

# *Insight-HXMT* 四年银道面扫描巡天的长期监测结果

报告人：王晨

导师：张双南

银道面扫描巡天组

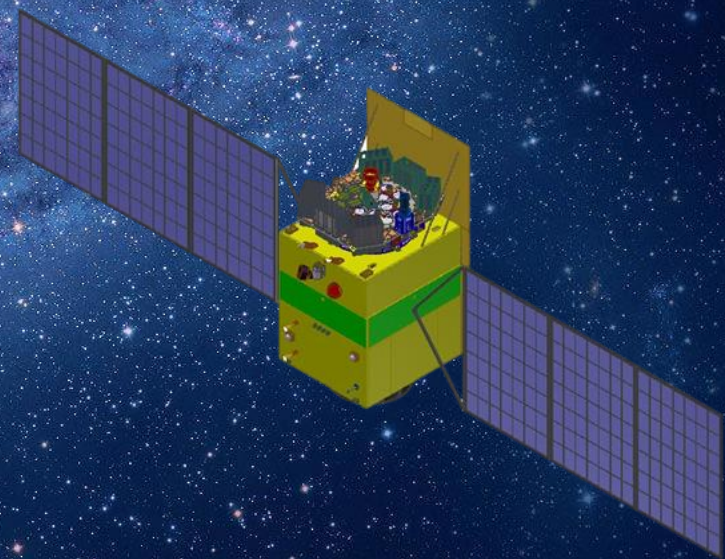
2022.11.03





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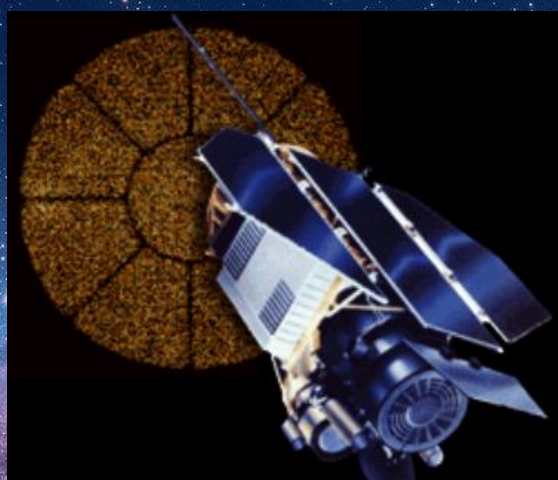
# 一、背景



Uhuru



Einstein



ROSAT



MAXI

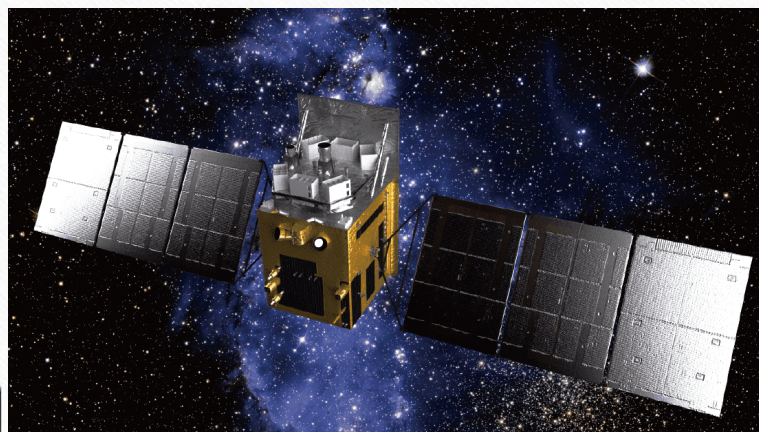
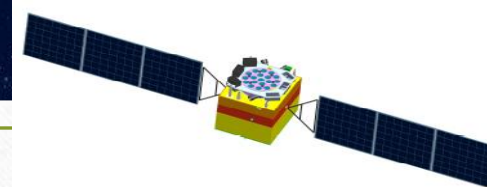


Swift

自上个世纪以来，发射过各种各样的X-ray天文卫星，他们在不同能段对不同天区以及不同深度的X射线源进行了大量的观测，每一个卫星在轨运行期间均具有重大发现或突破性进展。



# 一、背景



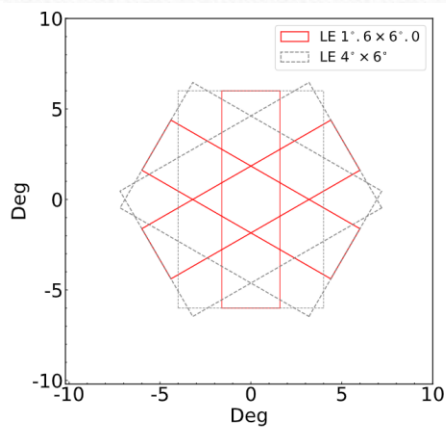
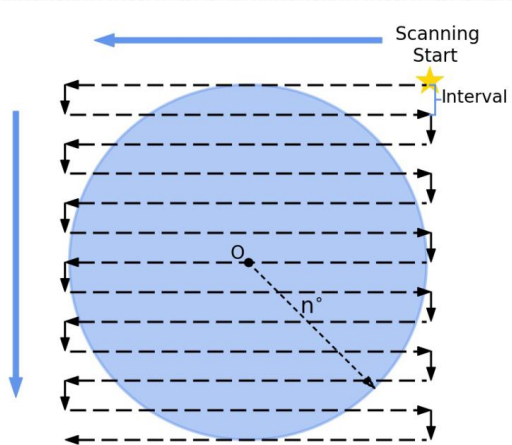
	HE	ME	LE
Geometrical Area (cm <sup>2</sup> )	5100	952	384
Small FOV (FWHM)	1°.1 × 5°.7	1° × 4°	1°.6 × 6°
Large FOV (FWHM)	5°.7 × 5°.7	4° × 4°	4° × 6°
Energy Band1 <sup>a</sup> (keV)	20 – 250	5 – 40	0.7 – 13
Energy Band2 <sup>b</sup> (keV)	25 – 100	7 – 40	1 – 7 <sup>c</sup>

Note—

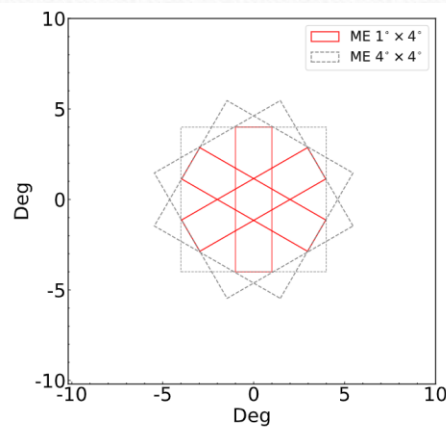
<sup>a</sup> The energy bands that three instruments covered.

<sup>b</sup> The energy bands that used in Insight-HXMT GPSS.

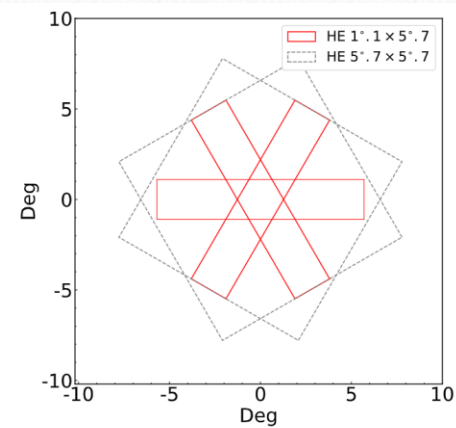
<sup>c</sup> This energy band is sub-divided into 1–2 keV, 2–6 keV, 2–4 keV, 4–6 keV, 3–5 keV, 5–7 keV and 1–6 keV.



