Feedback Dominated Accretion Flows

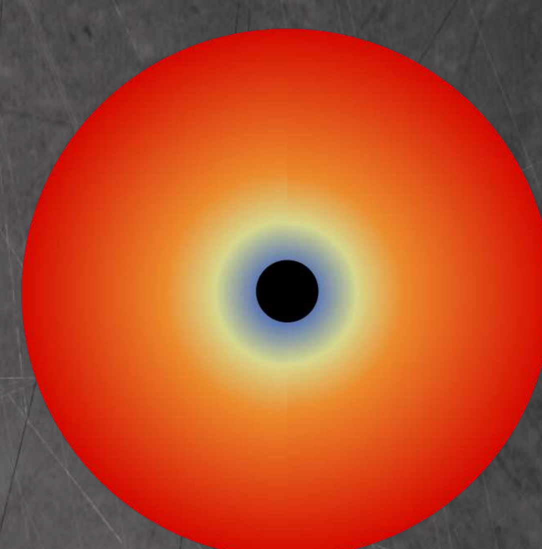
Shmuel Gilbaum, Nicholas C. Stone

shmuel.gilbaum@mail.huji.ac.il

Feedback from black holes in AGN[1] accretion disks, may solve self consistancy issues with previous models and explain BBH[2] merger population.

Shakura & Sunyaev (1973)

Model - Angular momentum exchange via local turbulence. Thermal stability - any heat gained from viscous interactions is radiated away.

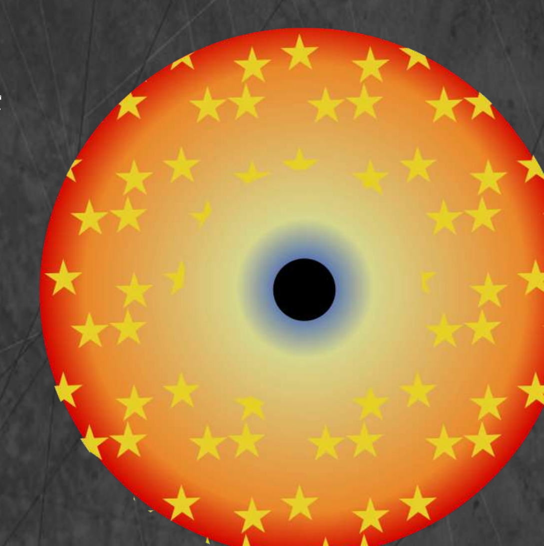


Main issues with AGN scale disks :

- The outer region of the disk is unstable to density pertubations (Toomre parameter $Q_T < 1$).
- Viscous timescales are too long.

Sirko & Goodman (2003), Thompson *et al.* (2005)

Model - Stars are forming due to fragmentation of the disk. The feedback from the stars (SNe[3] and winds) heats the disk and stabilizes it ($Q_T = 1$)



