What are the processes controlling the quenching of star formation?

Jorge Moreno
@astroboy_moreno
jorge.moreno@cfa.harvard.edu

The Changing Face of Galaxies
Hobart, Tasmania, Australia (9/20/2016)

HARVARD-SMITHSONIAN
CENTER FOR ASTROPHYSICS

CAL POLY POMONA

A. F. L. Bluck | H. Teimoorinia | B. Henriques
S. L. Ellison | D. R. Patton | J. T. Mendel
L. Simard |E. Starkenburg | C. Bottrell
P. Torrey | L. E. Hernquist | P. F. Hopkins
+ FIRE Collaboration

AZTLÁN INSTITUTE
BANNEKER INSTITUTE

Remi Rimple | Adrianna Pérez | Luis Nuñez | José Flores | Areli Rojas
(Not Shown: Francisco Mercado)

Award #1516374

National Science Foundation
WHERE DISCOVERIES BEGIN

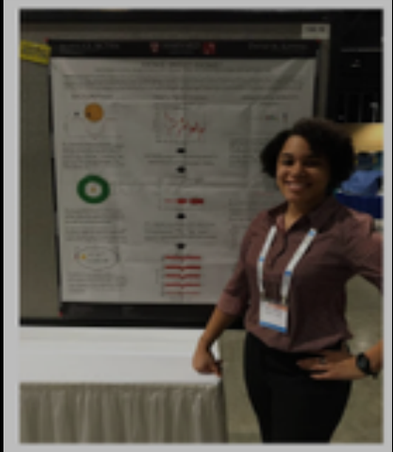
CSMA
Committee on the Status of Minorities in Astronomy

Astronomy in Color

In pursuit of social justice, diversity and excellence in astronomy

http://astronomyincolor.blogspot.com

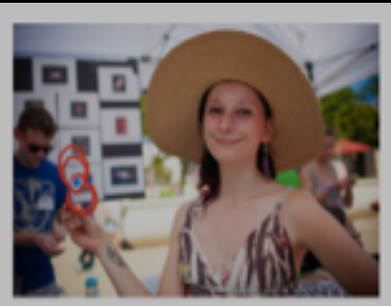
AAS



Moiya McTier (Harvard '16)
Recipient of the 2016 Chambliss Award

Dr. Elisa Quintana, NASA Senior Research Fellow at NASA AMES, lead discoverer of the Earth analog Kepler-186f, and 2015 Hispanic Scientist of the Year

Carl Fields, ASU Astrophysics and Physics major and recipient of the Beth Brown Memorial Award and Carl Rouse Fellowship

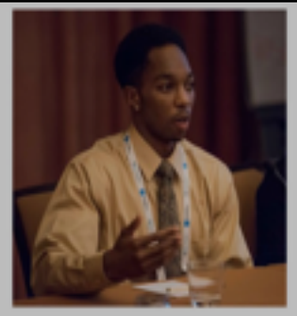


Ivanna Escala, graduate student at Caltech
Award recipient at the 2015 CAMP Symposium

Amy Steele (PhD Candidate, UMPC)
Hon. Mention, 2016 Chambliss Award

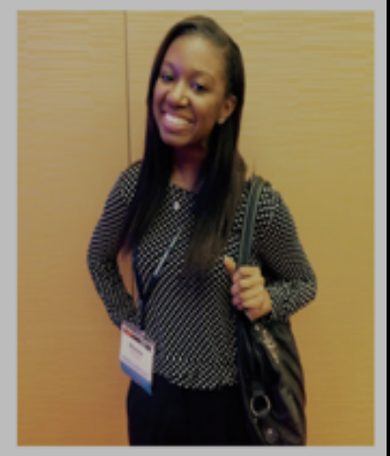
Dr. Lia Corrales, Postdoc at MIT
Recipient of the Einstein Prize Fellowship

Katy Rodriguez Wimberly . Master's student at CSU Long Beach
Recipient of an NSF Graduate Research Fellowship
Next Fall: Ph.D Candidate at UC Irvine



Christopher Moore, University of Colorado graduate student and Beth Brown Memorial Prize recipient, speaking at the 227th AAS meeting.

Greg Mosby is a PhD student at the University of Wisconsin - Madison
He is the recipient of a NASA Postdoctoral Fellowship



Brianna Thomas (Howard '17)
Recipient of the 2016 Chambliss Award

Xzavier Flowers, undergraduate Astronomy and Astrophysics major at Florida Institute of Technology and Founder and CEO of Future Astronomers.

Dr. Maritza Lara López
Assistant Professor at the IA-UNAM
Recipient of the 2016 L'Oreal's Award

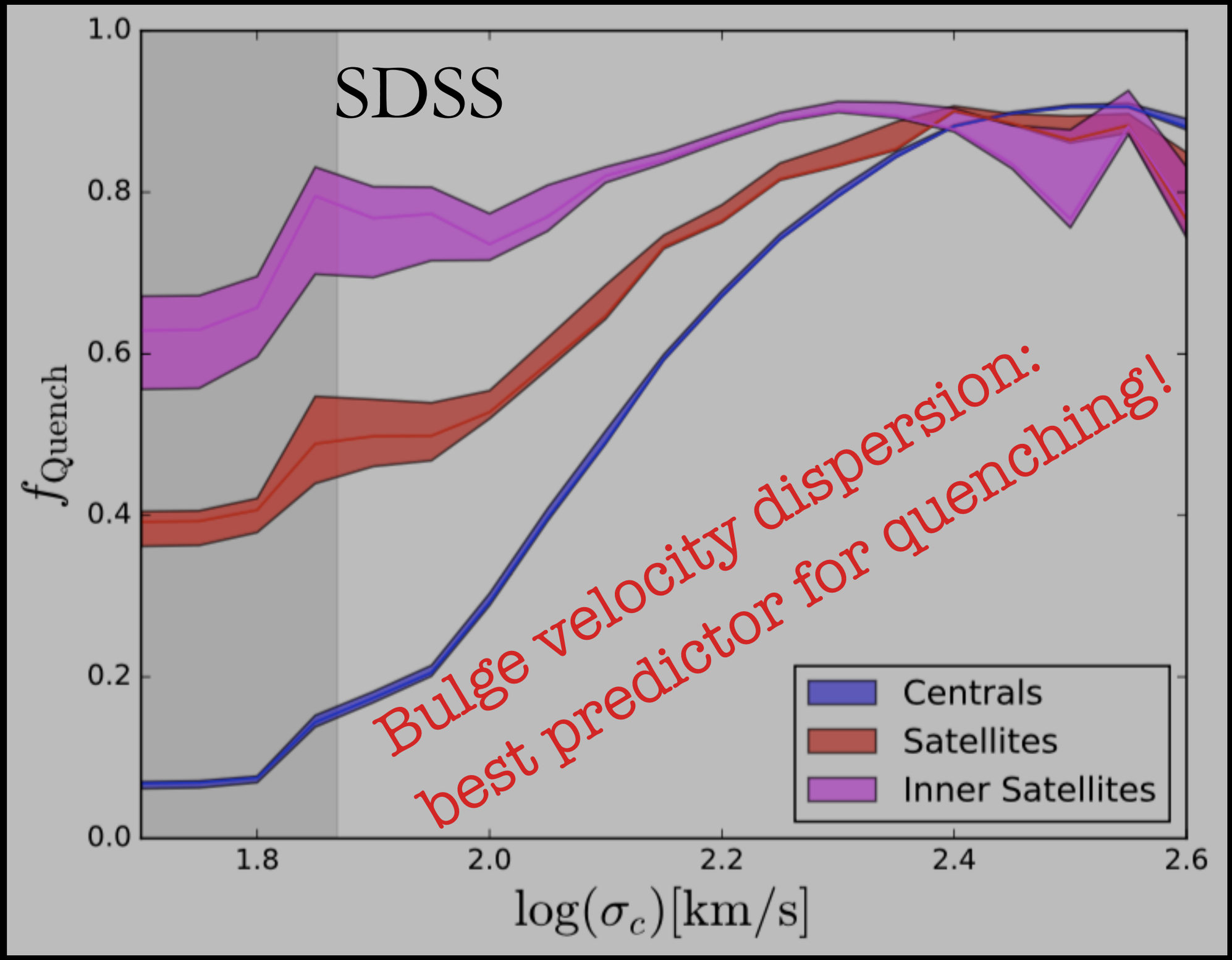
Dr. Louise Edwards
Now: Astronomy Lecture at Yale
Next: Assistant Professor at Cal Poly San Luis Obispo

CSMA Chair: Jorge Moreno (2016-2019 ++)

Let's make this a worldwide effort!