(a) LE

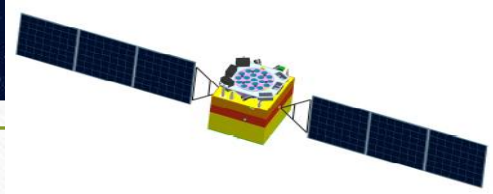


(b) ME

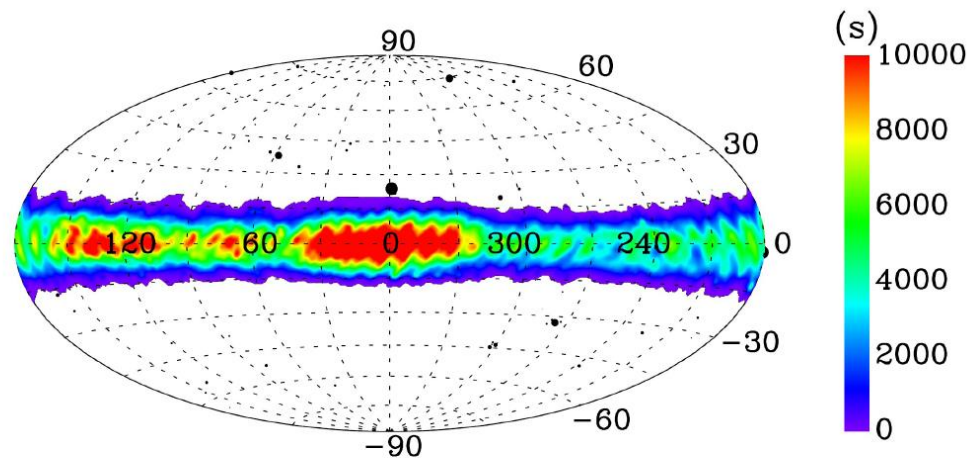


(c) HE

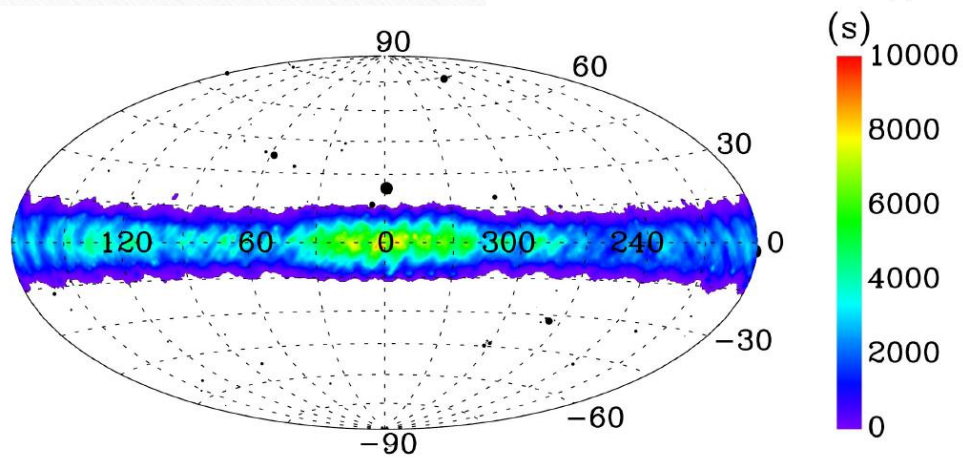




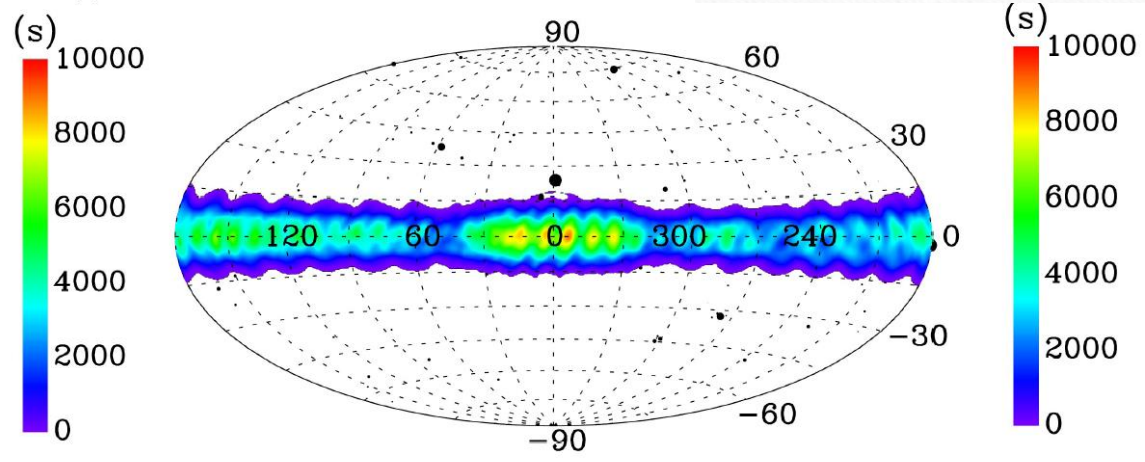
# 一、背景



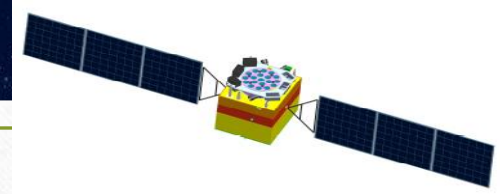
(a) LE



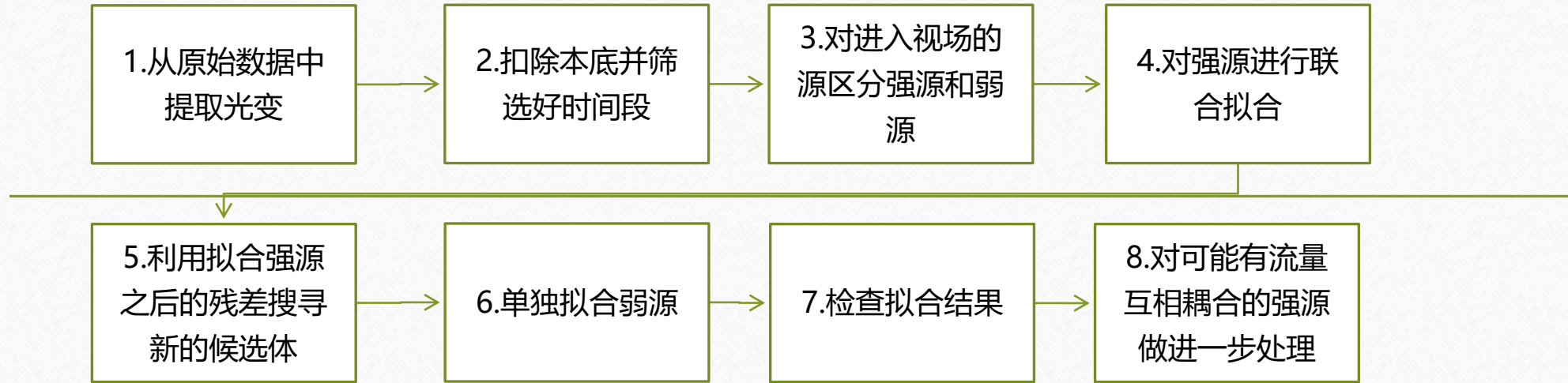
(b) ME



(c) HE



## 二、扫描数据处理流程和光变分析

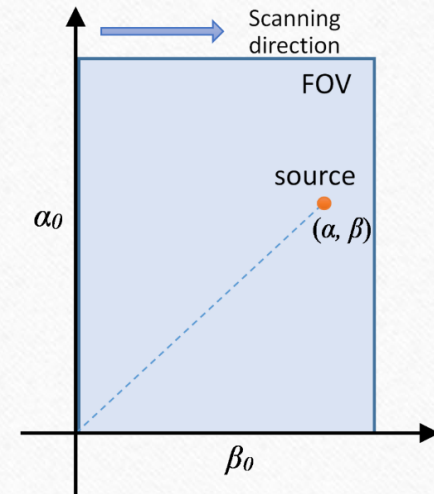


6

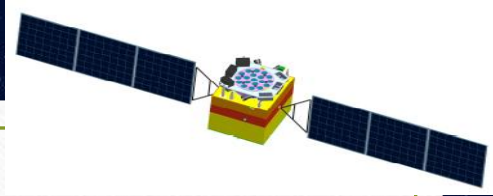
- 使用逐行扫描模式时，扫描区域中的源会多次经过视场。从 *Insight-HXMT* 的扫描观测的光变中，我们可以看到各种三角峰，这些三角峰是信号源通过视场时产生的信号，且强度是视场角度的函数，可以将其视准直型望远镜的点扩展函数 (PSF)

$$f(\alpha, \beta) = C \frac{(1 - \frac{\text{abs}(\tan(\alpha))}{\tan(\alpha_0)})(1 - \frac{\text{abs}(\tan(\beta))}{\tan(\beta_0)})}{\sqrt{\tan^2(\alpha) + \tan^2(\beta) + 1}}, \quad (1)$$

