Statistics and Gas Kinematics of Lyα Blobs

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Fabian Walter, Roberto Decarli (MPIA), Axel Weiss (MPIfR), Helmut Dannerbauer (CEA, Wien)

Outline

1. How Lyα Blobs will evolve into the present day?

- Number density, Environment, Clustering

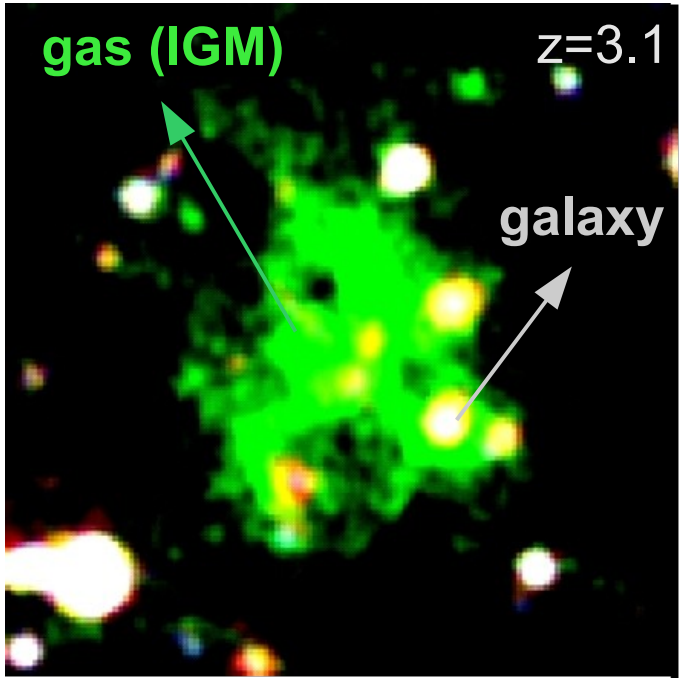
2. Gas kinematics?

- Inflow vs outflow?

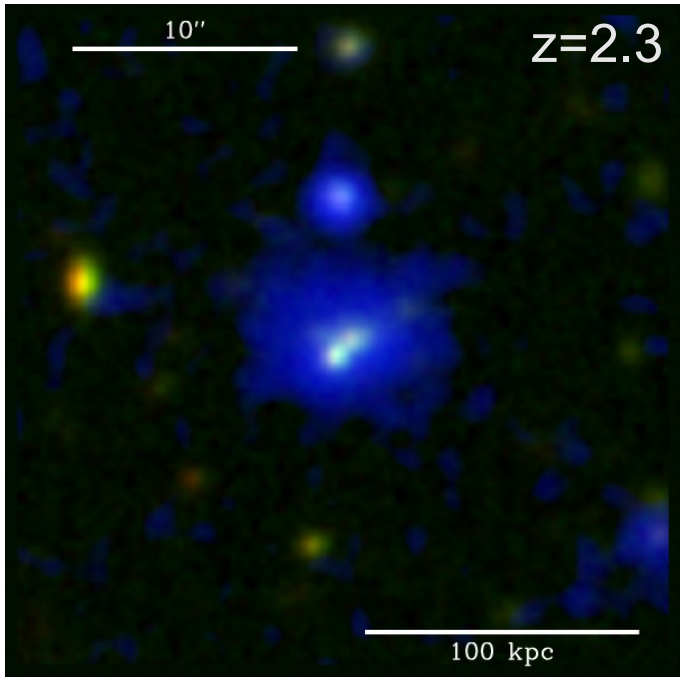
3. Energy source of Lyα Blob?

- Dust and molecular gas properties of SSA22-LAB01

What are Lyα Blobs?



25″ ~ 200kpc
Steidel blob 1 (Matsuda+04)

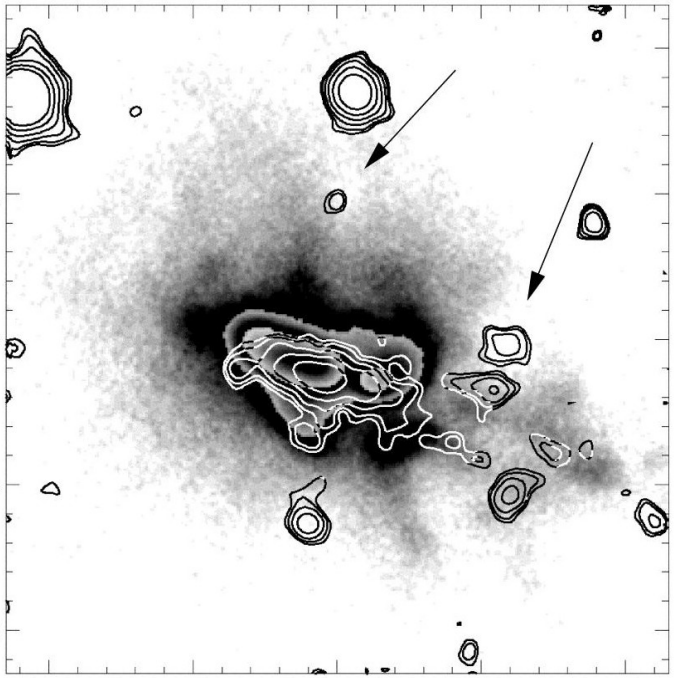


Yang et al. (2010)
CDFS-LAB02

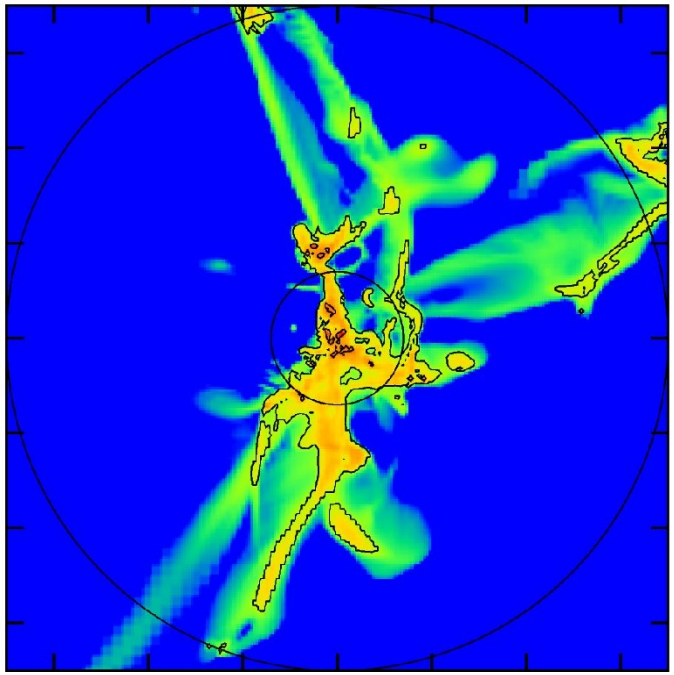
- Discovered by narrow-band imaging (not radio-loud)
- Extended more than embedded galaxies: size = ~10″, 100 kpc
- Direct 2D image of intergalactic medium!

Nature of Lyα Blobs

Superwind
Galactic wind in M82



High-z radio galaxy, AGN
(Reuland+03)



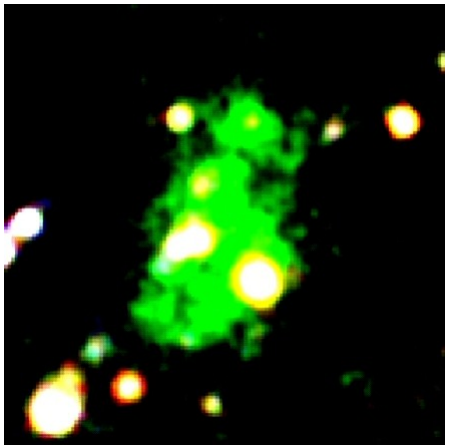
Cold accretion/stream
(Goerdt+10)

Energy source?

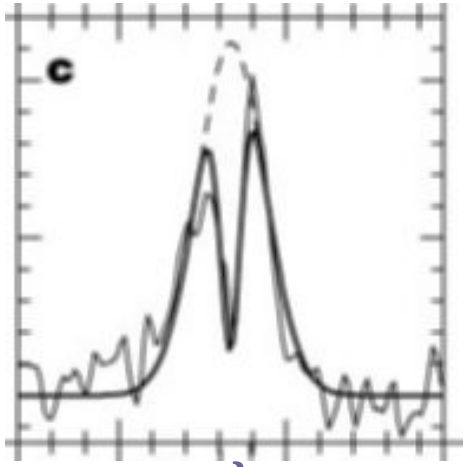
- Super/Hyper-wind driven by stars, SNe or AGN? (Taniguchi & Shioya+00)
- Photo-ionization by AGNs? (Geach+09)
- Cooling radiation? Cold accretion/streams? (Nilsson+06, Faucher-Giguère+10)
- Star formation? Resonant scattering? (Steidel+11)

Gas kinematics? Inflow vs outflow?

Is Gas outflowing or infalling?



Lyα blob 2



Why so difficult to figure out?

(e.g. AGN, SF, superwind, cooling)

— only one emission line observed

— hard to interpret Lyα line

(Wilman+05, Dijkstra+06, Verhamme+07)

Steidel et al. (2000)

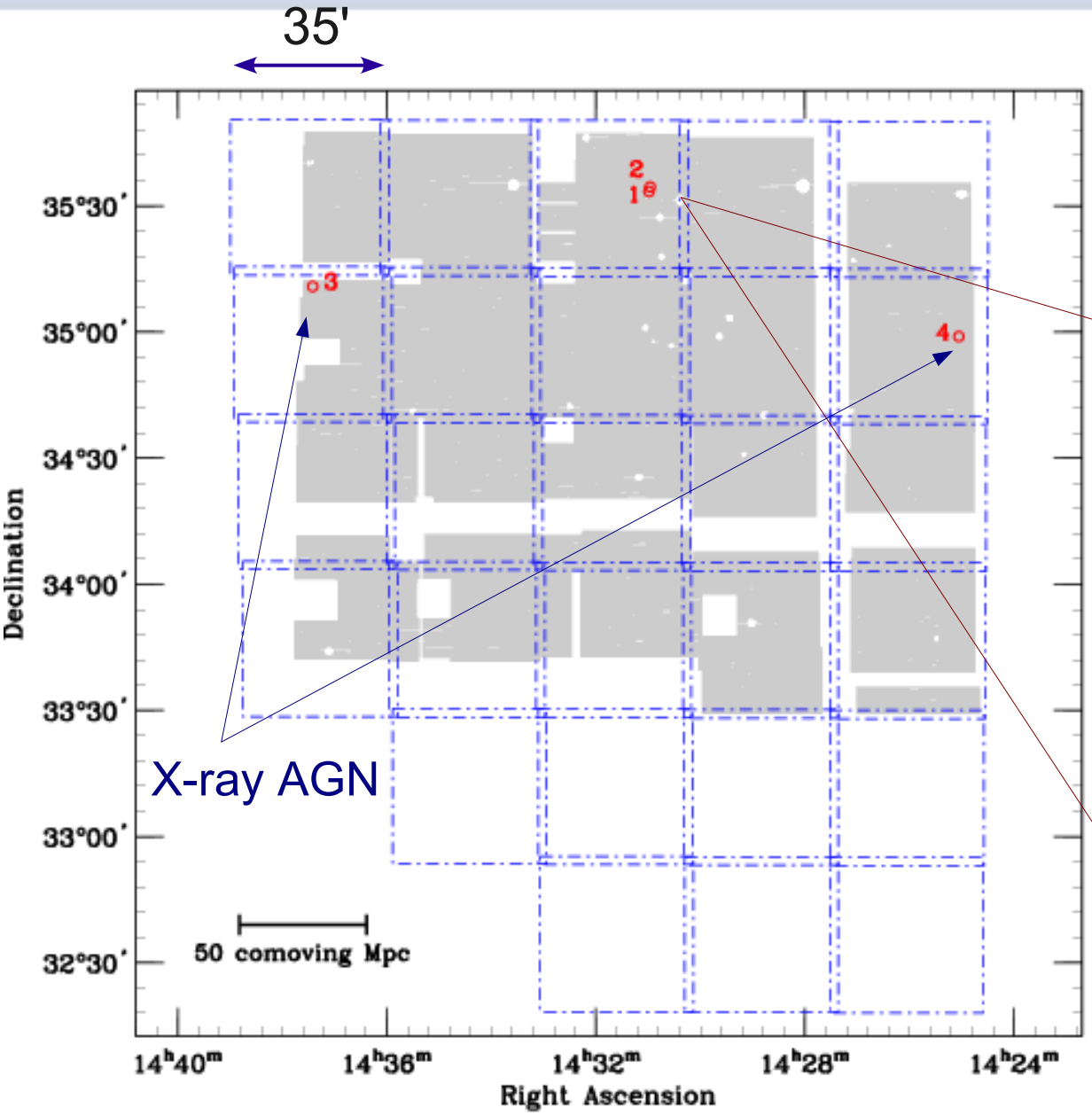
Subaru survey (Matsuda+2004, 2011)

→ 200+ blobs in SSA22 protocluster (z=3.1)

→ Need optically thin (Hα) line!
i.e. systemic velocity (v_{sys})

