Integral-field spectroscopy of broad-line BCGs and the AGN “connection”

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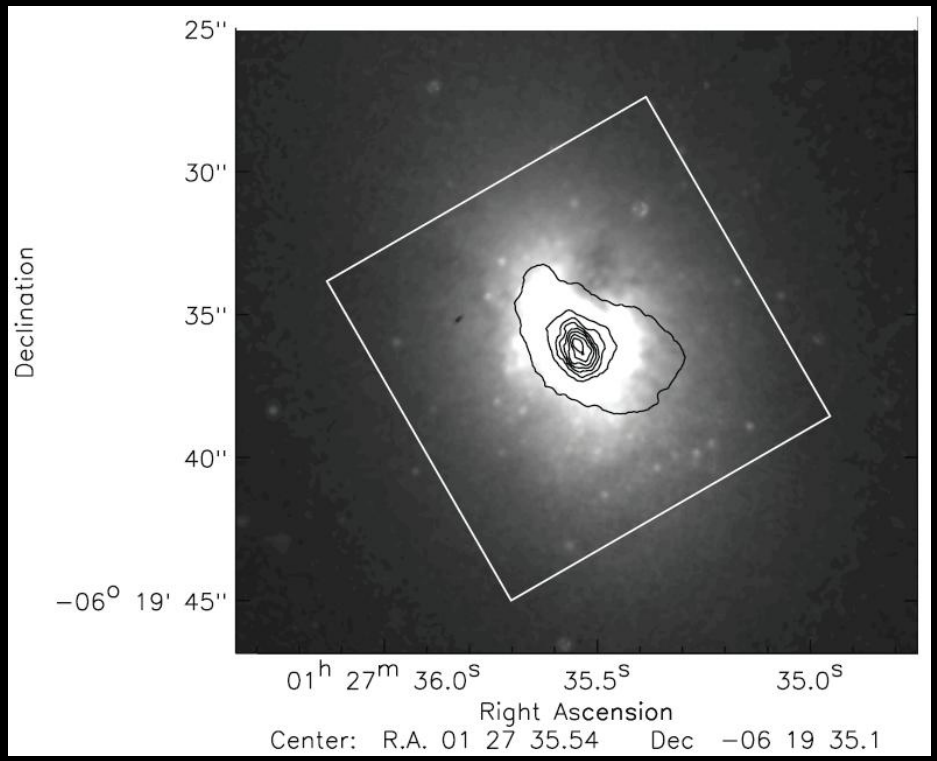
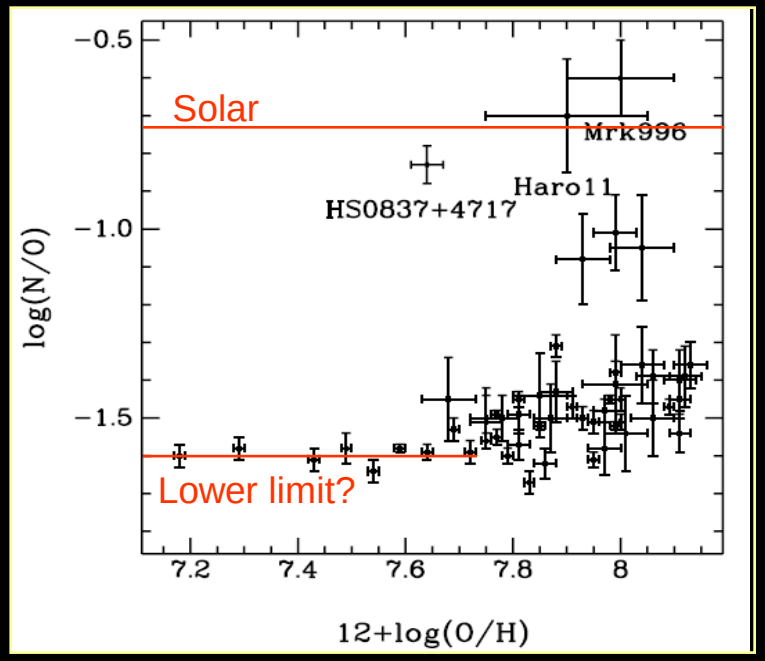
Markarian 996



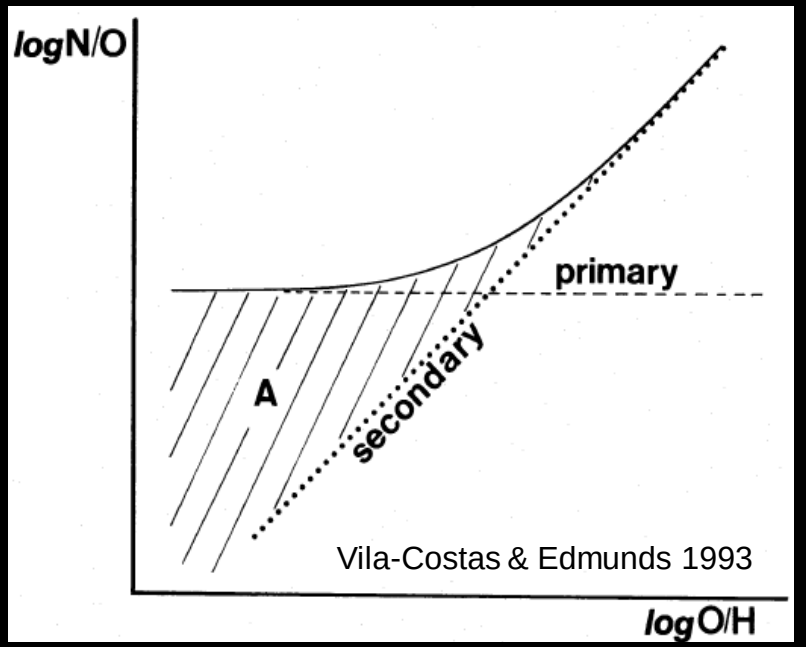
Thuan, Izotov & Lipovetsky (1996):

