BLACK HOLE MASS SCALING RELATIONS FOR SPIRAL GALAXIES DETERMINED FROM PITCH ANGLES AND MULTICOMPONENT STRUCTURAL DECOMPOSITIONS

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Abstract

In an effort to derive accurate bulge magnitudes for the current full sample of 43 spiral galaxies with directly measured supermassive black hole masses, we have analysed their images and light profiles in exquisite detail. We found that it was important to account for not just the bars, but also the rings and partial rings, i.e. ansae, at the ends of these bars. We have additionally performed a careful measurement of the spiral-arm "pitch angles" for these galaxies. This has enabled us to revise the black hole scaling relations for spiral galaxies, using more accurate measurements than ever before, and with a sample size which is double that of previous works. A symmetric Bayesian analysis finds $\log(M_{BH}/M_\odot) = 2.32\log(\upsilon_{IMF}M_{*,sph}/1.5\times10^{10}\,M_\odot) + 7.23$, with υ_{IMF} an initial mass function dependent, stellar mass-to-light ratio term. This reinforces previous observational studies and several simulations, which have shown a near-quadratic slope at the low-mass end of the M_{BH}-$M_{*,sph}$ diagram. The non-linear slope additionally rules out the idea that many mergers, coupled with the central limit theorem, produced this scaling relation, and it has important implications for the formation pathway of supermassive black holes.

The (Black Hole Mass)—(Spiral Arm Pitch Angle), M_{BH}—ϕ, Relation
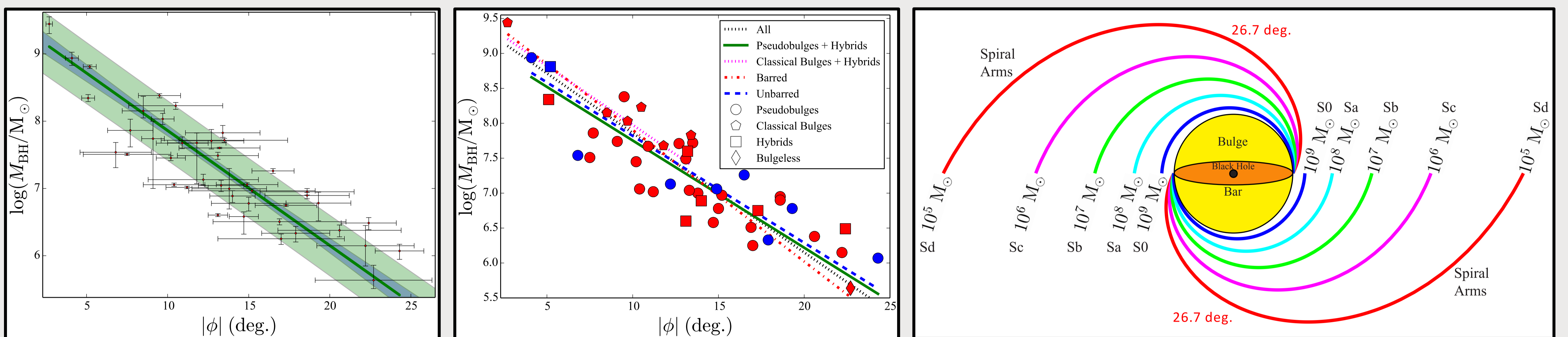
$\log(M_{BH}/M_\odot) = (7.01 \pm 0.07) - (0.171 \pm 0.017)[|\phi| - 15°]\text{deg.}^{-1}$ • Davis et al., *MNRAS*, Volume 471, Issue 2, 21 October 2017, Pages 2187-2203

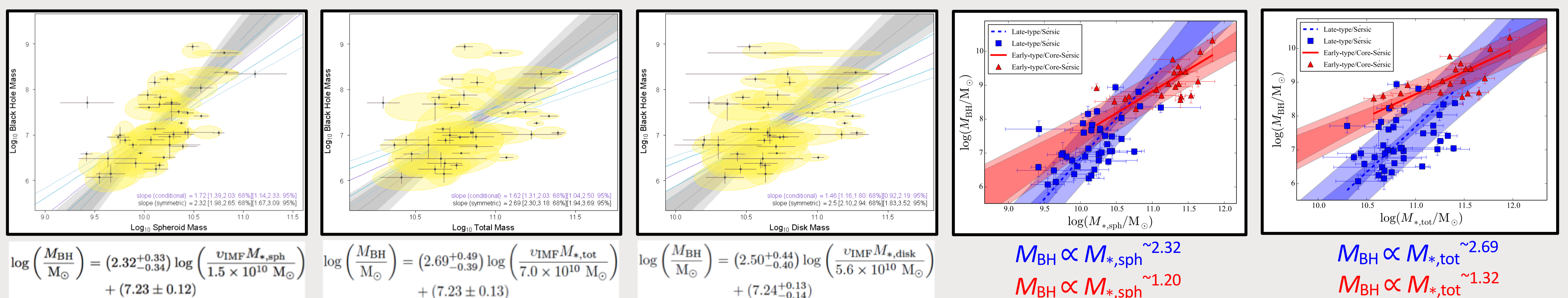## Multicomponent Surface Brightness Profile Decompositions

