The Einstein Probe Mission

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Einstein Probe (EP) mission

basic goals
- Discover X-ray transients & monitor source variability with improved sensitivity
- Characterise transients/variables by quick X-ray follow-ups
- Disseminate transient alerts to community in time

milestones
- Proposed (2012), R&D (2011-2017)
- Adoption (2017/12; planned launch 2022/12)
- Joined by ESA & MPE (2018), CNES (2022)
- Pathfinder **LEIA** launched (2022/07)
- Satellite FM assembly & tests (2023/06-11)
- **Launch**: Jan. 9 2024
- Lifetime: 3 yr (goal 5 yr)
Instruments & spacecraft

**Wide-field X-ray Telescope**
WXT (12 modules)
- Lobster-eye MPO + CMOS
- FoV: ~3,600 sq deg (1.1 sr)
- Band: 0.5 – 4 keV
- Resolution: ~ 5’ (FWHM)
- Sensitivity: ~1mCrab @1ks

**Follow-up X-ray Telescope**
FXT (2 units)
- Wolter-1 + pn-CCD (eROSITA)
- FoV: ~1 deg
- Band: 0.3 -10keV
- Resolution: 24” (HPD, on-axis)
- Effe. area: ~300 cm² @1keV (x 2 units)

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

**Telemetry**
- X/S-band (several hours)
- BD (down/up-link; minutes)
- VHF (down-link; minutes)

Yuan, et al. 2022 *Handbook of X-ray and Gamma-ray Astrophysics*
Observation modes

- Circular orbit
  - Height 592km, period 96min
  - Inclination angle 29 deg.

- **Observation modes**
  - Survey (primary WXT)
  - Autonomous follow-up (FXT)
  - ToO (FXT, WXT)
  - Calibration

- **WXT survey mode**
  - Pointing to night sky
  - 3 pointings/orbit, ~20min each
  - ~ 1/2 sky covered in 3 orbits (~ 5 hr)
  - Whole sky coverage in ½ year
  - FXT pointed to pre-selected targets
Status: commissioning phase

- Most in-orbit verifications have been completed
  - Spacecraft and payloads
  - Satellite-ground interface and workflow (X-band, VHF)
- First light achieved for WXT (Jan. 19) and FXT (Feb. 22)
- Performance verification observations for one week (Mar. 22)
- WXT calibration mostly completed; FXT calibration on-going
- **Spacecraft & instruments working normally**
- EP Science Centre (EPSC): commissioning tests
- TBD: automated FXT follow-up obs. triggered onboard
- Commissioning completion: June 2024
- Formal science operations: plan to start in June
WXT 首光X-射线图像  X-ray First light  2024 Feb. 19

仙后座 A 超新星遗迹（星云）
Cassiopeia A supernova remnant (nebula)

图像大小 Image size 9.3° X 9.3°
曝光时间 2.2万秒
exposure 22 kilo-seconds

Red: 450 to 1000 eV
Green: 1000 to 2000 eV
Blue: 2000 to 5000 eV

X-ray spectrum obtained at the same time

Si He 1.83
S He 2.41

X-ray data credit: EPSC, image credit: Chen Zhang, Huaqing Cheng.
Central region of our Galaxy

WXT covers 1/11 area of the entire sky in one snapshot

X-ray data credit: EPSC, image credit: Chen Zhang, Huaqing Cheng.
FXT First light
M87 central galaxy in Virgo cluster of galaxies
supermassive black hole

SDSS optical image

FXT X-ray image
0.3-10 keV
FoV 1°x1°
Exposure time: 39 ks

冷锋 cold front
FXT 首光 X-射线图像
FXT X-ray First light
蟹状星云 超新星遗迹
Crab nebula supernova remnant
能段 0.3-10 keV
曝光时间 Exposure 2600s

中心的中子星脉冲/自转周期 33.8 ms
Central neutron star spin/pulsation period 33.98 ms
FXT 首光 X-射线图像
FXT X-ray First light (0.3-10 keV)

船尾座 A 超新星遗迹（星云）
Puppis A supernova remnant (nebula)

FXT 同时获得的 X 射线光谱
FXT X-ray spectrum obtained at the same time
The first X-ray transient discovered by WXT on Feb 19, 2024, alert released on Astronomer's Telegram.

- Duration < 200s
- Peak flux: $5 \times 10^{-9}$ erg/cm$^2$/s (1/5 Crab nebula)
- Subthreshold GRB signal found in Fermi/GBM data (Zhang ATel #16473)
- Undetected by Swift/XRT 39 hours later
- Atel sent from EPSC: 1st EP alert!
- No optical counterpart found (starting T0+3 days)

9.3° by 9.3 °, 1 time-frame = 33.3 sec
**EP240315a: 1st transient with measured redshift**

Onboard trigger, confirmed by on-ground analysis

Marked difference in LC of soft X-ray and hard X/γ rays

*Liu Y., et al. (arXiv:2404.16425)*
EP240315a: 1st transient with redshift

- GCN 35931 Einstein Probe detection of a fast X-ray transient EP240315a

- GCN 35932 ATLAS detection of a possible optical counterpart AT2024eju
  Precision localization

- GCN 35936 VLT/X-shooters pectroscopic z = 4.859
  Redshift measurement

- GCN 35951 EP-FXT detection of the X-ray afterglow
  Very first X-ray follow-up observation

- GCN 35971 GRB 240315C / X-ray transient EP240315a: Swift/BAT detection

- GCN 35972 Konus-Wind detection of GRB 240315C
  GRB counterpart

Gillanders J.H., et al. arXiv:2404.10660 (ATLAS optical/radio counterpart, z)
Levan A., et al. arXiv.2404.16350 (Stargate optical pho. and spec., z)
Liu Y., et al. arXiv:2404.16425 (jointly with Swift, Konus-Wind, Stargate teams)
WXT探测到的已知X-射线源：2100
WXT has detected known X-ray sources: 2100
暂现源 transients: 17（亮 bright), ~100（暗弱 faint）
恒星耀发 stellar flares: 168
Summary

- EP has been in commissioning tests and calibration since launch on January 9
- Most in-orbit performance verifications have been completed
- Spacecraft & instruments working as expected
- Some issues/challenges yet to be resolved or improved
- > dozen fast X-ray transients (>100 faint ones) and other transients detected
- Formal science operations expected to start in June

http://ep.bao.ac.cn