RELATIVISTIC ACCRETION DISKS

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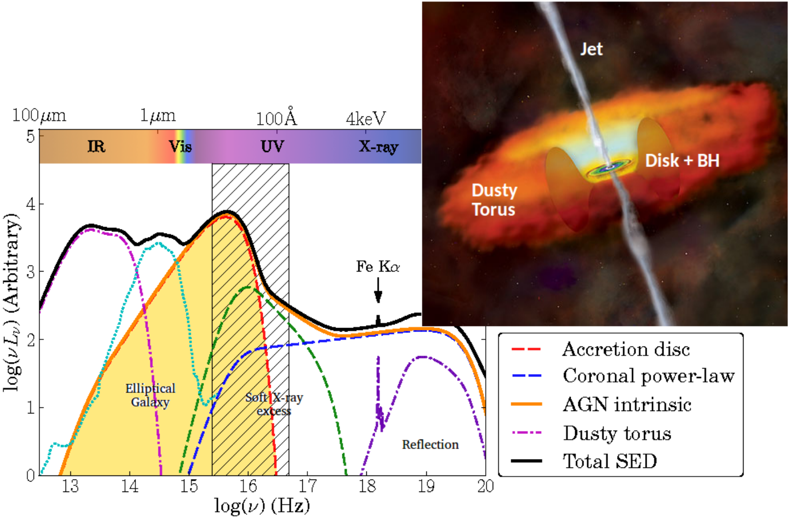
Active Galactic Nuclei 13: Beauty and the Beast
2018

Introduction

AGN central engine: components



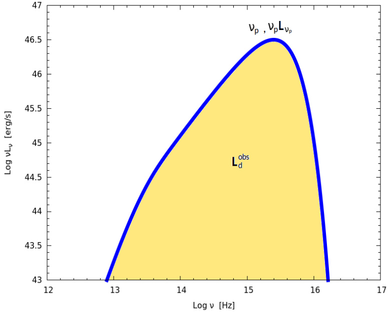
(figure from Collinson+ 2016)

Shakura & Sunyaev model

Basic equations

A multi-temperature blackbody model for a thin, steady state, non relativistic accretion disk around a non-rotating BH (Shakura & Sunyaev 1973)

- Analytical approximation (Calderone+ 2013)



- Observed disk luminosity

$$L_{\rm d}^{\rm obs}(\theta) = \int L_\nu d\nu = 2\cos\theta\ \eta \dot{M} c^2$$

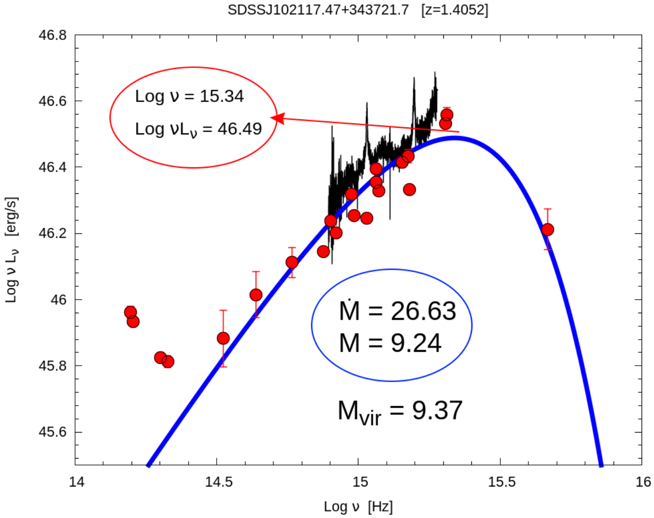
- Spectrum peak

$$\nu_{\rm p} \propto \dot{M}^{1/4} M^{-1/2}$$

$$\nu_{\rm p} L_{\nu_{\rm p}} \propto \dot{M} \cos\theta$$

Shakura & Sunyaev model

Fit: example



KERRBB

Basic equations

A multi-temperature blackbody model for a thin, steady state, general relativistic accretion disk around a Kerr BH, which includes frame-dragging, light-bending, returning radiation (Li+ 2005)

- Analytical approximation (Campitiello+ 2018)

Observed disk luminosity $L_{\rm d}^{\rm obs}(\theta, a) = f(\theta, a)\ \eta \dot{M} c^2$

