Lyα Blobs:
Seeds of Galaxy Groups

Agnar Hall

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New Mexico Symposium

Outline

- intro to Lyα blobs
- background
- our blobs
- detecting overdensities
  - method
  - results
- constraining membership
  - motivation/method
  - results
- future work
- conclusions

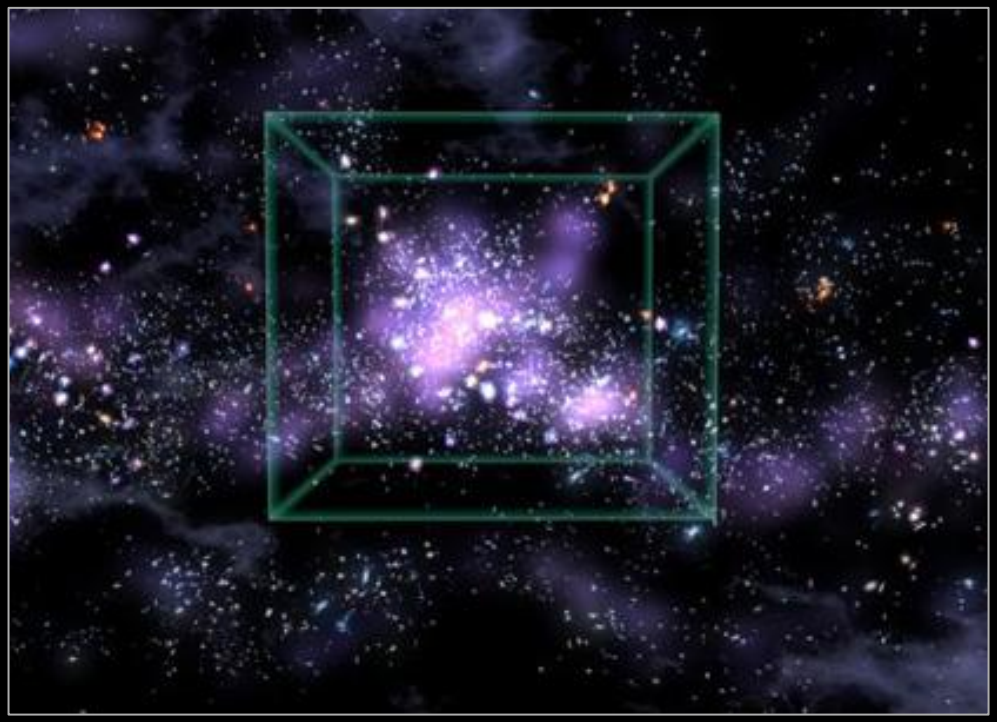


Image credit: University of Tokyo Kiso Observatory (via The Daily Galaxy)

What are giant Lyα blobs?

- Cosmic web should glow in Lyα:
  - photoionization by AGN and/or star formation
  - gravitational cooling
  - scattering
  - galactic winds and shocks
- This glow is typically too faint to observe…
- Nodes of cosmic web are brighter
  → giant Lyα blobs!

