What Powers Lyman-alpha Blobs?

Chelsea Sharon

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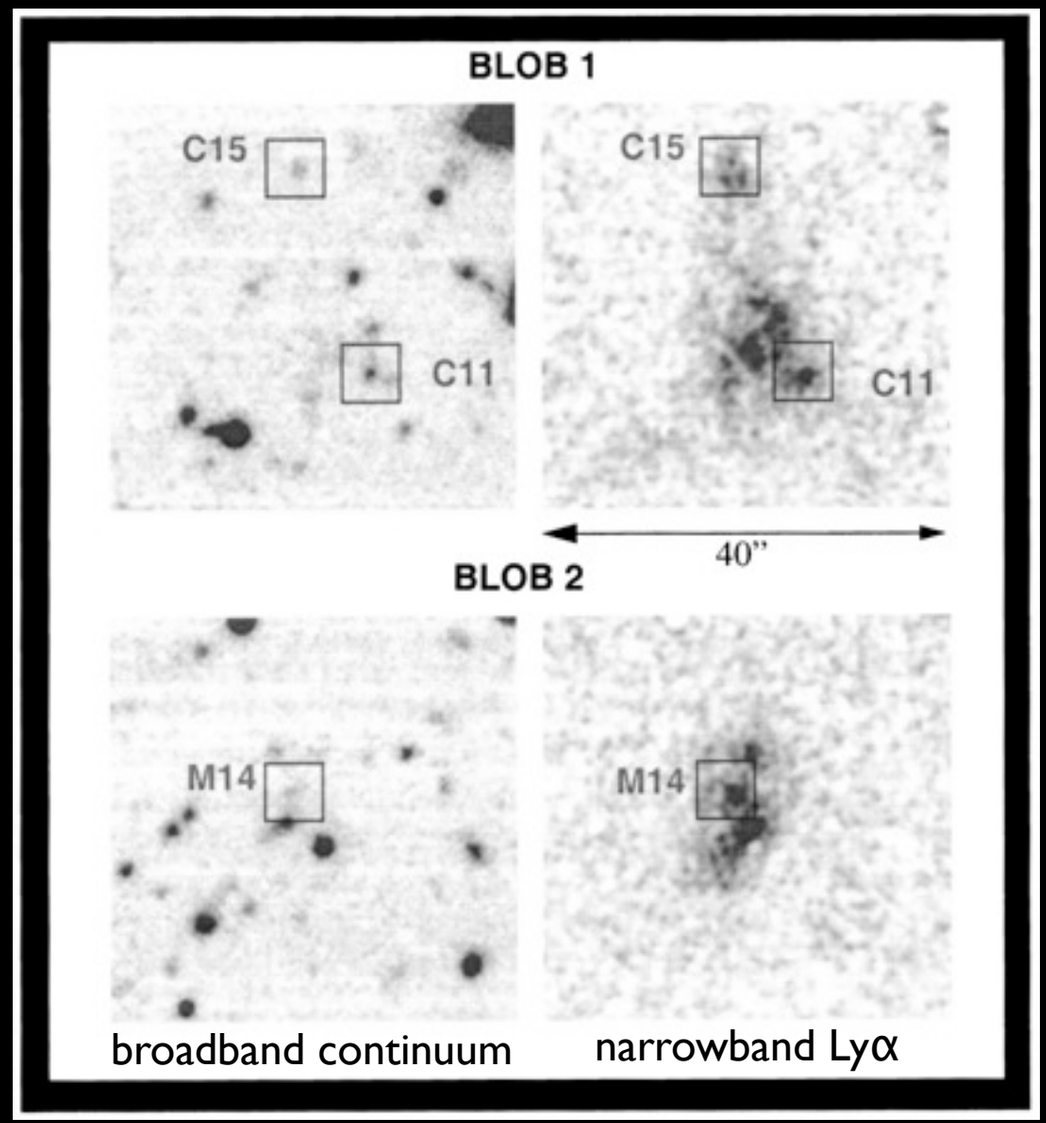
Outline

- What are Lyα blobs?
- What powers Lyα blobs?
  - Photoionization
  - Superwinds
  - Cooling
- What does the evidence support?

Discovery

Steidel et al. 2000

- Serendipitous discovery as part of Lyα imaging of proto-cluster at z=3.09
- Luminous, extended, large equivalent widths
  - ~21 Magnitude in Lyα
  - $W_\lambda \geq 370$ Å (rest frame)
  - Size ~ 125 kpc
- Similar size/luminosity to Lyα nebulae associated with high-z radio galaxies... but no observed radio sources