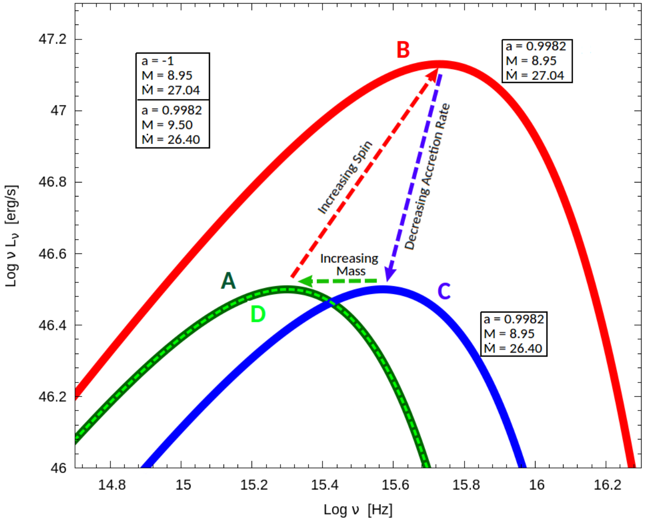
Spectrum peak frequency and luminosity $\nu_{\rm p} \propto \dot{M}^{1/4} M^{-1/2} g_1(\theta, a)$

$\nu_{\rm p} L_{\nu_{\rm p}} \propto \dot{M} \cos\theta\ g_2(\theta, a)$

$\rightarrow$ Range of black hole masses & Accretion rates: parameter degeneracy ($\dot{M}$, M, a)

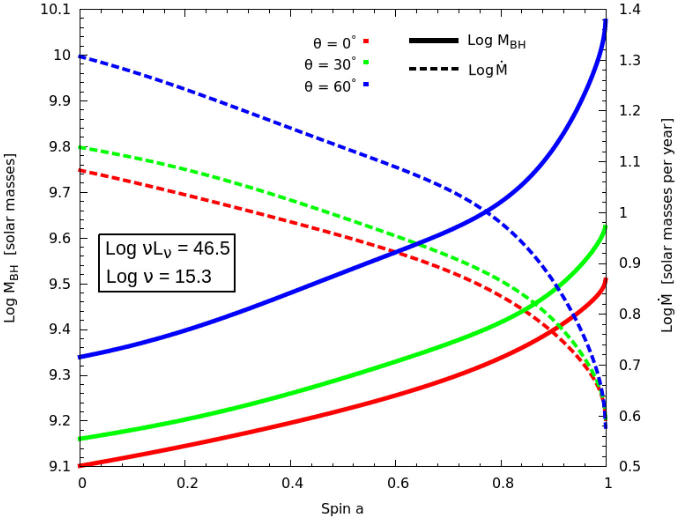
KERRBB

Parameter degeneracy



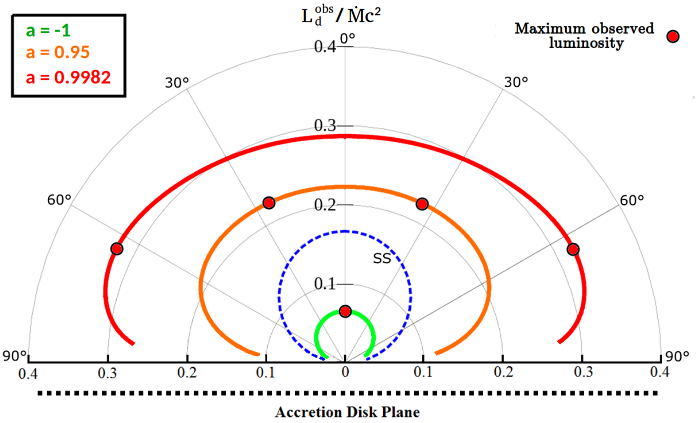
KERRBB

Parameter degeneracy



KERRBB

Radiation pattern



SLIMBH

Basic equations

A model of a general relativistic stationary slim accretion disk around a Kerr BH, which includes the vertical structure of the disk (e.g. Abramowicz+ 1988; Sadowski 2009)

