NEAR-INFRARED ASTROMETRY: PROGRESS AND PROSPECTS at USNO

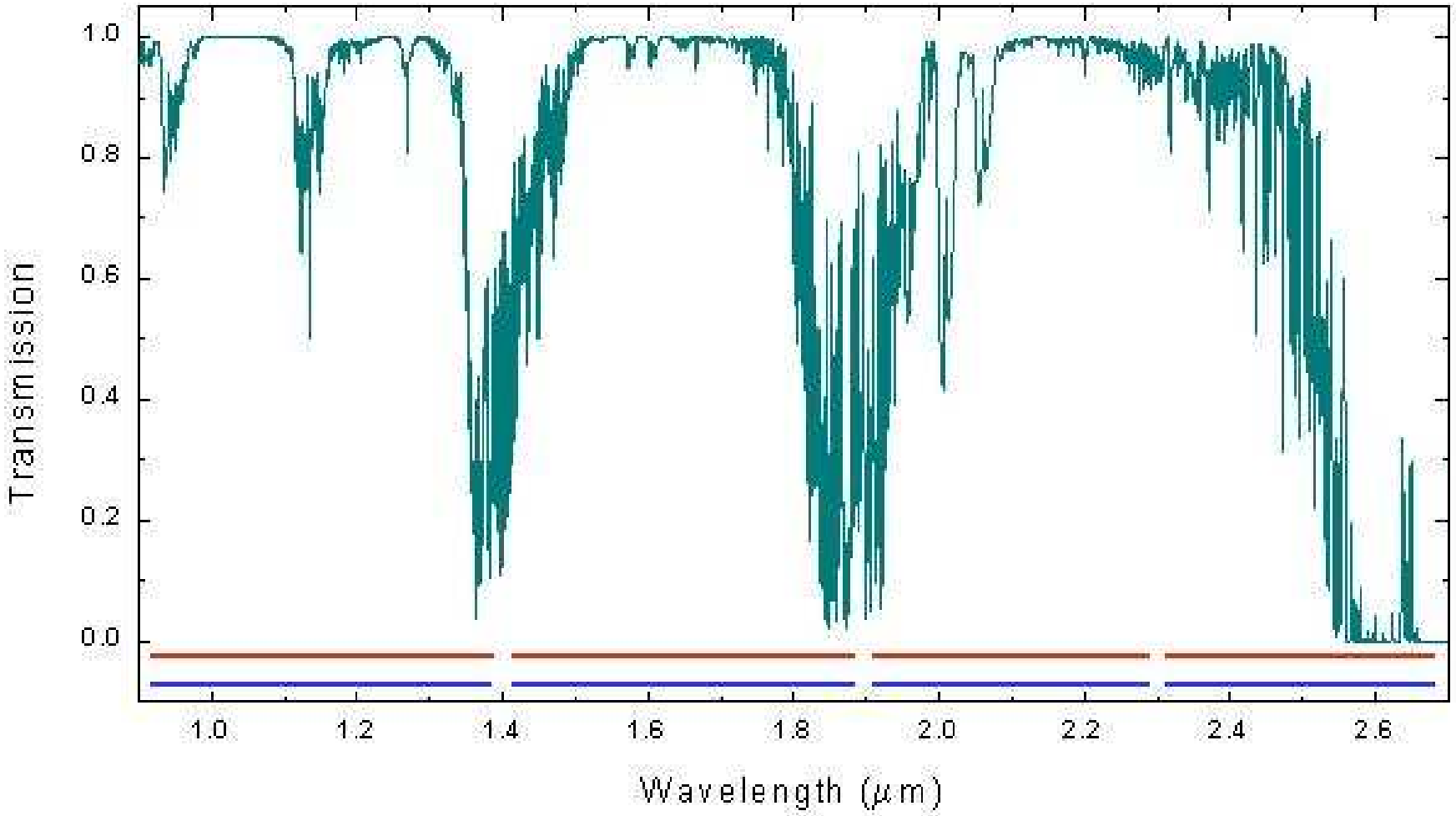
Frederick J. Vrba
U.S. Naval Observatory, Flagstaff Station
10391 W. Naval Observatory Road,
Flagstaff, AZ 86001-8521
tel: (928) 779-5132, e-mail fjv@nofs.navy.mil

TALK OUTLINE

- Brief history of IR sky surveys/astrometry
- Why these wavelengths are important
- November 1997
- USNO near-IR astrometry program
- Next generation detectors/cameras
- Some future DoD applications

Wavelength Nomenclature

- Optical: 0.34 – 0.9 μm
  (Sun: 5800K → 0.5 μm)
- Near-IR: 1.0, 1.25, 1.65, 2.2, 3.5 μm
  (Sub-stellar, exhaust 1300K → 2.2 μm)
- Mid-IR: 5, 10, 20 μm
  (Planets, sats, etc 300K → 10 μm)
- Far-IR: 20+, 100 μm, 200 μm, sub-mm
  (cold celestial objects 30K → 100 μm)


Transmission
1.0
0.8
0.6
0.4
0.2
0.0
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Wavelength (μm)

The Two Micron Sky Survey

- Neugebauer & Leighton (1969)
- 62-inch telescope
- Monolithic detector
- 70% sky coverage
- 5700 objects (5000 point sources)
- Positions to a few arcsec

2MASS:Two Micron All Sky Survey

- Observations obtained during1997-2001
- Two 1.3-m telescopes in N/S hemispheres
- 256x256 HgCdTe
- 100% sky coverage for |b| > 10 deg
- 300M objects (1M galaxies)
- S/N = 10 limiting mags: J, H, K_s = 15.8,15.1,14.3
- Astrometric σ ~ 100-130 mas (70 mas best)
  (Monet, Stone, Zacharias @ USNO and others)

AFCRL IR Survey

- Walker and Price (1975)
- Series of rocket flights
- 90% sky coverage
- 2000 sources @ 4 μm, 11 μm, & 27 μm
- Astrometric σ ~ 1300 mas

IRAS: Infrared Astronomical Satellite

- 0.6-m aperture satellite – Jan 1983 launch
- All-sky
- 12 μm, 25μm, 60 μm, & 100 μm
- 350,000 sources (250,000 point sources)
- Astrometric σ ~ 2000 mas

November 1997 (I): 5th Astrometry Forum

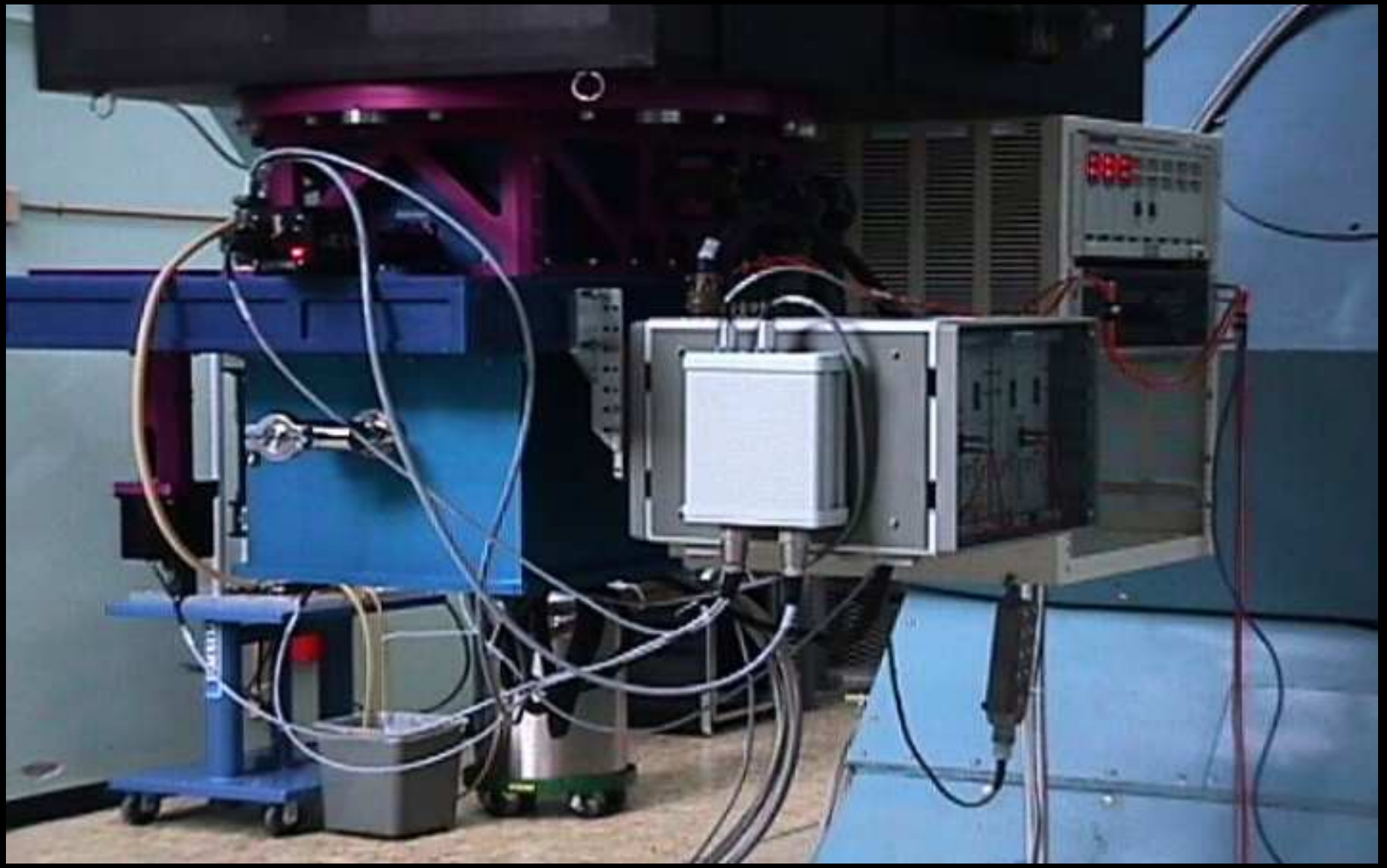
- IRCAM – 256x256 HgCdTe test system @ NOFS 1.55-m telescope-operational1995
- Can you operate 1-2 μm system on non-IR optimized telescope? – Yes
- Astrometric testing results – σ ~ 13 mas