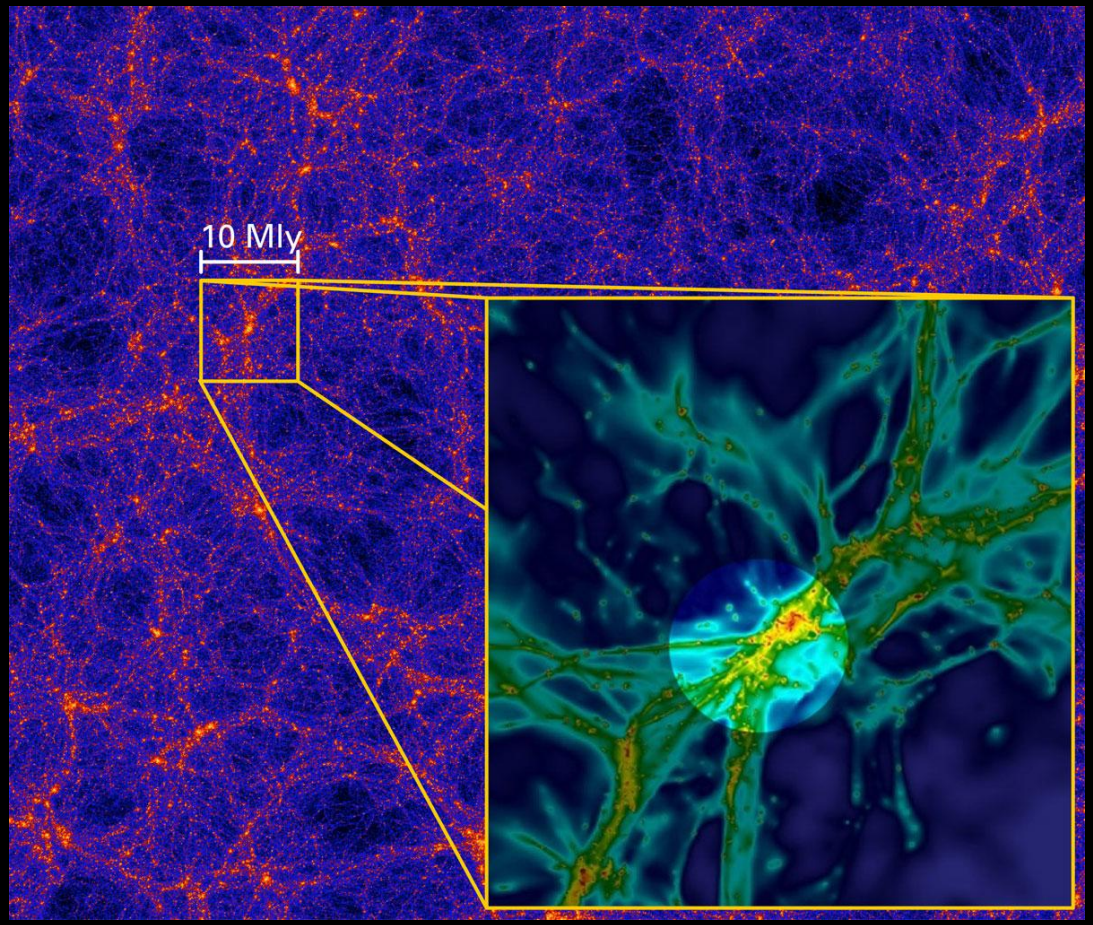


Image credit: Anatoly Klypin (NMSU) & Joel Primack (UCSC), inset by Sebastiano Cantalupo (UCSC)

What are giant Lyα blobs?

- >~100 kpc across
- found at roughly $1 < z < 6$
- extremely luminous in Lyα ($\sim 10^{42}$ - 10^{44} erg s^{-1})
- ~30-some blobs currently known (first detection 1997)
- complex morphologies
- powering mechanisms debated
- contain obscured AGN and/or star-forming galaxies
- overdense?
  - individual blobs have been found to be overdense
  - statistically overdense? → purpose of this work

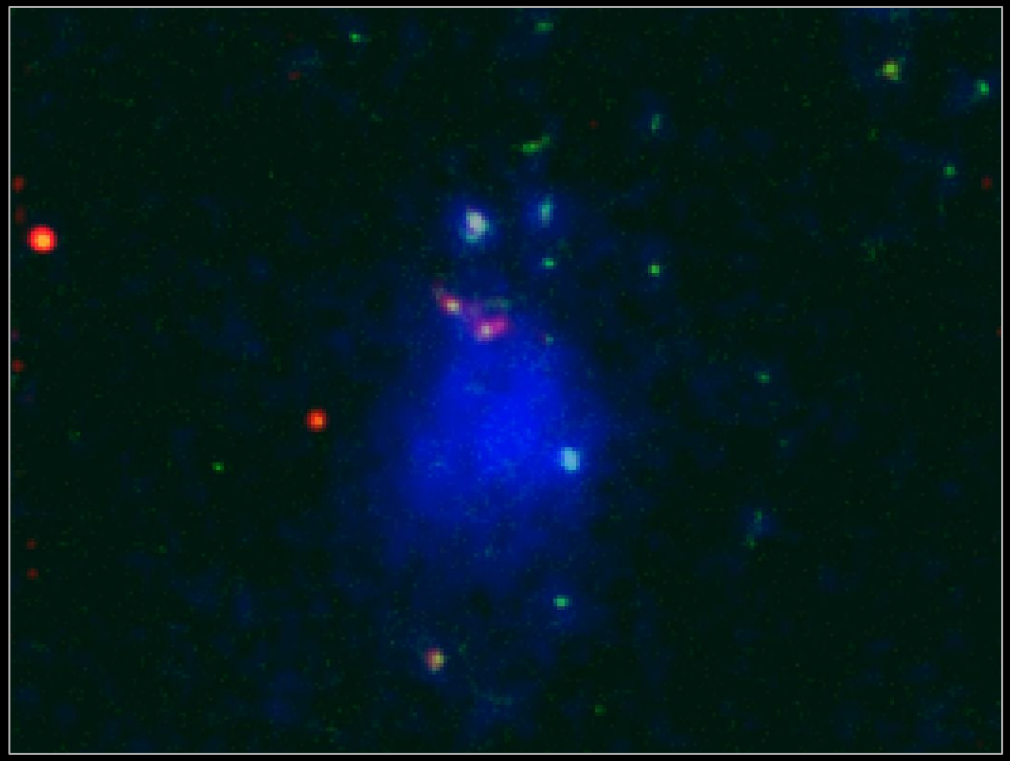
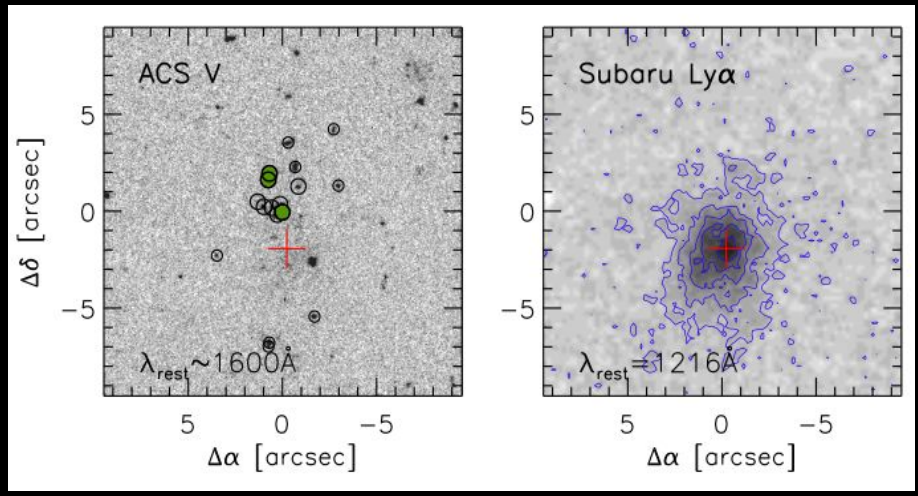


