(Ultra) Wide-field Optical Systems for Space Surveillance Activities: the **TANDEM** and **ASTRA** Projects

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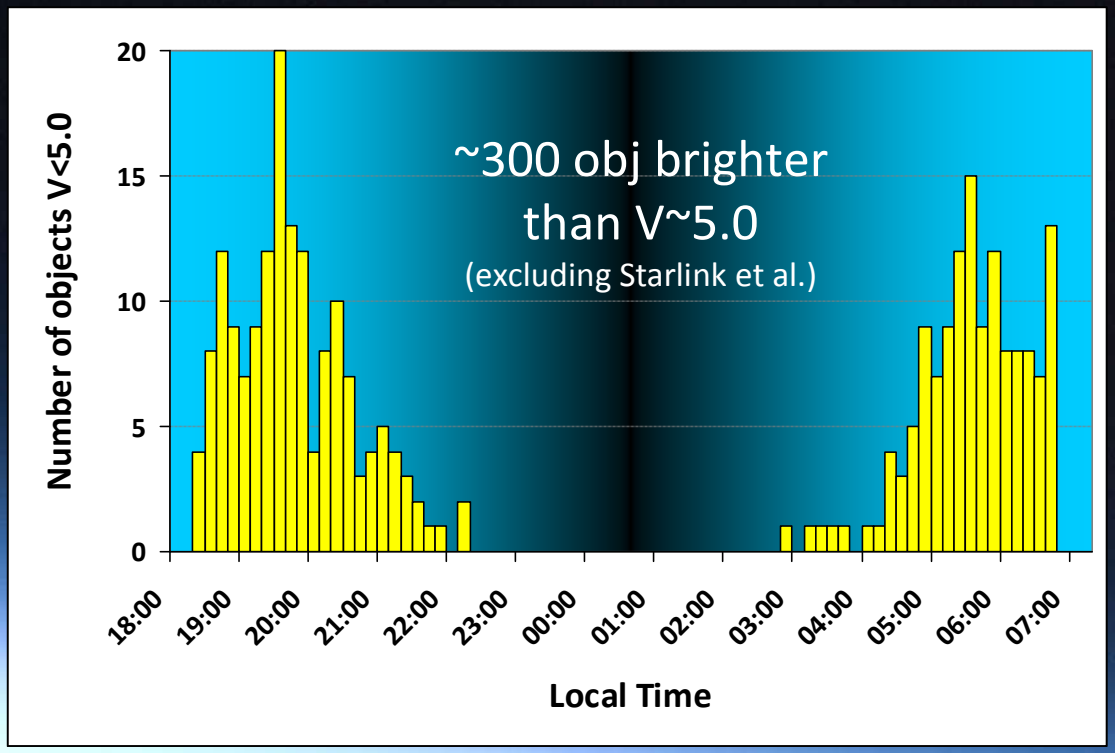
Shadowing and Crossing time