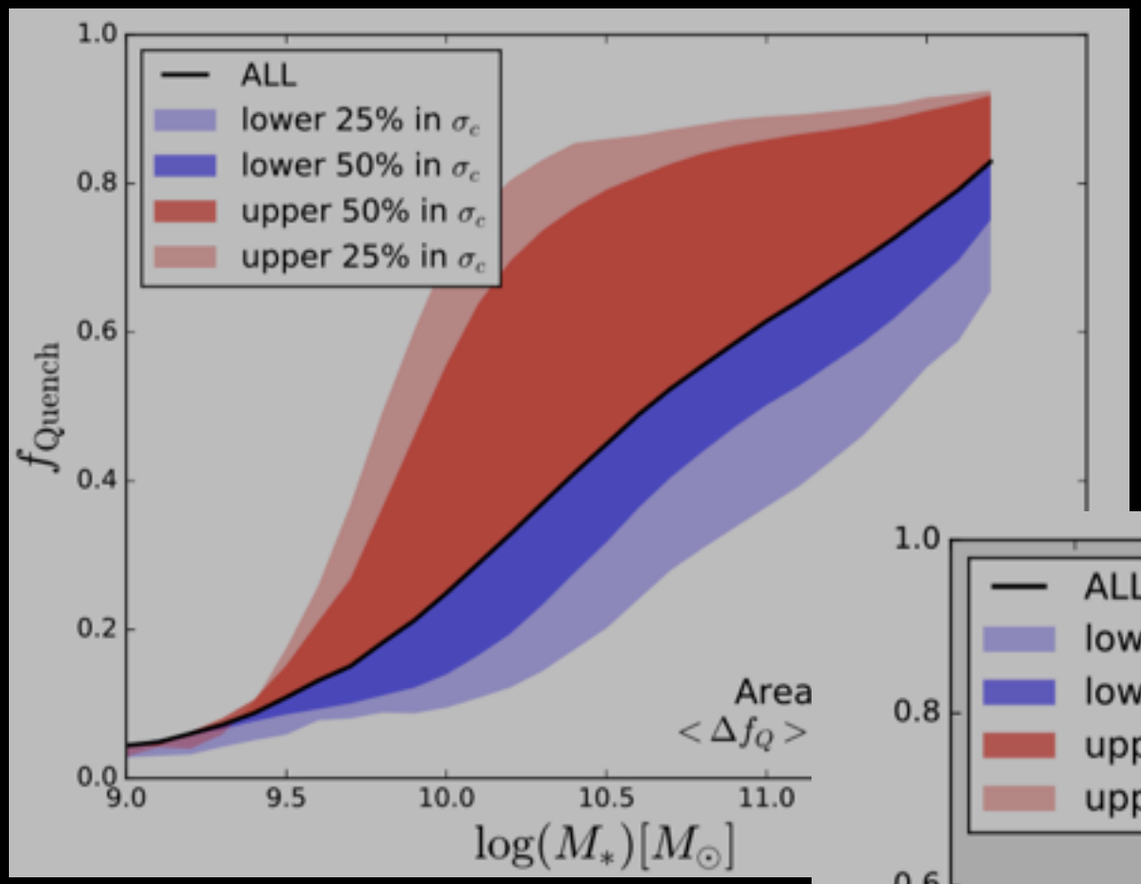
Galaxy Quenching in the SDSS

Centrals versus Satellites

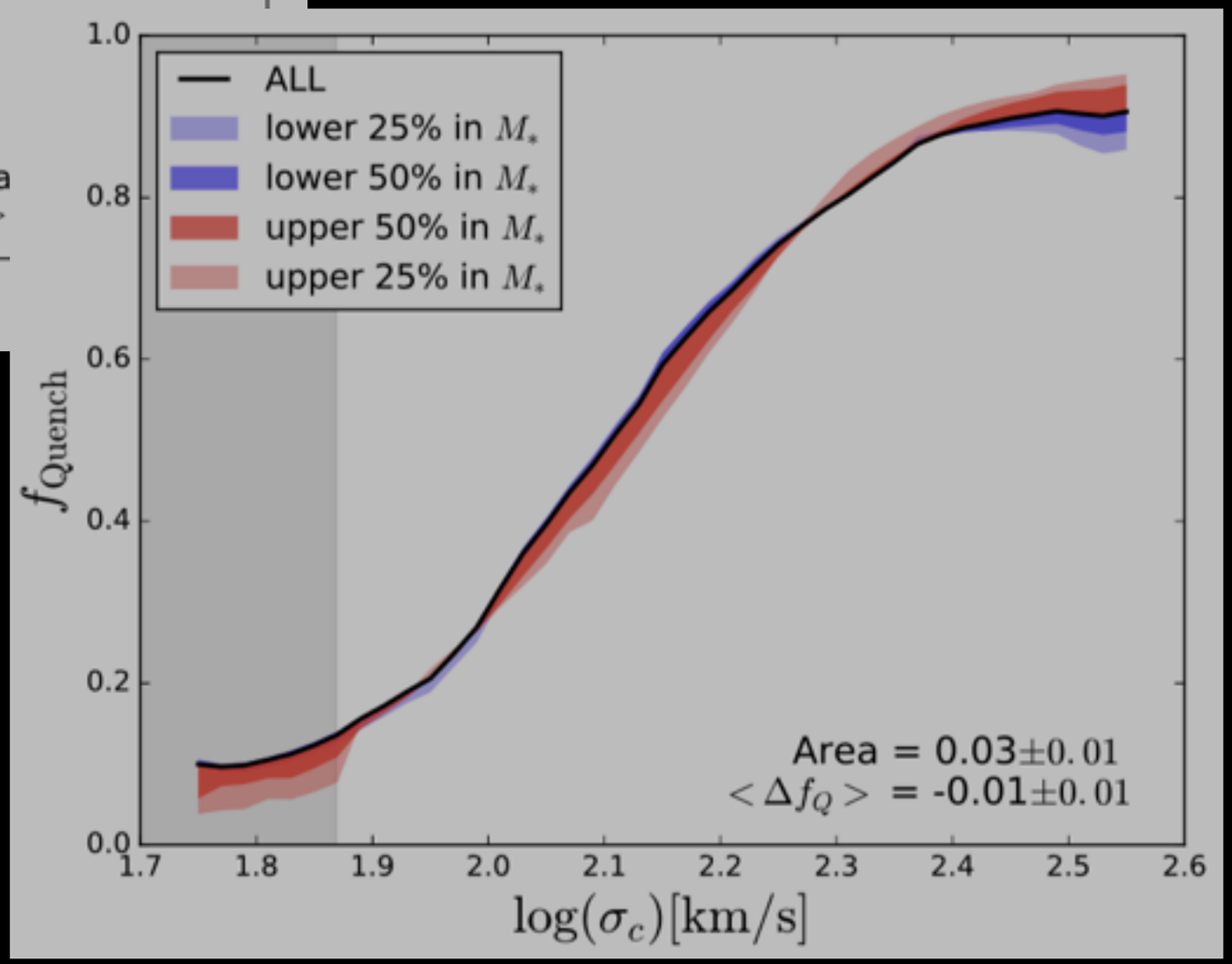


Bluck+16 (see also Teimoorina+16 and Bluck+14)

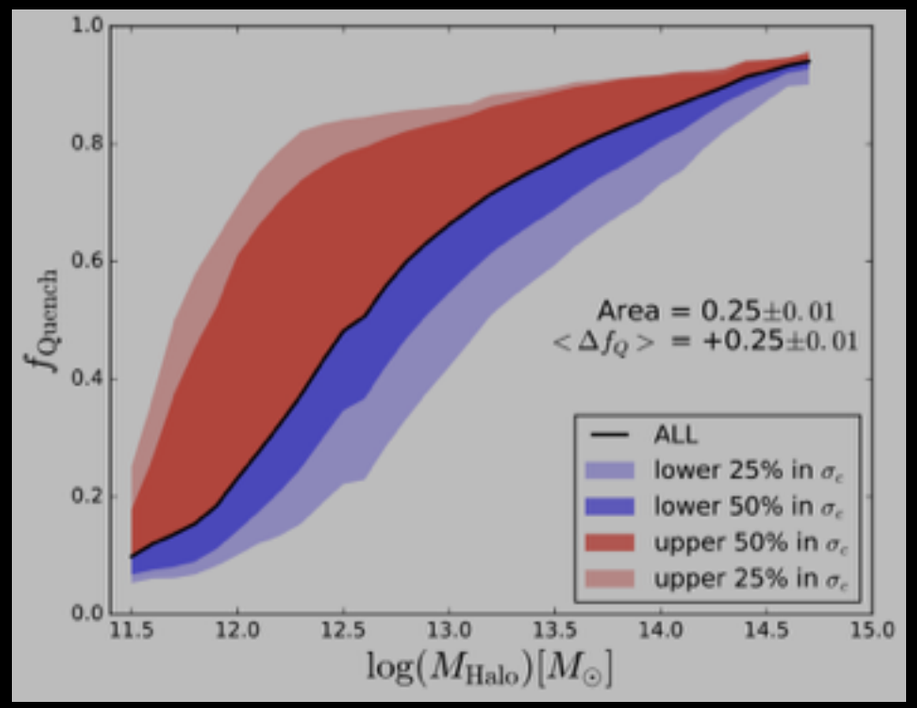
Centrals: Stellar Mass Quenching?

