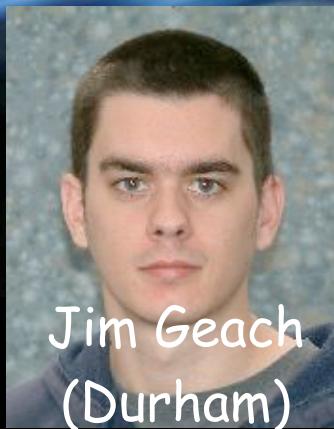


Evidence for Large-Scale Energetic Outflows from Distant Radio-Quiet AGNs

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Jim Geach
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Bret Lehmer
(Durham)



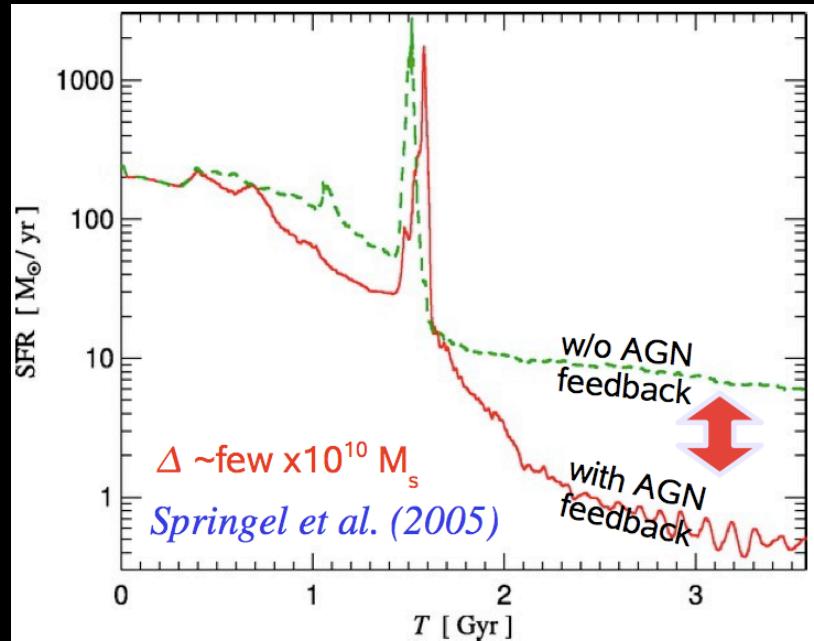
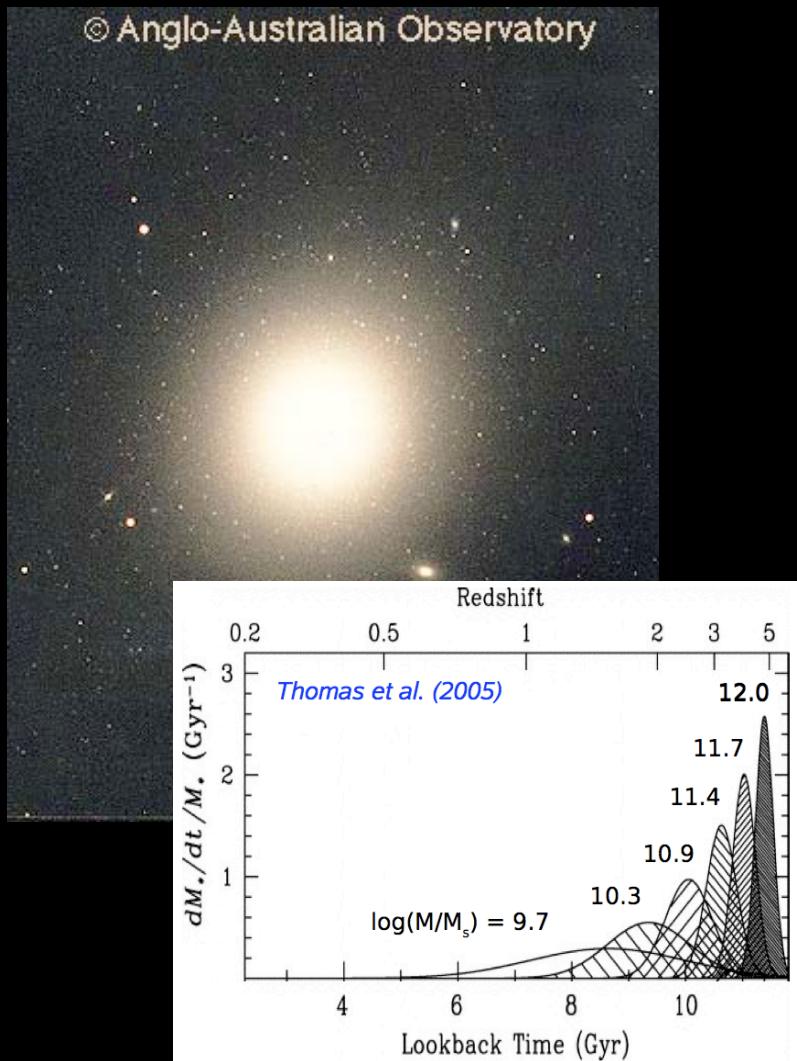
Ian Smail
(Durham)



M Swinbank
(Durham)

