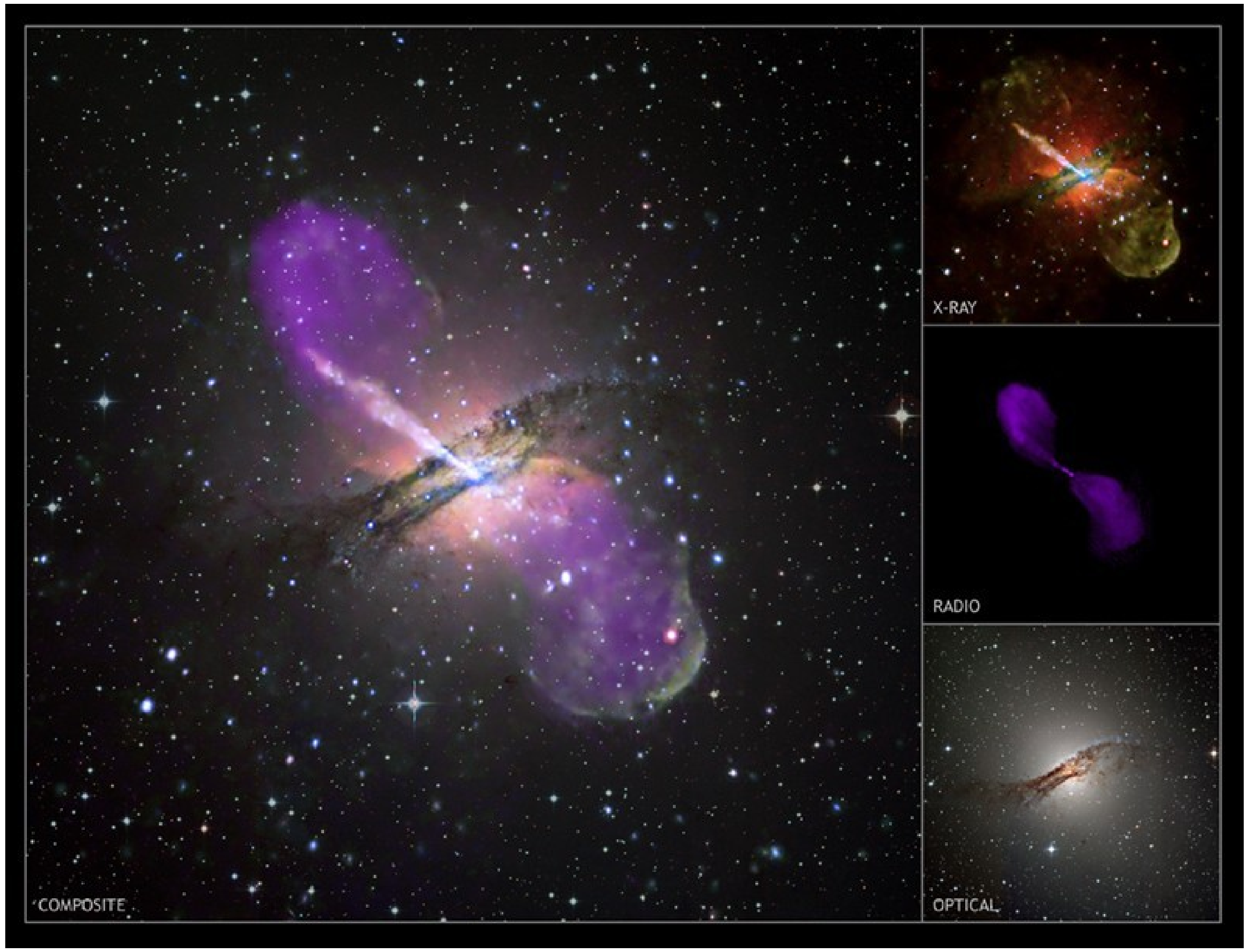
Searching for the seeds of supermassive Black Holes

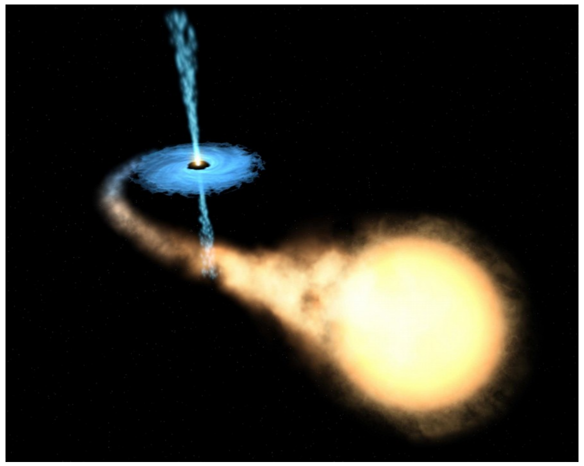
Treasures hidden in High Energy Catalogues

Speaker:
Filippos Koliopanos

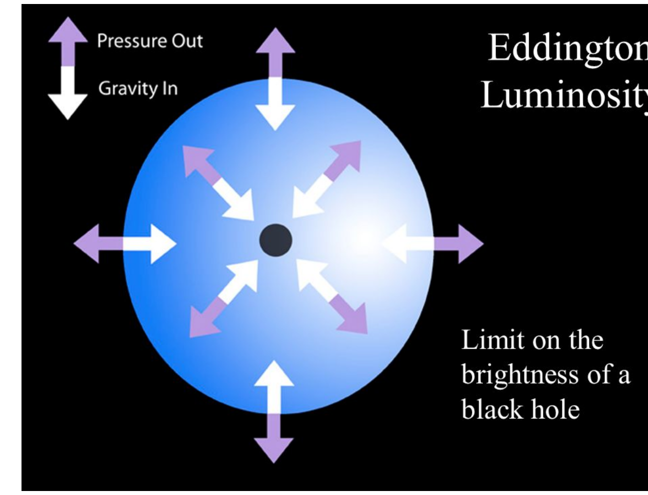
How do supermassive black holes form ?