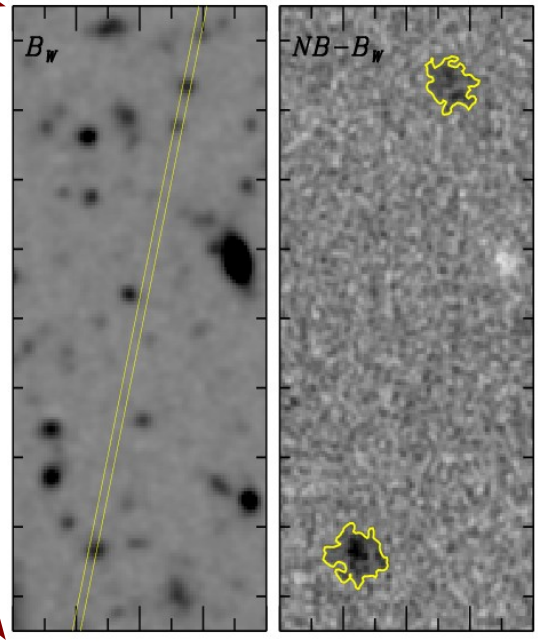
→ First, need to find blobs at z=2.3!
Number density & clustering

Wide-field Lyα Blob Survey: Blob Pair



survey area = 4.82 sq. deg

survey vol. = 2.1×10^6 Mpc^3



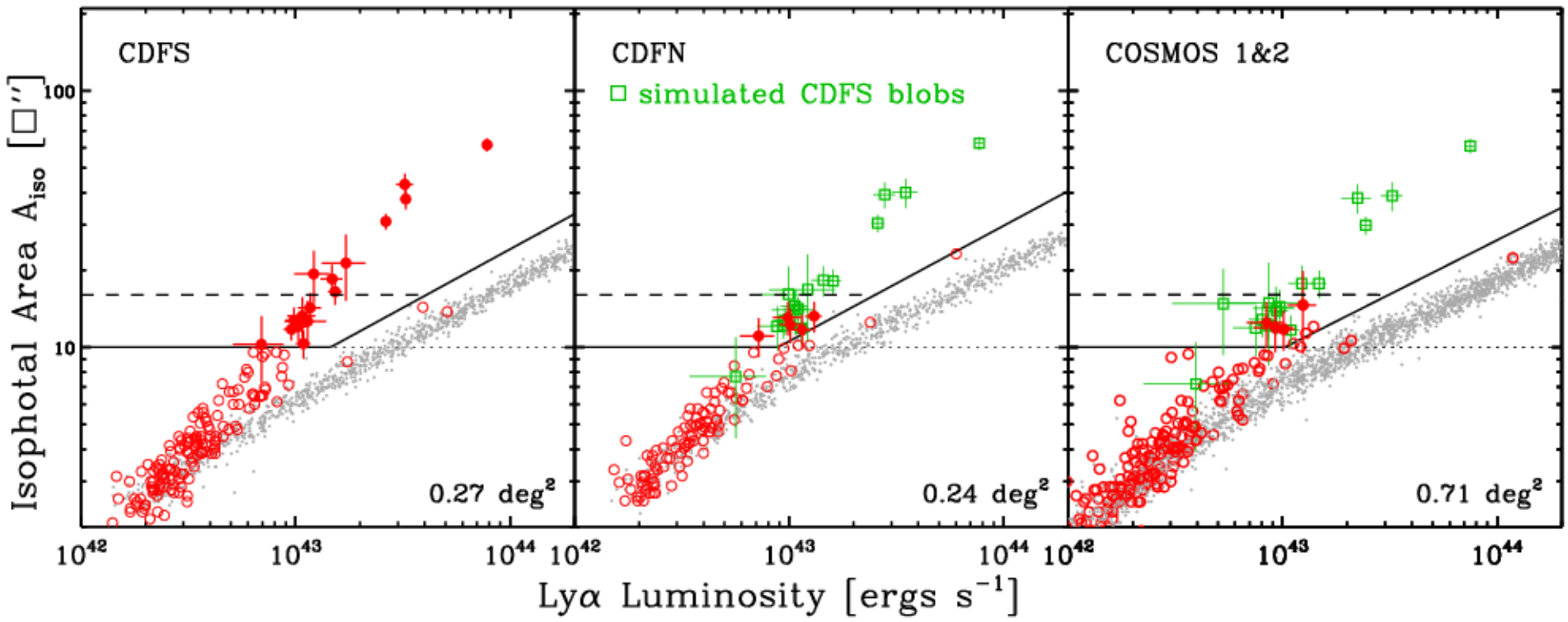
70″ ~ 550kpc

$\delta z = 0.001 \sim 360$kpc

NOAO - Bootes Field
2.3m telescope + 1 deg imager

Yang et al. (2009)

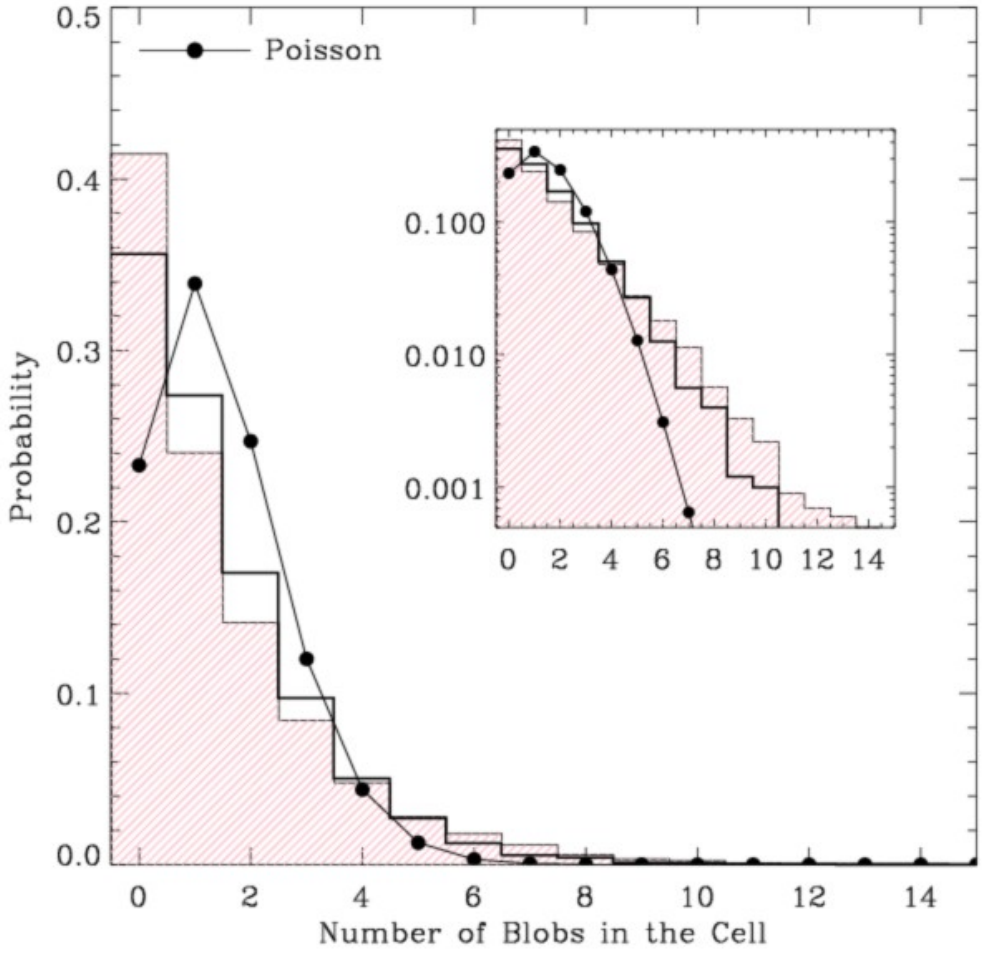
Lyα Blob Survey: Strong F-to-F Variation



- Strong field-to-field variation of blob population (>130%)
- Found 6-8 brightest blobs only in one survey field (CDFS)
- Lyα blobs likely reside in ~$10^{12.5\text{-}13}$ $M_\odot$ halos (*duty cycle=10-100%*)
- Blobs will evolve into present-day rich-groups or typical clusters

Yang et al. (2010)

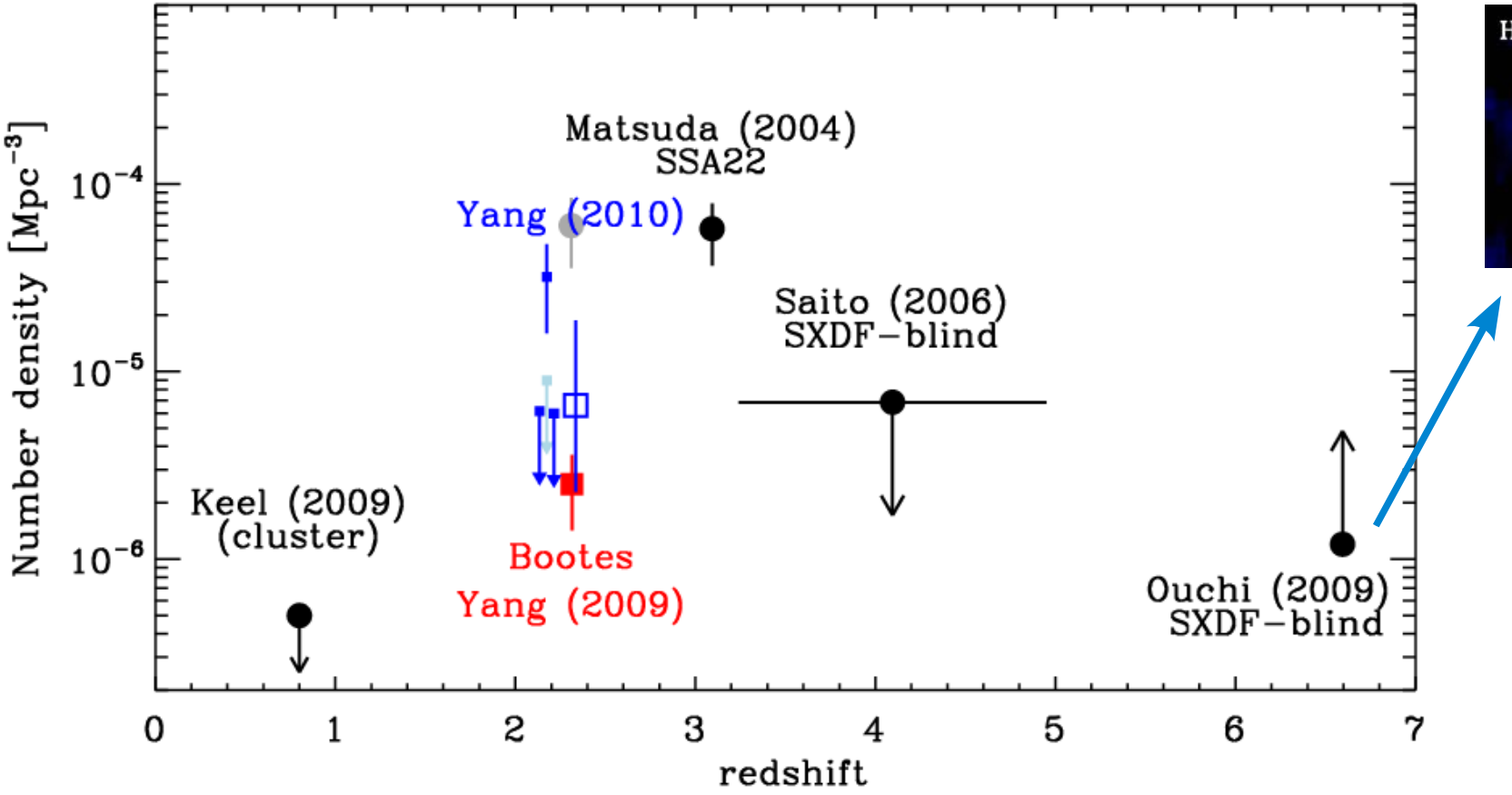
Blobs Reside in Massive DM Halos

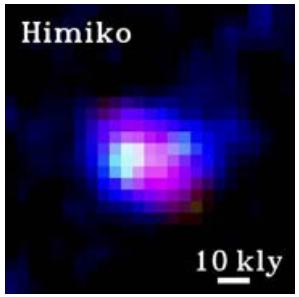


- Counts-in-cells distribution from N-body simulation (L=1 Gpc)
- Cell size = 50 cMpc
- $N_{\mathbf{blob}} = 1.2\times10^{-5}\,\mathrm{Mpc}^{-3}$
- *Assume duty cycle = 100%*
- $M_{\mathbf{halo}} \sim 1\times10^{13}\,M_{\mathrm{sun}}$ @z=2.3
  $\rightarrow 1\times10^{14}\,M_{\mathrm{sun}}$ @z=0