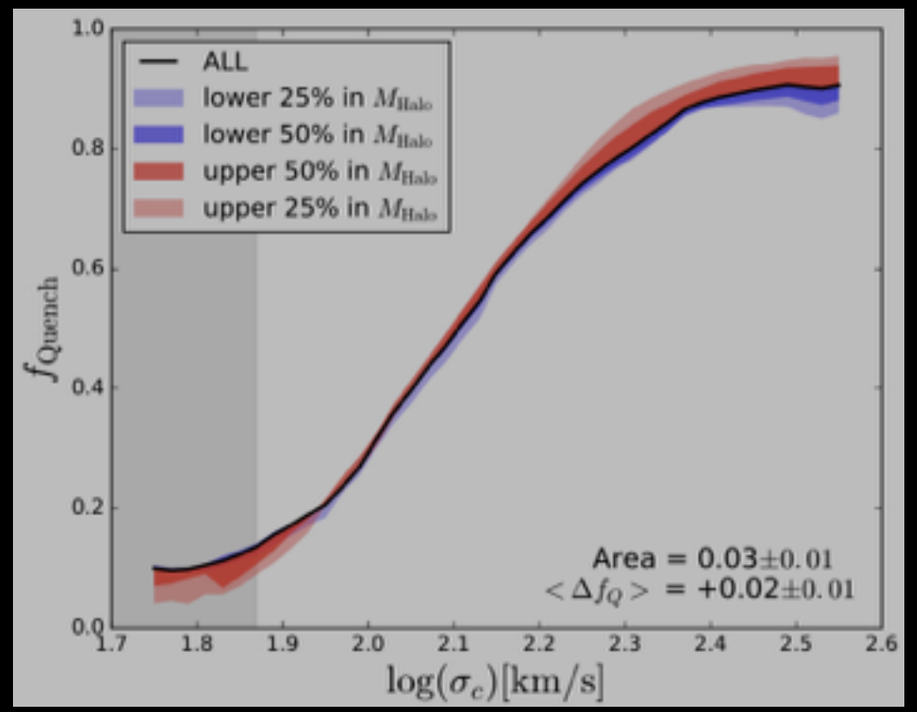


Bluck+16

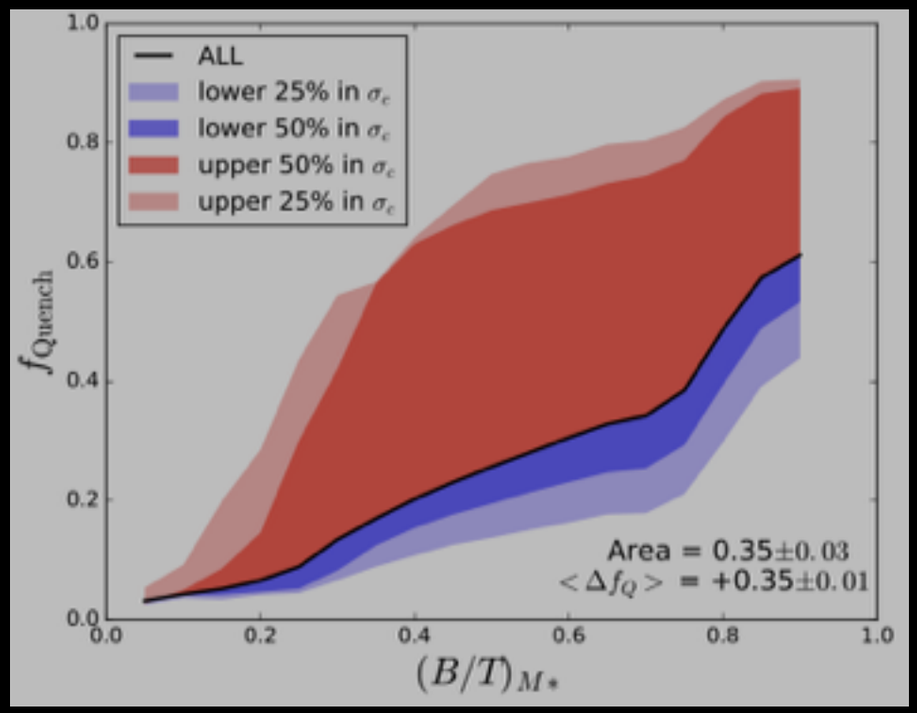


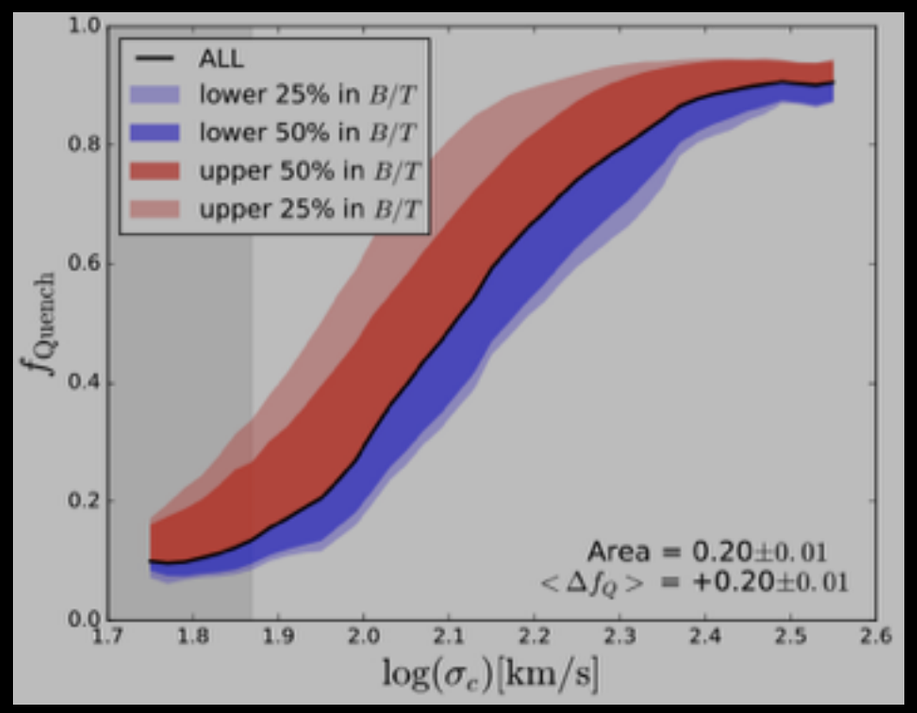
Centrals: Halo Quenching?





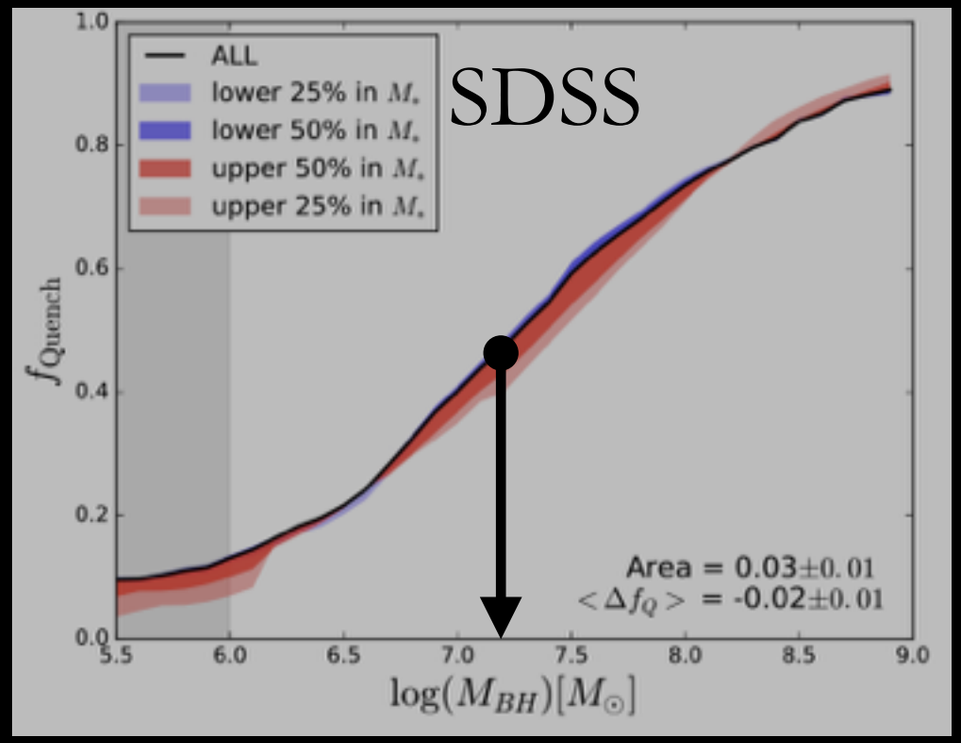
Centrals: Morphological Quenching?