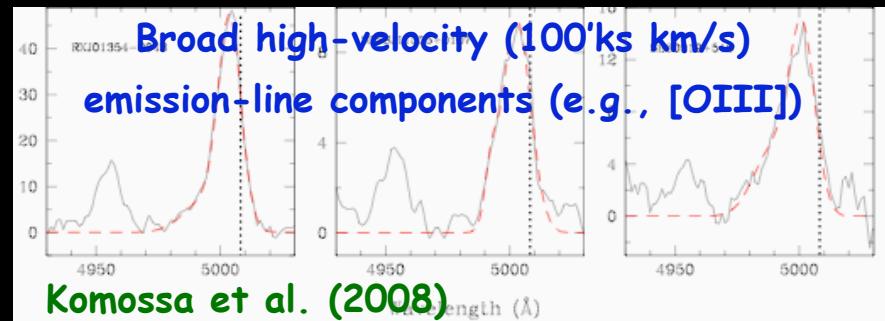
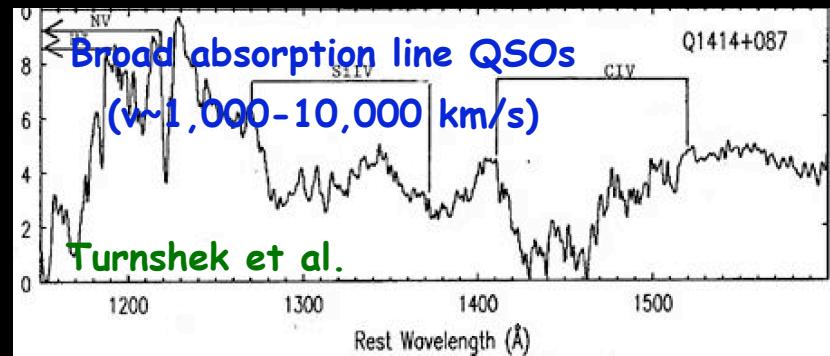
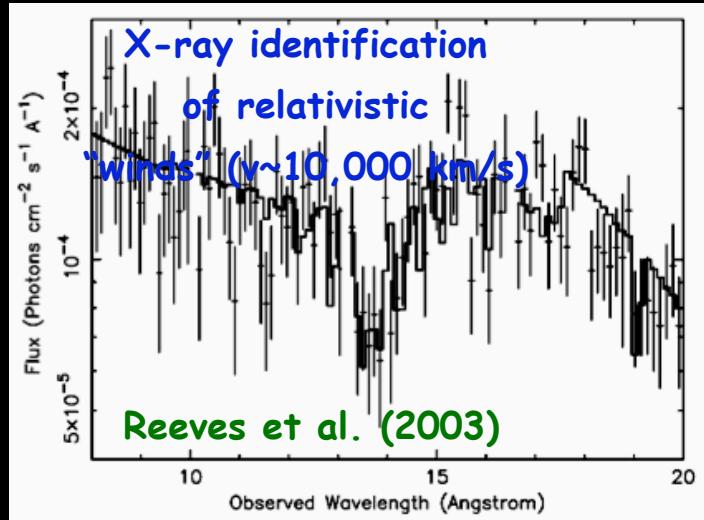
Also Ana Basu-Zych, Andrew Blain, Richard Bower, Franz Bauer, Niel Brandt,
Scott Chapman, Richard McDermid, Yuichi Matsuda, Karin Menendez-
Delmestre, Nicole Nesvadba, Caleb Scharf, Marta Volonteri, Toru Yamada

Cosmological importance of outflows/feedback

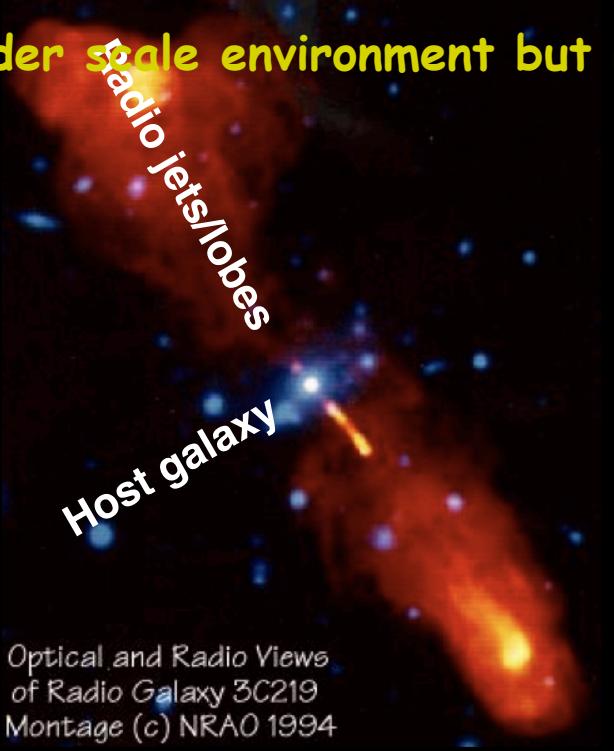


AGN outflows: a lever arm for black hole/AGN to “orchestrate” star-formation (e.g., Springel et al. 2005; Bower et al. 2006;

Evidence for AGN outflows



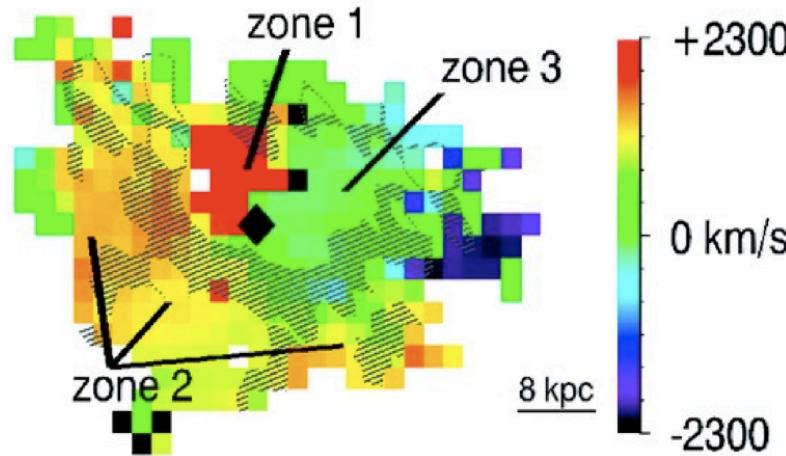
Radio-loud AGN: interaction with wider scale environment but rare