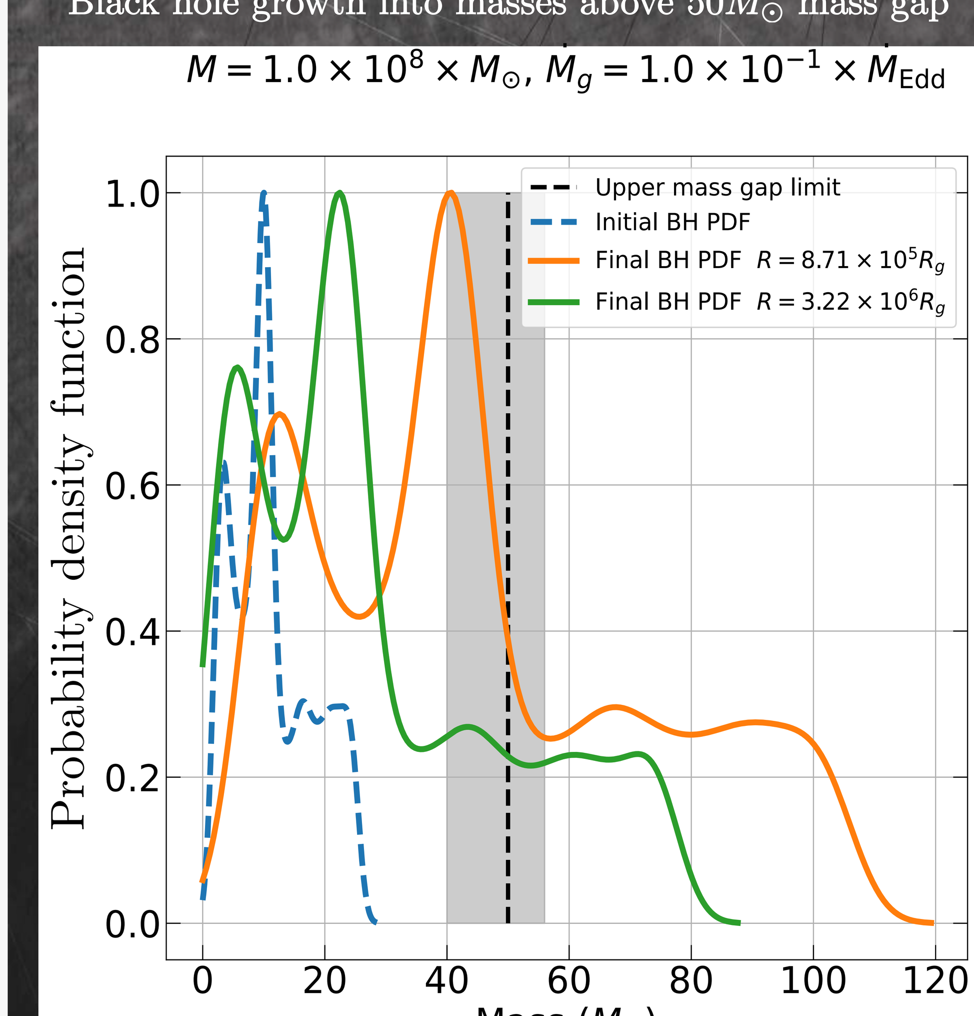
Main issues with this model :

- SNe are temporally and spatially discrete events, and might not heat the disk evenly.
- Neglects to consider the feedback from the black hole remnants of the SNe.

Main Attributes of our model :

- A combined regime, CMFI at small radii and pileup at large radii.
- A large number of embedded compact objects in the disk.
- Thicker disk - large scale height of the disk
- Shorter viscous timescales.
- Mass growth of black holes beyond the mass gap.
- Mass growth of neutron stars which might collapse into black holes.

Black hole growth into masses above $50 M_\odot$ mass gap



Gilbaum & Stone (2022)

If stars are formed in the disk ⇒ stellar mass black holes are formed. Black holes embedded in gas will accrete gas and in retun will heat the surrounding gas via radition :

$$L_\bullet = \eta c^2 \times \min\left(\dot{m}_{\rm RBH}, \dot{m}_{\rm Edd}\right)$$

η is an efficiency prefactor and c is the speed of light
$\dot{m}_{\rm RBH}, \dot{m}_{\rm Edd}$ - Are the Bondi-Hoyle-Lyttleton and Eddington accretion rates respectively.

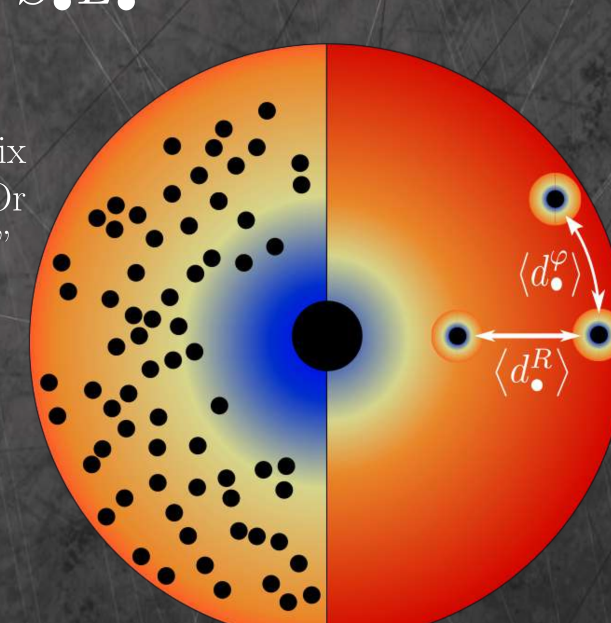
With enough black hole we can define a number surface density of BHs - $S_\bullet$. Thus the total heating per unit area from accretion feedback is :

