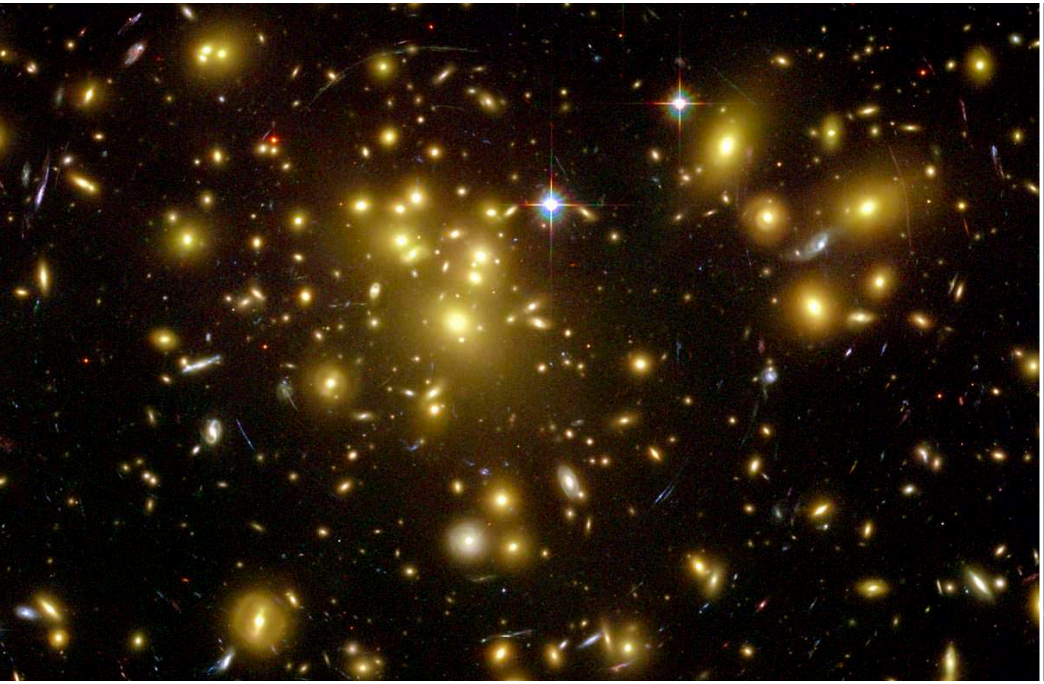



KYOUNG-SOO LEE (PURDUE UNIVERSITY)