- Prob(6,0,0,0) = 0.5% - 1.5%
  → compared to max 42%
  → plausible

Lyα Blob Survey: Environment & Abundance



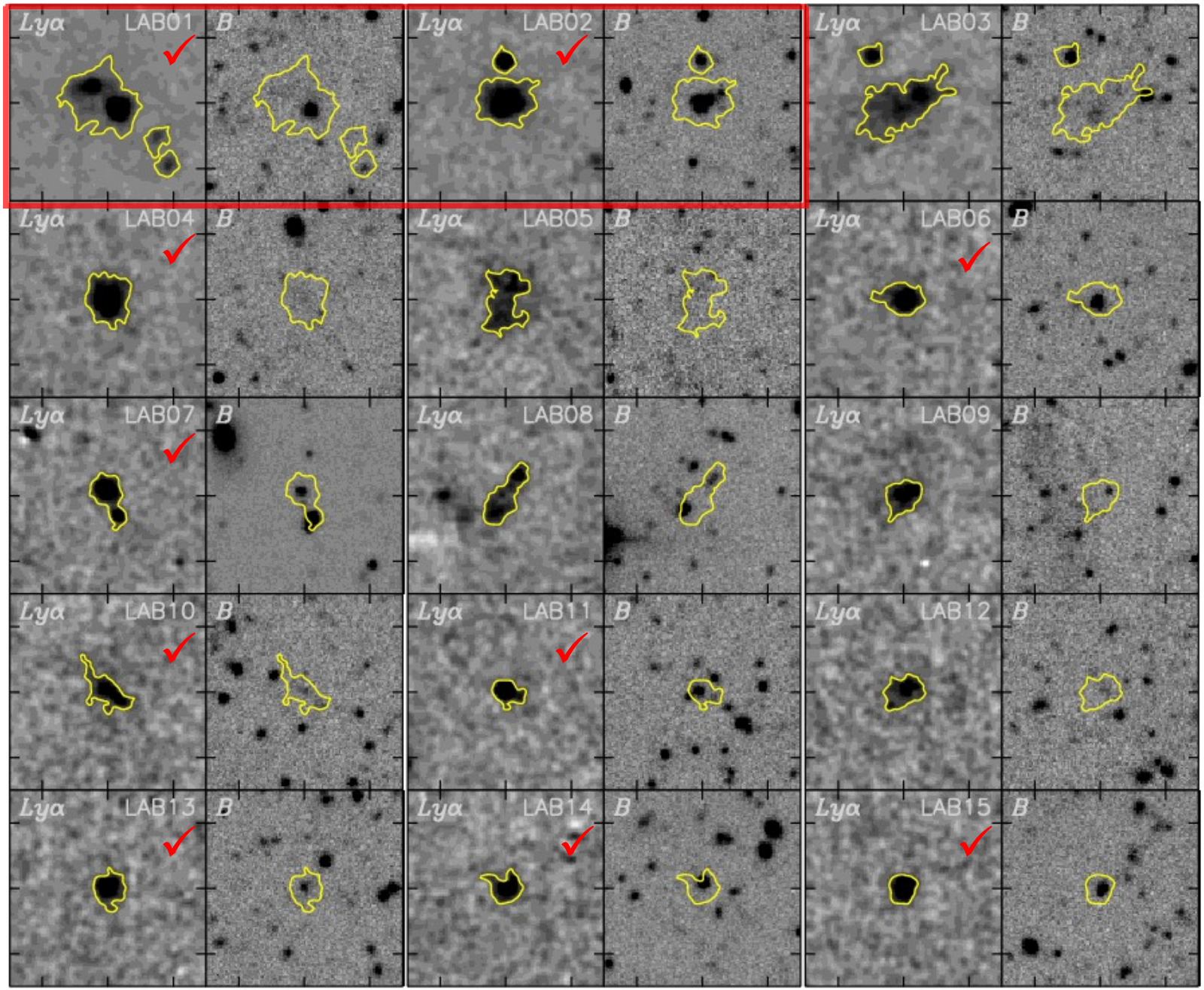


- Strong field-to-field variation poses challenge for number density and halo mass measurements.
- This plot is **NOT** redshift evolution of Lyα blob number density.

Lyα Blobs in E-CDFS

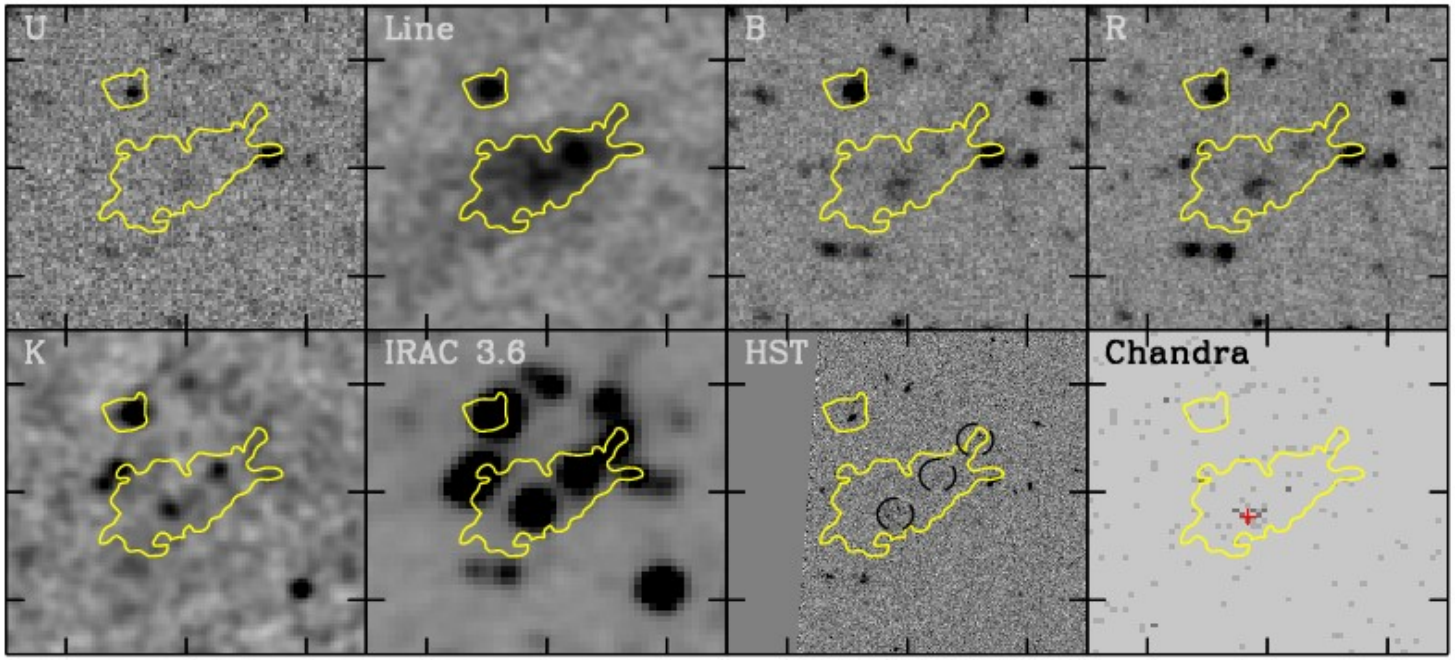
✓ z-confirmed

contours: 4×10^{-18} cgs



30"
~ 250kpc

Lyα Blob in CDFS (Closer Look)



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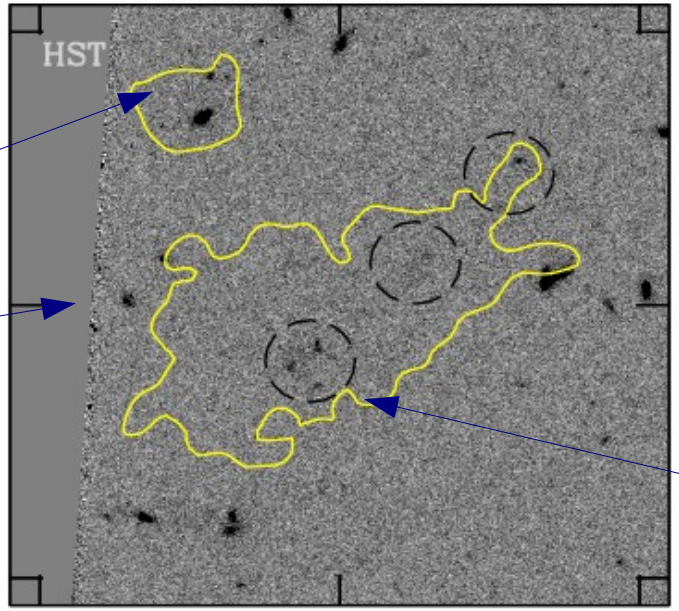
~ 250kpc

CDFS-LAB03



z=2.2916

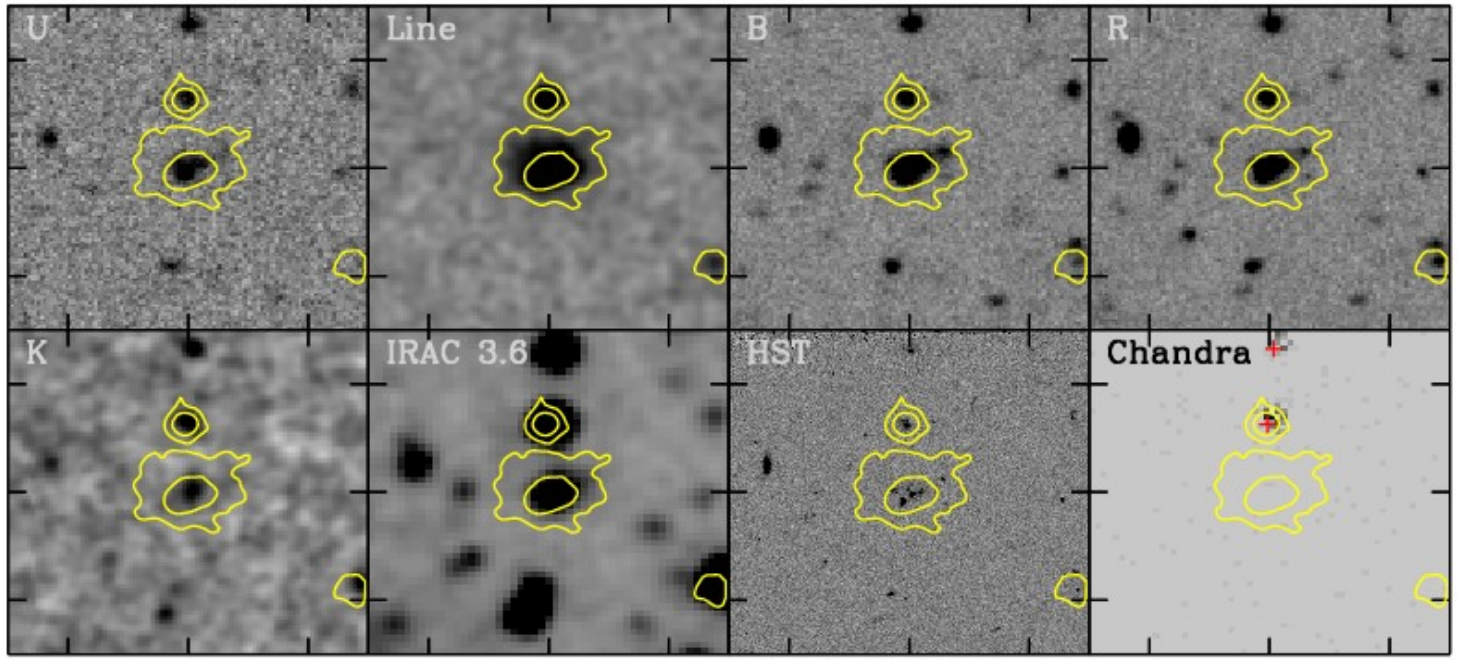
z=2.2960

X-ray src

Witnessing formation of galaxy group?

see also Prescott+11

Lyα Blob in CDFS (Closer Look)



30"
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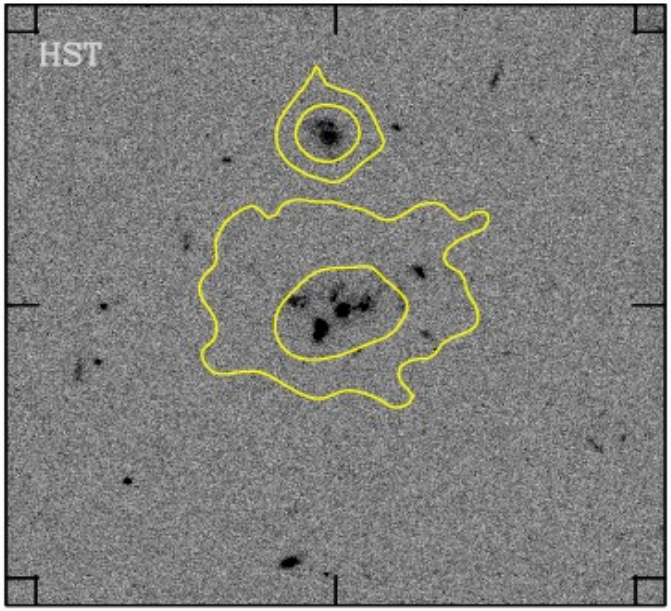
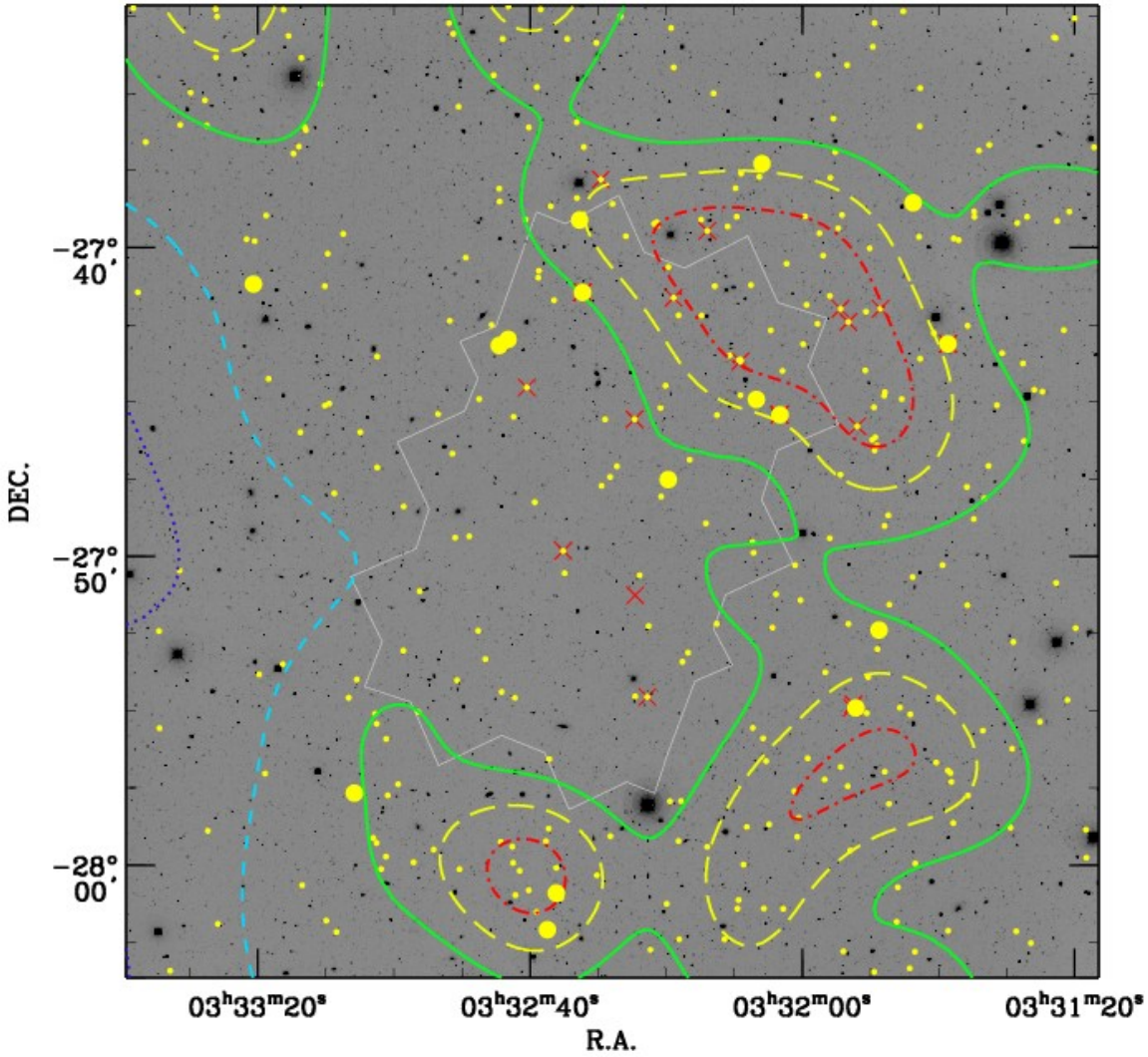
CDFS-LAB02