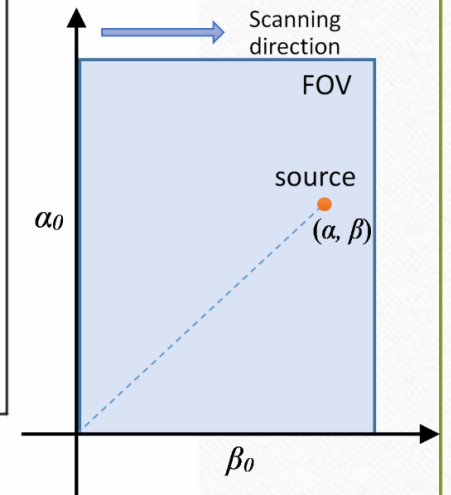
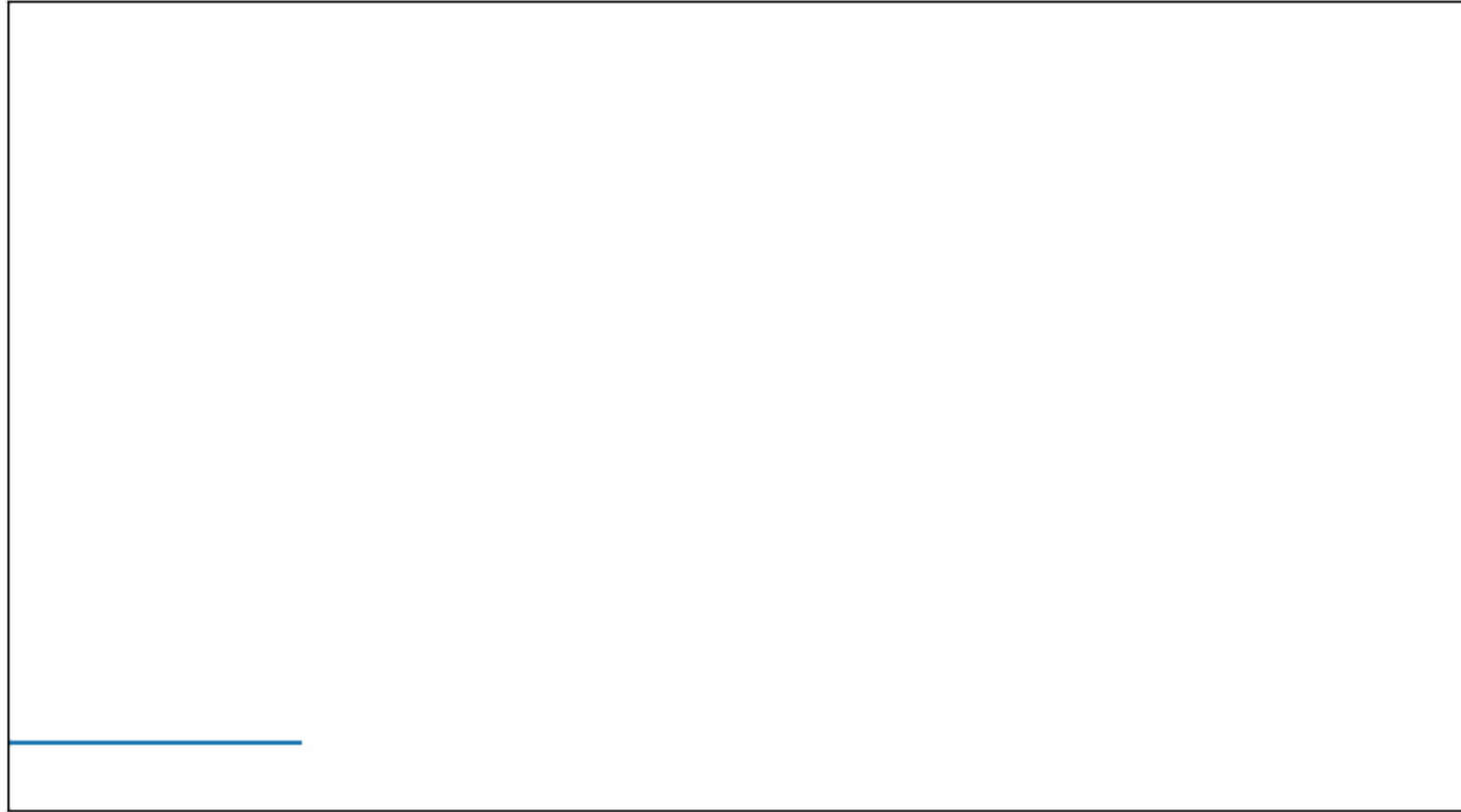
- 三个望远镜的所有准直器都具有矩形视场，具有不同的大小和方向，可以用几何PSF模型描述为 (1)

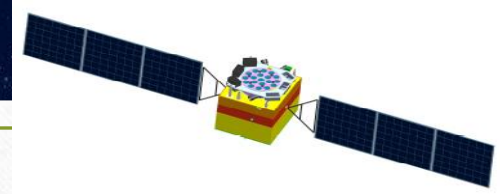




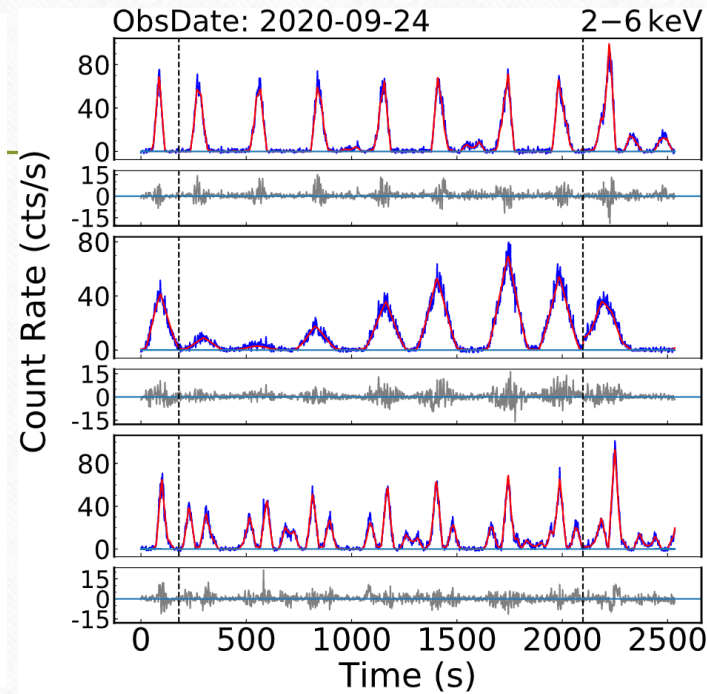
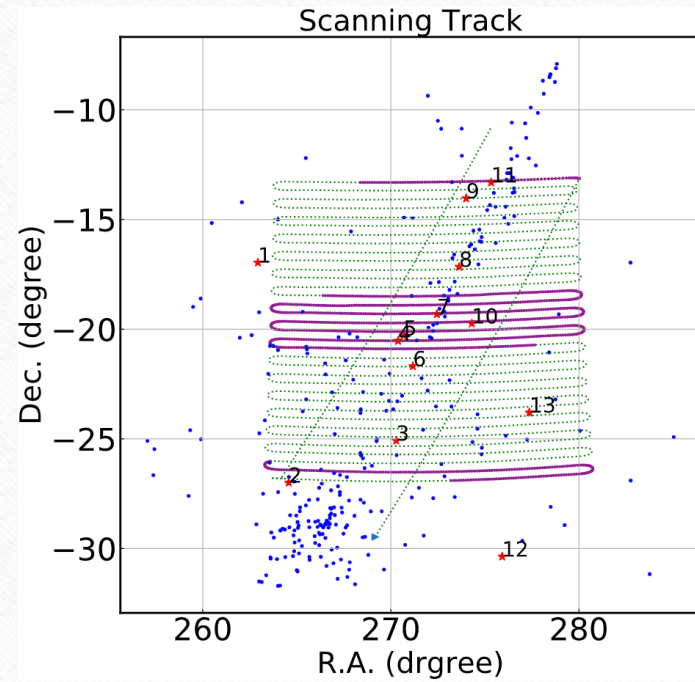