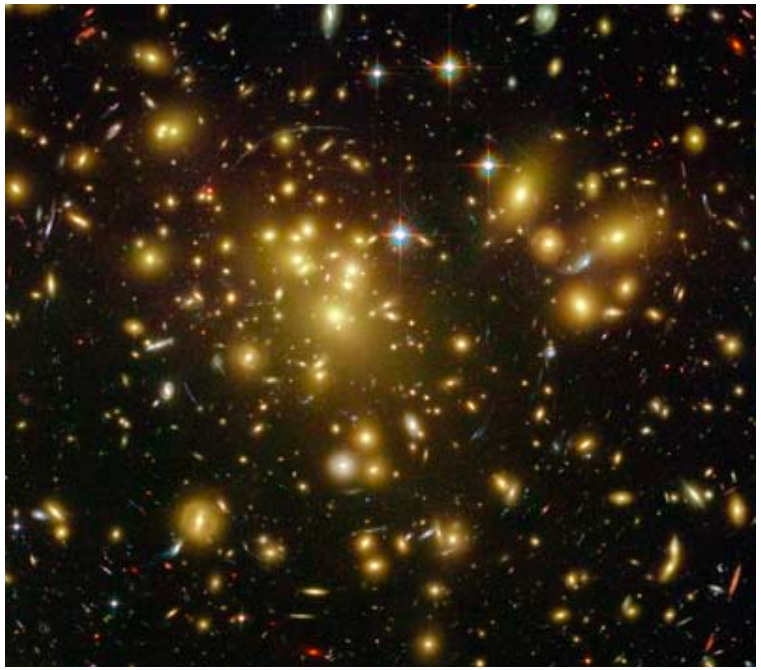
COSMIC STRUCTURE SIG SPECIAL SESSION, 237TH AAS MEETING

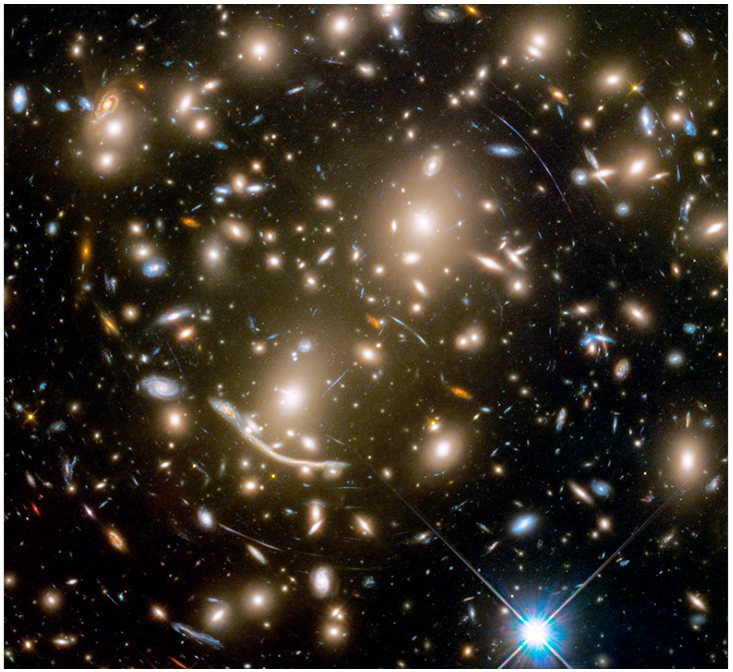
JANUARY 14 2021

THE ODIN SURVEY: HUNTING FOR THE LARGEST COSMIC STRUCTURES IN THE DISTANT UNIVERSE

PROTOCLUSTERS

- Cosmic laboratories to study how galaxy formation and evolution are affected by their large-scale environment.
- At low-z, cluster galaxies dominated by old early-type galaxies skewed towards high masses (cluster red sequence).
- `Fossil records' suggest early mass assembly massive assembly early (*Thomas+2005, Mei+2006, van der Marel & van Dokkum 2007*), but unclear why/how/when cluster galaxies grow and quenched.
- Clear star formation-density relation persists out to z~1.5; *Tran+2010, Brodwin+2013, Alberts+2014.* In the realm of protoclusters (z>~2), a clear picture has yet to emerge.





