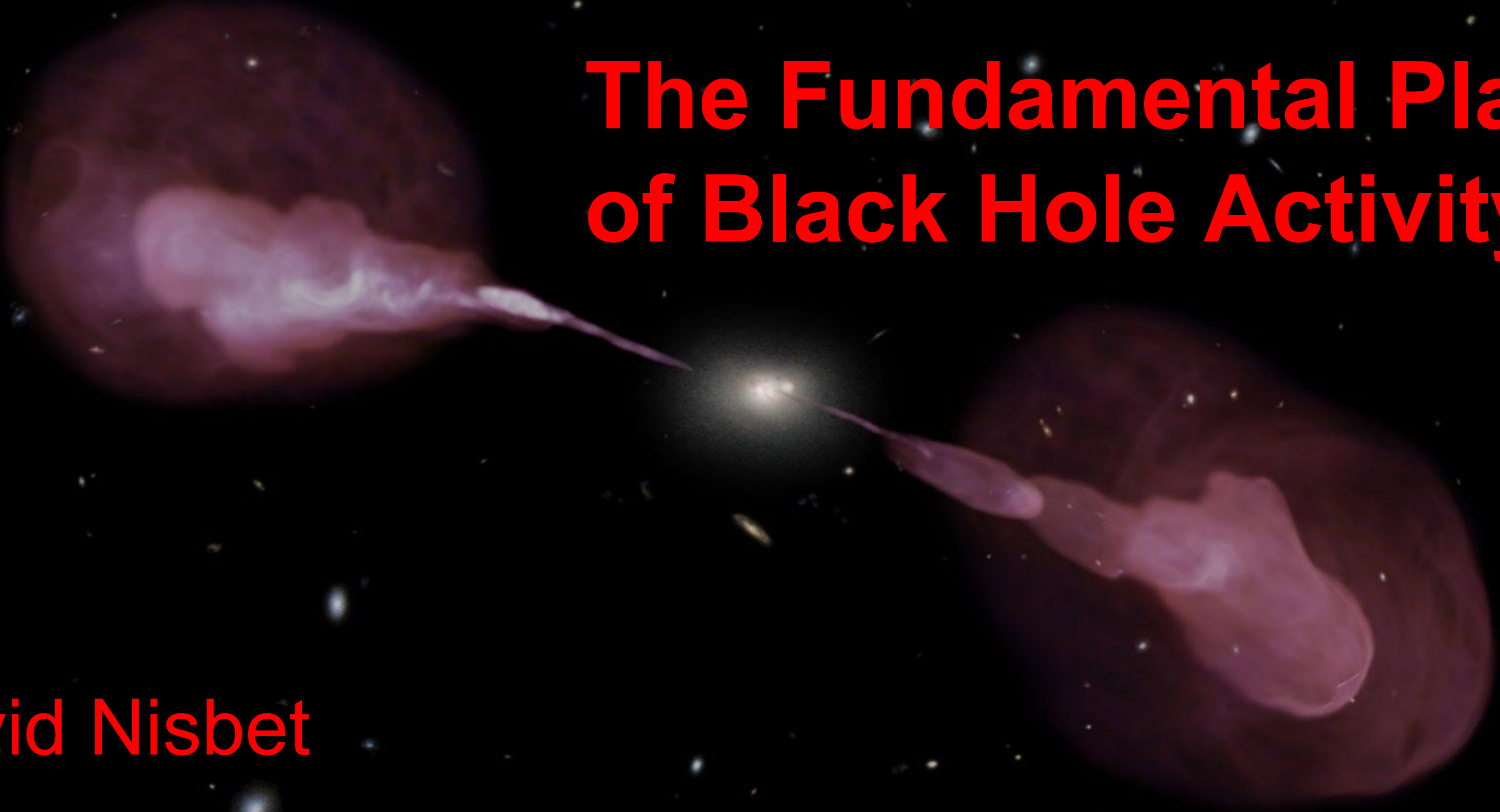
The Fundamental Plane of Black Hole Activity