O/H ~ 0.10 x Solar
N/O ~ 1 – 5 x Solar

The evolution of Nitrogen abundances in BCDs



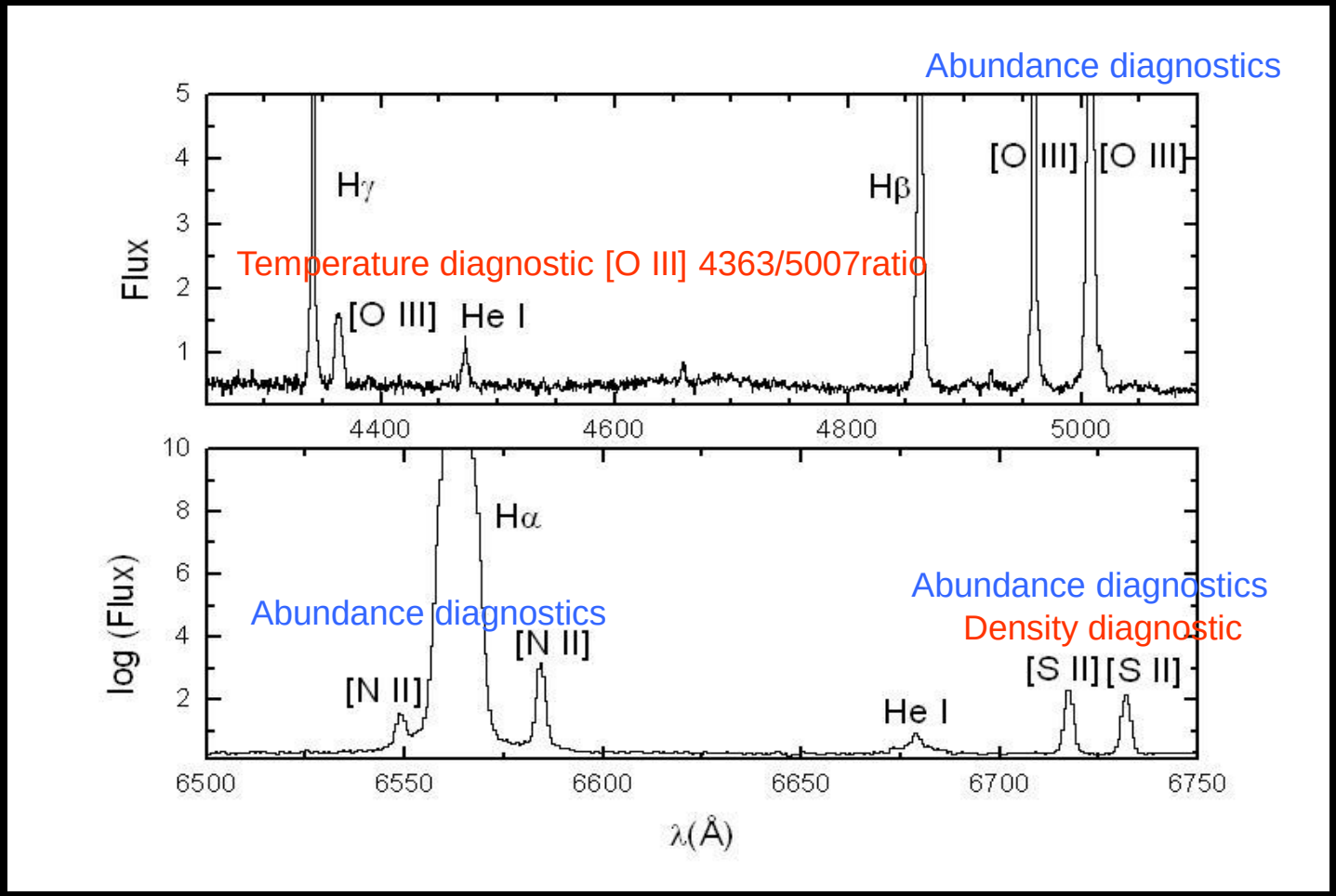
Pustilnik et al. 2004



At low *Z* primary Nitrogen is produced with Oxygen from massive stars (M > 9 Msol)

As the starburst ages, secondary N from stars of all masses and primary N from AGBs is produced: resulting scatter. Outlying galaxies with ~solar N/O seem rare and require an explanation. They contain Wolf-Rayet stars and/or show evidence of mergers. Nitrogen enrichment from WR-winds? Inaccurate analyses?

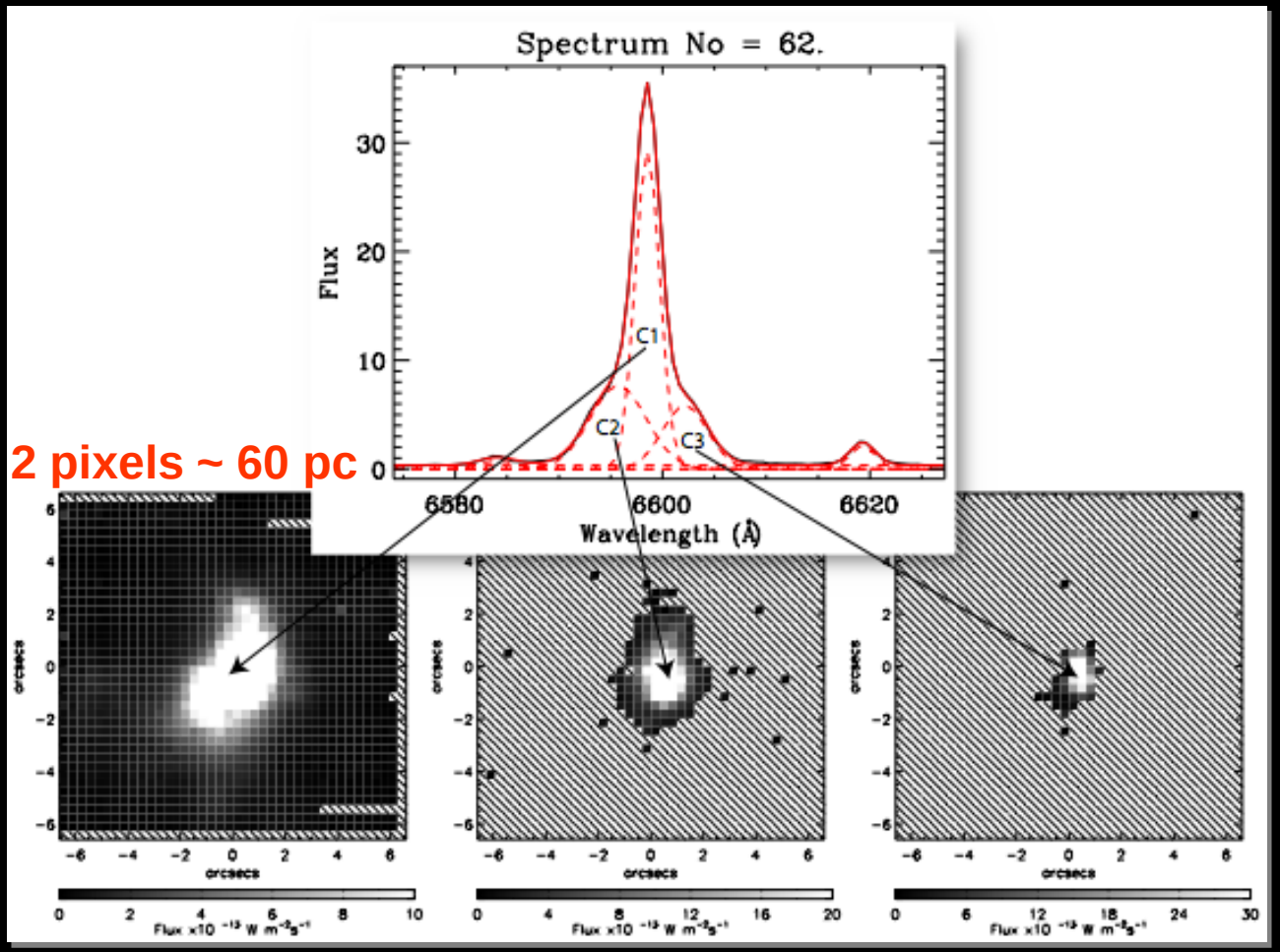
Spectrum extracted from a 0.33” x 0.33” VLT VIMOS pixel



Velocity resolution ~ 120 km/s FWHM

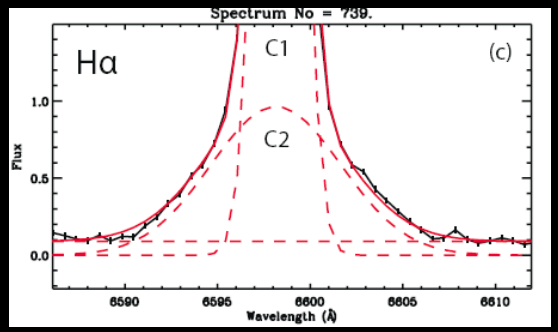
~ 30 min exp.