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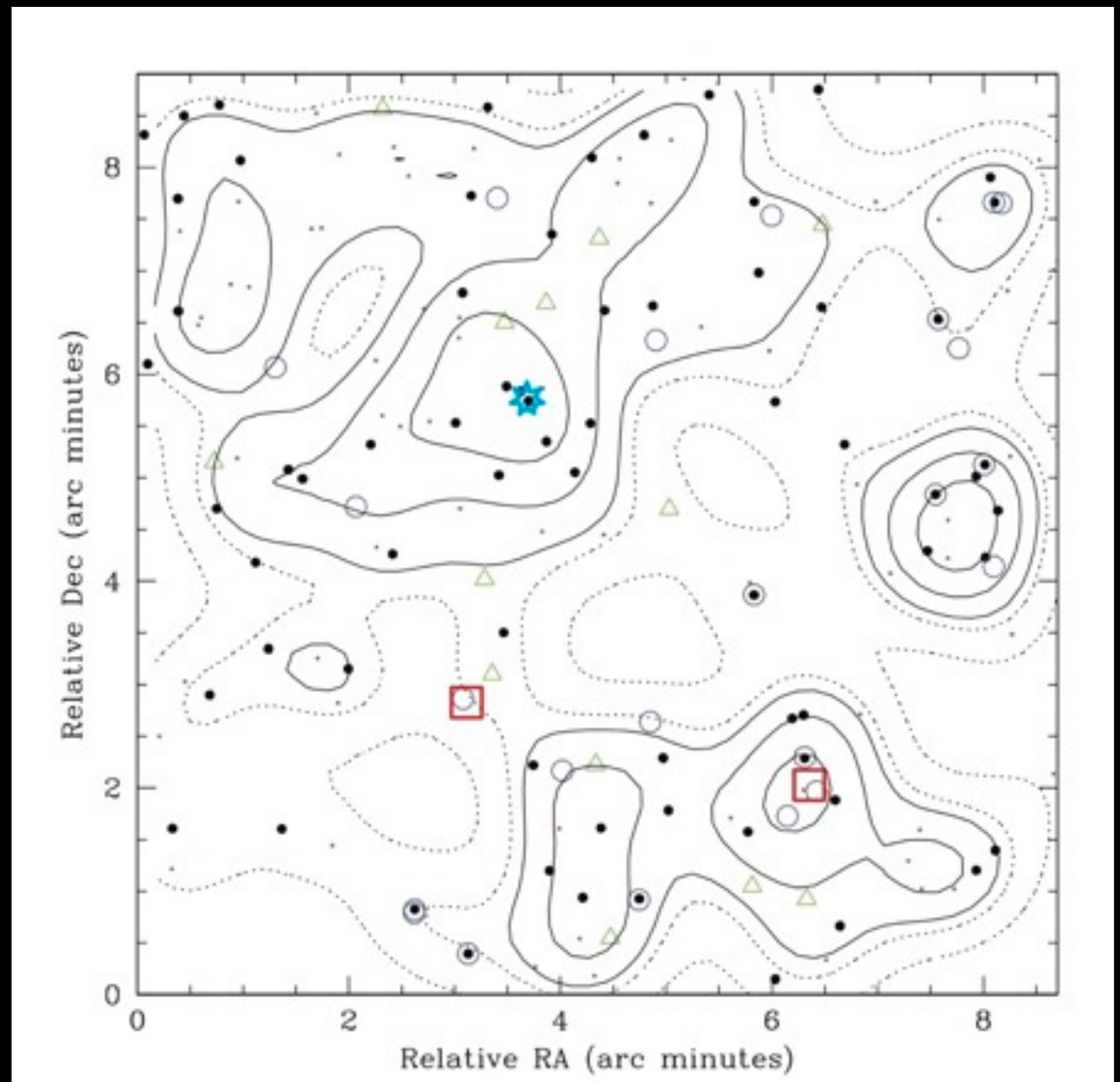


Photoionization

A central AGN or rapid star formation
could produce large quantities of high energy photons

- Would need to identify these energetic counterparts, which is hard enough at high redshift, and is likely complicated by obscuration

- Other ultra-luminous systems with hard spectra have been identified, do they have LAB-like features?

Superwinds

Supernovae from rapid star formation phase shock-heats the ambient medium to emit in Lyα

- Would still need to identify a counterpart galaxy that has active star formation

- Given fluctuations in ambient density, superwind-created LABs should have a complex morphology, possibly containing bubbles and bipolar outflows

Cooling

Primordial gasses are falling into a potential well which is shock heated, and (eventually) cools via Lyα emission.