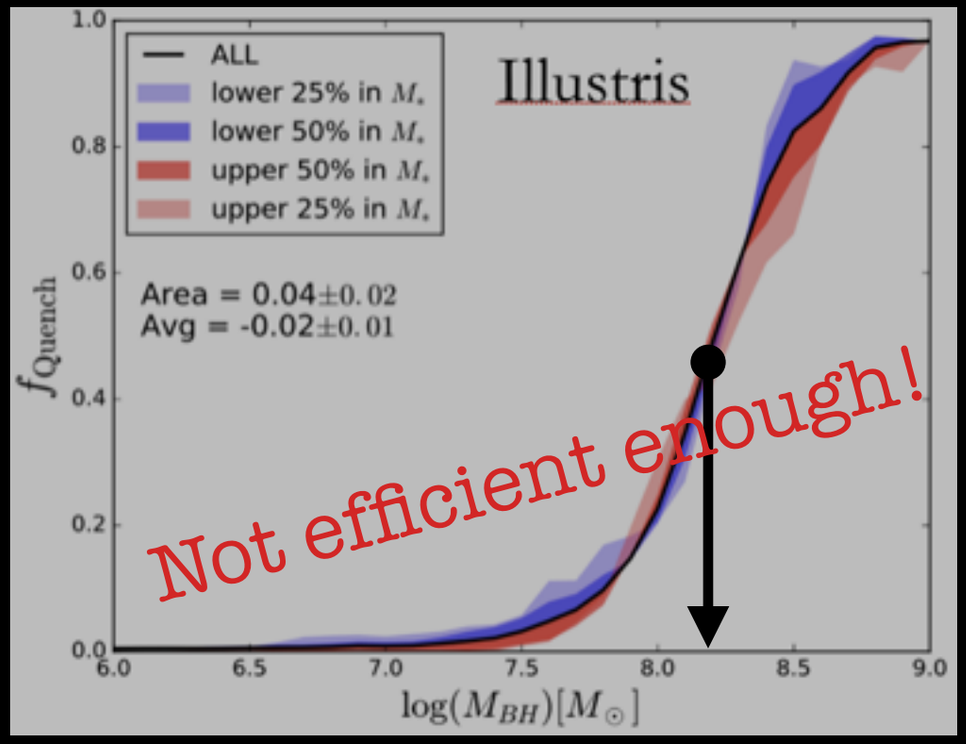


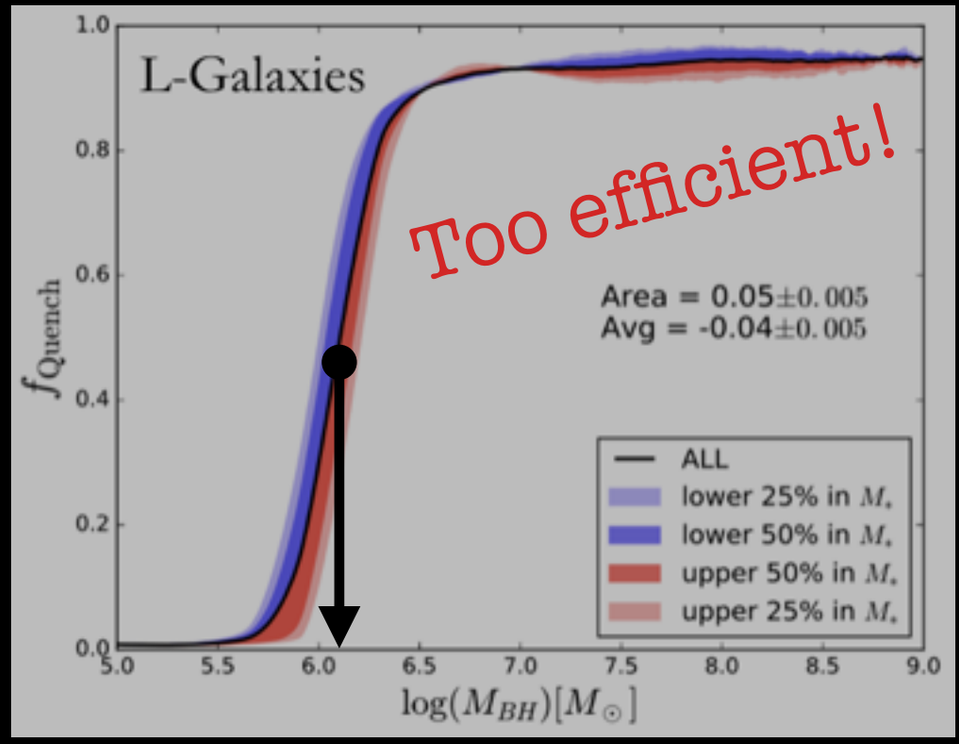


Galaxy Quenching in Simulations

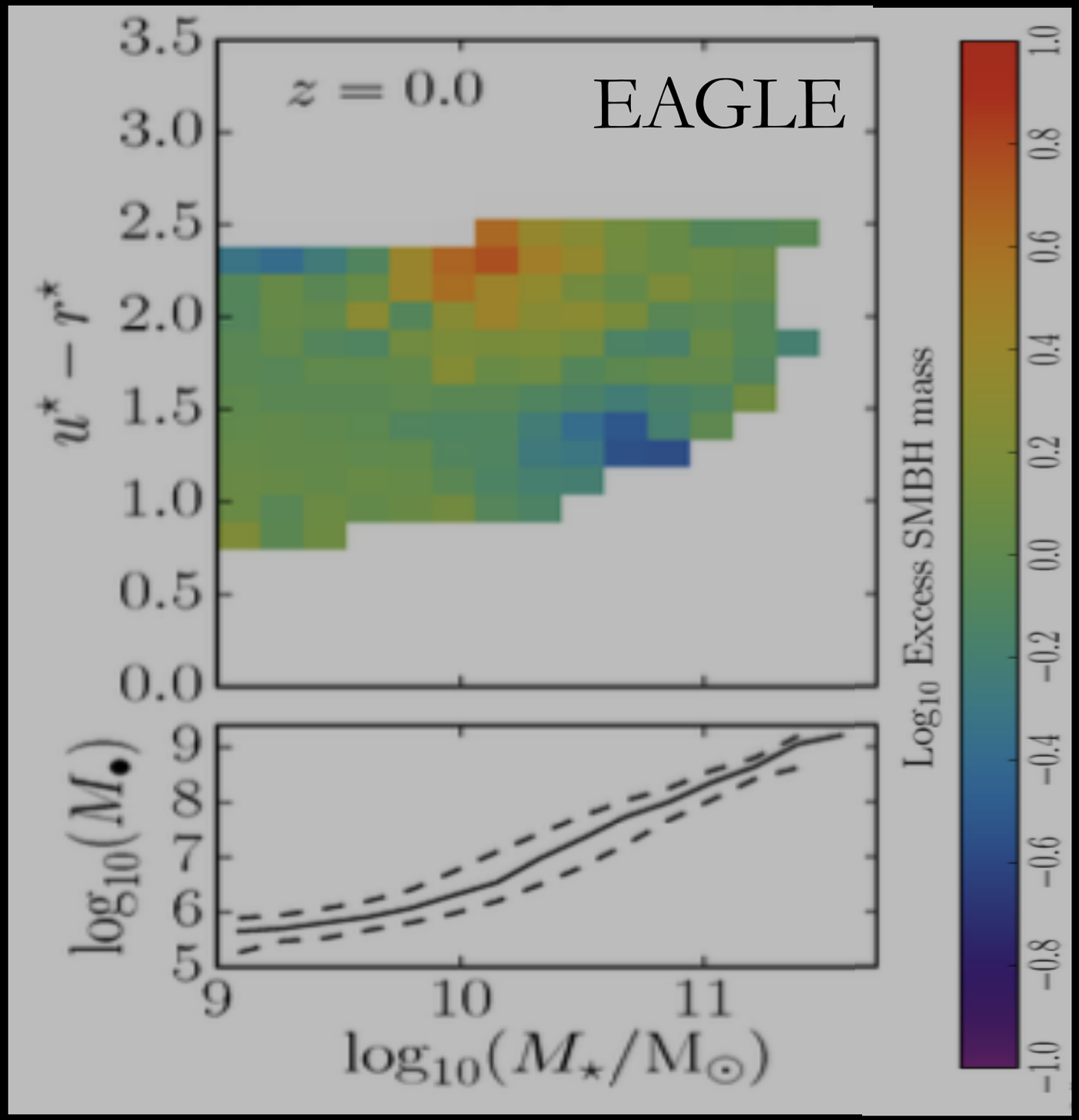
SDSS versus Simulations







Colors versus SMBH mass in EAGLE

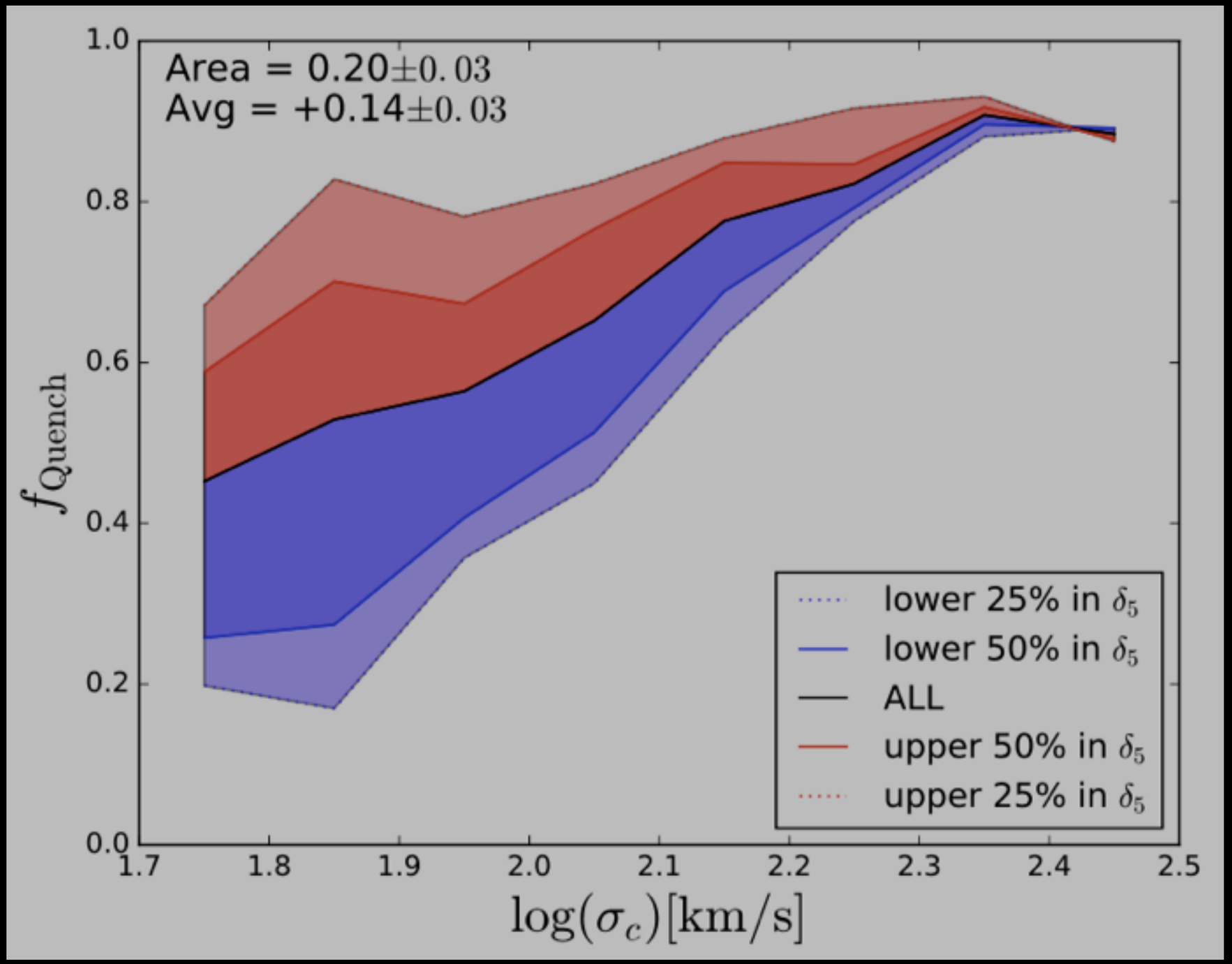


Trayford+16 (adapted)

AGN feedback quenches galaxies!

