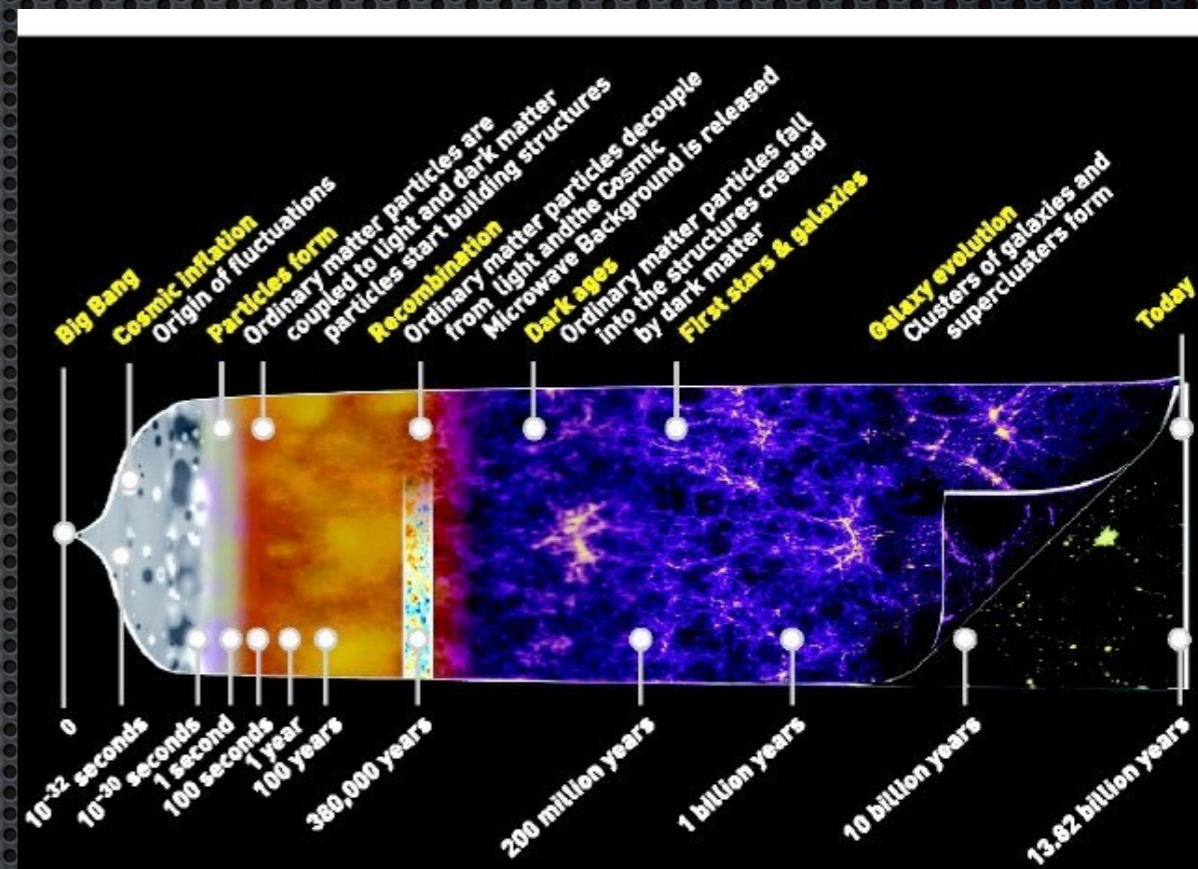


Key extragalactic science for Chandra

Fabrizio Fiore

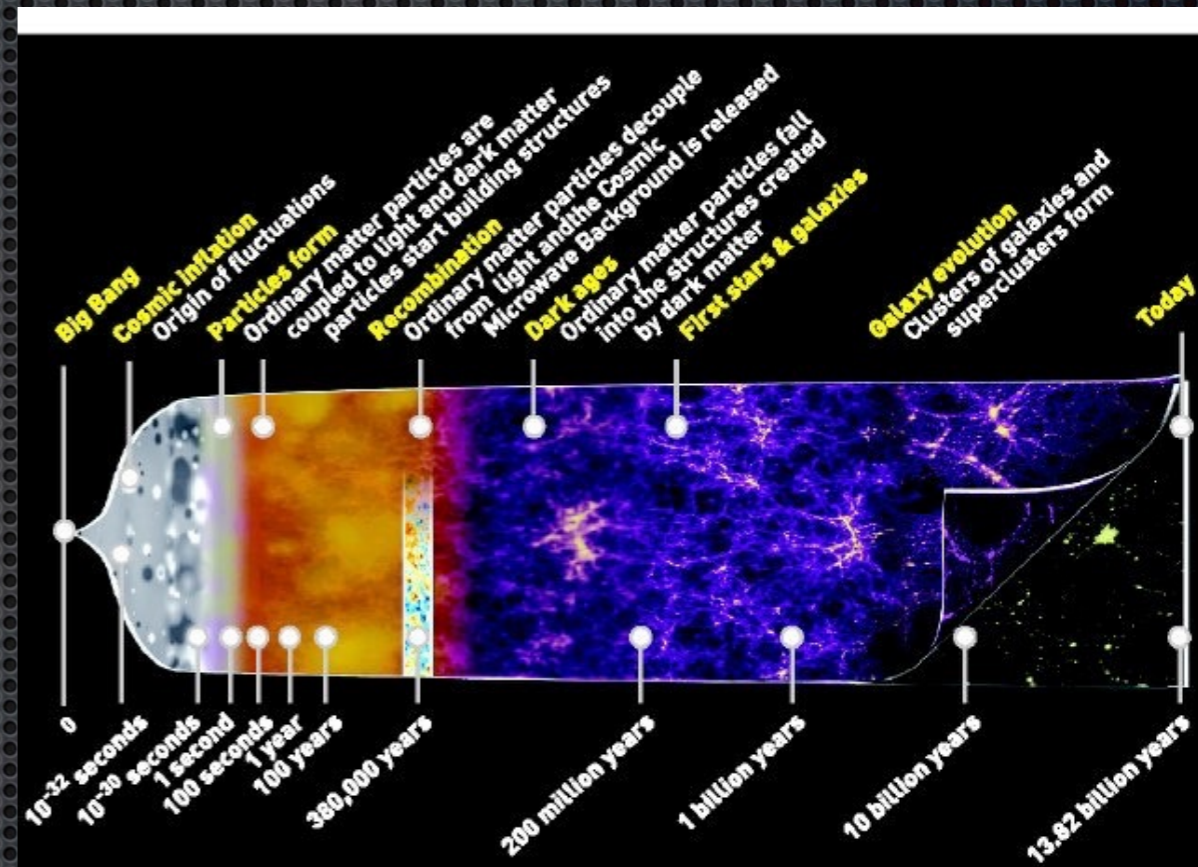
INAF - Osservatorio Astronomico di Roma

Formation of first structures & the role of feedback



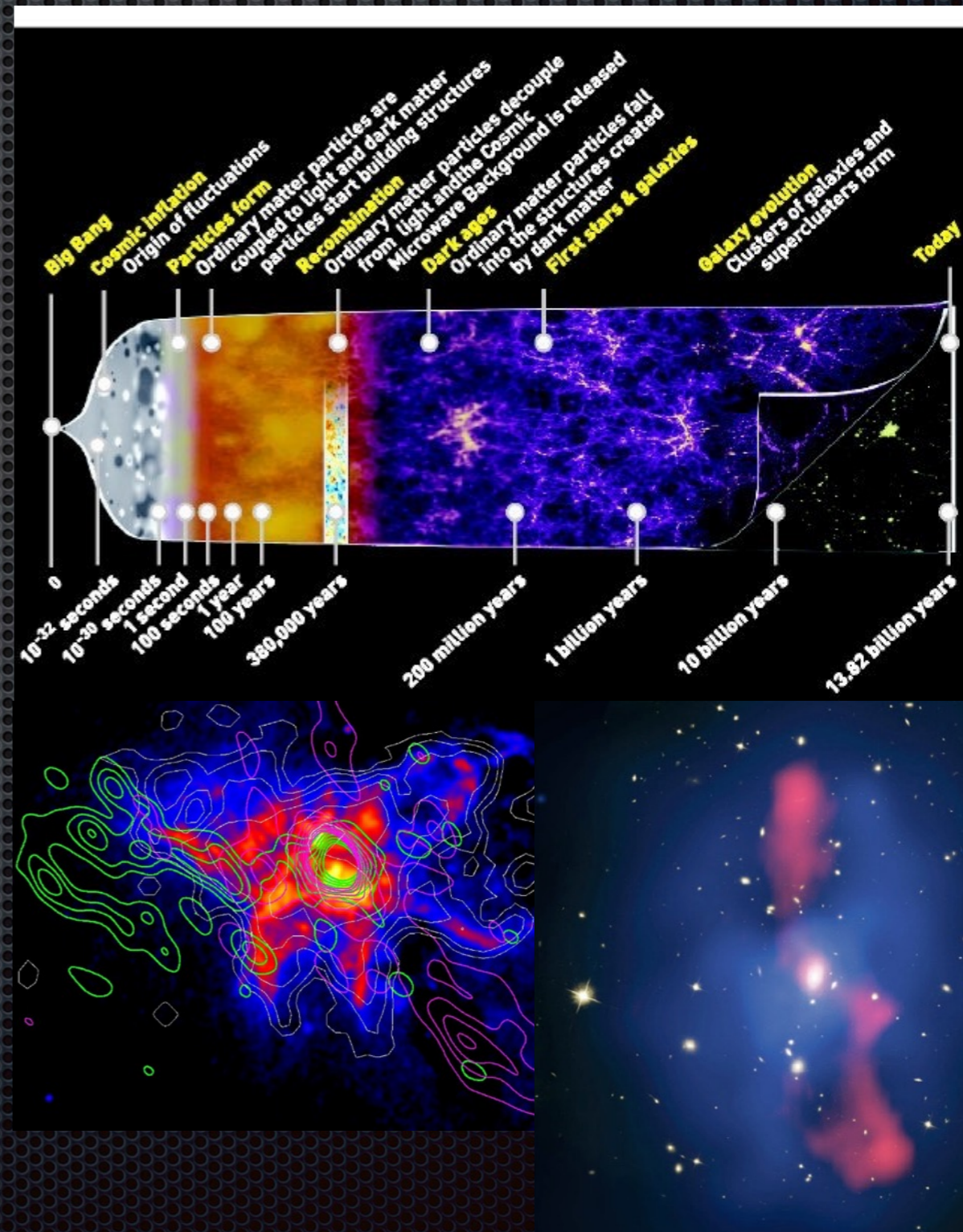
Formation of first structures & the role of feedback

- **The first accreting BHs & EoR**
—> **JWST!**, ALMA, Euclid, ELTs, SKA, Athena
- **The first groups & clusters**
—> Herschel/Planck, ALMA, JVLA, SKA, Athena



Formation of first structures & the role of feedback

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- **Feedback through the cosmic time**
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The first accreting BHs & the EoR

