

A particular stellar-mass black hole GRS 1915+105: 15 years of X-ray and radio monitoring

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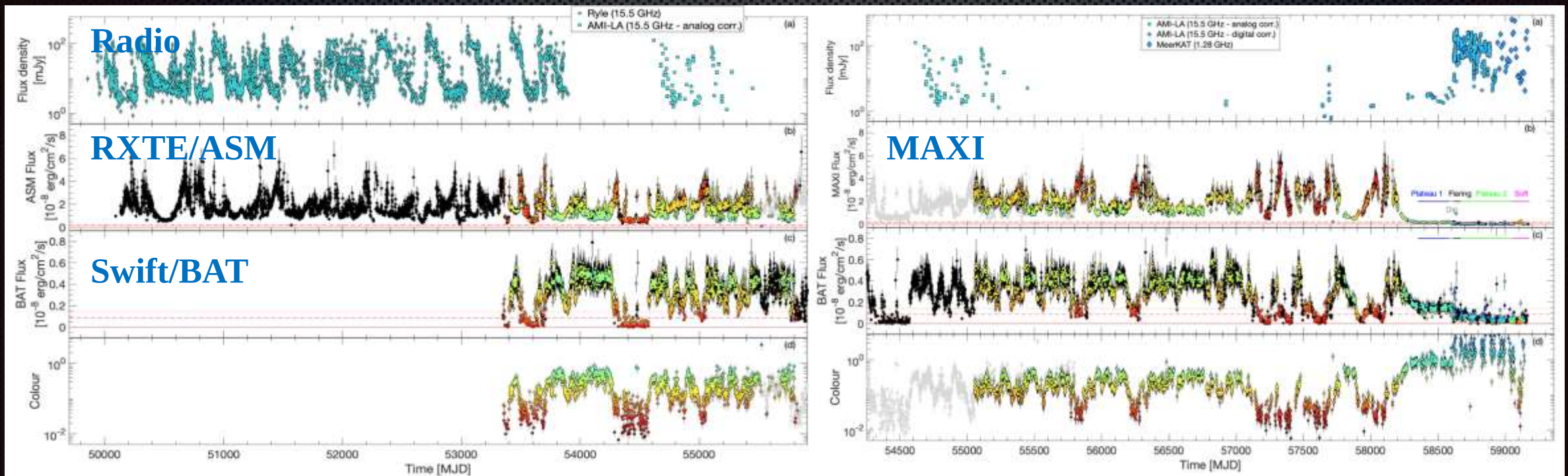
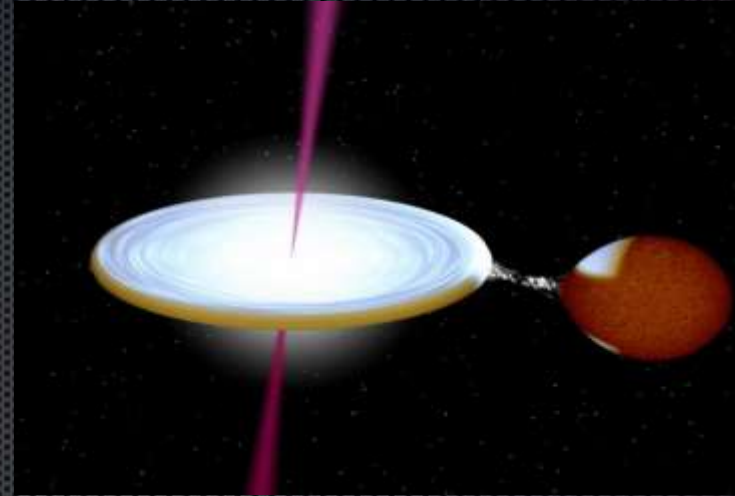


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Institute of High Energy Physics
Chinese Academy of Sciences

X射线天文学60周年研讨会, 2022年06月16日

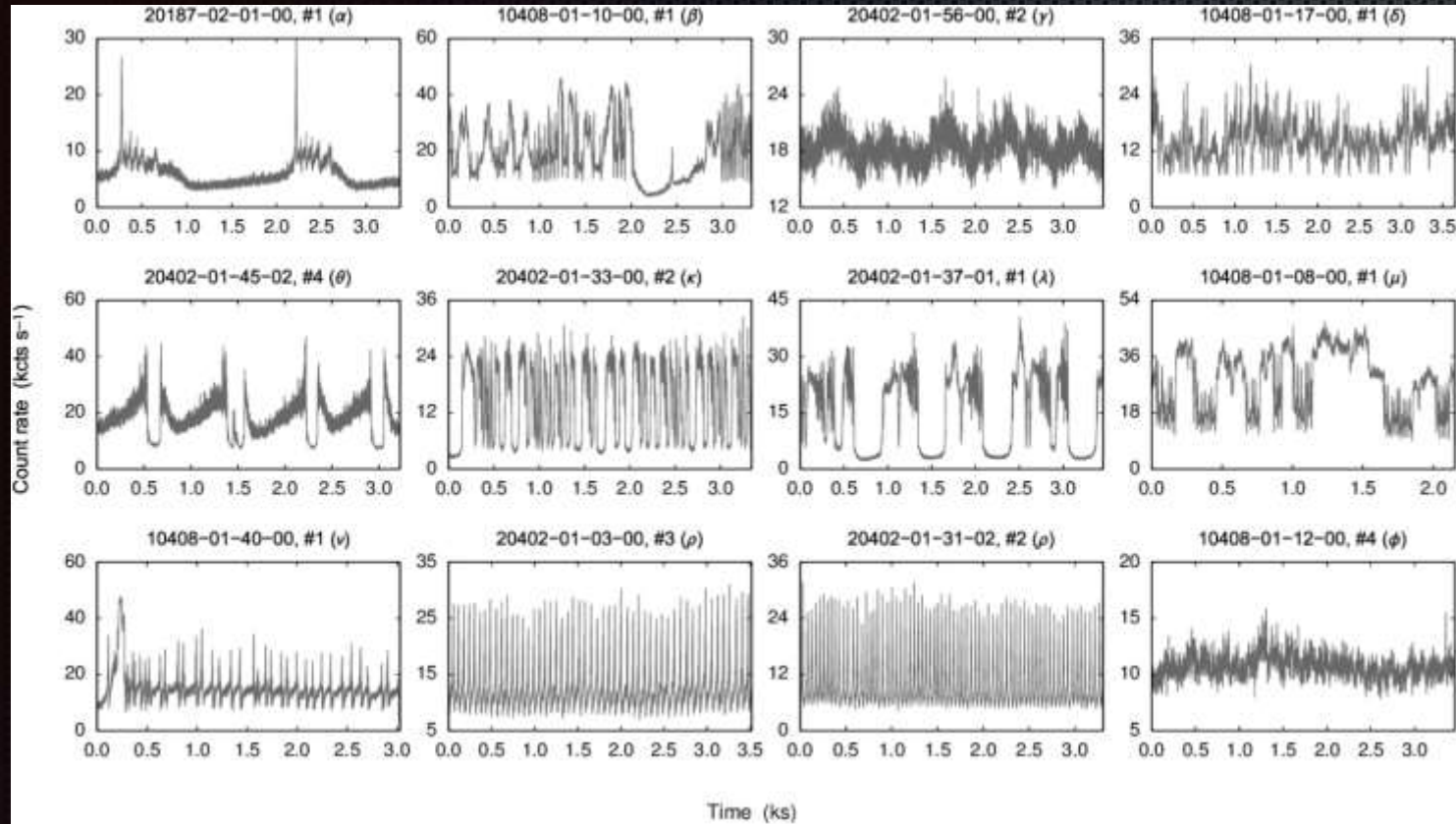
GRS 1915+105

- 低质量黑洞X射线双星暂现源：
黑洞： $\sim 12 M_{\odot}$, 极端高自旋 ($a_* > 0.9$)
伴星：KIII
轨道周期：812 $\pm$ 4 hour
倾角：60 $\pm$ 5 deg



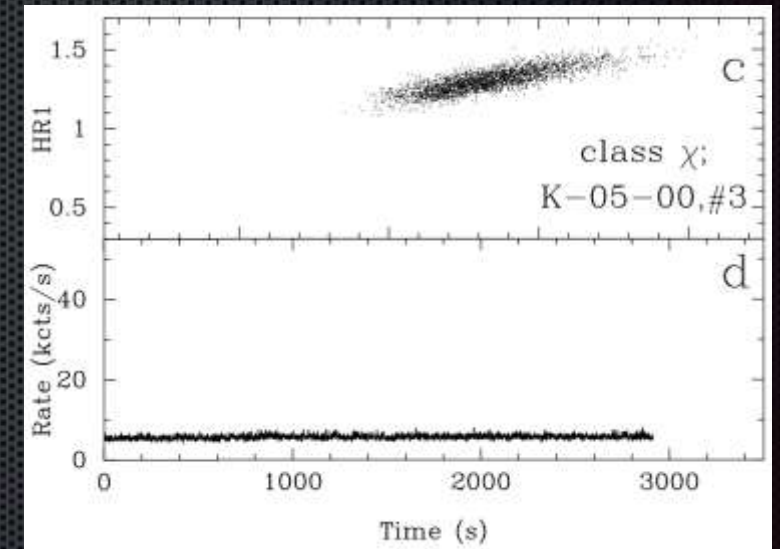
GRS 1915+105

不同的光变形态:



Belloni et al. (2000)

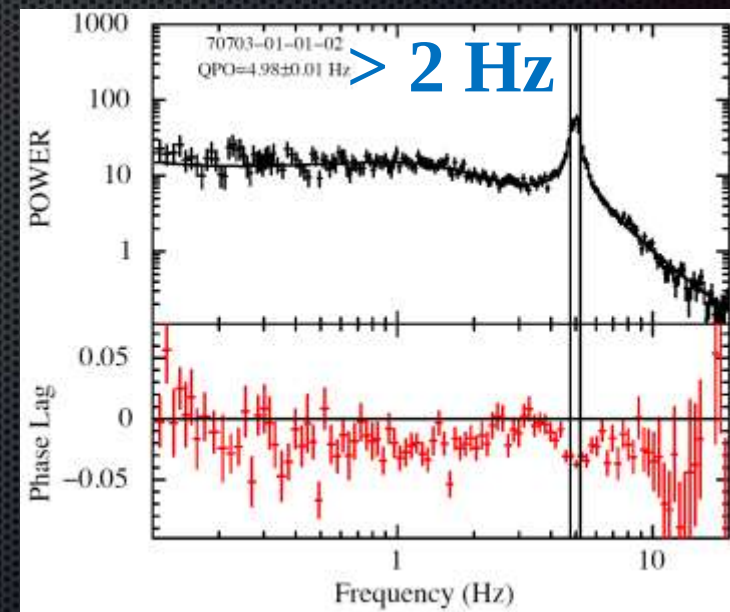
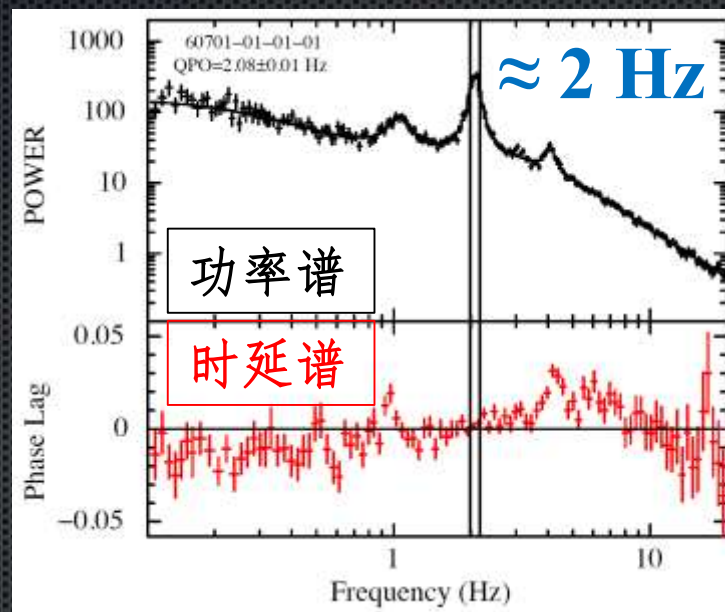
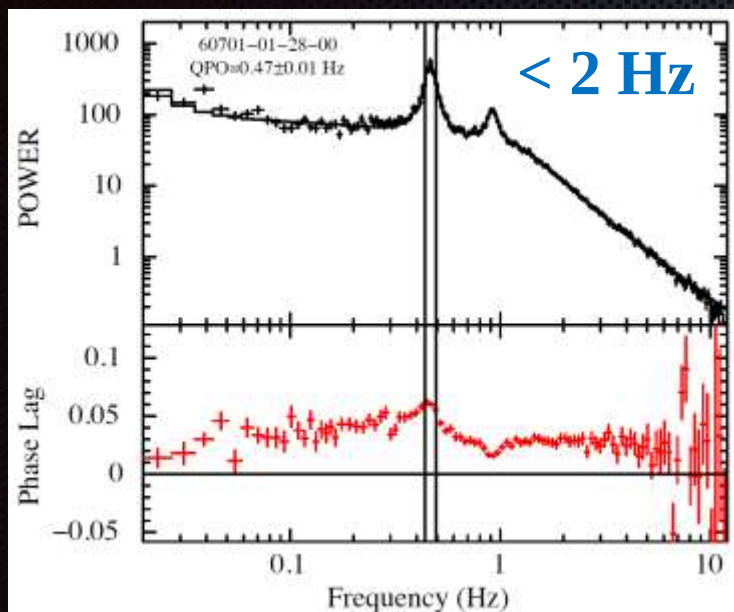
平稳变化态 (χ state):



- 能谱对应其他黑洞X射线双星的硬态/硬中间态
- 存在0.1-10 Hz的QPO
- 存在稳定的喷流

GRS 1915+105中的QPO

χ state典型的功率谱和时延谱:

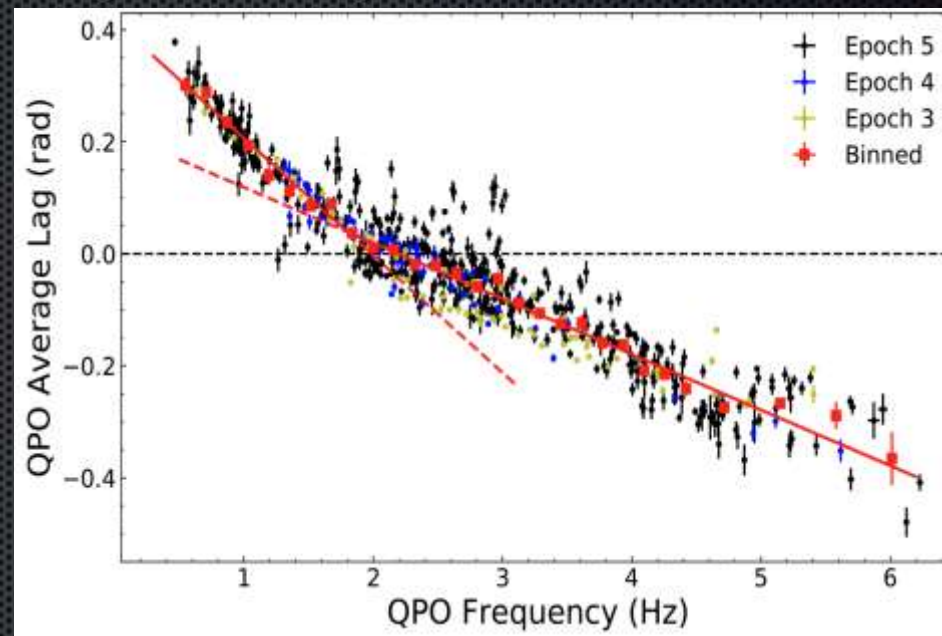
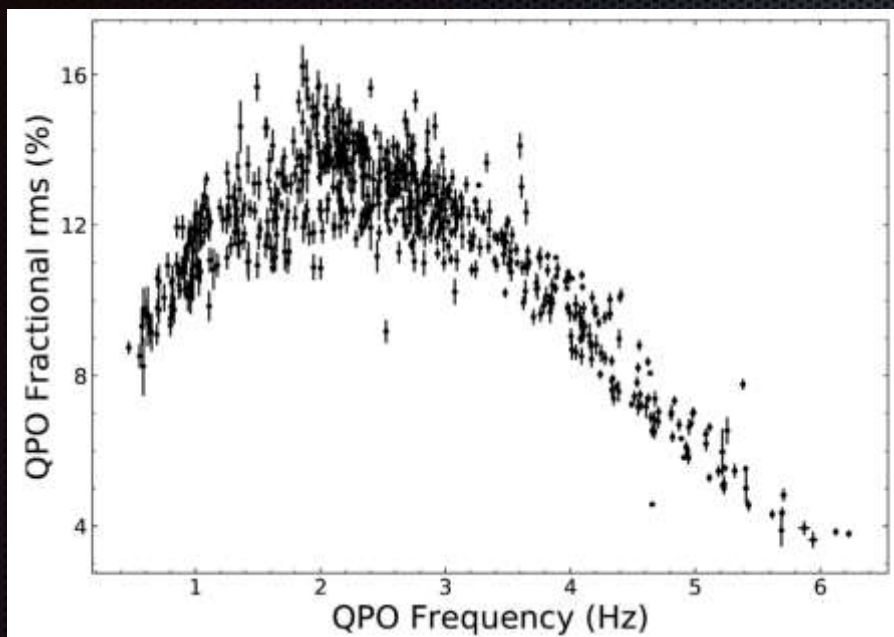


Zhang et al. (2020)