Spectral maps of MRK 996 in the light of Hα 6563 Å: multi-component line fitting (x 1600)

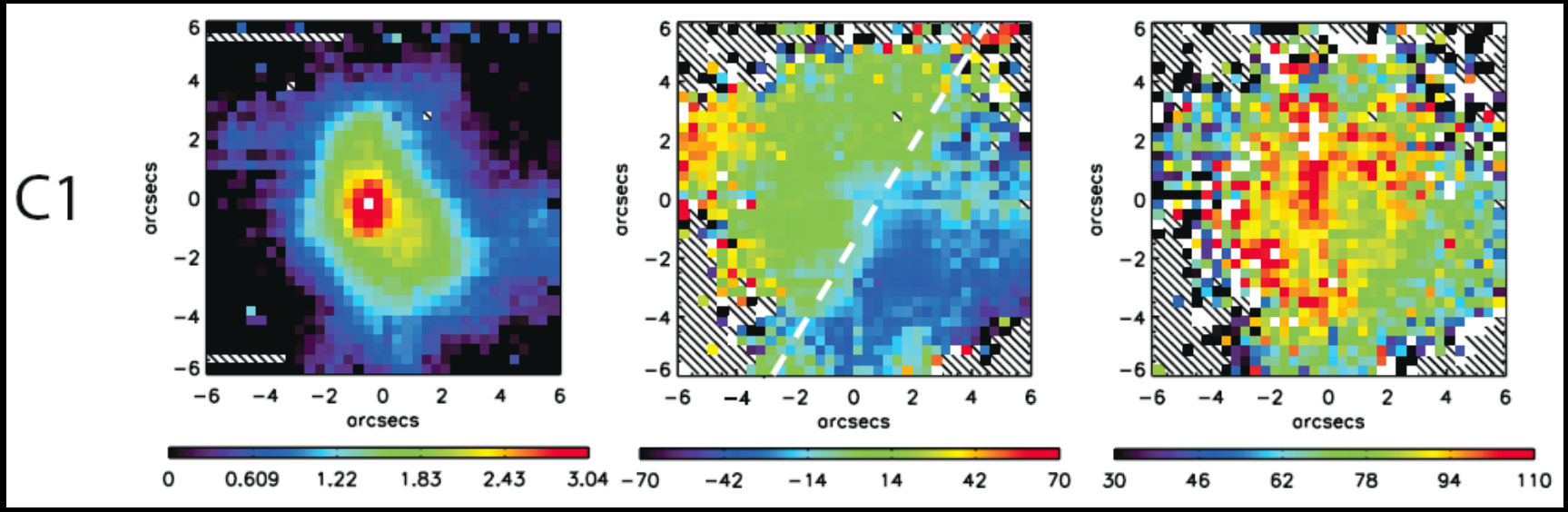


James, Tsamis, et al. (2009), MNRAS, 398, 2

Flux, radial velocity, and FWHM maps of the various components of Hα

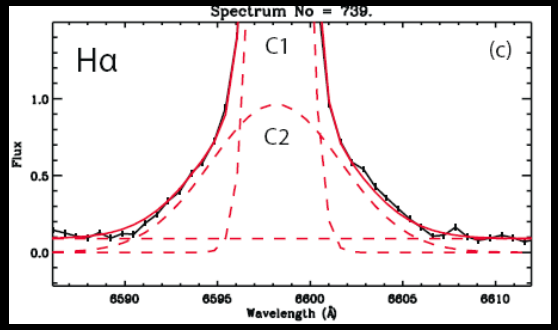


		FWHM (km/s)
6563 Hα	C1	116.5± 0.9

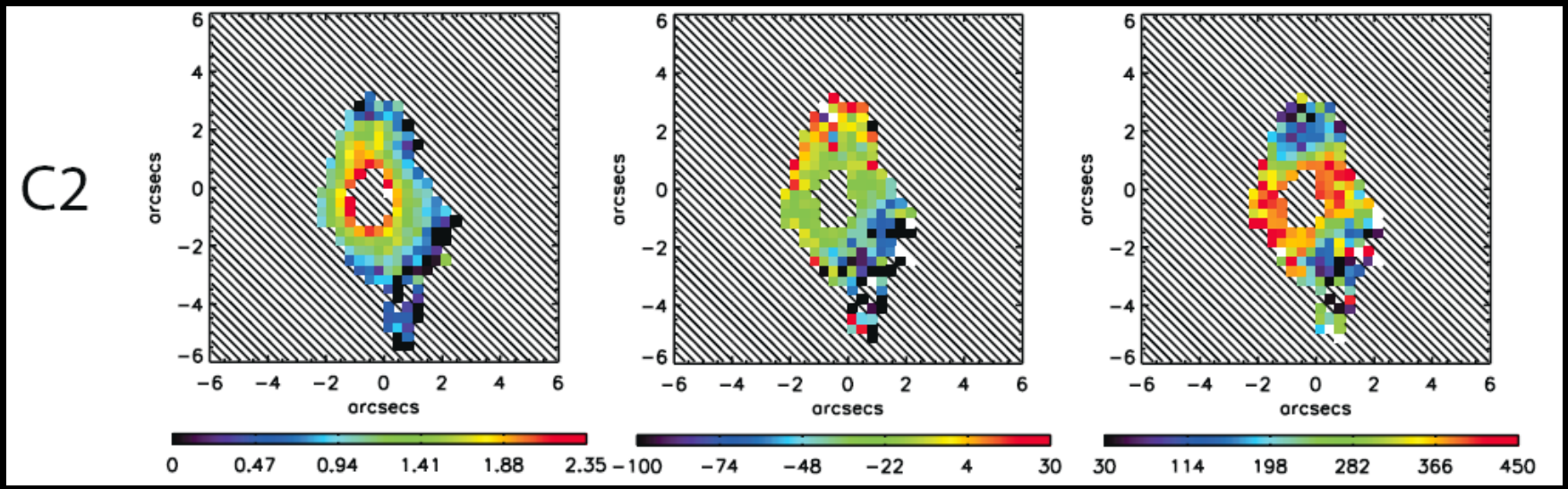


Flux **Radial velocity (km/s)** **FWHM (km/s)**

Flux, radial velocity, and FWHM maps of the various components of Hα



