Black Holes from Stars to Galaxies – Across the Range of Masses
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Formation history of supermassive black holes in a viable cosmological window

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Abstract. We show, performing a viable cosmological window, that only the magneto hydrodynamic (MHD) disk model is capable to explain how an intermediate mass black hole (IMBH) (with masses $\sim 10^3 M_\odot$) grows unto a supermassive black hole (SMBH) (with masses $\sim 10^7 M_\odot$). We still calculate the supermassive stars sequence of stability. Those stars, with synthetized helium or oxygen cores, collapse to form IMBHs. In our calculation we show that the primordial stars must have rapid rotation if they are in the stable part of the sequence.

Keywords. Black holes – quasars – first stars

1. First stars: sequence of stability

We consider that to form an intermediate mass black hole (IMBH) it is necessary a progenitor as a supermassive star. The existence of a such object can be tested by studying its stability. We perform this study by modelling a star with rotation, composed by a hydrogen envelop plus a helium or oxygen core. Geometrically the core is a Maclaurin ellipsoid with range of mass around 150–5000$M_\odot$ with an oblate parameter $e_\lambda = (a_3/a_1)^{2/3}$ – where a_3 and a_1 are respectively the equatorial and the polar radius of the ellipsoid – and where we apply post- and post-post-Newtonian criteria in the energy functional of the star. In Fig. 1 we show the sequence of stability for our star and the behavior of the rotation energy $T/|W|$ with the oblate parameter. The star necessarily has rapid rotation if it is in the stable part of the sequence (the left region of the Fig. 1b).

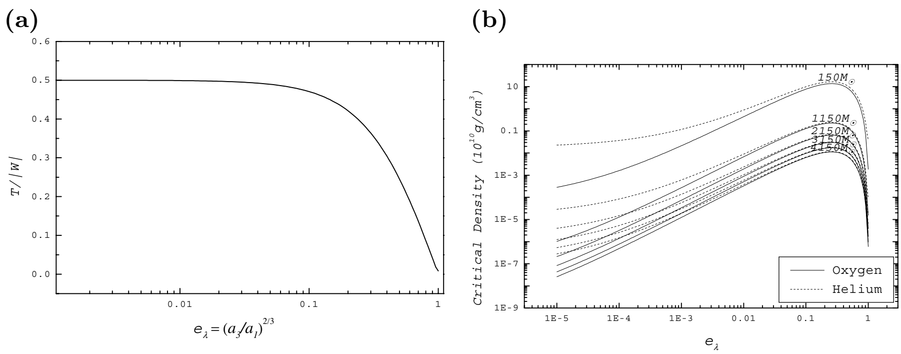

Figure 1. (*a*) The rotation energy $T/|W|$ versus the defined e_λ eccentricity. (*b*) Graphic showing the stability of the star. The behavior is different for both helium and oxygen cores.

2. Accretion onto black holes

In what follows we calculate how much time is necessary for a $10^3 M_\odot$ IMBH formed from our supermassive star to grow unto a $10^8 M_\odot$ supermassive black hole (SMBH). Here we adopt a ΛCDM model and use the WMAP cosmological parameters (Bennet *et al.* 2003; Spergel *et al.* 2003). The oldest QSO has redshift $z = 6.43$ (QSO $1148 + 525$, Fan *et al.* 2003) what means $t_{QSO} = 0.87$Gyrs. We consider that the accretion cosmological window begins at the creation of first stars ($z \sim 40$ or $t_{stars} \sim 0.067$Gyrs) and finish at the QSO $1148 + 525$ formation epoch. According to our calculation, the maxim life time of a first supermassive star is around $t \approx 0.01$Gyrs. An important parameter to unravel how supermassive black holes grow comes from the ratio R between the observed AGNs luminous density and the local SMBHs mass density. This parameter has a profound correlation with the efficiency η_M to convert rest mass in luminous energy in accretion disks. Recent measurements suggest that $0.1 < R < 0.2$ (Yu & Tremaine 2002). It is possible that the efficiency η_M is not a fixed parameter, but presents a variation related to the black hole spin. Following the model of McKinney & Gammie (2004) for MHD discs, we find that for a high speed rotating black hole, $\eta_M \to 0.19$. The deduction for the black hole mass function gives $M(t) = M_0 \exp\left[\frac{\eta_L(1-\eta_M)}{\eta_M}\frac{t-t_0}{\tau}\right]$, where η_L is the ratio between the object luminosity and Eddington luminosity (here we consider $\eta_L \to 1$), t_0 is the initial time (here we suppose t_0 is constrained by the first stars at $z \sim 40$) and τ is a temporal measure related to the chemical environment. In Fig. 2 we show that only MHD disks can explain how IMBHs become SMBHs in our cosmological window.

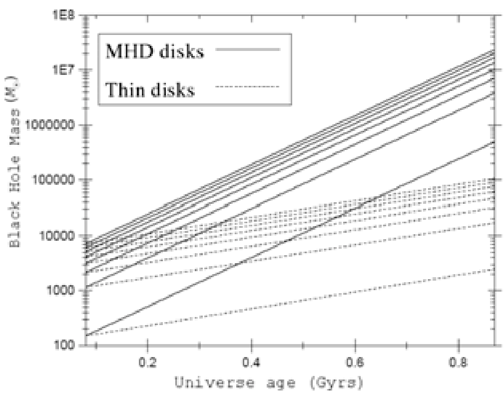

Figure 2. Growth of black hole masses for a initial range of masses M_0 equal to $150 - 6000 M_\odot$, growing by disk accretion: thin disk (dotted line) and MHD disk (solid line).

Acknowledgements

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