AGN Feedback in Moderate Power high-z Radio Galaxies

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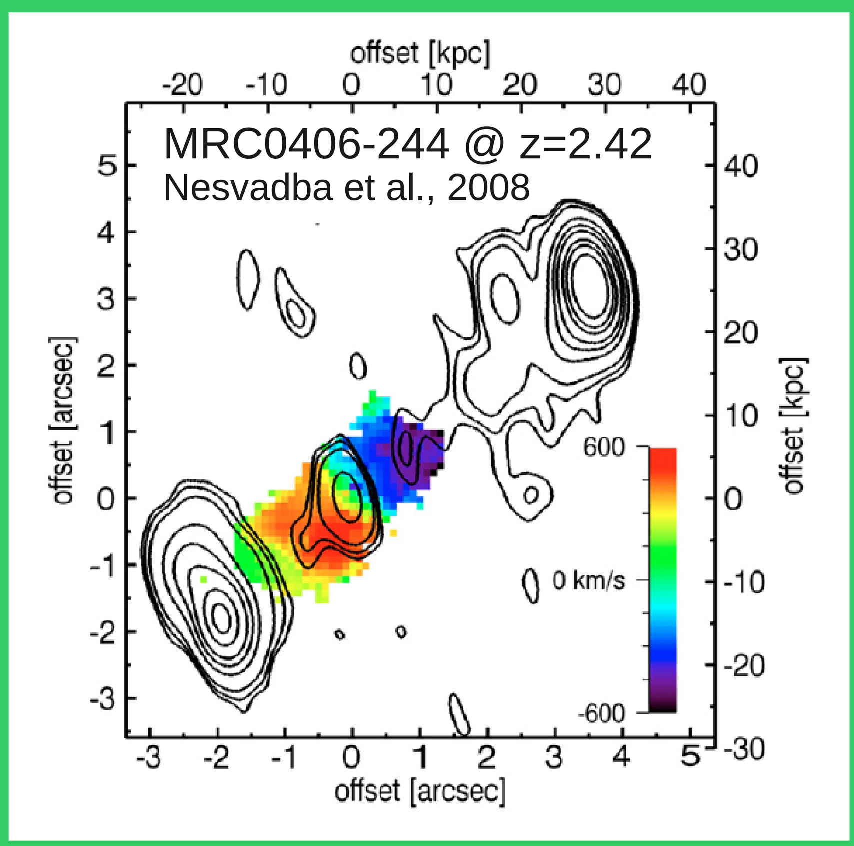
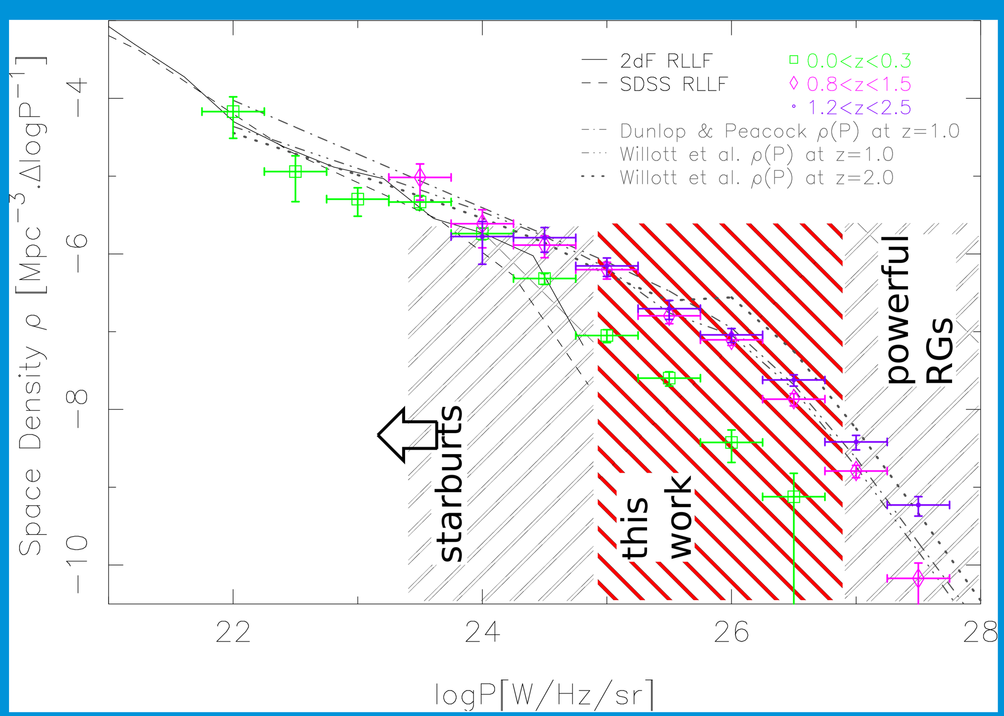
AGN feedback is now a widely invoked mechanism in models of galaxy formation. However, we still lack a deep understanding of how the immense amounts of energy emitted by the supermassive black hole are injected into the interstellar medium to suppress star formation. We study the role of radio jets to estimate the significance of this feedback mode over a large range of radio power. To that end, we use the integral field spectrograph SINFONI at the VLT to study the ionized gas in 9 moderately powerful radio galaxies at high redshift (z ~ 2–3), drawn from the catalogues of Broderick et al. (2007) and Bryant et al. (2009a,b).