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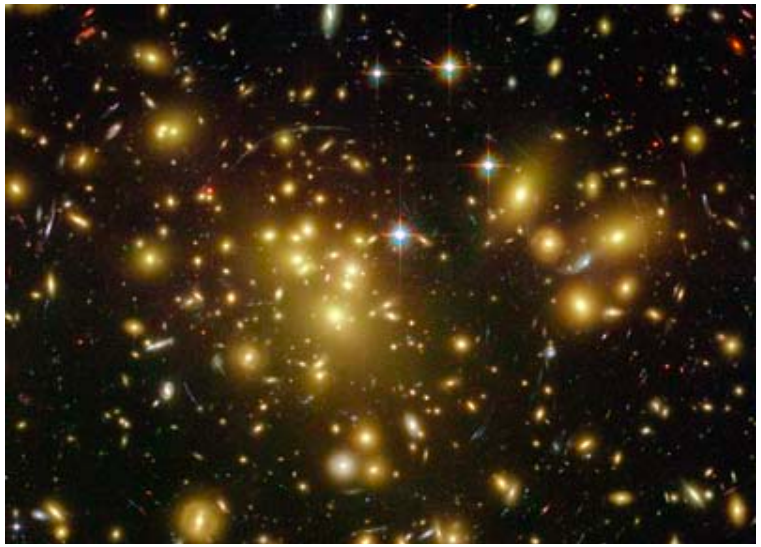
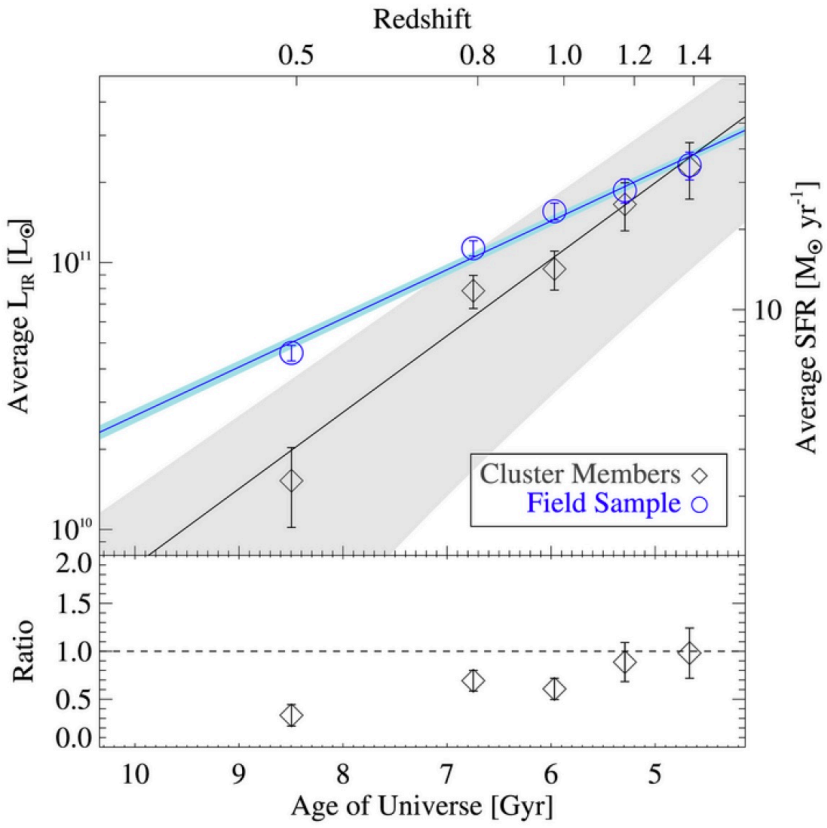
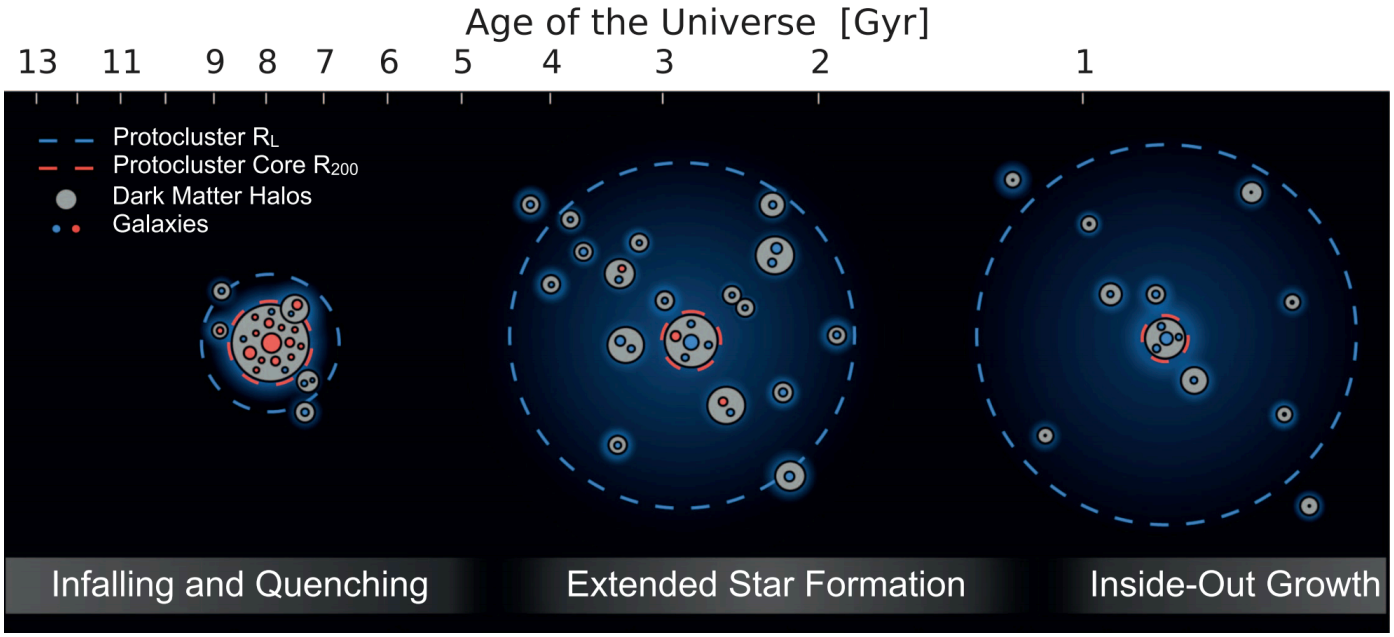




THE ASSEMBLY OF CLUSTERS AND GALAXY EVOLUTION THEREIN



Dense environments = higher merger rates
= more gas, star formation, dust
= more massive (older) host halos
= faster-growing halos (top-heavy mass function)?