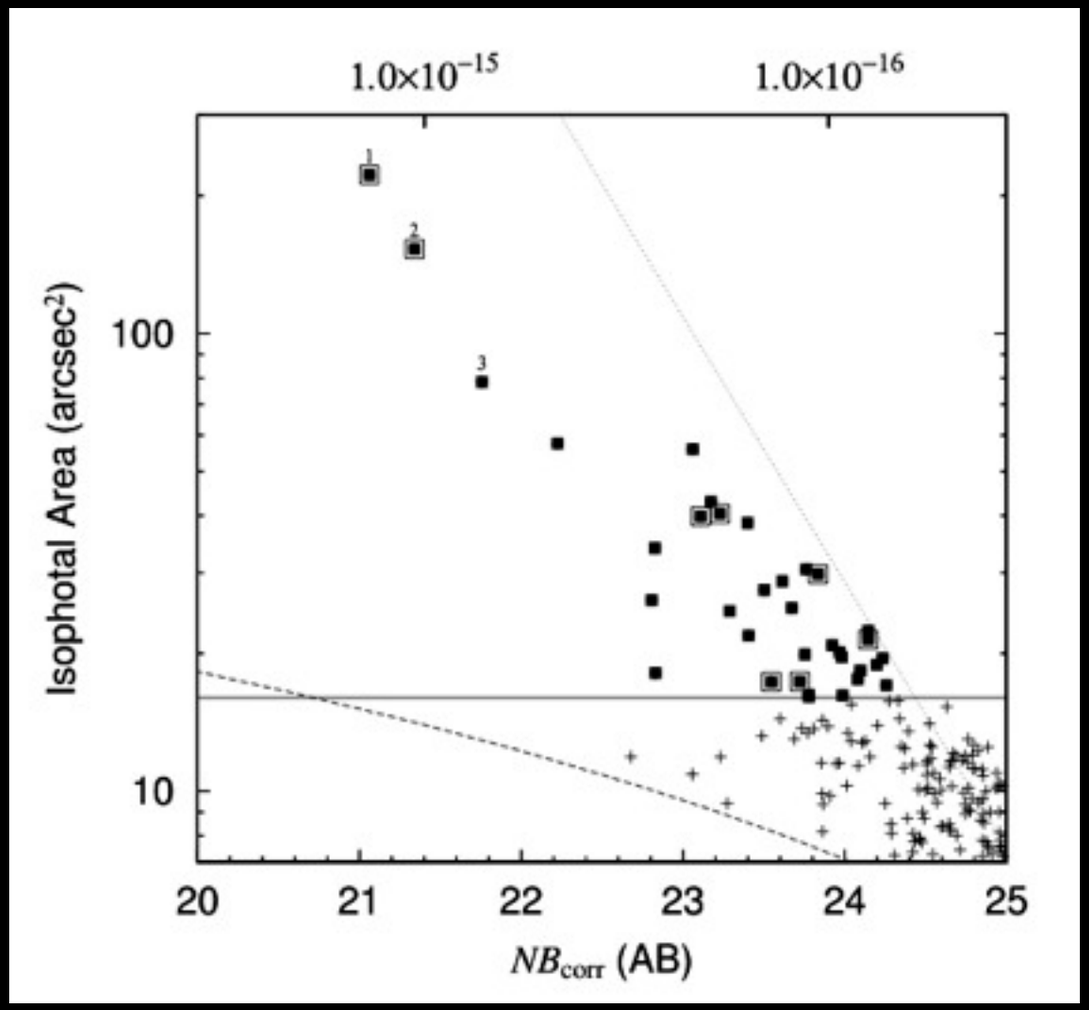
- Simulations of galaxy formation show that material is built up from the collisions of smaller clumps, not a continuous stream of matter

- Infalling gas and outflowing gas are difficult to distinguish between dynamically, and requires counterpart identifications (or a lack thereof) to back up claims

Extending the Search

Matsuda et al. 2004

- Deeper Lyα survey in original discovery field
- 33 robust new LABs:
  - BV - Lyα > 0.7
  - Isophotal area > 16”^{2}
- Distribution LABs is more closely related to the high density region, than to LAEs



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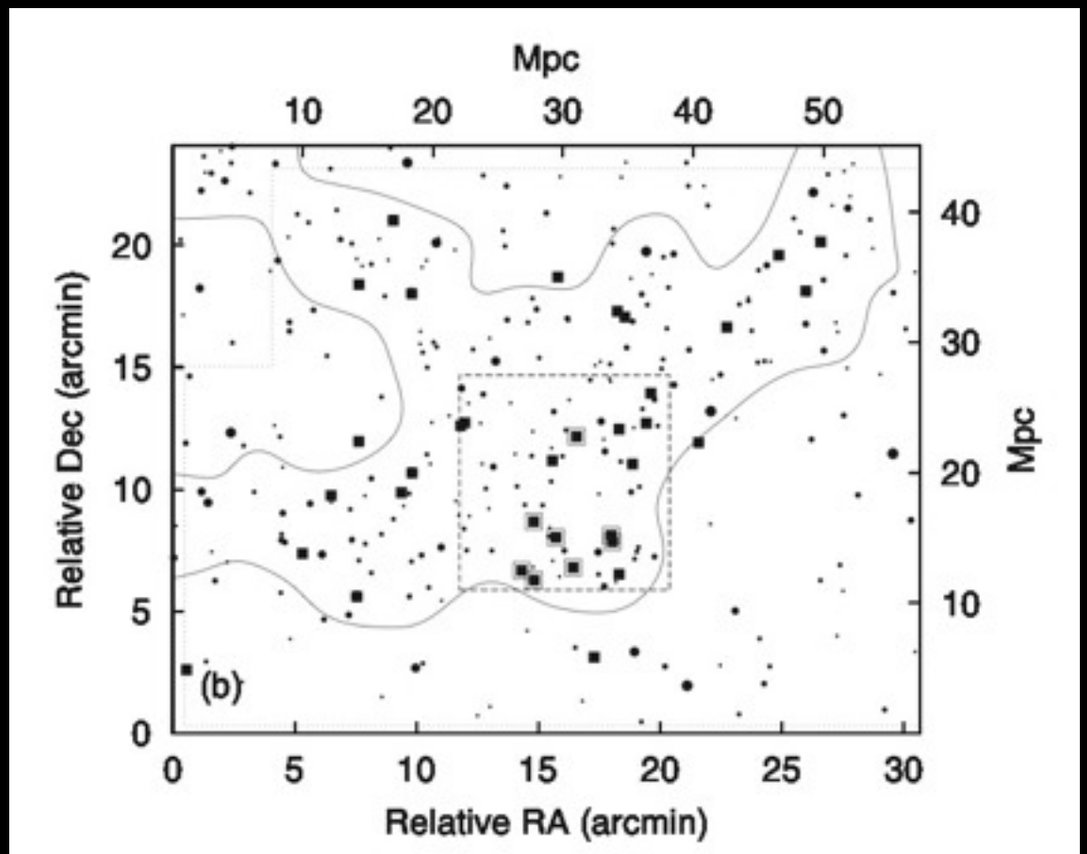

