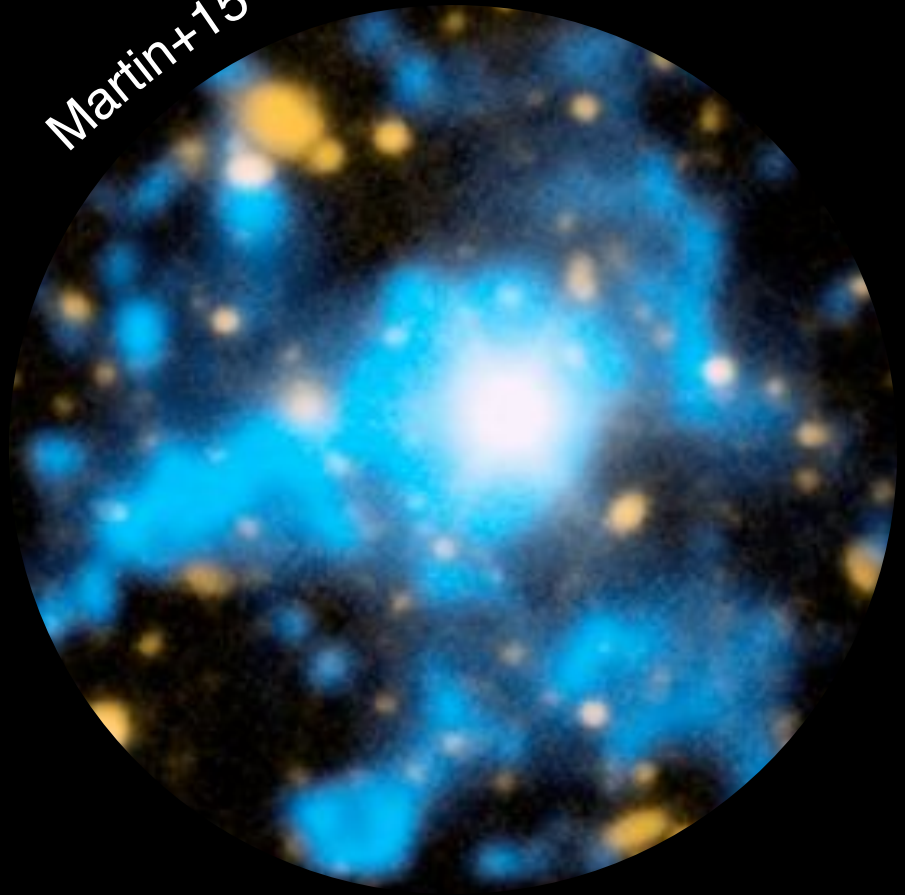
A 100-kpc Lyα nebula in the core of an X-ray cluster at z=2