Accretion onto smaller seeds



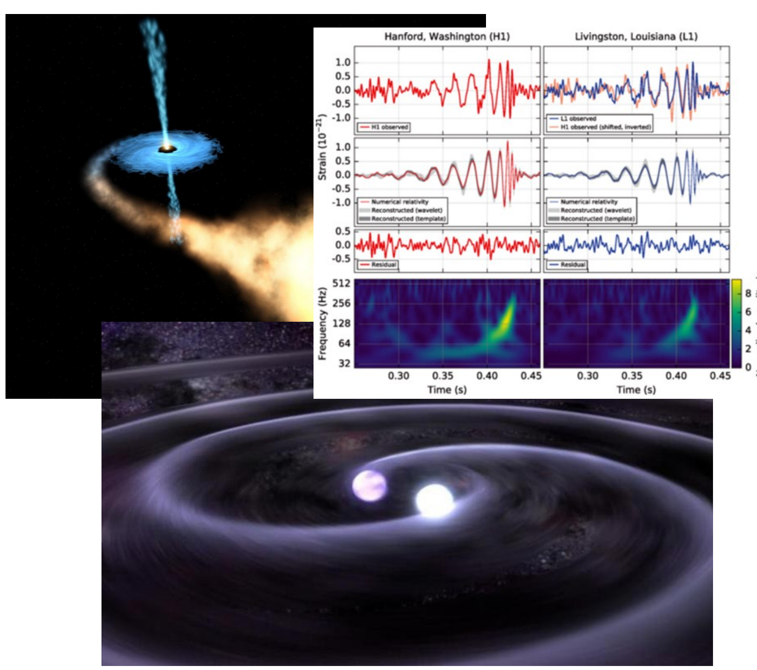


The Eddington limit



Intermediate mass black holes: 10^3-$10^5 M_\odot$

See reviews by Mezcua 2017
Koliopanos 2018



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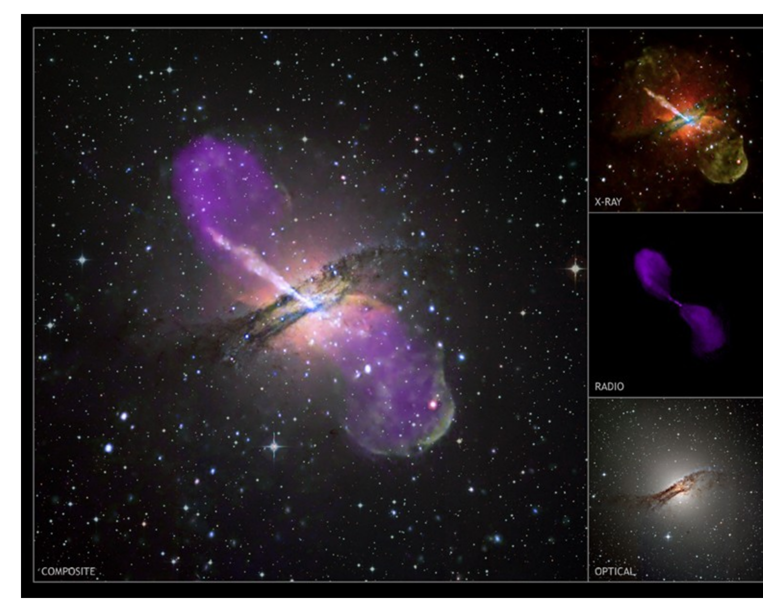
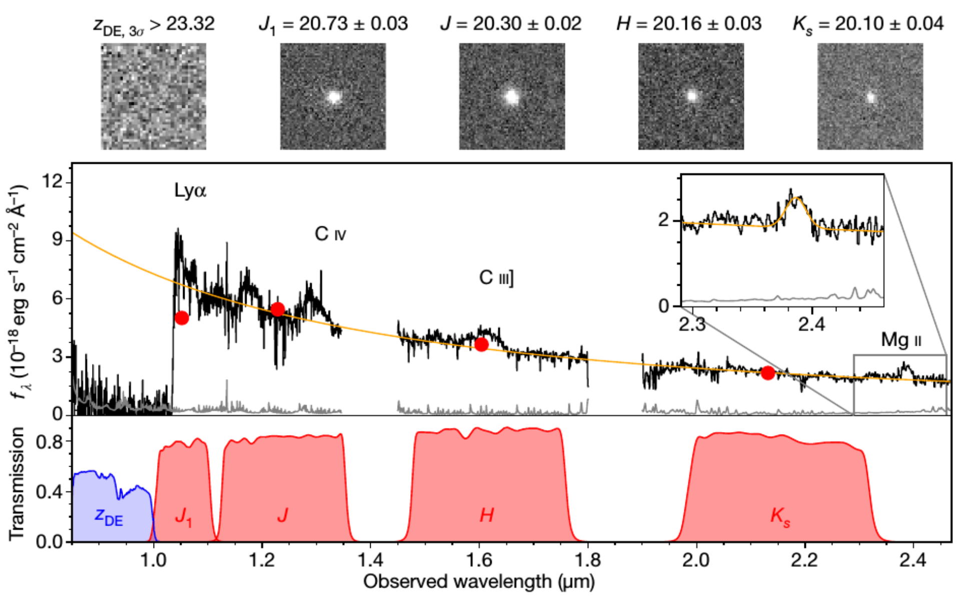


X-ray - NASA, CXC, R.Kraft (CfA), et al.;
Radio - NSF, VLA, M.Hardcastle (U Hertfordshire) et al.;
Optical - ESO, M.Rejkuba (ESO-Garching) et al.