## 二、扫描数据处理流程和光变分析



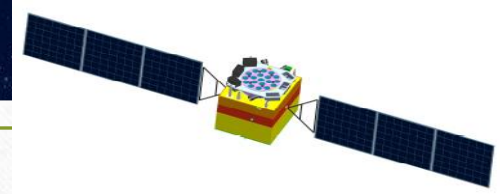


## 二、扫描数据处理流程和光变分析

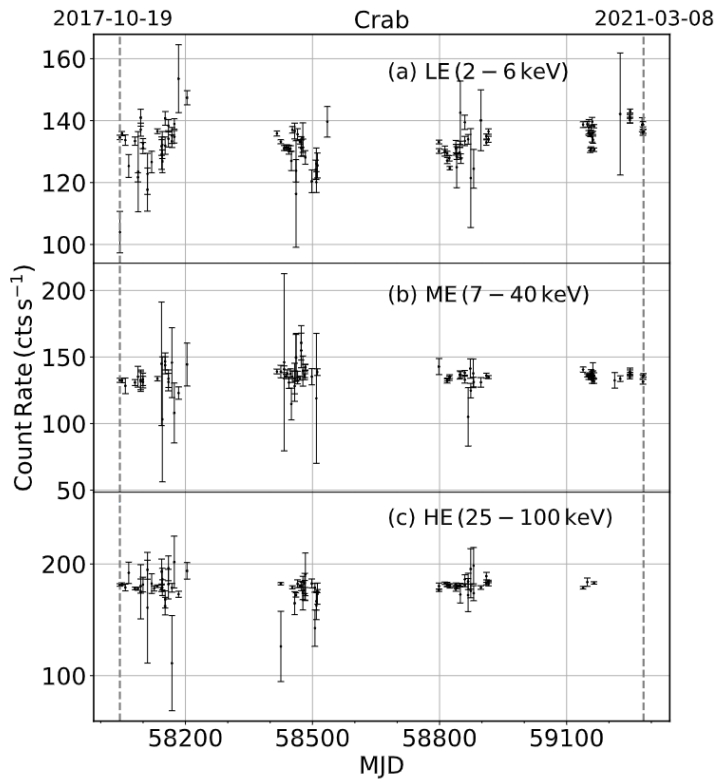


Number	Source Name	R.A. (deg)	Dec. (deg)	Rate (cts s <sup>-1</sup> )	S/N
(1)	(2)	(3)	(4)	(5)	(6)
1	3A 1728 - 169	262.93	-16.96	30.3	23.9
2	SLX 1735 - 269	264.57	-26.99	2.7	5.1
3	GX 5 - 1	270.28	-25.08	127.2	56.3
4	GX 9 + 1	270.38	-20.53	58.1	42.1
5	IGR J18027 - 2016	270.67	-20.29	8.8	6.3
6	HESS J1804 - 216	271.17	-21.68	5.1	4.8
7	AX J1809.8 - 1918	272.45	-19.31	1.4	4.1
8	GX 13 + 1	273.63	-17.16	41.0	14.8
9	GX 17 + 2	274.01	-14.04	74.1	51.5
10	IGR J18172 - 1944	274.31	-19.74	1.5	6.5
11	IGR J18214 - 1318	275.33	-13.31	3.1	4.8
12	H 1820 - 303	275.92	-30.36	41.2	30.9
13	Ginga 1826 - 24	277.37	-23.80	30.8	28.9

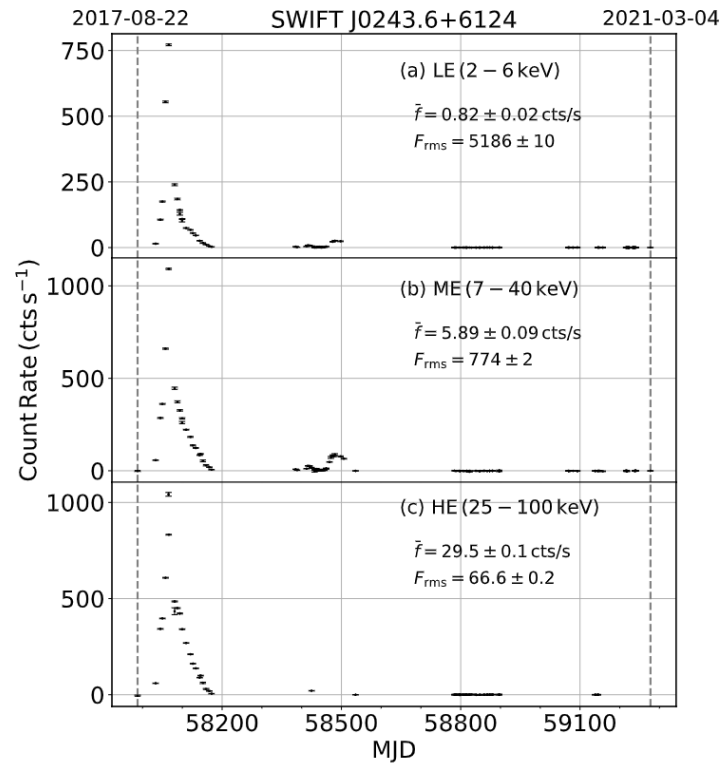




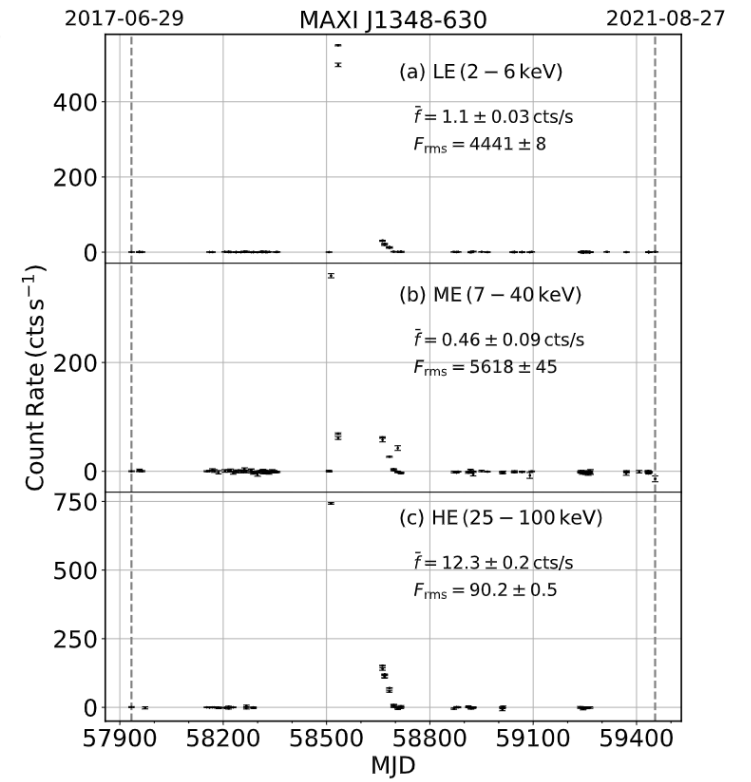
## 二、扫描数据处理流程和光变分析



(a)

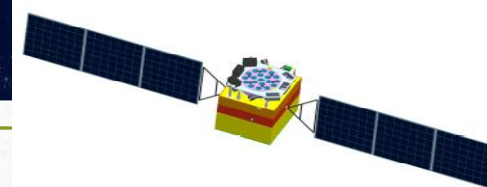


(b)



(c)





### 三、银道面扫描巡天的结果

#### 3.1 源表

生成了四年的监测源表，分别包括来自三个望远镜的9个不同能段（1—2 keV, 1—6 keV, 2—4 keV, 2—6 keV, 3—5 keV, 4—6 keV, 5—7 keV, 7—40 keV 和 25—100 keV）的信息：

1. 源的名字
2. 源的位置
3. 源的类型
4. 源的平均流量和误差
5. 不同能段Frms和误差
6. 硬度比和误差

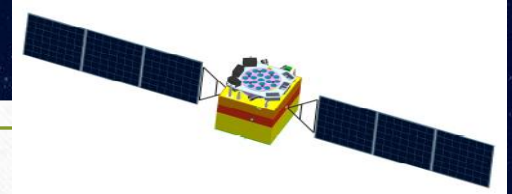
$$S^2 = \frac{1}{N-1} \sum_i^N (f_i - \bar{f})^2$$

$$F_{\text{rms}} = \frac{S^2 - \bar{\sigma}^2}{\bar{f}^2}$$

$$\Delta F_{\text{rms}} = \sqrt{\left( \sqrt{\frac{2}{N}} \times \frac{\bar{\sigma}^2}{\bar{f}^2} \right)^2 + \left( \sqrt{\frac{\bar{\sigma}^2}{N}} \times \frac{2\sqrt{F_{\text{rms}}}}{\bar{f}} \right)^2}$$

