PRECURSOR FLARES IN OJ 287


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ABSTRACT

We have studied three most recent precursor flares in the light curve of the blazar OJ 287 while invoking the presence of a precessing binary black hole in the system to explain the nature of these flares. Precursor flare timings from the historical light curves are compared with theoretical predictions from our model that incorporate effects of an accretion disk and post-Newtonian description for the binary black hole orbit. We find that the precursor flares coincide with the secondary black hole descending toward the accretion disk of the primary black hole from the observed side, with a mean z-component of approximately $z_c = 4000$ AU. We use this model of precursor flares to predict that precursor flare of similar nature should happen around 2020.96 before the next major outburst in 2022.

Key words: BL Lacertae objects: individual (OJ 287) – quasars: individual (OJ 287)

Online-only material: machine-readable table

1. INTRODUCTION

OJ 287 is a blazar at redshift $z = 0.306$ that exhibits nearly periodic double-peaked outbursts at intervals of approximately 12 years in the optical regime (Sillanpää et al. 1988, 1996a, 1996b). This periodicity is not exact, as was definitely demonstrated by the observed outbursts in 2005 and 2007 (Valtonen et al. 2006b, 2008a, 2008b). Both the double-peaked structure and the dwell in the outburst interval have been successfully explained by a precessing binary black hole model (Lehto & Valtonen 1996; Sundellius et al. 1996, 1997; Valtonen et al. 2011). In this model, the double optical outbursts are caused by a secondary black hole impacting the accretion disk of the primary black hole, twice in one period.

The orbit of the secondary is sufficiently compact and eccentric ($e \sim 0.7$) to bring it close enough to the primary for strong relativistic precession of the orbit (Valtonen & Lehto 1997; Valtonen 2007). The magnitude of the precession has been established at approximately 39.1 per cycle (Valtonen et al. 2010b). The binary black hole with orbital speeds close to 10% of the light speed enabled probing the conservative aspects of general relativistic binary dynamics at the second post-Newtonian order, including the effects of dominant order spin–orbit coupling (Valtonen et al. 2010b). Further, the possibility of testing the orbit of the secondary in the near future general relativity and black hole properties using the binary black hole in OJ 287 makes the detailed understanding of the binary black hole especially important (Valtonen et al. 2011).

In this paper we discuss an aspect of OJ 287 binary black hole that has attracted rather little attention so far. The repeated impacts of the secondary black hole on the accretion disk of the primary create a corona of high-velocity gas clouds above the standard geometrically thin but optically thick accretion disk. As the secondary travels through this disk, it may accrete some of the clouds, and these accretion events may lead to quite prominent brightening of the OJ 287 system as a whole. They could be contrasted with similarly fast brightening events of black holes accreting whole stars, as has been recently reported (Gezari et al. 2012), but with a different timescale and mechanism of action. If such events can be identified, they would allow the detection of the secondary black hole, in addition to the primary which is normally responsible for the emission of OJ 287.

The type of light curve features we will discuss is shown in Figure 1, which displays the optical light curve of OJ 287 since 1990. Besides the double-peak structure indicated by the vertical lines, there are prominent outbursts prior to each cycle called precursors by Kidger & Takalo (1993). They are marked by arrows in Figure 1. The first one peaked at 1993.93 and it was studied by Kidger & Takalo (1994) and Kidger et al. (1995). The second one peaking at 2004.27 was studied by Valtonen et al. (2006a). They also discussed a possible origin of the precursors. The third precursor occurred only recently, peaking at 2012.29, and the data related to this precursor are reported here. We will also describe two possible scenarios with regard to the origin of precursors and finally settle on a model that seems to fit the limited amount of data.