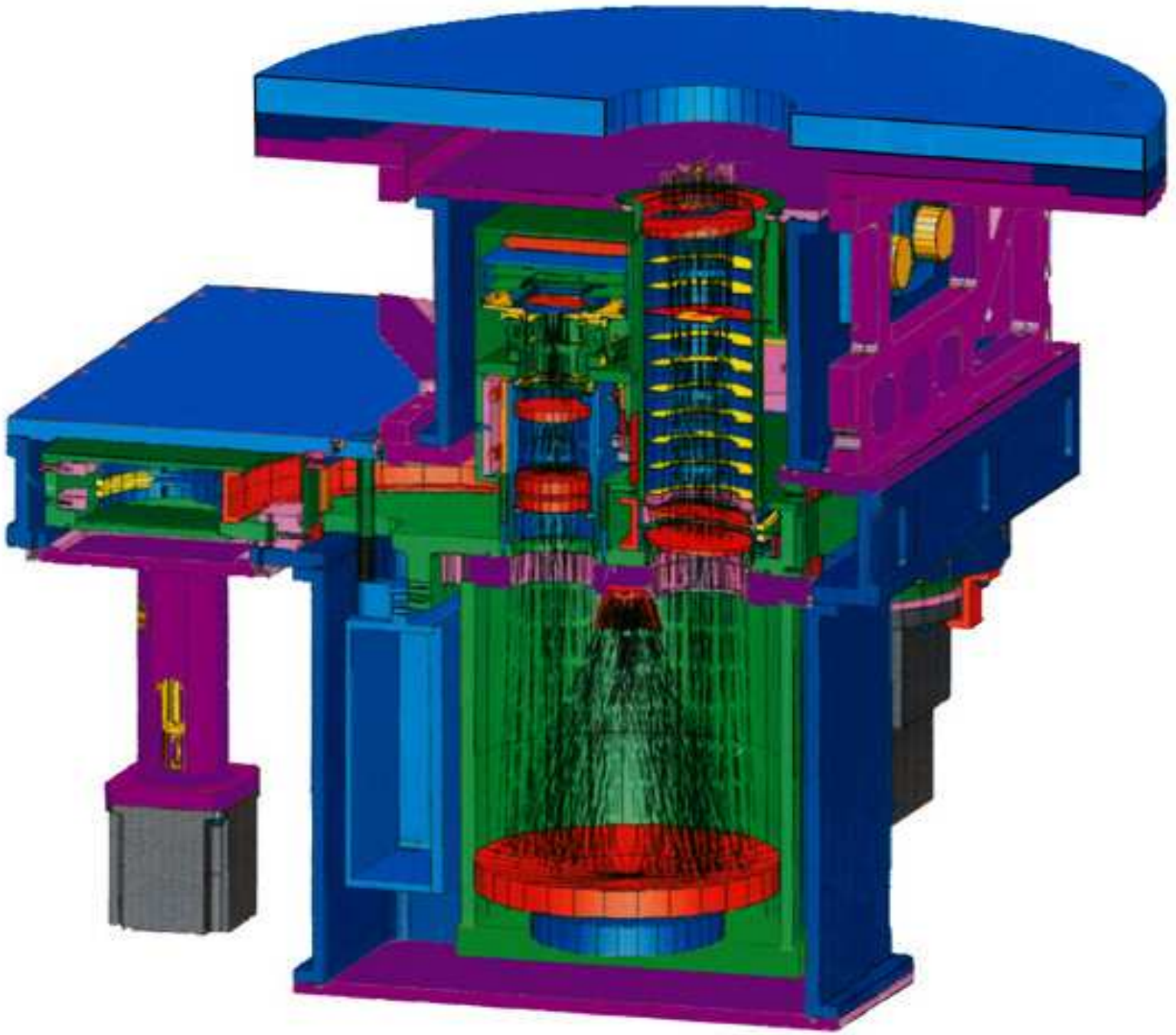
November 1997 (II): 5th Astrometry Forum

- IRCAM only test system – small FOV, marginal pixelization, residual images, etc
- Anticipated new 1024x1024 InSb devices (USNO/NOAO sponsored) in 1998 (science grade delivered 2000)
- Anticipated new camera system for InSb (ASTROCAM) in 1998 (delivered 1999)

IRCAM vs. ASTROCAM

	IRCAM	ASTROCAM
Detector	HgCdTe	InSb
Format	256x256	1024x1024
Pix Pitch	40 μm	27 μm
Pixelization	0.54 arcsec/pix	0.365 arcsec/pix
Wavelength	1.2 – 2.2 μm	1.0 – 3.5 μm
Q.E.	20-60%	90%
Charge Capacity	200K e^-	400K e^-
Manufacturers	Rockwell/UCLA	Raytheon/MKI