F. Valentino, E. Daddi, A. Finoguenov et al. 2016

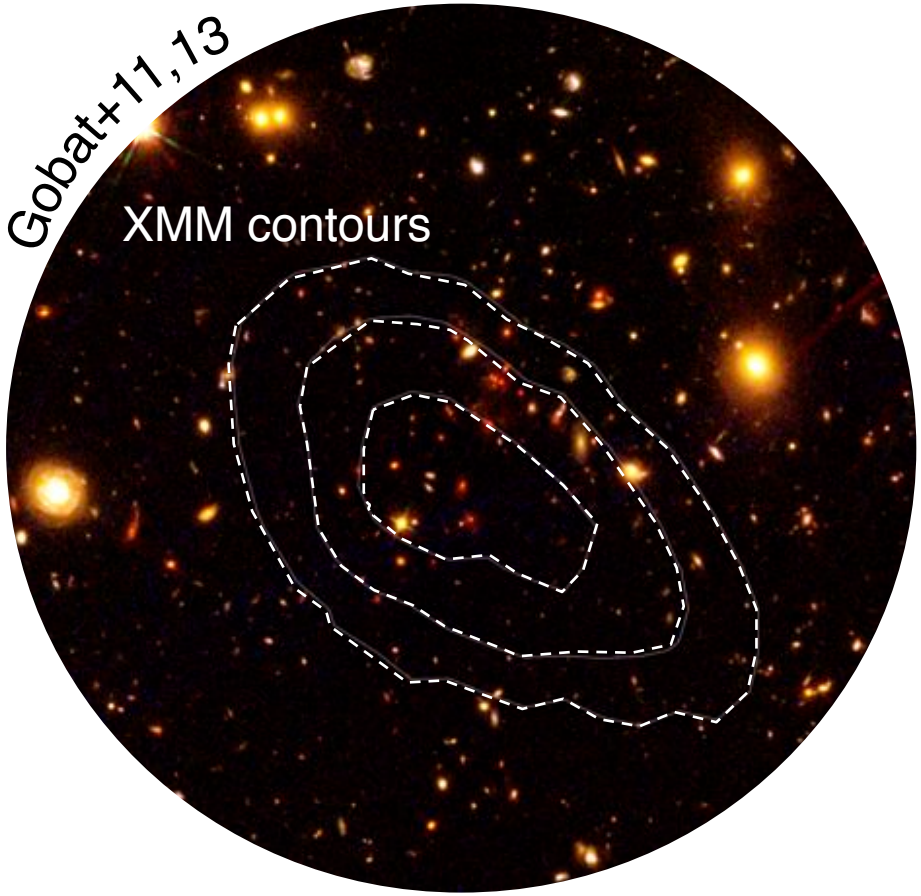
ApJ submitted

Kolymbari, April 28th


HST Abell 2744


Martin+15

Clusters diaries



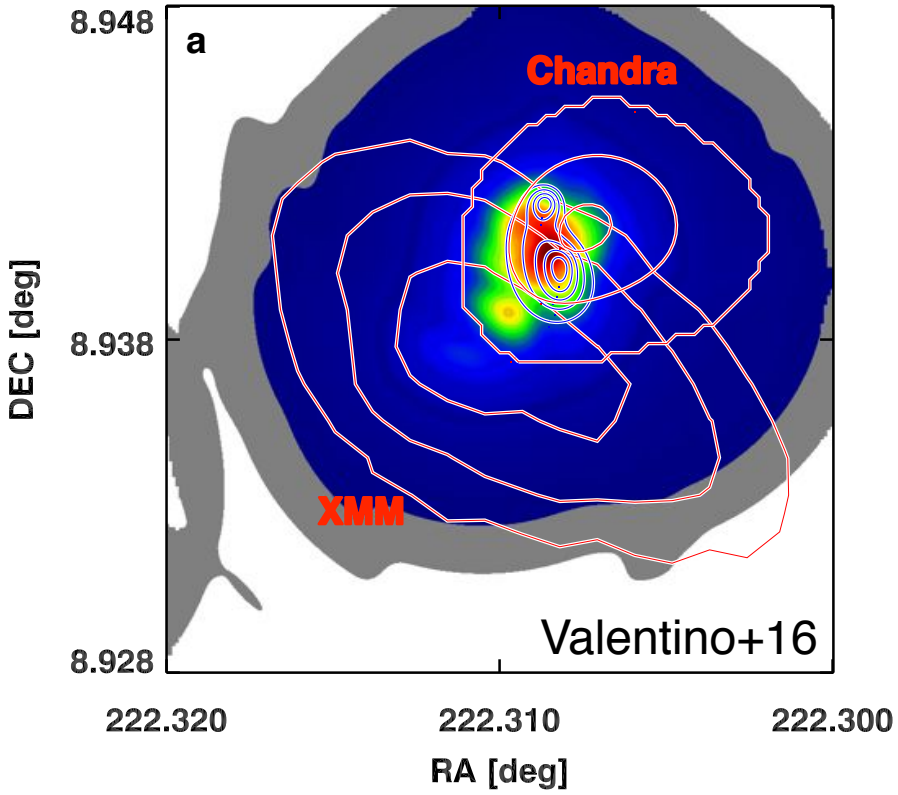
CL J1149+0856 at ***z* =1.99** is among the most distant clusters known to date, **the most distant X-ray detected** (Gobat+2011).

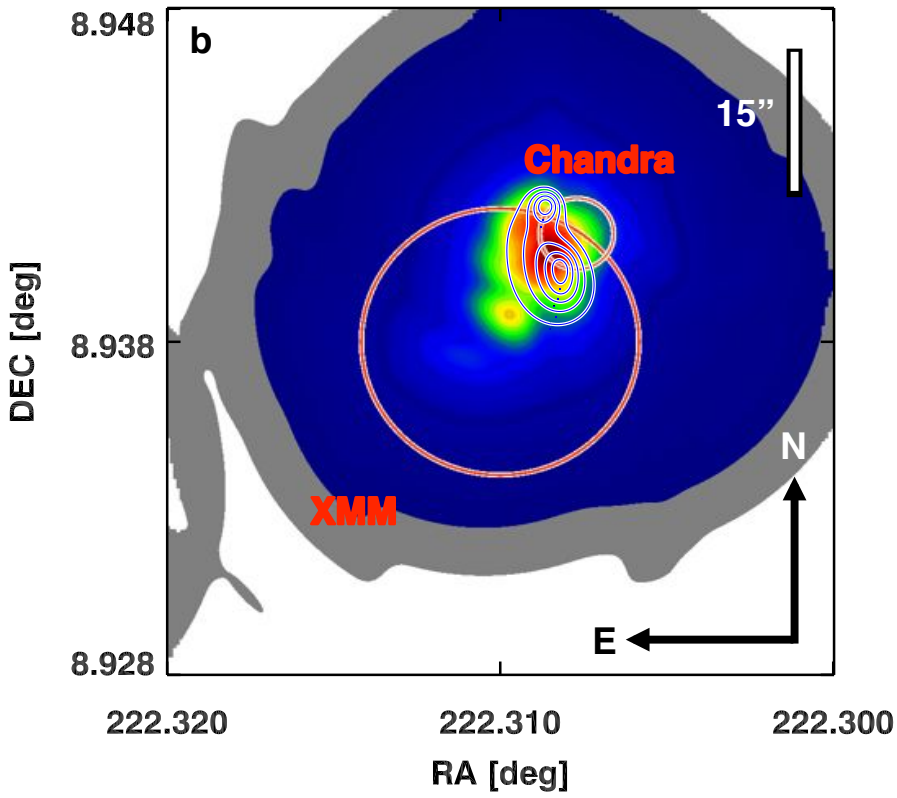
Massive, red, quiescent members in its core (Strazzullo+2013, Gobat +2013)

Yet, hosting a significant activity (**two X-ray AGN, several SFGs**, including the proto-BCG, Valentino +2015a)