- GRS 1915+105是**唯一**一个存在QPO延迟符号明显变化的黑洞X射线双星。

QPO的振幅和延迟

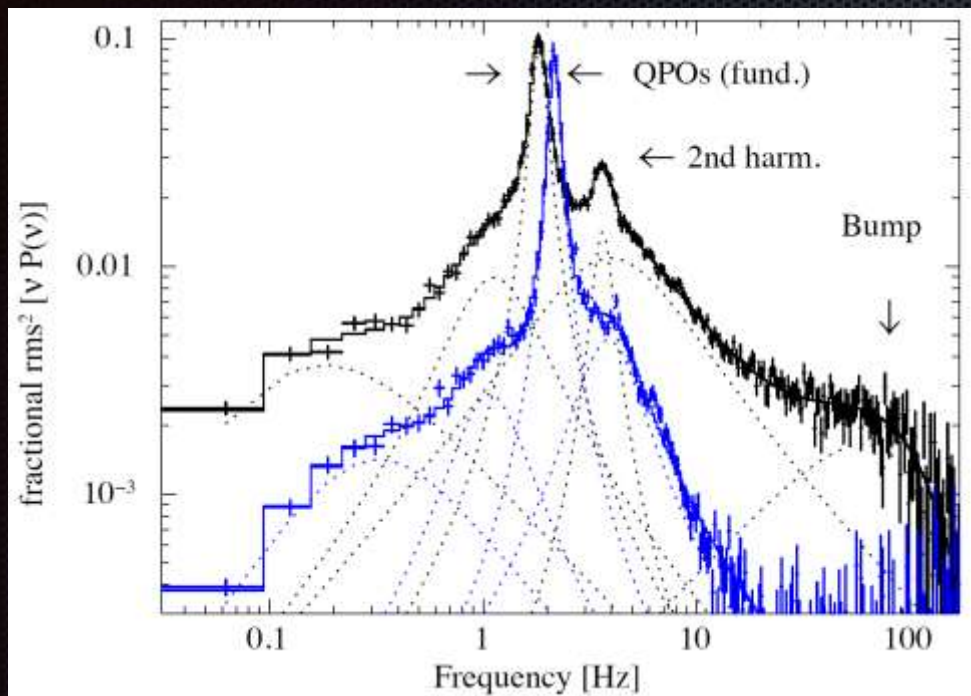
大样本统计性分析结果：620个频率稳定的C型QPO



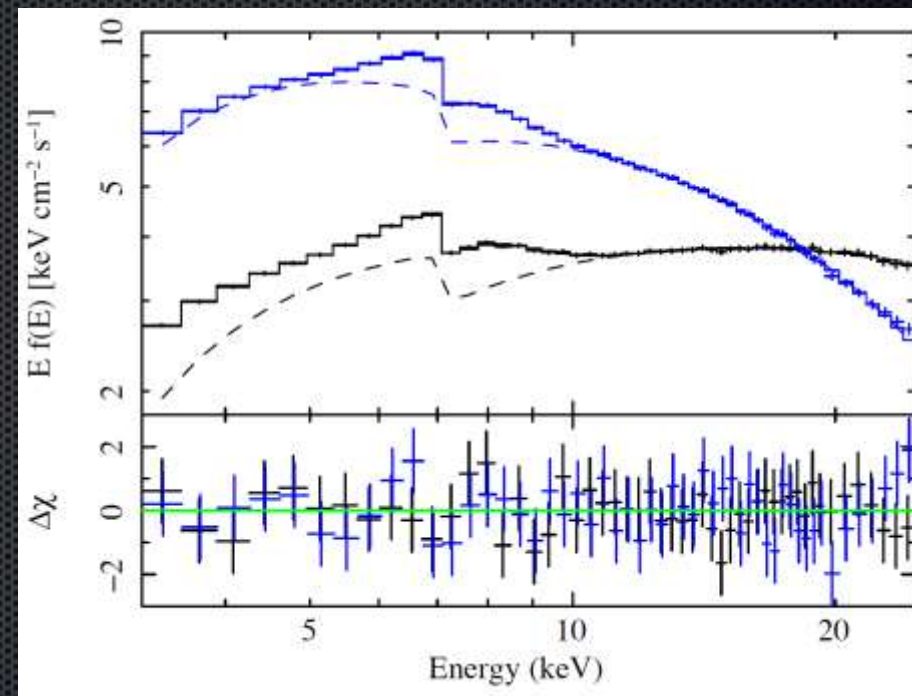
Zhang et al. (2020)

- QPO的振幅在2 Hz附近达到最大值
- QPO的延迟随频率减小，在2 Hz附近由正延迟变为负延迟

功率谱和能谱的比较



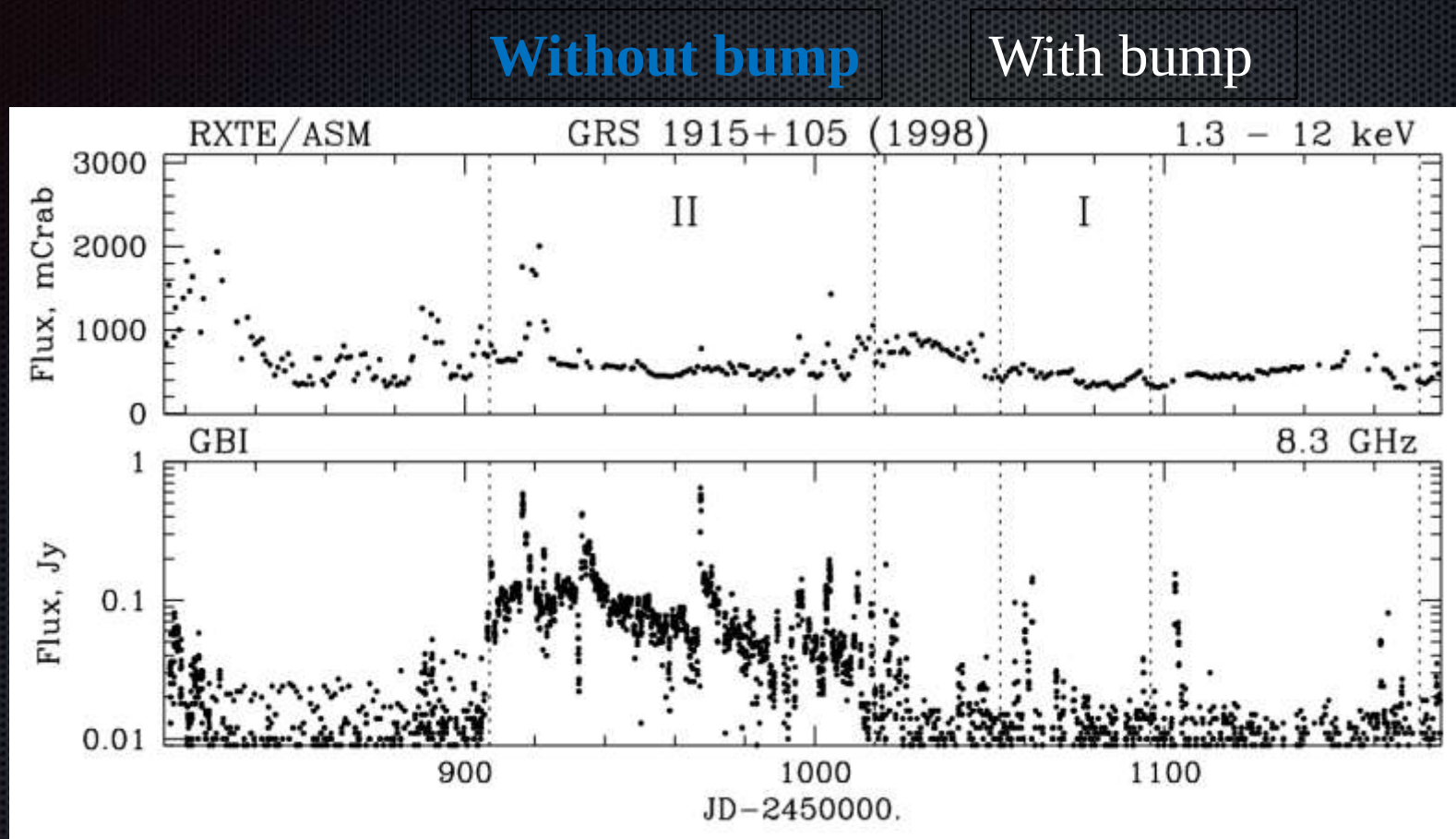
高能Bump只在电子温度较高的观测中出现



电子温度:

- $kT_e = 10.9 \pm 0.8$ keV
- $kT_e = 6.3 \pm 0.5$ keV

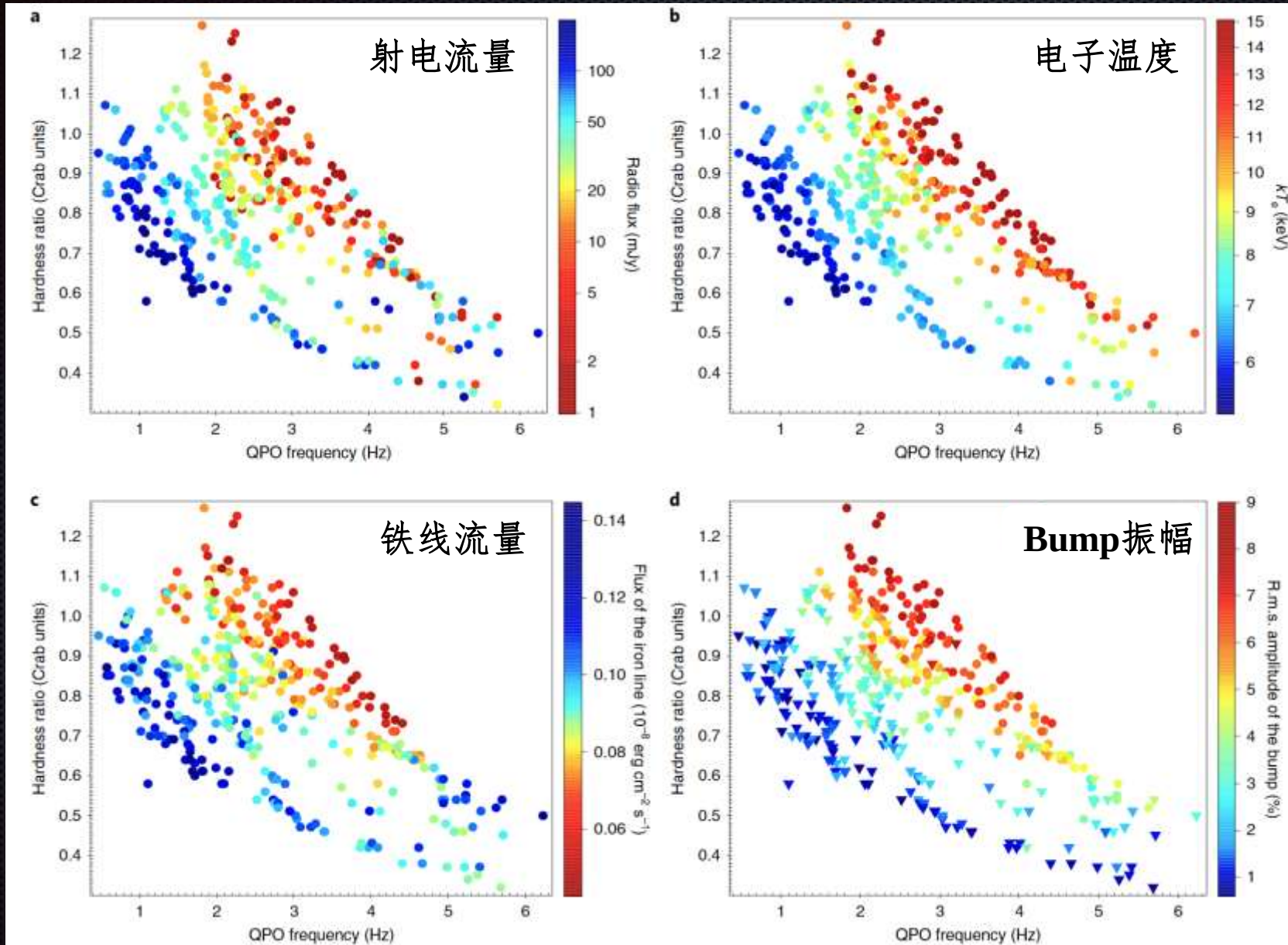
射电流量的比较



Trudolyubov et al. (2001)

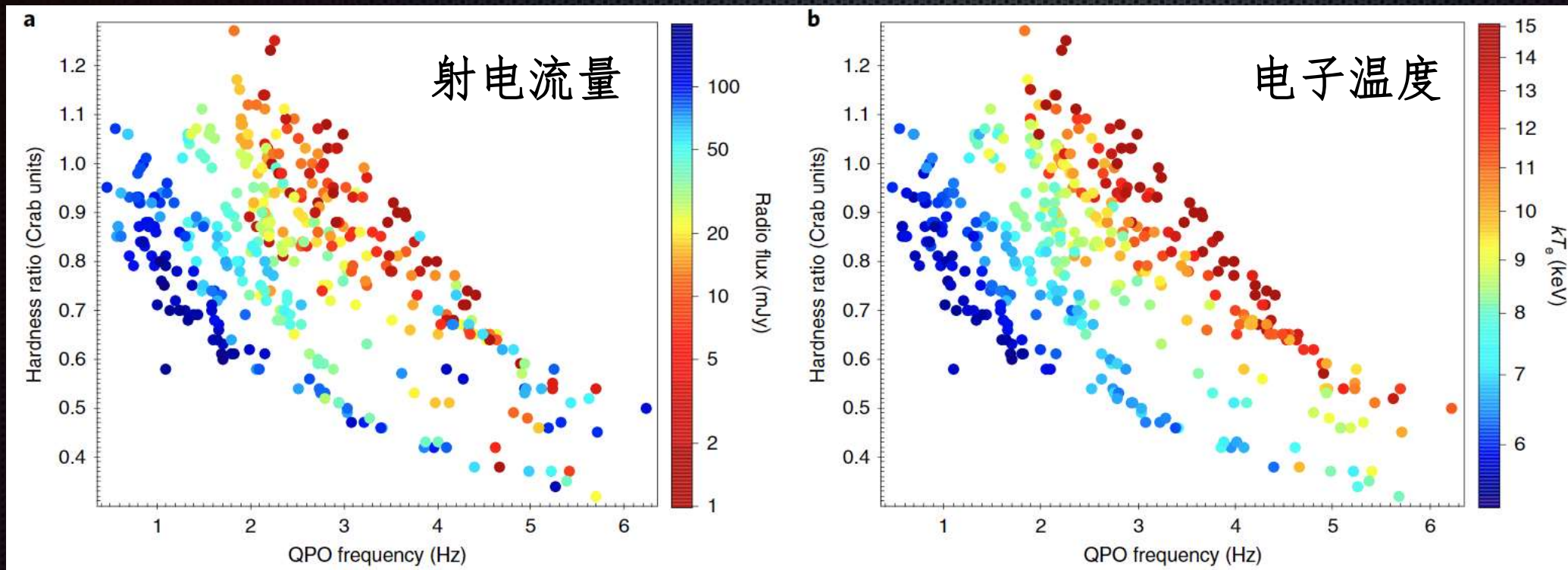
- 功率谱中存在Bump的时刻射电流量较低。

系统分析：不同参量之间的相关关系



Mendez et al. (2022)
Nature Astronomy

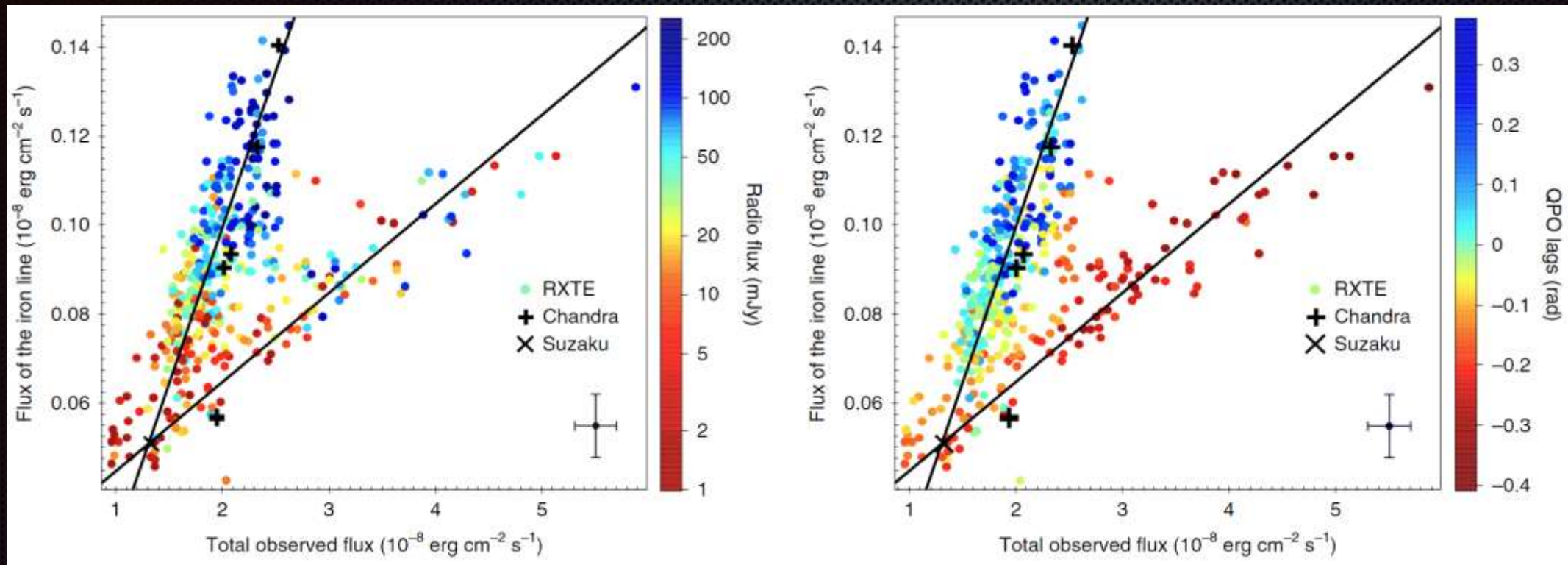
冕的电子温度与射电流量之间的关系



Mendez et al. (2022)

