SUBSTRUCTURE IN SCALING RELATIONS AND ITS EFFECT ON THE COEVOLUTION OF SUPERMASSIVE BLACK HOLES WITH THEIR HOST GALAXIES

Benjamin Davis, Swinburne University of Technology

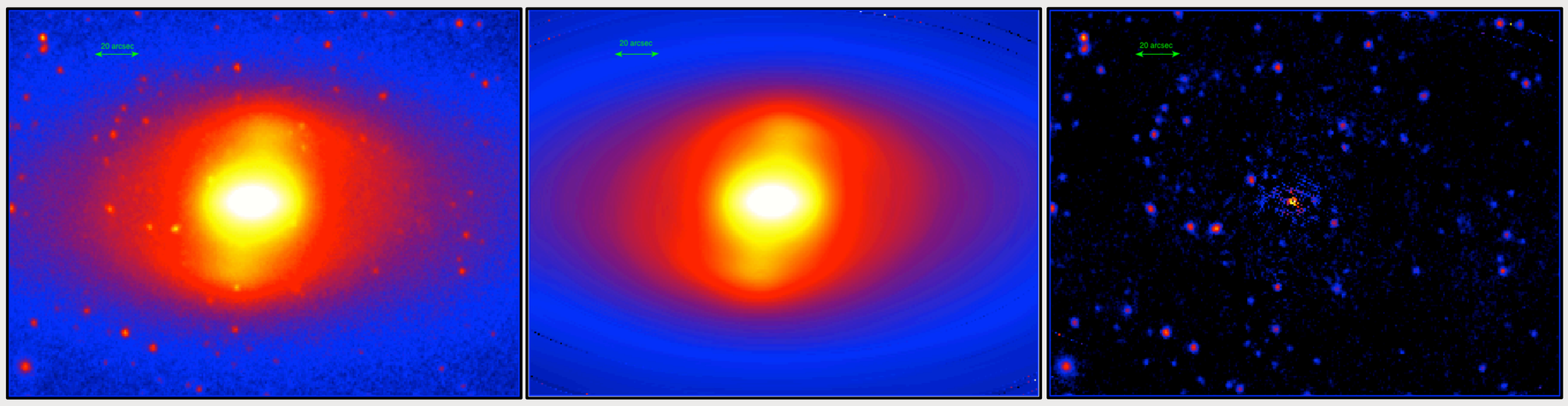
Email: benjamindavis@swin.edu.au, Mobile: +61 420 690 906, Website: bendavis007.github.io

Abstract

Our multi-component photometric decomposition of the largest galaxy sample to date with dynamically measured black hole masses nearly doubles the number of such galaxies. We have discovered substantially modified scaling relations between the black hole mass and the host galaxy properties, including the spheroid (bulge) stellar mass, the total galaxy stellar mass, and the central stellar velocity dispersion. These refinements partly arose because we were able to explore the scaling relations for various sub-populations of galaxies built by different physical processes, as traced by the presence of a disk, early-type versus late-type galaxies, or a Sérsic versus core-Sérsic spheroid light profile. The new relations appear fundamentally linked with the evolutionary paths followed by galaxies, and they have ramifications for simulations and formation theories involving both quenching and accretion.

Multicomponent Surface Brightness Profile Decompositions

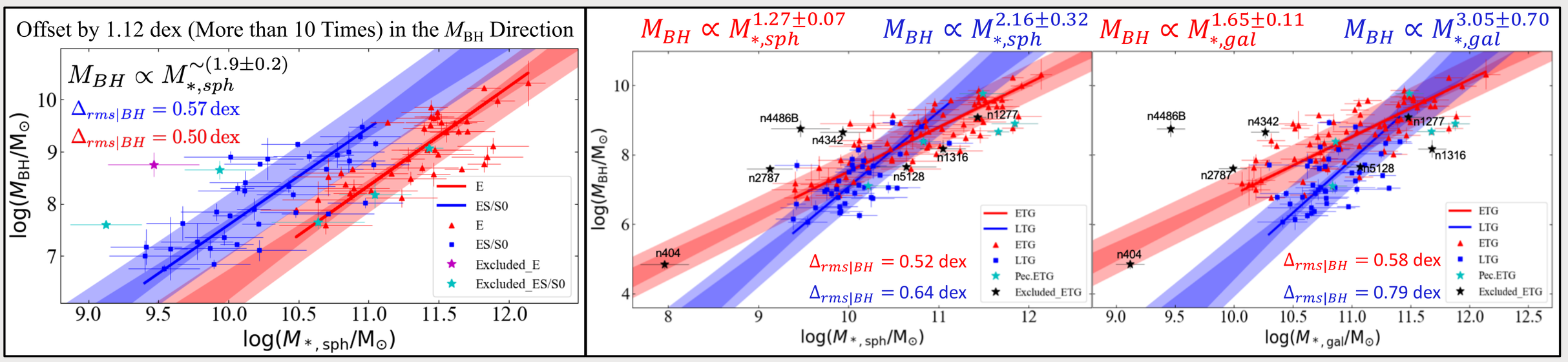
NGC 4371: Spitzer 3.6-micron Image | **Isophotal Model via ISOFIT and CMODEL** | **Residual = Image – Model** | **Surface Brightness Profile via PROFILER**