Two key questions (e.g. Comastri talk):

- ✦ *Which are the seeds of super-massive black holes?*

- ✦ PopIII stars BHs ($\sim 100 M_{\text{Sun}}$) + super-Edd. growth

- ✦ Direct Collapse BHs ($\sim 10^5 M_{\text{Sun}}$)

- ✦ *Do accreting BHs play a major role for the Reionization?*

More luminous but rarer than galaxies:

- ✦ Patchy reionization (as suggested by large scale opacity fluctuations in the Ly α forest, Chardin+ 2016)

- ✦ Patchy IGM heating (affects the spatial structure of the 21cm signal)

Search for high- z accreting BHs

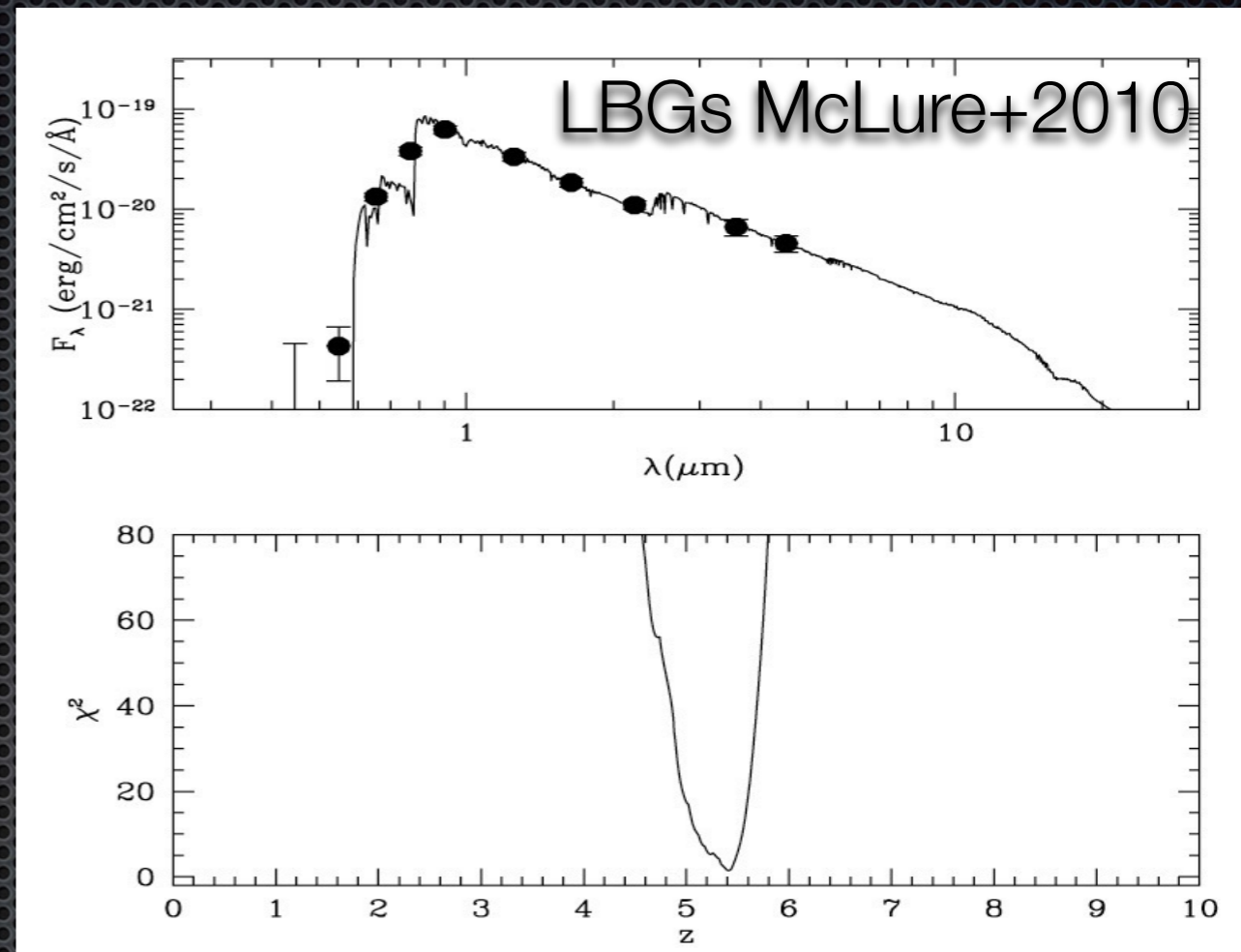
- Chandra can detect sources **a few 10^{43} erg/s at $z=6-7$** in a Msec observations
 - Seyfert type AGN at $z=6-7$
 - Eddington limited $10^5 M_{\text{Sun}}$ BH (DCBHs candidates)
- **But few candidates proposed so far. Why?**
 - Intrinsic paucity of high- z , accreting BHs (e.g. Schawinski talk)
 - Obscuration (e.g. Comastri talk)
 - Redshift determination

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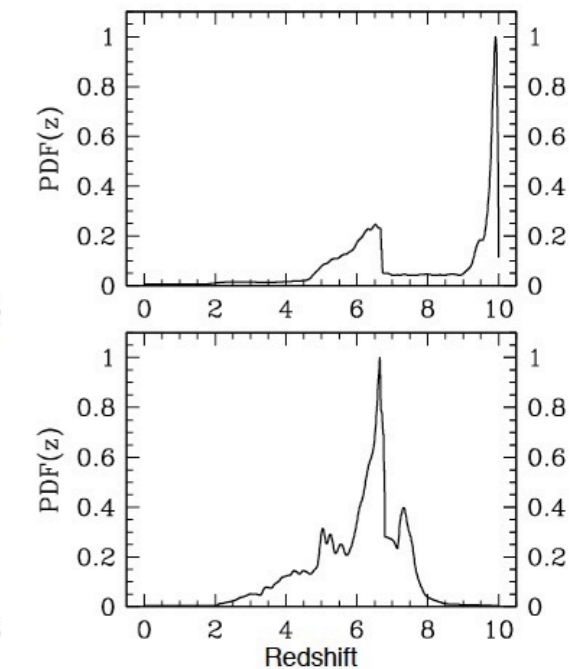
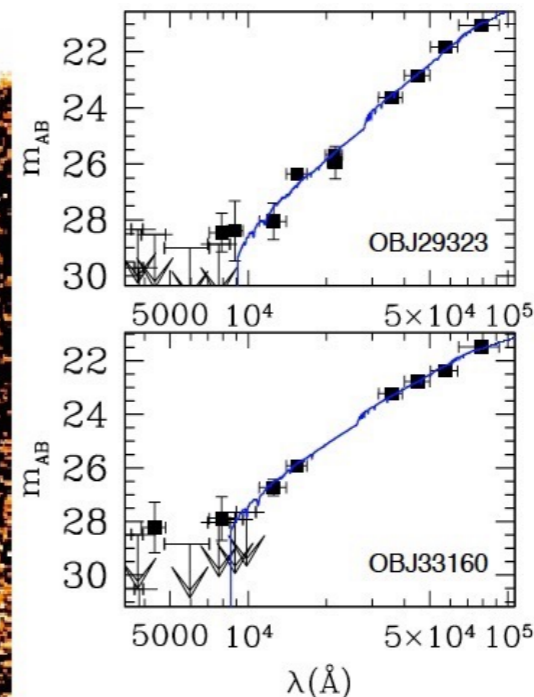
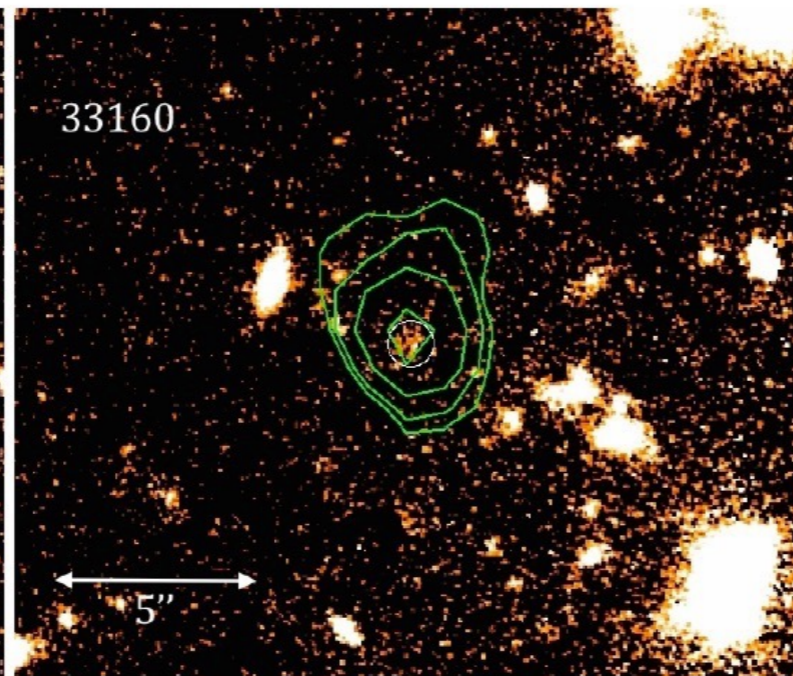
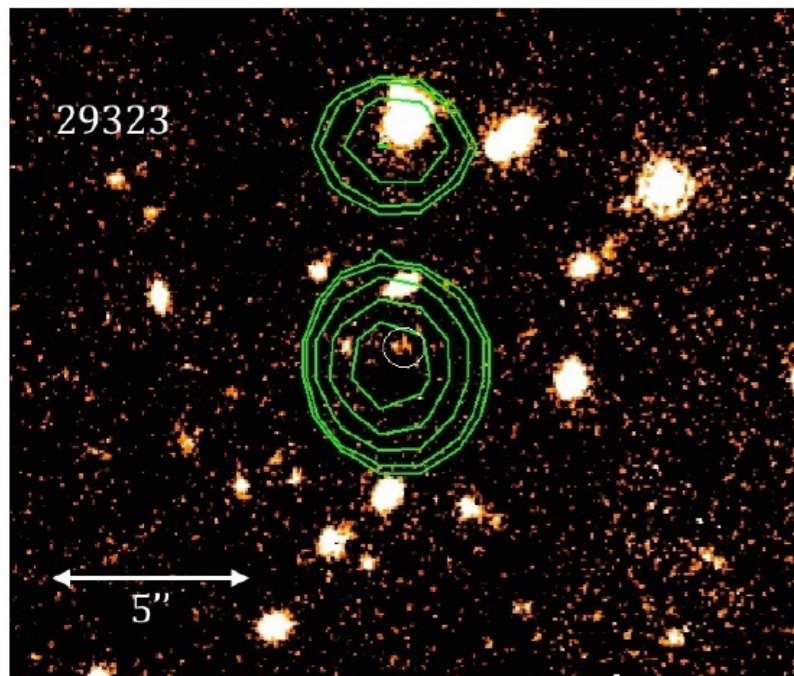
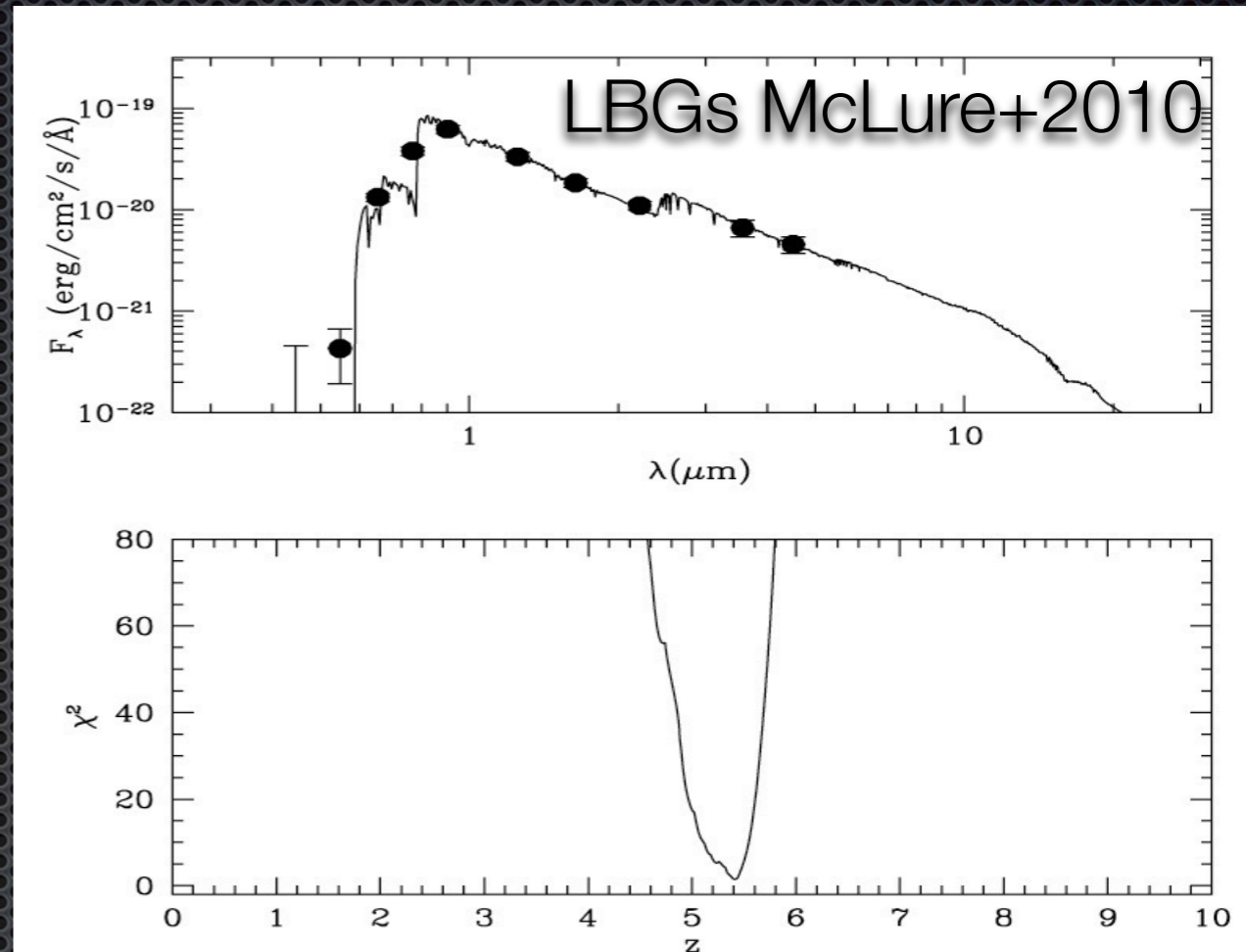
High- z accreting BHs redshift determination