- Analytical approximation (Campitiello+ arXiv: 1809.00010)

$$f(\theta, a) \quad \rightarrow \quad f_{\rm s}(\theta, a, \lambda_{\rm Edd})$$

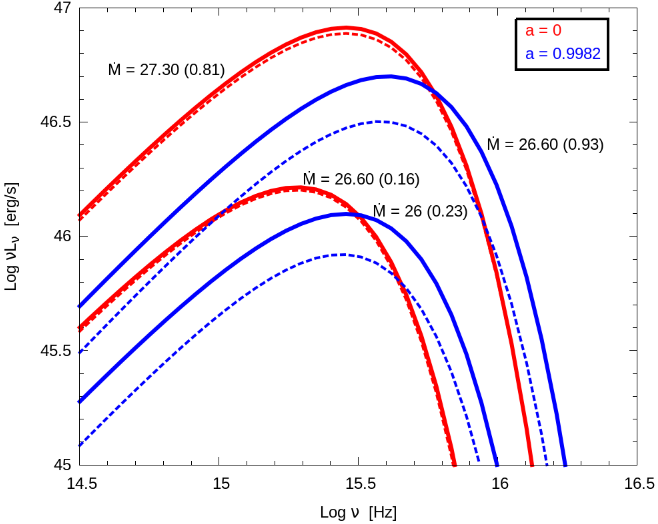
$$g_1(\theta, a) \quad \rightarrow \quad g_{1,\rm s}(\theta, a, \lambda_{\rm Edd})$$

$$g_2(\theta, a) \quad \rightarrow \quad g_{2,\rm s}(\theta, a, \lambda_{\rm Edd})$$

→ Photon trapping: lower radiative efficiency
→ Dimmer than KERRBB, with the same parameters

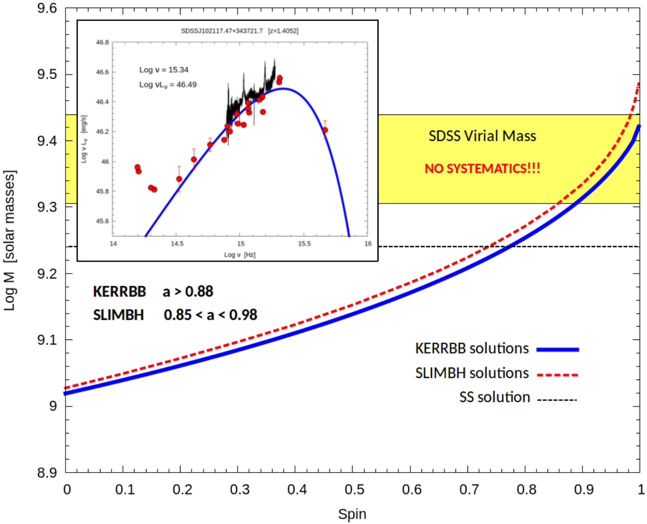
SLIMBH

Comparison with KERRBB



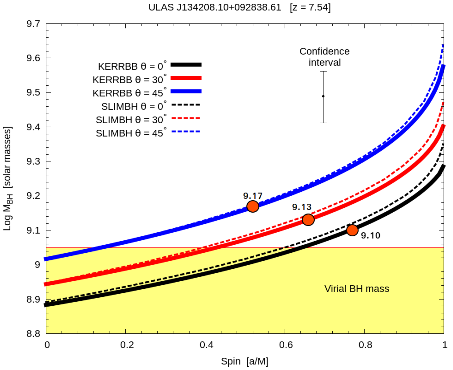
Application

Black hole mass and spin estimates



Application

Mass and spin estimates of ULASJ1342[1] (Campitiello+ arXiv: 1809.00010)



- We fitted the spectrum assuming a viewing angle $\theta_{\rm v} < 45^\circ$ (to avoid a possible torus absorption)

- Results are compatible with a slowly spinning black hole ($a < 0.6$)

