In the case of NGC 1275 an expression for $\Sigma_0$ can be found using the observational constrain given by Walker et al. (2000) where using the observed absorption of the counterjet emission at low radio frequencies, they found that the emission measure of the absorbing gas at a projected distance from the core of 2.5 pc, could be represented by the law $\ln I(\nu) \propto T(\nu)^{-1.5}$ where $I(\nu)$ is the projected size along the line of sight, in units of pc, $n_e$ the electron density, in $\text{cm}^{-3}$, $T_e$ the electron temperature, in units of $10^6$ K, $g_4$ the Gaunt factor, in units of its value at $T = 10^6$ K, and $r_\Sigma_0$, the projected distance to the core, in units of 2.5 pc. Using this constrain we were able to find an expression for $\Sigma_0$ as a function of $s$ and $a$.

The combined action of the Lense-Thirring effect with the inner viscosity of the disc causes the alignment of the angular momenta of the disc and the Kerr black hole; this is known as Bardeen-Petterson effect (Bardeen & Petterson 1975) and tends to affect only the innermost parts of the disc due to the short range of the Lense-Thirring effect, while the outer parts tend to remain in its original configuration. The transition radius between these two regions is known by Bardeen-Petterson radius and its location depends of the accretion disc configuration (Bardeen & Petterson 1975; Kumar & Pringle 1985; Nelson & Papaloizou 2000, Fragile & Anninos 2005).

Considering conservation of the total angular momentum of the system formed by the accretion disk and the black hole, the torque on the black hole will be equal to the torque produced on the disc by the Bardeen-Petterson effect. We will assume that the disk is aligned with the rotation axis of the black hole up to the Bardeen-Petterson radius and maintains its original inclination farther out. Using this fact, the alignment timescale can be calculated as:

$$ T_{\text{align}} = J_{\text{BH}} \frac{2\pi}{\Omega_{\text{BH}}} \int \left( \frac{r}{R_{\odot}} \right)^2 \frac{d\Omega_{\odot}}{dr} dr $$

where $R_0$ is the radius of the accretion disk and $R_{BP}$ is the Bardeen-Petterson radius defined as being

$$ R_{BP} = \frac{r_{\Sigma_0}}{\Omega_{\odot}(r_{\Sigma_0})} \left( \frac{r_{\Sigma_0}}{R_{\odot}} \right) $$

and

$$ \Omega_{\odot}(r) = \frac{M_{\odot}}{2\pi c^2} \left[ \frac{d\ln \Omega}{dr} r^2 - \frac{1}{r} \left( \frac{R_{\odot}}{r} \right)^2 \Omega_{\odot}(r) - \frac{1}{r} \right] $$

where $\nu_{i}(r)$ is the viscosity acting on a direction perpendicular to the disk, $\nu_{i}(r)$ is the azimuthal kinematic viscosity, $M$ is the accretion rate onto the black hole and $T(a) = 2(1+7a)^{3/2}/(2+4a)$ (Ogilvie 1999).

Finally, we will assume that the precession period is equal to the alignment timescale ($T_{\text{pre}} = T_{\text{align}}$), as found in analytical calculations considering steady-state configuration (Scheuer & Feiler 1996).

IV. Results

IV.1 The radio image

Using the precession model of Abraham & Romero (1999) and the observational constrains, we were able to reproduce the radio image. In the figure 1 we present our model overlaid to the 0.5 – 7 keV X-ray image obtained with Chandra by Fabian et al. (2000) which is also overlaid to the 332 MHz VLMA map of Pedlar et al. (1990).

References


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Figure 1: Precession model overlaid to the Chandra X-ray image and VLA 332 MHz contours (Fabian et al. 2000; Pedlar et al. 1990).

We found that the best precession parameters that fits well the jet are: $\phi_0=30^\circ$, $\eta_0=47^\circ$ (measured from north to east) and $v_j=100 \text{ km s}^{-1}$. We are also assuming that the angle $\phi(t)$ follows the behavior given by the equation 19 of King et al. (2005) using $\phi(t)=120^\circ$ and $J_2(t)/J_\text{BH}=1.1$.

Figure 2: Alignment timescale for different values of $\sigma^*$ and $s$. The horizontal line represents the alignment timescale found by Falceta-Gonçalves et al. (2010).