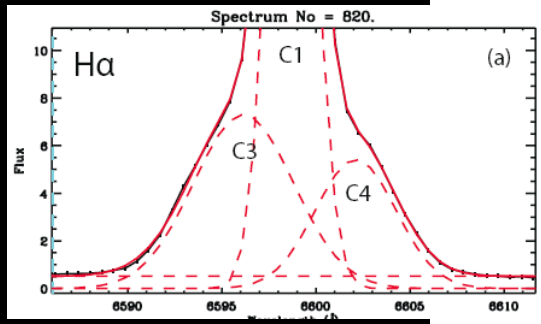
		FWHM (km/s)
6563 Hα	C2	420.5± 7.3

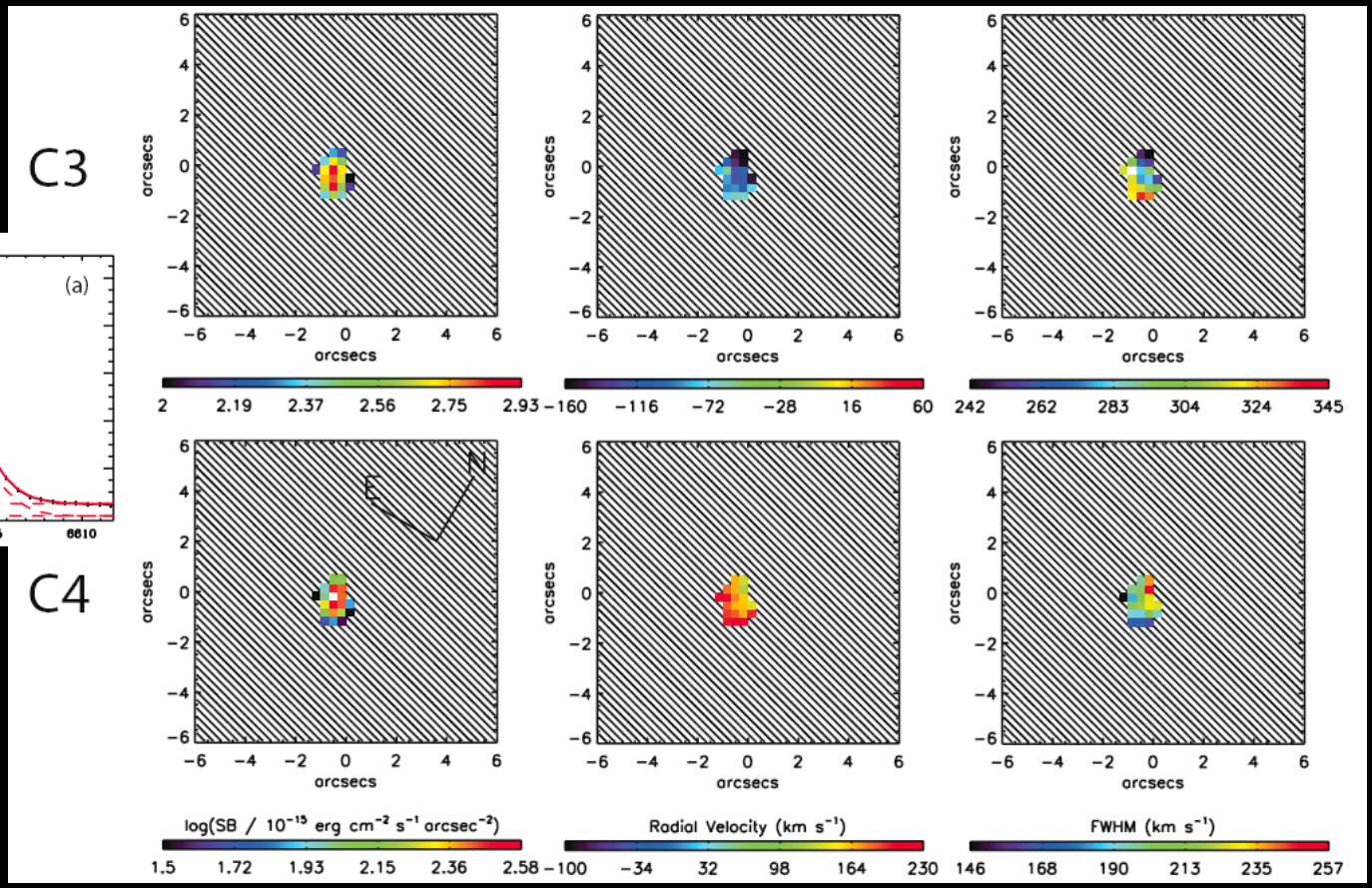


Flux **Radial velocity (km/s)** **FWHM (km/s)**

Flux, radial velocity, and FWHM maps of the various components of Hα

FWHM~200-300 km/s

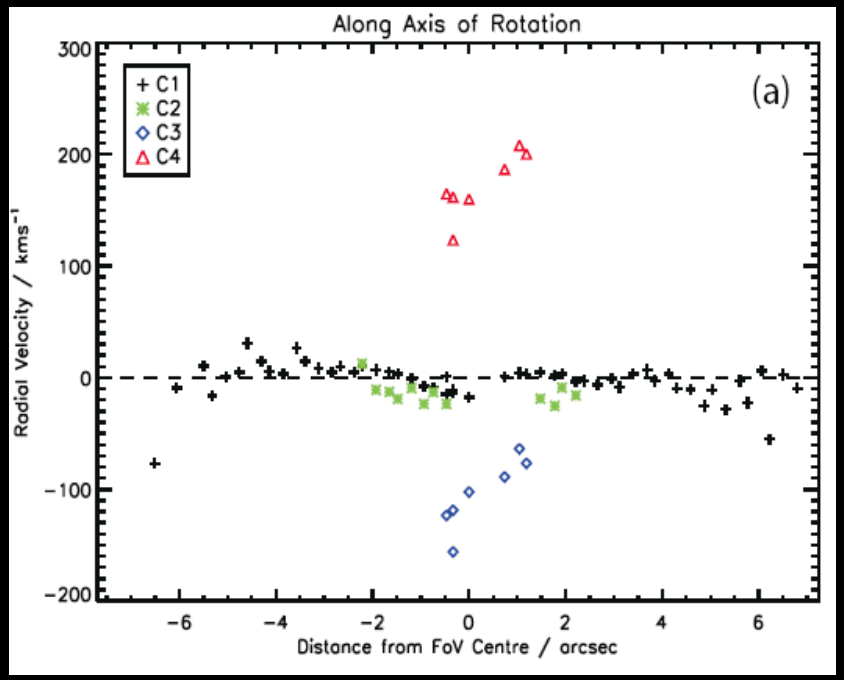


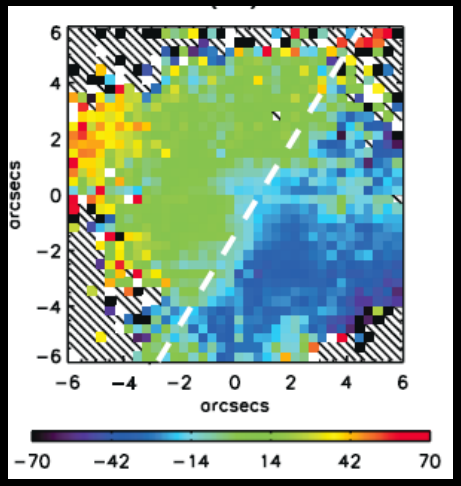


Flux **Radial velocity (km/s)** **FWHM (km/s)**

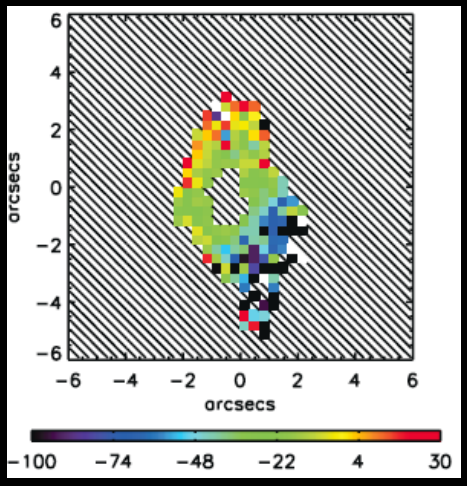
Kinematics: Identification of a mini-spiral (2”, ~200 pc) in the nucleus