AGN SF and starburst quiescent galaxies Lyα nebulae

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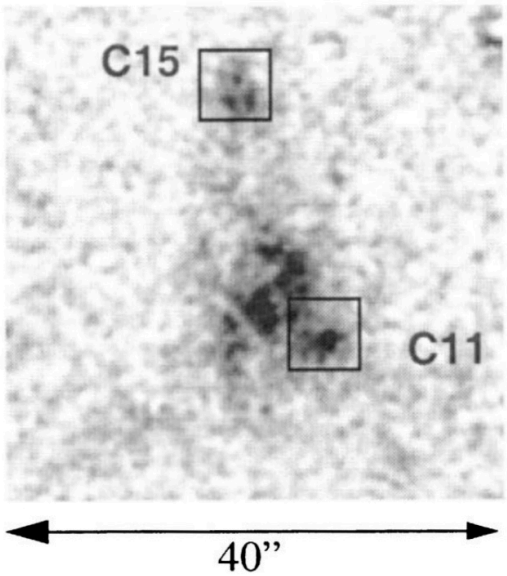
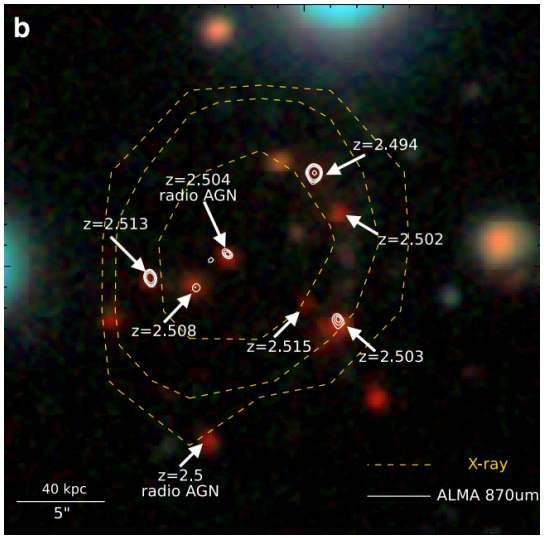
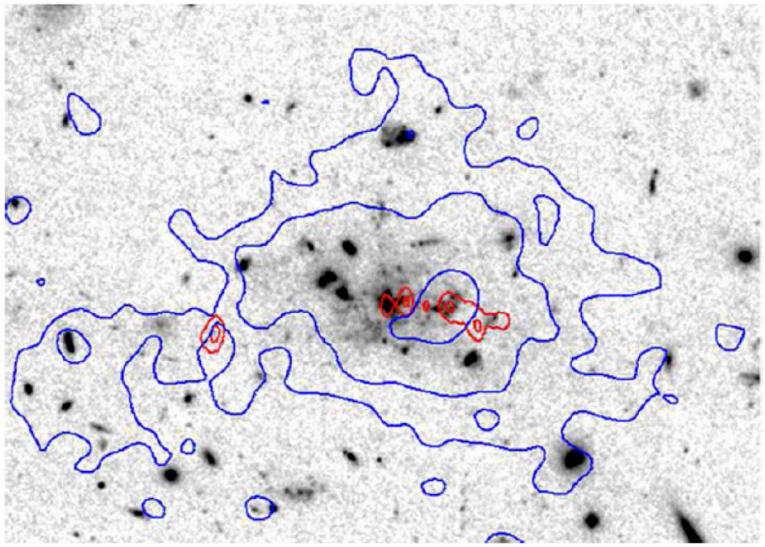