800 Million solar mass SMBH at z>7

- These accreting **supermassive BHs** (>10^8Msol) appear to have been formed within a less than **700Myr** from the Big Bang. (e.g.,Mortlock et al. 2011; Banados et al. 2018)



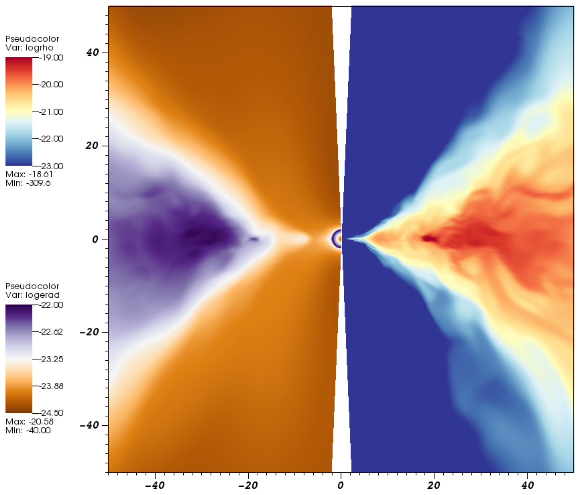
Banados et al. 2018

- **How are these "Titans of the early universe": formed?**

- With a ≤**10^3M⊙** seed it will need to constantly accrete at the Eddington limit

Seed mass and formation mechanisms

- **Light Seeds** ($M<10^3 M_{sol}$): Prolonged **super**-Eddington accretion, or episodic **hyper**-Eddington **accretion**
  Slim Disks?
  (Volonteri & Rees 2005; Wyithe & Loeb 2011; Alexander & Natarajan 2014; Madau et al. 2014; Volonteri et al. 2014; Pacucci et al. 2016)



- Massive outflows.

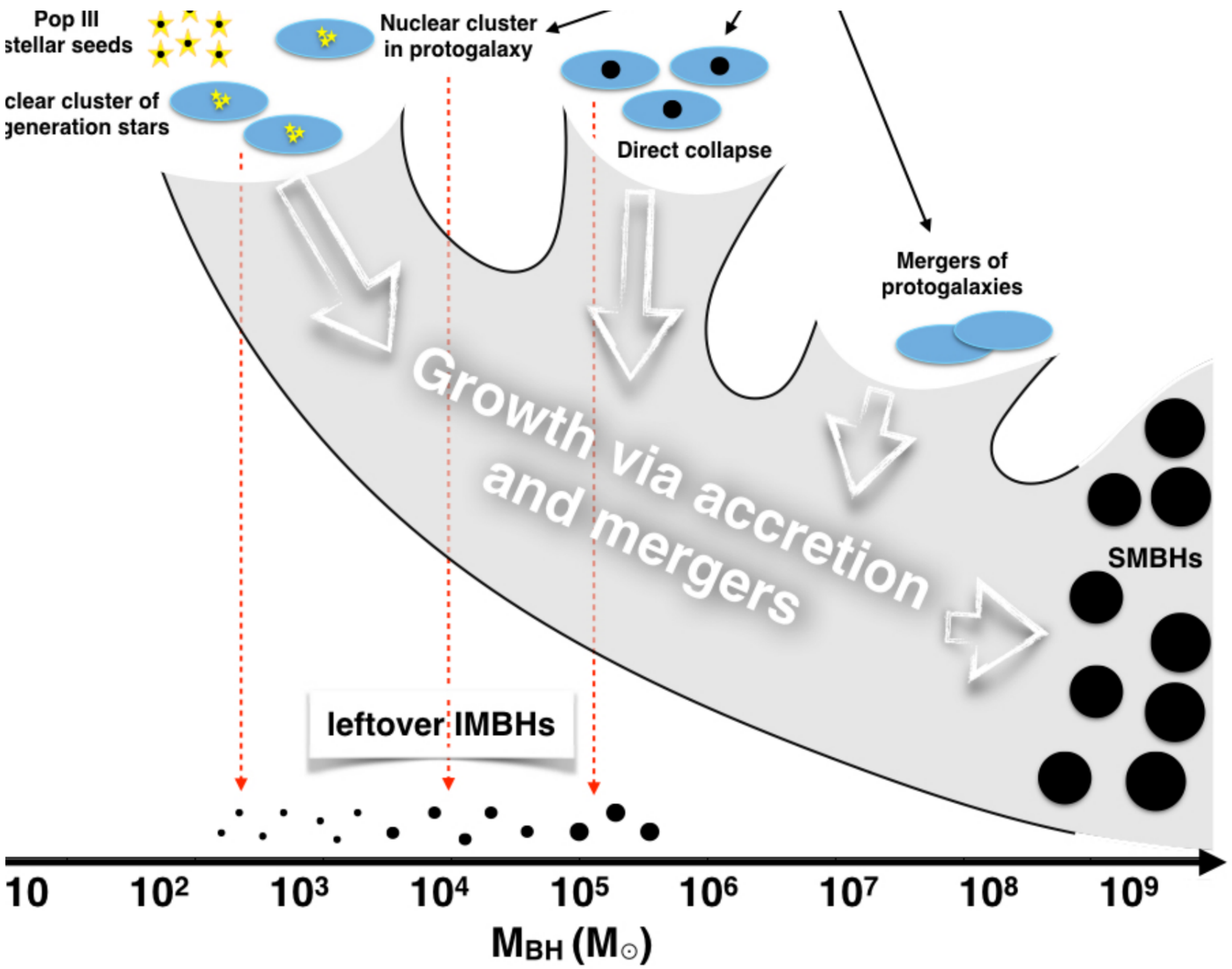
- Ionizing feedback

- **Heavy Seeds:** Direct collapse to a $>10^5 M_{sol}$ black hole
  -Collapse of pristine gas formation of supermassive star
  (e.g., Oh & Haiman 2002; Bromm & Loeb 2003; Tanaka & Li 2014; Woods+ 2017)

  -Merger driven inflows result in direct collapse of ultra-dense, disky core
  (e.g., Mayer, Kazantzidis et al. 2010; Bonoli et al 2014; Mayer 2015)