Environmental Quenching

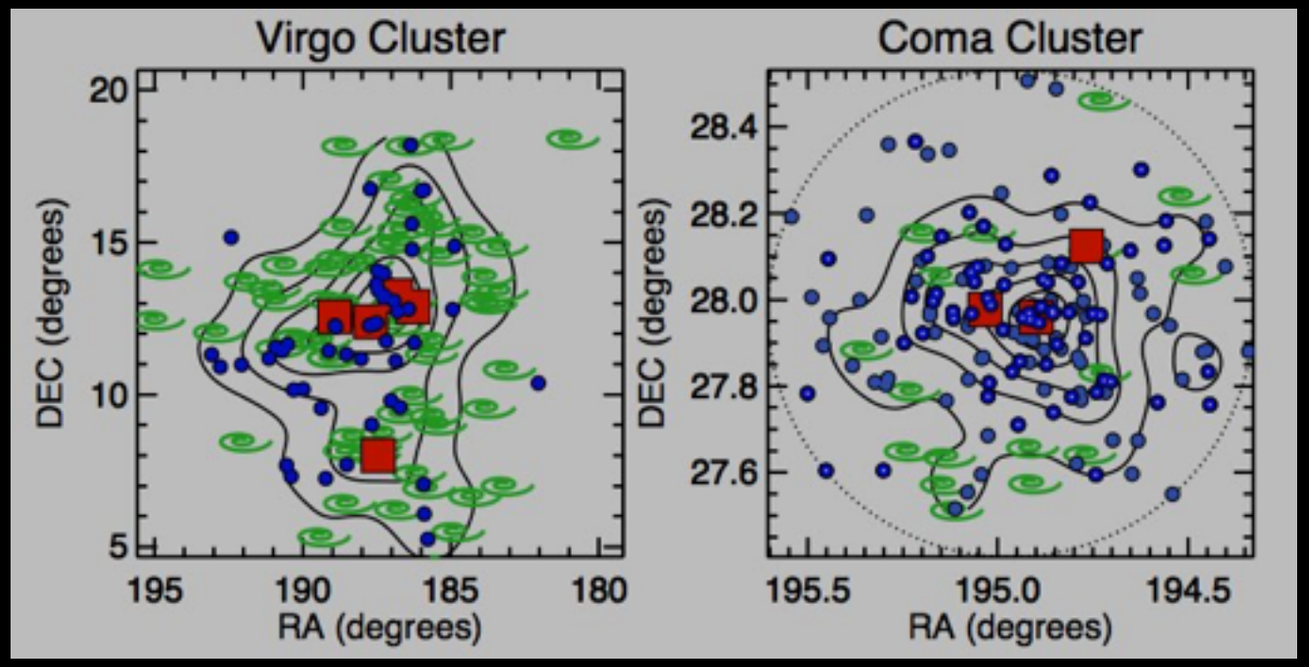
Satellite Quenching



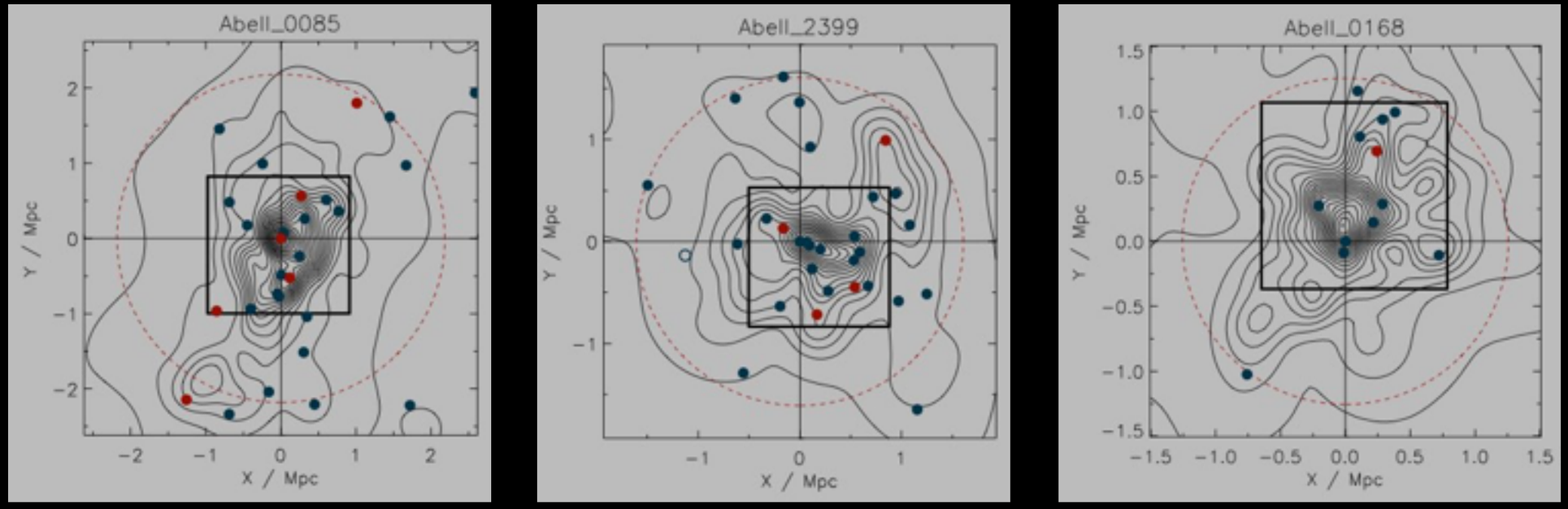
Bluck+16

Local galaxy density: best environmental predictor for quenching!

Local galaxy density

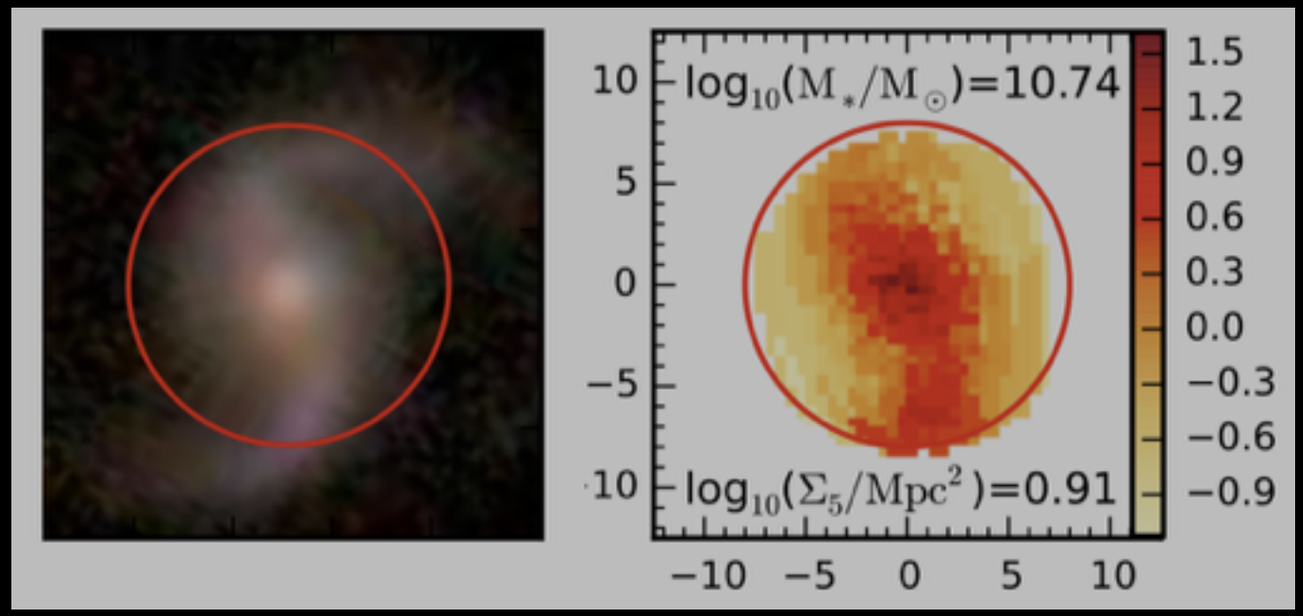


Cappellari 13 (ATLAS-3D) | See also Cappellari+11

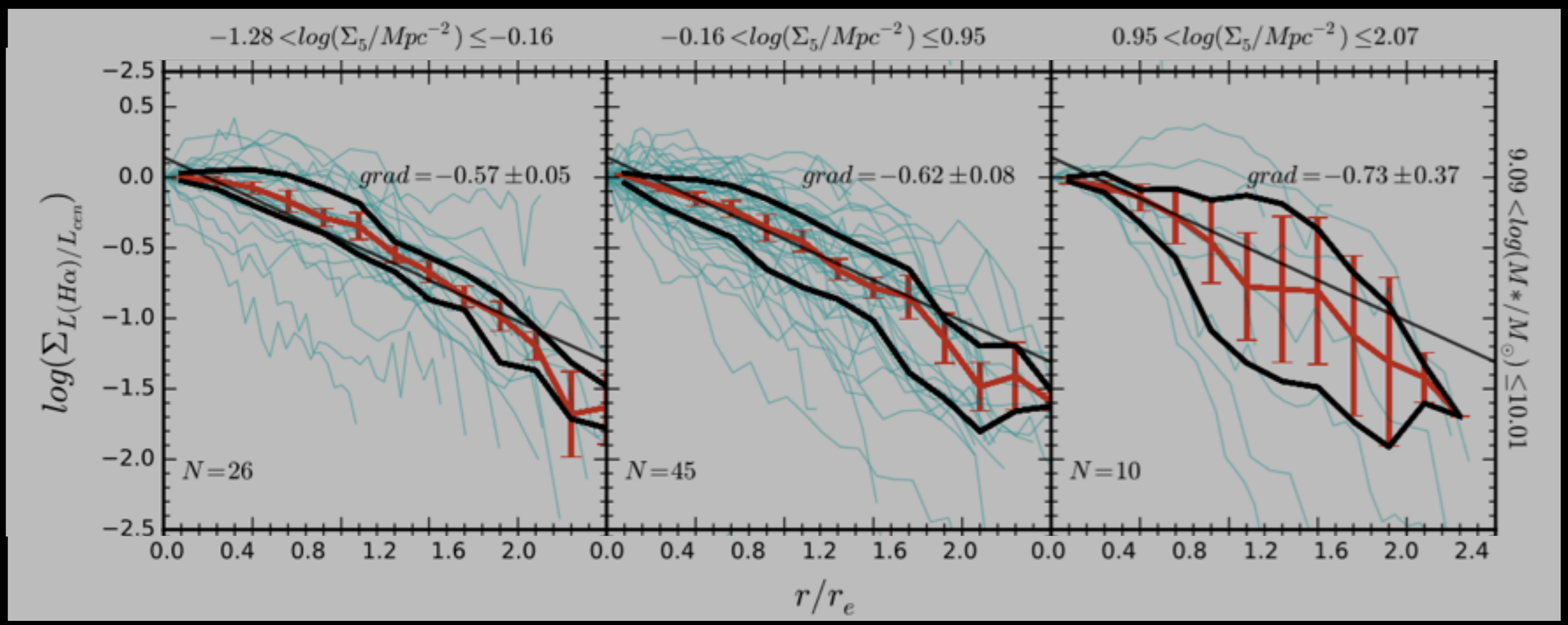


Fogarty+15 (SAMI) | See also D'Eugenio+13, Houghton+13 & Scott+14
plus Sarah Brough's talk!

Best sites for galaxy interactions! (Moreno+13)



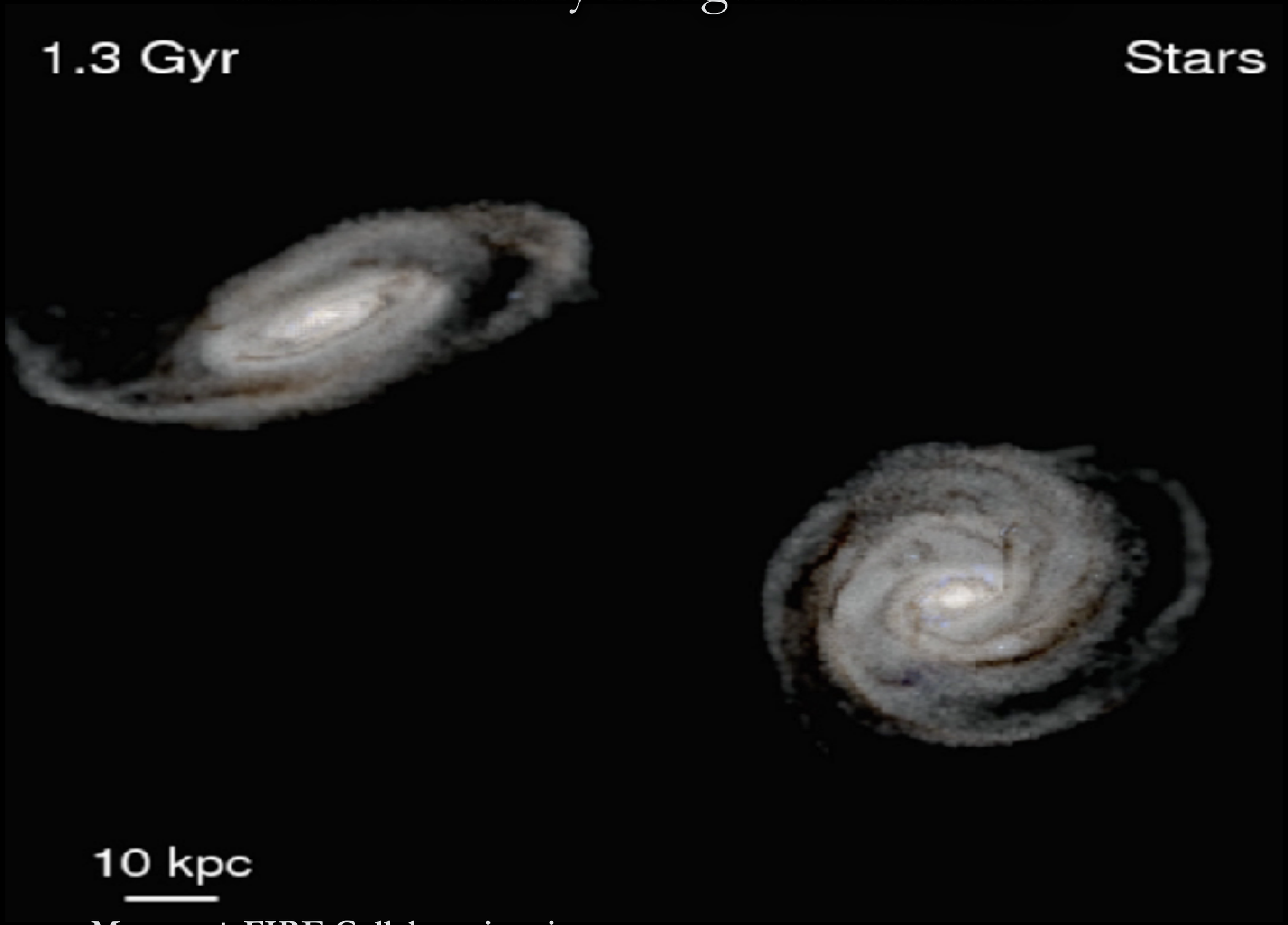
Schaefer+16 (SAMI)