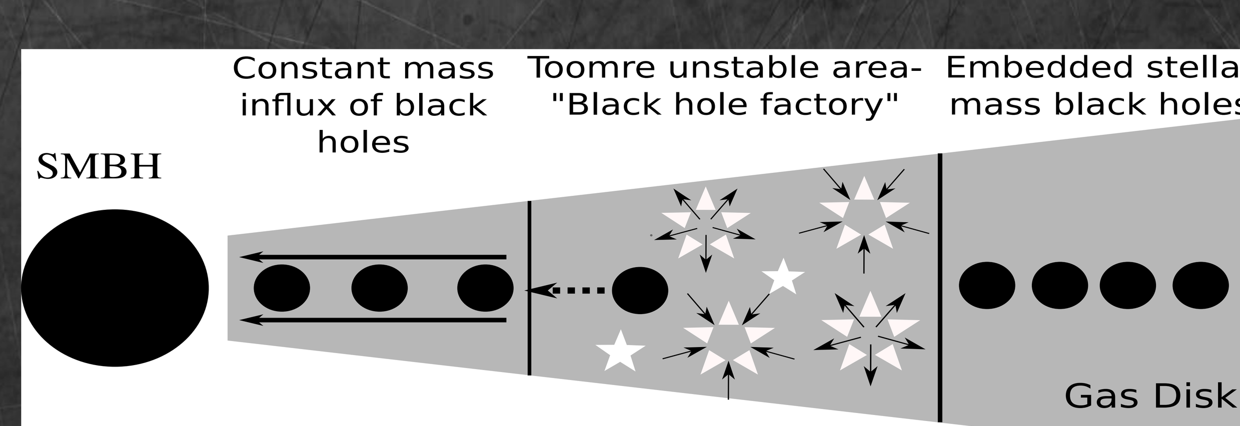
$$Q^+_\bullet = S_\bullet L_\bullet$$

Heat from BHs feedback can efectively mix and change disk structre if $\langle d_\bullet\rangle < H$. Or expressed by the "Heat mixing parameter"

$$\mathfrak{M}_\varphi \approx S_\bullet H^2 \geq 1$$

$\langle d_\bullet\rangle$ is the average distance between two black holes, H is the scaleheight of the disk..





Shakura & Sunyaev disk structure, possible migration traps. | No Steady state, ongoing work. | Steady state solution, no black hole migration.

$$\Sigma = 2\rho H$$

$$c_s = \left(\frac{GM}{R^3}\right)^{\frac{1}{2}} H = \Omega H$$

$$c_s^2 = \gamma \frac{P}{\rho}$$

$$P = \frac{k_B}{\mu m_p}\rho T_c + \frac{\tau\sigma}{2c}T_c^4\left(\frac{3}{8}\tau + \frac{1}{2} + \frac{1}{4\tau}\right)^{-1}$$

$$\sigma T_c^4\left(\frac{3}{8}\tau + \frac{1}{2} + \frac{1}{4\tau}\right)^{-1} = \frac{9GM}{8R^3}\nu\Sigma + S_\bullet L_\bullet$$