IMBHs as seed relics

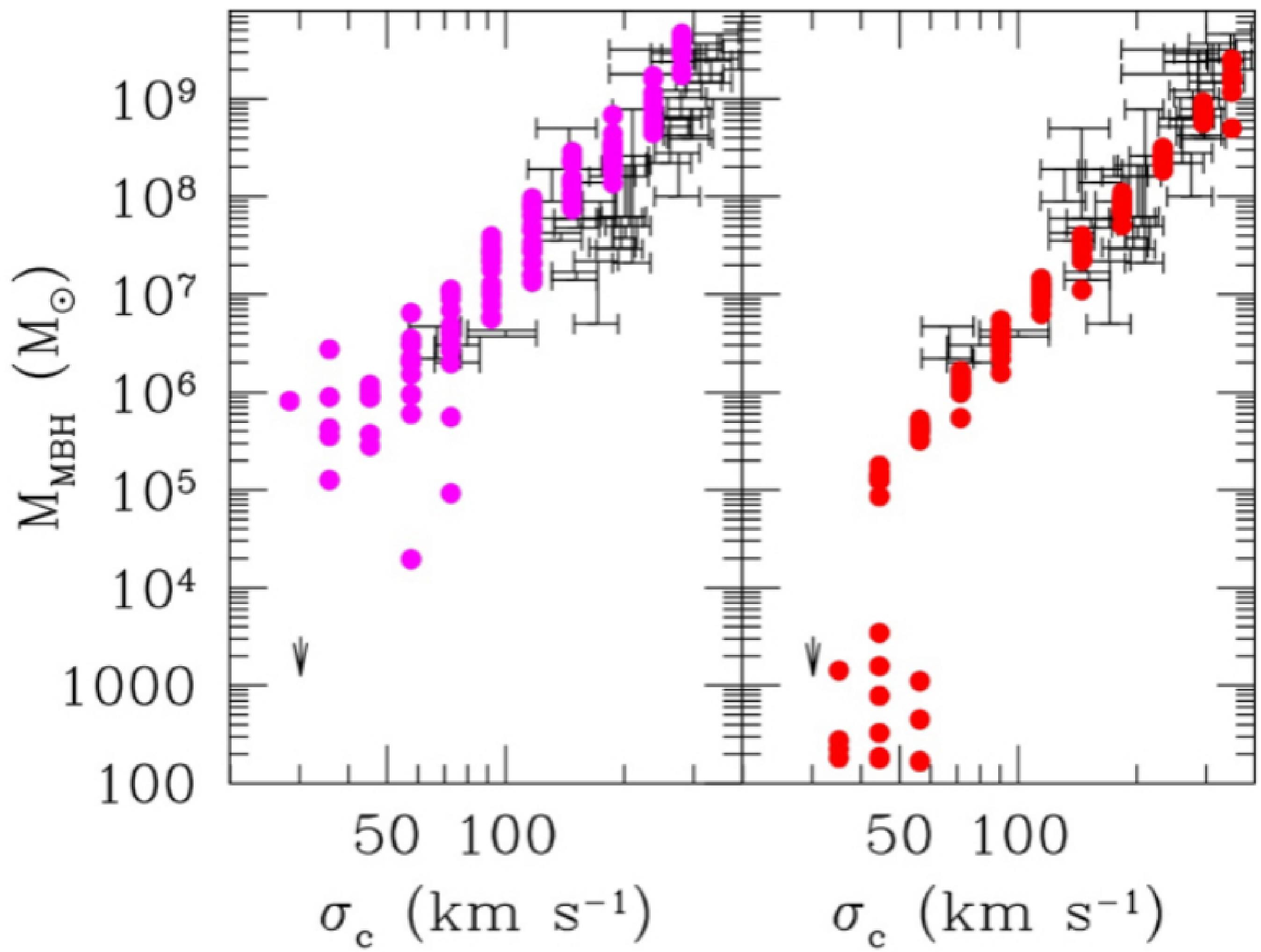
- Relics of the different mechanisms
  - *- Evolution of Pop III stars*
    (e.g. Haiman &Loeb 2001; Madau & Rees 2001; Schneider+ 2002; Ryu+ 2016)
  - *- Direct collapse of 10^8 M_{sol} gas*
    ds+ 2017)



Mezcua 2017

IMBH demographics

- **What are the lower mass IMBHs?**
  - Populating the **M-σ diagrams** may reveal seeds of SMBHs