Image credit: Moire Prescott & Arjun Dey (2010)

Background

- LABd05: Prescott et al. 2012b examined substructure
- found to be overdense by factor of at least ~4
- similar method used in this work

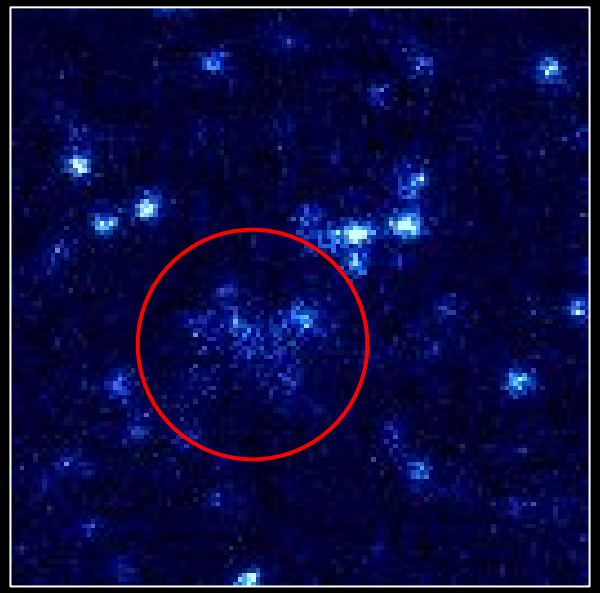


LABd05 galaxies and blob from Prescott et al. 2012b

- MMT: blobs PRG1, PRG2, PRG3 found in NDWFS Boötes field
- confirmed spectroscopically (Prescott et al. 2012a)
- HST: images taken in 3 bands for each blob (WFC3-UVIS)
- bands picked to bracket the Balmer/4000 Å break

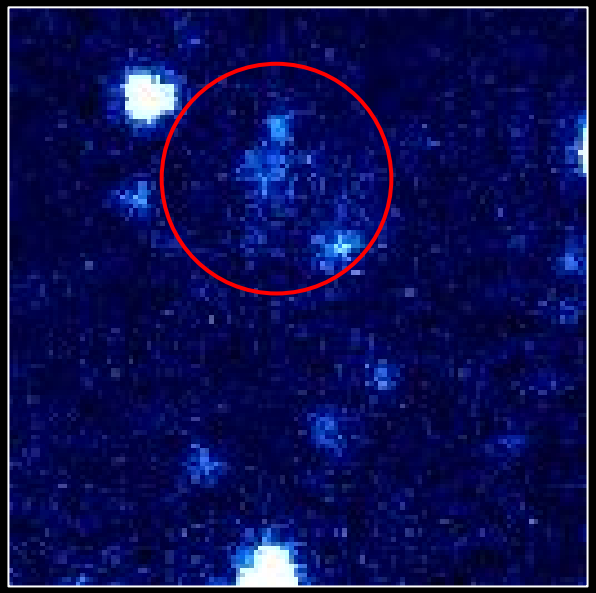
Meet the blobs!

PRG1



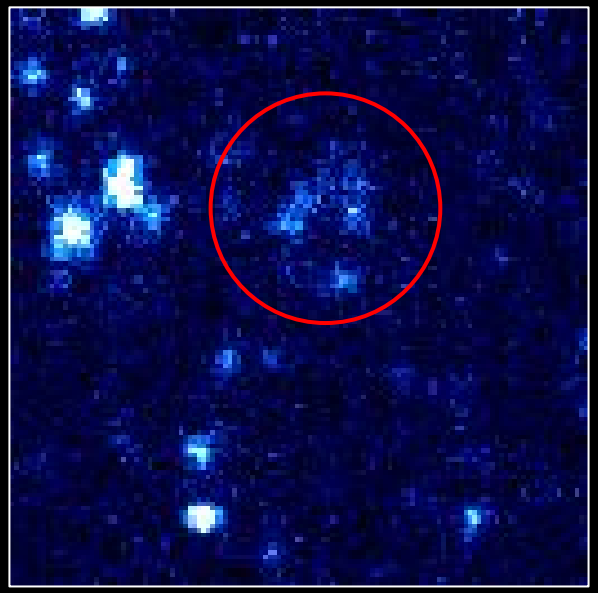
- z = 1.67
- Lyα diameter = 78.3 kpc
- isophotal area ~3100 kpc^2