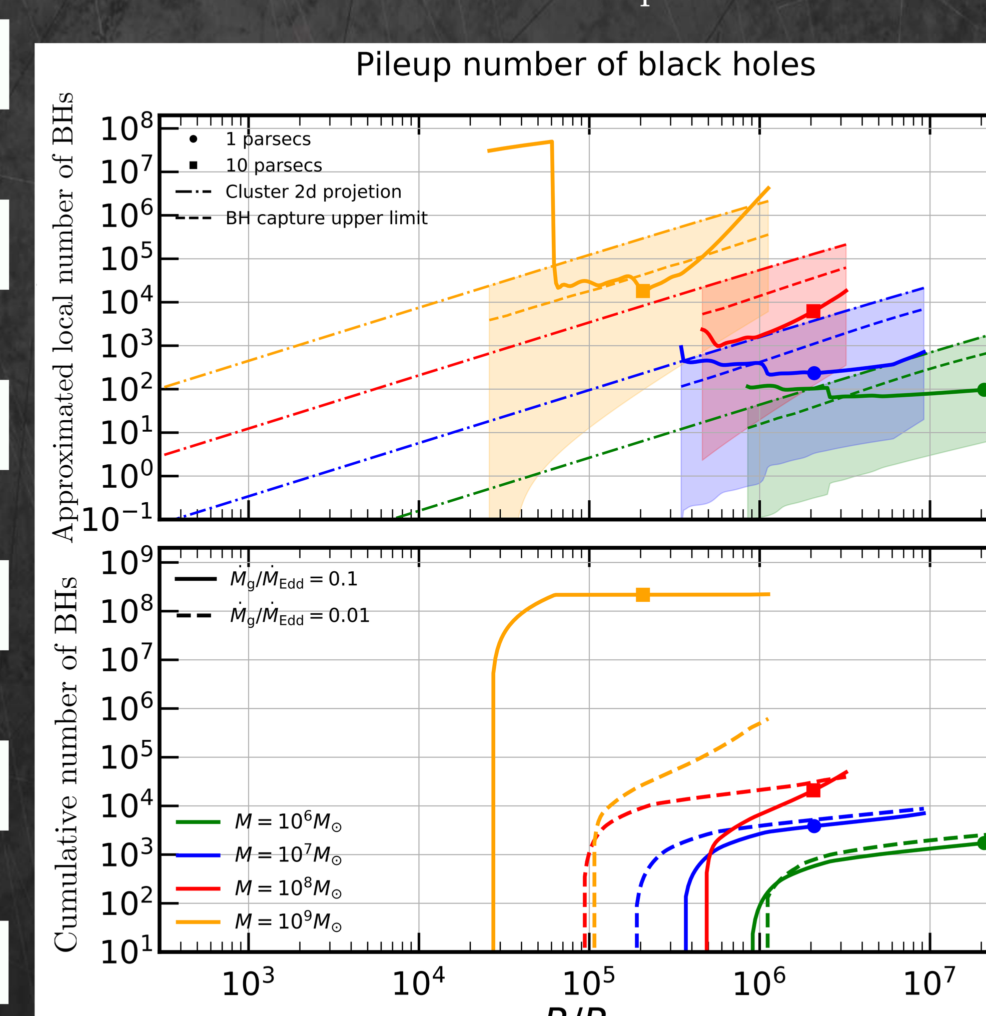
$$\tau = \frac{\kappa_R \Sigma}{2}$$

$$\nu = \alpha c_s H$$

$$\nu\Sigma = \frac{\dot{M}}{3\pi}\left(1 - \left[\frac{R_0}{R}\right]^{1/2}\right)$$

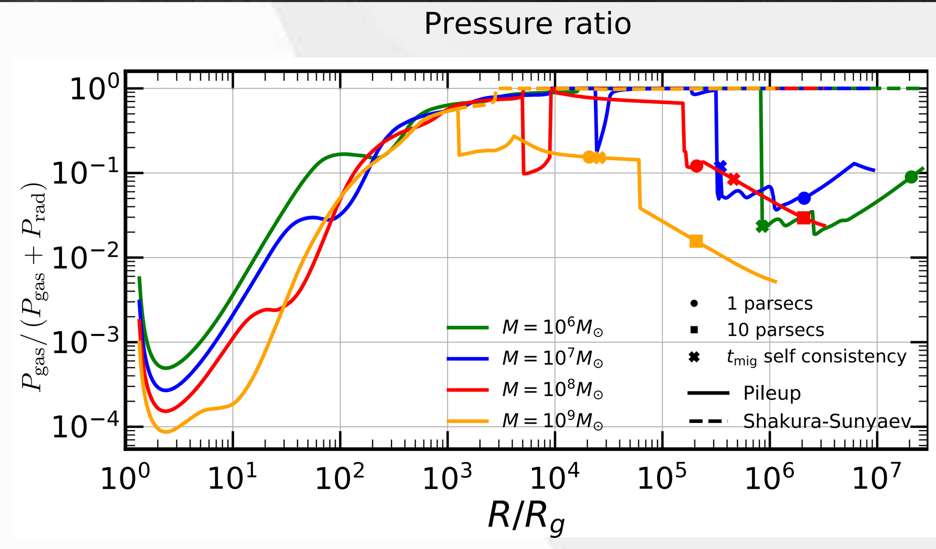
$$\begin{cases} Q_T = 1 & \mathfrak{M}_\varphi > 1 \\ \mathfrak{M}_\varphi = 1 & \text{otherwise.} \end{cases}$$