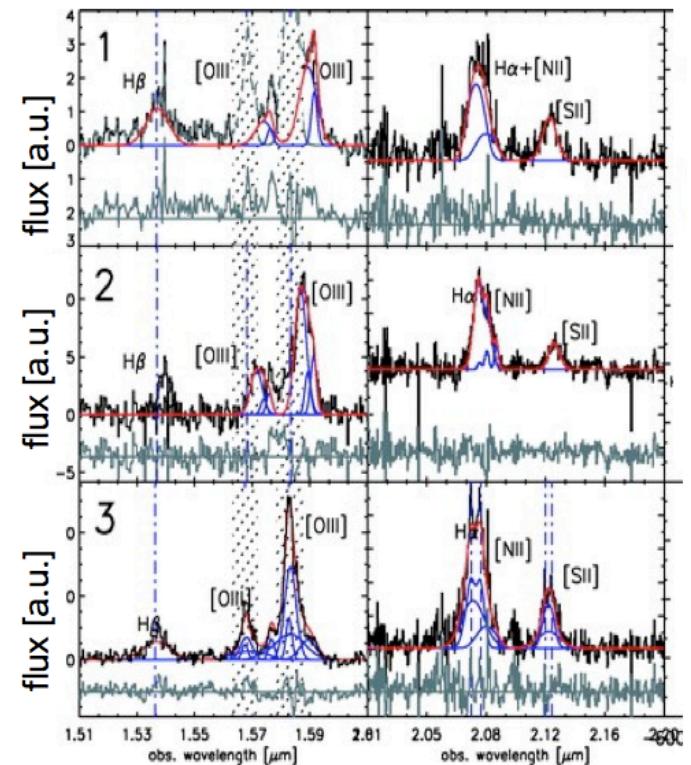
Need to determine if gaseous outflows can occur over large galactic scales... importantly, are they ubiquitous at high redshift, when they should be effective?

IFU observations: identification of large-scale gaseous outflows in distant radio galaxies

PKS1138-262: $z=2.16$ radio-loud AGN



Nesvadba et al. (2006, 2007, 2008)



Extended, high velocity, broad [OIII]: signature of an AGN outflow

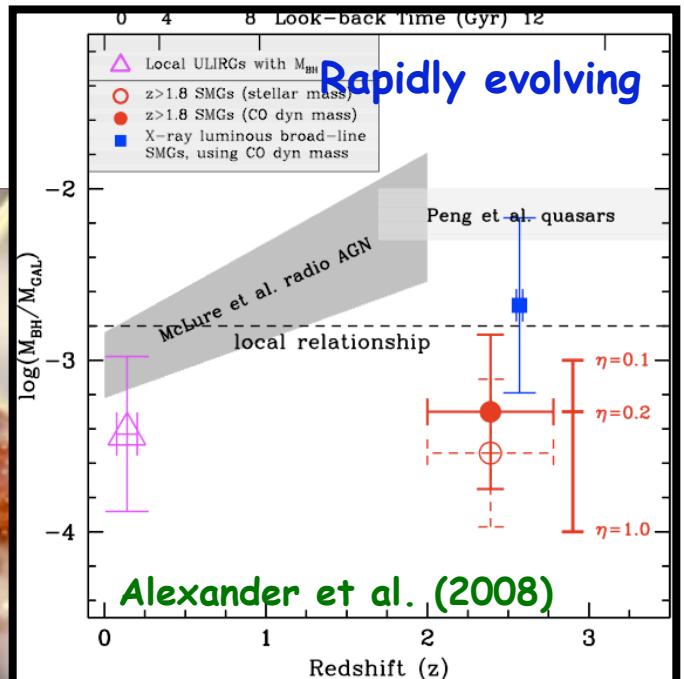
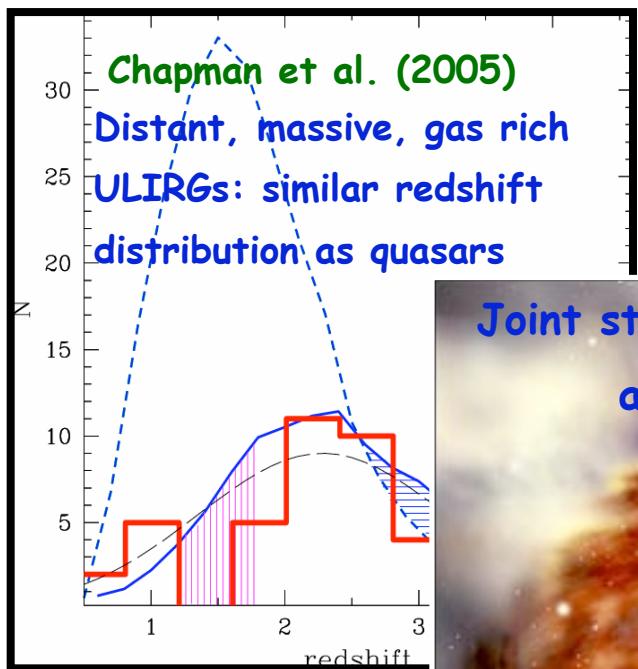
Large-scale outflows common in $z>2$ radio galaxies

Nesvadba et al. (2006, 2007, 2008) have identified kinematically complex [OIII] emission on kpc scales in 6 $z>2$ radio-loud AGNs:

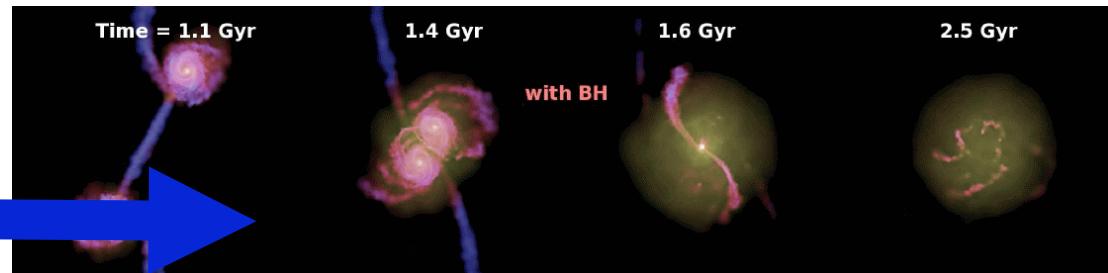
- [OIII] velocities \sim 200-2000 km/s; FWHM \sim 600-3000 km/s; extent \sim 2-20 kpc
- Kinetic energy injection to produce [OIII] features of order \sim 10⁴³-10⁴⁶ erg/s, corresponding to (of order) \sim 10⁵⁸-10⁶¹ erg over 10⁷ yr lifetime: potentially sufficient to unbind gas from the host galaxy
- [OIII] emission within extent of radio emission: gas quiescent beyond
- Argued that radio emission can account for the outflow, although radiatively driven wind from the accretion disk

However, could also potentially drive the outflow and the identification of large-scale outflows in more typical radio-quiet AGNs would make strongest case for feedback being ubiquitous in the distant Universe

Good candidates for hosting energetic outflows: z~2 submillimeter-emitting galaxies



Rapid build up of todays
massive ellipticals...
evidence for outflows?