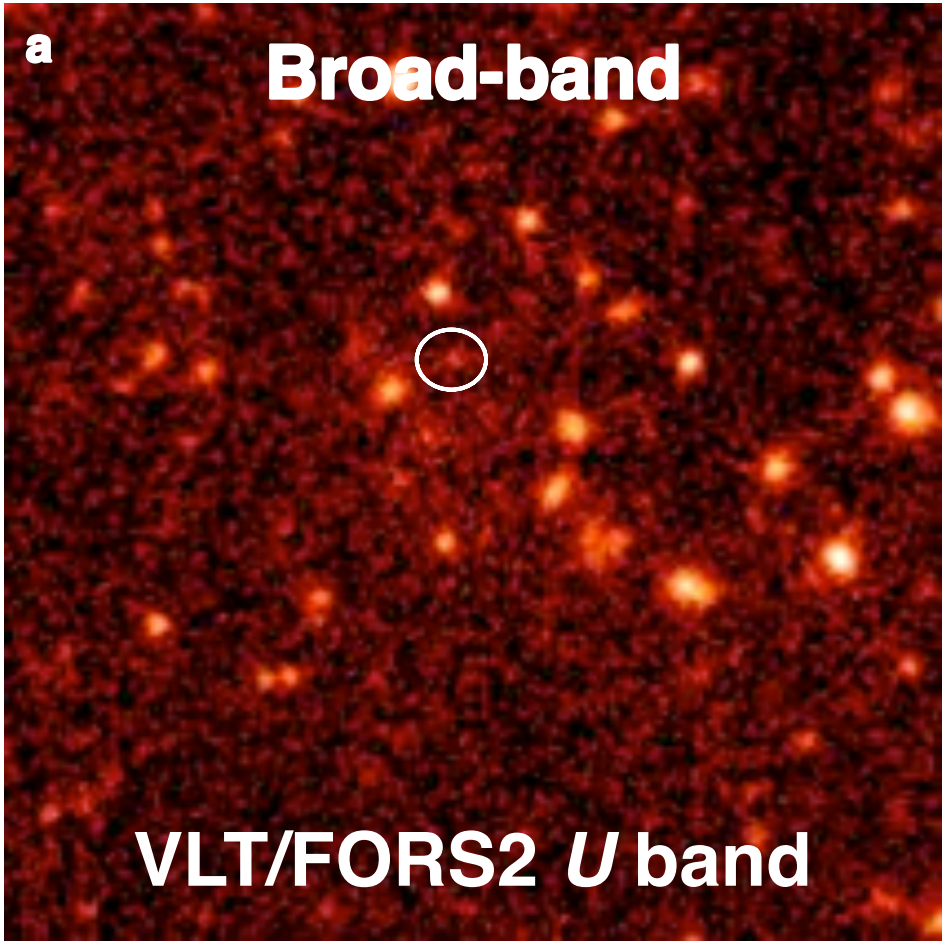
Clusters diaries

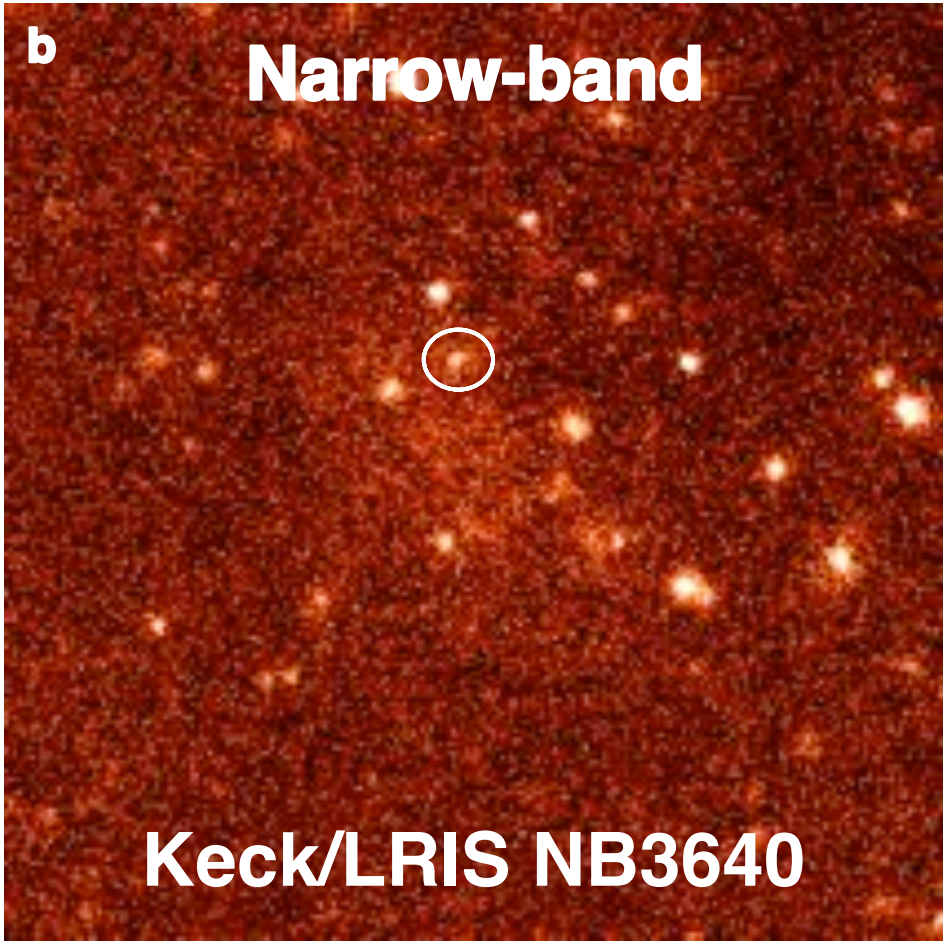
New Chandra 100ks: $L(x) = (9 \pm 3)\times10^{43}$ erg s^{-1} $M_{halo} = (5 - 7)\times10^{13} M_{\odot}$





