MUSE 3D Spectroscopy and Kinematics of the Interacting Radio Galaxy PKS 1934-63

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Abstract

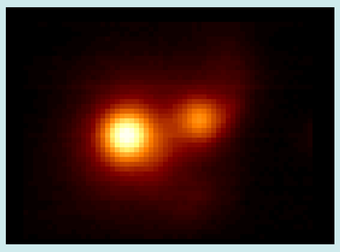
We observed the radio galaxy PKS 1934-63 (at $z = 0.1825$) using MUSE (Multi Unit Spectroscopic Explorer) on the VLT. This is a GigaHertz Peaked Source believed on the basis of very compact radio morphology (0.13 kpc aligned E-W) to be in a very early stage of evolution[1,2]. Our imaging and spectroscopy show an interacting pair of galaxies separated by 9.1 kpc and 216 km s^{-1}. The AGN host is a $10^{11}M_{\odot}$ elliptical and the companion galaxy a probable disk-type with extended star-formation visible in Hα. We map the kinematics in Hα and other lines, find rapid rotation in both galaxies and verify the interaction is prograde-prograde. The fast rotation seen in Hα for the primary galaxy may be a sign of star-formation around the AGN. This is probably the first close passage of the two galaxies, which trigged star-formation (in both?) from $\sim$ 10–20 Myr ago, followed by the radio outburst.

Observational Data

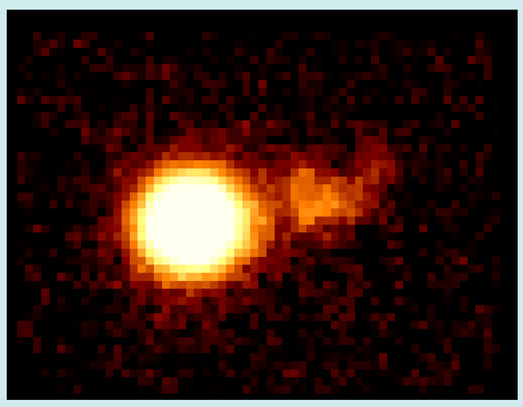
For the Science Verification run of the new MUSE spectrograph on the European Southern Observatory VLT we proposed observations of the radio galaxy PKS 1934-63, which were taken in June 2014, 6 exposures totalling 4040s. These we reduced and combined into a datacube which had continuous 3D imaging/spectroscopy over 1×1 arcmin, with 0.2 arcsec spatial and 1.25Å spectral pixels, coverage 4800–9300Å.

Imaging/Morphology

Like many radio galaxies PKS 1934-63 is interacting and has visible tidal features [3,4,5]. From the MUSE datacube we extract narrowband images in Hα and other lines.



MUSE image of PKS 1934-63 in a broad red band (6400–8000Å), showing 12×9 arcsec.



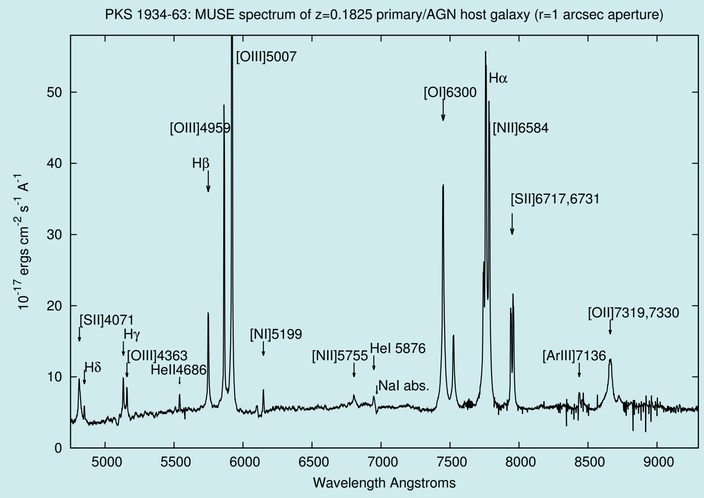
Continuum-subtracted Hα (7750–7774Å) image of PKS 1934-63, the bright primary galaxy hosting the AGN and the more irregular companion galaxy to the right (west). Nuclei are separated by 2.96 arcsec (9.10 kpc), on a PA $-77.0°$. Integrating the profiles gave total Hα fluxes 8.6×10^{-15} erg cm^{-2}s^{-1} ($L_{H\alpha} = 10^{41.91}$ erg s^{-1}) for the primary (AGN) and 3.5×10^{-16} erg cm^{-2}s^{-1} ($L_{H\alpha} = 10^{40.52}$ erg s^{-1}) for the second galaxy, which has no evidence of an AGN but the Hα signifies star-formation activity, at a rate 0.16–0.55 $M_{\odot}yr^{-1}$.