Position-Velocity diagram along the rotation axis

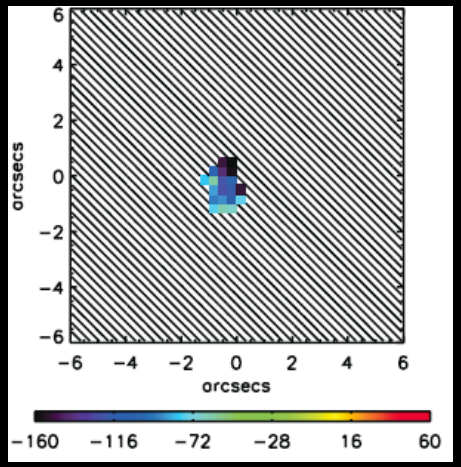




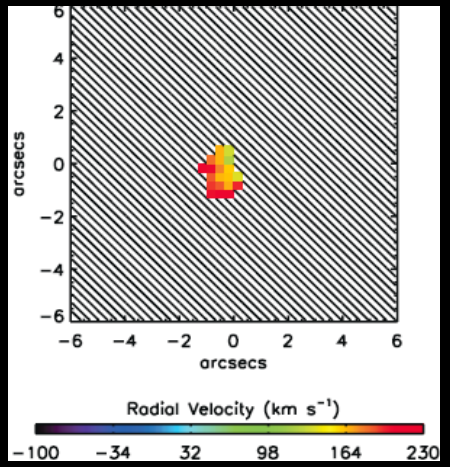
C1



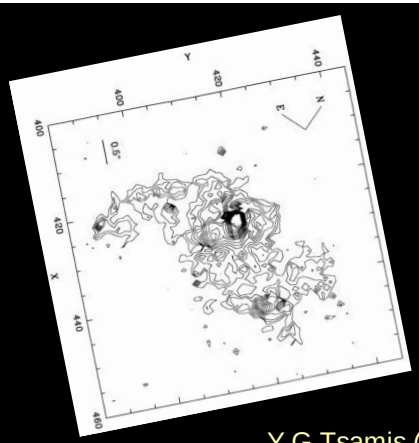
C2



C3

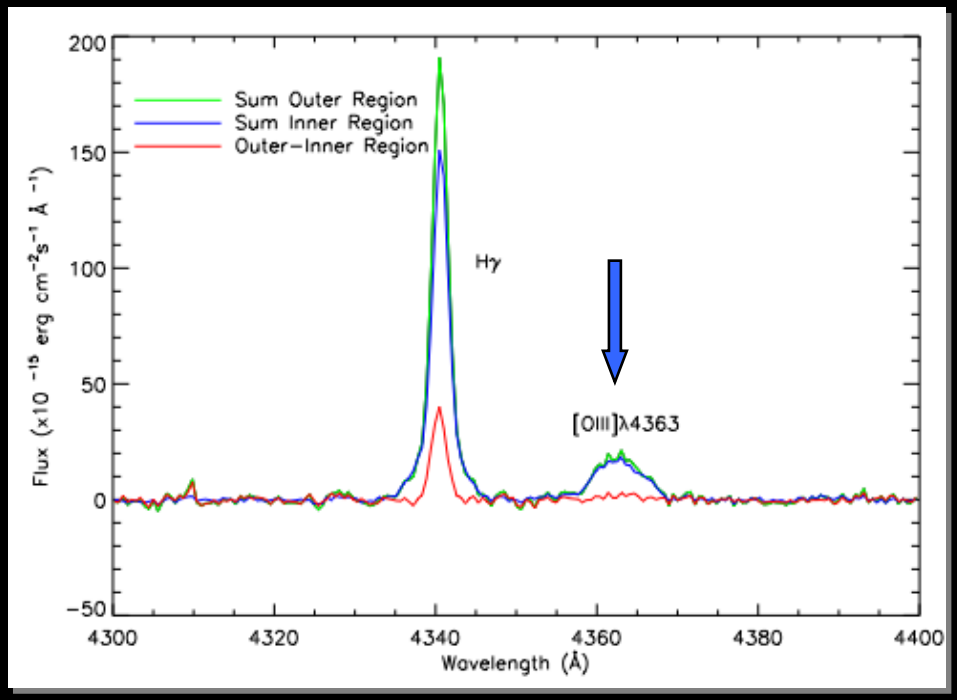


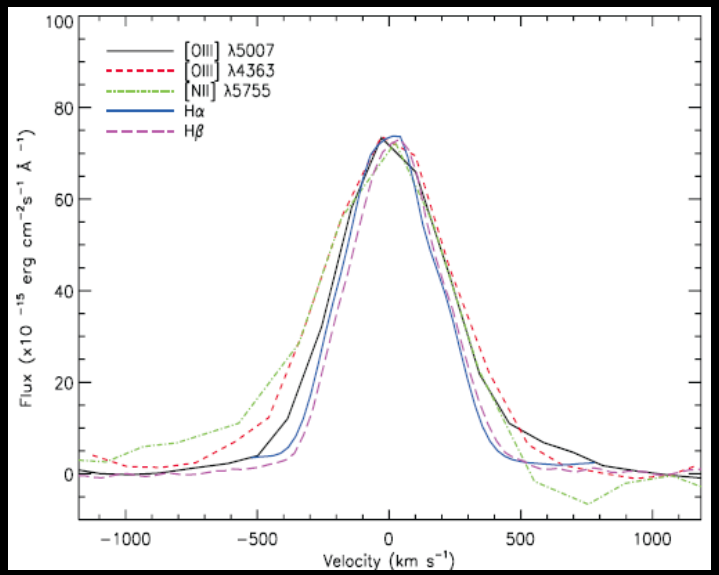
C4



Thuan et al (1996)

Physical conditions: the [O III] 4363 Å width in the inner/outer galaxy

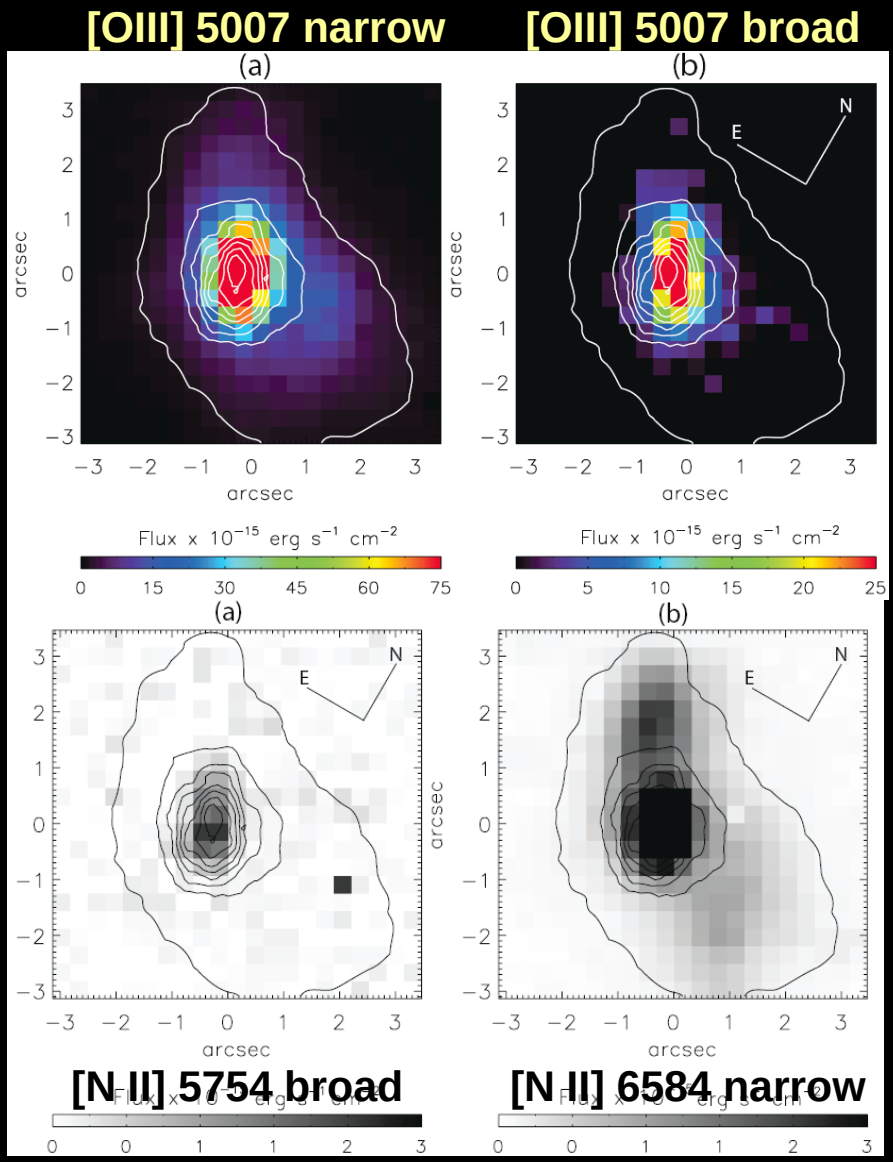




The narrow component of [O III] 4363 is not present:

Temperatures based on the integrated [OIII] 4363/5007 ratio would be too high and the resulting abundances too low

Chemical abundances and N enrichment



O/H > 0.5 solar
(>3 x higher than previously)

N/O (narrow) ~ 0.20 x solar
N/O (broad) ~ 4 x solar

✓ N/H in dense broad-line gas is **20x** that in extended narrow-line region

✓S/O and Ar/O ~ Solar (in both broad/narrow region).