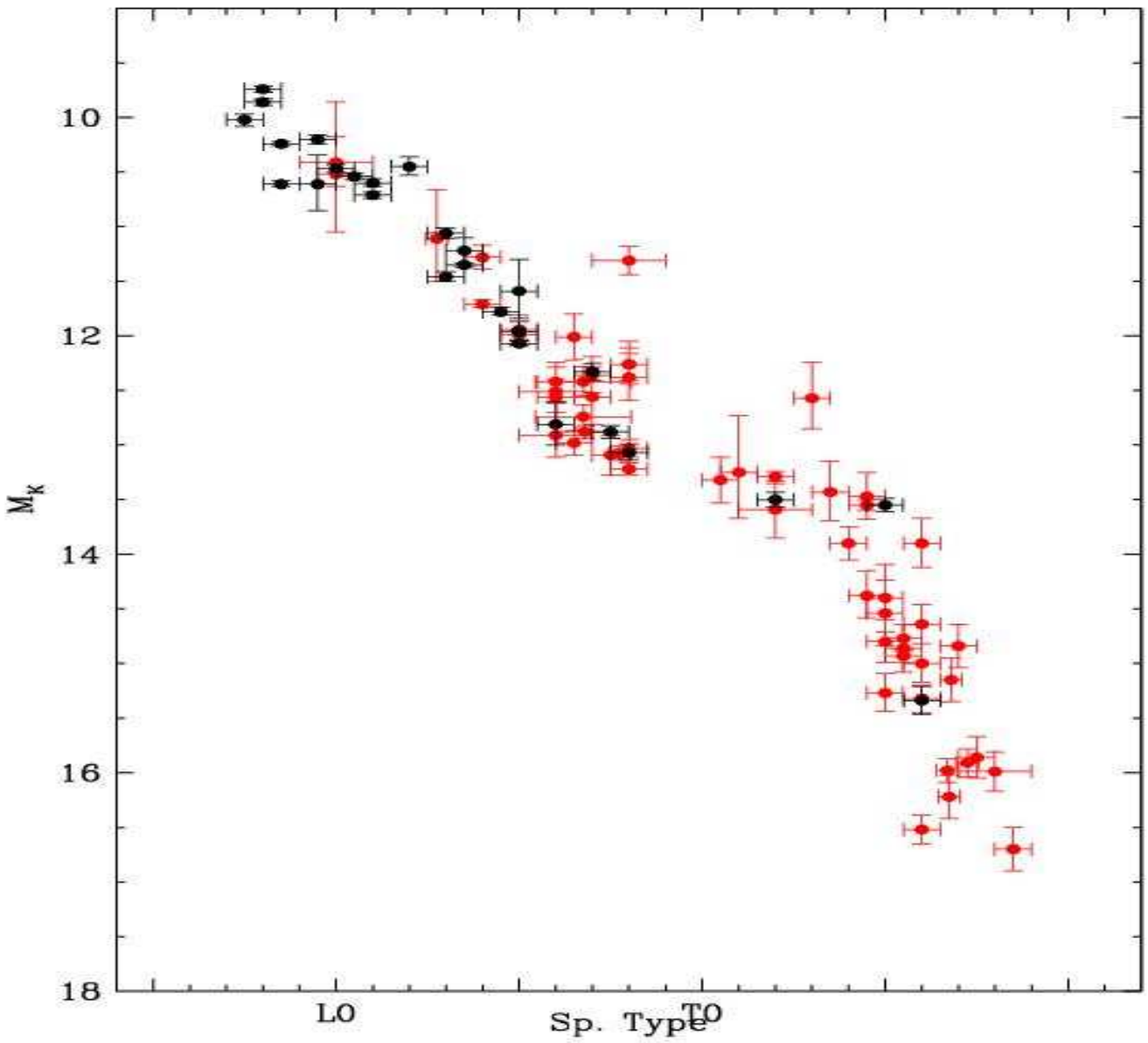


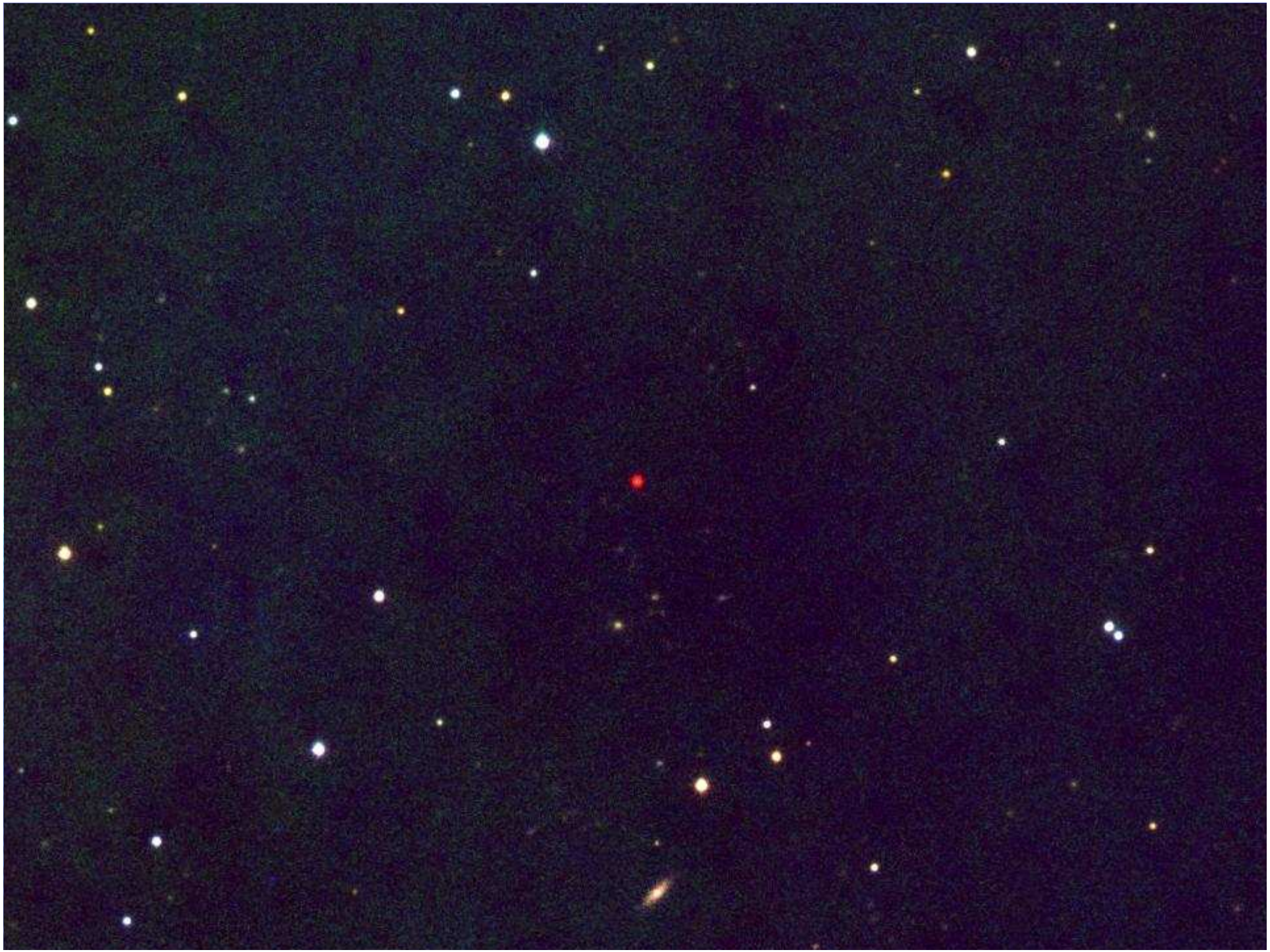
Near-IR Astrometry Program

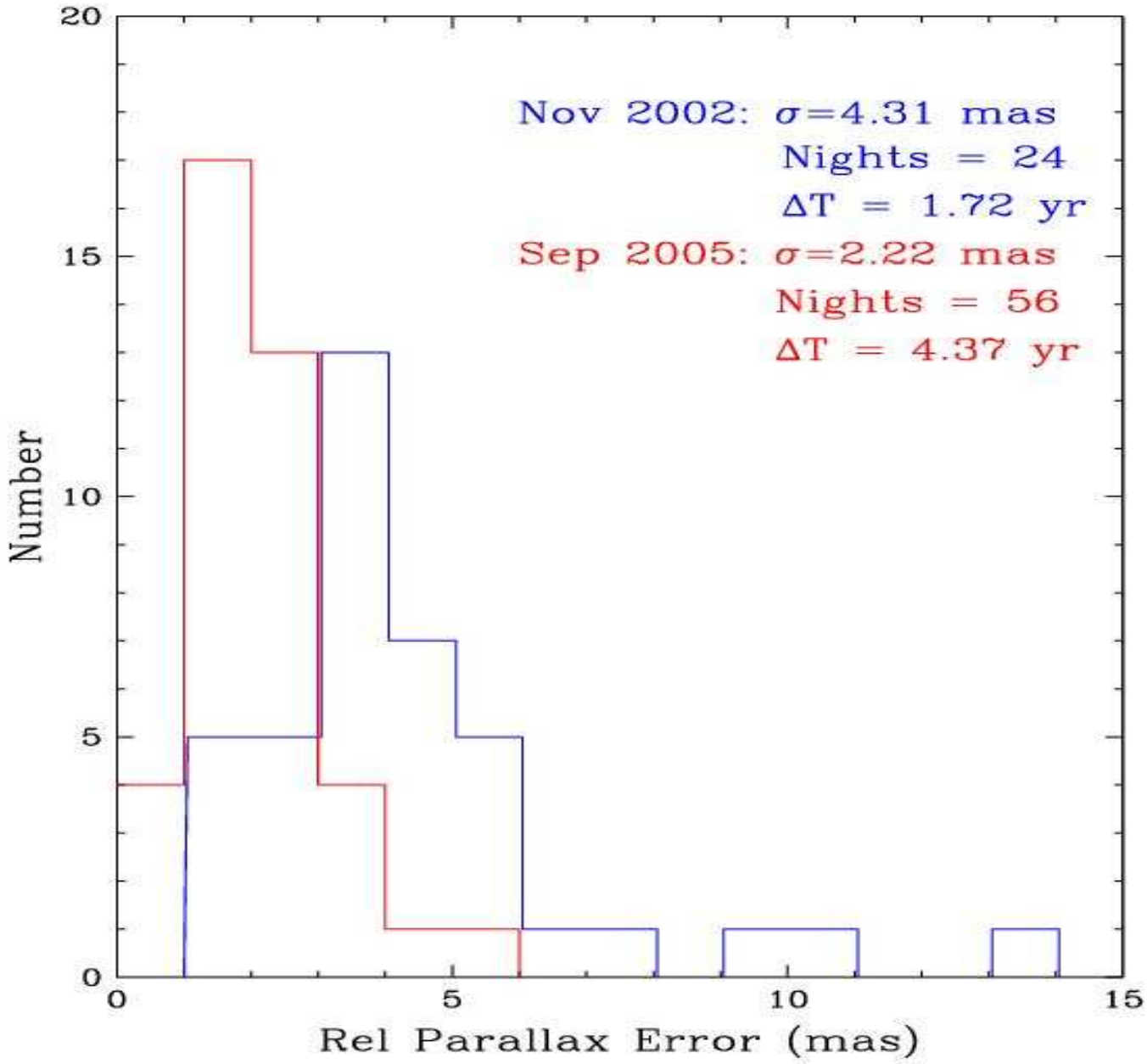
- Began September 2000 w/ 40 objects
- 22 L dwarfs (1300 - 2400K) (H-band)
- 18 T dwarfs (700 – 1300K) (J-band)
- From 2MASS and SDSS
- Today program expanded to ~ 70 objects
- Program delivers both science & astrometric testing
- Preliminary results in May 2004 Astron.J.

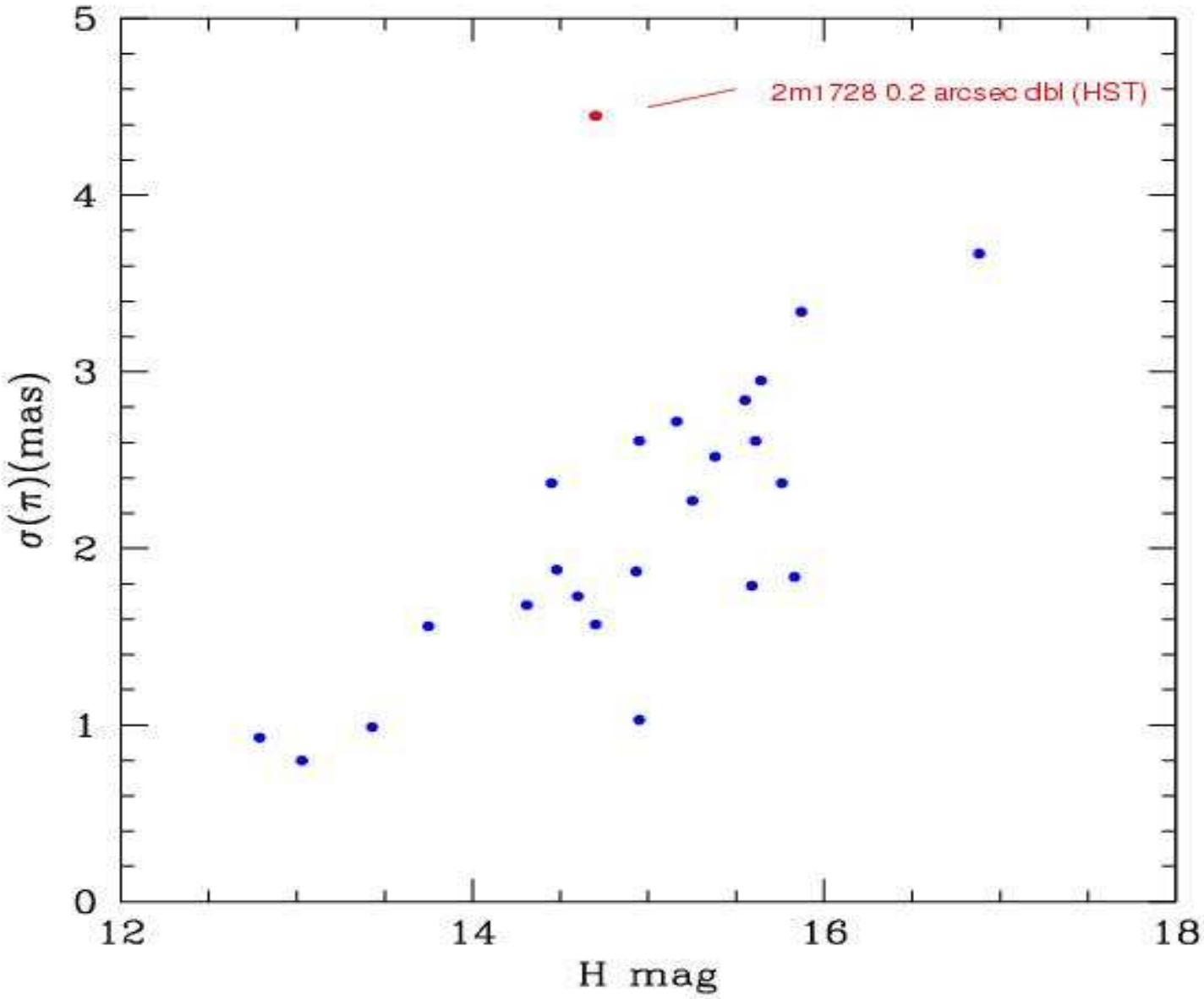
Questions & Reminder

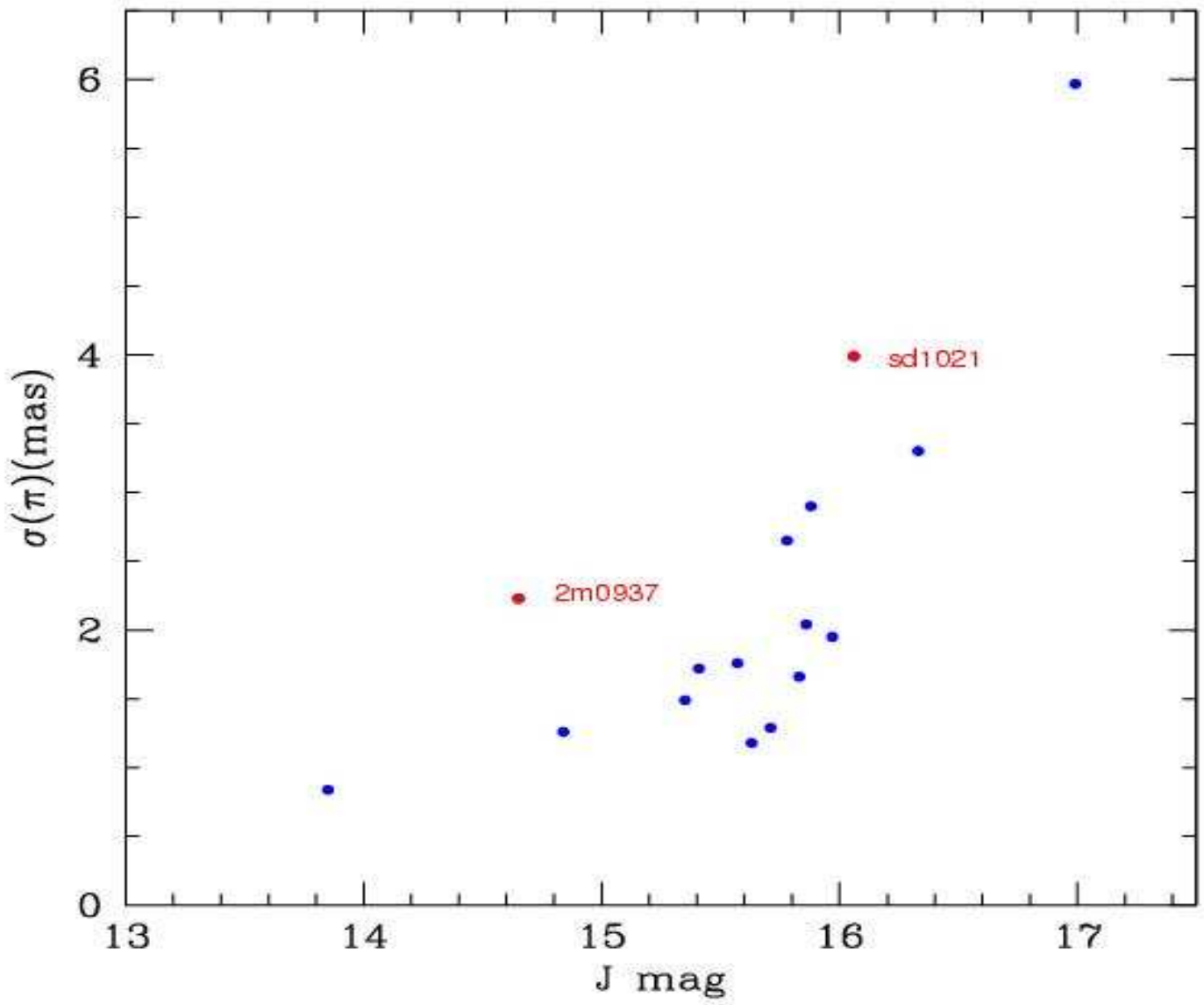
- How well can you do small angle near-IR astrometry with a camera specifically designed for this purpose?
- Long-term stability - $\sqrt{n}$ statistics
- σ of a single measurement of unit weight
- The near-IR sky is much different than the optical!