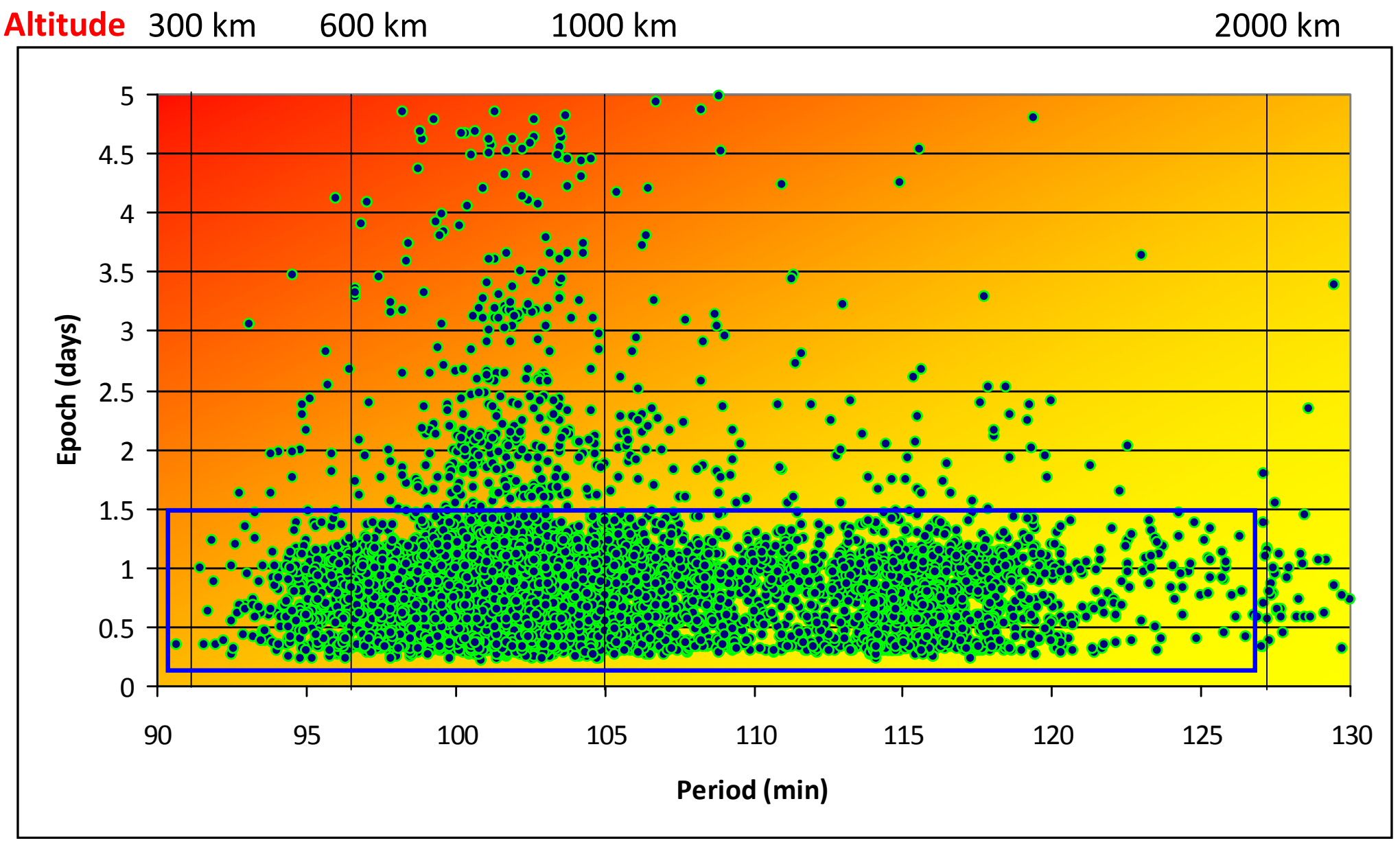
2000 km → 0.2°/sec

1000 km → 0.4°/sec

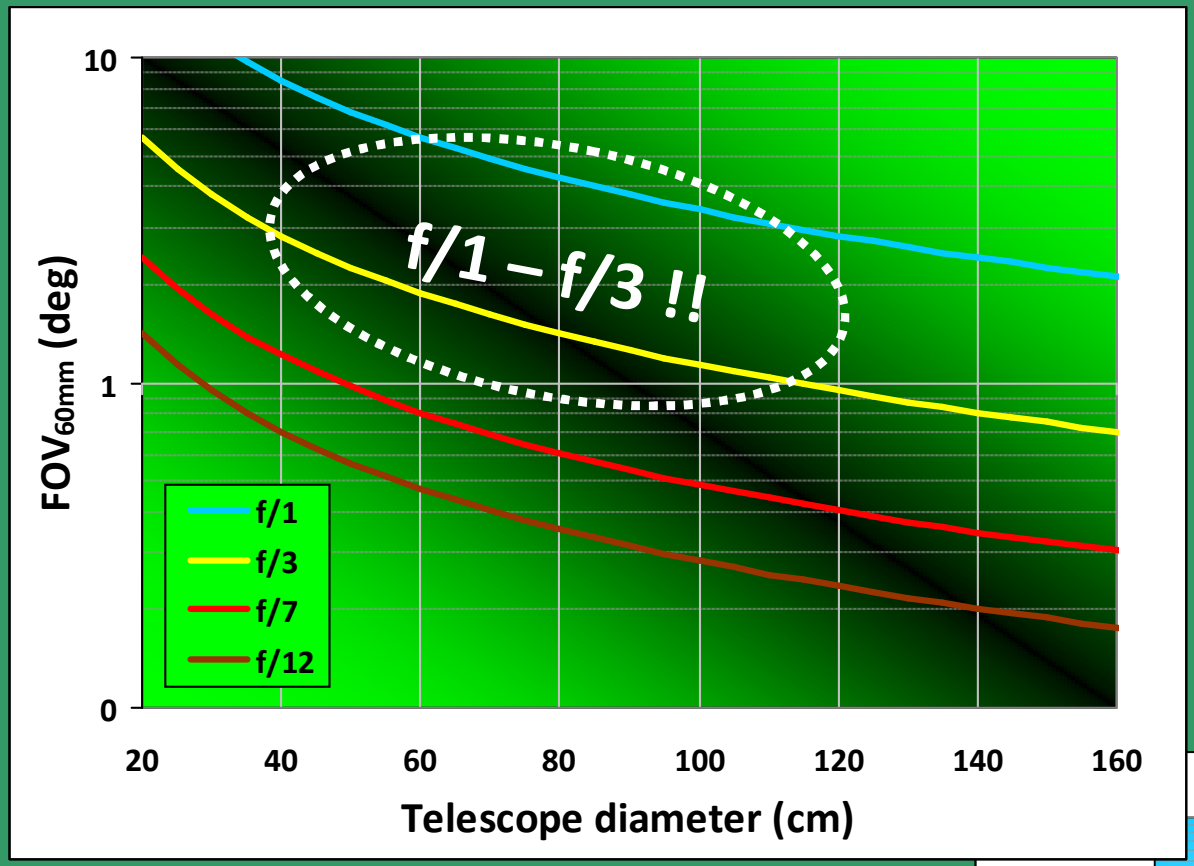
600 km → 0.7°/sec

300 km → 1.5°/sec

Timeliness!


Altitude
300 km
600 km
1000 km
2000 km
Epoch (days)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
90
95
100
105
110
115
120
125
130
Period (min)

