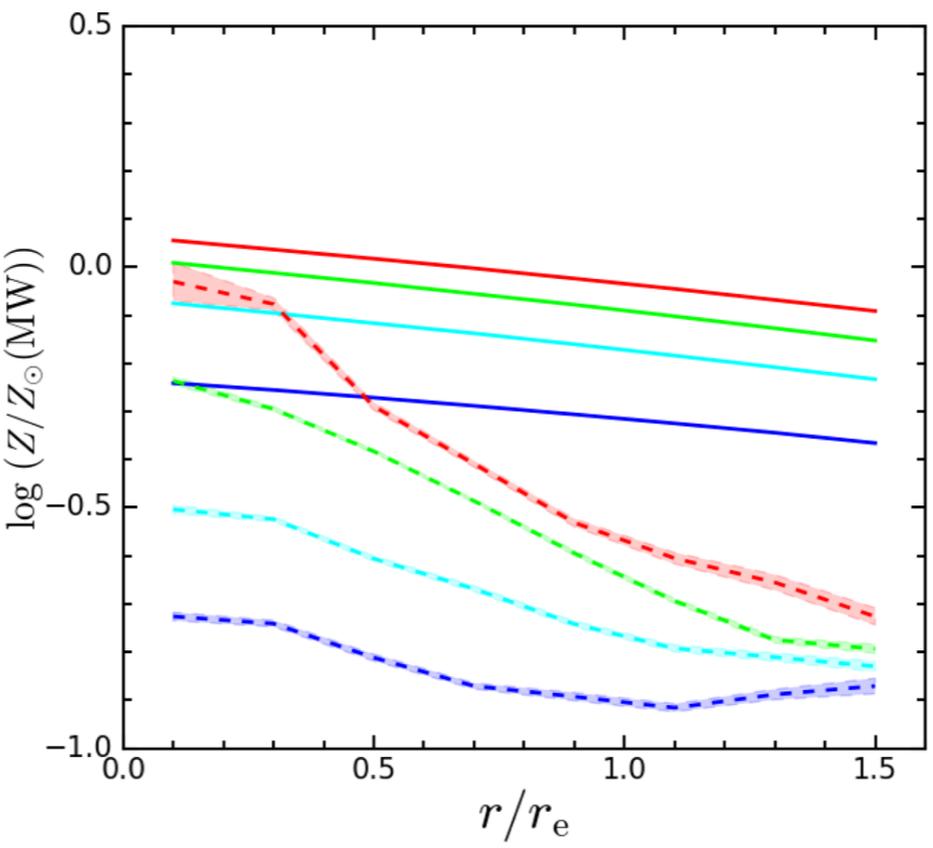
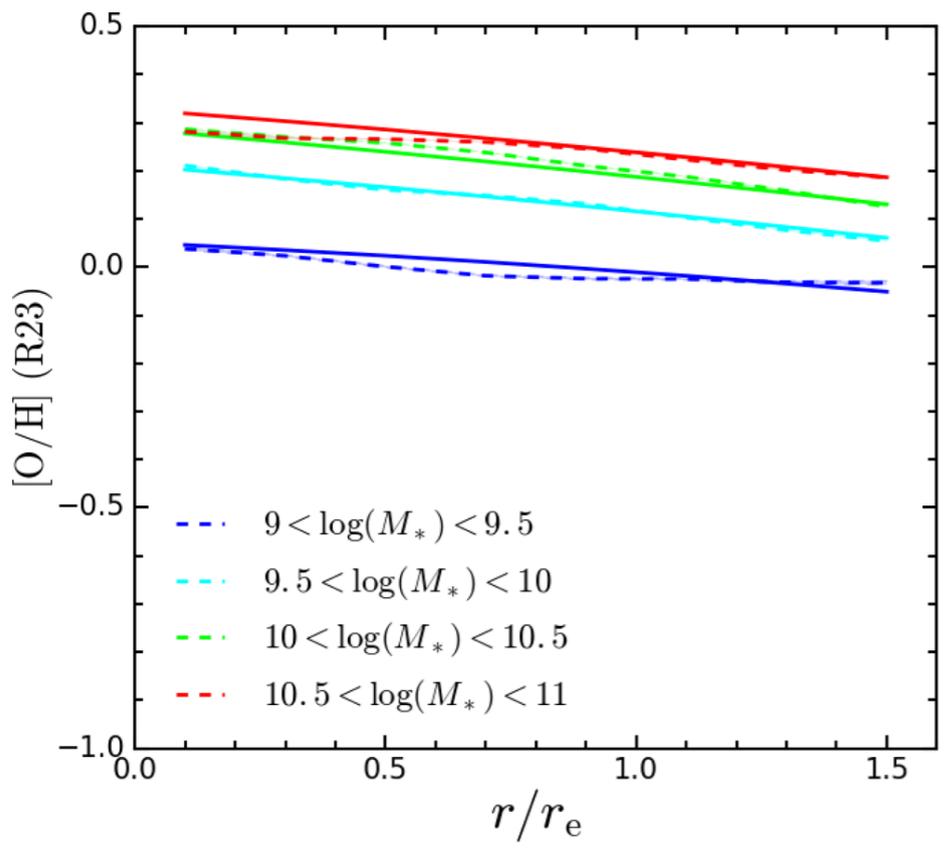