UGC 3789
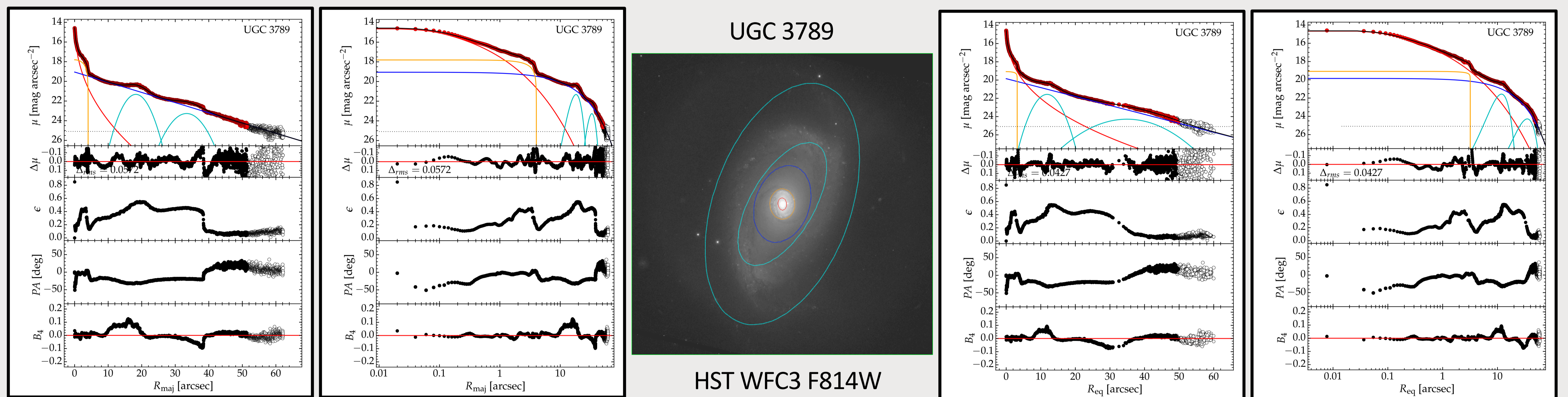
HST WFC3 F814W

HST WFC3 *UVIS2 F814W* surface brightness profile for the major-axis (left two panels) and the equivalent-axis, $R_{eq} = R_{maj}(1-\epsilon)^{1/2}$, (right two panels) of UGC 3789 after sky subtraction and PSF convolution. With an estimated distance of 49.6 Mpc, the physical sizes can be converted via 0.2405 kpc/". $\log(M_{BH}/M_\odot) = 7.06 \pm 0.07$, $\log(M_{*,sph}/M_\odot) = 10.41 \pm 0.13$, $\log(M_{*,tot}/M_\odot) = 10.85 \pm 0.12$, and $\log(M_{*,disk}/M_\odot) = 10.65 \pm 0.12$.

Sérsic Bulge • Exponential Disk • Ferrers Bar • Gaussian: Ring & Spiral Arm

Ciambur (2015), ApJ, 810, 120 • Ciambur (2016), *PASA, 33*, E062 • Davis, Graham, & Cameron (submitted to ApJ)

Black Hole Mass Scaling Relations Involving Stellar Mass

$$\log\left(\frac{M_{BH}}{M_\odot}\right) = \left(2.32^{+0.33}_{-0.34}\right)\log\left(\frac{\upsilon_{IMF}M_{*,sph}}{1.5\times10^{10}\,M_\odot}\right) + (7.23 \pm 0.12)$$

$$\log\left(\frac{M_{BH}}{M_\odot}\right) = \left(2.69^{+0.49}_{-0.39}\right)\log\left(\frac{\upsilon_{IMF}M_{*,tot}}{7.0\times10^{10}\,M_\odot}\right) + (7.23 \pm 0.13)$$

$$\log\left(\frac{M_{BH}}{M_\odot}\right) = \left(2.50^{+0.44}_{-0.40}\right)\log\left(\frac{\upsilon_{IMF}M_{*,disk}}{5.6\times10^{10}\,M_\odot}\right) + (7.24^{+0.13}_{-0.14})$$

$$\upsilon_{IMF} = \frac{\Upsilon_{*,Chabrier}}{\Upsilon_{*,You}}$$

$M_{BH} \propto M_{*,sph}^{\sim2.32}$
$M_{BH} \propto M_{*,sph}^{\sim1.20}$

$M_{BH} \propto M_{*,tot}^{\sim2.69}$
$M_{BH} \propto M_{*,tot}^{\sim1.32}$

Davis, Graham, & Cameron (submitted to ApJ) • Early-type galaxies from Savorgnan et al. (2016), ApJ, 817, 21