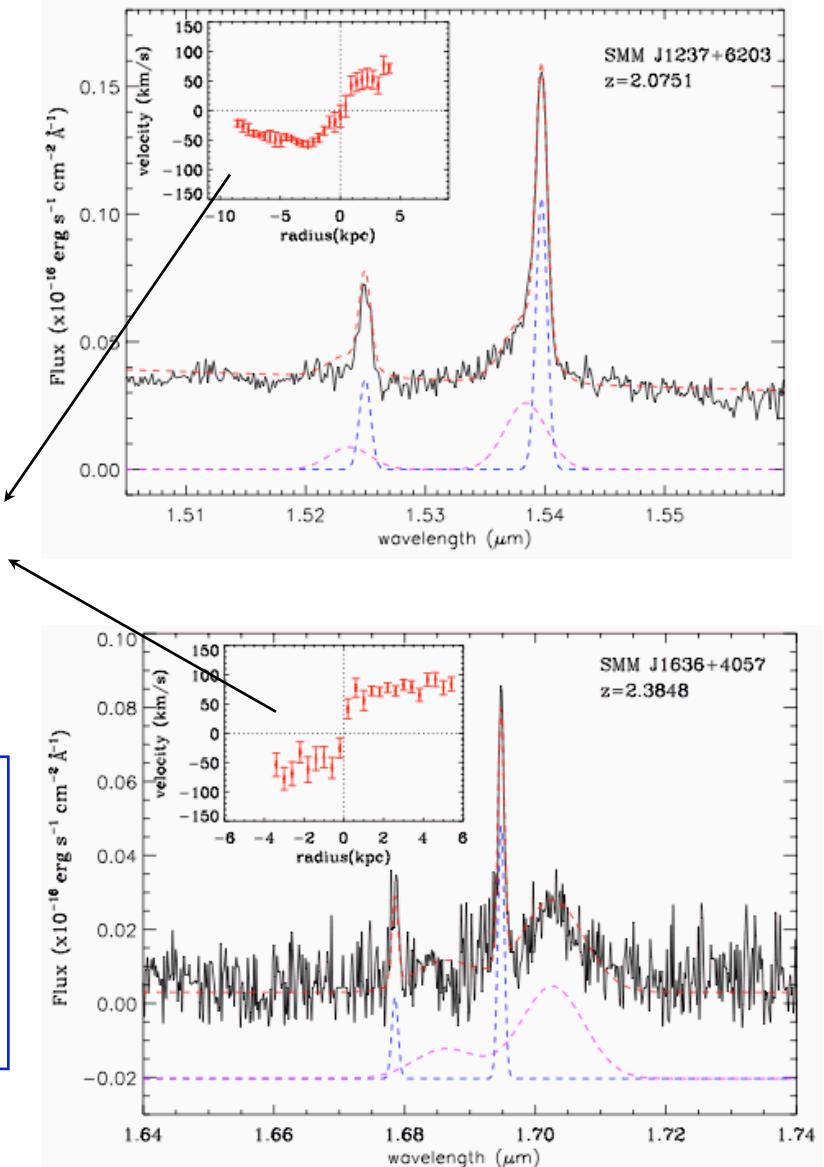
Gemini NIFS observations of [OIII]-bright SMGs

Selected targets: comparable [OIII] luminosities to distant radio-loud AGNs... but ~3 orders of magnitude lower radio luminosities

Narrow [OIII] velocity field components

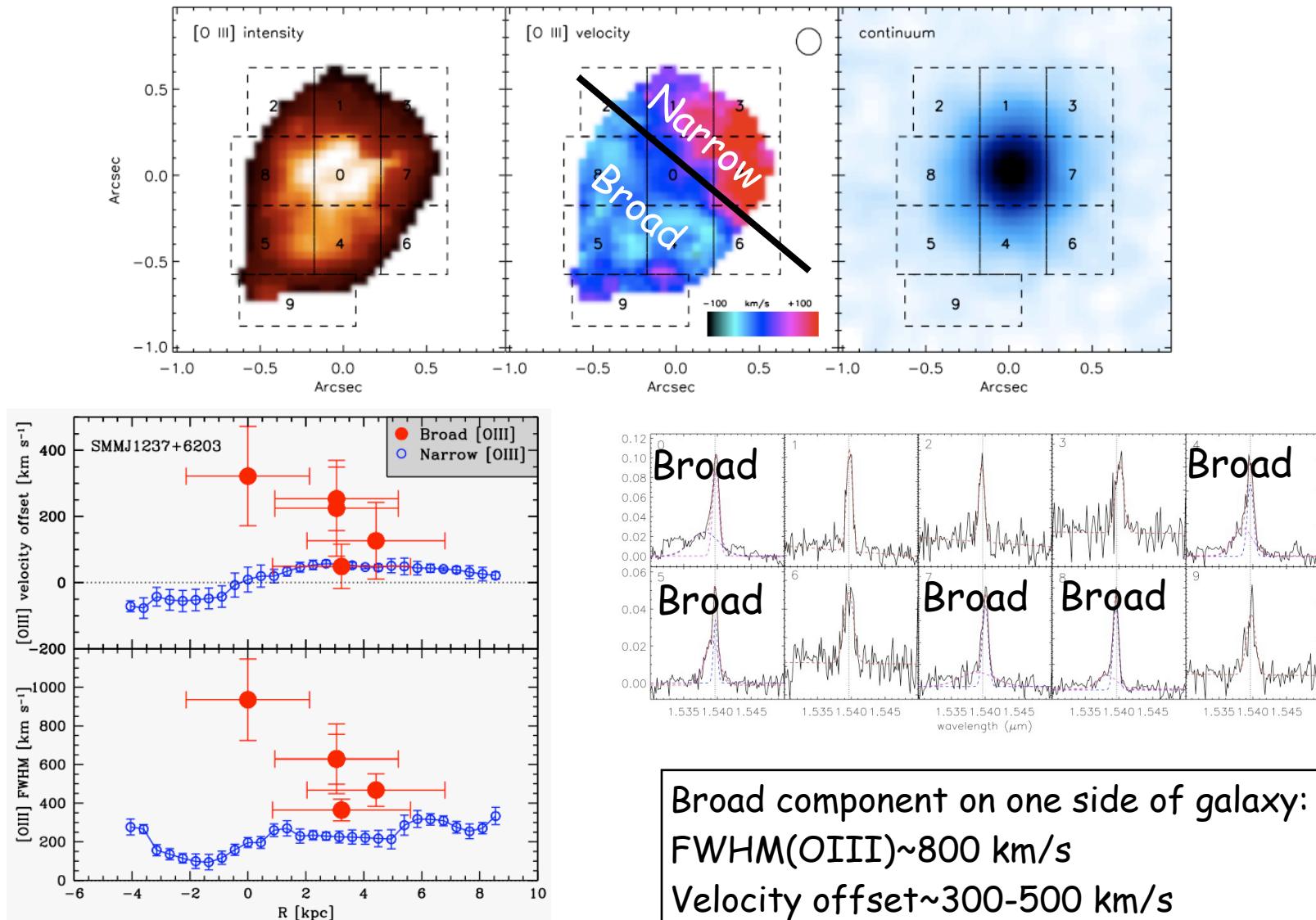
~8hr Gemini NIFS IFU observations of two z~2 SMGs:

further 3 targets scheduled for the coming semester



Alexander, Swinbank et al. (in prep)

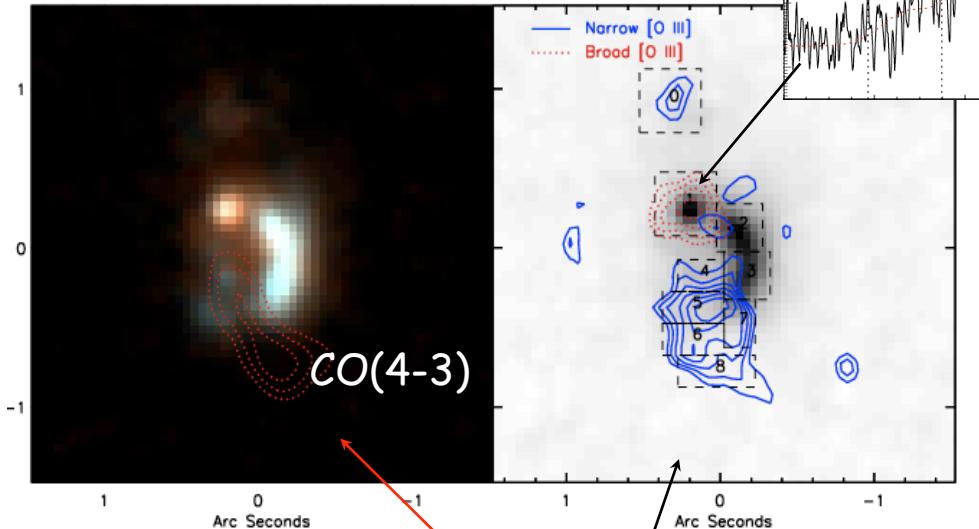
Large-scale energetic outflow in a radio-quiet AGN



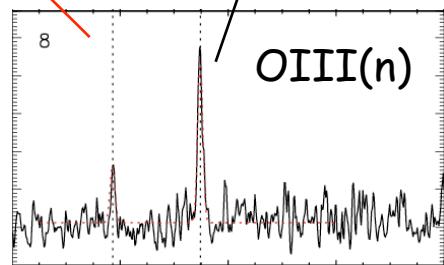
A binary AGN and an energetic outflow

N2 850.4 ($z=2.38$)