gas



Lian et al 2018b

# Gas vs stars and IMF

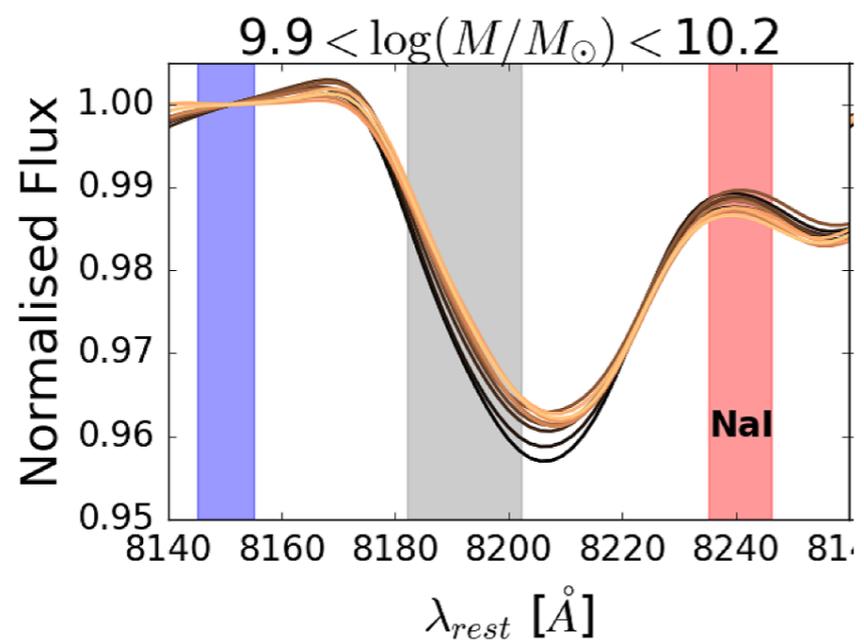


Jianhui Lian

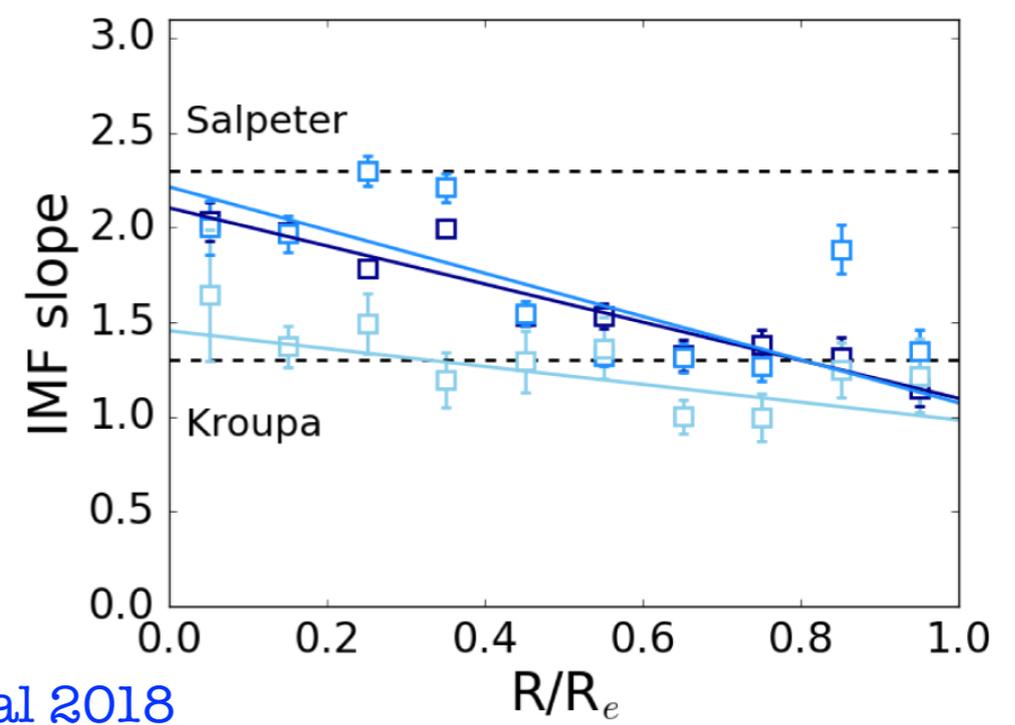
Lian et al 2018a,b



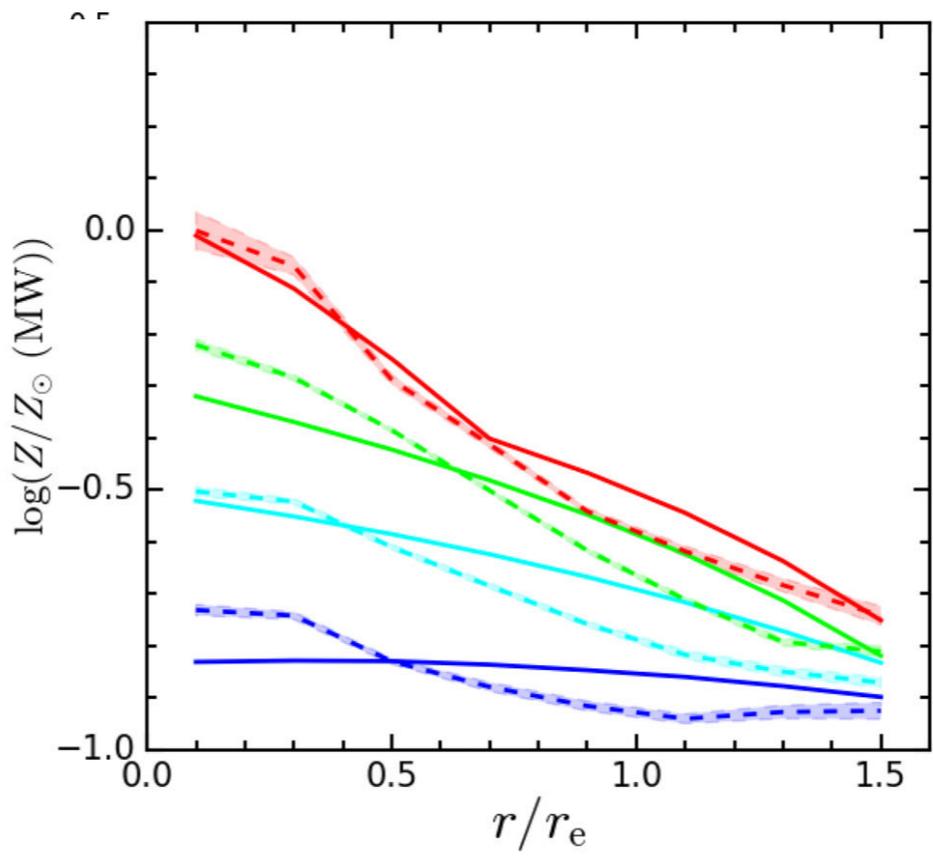
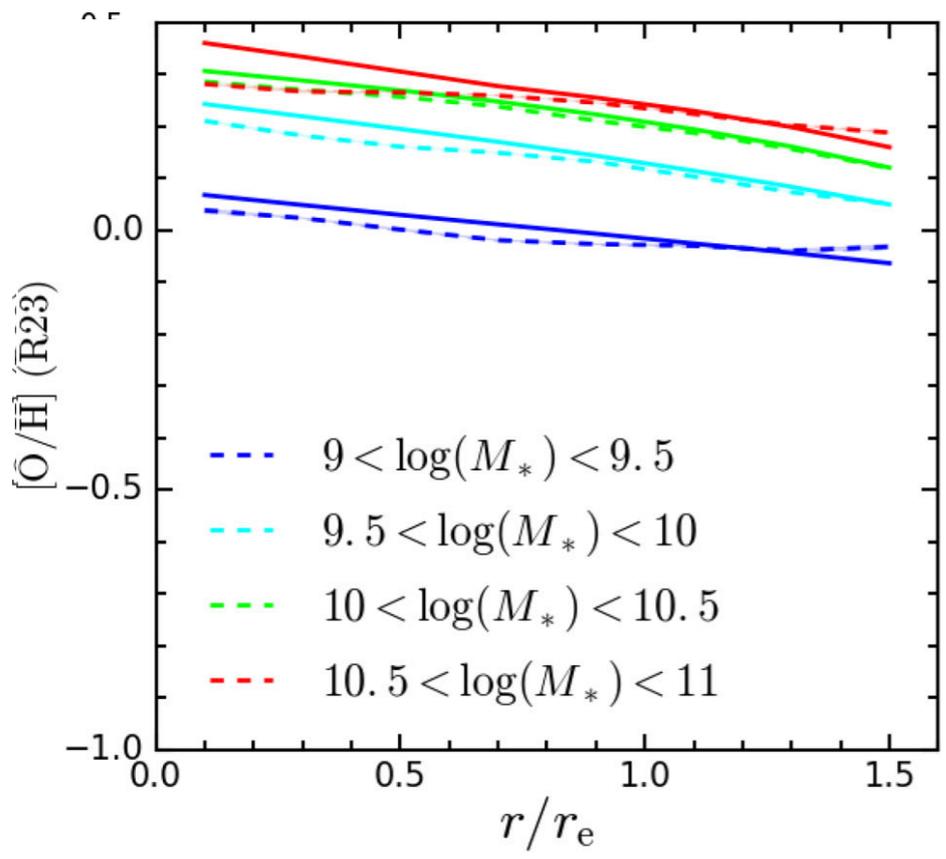
Taniya Parikh