Already Observed

Outflows of ionized gas (colored pixels) driven by radio jets (contours) have already been observed in very powerful radio galaxies.
However, such extreme objects are not representative of the average massive galaxy in the early Universe.
Nonetheless, we can use them as benchmarks.



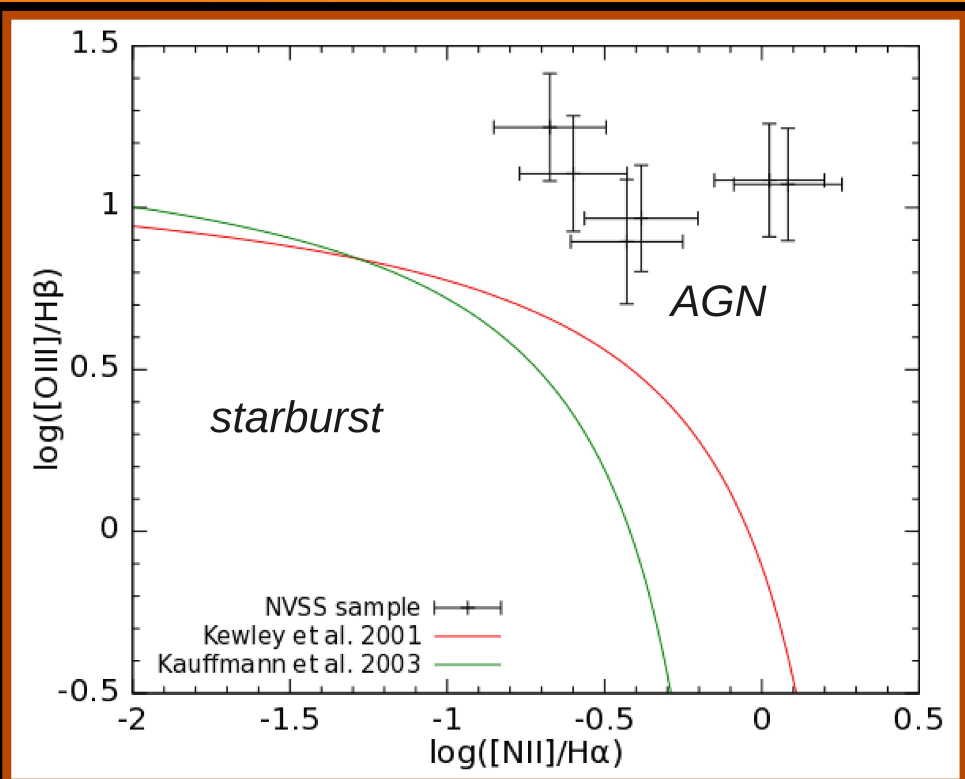
More Frequent Radio Galaxies at z~2



Radio galaxies less powerful than MRC0406-244 (by about 1–2 orders of magnitude) are also ~100× more common. They may represent a significant fraction of massive galaxies at z~2-3, up to 40% of ULIRGs (eg, Sajina et al, 2007).

Radio luminosity function (adapted from Gendre et al., 2010, MNRAS, 404:1719)

