Viscous Instability In Close Low Mass X-ray Binaries And The Formation of Redback Pulsars

Kun Jia[1] and X.-D. Li[1;2]

[1]*Department of Astronomy, Nanjing University*

[2]*Key laboratory of Modern Astronomy and Astrophysics (Nanjing University), Ministry of Education*

ABSTRACT

Redback pulsars are a sub population of eclipsing millisecond pulsars (MSPs) in close binary systems. So far, all the three discovered transitional systems (with recurrent radio pulsar⇆X-ray binary switches) are redback systems. Formation mechanism of these systems is not very clear, and several models have been proposed from different aspects (Chen et al. 2013; Benvenuto et al. 2014, 2015; Smedley et al. 2014). Most recently, channeled accretion has been detected in the disk state of PSR J1023+0038 and XSS J12270-4859, adding PSR J1824-2452I as an typical accreting millisecond X-ray pulsars (AMXPs) in outburst state, all the three transitional redback pulsars exhibit as AMXPs at disk or outburst state. As we know AMXPs are all transient systems due to viscous unstable disks, which promote us to investigate the secular evolution of close binary systems considering the disk instability model (DIM) and the effect of evaporation wind in this work.

THE PARAMETER SPACE FOR DIM IN LMXBS

Fig. 1 presents our calculation results where the disk of LMXB system becomes thermally and viscously unstable with different donor masses (M_2). Here we adopt the critical value of mass transfer rate for a irradiation disk given by Dubus et al. (1999). Various evolutionary states, Roche-lobe detachment, stable disk accretion, and unstable disk accretion are indicated with different linestyles, the asterisk symbol indicates when the NS has accreted 0.1 $M_\odot$.

