NEW PERSPECTIVES 2021

RUNNING WITH BUFFALO ON THE FRONTIER

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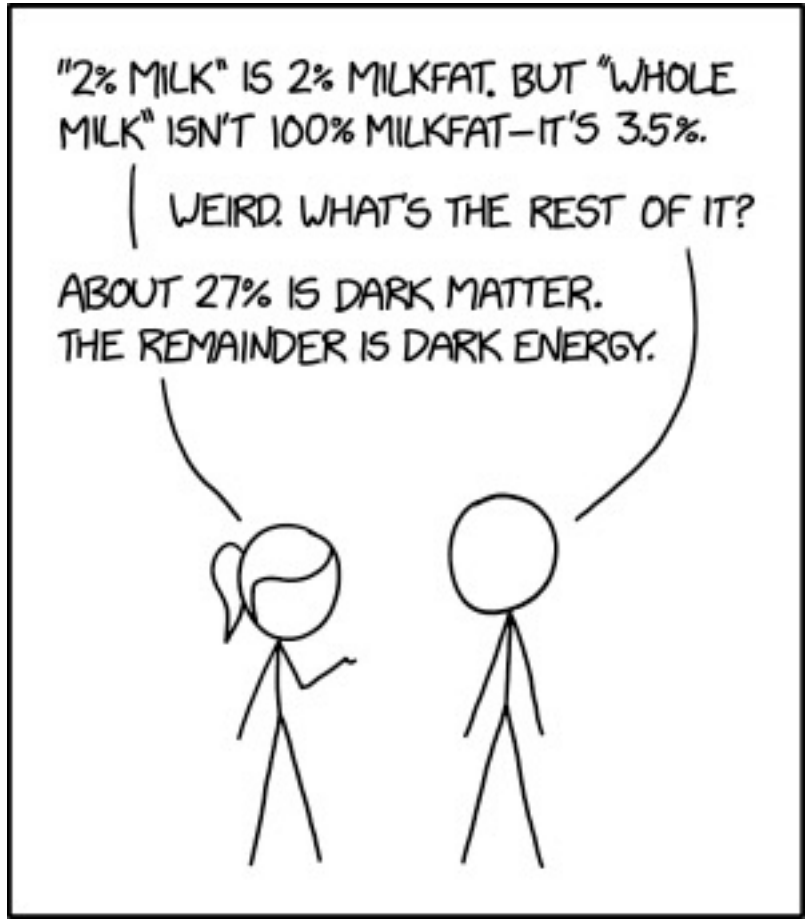
Image Credit: NASA, ESA, S. Rodney (John Hopkins University, USA) and the FrontierSN team; T. Treu (University of California Los Angeles, USA), P. Kelly (University of California Berkeley, USA) and the GLASS team; J. Lotz (STScI) and the Frontier Fields team; M. Postman (STScI) and the CLASH team; and Z. Levay (STScI)

THINGS I WORK ON

- Photometry in crowded environments (also not crowded!)
  - Hubble Frontier Fields and BUFFALO
  - Exploring machine learning algorithms to denoise astronomy images
- Open questions that are applicable to large and small scales
  - Cross-over with Dark Energy Survey

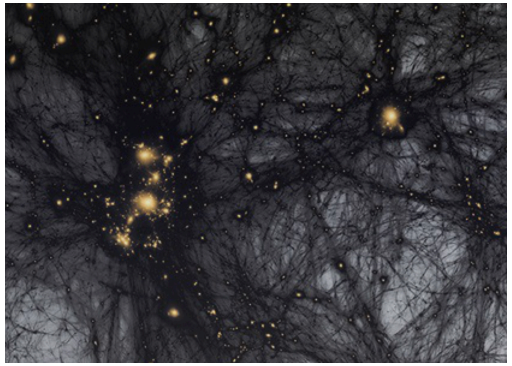


https://xkcd.com/2216/

WHAT ARE CLUSTERS?

- Clusters represent the high density tails of matter distribution in the universe
- 10^{14}-10^{15} solar masses
- 100s to 1000s of galaxies per cluster, called richness

CLUSTERS GIVE US ACCESS TO INFORMATION ON MULTIPLE SCALES



Frank van den Bosch

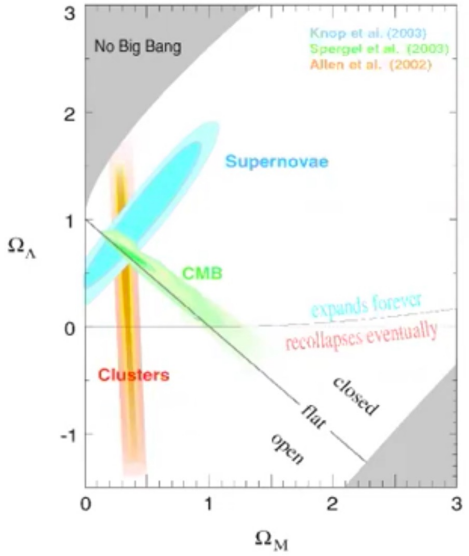
Clusters

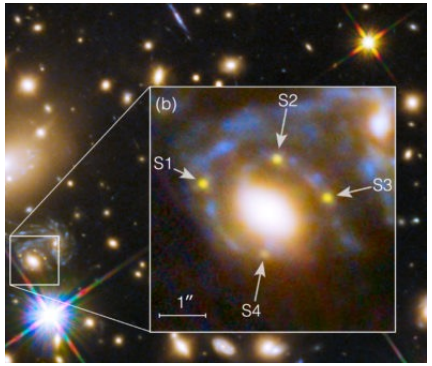
Large scales

- Structure formation
- **Gravitational lensing**
- Time delay cosmology

Small scales

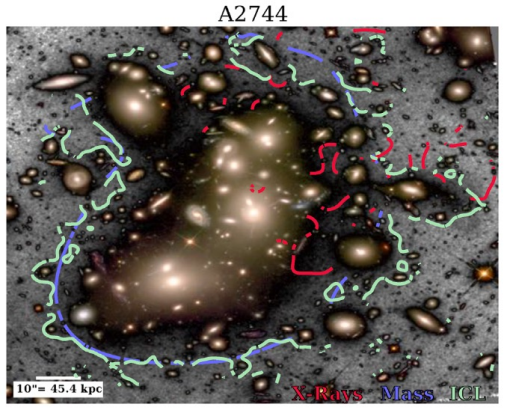
- Galaxy dynamics and evolution
- **Gravitational lensing**
- Environmental effects
- Intracluster medium
- High-z galaxies



