Evolution in M_{BH}/M_{Bulge} since z~2?

Hα dynamical masses for HE0047-1756 (and friends)

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0 summary

The strong correlation between the masses of bulge and central supermassive black hole within massive galaxies is a crucial ingredient of models of galaxy formation and evolution. It is important that we understand the behaviour of this relationship over a wide range of cosmic epochs, particularly at higher redshifts when neither galaxies nor black holes had yet reached their current masses. In this study, we use PARSEC/SINFONI to attempt to determine bulge masses from the Hα gas kinematics within the host galaxies, for a pilot sample of Type 1 QSOs.

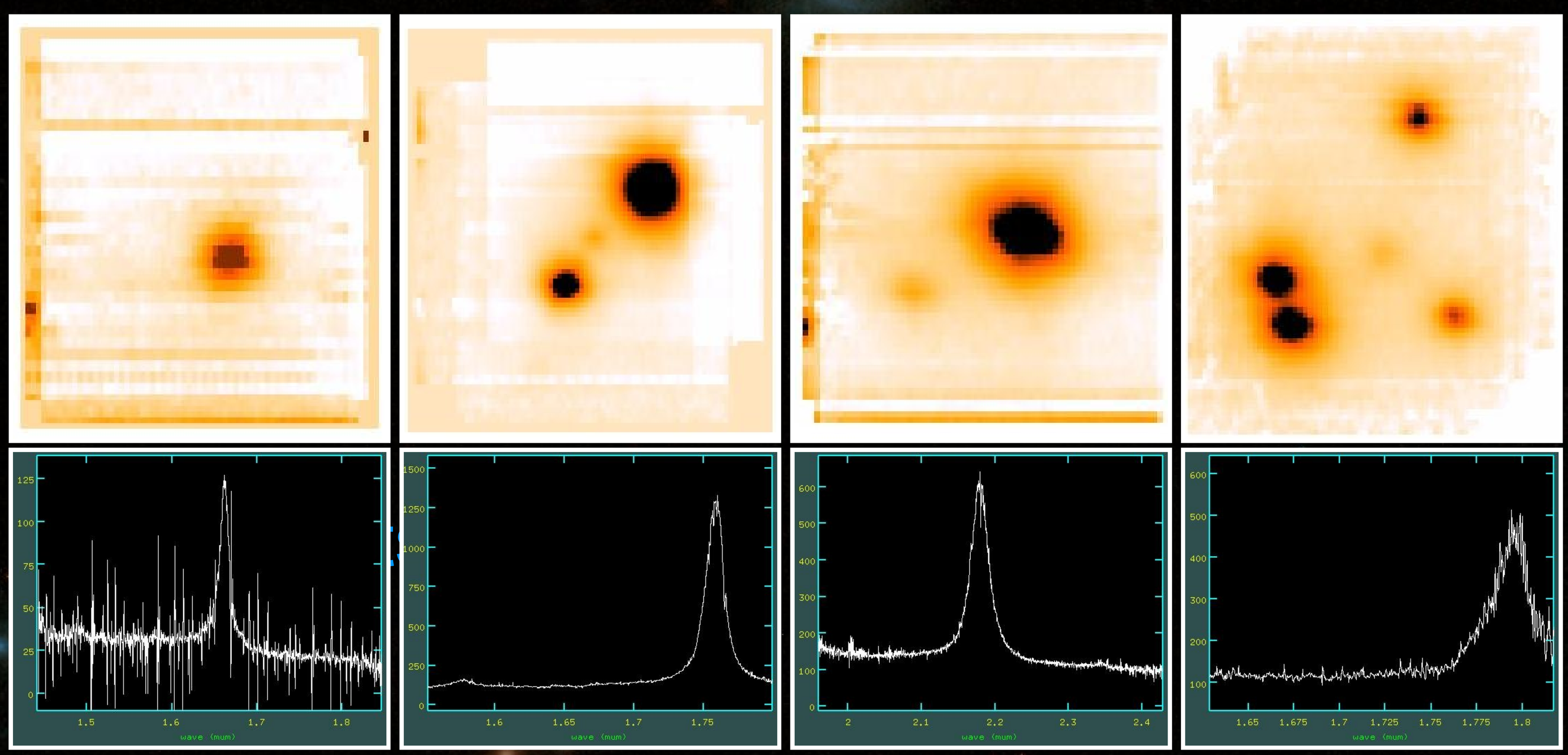

Fig 1: Median images of data cubes (top), with QSO peak-spaxel spectra (bottom)

1 observations

Our pilot sample consists of four sources

- 3 lensed QSOs from the CASTLES project[1]
- 1 SDSS DR3 QSOs with a nearby tip-tilt guide star, and a redshift which places Hα in the H-band.

Source	RA	Dec	Redshift	Time on Target
SDSSJ015410.38	01 54 10	-00 52 11	1.53	3600s
HE0047-1756	00 50 29	-17 40 08	1.66	4800s
HE1104-1805	11 06 33	-18 21 24	2.32	6000s
PG1115+080	11 18 17	+07 45 57	1.72	6300s

Observations were carried out with SINFONI[2,3]/PARSEC, and reduced using the standard ESO SINFONI reduction pipeline, with some additional adaptations (see forthcoming paper for details). Fig. 1 displays the median collapsed datacube, together with the spectrum extracted from the QSO peak-intensity spaxel, for each source.