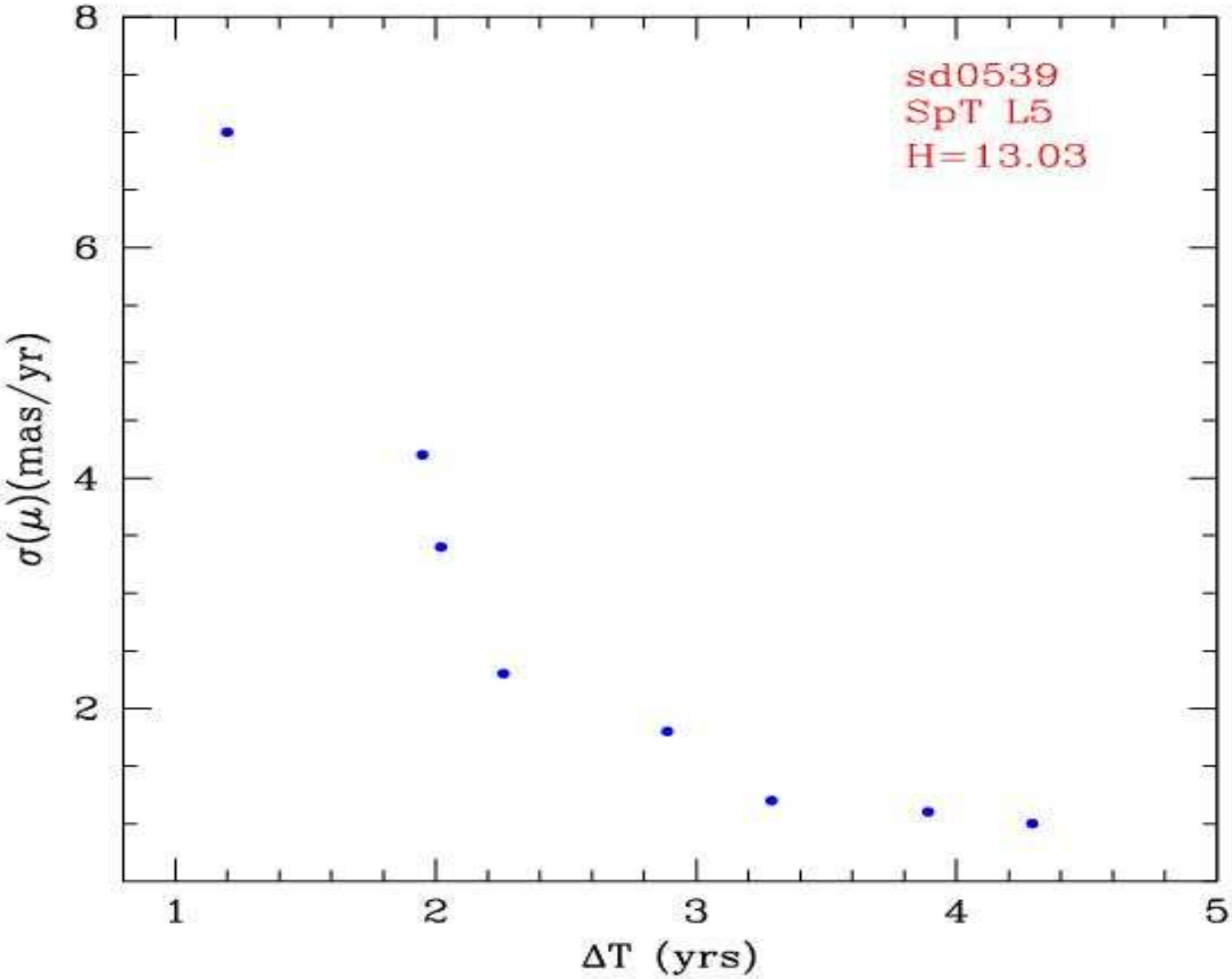

10
12
14
16
18
M_k
L0
Sp. Type
T0

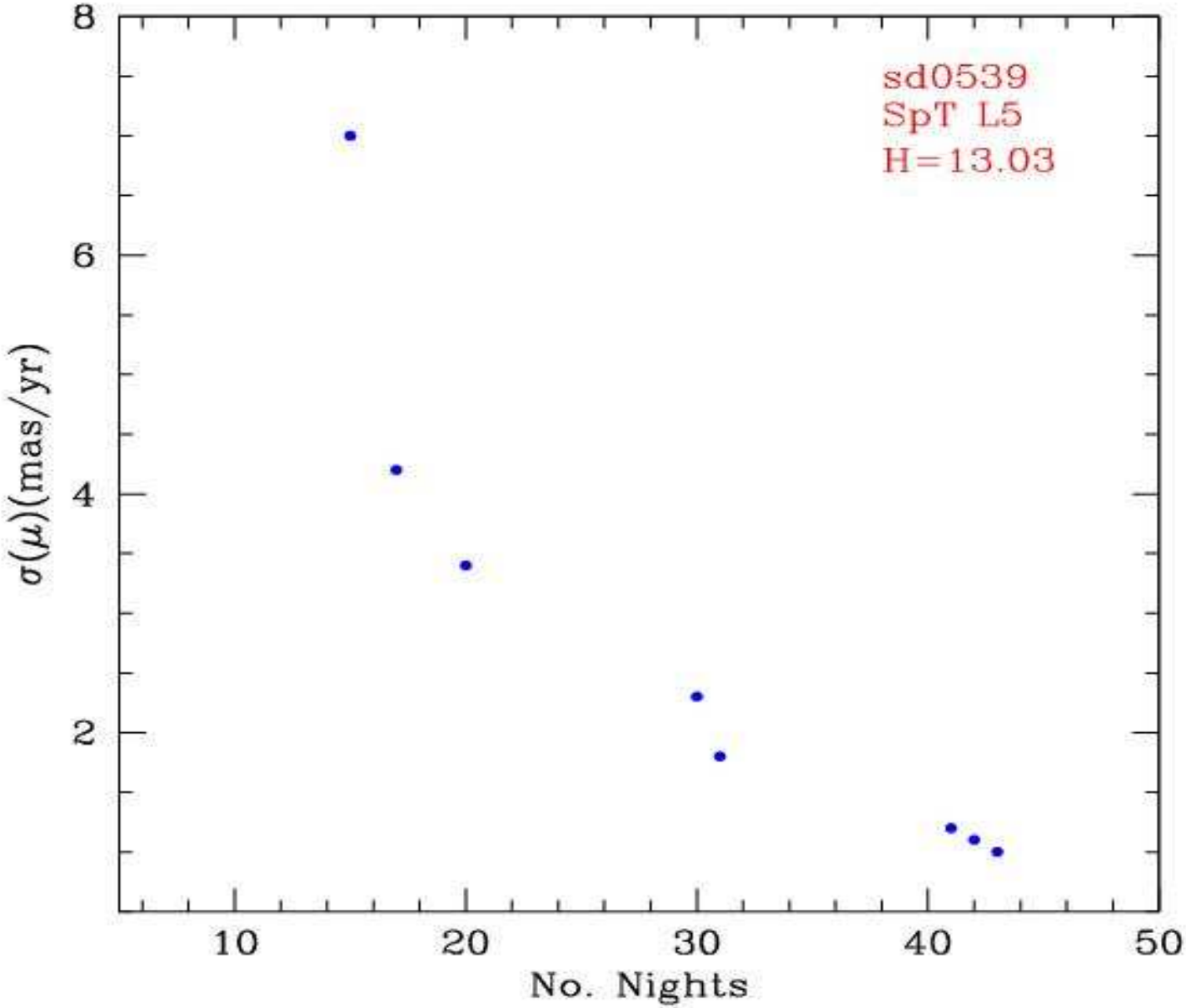


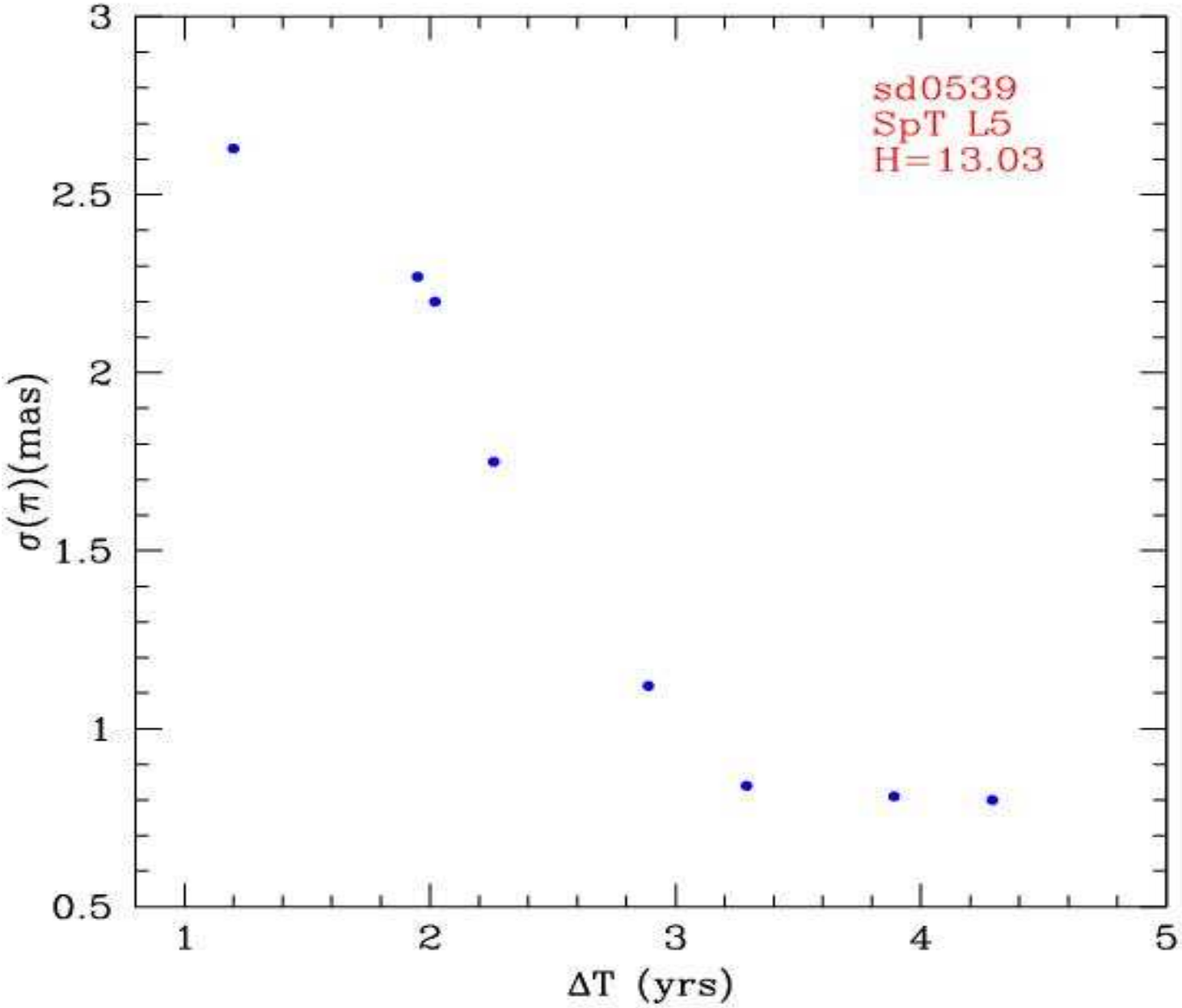

Nov 2002: σ=4.31 mas
Nights = 24
ΔT = 1.72 yr
Sep 2005: σ=2.22 mas
Nights = 56
ΔT = 4.37 yr
Number
Rel Parallax Error (mas)
0
5
10
15
20