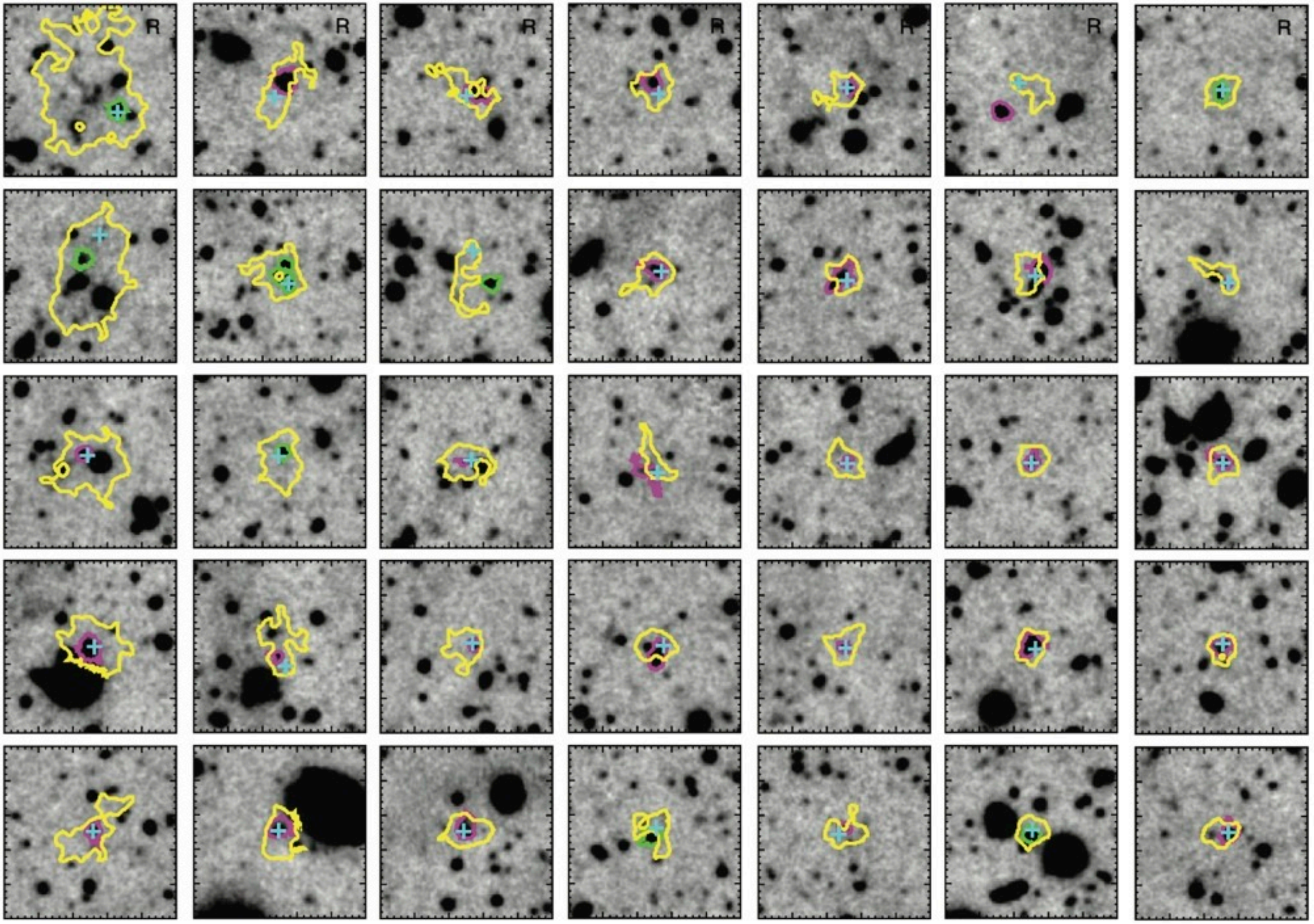
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Extending the Search cont'd