Proto-cluster (overdensity) @ z = 2.3 in ECDFS



50 comoving Mpc

Yang et al. (2010)

- Large-scale structure over ~10 cMpc
- Blobs reside in over-dense region
- Effective technique to find proto-clusters @ high-z? (wide-FOV tunable filter)

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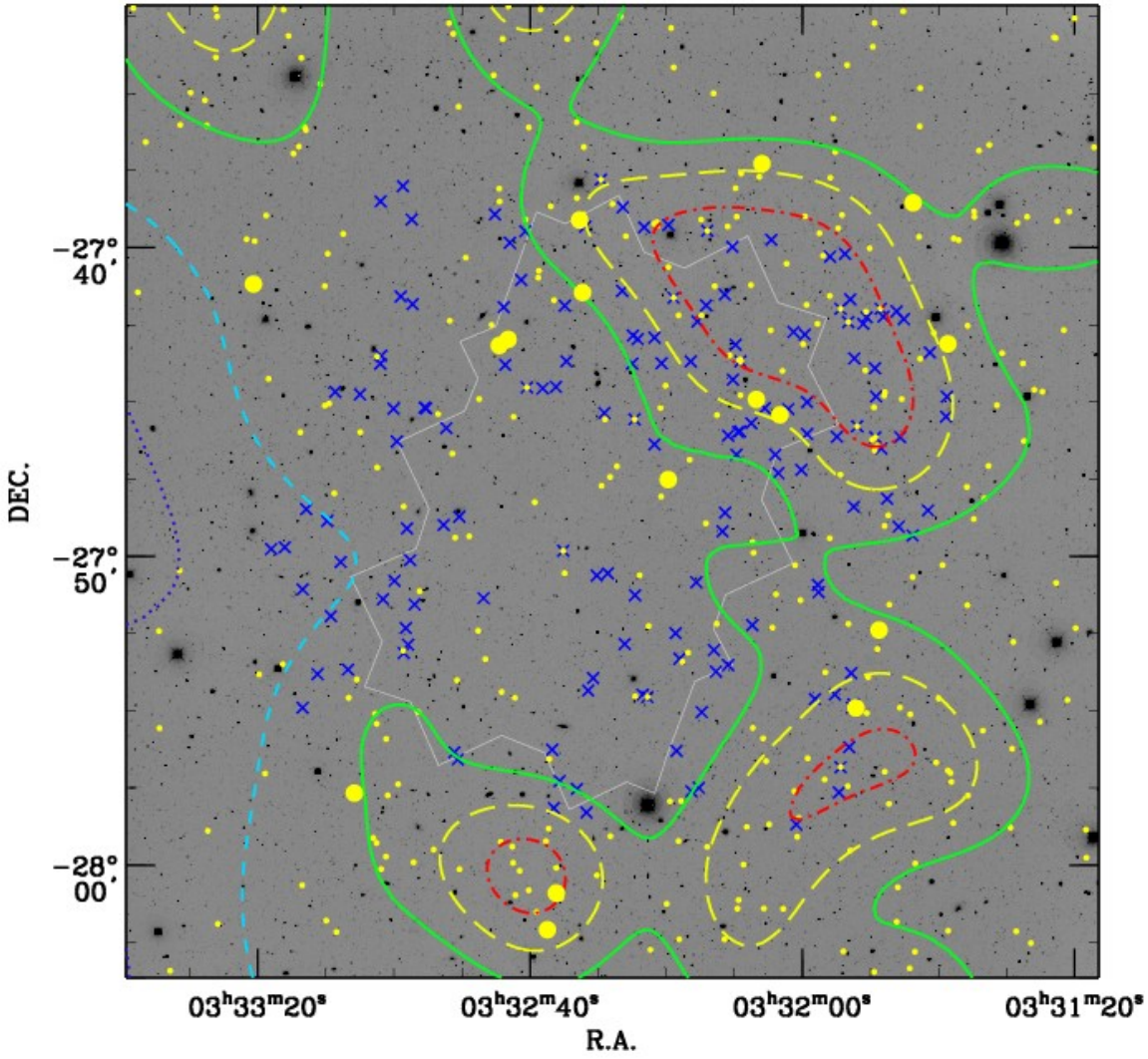

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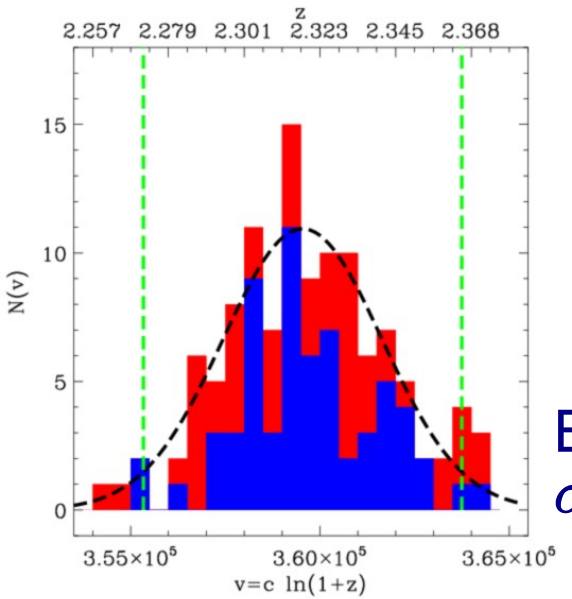
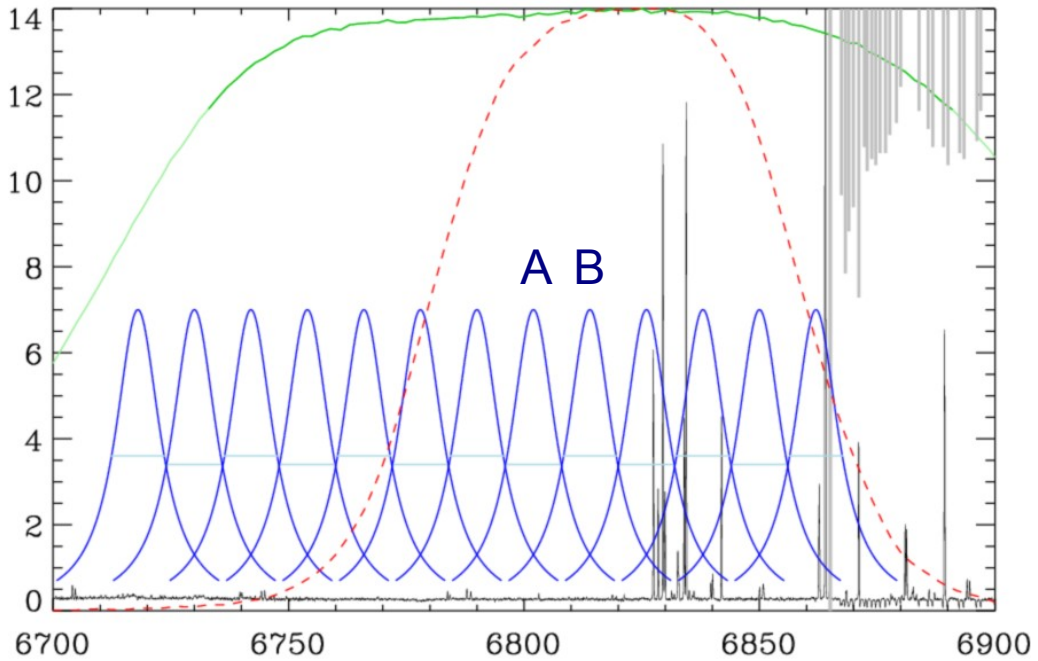
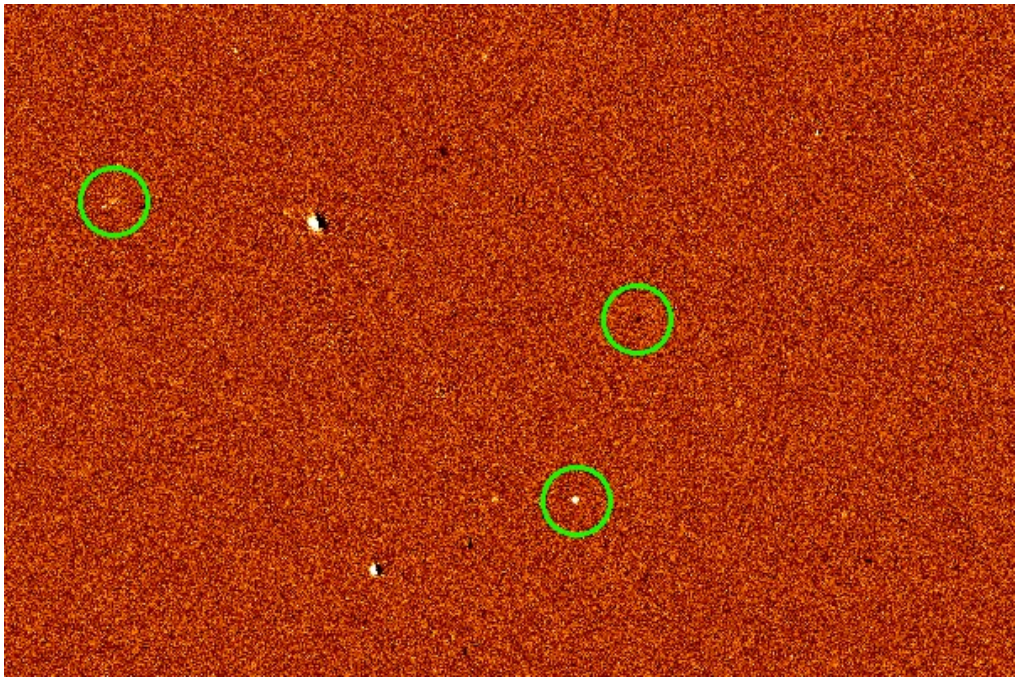


Balestra+10
σ = 2100km/s

Search for Protoclusters using Tunable Filter





A⟶ B⟶ (A-B)

- IMACS/MMTF (Magellan-Maryland Tunable Filter) survey:
  - 26′ diameter FOV (PI: Ann Zabludoff, 7nights in Magellan)
  - Scan in z-direction by ~12A step at z=4.5 (1hr per wavelength)
  - perfect continuum subtraction, 5e-18 cgs within 1hr (3σ)
  - Extended CDFS, COSMOS fields

(Y. Yang, A. Zabludoff, B. Weiner; work in progress)

Outline

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- Number density, Environment, Clustering