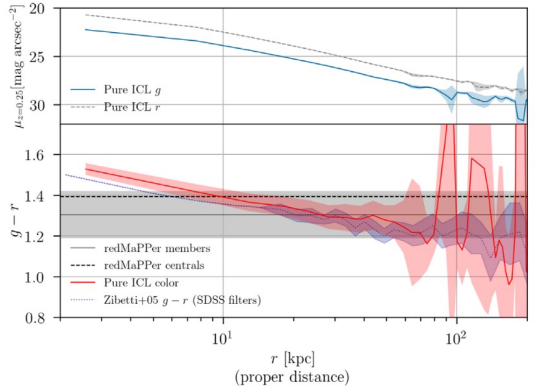


C. Grillo et al 2018

Binney and Tremaine

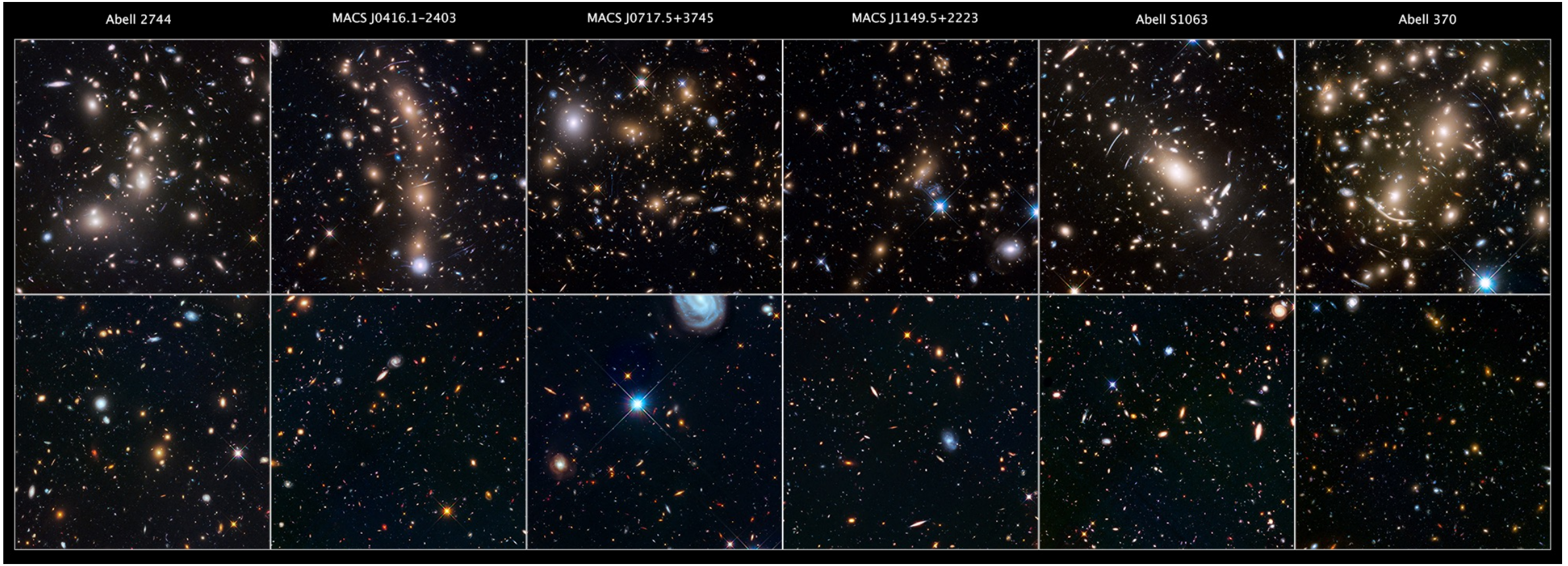


Montes et al 2019



Zhang et al 2019

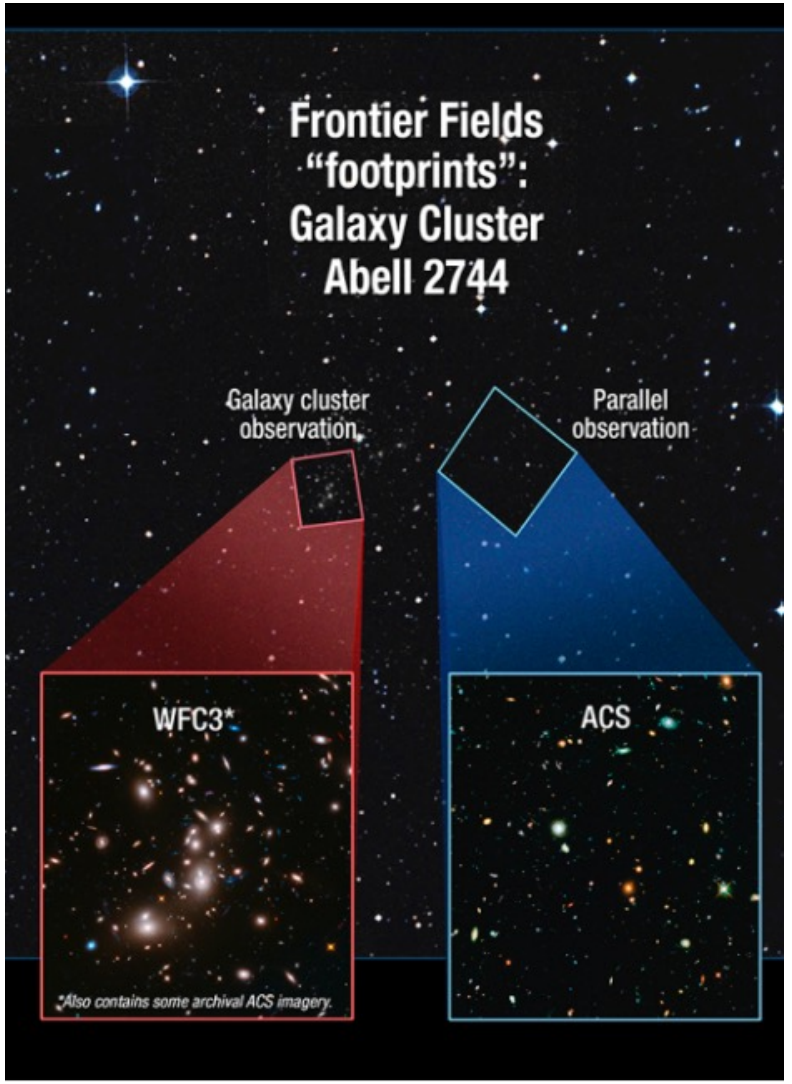
MEET THE HUBBLE FRONTIER FIELDS

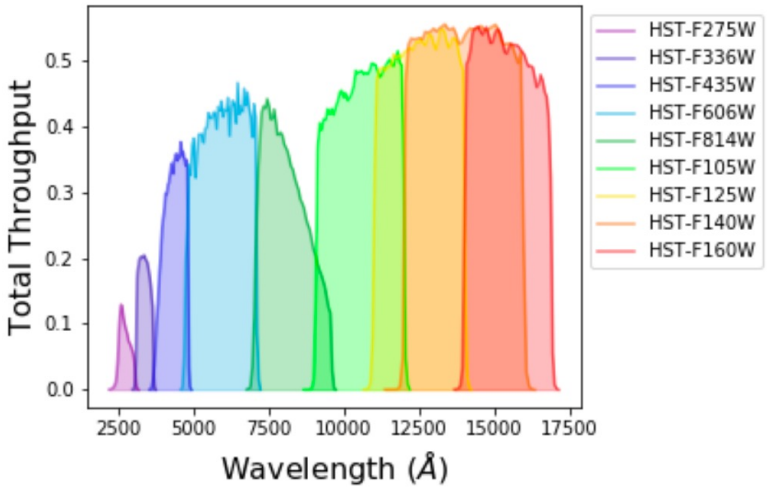


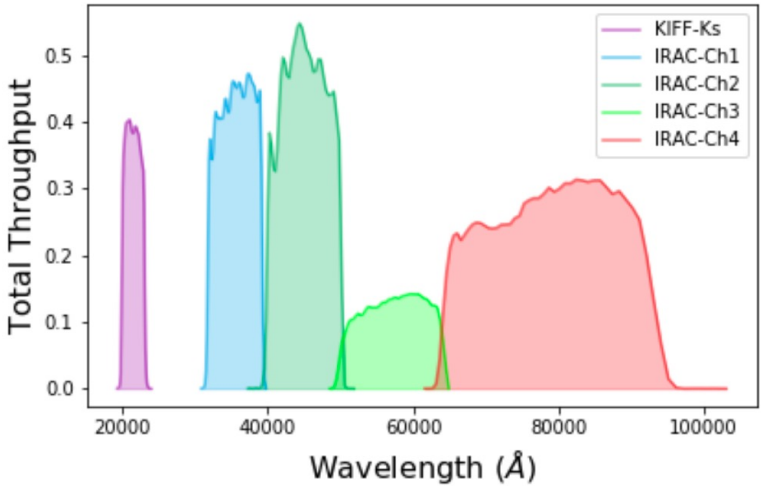
Credits: NASA, ESA, STScI, and the HFF team