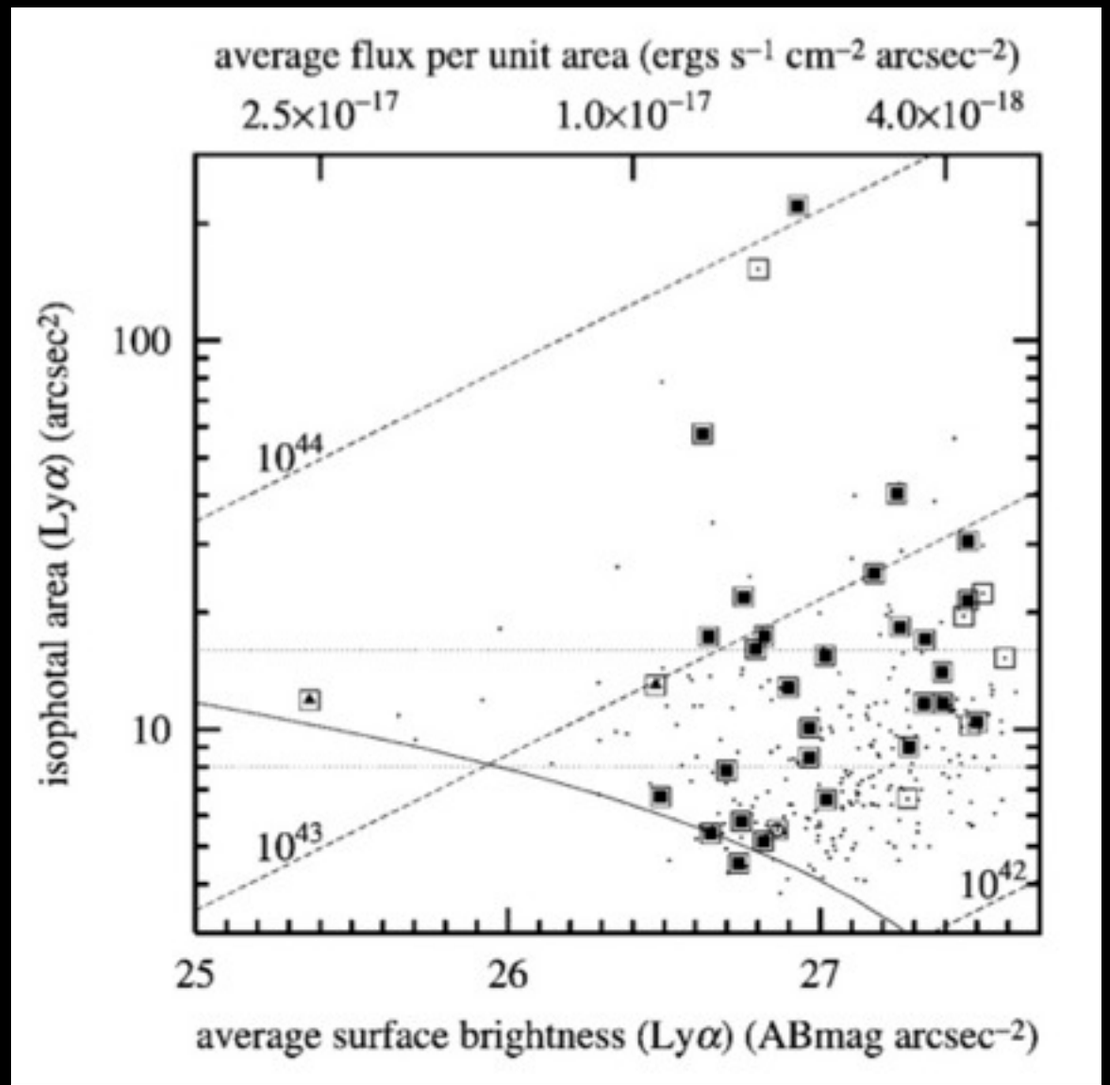
Matsuda et al. 2004

- Photoionization?
  - SFR as measured by Lyα is too large compared to UV SFR of associated continuum sources for ~1/3 of LABs
  - Possible explanations include: unique stellar populations, ionization source is a hidden AGN, ionization source is otherwise obscured, or ionization source is a diffuse UV background
- Superwinds?
  - Strange morphology of LAB 1 and 2 might be from superwind bubbles
  - Roughly consistent with estimates of ongoing SFR
- Cooling?
  - Sizes and luminosities consistent with cooling gas seen in galaxy formation simulations

Kinematic Follow-up

Matsuda et al. 2006

- High resolution spectroscopic observation of Lyα emitting sources in the original field
- Classified sources based on isophotal size (LABs > 16”^{2}, compact LAEs < 8”^{2})
- Found rough correlation between source size and line width:
  - Mean FWHM LABs = 780 km/s
  - Mean FWHM LAEs = 280 km/s
- LAB line widths interpreted as either winds or cooling means these are massive systems