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Two Types of AGN

Radiative-Mode AGN: Accrete at $> \sim 1\%$ of Eddington Limit

Jet-Mode AGN: Accrete at $< \sim 1\%$ of Eddington Limit

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Accretion Flow: X-ray Luminosity

Black Hole: Mass

Radio Jets: Radio Luminosity

$$L_R = a \; L_X^{\beta} \; M_{BH}^{\gamma}$$

or

$$\log L_R = \alpha + \beta \log L_X + \gamma \log M_{BH}$$

Data Base

Jet-mode AGN : 3XMM + SDSS + FIRST

+ quality controls

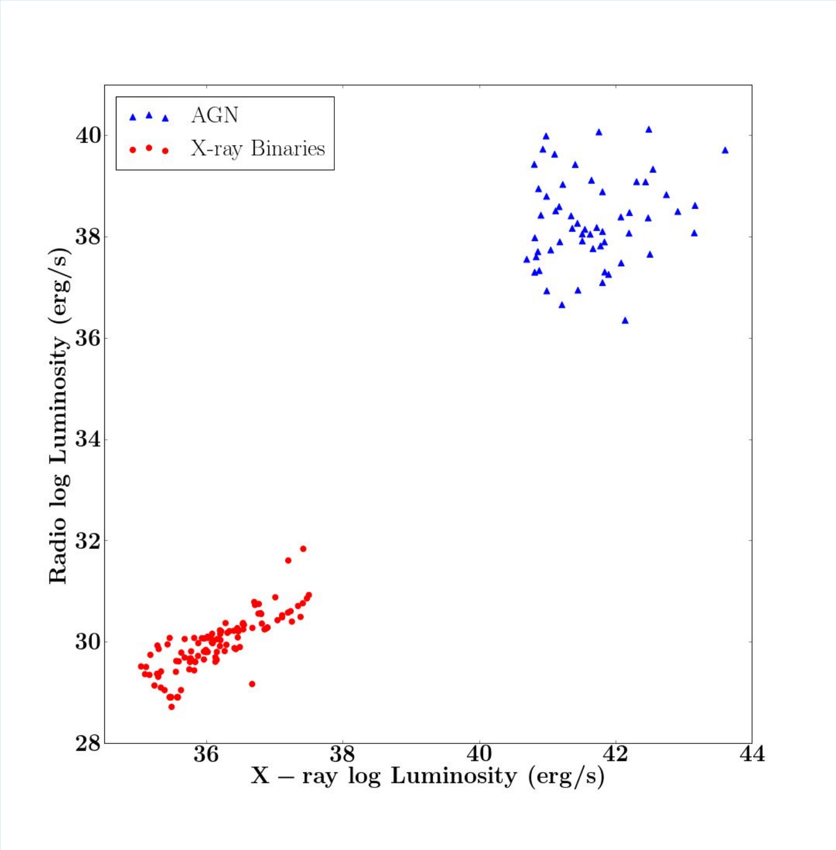
+ 5 diagnostic tests

= 576 LINERs

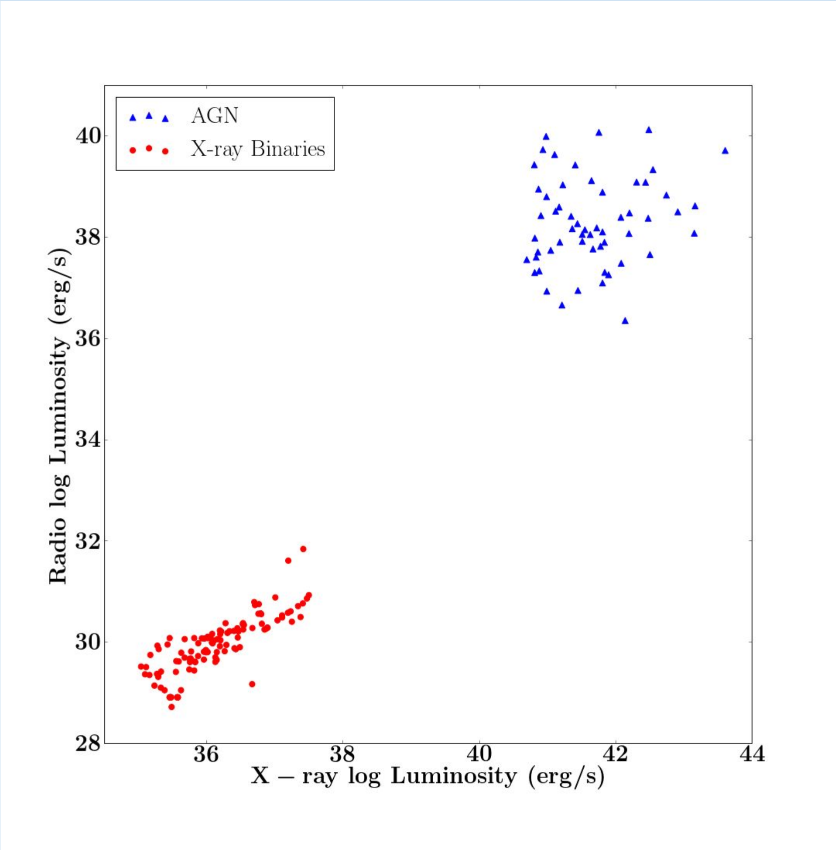
X-ray Binaries : 130 observations from 7 XRBs

Sagittarius A* : Black Hole at the centre of the Milky Way

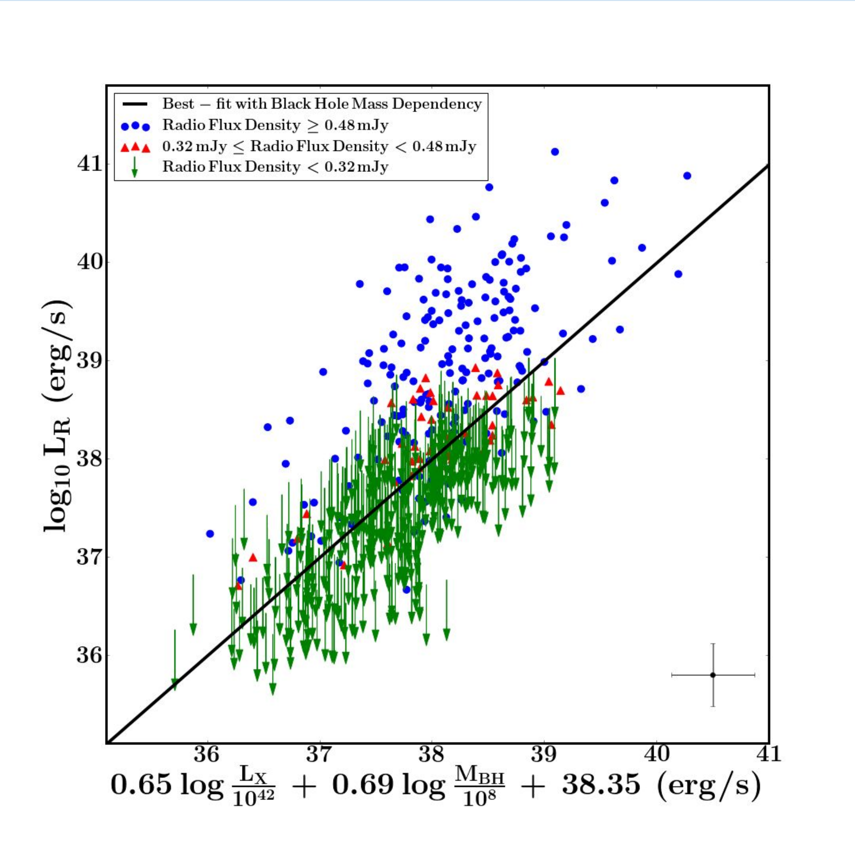
One Approach ….