PRG2



- z = 2.27
- Lyα diameter = 99.0 kpc
- isophotal area ~7000 kpc^2

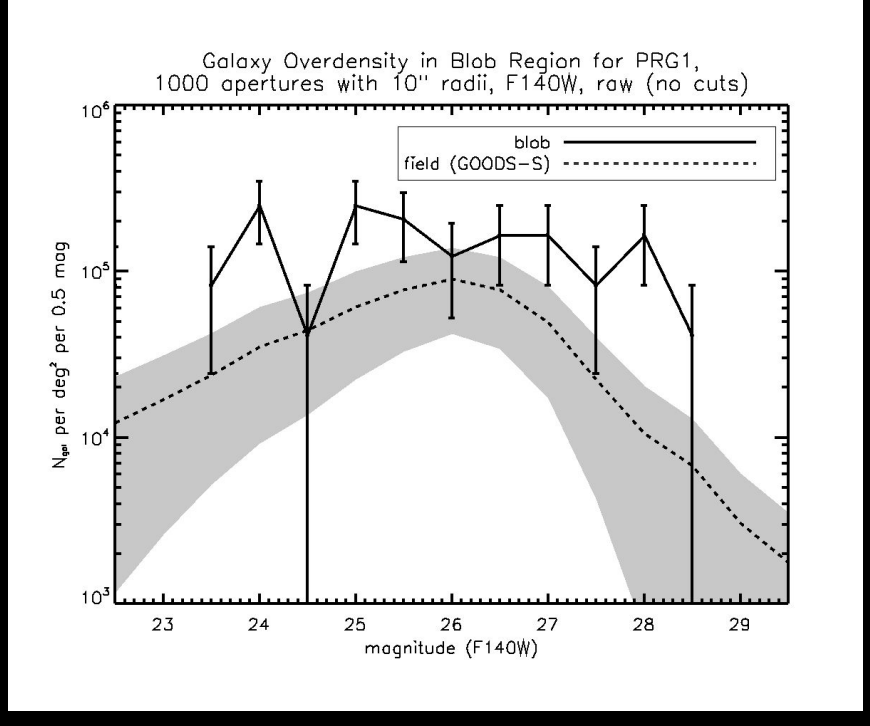
PRG3

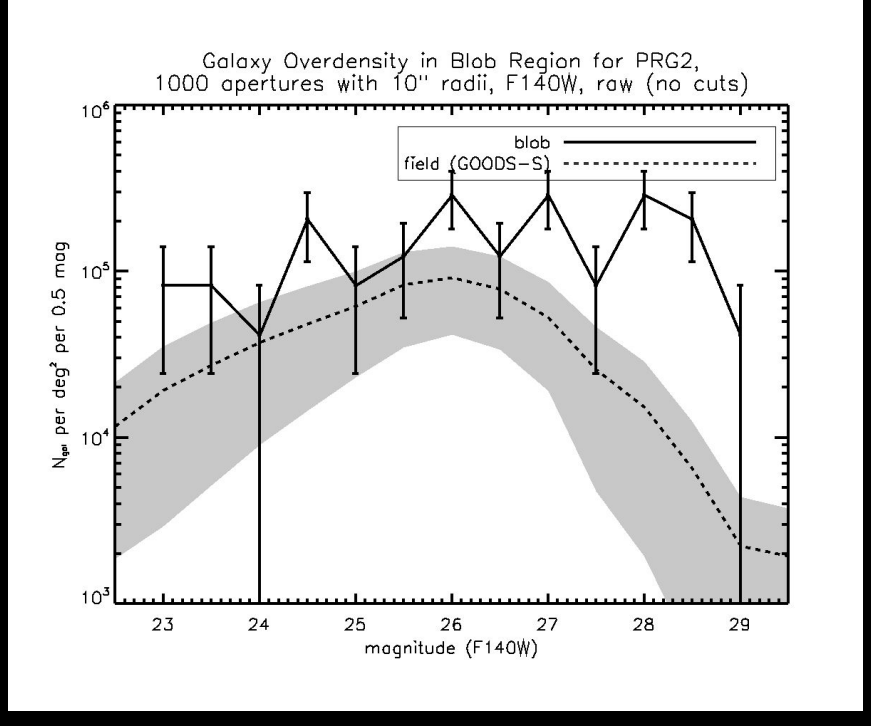


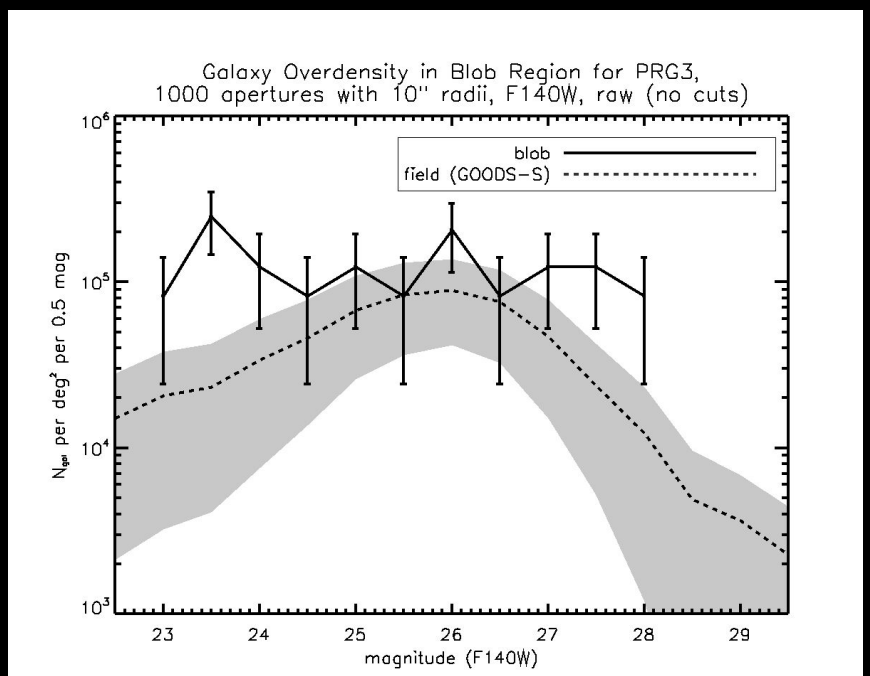
- z = 2.14
- Lyα diameter = 74.4 kpc
- isophotal area ~5500 kpc^2

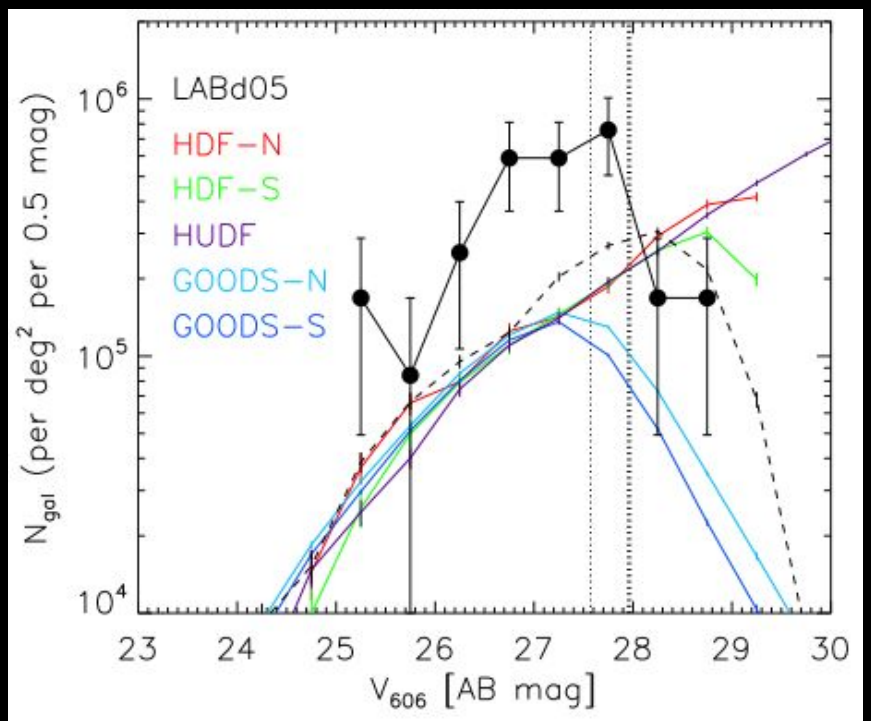
Detecting Overdensities

- blob density
  - place aperture on blob (radius of 10”)
  - count up galaxies inside aperture
- field density: GOODS-S (3DHST)
  - place random apertures all over image
  - count up galaxies in each aperture
  - calculate density in each aperture
  - average all apertures for final field density
- results? (drumroll…)


Galaxy Overdensity in Blob Region for PRG1,
1000 apertures with 10'' radii, F140W, raw (no cuts)
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)