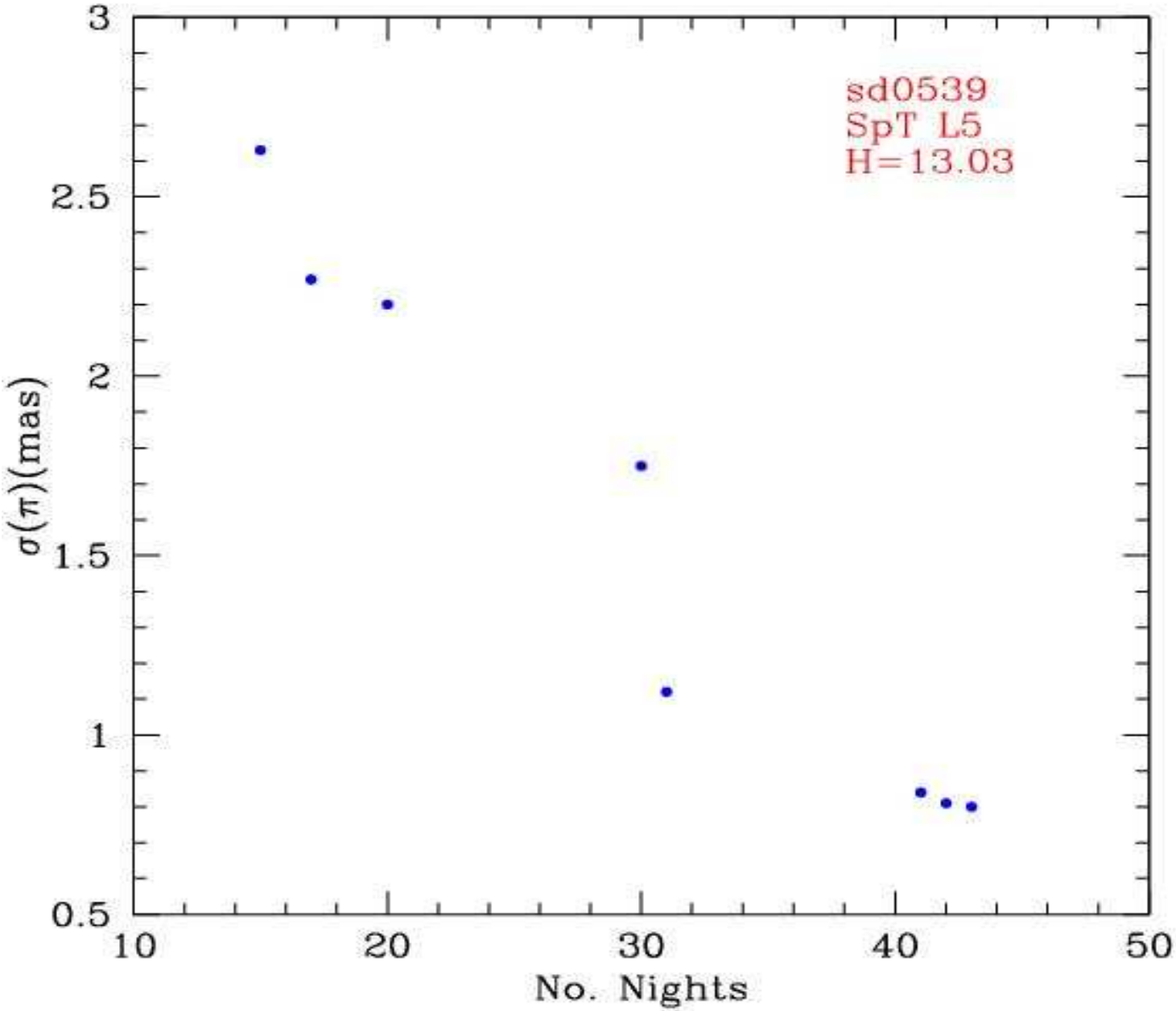

2m1728 0.2 arcsec dbl (HST)
σ(π)(mas)
H mag
0
1
2
3
4
5
12
14
16
18

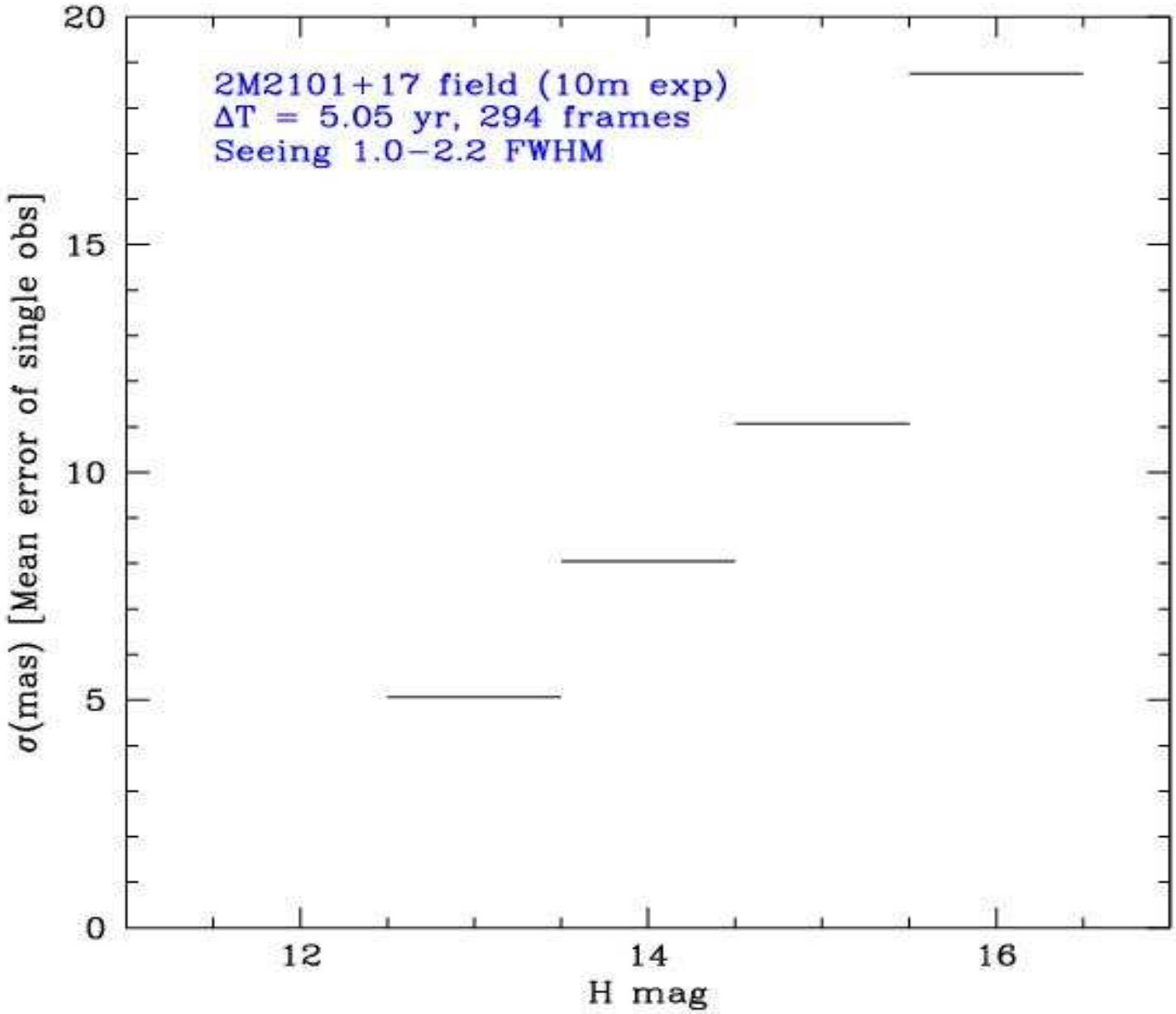

6
4
2
0
σ(π)(mas)
sd1021
2m0937
13
14
15
16
17
J mag

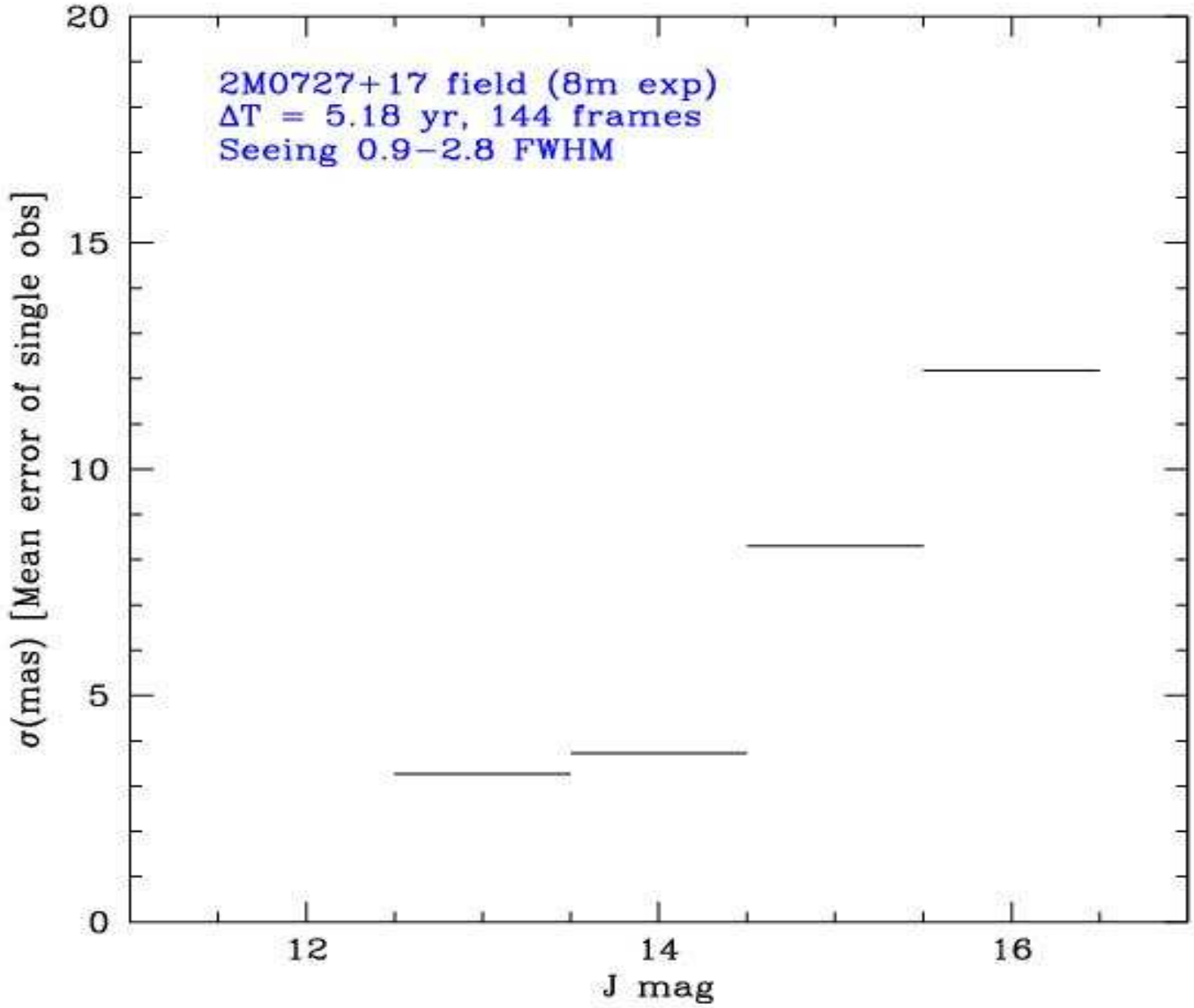

sd0539
SpT L5
H=13.03
σ(μ)(mas/yr)
ΔT (yrs)
8
6
4
2
1
2
3
4
5


sd0539
SpT L5
H=13.03
σ(μ)(mas/yr)
No. Nights
8
6
4
2
10
20
30
40
50


sd0539
SpT L5
H=13.03
σ(π)(mas)
ΔT (yrs)
3
2.5
2
1.5
1
0.5
1
2
3
4
5


sd0539
SpT L5
H=13.03
σ(π)(mas)
No. Nights
3
2.5
2
1.5
1
0.5
10
20
30
40
50


2M2101+17 field (10m exp)
ΔT = 5.05 yr, 294 frames
Seeing 1.0−2.2 FWHM
σ(mas) [Mean error of single obs]