Parikh et al 2018



# Gas vs stars and IMF

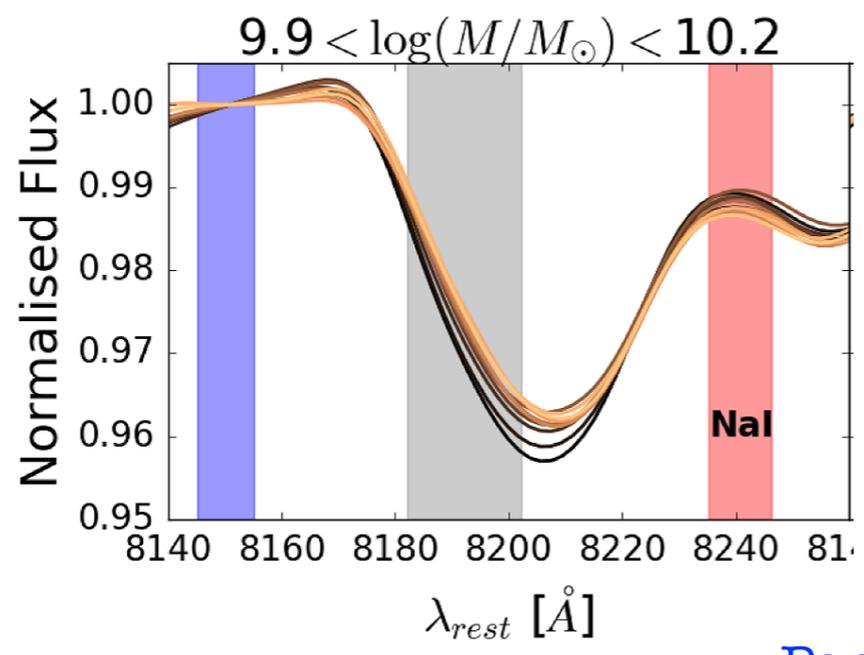


Jianhui Lian

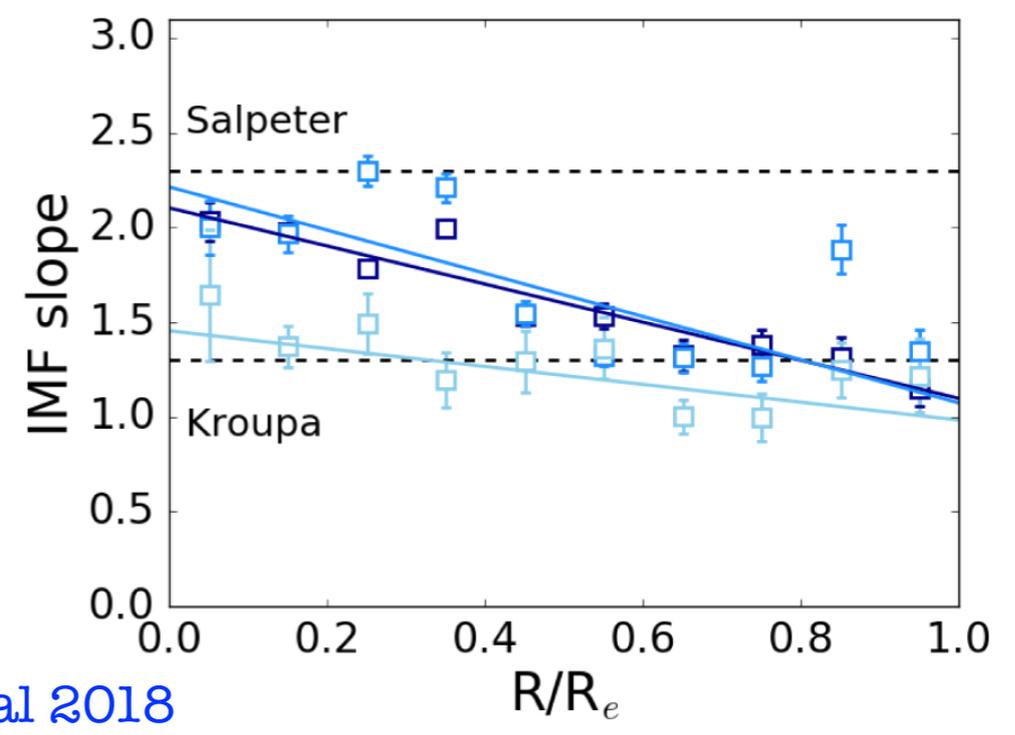
Lian et al 2018a,b



Taniya Parikh



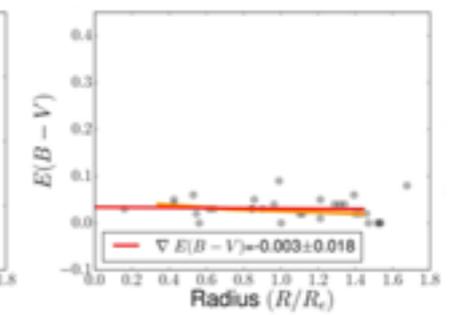
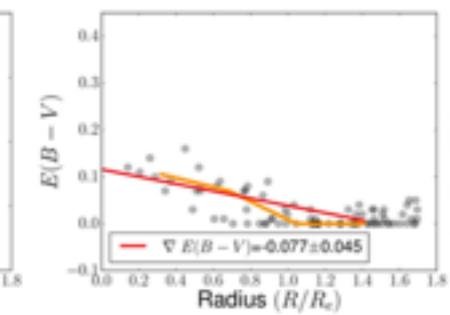
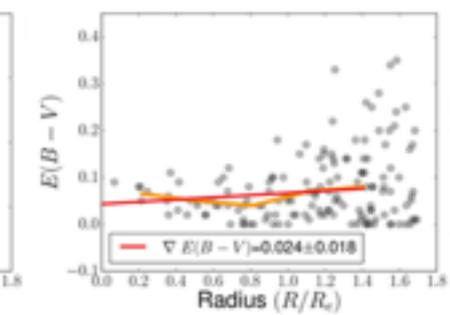
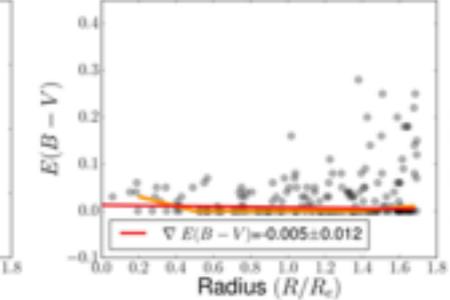
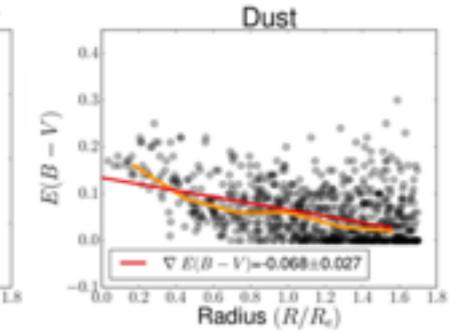
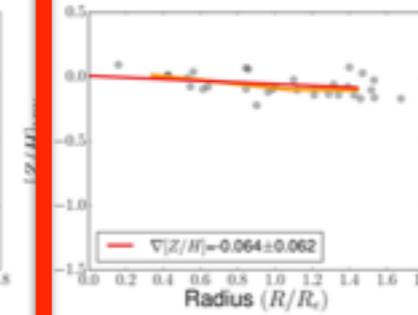
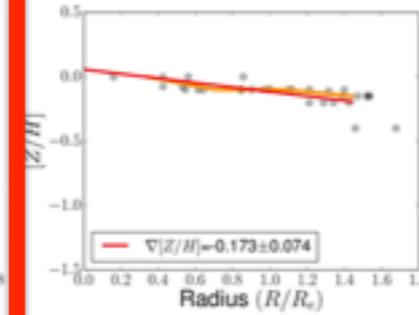
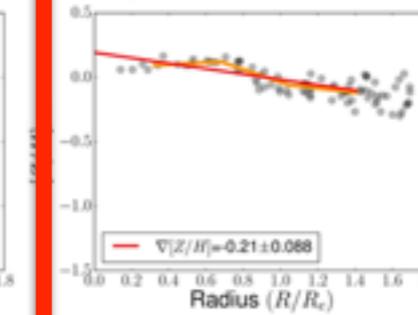
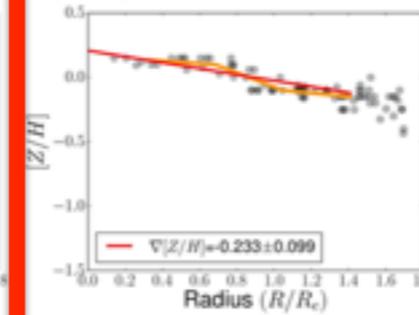
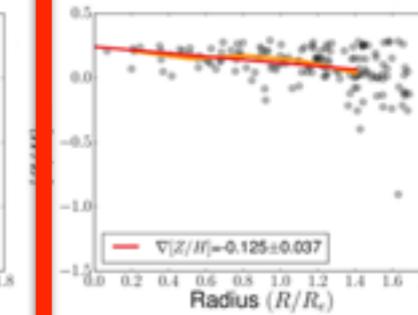
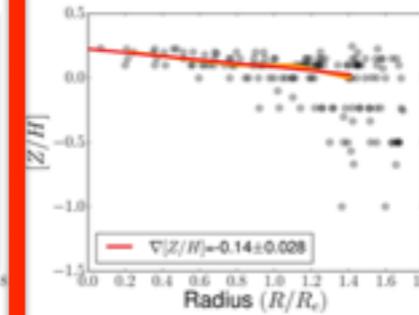
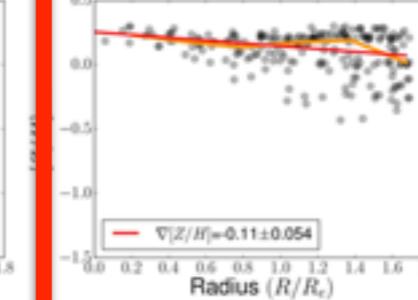
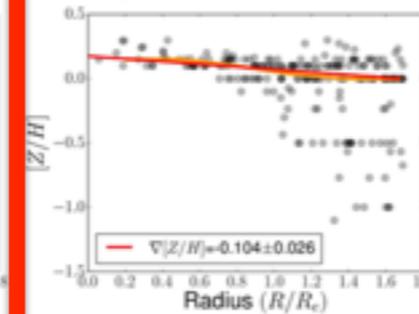
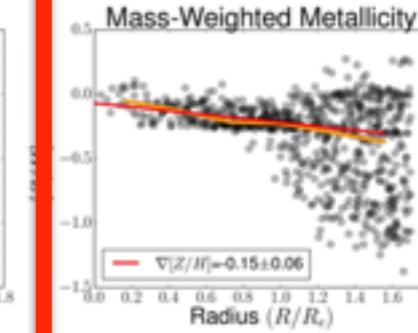
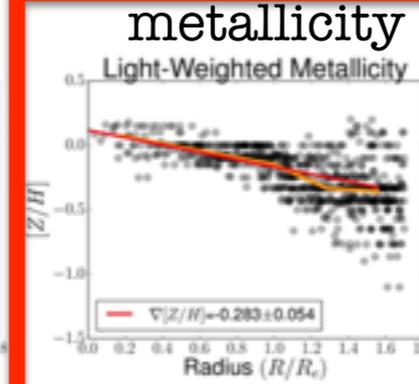
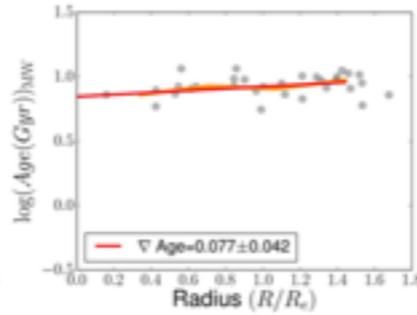
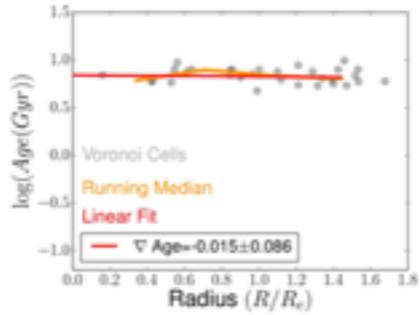
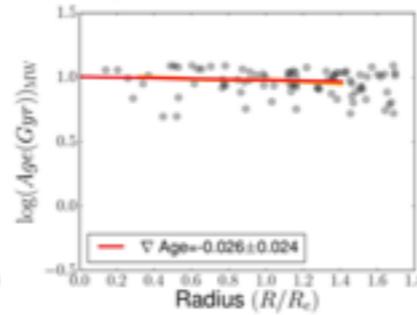
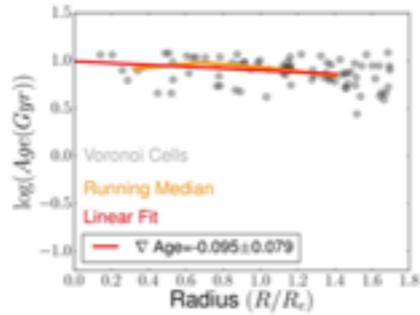
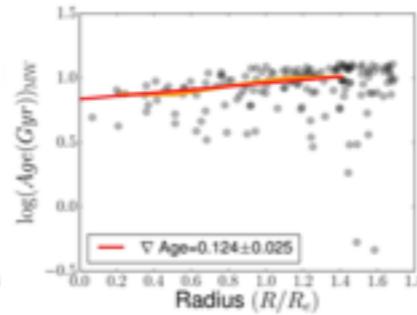
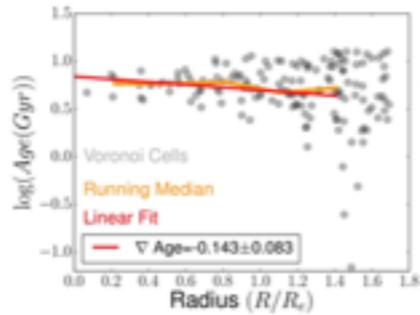
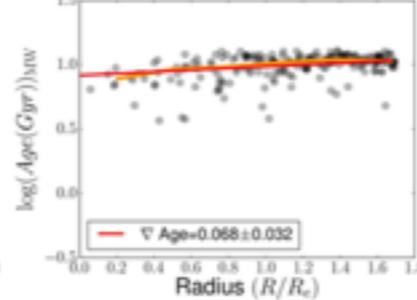
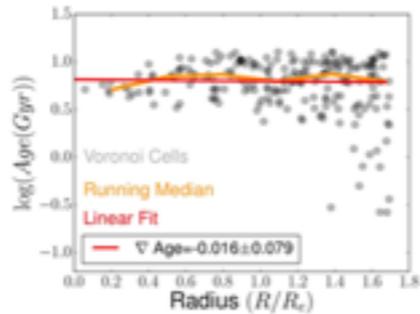
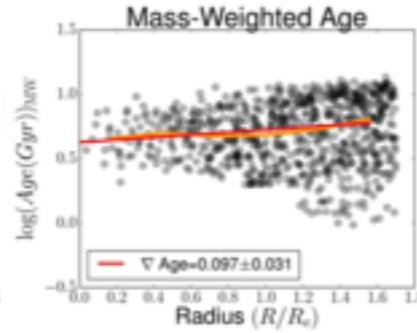
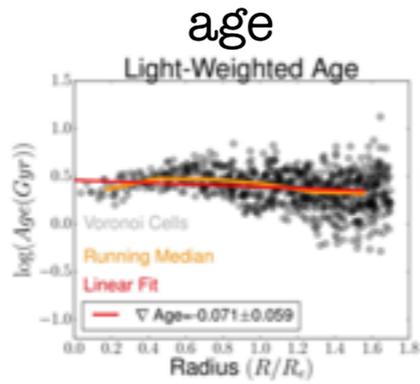
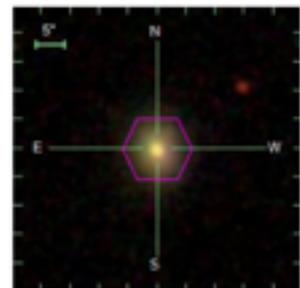
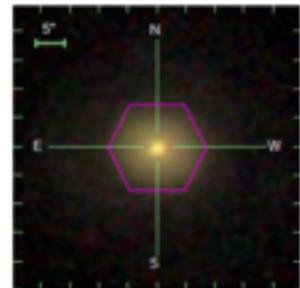
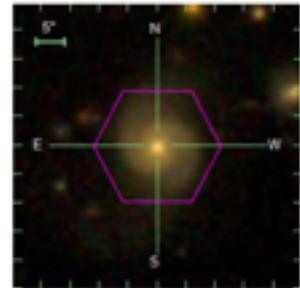
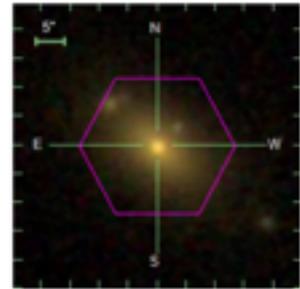
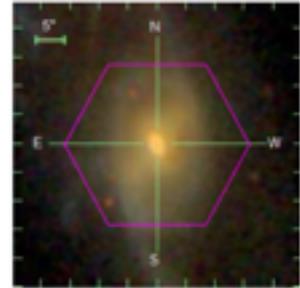
Parikh et al 2018