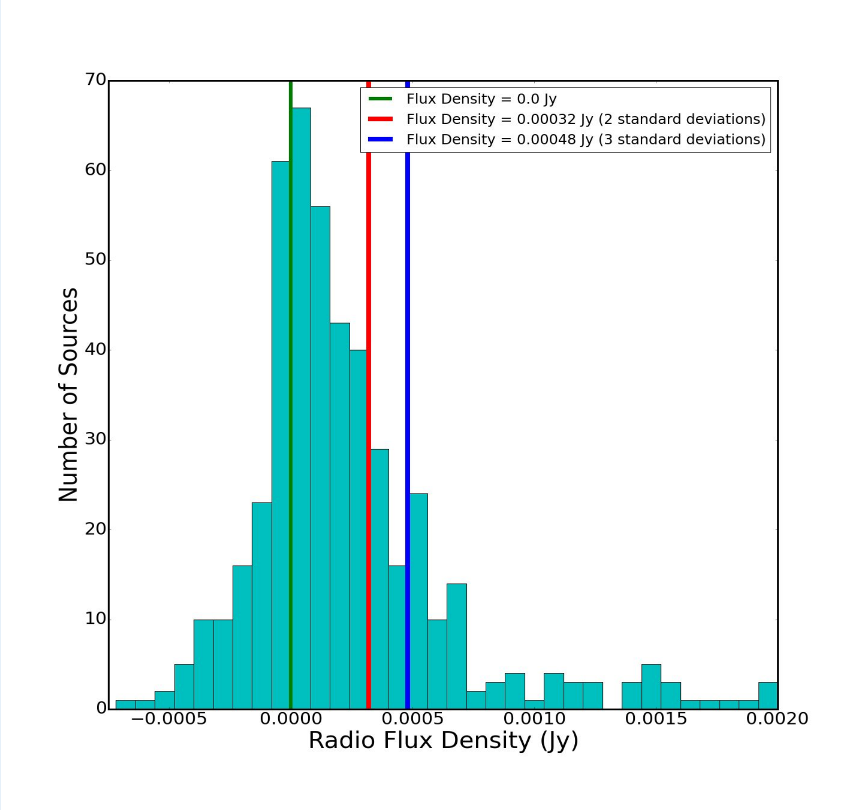
One Approach ….



