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WARPING AND PRECESSION IN EXTRAGALACTIC MASER ACCRETION DISCS

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RESUMEN

Las observaciones interferométricas de la emisión maser han sido utilizadas para explorar las condiciones físicas de discos de acreción extragalácticos a escalas de sub-parsec. La cinemática derivada de los maser de agua presenta pequeñas desviaciones respecto al movimiento Kepleriano, éstas han sido atribuidas al combado y torcedura del disco a escalas de parsec. Sin embargo, su origen físico es aún materia de debate en la literatura. Motivados por esto, analizamos el efecto relativístico Bardeen-Peterson, producido por un agujero negro de Kerr, como un potencial mecanismo físico responsable del combado y precesión del disco en las galaxias Seyfert 2 cercanas NGC 1068 y NGC 4258. Suponiendo un disco de acreción tipo ley de potencias, cuyos parámetros fueron obtenidos a partir de los datos observacionales, derivamos las cantidades básicas relacionadas con el efecto Bardeen-Peterson para ambas fuentes. Presentamos además algunas consecuencias de este peculiar mecanismo físico.

ABSTRACT

Interferometric maser observations have been used to probe the physical conditions of extragalactic accretion discs at sub-parsec scales. The inferred kinematic of the water maser spots presents small deviations from Keplerian motions, which have been attributed to the warping and twisting of the parsec-scale disc. However, their physical origin is still a matter of debate in the literature. Motivated by this, we analyzed the general relativistic Bardeen-Petterson effect, driven by a Kerr black hole, as the potential physical mechanism responsible for the disc warping and precession in the nearby Seyfert 2 galaxies NGC 1068 and NGC 4258. Assuming a power-law accretion disc, whose parameters were constrained by the observational data, we derived the basic quantities concerning the Bardeen-Petterson effect for both sources. Some consequences from this peculiar relativistic mechanism are also presented in this work.

Key Words: accretion, accretion discs — black hole physics — galaxies: ctive — galaxies: individual (NGC 1068, NGC 4258) — masers

1. NGC 1068 AND NGC 4258

The word *maser* is an acronym for microwave amplification by stimulated emission of radiation, implying in an overpopulation of the non-grounded energy levels when compared to that predicted from the thermal equilibrium condition (see e.g. Elitzur 1992 for a more detailed discussion). Water and hydroxyl molecules have been observed from maser transitions in galactic and extragalactic sources.

Concerning extragalactic water masers, they were firstly observed in star forming regions of the nearby galaxy M 33 (Churchwell et al. 1977), while the first water mega-maser was discovered in NGC 4945 (dos Santos & Lepine 1979). These mega-masers are observed in high-density warm molecular gas (typically $10^8 - 10^{10}$ cm^{-3} and 300–1000 K), usually associared with parsec-scale accretion disc and/or post-shocked gas in jet/outflow molecular gas interaction in Seyfert 2 and LINER active galaxies (e.g., Lo 2005).

Interferometric water maser observations are excellent probes of the physical conditions of accretion discs at parsec and sub-parsec scales. At these scales, masers are produced in very compact regions that present small deviations from pure Keplerian rotation (e.g., Greenhill et al. 1996; Herrnstein et al. 2005). This is the case of the nearby Seyfert 2 galaxies NGC 1068 and NGC 4258, for which the departures from Keplerian motions have been attributed to the presence of a warped and twisted accretion disc (e.g., Gallimore et al. 2004; Herrnstein et al. 2005).