MEET THE HUBBLE FRONTIER FIELDS

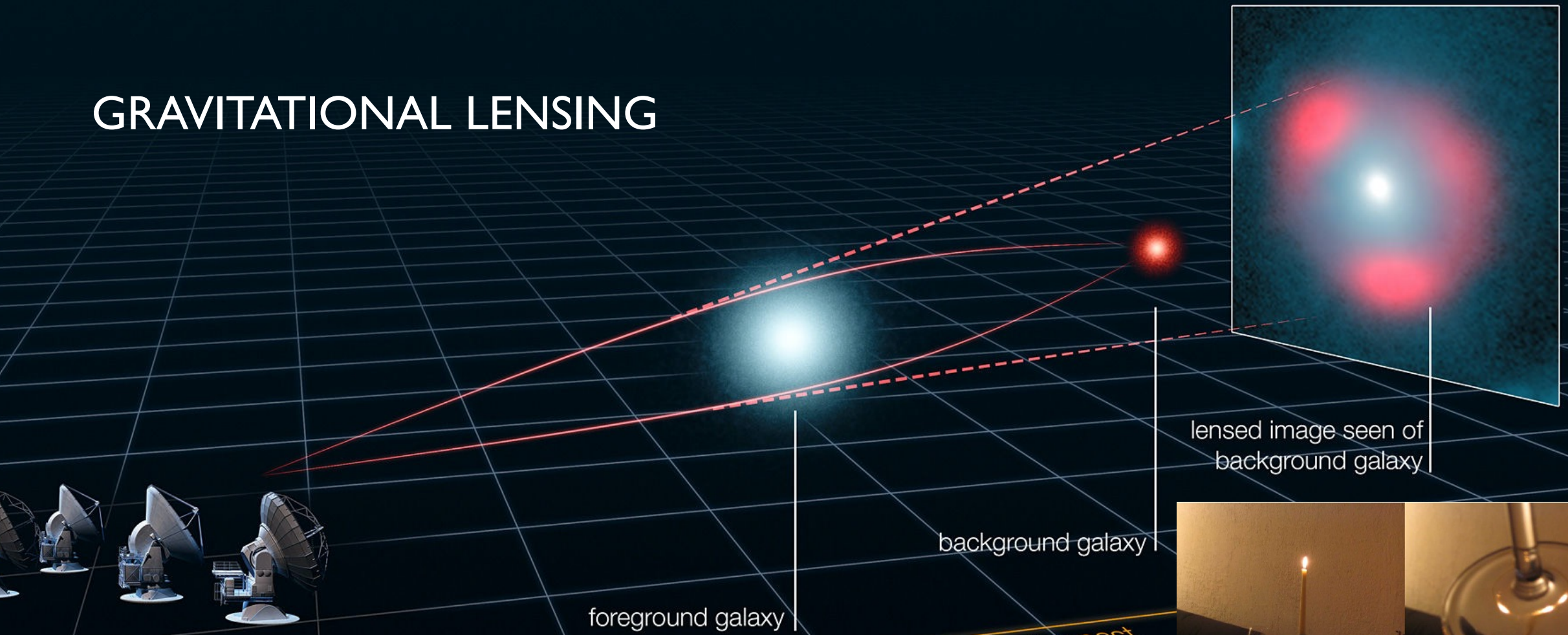
- Deep imaging of 6 massive clusters and their parallel (infall) fields
- Massive clusters = strong lensing, "Nature's magnifying glass"
- Data from >10 HST bands, 1 Ks band, and 4 Spitzer bands—large wavelength coverage

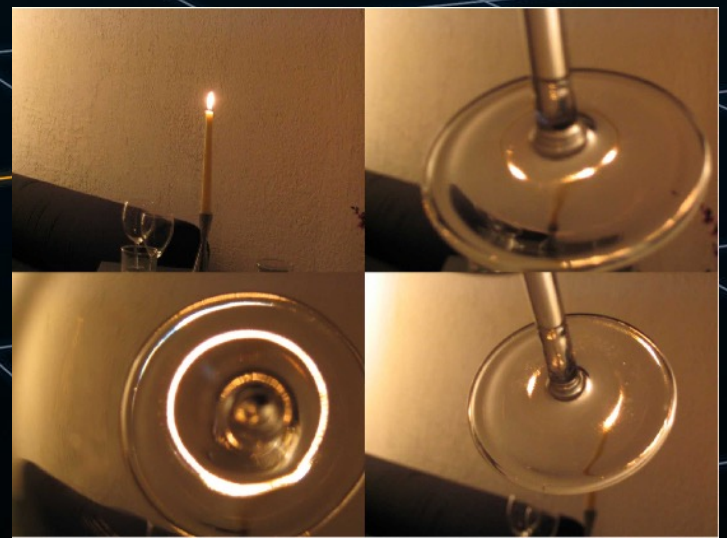






GRAVITATIONAL LENSING





- Typical magnification in strong lensing ~ 10
- Preserves surface brightness
- Lensing is achromatic

ALMA (ESO/NRAO/NAOJ), L. Calçada (ESO), Y. Hezaveh et al.

WHAT CAN CLUSTER STUDIES TELL US?

1

Understand how the galaxy properties evolve in different environments

2

Understand galactic assembly and clustering

3

Probe the high redshift universe

4

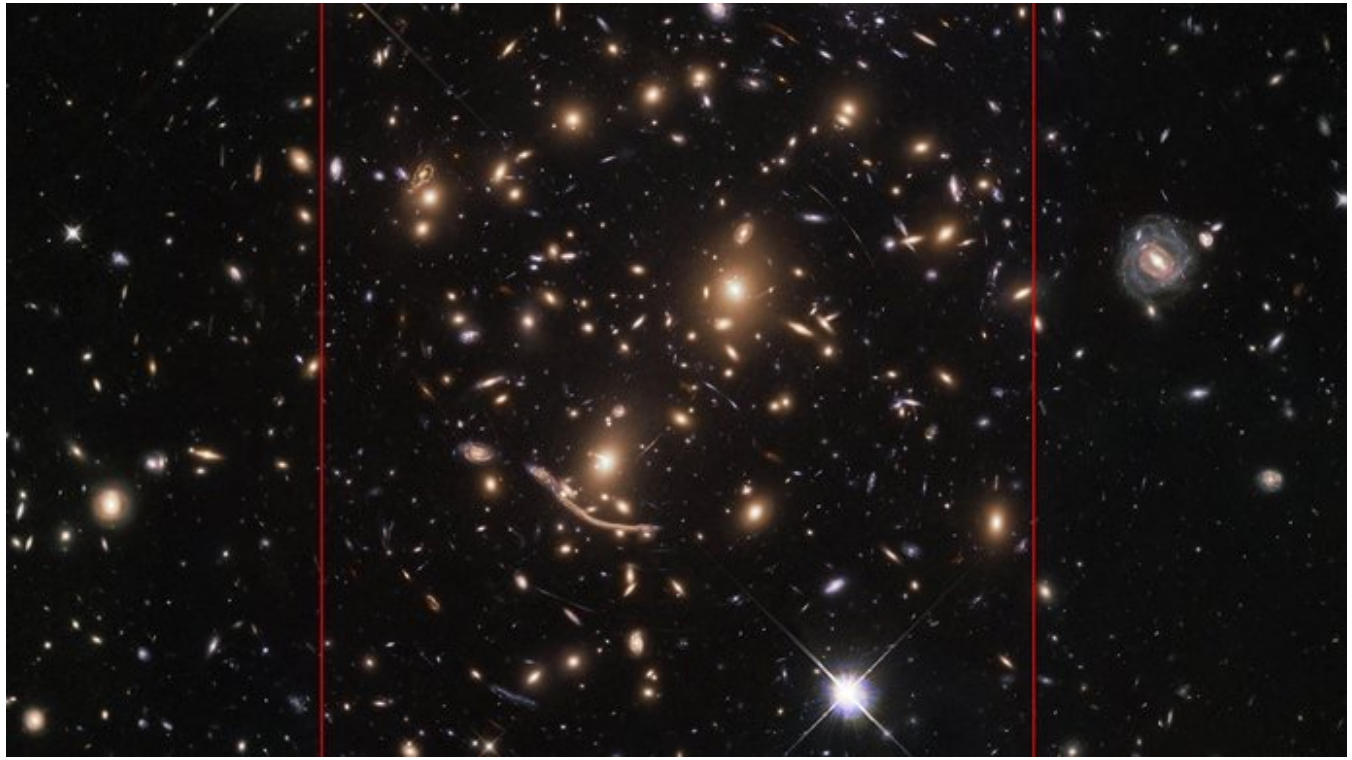
Prepare for future surveys, such as JWST and LSST