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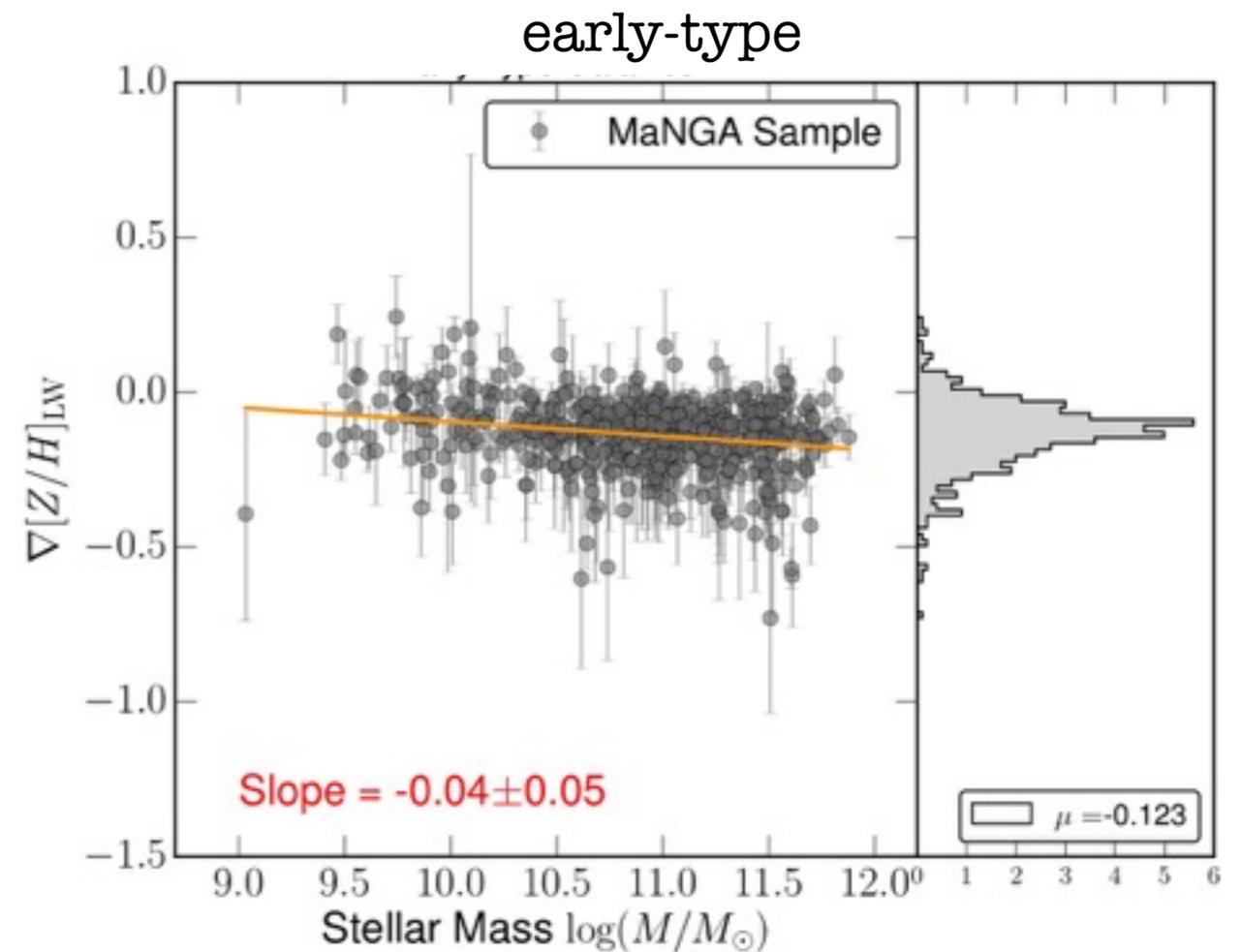
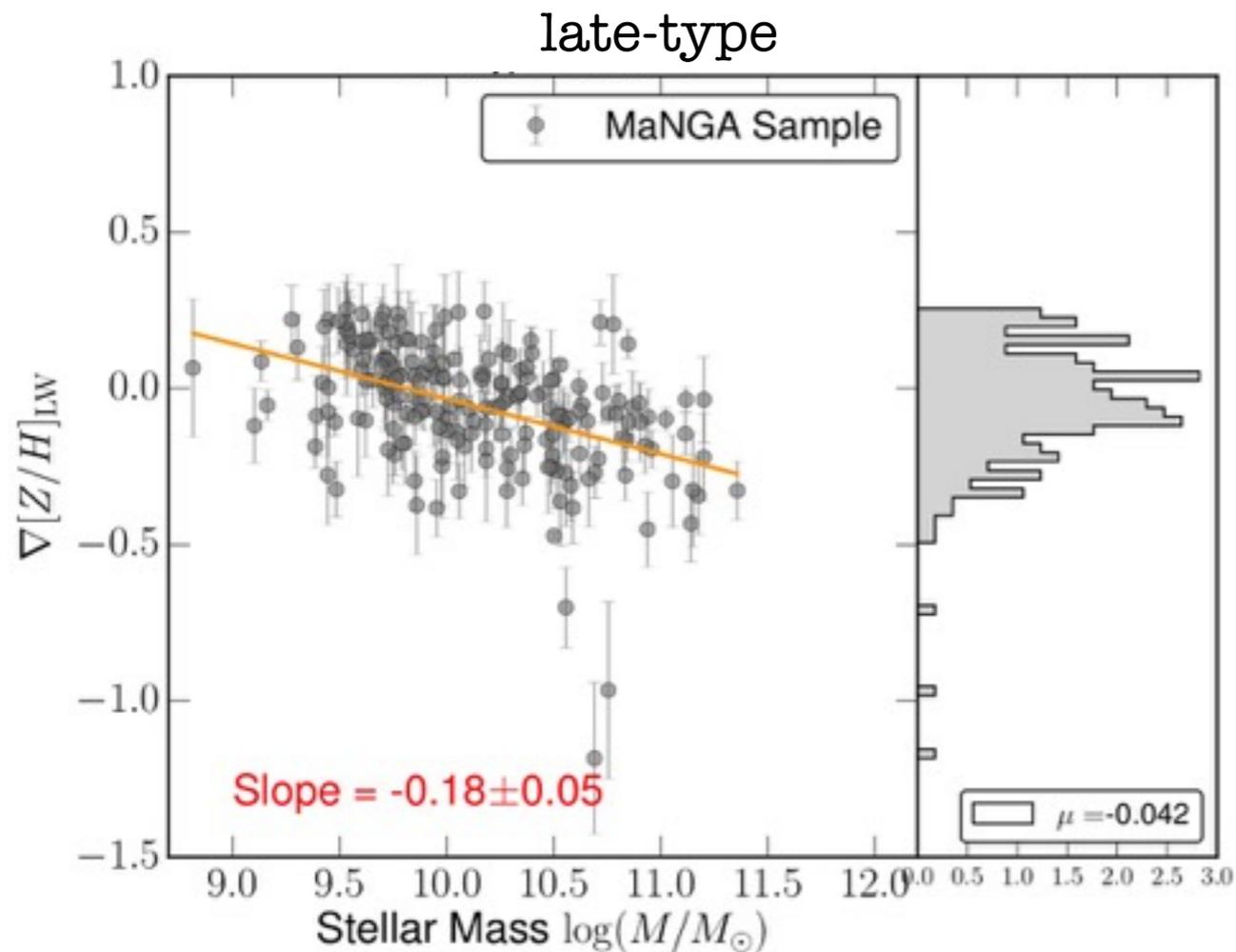
# Stellar population gradients



Goddard

# Z-gradient steepens with galaxy mass

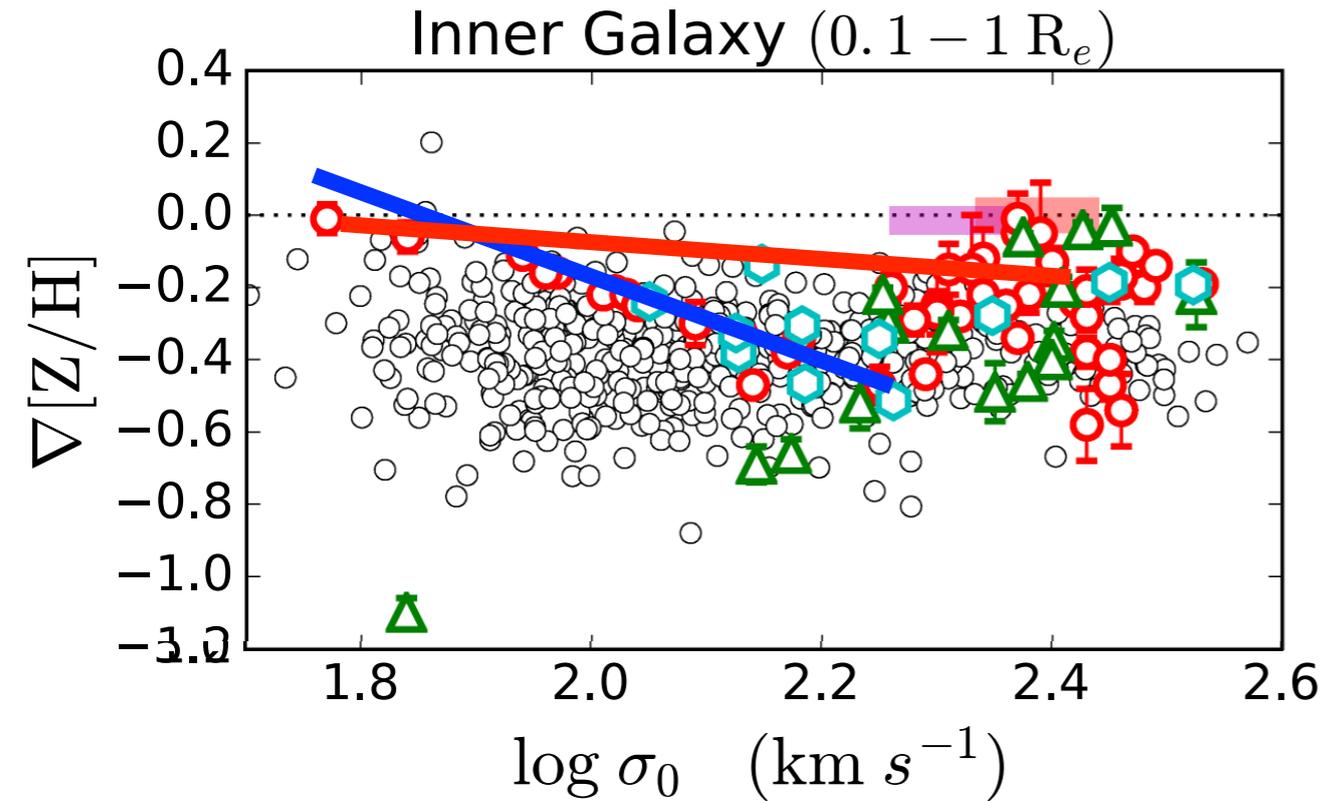
- Negative metallicity gradient steepens with increasing galaxy mass
- **This trend is stronger in late-type galaxies**
- Dip seen at intermediate galaxy masses likely caused by transition from late to early type