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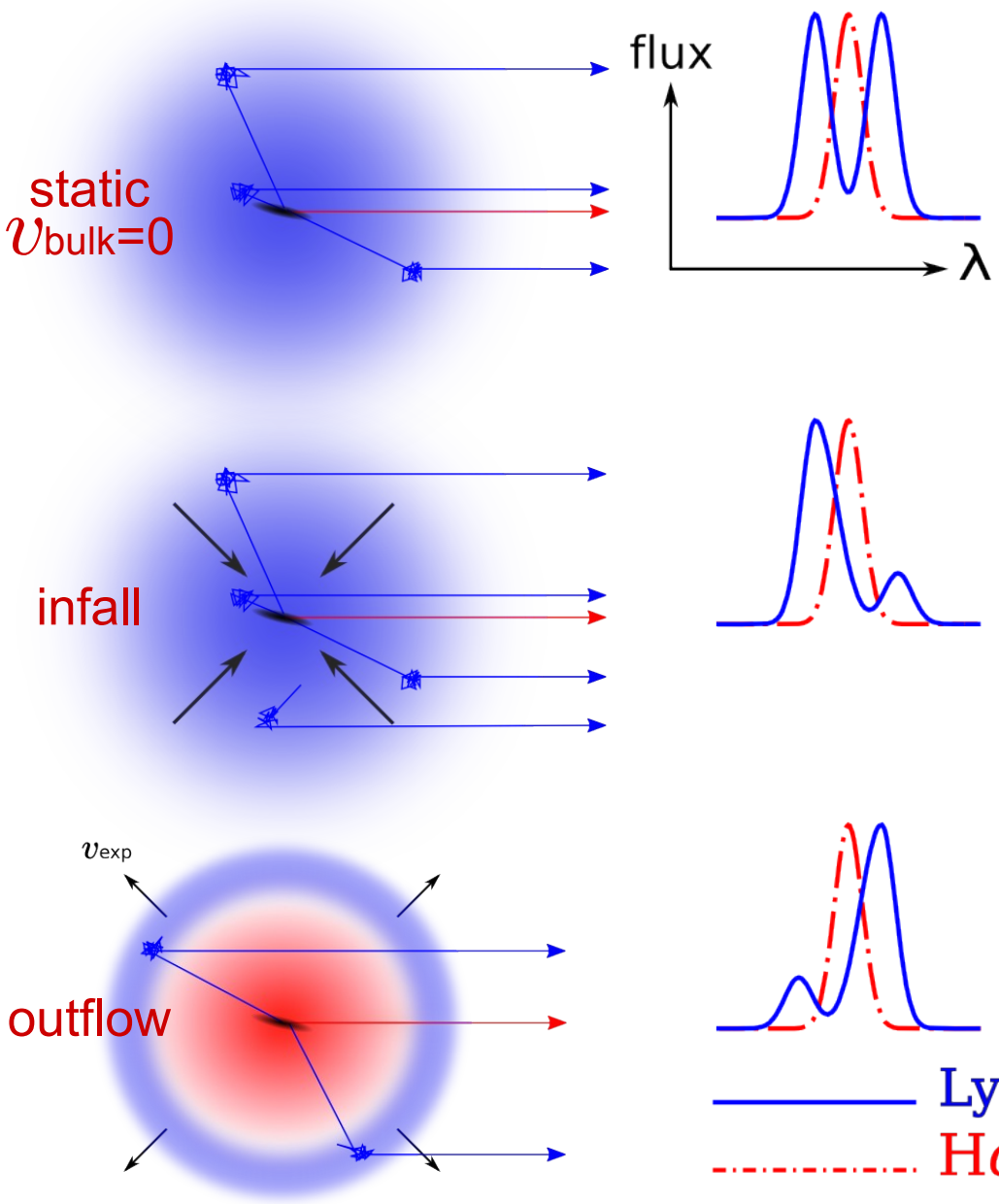
- **Inflow vs outflow?**

3. Energy source of Lyα Blob?

- Dust and molecular gas properties of SSA22-LAB01

Radiative Transfer of Lyα Photon



- Lyα : resonant line (n=2→1)
- Always optically thick
- In *static* cloud:

  Lyα double-peaked
- In *infalling* gas:

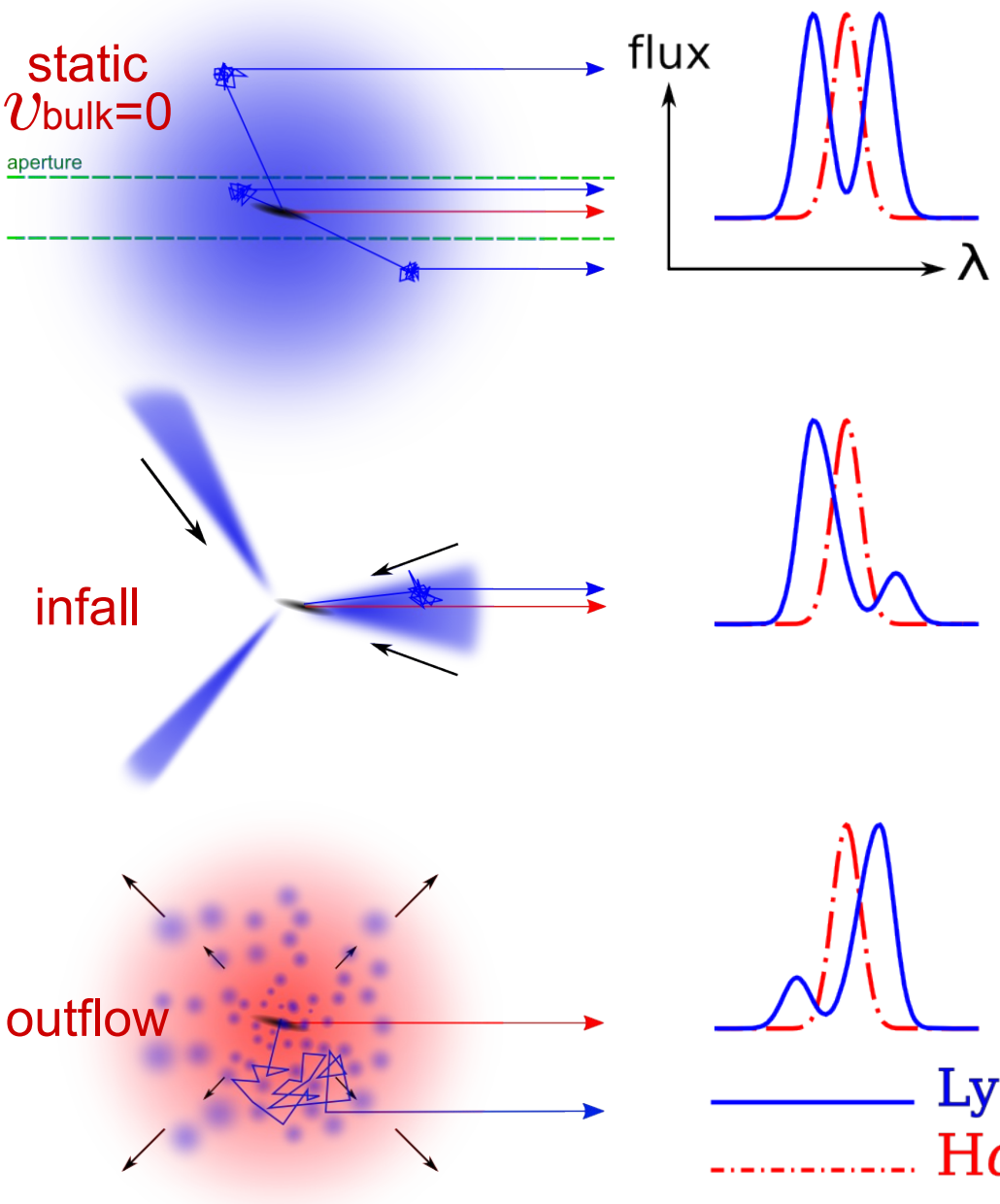
  Lyα red peak suppressed &

  blueshifted against "true"

  line center (i.e. Hα)
- see Dijkstra+06, Verhamme+07, Faucher-Giguère+10

outflow speed: Vexp ~ 0.5×Δv (Lyα)

YES... We Understand Your Concerns...



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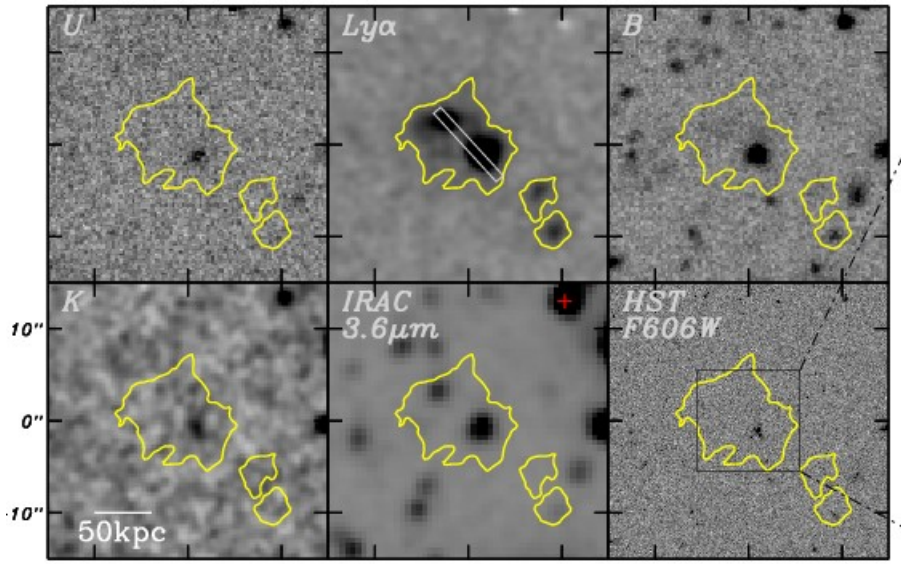
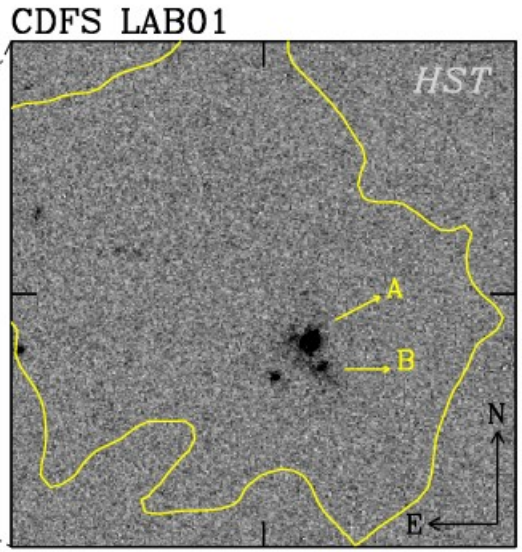
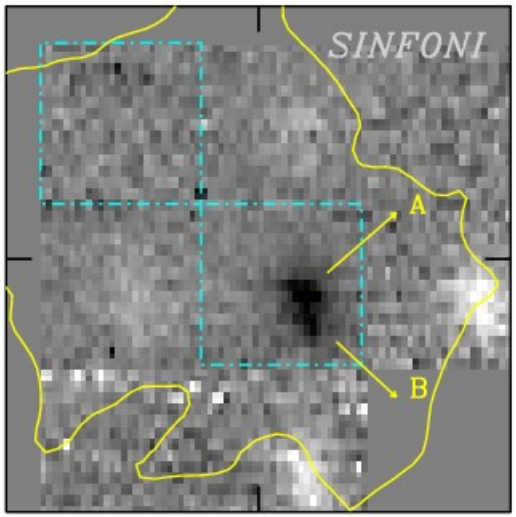
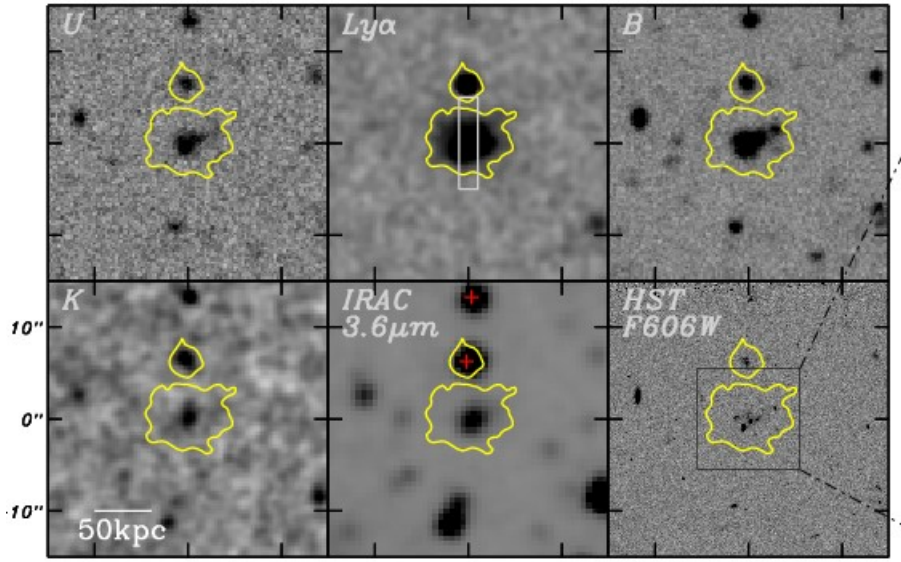
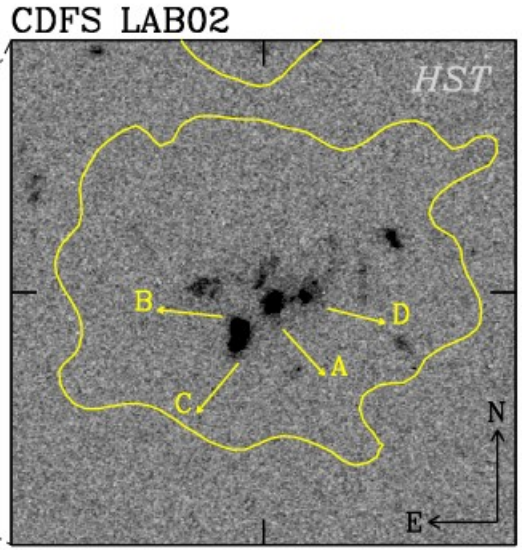
Follow-up with High-res (R~4000) Optical/NIR

