Revisiting the black hole – host galaxy scaling relations with the SMASHING sample

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Black hole demographics

- More than 100 SMBH dynamical measurements for nearby galaxies
- Morphological bias
- Small number of galaxies measured below $\sigma_*=100$ km/s
- Dynamical measurements only for the nearby universe

Thater et al. (in prep.)
How to measure MBH dynamically

- Direct measurement: Use a dynamical tracer (gas/stars) which is accelerated by the black hole (→ Kinematics)
- The collective potential of stars or gas on scales of the black hole sphere of influence is modeled, with the central mass as a free parameter

\[ \phi_{\text{all}} = \phi(M_{\text{BH}}) + \phi(M_{\text{G}} \cdot M/L) \]

Morphology:
- Gas-rich Galaxies
- Gas-poor Galaxies
- Type 2 AGNs
- Type 1 AGNs

Primary Methods:
- Gas Dynamics
- Stellar Dynamics
- Water Megamasers
- Reverberation Mapping
Comparison of different methods

- Different tracers often give discrepant results
- Ionized gas measurements usually give lower black hole masses (about 2-3)
- In order to understand this problem we need a good understanding of the assumptions and systematics of the different methods

Onishi 2017 (PhD thesis)
NGC 6958 – an ideal candidate

- Isolated elliptical galaxy
- Signature of CO disk in the center
- Distance = 35 Mpc
  → 170 pc/arcsecond
- Velocity dispersion: $\sigma = 200 \text{ km/s}$
  → expected black hole mass: $M_{\text{SMBH}} = 1.7 \times 10^8 M_{\odot}$
- Sphere-of-influence: $r_{\text{SOI}} = 0.13 \text{ arcsec}$
- We have obtained MUSE LGS AO data and ALMA cycle 3 data.
Project 1: A consistency test between 2 different methods

Stellar Kinematics
- Use stars as tracer of the galaxy potential
- Modeling is either done by solving the Jeans equations or with orbit-based dynamical modeling
- Resolution is set by HST/AO
- Works best in early-type galaxies
- Problems can arise due to varying stellar populations

Molecular Gas Kinematics
- Use molecular gas disk as tracer of galaxy potential
- Modeling of the galaxy velocity field (full cube or PVD diagram)
- Resolution currently set by ALMA
- Can be applied to a wide range of galaxies
- Cold gas is less affected by turbulent motion than ionized gas
Project 1: A consistency test between 2 different methods

Stellar Kinematics

M_{SMBH} = 5.2 \pm 0.2 \times 10^8 \, M_{\odot}

M_{SMBH} = 1.4 \times 10^8 \, M_{\odot}

Thater et al. (in prep.)
Project 2: SMASHING

- 19 mainly early-type galaxies
- Subsample of the Atlas$^{3D}$ survey (Cappellari+2011)
- High-resolution observations with GEMINI/NIFS and VLT/SINFONI using LGS and NGS AO
- Integrated bulge stellar velocity dispersions known from ATLAS$^{3D}$ (Cappellari+2013)
The SMASHING sample

Krajnović et al. 2018, Thater et al. 2018 (soon submitted), Thater et al. 201X

The Carnegie-Irvine Galaxy Survey, SDSS

July 19th, 2018

Sabine Thater: The SMASHING sample

The Physics of Galaxy Scaling Relations
Kinematic results – a few cases

Thater et al. (in prep.)
The $M_{BH} - \sigma_e$ relation

Thater et al. 2017, Krajnović et al. 2018, Thater et al. (in prep)
The $M_{BH} - \sigma_e$ relation

Thater et al. 2017, Krajnović et al. 2018, Thater et al. (in prep)

![Graph showing the $M_{BH} - \sigma_e$ relation with data points and trend lines.]

**Log $M_{BH}$ (M$_{\odot}$) vs. Log $\sigma_e$ (km/s)**

- Saglia+2016 (All)
- McConnell+2013 (All)

**Data Points:***
- Ellipticals
- S0
- Spirals
- SMASHING
$M_{\text{BH}} - \sigma_e$ relation

Thater et al. 2017, Krajnović et al. 2018, Thater et al. (in prep)

$$\log_{10} M_{\text{BH}} = (4.51 \pm 0.4) \log_{10} (\sigma) - 1.94 \pm 0.8$$
Summary and Outlook

• Mass measurements from different tracers sometimes give discrepant results. Understanding the systematics related to the methods is crucial to understand the discrepancy.

• MBH sample and mass range are limited, so populating the scaling relations with more measurements is important.

• We have analyzed 20 early-type galaxies and constrained 17 SMBH masses (with stellar kinematics) confirming the idea of different scaling relations for early-type and late-type galaxies, maybe because of different formation scenarios.