Most $z > 6$ galaxies with reliable z_{phot} are LBG or LAE.
Fraction of X-ray AGN in LBG & LAE is small, $\sim 1\%$.



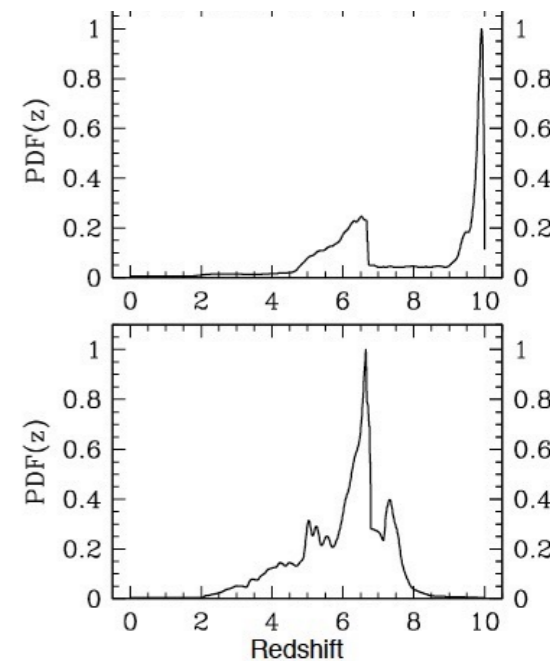
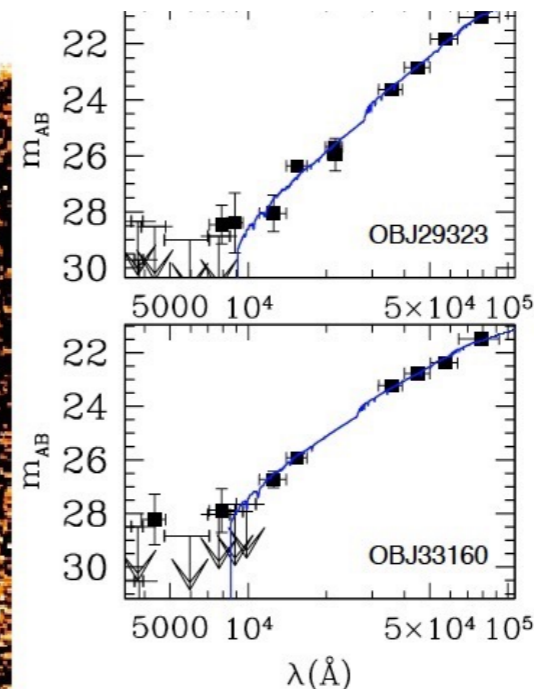
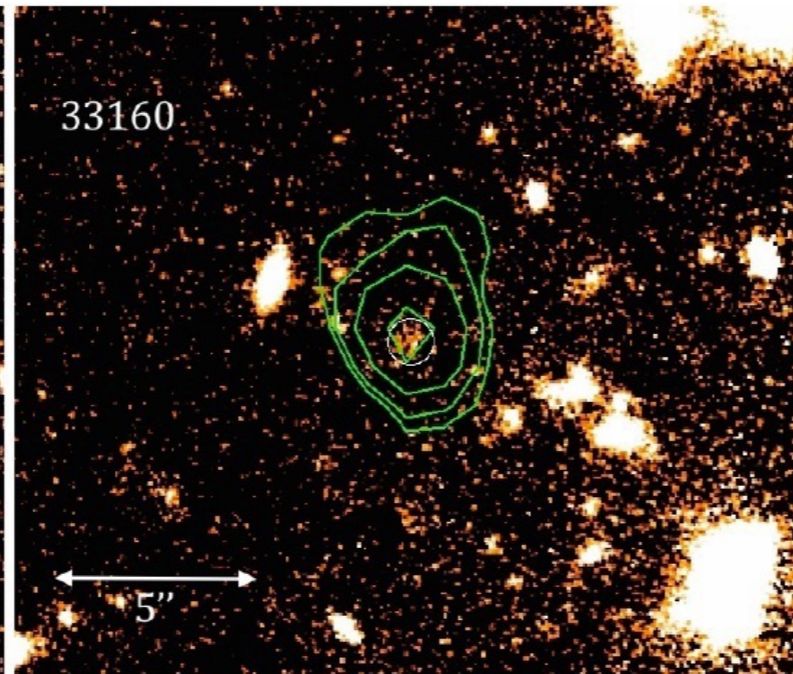
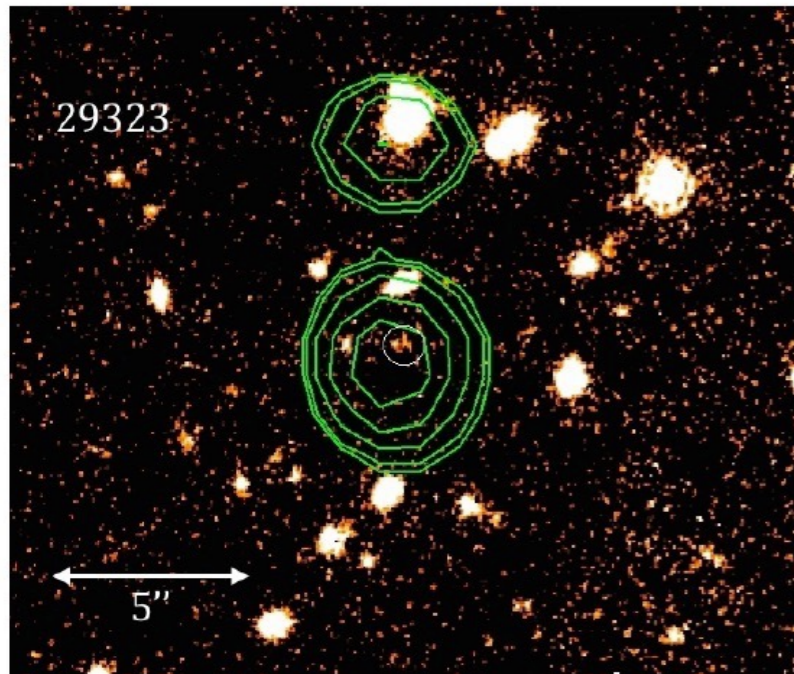
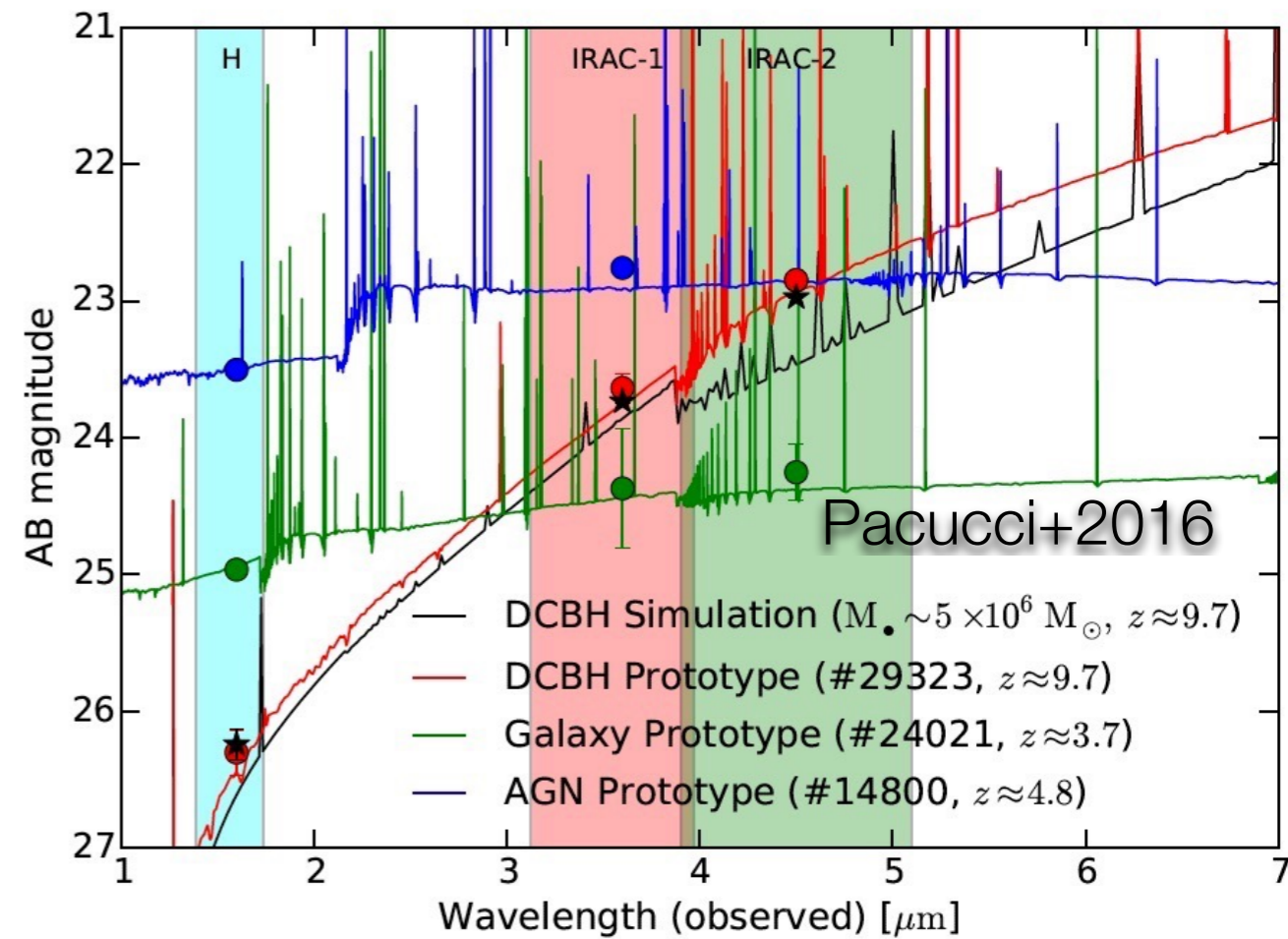
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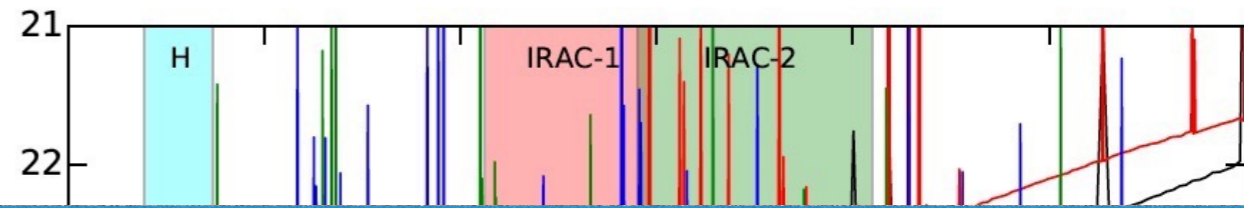