BEHIND THE SCENES

- This science is based on the existence of (galaxy) catalogs
- Raw products are (beautiful) images
- Data reduction and processing is an important building block in doing cluster science

HOW DO YOU GO FROM

This



Images courtesy of the BUFFALO collaboration

This?

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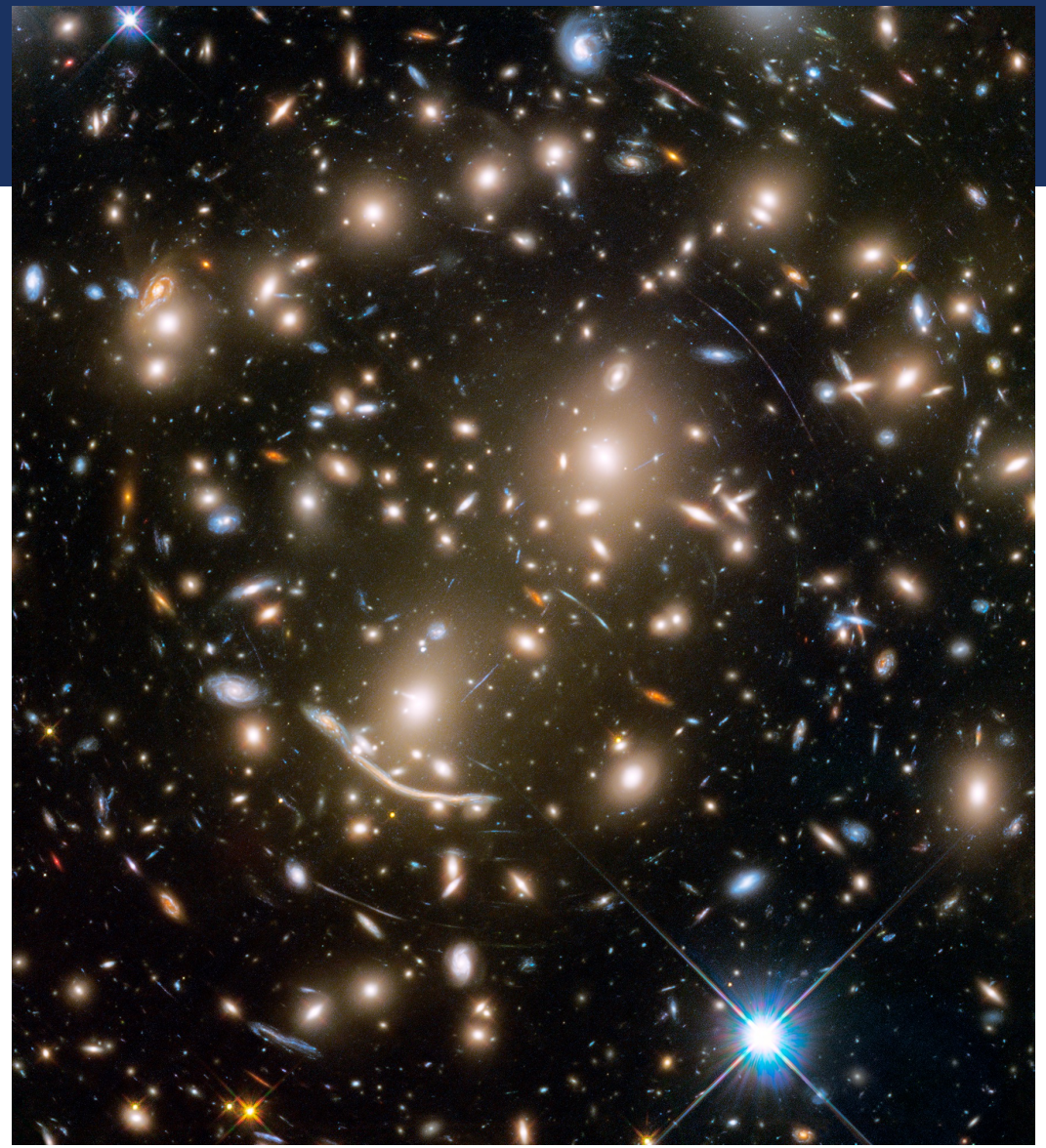
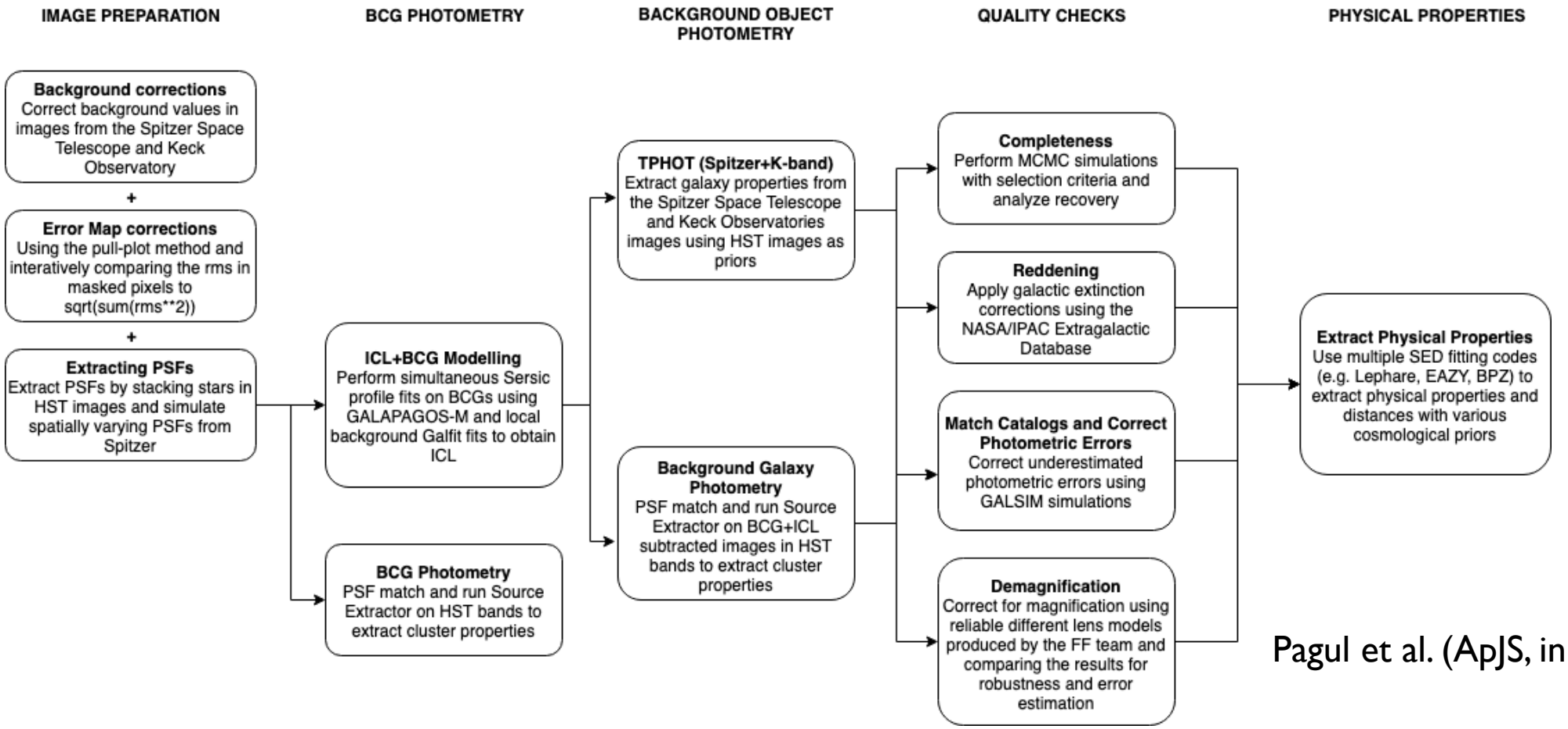
WHY IS THIS DIFFICULT?

