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EVIDENCE FOR THE COLD-STREAM TO HOT-ACCRETION TRANSITION AS TRACED BY Lyα EMISSION FROM GROUPS AND CLUSTERS AT 2<z<3.3

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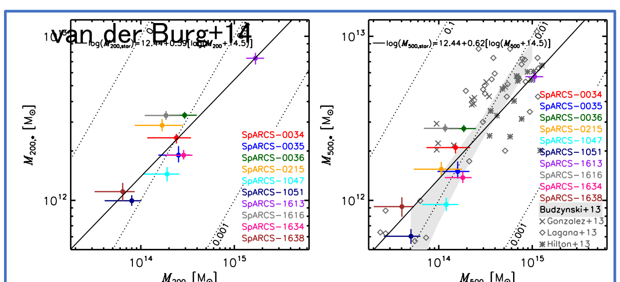
まとめ：Keck KCWIでz=2–3.3銀河団を囲むGiant LgA Halo の観測 => cold–stream と hot accretionのtransitionらしきものを見つけた

Background:

- 理論予想では、
  - M_DM<M_shock~1e12Msun にある銀河はcold accretionでガス供給される。=> Hi-zの銀河が星形成率が高い原因
  - M_DM>M_shockだとショック加熱で落ちてくるガスが加熱される
  - M_shockはcooling timeとdynamical timeが釣り合うDM質量
- ただし、シミュレーションによるとhi-zではM_DM>M_shockのようなmassive haloでもほそいcold streamになってガスが加熱されずに中心銀河まで落ちれる(DB06)
- M_stream = Cold steram modeが効くlower halo mass
  ：M_stream~1e12.Msun (z=2), 1e13.5Msun(z=3)
- Cold streamの観測的な証拠はない。ただし、cold streamのcollision加熱によるLyAで観測可能なはず

観測:

- Keck/KCWIによるz=2–3.5の９個の銀河団観測
- 8天体から100kpcを超えるサイズのdiffuse LyAを検出
- いちばんmassiveなXLSSC122からは検出できず。
- M_DMの推定は
  - x-ray or SZ、または
  - M* =から van der Burg+14を使って
- SFRの推定は遠赤外線観測から



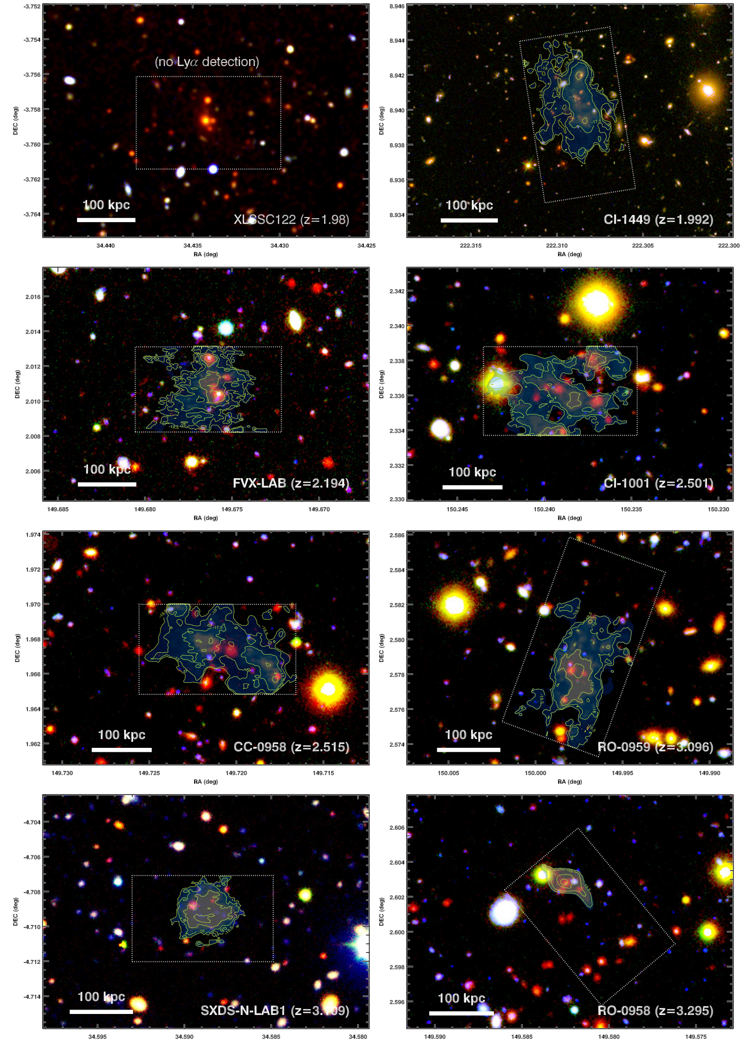


FIG. 1.— Color images of spectroscopically confirmed targets for which KCWI Lyα observations are first presented here (BzK for most, or close variations; North is up and East is left). Cl-1449 is from HST, the rest is ground-based. See D21 for a similar RO-1001 image. The blue soft layer shows Lyα emission, with contours displayed in log steps from -18.5 to -17.5 erg s^{-1} arcsec^{-2} as labeled. The dotted lines show the KCWI field. The orientation of the RO-fields was chosen to maximise overlap with the radio detections.