Chronicles of a discovery





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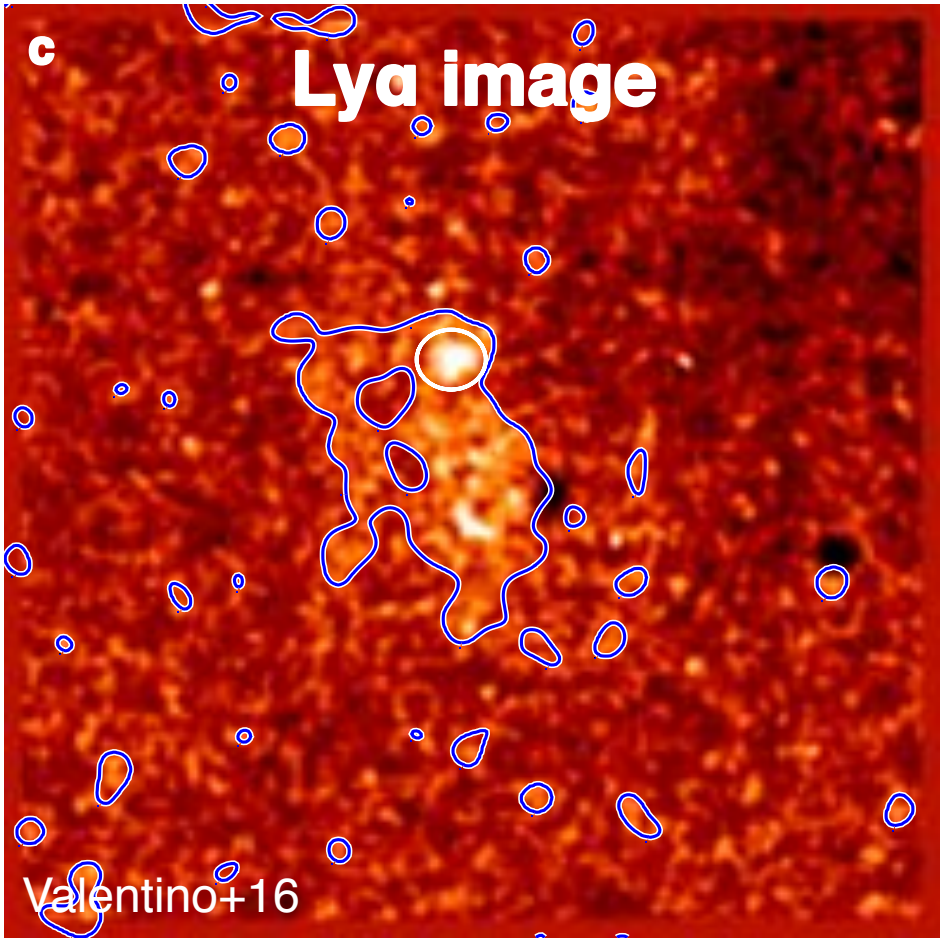