H mag
0
5
10
15
20
12
14
16


2M0727+17 field (8m exp)
ΔT = 5.18 yr, 144 frames
Seeing 0.9−2.8 FWHM
σ(mas) [Mean error of single obs]
J mag
0
5
10
15
20
12
14
16

Numbers to remember

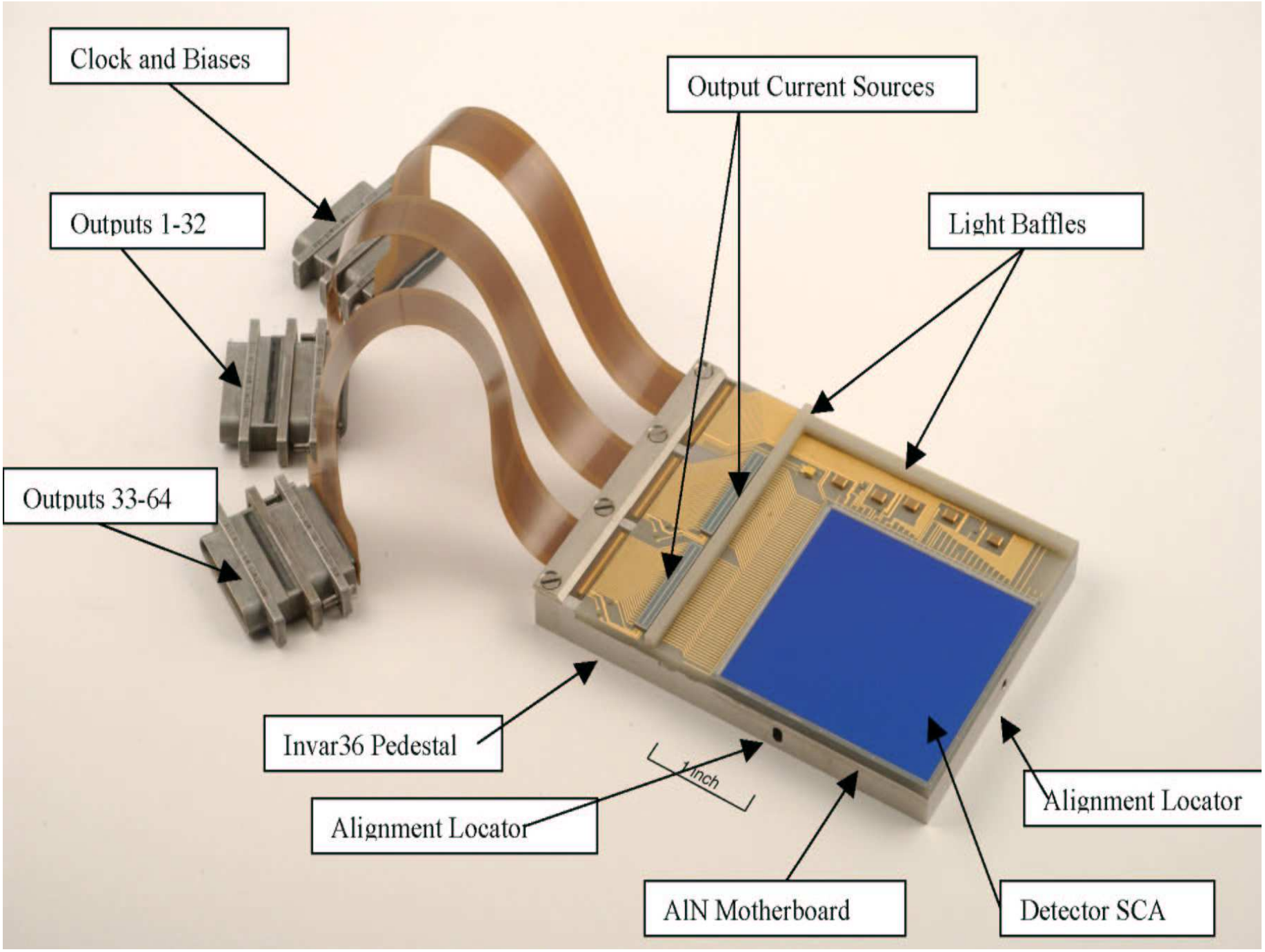
- Parallax accuracy demonstrated to <1 mas (<0.8 mas)
- Proper motion accuracy demonstrated to < 0.7 mas/yr
- Mean σ of single observation ~ 3 mas in each coordinate → ~5 mas total error
- 5 mas @ GEO → ~ 1-meter

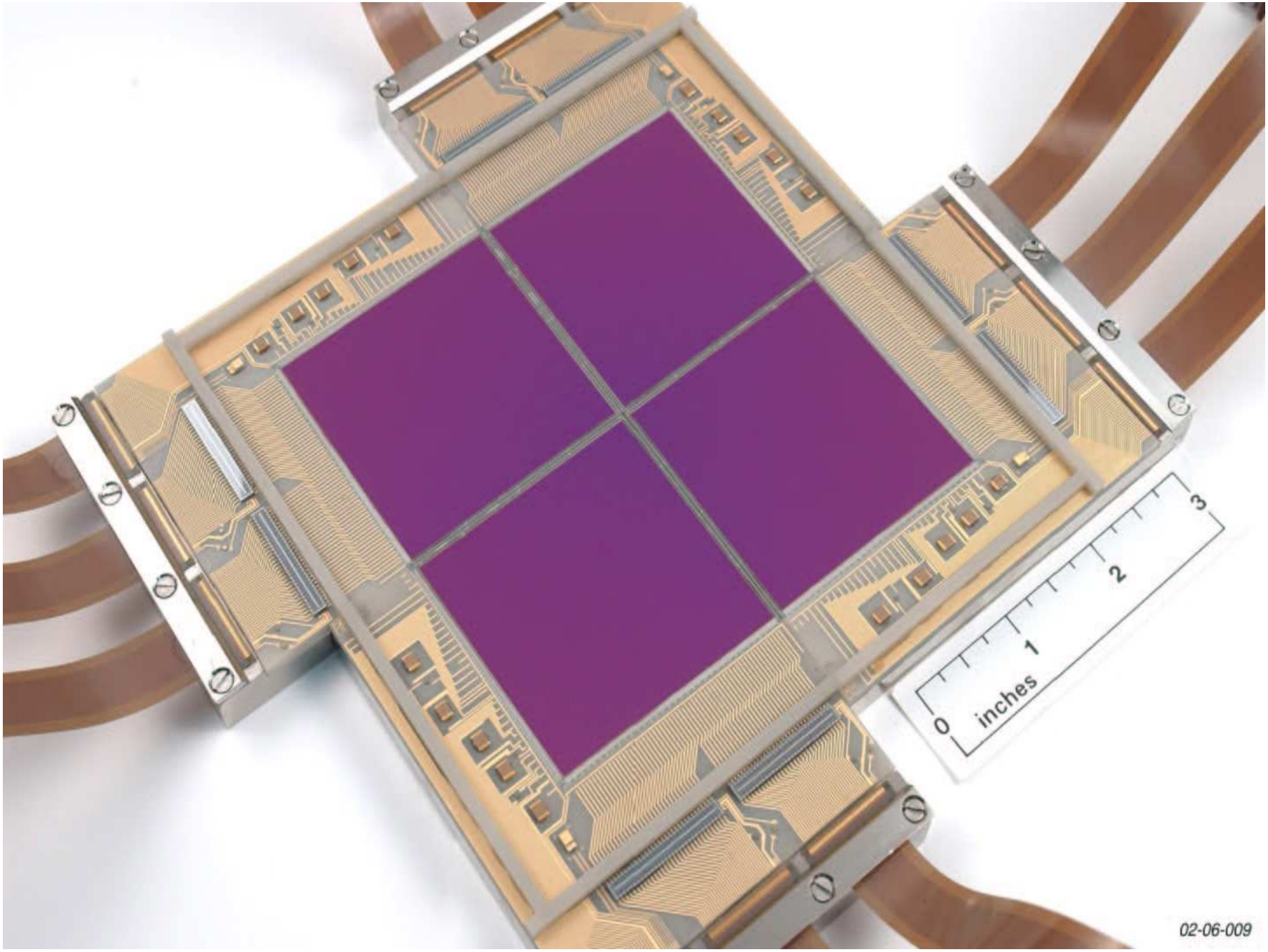
FUTURE

- Near-IR array detectors
- Imaging cameras
- Telescopes
- Space Situational Awareness (SSA)/ Space Object Identification (SOI) Projects