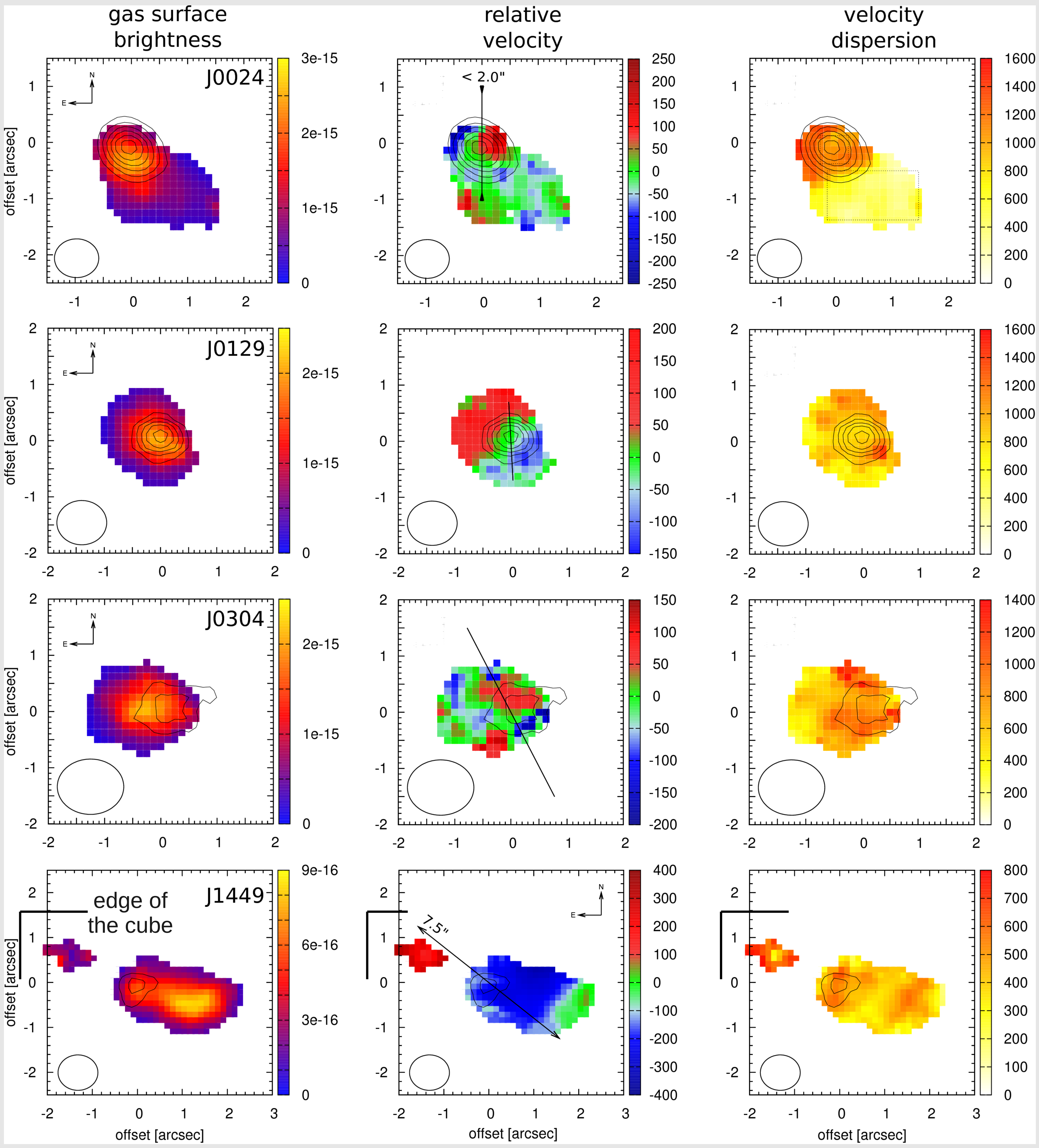
BPT Diagram



The ionized gas in our targets is excited by the AGN and not by the star formation

Results for Moderately Strong Radio Galaxies

Some maps derived from our sample of moderately strong radio galaxies.
Left: Maps of surface brightness (in $erg.s^{-1}.cm^{-2}.arcsec^{-2}$)
Center: Maps of relative velocity (in $km.s^{-1}$)
Right: Maps of velocity dispersion (in $km.s^{-1}$)
Black line (in maps of relative velocity): Radio jet axis (PA and size) ; Contours: Continuum



Conclusions:

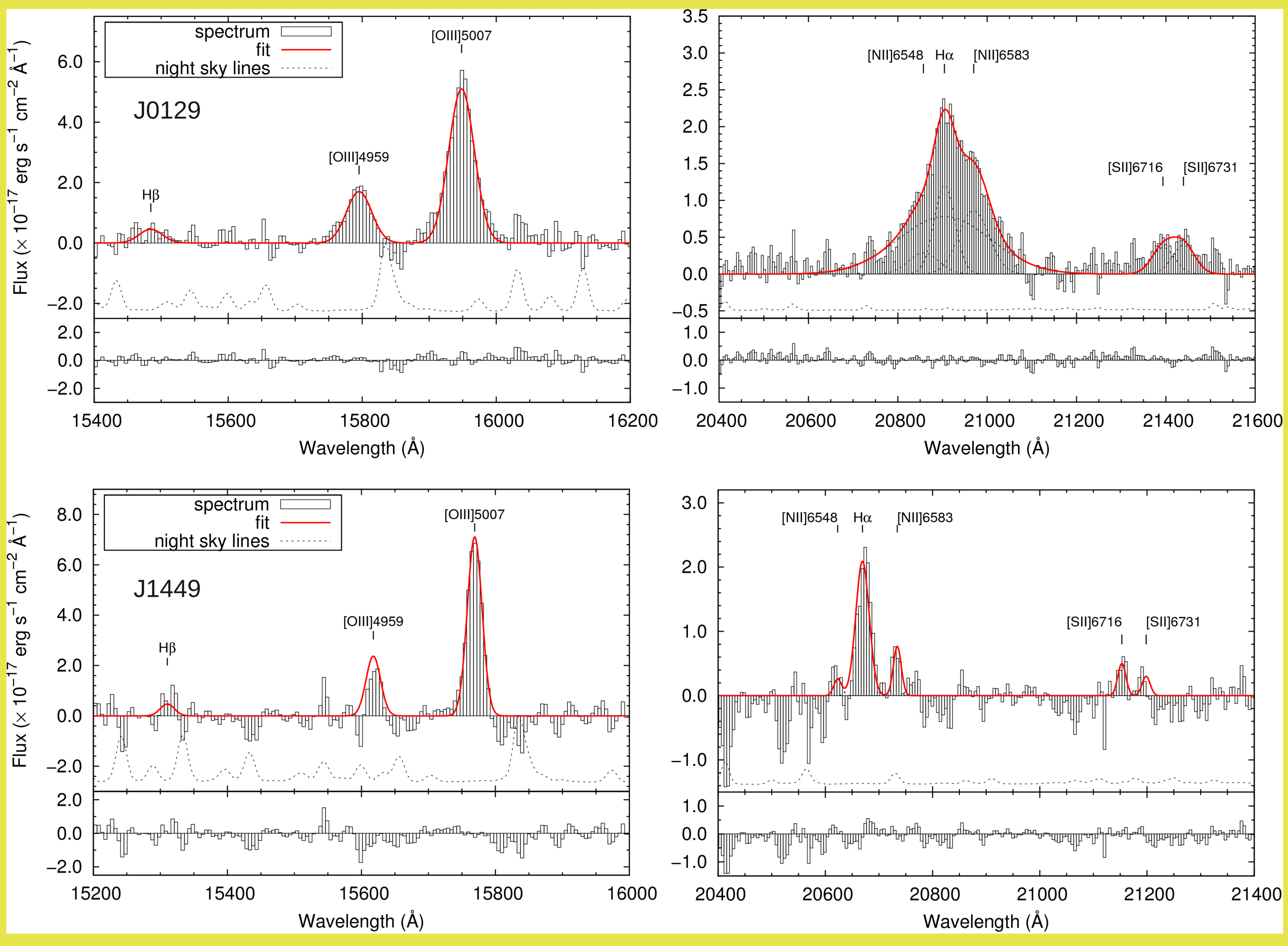
Compared to very powerful radio galaxies, we find more variety in our less powerful sample. We observe:

- both extended (*eg*: J1449) and compact (*eg*: J0304) emission line regions, correlated with the radio structure.
- both clear velocity gradients (*eg*: J0129) and irregular velocity fields (*eg*: J0024).
- common to all sources: broad lines of strongly perturbed ionized gas (FWHM ≤ 1000 $km.s^{-1}$).

Assuming a temperature of $T{\sim}10^4$ K, an electron density of $n_e{\sim}700\ cm^{-3}$ and case B recombination (Osterbrock, 1989), we find masses of ionized gas between $0.3–2.2{\times}10^9\ M_\odot$.
This is one order of magnitude less than in most powerful radio galaxies. Nonetheless, this represents a significant fraction of the typical gas mass of high-*z* galaxies.

References: Greene & Ho, 2005, ApJ, 630:122 ; Croton et al., 2006, MNRAS, 365:11 ; Nesvadba et al., 2006, ApJ, 650:693 ; Sajina et al, 2007, ApJ, 667:L17 ; Broderick et al., 2007, MNRAS, 381:341 ; Nesvadba et al., 2008, A&A, 491:407 ; Bryant et al., 2009, MNRAS, 394:2197 ; Bryant et al., 2009, MNRAS, 395:1755 ; Gendre et al., 2010, MNRAS, 404:1719

Spectra



Spectra of J0129 (top) and J1449 (bottom), showing Hβ, the [OIII] doublet, the Hα + [NII] complex and the [SII] doublet.

J0129 has a broad Hα component, that we can use to estimate the black hole mass (following Greene & Ho, 2005): $M_{BH} = 3.0{\times}10^8\ M_\odot$