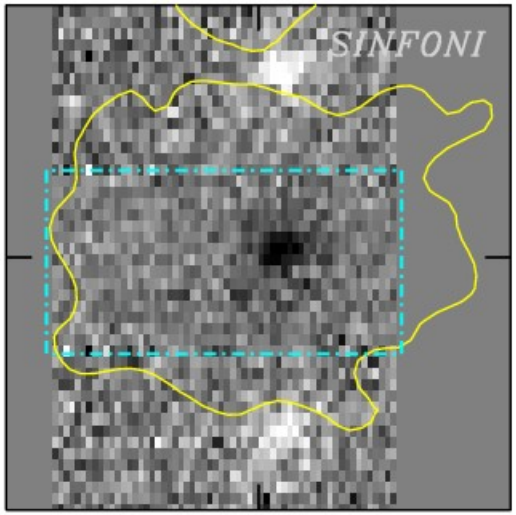












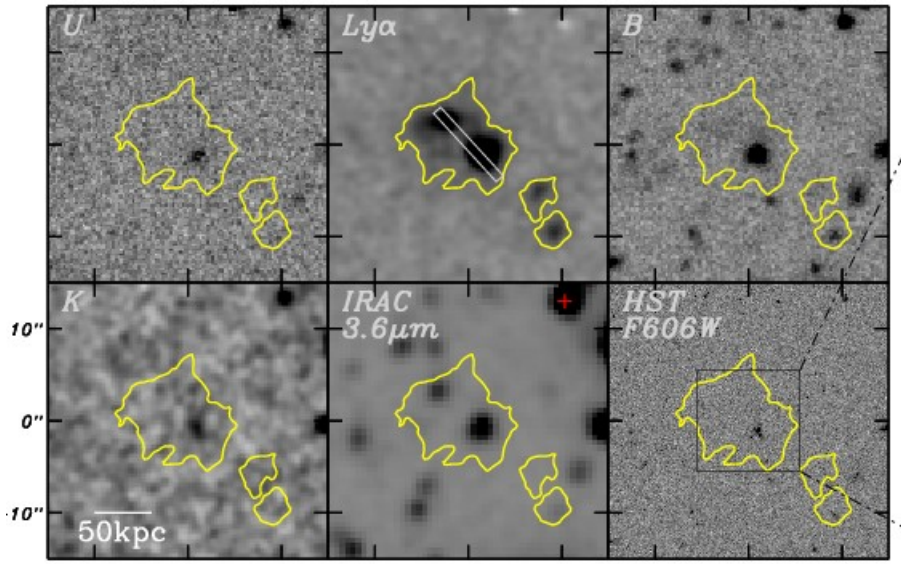
Images from GEMS, COMBO-17, MUSYC

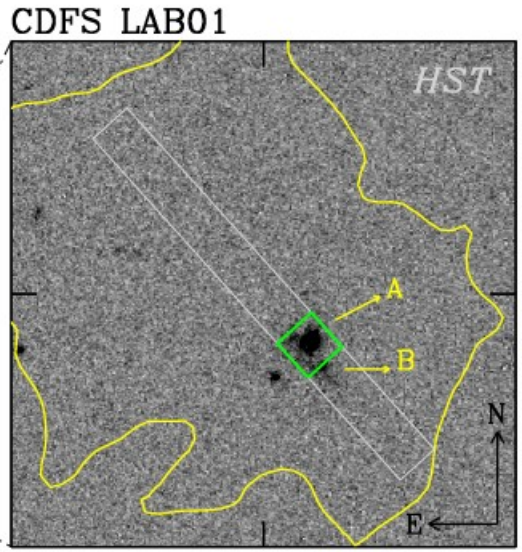
Magellan/MagE

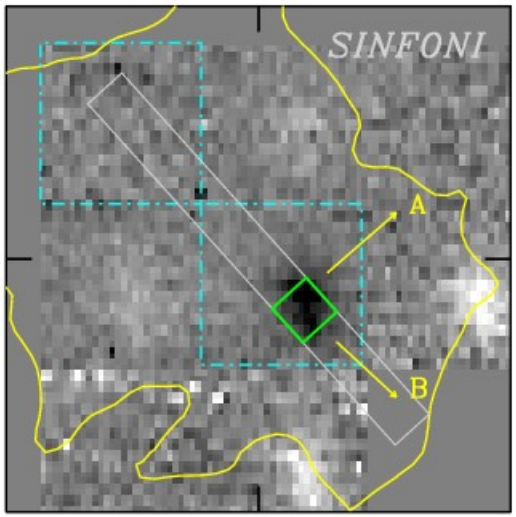
VLT/SINFONI IFU

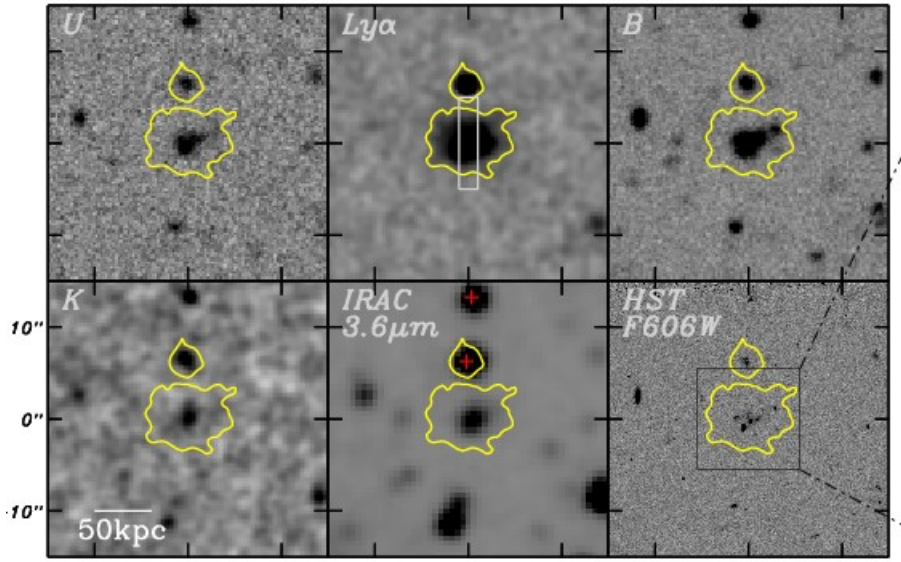
Hα

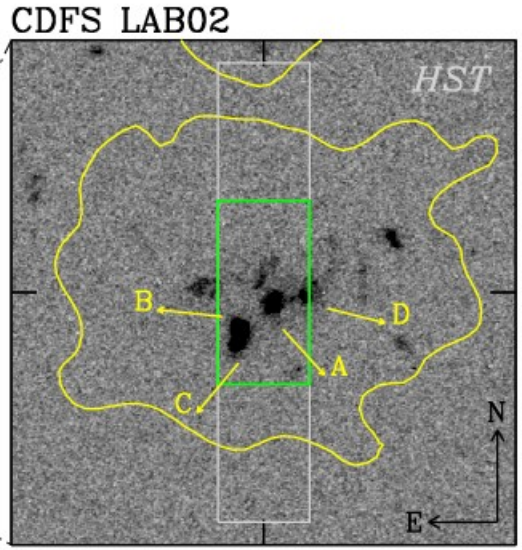
Follow-up with High-res (R~4000) Optical/NIR

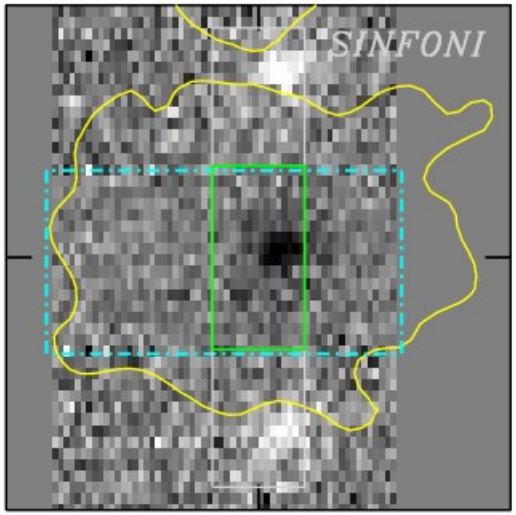












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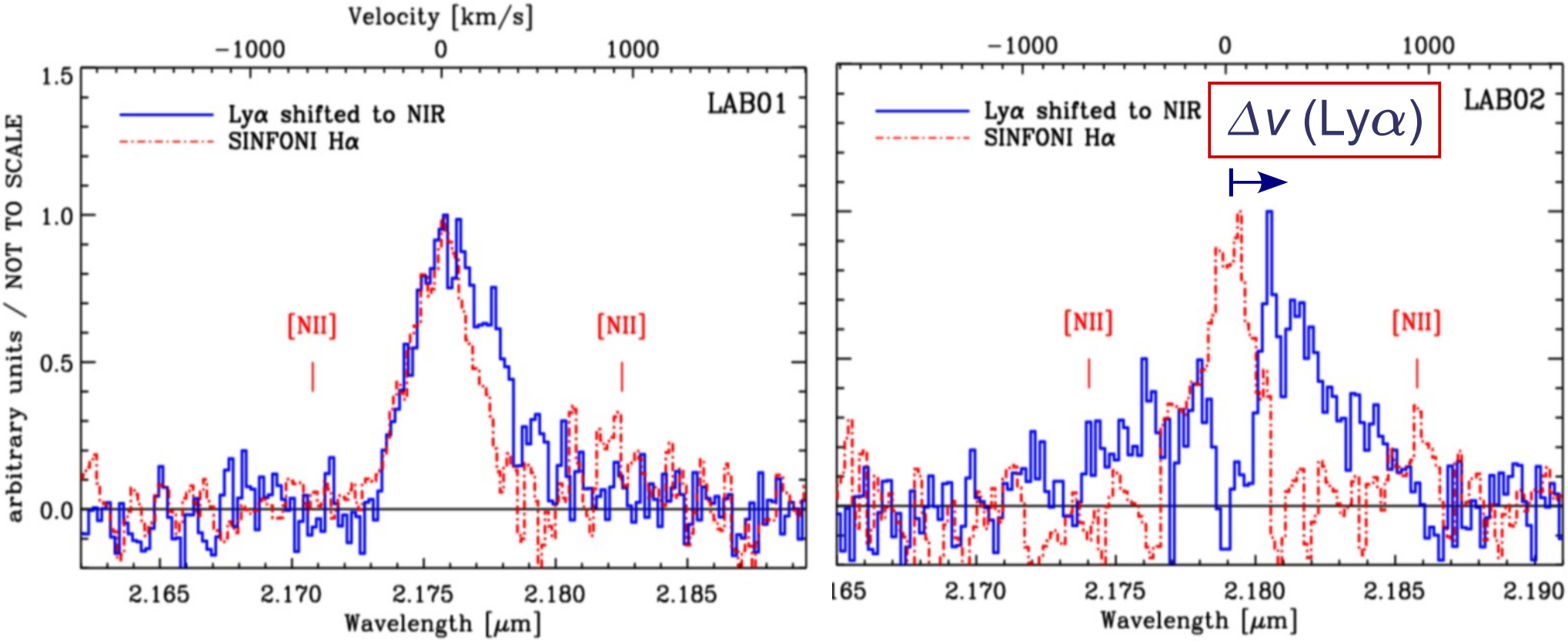
VLT/SINFONI IFU

Hα

Comparison between Lyα & Hα

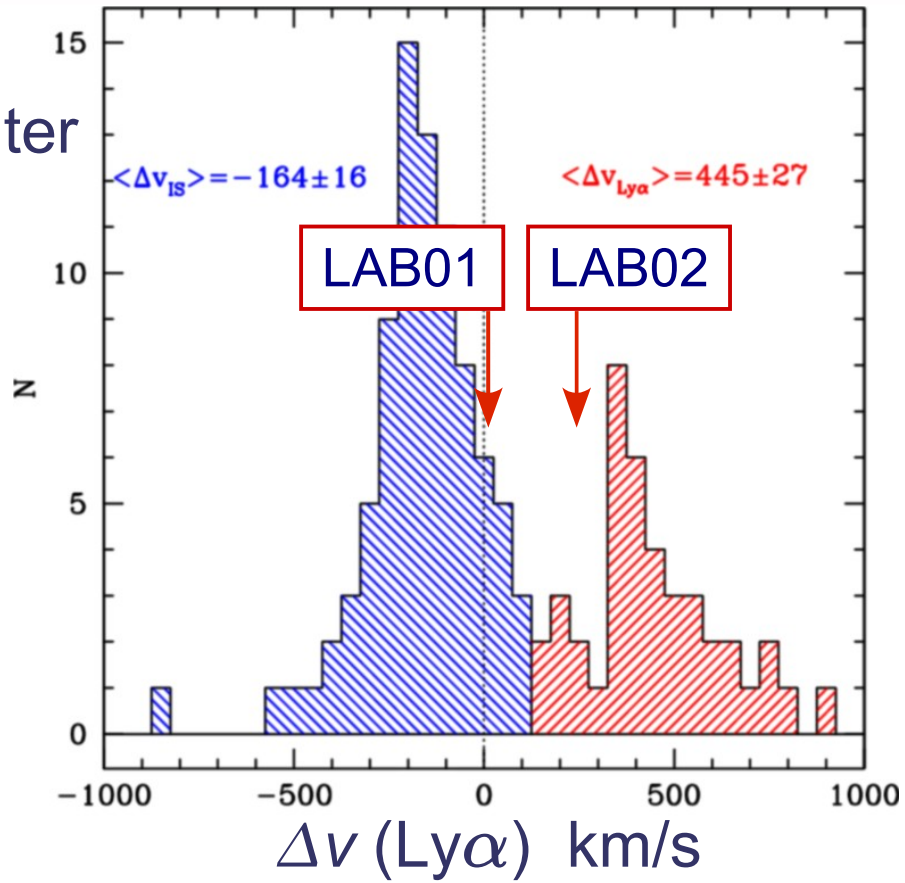


- Velocity offset: $\Delta v \cong 0$ and +230 km/s for LAB01 and LAB02.
- No strong “super/hyper”wind: 450km/s wind common for LBGs
- Need Lyα & Hα measurements for larger sample!
  (VLT/XSHOOTER, LBT/LUCI program)

Yang et al. (2011a)