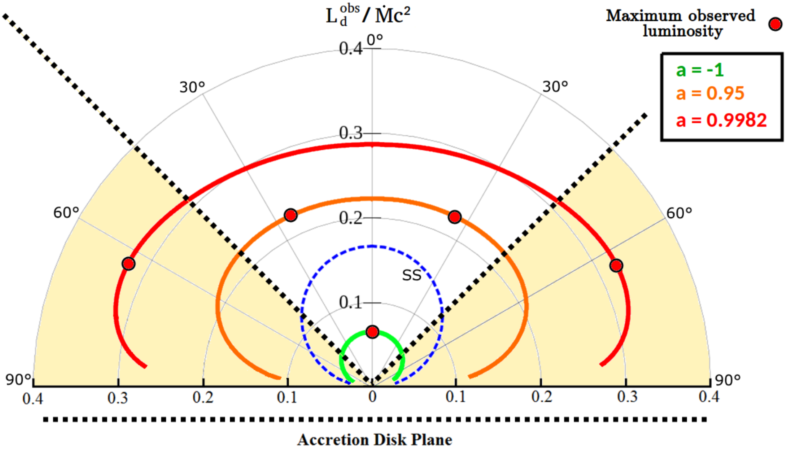
- No systematics involved!

We use the same procedure for ULASJ1120 ($z = 7.08$) finding a spin also compatible with a slowly rotating BH.

[1] Venemans+ 2017; Bañados+ 2018

Application

Disk radiation pattern and torus [Campitiello et al. in prep.]



Application

Disk radiation pattern and torus [Campitiello et al. in prep.]

Main assumptions on the torus:

- The torus structure is symmetric with an aperture angle $\theta_{\rm T}$ measured from the disk normal

- The torus emits **isotropically** all the radiation that absorbs from the disk:

$$L_{\rm T}^{\rm obs} \approx L_{\rm abs} = L_{\rm d} \underbrace{\int_{\theta_{\rm T}}^{\pi/2} f(\theta, a) \sin\theta d\theta}_{=\mathcal{I}(\theta_{\rm T}, a)}$$

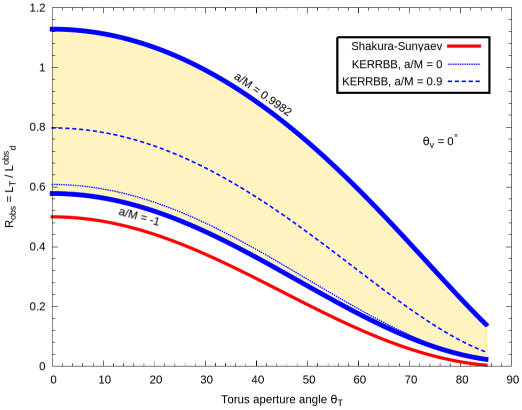
where $\mathcal{I}(\theta_{\rm T}, a)$ is a sort of *covering factor*. The observed disk luminosity is:

$$L_{\rm d}^{\rm obs} = f(\theta_{\rm v}, a) L_{\rm d}$$

$$\rightarrow \qquad R_{\rm obs}(\theta_{\rm v}, \theta_{\rm T}, a) = L_{\rm T}^{\rm obs}/L_{\rm d}^{\rm obs} \sim \mathcal{I}(\theta_{\rm T}, a)/f(\theta_{\rm v}, a)$$

Application

Disk radiation pattern and torus [Campitiello et al. in prep.]



$R_{\rm obs} = 0.4 \quad \rightarrow \quad 35^\circ < \theta_{\rm T} < 70^\circ$ no spin constraint

$R_{\rm obs} = 1 \quad \rightarrow \quad \theta_{\rm T} < 30^\circ$ $a > 0.98$

Castignagni & De Zotti 2014 $\rightarrow$ $R \sim 1$ for a small sample of blazars

Summary

- AGN engine: accreting gas + dusty torus $\rightarrow$ IR-Optical-UV emission
- Optical-UV emission: accretion disk models:
  - *Shakura & Sunyaev model*: easy to implement; no relativistic effects (Shakura & Sunyaev 1973)
  - **KERRBB/SLIMBH**: relativistic effects included (i.e. spin) (Li+ 2005; Sadowski 2009)
    - Analytical approximation (Campitiello+ 2018; arXiv: 1809.00010)

- Application:
  - *Black hole mass estimate*:
    - constraint on the solutions from a reasonable BH spin choice
  - *Black hole spin estimate*:
    - using virial mass estimates (*large uncertainties*)
    - using the disk radiation pattern (*torus emission, possible UV absorption*) $\rightarrow$ Campitiello+ in prep.