Monolithic vs. Telescope Array

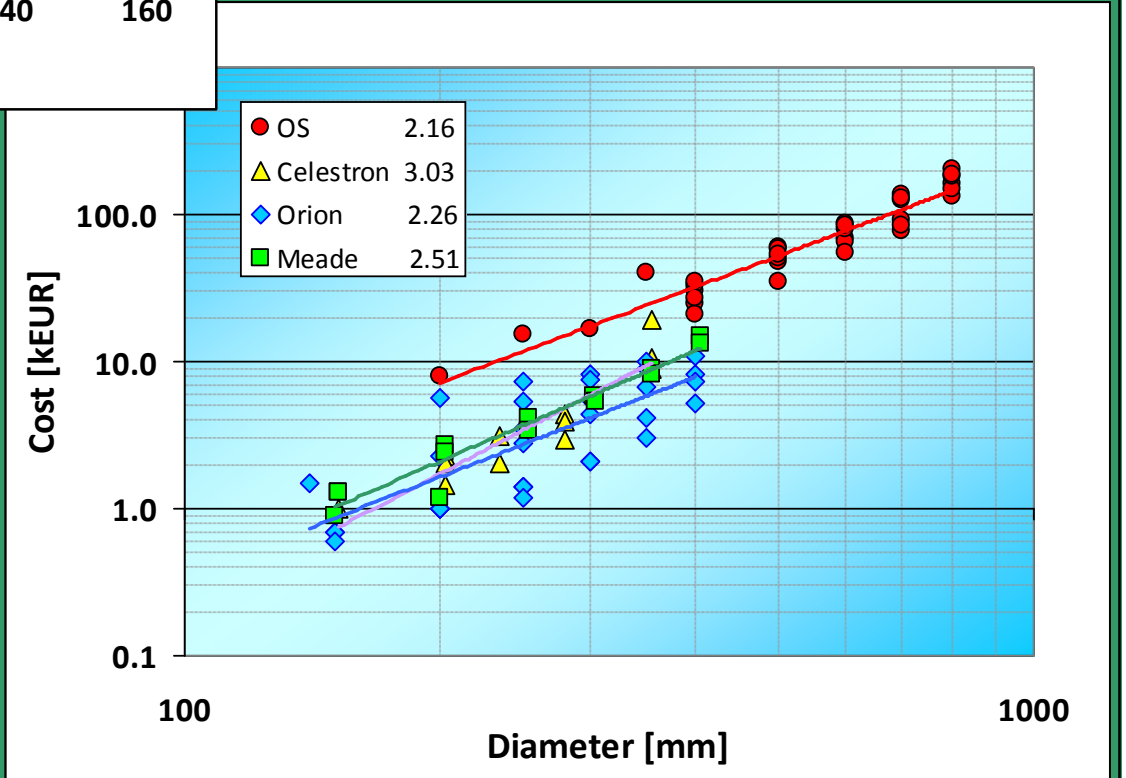


$$n \times T \Rightarrow \begin{matrix} D = d_{array}\sqrt{n} \\ f/\# = f_{array}/\sqrt{n} \end{matrix}$$

$$Cost \propto d^{2.4}$$

$$\frac{C_{array}}{C_{mono}} = \frac{n \times d^{2.4}}{\left(d\sqrt{n}\right)^{2.4}} = n^{\left(\frac{2-2.4}{2}\right)} \approx n^{-0.2}$$

Buzzoni et al. (2024)