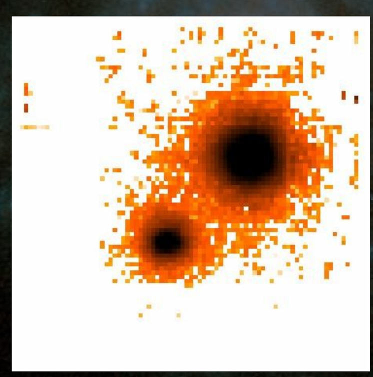

Fig 2: PSF image for HE0047-1756. [Note that the lensing galaxy visible in Fig. 1 between the two QSO components no longer appears]

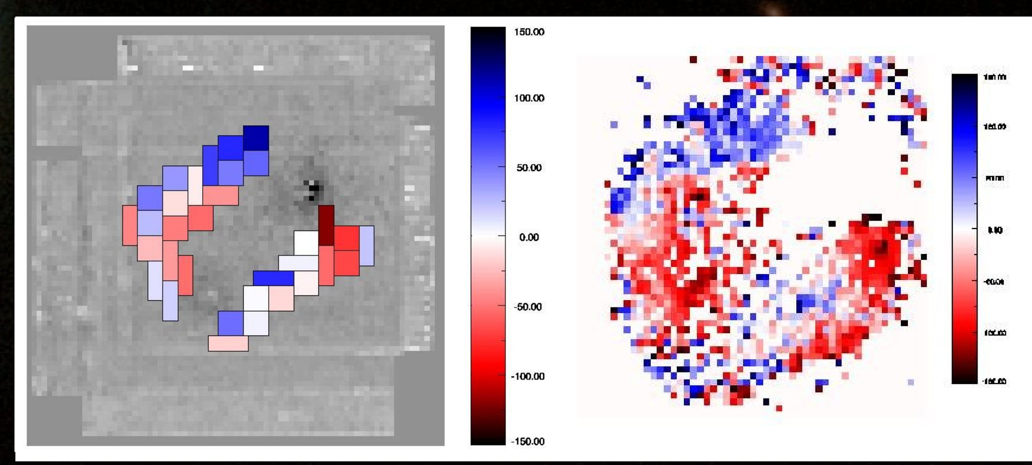

Fig 3: Velocity field observed for (left) multi-spaxel regions around HE0047-1756's Einstein Ring overlaid on the PSF-subtracted median image, and (right) an expanded view of the individual-spaxel kinematics (low line flux spaxels masked)

2 analysis

Although we only consider HE0047-1756 for the remainder of this poster, identical analysis methods have also been applied to the other three sources.

In order to obtain Hα velocities from the underlying host galaxy, the bright quasar emission must itself be removed. As this emission behaves as a point source, the broad emission lines can be used to model the PSF.

Working within wavelength ranges which do not contain narrow Hα, we remove the underlying continuum emission and (for each quasar component where lensed) determine the relative strength of broad line emission in each spaxel.

The resulting PSF scaling map (Fig. 2) is multiplied by the peak spaxel spectrum for each lensed QSO component, which consists almost entirely of AGN emission, thus creating a quasar emission datacube.

Subtraction of this datacube effectively removes all quasar emission from our data, allowing us to probe the remaining Hα emission due to the host galaxy itself.

The narrow Hα emission from the host galaxy is located and modelled, allowing a relative velocity field to be generated for this source (Fig. 3). For HE0047-1756, conversion between image plane and source plane can be achieved using existing, very precise, lensing models[5] (Fig. 4).

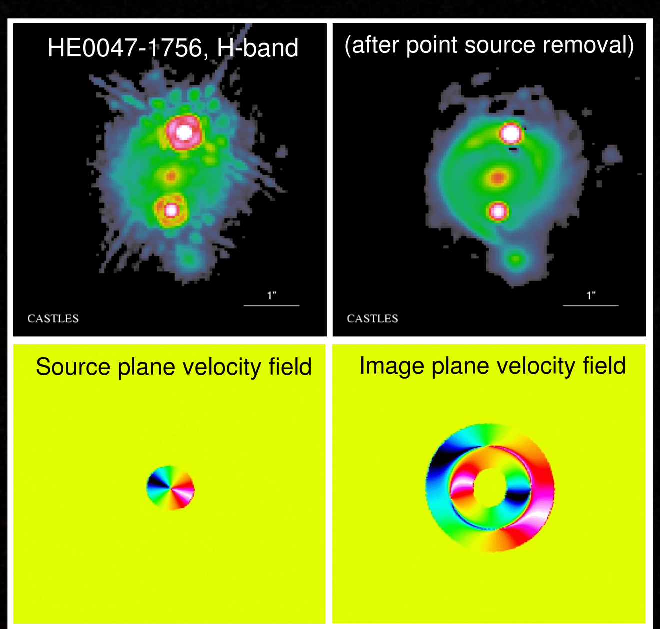

Fig 4: (top) H-band images of HE0047-1756 before and after point source removal. (bottom) Lensing model for HE0047-1756.