- Extracting galaxy properties in crowded fields is a difficult problem
  - Blending
  - Bright cluster members
  - Intra-cluster light



PUFFIN PIPELINE

Photometric Utilities in the Frontier Fields INitiative

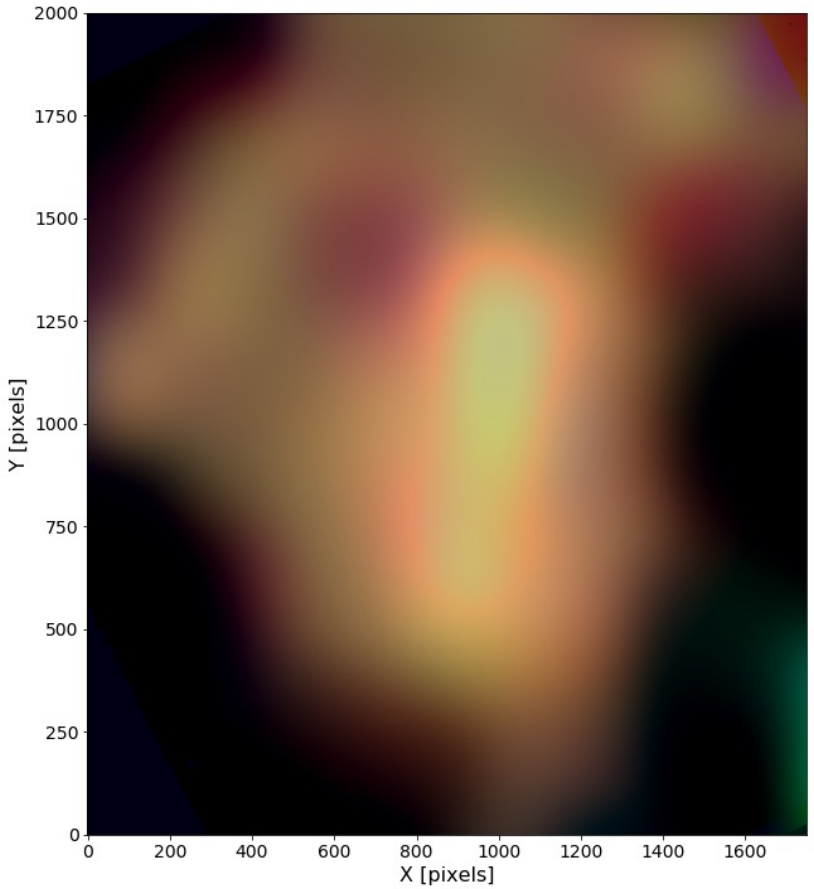


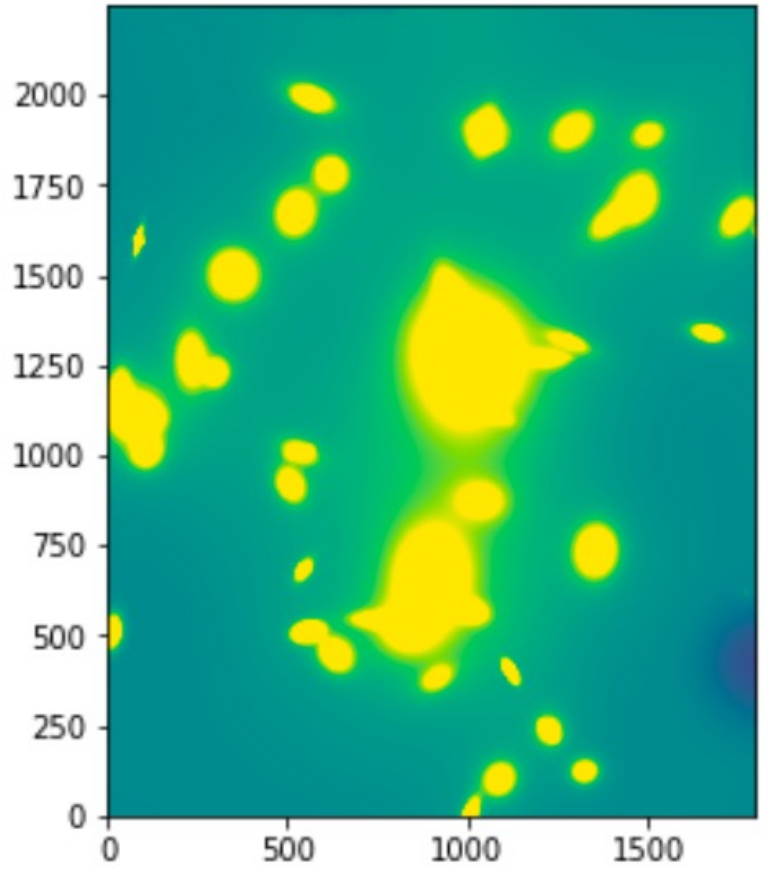
Pagul et al. (ApJS, in press)

PUFFIN PIPELINE

ICL+BCG Modelling
Perform simultaneous Sersic profile fits on BCGs using GALAPAGOS-M and local background Galfit fits to obtain ICL