- 射电流量和冕的电子温度**反相关**；
- 冕和喷流可能来自于同一能量源：当更多的能量用于加热冕，剩下的用于触发/加速喷流的能量就会相对减少，反之亦然。

铁线

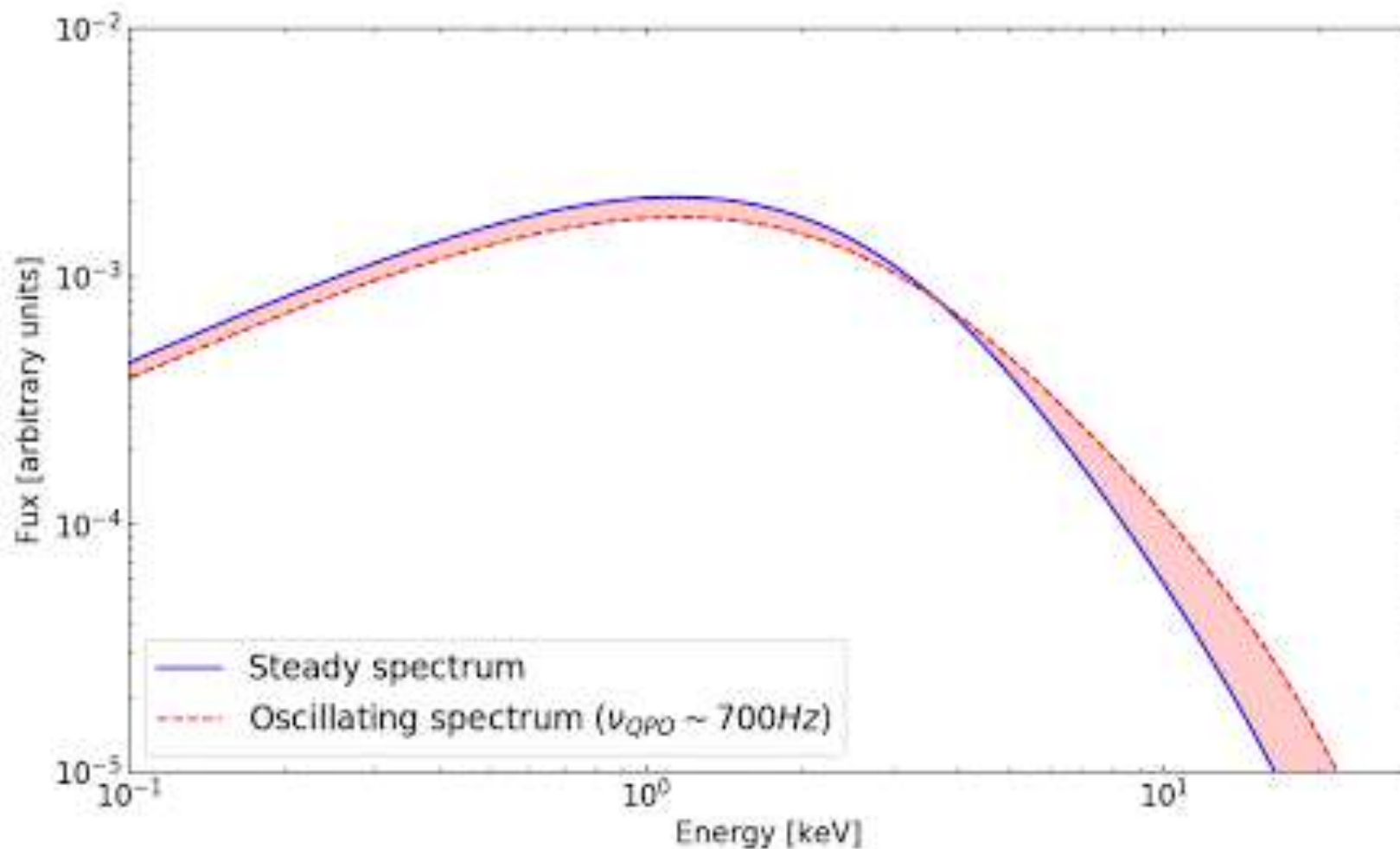


Mendez et al. (2022)

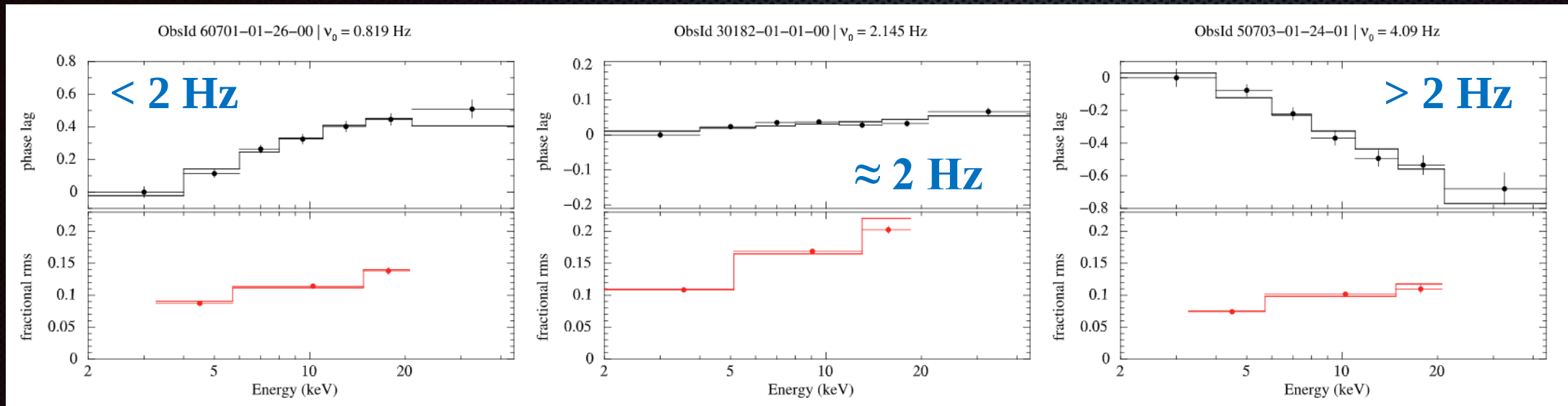
- 铁线流量和总流量之间的关系存在不同的分支；
- 不同分支的射电流量和QPO延迟性质存在明显差异。

基于康普顿化的能谱-时变模型

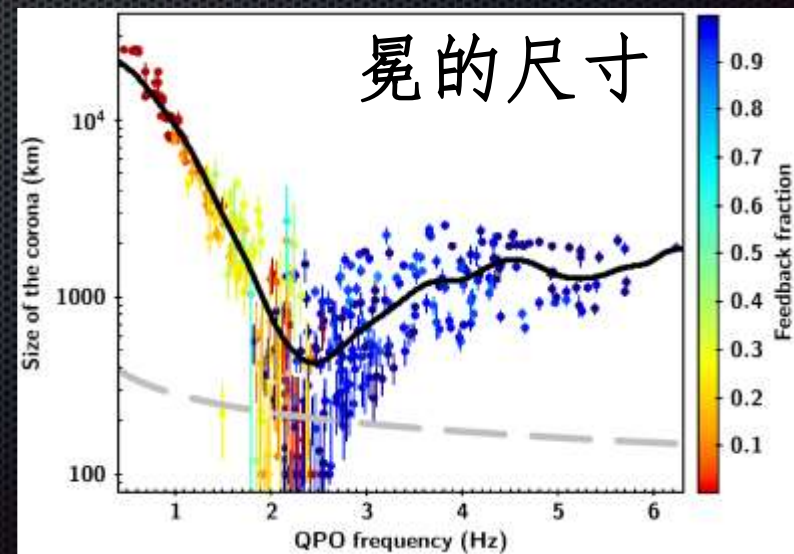
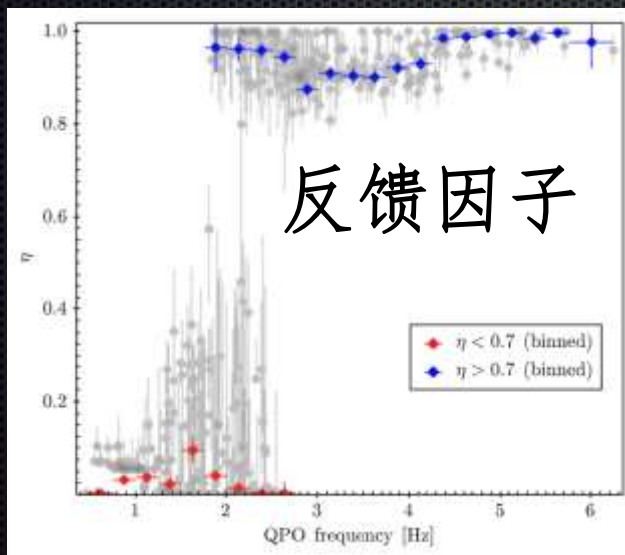
Escaping
photon