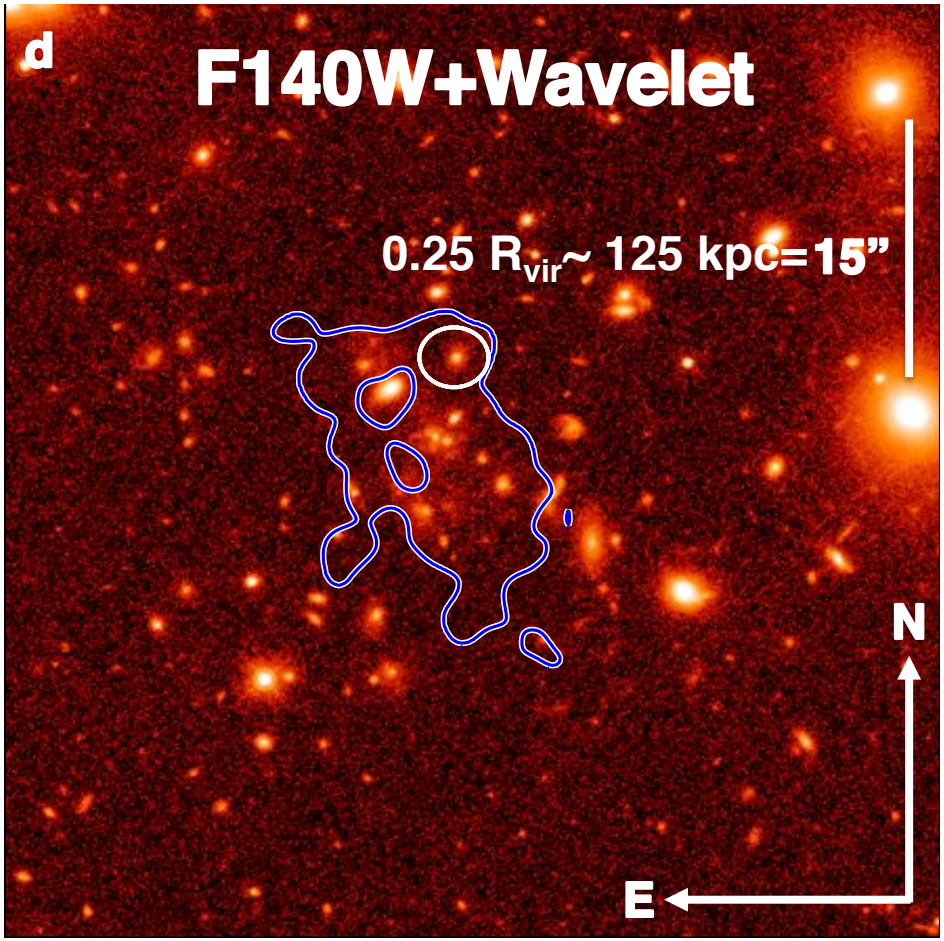

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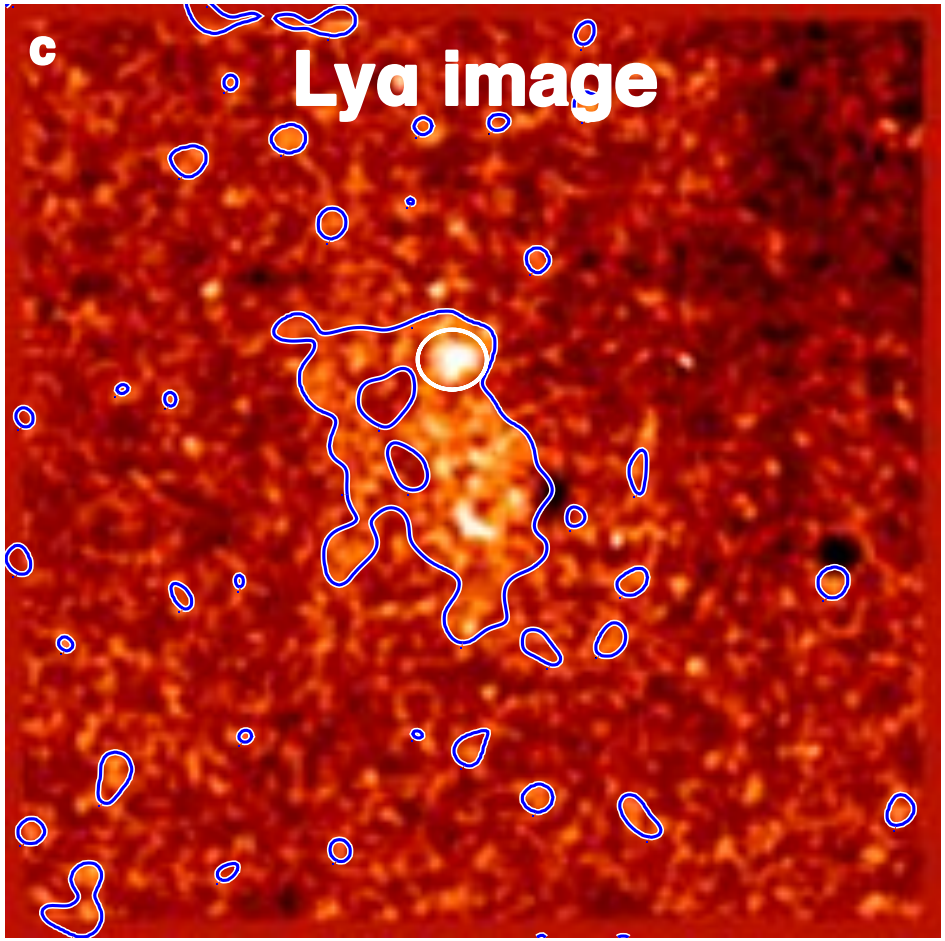
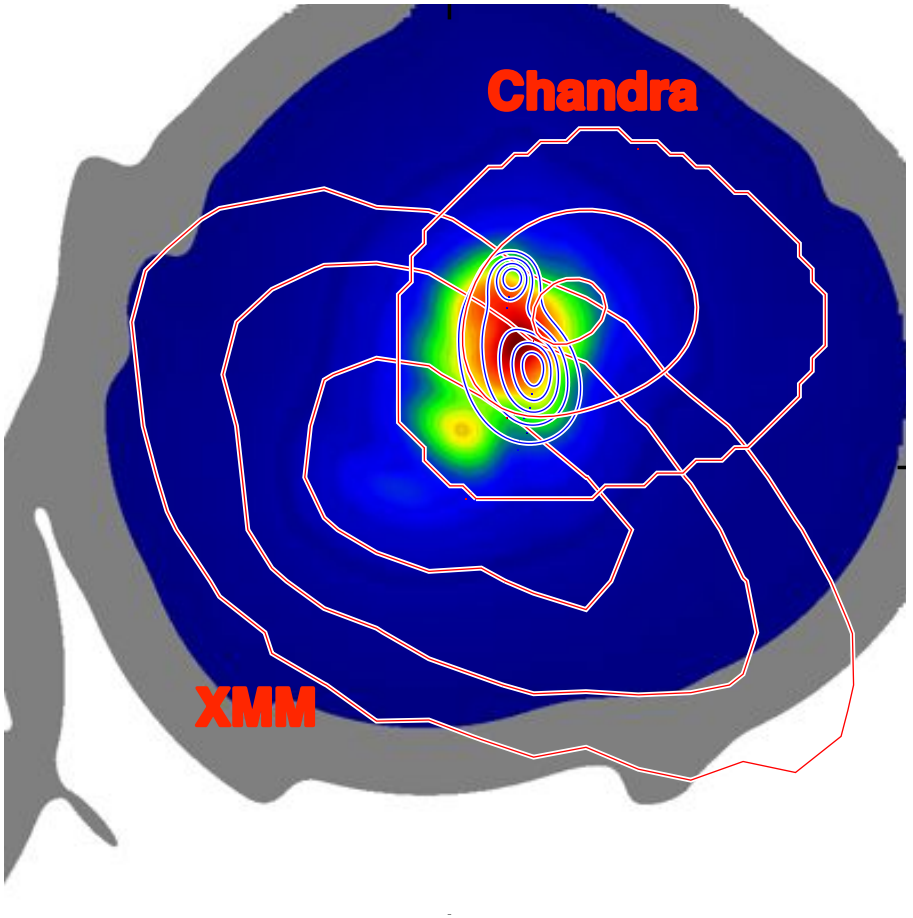
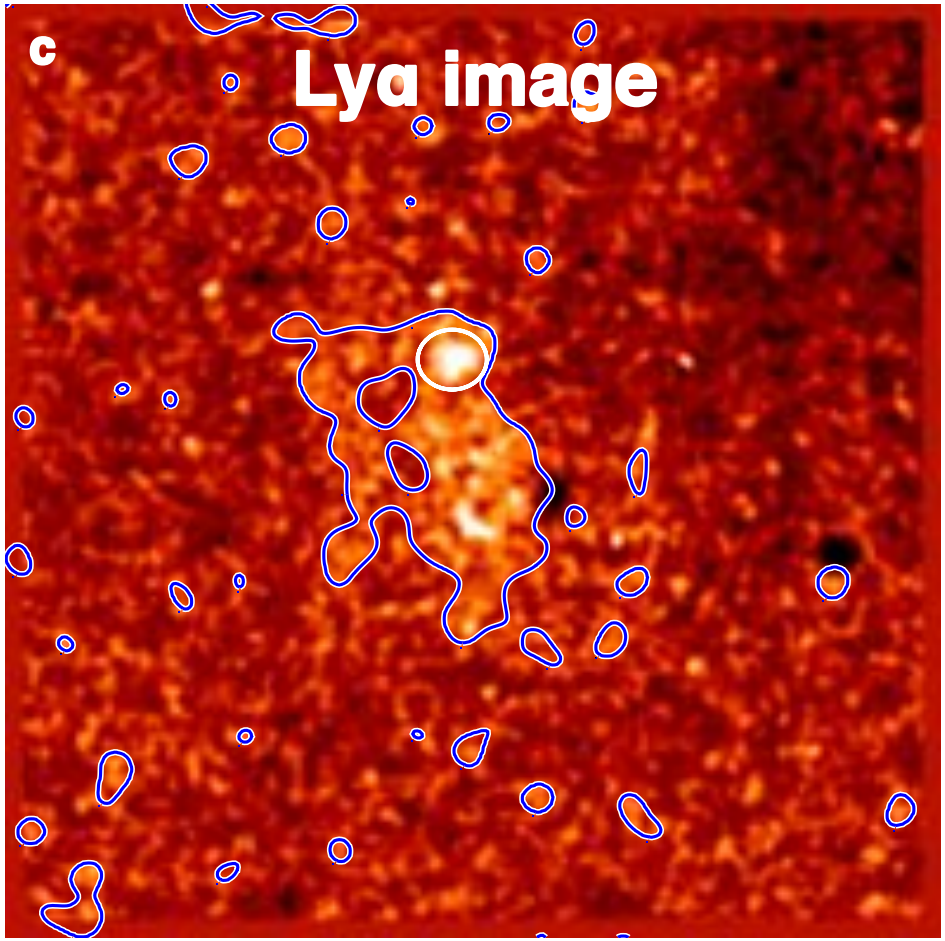