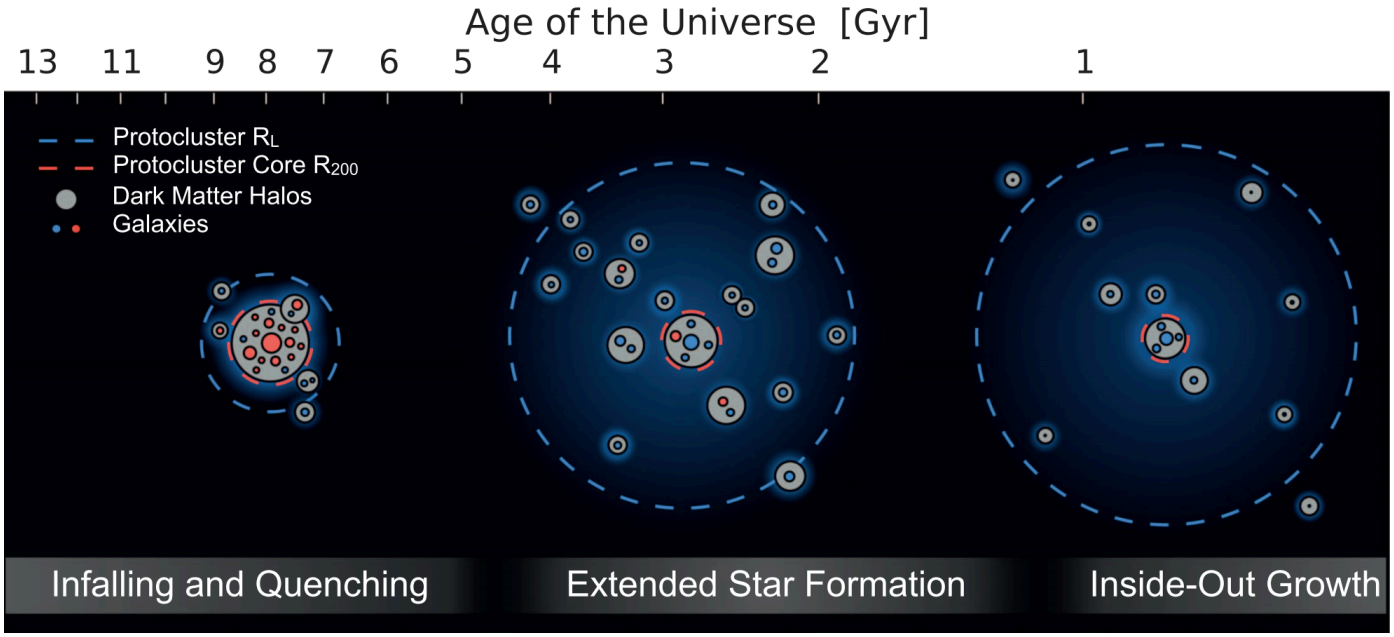




Abundance of AGN, sub-mm galaxies (SMGs), radio galaxies, Lya nebulae, older/ quiescent galaxies? *Steidel+(2000, 2005), Umehata+(2015,2019), Wang+(2016), Dannerbauer+(2014), Hatch+(2011), Casey+(2015), Planck Collaboration XXVII 2015, Shi, KSL+(2019a,b), Kubo+(2016), Lemaux+(2020), Ito+(2020)…(see review by Overzier 2016)*

AGN SF and starburst quiescent galaxies Lya nebulae

THE ASSEMBLY OF CLUSTERS AND GALAXY EVOLUTION THEREIN



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AGN SF and starburst quiescent galaxies Lyα nebulae

- To capture the full picture, sensitive panchromatic observations are needed
- To tie these obs to present-day clusters, also need the structural context

PROTOCLUSTERS ARE ENORMOUS!

pre-virialized cosmic volume of protoclusters

virialized cosmic volume of protoclusters

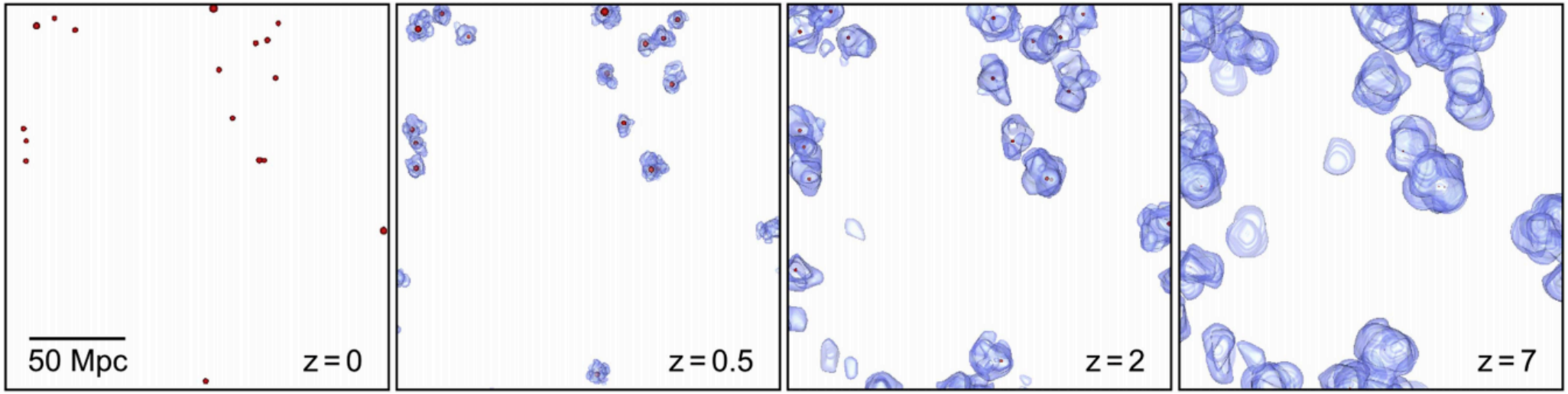


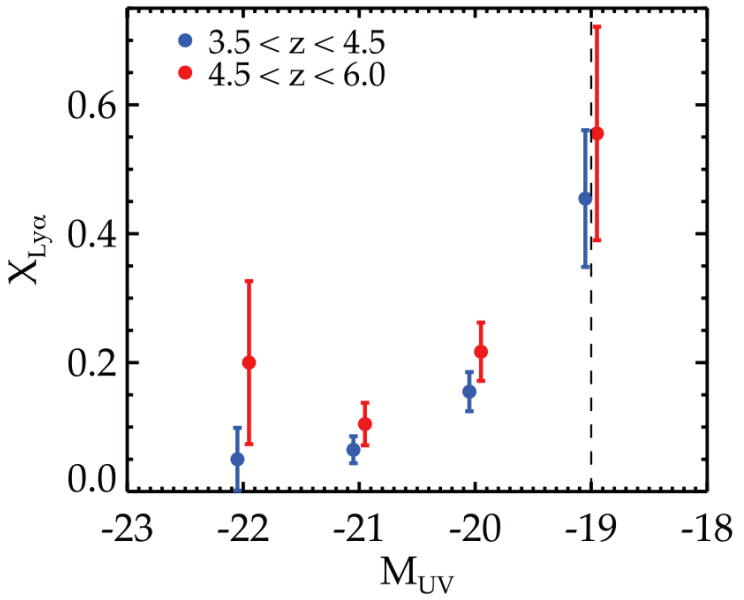
Figure 1. Cosmic volumes occupied by (proto)clusters of $M_{z=0} > 10^{14}\ M_{\odot}$ at $z = 0$, 0.5, 2, and 7 in a slab of 200 × 200 × 50 comoving Mpc^3. Blue surfaces indicate the Lagrangian boundaries of (proto)clusters. Red spheres indicate the virial radii of the most massive core halos.