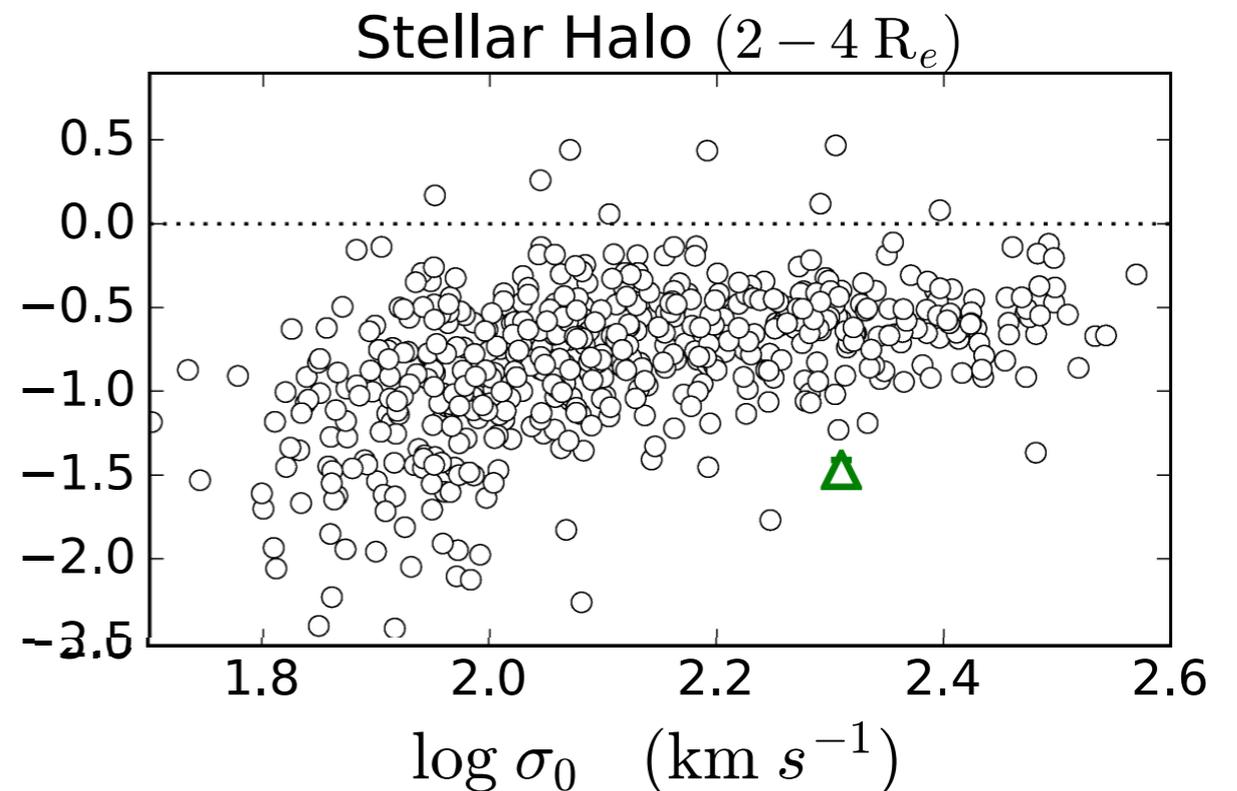
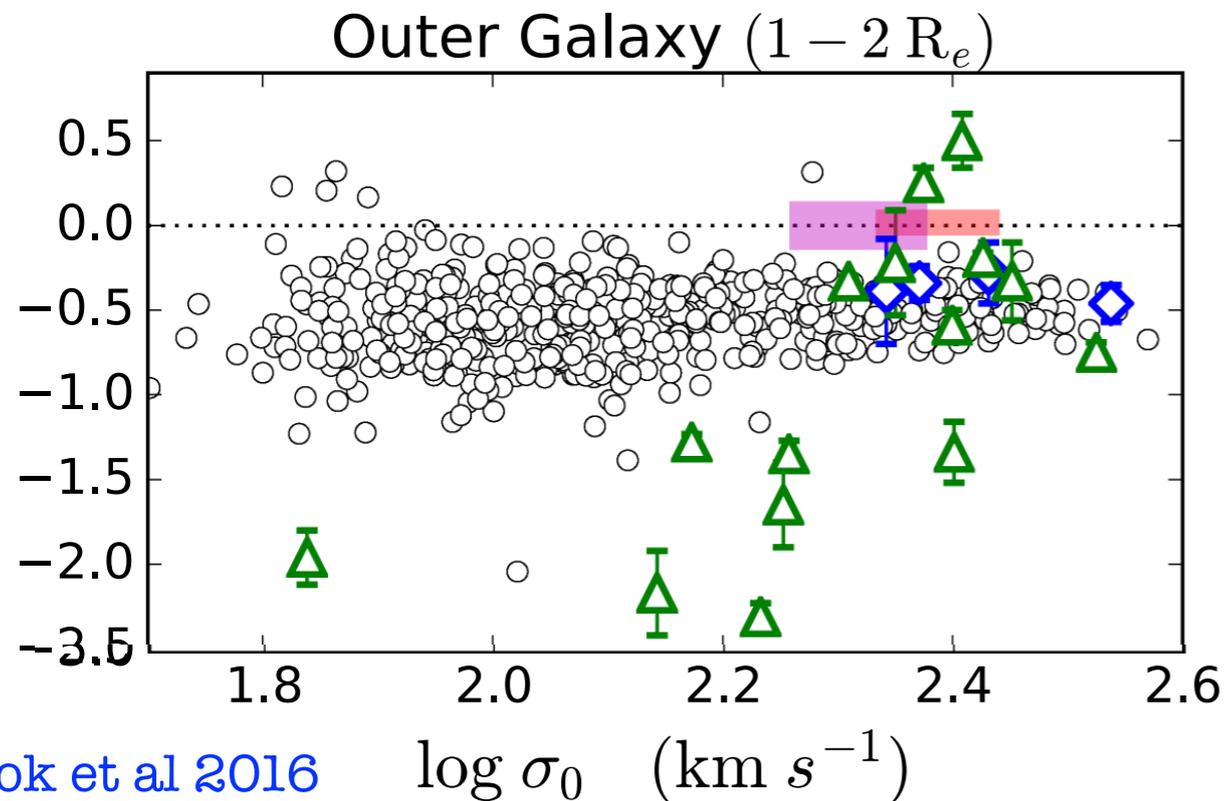
Goddard et al 2017a,b



# Metallicity gradients in transition



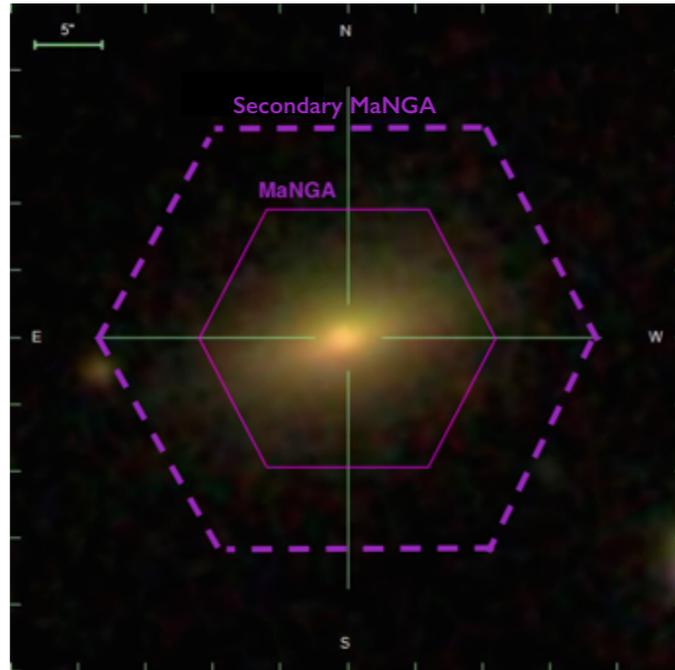
- Update with MaNGA:
- Steepest gradient at **transition between late and early type**
- Stellar halo characterised by **flat gradient**



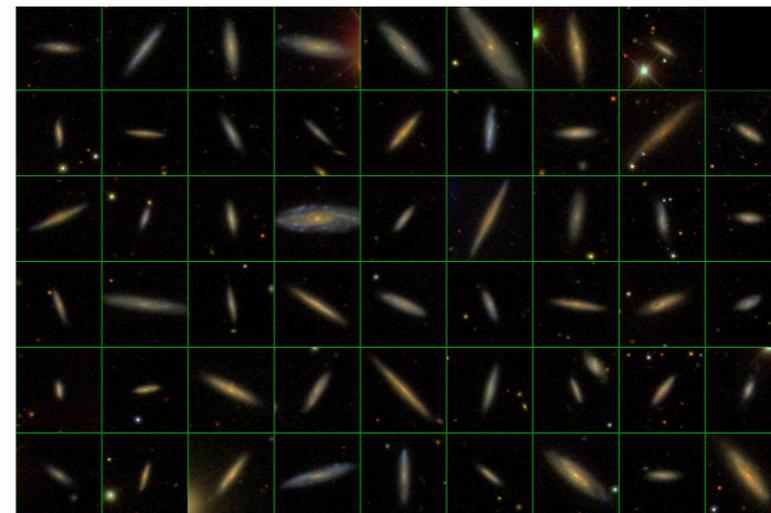
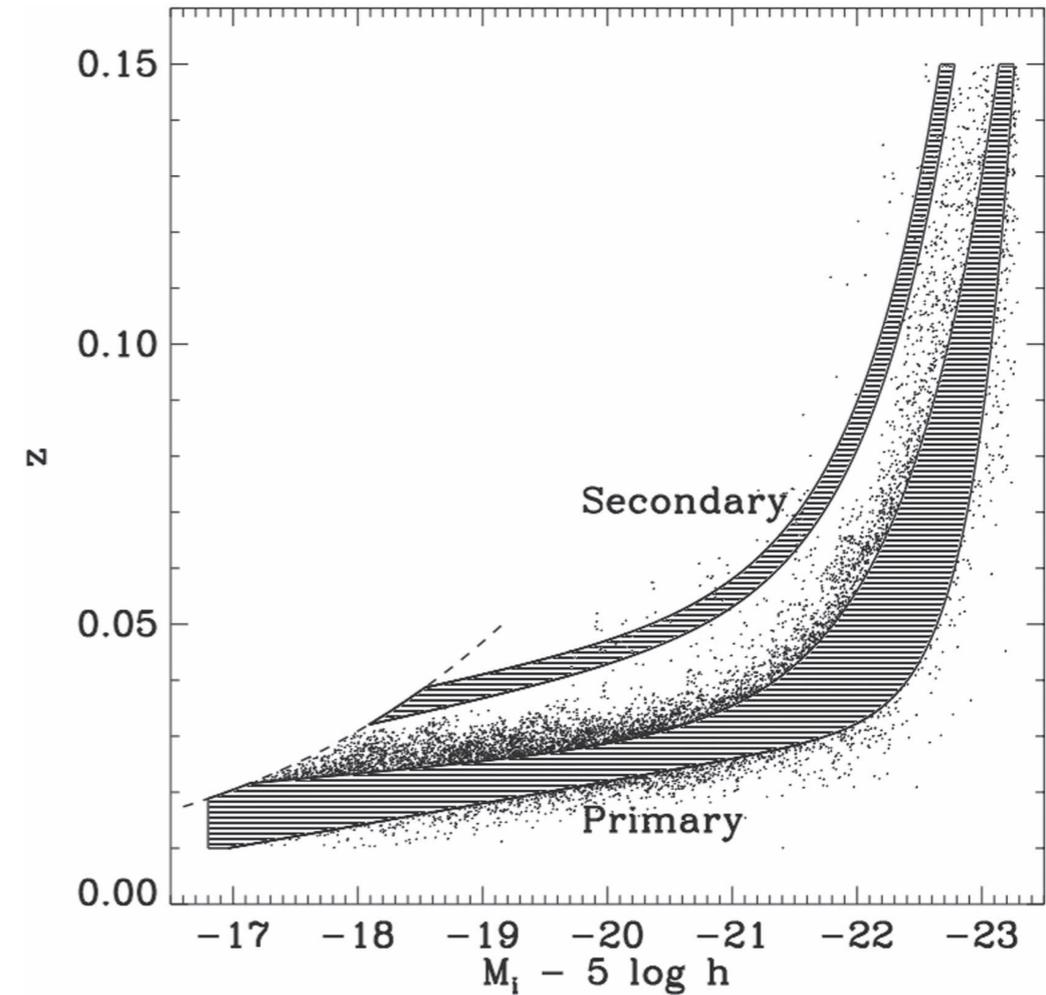
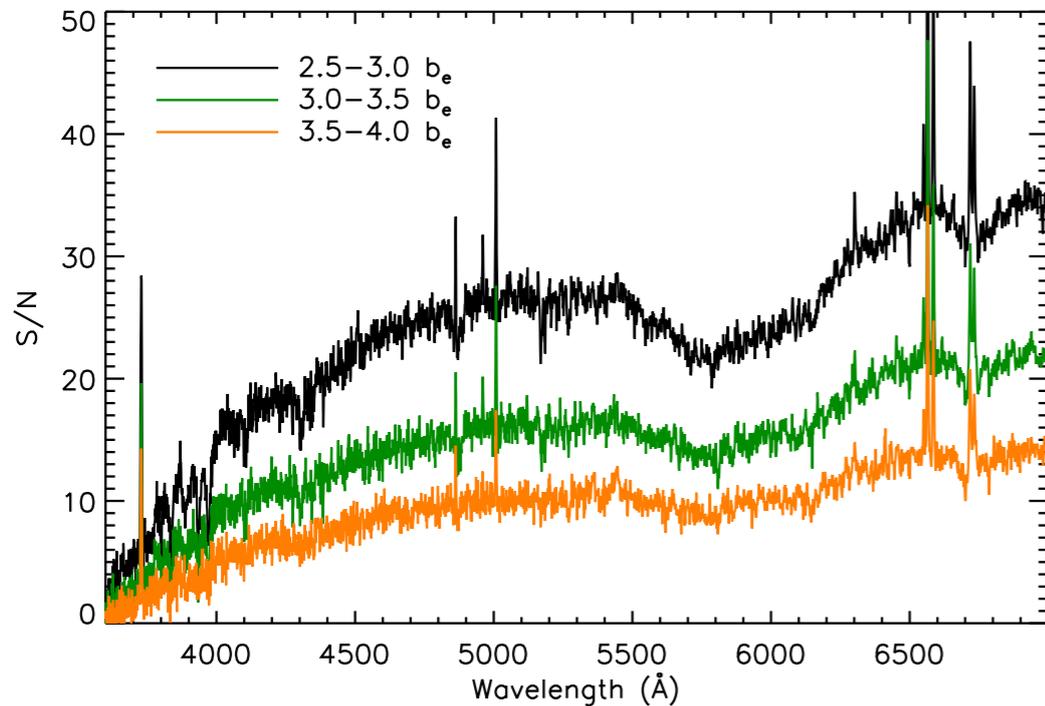
# Pushing MaNGA beyond 1.5 Re