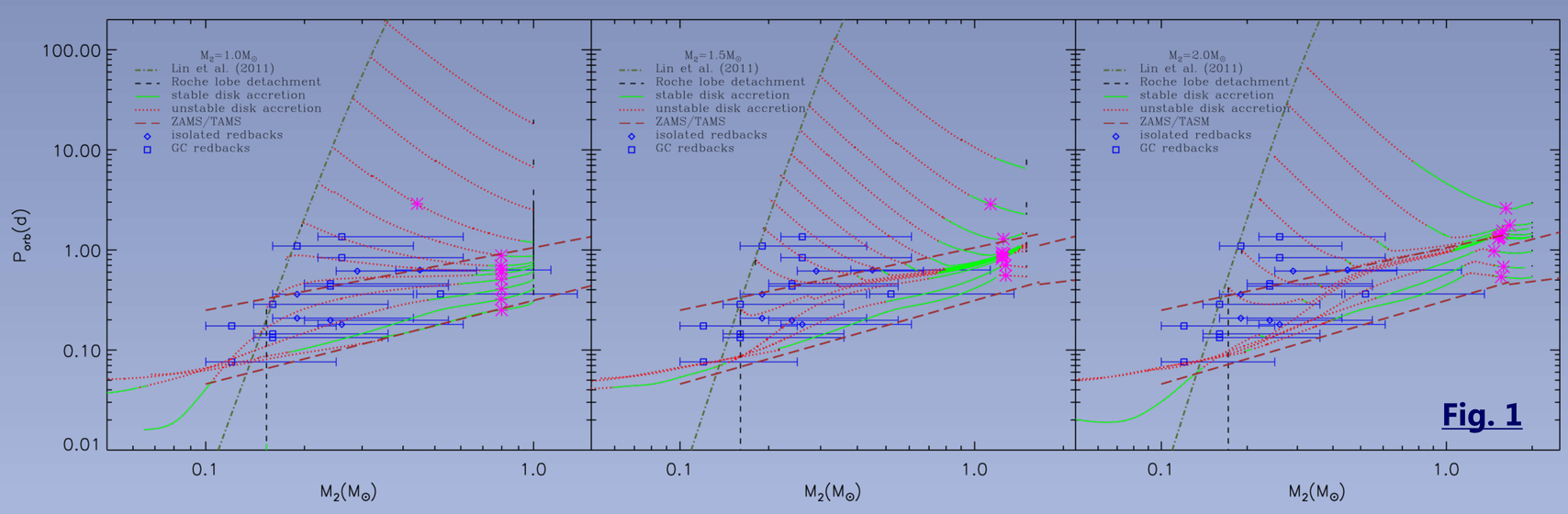

Fig. 1

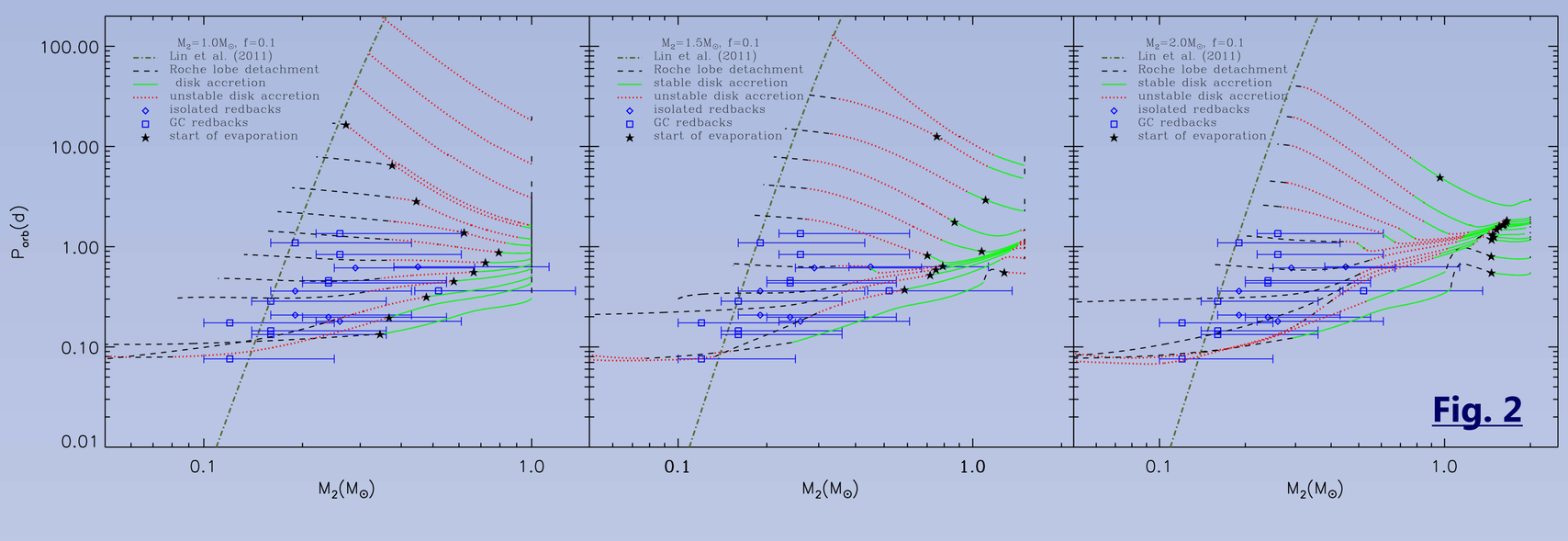

Fig. 2

EVAPORATION AND FORMATION OF REDBACKS

Fig. 2 is similar to Fig. 1 when taking the evaporation wind with a efficiency factor f=0.1 (Stevens et al. 1992) into calculations. We simply assume the donor evaporation would take place once two conditions are satisfied: (1) the pulsar has accreted 0.1 $M_\odot$ mass to be recycled as a MSP (Lipunov & Postnov 1984; Tauris et al. 2012), (2) the accretion disk becomes unstable as we calculate above. We argue the redbacks are formed during the MSP binary systems in the quiescent state of the DIM duty cycle.

CONCLUSIONS

1. Almost all LMXBs are subject to the thermal and viscous instability and experience transient phase(s) sooner or later in their evolution. If the NSs have be spun up to millisecond periods, the reduction of the mass transfer rate during quiescence provides a plausible mechanism for the switch on the pulsar activity and the formation of redbacks, besides the disrupted MB and irradiation instability models.

2. In this scenario, the redback companions can be MS stars, evolved stars, or (proto-) WDs with either Roche lobe filling or under filling.

3. Consider the influence of evaporation on binary evolution, part of redbacks evolving along the converging tracks may become black widows, while the wide ones may form MSP-He WD binaries. The final products are heavily dependent on the evaporation efficiency and the AML model, both of which deserve further study.

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