

RESULTS OF THE TIMING ANALYSES OF X-RAY PULSARS
OBSERVED BY HAKUCHO AND TENMA

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ABSTRACT. A dozen of X-ray pulsars have been observed with the Japanese X-ray astronomy satellites *Hakucho* and *Tenna* between 1979 and 1984. The observations revealed remarkable pulse period changes both in disk-fed and wind-fed pulsars. From the histories of the pulse period changes so far measured, we are able to classify the X-ray pulsars into three categories:

(1) Pulsars which exhibit a steady spin-up with a constant rate of period change (e.g., 4U 1626-67 and GX 1+4).

(2) Disk-fed pulsars in which considerable period changes are superposed on the secular trend of spin-up (e.g., Her X-1 and Cen X-3).

(3) Wind-fed pulsars whose pulse periods fluctuate randomly about the average pulse period on time scales from days to years (e.g., Vela X-1 and GX 301-2).

Among the dozen X-ray pulsars observed by *Hakucho* and *Tenna*, Vela X-1 was most extensively studied. Timing studies of Vela X-1 revealed an episode of secular spin-down of the pulsar between 1979 and 1982, and large rates of short-term period fluctuations superimposed on the secular trend. Recent studies of the wind-fed pulsar suggest that the angular momentum transfer expected from the wind accretion is too small to account for the observed rates. Spectroscopic studies of Vela X-1 by *Tenna* observations provided a variety of phenomena related to the binary system and detailed properties of matter surrounding the system, especially using an iron emission line fluoresced thereby as a probe.

Formation of a disk in the wind-fed pulsar is proposed to accommodate a variety of phenomena observed from Vela X-1. A disk is expected to be formed through the interaction of the spherically accreting matter with the rotating magnetosphere, under the assumption that the closed magnetosphere extends to the corotation radius. Application of this model to Vela X-1 requires a large magnetic moment of $\mu \approx 10^{32}$ gauss cm^3 ($10^{13} \leq B \leq 10^{14}$ gauss, depending on the stellar parameters), but once the large value is accepted, this model fits well with the large rates of period change and phenomena which would otherwise be regarded as strange. If this model works for Vela X-1, it will be also applied to some of other wind-fed pulsars.