



# “夸父一号”卫星 太阳硬X射线成像仪

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on behalf of ASO-S/HXI team

2023/12/5

中國科學院紫金山天文台  
Purple Mountain Observatory, Chinese Academy of Sciences

第十届海峡两岸天文望远镜与观测前沿技术研讨会@台北



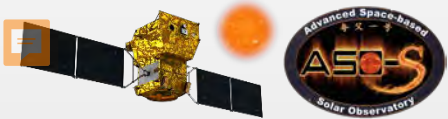
# 报告提纲

项目背景

设计与研制过程

在轨测试与观测结果

小结和展望



# 项目依托单位

## 中国科学院紫金山天文台

### 暗物质与空间天文研究部

暗物质间接探测的相关物理研究组

太阳高能及相关物理过程研究组

太阳活动的多波段观测研究组

紫外和X射线天文研究组

宇宙伽马暴、中子星及相关物理研究组

暗物质和空间天文实验室(组)



### 空间天文观测科学目标及需求

探测器及电子学研究  
探测模拟及数据处理  
空间结构及热控设计

提出空间天文探测卫星计划  
研制空间探测科学有效载荷



1976

空间天文实验室成立



1976-80

天文一号卫星

1980-94

中日远洋气球观测



1990-03

载人航天工程神舟二号有效载荷



1998-08

国际合作暗物质观测

2002-13

探月工程嫦娥一号二号三号载荷

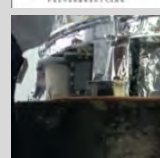


2004-07

SJ-8返回式乳胶室探测器实验

2005-08

中法合作SMESE卫星



2010

院重点实验室成立



2011

暗物质粒子探测卫星立项

2015

“悟空号” 发射



2017

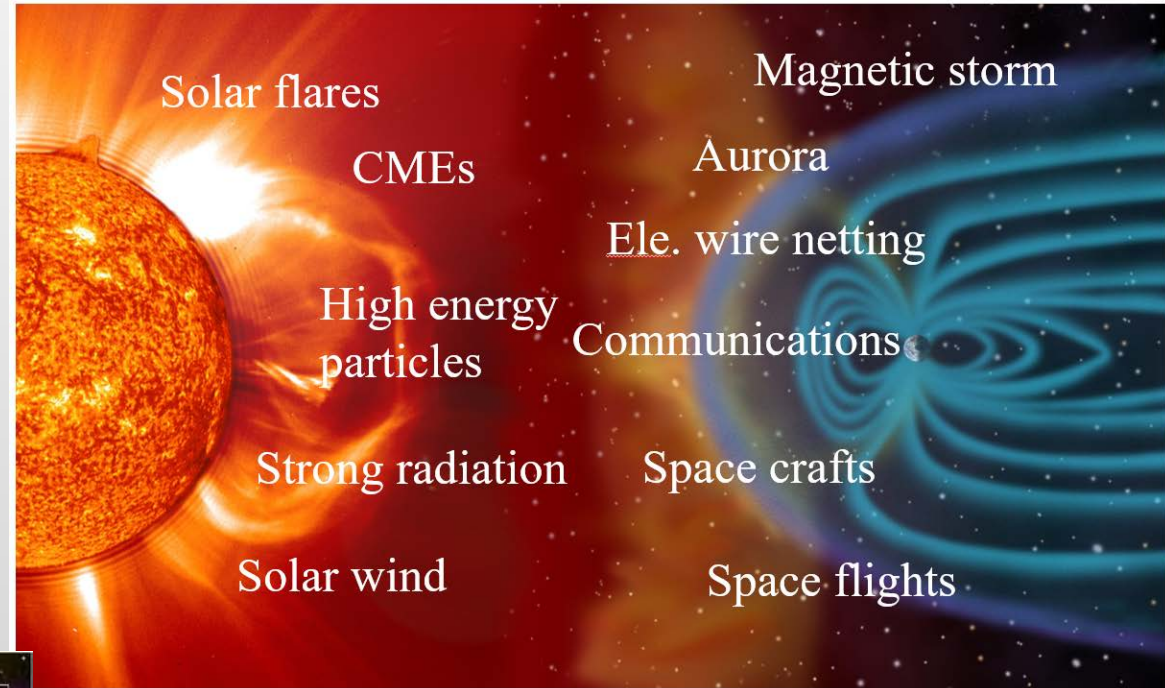
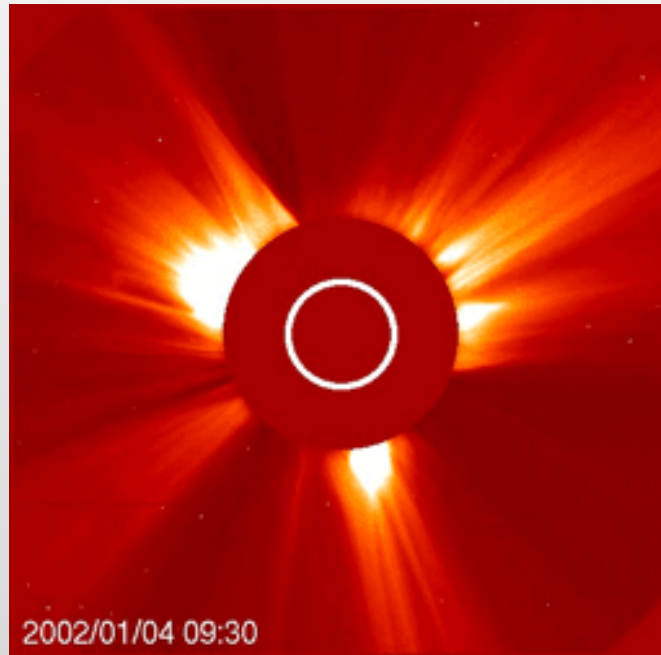
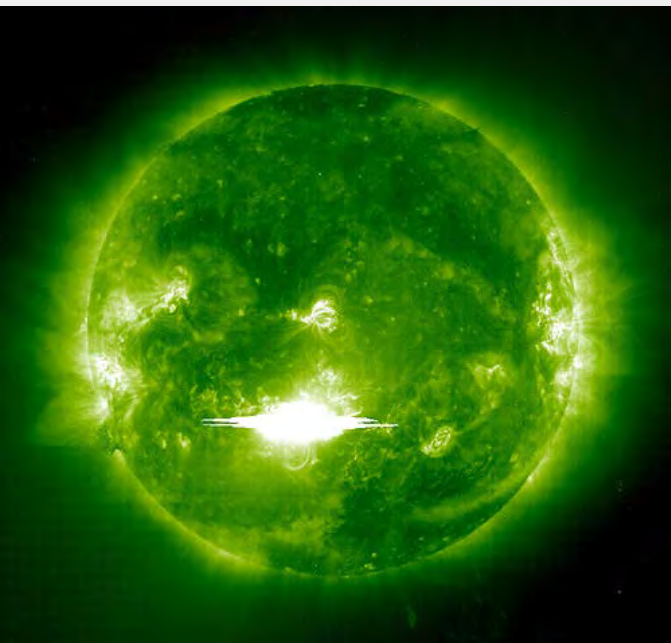
先进天基太阳天文台立项

2021

月球及深空探测嫦娥七号

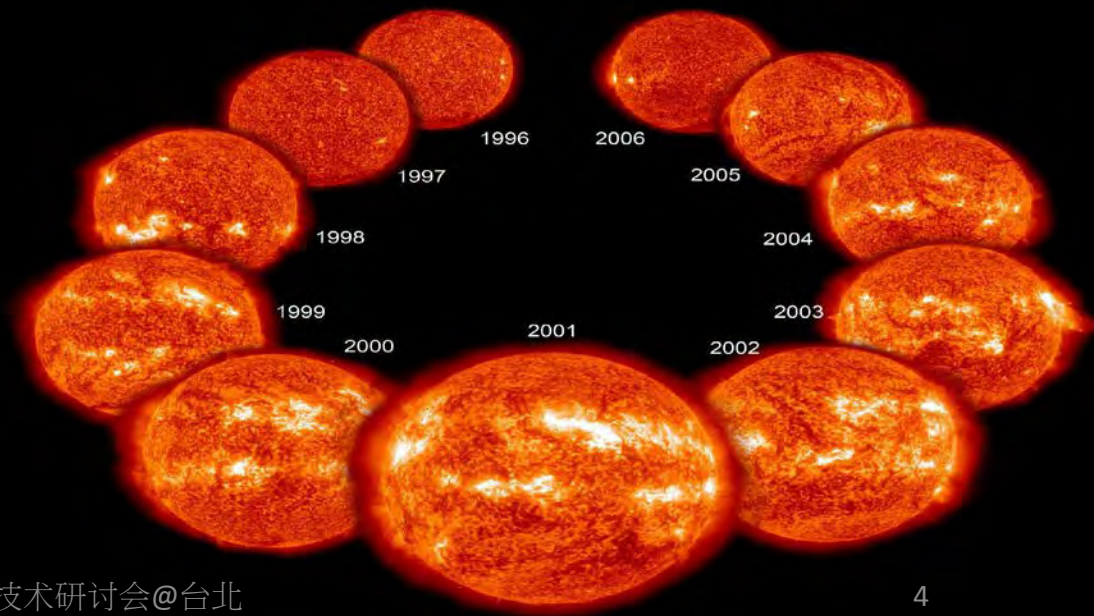
2022

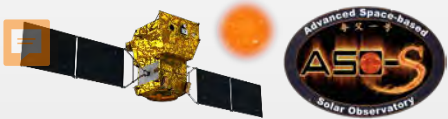
“夸父一号” 发射



# HELIOPHYSICS SYSTEM OBSERVATORY

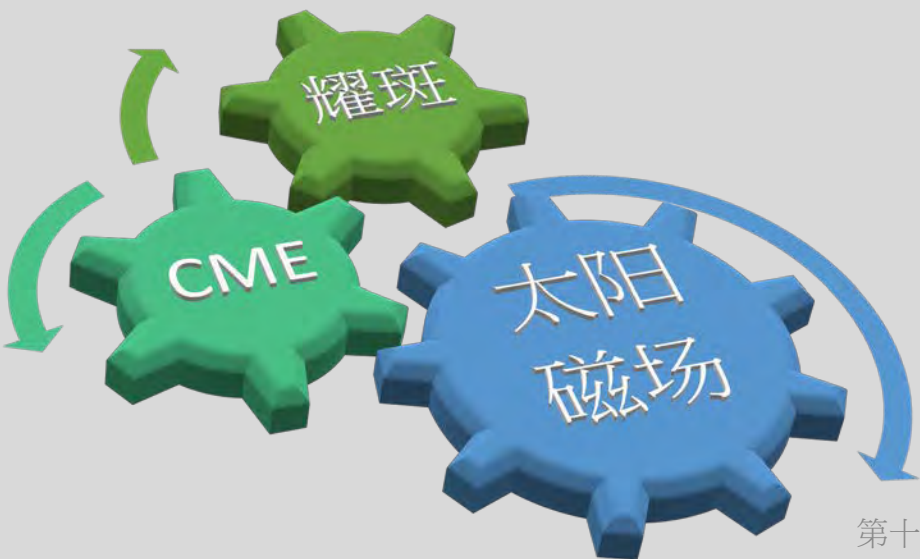
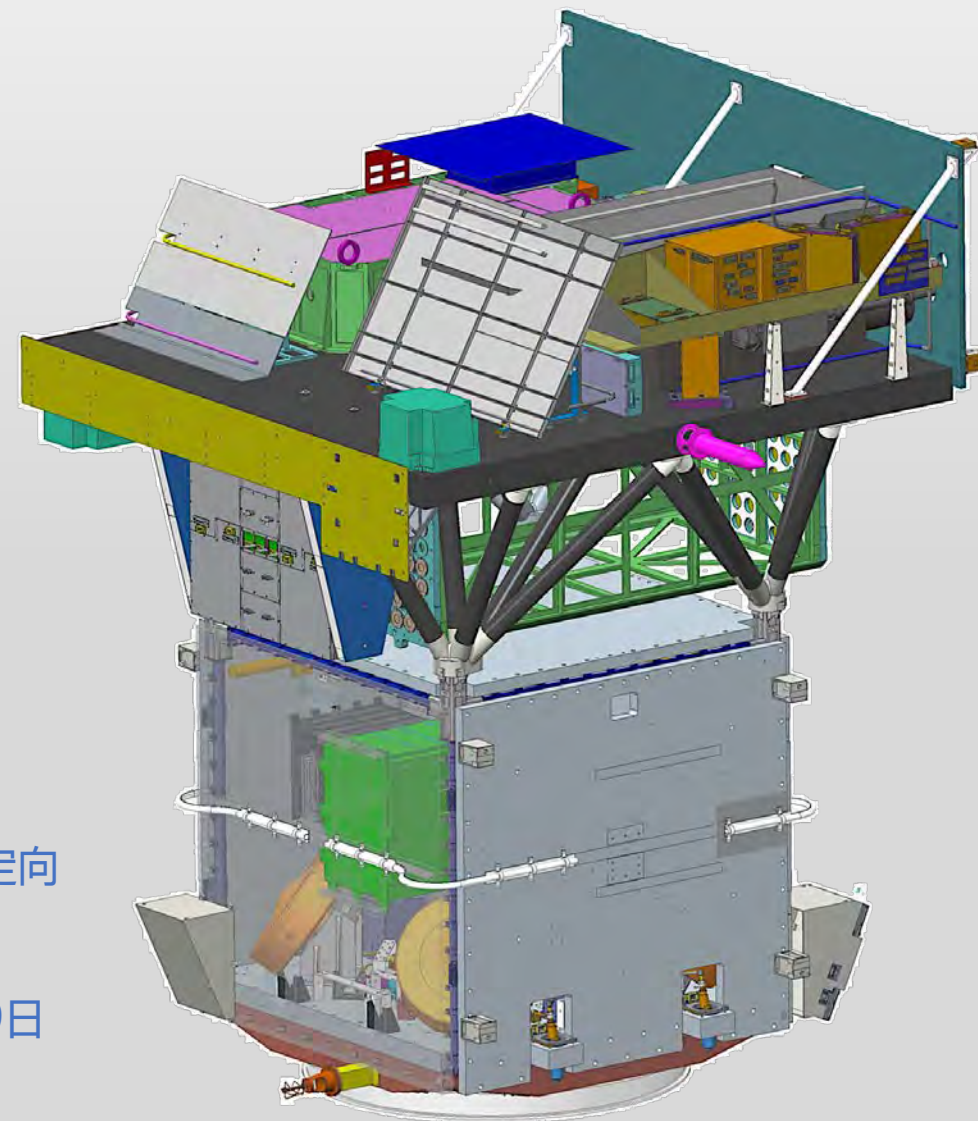
- 20 Operating Missions with 27 Spacecraft
- 6 Missions in Formulation



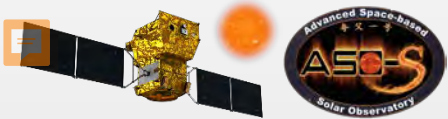


# “夸父一号” 卫星

- 历史意义：46年前提出发射太阳探测卫星
- 卫星定位：中国首颗综合性太阳探测卫星
- 科学目标：“一磁两暴”  
太阳磁场、太阳耀斑和日冕物质抛射  
核心科学问题：三者之间关系
- 载荷构成：LST + FMG + HXI  
LST: 莱曼阿尔法太阳望远镜  
FMG: 全日面矢量磁象仪  
HXI: 太阳硬X射线成像仪



轨道	720 km SSO
姿态控制	三轴稳定对日定向
任务周期	不小于4年
发射时间	2022年10月09日
运载	长征2号丁

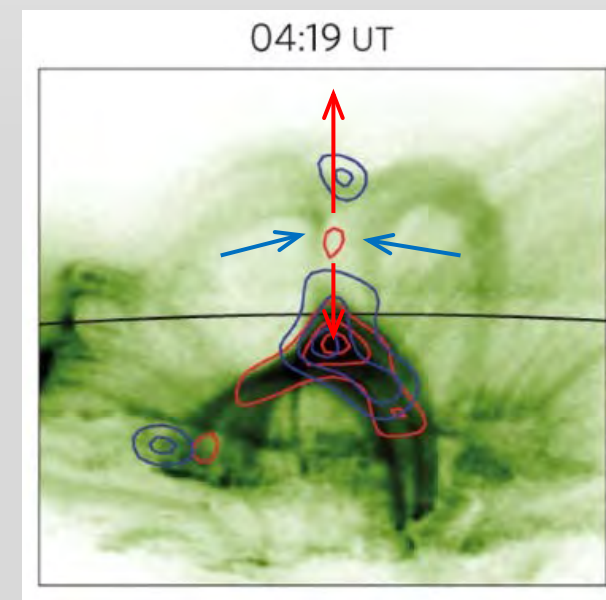
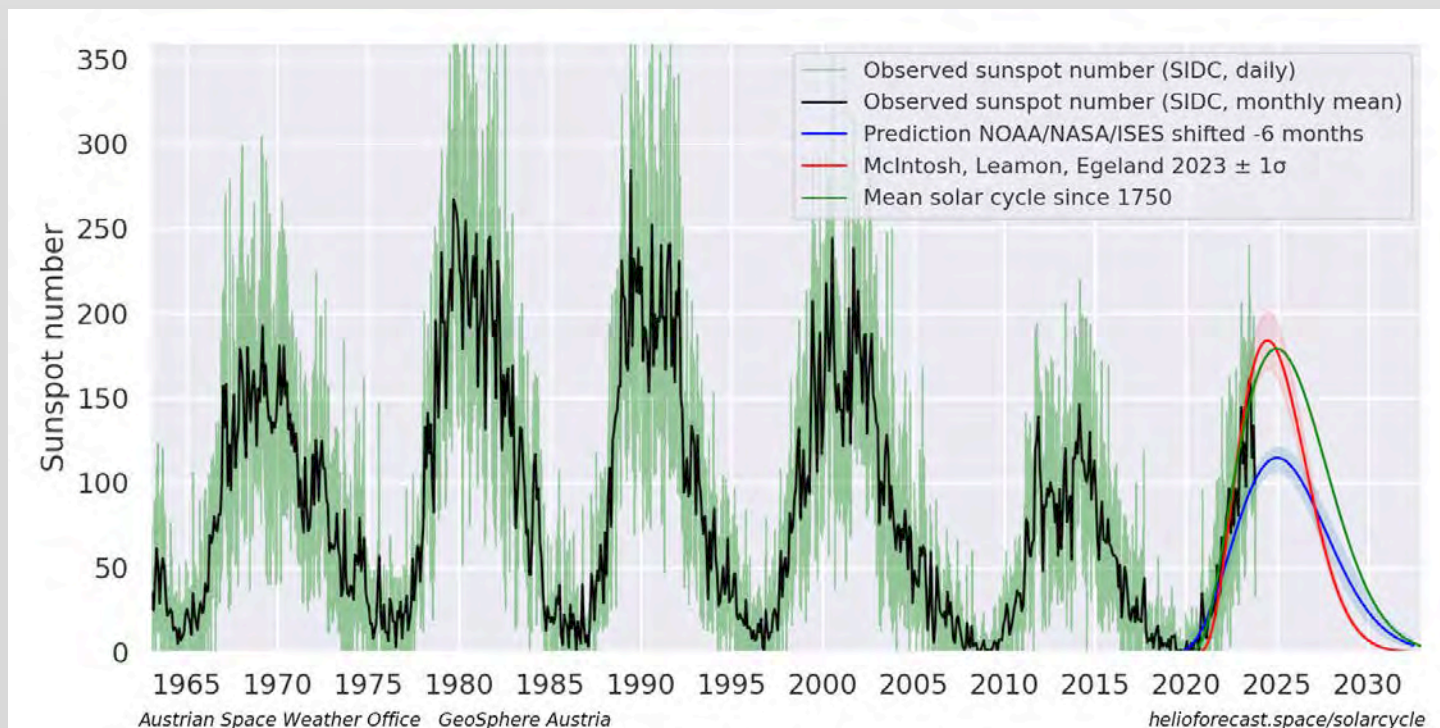


# HXI-太阳硬X射线成像仪

来源：  
苏杨，2022.12  
HXI首图发布会

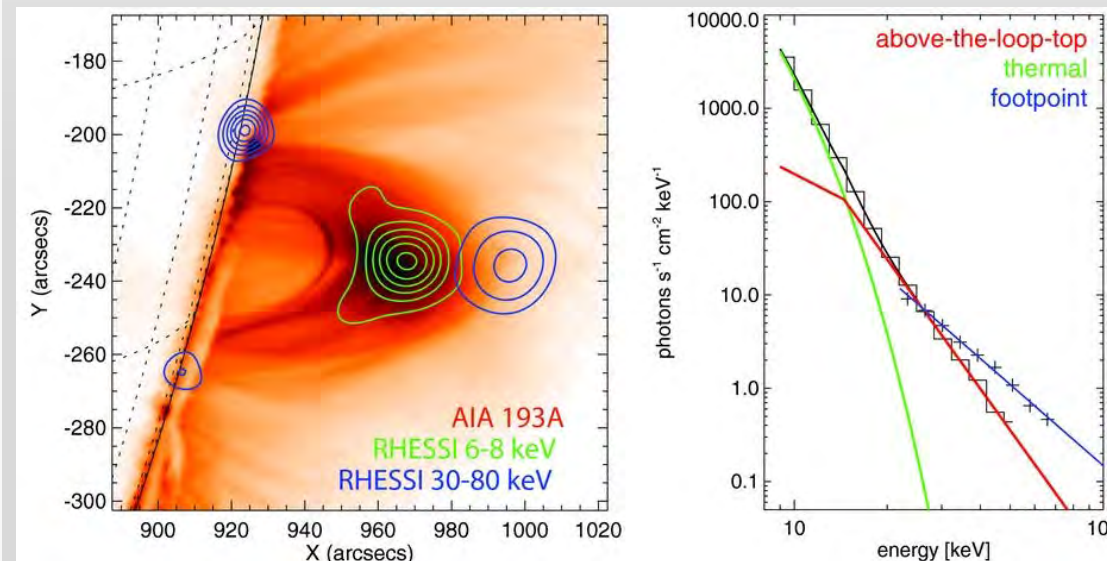
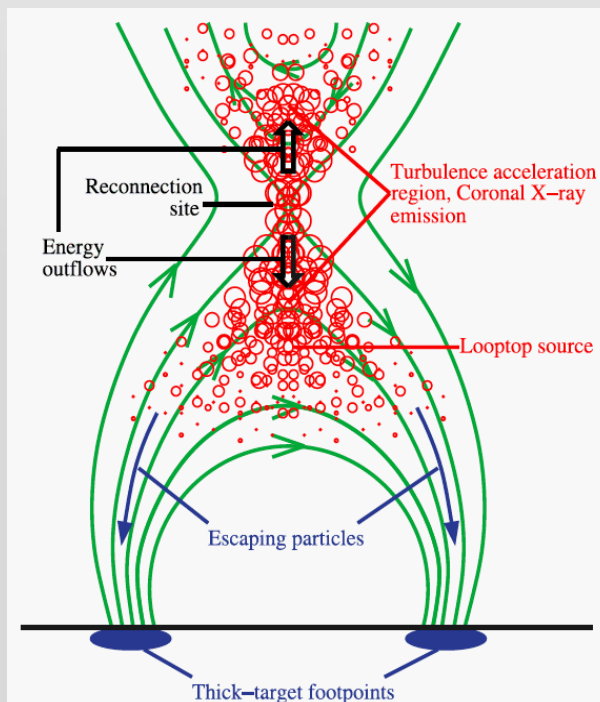
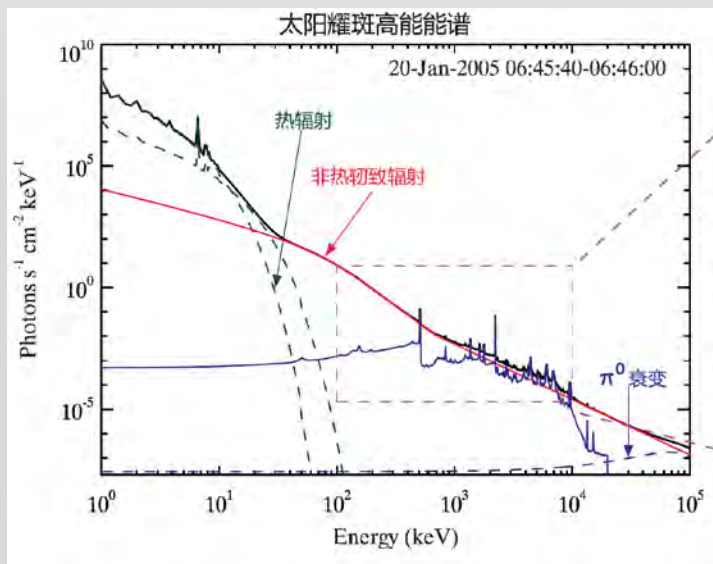
**HXI 科学目标：研究耀斑粒子加速机制及能量释放过程；理解耀斑和CME的本质关系**

- 目前唯一可提供第25太阳活动周地球视角高能成像的设备
- 国内首个太阳高能成像仪；空间分辨率达到国际先进



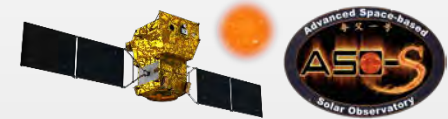
X射线+极紫外，认证磁重联过程  
Su+ Nature Physics, 2013

## HXI 观测目标：硬X射线光变、能谱、成像、像谱



Krucker and Battaglia, 2014  
RHESSI结果

苏杨，陈维等《中国科学》2020



# 研制历程

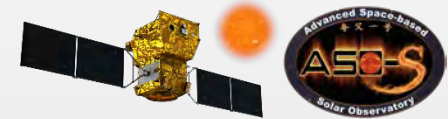


中国科学院空间科学战略性科技先导专项：

- 预先研究
- 背景型号研究
- 卫星工程

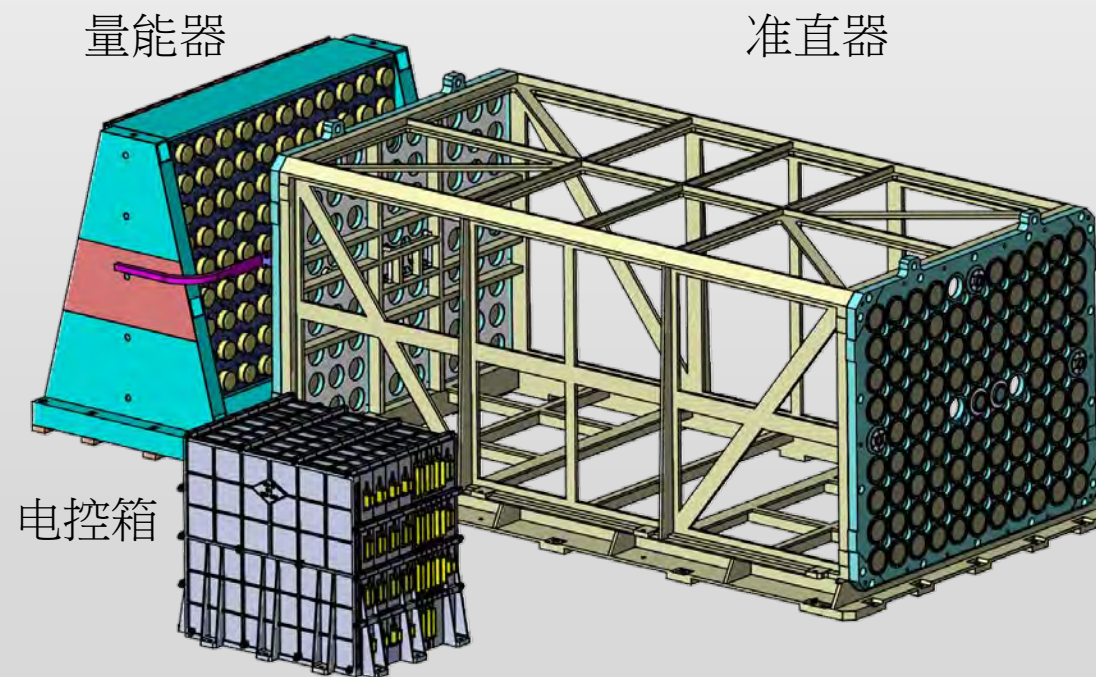
## 国际同类载荷发展

			
<p><b>YOHKOH/HXT</b> (1991~2001) 空间调制成像 观测能段: 14~93keV 空间分辨: 8"</p>	<p><b>RHESSI</b> (2002~2018) 旋转调制成像 观测能段: 3keV~17MeV 空间分辨: 2.3"~3'</p>	<p><b>Solar Orbiter/STIX</b> (2020~) 空间调制成像 观测能段: 4~150keV 空间分辨: 7"</p>	<p><b>ASO-S/HXI</b> (2022~) 空间调制成像 观测能段: 30~200keV 空间分辨: 3"</p>

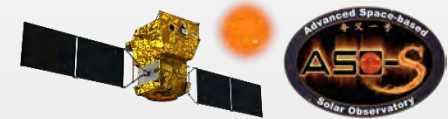


# HXI-太阳硬X射线成像仪

Characteristics	Design	Ground test	In-orbit test
Energy range	30~200keV	Better than 30~400 keV	Better than 15~300 keV
Energy res.	Better than 27%32keV	Better than 23.7%@32keV	Better than 22%@32keV
Spatial res.	6"@30keV	~3.2"@30keV	~3"@30keV
Acc. of sun's center	Better than 2"	0.63 "	Better than 0.3"
FOV	40'/full disk	40.3'	-
Time res.	0.125/0.25/0.5/1/4 s (self-adaptive)	0.125/0.25/0.5/1/4 s (self-adaptive)	0.125/0.25/0.5/1/4 s (self-adaptive)
Weight	160kg	153.95kg	-
Dimensions	1620×710×700 mm	1618×708×700 mm	-
Data rate	~10 GB/day	-	~10 GB/day



- **HXI-C:** X-ray optics, providing 91 independent sub-collimators, solar aspect system( two white light cameras)
- **HXI-S:** X-ray recorder LaBr<sub>3</sub>, detector modules coupled with R1924A PMT
- **HXI-E:** power supply (DC-DC and high voltage power) and data manager



# HXI-太阳硬X射线成像仪

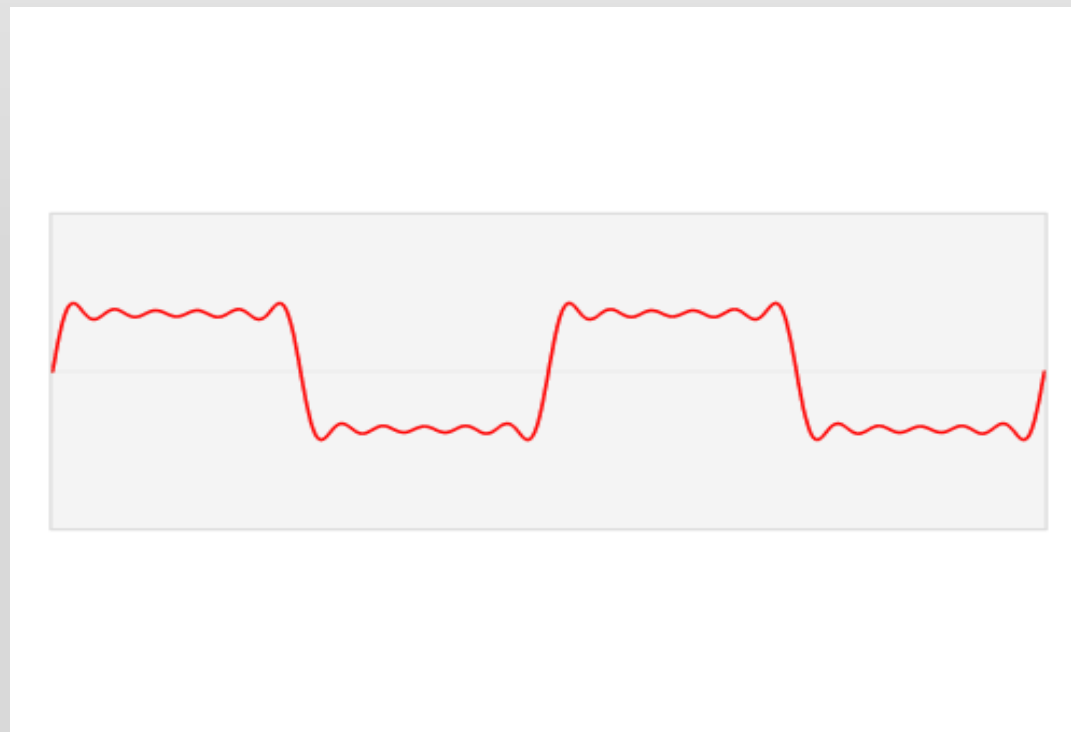
## HXI 成像原理

射电天文中的  
甚长基线干涉技术 (VLBI)

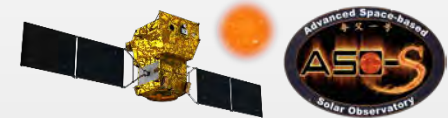
傅里叶变换合成成像



M87中心黑洞  
EHT (20190410)



一维情形



# HXI-太阳硬X射线成像仪

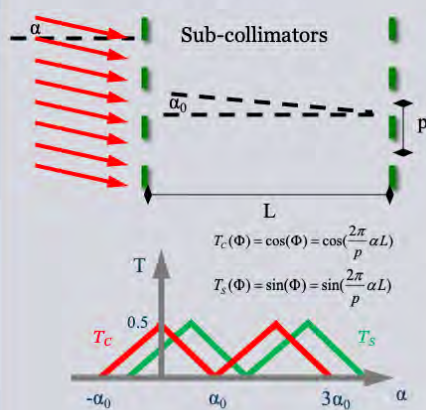
## 双光栅准直器调制

### Imaging procedure

#### Flare Eruption



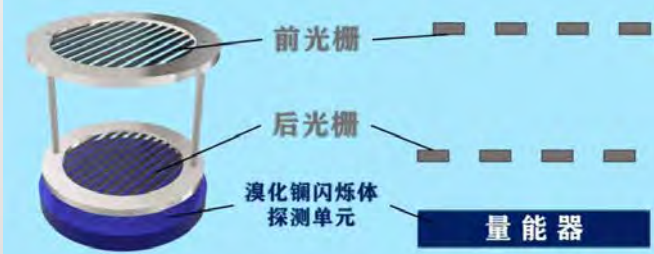
#### Modulation



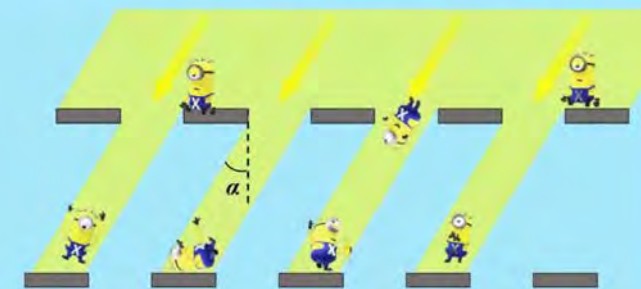
#### Image Reconstruction



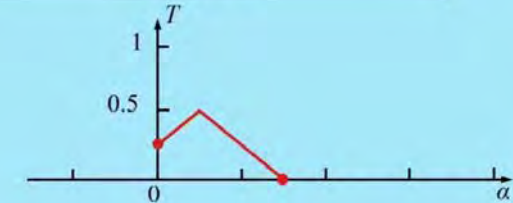
简单起见  
先把光栅简化为一维挡板



X射线入射角度( $\alpha$ )的变化  
会使透过前后光栅的总强度( $T$ )有规律地变化

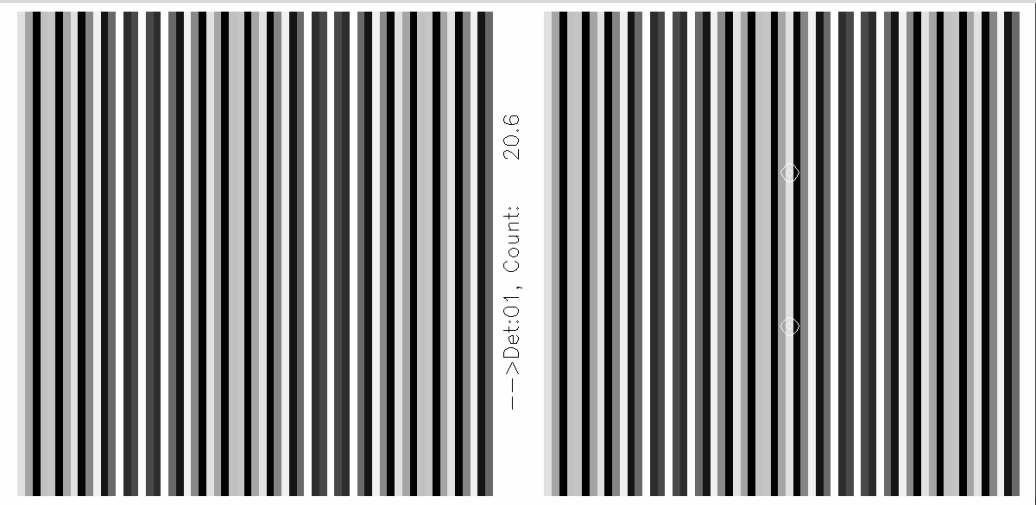


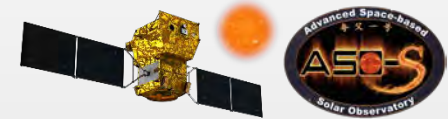
#### 量能器



不同宽度\*的光栅, 调制曲线不同  
通过组合不同宽度的光栅对  
就可以得到准确的X射线源位置

\*这里的宽度指节距  
节距=狭板+缝宽





# 项目参与单位

参与单位



国家空间科学中心，北京

- 电控箱



微小卫星创新研究院，上海

- 在轨热控设计与实施



紫金山天文台，南京

- 总体负责单位，除以上



西安中科微精，西安

- 光栅加工



西安光学与精密机械研究所，西安

- 准直器结构加工与装配

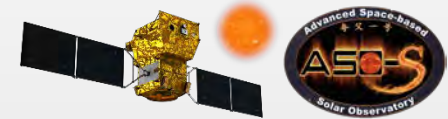


航天5院513所，烟台

- 量能器电装&准直器束流标定

主要外协单位





# HXI工程团队与科学团队的分工配合

## 工程团队

张哲、伍健 +  
多个单位

- **HXI**
  - 光栅和准直器
  - 探测器
  - 电控箱
  - 指向镜系统
- 地面测试和定标
- 束流实验
- Geant4 仿真模拟

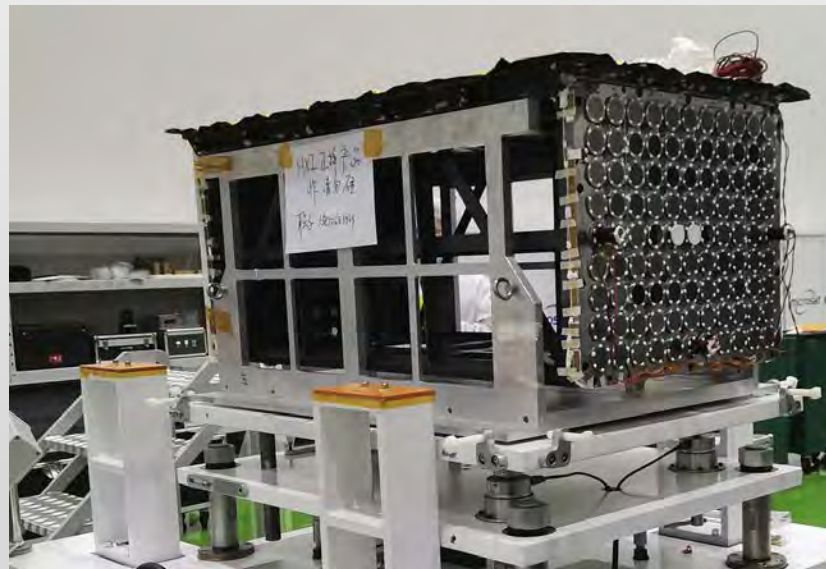
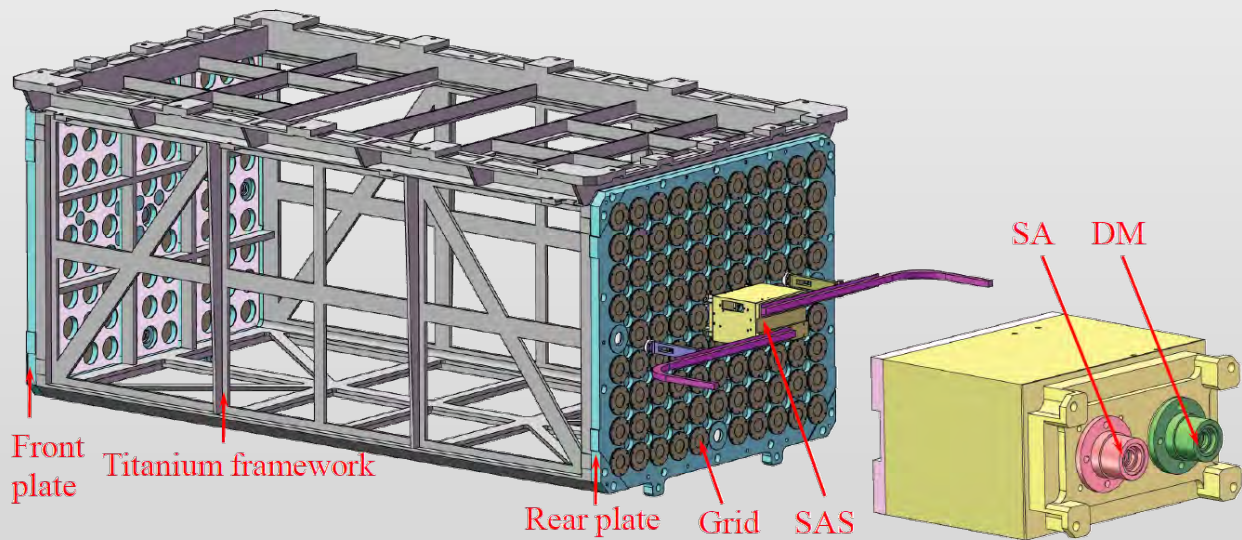
## 科学团队

苏杨 +

- **HXI 设计**
- 指标优化
- 光栅参数优化
- 探测器响应矩阵
- 束流实验分析
- 指向镜零位定标
- 在轨测试和标定

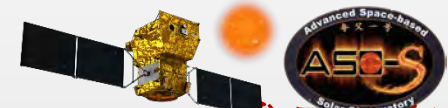
- 数据生产和处理
- 成像模拟
- 成像算法
- 抖动修正算法
- 模拟数据
- 生产软件
- 科学分析软件
- 能量定标和光栅定标

# 太阳硬x射线成像仪-准直器组成



- 91 对光栅子准直器
- 3个开放光栅全流量探测
- 5个全闭光栅粒子背景探测
- 太阳指向镜与形变监测镜
- 钛合金框架
- 主动热控系统

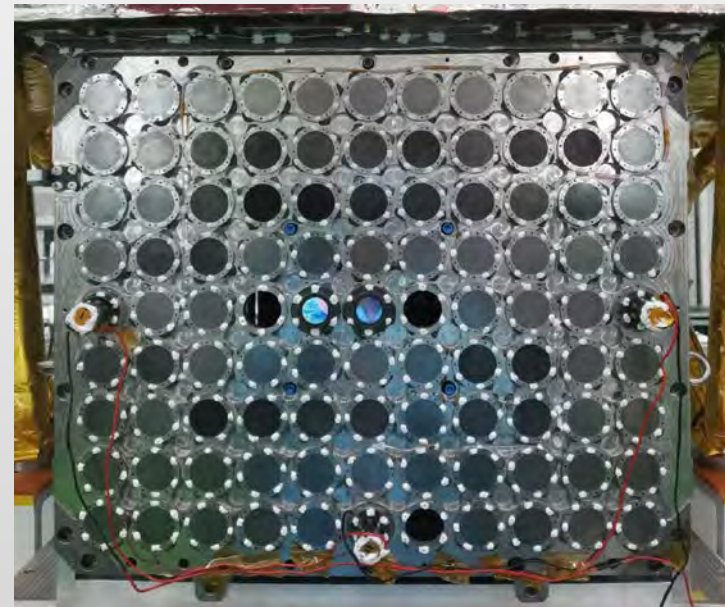
**核心问题（关键技术）：实现前后光栅空间位置上的精确对准和稳定**



# 准直器光栅配置

优化：对应高分辨细节的小节距（高频成分）光栅选择加密  
效果详见在轨成像结果

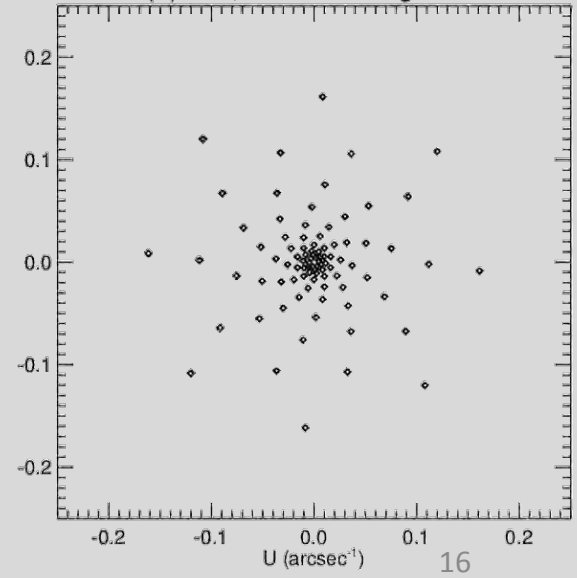
Pitch/ $\mu\text{m}$	36	52	76	108	156	224	344	524	800	1224
Thickness/mm	1.0	1.4	1.7	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Quantity/ $\Delta\phi=0^\circ$	4	5	5	5	5	5	5	5	3	3
Quantity/ $\Delta\phi=90^\circ$	4	5	5	5	5	5	5	5	3	2
Quantity/ $\Delta\phi=120^\circ$	0	0	0	0	0	0	0	0	0	1
Quantity/ $\Delta\phi=240^\circ$	0	0	0	0	0	0	0	0	0	1
Nominal spatial res./"	3.1	4.5	6.5	9.3	13.4	19.3	29.6	45.1	68.8	105.2
Position angles/ $^\circ$	25/	5/	32/	23/	14/	5/	23/	5/	23/	53/
	70/	41/	68/	59/	50/	41/	59/	41/	83/	113/
	115/	77/	104/	95/	86/	77/	95/	77/	143	173
	160	113/	139/	131/	122/	113/	131/	113/	143	173
Material & Fabrication	0.1mm tungsten foil each by laser processing in company Xi'an Micromach Technology, stacked one by one to the requirement thickness.									
Distance	L=1190 mm (distance between the front and rear grid).									
Effective area	The diameter of front grid ( $\phi_f$ ) is set as 36 mm and for the rear grid ( $\phi_r$ ), it is set as 22mm. The difference between these two diameters and the distance between the front and rear grids is determined by the field of view of each sub-collimator, more than $40'$ .									



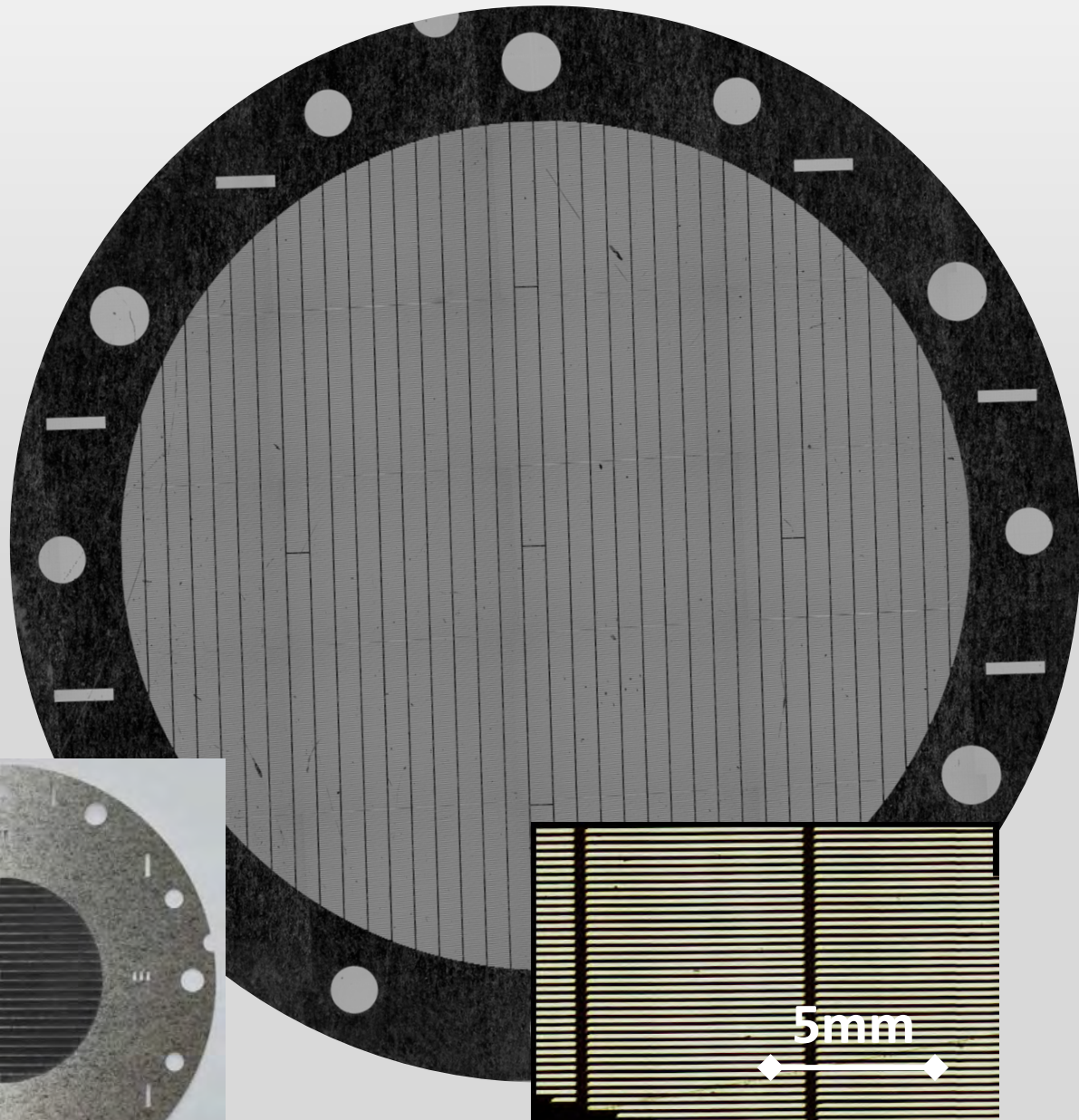
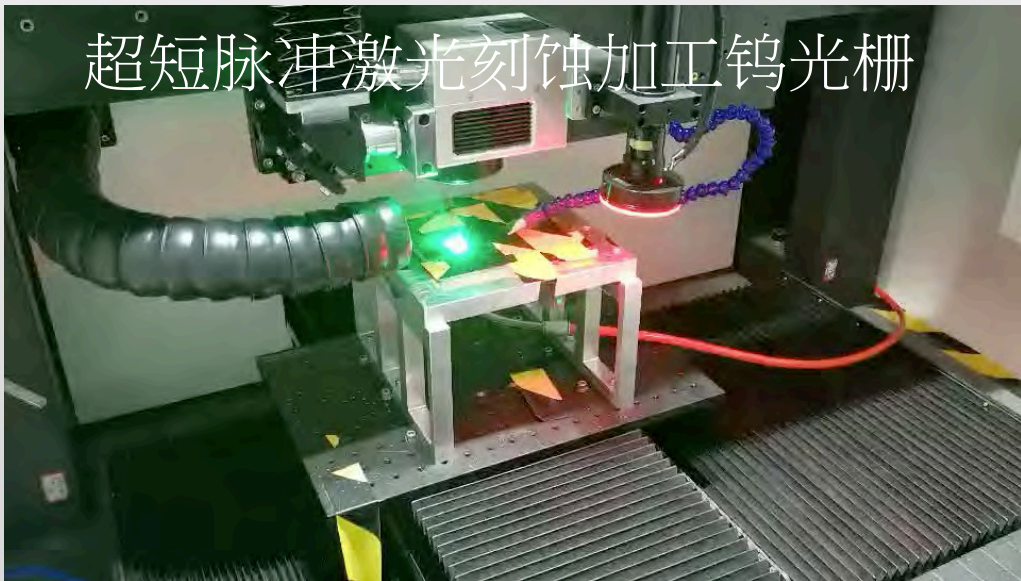
Interface plate: front view of rear plate(from HXI-S to the solar)

1224 53°	156 50°	524 41°	156 14°	344 23°	800 23°	1224 173°	156 158°	156 158°	224 149°	800 143°
344 59°	36 70°	36 70°	76 176°	52 41°	52 41°	76 176°	52 149°	52 149°	108 131°	344 131°
156 14°	76 68°	52 77°	52 77°	52 5°	52 5°	36 160°	36 160°	36 115°	76 104°	524 113°
800 83°	524 77°	108 95°	108 95°	224 5°	524 5°	344 95°	224 113°	36 115°	76 104°	1224 113°
frosted glass	1224 113°	344 95°	344 95°	OPEN	DM	SA	OPEN	224 77°	524 77°	frosted glass
524 113°	1224 113°	52 113°	52 113°	344 167°	800 23°	524 23°	156 86°	156 86°	76 68°	800 83°
344 131°	156 122°	76 139°	76 139°	156 122°	76 32°	76 32°	36 25°	36 25°	156 50°	108 23°
224 149°	108 131°	108 167°	108 167°	1224 173°	224 5°	108 23°	224 77°	108 59°	108 59°	224 41°
800 143°	524 149°	524 149°	524 149°	OPEN	frosted glass	344 23°	524 41°	224 41°	344 59°	1224 53°

(d) HXI, current configuration

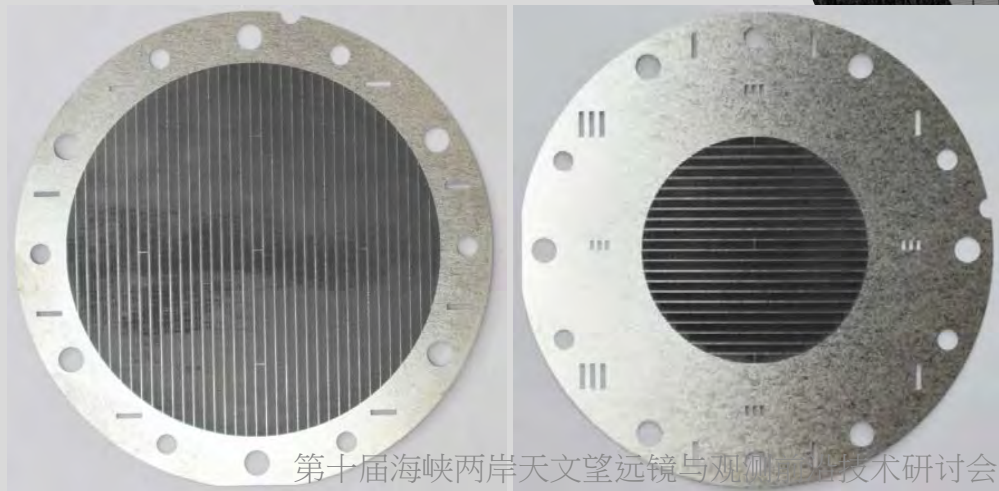


# 准直器光栅加工

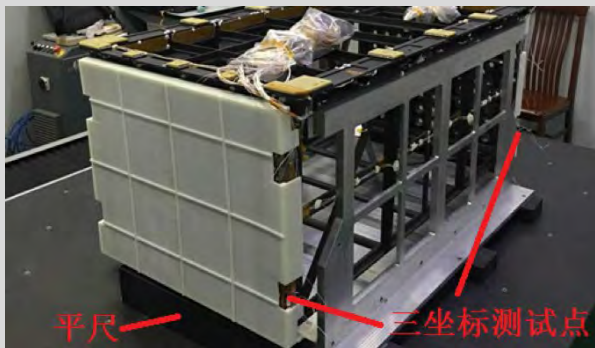
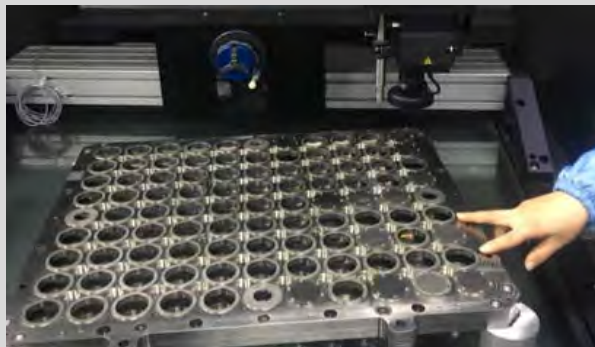


## 难点：

- 硬质金属 钨
- 高深宽比  $\sim 5$
- 窄缝宽  $\sim 20\mu\text{m}$
- 高一一致性要求
- 大规模
- 高效率



# 关键技术-准直器光栅精密装校工艺

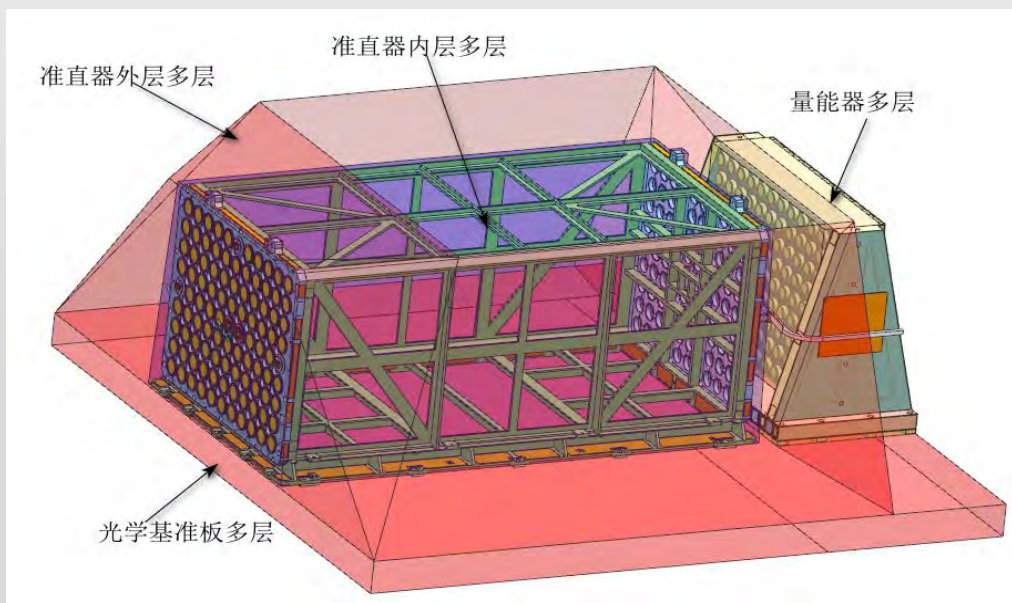


- 光栅胶叠对准  $\sim 3\mu\text{m}$
- 光栅对准  $\sim 36\mu\text{m}$
- 扭曲控制  $\sim 10''$
- 通过环境试验

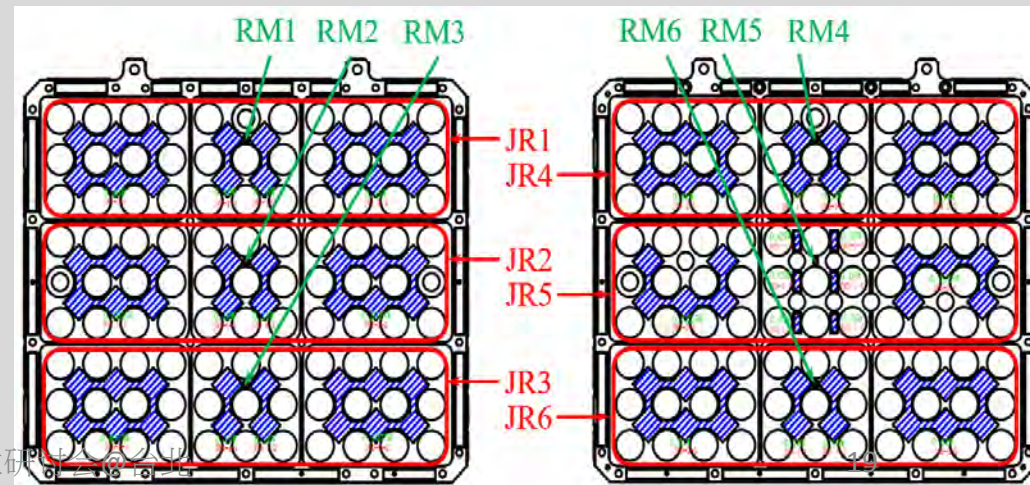
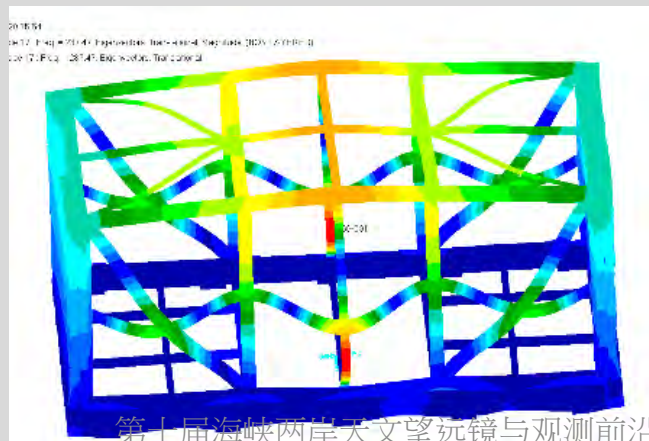
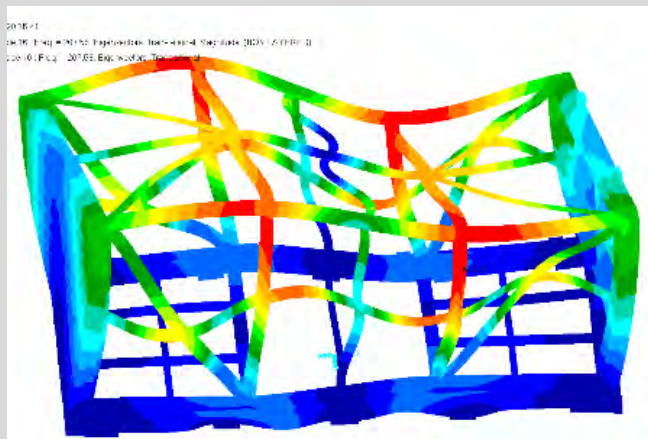
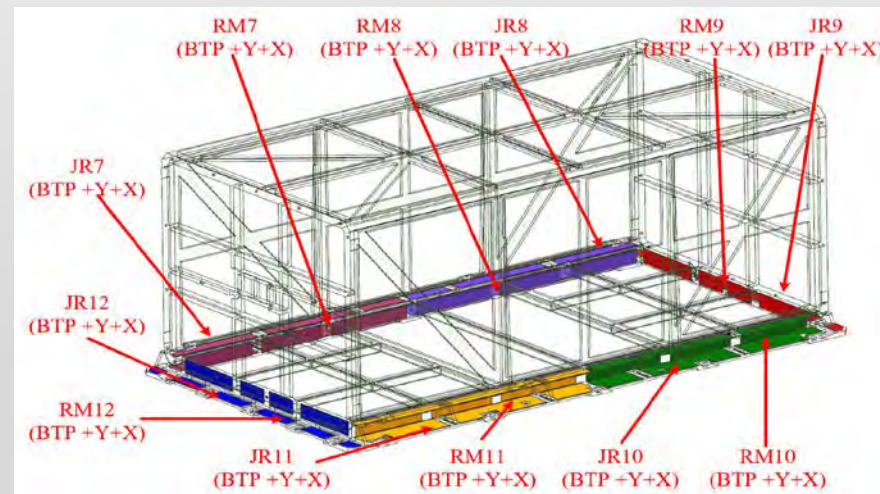
第十届海峡论坛暨两岸光电与探测前沿技术研讨会@台北



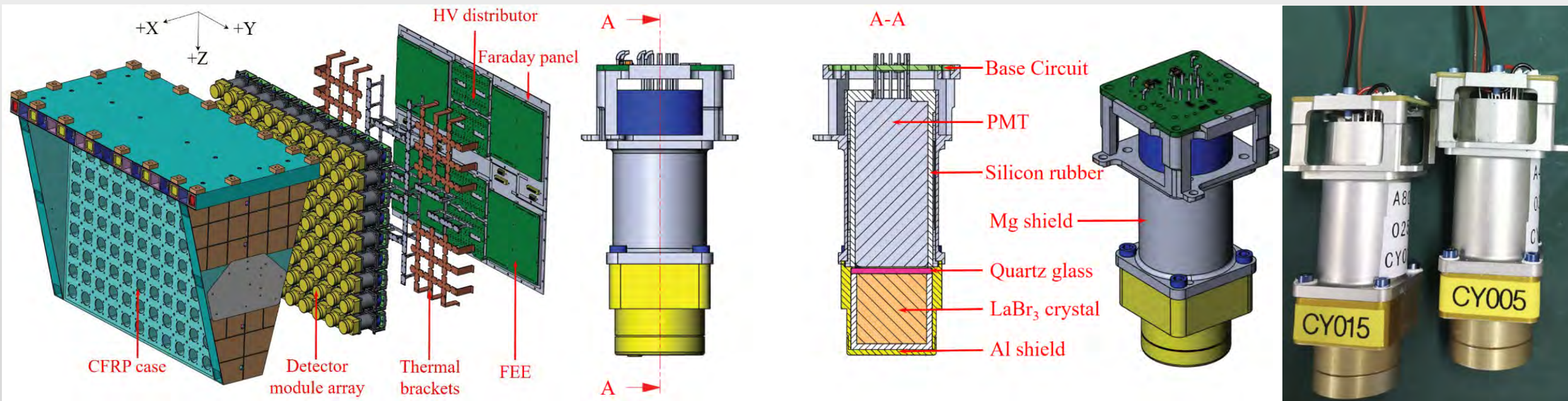
# 准直器结构热控的仿真与验证



前后光栅温差及温度梯度小于 $1^{\circ}\text{C}$



# 太阳硬x射线成像仪-量能器

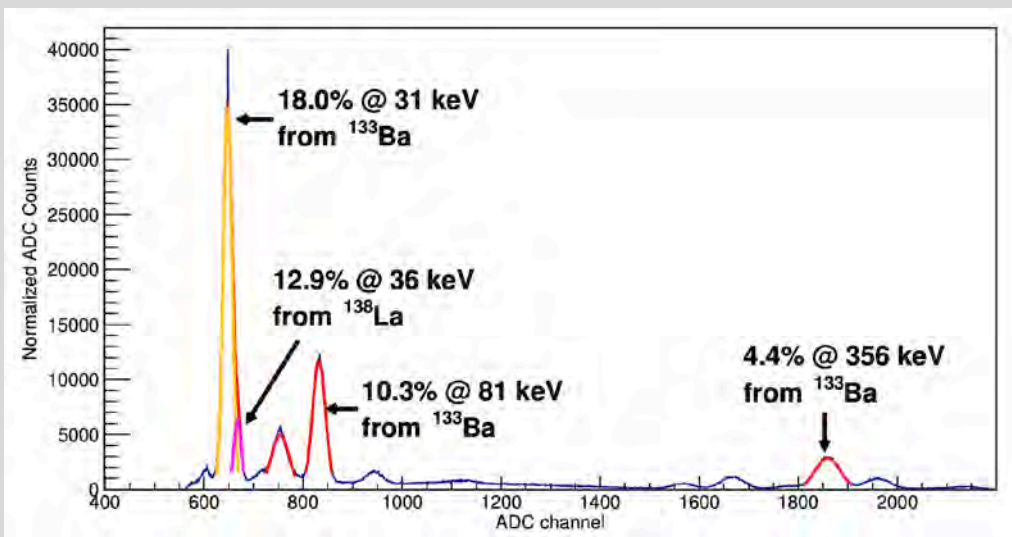
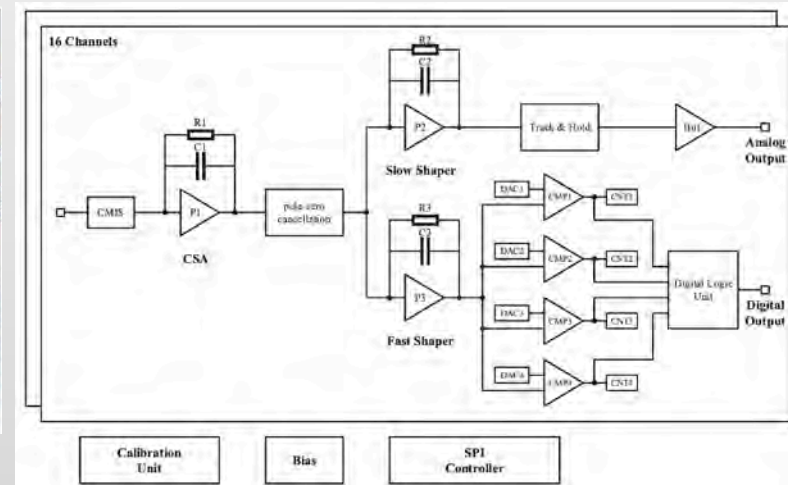
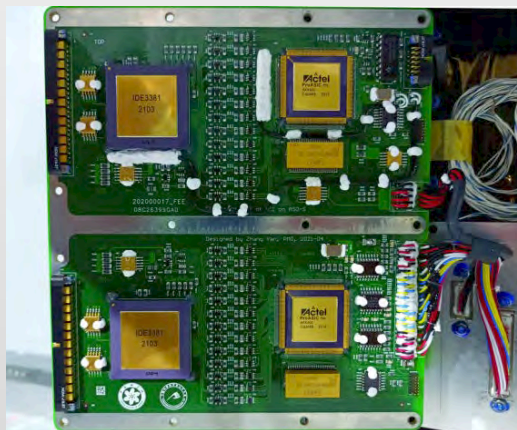


Components	Function	Notes
Detector modules	Used for x-ray record	99 modules (including 1 thinner cap for flux monitor)
Front end electronics	Electrical information process	4 sets (each set including 2 identical pcs)
HV distributor	HV distribution to each PMT	8 identical pcs
Framework support	Structure stability	CFRP support (provided by No. 149 Institute)
Thermal brackets and heater units	Thermal homogenous holding	Active TC: heaters were used by closed loop control Passive TC: multi-layers/insulation/radiation plate for cooling

# 探测系统-探测单元、前端电子学



1英寸溴化镧晶体（北玻院）  
1英寸PMT-R1924A（滨松）

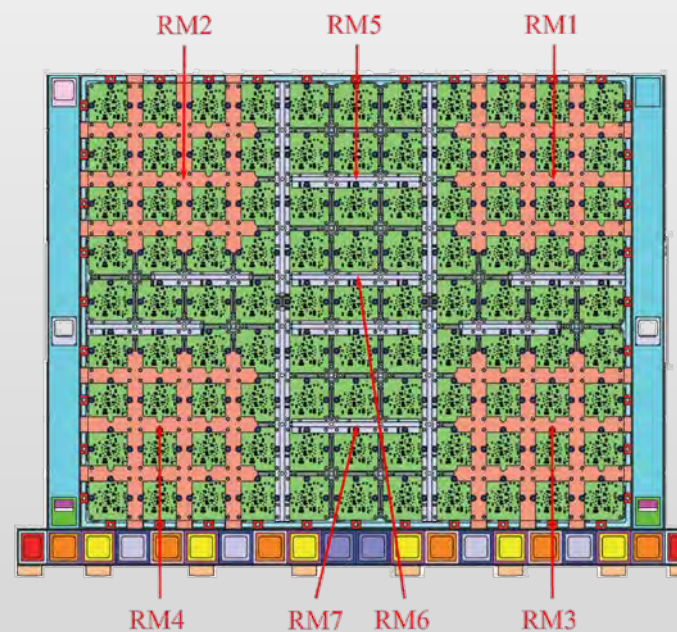
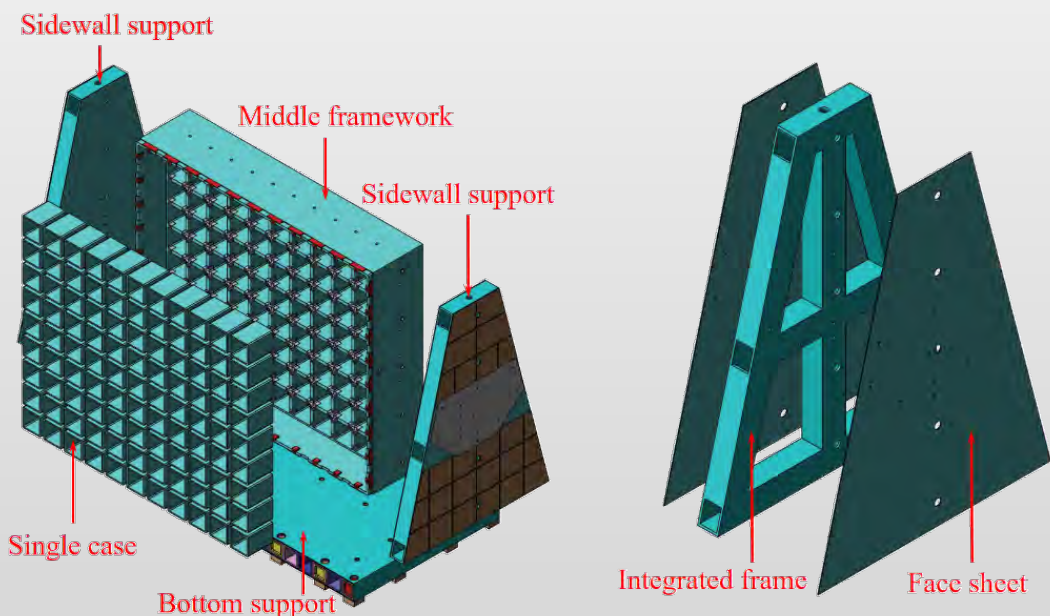


## ASIC IDE3381（挪威IDEAS）

- 16通道
- 5~800pC动态范围
- 三种数据类型
  - 能谱测量 2us死时间
  - 计数测量 200ns死时间
  - 逐事例数据

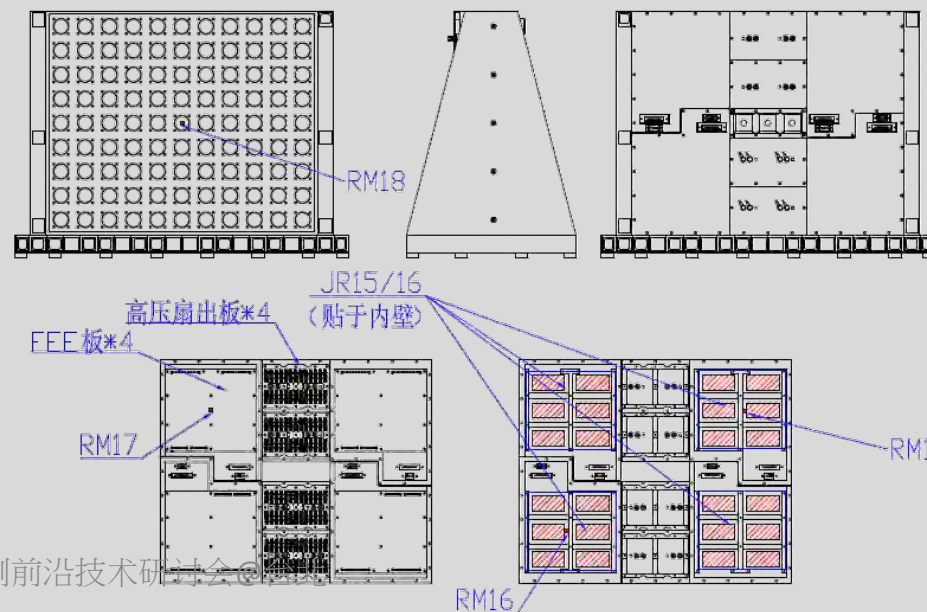
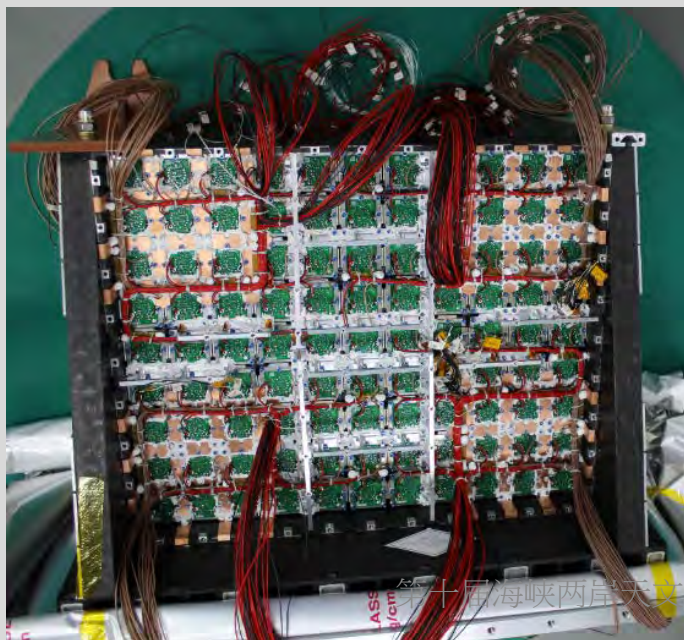
探测系统的计数率线性范围达 $10^6/\text{s}/\text{cm}^2$ -适应太阳爆发观测

# 探测系统-结构与热控



量能器  
正样产品  
(背面)

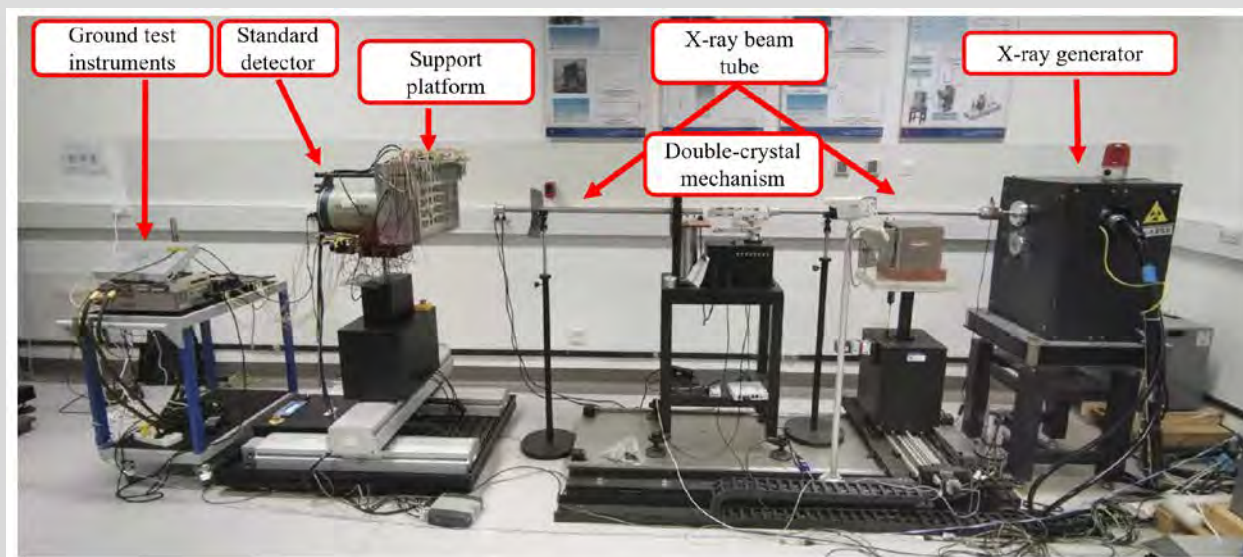
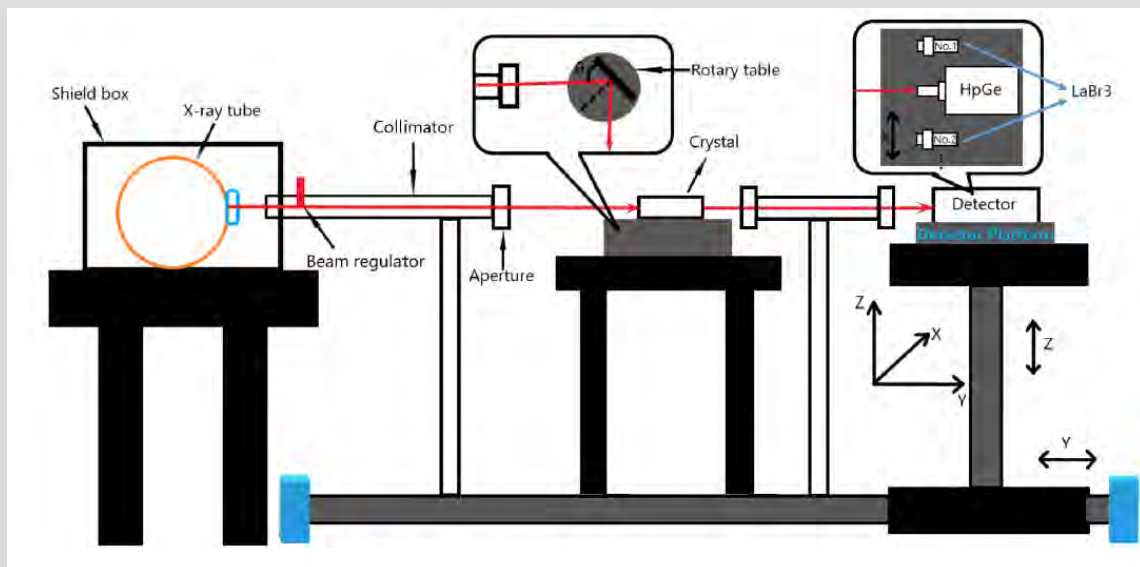
Chen et al. (2020, JINST)



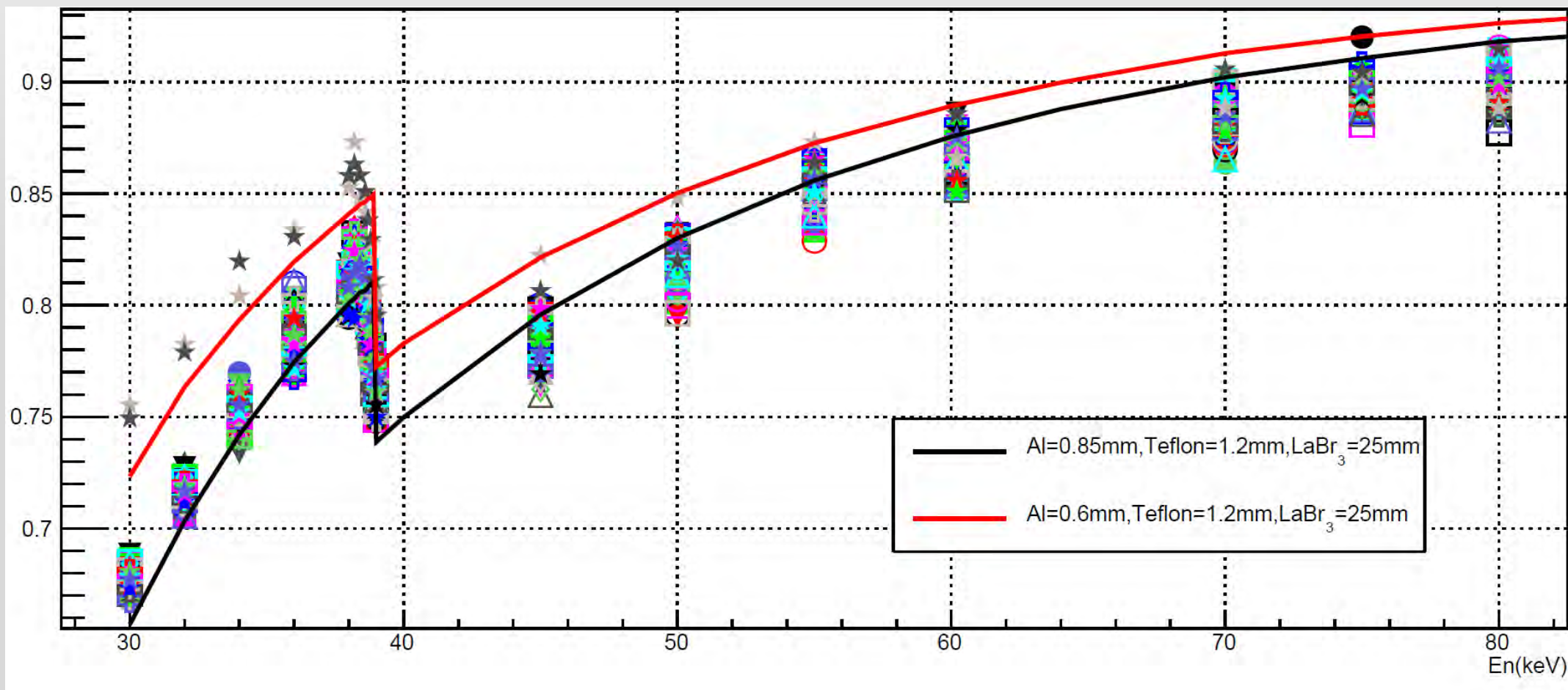
## ■ 量能器探测单元定标

➤ 探测效率定标

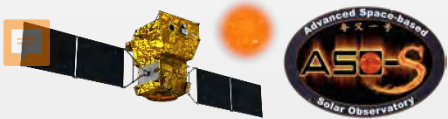
中国计量院 单能X射线装置



## Absolute detection efficiency

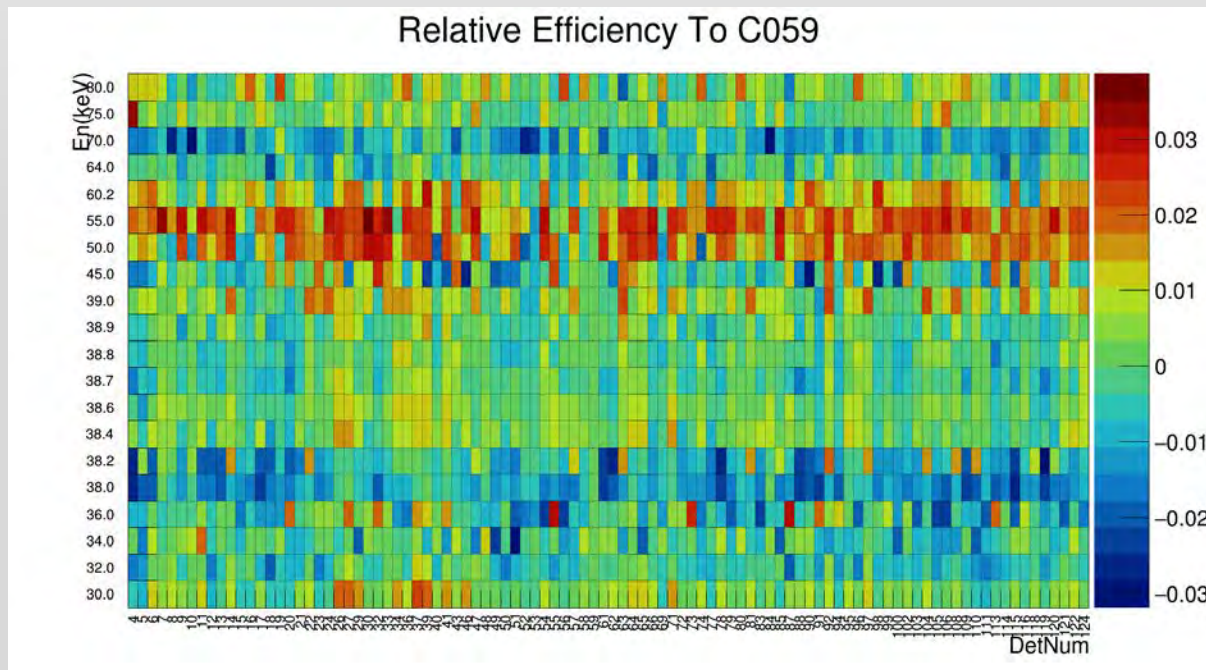


*Liu et al. (2022, JINST)*

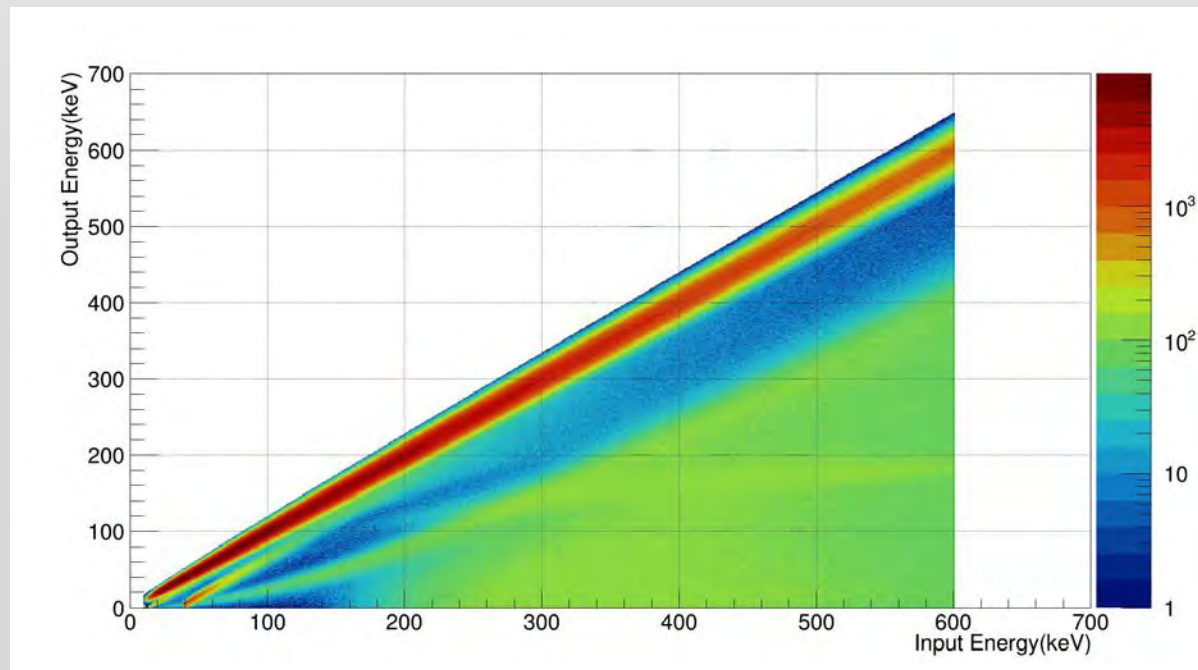


# 地面标定测试-探测单元标定

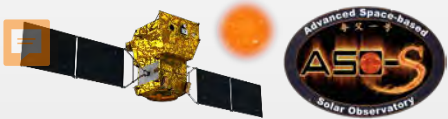
## Relative detection efficiency



## Energy response matrices



*Liu et al. (2022, JINST)*

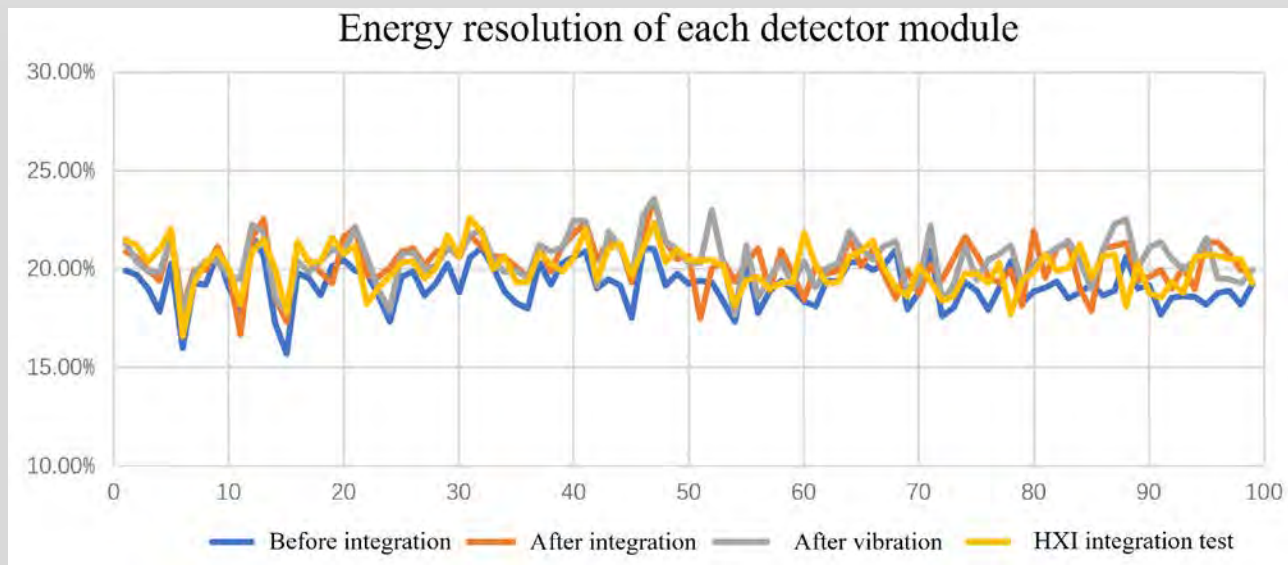


# 地面标定测试-探测单元标定

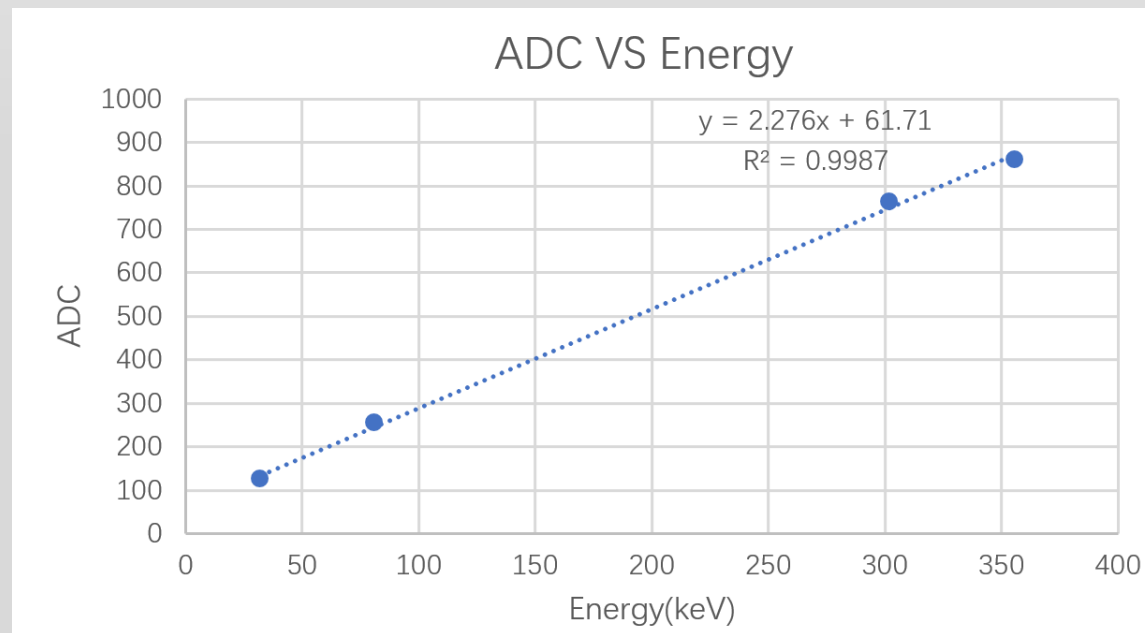
## ■ 量能器探测单元定标

➤ 能量定标      放射源

### Energy resolution variation

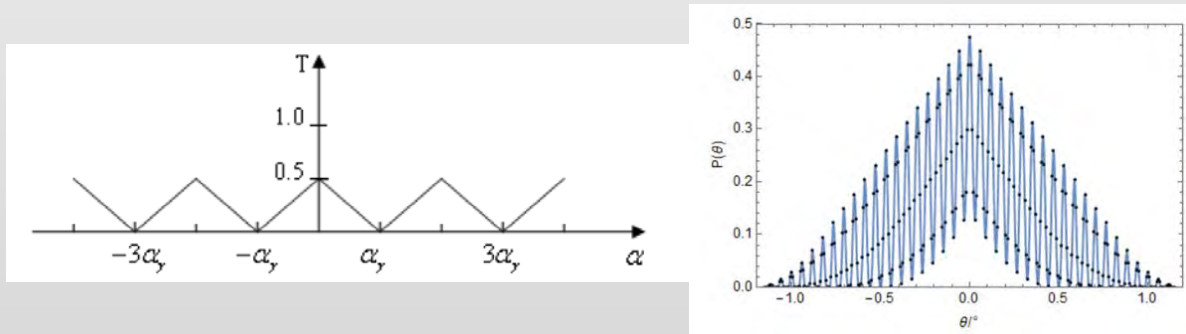


### Energy linearity



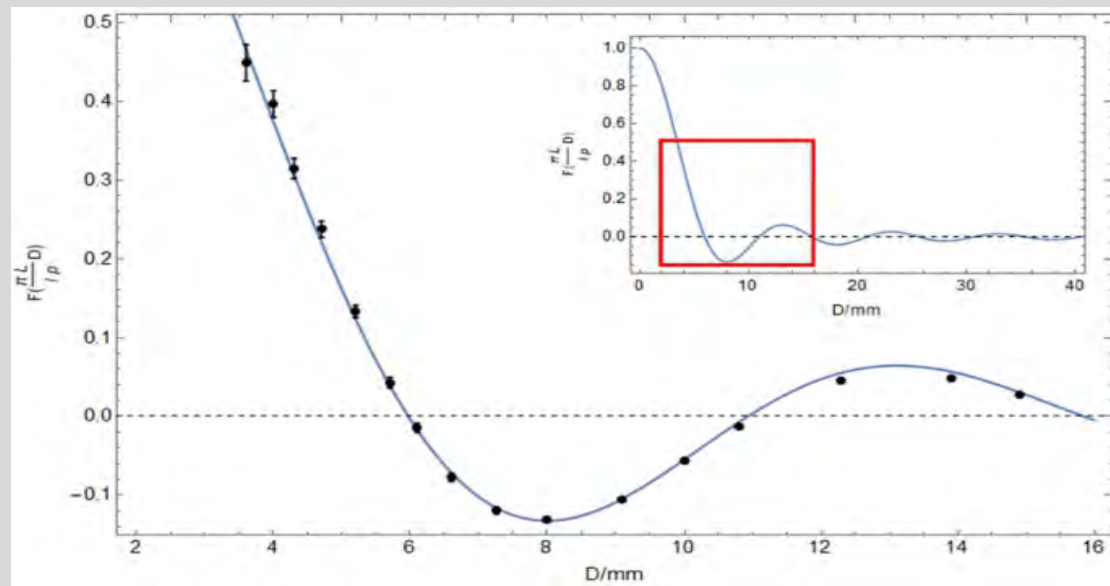
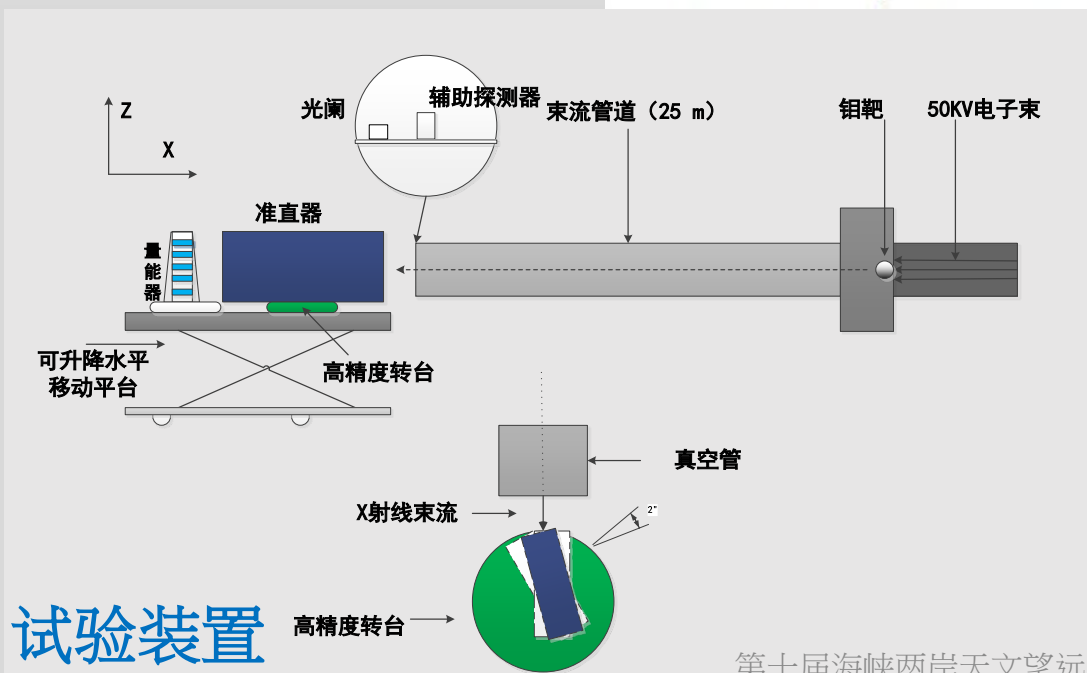
*Liu et al. (2022, JINST)*

## 方向调制关系



## 调制过程的解析数学模型

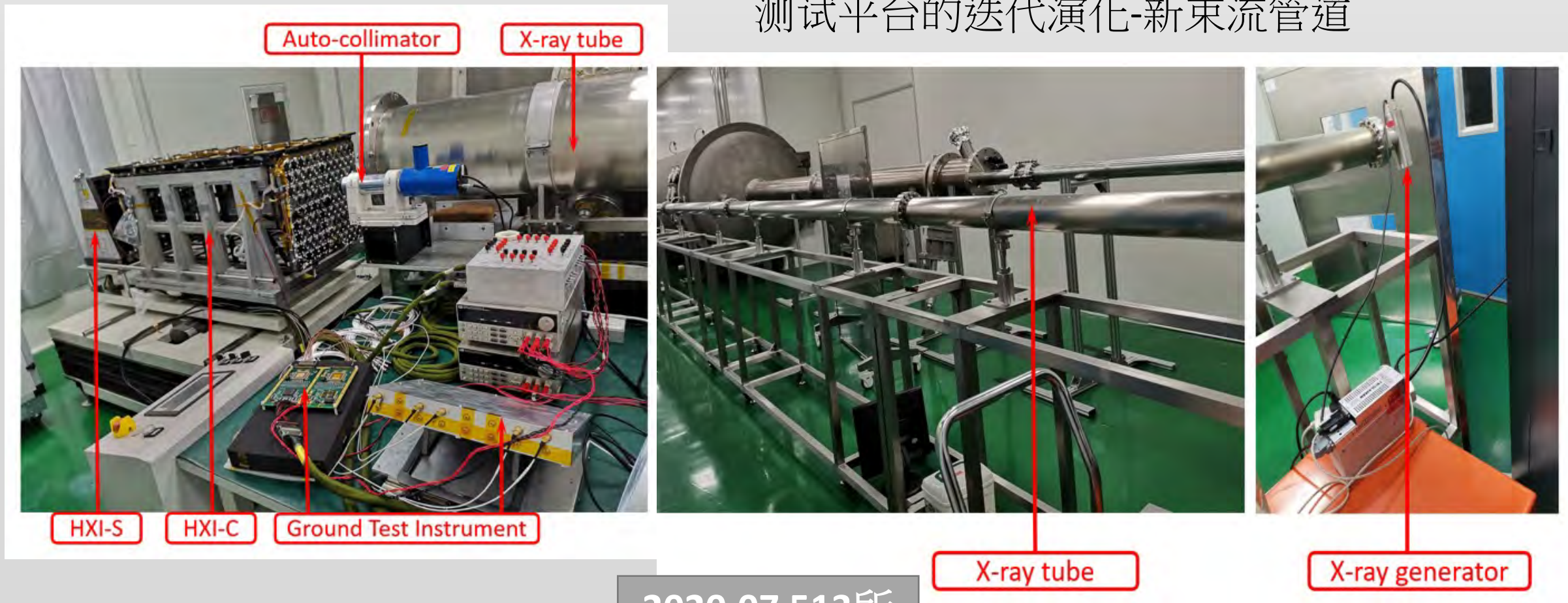
$$P(\theta, \varphi) = g_0(\theta_t)g_0(\theta_b) + \sum_{n=1}^{\infty} g_n(\theta_t)g_n(\theta_b) \frac{J_1\left(r\sqrt{a_{nn}^2 + b_{nn}^2}\right)}{r\sqrt{a_{nn}^2 + b_{nn}^2}} \cos(c_{nn}).$$



试验装置

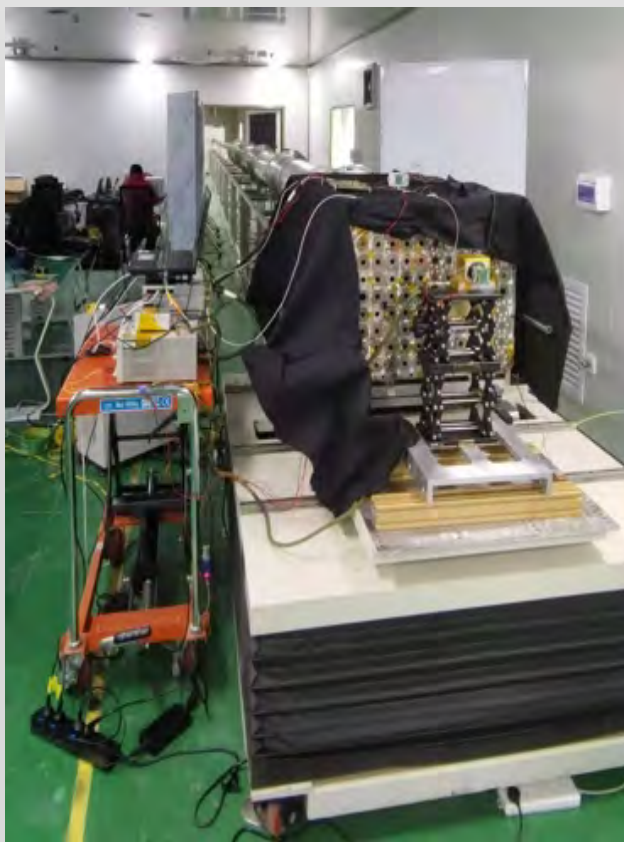
# 准直器X射线束流测试

## 测试平台的迭代演化-新束流管道



# 准直器X射线束流测试

测试平台的迭代演化-高流强高稳定光机

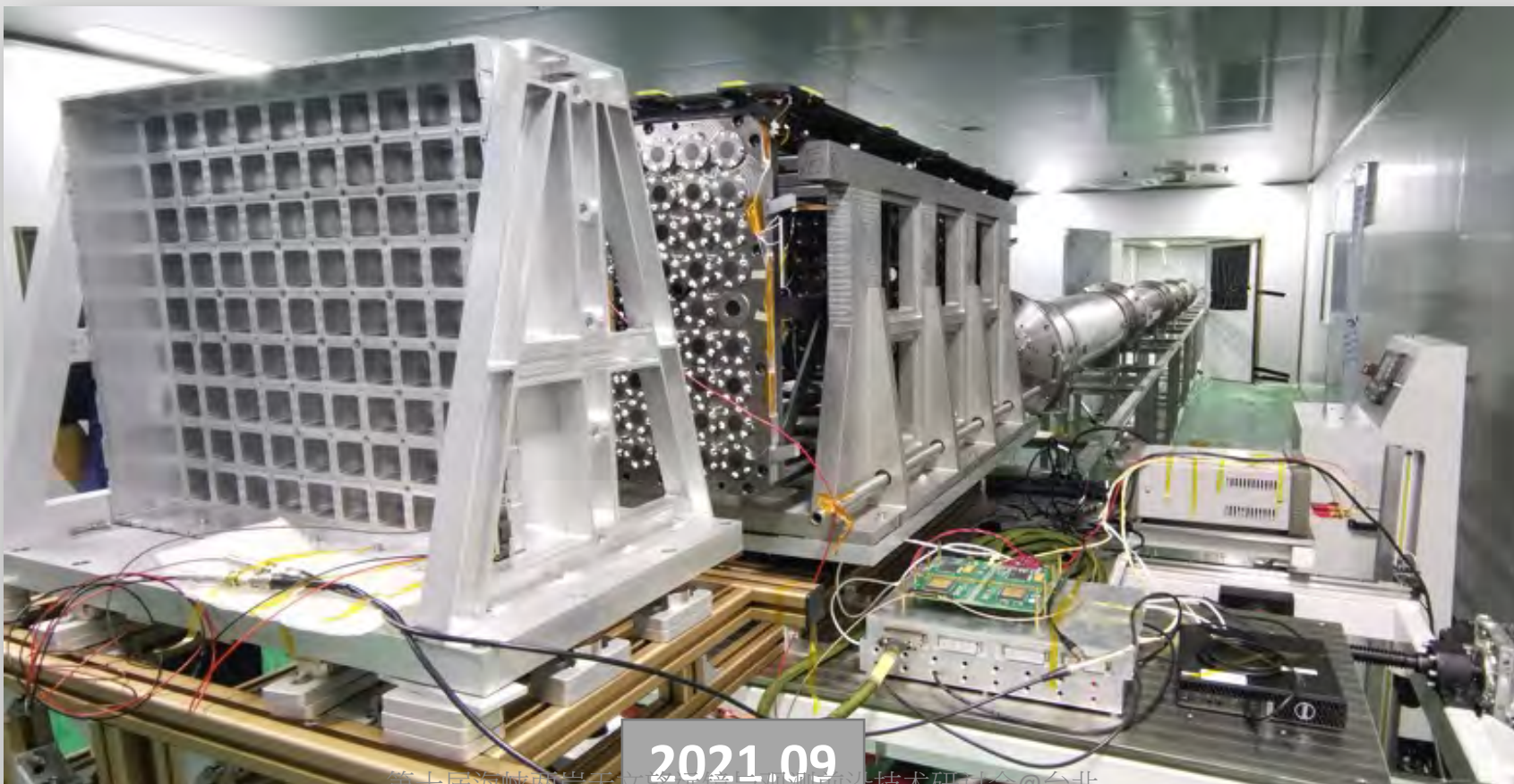


2021.03

# 准直器X射线束流测试

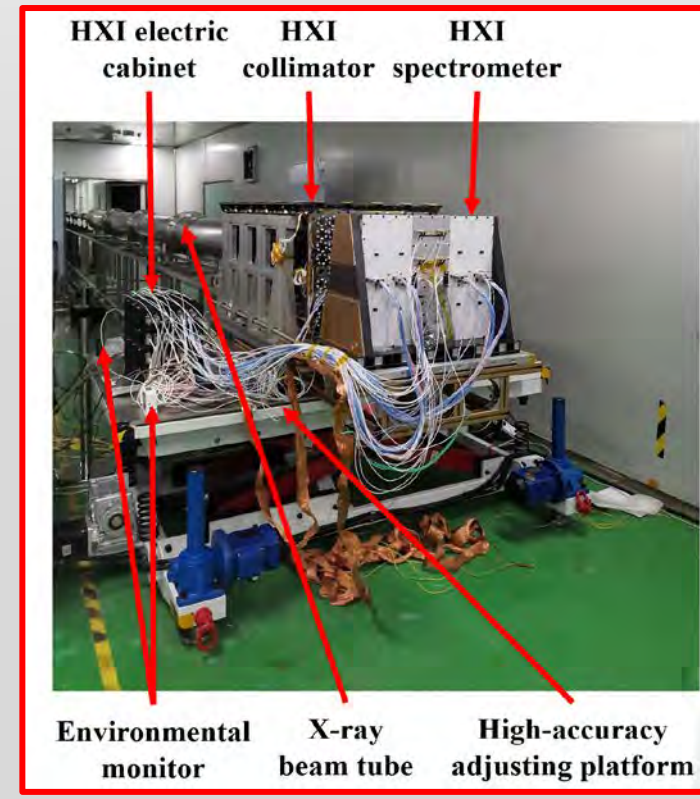
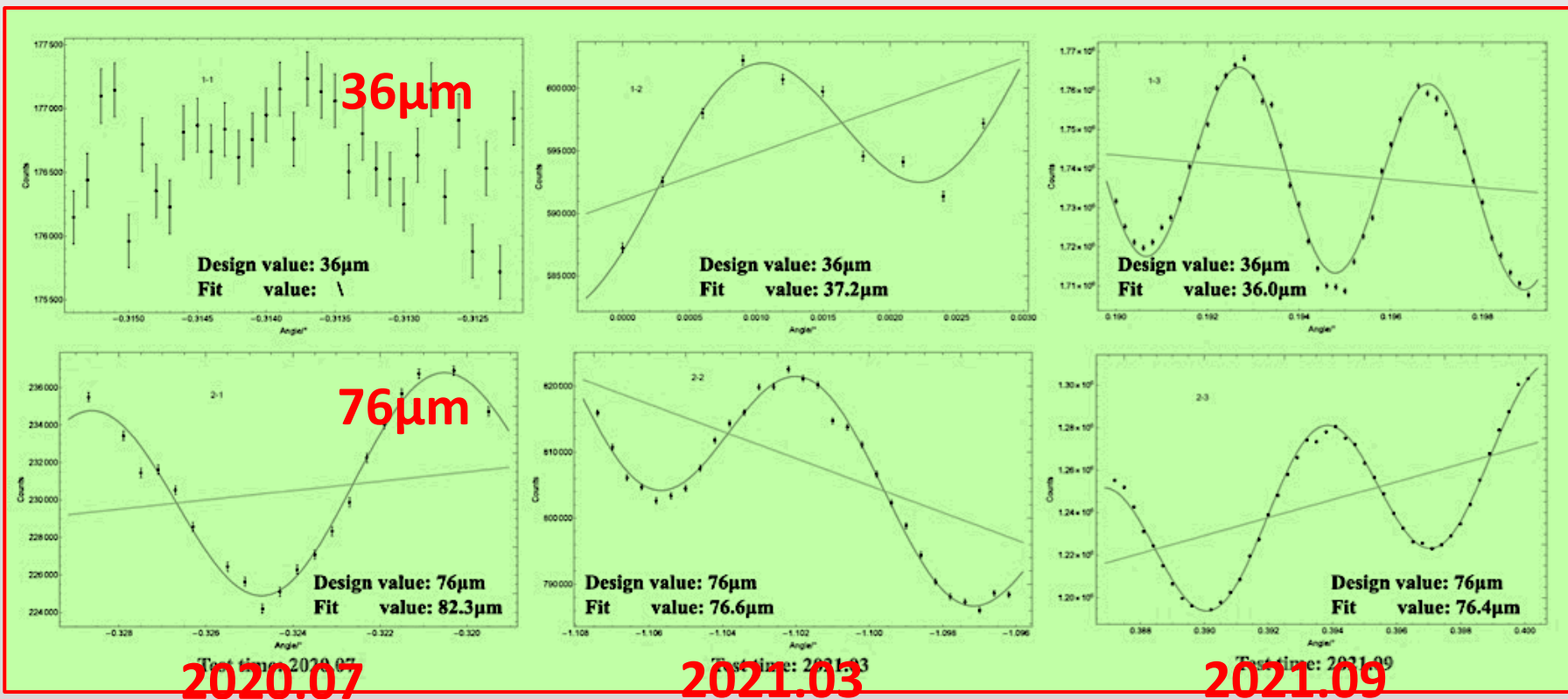
流强提高一个数量级  
平行度提高5倍

测试平台的迭代演化-稳定位移台



2021.09

## 准直器X射线束流测试



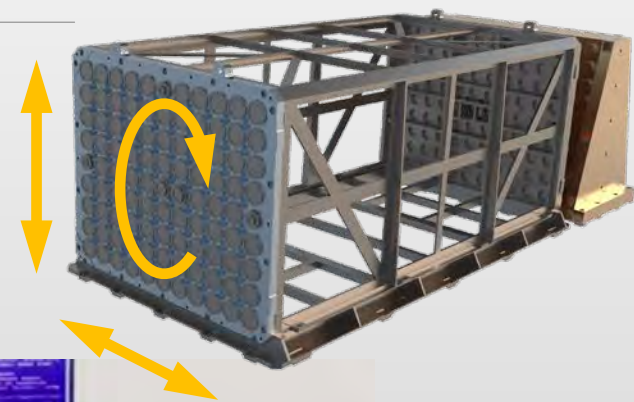
- 直接证明所有光栅调制功能正常，调制参数符合设计要求
- 可以保证HXI在轨成像观测顺利实施
- 获得的调制参数数据有助于调制响应矩阵的建立和分析

# 形变监测

## Requirements :

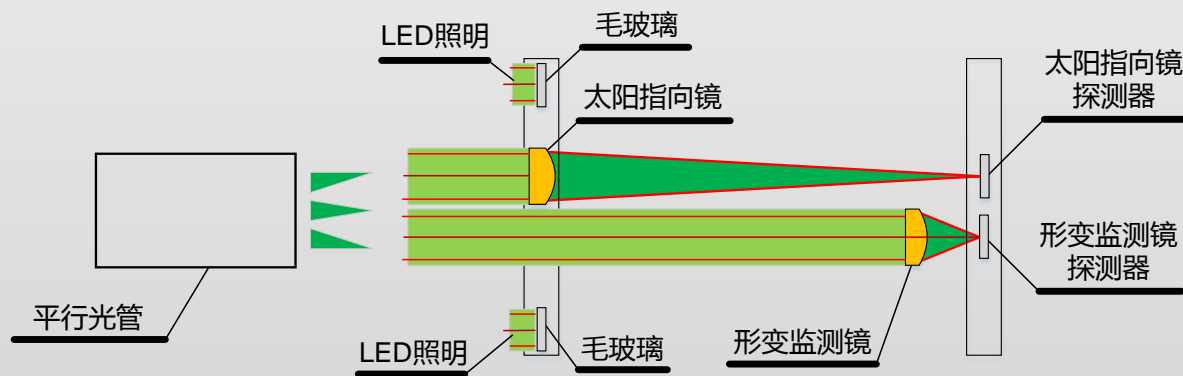
- Relative shift: less than 36um
- Relative rotation: less than 10"

Method 1: Direct measurement by coordinate measuring machine (CMM)

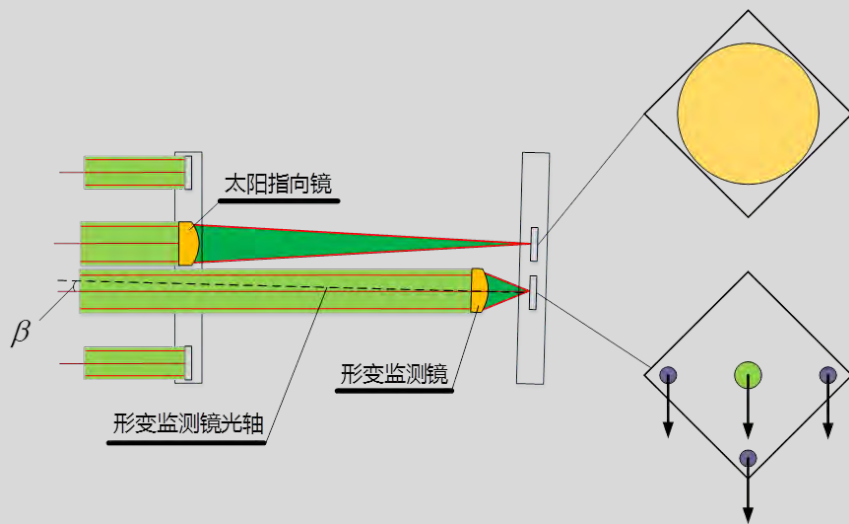


# 形变监测

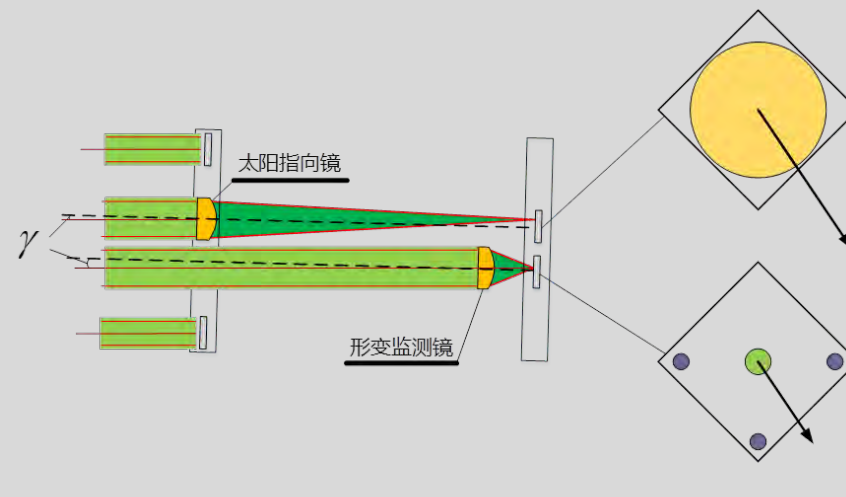
## Method 2: Zero point calibration measurement by SAS (SA & DM)



Parallel light source used to remove the effect of optical axis variation of DM



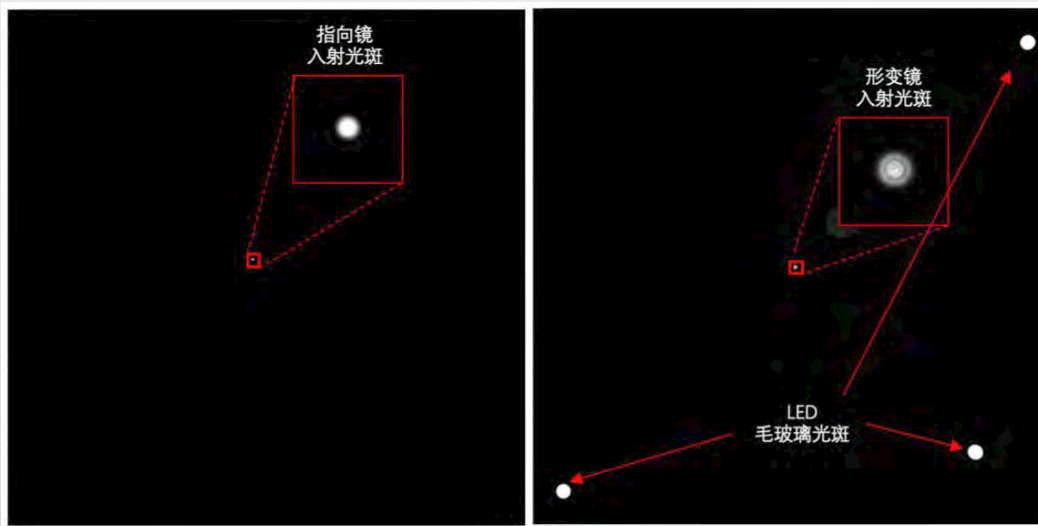
$\beta$ : direction variation of optical axis of DM



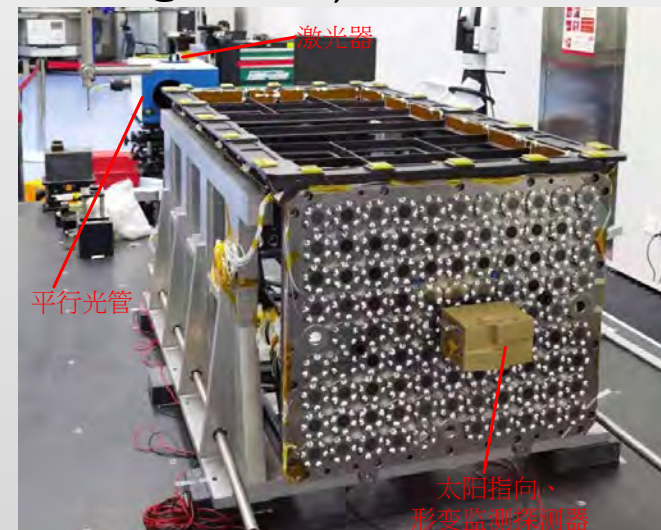
$\gamma$ : direction variation of incident light

# 形变监测

Monitoring state  
(By method 1 & method 2)



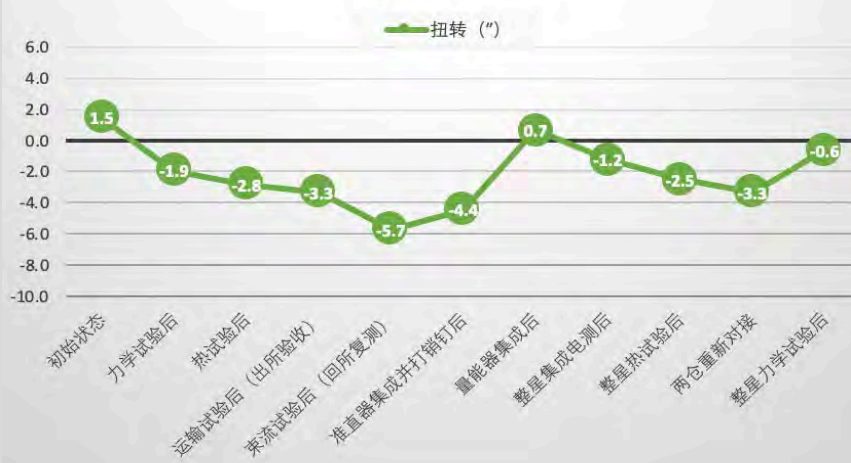
@ XIOPM, Xian



平移量监测



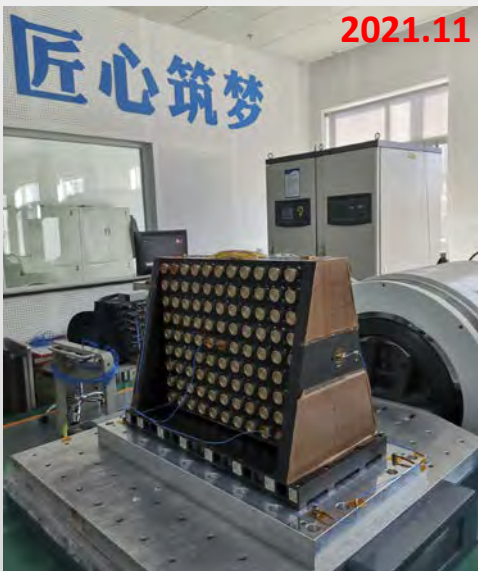
扭转量监测



@IAM, Shanghai



# 单机环境试验验证



2021.11

**HXI-S vibration and TV test**



2021.12



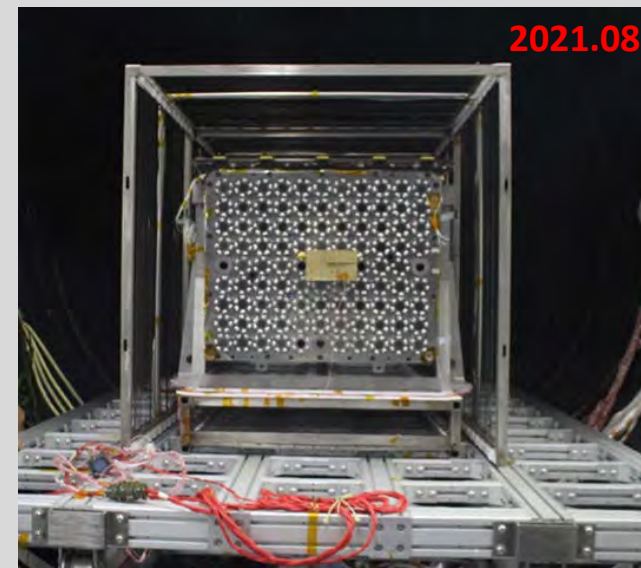
2021.07

**HXI-C vibration test**



2021.11

**HXI-S EMC test**



2021.08

**HXI-C TC test**

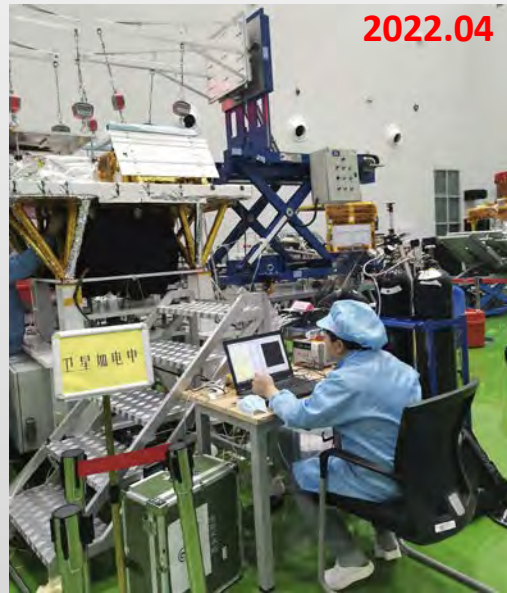
# 整星环境试验验证



2022.04~2022.06

iQOO 9  
2022/04/21 10:59

**Sleep in Conference room**



2022.04

**HXI-C installation**



2022.05

**HXI-S installation**



2022.06

**TV and TB test**



2022.07

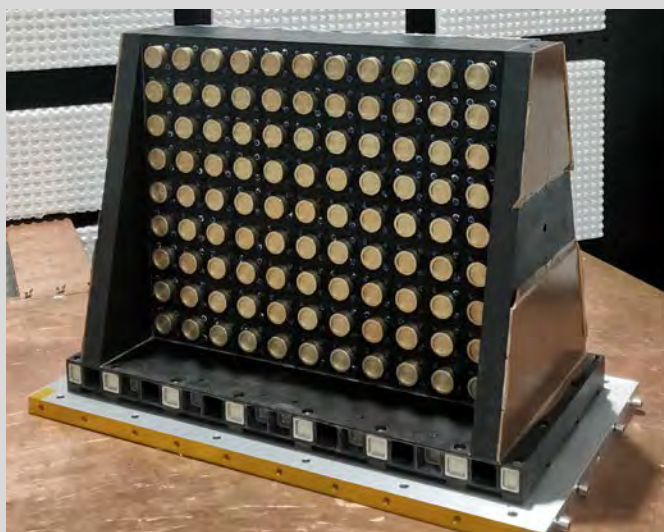
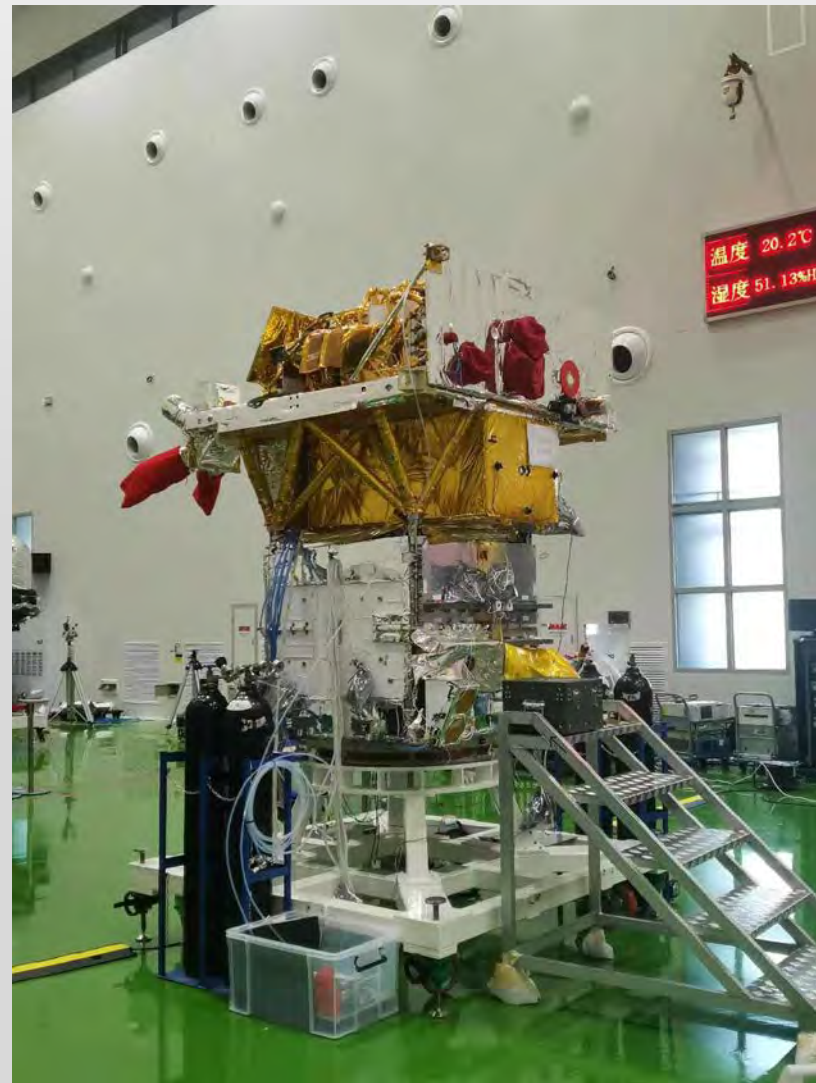
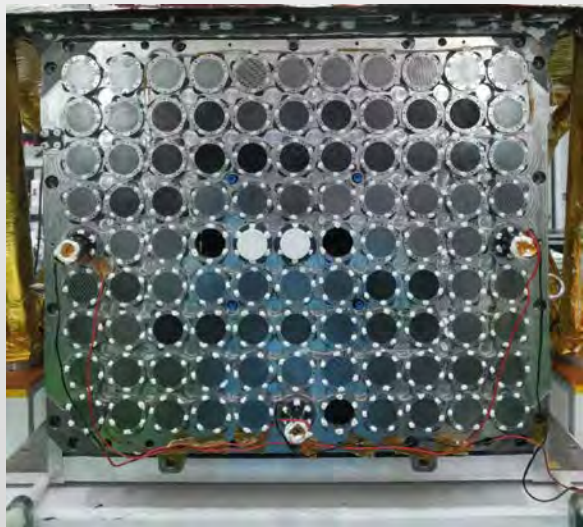
**Vibration test**



2022.07

**Noise test**

# HXI单机及整星



# 发射场测试

2022.08



2022.09 (23:00)



2022.09 08:30



2022.09



2022.09

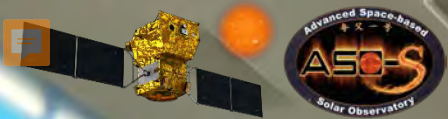


Half an hour before launch



2022.10.07 Launch





# 在轨测试与运行

2022.10.09~10.17

卫星发射入轨

HXI载荷温度控制

2022.10.17~10.18

载荷加电

初始化设置

2022.10.18~10.31

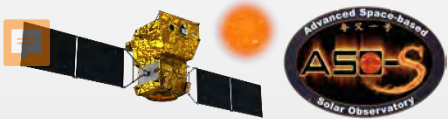
功能性能测试

载荷定标

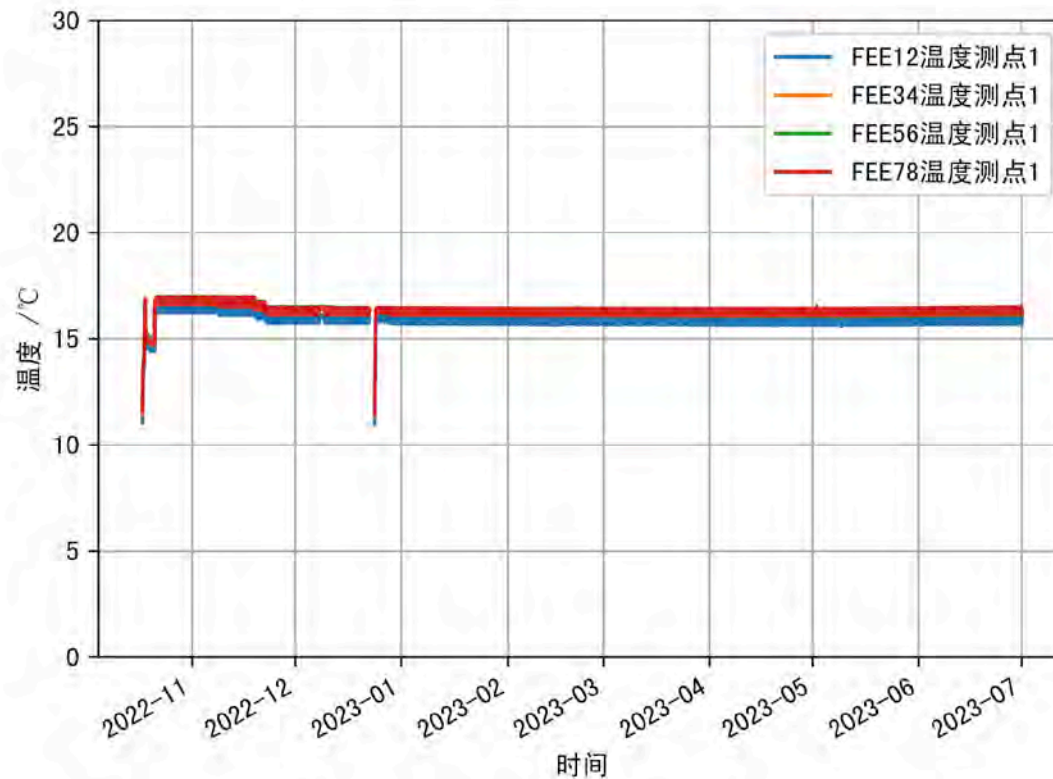
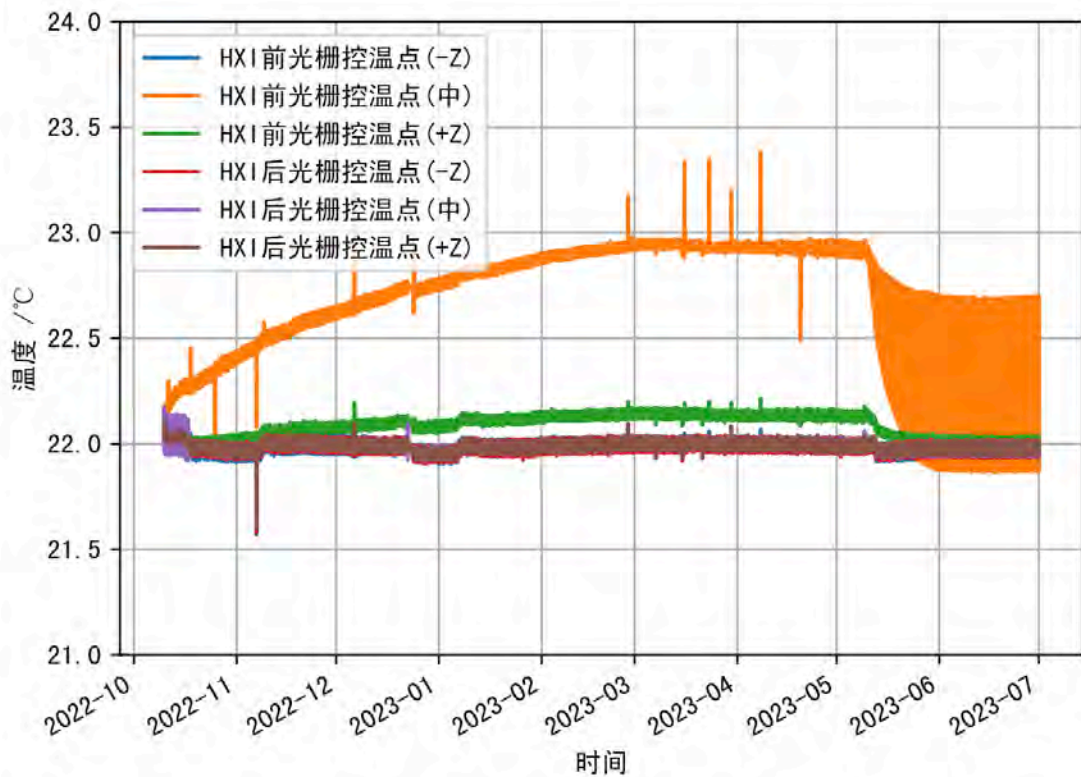
2022.11.01~至今

性能优化

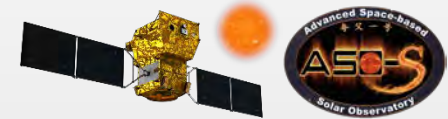
科学观测



# 测试内容-温度控制



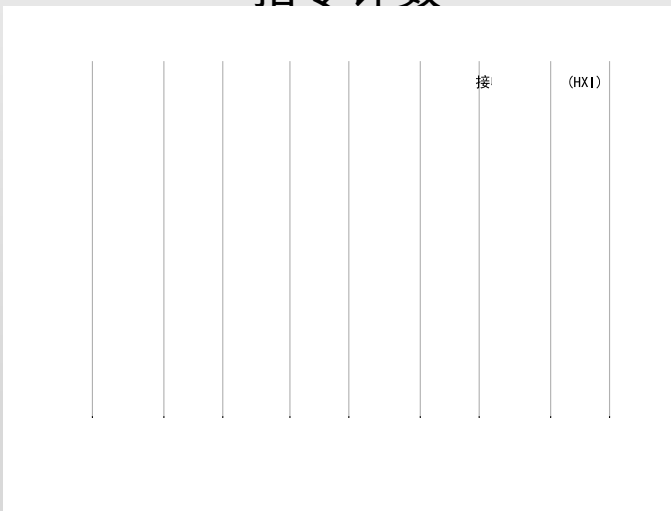
- Temperature difference:  $\sim 1^{\circ}\text{C}$
- Temperature stability :  $\sim 0.1^{\circ}\text{C}$  in 10 days



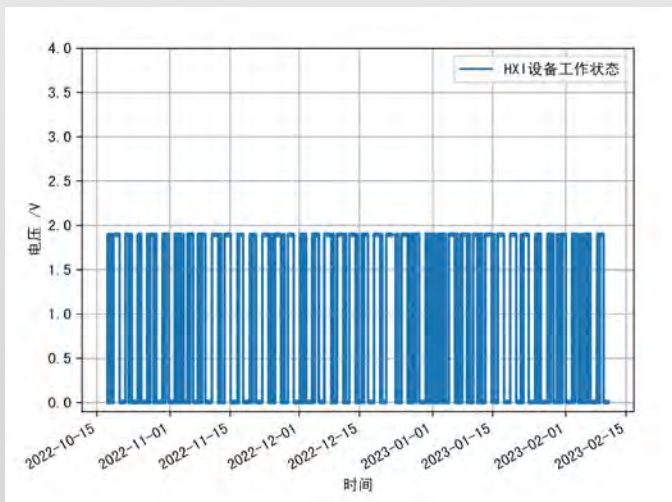
# 测试内容-运行状态

稳定运行，未发生  
重启等异常情况

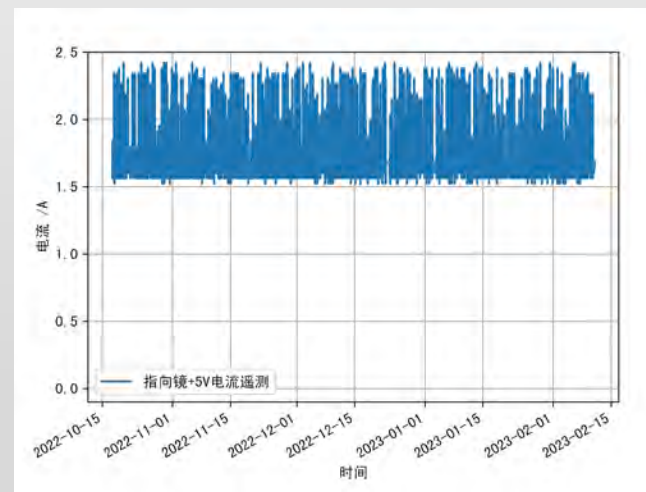
### 指令计数



### 电控箱



### 准直器指向镜

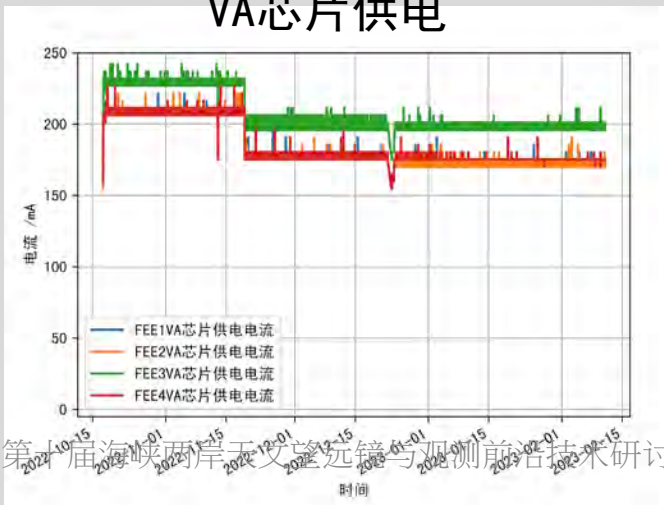


### 量能器

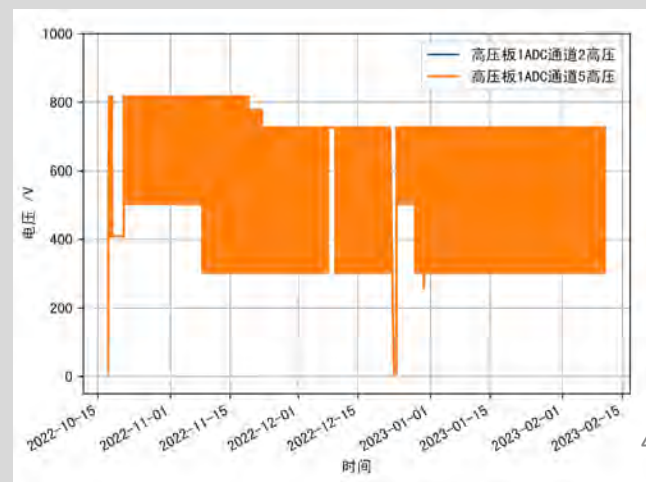
### FEE供电



### VA芯片供电



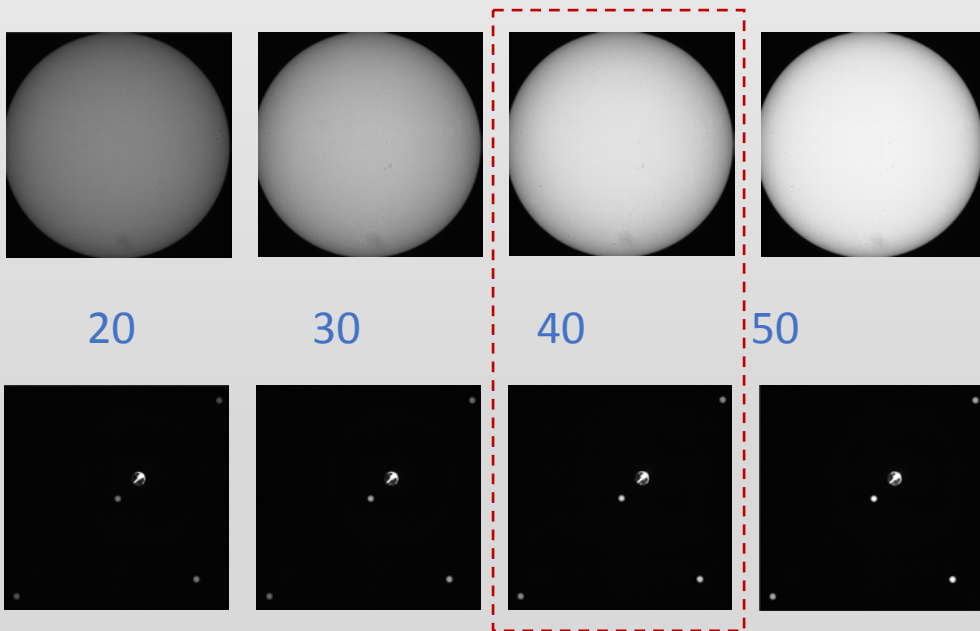
### 高压供电板



- 指向镜定标与优化

指向测量精度优于0.3角秒

太阳指向镜



曝光档位  $\times 50\mu\text{s}$

20

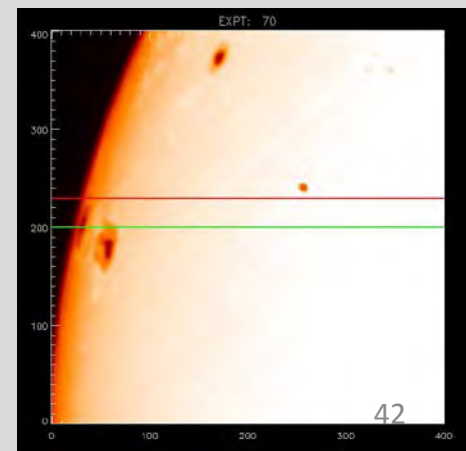
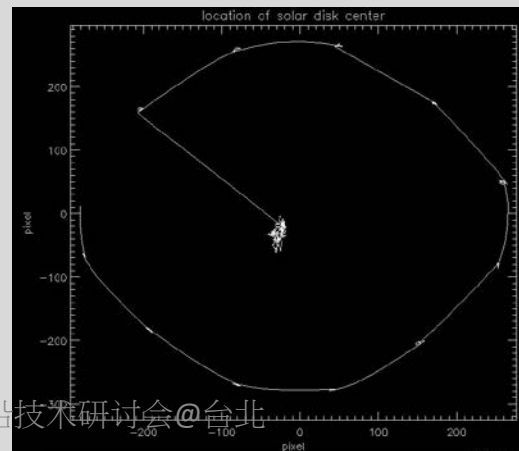
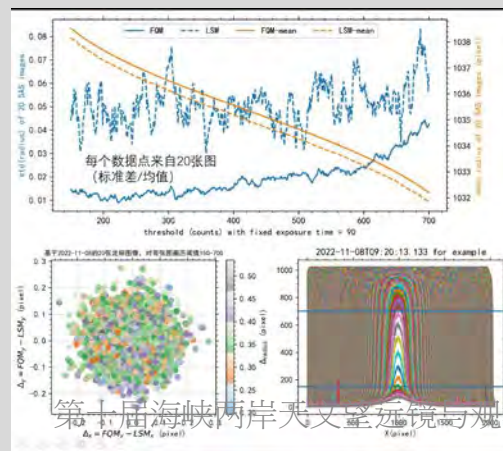
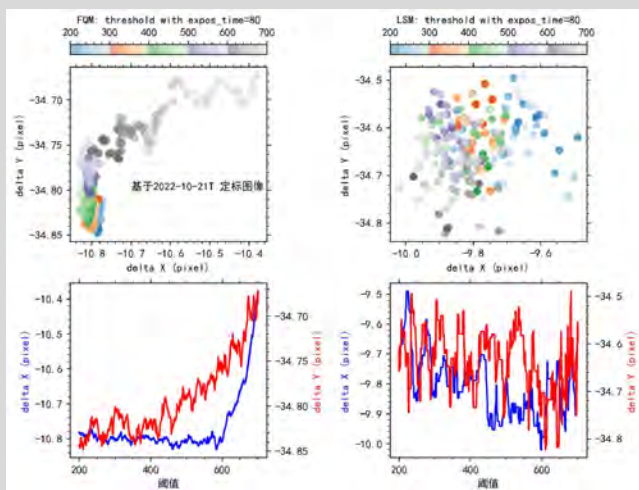
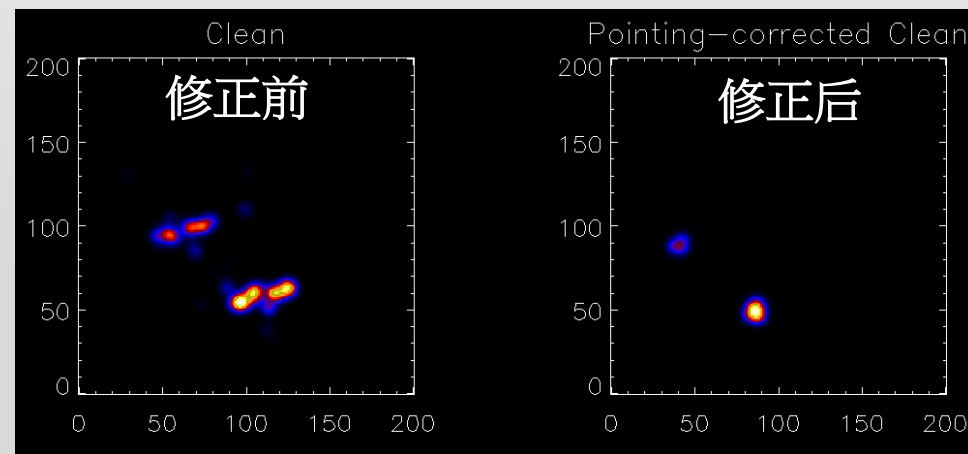
30

40

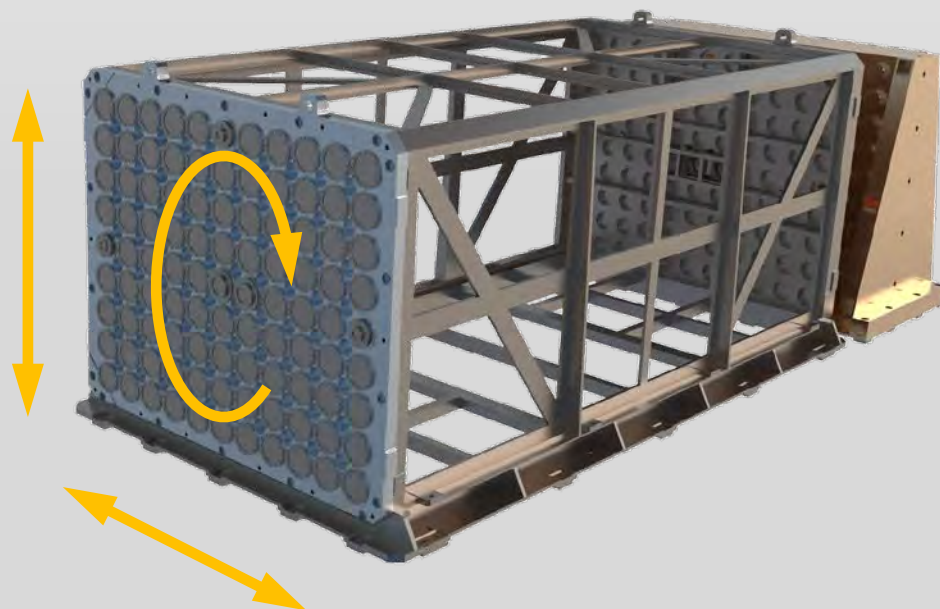
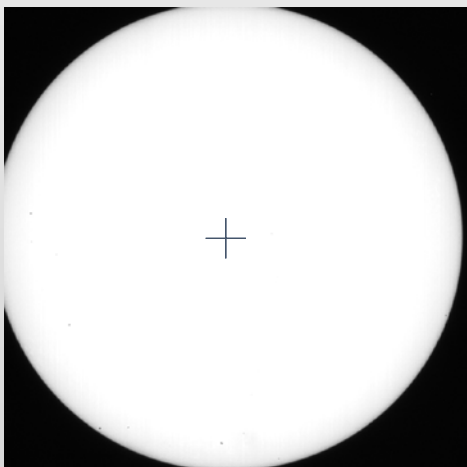
50

形变监测镜

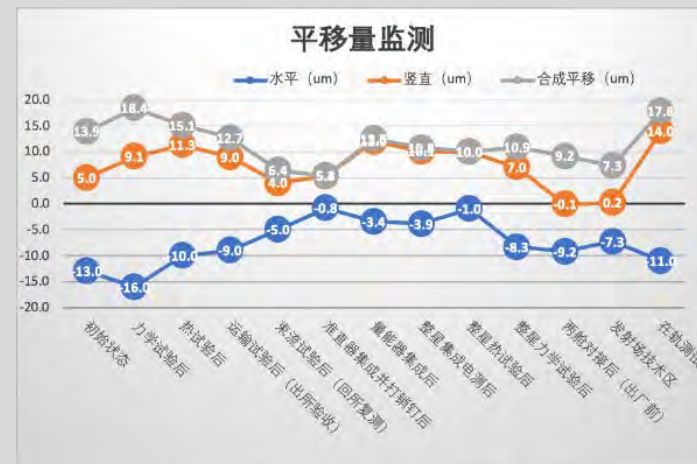
指向镜数据用于在成像中修正平台指向抖动

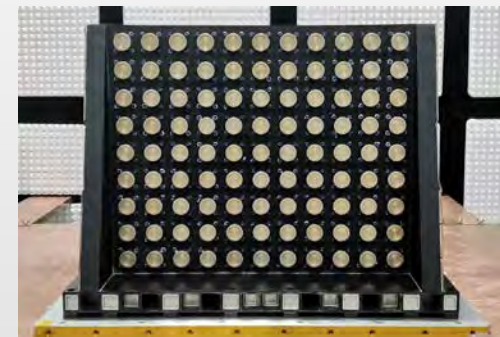


- 准直器形变监测（零位定标）



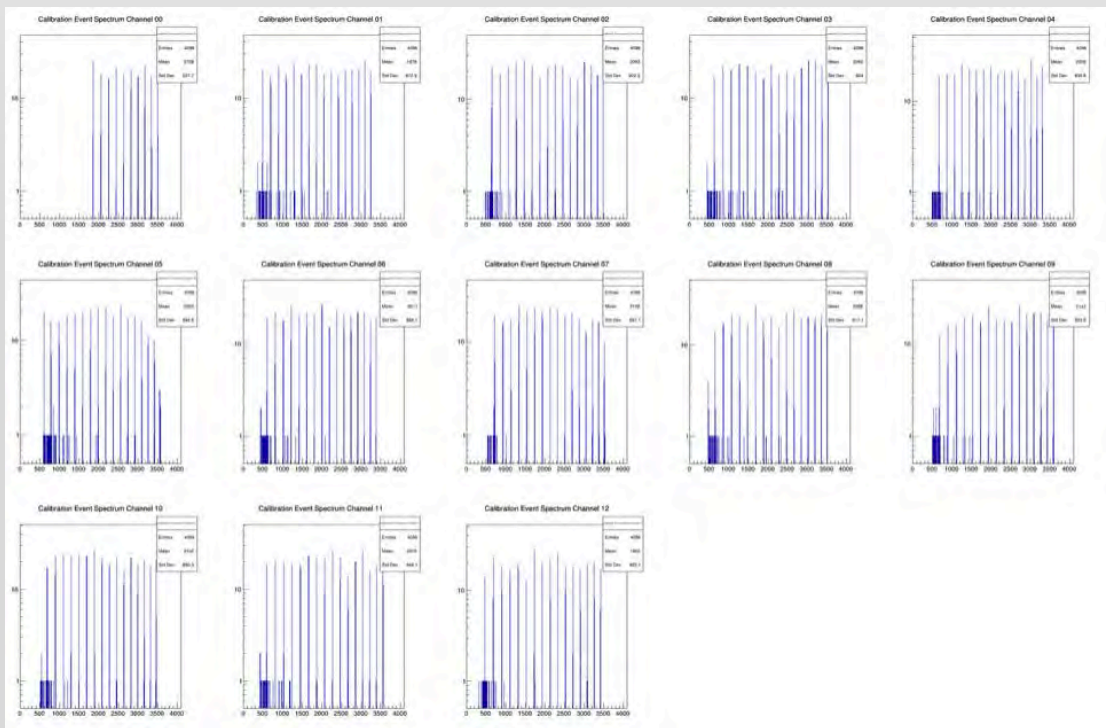
扭转~-0.7"，平移~17.8 $\mu\text{m}$



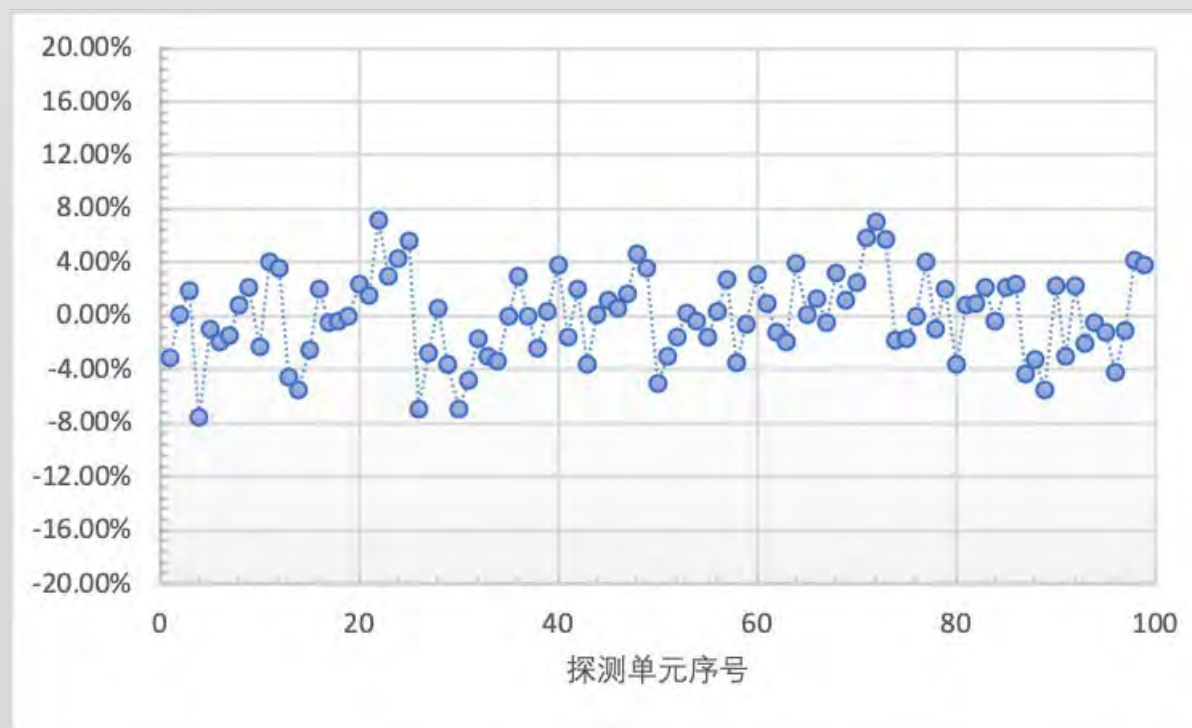


- 电子学线性定标与增益均匀性

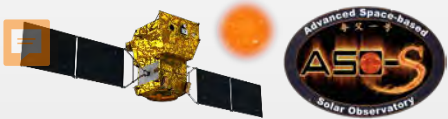
定标信号谱



探测单元通道增益差异



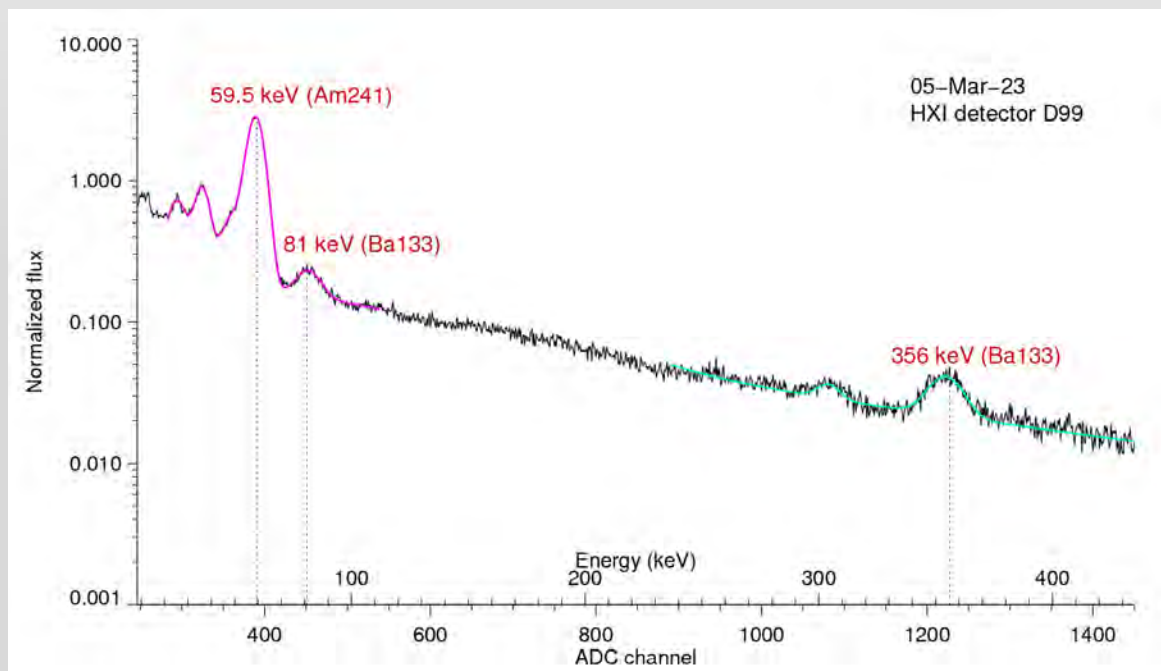
优于±8%



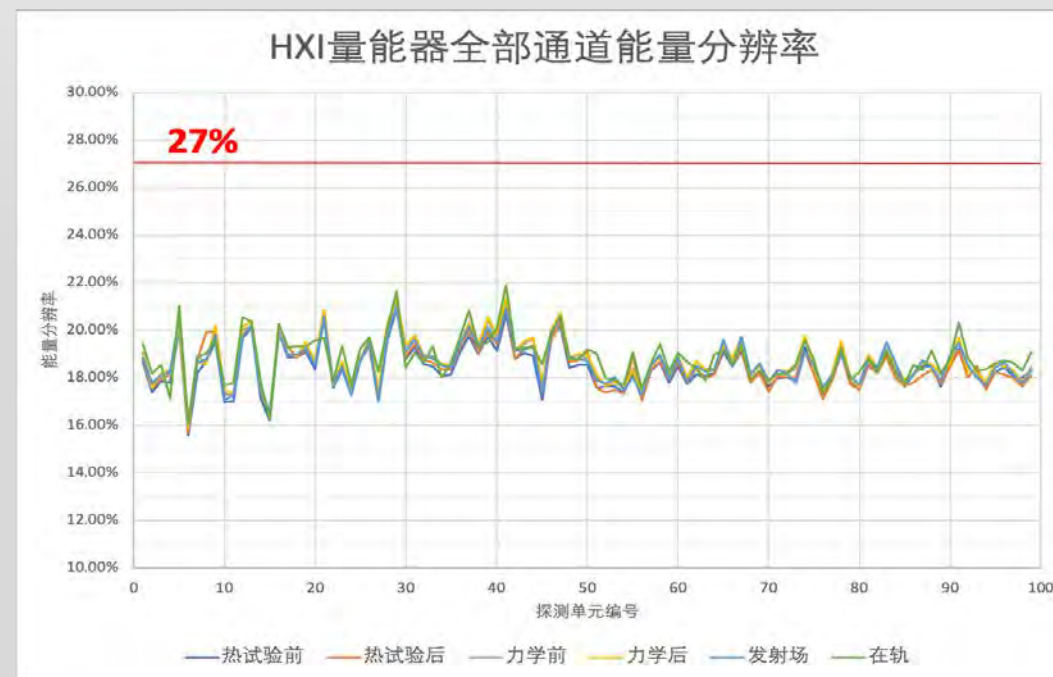
# 测试内容-量能器性能

- 探测单元能谱与能量分辨定标

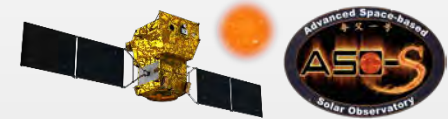
## 定标能谱



## 探测单元能量分辨



优于22%@32keV



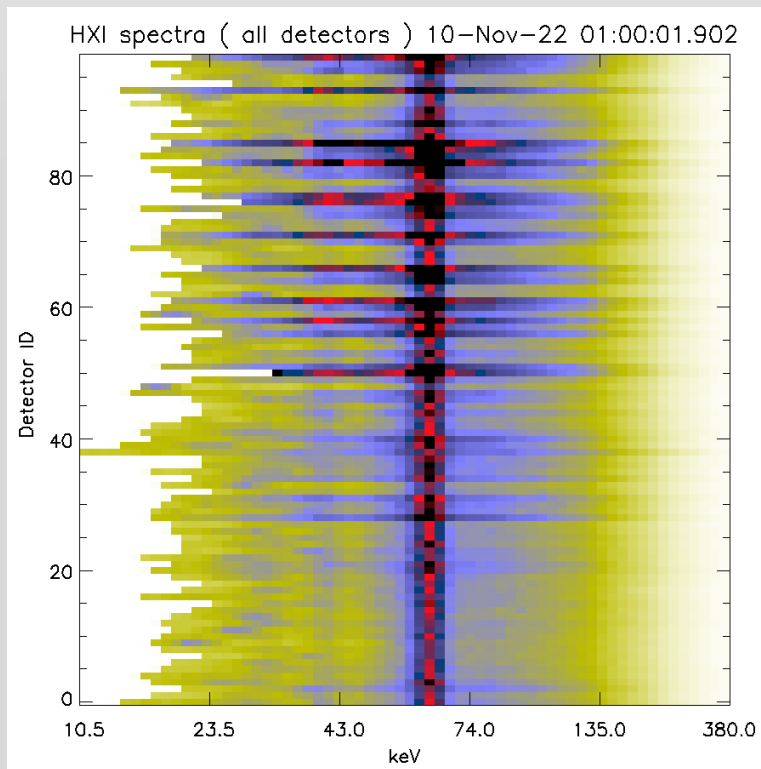
# 测试内容-量能器性能

- 能量测量范围的调节和优化

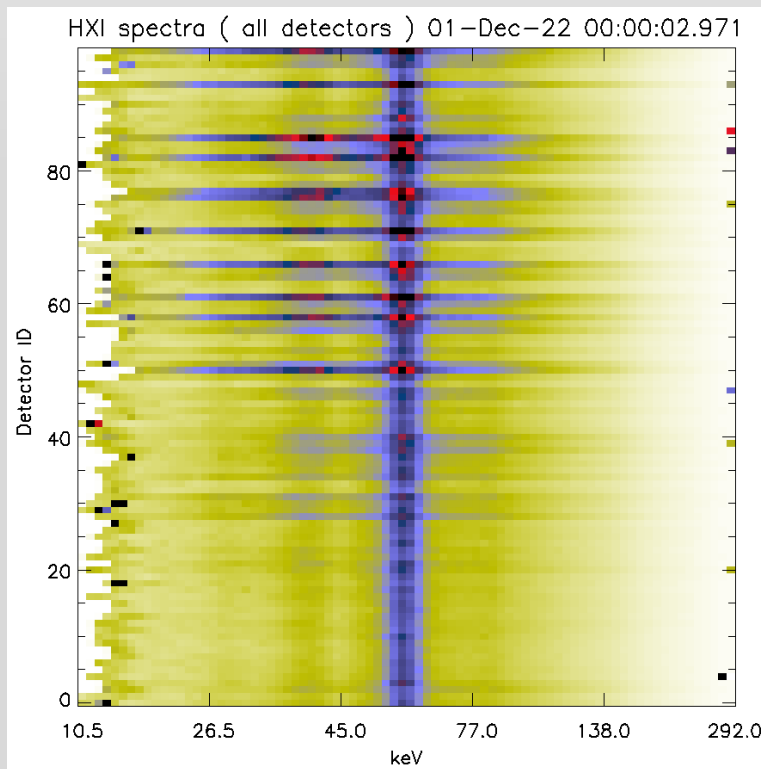
Critical point : Balance of 99 detector units

**Optimization result :**  
**15~294keV(imaging) , 10~300 ( spectrum )**

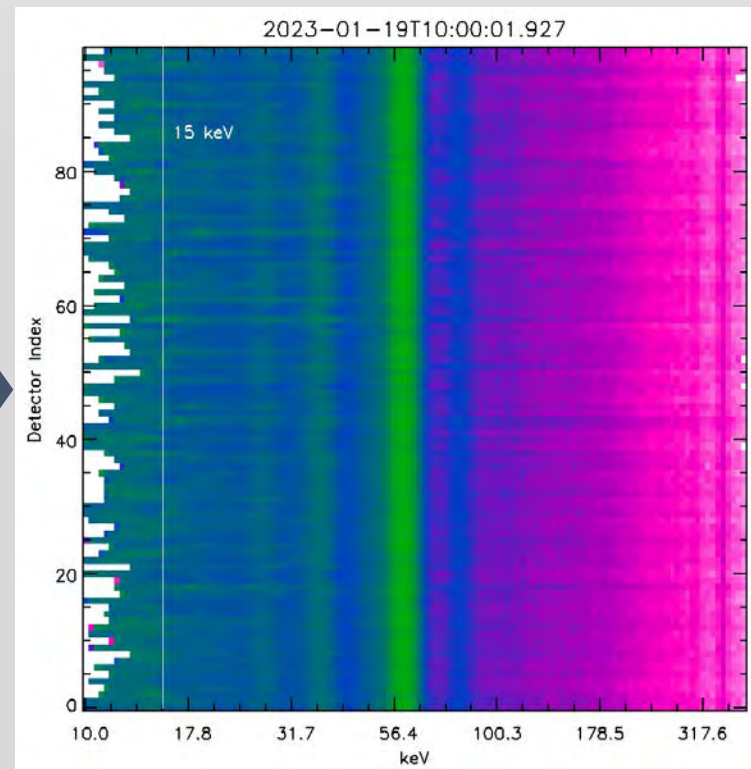
- Expand the range of energy spectrum measurement
- Lower the high voltage setting
- Reduce baseline noise



2022.11.10



2022.12.01



2023.01.19

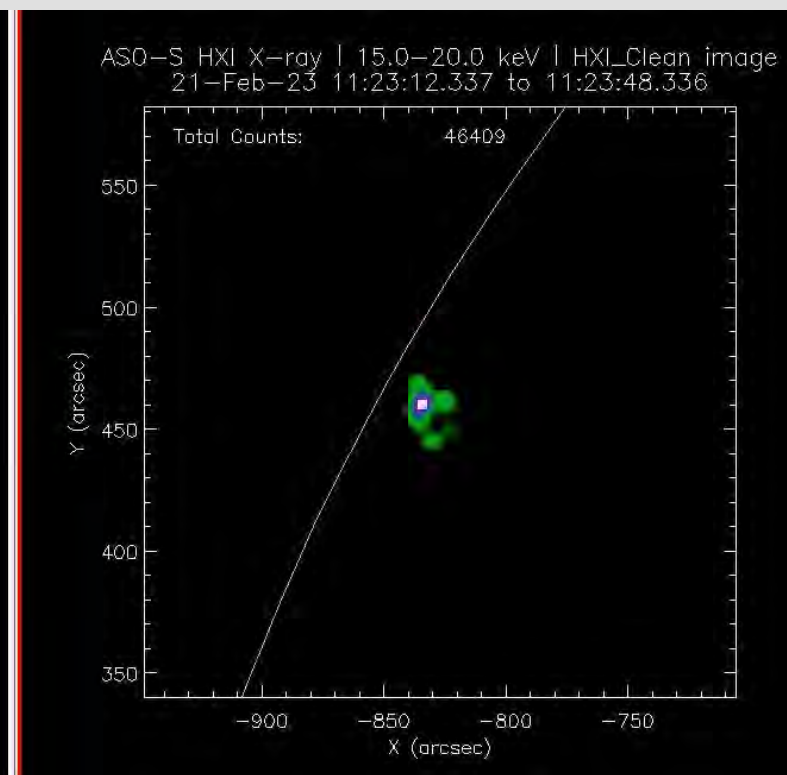
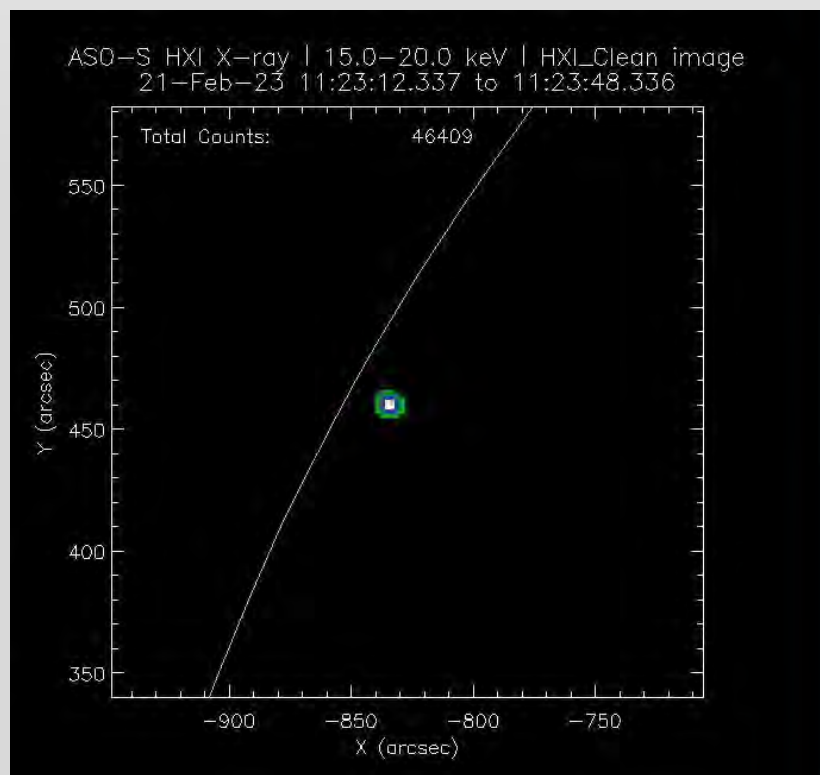
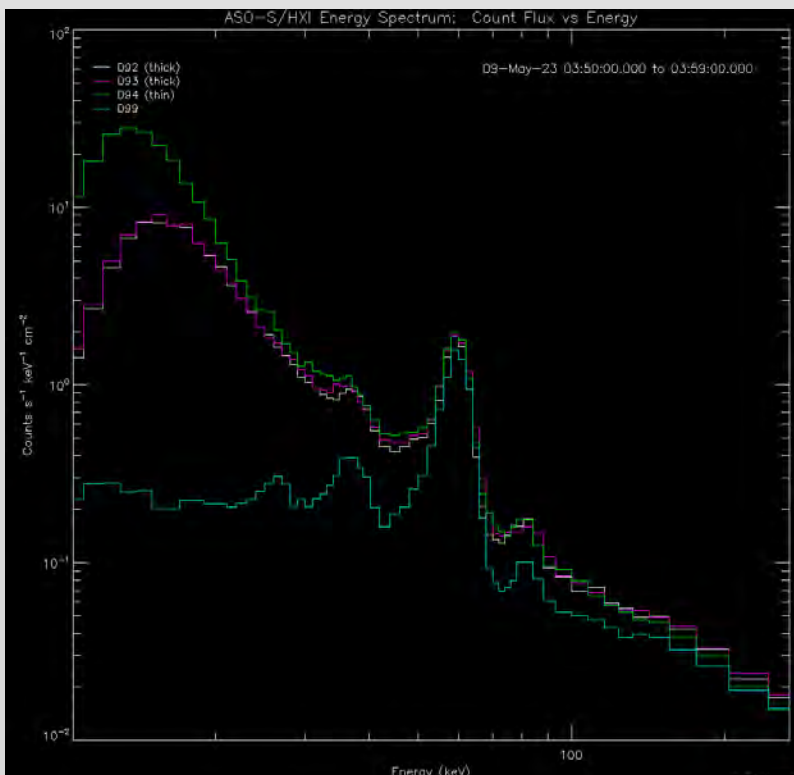
- 不同通道（子准直器+探测单元+电子学）之间的一致性

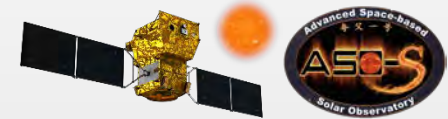
对点源（近似）的成像效果

能谱的一致性

标定后

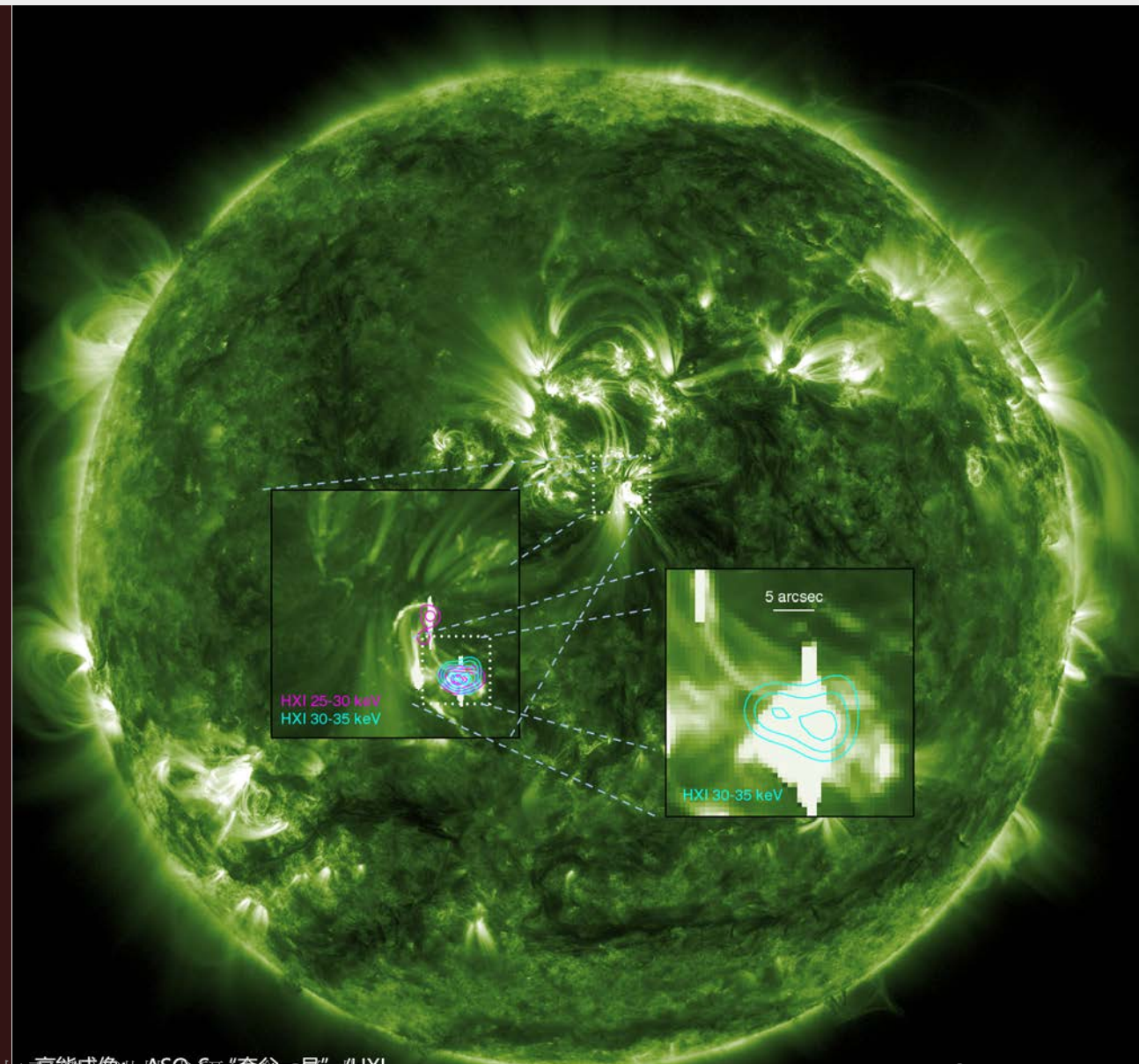
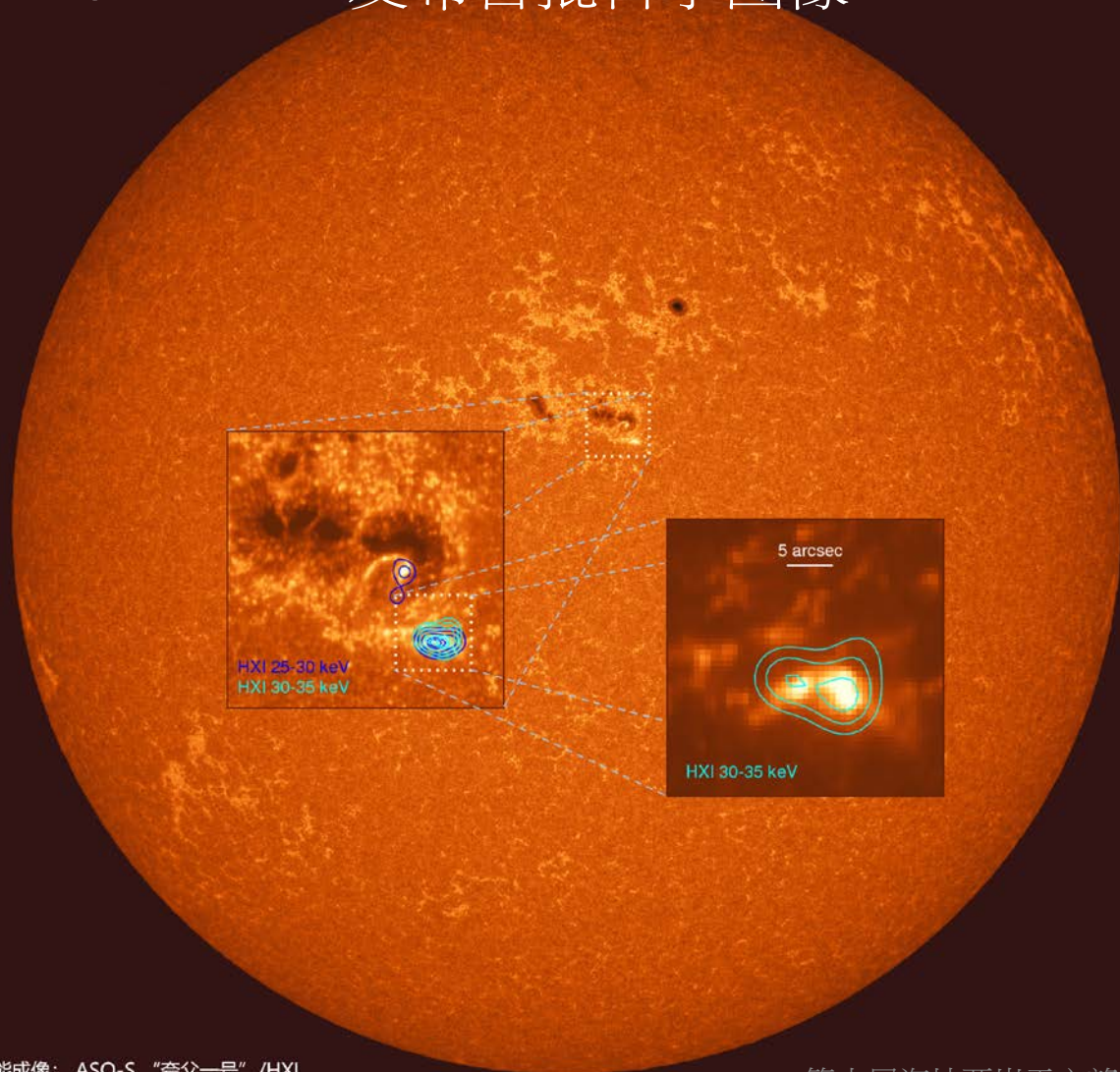
标定前





# 硬X射线成像

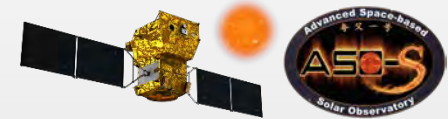
2022.12.12 发布首批科学图像



高能成像: ASO-S “夸父一号” /HXI  
背景图像: SDO/AIA 1700 Å 2022-11-11 01:49:16 UT

第十届海峡两岸天文望远镜与观测前沿技术研讨会@台北

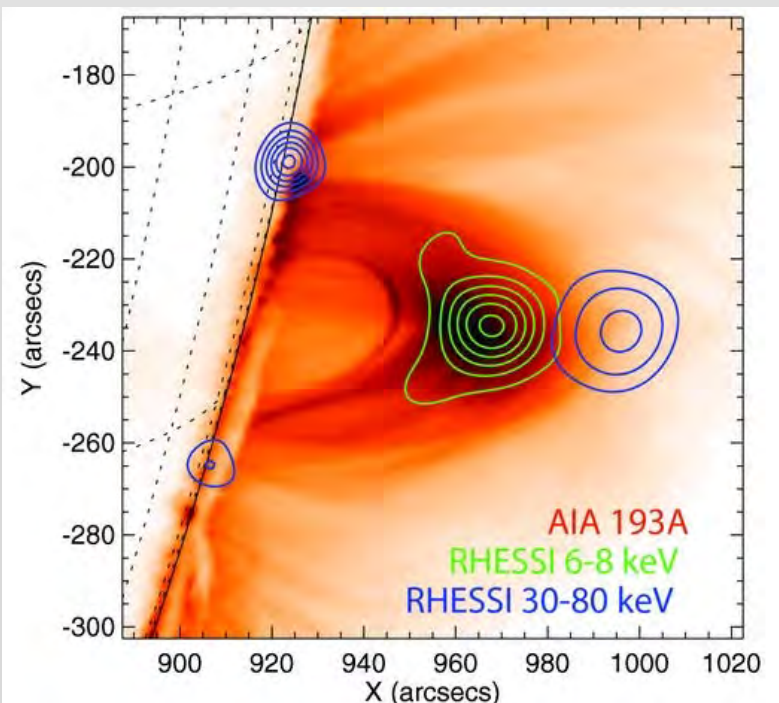
高能成像: ASO-S “夸父一号” /HXI  
背景图像: SDO/AIA 171 Å 2022-11-11 01:49:21 UT



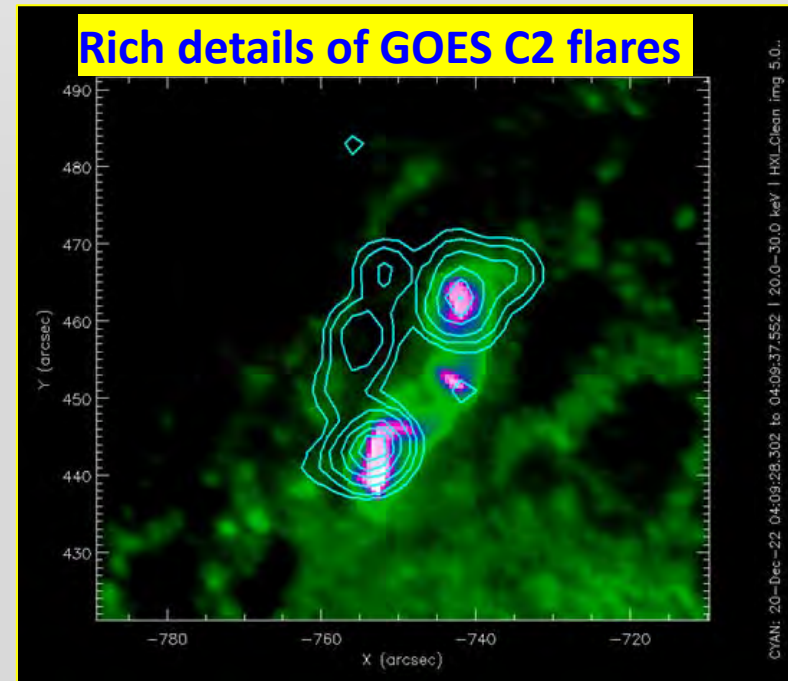
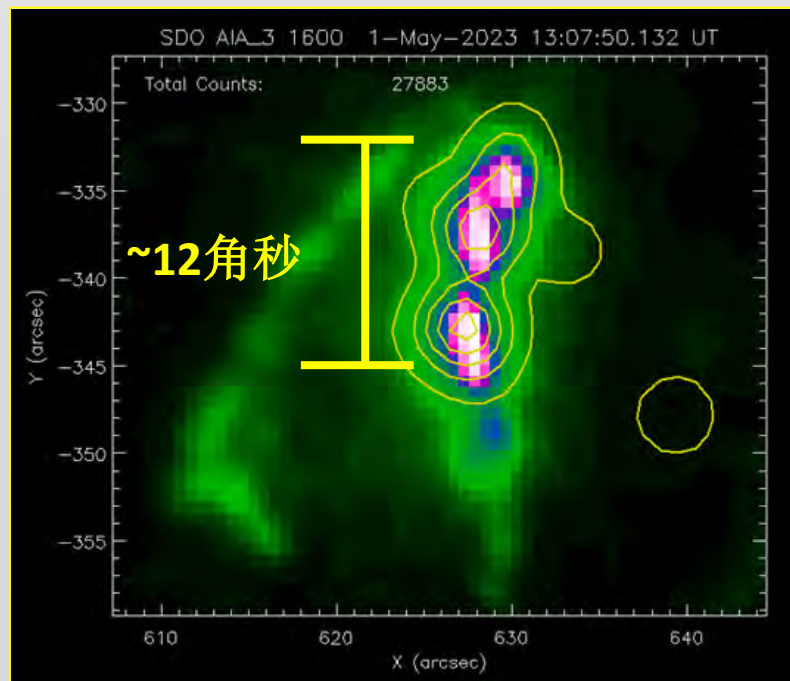
# 硬X射线成像

- 截止目前，探测到C级以上耀斑硬X射线暴超过300次
- HXI的成像特点：普遍呈现丰富的细节信息

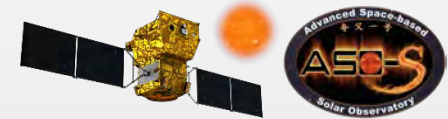
RHESSI的典型图像：  
(也有HXR带状源但较少)



HXI成像显示出以往少有的细节结构



CYAN: 20-Dec-22 04:09:28.302 to 04:09:37.552 | 20.0-30.0 keV | HXI\_Clean\_img\_5.0..

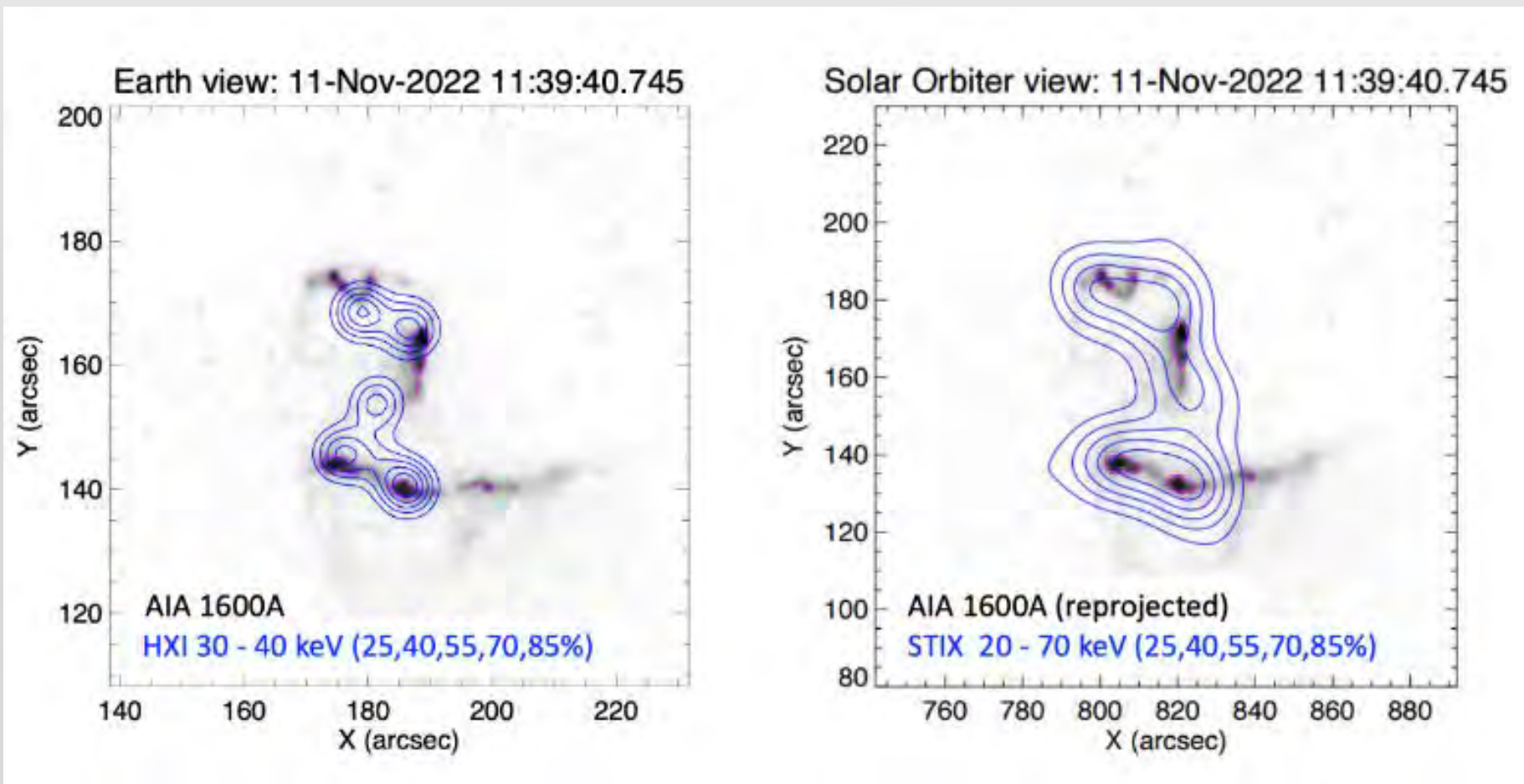


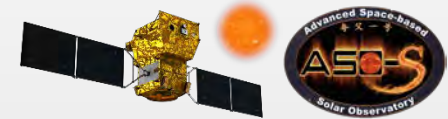
# 硬X射线成像

- HXI的成像特点：普遍呈现丰富的细节信息

夸父一号/HXI

欧洲SO/STIX



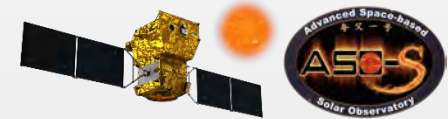


## 技术类研究布局：

- Pattern的解析计算（江贤恺+，已发表）
- 图像重构质量和PSF的评估方法（李振同+，已完成）
- 各种成像算法评估和参数研究（于文慧+，已完成）
- 机器学习新成像算法（夏悦函+，已投稿）
- HXI在轨测试和定标（苏杨+，初步完成）
- HXI-STIX交叉定标（李振同+，进行中）

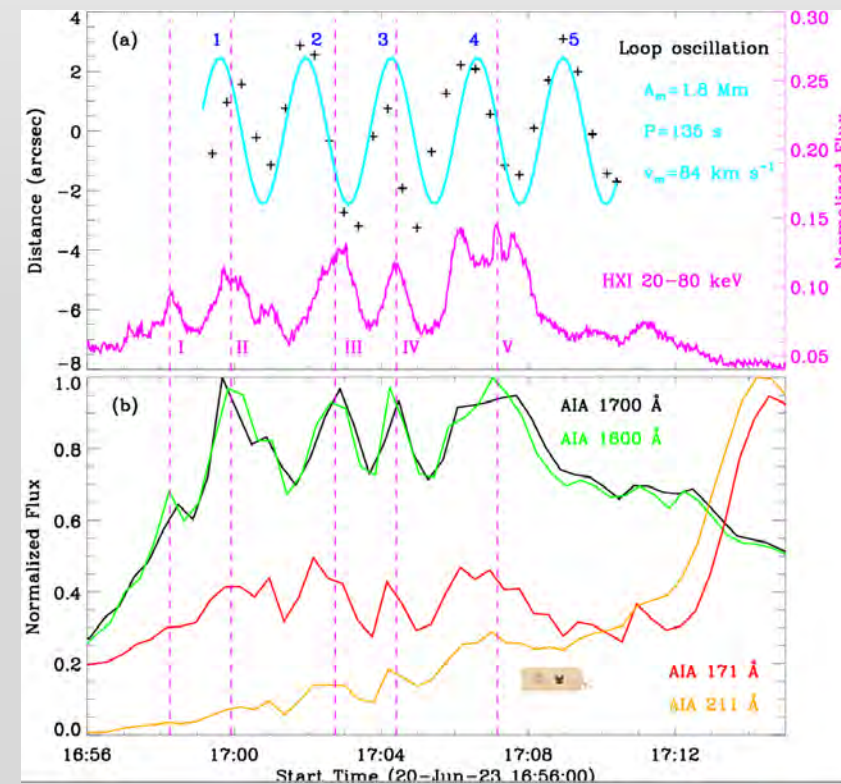
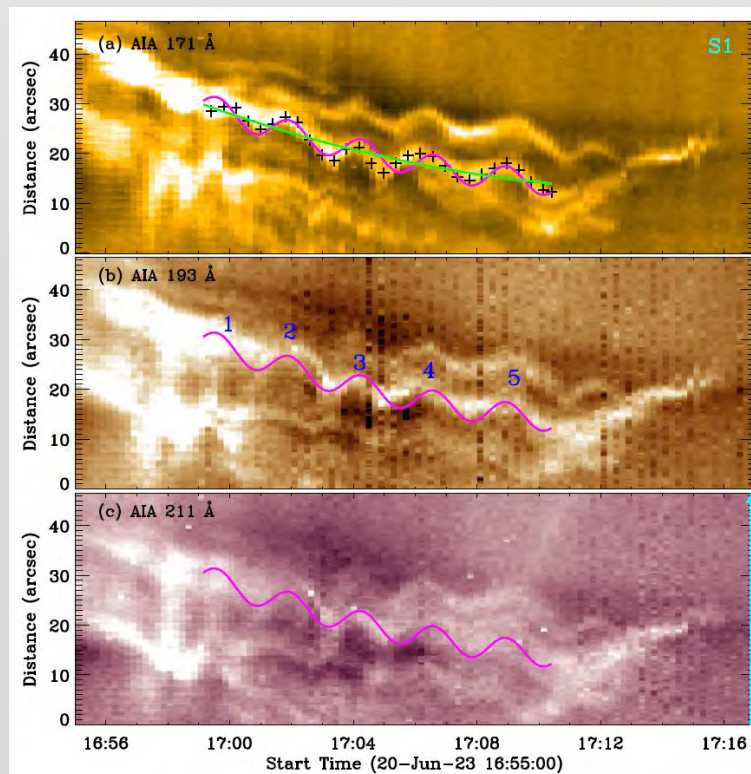
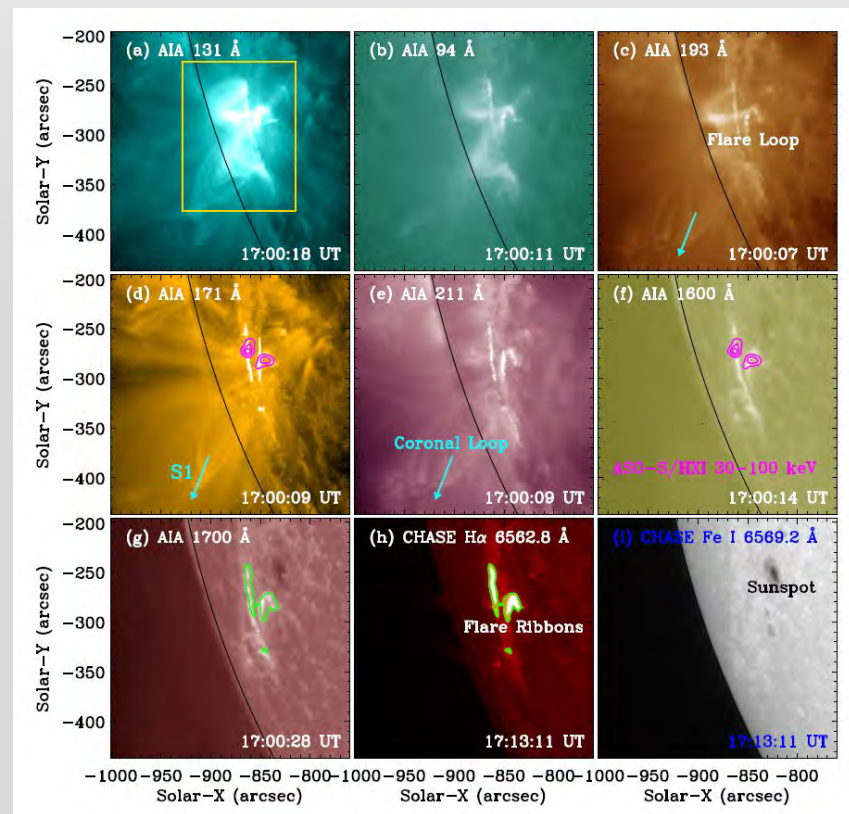
算法

定标  
(研究基础)

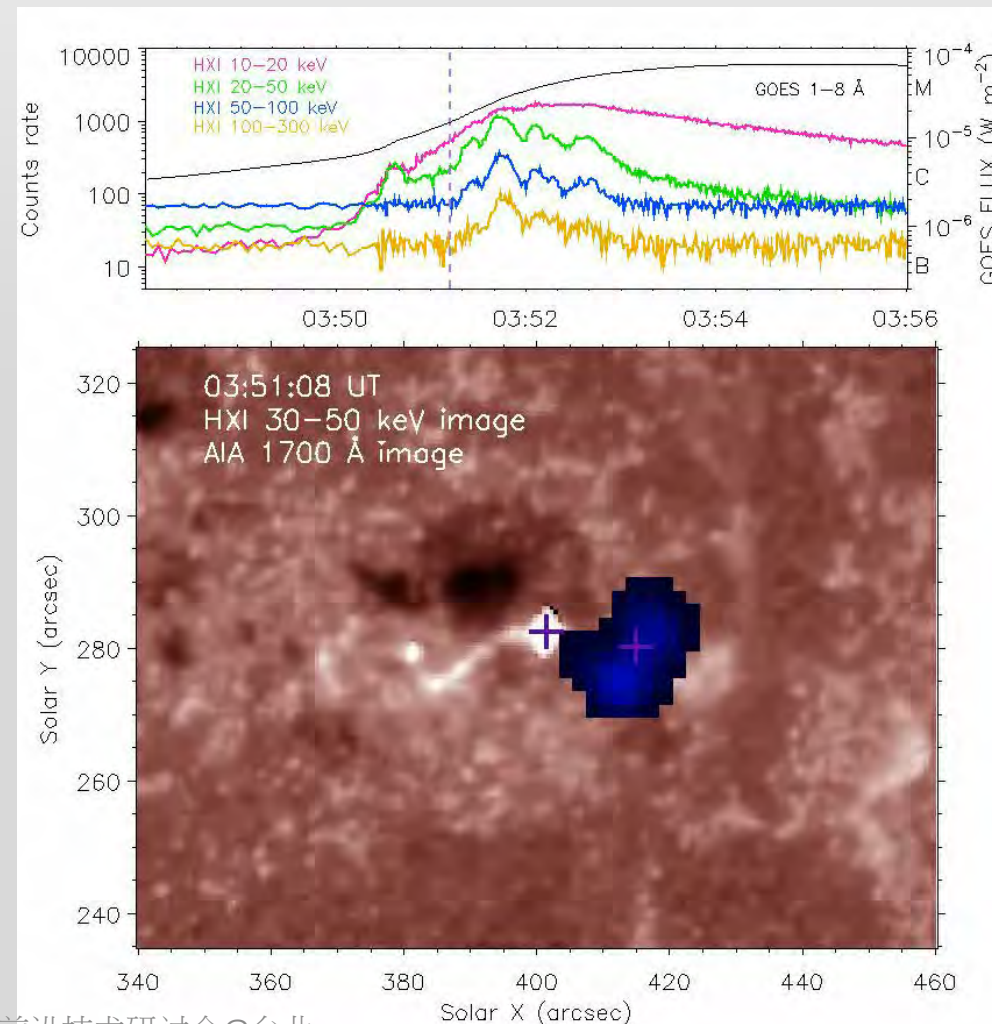
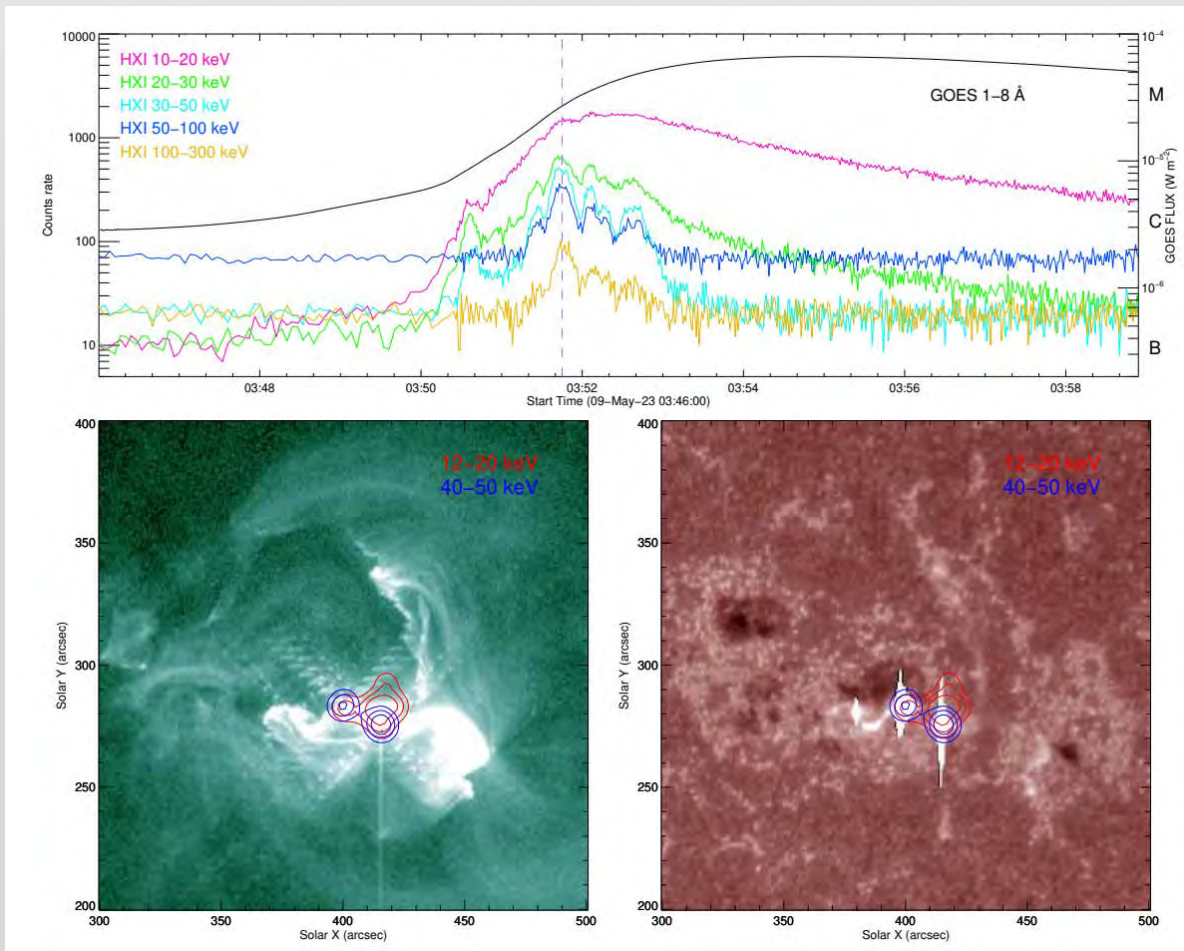


# 初步研究结果

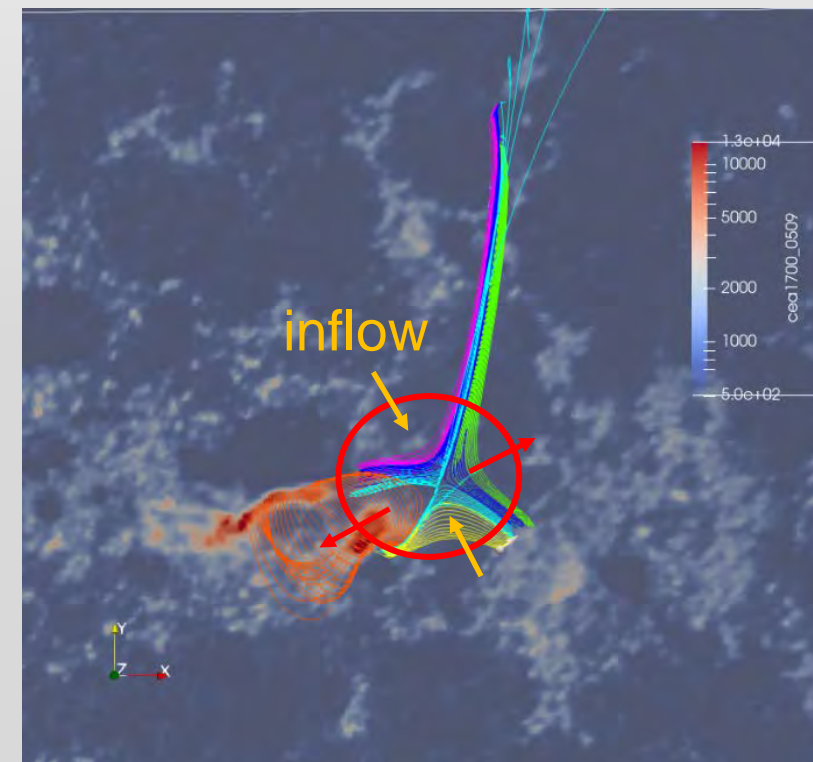
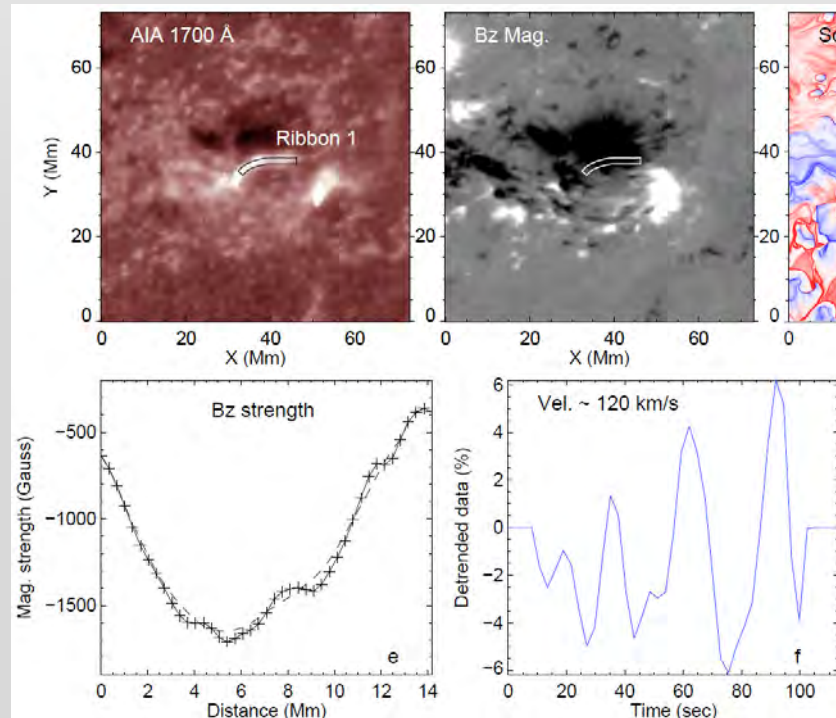
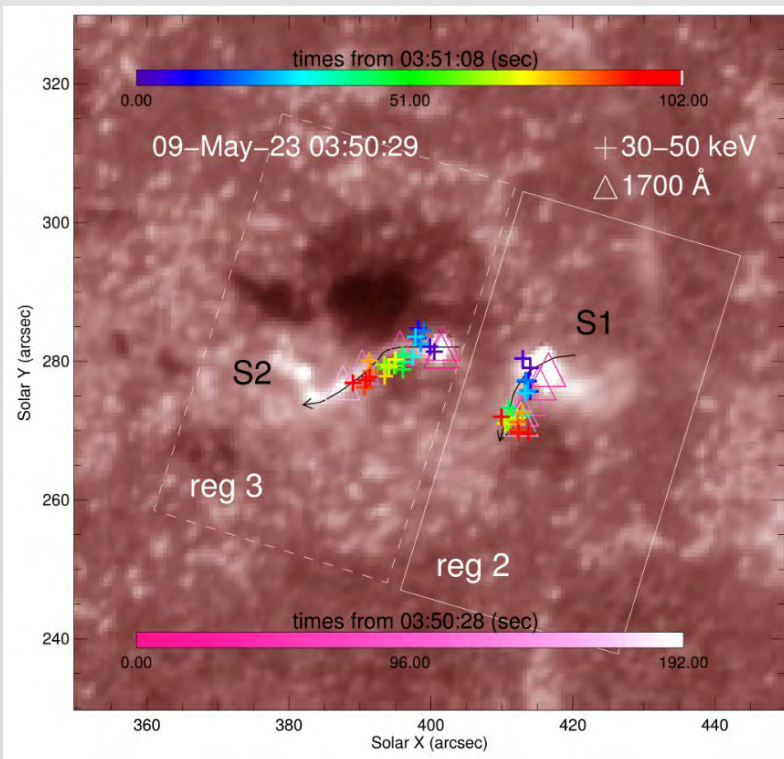
李东+ : 耀斑能量释放导致冕环振荡 ( submitted to ApJL )



## 重点成果1：陈昌雪+：耀斑足点源的运动和QPP的起源

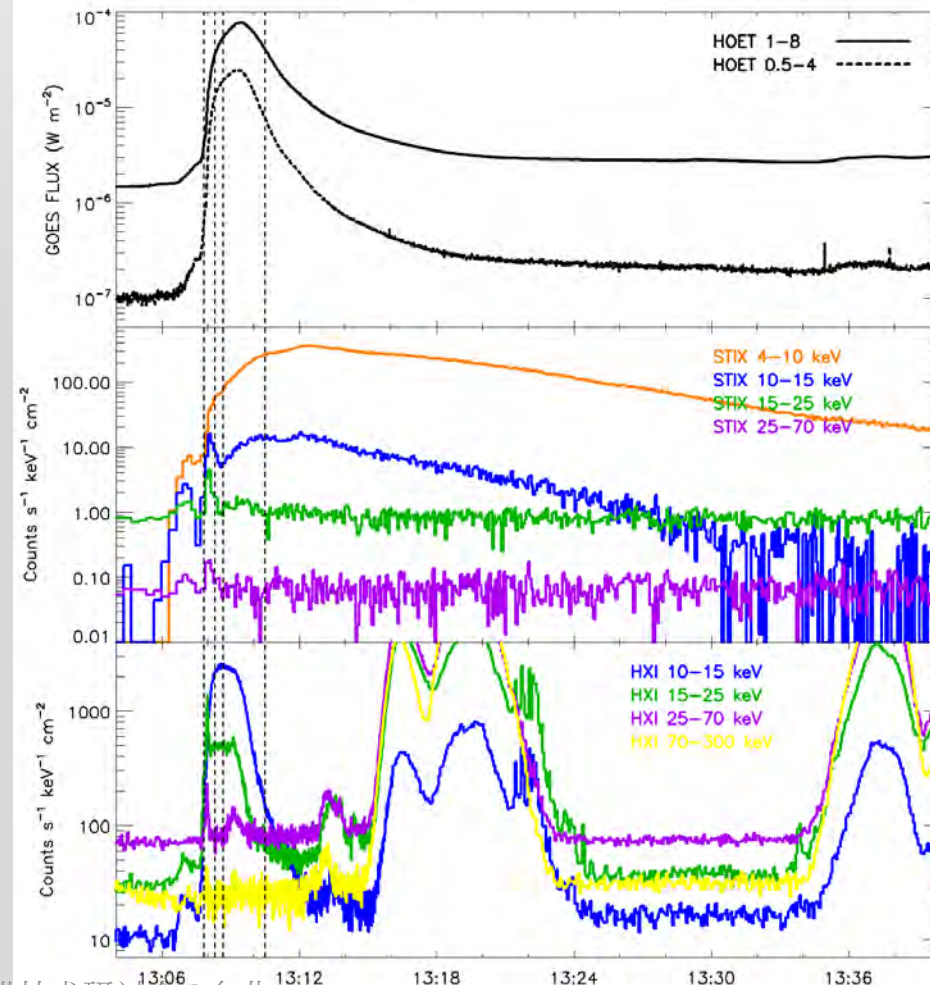
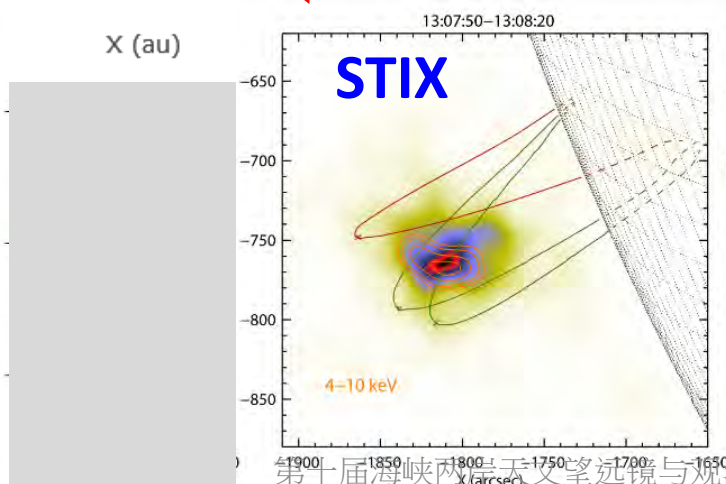
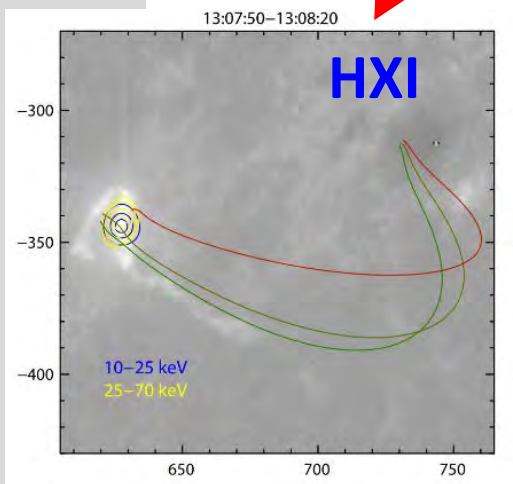
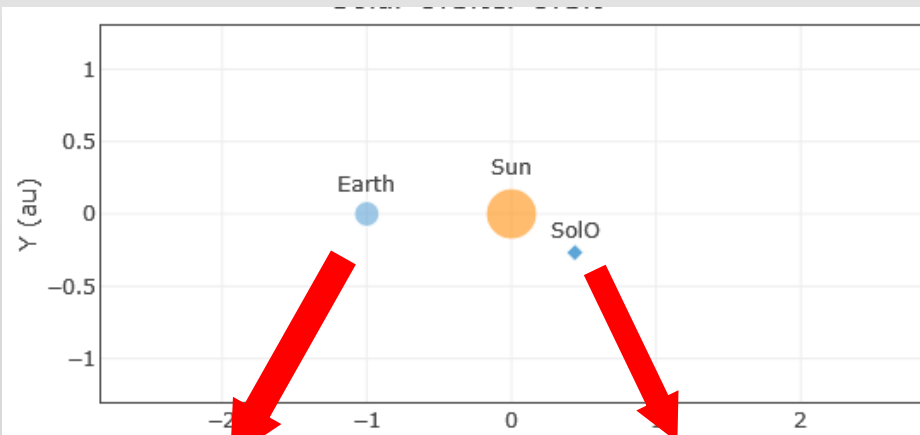


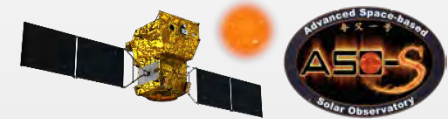
## 重点成果1：陈昌雪+：耀斑QPP和足点源的运动



## 重点成果2：夏凡小雨+：首次双视角HXR成像+耀斑SEP电子起源

HXI和STIX已观测到盼望已久的边缘事件

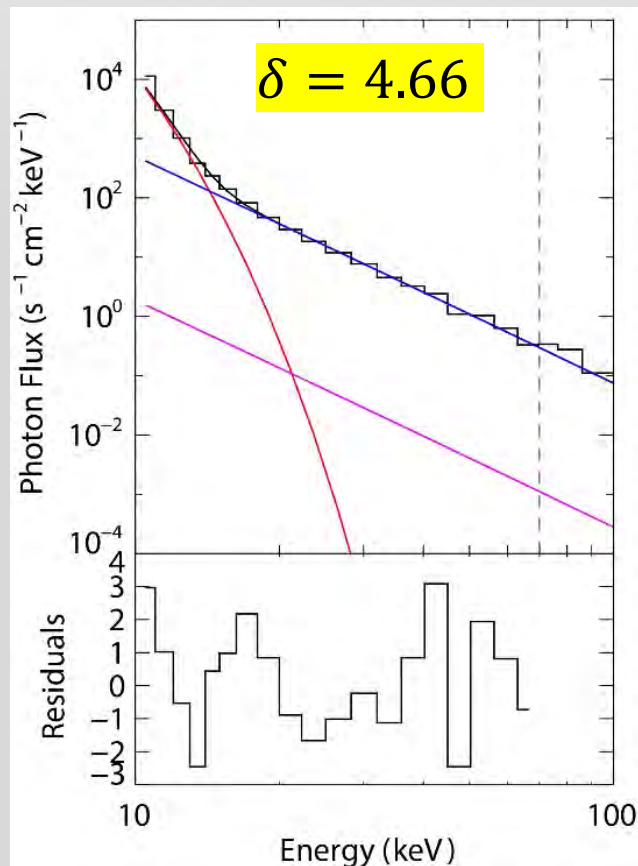




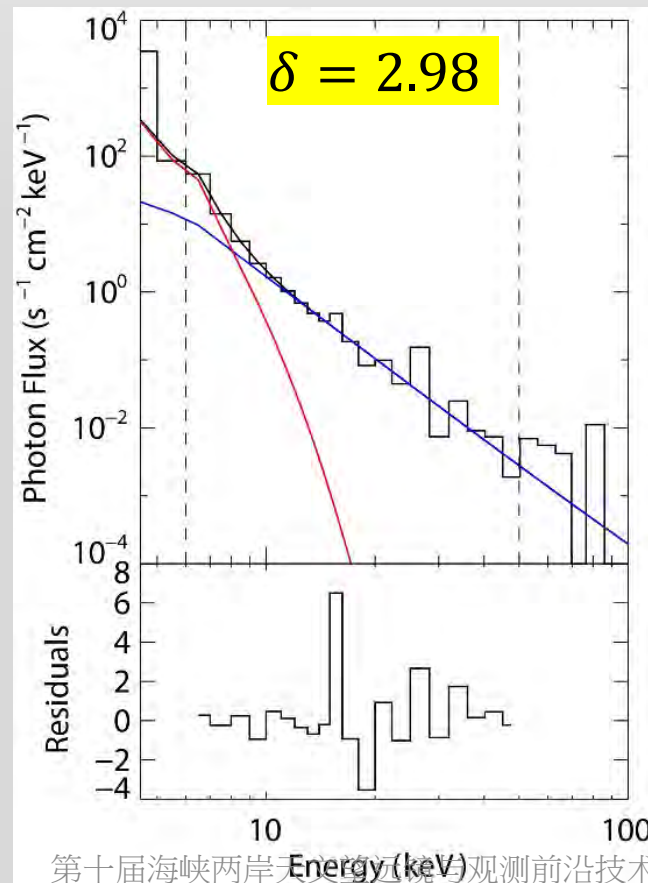
# 初步研究结果

## 重点成果2：夏凡小雨+：首次双视角HXR成像+耀斑SEP电子起源

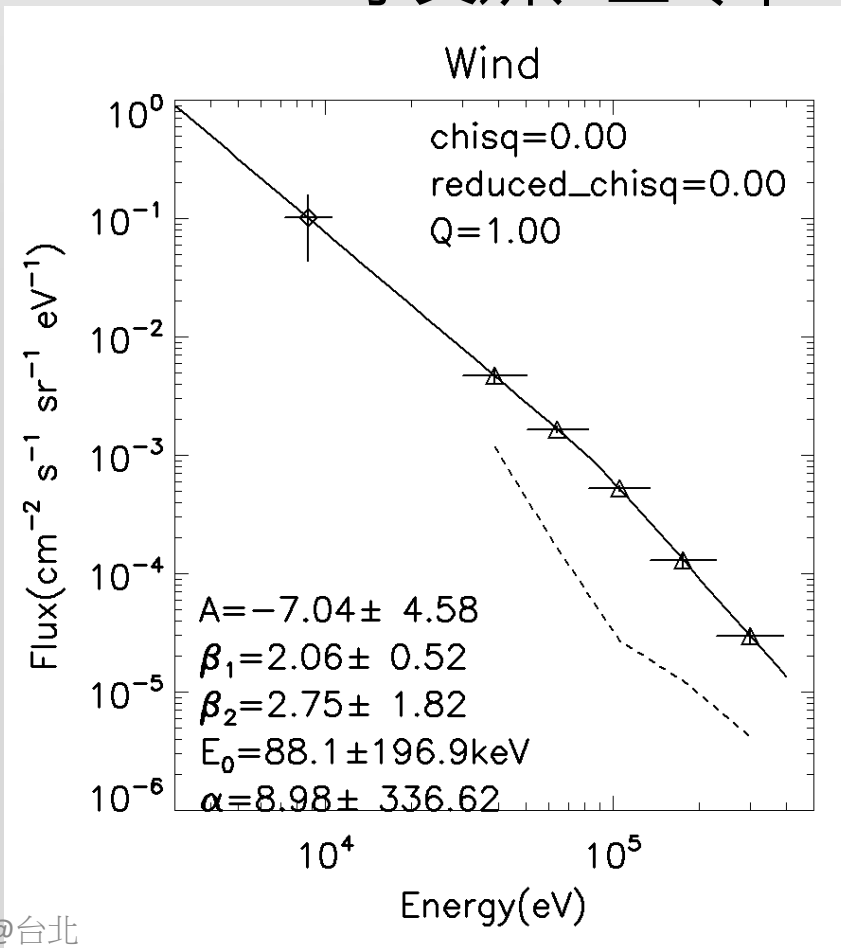
HXI：足点thick+vth



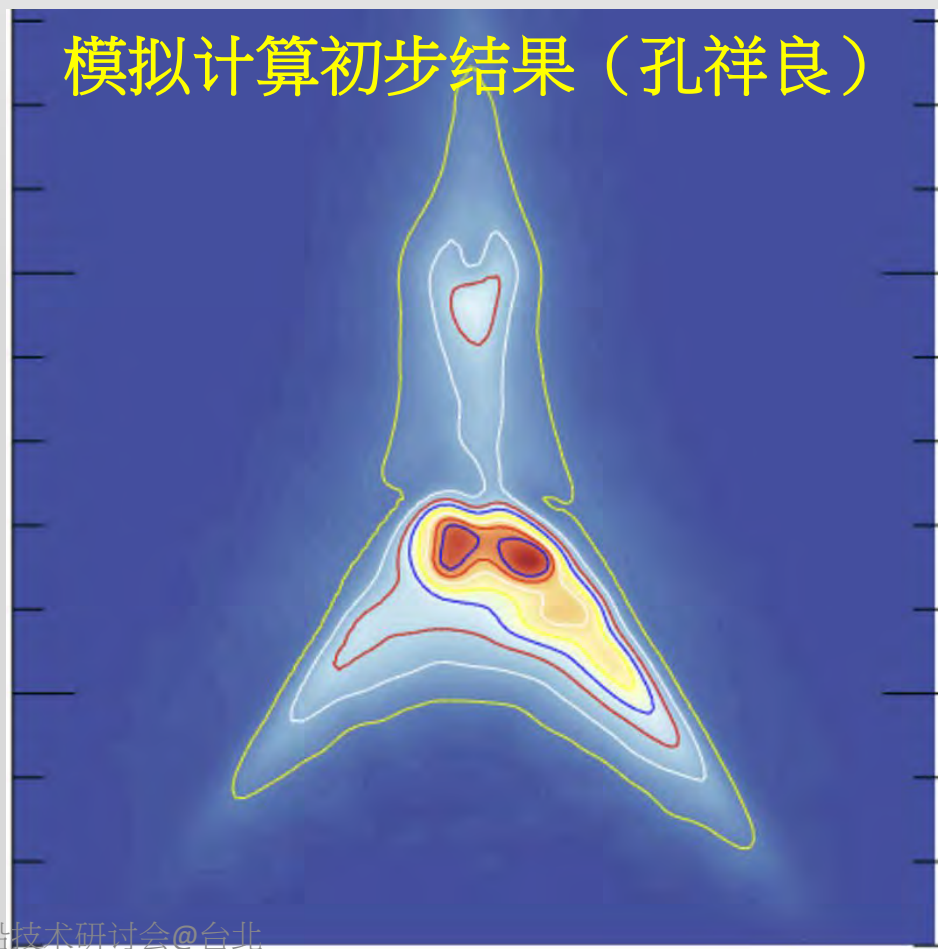
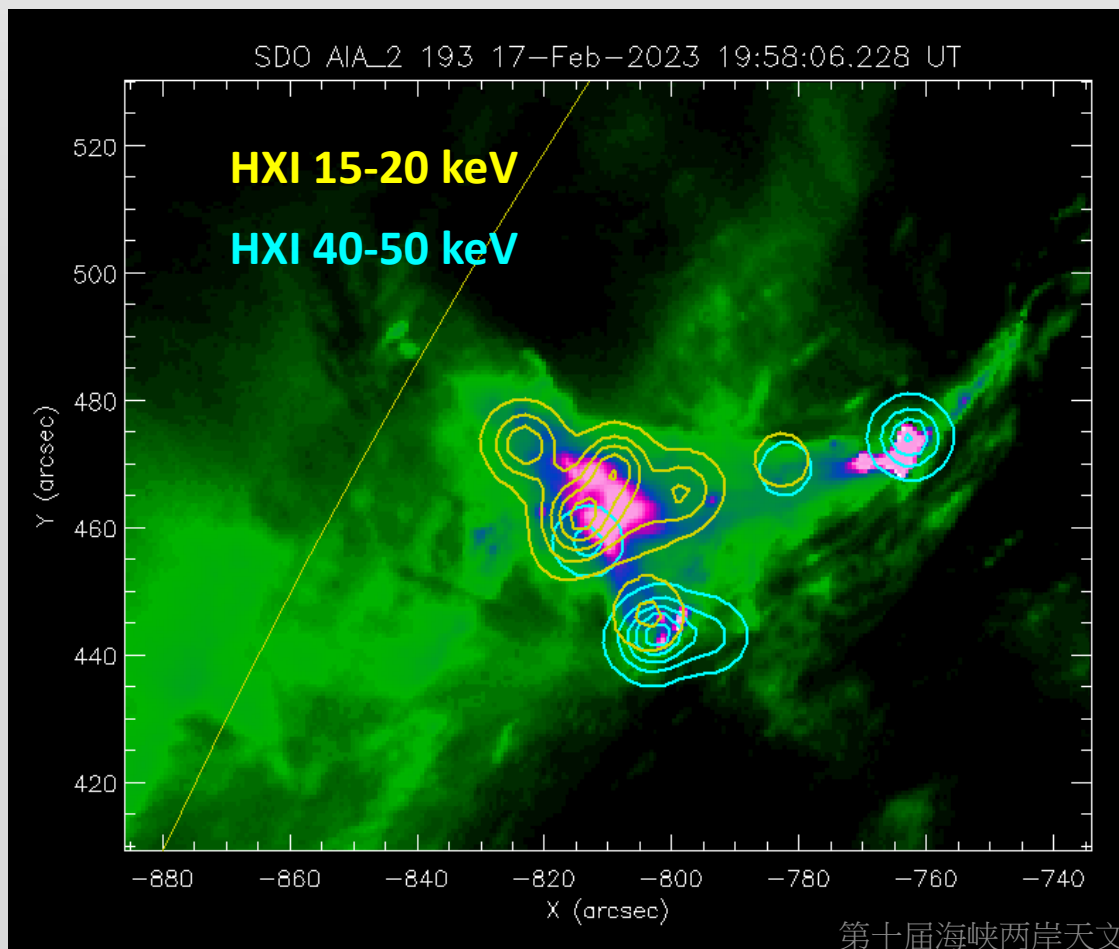
STIX：日冕thin+vth

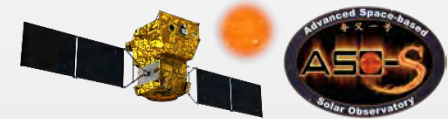


SEP：李文妍、王玲华



## 重点成果3：苏杨+：耀斑新日冕源和环顶终止激波的硬X射线细节结构





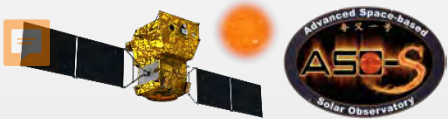
# 小结

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- HXI 载荷完成了在轨测试，各方面性能超出预期，测试总结获得满分评价，成像性能达到国际一流水平，已在轨交付给科学用户；
- 已观测到超过300次耀斑硬X射线暴事件，初步完成了在轨定标和数据版本更新，2023年4月起，全部数据向全球公开发布；
- 科学团队正在开展第一批重要科学成果的分析 and 投稿；

**ASO-S Data & software download**

<http://aso-s.pmo.ac.cn/>



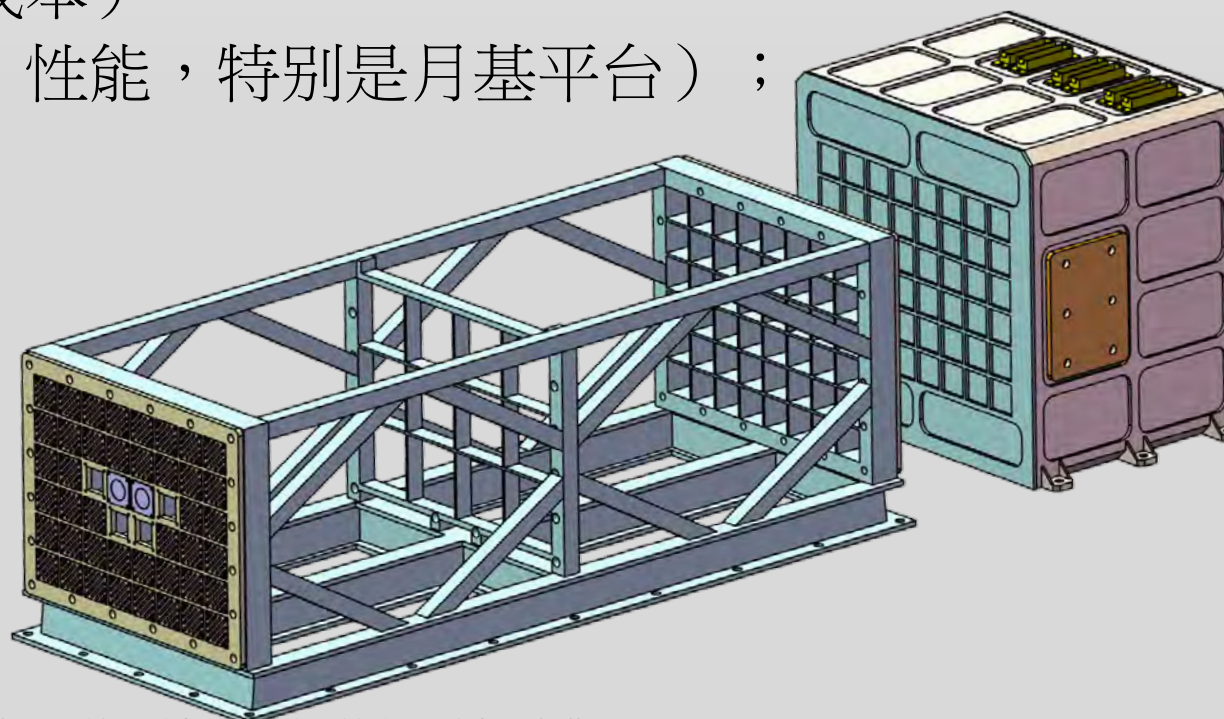
# 展望：从HXI到未来的太阳高能成像技术

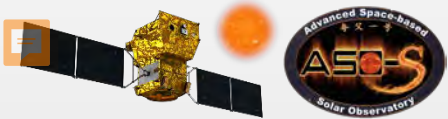


- 科学目标：太阳爆发和粒子加速
- 工程目标：应用于各类深空平台等有限资源下的高能成像仪统一架构
- 优势：
  - 极小的重量等资源占用（相比HXI减少一个量级以上）；
  - 统一架构（优化资源、降低成本）
  - 模块化设计（便于扩展功能、性能，特别是月基平台）；

## “夸父二号”太阳极轨探测任务 太阳X射线成像望远镜

参数	SPO/XIT
能量探测范围	4-120 keV (全日面成像) 0.5-10 keV (局部视场)
能量分辨	优于4keV@59.5keV
空间分辨	优于7"
视场	46'
外形尺寸	1000×300×300mm
重量	~10 kg

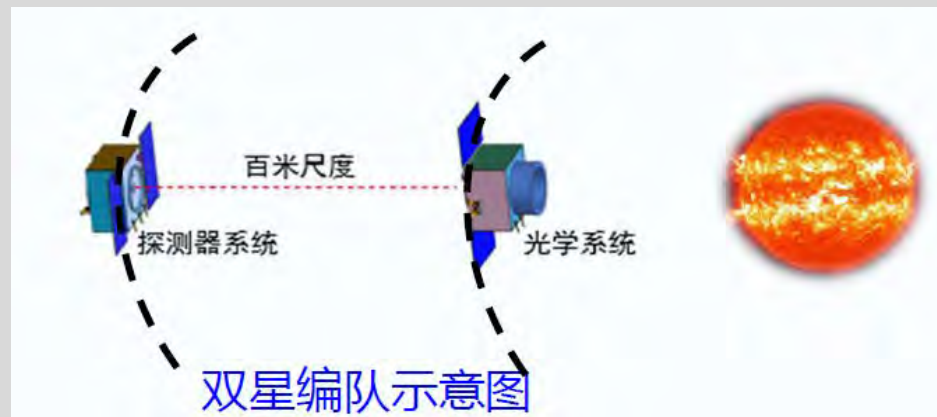
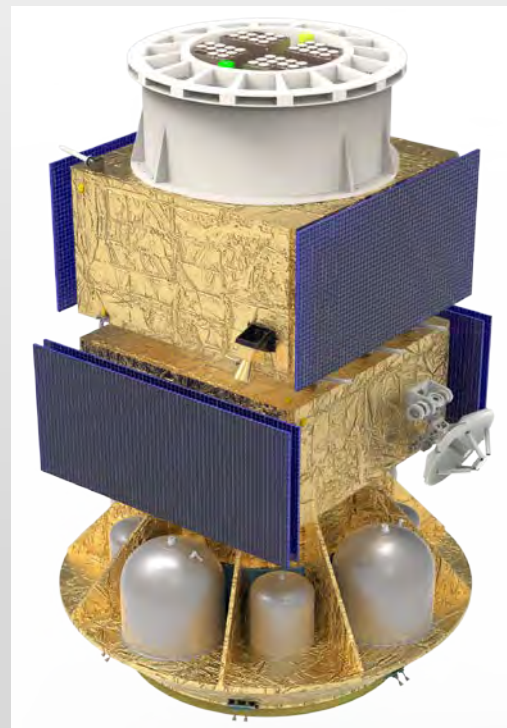


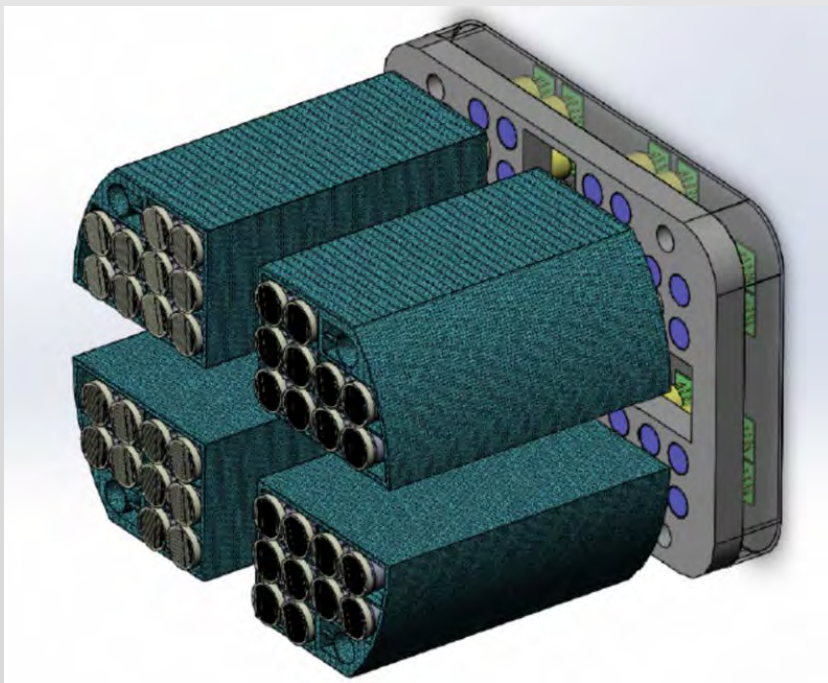


# 编队飞行太阳高能天文台

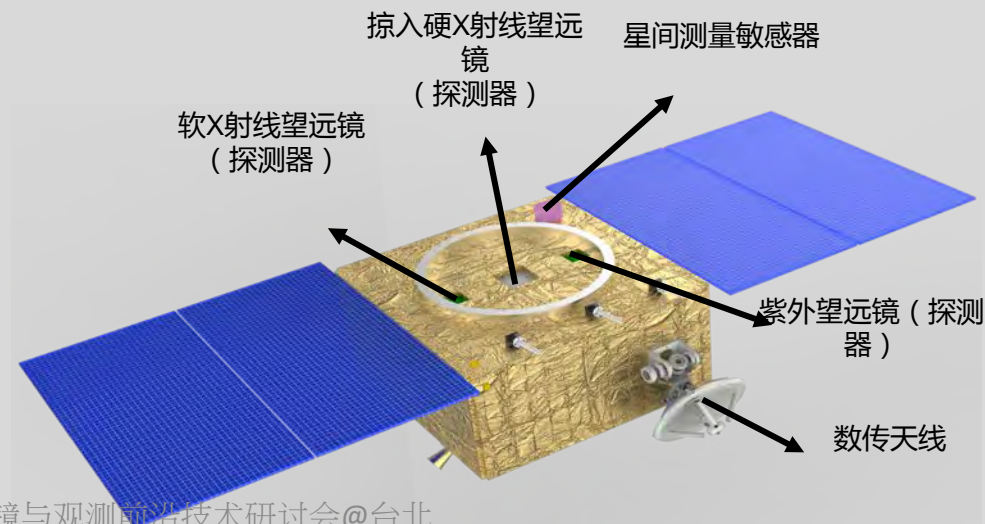
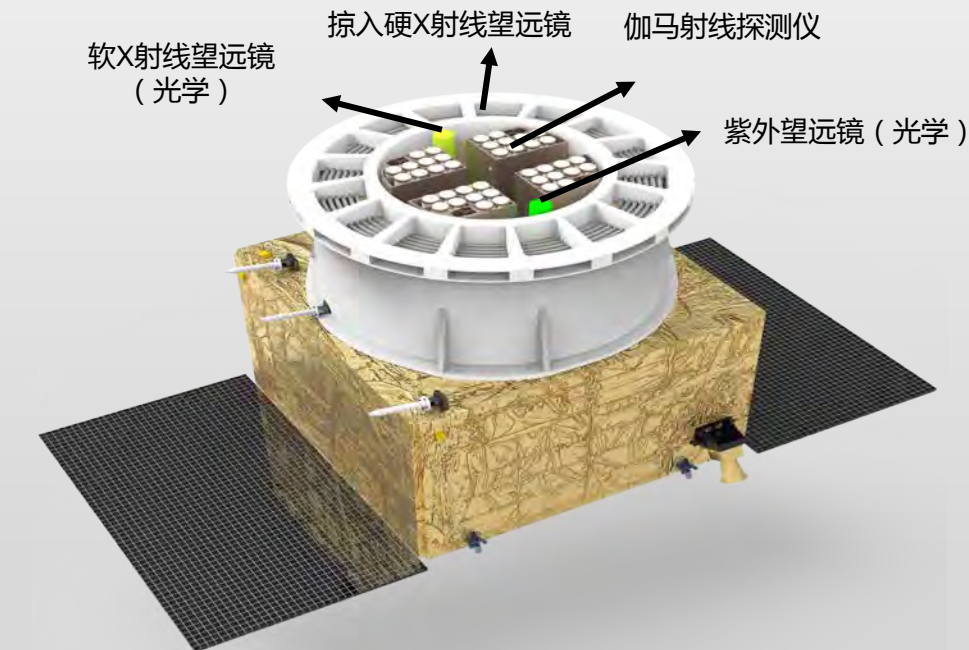
来源：  
黄宇、苏杨，  
2022.12

- 科学目标：日冕加热难题和爆发精细结构
- 工程目标：当前最高空间分辨率的硬X射线、极紫外、伽马射线成像
- 优势：
  - 硬X射线（掠入射直接成像+0.5"+高动态范围）；
  - 极紫外（衍射成像+轻量化+0.1"）；
  - 伽马（继承HXI调制成像+优于12"）
- 难度：集成众多载荷和平台新技术，已经过两轮预研
- 预期发射：2030-2035





伽马射线成像仪示意图



# Thanks ! !

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**Mobile: +86 13675111315 (Wechat)**