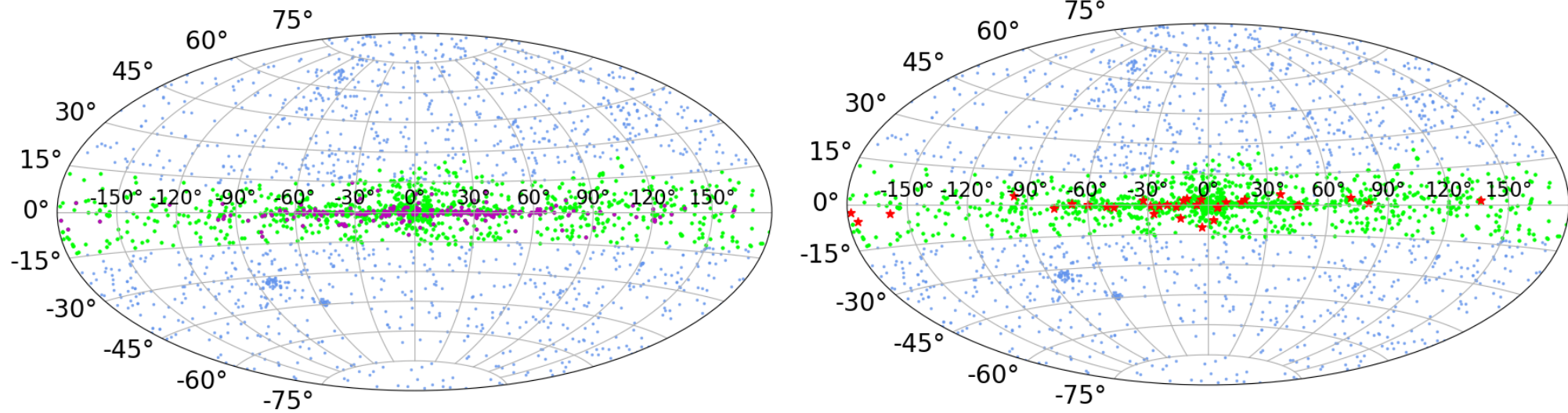
$$\text{HR} = \frac{H}{S}, \quad \sigma_{\text{HR,stat}} = \frac{H}{S} \sqrt{\frac{\sigma_{S,\text{stat}}^2}{S^2} + \frac{\sigma_{H,\text{stat}}^2}{H^2}}$$





### 三、银道面扫描巡天的结果

#### 3.1 源表



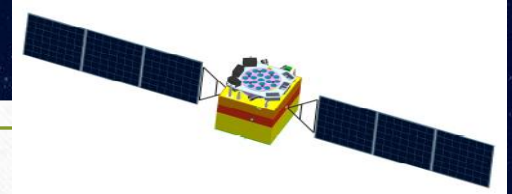
蓝色: Swift, INTEGRAL和MAXI联合源表中的源, 共2881个

绿色: *Insight-HXMT* 扫描监测到的源, 共1345个

粉色: 223个亮源; 红色: 三个主要能段均是亮源的

- 一共有223个源在2—6 keV、7—40 keV和 25—100 keV中任一个能段 $S/N > 5$ .
- 33个源在三个能段 $S/N$ 均大于5.





### 三、银道面扫描巡天的结果

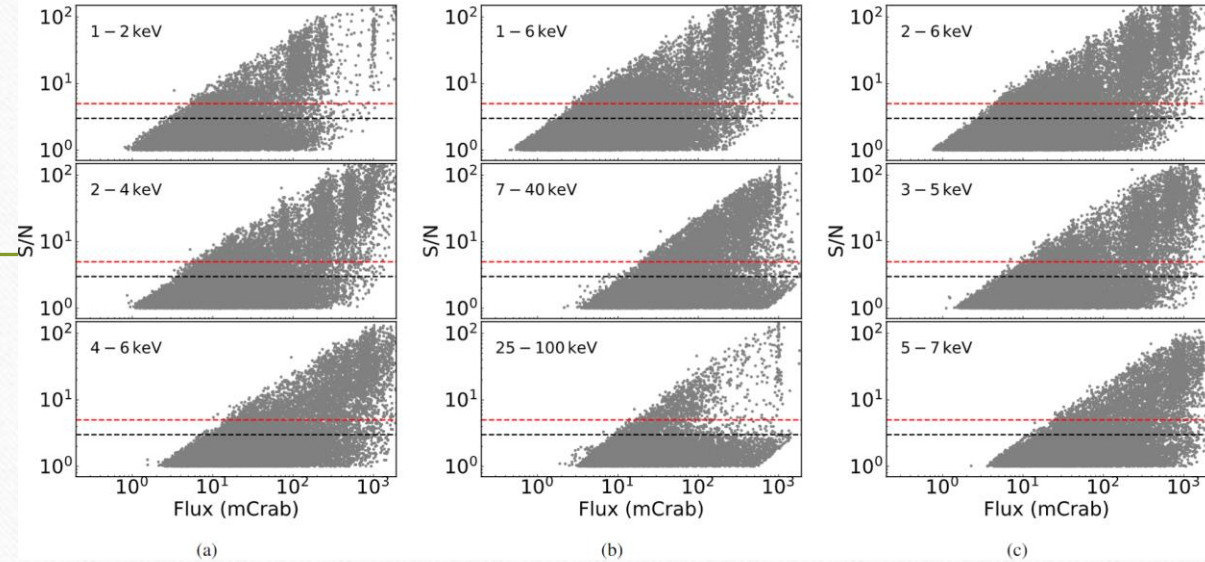
#### 3.2 探测器的性质

$$\sigma_{\text{total},i}^2 = \sigma_{\text{sys}}^2 + \sigma_{\text{stat},i}^2$$

$$\bar{f} = \frac{\sum \omega_i f_i}{\sum \omega_i}$$

$$\omega_i = \frac{1}{\sigma_{\text{total},i}^2}$$

$$\sum_i^N \frac{(f_i - \bar{f})^2}{\sigma_{\text{total},i}^2} = N - 1$$



	LE						ME	HE	
	1-2 keV	2-4 keV	4-6 keV	2-6 keV	3-5 keV	5-7 keV	1-6 keV	7-40 keV	25-100 keV
$\sigma_{\text{sys}}$ (%)	2.16	3.35	2.61	3.43	3.09	3.49	3.46	1.42	0.83
Source Num. <sup>a</sup>	1337	1345	1342	1343	1343	1343	1336	957	935
Bright Source Num. <sup>b</sup>	261	266	230	294	248	210	268	65	59
Sensitivity1 (mCrab) <sup>c</sup>	4.7	4.6	13.2	4.1	8.9	21.2	2.5	17.6	12.7
Sensitivity1 ( $10^{-10}$ erg s <sup>-1</sup> cm <sup>2</sup> )	0.44	0.40	0.63	0.55	0.55	0.82	0.57	3.16	1.61
Sensitivity2 (mCrab) <sup>d</sup>	0.70	0.69	1.97	0.61	1.33	3.17	0.37	2.35	2.19
Sensitivity2 ( $10^{-11}$ erg s <sup>-1</sup> cm <sup>2</sup> )	0.66	0.60	0.94	0.82	0.82	1.23	0.85	4.21	2.78

Note—

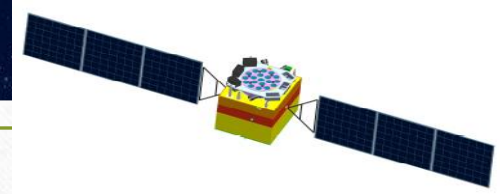
<sup>a</sup> The total source number that has been covered at each energy band.

<sup>b</sup> One is considered as a bright source when its averaged S/N is higher than 5 and averaged flux is positive.

<sup>c</sup> Sensitivity of one scanning observation (~2.3h).

<sup>d</sup> Cumulative sensitivity from June 2017 to August 2021.