References

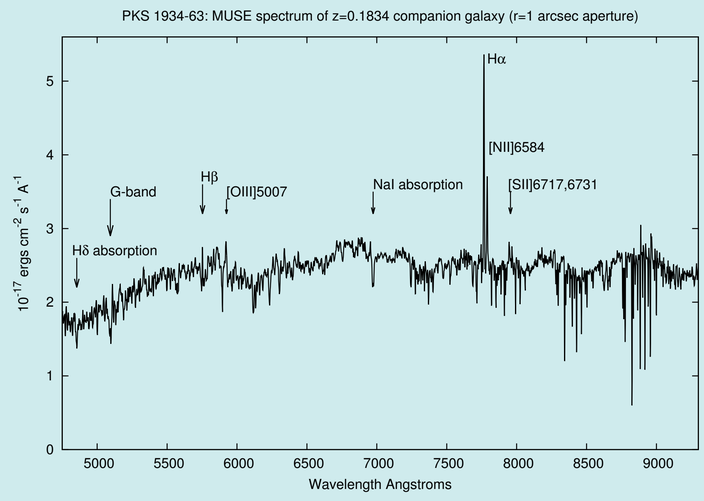
[1] Tzioumis A. *et al.*, 1989, AJ 98, 36.
[2] Ojha R.*et al.*, 2004, AJ 127, 1977.
[3] Heckman T.M. *et al.*, 1986, ApJ 311, 526.
[4] Inskip K.J. *et al.*, 2010, MNRAS 407, 1739.
[5] Ramos Almeida C. *et al.*, 2011, MNRAS 410, 1550.
[6] Kawakatu N., Nagao T. and Woo J.-H., 2009, ApJ 693, 1686.
[7] Cid Fernandes R. *et al.*, 2013, A&A 557, 86.
[8] Labiano A., *et al.*, 2008, A&A 477, 491.

Spectra

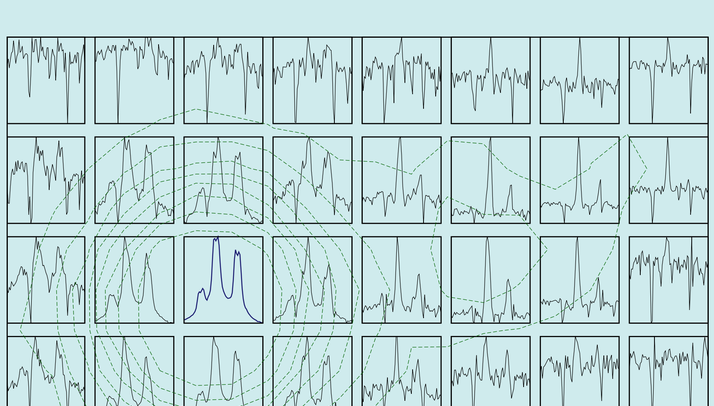
The primary galaxy/AGN shows many emission lines, [OIII]5007 the strongest. There is a high [OIII]5007/Hβ ratio (7.8) but also high ratios of [OI]6300 and [OIII]4363 to [OIII]5007 (0.56 and 0.047), which are characteristic of young radio-loud AGN (rather than typical Seyferts)[6].