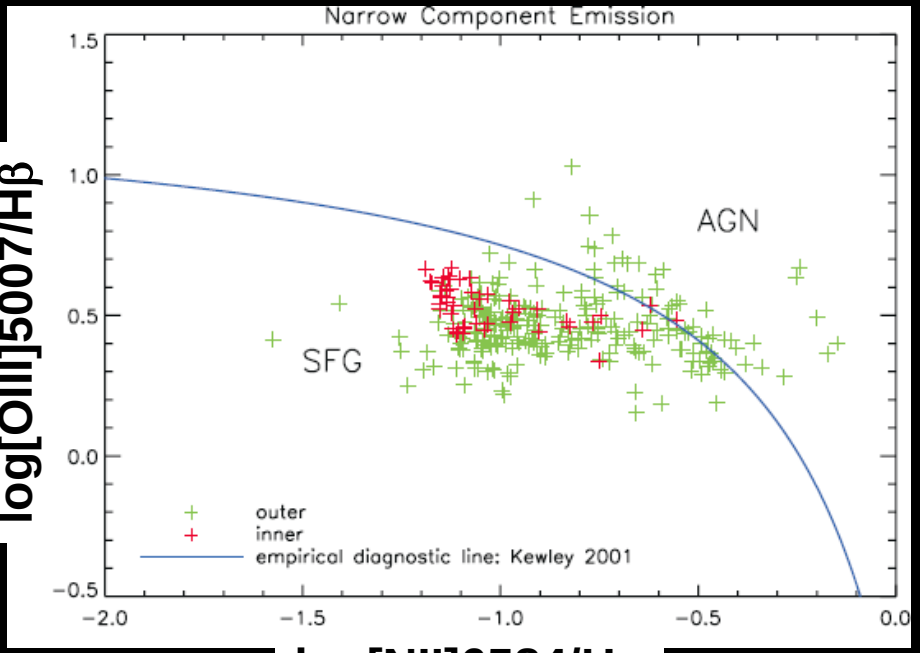
✓No He/H differential between narrow/broad regions.

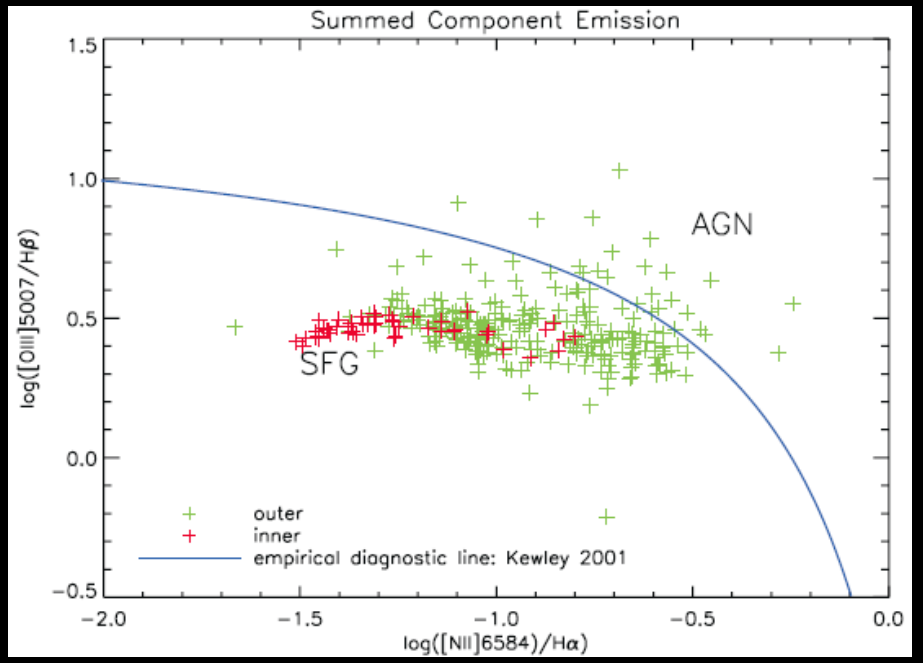
✓3000 Wolf-Rayet stars in nucleus responsible for the high N/O ratio in the broad-line regions

Diagnostic excitation diagrams

Narrow component gas only

Full line profile (narrow+broad)

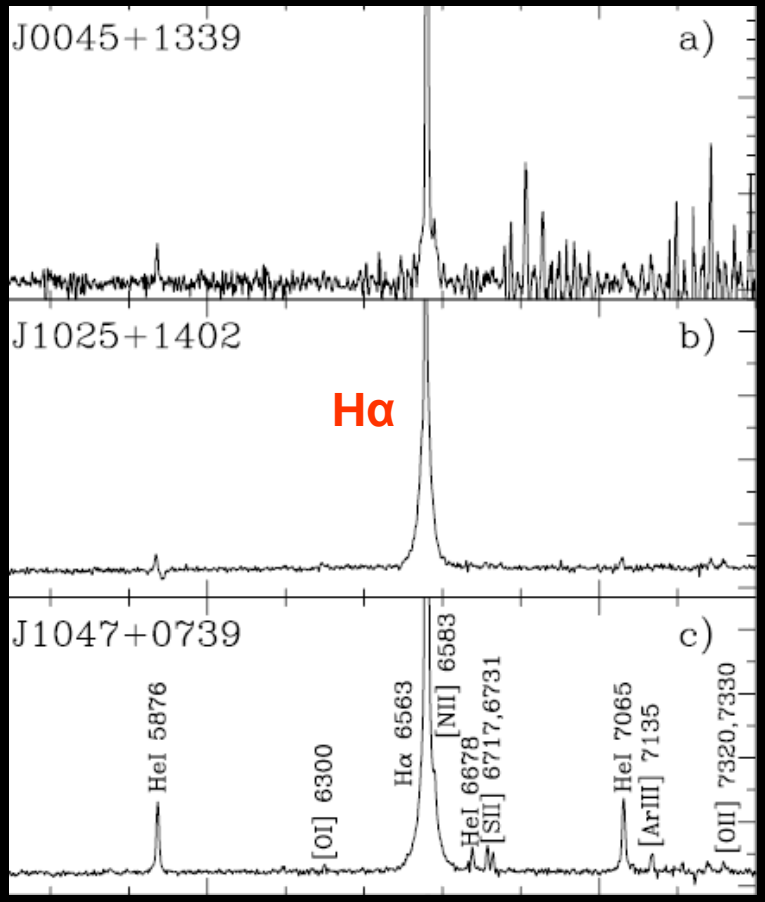




Diagrams in the literature make use of integrated line ratios (right-hand side), but note the introduced bias when the diagnostic lines are not resolved

SDSS Broad-line BCGs: potential AGN?