ORION: Next Generation InSb Detector

- USNO/NOAO/NASA-Ames collaboration at Raytheon
- 2048x2048 2-side buttable array
  → effectively 4096x4096 array
- Development project 2001-2006
- Science grade devices are available now
- 0.25 arcsec pixelization → 292 arcmin^2 FOV
  (IRCAM 5 arcmin^2, ASTROCAM 39 arcmin^2)


Clock and Biases
Output Current Sources
Outputs 1-32
Light Baffles
Outputs 33-64
Invar36 Pedestal
1inch
Alignment Locator
Alignment Locator
AlN Motherboard
Detector SCA


0
1
2
3
inches
02-06-009

Mid-IR Arrays

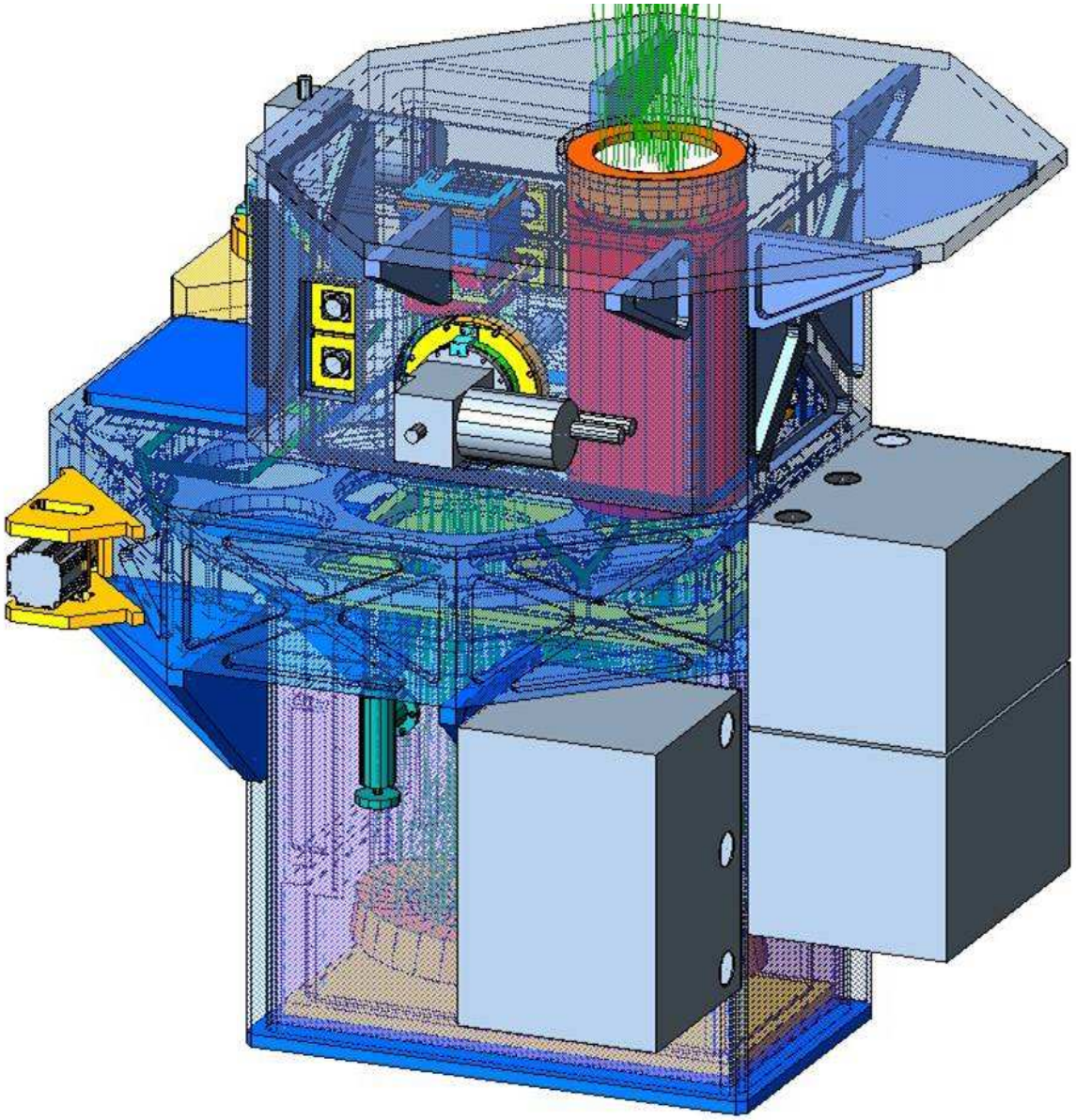
- Si:As (5 – 26 μm) 256x256 now available
  1024x1024 within 2-3 years

- Si:Sb (14 -38 μm) 128x128 now available
  256x256 within 2-3 years

Next Generation Near-IR Camera

- Is a camera for 2x2 ORION mosaic feasible?
- USNO-commissioned MKI concept design study for the DCT/Lowell 4.2-m telescope
- Answer: Yes. Optics, Readout Electronics, Filter Size, etc are now not issues
- But weight 2500-3000+ lbs

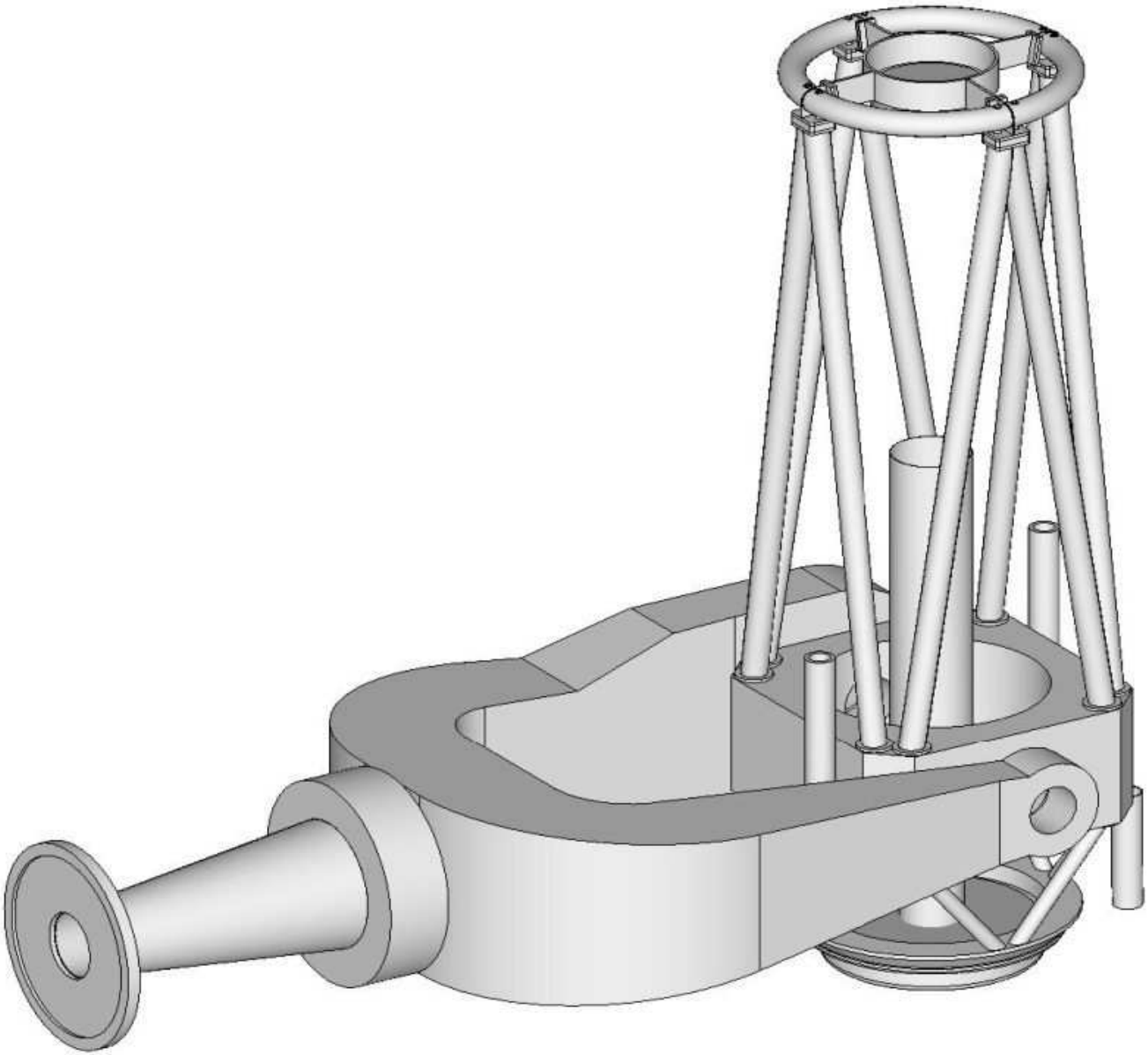
  → bigger telescope platform

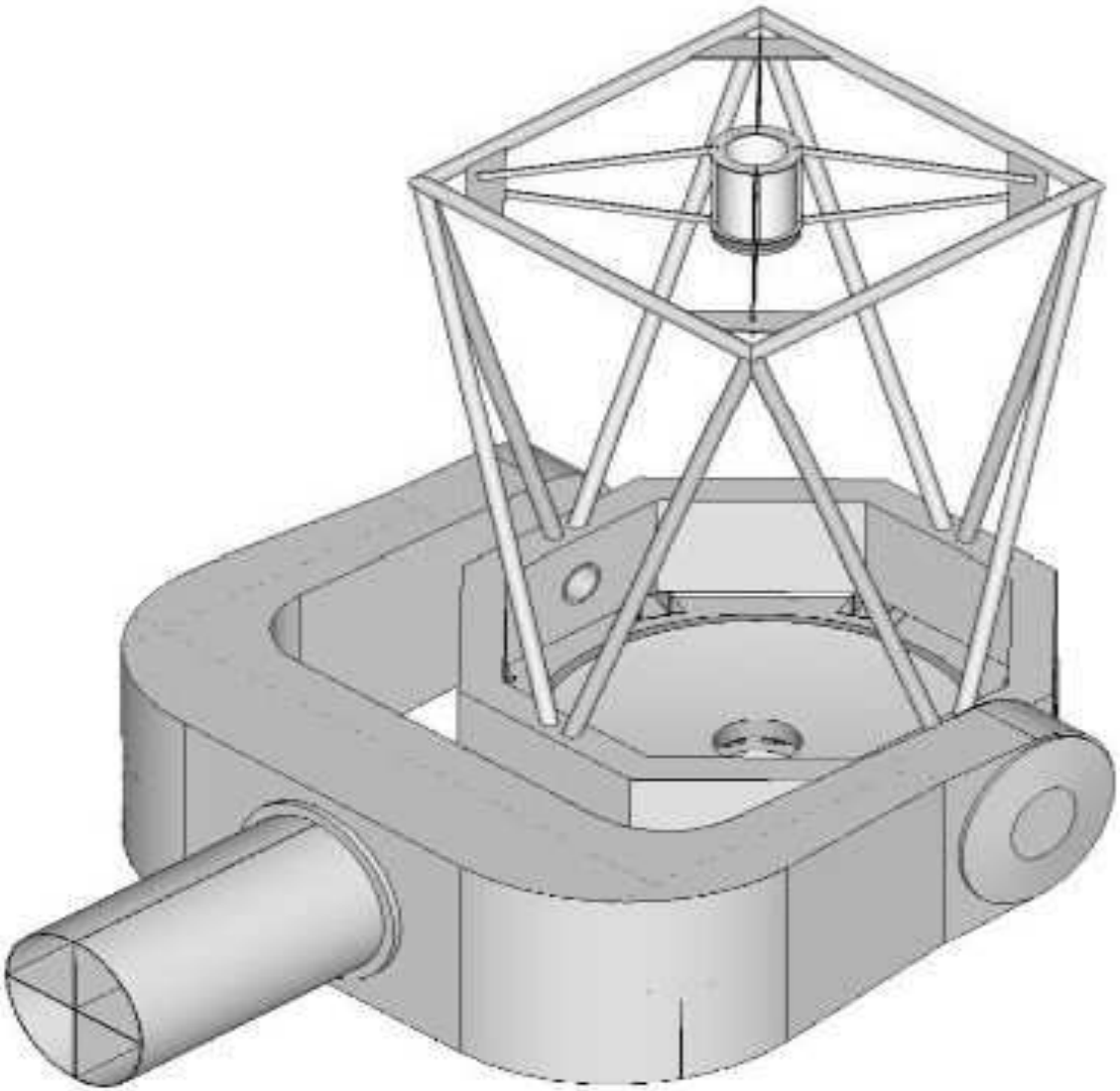


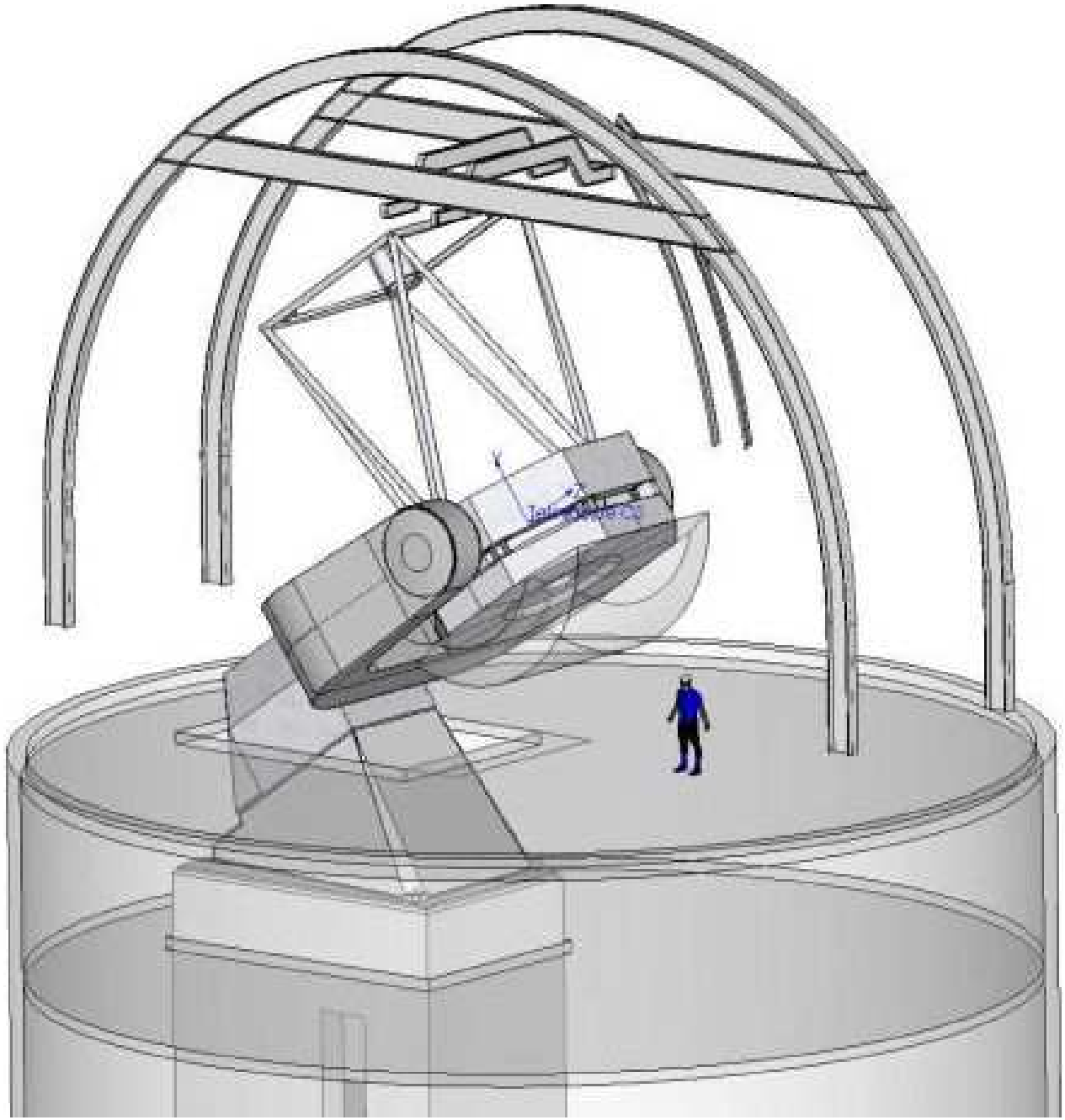
Next Generation Telescope

- DCT still possibility
- A new 3.5-m telescope to replace the 1.55-m in existing facility?
- EOS Technologies Feasibility Study (2005) says YES
- IR-optimized: 0.34 – 20 μm observations
- Total cost of new 3.5-m telescope
  + 2x2 ORION mosaic system ~ $15M

hgfghf







SSA Capabilities of an IR 3.5-m Telescope

- Astrometric Sky Surveys: Near- and mid-IR

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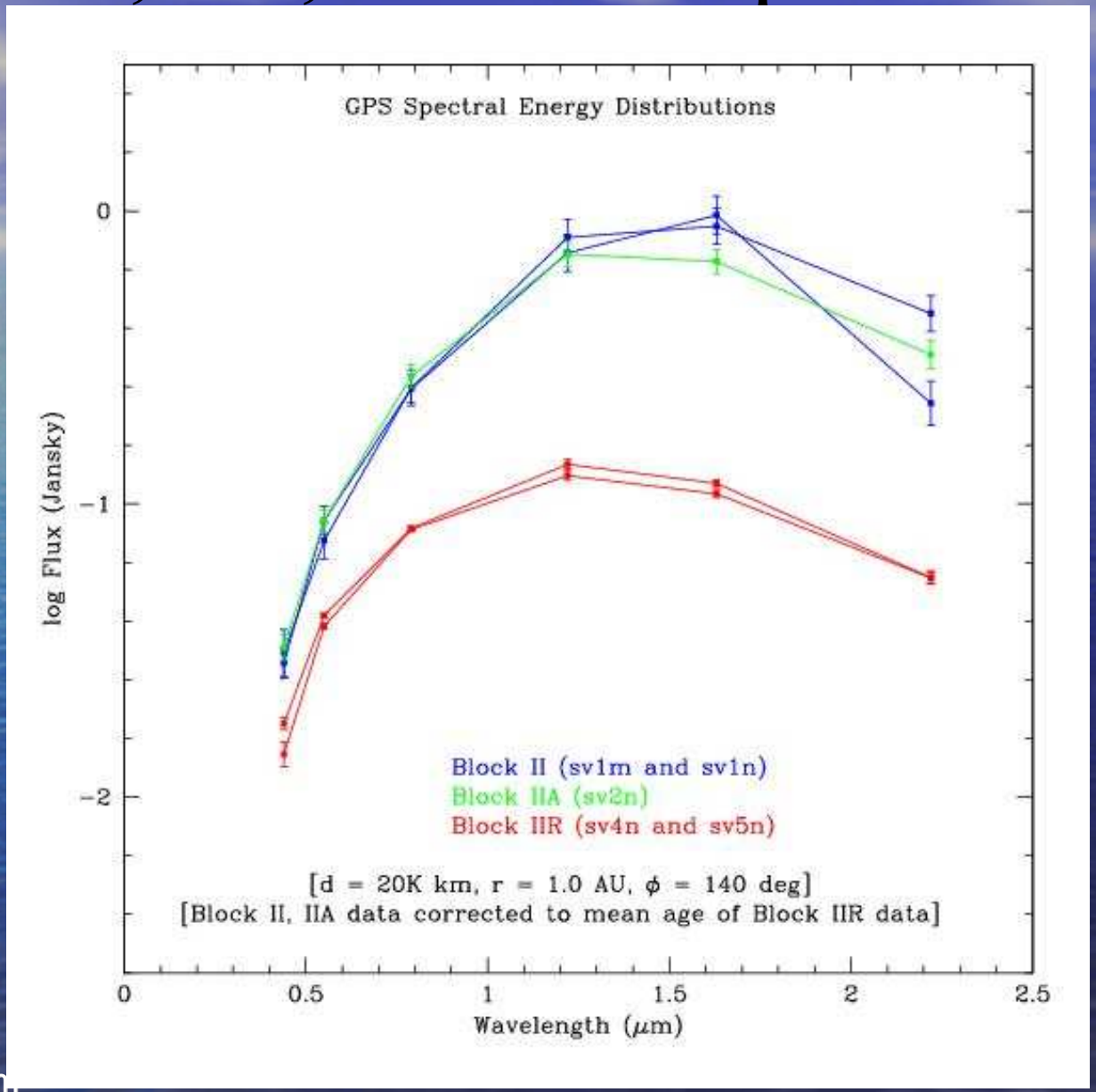
- Astrometric Sky Surveys: Near- and mid-IR
- Deep GEO Belt: to d < 10 cm every night
- Extreme SOI: optical + near-IR + mid-IR
- Adaptive Optics: 50-100 mas PSF – faint objects at lethal distances at GEO

Block II,IIA,& IIR – Opt+IR



Notional Extreme SOI

- Optical → spectra → materials
  (Monet et al. @ USNO)

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- Mid-IR Flux → T x emissivity (ε) x Size
  (Witte et al. @ AEOS)

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- f_λ [a + ε ≈ 1]

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- f_λ [a + ε ≈ 1]
- → materials, T, size (d << 10 cm @ GEO)

BACKUP SLIDES

Astrometry Forum
01 March 2006

Spectra of stars (smears) and Satellites (points + spectra)