# 四、长期光变和MAXI合并

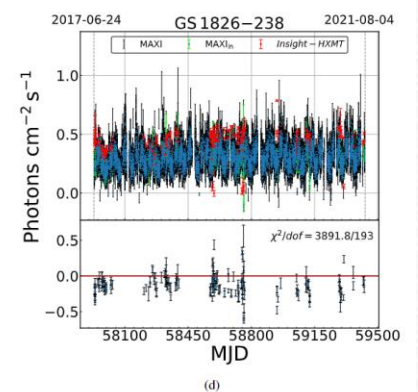
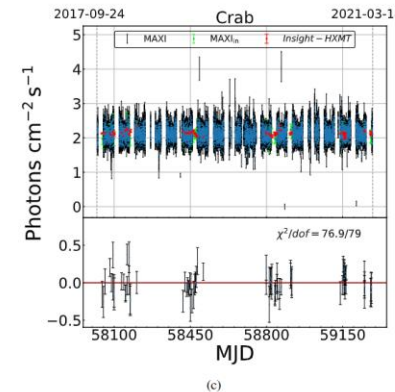
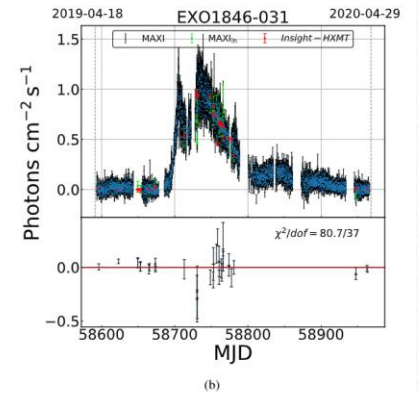
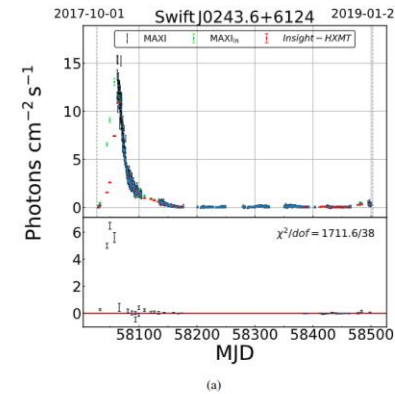
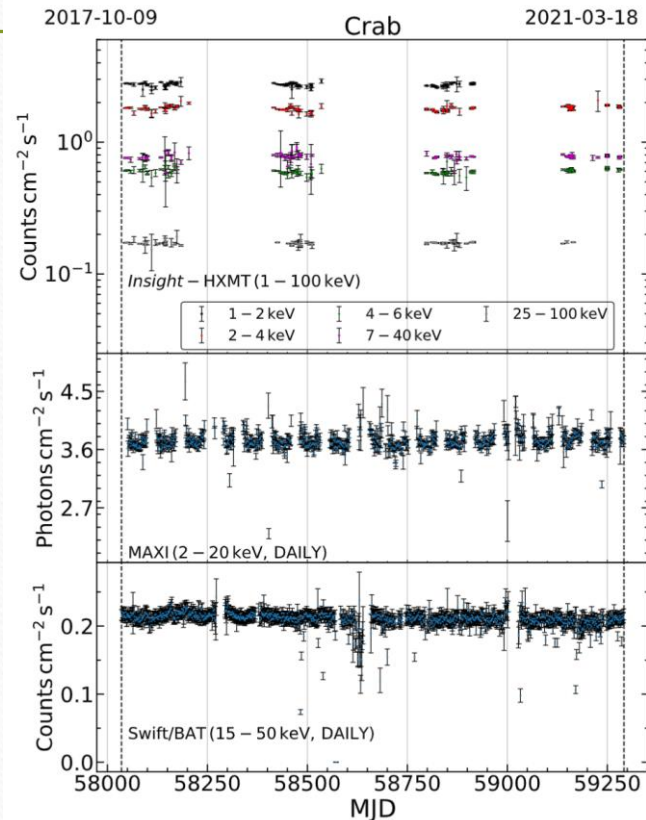
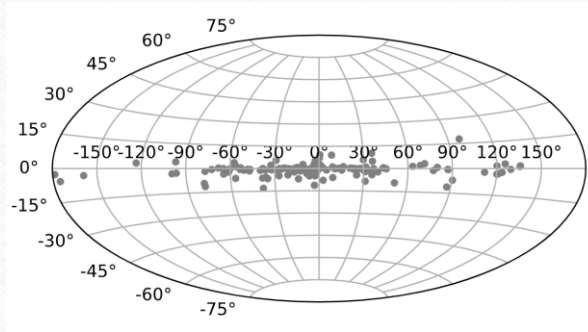
Insight-HXMT对监测已知源的

优势：覆盖宽波段(1—100 keV) 劣势：长期光变存在gap

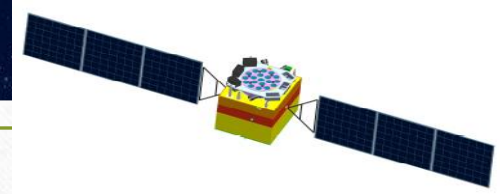
可与其他卫星长期光变合并以弥补不足，通过对Crab长期监测的流量差值的分布来判断是否可以合并：

$$F_{diff} = f_M - f_H$$

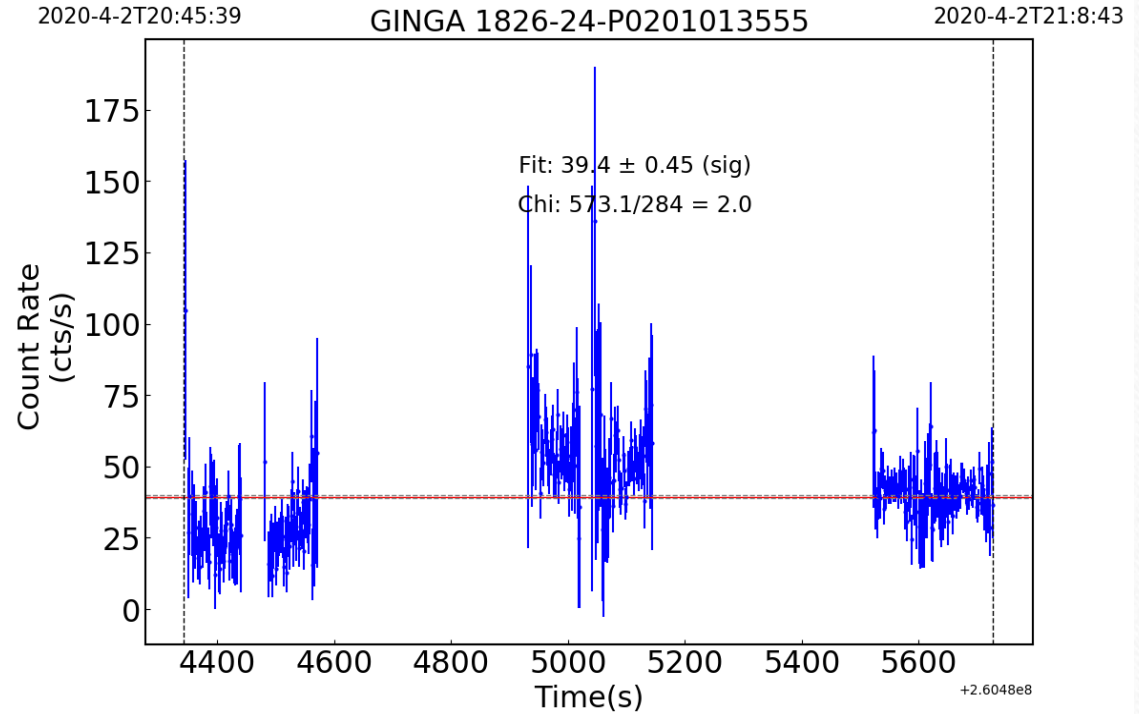
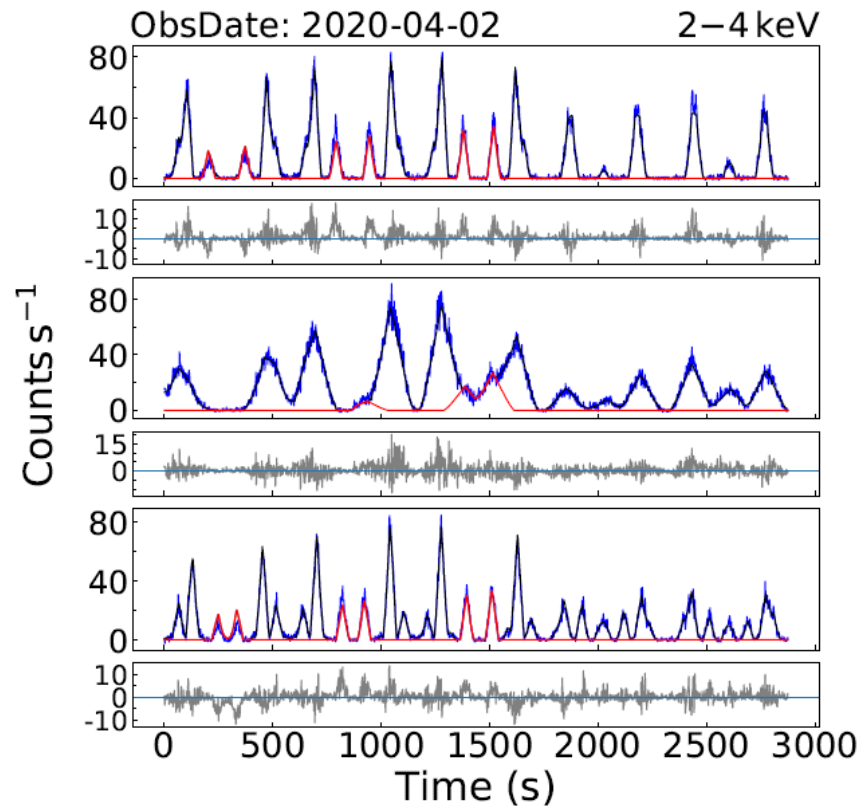
$$\chi^2_{diff} = \sum_{i=1}^N \frac{(f_{M,i} - f_{H,i})^2}{\sigma_{M,i}^2 + \sigma_{H,i}^2}$$