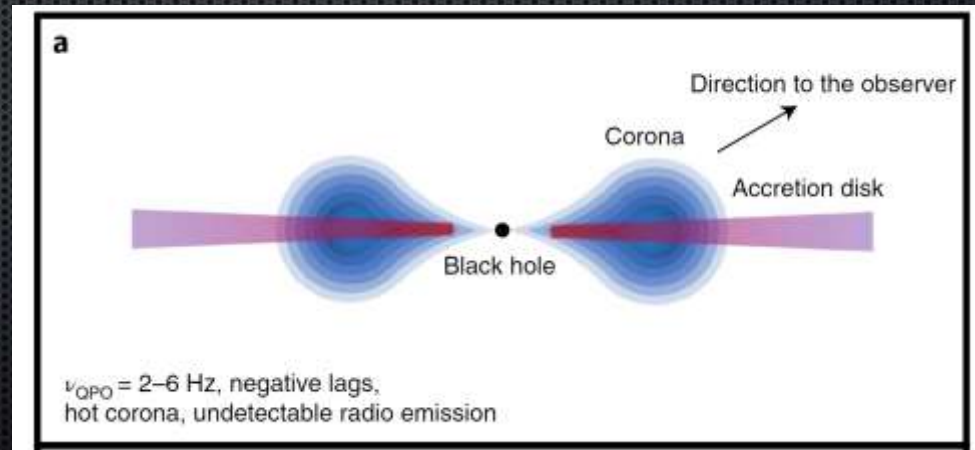
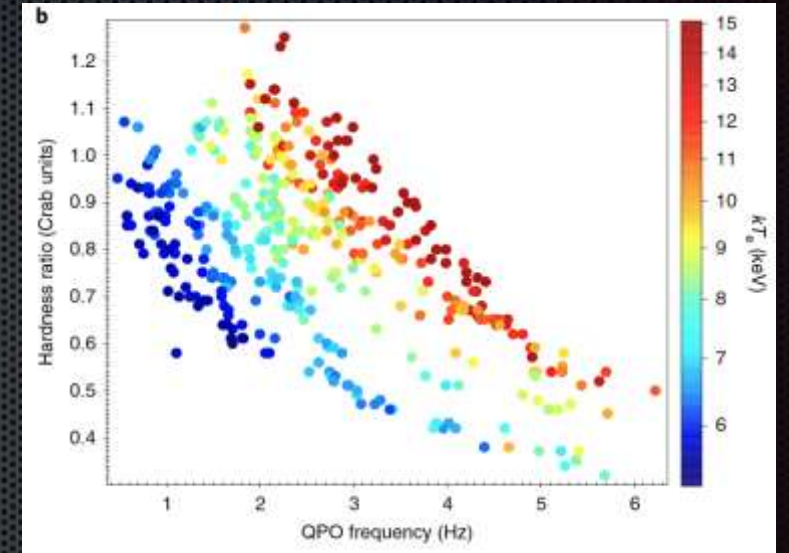
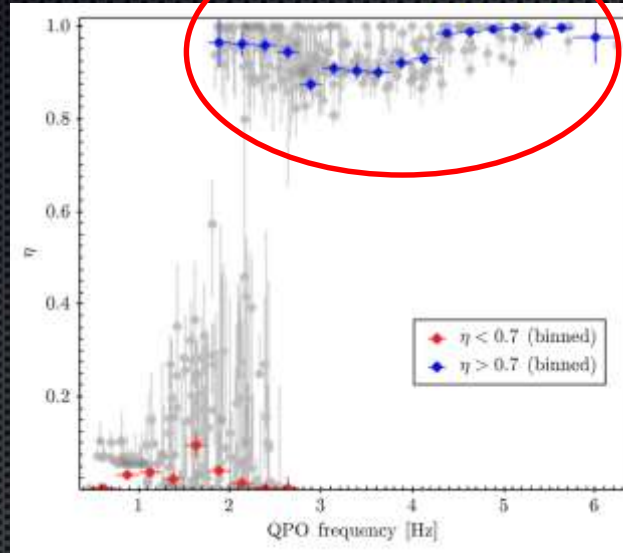
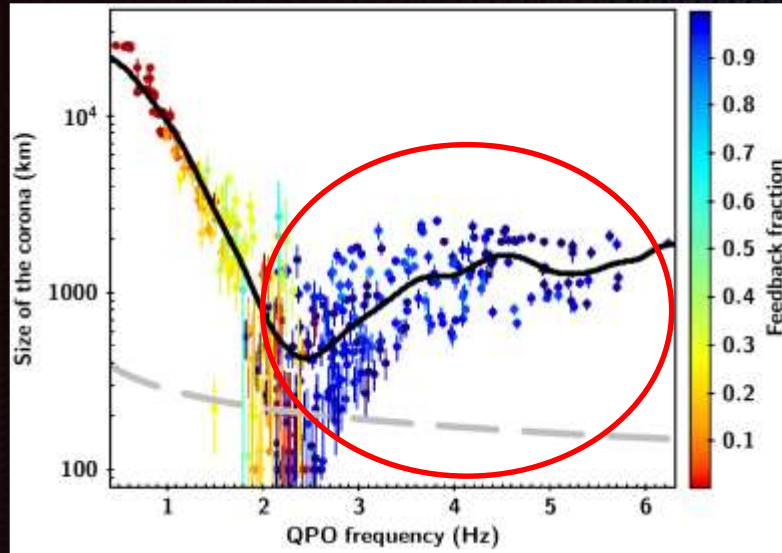
模型拟合结果



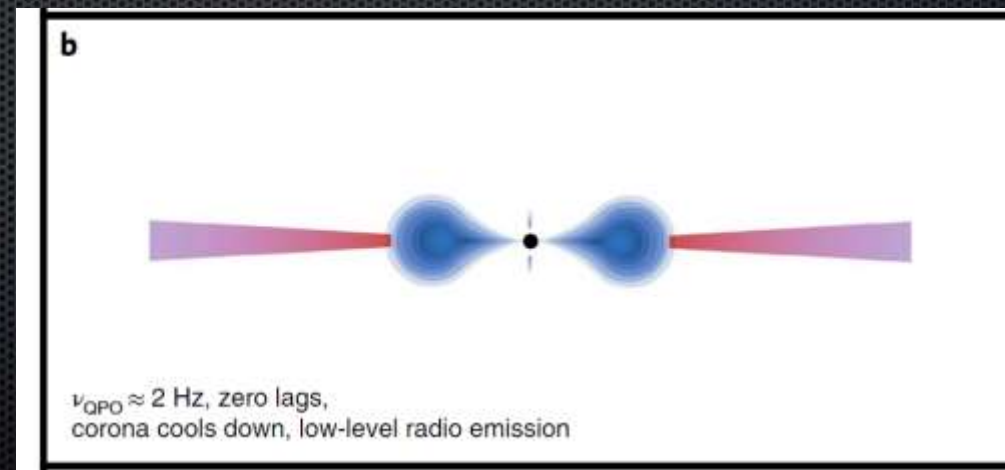
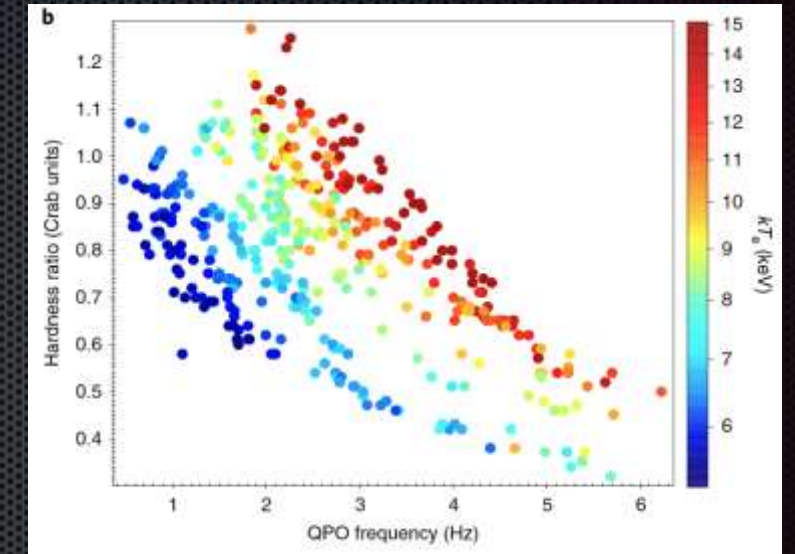
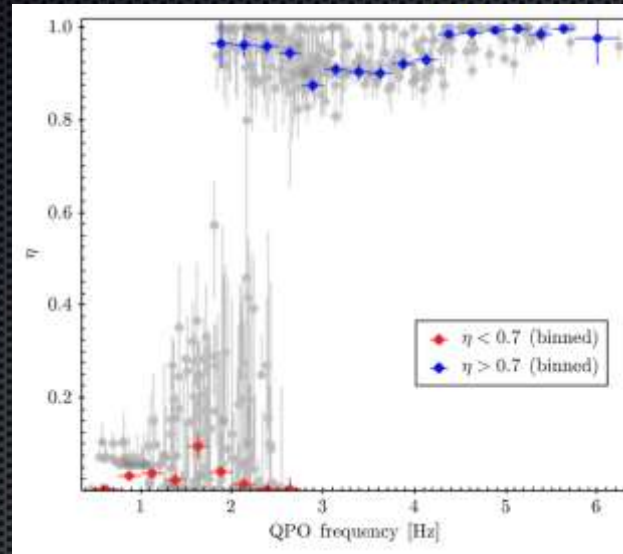
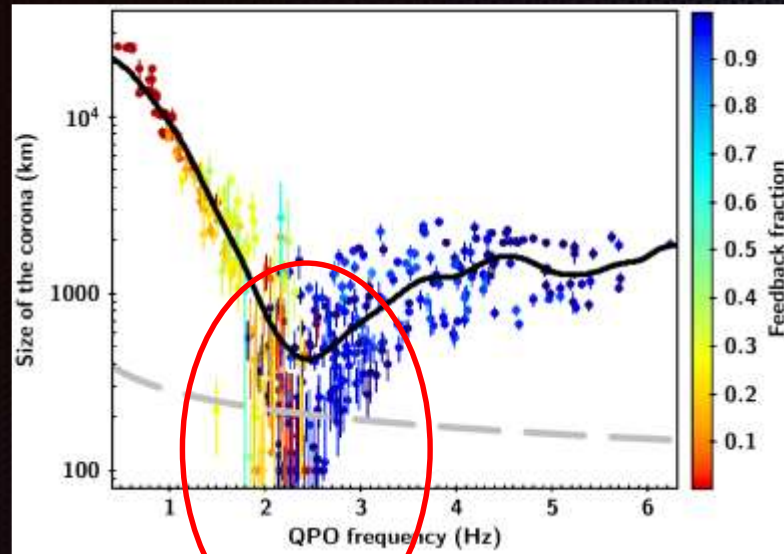
Garcia et al. (2022)