Comparison between Lyα & Hα

LBGs: x10 fainter Lyα halo



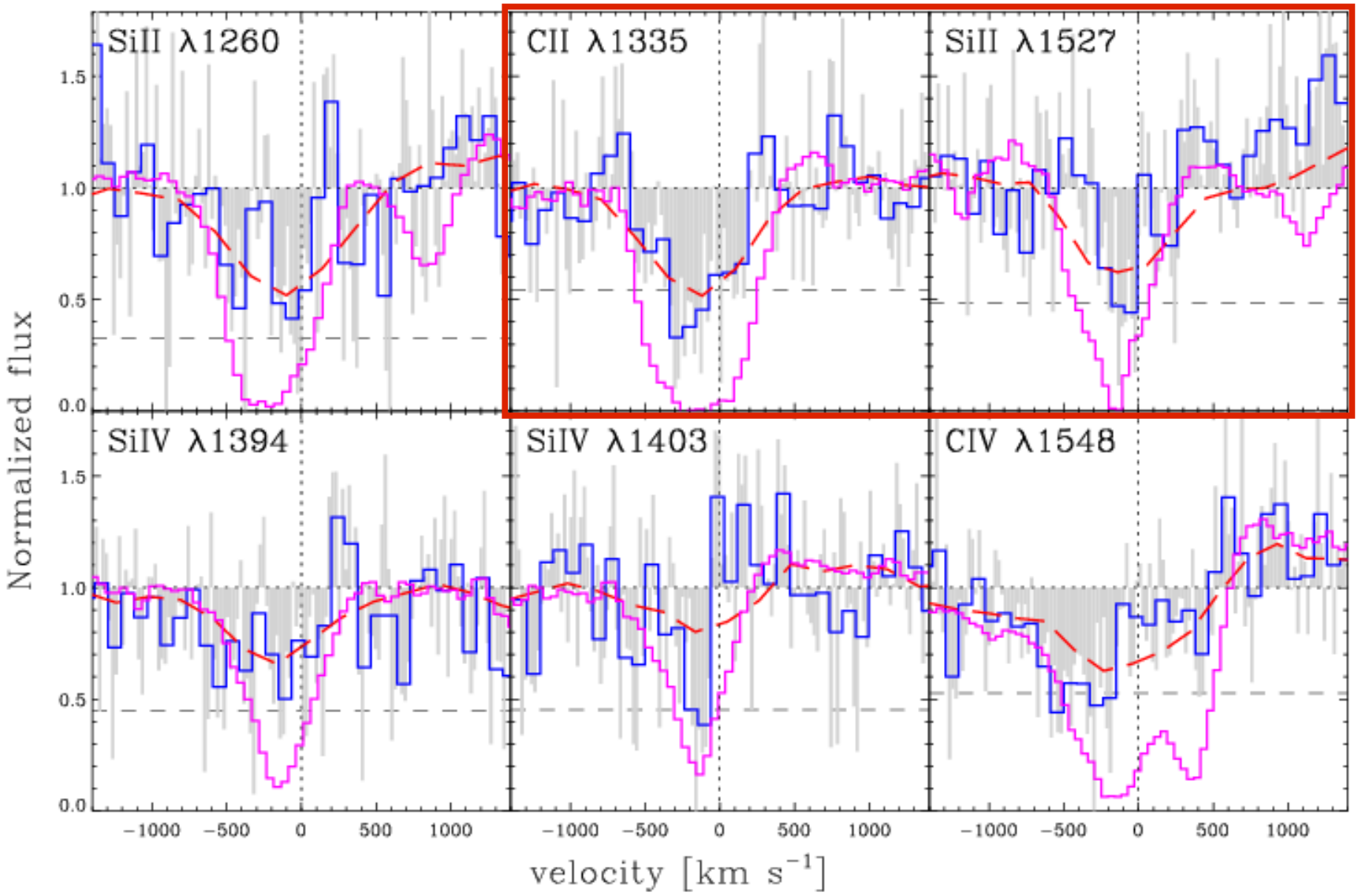
Distribution of Δv (Lyα) for z~2 LBGs (Steidel+10)

Δv (Lyα) ~ 300km/s (Rakic+2011)

- Velocity offset: $\Delta v \cong 0$ and +230 km/s for LAB01 and LAB02.
- No strong “super/hyper”wind: 450km/s wind common for LBGs
- Need Lyα & Hα measurements for larger sample!
- see also McLinden+11, Finkelstein+11 for compact emitters (LAEs)

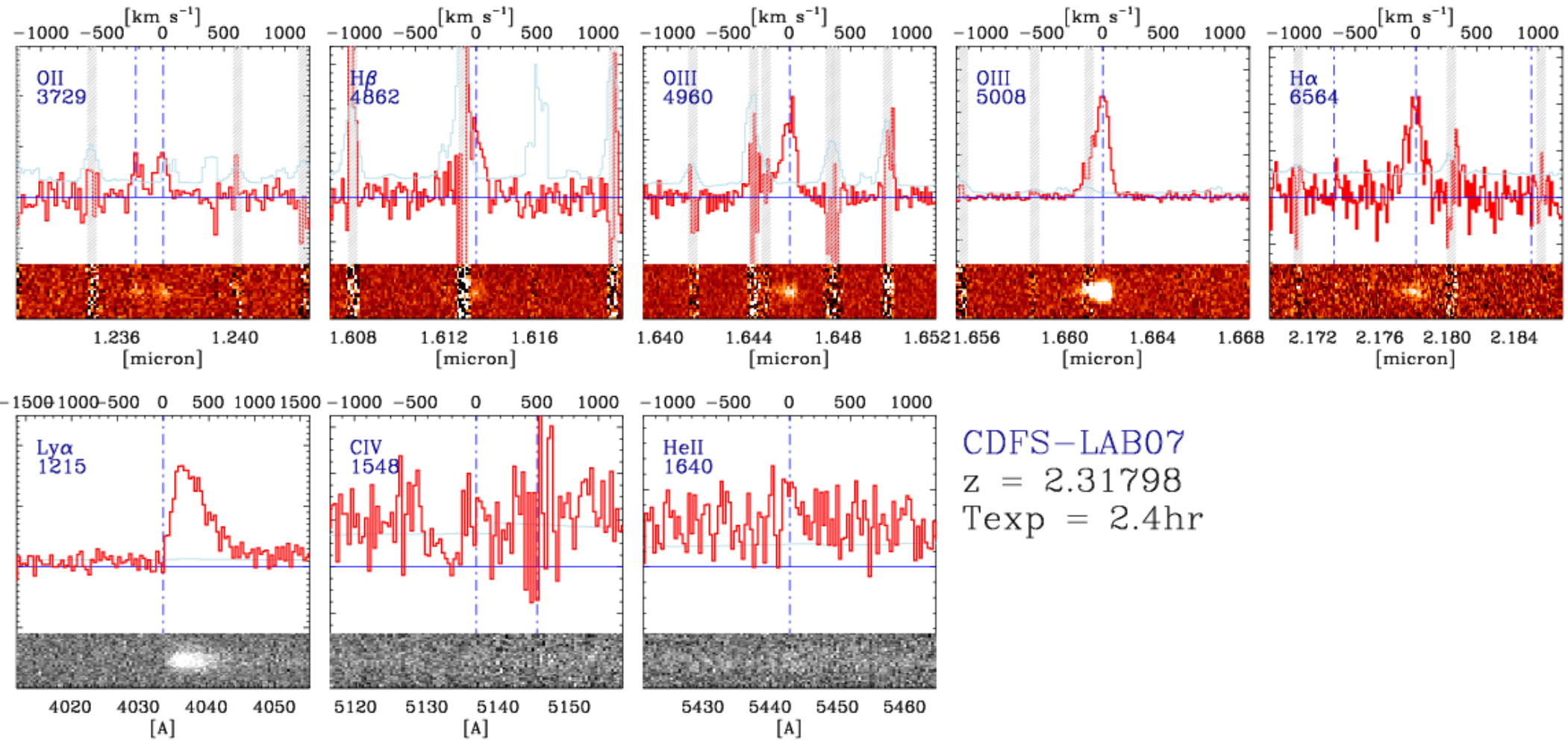
Kinematics from Absorption Lines

LAB02



- Small outflow velocity confirmed by IS absorption lines

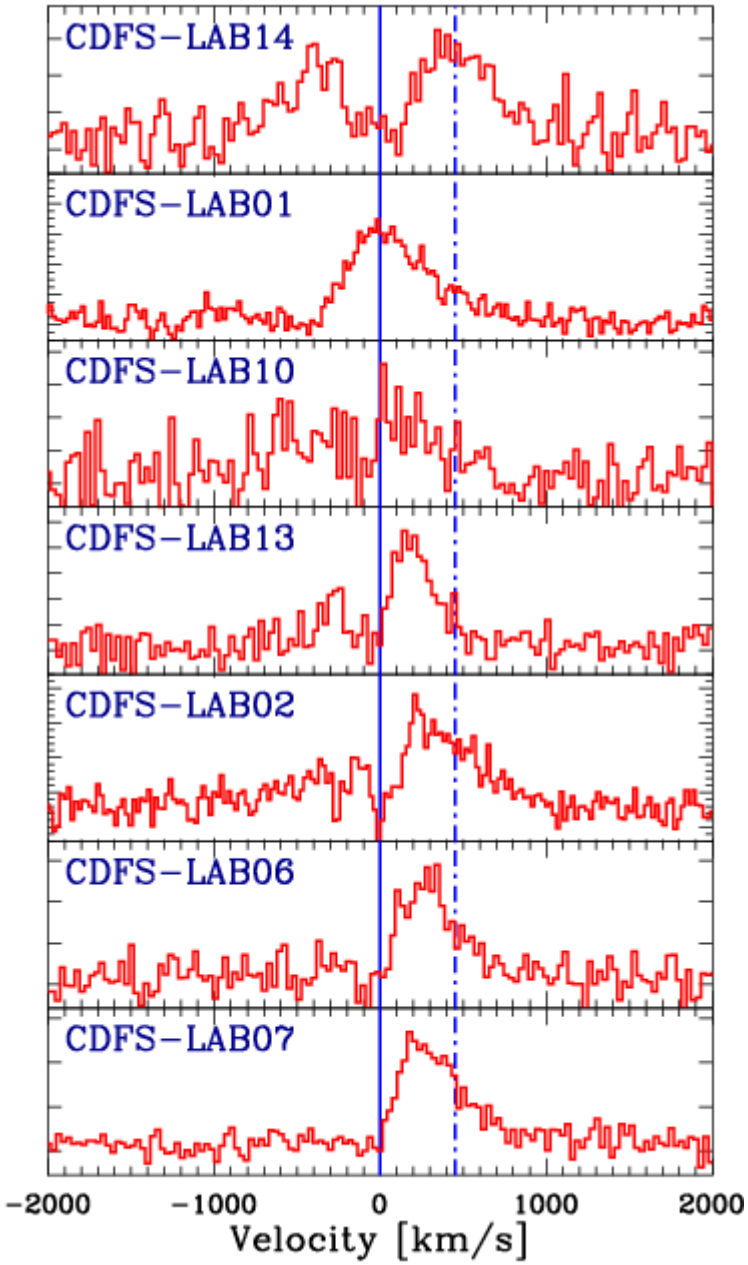
Preliminary Results from XSHOOTER

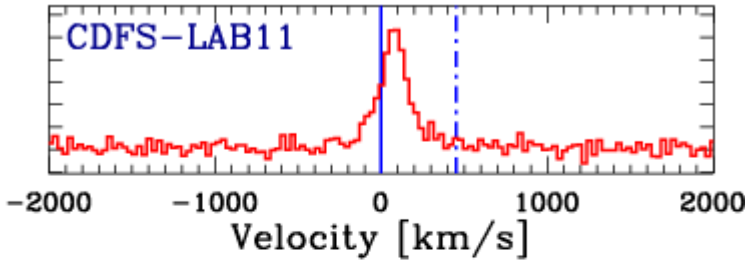


CDFS−LAB07
z = 2.31798
Texp = 2.4hr

Yang et al. in prep.

Preliminary Results from XSHOOTER





- Diverse Lyα line profiles
- Velocity offset: $\Delta v < +300$ km/s for 7 galaxies

Yang et al. in prep.