***redshift* ~ 0.10 – 0.30**



O/H ~ 0.1 - 0.2 solar
(Izotov & Thuan 2008, ApJ, 687)

✓ Ha Broad-line luminosities between 40 – 150% of the narrow line luminosity
(versus ~ 40% for Mrk 996)

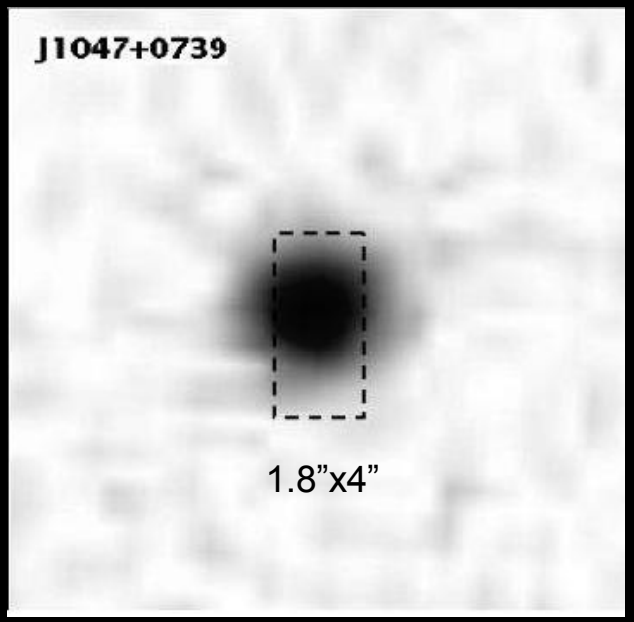
✓ FWHM ~ 1500 – 2000 km/s
(versus ~ 500 km/s for Mrk 996)

? New class of low *Z* AGN which have been elusive until now?
Z(AGN) >~ solar + scaling with stellar mass of host galaxy.

? Mis-identified higher *Z* galaxies?

VLT *X-shooter* observations of BCG/AGN "candidates"

Tsamis, Vílchez, et al.



IFU image/slicer 1.8" x 4"

λ = 300 – 2500 nm
near-UV/Optical/Near IR spectral cube

✓ Definitive measure of broad-line luminosities

✓ High spectral resolution to resolve (~ 30 km/s) the T-sensitive [OIII] 4363A, [NII] 5754-A lines and separate the narrow+broad region contribution

✓ To be coupled with *Chandra* spectra to study the *X*-ray sources and unveil any AGN

Open Questions worthy of an Estallidos collaboration

? How *low* can the metallicity/mass of an AGN host galaxy get?

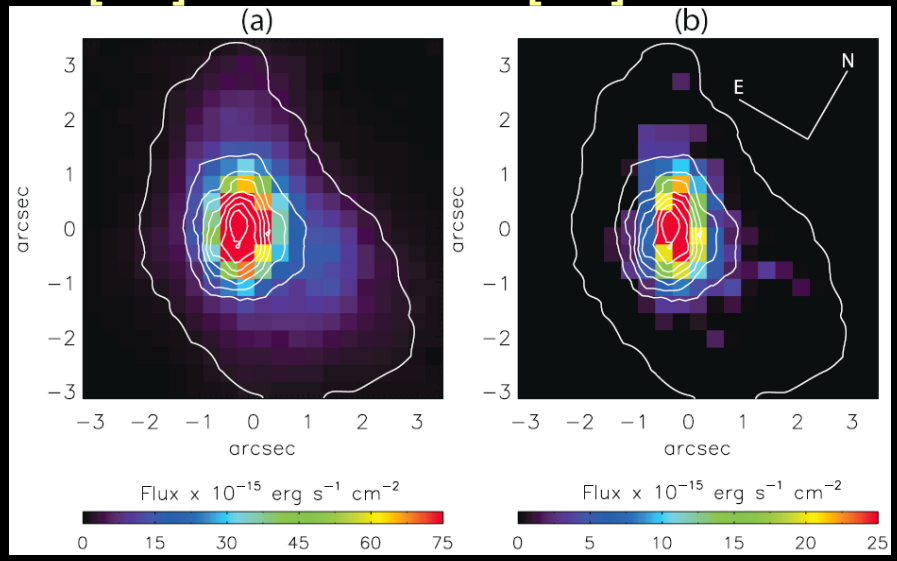
? Would we find the lowest metallicity AGN amongst BCGs? How should we be looking?

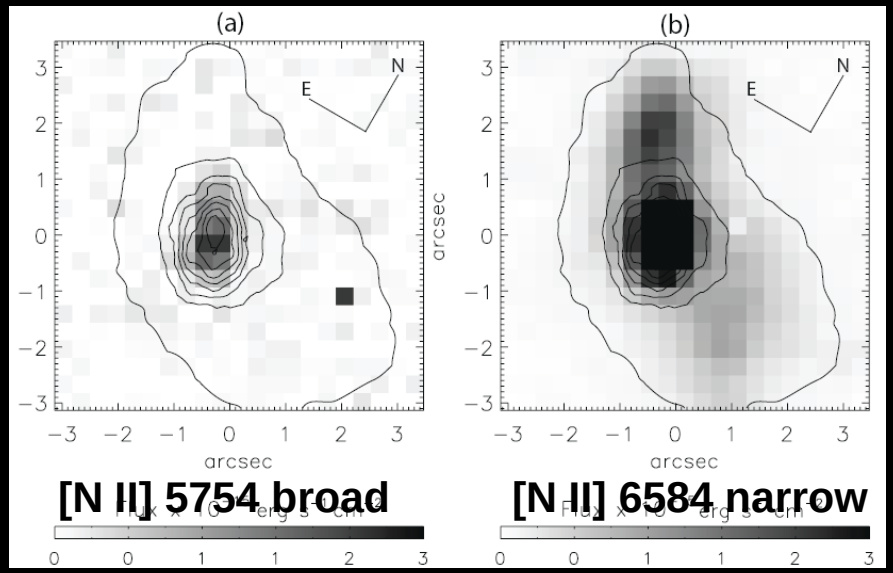
? How accurate are existing analyses of BCGs with broad-line features?

✓ Integral-field spectroscopy is the ideal observational tool to help us study these issues

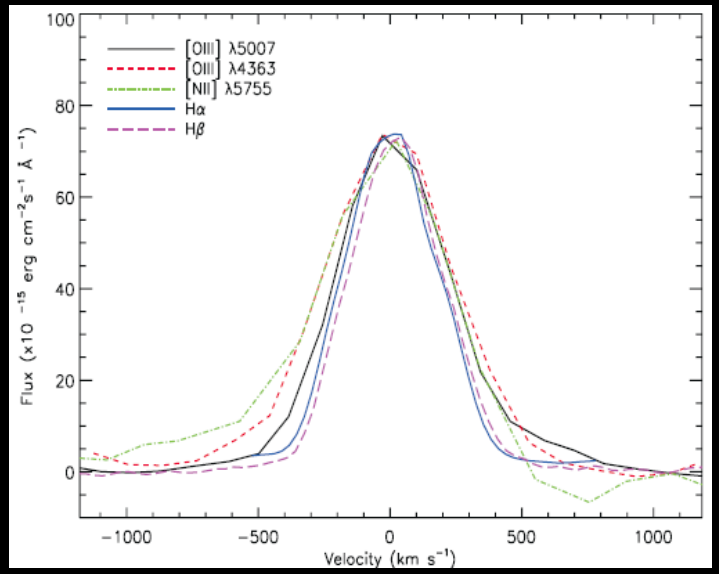
Tracking the width of broad/narrow diagnostic lines