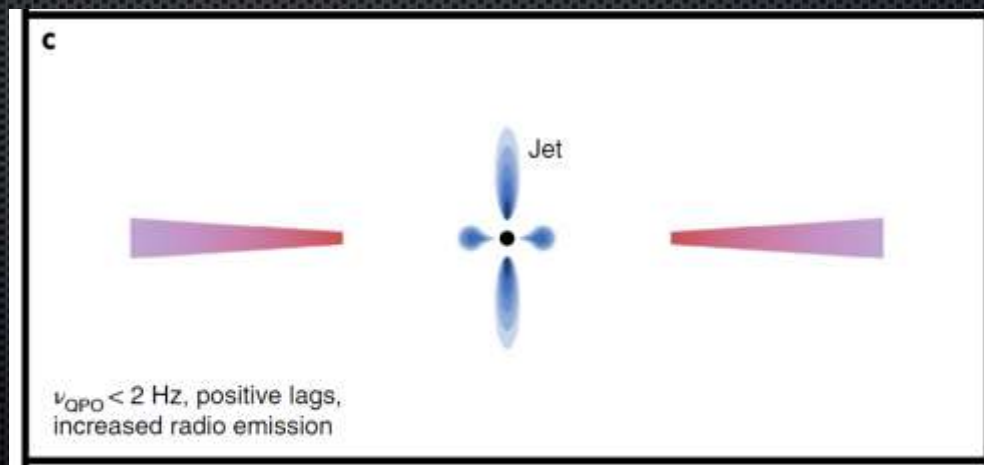
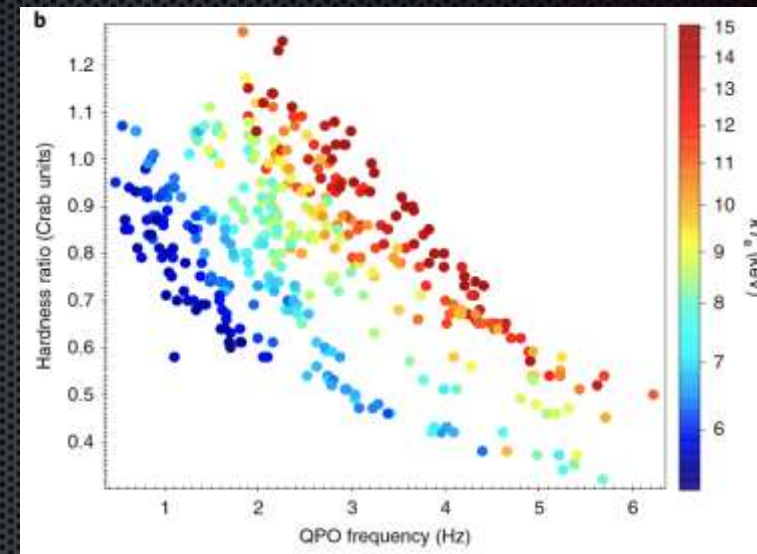
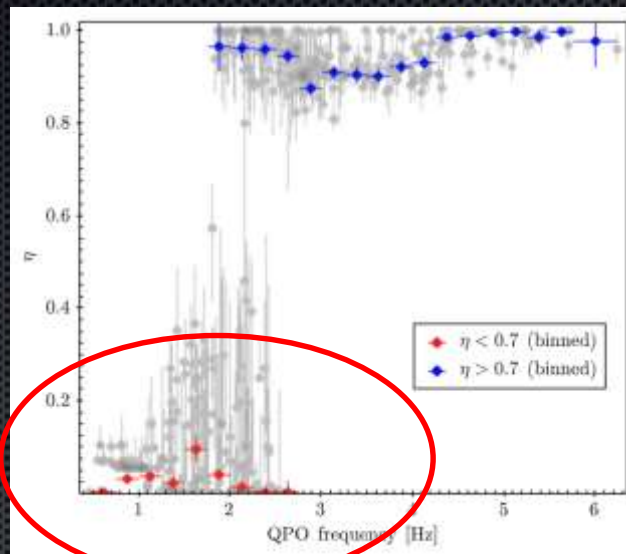
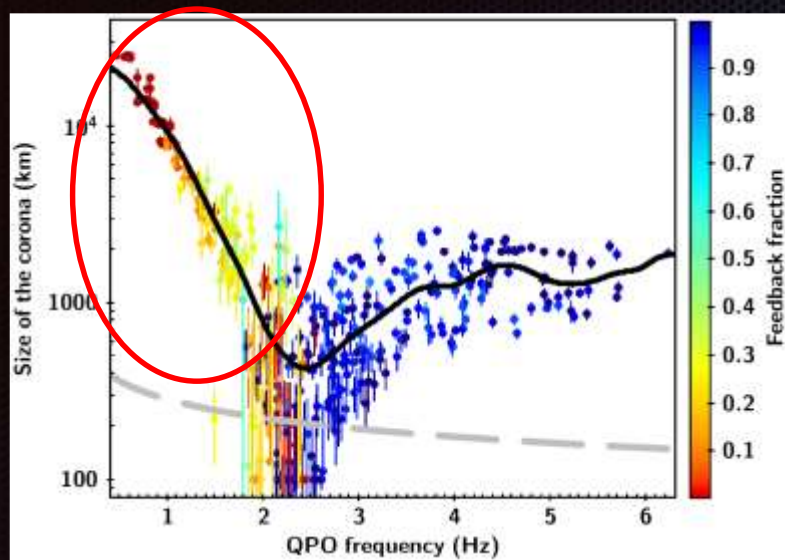
吸积几何演化 ($QPO > 2 \text{ Hz}$)



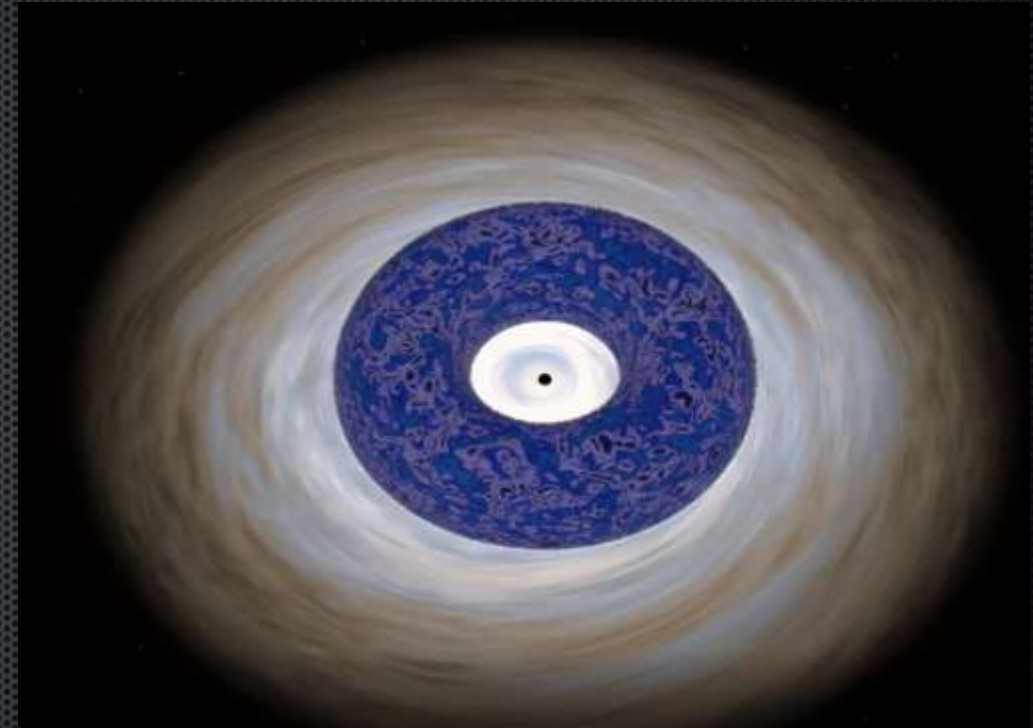
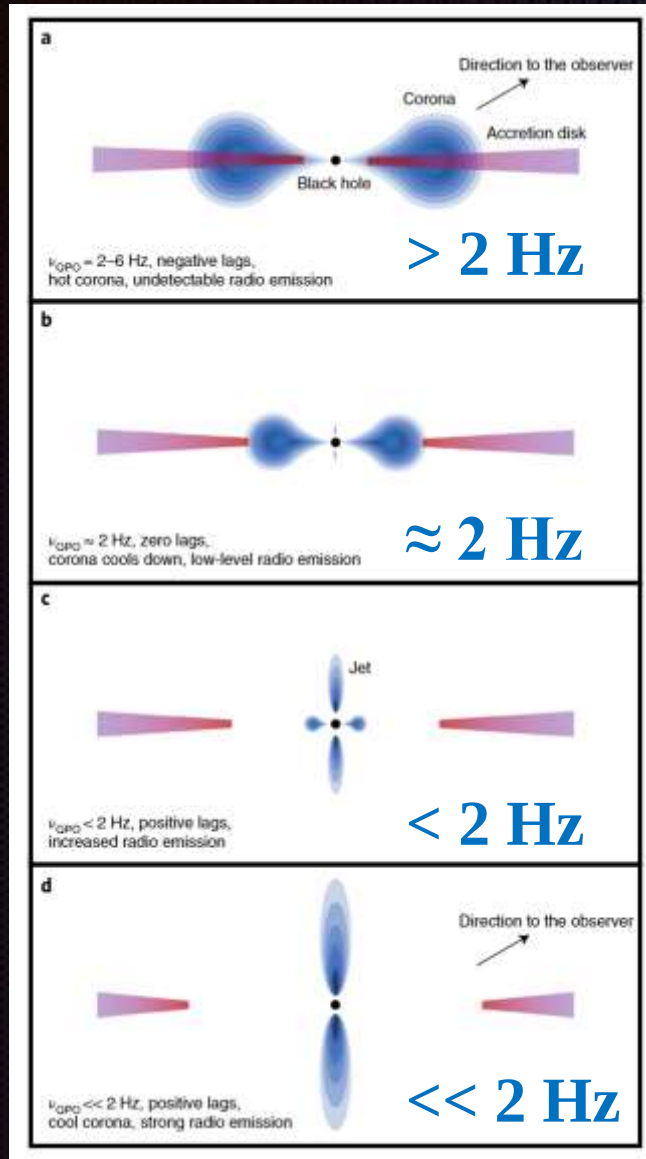
吸积几何演化 ($\text{QPO} \approx 2 \text{ Hz}$)