TABLE 1
GALAXY GROUPS AND CLUSTERS USED IN THIS WORK.

ID	RA	DEC	z (1)	log(M$_{DM}$) (M$_\odot$) (2)	log(L$_{Ly\alpha}$) (erg s^{-1}) (3)	log(SFR) (M$_\odot$ yr^{-1})	log(L$_{AGN}$) (erg s^{-1}) (4)	log(BAR) (M$_\odot$ yr^{-1})	log($\frac{M_{stream}}{M_{DM}}$)	T$_{int}$ h	SB corr dex
XLSSC122	02:17:44.19	-03:45:31.5	1.98	14.2	< 43.0	< 2.3	< 45.3	4.4	-1.8	0.75	–
Cl-1449	14:49:14.05	08:56:24.6	1.992	13.8	43.5	2.8	45.5	3.9	-1.4	3.6	–
FVX-LAB	09:58:42.32	02:00:39.3	2.194	13.0	43.6	2.1	45.3	3.1	-0.4	1.0	–
Cl-1001	10:00:57.18	02:20:08.4	2.501	13.9	43.6	3.2	45.0*	4.2	-0.9	5.0	–
CC-0958	09:58:52.97	01:58:02.8	2.515	13.6	43.9	2.3	< 44.6*	3.9	-0.6	2.0	–
RO-1001	10:01:23.06	02:20:04.9	2.915	13.6	44.1	3.1	44.9*	4.0	-0.1	8.5	–
RO-0959	09:59:59.48	02:34:41.7	3.096	12.8	44.0	3.2	45.1	3.1	0.9	1.5	0.07
SXDS-N-LAB1	02:18:21.31	-04:42:33.1	3.109	13.1	44.0	2.2	< 44.9*	3.4	0.6	1.0	0.08
RO-0958	09:58:19.79	02:36:10.1	3.295	12.9	43.3	3.2	45.5*	3.2	1.0	1.25	0.18

Notes: (1) the redshift is from the luminosity weighted Lyα emission for all but XLSSC122 where it is from optical spectroscopy (Willis et al. 2020); (2) we use M_{200}; for XLSSC122 we converted M_{500} into M_{200} with a $\times$1.7 scaling; (3) SB corrections are already applied; (4) * indicate values inferred from Lyα point-source components (or lack there-of);

結果:

- Baryon Acrretion Rate (BAR)

$$BAR \simeq 137(\frac{M_{\rm DM}}{10^{12}M_\odot})^{1.15}(\frac{(1+z)}{(1+3)})^{2.25}M_\odot yr^{-1} \qquad (1)$$

- M_shock=6e11Msun
- M_stream

$$\log M_{\rm stream} \simeq \log M_{\rm shock} + 1.11\times(z-1.4) \qquad (2)$$

=> z>1.4で、

  - M_DM<M_streamの銀河はcold streamでガス供給を受ける (BAR=BAR_cold)
  - M_DM>M_streamだと BAR_coldは小さくなっていく

- Cold accretion によるbaryon accretionは

$$BAR_{\rm cold} \simeq \begin{cases} BAR(\frac{M_{\rm stream}}{M_{\rm DM}})^\alpha & M_{\rm DM} > M_{\rm stream} \\ BAR & M_{\rm DM} \lesssim M_{\rm stream} \end{cases} \qquad (3)$$

- LyA luminosityがBAR_coldのindicator (L_Lya=C_Lya x BAR_cold)だとすると
  - M_DM<M_streamで L_Lya/BAR=const
  - M_DM>M_streamで L_Lya/BARは傾きαのpower-law

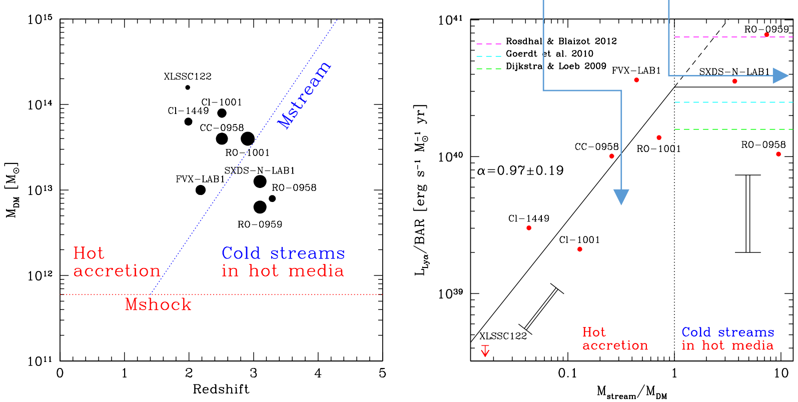


FIG. 2.— (Left:) Our sample in the DB06 diagram. Symbol sizes are proportional to $L_{Ly\alpha}$ (Tab. 1). The blue diagonal line defines $M_{\rm stream}$ (Eq. 2). Right: the ratio of extended Lyα luminosity in the structures is plotted versus the $M_{\rm stream}$ to halo-mass ratio. The relation in Eq. 4 is fitted (solid black line). Typical uncertainties are shown: 0.2 dex along the slope above $M_{\rm stream}$, 0.3 dex along the y-axis below $M_{\rm stream}$. Predictions for $M_{\rm DM} < M_{\rm stream}$ (cold-stream regime) are shown (colored dashed lines).