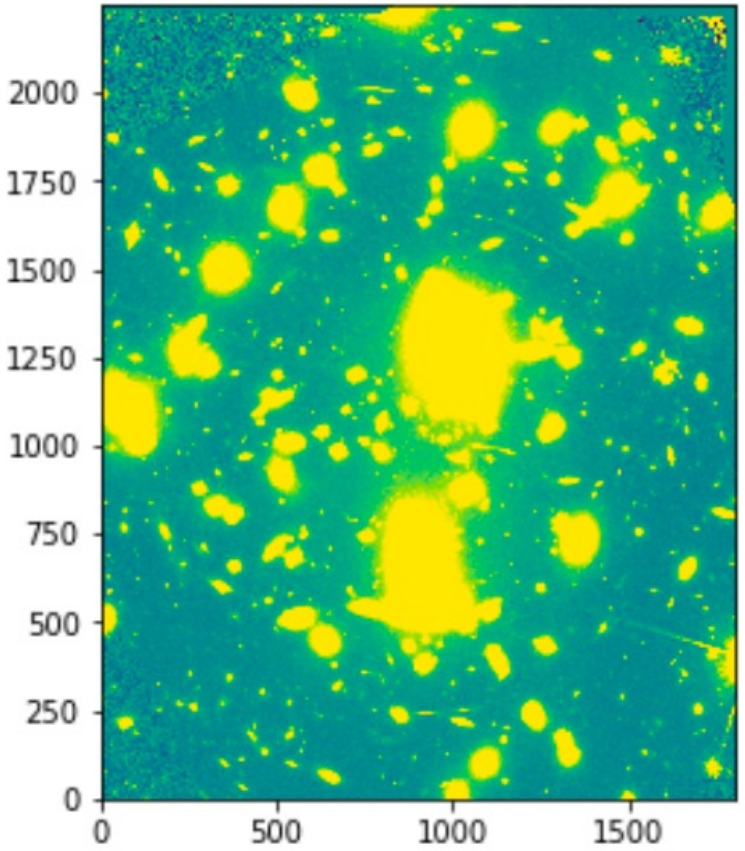
BCG Photometry
PSF match and run Source Extractor on HST bands to extract cluster properties



