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TITLE: JOINT TIMING ANALYSIS OF A0535+26 AT 1980 OUTBURST

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JOINT TIMING ANALYSIS OF A0535+26 AT 1980 OUTBURST

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ABSTRACT

The pulse-timing data of A0535+26, obtained by the Hakucho satellite in October 1980 is analyzed taking into consideration other observations. The results show that a considerable fraction of the observed period change is intrinsic.

1. INTRODUCTION

The Hakucho satellite observed the transient X-ray pulsar A0535+26 in October 1980. Nagase et al.¹ analyzed the timing data and obtained constraints on the orbital parameters. Here, the Hakucho pulse-timing data is combined with the SAS 3 data² and the pulse period measurement by a balloon experiment, using fits to a Keplerian orbit.

2. JOINT FITTING OF HAKUCHO AND SAS 3

We used three sets of pulse-timing data: I) 25 epochs of arrival times in 1975 November (SAS 3)³, II) 45 epochs in 1978 April (SAS 3)⁴, III) 188 epochs in 1980 October (Hakucho).

The SAS 3 data sets are provided to us by Rappaport and Kelley². The analysis were made combining two out of the three data sets in two cases: 1) I + II, 2) II + III. We fit the data to a Keplerian orbit, where no intrinsic pulse period change is assumed during the outburst, but different intrinsic period is allowed for the different sets of data. The chi-square contour in parameter space (Fig. 1) for case 2, is a series of narrow islands (vertical bars). Case 1 gives a similar figure except that the vertical bars are two times as dense as case 2. Several discrete values are allowed for the orbital period, depending on how many orbital cycles are assumed between the two data sets. The values of the P_{orb} at the center of each island is

$$P_{orb} = 1805/n \text{ days, } n=1,2,3,\dots,40 \quad (1)$$

for case (1), and

$$P_{orb} = 910/n \text{ days, } n = 1,2,3,\dots,23 \quad (2)$$

Fig. 1. The acceptable region of the orbital parameters of A0535+26 for the joint SAS 3 (1978)/Hakucho (1980) data, where no intrinsic P is considered. Each vertical bar indicates the allowed region with 90% confidence. Dashed curves indicate constant mass function.

Fig. 2. The acceptable region of the orbital parameter of A0535+26 for the joint Balloon/Hakucho data, where no intrinsic P is considered. The 90% confidence region is hatched. Dashed curves indicate constant mass function.

for case (2). Although the allowed regions of orbital parameters for the two cases look similar, there is no overlapping between the two cases. For example, one of the best-fit orbital periods for case 1) is 112.8 days ($n=16$ in (1)), while one for case 2) is 113.7 ($n=8$ in (2)). The allowed regions for the two cases are separated by the difference in orbital period of 0.9 days, whereas the width of allowed region in orbital period is about 0.02 days for each case. This leads to a conclusion that if the intrinsic period changes are not taken into account there is no solution consistent through the three data sets.

3. JOINT FITTING WITH THE BALLOON PERIOD

Prior to our observation in 1980 October, a longer pulse period of 103.79 s was observed with a balloon experiment, on September 25 by Hameury et al.⁵. We combined the balloon pulse period to the Hakucho data, fitted to a Keplerian orbit where we assume no intrinsic P . The results shown in Fig. 2 indicate that there is no solution with a mass function less than $100 M_{\odot}$. Since the companion of A0535+26 is identified as a Be star with $15 M_{\odot}$, this constraint on the orbit is clearly contradictory. This analysis demonstrates the necessity of an intrinsic period change during the outburst.

We next assumed that the rate of intrinsic period change is proportional to $L_x^{6/7}$ (L_x : X-ray luminosity), and fit the Hakucho/Balloon data. Here, two additional parameters are introduced. One is the ratio of intrinsic $\dot{P}$ to $L_x^{6/7}$, the other describes the estimation of the integrated X-ray flux during the interval from the balloon observation to the beginning of the Hakucho observation. We find that an appropriate choice of the two parameters allows a solution with mass function less than $20 M_{\odot}$. The resulting intrinsic P is more than 4×10^{-8} on October 9, while the apparent P , including the Doppler effect, is 8×10^{-8} . As the X-ray intensity decreases, the intrinsic P decreases until the end of the observations. Thus, at least half of the observed period change at 1980 outburst (103.79 s to 103.61 s) is attributed to the intrinsic period change.

CONCLUSION

The Hakucho pulse-timing data, when combined with the SAS 3 or the balloon data, clearly indicate the existence of considerable intrinsic period change during the outburst. The analysis of the Hakucho/Balloon data shows that an accretion torque model can explain the period change during the 1980 outburst.

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