… and Ours

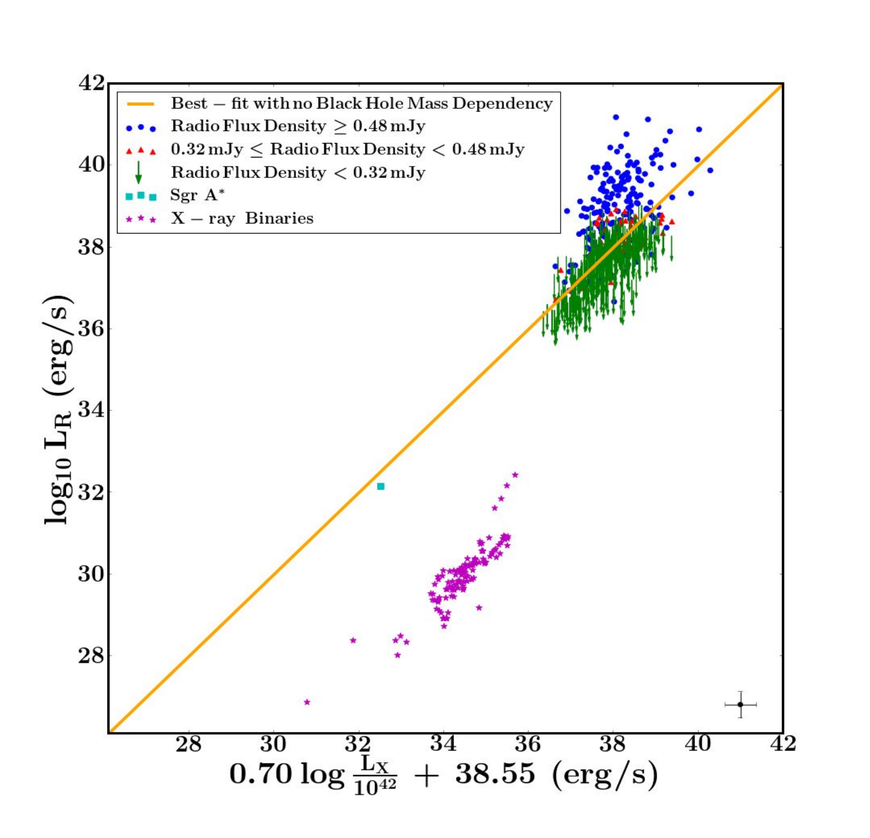


Noisy Radio Data

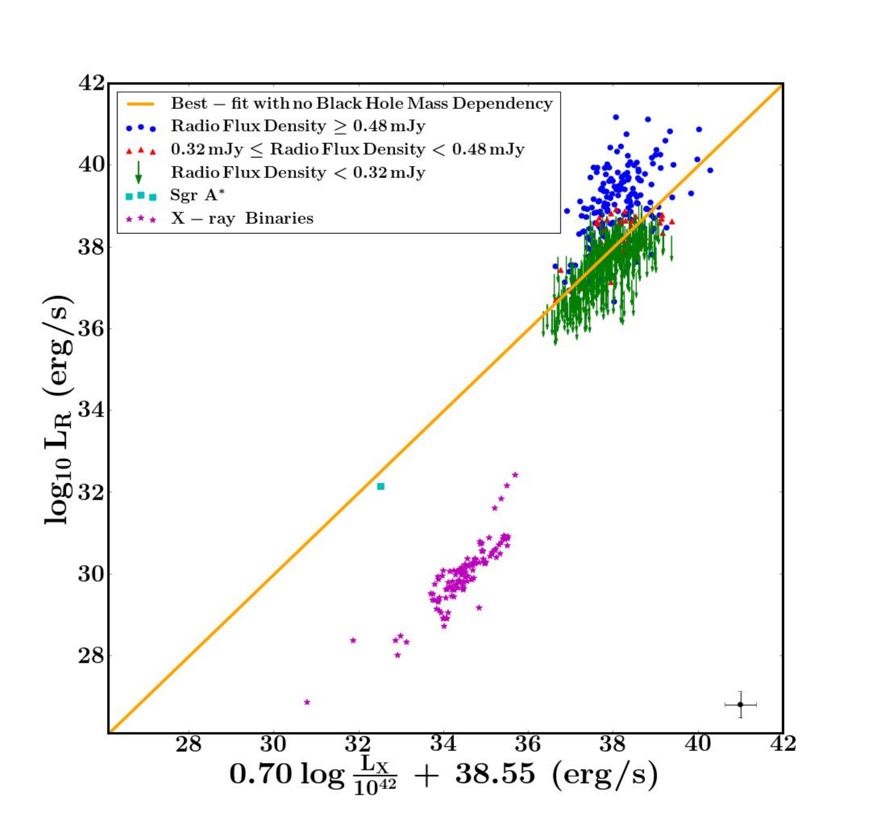


S / N	Number of Sources
> 3	194
2 - 3	45
0 - 2	208
< 0	129