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High-z accreting BHs redshift determination

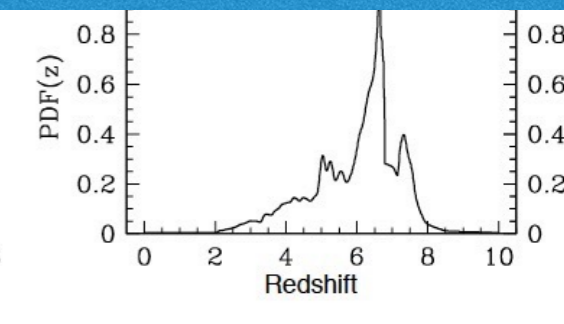
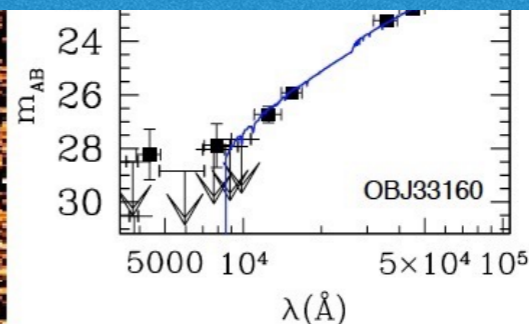
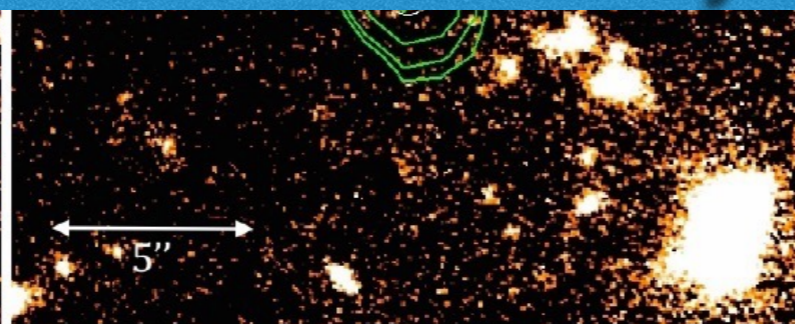


High quality NIR photometry/spectroscopy is mandatory

- Today spectroscopy with 8m class telescopes is insufficient
- Spitzer photometry is limited by both sensitivity and confusion

JWST will provide the needed breakthrough

Target with Chandra Msec observations fields that will be observed by JWST



The first groups & clusters

When did galaxy groups and clusters form and how they evolved?

X-rays *uniquely* probe the relative importance of *gravitational* and *non-gravitational* heating

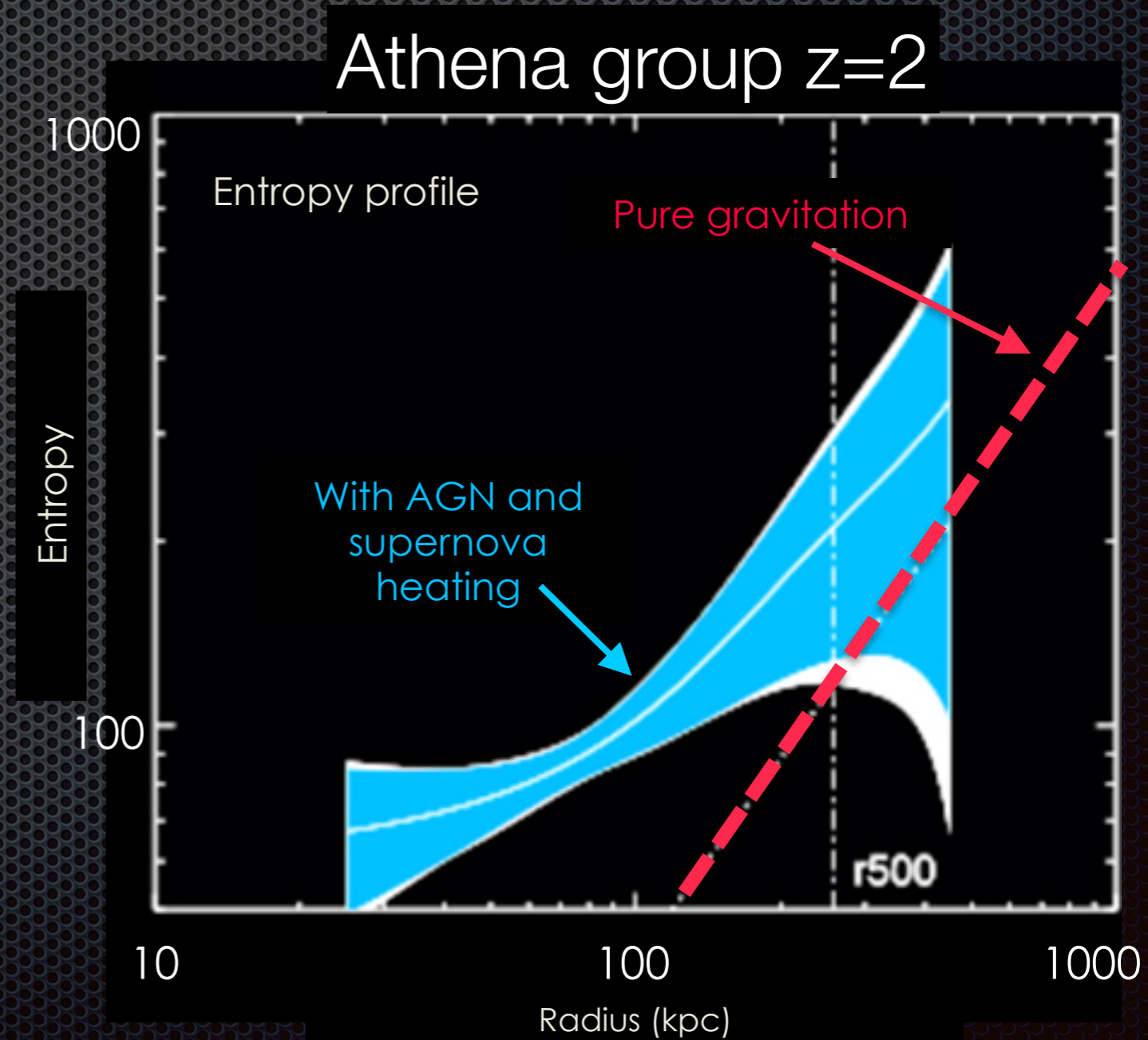
- Measure thermodynamics
- AGN feedback

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Blind search requires large areas covered with sensitive observations: big survey speed. Difficult with Chandra

More efficient targeting candidate protoclusters:

- Radio selection
- FIR selection
- X-ray (XMM, eRosita)