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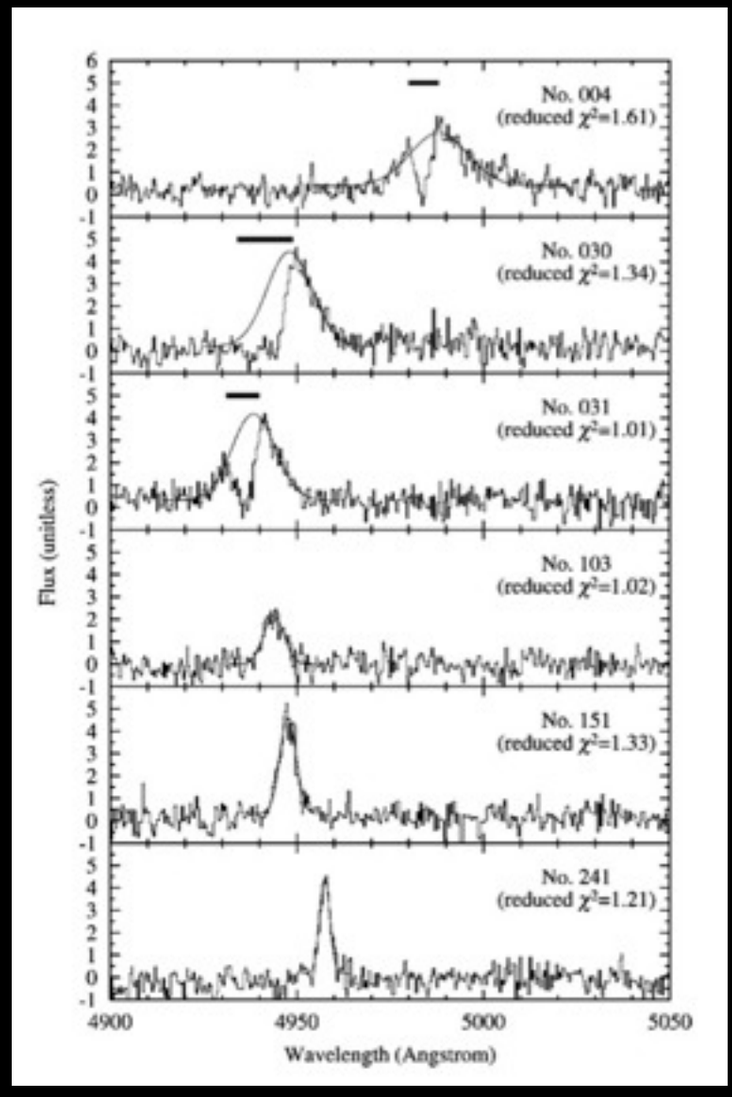
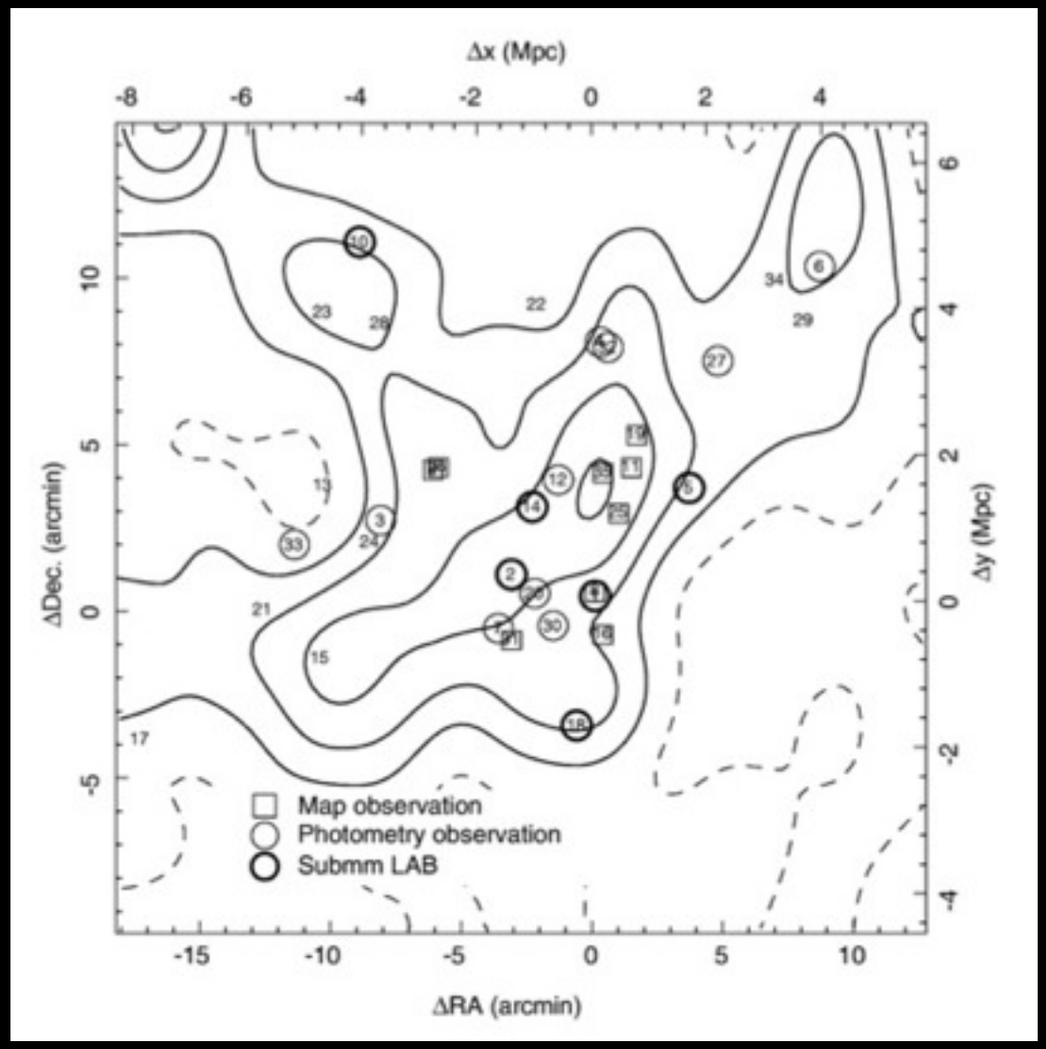


Submm Observations

Geach et al. 2005

- ≥3.5 sigma detection for 4 of 23 LABs at 850 μm in original field
- Submm-detected LABs are not significantly more correlated with over-densities
- Calculate bolometric luminosity from modified black body and 850 μm flux
- Weak correlation between Lyα and bolometric luminosity consistent with causal connection
- "The most likely mechanism that would provide this link is winds..."