- Secondary sample covering 2.5 Re

2,000 of these



- Stack edge-on galaxies along minor axis

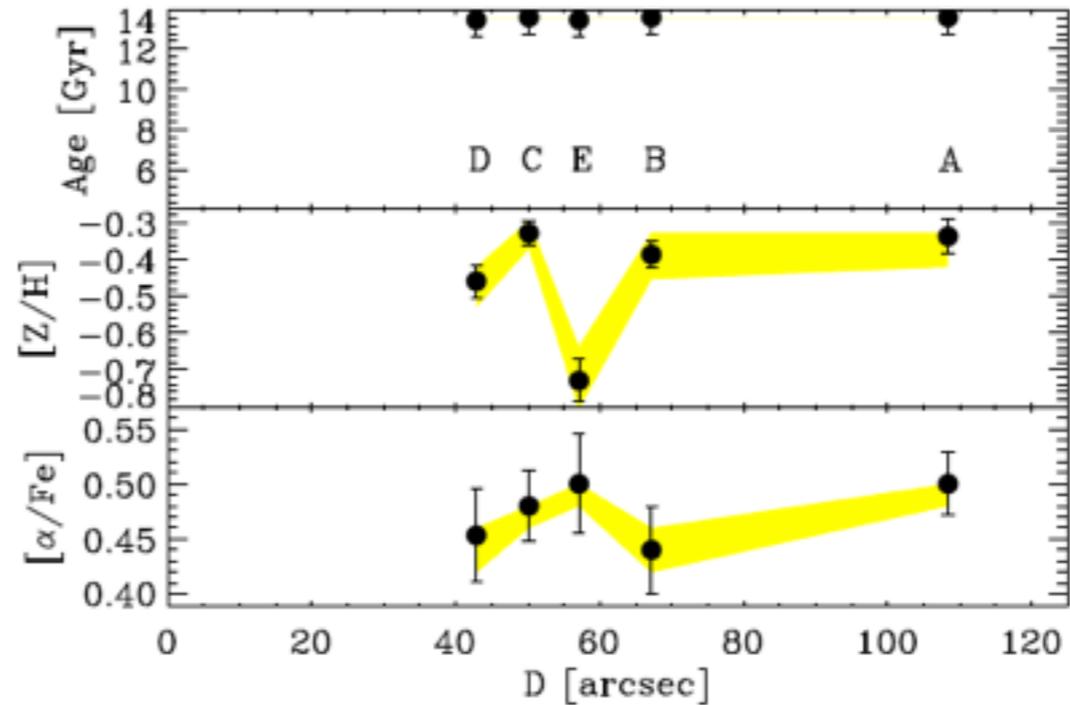
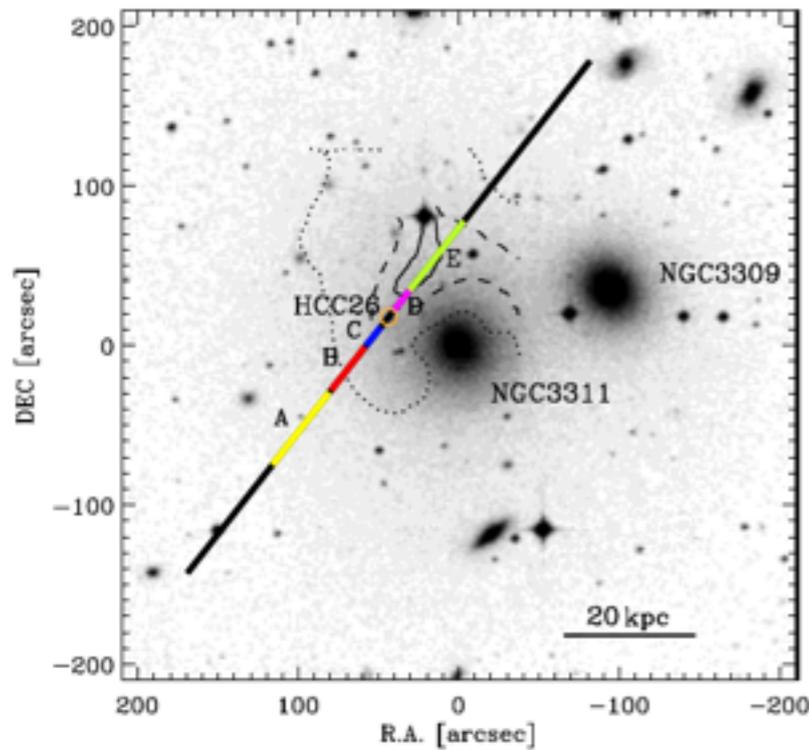


Jones et al 2017

- Coma cluster deep observations (Meng Gu)

# Spectroscopy far out

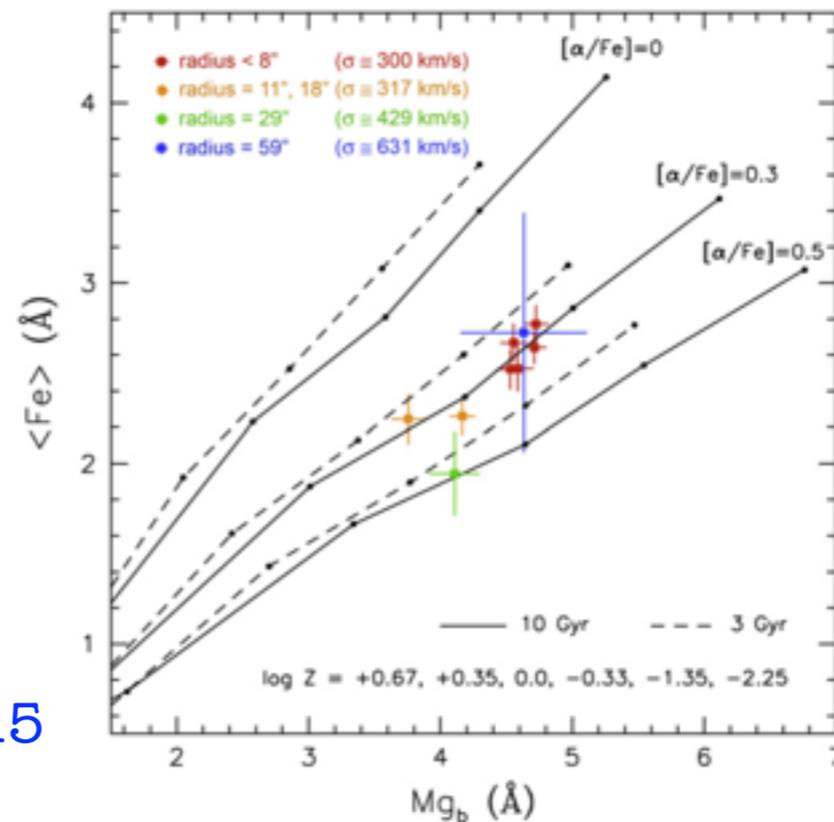
NGC 3311



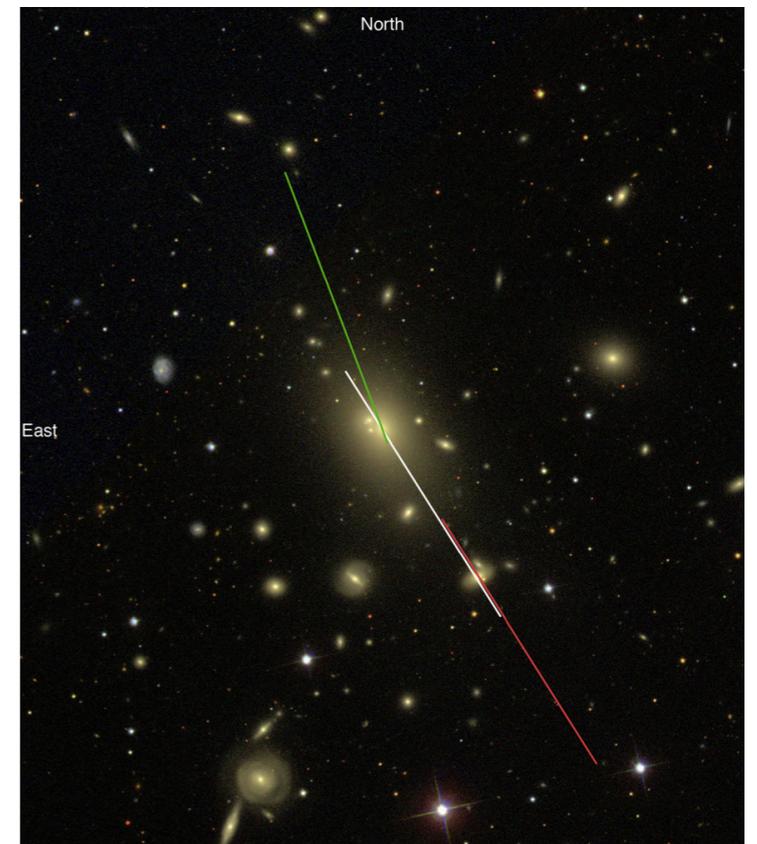
Cocato et al 2011

- Low surface brightness makes spectroscopy hard
- Stellar populations old, alpha-enhanced and metal-rich