Radio selection

MRC1138-262

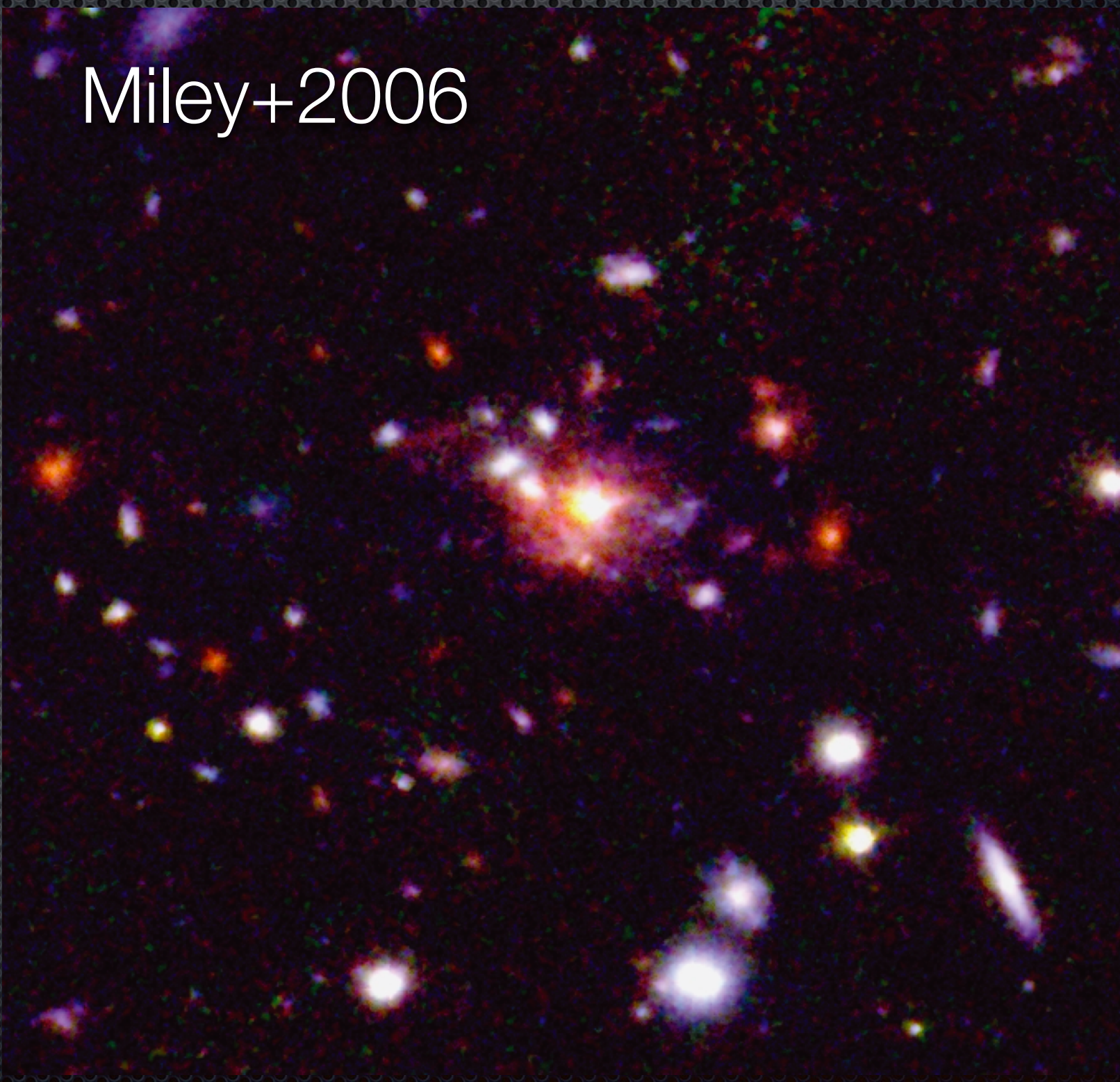
the Spiderweb galaxy

$z \sim 2$

Complex dynamics of
galaxies merging into the
FR-II radio galaxy

$\text{SFR} > 300 M_{\text{sun}}/\text{yr}$

Miley+2006



Radio selection

MRC1138-262

the Spiderweb galaxy

$z \sim 2$

Complex dynamics of
galaxies merging into the
FR-II radio galaxy

$\text{SFR} > 300 M_{\text{Sun}}/\text{yr}$

$M_{200}(z=0) = 1.5 \cdot 10^{15} M_{\text{Sun}}$

AGN

$L_{0.5-2} = 1.4 \cdot 10^{44} \text{ erg/s}$

$T_x = 3.8 \text{ keV}$

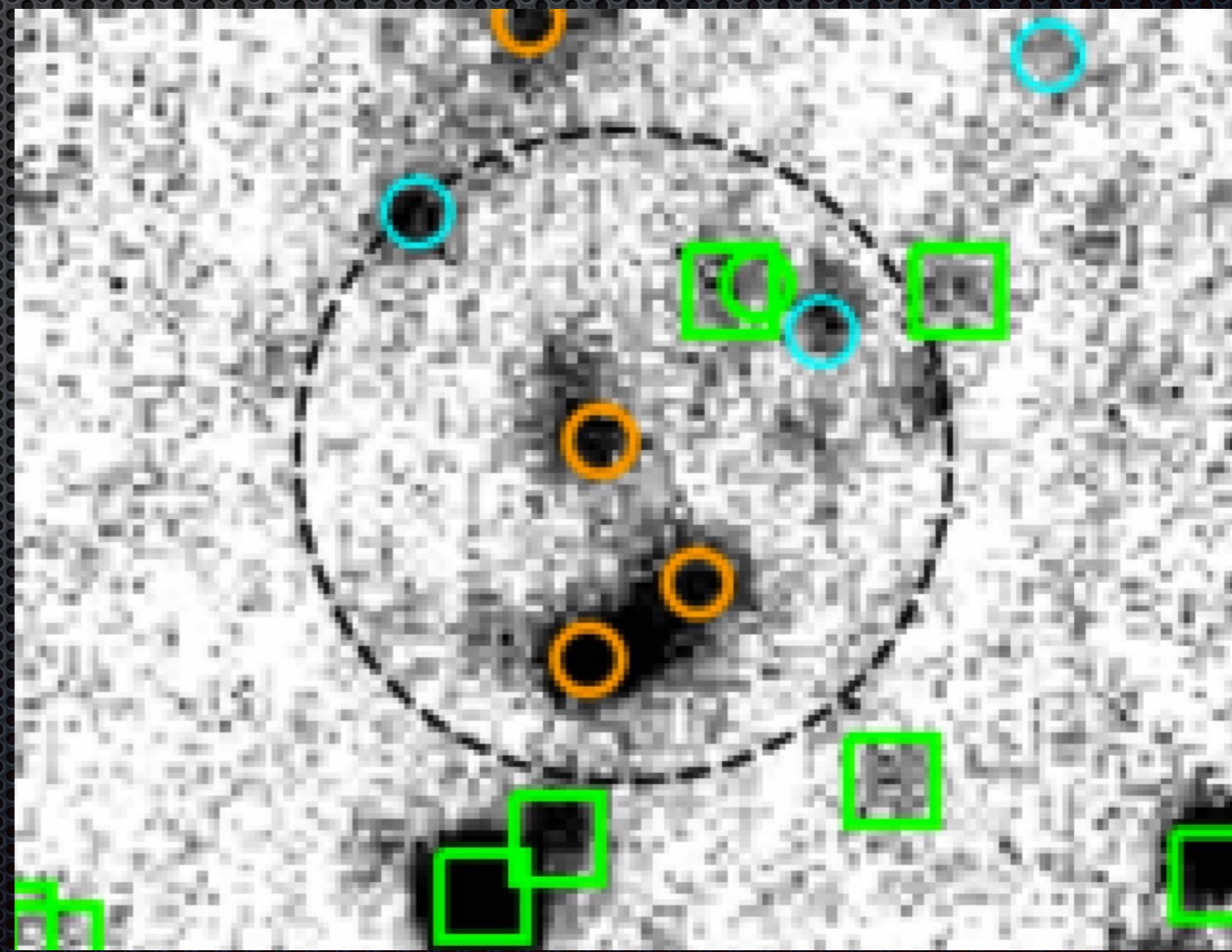
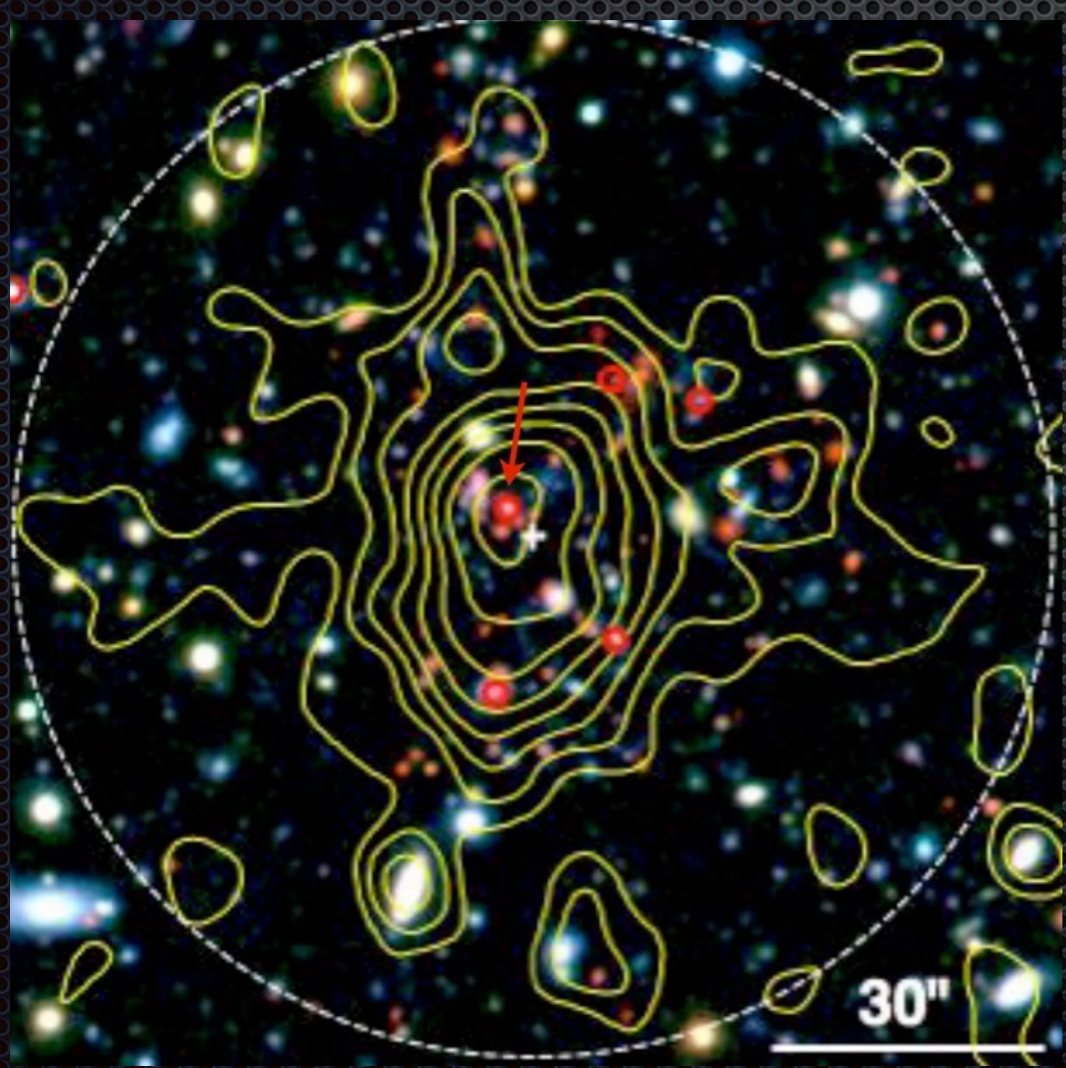
$Z_{\text{Fe}} = 0.57 Z_{\text{Sun}}$