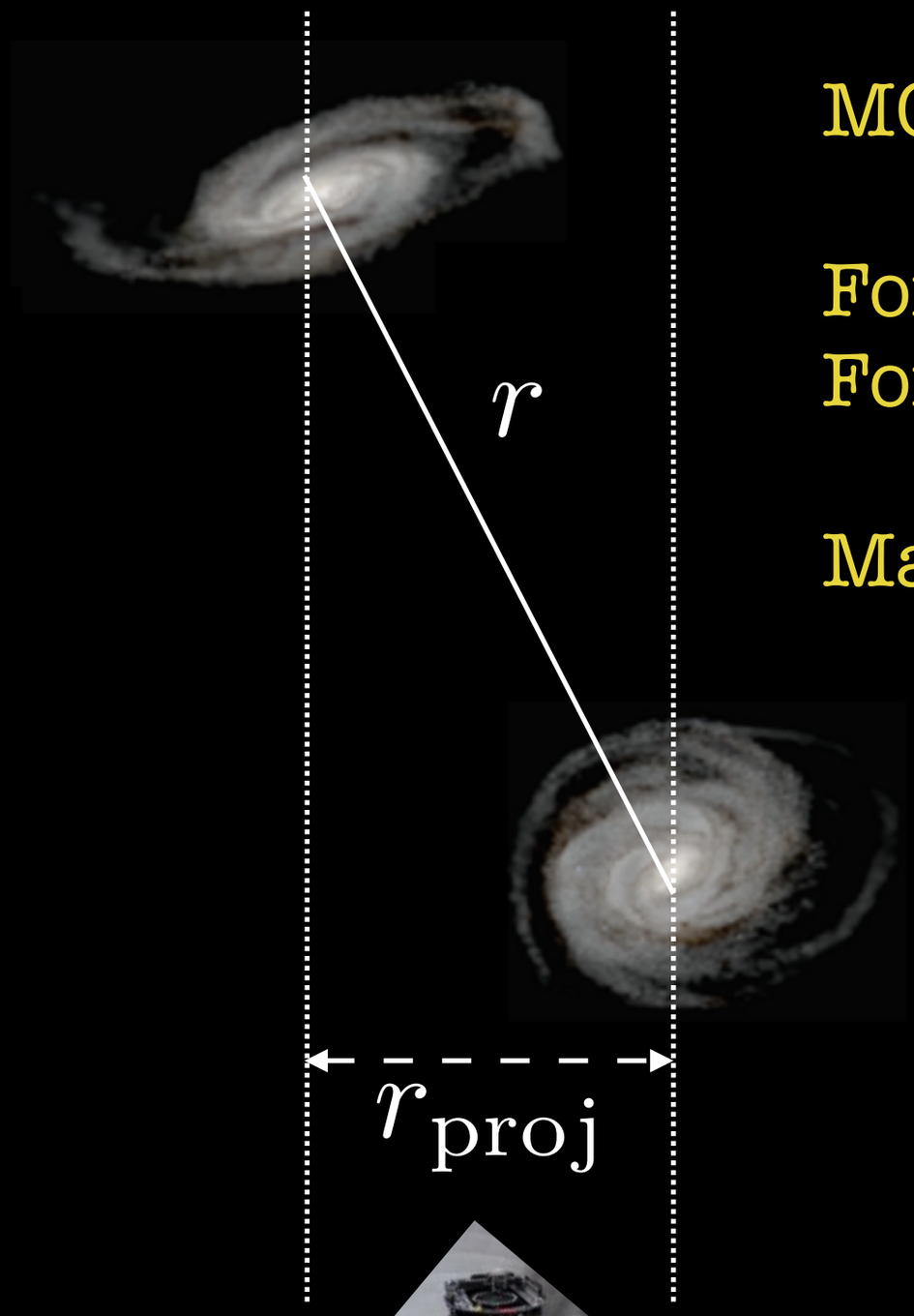
Outside-in quenching: driven by galaxy interactions?

Galaxy Interactions on FIRE: Mock Survey

Suite of Galaxy Merger Simulations



Moreno + FIRE Collaboration, in prep
(see also Moreno+15)



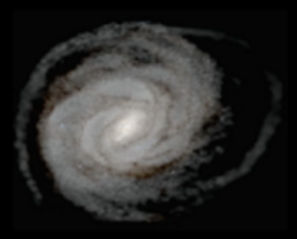
MOCK SURVEY:

For Every Merger
For Every Time Snapshot

Many Random Views!

$SFR_{\rm iso}$

$SFR_{\rm int}$



log SFR (interacting) / SFR (isolated)

SFR Enhancement

Median

Some galaxies are quenched!

Consistent with SDSS!
(Ellison et al., 2011)

2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0

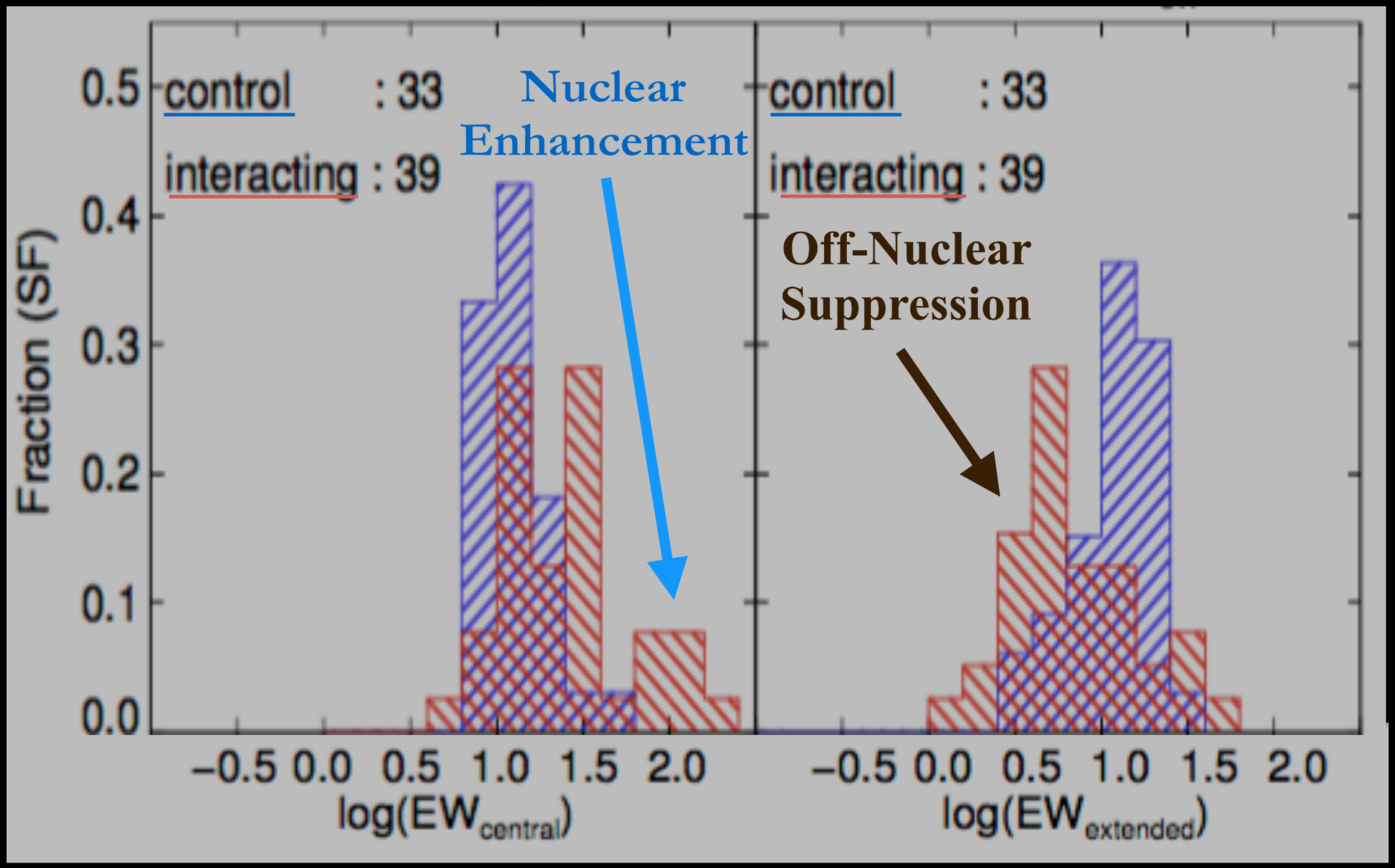
0
20
40
60
80
100
120
140

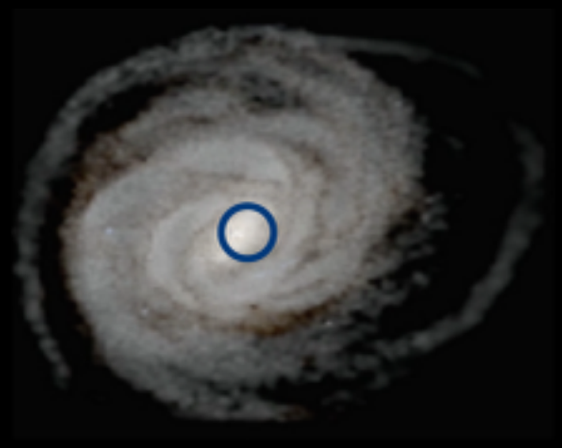
Projected Separation

Spatial Extent of Star Formation in Galaxy Interactions

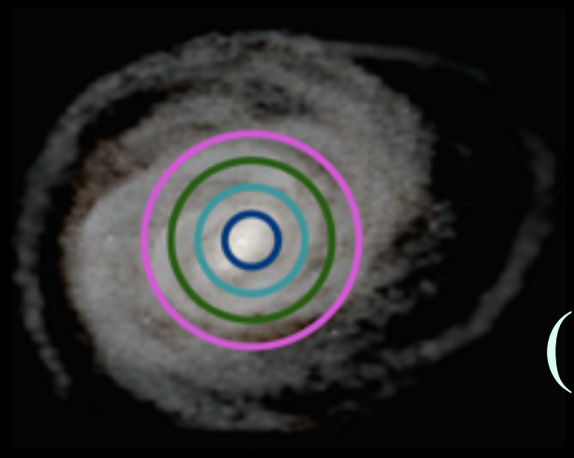
Spatial Extent of SFR in CALIFA

(Barrera-Ballesteros + CALIFA Collaboration)