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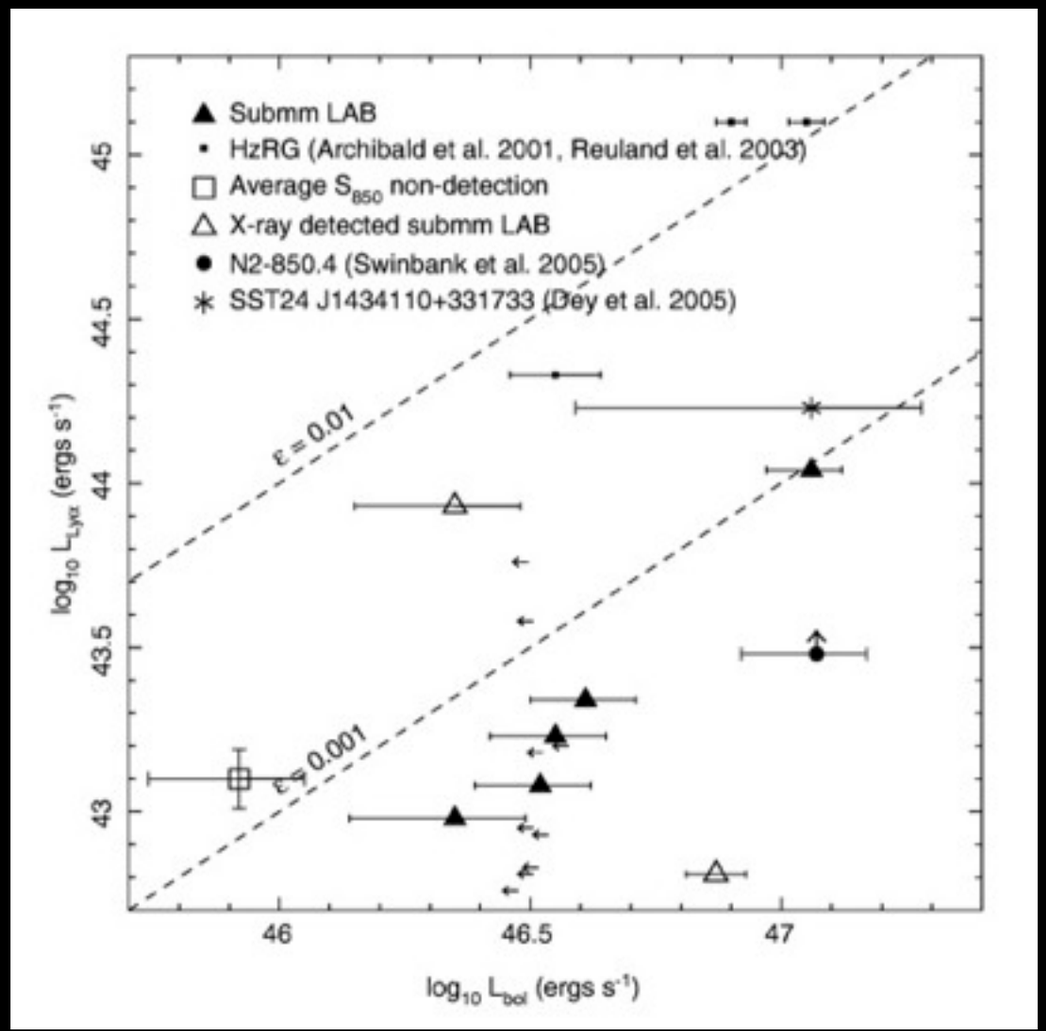
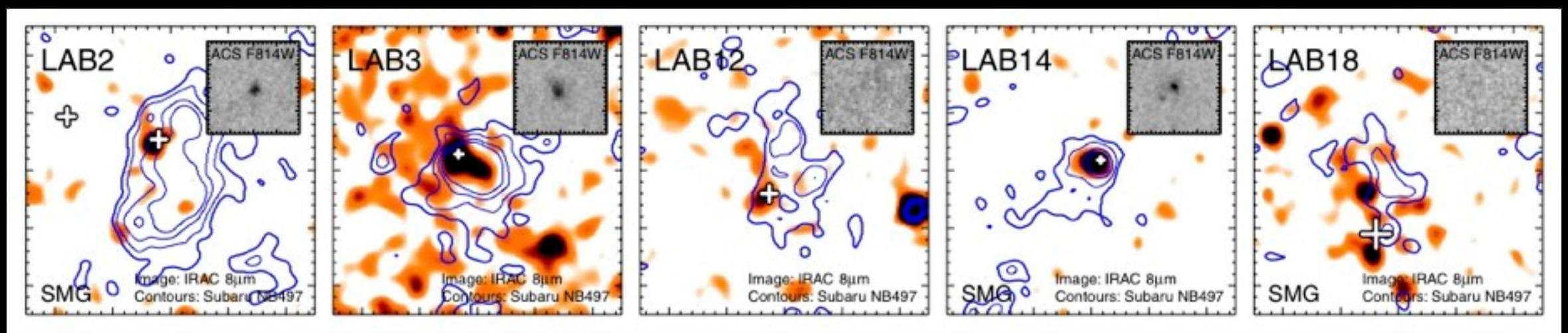