Saro+2008 gas density



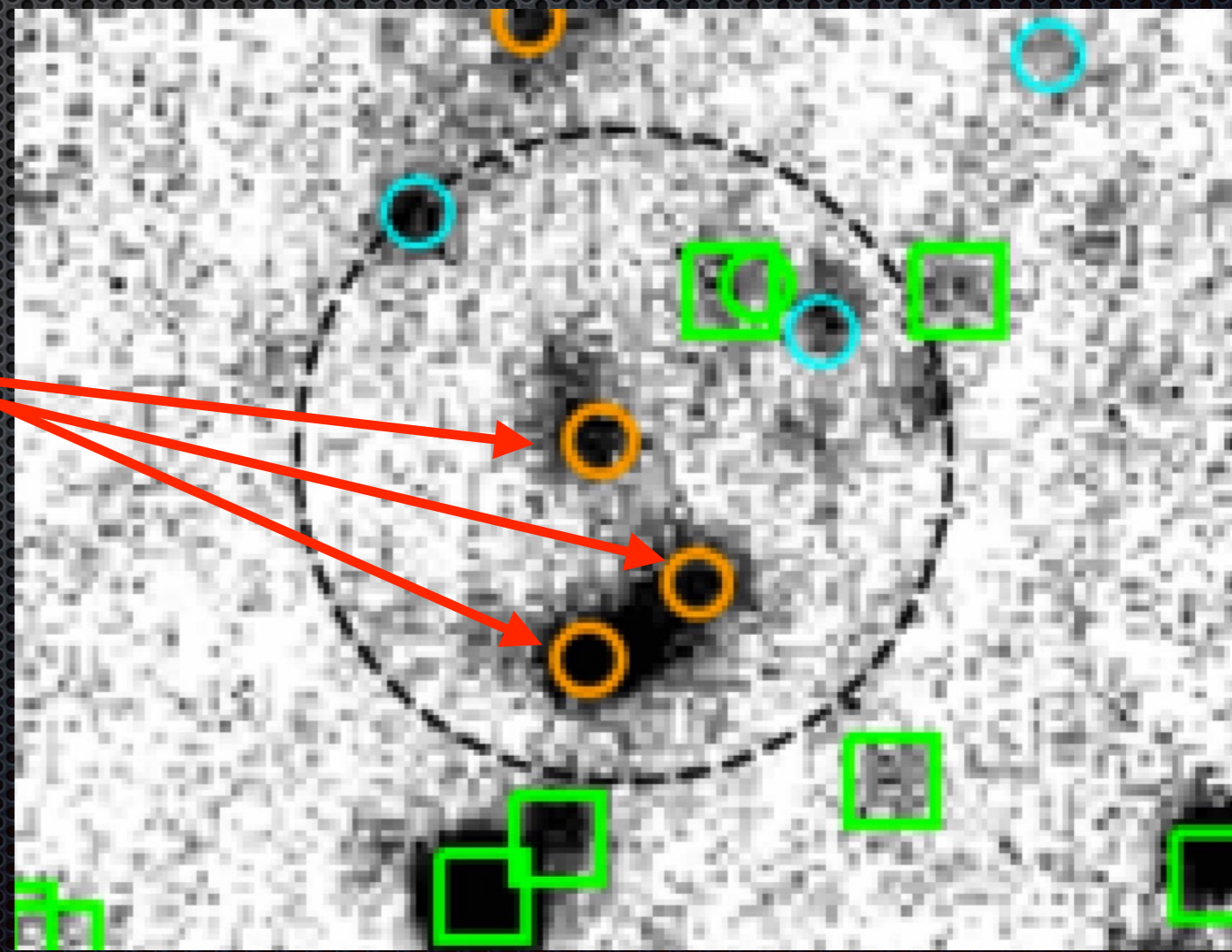
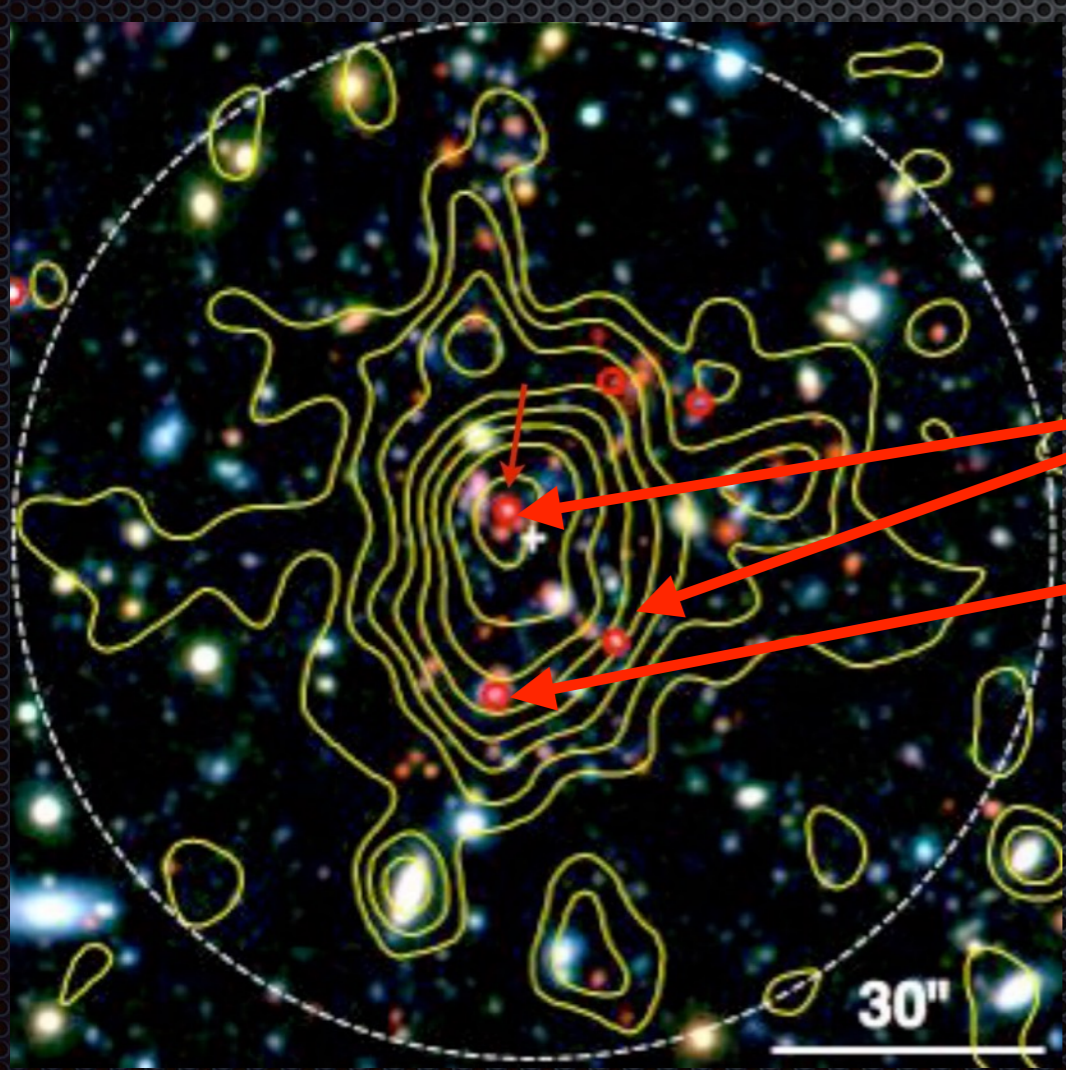
XDCPJ0044.0-2033 $z=1.58$

- $R_{500} \sim 0.5 \text{ Mpc}$
 - virial mass $M_{500} \sim 3 \times 10^{14} M_{\text{Sun}}$
 - $\text{SFR}(\text{core}) \sim 1500\text{-}2000 M_{\text{Sun}}/\text{yr}$ higher than in outskirts:
reversal of the SF-density relation at $z=1.6$
- PACS 100 μm



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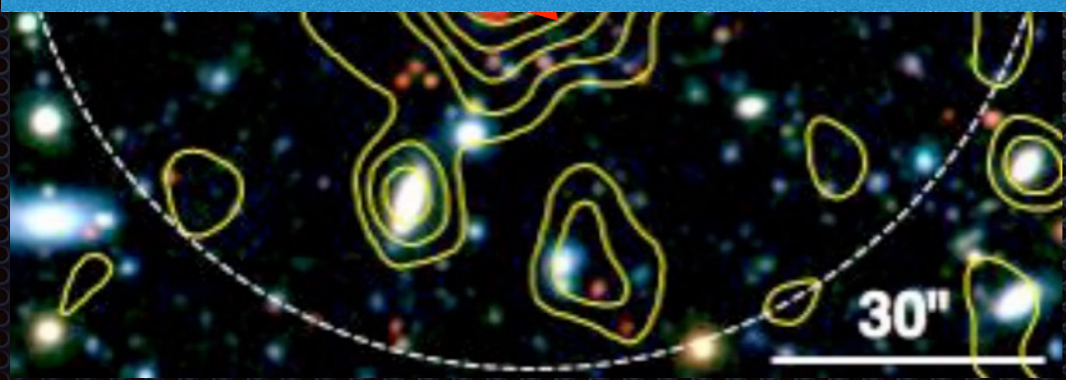
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Target with deep Chandra pointings **Radio, FIR, X-ray selected protoclusters $z > 2$**

- Gas thermodynamics
- Search for X-ray point sources: AGN

Follow-up AGN at **NIR/mm/radio** wavelengths to search for *winds and jets*



Feedback through the cosmic times

Feedback: *galaxy growth hormone*

“regulates and modulates galaxy and BH growth”

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Feedback through the cosmic times