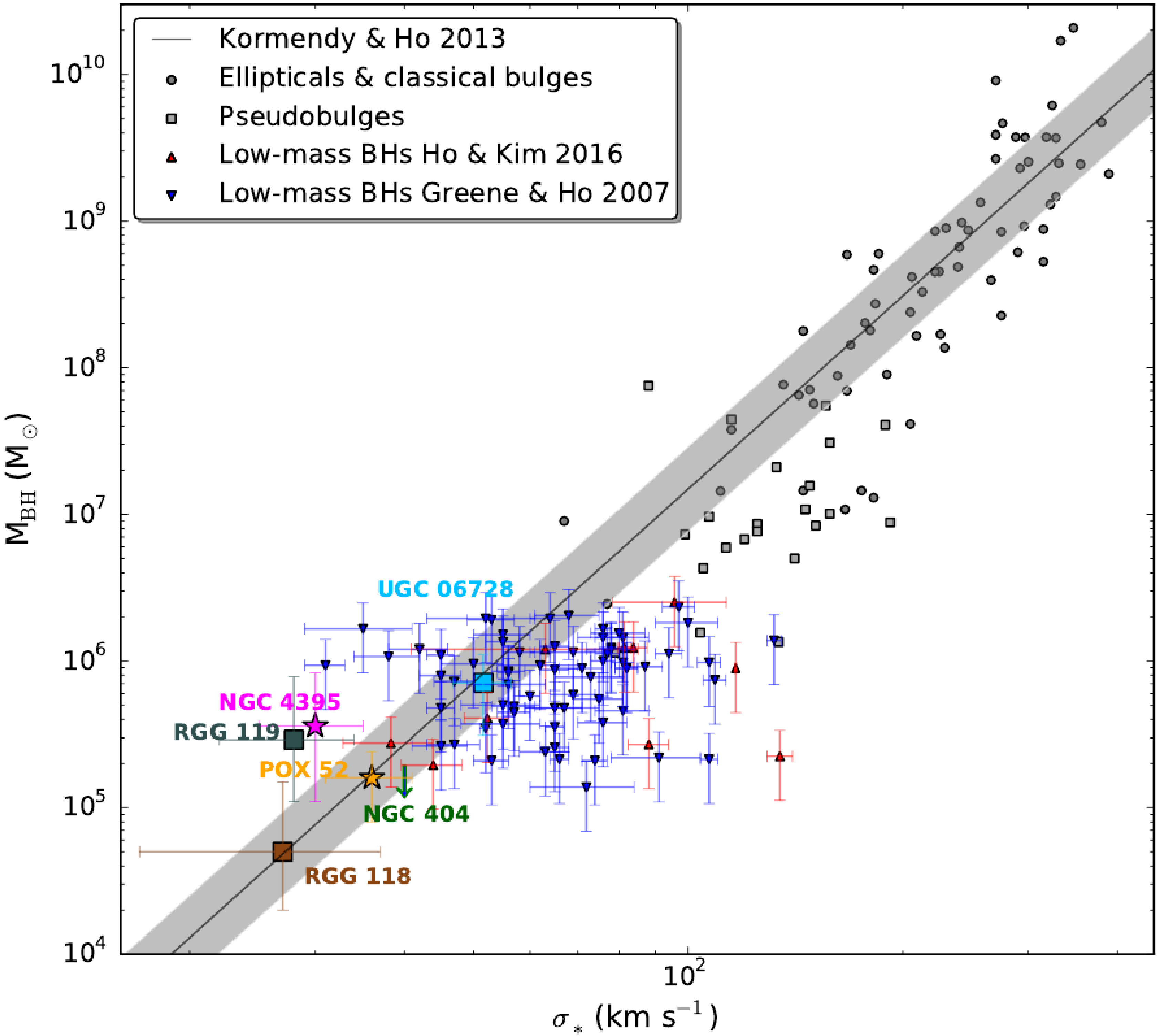


Volonteri et al. 2008

- **What do current measurements reveal?**

IMBH demographics

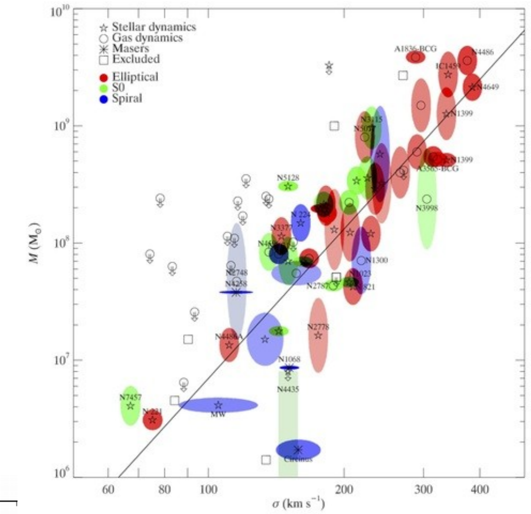
- What are the lower mass IMBHs?