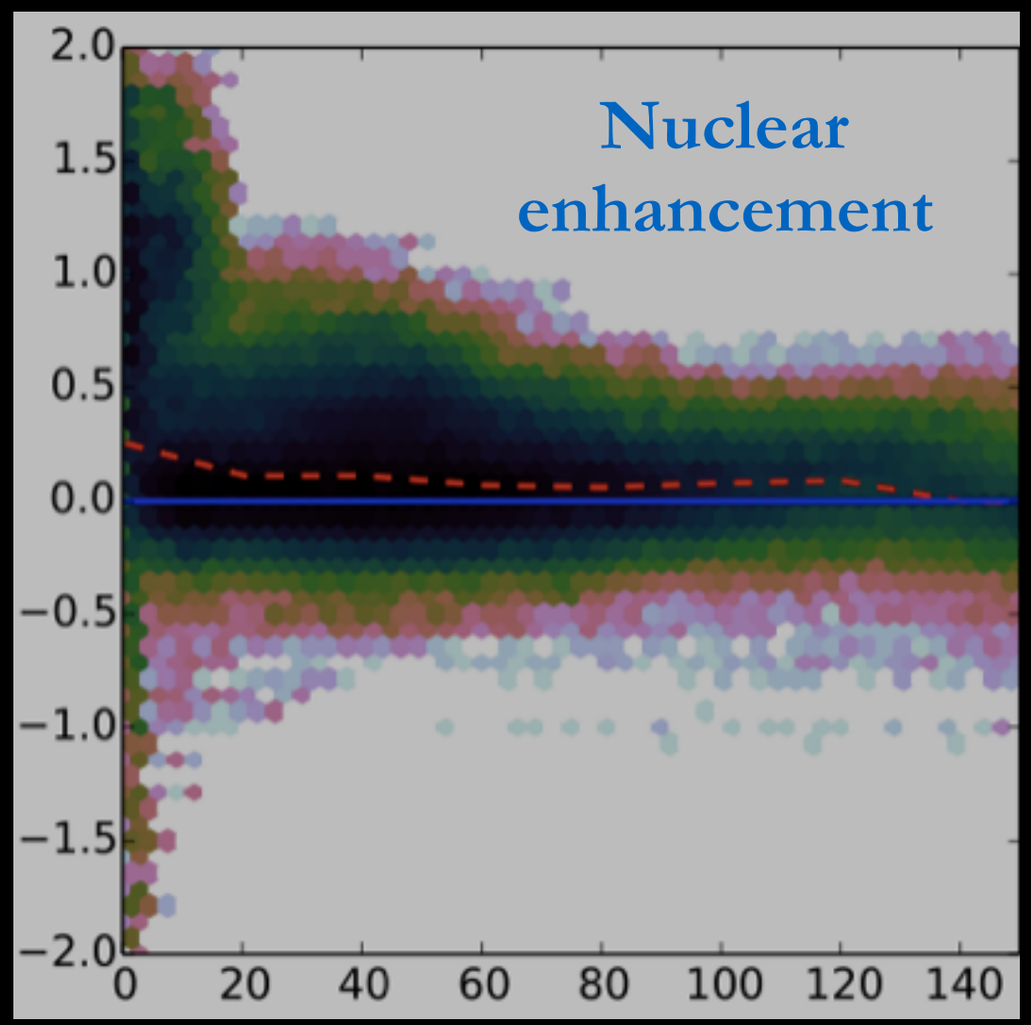


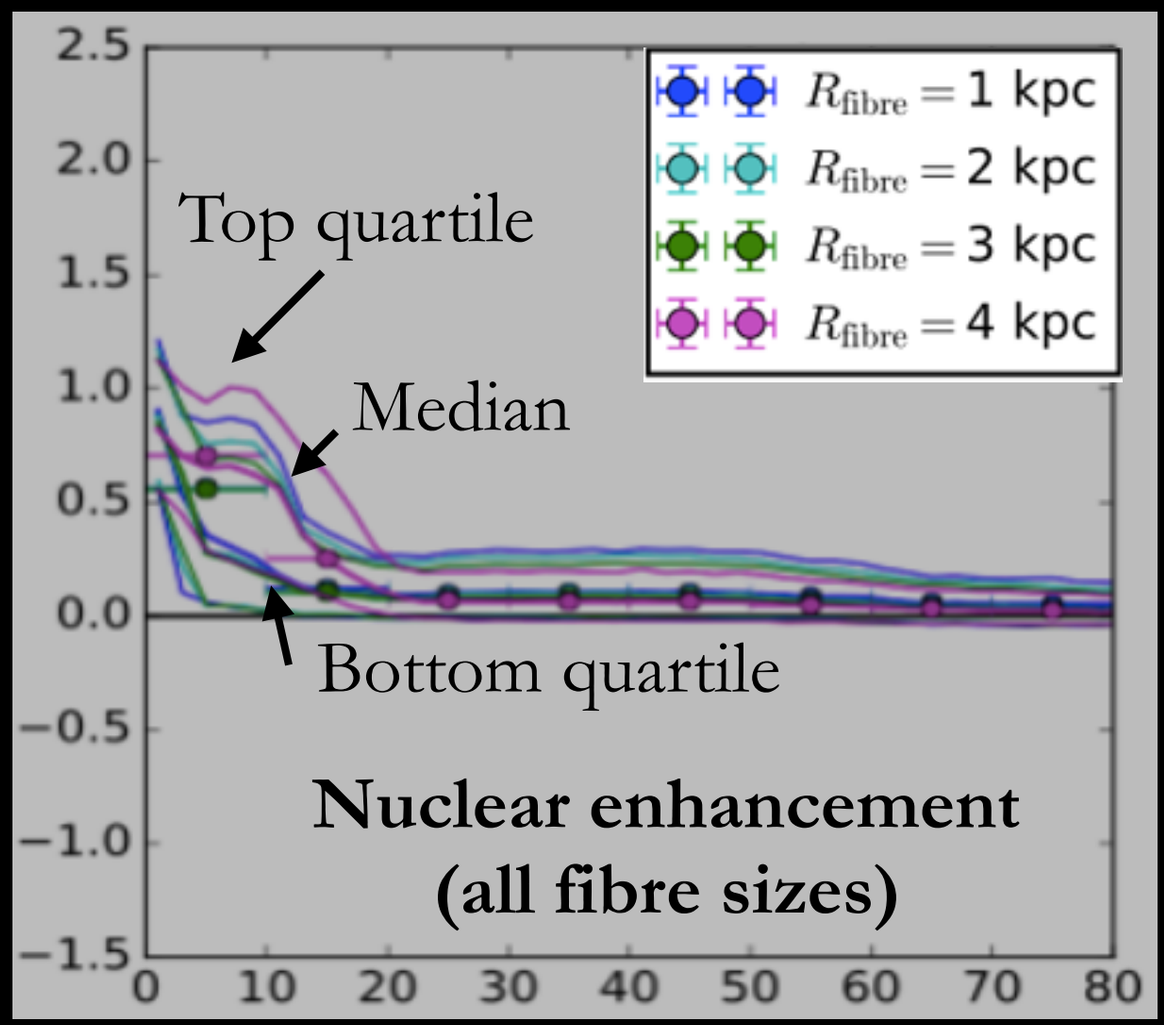


Nucleus
(0 -1 kpc)

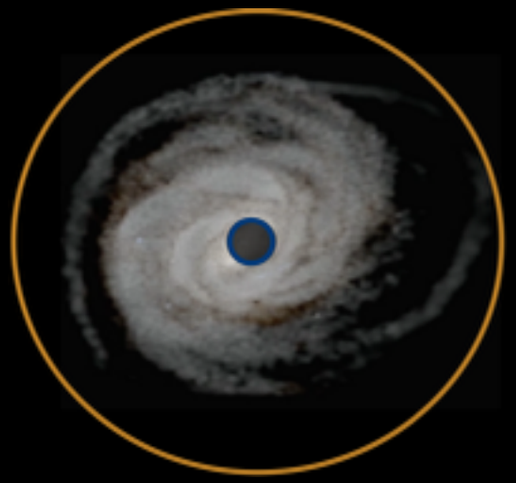


Nucleus
(varying sizes)