Cold 10^4 K plasma

Hot 10^7 K plasma

Chronicles of a discovery

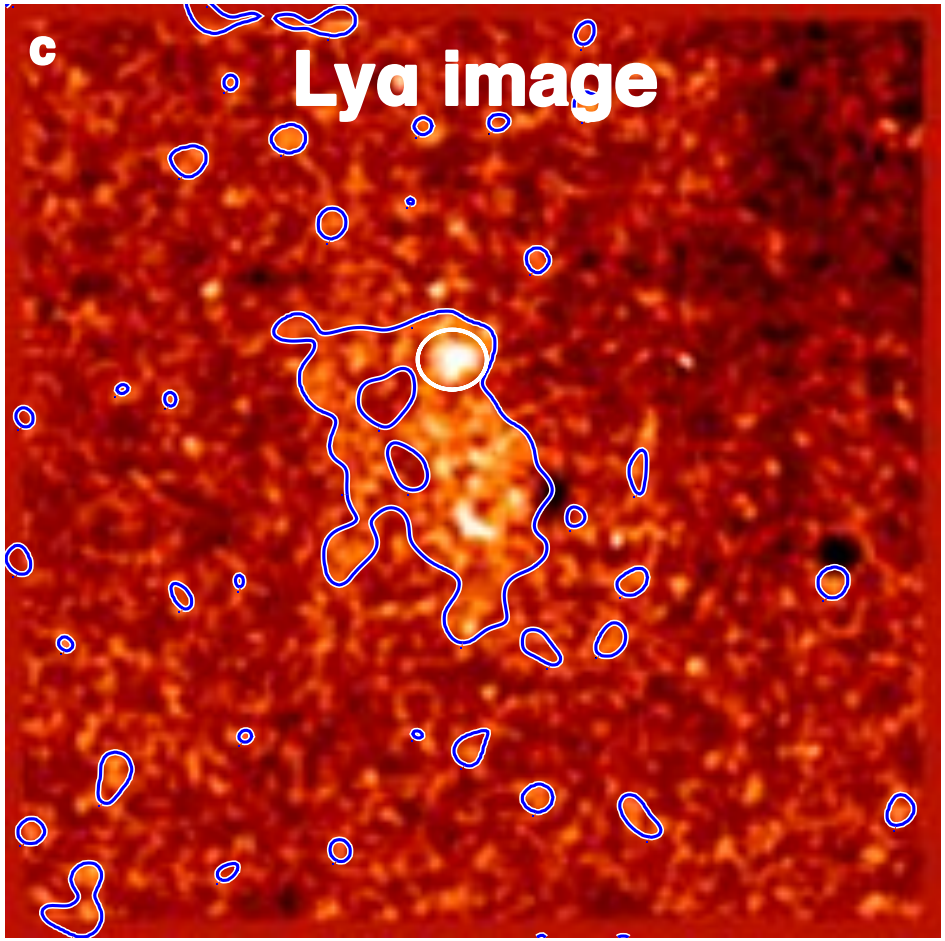


Luminosity = (2.3±0.2)x10^{43} erg s^{-1}
Radius ≈ 46 kpc
Mass = (1 – 10) x 10^9 $M_\odot$
Electron density = 0.9 - 9 cm^{-3}

Uncertainties from the **volume filling factor *f* = 10^{-5} – 10^{-3}**

Powering mechanism:
✗ SFR (EW = (271 ± 88) Å, size)
✗ Cooling from X-ray (L(Lyα)/L(X) = 0.3, **>100x** more than observed locally)
✗ Cosmological cold flows
✓ **AGN**