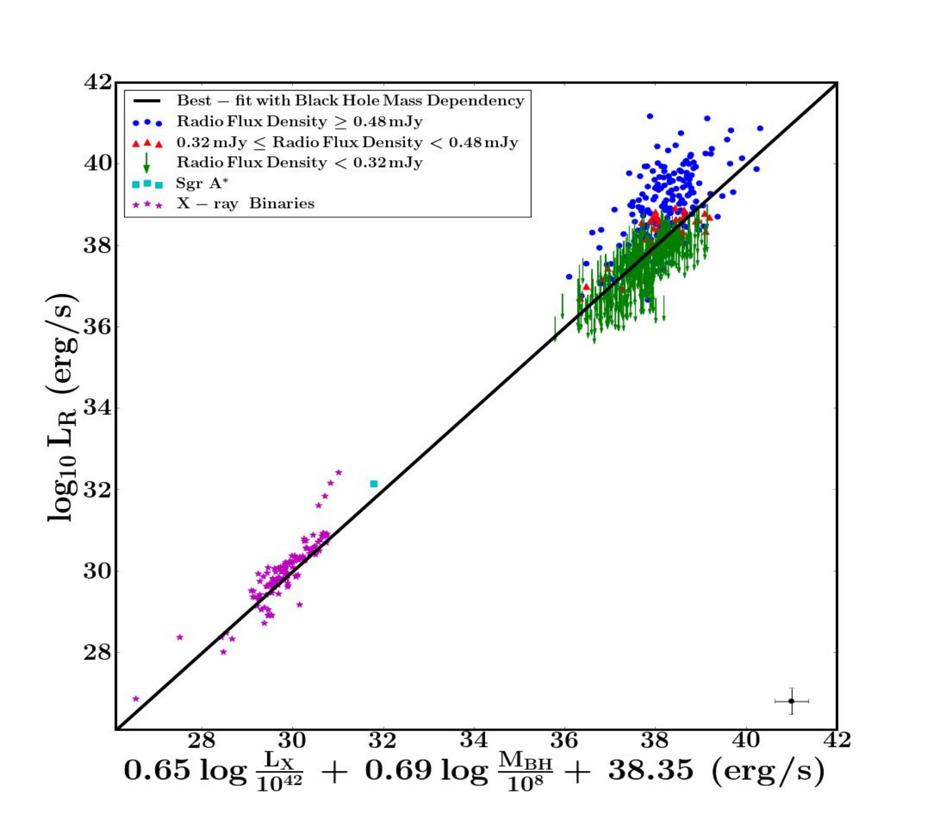
Without M_{BH} Dependency



Without M_{BH} Dependency



With M_{BH} Dependency



M_{BH} - sigma Relationship

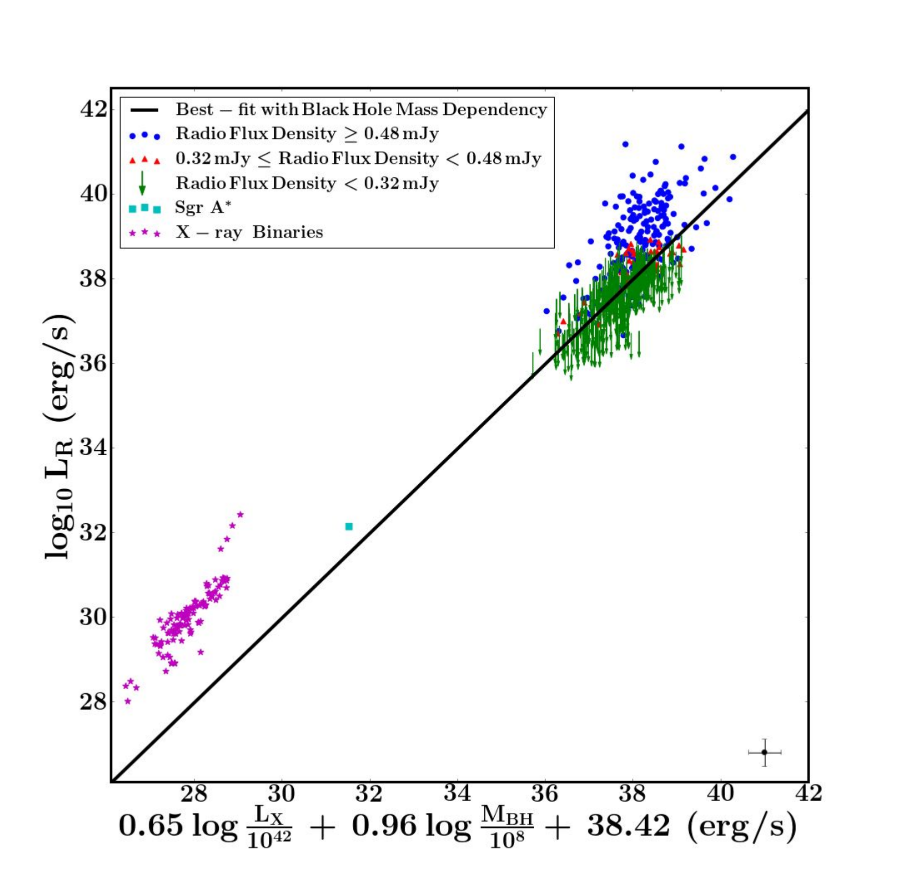