HST IH colour



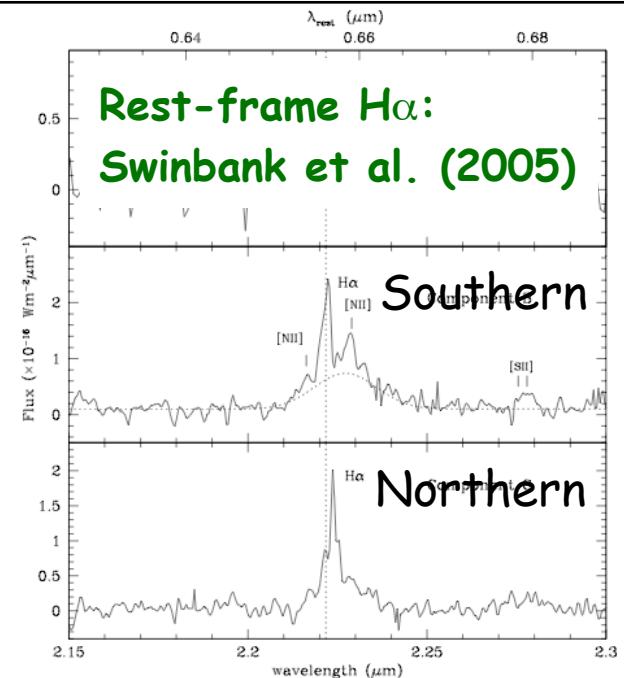
Southern AGN
photo-ionising
gas



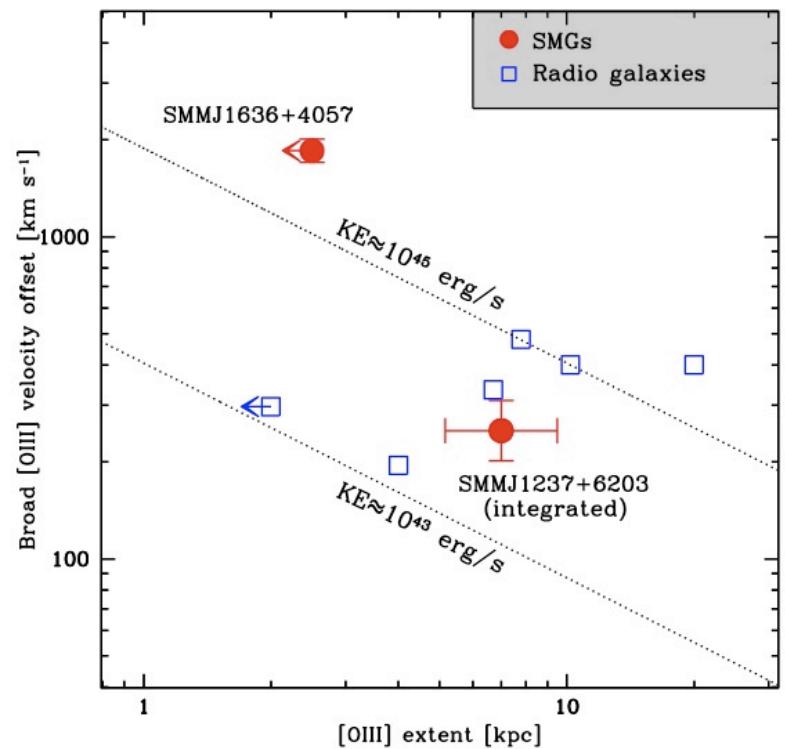
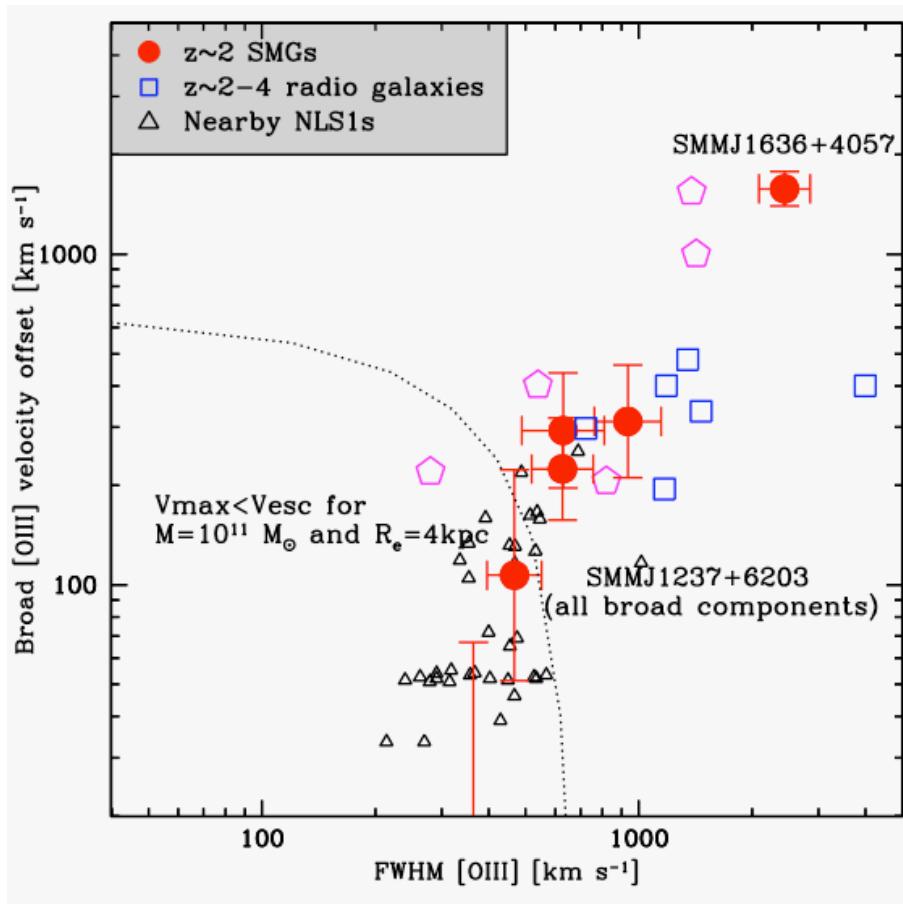
Complex system with many
on-going feedback effects

Northern AGN shocking
and accelerating gas
(AGN outflow?)

FWHM(OIII)~2500 km/s!
Velocity offset~2000 km/s!
Unresolved ($r < 2.5$ kpc)