- ≈140 galaxies modeled, and surface brightness profiles decomposed.
- ISOFIT and CMODEL
  - Uniformly samples elliptical isophotes via eccentric anomaly parameter.
  - Quantifies perturbations in each isophote by including higher-order Fourier harmonic coefficients.
- PROFILER: analyzes the radial surface brightness profiles of galaxies.

ISOFIT and CMODEL
Ciambur (2015), ApJ, 810, 120
PROFILER
Ciambur (2016), PASA, 33, e062
Ciambur (2017), ascl:1705.010

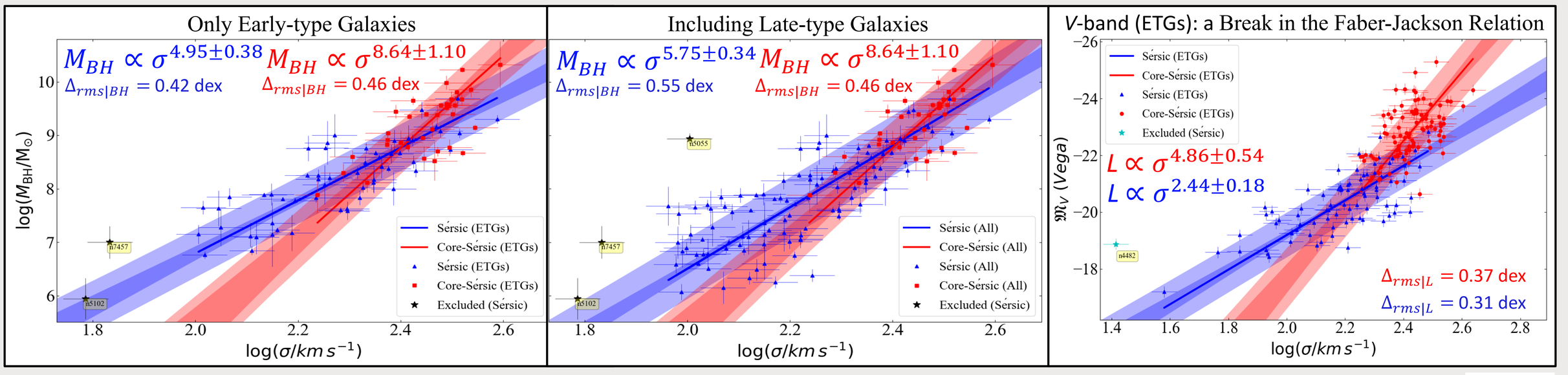
Morphology-dependent Black Hole Mass Scaling Relations



- 76 early-type galaxies (ETGs) and 40 late-type galaxies (LTGs), all with directly measured supermassive black hole masses.
- ETGs with (ES/S0) and without (E) disks are offset due to the exclusion of the disk mass in ES/S0 galaxies.
- Black holes and their host galaxies **DO NOT** grow in lockstep; their coevolution is non-linear (slopes > 1).
- Black holes in LTGs follow scaling correlations with slopes approximately twice that of ETGs.

Davis et al. (2018), ApJ, 869, 113
Davis et al. (2019), ApJ, 873, 85
Sahu et al. (2019a), ApJ, 876, 155

Revealing Hidden Substructures in the $M_{BH}-\sigma$ Diagram, and Refining the Bend in the $L-\sigma$ Relation



- 145 early- and late-type galaxies, all with directly measured supermassive black hole masses.
- The bent relation is linked with the evolutionary paths of Sérsic and core-Sérsic galaxies.
- Core-Sérsic: Dry (gas poor) major mergers; Sérsic: Gas abundant (wet) mergers or gas abundant accretion.

Sahu et al. (2019b), ApJ, 887, 10

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