$$M_{BH} = \alpha \ \sigma^{\beta}$$

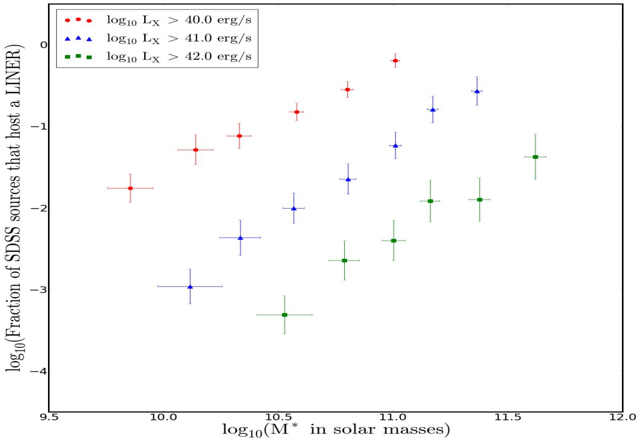
Tremaine et al (2002): $\beta = 4.02 \pm 0.32$

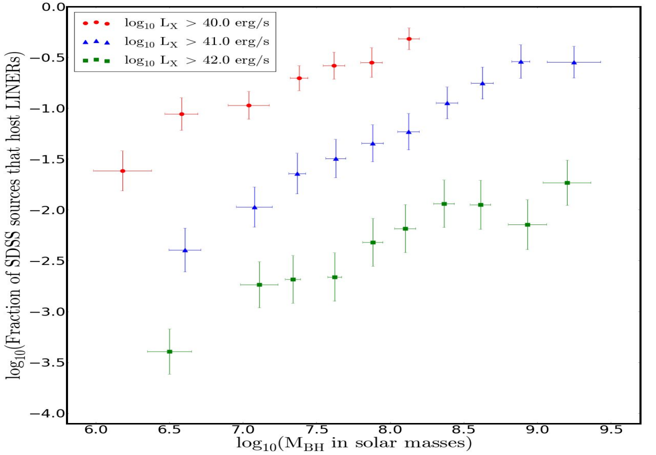
Novak et al (2006): $\beta = 4.59 \pm 0.34$