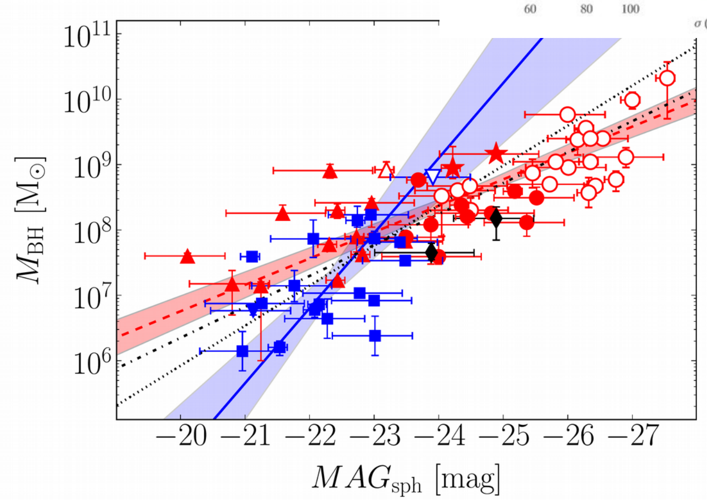
Mezcua 2017

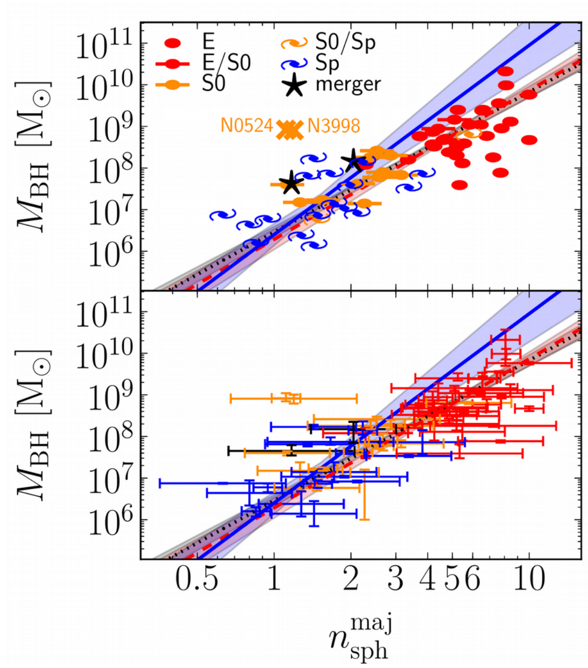
Measuring the Black Hole Mass

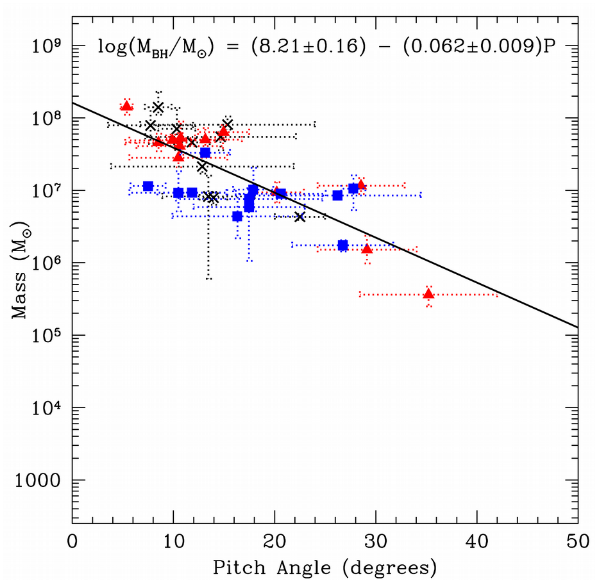
BH mass and Galactic properties



- The **M**

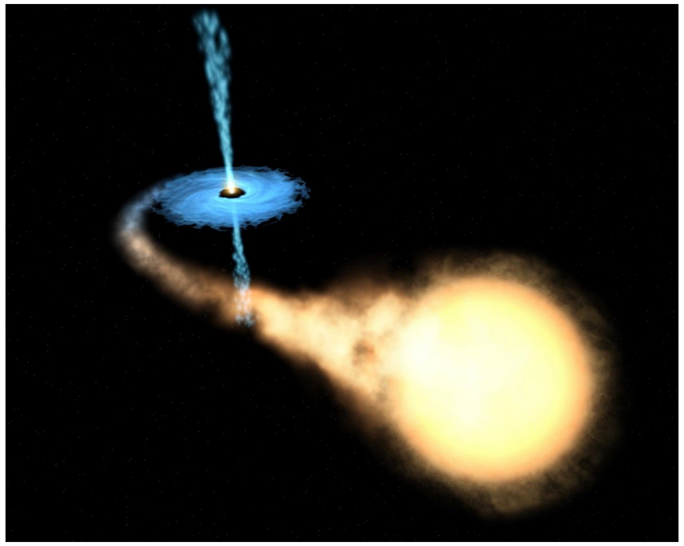






- The **M_{BH}-n_{sph}** and **M_{BH}-*PA*** relation
  - Independent of distance and of other relation
  - Empirical relations. Underlying physics not yet fully established
  - Limited to low z.

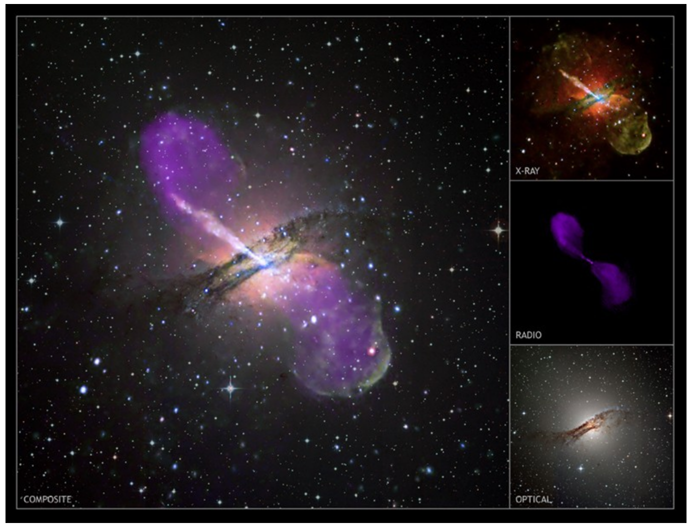
Measuring the Black Hole Mass



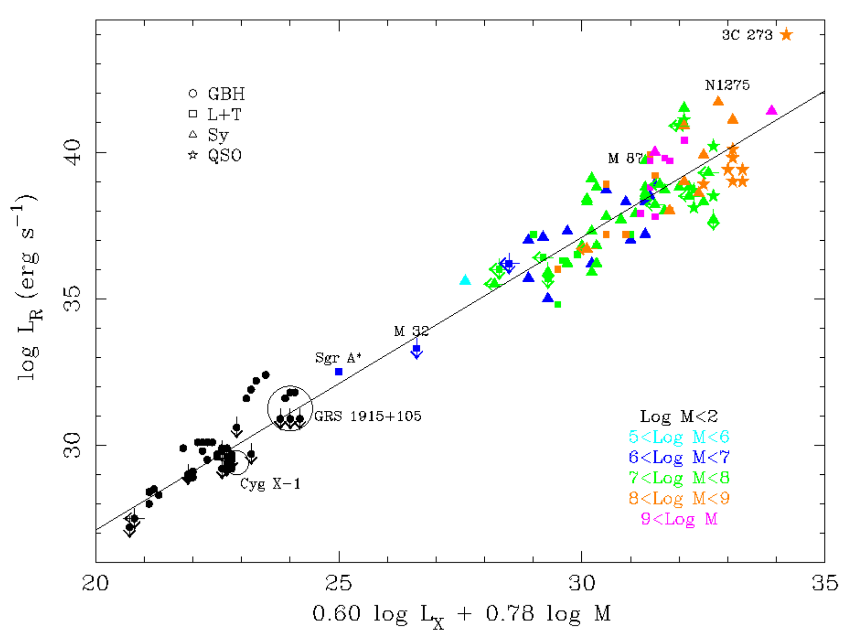
X-ray and Radio:

➢ Are they **accreting** mass ?

- **Eddington** Luminosity (L~1.3 10^{38}M/Msol)