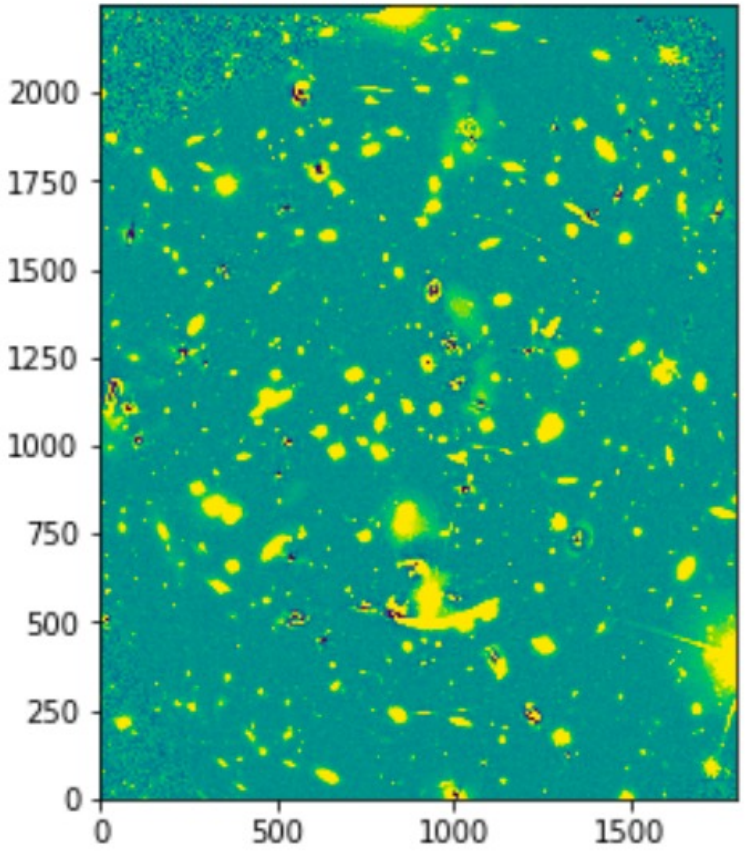


RESULTING IN…

Original

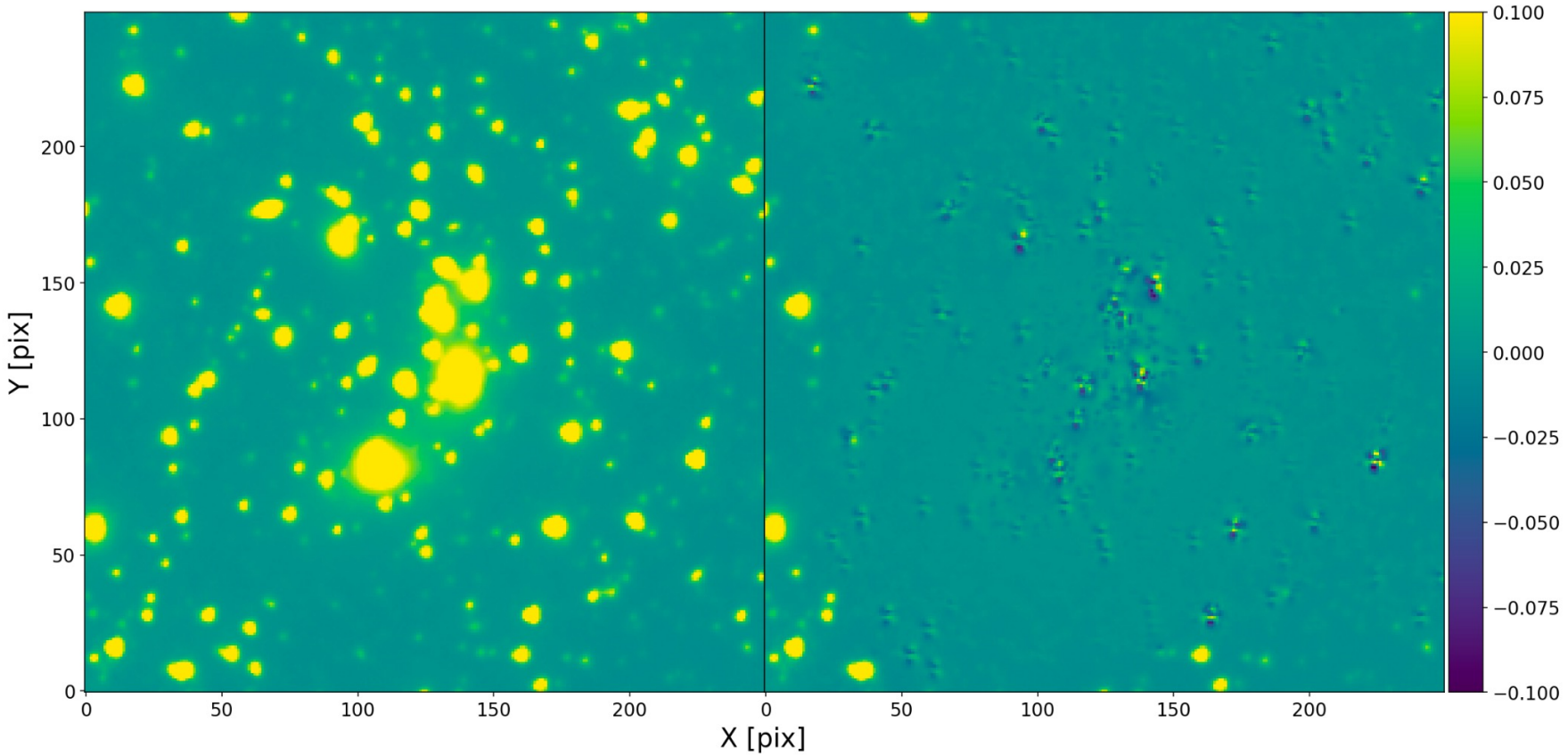


After ICL+BCG subtraction

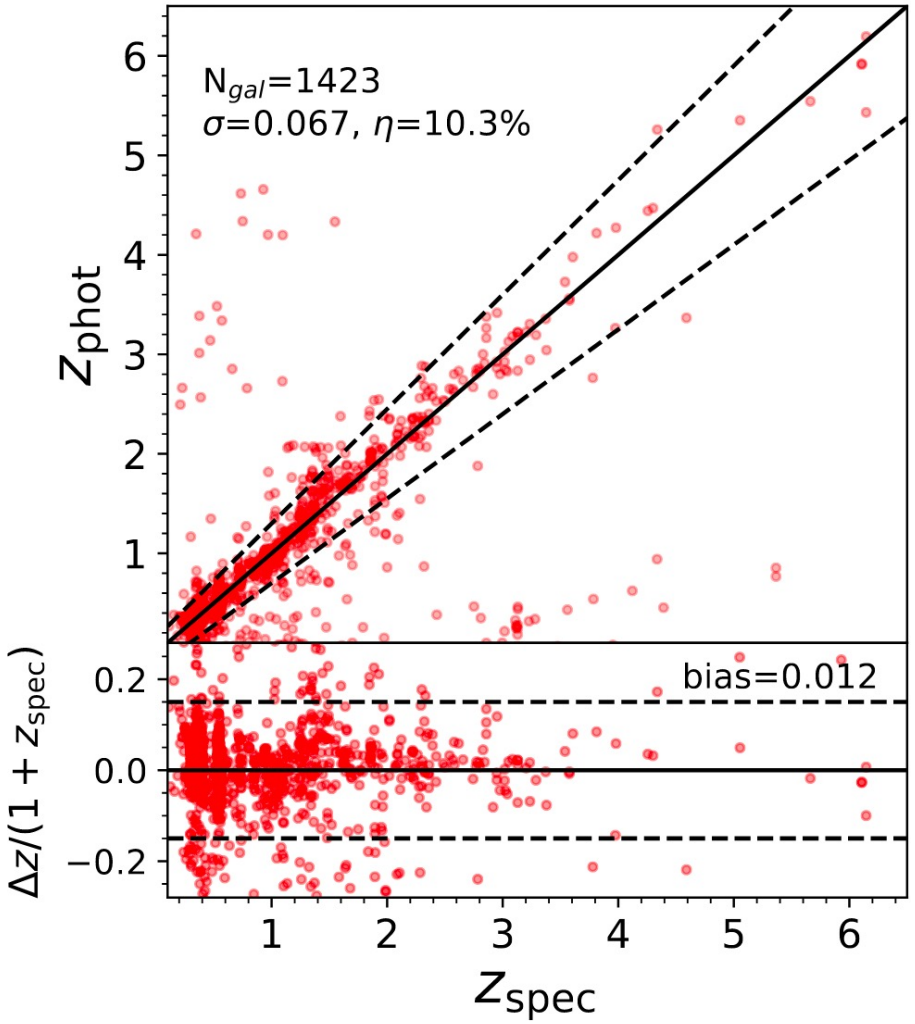


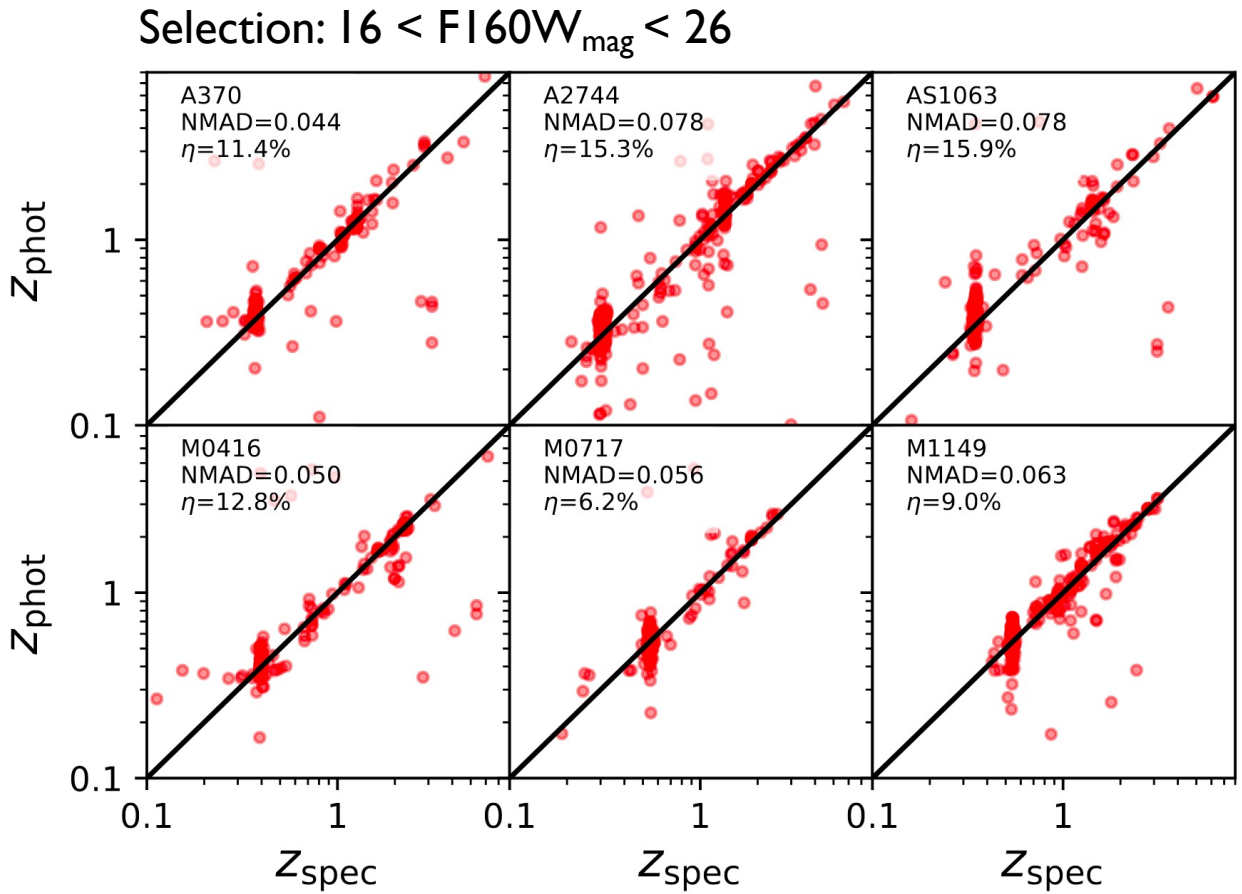
REDUCING ANCILLARY DATA

IRAC Channel 1 TPHOT Residual



CATALOG DIAGNOSTICS & RESULTS





Pagul et al. (ApJS, in press)

WHAT CAN CLUSTER STUDIES TELL US?

1

Understand how the galaxy properties evolve in different environments

2

Understand galactic assembly and clustering

3

Probe the high redshift universe

4

Prepare for future surveys, such as JWST and LSST

WHAT CAN CLUSTER STUDIES TELL US?