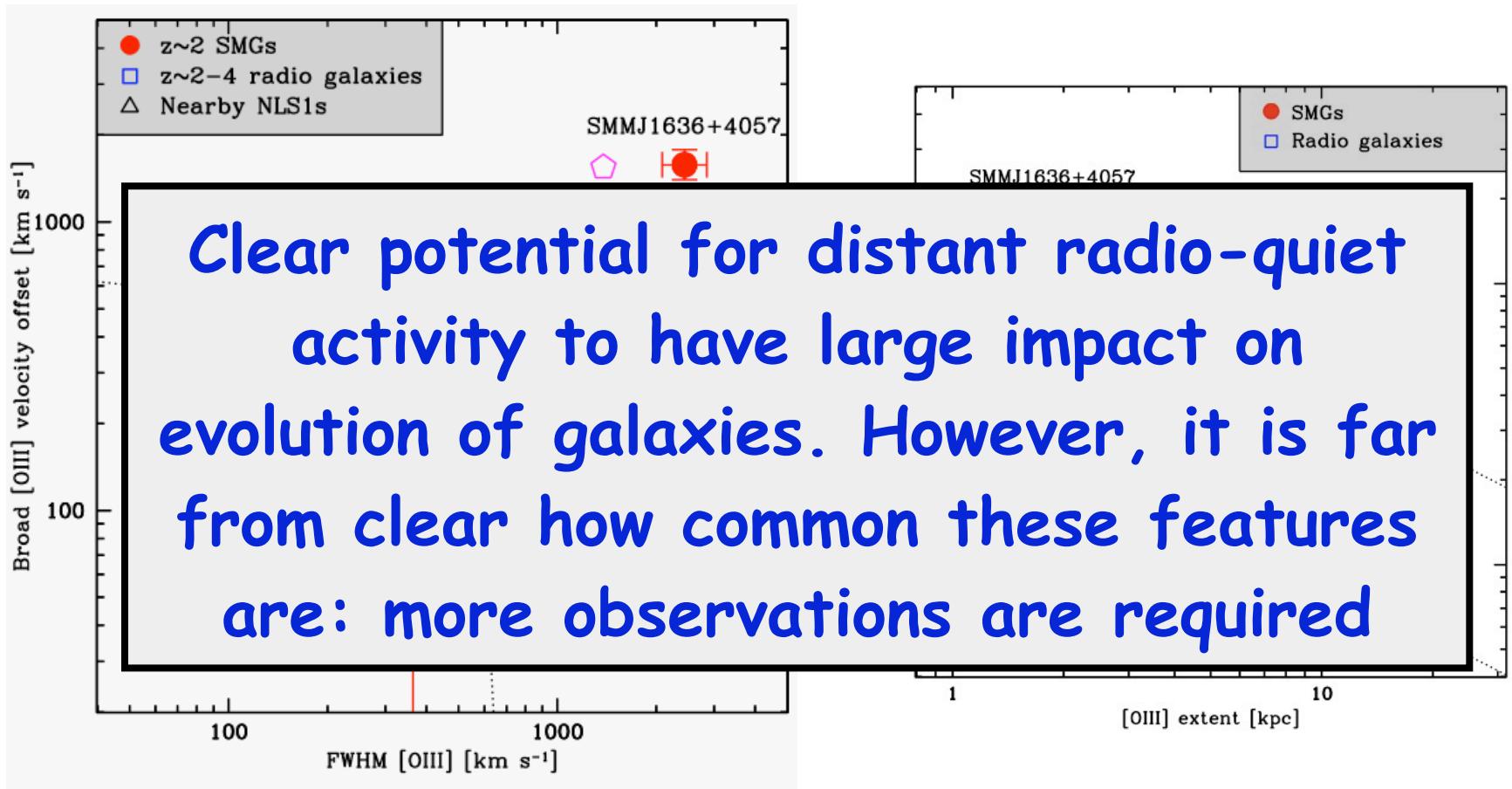


[OIII] properties similar to distant radio galaxies



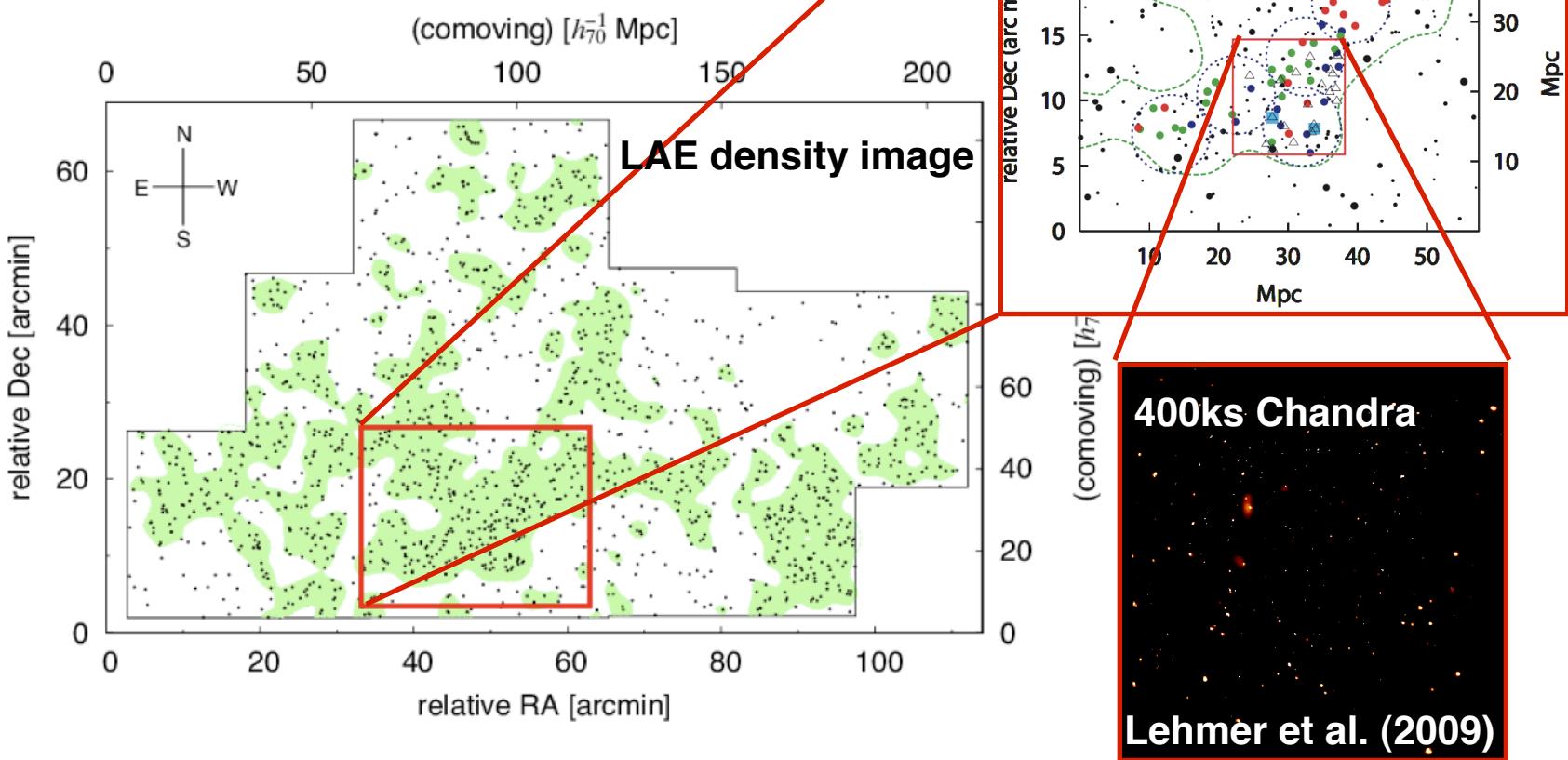
Comparable range of implied kinetic energies as radio galaxies ($\sim 10^{44}-10^{45} \text{ erg/s}$; $\sim 10^{59}-10^{60} \text{ erg over } 10^7 \text{ years}$), although very uncertain calculations... the low radio luminosities suggest radio jets are insufficient to drive the SMG outflows: AGN radiative winds? Starburst/SNe winds plausible in some cases?