- **Fundamental Plane** of BH activity

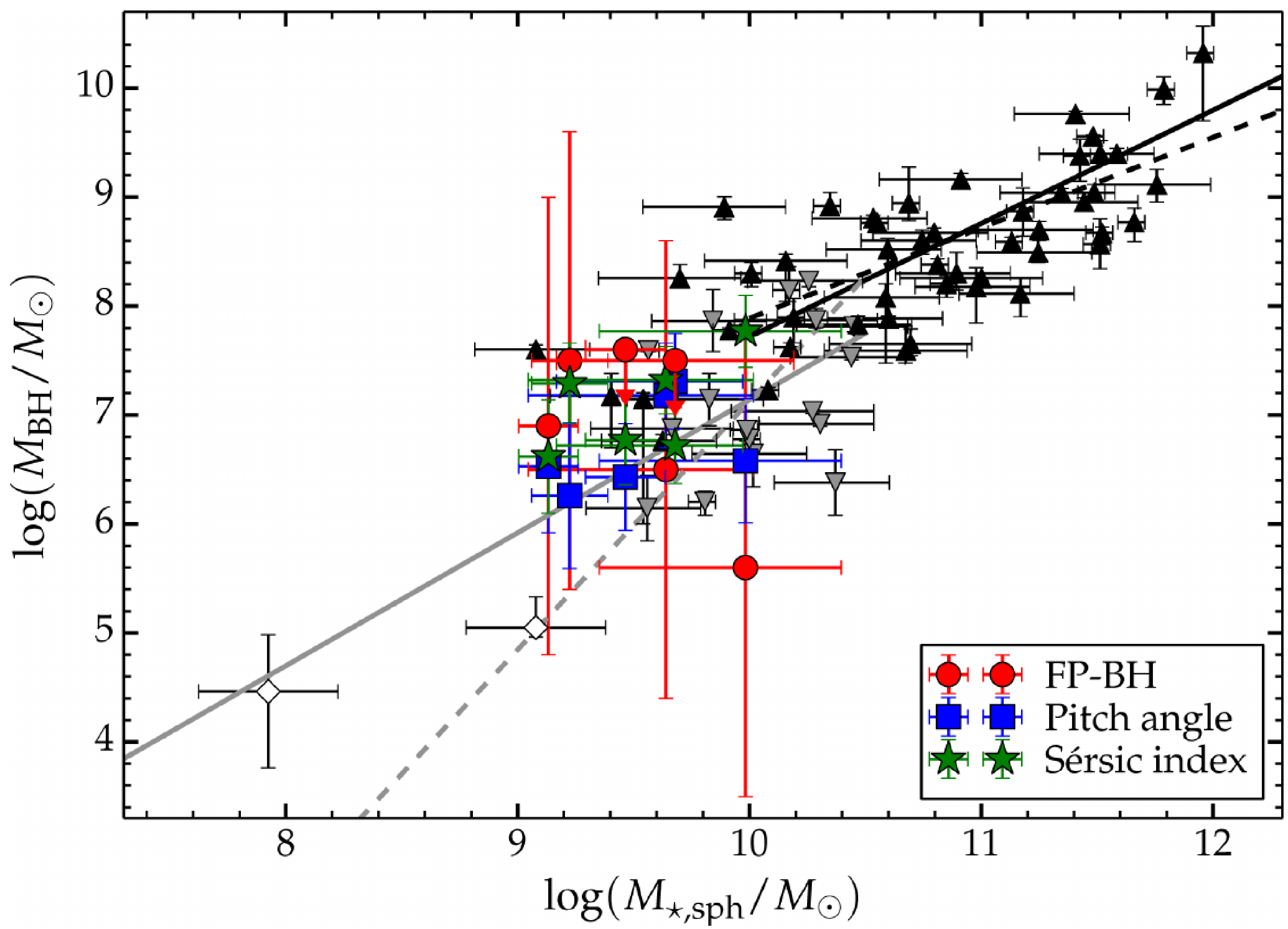


Heinz & Sunyaev 2003; Merloni et al. 2003; Falcke et al. 2004

- Scale-invariance of disk-jet mechanism.
- Estimate masses from GBHs to AGN.
- Large inherent scatter.

Multi-wavelength future

- **Multi-wavelength approach**
- - Combining independent scaling relations provide robust average prediction.
  - Mitigates issues from outliers from any one relation



Koliopanos+ 2017

A complete census of IMBH masses in nearby LLAGN

PHASE I

- Create a **virtual observatory** for **LLAGN** (within ~150 Mpc) with **quiet** merging and accretion history

Combine:
- X-ray (XMM-Newton, Chandra)
- Optical (Palomar Survey, 4th SDSS)
- Radio (VLA and e-Merlin)

Use:
- Multi-wavelength method
  Koliopanos+ 2017

This study can LOCATE and CLASSIFY the relics of SMBH seeds
Provide the most robust assessment on *Light vs Heavy* seed to date

First large scale mass estimation of central black holes in CONFIRMED AGN in the low mass regime

- Computational challenge: More than 1000 different observations

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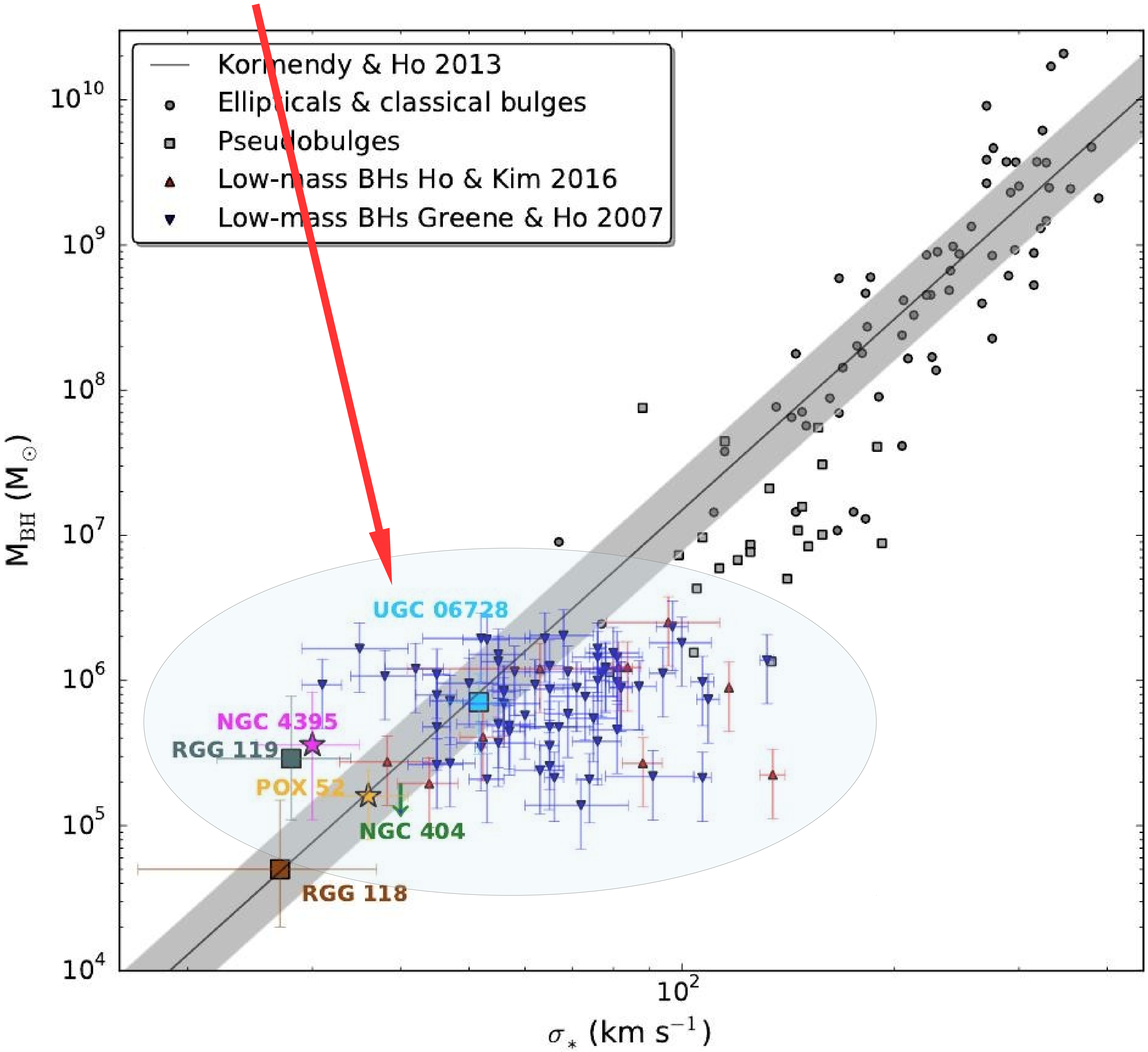
PHASE II