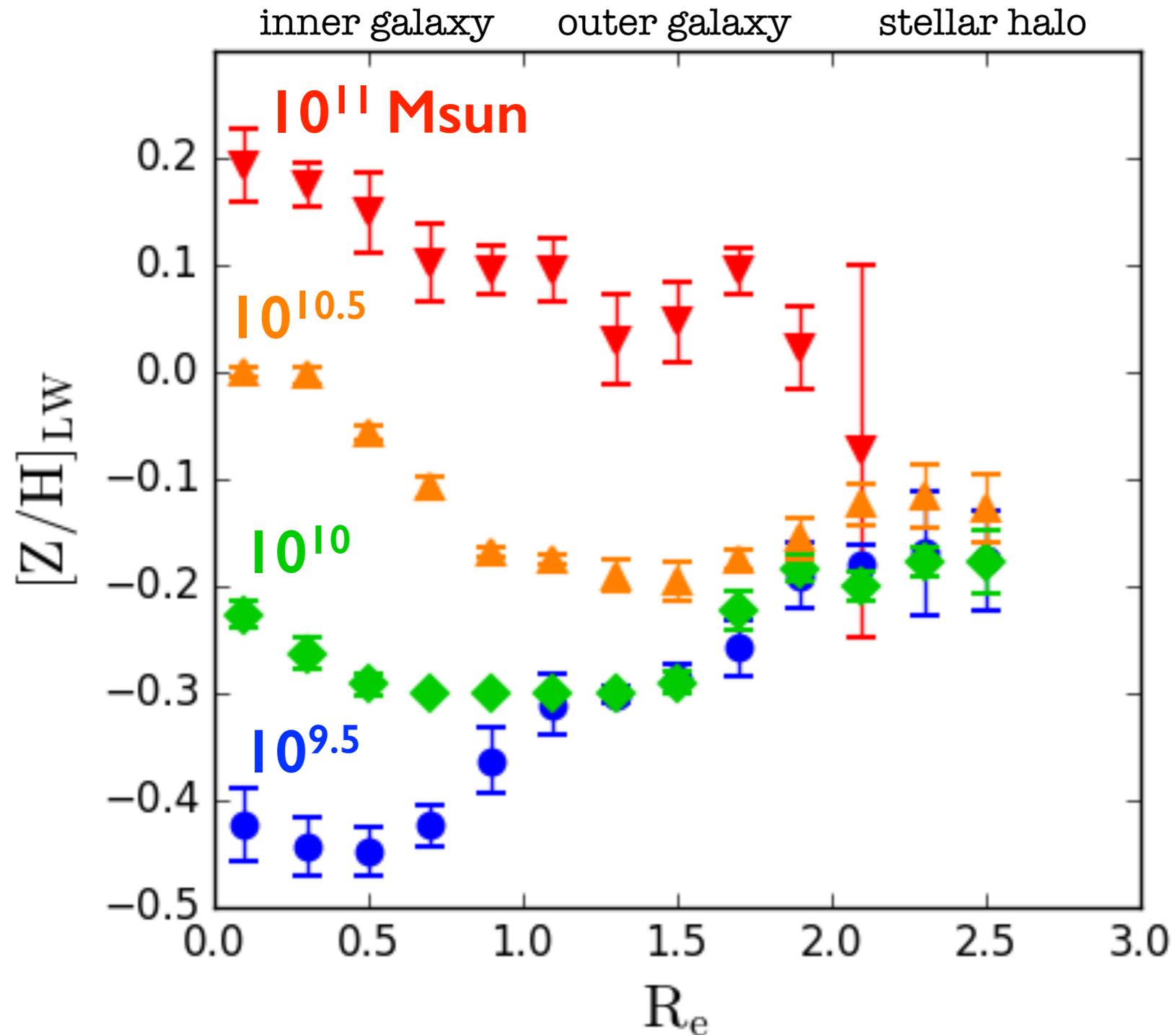
Bender et al 2015



NGC 6166



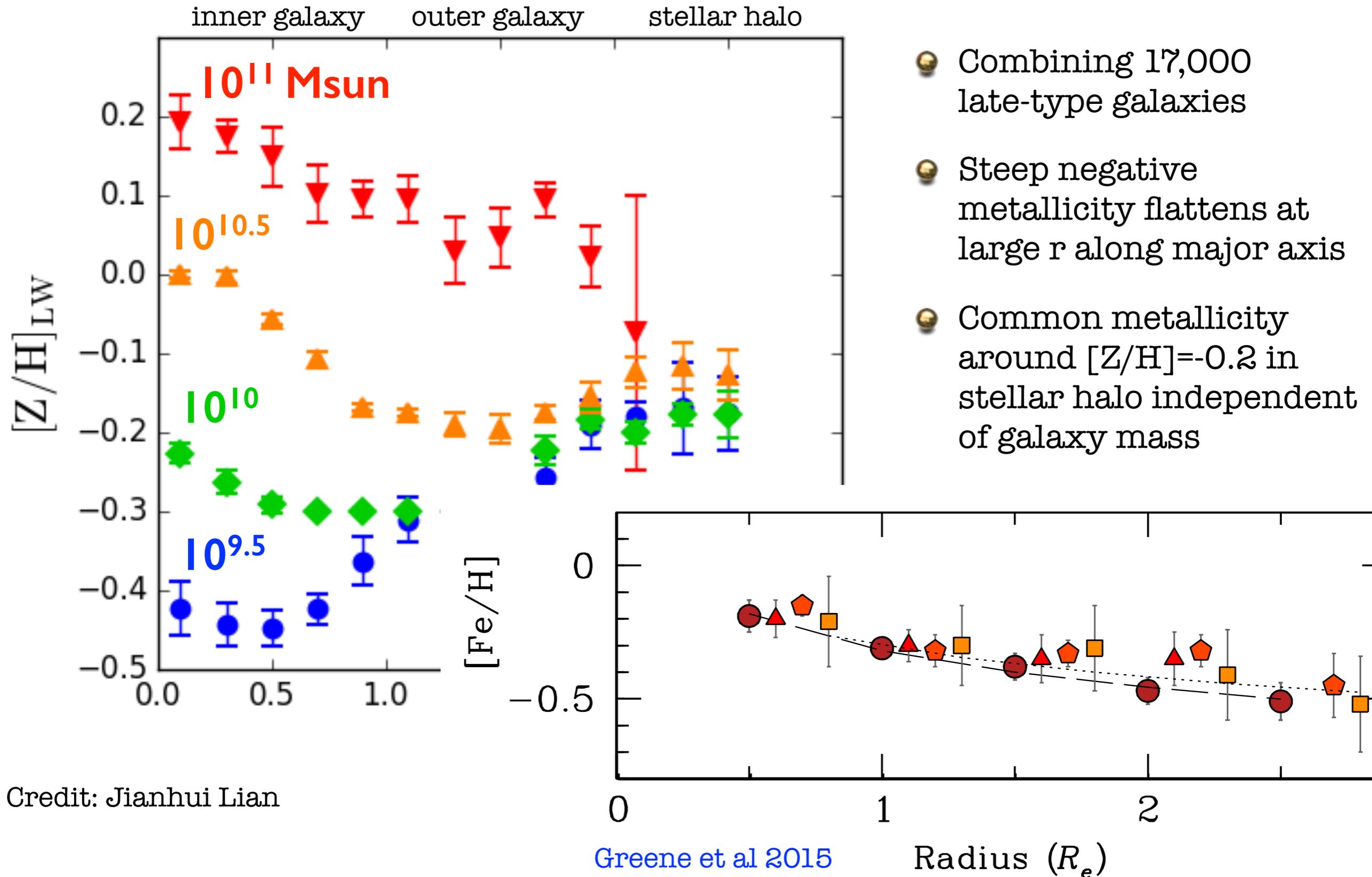
# MaNGA gradients out to $2.5 R_e$



- Combining 17,000 late-type galaxies
- Steep negative metallicity flattens at large  $r$  along major axis
- Common metallicity around  $[Z/H] = -0.2$  in stellar halo independent of galaxy mass

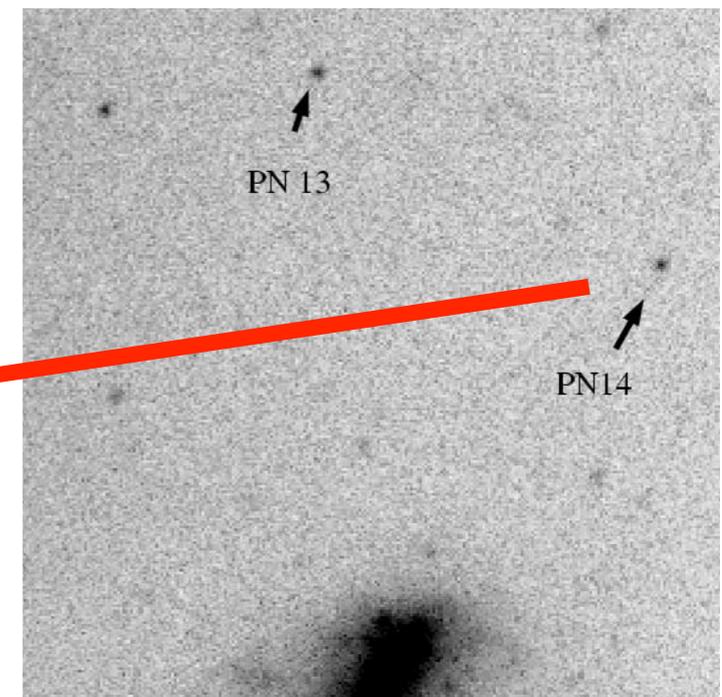
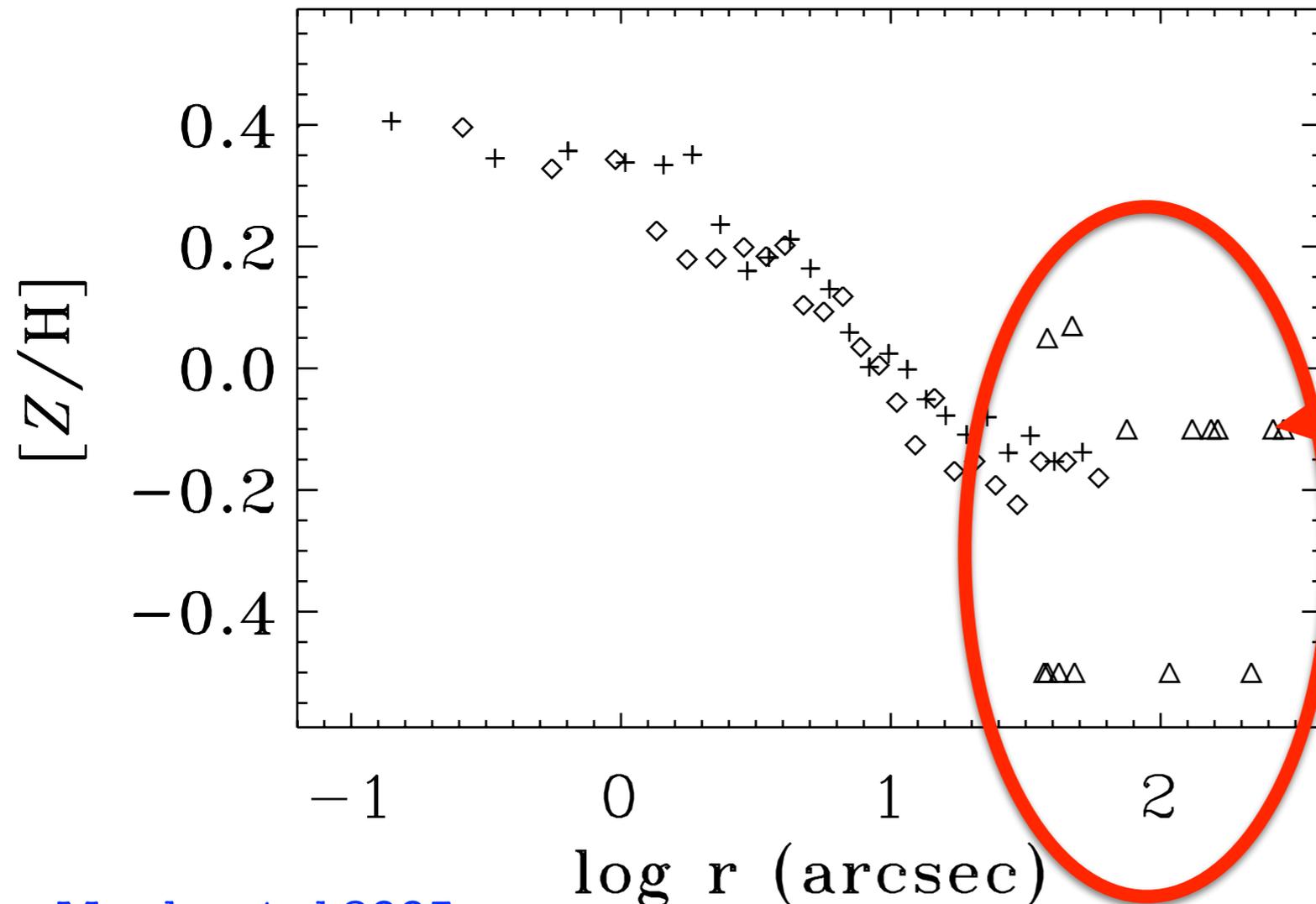
Credit: Jianhui Lian