The AGN host galaxy spectrum is fitted (Starlight models [7]) by a $\sim 10^{11}M_{\odot}$, 10 Gyr age stellar population typical of an elliptical, plus $\sim 10^{7}M_{\odot}$ of young (< 20 Myr) stars.

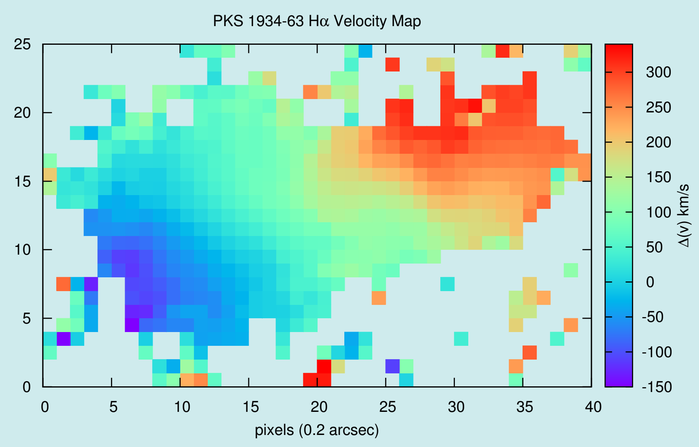


The star-forming companion galaxy spectrum is fitted by 1-10 Gyr old (mean 4 Gyr) stars plus a few $10^{6}M_{\odot}$ of very young (<20 Myr) stars. No evidence (e.g. strong Hδ absorption) of any previous starburst (30 Myr-1 Gyr ago).

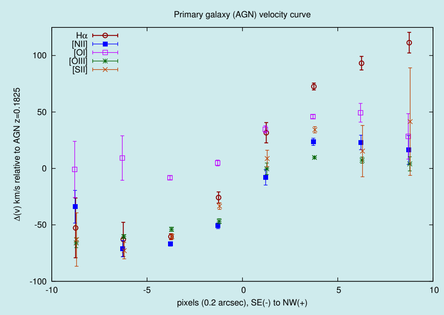


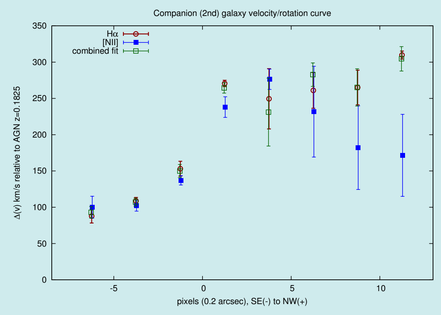
The Hα/[NII] spectral region in 1 arcsec^2 areas showing how the line profiles and ratios vary over the two galaxies, outlined by the green contours (of Hα brightness).

Kinematics



With the MUSE data we map the line-of-sight velocity shift in Hα and other lines, revealing the rotation of the two galaxies as well as their relative velocity $\Delta(v) = 216$ km s^{-1}. They are all in a similar direction (SE to NW) making this a prograde-prograde merger.





Rotation curves of the two galaxies (in Hα and other lines) measured along the kinematic axis, determined as position angle $-45°$ for the primary and $-34°$ for the companion, which has the ≥ 100 km s^{-1} rotation typical of a spiral.

Star-formation and the AGN

The current position of the companion galaxy appears almost aligned with the radio axis (E-W). The fast rotation (for an elliptical) of the primary galaxy, on $\phi = -45°$ is instead aligned with a central region of UV emission which was seen in HST data by [8]. For this galaxy we see a stronger signal of rotation in Hα compared to other lines, which may be evidence this is a fast-rotating star-forming region surrounding the AGN. It appears this system is at an early stage – the first close passage (perigalacticon) of the two galaxies, which $\sim$ 10–20 Myr ago began triggering star-formation, extensively in the disk galaxy and perhaps in the centre of the primary, quickly followed by the radio outburst.