- Revisit the relation between M_{BH} and central velocity dispersion – **M_{BH}-σ**

See Mejía-Restrepo et al. 2017 in Nature Astronomy Letters

Is this real?

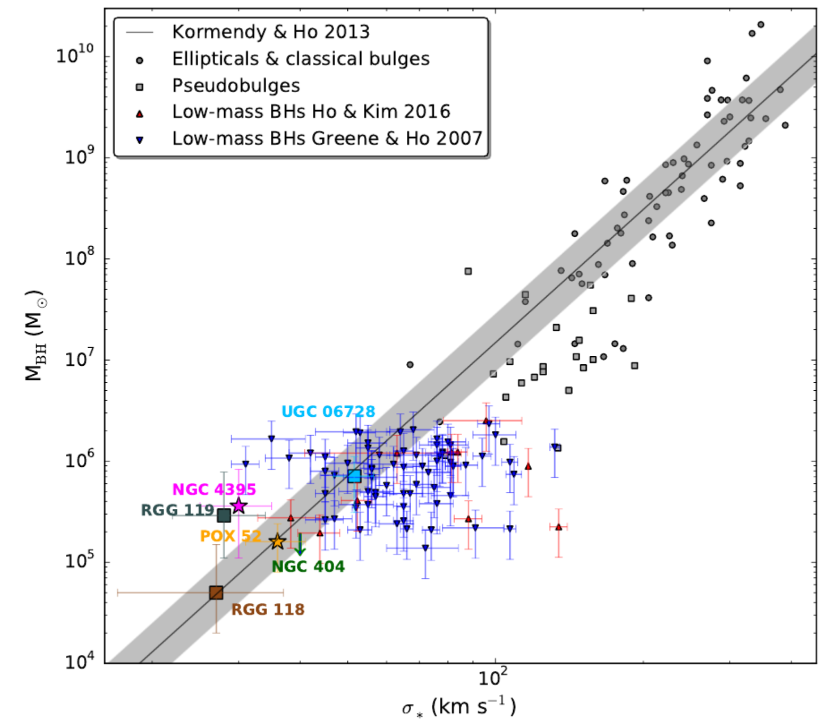


Mezcua 2017 IMBHs review

IMBH demographics

➢ Can the M-σ probe the low mass regime?

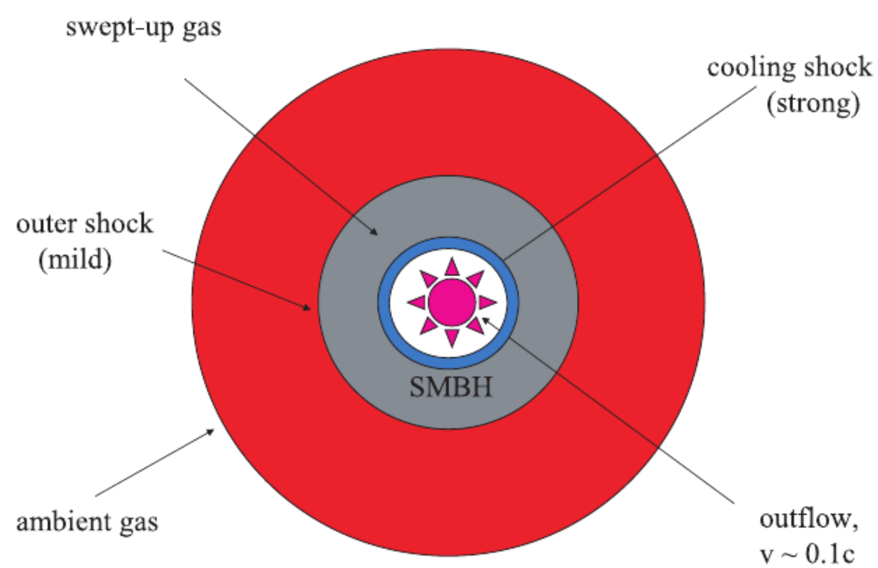
- What is the origin of the velocity dispersion?
- Outflows driven by super-Eddington accretion?
- Dwarf galaxies have quiet merger history



➢ Momentum driven bubble

$$R_C \sim 520\, \sigma_{200}\, M_8^{1/2}\, v_{0.1}^2 \left(\frac{f_g}{f_c}\right)^{1/2} \text{pc.}$$

King 2003; Zubovas & King 2013



King 2010

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PHASE II

- Revisit the relation between M_{BH} and central velocity dispersion – **M_{BH}-σ**
- Use **MUSE-VLT** to obtain 2D kinematics of select sources.
- **XMM-Newton Large Program** to complete the survey

FUTURE **Provide the sample for the next generation survey by ATHENA and SKA**