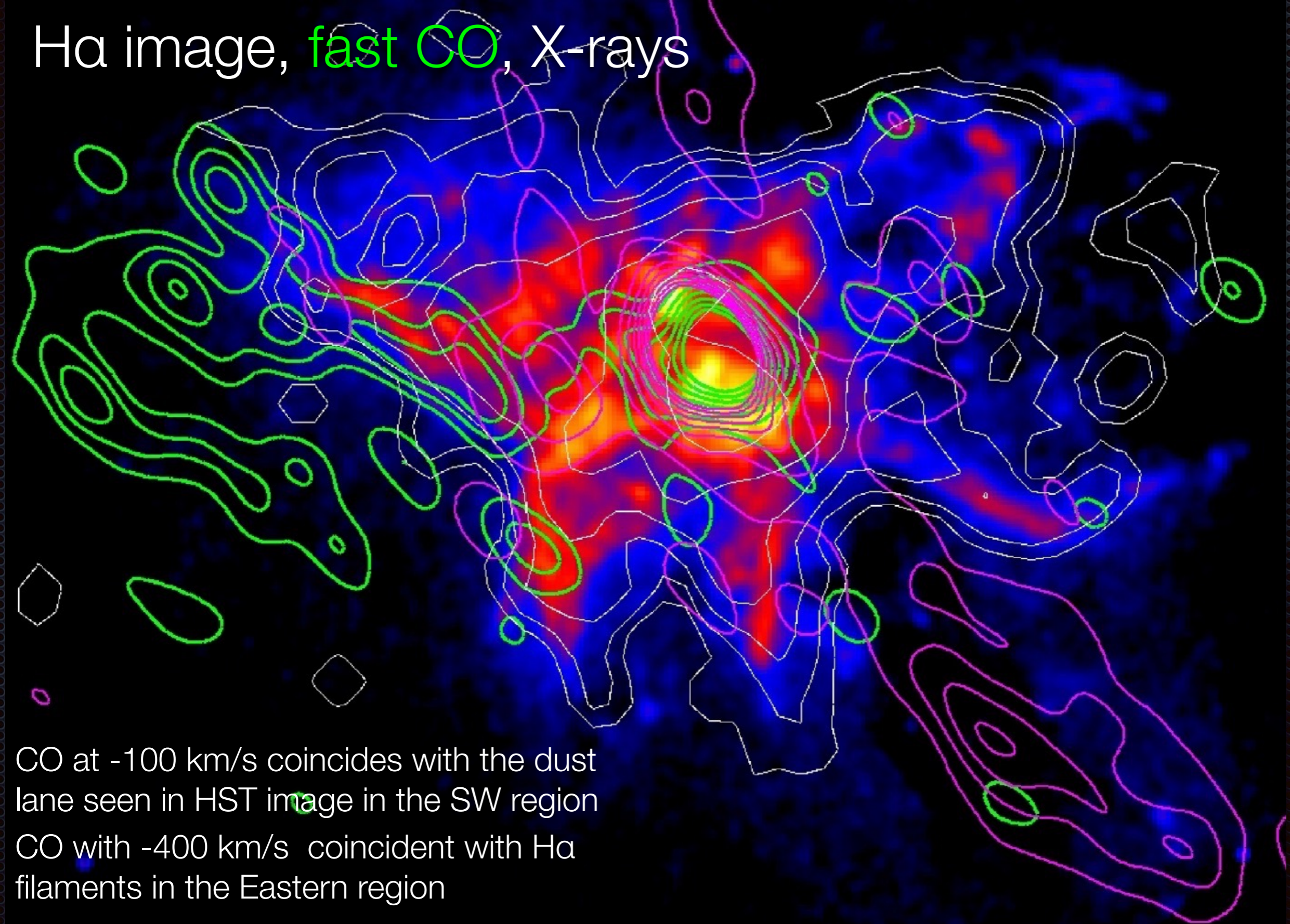
Feedback: *galaxy growth hormone*

“regulates and modulates galaxy and BH growth”

- ✦ EoR
- ✦ Peak of AGN/galaxy evolution, formation of first clusters
- ✦ **Local Universe**
 - UFOs: nuclear winds
 - **Shocks**: how outflows propagate on galaxy scales (e.g. Maksym, Fabbiano talks) or ICM (e.g. Randall talk)
 - **Extended hot/warm haloes & CGM**: the fate of outflowing gas

The case of NGC 6240

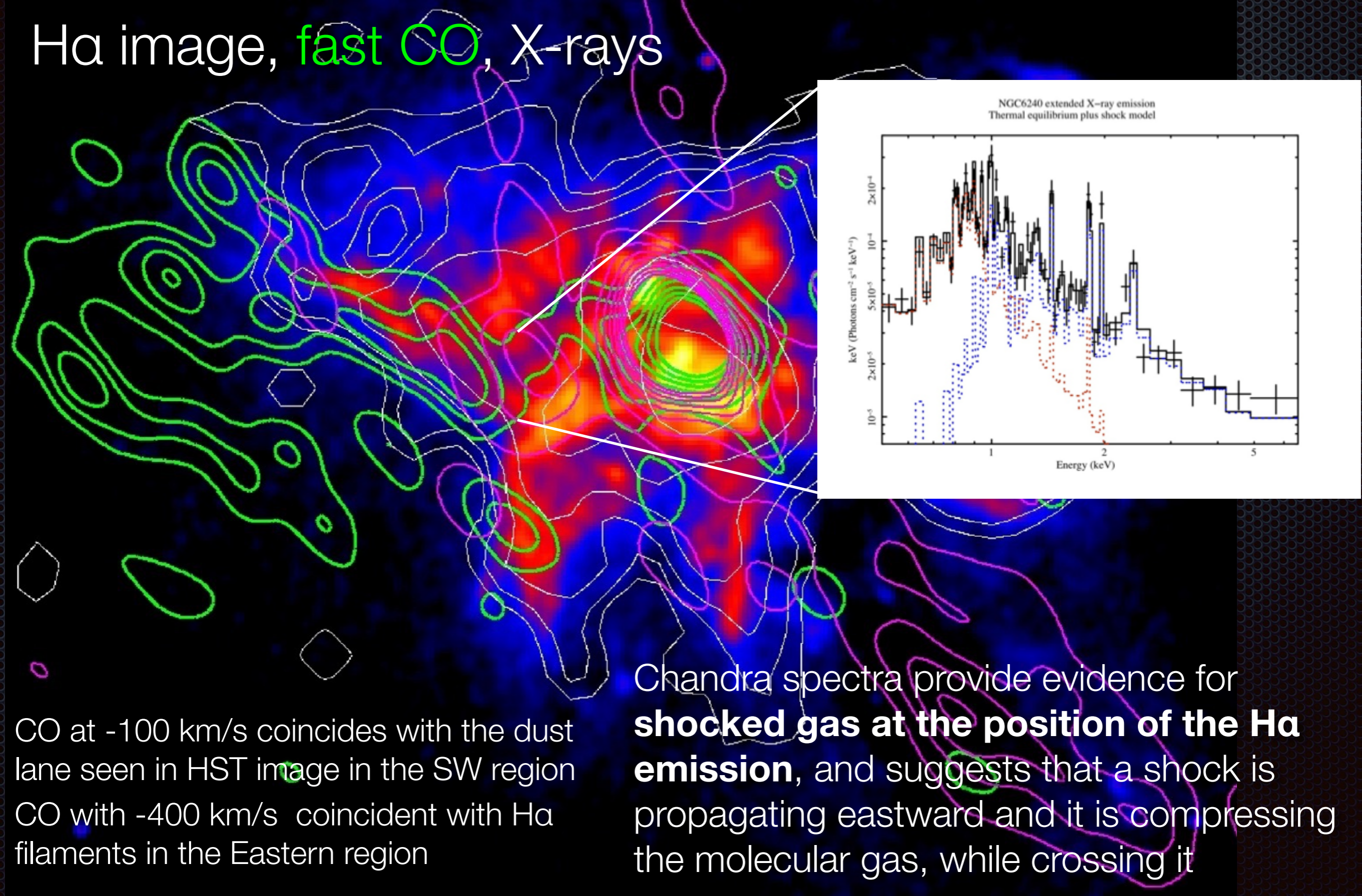
H α image, **fast CO**, X-rays



CO at -100 km/s coincides with the dust lane seen in HST image in the SW region
CO with -400 km/s coincident with H α filaments in the Eastern region

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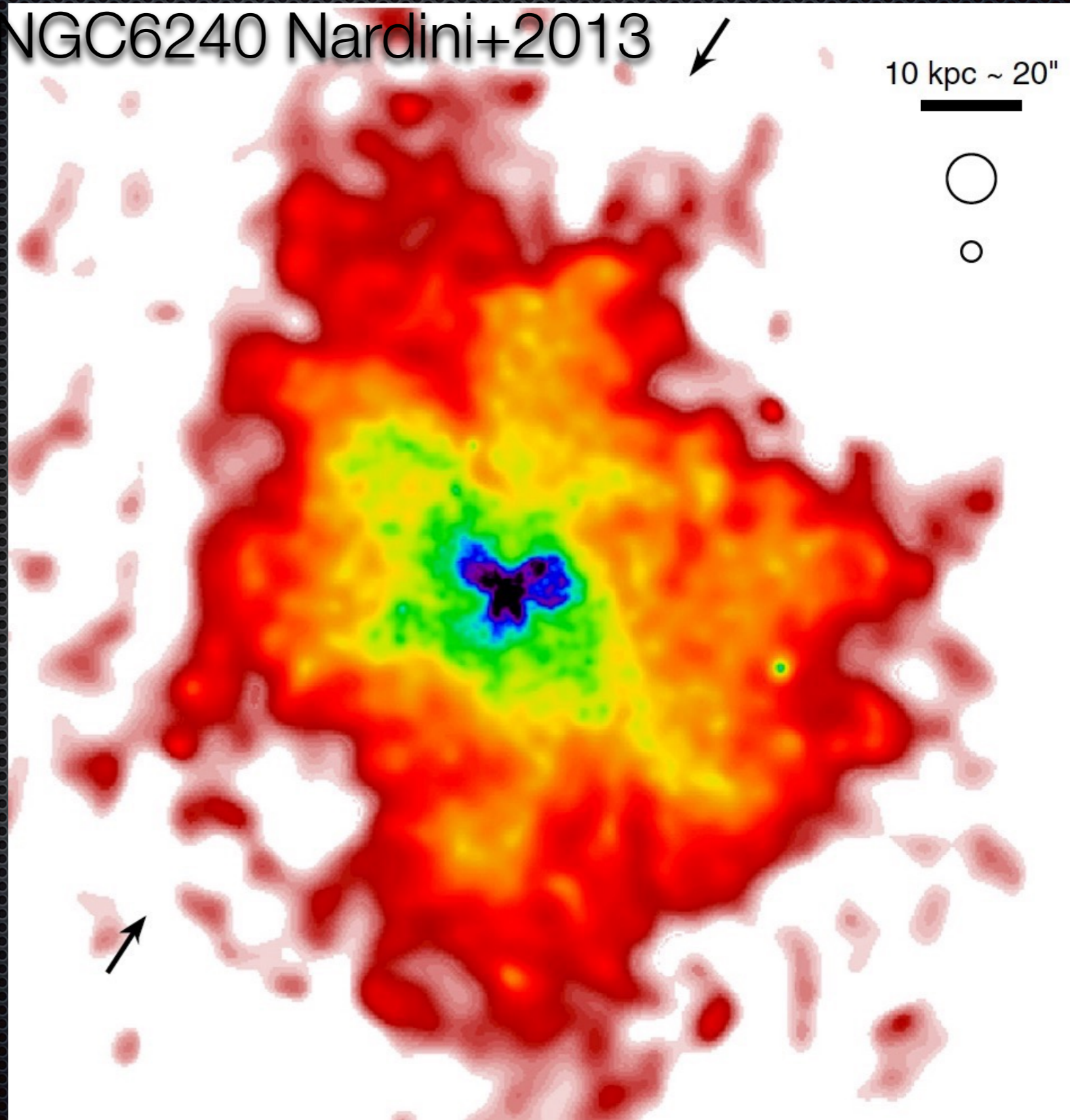
Chandra spectra provide evidence for **shocked gas at the position of the H α emission**, and suggests that a shock is propagating eastward and it is compressing the molecular gas, while crossing it