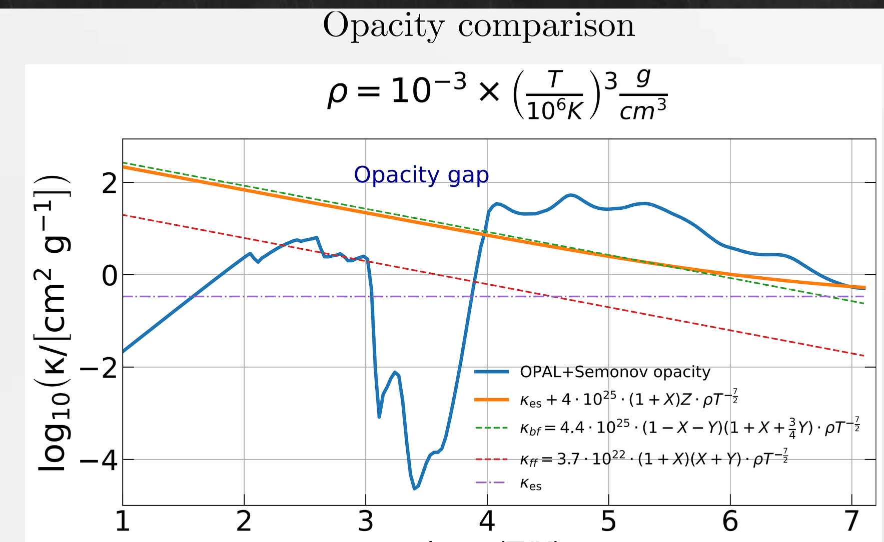
Black hole numbers in our model compared to nuclear cluster

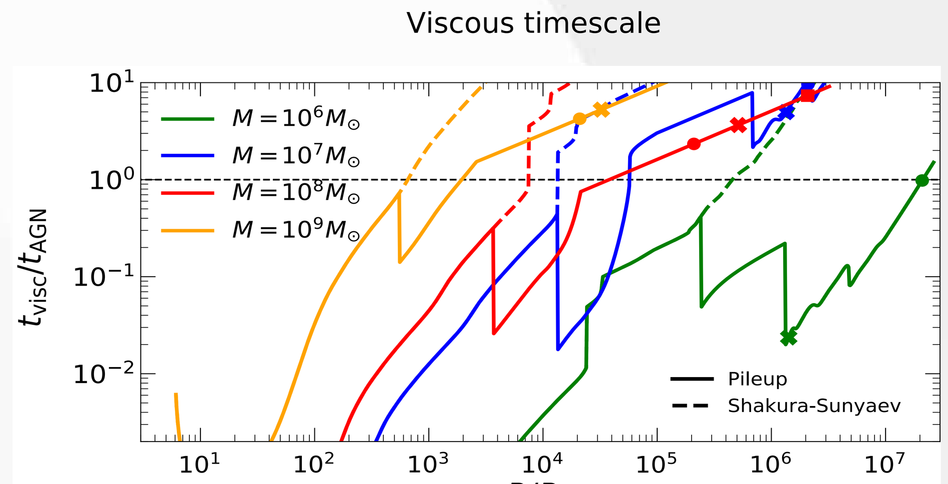


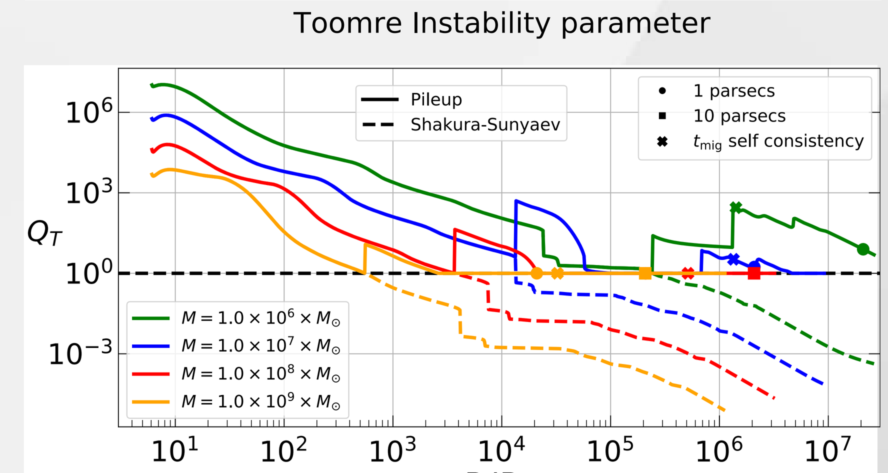
1 - Active Galactic Nucleii
2 - Binary Black Holes
3 - Supernovae

* Toomre instability parameter, if $Q_T < 1$ gas is unstable to density perturbations and potentially stars may form.









THE HEBREW UNIVERSITY OF JERUSALEM