- Fig2 右:L_Lya/BAR vs M_steram/M_DM
  - α=0.97
  - C_Lya=1e41.51 : いろんなモデル(重力エネルギーの1%程度がLyAとして放射される)と2倍以内で合致
- Fig3 : SFR, AGNについてのプロット。傾向は何となく見られる？
  - M_DM<M_streamだとcold streamのガスの20-50%が星形成に使われる？

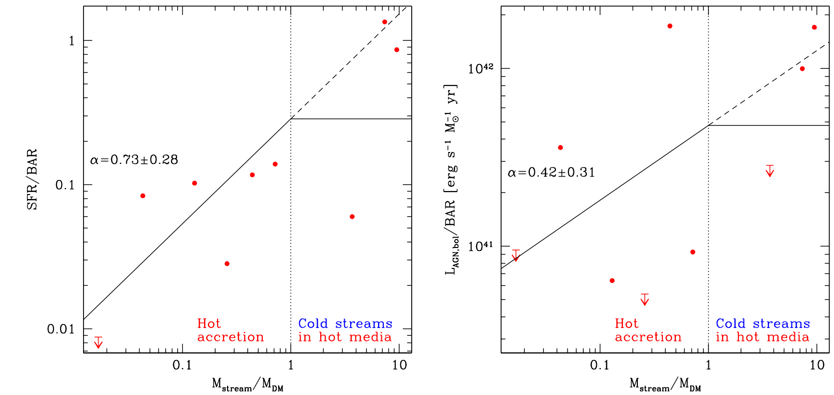


FIG. 3.— As in Fig. 2-right but for SFR (left) and AGN (Right). Notice the especially poor correlation with $L_{\rm AGN}$/BAR.

議論

- fig2.右の相関は、cold accretion のポテンシャルエネルギーがLyAとして放出されているものなのか?
  - 星形成からのUVによる電離はほぼ無視できる(ionization photonは銀河から出てこれない)
  - AGNの寄与:最大限見積もっても、4/9の銀河団しか説明できない。(Fig4)
- L_LyAは

$$\log L_{Ly\alpha}/{\rm erg\ s^{-1}} \sim 43.6 + \log\frac{M_{\rm DM}}{10^{13}M_\odot} + 2.25\log\frac{1+z}{1+3}, \quad (5)$$

$$L_{Ly\alpha}/{\rm erg\ s^{-1}} \sim 10^{42.6}(\frac{1+z}{1+1.4})^{\sim 7} \ \ {\rm for}\ M_{\rm DM} > M_{\rm stream} \quad (6)$$

:一定、z=2で1e43.3, z=3で1e44

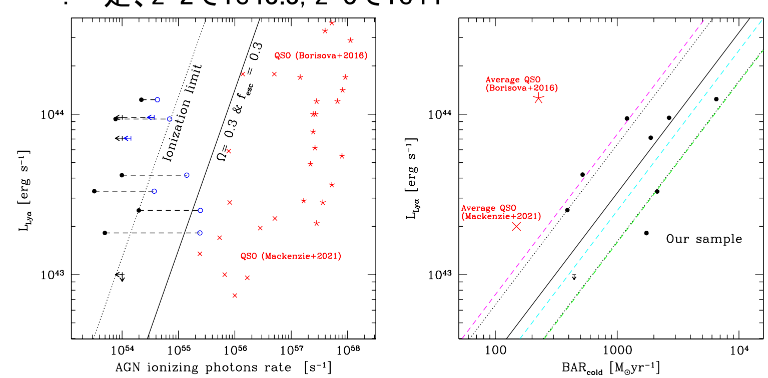


FIG. 4.— (Left) The Lyα luminosity versus the AGN ionizing photon rates for our sample (black points estimated from the ultraviolet luminosity, blue empty point connected by dashed lines are computed from $L_{\rm bol,AGN}$, see text). The diagonal lines show the Lyα luminosity that AGN can ionise: theoretical maximum (dotted) and (solid) assuming a 30% escape fraction (Smith et al. 2020) and an opening angle Ω = 30% (Simpson et al. 2005). (Right) The Lyα luminosity versus the cold accretion rate, as resulting from Eq. 3. The solid (dotted) line(s) show the average linear trend (1σ range). The colored dashed lines are models as in Fig. 2-right (Dijkstra & Loeb 2009; Goerdt et al. 2010; Rosdhal & Blaizot 2012). In both panels QSO-selected Lyα nebulae are shown, individually in the left-panel and averaged in the right-panel where the QSOs' average hosting $M_{\rm DM}$, hence BAR, are estimated from Eftekharzadeh et al. (2015).