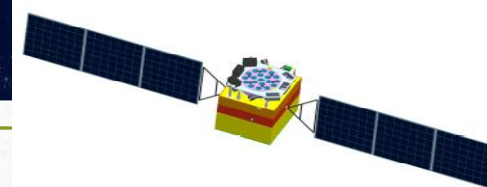


## 四、长期光变和MAXI合并



Insight-HXMT具有分辨短时标变源的优势，  
可以给出2s一个bin的变化情况



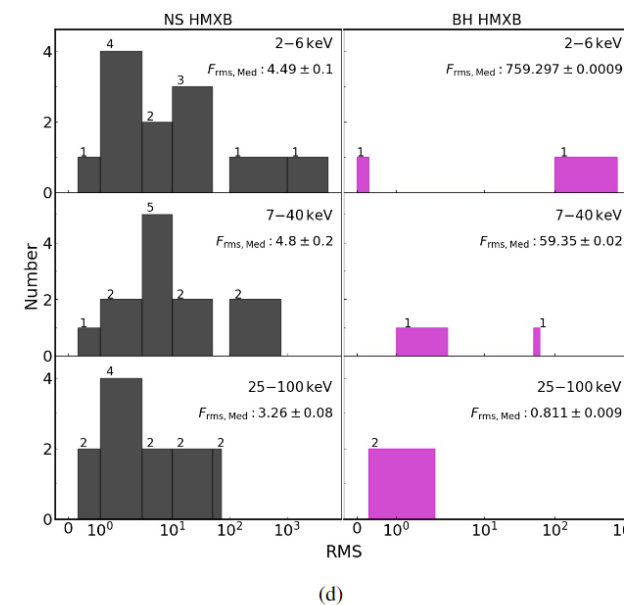
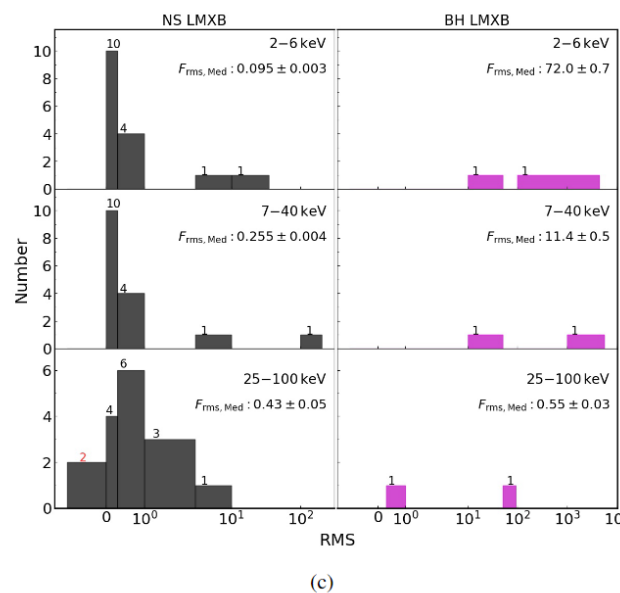
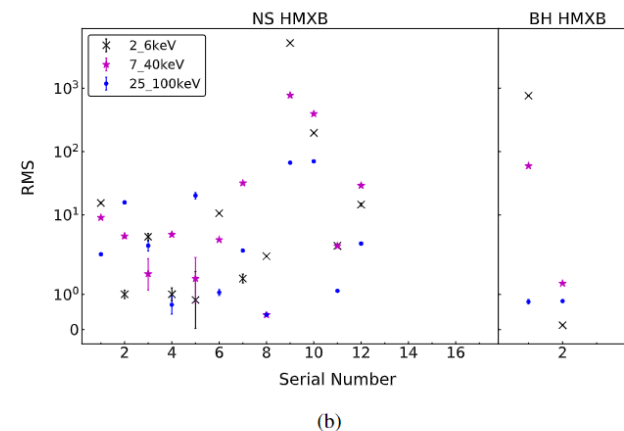
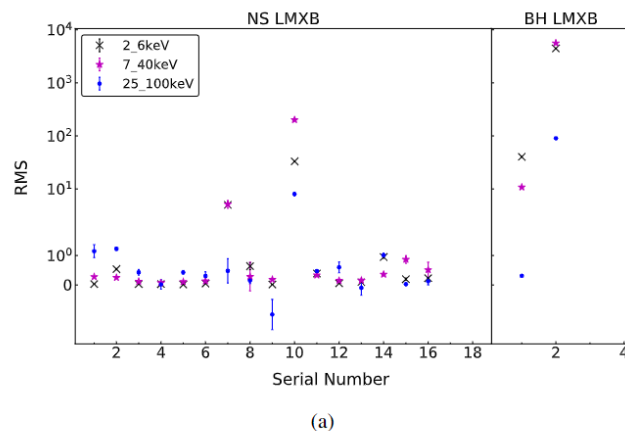


## 五、部分巡天结果的统计分析

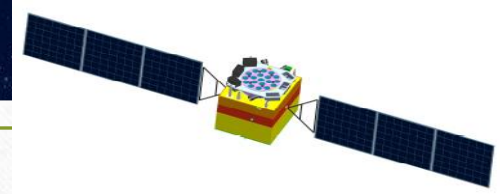
### 5.1 亮源的RMS

在三个能段信噪比均大于5的双星的rms分布情况:

- NS LMXB的rms随着能段的升高而增加, 这和Mitsuda+1984 中描述的情况一致
- BHB (样本少) 要比NB的流量变化更加剧烈
- HMXB在任意一个能段的流量变化情况均比LMXB要活跃
- HMXB随着能段的变化没有显著的增高或降低的规律







# 五、部分巡天结果的统计分析

## 5.2 硬度比的计算

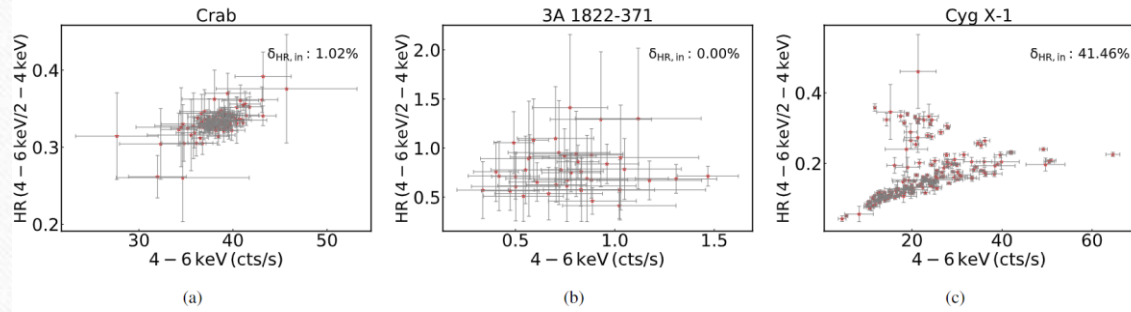


图 1.

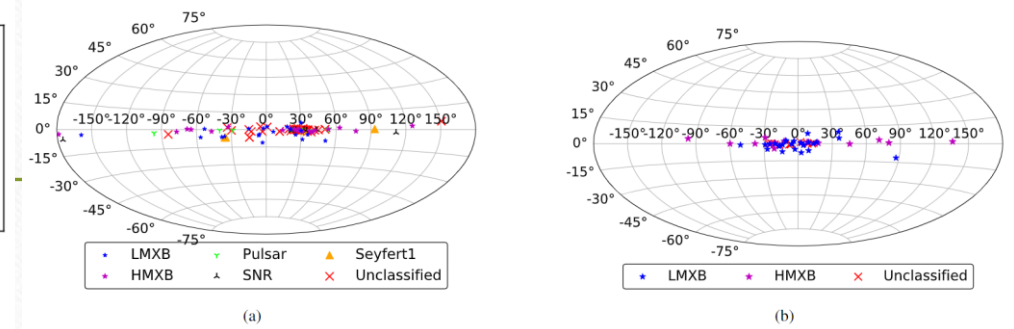


图 2.

