Introduction to the IXPE On-line Proposal Tools

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Purpose

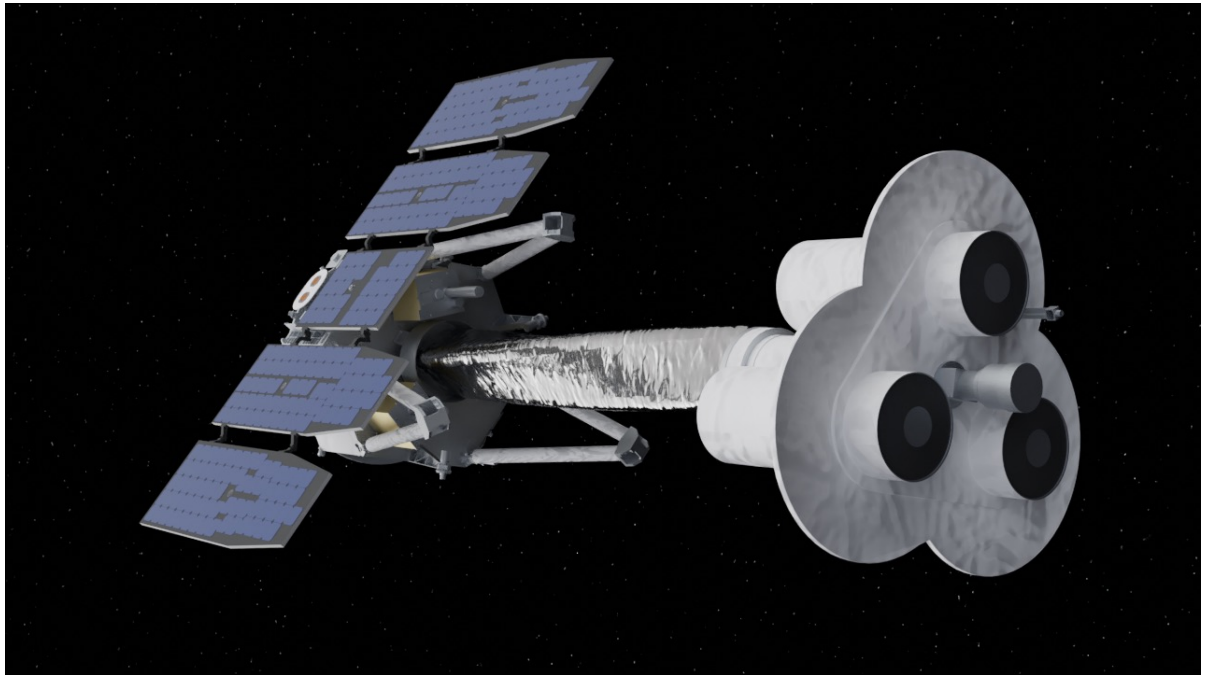
The goal of this presentation is to help the User Community assess Technical Feasibility of potential IXPE observations using basic online tools for the purpose of responding to the

IXPE Cycle 1 Call for Proposals

Mission Overview

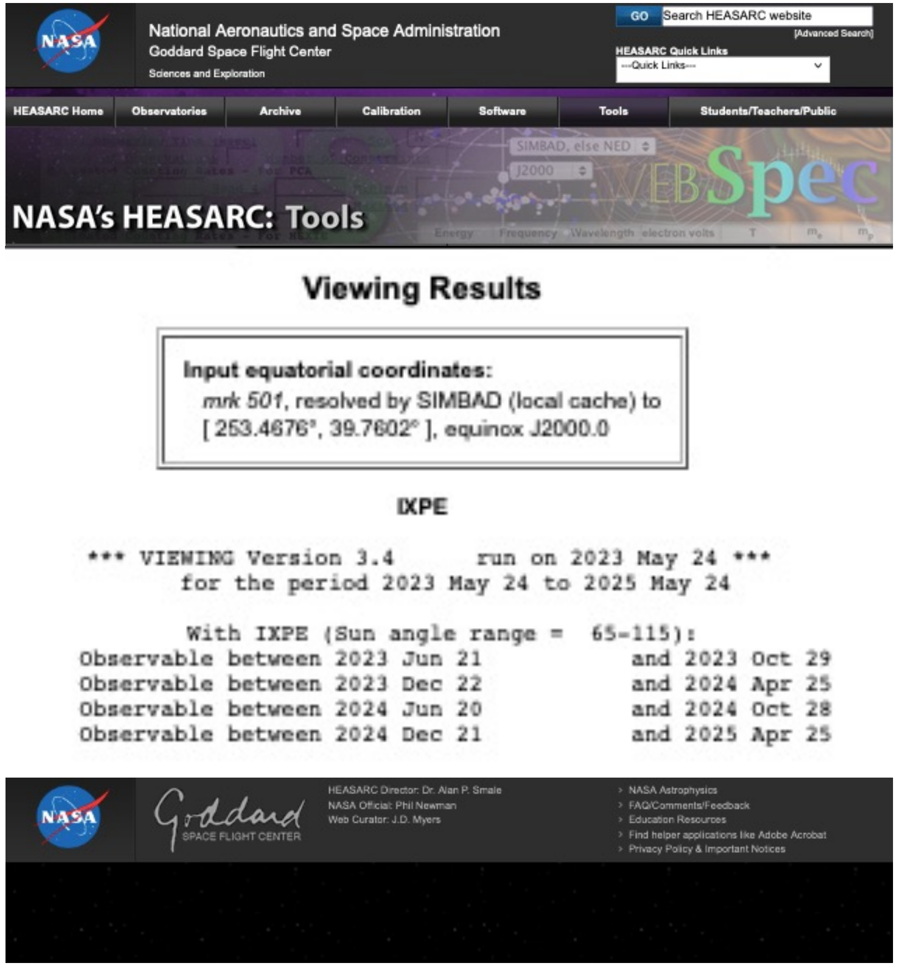
IXPE essential features:

- Three, nearly identical, co-aligned telescopes
    - 3 sets of spectro-polarmetric data
    - 2-8 keV polarization sensitivity
    - D=10’ effective FOV, 30’’ HPD
- LEO at almost 0^0 inclination, fixed solar panels oriented +/- 25^0 of the Sun, (+dither)
    - point & stare for large portion of orbit (longer towards the ecliptic poles), ~50 day visibility (x2/year)
- Photon counting —> E, t, x, y, Stokes I,Q,U
    - spectral, timing, imaging, and polarization
- All IXPE baseline mission data are publicly-available as calibrated “Level 2” FITS event files



Artist’s impression of IXPE showing 3 co-aligned mirror assemblies (right). The 3 detector units and S/C hardware and all electronics are hidden behind the 5 solar panels (left).

HEASARC's Viewing Tool



https://heasarc.gsfc.nasa.gov/cgi-bin/Tools/viewing/viewing.pl

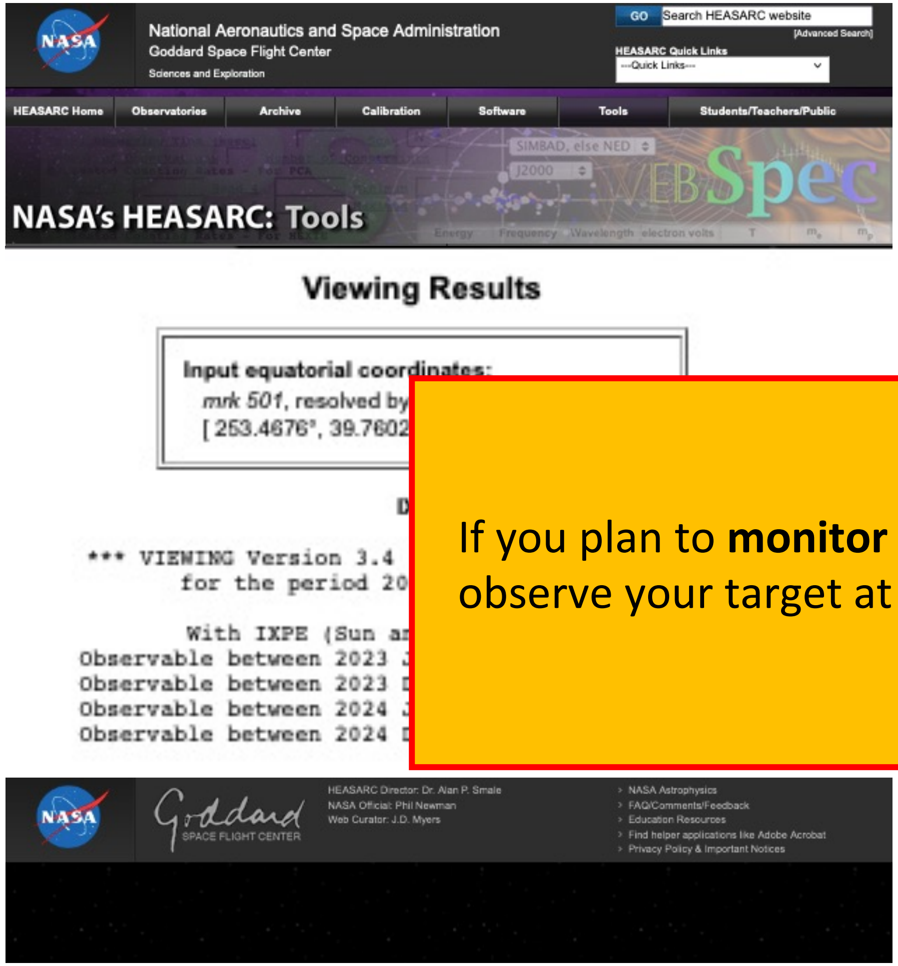
Simple Input:

1. Select Mission (IXPE)
2. Select Object Name or Coordinates

Output:

1. Returns list of all observable windows start/end dates (year, month, day)
2. Returns results for 1 year period beginning on day of query

HEASARC's Viewing Tool



https://heasarc.gsfc.nasa.gov/cgi-bin/Tools/viewing/viewing.pl

Simple Input:

1. Select Mission (IXPE)

…vs start/end

…ginning on

If you plan to **monitor** a target, take the simple step to ensure you can observe your target at the cadence you need.

IXPE Baseline Mission

As-Run Target List

https://ixpe.msfc.nasa.gov/for_scientists/asrun.html

OBSID	Start Time	Stop Time	Name
01001301	2022-01-11T11:23	2022-01-29T12:39	Cas A
01006501	2022-01-29T12:39	2022-01-31T06:58	Cen X-3
01003299	2022-01-31T07:23	2022-02-27T19:14	4U 0142+61
01004301	2022-02-15T00:13	2022-02-17T13:52	Cen A
01001899	2022-02-17T13:52	2022-02-24T19:36	Her X-1
01001099	2022-02-21T16:12	2022-03-08T02:38	Crab
01003499	2022-02-27T19:14	2022-03-24T01:51	Sgr A complex
01004501	2022-03-08T02:38	2022-03-10T08:19	Mrk 501
01002701	2022-03-24T01:51	2022-03-27T05:39	4U 1626-67
01004601	2022-03-27T05:39	2022-03-29T07:14	Mrk 501
01002801	2022-03-29T07:14	2022-03-31T09:20	GS 1826-238
01005301	2022-03-31T09:20	2022-04-05T19:50	S5 0716+714
01001299	2022-04-05T19:50	2022-04-30T10:33	Vela Pulsar

Long-Term Plan

https://ixpe.msfc.nasa.gov/for_scientists/ltp.html

S	Name	RA	Dec	Start	buffer
1	RX J1713.7-3	257.967	-39.579	2023-08-25T12	522.2
1	Sco X-1	244.979	-15.640	2023-08-28T12	3076.9
2	RX J1713.7-3	257.967	-39.579	2023-08-29T00	1759.8
1	Sgr A cloud	266.570	-28.890	2023-09-03T00	435.4
0	Swift J1727.	261.931	-16.205	2023-09-07T18	3464.2
2	Sgr A cloud	266.570	-28.890	2023-09-08T06	1160.9
0	Swift J1727.	261.931	-16.205	2023-09-16T12	3140.6
3	RX J1713.7-3	257.967	-39.579	2023-09-17T00	137.7
0	Swift J1727.	261.931	-16.205	2023-09-28T00	1592.8
3	Sgr A cloud	266.570	-28.890	2023-09-28T12	498.8
0	Swift J1727.	261.931	-16.205	2023-10-02T06	1429.4

IXPE Baseline Mission

As-Run Targe

https://ixpe.msfc.nasa.gov/for ... s/ltp.html

OBSID	Start Time	Stop T
01001301	2022-01-11T11:23	2022-0
01006501	2022-01-29T12:39	2022-0
01003299	2022-01-31T07:23	2022-0
01004301	2022-02-15T00:13	2022-0
01001899	2022-02-17T13:52	2022-0
01001099	2022-02-21T16:12	2022-0
01003499	2022-02-27T19:14	2022-0
01004501	2022-03-08T02:38	2022-0
01002701	2022-03-24T01:51	2022-0
01004601	2022-03-27T05:39	2022-0
01002801	2022-03-29T07:14	2022-0
01005301	2022-03-31T09:20	2022-0
01001299	2022-04-05T19:50	2022-0

	buffer
5T12	522.2
8T12	3076.9
9T00	1759.8
3T00	435.4
7T18	3464.2
8T06	1160.9
6T12	3140.6
7T00	137.7
8T00	1592.8
8T12	498.8
2T06	1429.4

Purpose of target lists is two-fold:

- Ensure your favorite source hasn't already been observed
- Find a source similar to yours and see what was observed

See also:

- HEASARC's IXPE Master List https://heasarc.gsfc.nasa.gov/db-perl/W3Browse/w3table.pl?tablehead=name=ixmaster&Action=More+Options
- HEASARC's IXPE-related publications list https://heasarc.gsfc.nasa.gov/docs/heasarc/biblio/pubs/ixpe.html

WebPIMMS

https://ixpe.msfc.nasa.gov/cgi-aft/w3pimms/w3pimms.pl

Recommend reading the introduction to PIMMS on the MSFC IXPE site

Standard PIMMS interface for selecting:

- Convert From/To (e.g., Flux to IXPE count rate)
- Input (required for Flux) and Output Energy Range
- Source Model parameters (Power Law, Blackbody, etc.)
  - (Only single-component models are available)
- Estimate Count Rate

WebPIMMS

https://ixpe.msfc.nasa.gov/cgi-aft/w3pimms/w3pimms.pl

Example output for a 1 mCrab source (results are for 3 telescopes combined):

PIMMS predicts 1.813E-01 cps with IXPE (2.000- 8.000keV)
The above is the total count rate.
The effective count rate for polarization is 0.1524
and the modulated count rate is 0.0474
for a modulation factor of 0.3108
Now estimating 99% confindence level minimum detectable polarization
(MDP_99) as a function of exposure time
In 10000.0 s, MDP_99 = 35.38%
In 100000.0 s, MDP_99 = 11.19%
MDP_99 scales as the inverse of the square root of the integration time.

Converting from Flux to IXPE count rate returns total, effective, and modulated count rates.

Also returns modulation factor and MDP_99, the 99% confidence level minimum detectable polarization, for a 10,000 s and for a 100,000 s exposure (or, the exposure time needed to reach a given MDP_99).

- ✦ MDP_99 scales as 1/sqrt(Exposure Time)
- ✦ Should use 2-8 keV energy range for MDP_99 sensitivity
- ✦ Should use 0.5-10 keV for total count rate estimate

$$\mathrm{MDP}_{99} = \frac{4.29}{\langle\mu\rangle C_S}\left[\frac{C_S + C_B}{T}\right]^{1/2} \approx \frac{4.29}{\langle\mu\rangle\sqrt{N}}$$

WebPIMMS

Example output for a 1 mCrab source (results are for 3 telescopes combined):

```
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MDP_99 scales as the inverse of the square root of the integration time.
```

Note that the Effective count rate and the Modulated count rate are related to the count-weighted modulation factor over the output energy range:

$$\langle \mu \rangle = C_M / C_E .$$

WebPIMMS does not account for:

- Background
- Spatial Extent
- Spectral Energy Broadening
- Source variability
- Multi-component Spectra

WebPIMMS

Example 1: Bright point source with negligible background
Gamma=2.05, N_H=2x10^{21} cm^{-2}, $F_{2\text{-}8}$=2.1x10^{-11} erg/s/cm^2
On the 2-8 keV range (input and output)

PIMMS predicts 1.813E-01 cps with IXPE (2.000- 8.000keV)
The above is the total count rate.
The effective count rate for polarization is 0.1524
and the modulated count rate is 0.0474
for a modulation factor of 0.3108
Now estimating 99% confindence level minimum detectable polarization
(MDP_99) as a function of exposure time
In 10000.0 s, MDP_99 = 35.38%
In 100000.0 s, MDP_99 = 11.19%
MDP_99 scales as the inverse of the square root of the integration time.

This is the simplest and most common case. The reported MDP_99 can be used straight away. To get a better estimate of the total count rate, change the output energy range to 0.5-10 keV.

WebPIMMS

Example 1: Bright point source with negligible background
Gamma=2.05, N_H=2x10^{21} cm^{-2}, F_{2-8}=2.1x10^{-11} erg/s/cm^2
on the 2-8 keV range (input and output)

```
PIMMS predicts 1.813E-01 cps with IXPE ( 2.000- 8.000keV)
The above is the total count rate.
The effective count rate for polarization is 0.1524
and the modulated count rate is 0.0474
for a modulation factor of 0.3108
Now estimating 99% confindence level minimum detectable polarization
(MDP_99) as a function of exposure time
It takes 1390952.9s to achieve an MDP_99 of 3.00%
```

This is the output when PIMMS is given an input MDP_99 (here, 3%). If you predict your source will deliver somewhat more than 3% polarization degree, then you should propose for at least this 1.4 Ms exposure time.

WebPIMMS

Example 2: Extended source with measurable background (same absorbed power law model as example 1)

```
PIMMS predicts 1.813E-01 cps with IXPE ( 2.000- 8.000keV)
The above is the total count rate.
The effective count rate for polarization is 0.1524
and the modulated count rate is 0.0474
for a modulation factor of 0.3108
Now estimating 99% confindence level minimum detectable polarization
(MDP_99) as a function of exposure time
In 10000.0 s, MDP_99 = 35.38%
In 100000.0 s, MDP_99 = 11.19%
MDP_99 scales as the inverse of the square root of the integration time.
```

Perform the following steps:

1. Estimate area of region of interest, ***A*** (limited to w/in an ~5' radius)
2. Estimate 2-8 keV flux in ROI and select a spectral model
3. Use PIMMS to determine source Effective count rate and modulation factor (ignore MDP_99 values)
4. Estimate background rate* in ROI: (***A***)(0.0012 cts/s/ arcmin^2 (following Di Marco et al. 2023)
5. Compute MDP_99 from:

$$\mathrm{MDP}_{99} = \frac{4.29}{\langle\mu\rangle C_S}\left[\frac{C_S + C_B}{T}\right]^{1/2}$$

*Background spectrum is approximately flat so, for other energy ranges, scale background rate linearly by band width

WebPIMMS

Example 3: Two-component point source; one component polarized

Polarized absorbed power law (see example 1)

```
PIMMS predicts 1.813E-01 cps with IXPE ( 2.000- 8.000keV)
The above is the total count rate.
The effective count rate for polarization is 0.1524
and the modulated count rate is 0.0474
for a modulation factor of 0.3108
```

Unpolarized 0.61 keV APEC, solar Z, N_H=2x10^{21} cm^{-2}, $F_{2\text{-}8}$=2.1x10^{-11} erg/s/cm^2

```
PIMMS predicts 3.900E-01 cps with IXPE ( 2.000- 8.000keV)
The above is the total count rate.
```

Perform the following steps:

1. Estimate 2-8 keV flux and a spectral model for both components
2. Use PIMMS to determine source Effective count rate and modulation factor (ignore MDP_99 values) for the polarized component
3. Use PIMMS to determine Total count rate in unpolarized component
4. Treat unpolarized component as a background and compute MDP_99 as before from:

$$\mathrm{MDP}_{99} = \frac{4.29}{\langle\mu\rangle C_S}\left[\frac{C_S + C_B}{T}\right]^{1/2}$$