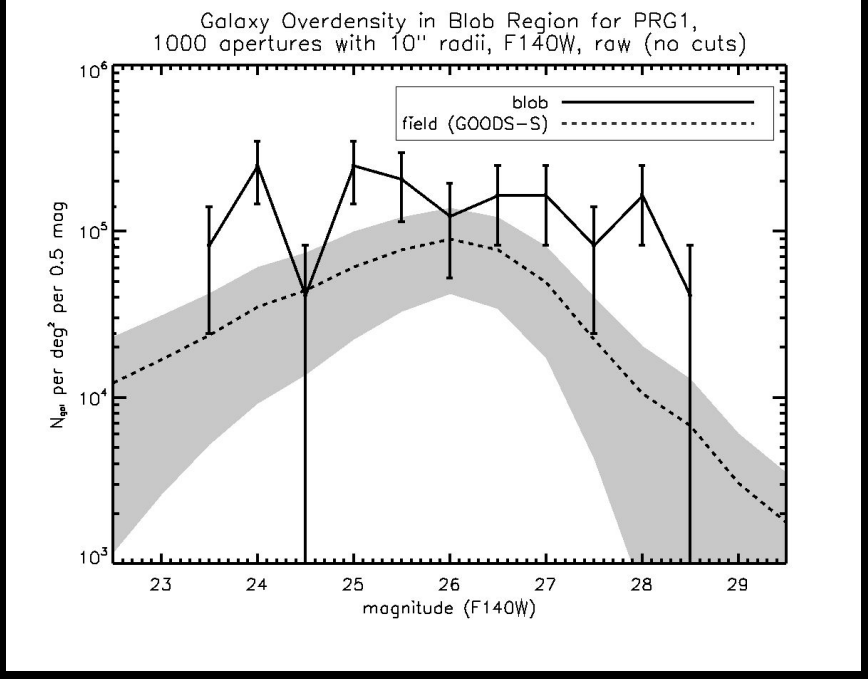

Galaxy Overdensity in Blob Region for PRG2,
1000 apertures with 10'' radii, F140W, raw (no cuts)
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)

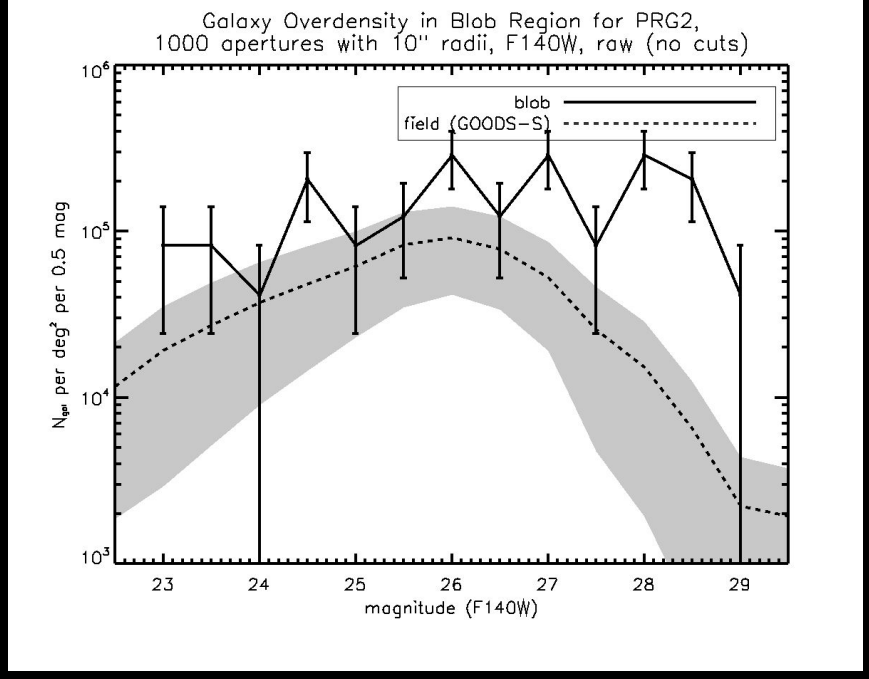

Galaxy Overdensity in Blob Region for PRG3,
1000 apertures with 10'' radii, F140W, raw (no cuts)
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)

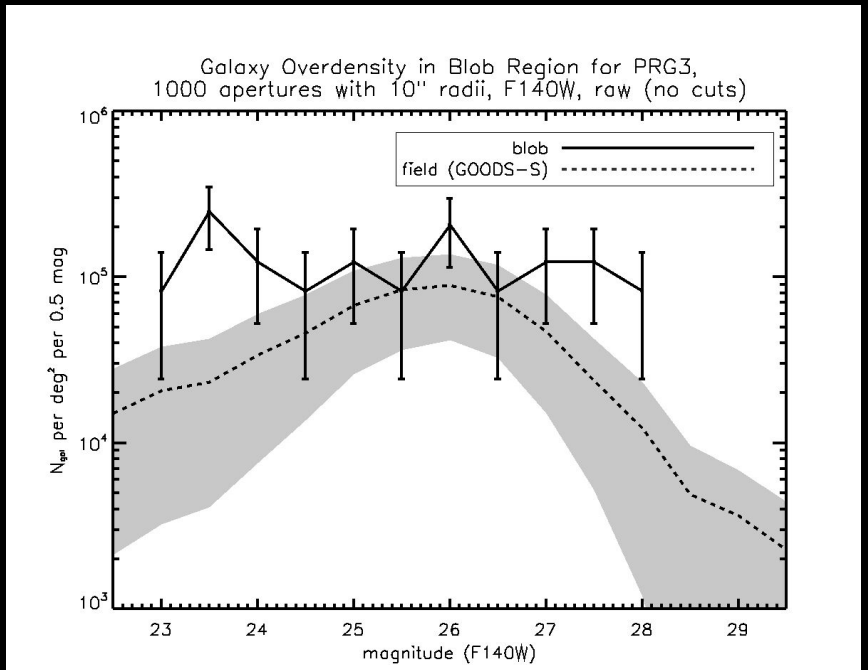

LABd05
HDF-N
HDF-S
HUDF
GOODS-N
GOODS-S
N_{gal} (per deg^2 per 0.5 mag)
V_{606} [AB mag]