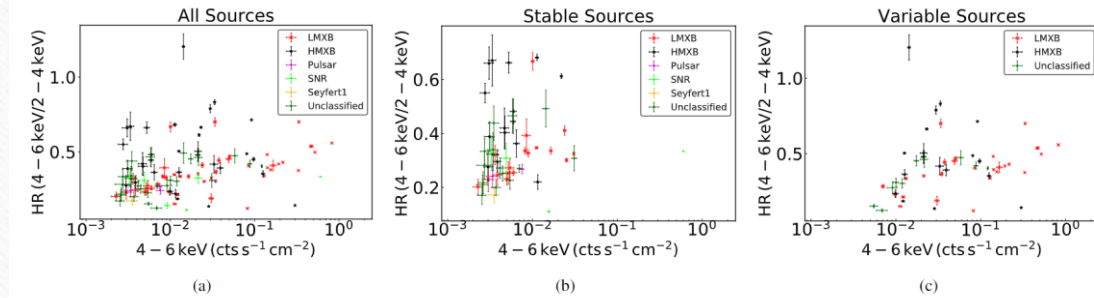


图 3.

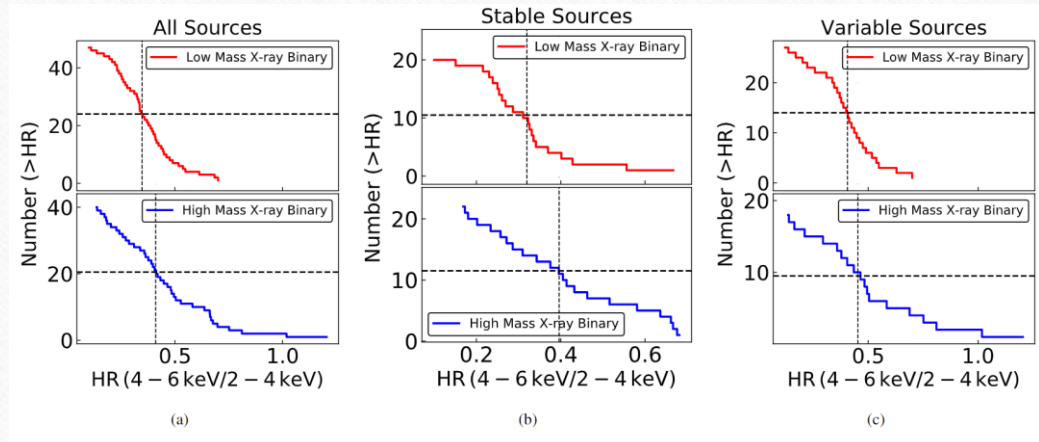
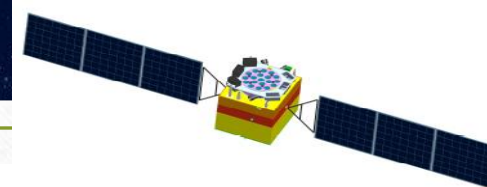


图 4.





## 五、部分巡天结果的统计分析

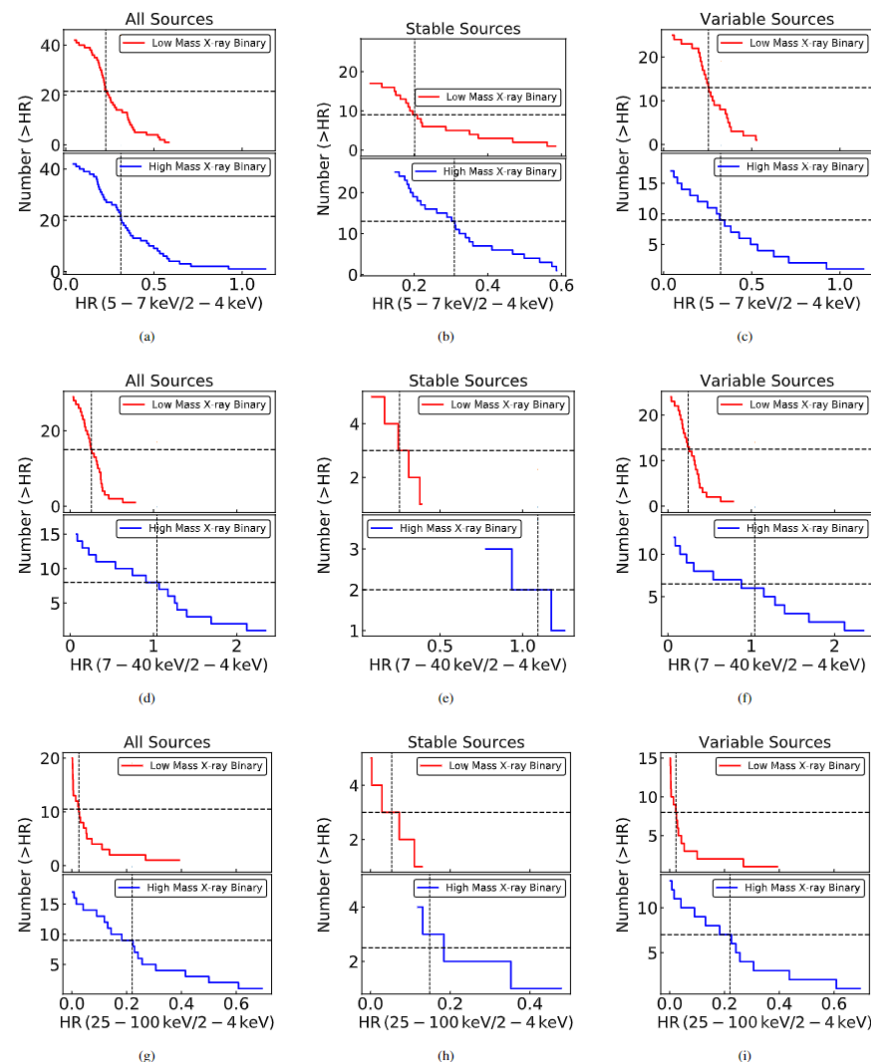
H band	HMXB <sup>a</sup>	HMXB <sup>b</sup>	HMXB <sup>c</sup>	LMXB <sup>a</sup>	LMXB <sup>b</sup>	LMXB <sup>c</sup>
4 – 6 keV	$0.41 \pm 0.05$	$0.4 \pm 0.04$	$0.45 \pm 0.01$	$0.347 \pm 0.004$	$0.32 \pm 0.006$	$0.405 \pm 0.003$
5 – 7 keV	$0.31 \pm 0.03$	$0.31 \pm 0.06$	$0.323 \pm 0.002$	$0.227 \pm 0.005$	$0.2 \pm 0.01$	$0.254 \pm 0.002$
7 – 40 keV	$1.0 \pm 0.1$	$1.1 \pm 0.1$	$1.041 \pm 0.004$	$0.25 \pm 0.07$	$0.25 \pm 0.07$	$0.243 \pm 0.001$
25 – 100 keV	$0.22 \pm 0.04$	$0.15 \pm 0.02$	$0.22 \pm 0.04$	$0.026 \pm 0.002$	$0.05 \pm 0.01$	$0.023 \pm 0.002$

Note—

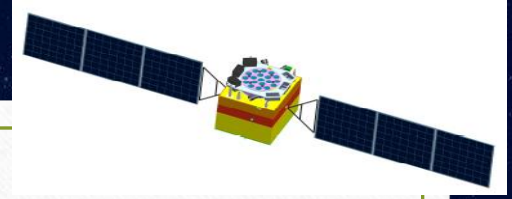
<sup>a</sup> All sources. <sup>b</sup> Spectrally stable sources. <sup>c</sup> Spectrally variable sources.

小结:

- (1) 无论H-band选择哪个能段, HMXB总是比LMXB更硬
- (2) 随着H-band能段的提升, 能谱不稳定的LMXB具有变软的趋势, 去除7-40keV以后这个规律也存在于其他双星中







## 六、总结

- *Insight-HXMT* 自2017.6—2021.8共2000多次银道面扫描：
  1. 累计灵敏度可达 0.37mCrab, 2.35mCrab 和 2.19mCrab
  2. 监测1300多个源的长期光变
  3. 223个源在2-100keV S/N 大于5, 其中33个源三个望远镜均探测到明显信号
- 和MAXI巡天结果相结合具有可行性和积极意义, 有助于反应已知源更完整的长期光变, 这对分析源的爆发规律, 活动周期等都具有重要意义
- 使用rms来量化32个双星的流量变化程度, 可得到以下结论:
  1. NS LMXB的rms随着能段的升高而增加, 这可能和其能谱构成有关
  2. BHB的流量比NSB的流量变化更加活跃
  3. HMXB在任意一个能段的流量变化情况均比LMXB要活跃
  4. HMXB的rms随着能段的不同变化复杂一些, 这可能和不同的HMXB更多样的吸积过程有关
- 通过分析HR和源类型的关系发现HMXB通常比LMXB更硬, 且随着H能段的提升, 双星的硬度比有变软的趋势

谢谢!!!