X-ray Observations

Geach et al. (in press)

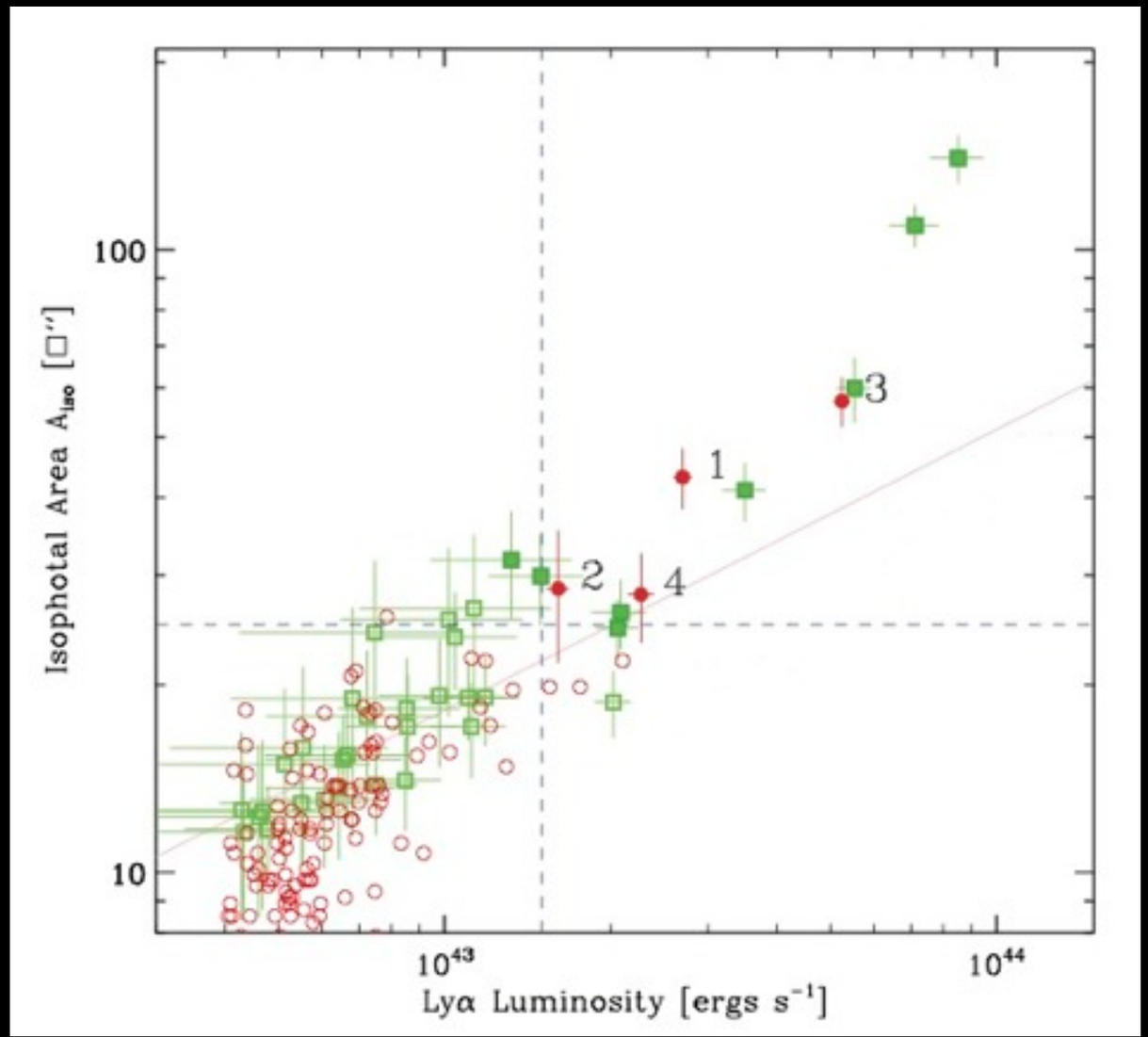
- 5 of 29 LABs are detected in x-ray
- All x-ray detected LABs have 8 μm counterparts
- 3 also have 850 μm counterparts
- Indicates that these systems have an obscured AGN (and likely active star formation)
- UV luminosities from SED modeling are easily large enough to power the Lyα emission



An Additional Field!

Yang et al. 2009

- Blind survey of NDWFS Boötes field, targeted to detect Lyα emission at z=2.3
- Found only 4 LABs, but they suffered from poor seeing and shallow observations
- 2 have x-ray counterparts
- Other 2 are a pair separated by 550 kpc (rest frame)
- All have B_W band counterparts from the NDWFS
- LABs are rare (at least at z~2) and likely associated with high density regions



Conclusions

- X-ray and optical counterparts currently favor photoionization for powering the LABs (but this is far from confirmed)
- LABs may be part of a continuous distribution of high redshift galaxies, possibly related to LAEs, LBGs, or radio galaxies
- These are rare objects, possibly associated with overdensities that will become modern rich clusters
- A larger statistical sample, and more/better multi-wavelength observations of LABs are necessary