2

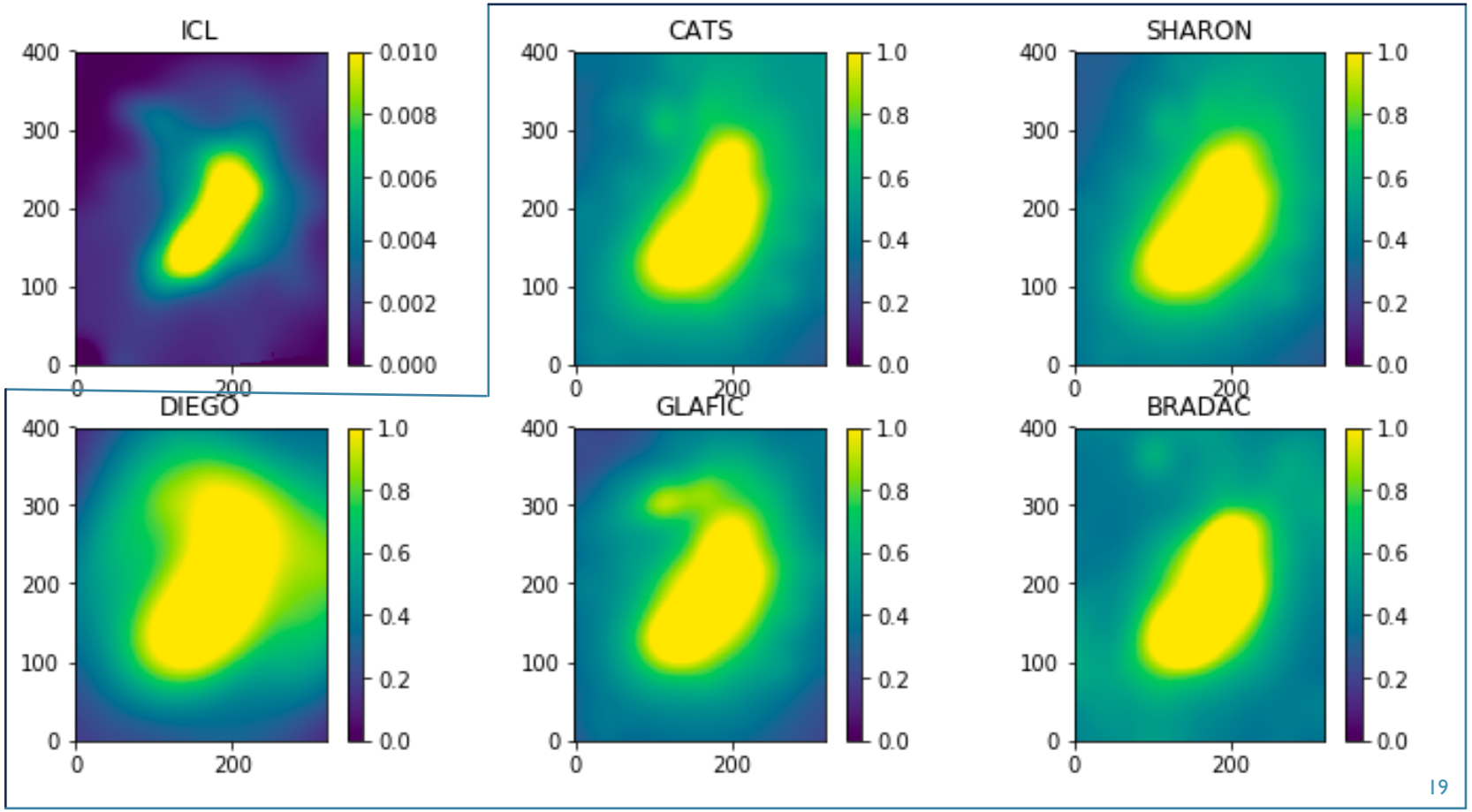
Understand galactic assembly and clustering

- Intra-cluster light is a significant contribution to light in clusters: 10-50% (Behroozi+ 13, Zhang+ 19)
- Is the ICL the same color as galaxies? Or stars?
- Can we infer properties about the gas from the ICL?
- Does the ICL trace matter? (Montes & Trujillo 19, Sampaio-Santos+ 20)
- Can the ICL help us make better mass maps?

WHAT CAN CLUSTER STUDIES TELL US?

2

Understand early galactic assembly and clustering



DM MASS MAPS

WHAT CAN CLUSTER STUDIES TELL US?

BEYOND ULTRA-DEEP FRONTIER FIELDS AND LEGACY OBSERVATIONS

3

Probe the high redshift universe

4

Prepare for future surveys, such as JWST and LSST

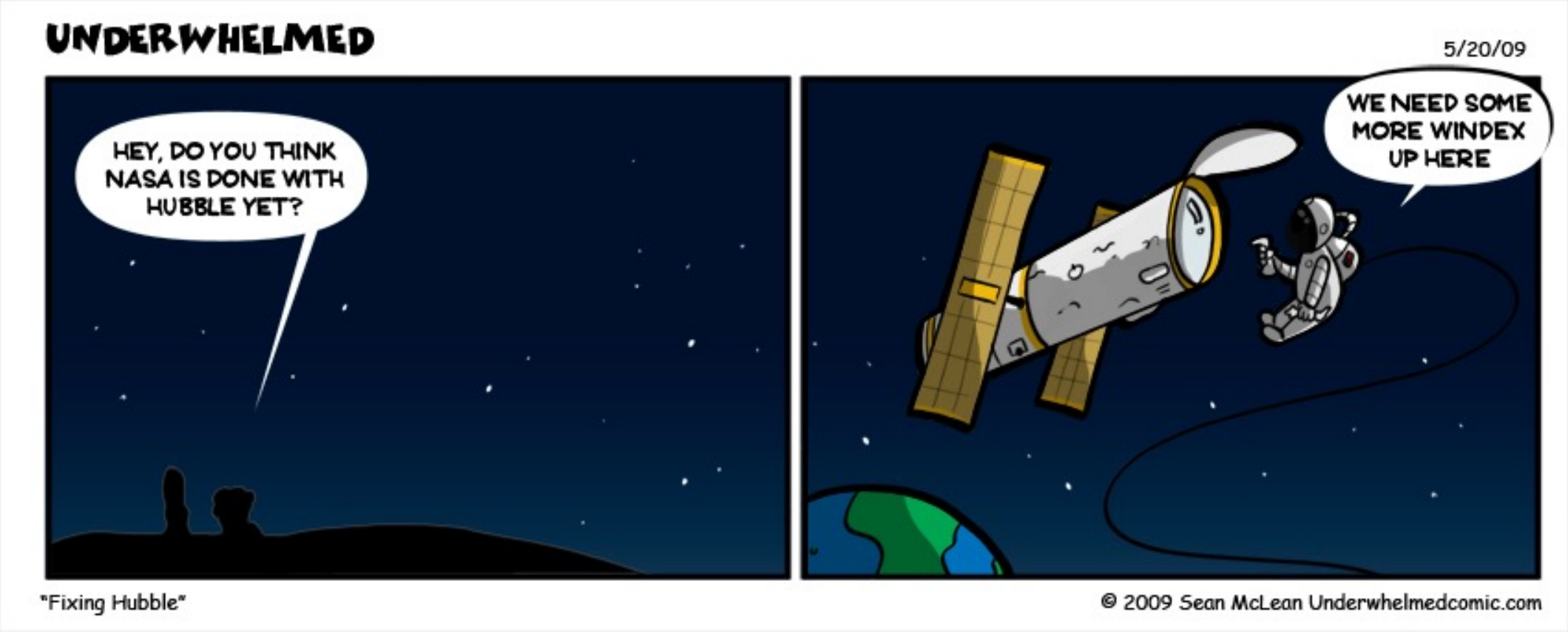
Steinhardt, Jauzac, and the BUFFALO collaboration (2020)

https://buffalo.ipac.caltech.edu/

SUMMARY

- Cluster science can help us answer questions about the universe at the smallest and largest scales.
- Cluster science is also very complex and efficiently capturing the data in a catalog is difficult.
- If you would like to use these HFF catalogs, please reach out to me at apagul@ucr.edu.
- Check out the work that BUFFALO is doing—potential for exciting new science!

THANK YOU FOR LISTENING!



BACKUP SLIDES

CATALOG DIAGNOSTICS & RESULTS

- Value added catalogs include >100 columns detailing positions, photometry, redshifts, and error/diagnostics in 15 HST+Ks+IRAC bands
- SED fitting done with LePhare

Arnouts & Ilbert