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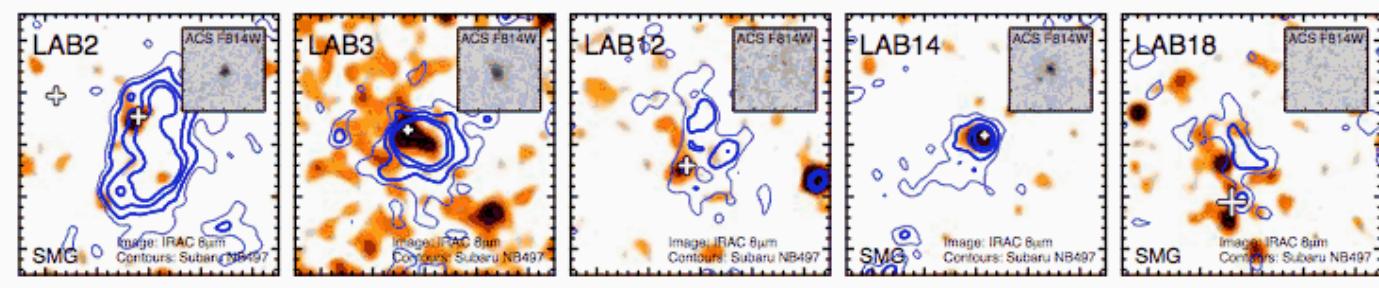
Searching for evidence of large-scale interaction in $z \sim 3$ protocluster



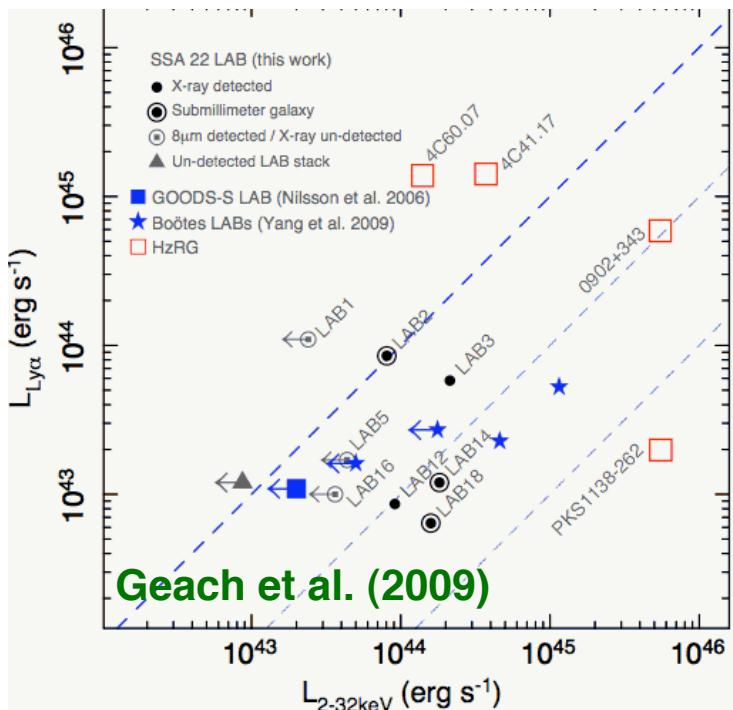
Yamada et al., in prep

AGN activity enhanced in SSA22 $z \sim 3$ protocluster: AGN fraction ~6x higher than in field (Lehmer et al. 2009): any evidence for the impact of AGN on the large-scale environment?

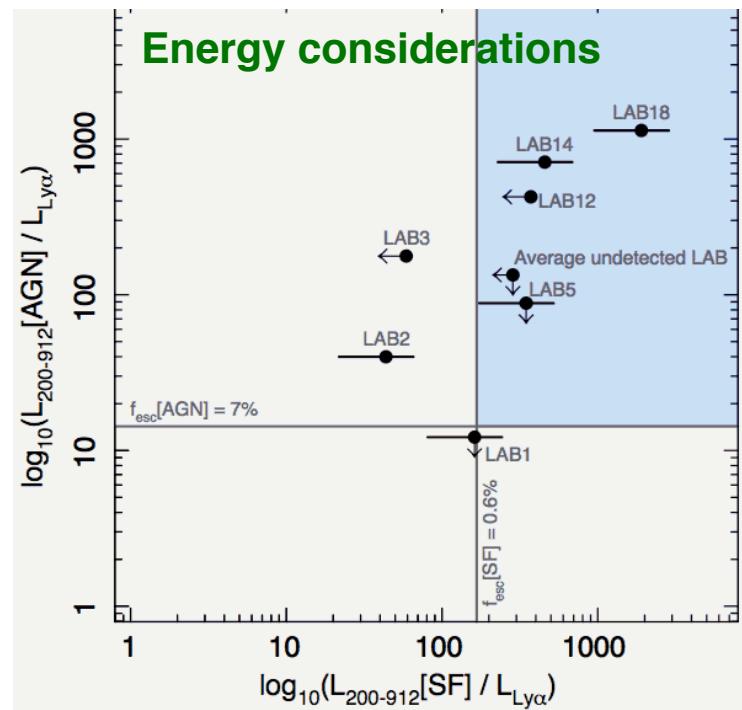
Large-scale AGN/SF heating in z~3 protocluster



Large Ly-alpha haloes ($\sim 30\text{-}100$ kpc) are driven by heating rather than cooling: could be due to either radio-quiet AGN activity or star formation



Geach et al. (2009)



NASA Chandra press conference on these results this Wednesday 6pm:
<http://www.nasa.gov/newsaudio>

Summary

Summary

Gemini NIFS observations of two z~2 radio-quiet AGNs hosting in submillimeter emitting galaxies (SMGs):

- 1) Evidence for large-scale (up to 7 kpc) energetic outflows in these systems, with comparable properties and therefore outflow energies as distant radio galaxies ($\sim 10^{44}\text{-}10^{45}$ erg/s)
- 2) Radio luminosities ~3 order of magnitude lower than those of distant radio galaxies, it seems unlikely that the catalysts for these outflows can be radio jets (radiative winds?)
- 3) Further NIFS observations scheduled to provide first-order constraints on ubiquity of distant large-scale energetic outflows

Also evidence for large-scale ($\sim 30\text{-}100$ kpc) heating in z~3 SSA22 protocluster by radio-quiet AGN activity or star formation: