Optical Polarimetry, Timing, ELTs and the eXTP

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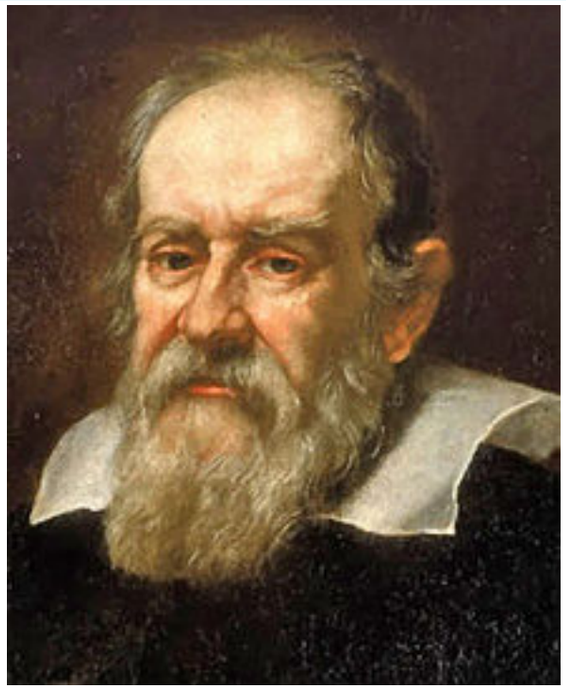
Chandra/HST - Hester et al, 2002

Optical flux sensitivity improvement over 400 years



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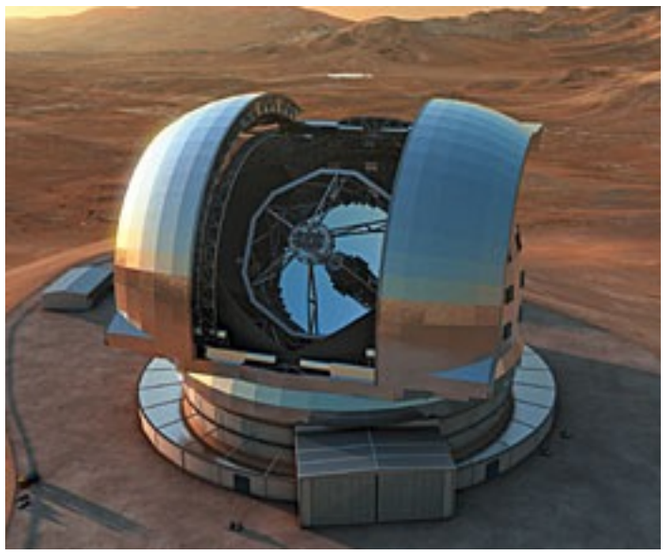
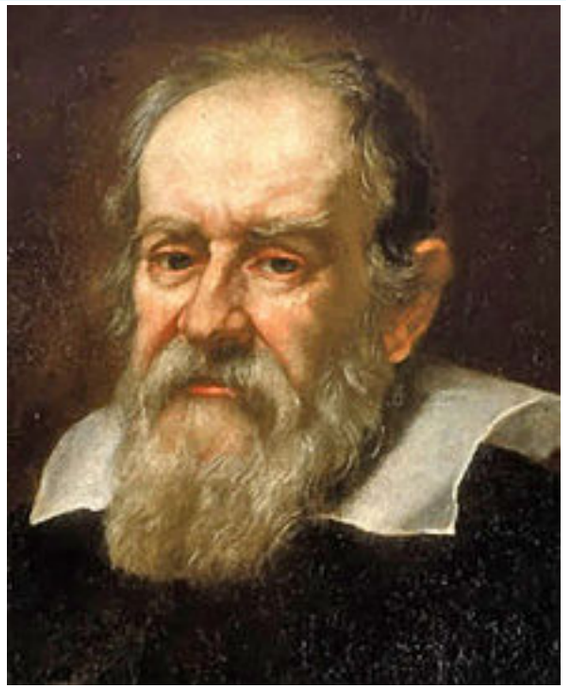
τ : ~30 ms
φ : m_V ~ 8.5

+



τ ~ 1 hour
φ ~ m_K ~ 30
or ~ 10^{-24} erg/s/cm^2
(or ~1 μCrab)

Time sensitivity, not so good



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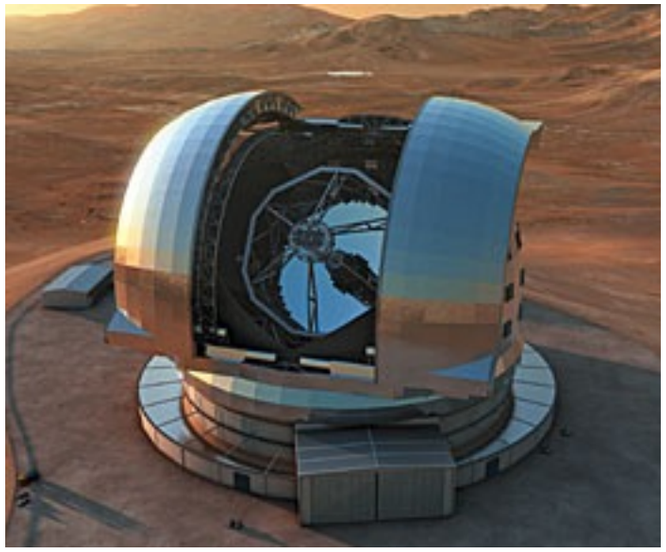


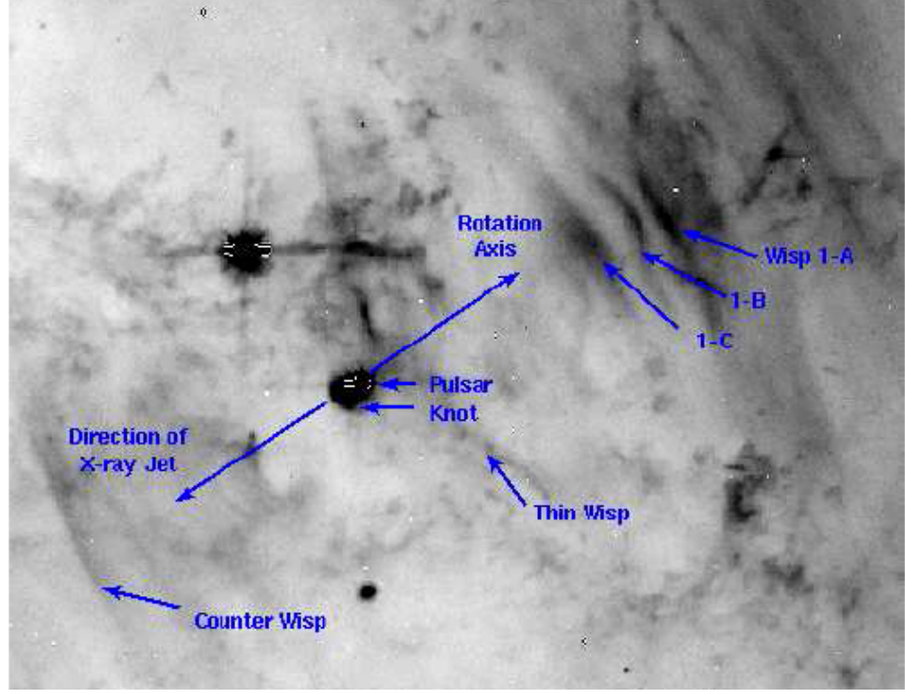
τ ~ 4 ms

φ ~ m_K ~ 18.3

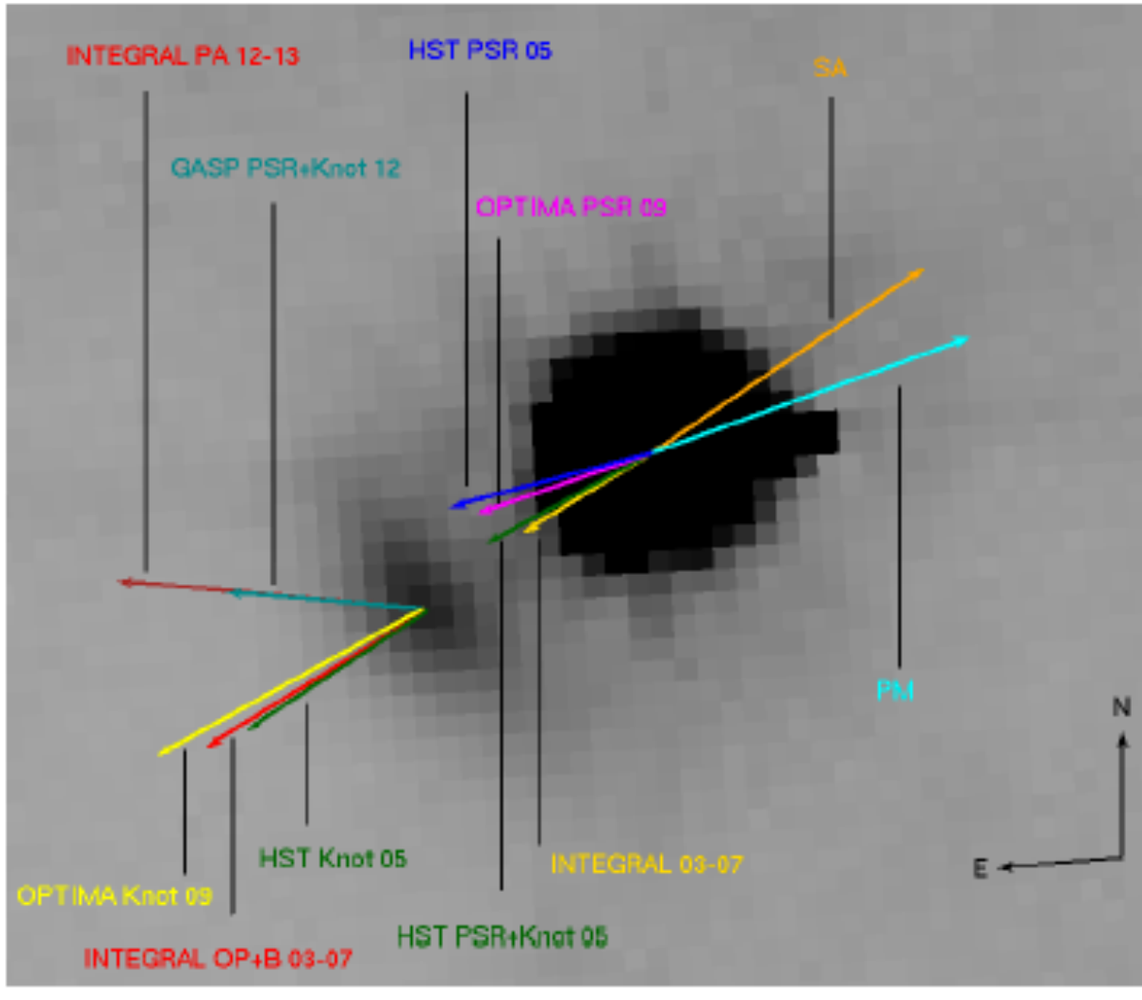
Some questions

Multiwavelength observations are important (see e.g. Emrah Kalemci's talk yesterday), *but observations in different wavebands should be compatible.*

- **Joint, near simultaneous optical - X-ray polarimetric observations explore different temperature, location and magnetic regions.**
- **What optical instrumentation**
  - **currently matches eXTP in terms of flux, time resolution and polarisation sensitivity?**
  - **will match once eXTP is launched?**



Moran et al, 2013, MNRAS, 433.2564M

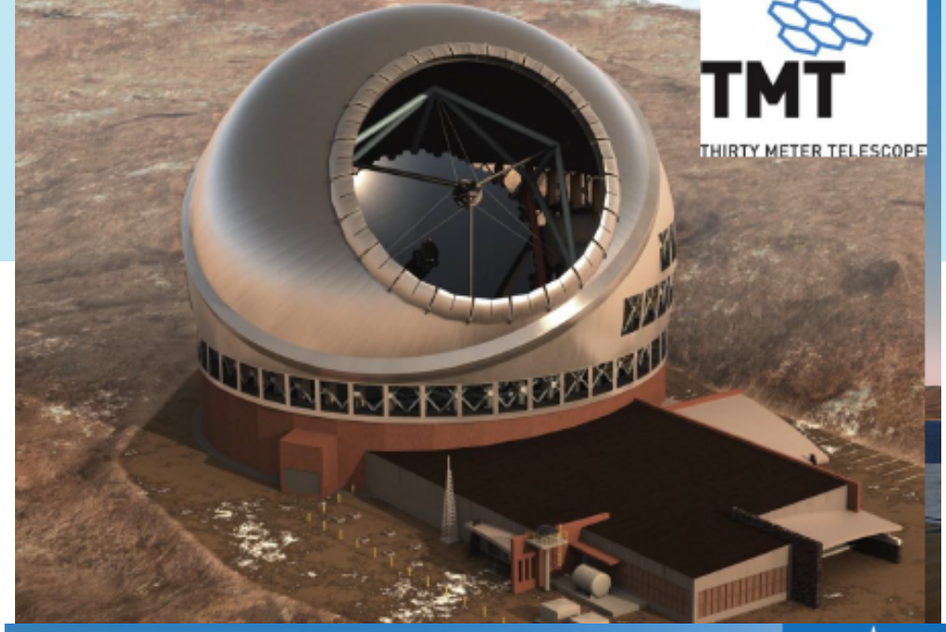


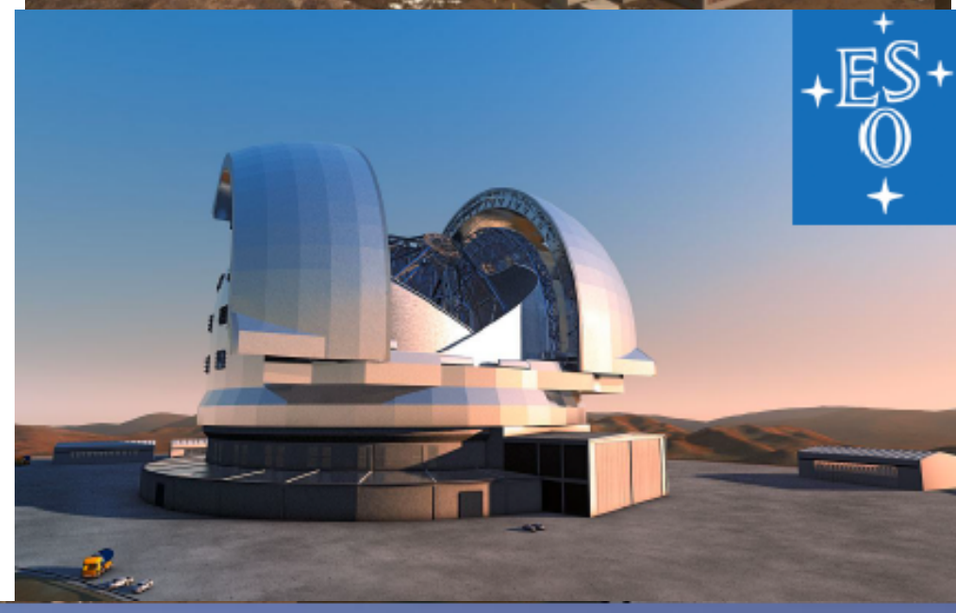
Moran et al, 2016, MNRAS, 456, 2974

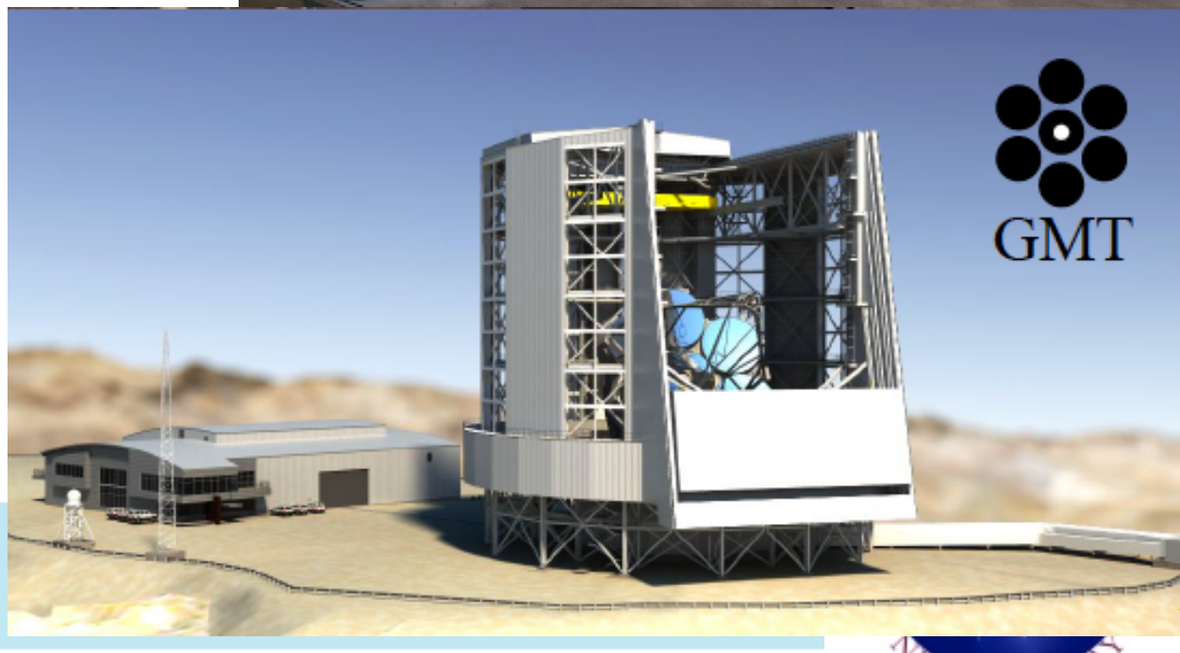
Some questions

- **What instrumental development (and lobbying?) is required to get such a match?**

- **Flux is not a problem - optical telescopes are good light buckets**
  - **timing - just a detector problem**
  - **polarisation - should be straight forward……..**



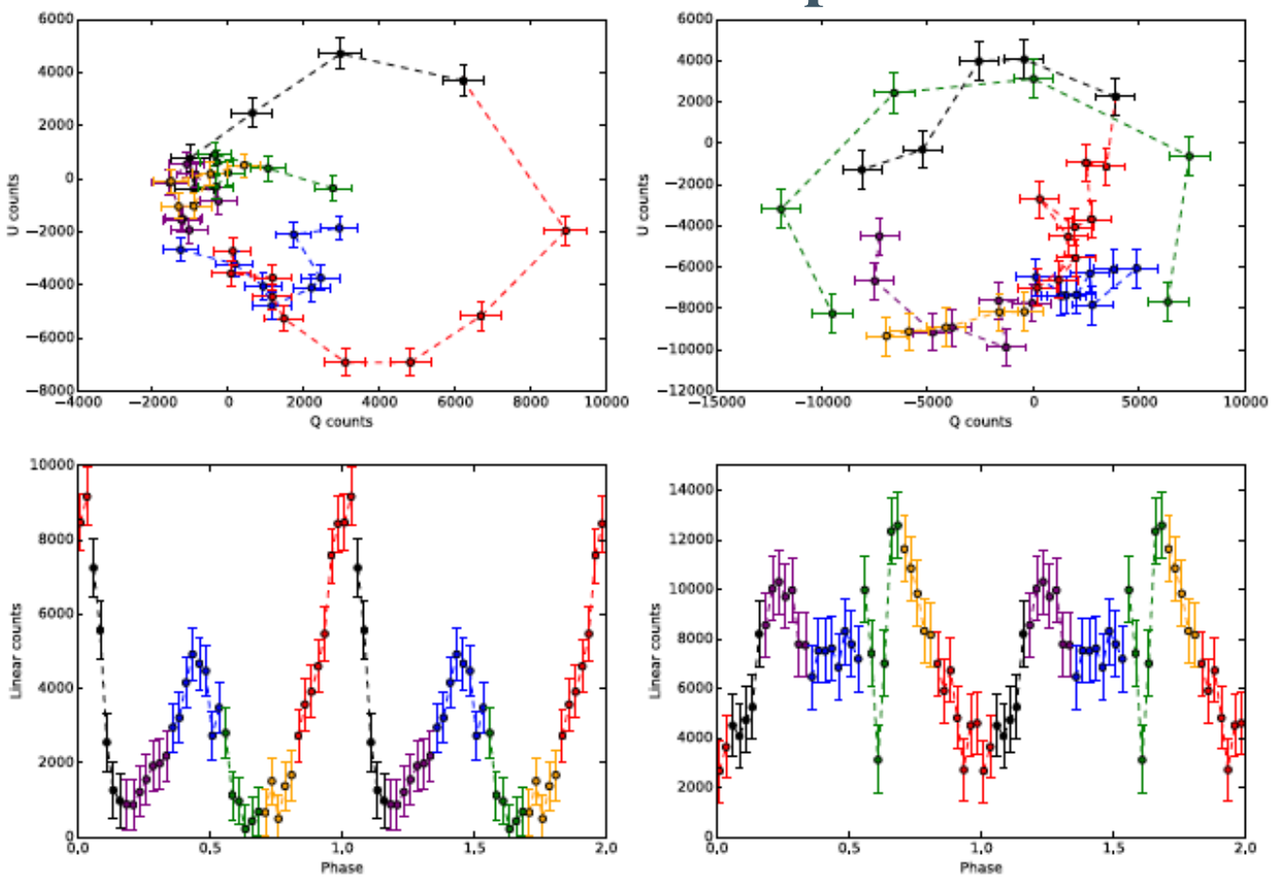




Current pretty big telescopes

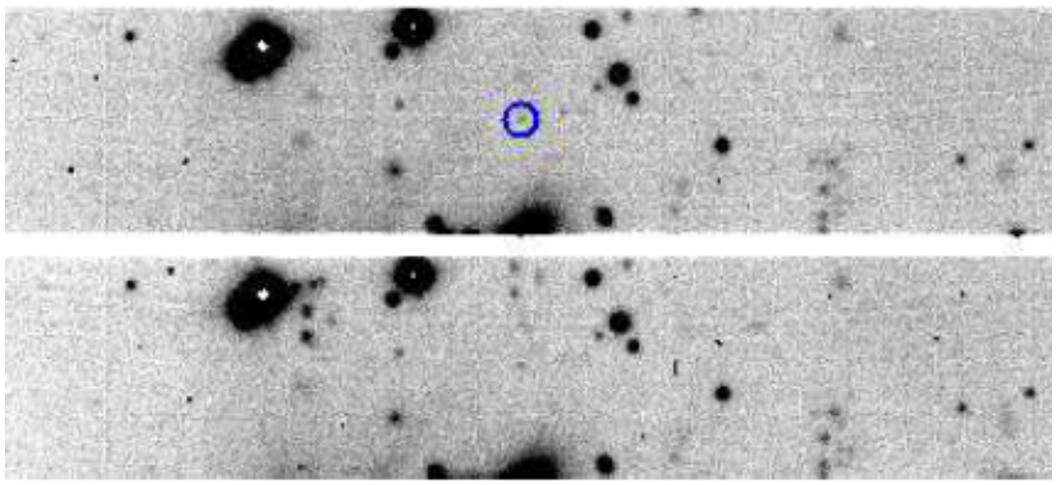
- **Current Observatory Polarimeters (not exhaustive)**
  - **SALT - RSS (a few Hz) - see e.g. Buckley et al, Nature Ast., 1E, 29**

AR Scorpii



- **VLT FORS2 (a few Hz)**

see e.g. Mignani et al, 2015, A&A...583A.105M



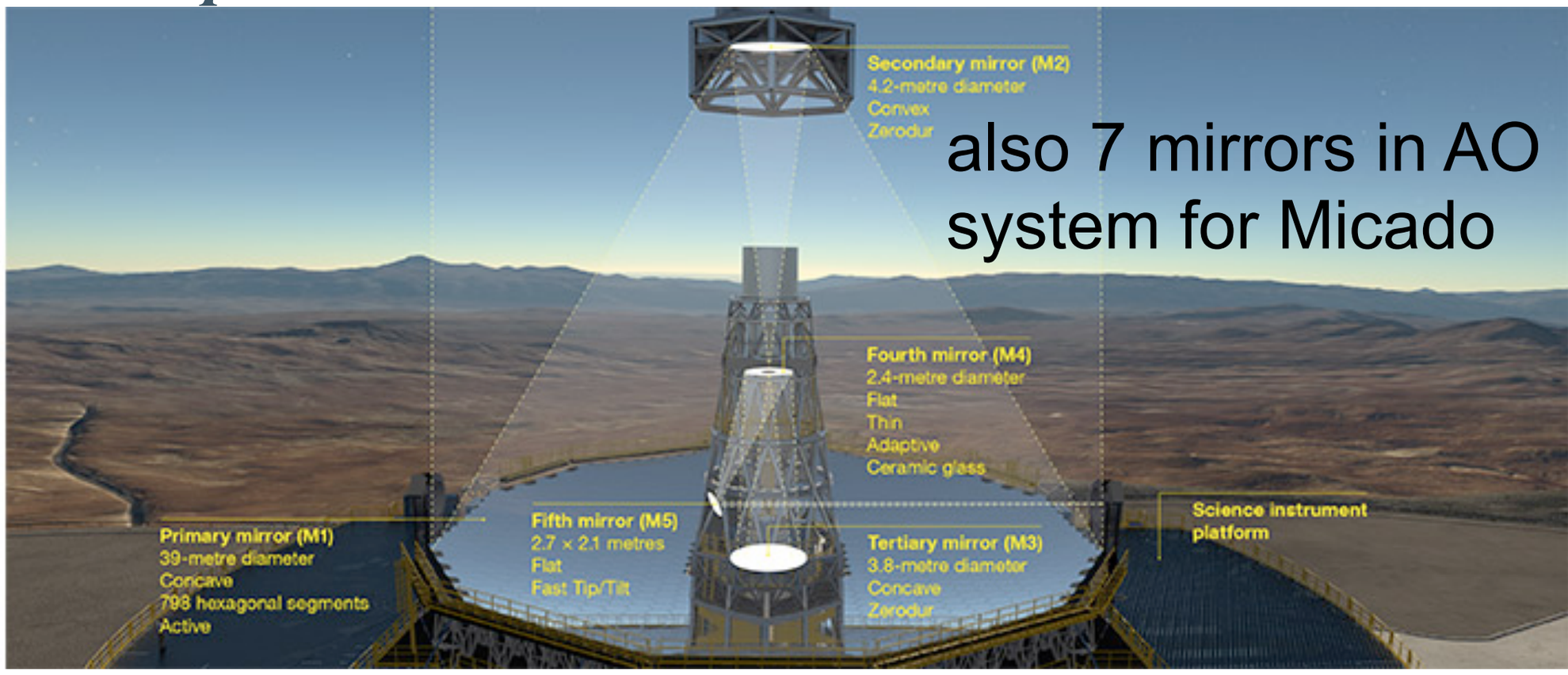
- **HST ACS (seconds)**
- **GTC - CIRCE (kHz)**
- **Subaru - FOCAS (seconds)**

Current observatory instruments are beginning to explore potential eXTP targets

Future - extremely large telescopes

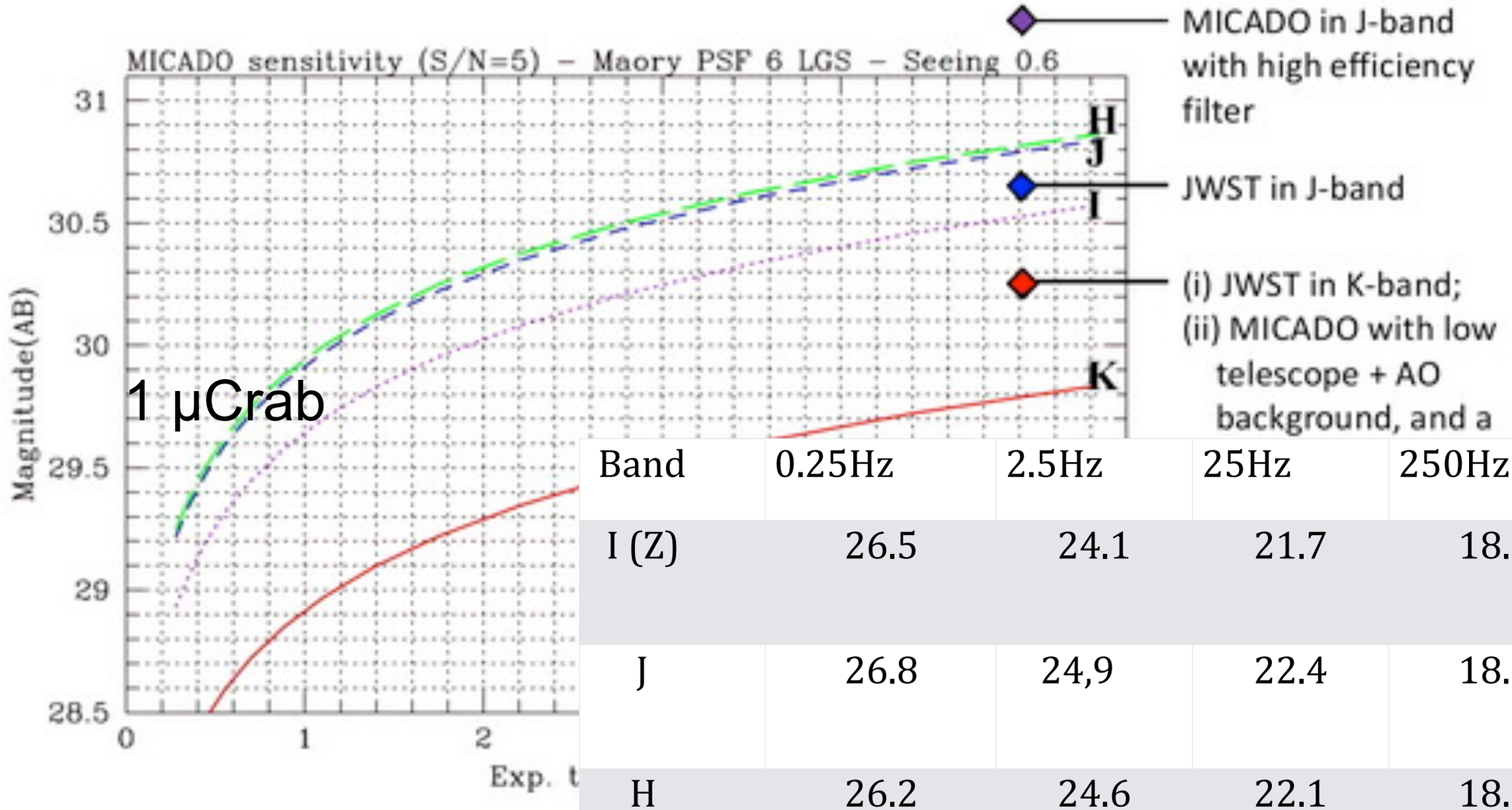
Future Observatory Polarimeters (not exhaustive)

- **JWST - no polarimetry (6.5m)**
- **LSST - no polarimetry (8m) - survey**
- **GMT - no first light polarimetry (25m)**
- **TMT - no first light polarimetry (30m)**
- **E-ELT - no polarimetry (39m) - "*..Ah, you have touched on the forbidden topic…….*"**



also 7 mirrors in AO system for Micado

E-ELT Micado / JWST Sensitivity

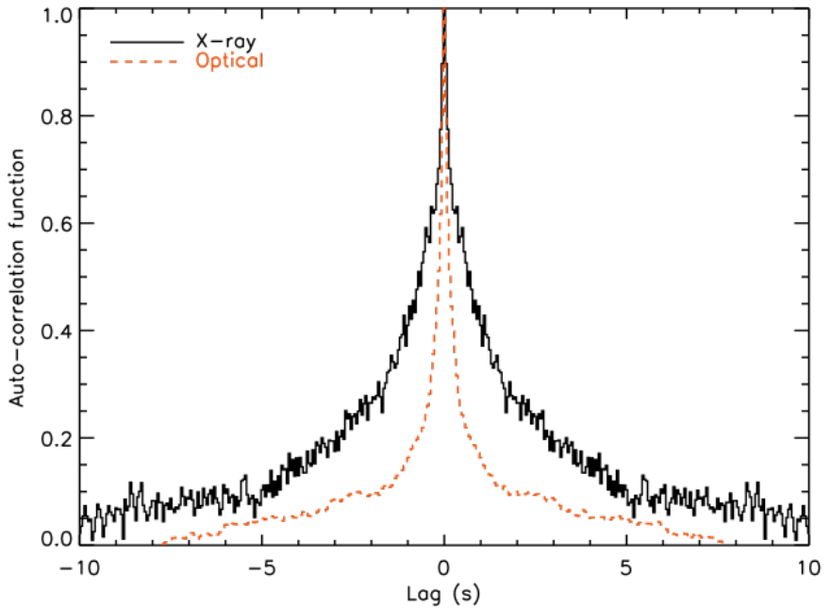


Band	0.25Hz	2.5Hz	25Hz	250Hz
I (Z)	26.5	24.1	21.7	18.0
J	26.8	24,9	22.4	18.9
H	26.2	24.6	22.1	18.9
K	25.3	23.9	21.9	18.3

Previous fast X-ray optical observations
Close Binary Systems

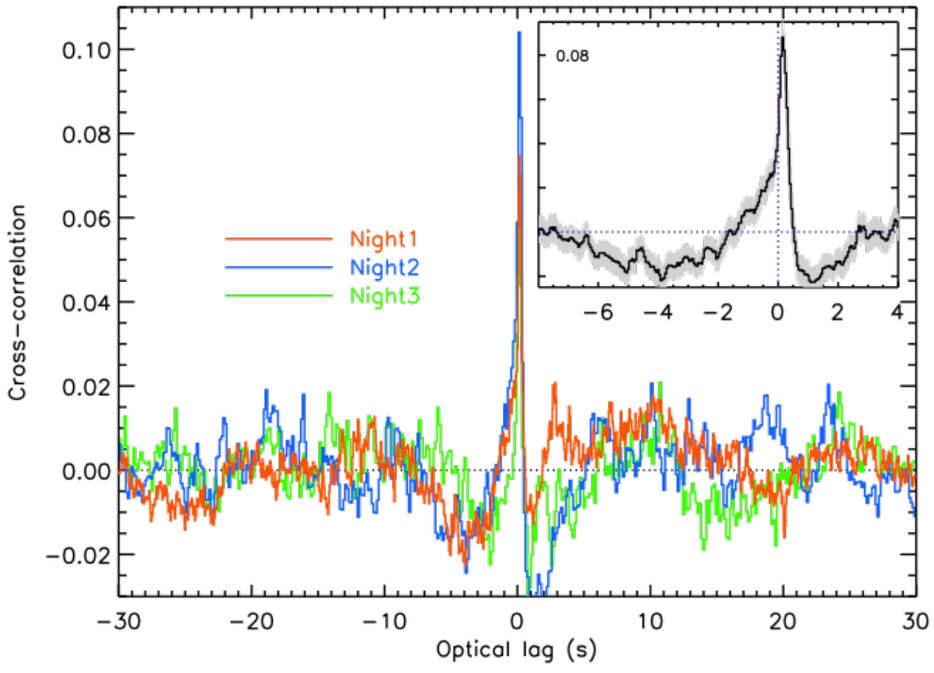
X-ray-Optical cross-correlations observed by UltraCam and Optima

Shown are UltraCam/VLT observations of the black-hole accretor GX339-4 simultaneous With RXTE - Gandhi et al (2008)



Time scales < 1 sec
Optical Autocorrelation indicated synchrotron emission from a possible jet structure rather than being driven by X-ray reprocessing.

GX339-4 is reasonably bright V~17. Other objects considerably fainter - E-ELT required to look at spectral variability



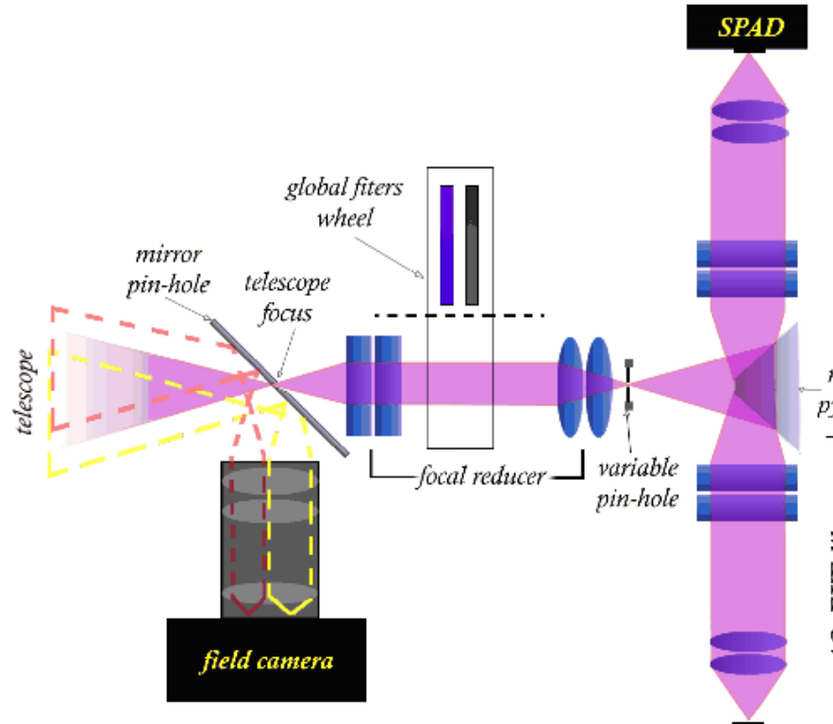
High Time Resolution Optical Polarimetry?

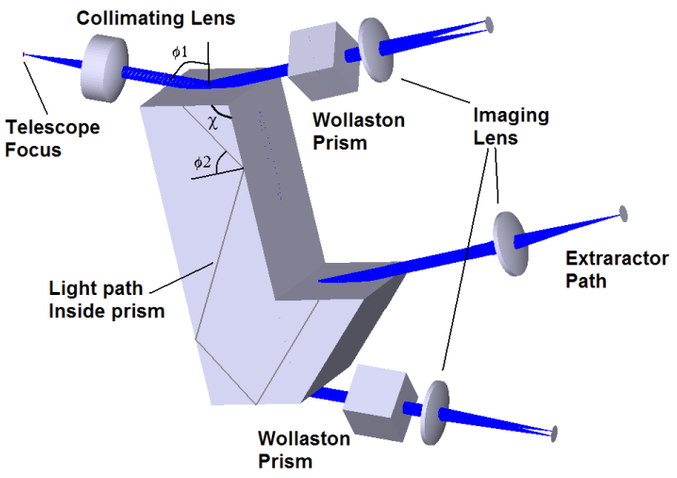
- High Time Observations need
  - fast detectors - **τ ~ μsec, maybe < 1 ns**
  - low read noise detectors in Optical/NIR : **n_e = 0**
    - **eAPDs [*Finger et al, 2014, SPIE, 9148, 17*]**
    - **MKIDS [*Mazin et al, 2013, PASP, 125, 1348*]**
  - high quantum efficiency detectors : **DQE ~ 100%**
  - high photon fluxes :
    - large collecting areas : **ELTs**
    - good throughput : ?
    - polarimetry without moving parts - division of amplitude polarimetry

See proceedings of 2014 Galway workshop - http://astro.nuigalway.ie/speedandsensitivity/

Current HTRA Instruments

Instrument	Detector	Group	τ (ms)	Type
UltraCam	Frame Transfer	Sheffield/ Warwick	5ms	Imager (3-Band)
UltraSpec	EMCCD	Sheffield/ Warwick	1ms	Spectrograph
GASP	EMCCD	Galway	600μs	Polarimeter
Optima	APD	MPE	1 ns	Photon counter
Iqueye	APD	Padova	0.1 ns	Photon counter
Arcons	MKID	UCSB	20 ns	Imager
CIRCE	HgCdTe Hawaii-2	Florida/ GTC	10 ms	NIR Imager/ Polarimter(?)



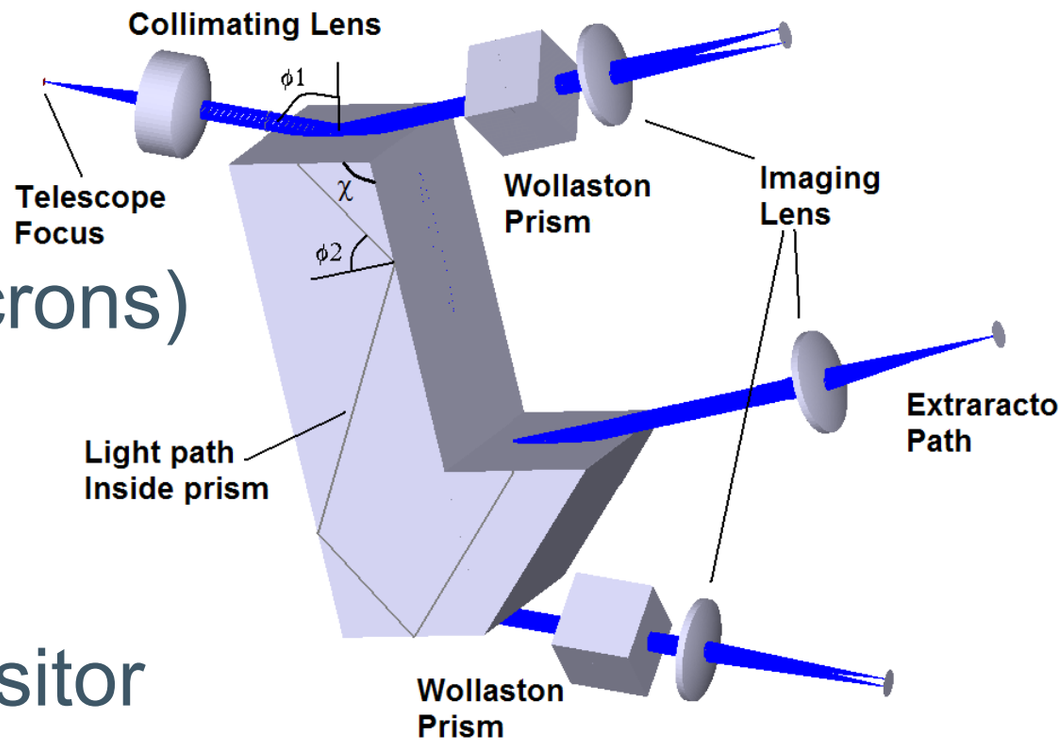


ESO - HTRA : Richichi et al 2009
see also - http://polarization.eu/index.php/list-of-instruments

Instrument	Modes	Detector	Time Rate (Window)
VISIR	Burst	DRS	12.5 ms SF
SOFI	Burst, FastPhot	Hawaii	4 ms (8 x 8), 15 ms (32 x 32)
ISAAC	Burst, FastPhot	Hawaii-1, Aladdin	3 ms (32 x 32), 6 ms (64 x 64)
ISAAC	Burst	Hawaii-1, Aladdin	9 ms (1024 x16)
NACO	Cube	Aladdin	7.2 ms (64 x 64), 350 ms (1024 x 1024)
HAWK-I	Fast	Hawaii-2RG	6.3 ms (16 x 16)
FORS2	HIT	CCD (charge shift)	up to 2.3 ms
VLTI	Fast	Various	up to 1 ms

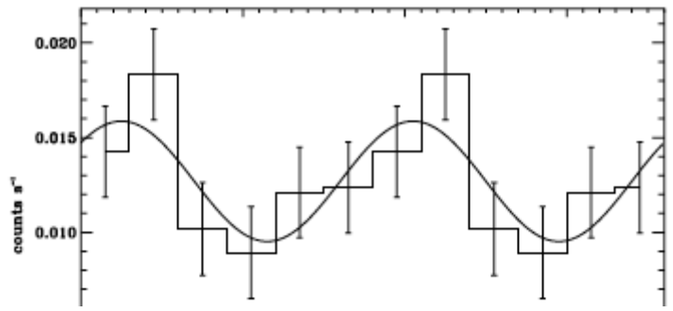
What is the ideal imaging optical polarimeter for eXTP era?

- Large aperture ~ 8m
- **2-D detectors**
- **Optical** and NIR sensitivity (0.5 - 2 microns)
- **Fast ~ τ ~ 100 μs**
- **Low (zero) read noise**
- Stable observatory instrument, not a visitor
- **Linear and Circular polarisation**
- Also
  - need faint polarimetric standards
  - **polarimetry and fast timing should be built into the design at the start**

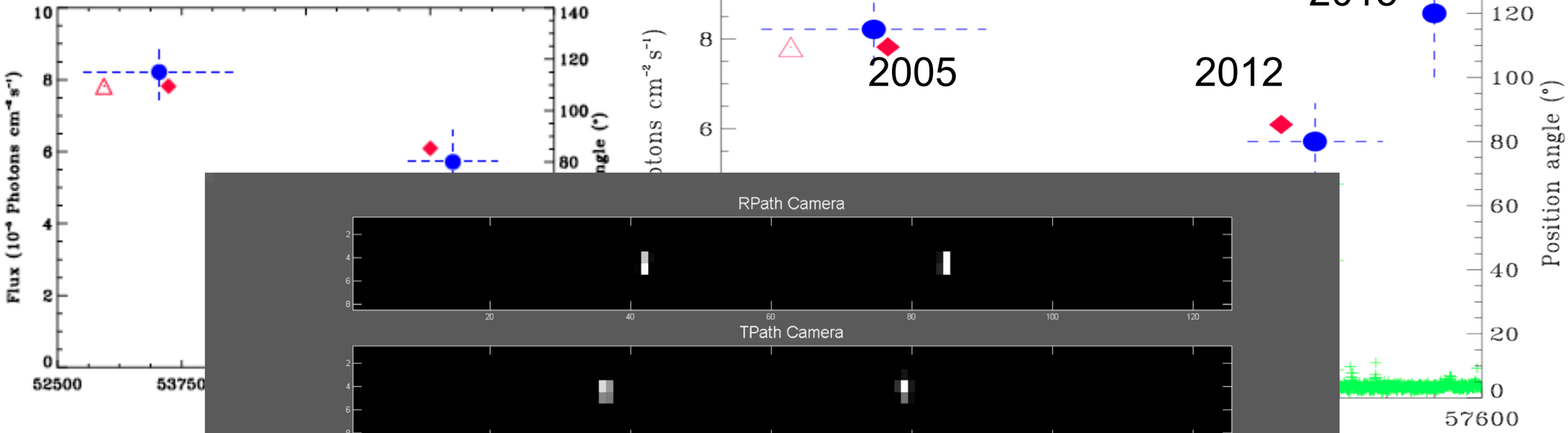


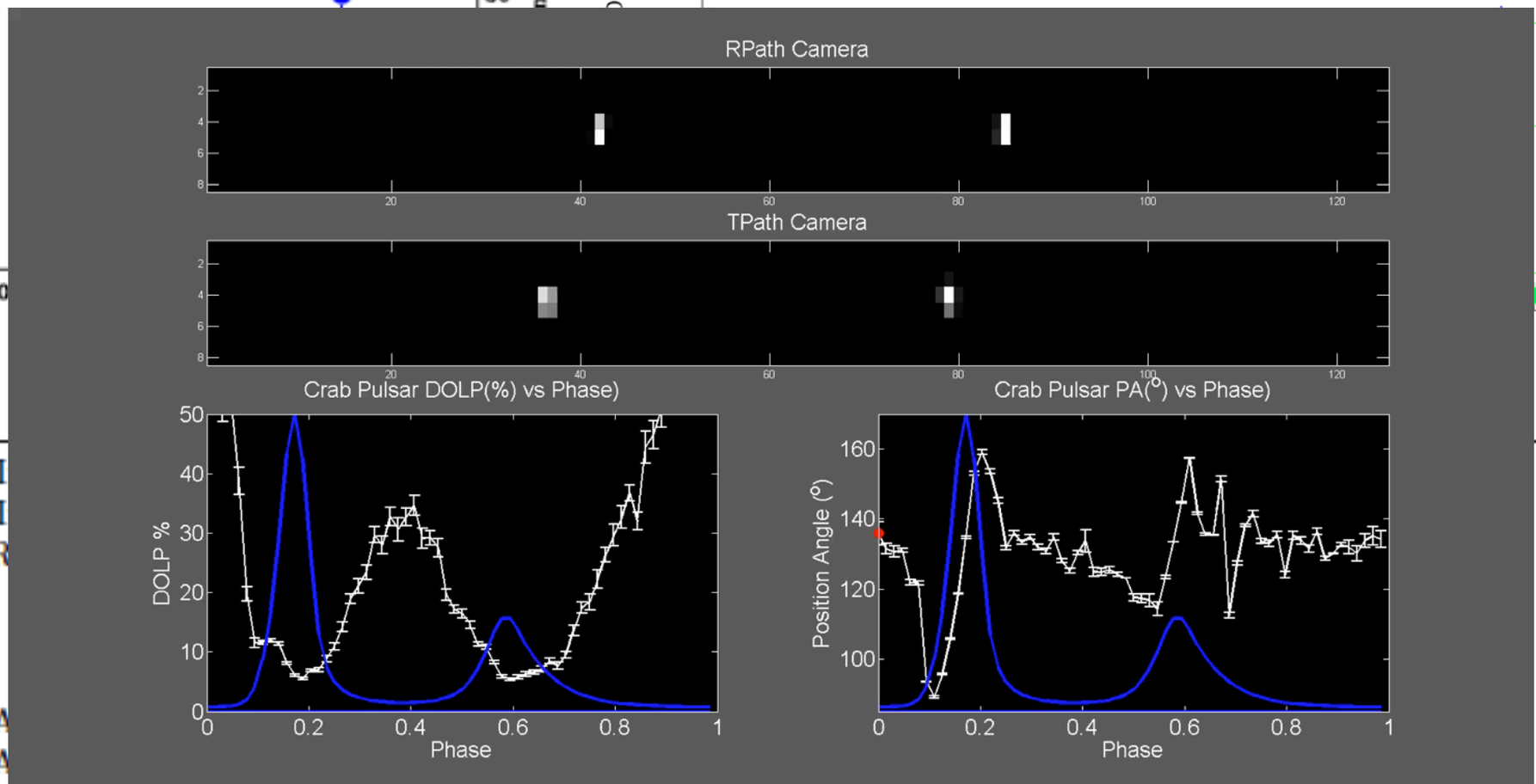
GASP - Galway Astronomical Stokes Polarimeter

- Collins et al, 2013, Exp Astr, 36, 479 & Kyne et al, 2016, Exp Astr, 41, 43
- Visitor instrument on WHT and Palomar
- Moran et al, 2016, MNRAS, 456, 2974



A recent change in the optical and γ-ray polarization of the Crab nebula and pulsar





γ-ray	I	[1]
γ-ray	I	[1]
Optical	R	[2]
Optical		[3]
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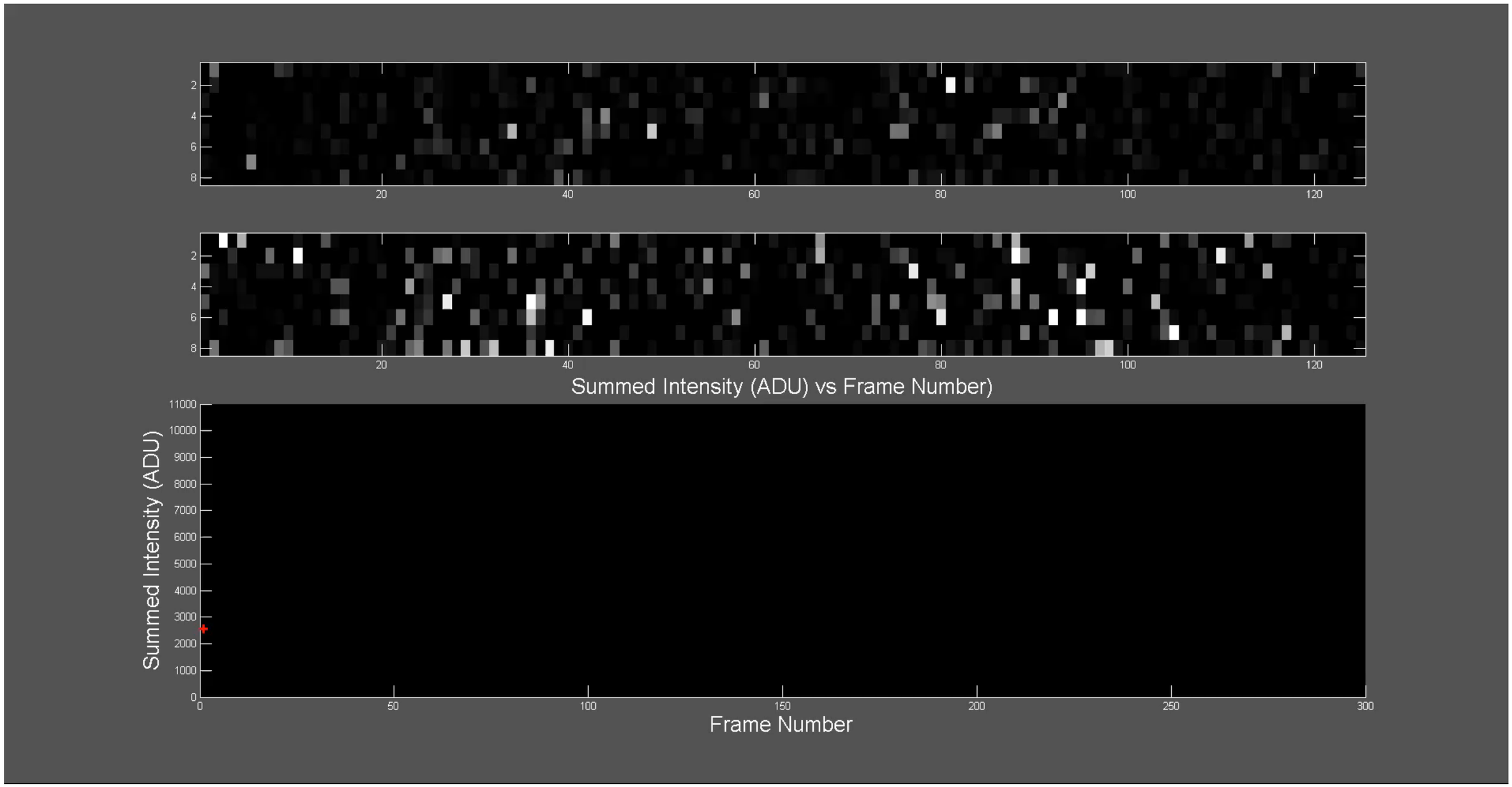
Optical	GA	[1]
Optical	GA	[1]

Summary what is needed - now & to 2024

- ELTs - no immediate polarisation plans, what happens to existing 4 and 8m class telescopes in the ELT (and eXTP) era
- Dedicated imaging polarimeters on 4-8m telescopes…..
  - optical response up to 2 microns, need fast NIR detectors, **eAPDs, MKIDs** ….
  - able to respond to transients
- Survey of faint polarimetric standards
- International collaboration to build such instruments - there already exist a good network of developers - Optima, Iqueye, GASP and UltraCam - **ní GASP or eGASP**?
- Need a good spread of telescopes - different longitudes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Summed Intensity (ADU) vs Frame Number)
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Summed Intensity (ADU)
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300
Frame Number