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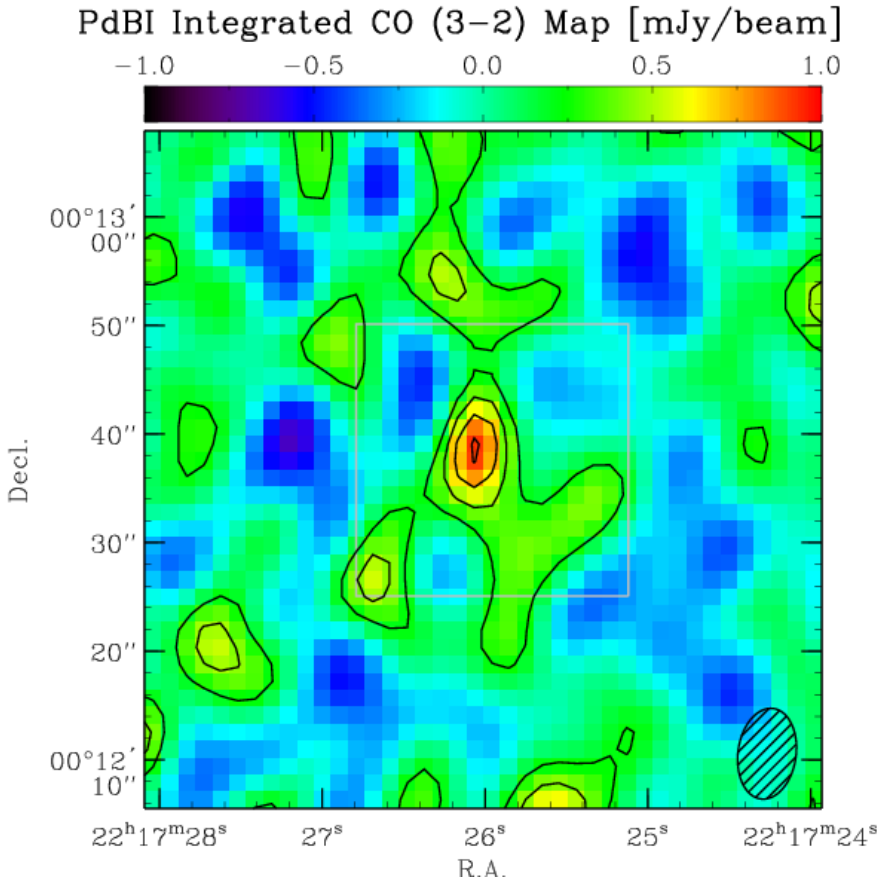
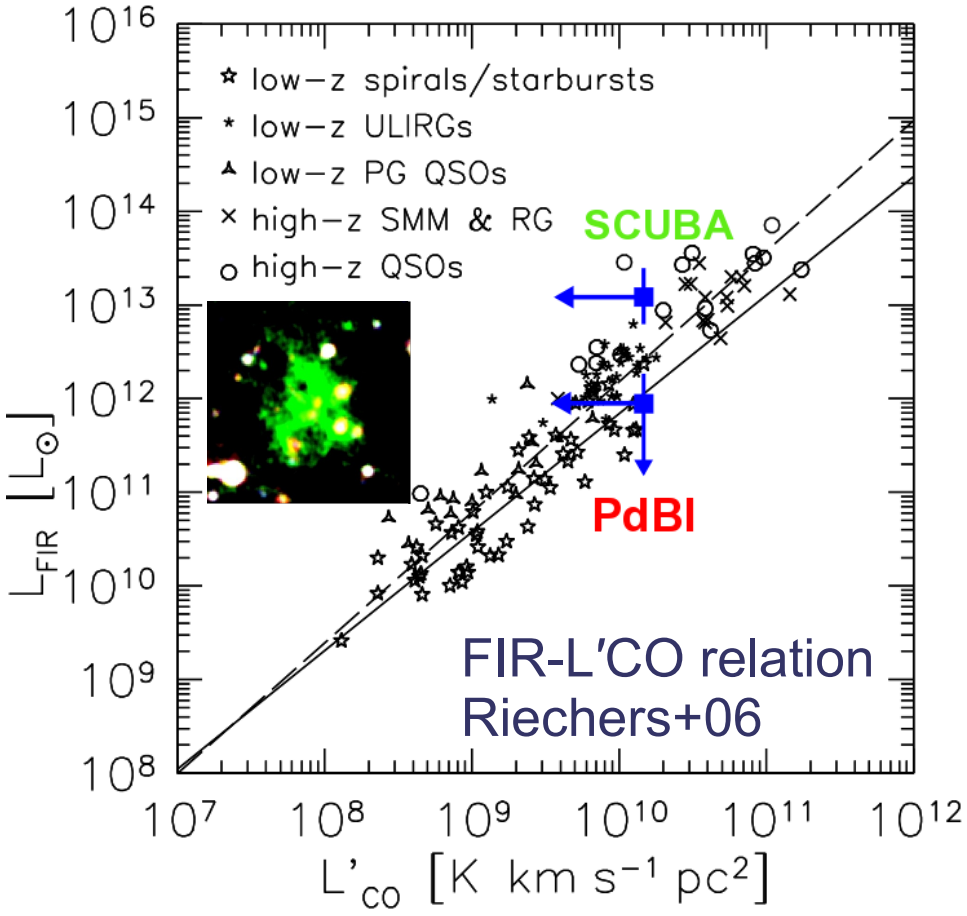
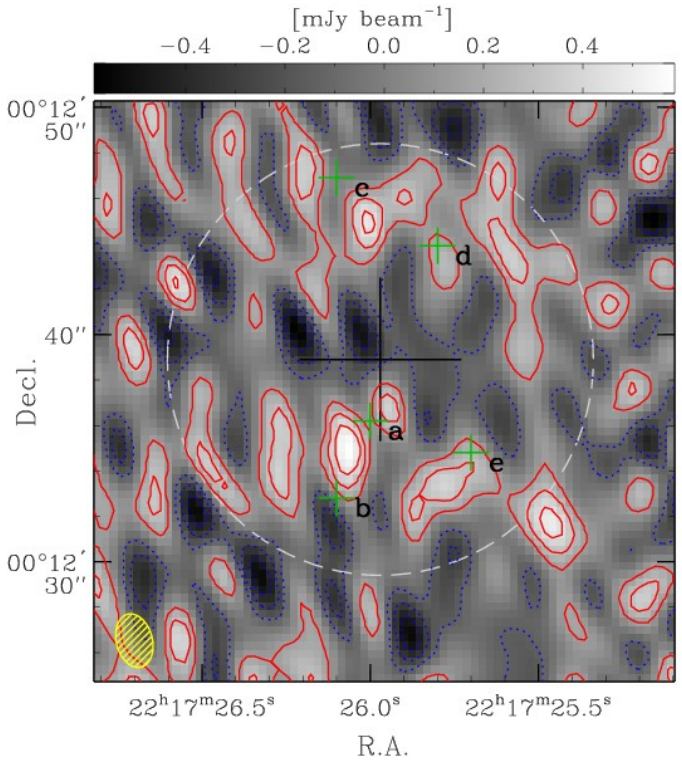
Use CO instead of Hα



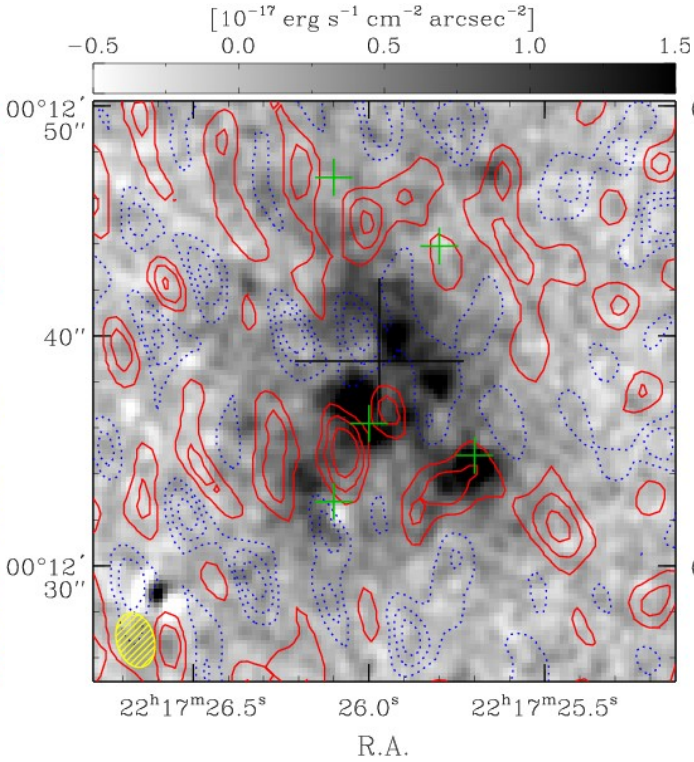


- Plateau de Bure Interferometer (PdBI) CO(3-2) observations
- CO(3-2) : No detection down to 0.5 mJy/beam, $M(H_2) < 10^{10}$ M_{sun}
- SMG in SSA22-LAB1: NOT detected: energy source still unknown.

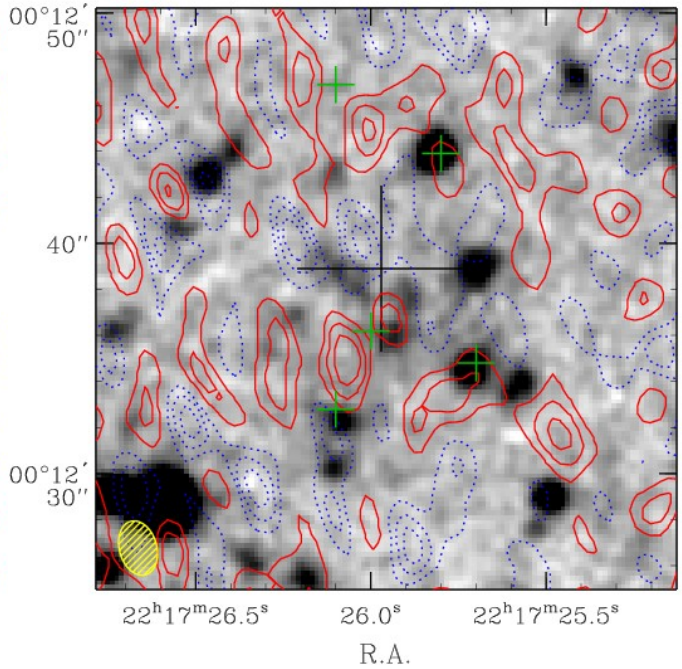
No submm galaxies in SSA22-LAB01



PdBI 1.2mm map



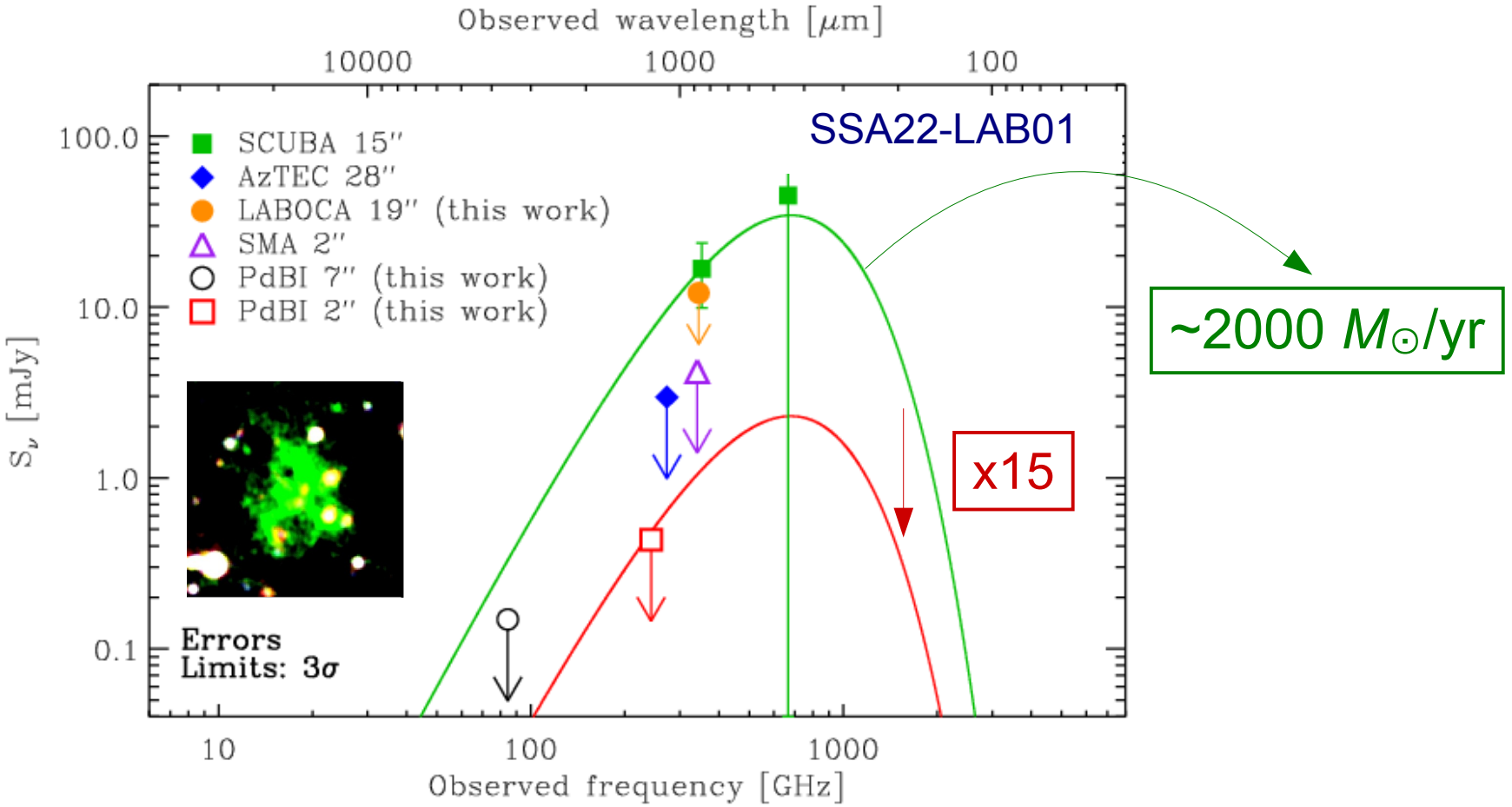
Subaru Lyα image



Subaru B+V

Energy Source of best-studied Lyα Blob?

- SF
- AGN
- Shock
- Cooling



- PdBI CO(3-2) & 1mm, APEX/LABOCA observations
- SMG in SSA22-LAB1: **NOT** confirmed, energy source still unknown.
- CO(3-2) *: also* not-detected

Summary & Future

Gas Kinematics of Lyα blobs

- Inconclusive YET.
- No infall/cold stream.
- No strong wind feature.
- No AGN signature (obscured?)

Statistics of Lyα blobs

- Strongly clustered
- Reside in massive DM halos
- Will evolve into rich-groups/cluster

Energetics of Lyα blobs

- Energy source of SSA22-LAB1
  to be determined

Future Work

- Need Lyα, Hα for larger sample
- Use CO lines instead of Hα
  (PdBI & ALMA)
- Expand survey to z>3
  with tunable filter