Constraining Membership

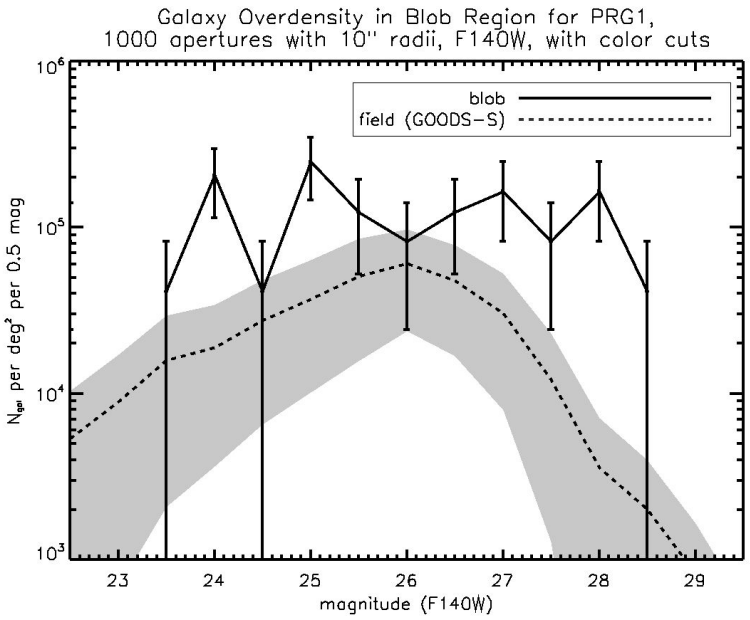
- all 3 blobs display an overdensity
- this is ALL galaxies in image, though… want to narrow down membership
- need to exclude inconsistent redshifts
- don't have spec-z for every galaxy in catalog…
- photo-z? → future work (more bands = better)
- for now, a simpler method: **color cuts**
  - narrow sample down to only galaxies with colors consistent with z (blob AND field)

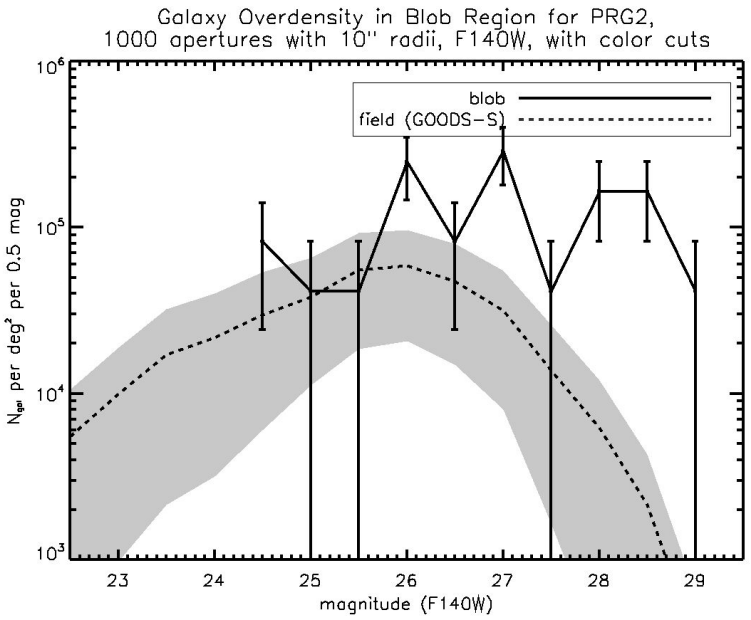

Galaxy Overdensity in Blob Region for PRG1,
1000 apertures with 10'' radii, F140W, raw (no cuts)
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)

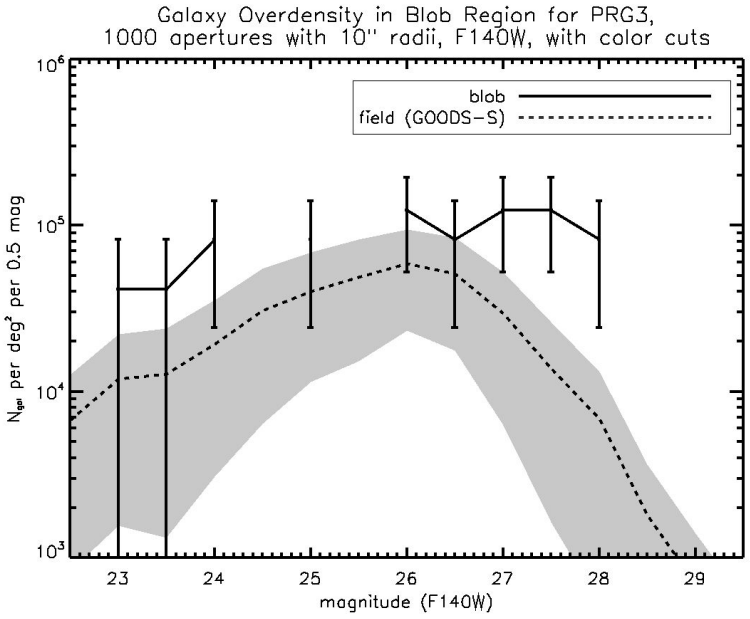

Galaxy Overdensity in Blob Region for PRG2,
1000 apertures with 10'' radii, F140W, raw (no cuts)
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)