# MaNGA gradients out to $2.5 R_e$



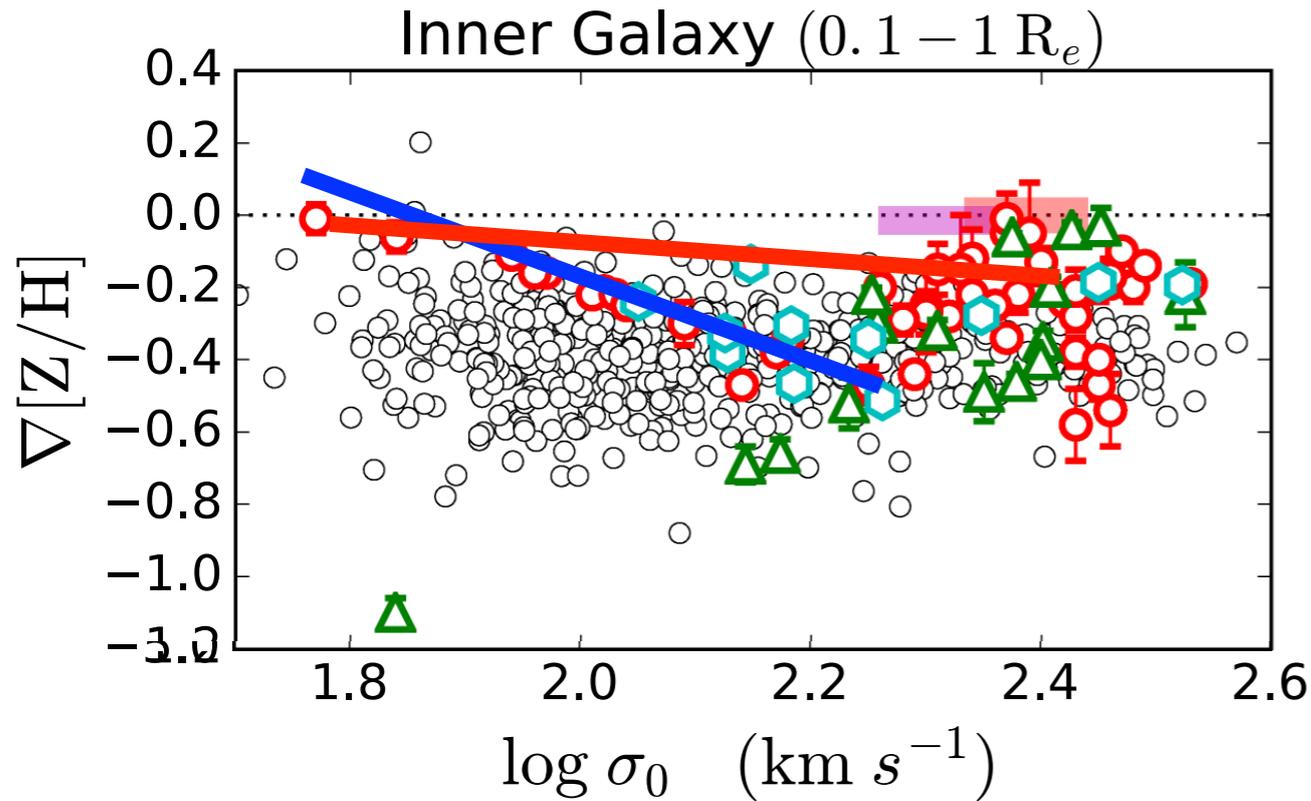
# Stellar halo Z with Planetary Nebulae

- NGC 4679
- Combine stellar light measurements with Planetary Nebula metallicities to reach stellar halo
- Flat Z gradient (but large scatter)

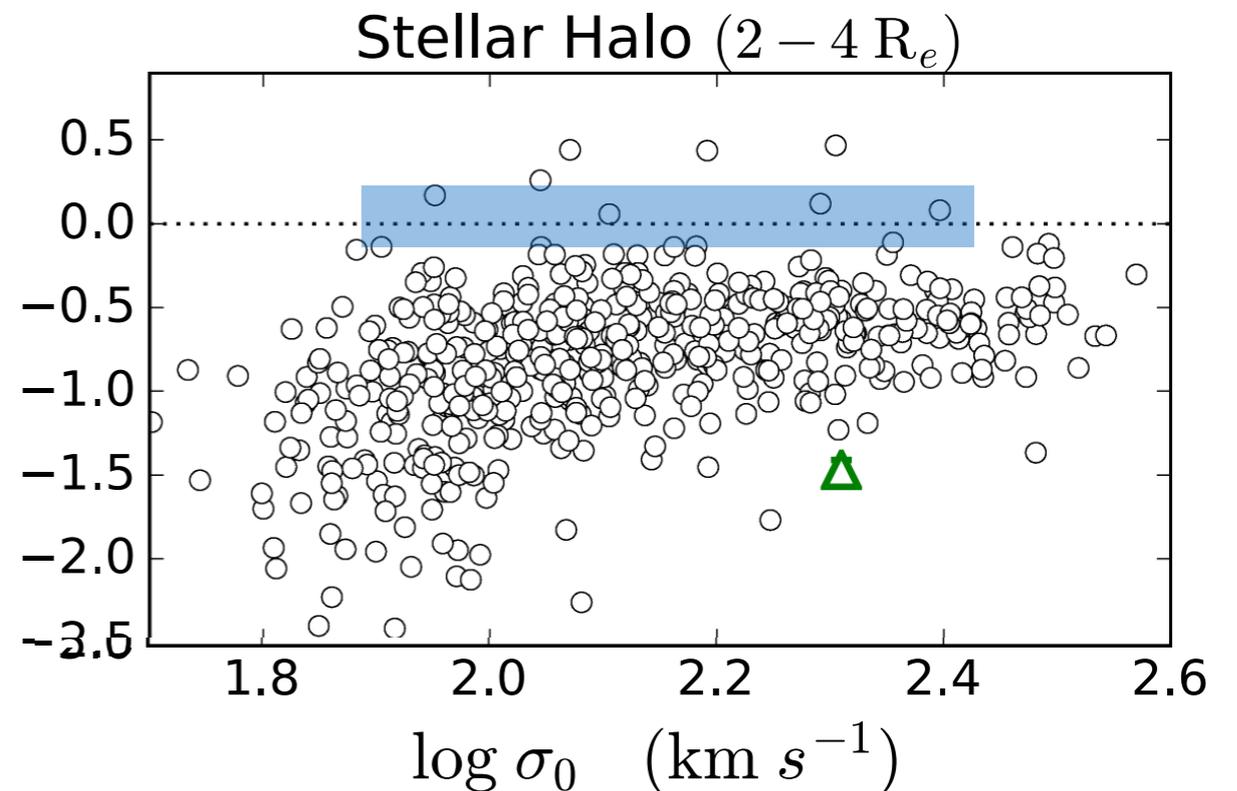
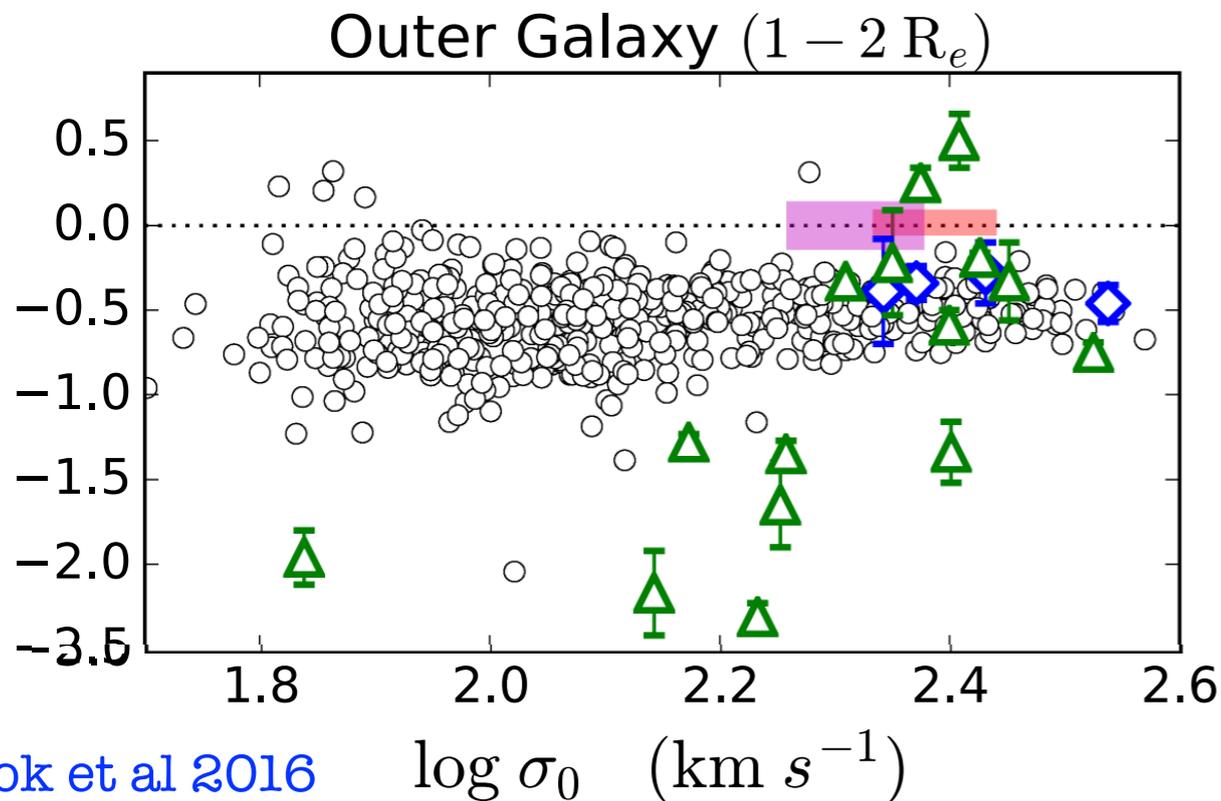


Mendez et al 2005

# Metallicity gradients in transition



- Update with MaNGA:
- Steepest gradient at **transition between late and early type**
- Stellar halo characterised by **flat gradient**



Cook et al 2016

# Table talk

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