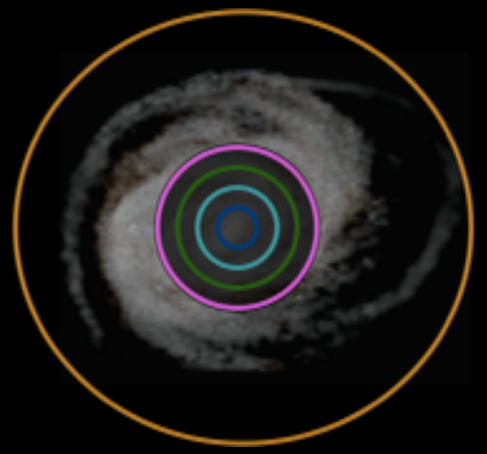




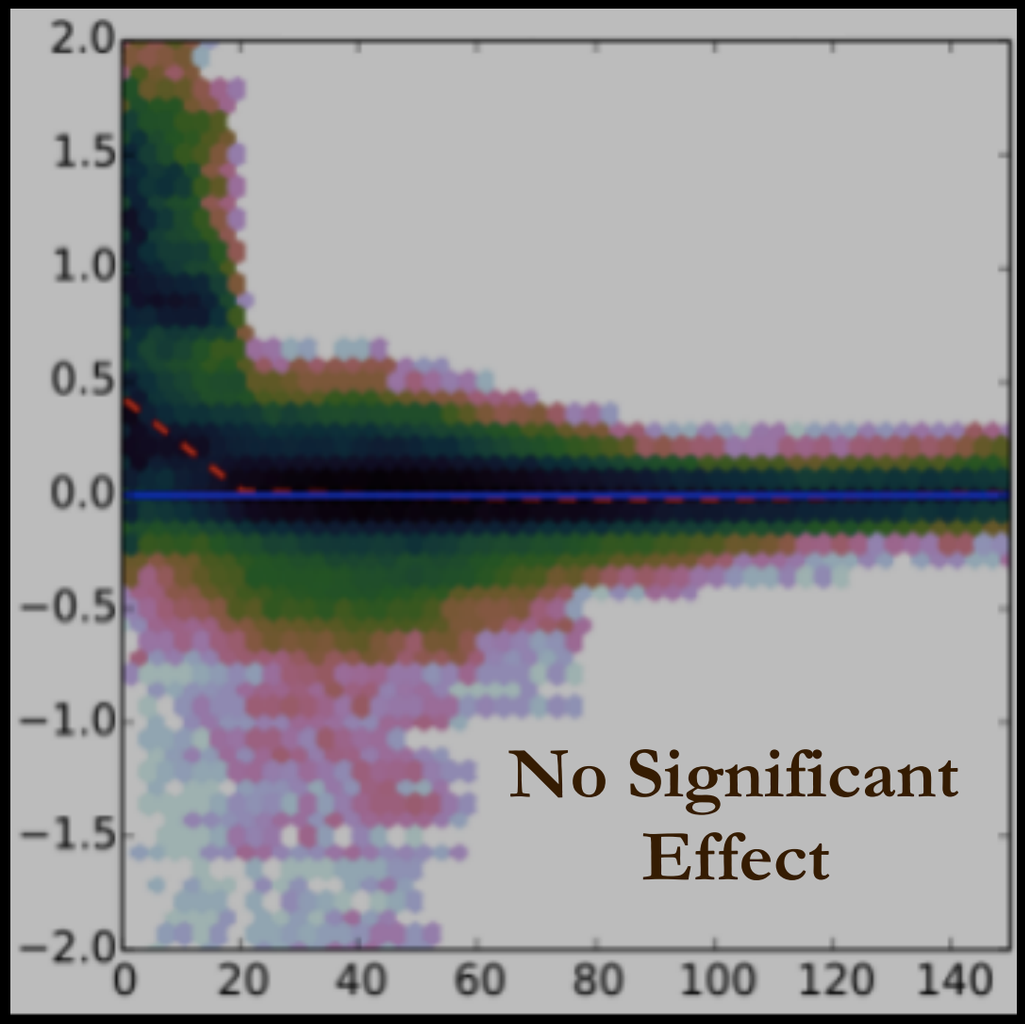
Consistent with CALIFA!



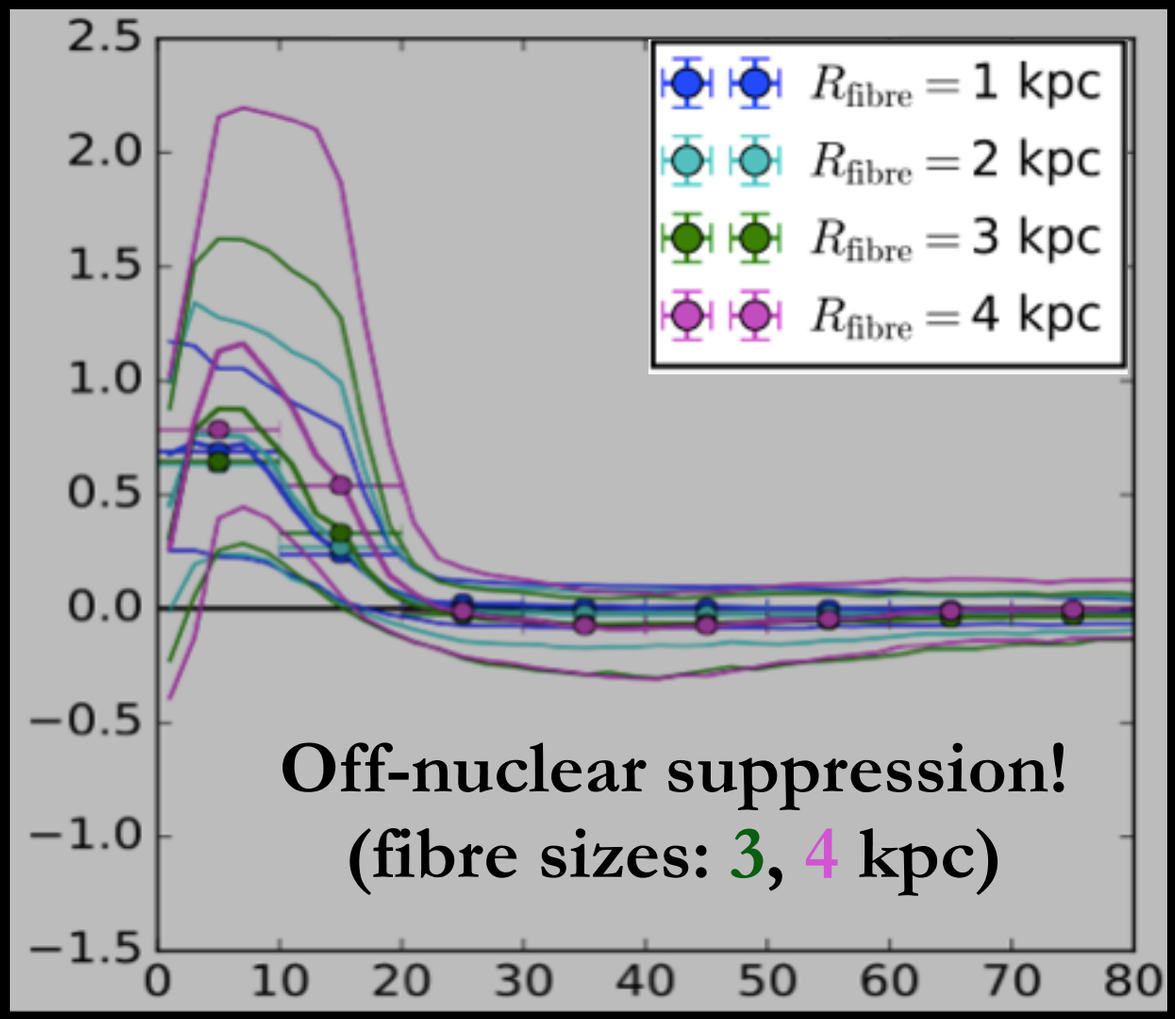
Outer Disk
(> 1 kpc)



Outer Disk
(varying sizes)



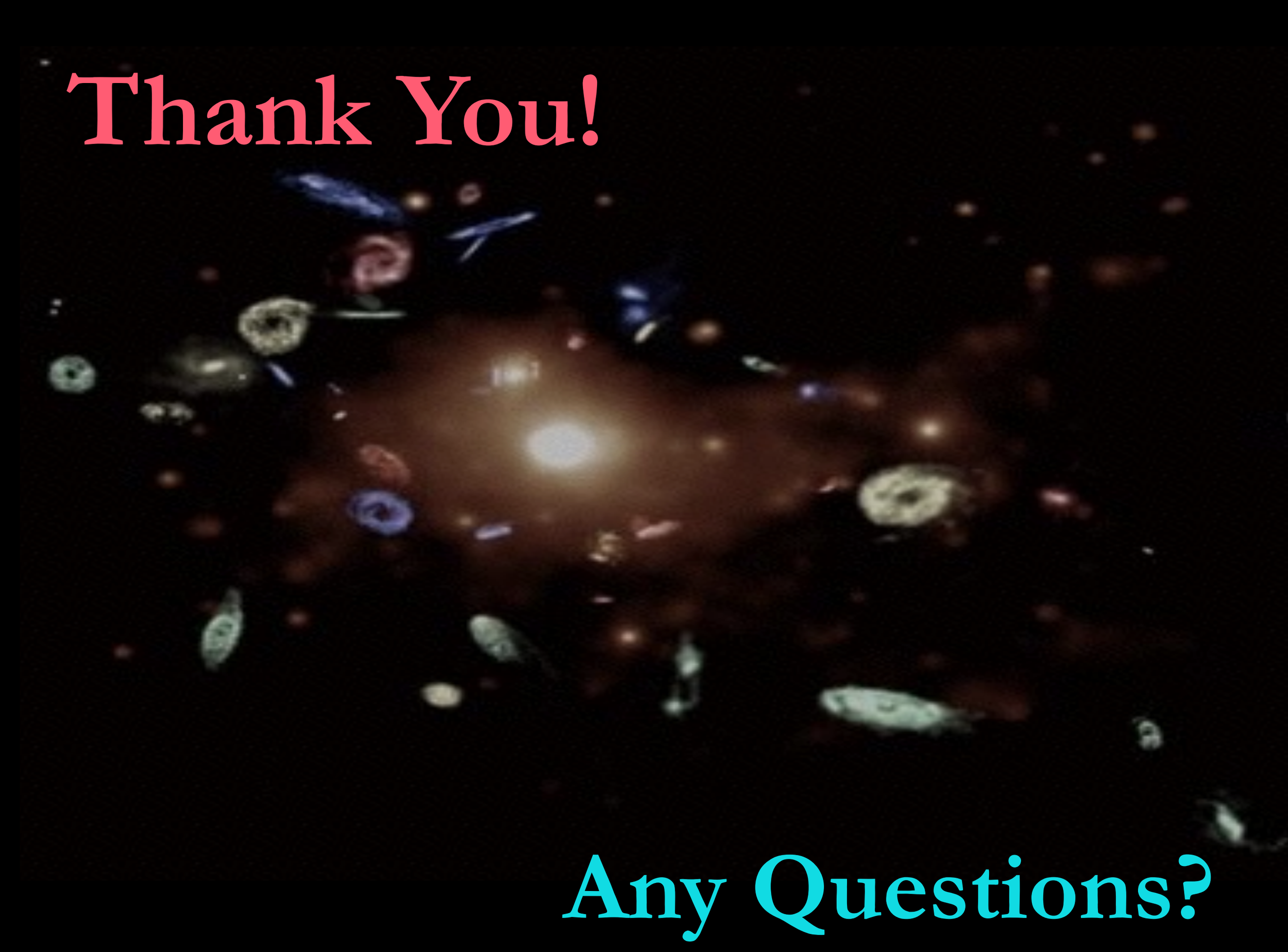
Projected Separation



Projected Separation

Consistent with CALIFA!

Thank You!



Any Questions?

Thank You!

Quenching in Cosmological Simulations:

- **Structure: Bulge velocity dispersion (AGN feedback?)**

  Illustris (too inefficient) | L-Galaxies (too efficient)

- **Environment: Local galaxy density (interactions?)**

Galaxy Interactions on FIRE:

- **Enhanced Nuclear Star Formation**
- **Suppressed Off-nuclear Star Formation (beyond 2-3 kpc)**
- **Agreement with observations (CALIFA)**

Any Questions?