Chronicles of a discovery

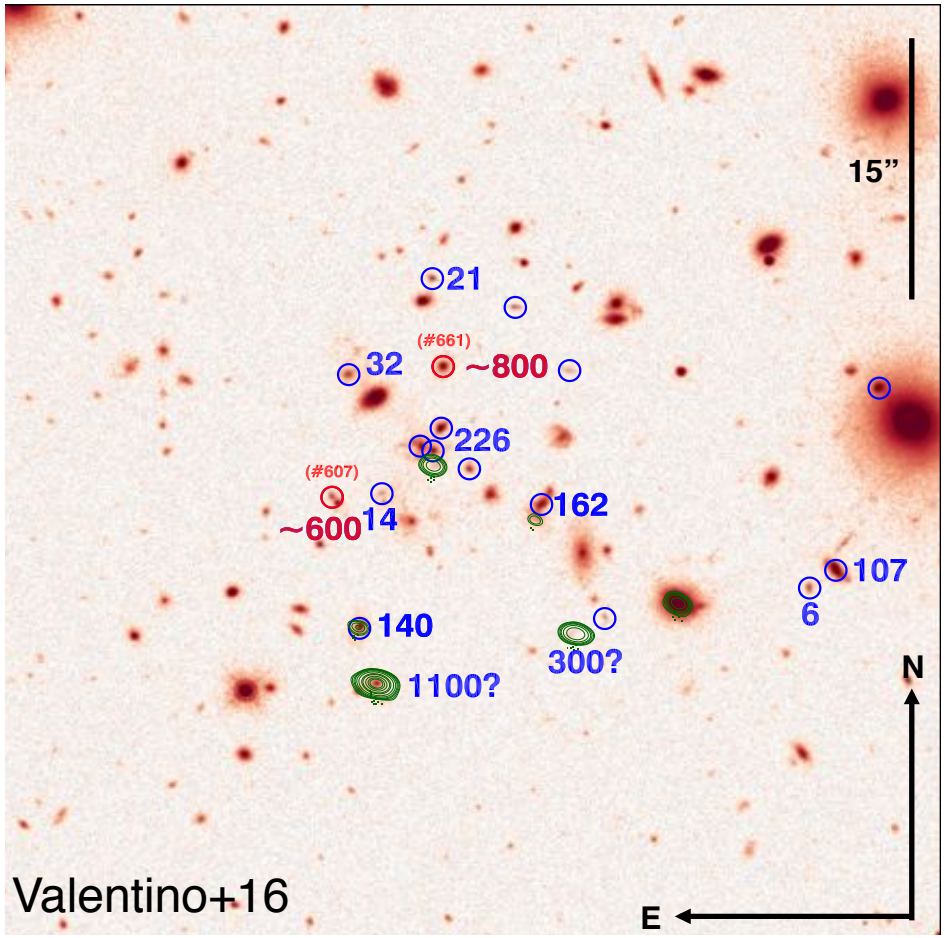


Time evolution:
Cooling time ~ 0.1 Myr
Evaporation time ≤ 10 Myr

Requires constant replenishment:
M_{repl} = M(Lyα) / t(evaporation)
≥ 1000 $M_\odot$ yr^{-1}

Can outflows sustain the replenishment?

Chronicles of a discovery



Huge mass outflow rates
(M_{out} ≈ SFR)

From SED modelling, Hα fluxes, and **ALMA 870 μm continuum emission**: **SFR ≈ 700 $M_\odot$ yr^{-1}**

From SED modelling and X-ray luminosity (Cicone+2014):
AGN ≈ 1400 $M_\odot$ yr^{-1}

A handle on a decade-standing issue

Instantaneous energy injection:

$$\dot{E}_{\rm kin} = \frac{1}{2}\dot{M}_{\rm out}v^2 = (4.9 - 5.3) \times 10^{44}\ {\rm erg\ s^{-1}}$$

≈ 75 - 85% from AGN (≈ 66% of the mass)

5× higher than L(X) > Offset cooling from X-ray

A handle on a decade-standing issue

Integrated energy injection:

$$E_{\rm kin} = \int_{t(z \geq 1.99)} \dot{E}_{\rm kin}\, dt \quad \longrightarrow \quad \dot{E}_{\rm kin} = \beta\, {\rm SFR}$$

A handle on a decade-standing issue

Integrated energy injection:

$$E_{\rm kin} = \int_{t(z \geq 1.99)} \beta \, {\rm SFR}(t) \, dt$$

$$\beta(z = 1.99) = 2.2 - 2.4 \times 10^{49} \ {\rm erg \ M_{\odot}}^{-1}$$

A handle on a decade-standing issue

Integrated energy injection:

$$E_{\rm kin} = \int_{t(z\geq 1.99)} \beta\,{\rm SFR}(t)\,dt$$
$$= \frac{\beta}{1-R}\int_{t(z\geq 1.99)} {\rm SFR}(t)(1-R)\,dt$$

A handle on a decade-standing issue

Integrated energy injection:

$$E_{\rm kin} = \int_{t(z\geq 1.99)} \beta\, {\rm SFR}(t)\, dt$$

$$= \frac{\beta}{1-R}\, M_\star$$

$$\begin{cases} M_\star = 2\times 10^{12}\ {\rm M}_\odot \\ R = 0.4 \end{cases}$$

(Mass return fraction, Bruzual & Charlot 2003)

A handle on a decade-standing issue

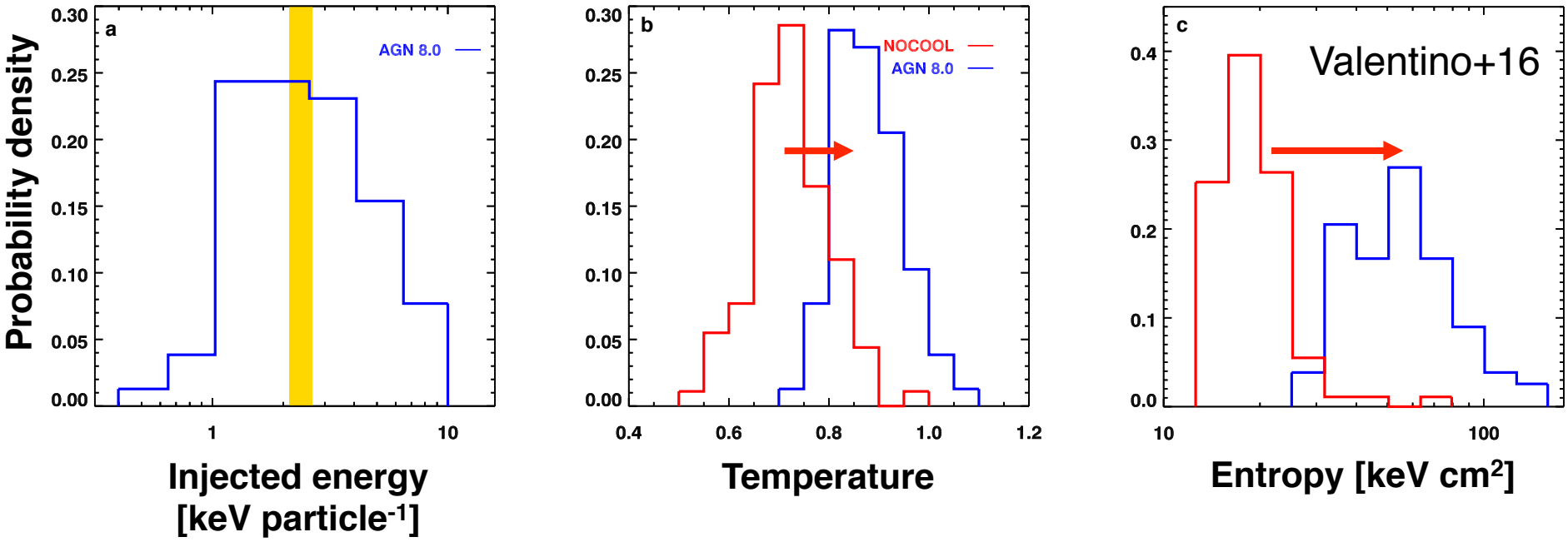
Integrated energy injection:

$$E_{\rm kin} = 4.4 - 4.8 \times 10^{61}\,{\rm erg}$$

$$\left.\begin{array}{l} 2.5{-}2.7\ {\rm keV} \\ E_{\rm therm} = 2 - 2.8\ {\rm keV} \end{array}\right\}$$

(per particle in the hot ICM, **depending on the gas fraction**)

A handle on a decade-standing issue



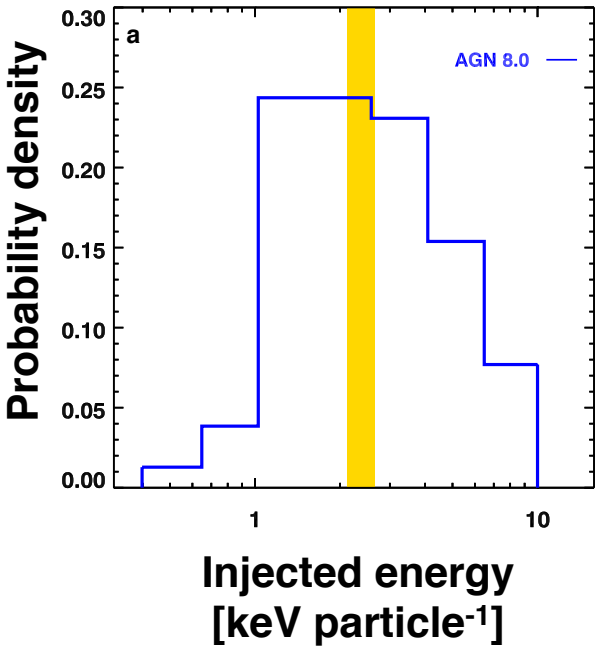
Suite of cosmological simulations **cosmo-OWLS** (Le Brun+2014):

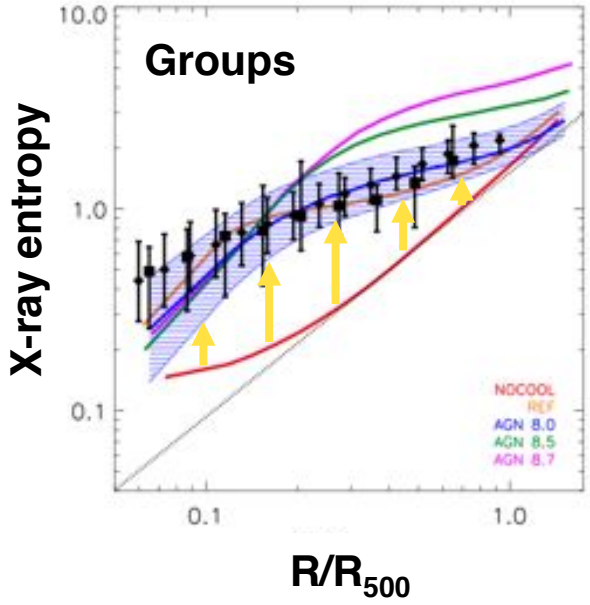
NOCOOL model

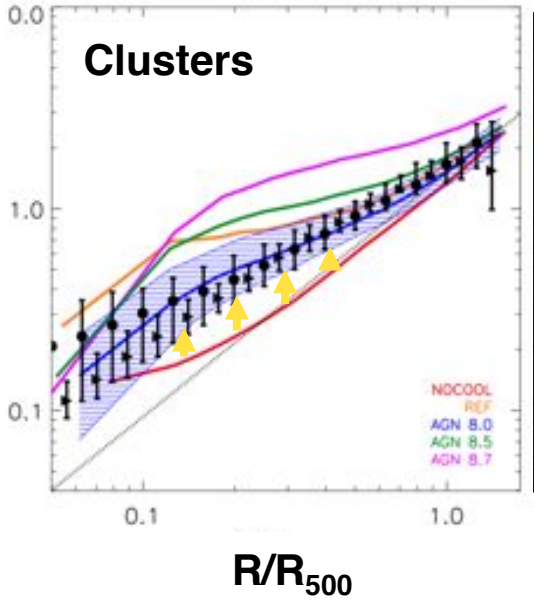
Fiducial model with AGN feedback

Our observations (adopting a baryon fraction $f_b = 0.15$)

A handle on a decade-standing issue







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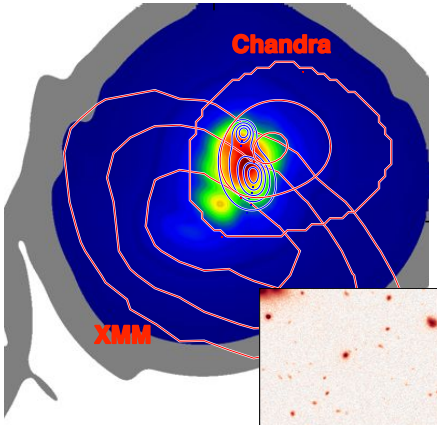
Summary

Discovery of a **100 kpc Lyα nebula** in the core of an **X-ray cluster at $z = 1.99$**

It needs constant gas replenishment to survive

Huge outflow activity in the core **(SFR ≈ 700 $M_\odot$ yr^{-1}, AGN ≈ 1400 $M_\odot$ yr^{-1})** can supply the gas

Outflows inject 2.5-2.7 keV per particle in the hot ICM, as predicted by simulations



Valentino+16
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