吸积几何演化 (QPO < 2 Hz)

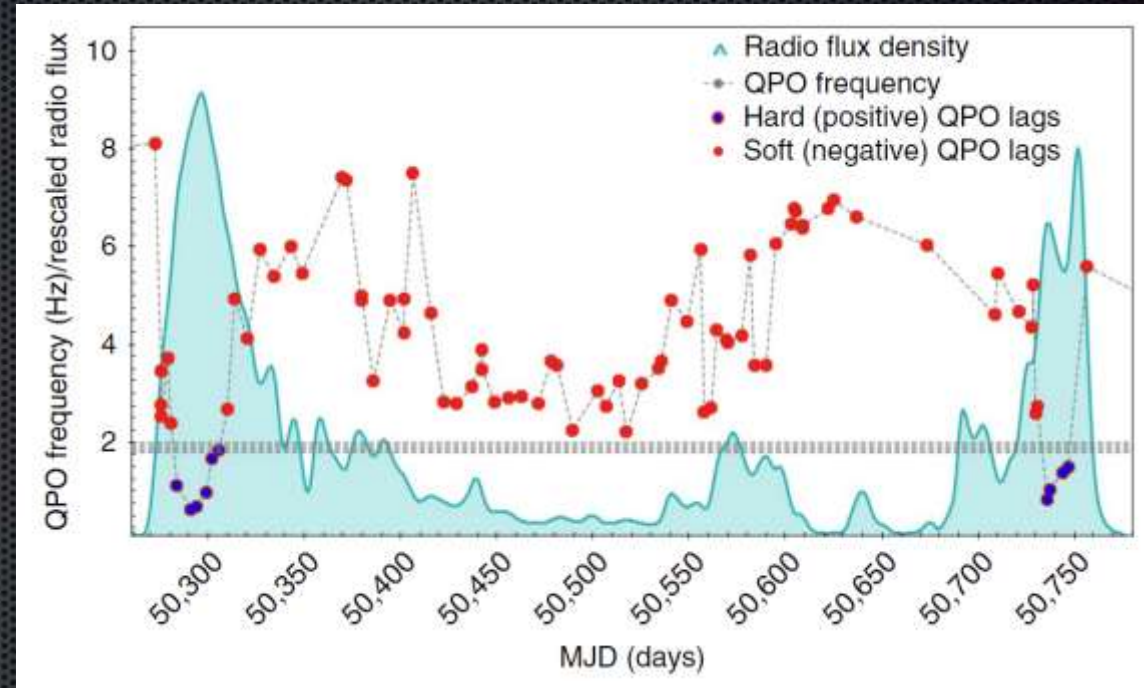
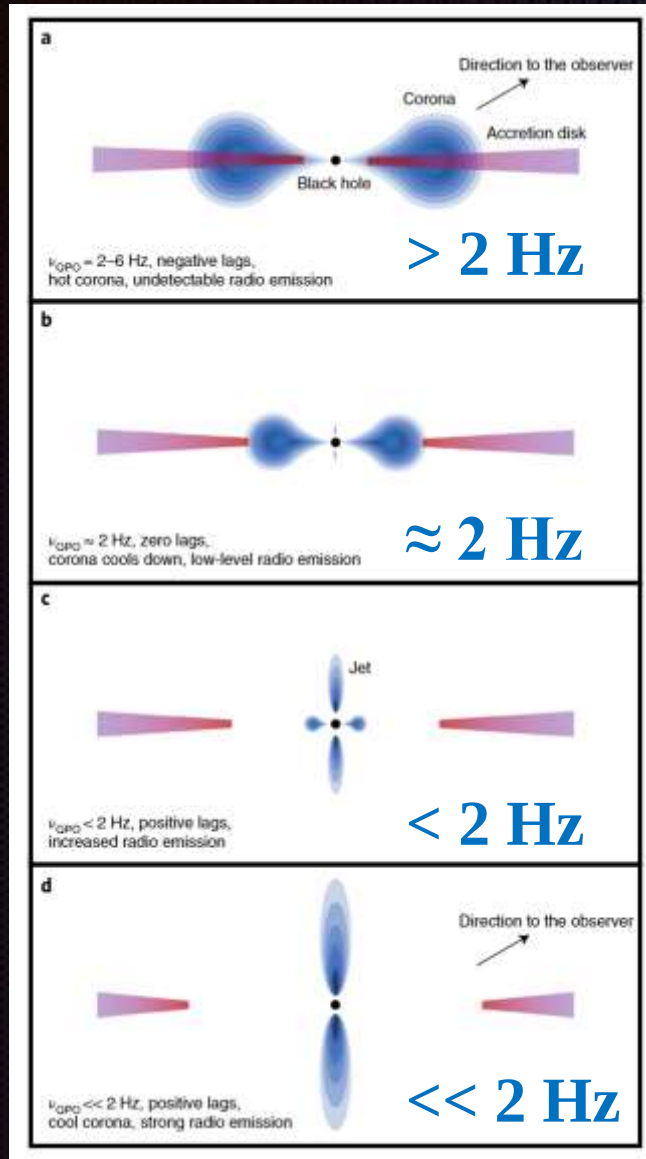


吸积几何演化



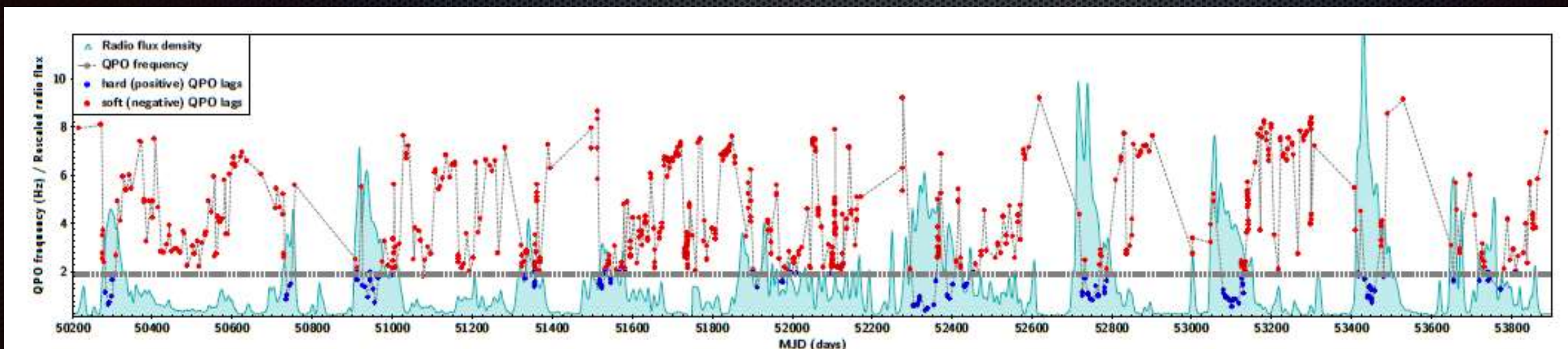
Mendez et al. (2022)

QPO频率和射电流量之间的关系



Mendez et al. (2022)

QPO频率和射电流量之间的关系



Mendez et al. (2022)

总结

- 利用长达十五年的X射线和射电波段对GRS 1915+105的监测，我们发现射电流量、铁线流量、冕的电子温度和高能bump的振幅之间存在很强的相关性；
- 冕和喷流可能来自于同一能量源：当更多的能量用于加热冕，剩下的用于触发/加速喷流的能量就会相对减少，反之亦然；
- 结合时变分析表明GRS 1915+105中随着QPO频率的减小，X射线冕逐渐演化为喷流。

Thanks for your attention!