Warm/hot haloes & CGM

The fate of
outflowing gas:
energy, entropy, and
metal transport into
the CGM

NGC6240 Nardini+2013 ↙

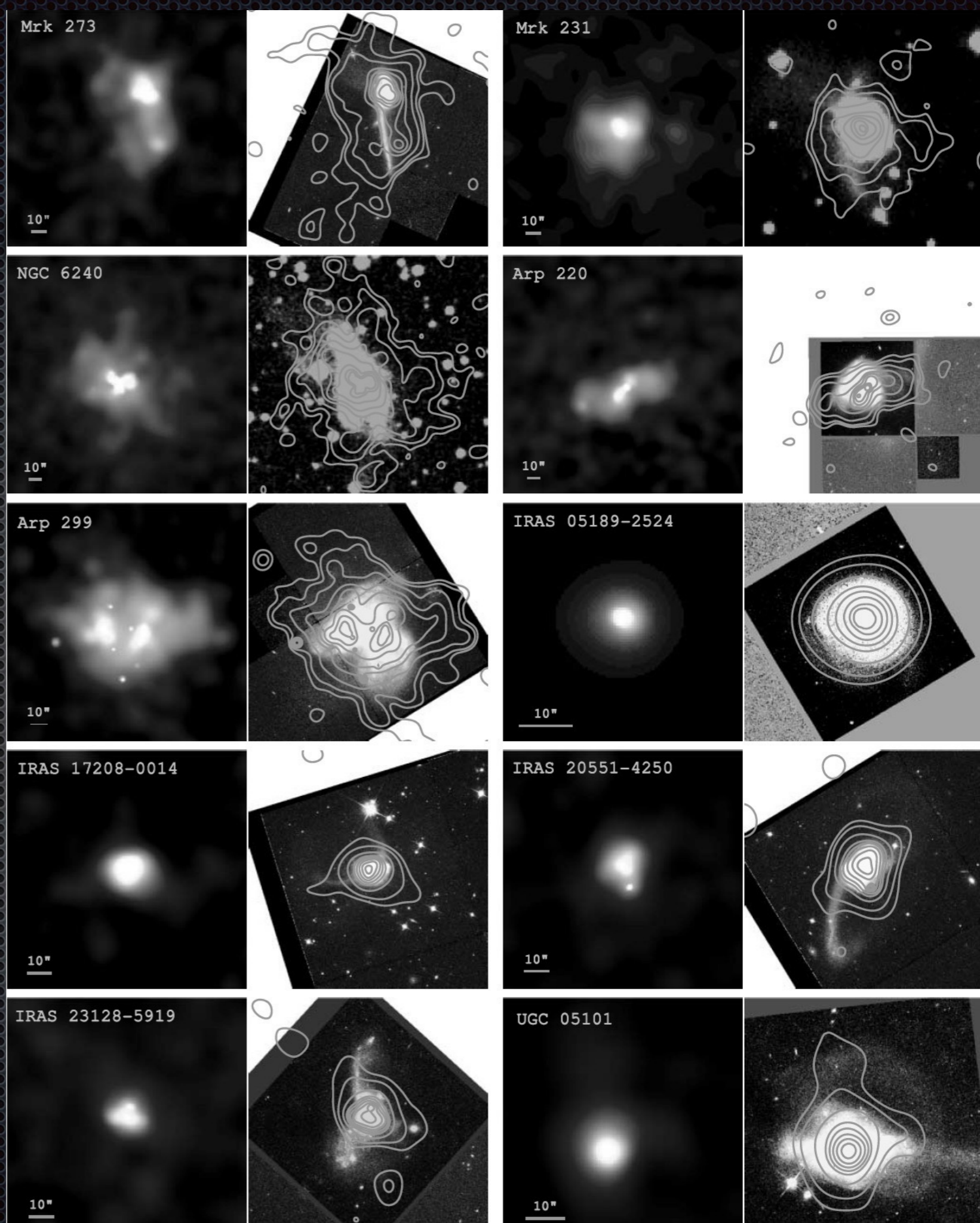
10 kpc ~ 20"



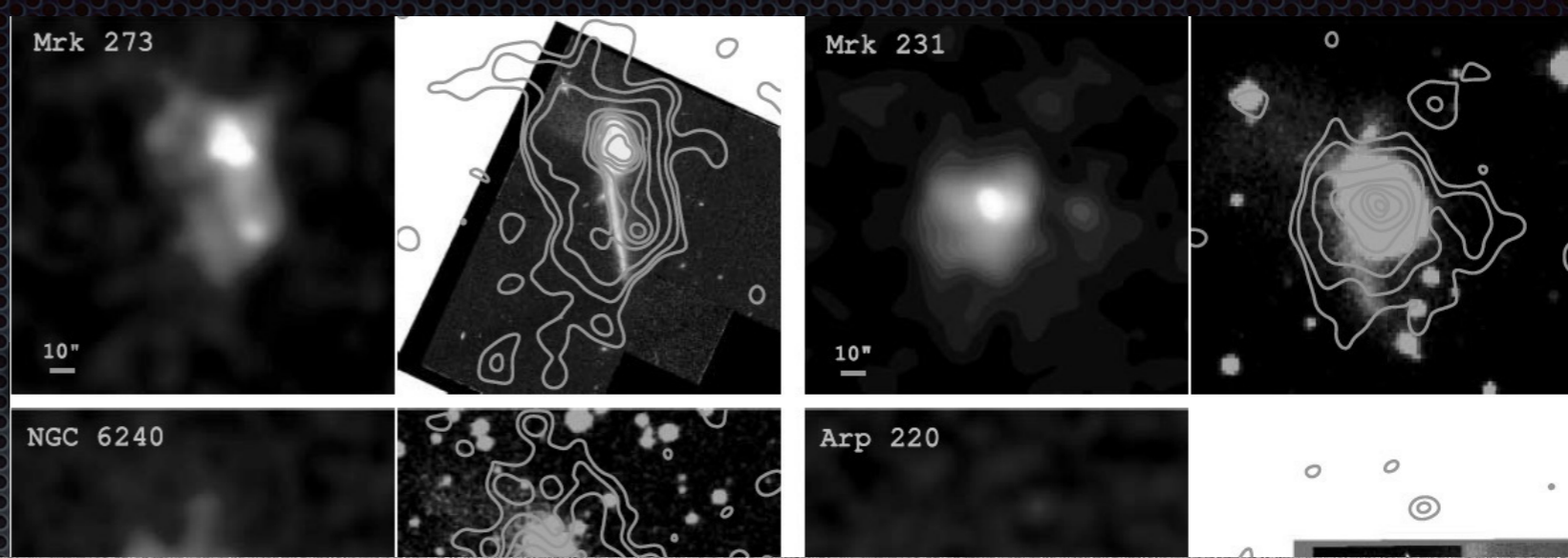
Warm/hot haloes & CGM

The fate of outflowing gas: energy, entropy, and metal transport into the CGM

Most AGN studied so far hosted in ULIRGs
Hue+ 2004



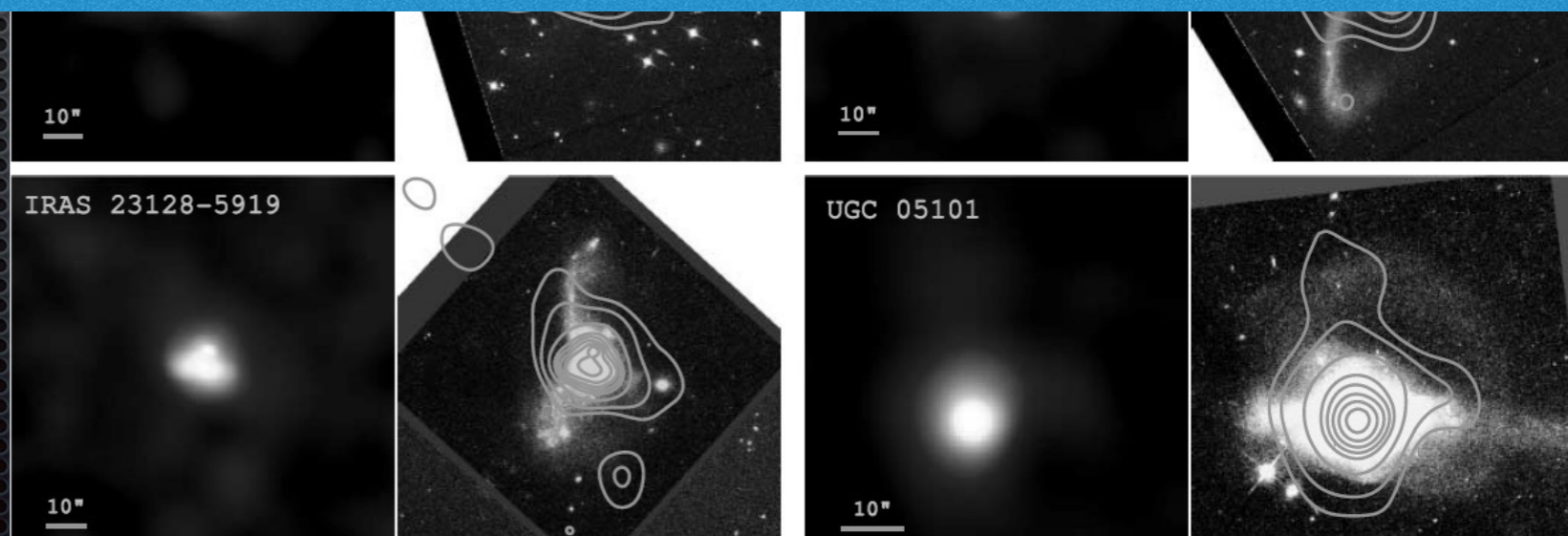
Warm/hot haloes & CGM



Complete survey of shocks and haloes in local AGN
(unbiased samples)

Push the search for shocks and haloes up to $z=1-2$

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Formation of first structures & the role of feedback

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- Exploit synergies
 - Today: ALMA, JVLA, LOFAR, 8m tel., XMM, etc
 - Tomorrow: JWST, eRosita
 - After tomorrow: LSST, Euclid, SKA, ELTs, Athena
- Msec programs require XVP or **multi-cycle LP** (see ESO, HST)