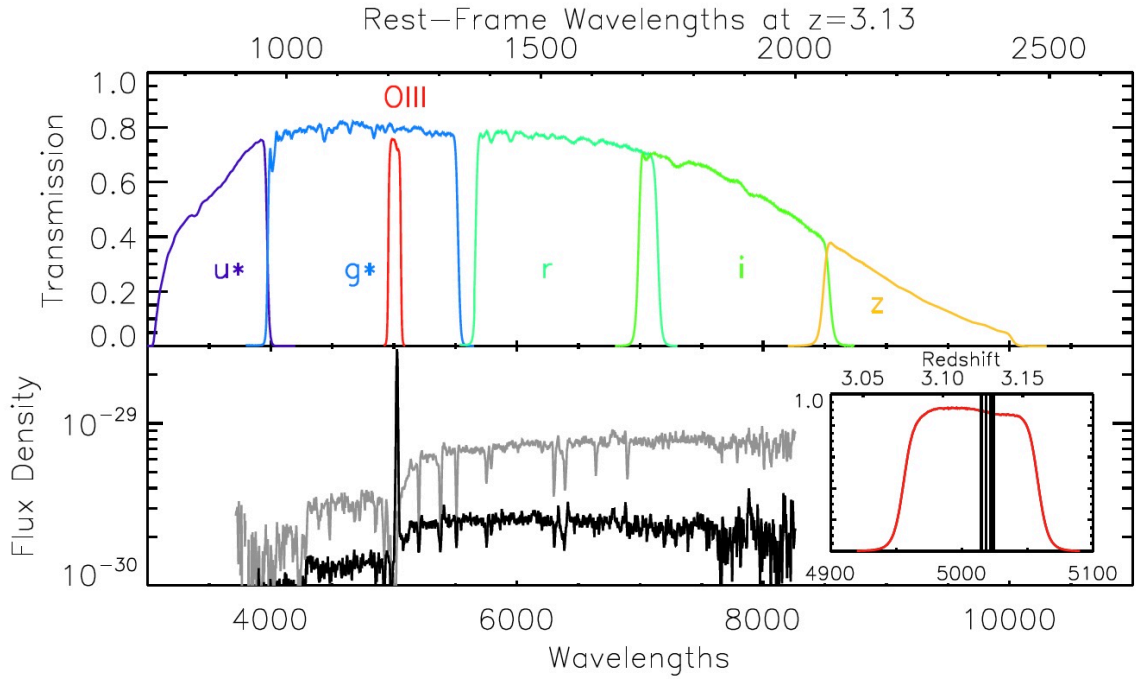
Chiang+2017

- the volume that will end up virialized by z=0 can be spread over ~20 cMpc across (>10′ on sky)
- Problematic for member identification as well as characterization of their structures
- Protoclusters are also extremely rare!

