Strategy and capability of
EP ToO-MM Obs

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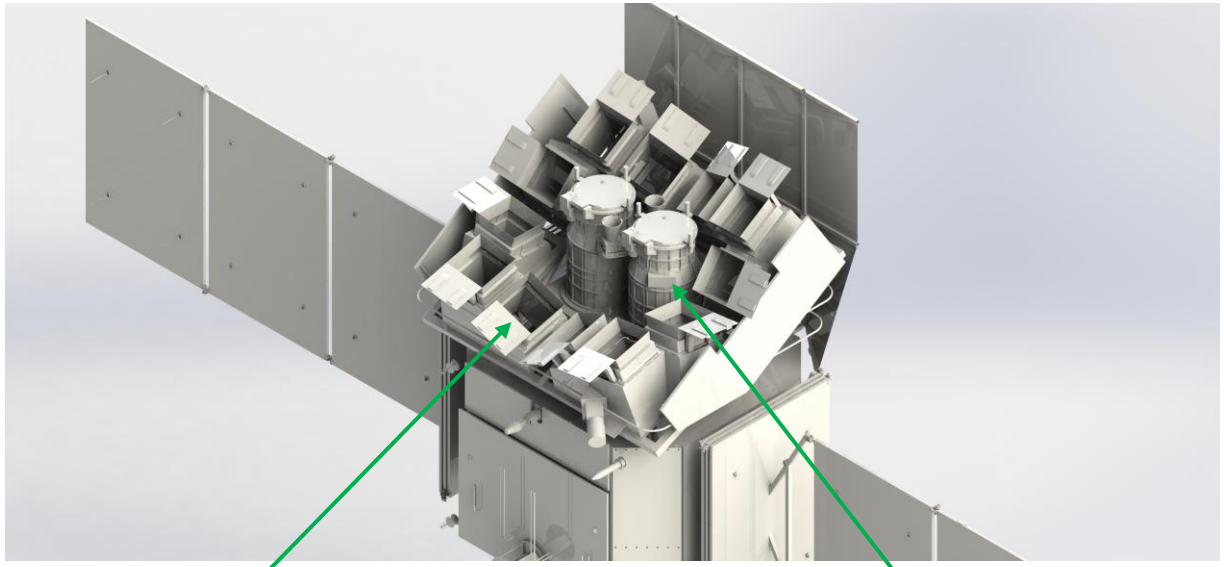
On behalf of EPSC

Instruments & SC



Spacecraft

On-board data processing
Quick slew & autonomous follow-up

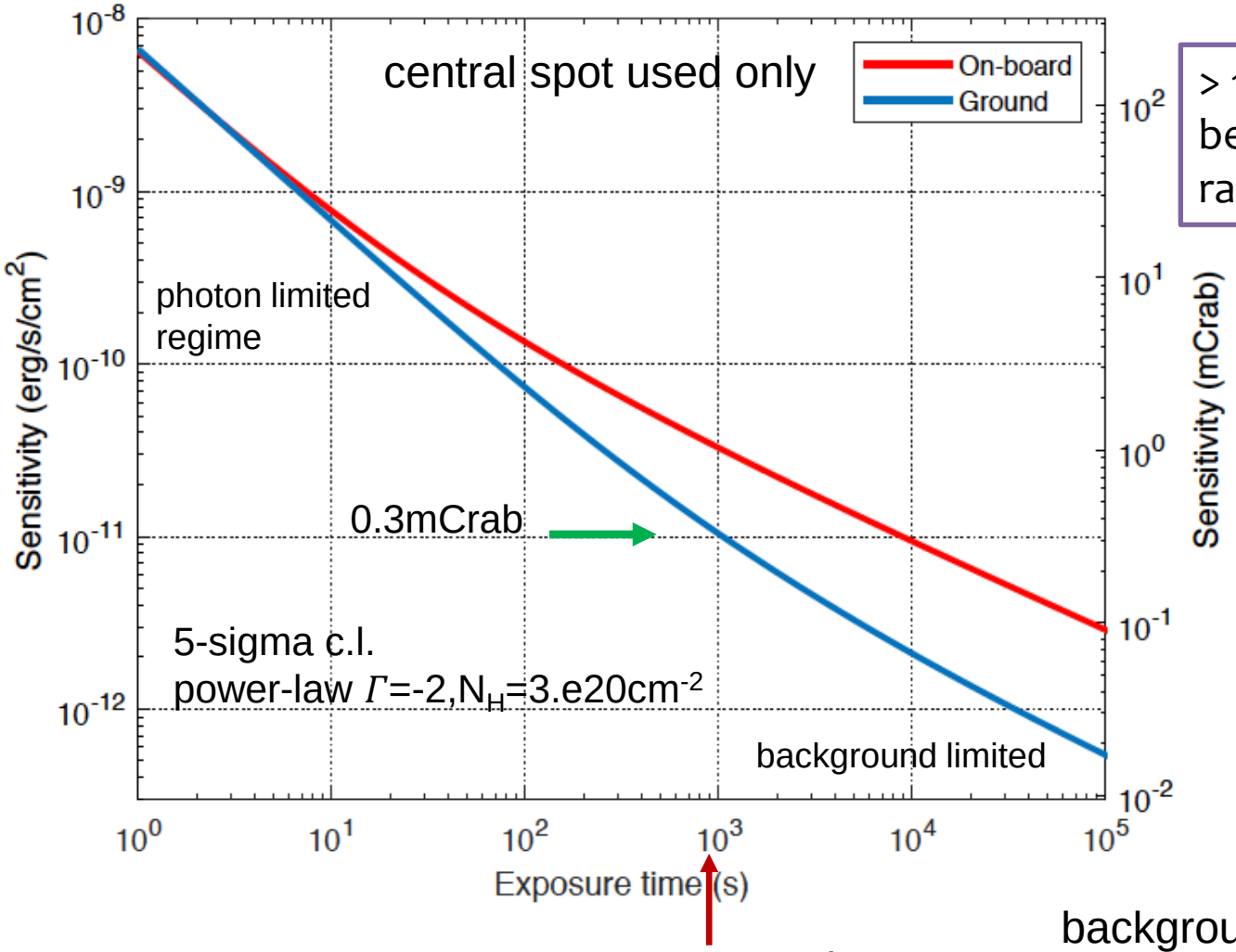
Wide-field X-ray Telescope
WXT (12 modules)

lobster-eye MPO
FoV: 3600 sq deg (1.1 sr)
band: 0.5 – 4 keV
spatial resolution: ~ 5’ (FWHM)
sensitivity: tens times better than current
positional error: 2’ (90% C.L.)

Follow-up X-ray Telescope
FXT (2 units)

Wolter-1 optics
FoV: ~1 deg
band: 0.3-10 keV
effective area: 300 cm^2 @1 keV (1 unit)
spatial resolution: 30” (HPD on-axis)
positional error: 10” (90% C.L.)

Simulated EP WXT sensitivity



> 1 order of magnitude better than current X-ray ASM (MAXI, Swift)

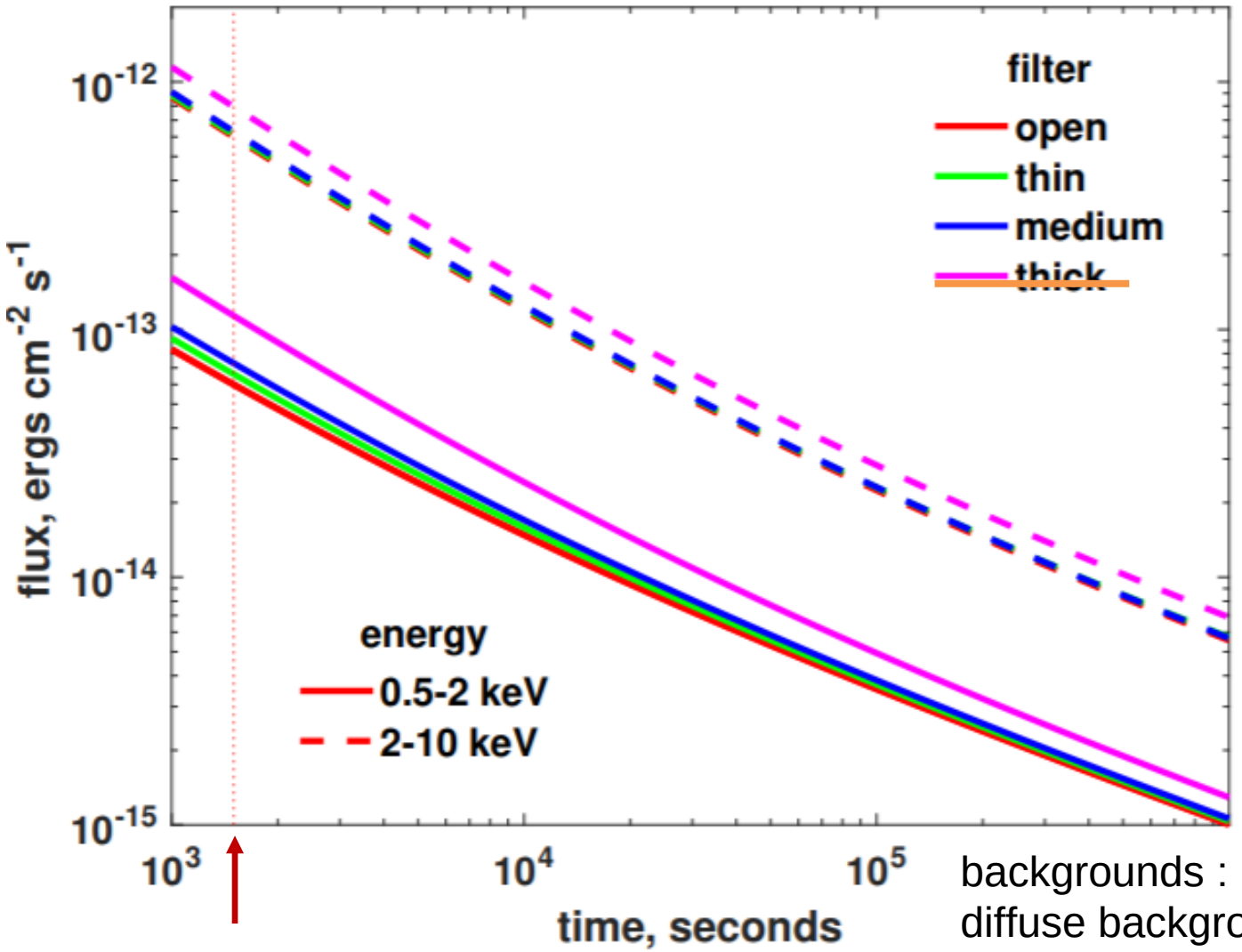
~ 1 survey snapshot

background 3.3 counts @ central spot

backgrounds : particles, diffuse background, with shielding

Zhao D. et al. 2017

Simulated EP FXT sensitivity



~ 1 survey snapshot

Similar to one module of eROSITA

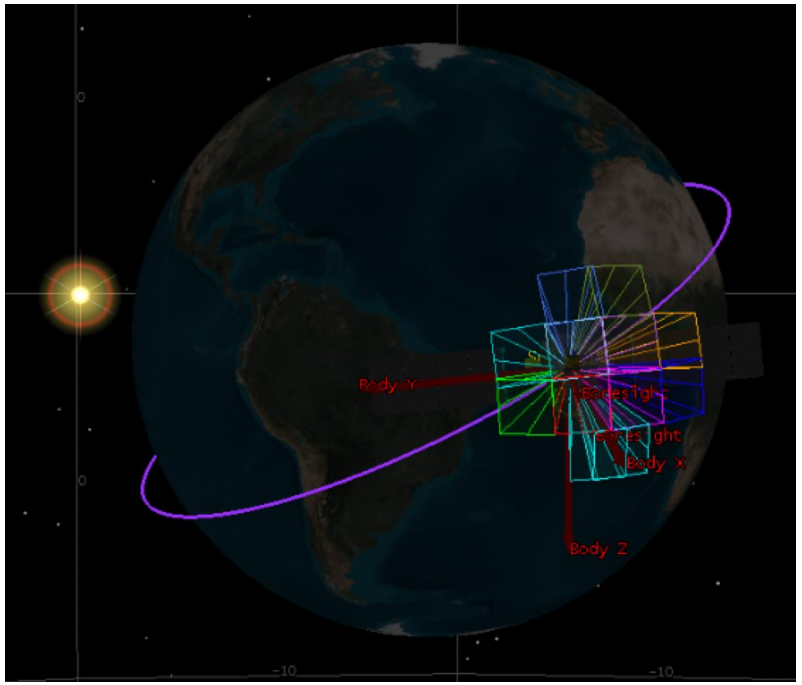
5-sigma c.l.
power-law Γ=2.05,N_H=2.e21cm^{-2}

backgrounds : particles, diffuse background

Zhang J. et al. 2022

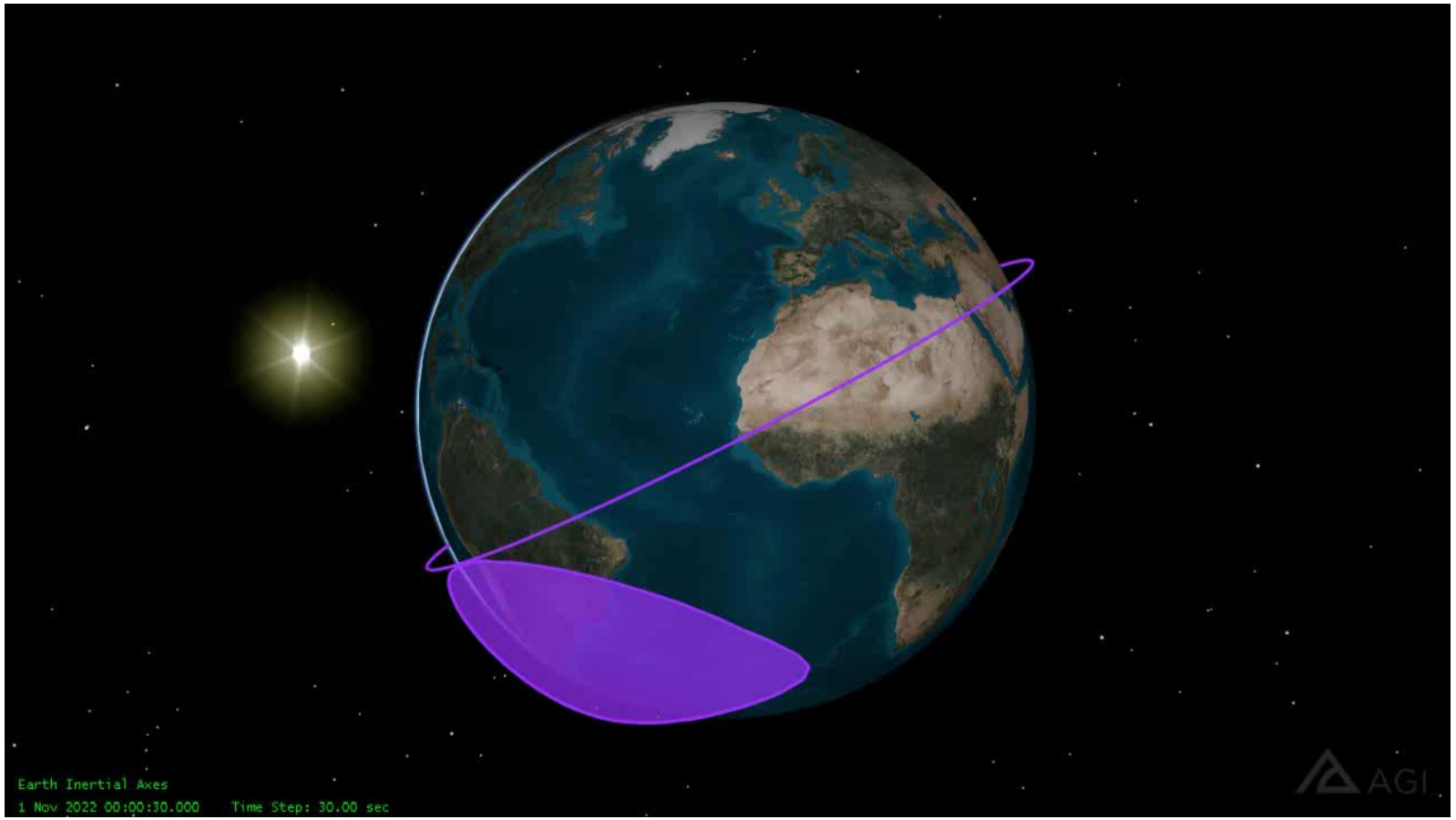
Mission profile

- Orbit: ~ 600 km (96min), incl. 29 deg
- Operation modes
  - **Survey (WXT)**
  - **Autonomous X-ray follow-up (FXT)**
  - **Target of opportunity (FXT, WXT)**
- Alert data rapid downlink
  - Beidou system (China)
  - VHF (CNES/France)
  - Transient alert information to be released immediately and publicly
- Target of opportunity command uplink
  - Normal (S-band): < 1 day
  - Time critical (Beidou): < 10 min

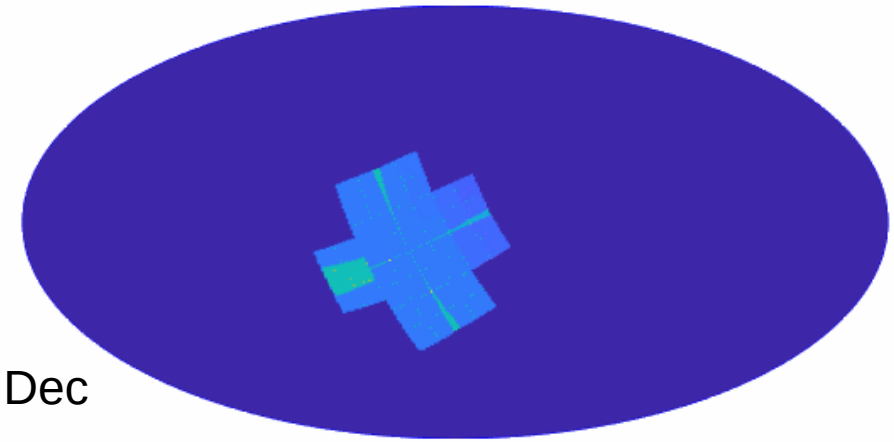


- EP Mission Centre @ NSSC/CAS
  ESA (GS telemetry support)
- EP Science Centre @ CAS
  NAOC+IHEP

EP all-sky survey mode

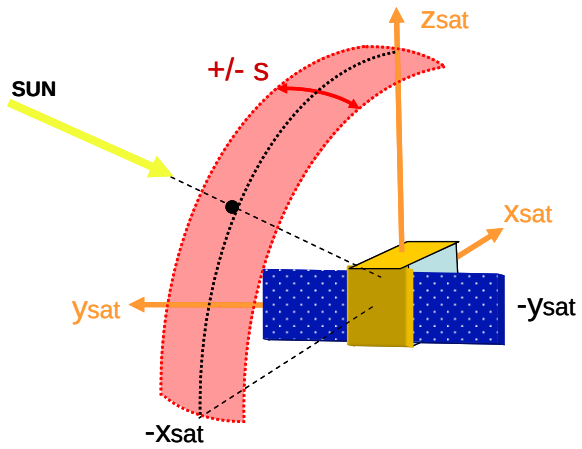


- anti-Sun pointings
- 3 snapshots per orbit, each ~20 min
- 3 orbits (~ 5 hr) cover half sky
- 1 day: ~ 45 snapshots



星上优先级管理

- ToO-MM观测卫星上优先级最高的观测模式，可打断任何其他观测
- 观测时间由上注指令决定，上注指令后立刻开始
- FXT光轴与太阳的夹角不低于65°
- 卫星指向应保证星体+/- y方向与太阳方向的夹角大于85°（限制滚动角）
- 卫星一轨内机动不超过10次；一轨内相邻指向间机动不大于5°；机动间隔不小于5分钟
- 观测指令通过测控或北斗通道上注：总延迟时间小于10分钟



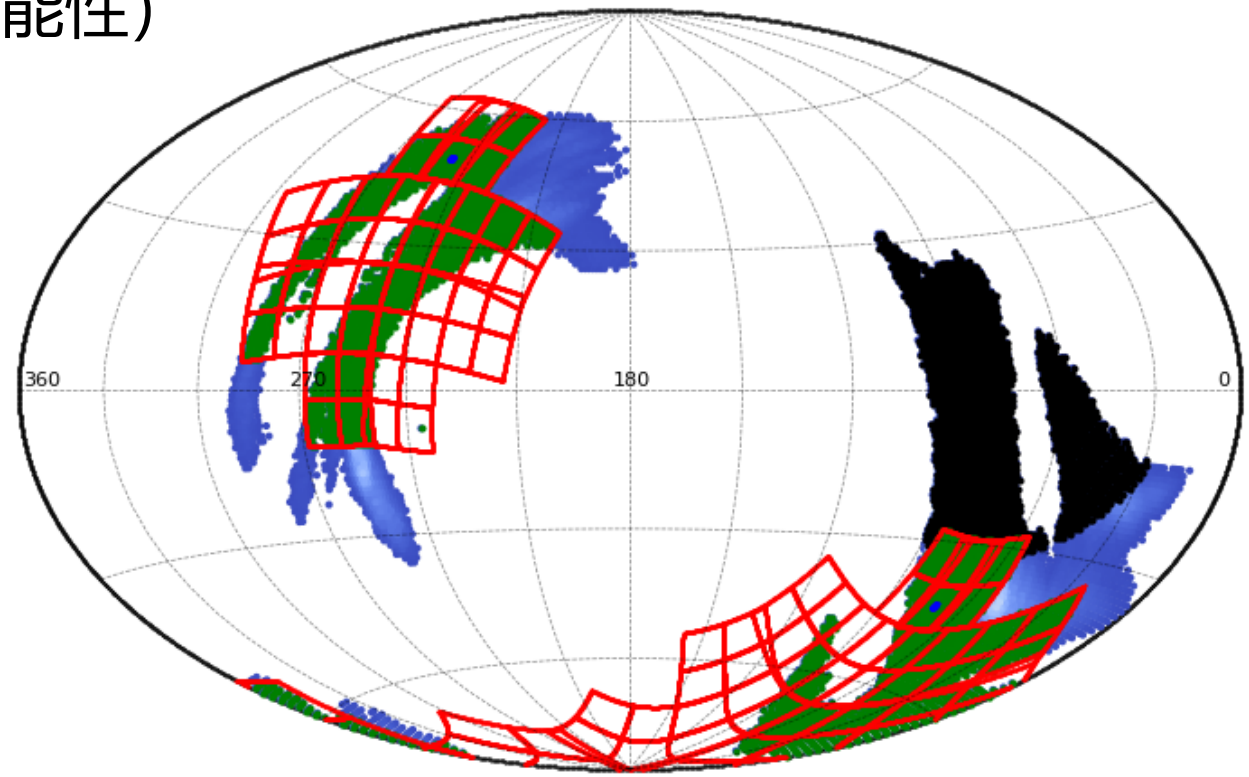
警报信息

警报信息类别	传输通道	信息内容	发送时机和频次
WXT A (触发后随)	北斗/VHF	源赤经、源赤纬、计数率、短时标光变幅度、硬度比、显著性、类别编码	触发时产生1次
WXT B, C	VHF	光子列表	触发时产生1次
WXT A (不触发后随)	VHF	源赤经、源赤纬、计数率、短时标光变幅度、硬度比、显著性、类别编码	达到阈值后每10秒（可配置）产生一次
FXT 关键数据	北斗/VHF	最多3个源的位置，流量，显著性	达到ToOMM时间上限或观测结束（可配置）且探测到源时产生1次
FXT ToOMM数据	VHF	384×384二值图像；流强较大的50个源的位置，流量，显著性	达到ToOMM时间上限或观测结束（可配置）产生1次

指向策略

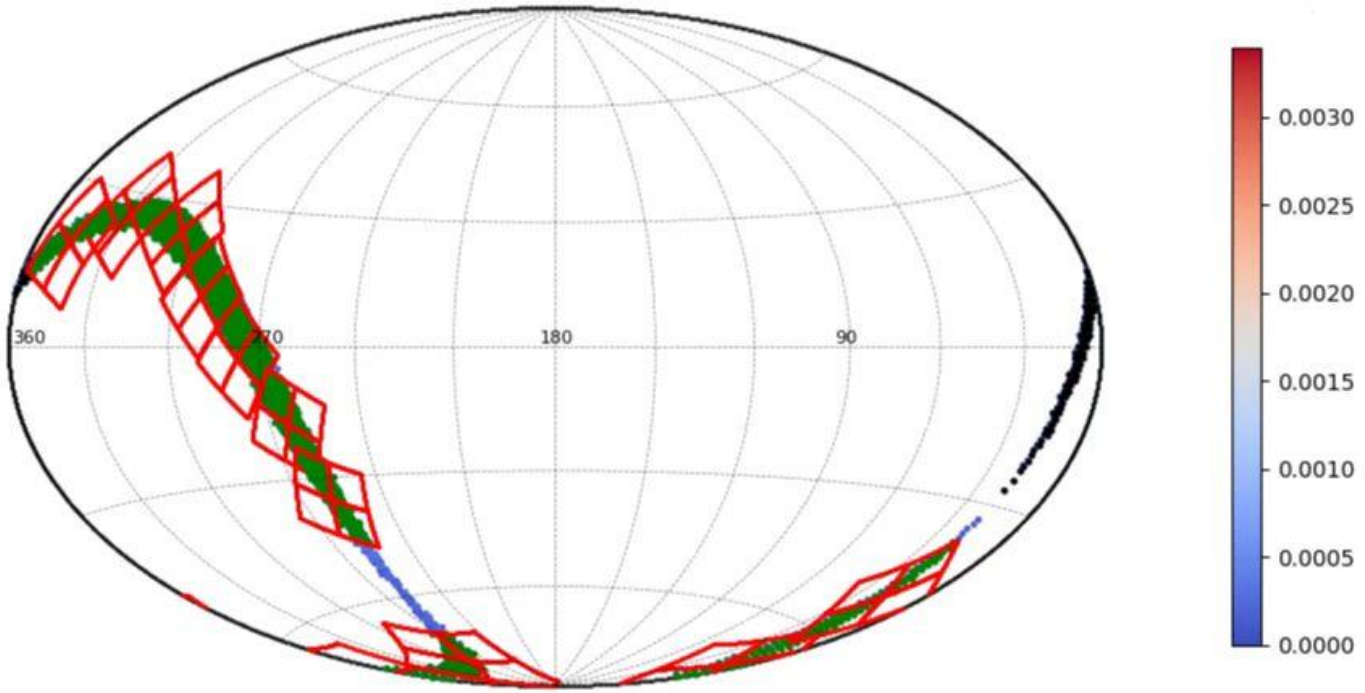
- 观测方式
  1. WXT覆盖（>100 deg2，天区积分概率）
  2. FXT拼接（<100 deg2，天区积分概率）
  3. FXT定点（三维星系表，星系可能性）
- 更新观测因素：
  - LVK天图更新
  - 收到WXT、FXT 北斗/VHF 警报
    （ToO-MM观测期间
    星载触发不会打断观测）
  - 其他卫星相关GRB定位
  - 其他波段候选体定位

GW190425 (90% region 7536 deg^2)
2轨 WXT覆盖 3489 deg^2 （49%概率）



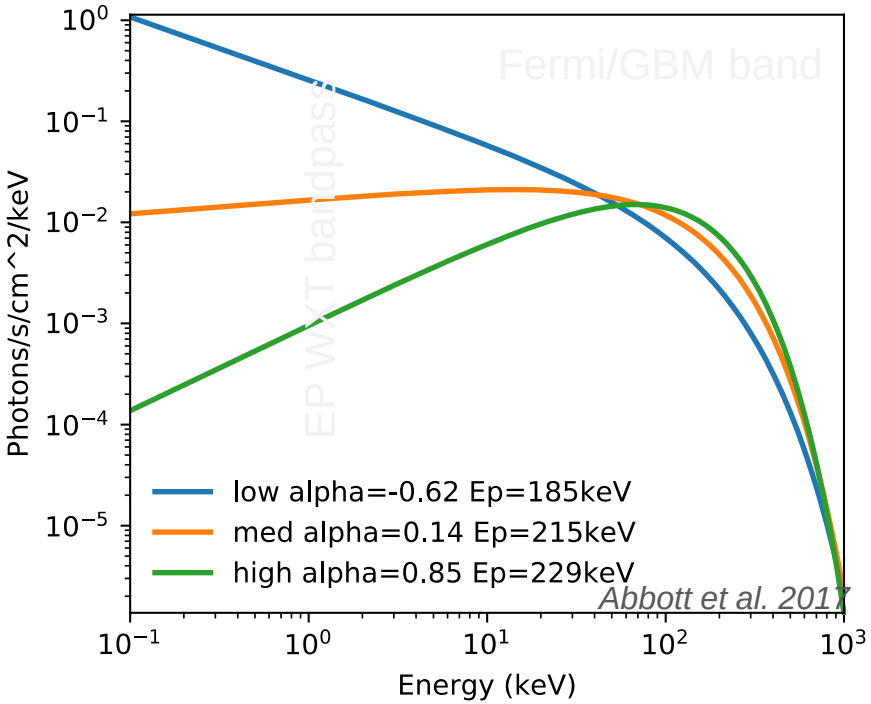
LEIA S2306050

LEIA 10: 2023-06-05T18:42:12 ra dec:17.822 -50.286 prob: 0.024 area: 93 add prob: 0.019 add area: 81

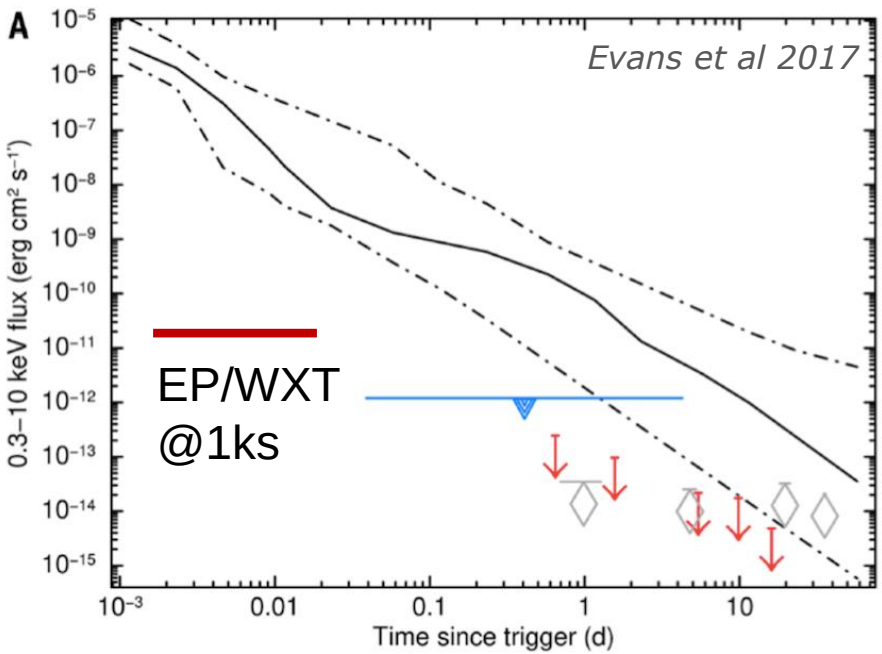


EP detectability for GW 170817: early X-ray

GRB prompt emission: several seconds



ability to detect early X-ray afterglow



Prompt emission: several WXT counts, marginal detection

Early afterglow: ??

magnetar-powered X-ray transients of mergers?

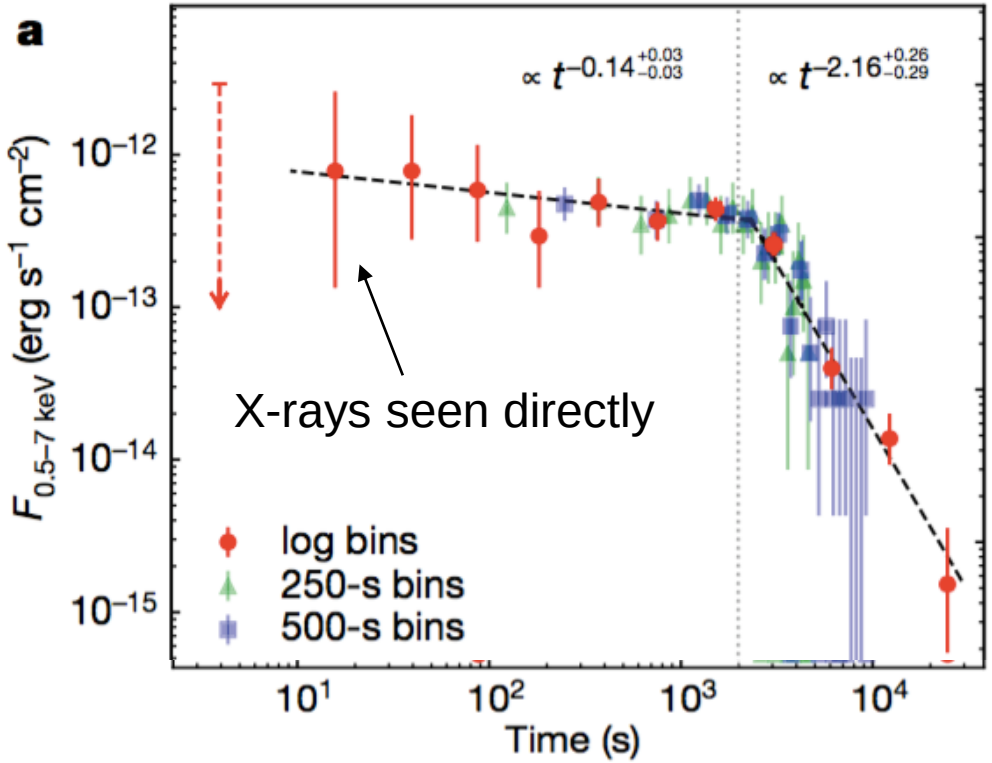
LETTER

https://doi.org/10.1038/s41586-019-1079-5

A magnetar-powered X-ray transient as the aftermath of a binary neutron-star merger

Y. Q. Xue[1,2]*, X. C. Zheng[1,2,3]*, Y. Li[4], W. N. Brandt[5,6,7], B. Zhang[8,9,10]*, B. Luo[11,12,13], B.-B. Zhang[11,12,13], F. E. Bauer[14,15,16], H. Sun[9], B. D. Lehmer[17], X.-F. Wu[2,18], G. Yang[5,6], X. Kong[1,2], J. Y. Li[1,2], M. Y. Sun[1,2], J.-X. Wang[1,2] & F. Vito[14,19]

CDF XT2
@ z=0.738



detectable with EP/WXT within ~300Mpc (LIGO horizon for NS-NS mergers)

讨论议题

- LVK O4 期间EP（LEIA）观测策略讨论和建议
- 科学准备（科学问题，软件，三维星系表，理论模型，多波段设备）
- 中微子，宇宙线联合观测（研究课题）建议
- STP3工作模式讨论
- 科学白皮书撰写

观测策略

- GRB-GW-EP/WXT 同时触发：按照正常后随流程
- GRB-GW 触发：按照GRB天图规划
- 仅GW触发：按照GW天图规划
  - 如果有NS，尽量在第一轨多覆盖不同天区（估计XT2在不同距离探测时间）；
  - 如果NS-BH，可以按照WXT覆盖；
  - 如果BH-BH，可以关注大质量BH情况（不紧急，可按保持正常巡天）
  - 建议EP项目正式和LIGO接触可能的合作事项（BH-BH质量信息，sub-threshold触发，后续给出详细建议）
- FXT拼接，能否避开一些区域（例如银心附近）

研究计划

- 引力波相关科学准备：
  - structure jet code准备； GW170817不同角度看，光变曲线；单独会议
  - GW 170817 早期GRB的X-ray辐射，计算需要观测时间
  - 调整170817的观测角度，光变可能有不同形状不是
  - O4 GW样本公开后与EP数据联合搜索
- 中微子相关科学准备：
  - 建议将几个中微子候选源加入巡天时FXT检测列表
  - FXT ToO follow-up 中微子信号
  - WXT 的监测数据与 neutrino 交叉相关研究
- 白皮书分工：中微子— 王祥玉；引力波 —范锡龙；观测能力—刘元
- STP 3 international meeting (in two weeks)

Summary

- X-ray sky is rich in various classes of transients and variables
- Future of monitoring dynamic X-ray sky is promising, enabled by Lobster-eye MPO technology
- Einstein Probe will discover/characterise a large number of faint X-ray transients, and monitor source variability
- Follow-up by ground- and space-based telescopes are essential
- Synergy with other Multi-Wavelength & Multi-Messenger facilities offers great science opportunities

http://ep.bao.ac.cn
https://www.bilibili.com/video/BV1mf4y1b7YJ