McConnell et al (2011): $\beta = 5.12$

McConnell & Ma (2013): $\beta = 5.64 \pm 0.32$







Other Results

1. Fraction of galaxies hosting a LINER is a strong function of both stellar mass and black hole mass.

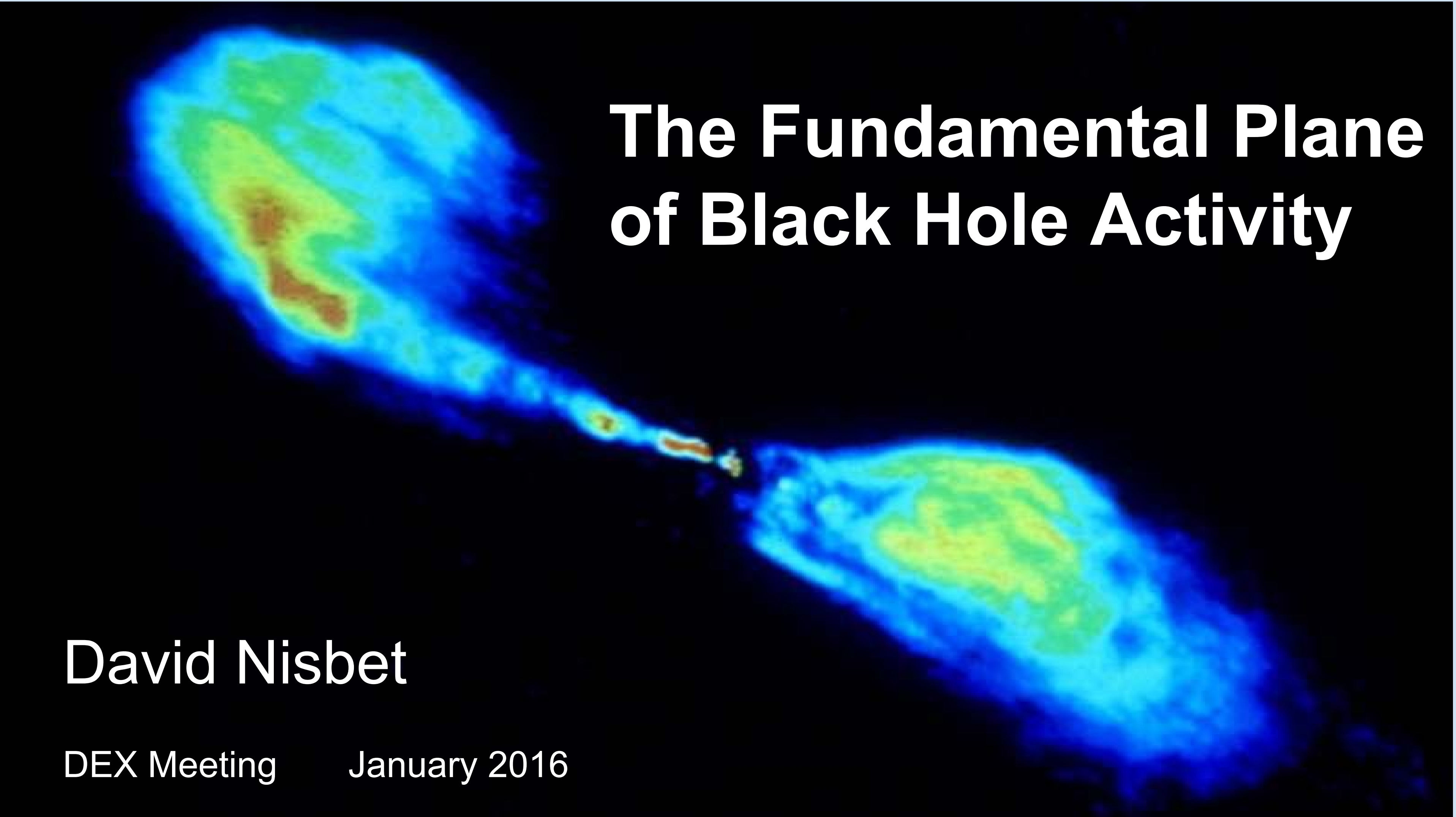
2. A significant proportion (> 50% on average) of the LINERs' energy is released in the jets.

3. That proportion rises with increasing black hole mass.

4. The Eddington ratio is inversely correlated with black hole mass.

5. Mechanical luminosity becomes progressively more dominant at lower Eddington ratios.

6. Hints that the properties of a black hole (or of its accretion flow) change at a mass of around 10^8 solar masses.



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Problem 2 : Unknown Scatter

Radio Flux — Known

X-ray Flux

Black Hole Mass

Timing Differences, beaming effects, absorption etc

Intrinsic Scatter — Unknown

Procedure to find the Best Fit

1. Make : initial estimates of α, β, γ, and σ.
2. Calculate: $\log L_R = \alpha + \beta \log L_X + \gamma \log M_{BH} + N_1 \sigma$.
3. Allow : N_1 to vary in small steps from -10 to +10.
4. Convert : each radio luminosity to the equivalent radio flux density.
5. Calculate : how many standard deviations, N_2, between each predicted radio flux density and the observed radio flux density.
6. Calculate : $N_{min,\,i} = (N_1^2 + N_2^2)^{½}$, the minimum value for each source, i.
7. Calculate: $\ln L = -0.5\ \Sigma_i\ (N^2_{min,i} + \ln(2\pi\sigma^2))$.
8. Determine: the values of α, β, γ, and σ that maximise the log likelihood function.