The main objective of this work was to study the warping and precession of the parsec-scale accretion discs of NGC 1068 and NGC 4258 in terms

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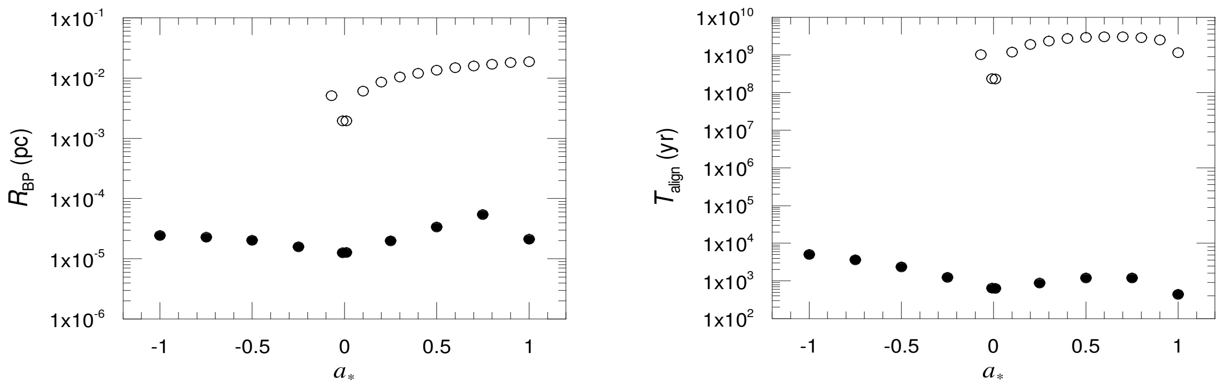

Fig. 1. Bardeen-Petterson radius (left panel) and alignment time-scale (right panel) as a function of the black hole spin for NGC 1068 (filled circles) and NGC 4258 (open circles). Such results correspond to the Model A found in Caproni et al. (2006) for NGC 1068, and to the model parameters represented by open triangles in Figures 3 and 4 in Caproni et al. (2007) for NGC 4258.

of the Bardeen-Petterson effect (Bardeen & Petterson 1975). The basis of this mechanism resides in the combination of the general relativistic Lense-Thirring precession and accretion viscosity in a disc misaligned with the equator of a spinning black hole. The angular momentum of the disc inside the Bardeen-Petterson radius is forced to align or counter-align with the angular momentum of the black hole (King et al. 2005). Bardeen-Petterson precession can be prograde or retrograde, depending only on the sense of black hole rotation in relation to the disc.

The basic parameters of Bardeen-Petterson effect are the Bardeen-Petterson radius $R_{\rm BP}$ and the timescale associated to alignment process of the disc with the black hole's equator $T_{\rm align}$. In order to calculate them, we used the basic equations for a thin or slim accretion disc (e.g., Shakura & Sunyaev 1973; Abramowicz et al. 1988), assuming a power-law surface density distribution for the disc $\Sigma = \Sigma_0(r/R_{\rm g})^s$, where r is the radial distance from the black hole and $R_{\rm g}$ is the gravitacional radius. The estimate of the value of Σ_0 is basically constrained to the optimum thermodynamical conditions for maser emission, being a function of s-parameter as well (see Caproni et al. 2006, 2007 for a more detailed discussion). In Figure 1, we show the values of $R_{\rm BP}$ and $T_{\rm align}$ for NGC 1068 and NGC 4258 as a function of black hole spin, considering $s = -1$.

2. FINAL REMARKS

Water masers can use to probe physical conditions at sub-parsec scales in Seyfert 2 galaxies NGC 1068 and NGC 4258. The kinematic of the maser spots in those sources suggests the presence of warping and precession in their accretion discs, which we interpreted in this work as a consequence of the Bardeen-Petterson effect. We estimated the range of the values of the Bardeen-Petterson radius ($\sim 10^{-5} - 10^{-4}$ pc in NGC 1068 and $\sim 2 \times 10^{-4} -$ 0.08 pc in NGC 4258) and the alignment timescale ($400 - 6 \times 10^4$ yr in NGC 1068 and 0.4–10 Gyr in NGC 4258). Consequences of the Bardeen-Petterson effect at larger scales can be seen from the jet kinematics at pc/kpc scales in NGC 1068 (Caproni et al. 2006) and from the anomalous arms in NGC 4258 (Caproni et al. 2007).

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