[Note, Fig. 4 is rotated by ~45 degrees with respect to Figs. 1, 2 and 3]

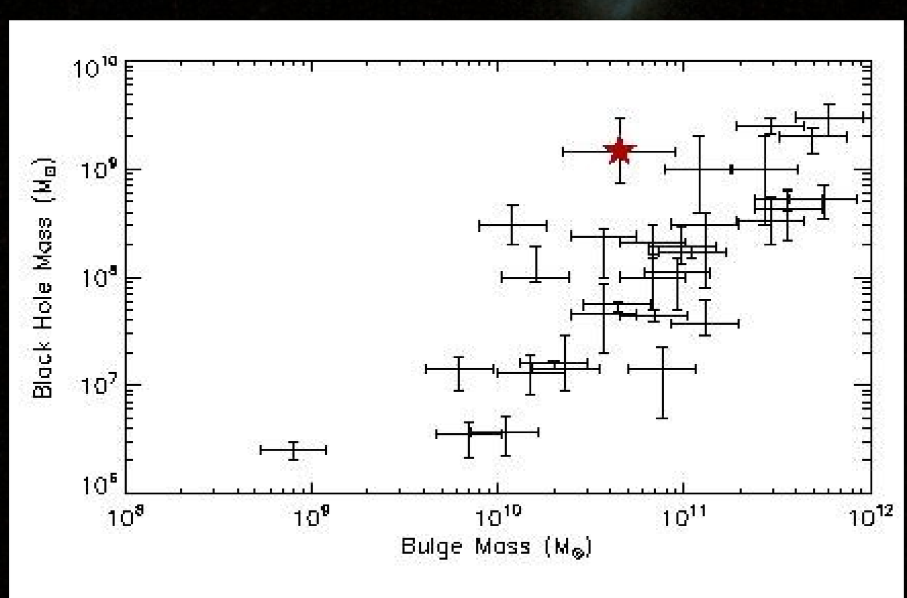

Fig 5: Plot of black hole mass vs. bulge mass for galaxies in the local universe, taken from Häring & Rix (2004)[8]. The derived position of the z=1.66 QSO HE0047-1756 is marked by the red star

3 estimating $\mathcal{M}_{BH}/\mathcal{M}_{Bulge}$

The mass of the black hole in HE0047-1756 has been previously determined by Peng et al[5] using the virial technique applied to the CIV emission line width and the local continuum luminosity, along with the normalisation of Onken et al[6] and BLR radius estimates of Kaspi et al[7]. This gives $\mathcal{M}_{BH} = 1.48\times10^9 M_\odot$.

The observed velocity field varies by up to ±150 km s^{-1} over a region which corresponds to ~0.73 arcsec in the source plane. At a redshift of 1.66, this corresponds to ±150 km s^{-1} over approximately 6.2 kpc.

Assuming we are observing a rotating system at an inclination angle of 45 degrees, this implies a dynamical mass of $\mathcal{M}_{Bulge} = 4.5\times10^{10} M_\odot$.

In Fig 5, we display the $\mathcal{M}_{BH}/\mathcal{M}_{Bulge}$ relation for the nearby galaxy sample of Häring & Rix[8], also including HE0047-1756. Our measured value of $\mathcal{M}_{BH}/\mathcal{M}_{Bulge}$ ~ 1/30 implies a considerably less massive galaxy than that typical of the hosts of comparable mass black holes at z=0.

A less precise means of estimating $\mathcal{M}_{Bulge}$ is to use the host galaxy magnitude. Although the M/L ratio is unknown, plausible values to bracket the true value can be assumed. For this source M_R~-23.69[5]. Using the M/L formularisation of Bell & de Jong[9] and assuming SEDs typical of either old or young stellar populations suggests stellar masses of $4.3\times10^{11} M_\odot$ and $1.3\times10^{11} M_\odot$ respectively, and $1/300 \lesssim \mathcal{M}_{BH}/\mathcal{M}_{Bulge} \lesssim 1/90$. Our dynamical mass suggests the upper limit for a younger, bluer galaxy is more plausible.

4 conclusions

Despite the technical challenges involved in this project - determining gas kinematics of gravitationally lensed quasar host galaxies using adaptive optics IFU spectroscopy is non-trivial at almost every stage - we have nonetheless demonstrated its feasibility.

For HE0047-1756, we have detected the inherent velocity field of the host galaxy, and determined an associated dynamical mass. Although this mass is ~3-10 times smaller than the host magnitude based mass, the resulting ratio $\mathcal{M}_{BH}/\mathcal{M}_{Bulge}$ is comparable to some other high-z CO-based measurements[10]. This would add further weight to the argument in favour of evolution in the $\mathcal{M}_{BH}/\mathcal{M}_{Bulge}$ relation, with massive black holes existing in relatively less massive host galaxies at earlier cosmic epochs.

5 references & acknowledgements

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