[OIII] 5007 narrow **[OIII] 5007 broad**

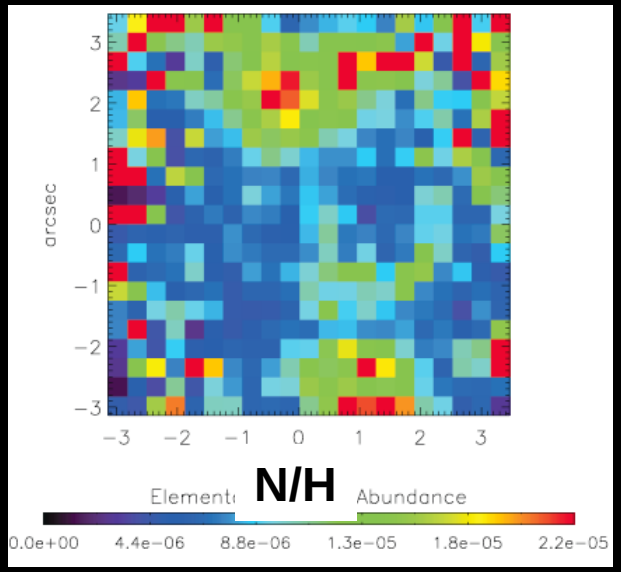


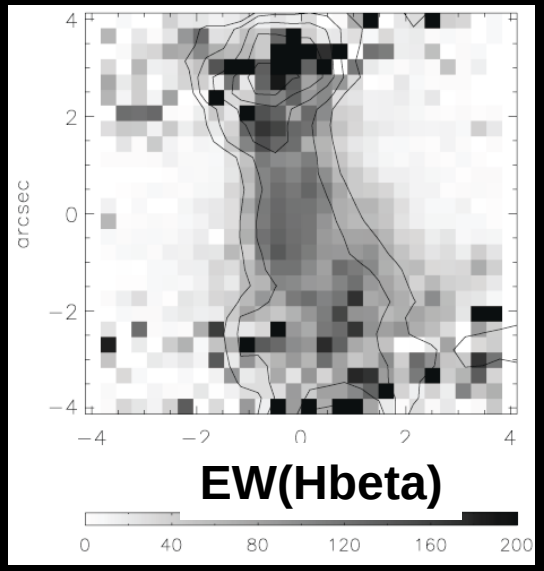


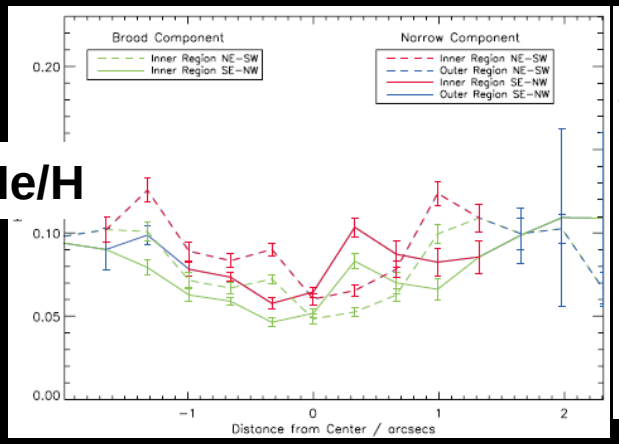
Crucially, the auroral lines [OIII] 4363 and [NII] 5754 Å are only found as broad components over the whole galaxy and cannot be used as straightforward temperature diagnostics

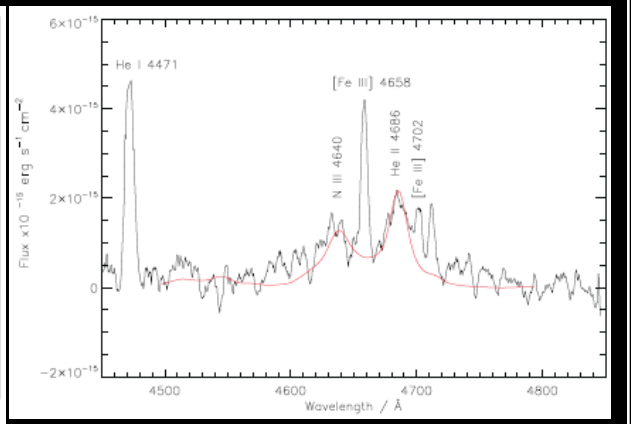


Abundances and N enrichment









Age ~ 3 – 5 Myr

O/H > 0.5 solar (at least 3 x higher than previously)

N/O (narrow) ~ 0.20 x solar
N/O (broad) ~ 4 x solar

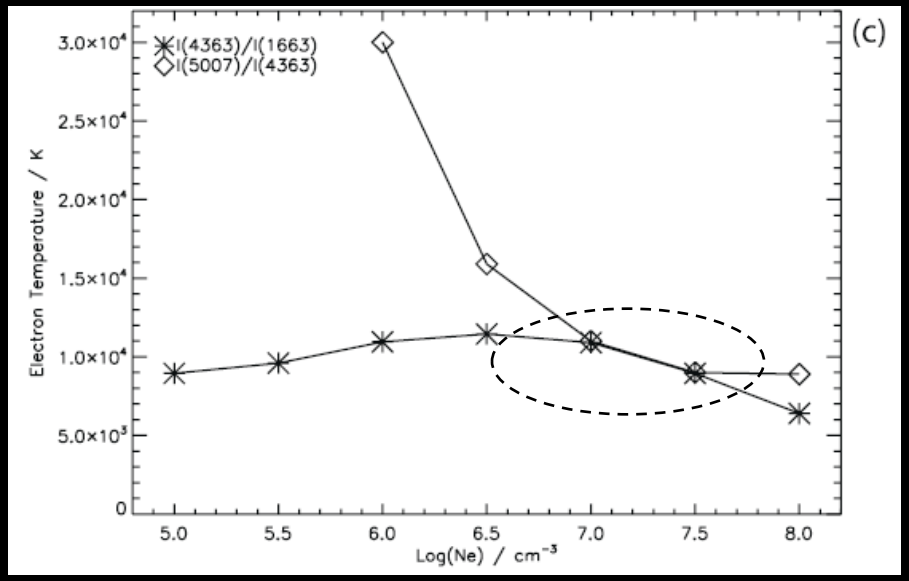
✓ N/H in dense broad line nuclear gas is 20x that in extended narrow line region

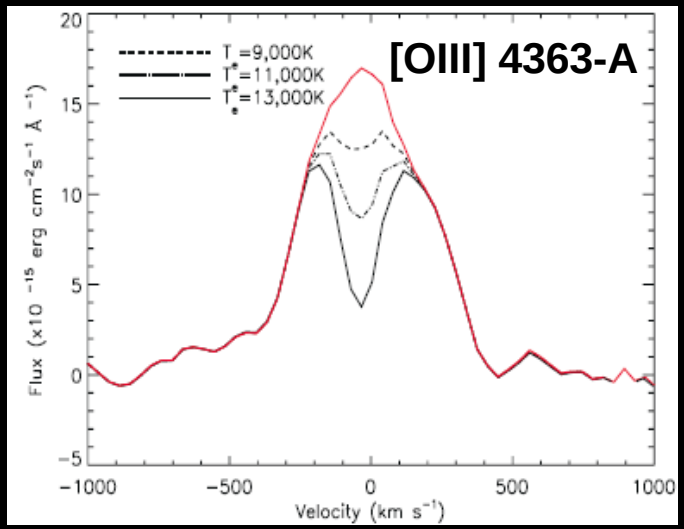
✓S/O and Ar/O ~ solar (in both broad/narrow region).

✓No He/H differential between narrow/broad regions.

✓3000 WR (WNL+WC stars in nucleus) and 150,000 OB-type stars

Physical conditions of broad and narrow line regions





Density of nuclear broad line region from [O III] 1663/4363, 4363/5007 line ratios again consistent as being very high

$N_e \sim 10^7$ cm^{-3}

The broad line region Te is normal ~ 11,000K

For the narrow line region an upper limit Te = 10,000K was found. Adopting the above values resulted in

O/H ~ 0.5 solar at least

3 x higher than published