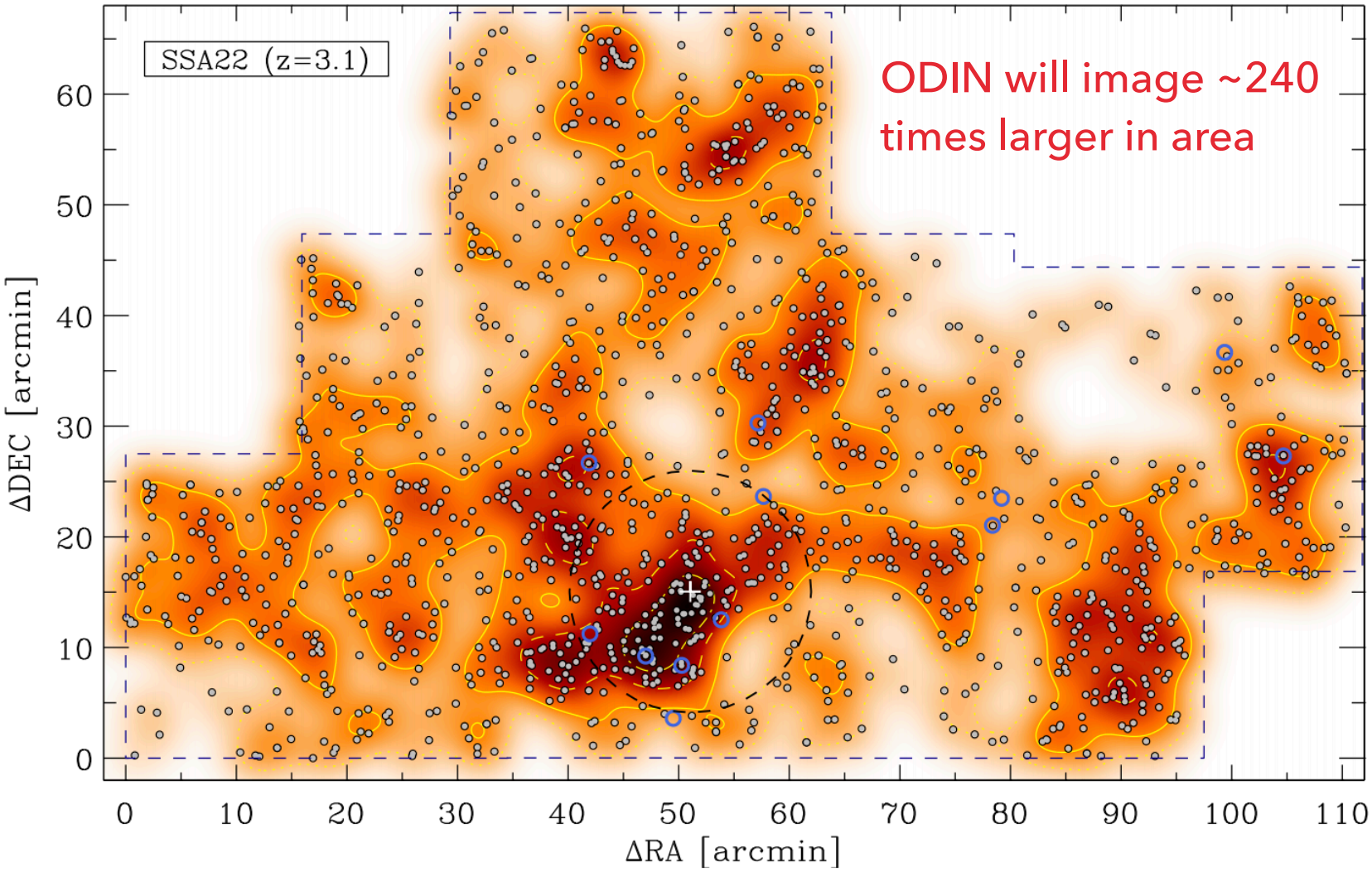
THE ODIN (LYMAN ALPHA) SURVEY

- The One-hundred-square-degree DECam Imaging in Narrowbands (ODIN) uses Lyα, the most luminous emission line from star formation
- a high fraction of low-luminosity/mass galaxies emit Lya *Stark+2010, Kusakabe+2020* effectively tracing the large-scale structure around massive structures (b~2)
- Provides a robust and direct way to identify the largest, most massive cosmic structures
- galaxy selection via narrow-to-broad-band flux ratios



