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

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.
• These accreting supermassive BHs ($>10^8$M$_{\text{sol}}$) appear to have been formed within a less than 700Myr from the Big Bang. (e.g., Mortlock et al. 2011; Banados et al. 2018)

• How are these “Titans of the early universe”: formed?

• With a $\leq 10^3$M$_{\odot}$ seed it will need to constantly accrete at the Eddington limit
Seed mass and formation mechanisms

• **Light Seeds** ($M < 10^3 M_{\text{sol}}$): Prolonged **super**-Eddington accretion, or episodic **hyper**-Eddington accretion

  Slim Disks?

  - Massive outflows.
  - Ionizing feedback

• **Heavy Seeds**: Direct collapse to a $> 10^5 M_{\text{sol}}$ 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 $10^8 M_{\text{sol}}$ gas

Mezcua 2017
What are the lower mass IMBHs?
- Populating the $M-\sigma$ diagrams may reveal seeds of SMBHs

What do current measurements reveal?

Volonteri et al. 2008
IMBH demographics

➢ What are the lower mass IMBHs?

What do current measurements reveal?

Mezcua 2017
BH mass and Galactic properties

• The $M_{\text{BH}}$-$\sigma$ relation
  - Primary mass measurement
  HOWEVER:
  - Low mass $\rightarrow$ Smaller size?
  - Luminosity bias.

• The $M_{\text{BH}}$-$L$ relation
  - Can be applied on more distant sources
  - No spectroscopy required
  - Depends on distance estimation

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

Catalog Treasures – 22.05.2018 – F.Koliopanos
X-ray and Radio:

➢ Are they **accreting** mass?

  • **Eddington** Luminosity \((L \sim 1.3 \times 10^{38} M/\text{Msol})\)

  • **Fundamental Plane** of BH activity

- 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
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
A complete census of IMBH masses in nearby LLAGN

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PHASE II

• Revisit the relation between $M_{BH}$ and central velocity dispersion – $M_{BH} - \sigma$

See Mejía-Restrepo et al. 2017 in
Nature Astronomy Letters
Is this real?

- Kormendy & Ho 2013
- Ellipticals & classical bulges
- Pseudobulges
- Low-mass BHs Ho & Kim 2016
- Low-mass BHs Greene & Ho 2007

Mezcua 2017 IMBHs review

Catalog Treasures – 22.05.2018 – F.Koliopanos
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
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PHASE II
• Revisit the relation between \( M_{\text{BH}} \) and central velocity dispersion – \( M_{\text{BH}}-\sigma \)
• 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