Galaxy Overdensity in Blob Region for PRG3,
1000 apertures with 10'' radii, F140W, raw (no cuts)
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)

before cuts


Galaxy Overdensity in Blob Region for PRG1,
1000 apertures with 10'' radii, F140W, with color cuts
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)


Galaxy Overdensity in Blob Region for PRG2,
1000 apertures with 10'' radii, F140W, with color cuts
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)


Galaxy Overdensity in Blob Region for PRG3,
1000 apertures with 10'' radii, F140W, with color cuts
blob
field (GOODS-S)
N_{gal} per deg^2 per 0.5 mag
magnitude (F140W)

after cuts

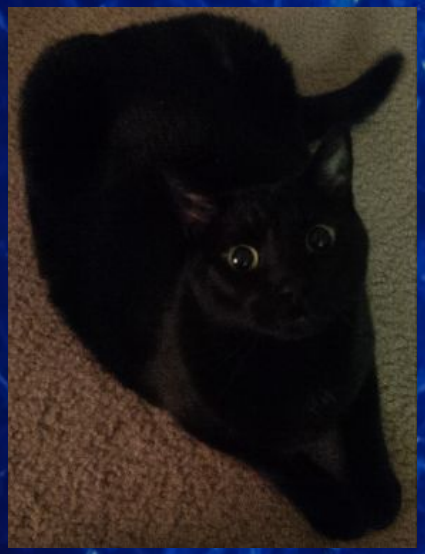
Future Work

- more blobs!
  - there are images and catalogs for other blobs
  - same analysis as PRGs
- determine probability of blob and overdensity being unrelated
  - probability of finding a blob & probability of finding overdensity of this scale
  - How often do we see a similar overdensity WITHOUT a blob?
- improve membership constraints (better cuts)
- compare to simulations
  - see if we can find a “blob” at right z that becomes a galaxy group/cluster by today

Conclusions

- All three blobs display an overdensity compared to the field in raw counts.
- After applying color cuts to narrow down membership of these systems, the overdensities persist.
- This result, combined with those of previous works, suggest that giant Lyα blobs statistically tend to be overdense.
- These objects are likely the progenitors of galaxy groups and clusters - seeds of large scale structure.

Questions?



Supplement: Blob Measurements

	PRG1	PRG2	PRG3
Aperture (arcsec)	1.5×5.04	1.5×7.84	1.0×5.60
$\lambda_{Ly\alpha,obs}$ (Å)	3249.61 ± 0.39	3971.41 ± 0.13	3813.28 ± 0.90
Redshift	1.6731 ± 0.0003	2.2668 ± 0.0001	2.1368 ± 0.0007
$F_{Ly\alpha}$ (10^{-17} erg s^{-1} cm^{-2})	44.1 ± 4.0	49.2 ± 1.1	10.2 ± 1.2
$L_{Ly\alpha}$ (10^{42} erg s^{-1})	8.2 ± 0.7	19.3 ± 0.4	3.5 ± 0.4
Lyα EW$_{rest}$ (Å)	257.1 ± 29.1	127.3 ± 6.3	47.1 ± 6.4
Lyα FWHM$_{obs}$ (Å)	9.19 ± 0.60	8.52 ± 0.19	23.36 ± 7.90
Lyα σ_v (km s^{-1})	361.2 ± 23.7	273.9 ± 6.1	782.1 ± 264.3
$F_{CIV\lambda1550}$ (10^{-17} erg s^{-1} cm^{-2})[a]	2.1 ± 1.1	1.8 ± 0.8	< 0.8
$F_{HeII\lambda1640}$ (10^{-17} erg s^{-1} cm^{-2})[a]	5.8 ± 1.0	1.8 ± 0.9	< 0.9
$F_{CIII\lambda1909}$ (10^{-17} erg s^{-1} cm^{-2})[a]	4.8 ± 0.9	3.0 ± 1.1	< 1.5
B_W Diameter Along Slit[b] (arcsec)	8.96	10.12	6.72
B_W Isophotal Area[b] (arcsec^2)	40.9	73.2	45.3
B_W Surface Brightness[b] (mag arcsec^{-2})	27.2	27.0	26.8
Lyα Diameter Along Slit[c] (arcsec)	9.24	12.04	8.96
Lyα Diameter Along Slit[c] (kpc)	78.3	99.0	74.4
Approximate Lyα Isophotal Area[d] (arcsec^2)	43.4	103.7	80.4
Approximate Total $L_{Ly\alpha}$[e] (10^{42} erg s^{-1})	47.2 ± 4.3	170.2 ± 3.7	49.6 ± 6.1

from Prescott et al. 2012a