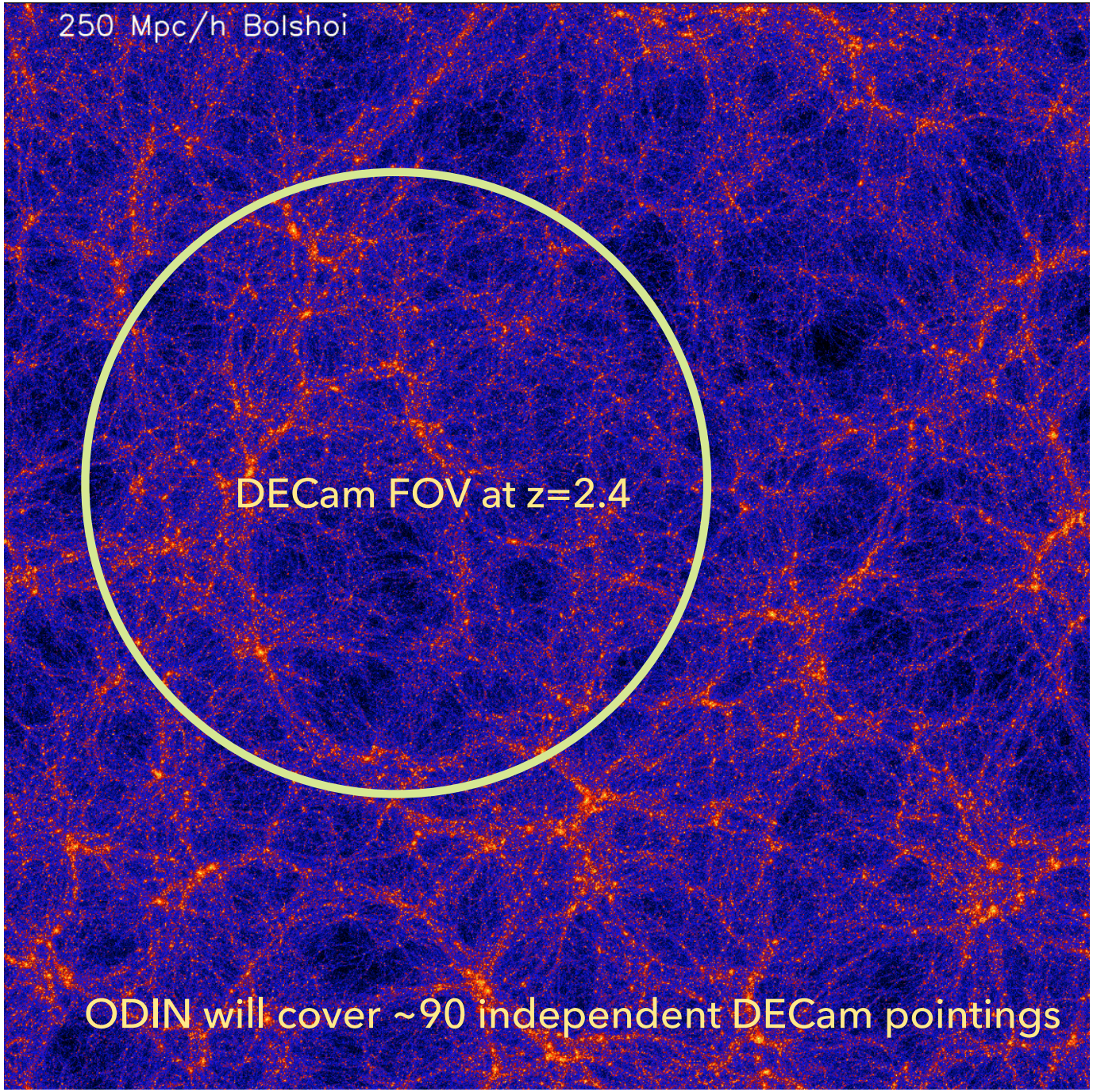


SSA22 PROTOCLUSER AT LYMAN ALPHA WAVELENGTH



THE ODIN SURVEY AT A GLANCE

- **Three** cosmic time slices – z~4.5, 3.1, 2.4 (t_{age}=1.3, 2.0, 2.7 Gyr since BB) – with three narrow-band filters to sample the peak epoch of cluster formation.
- Image **91 deg²** with 3 filters down to 25.5-26.0 AB (5σ, 2″) over 3 years (starting in 2021A).
- **Seven** deepest wide-field imaging data (in existence and upcoming): **four** LSST Deep Drilling Fields, **two** Euclid Deep Fields, **three** SSP fields, and **one** HETDEX field.
- Samples the total volume: **0.24 Gpc³** (~70% of the Millennium sim)
- **65,000** Lya-emitting galaxies, **~45 Coma** progenitors, **~600** Virgo progenitors, and **200-1,000** extreme Lya nebulae


250 Mpc/h Bolshoi
DECam FOV at z=2.4
ODIN will cover ~90 independent DECam pointings

SYNERGY WITH EXISTING AND UPCOMING MISSIONS

Rubin/LSST

- identify star-forming member galaxies;
- characterize the key statistics (SF activity, dust properties, Lyα escape fraction, etc.) as a function of large-scale environment

DESI

- identify AGN to test the hypothesis of AGN overabundance in structures;
- detect line-absorbers (probing HI gas and low-mass galaxies) in nearby quasar sightlines;
- confirm bright member galaxies; test LAEs as cosmological probes (BAO at $z>\sim2$)

HETDEX

- confirm AGN and star-forming members (with strong emission);
- expand the correlation function analysis to higher z ($z>3.5$) and to lower luminosities

SYNERGY WITH EXISTING AND UPCOMING MISSIONS (CTND.)

James Webb

- unbiased spectroscopic identification of *all* members regardless of types;
- measure protocluster stellar mass function;
- constrain chemical evolution and ionization mechanisms

Euclid

- rest-UV morphologies, stellar mass measurements, identification of star-formers via line detection

Roman

- identify massive quiescent galaxies to constrain the evolution of quenching process in clusters

wide-field (medium-resolution) spectroscopic capabilities, 15’ or larger, will be most useful for the protocluster science (or for similarly extended objects)