The TANDEM project

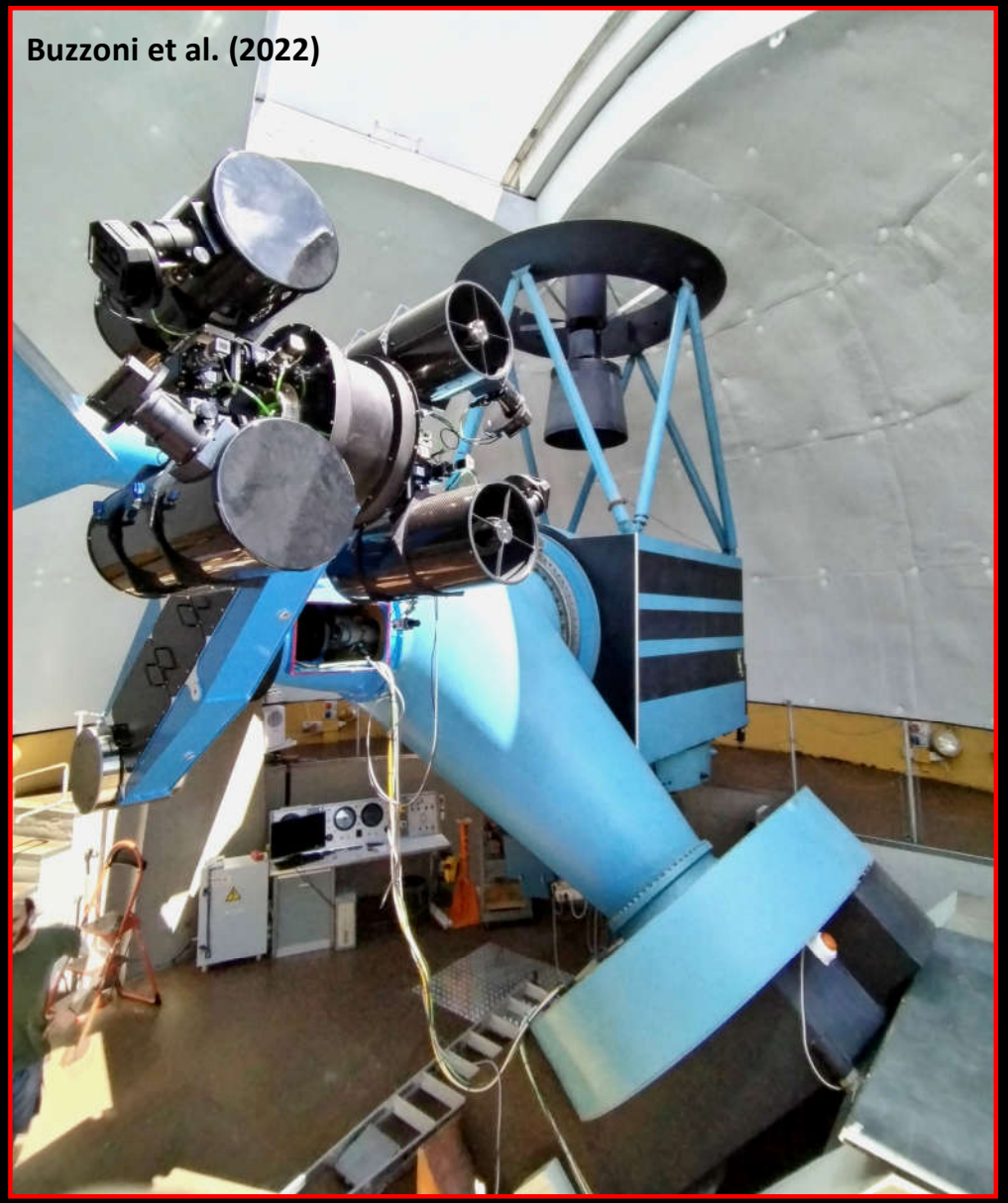
4x telescopes Ø 35 cm f/3

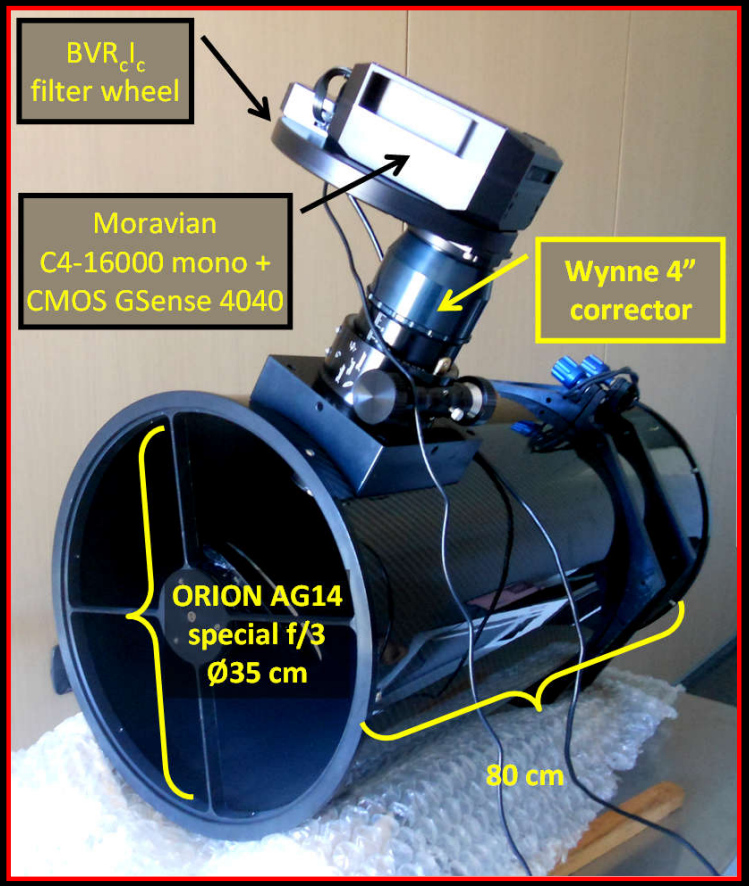
FOV = 16 □^{2} V_{lim} ~ 19

≈

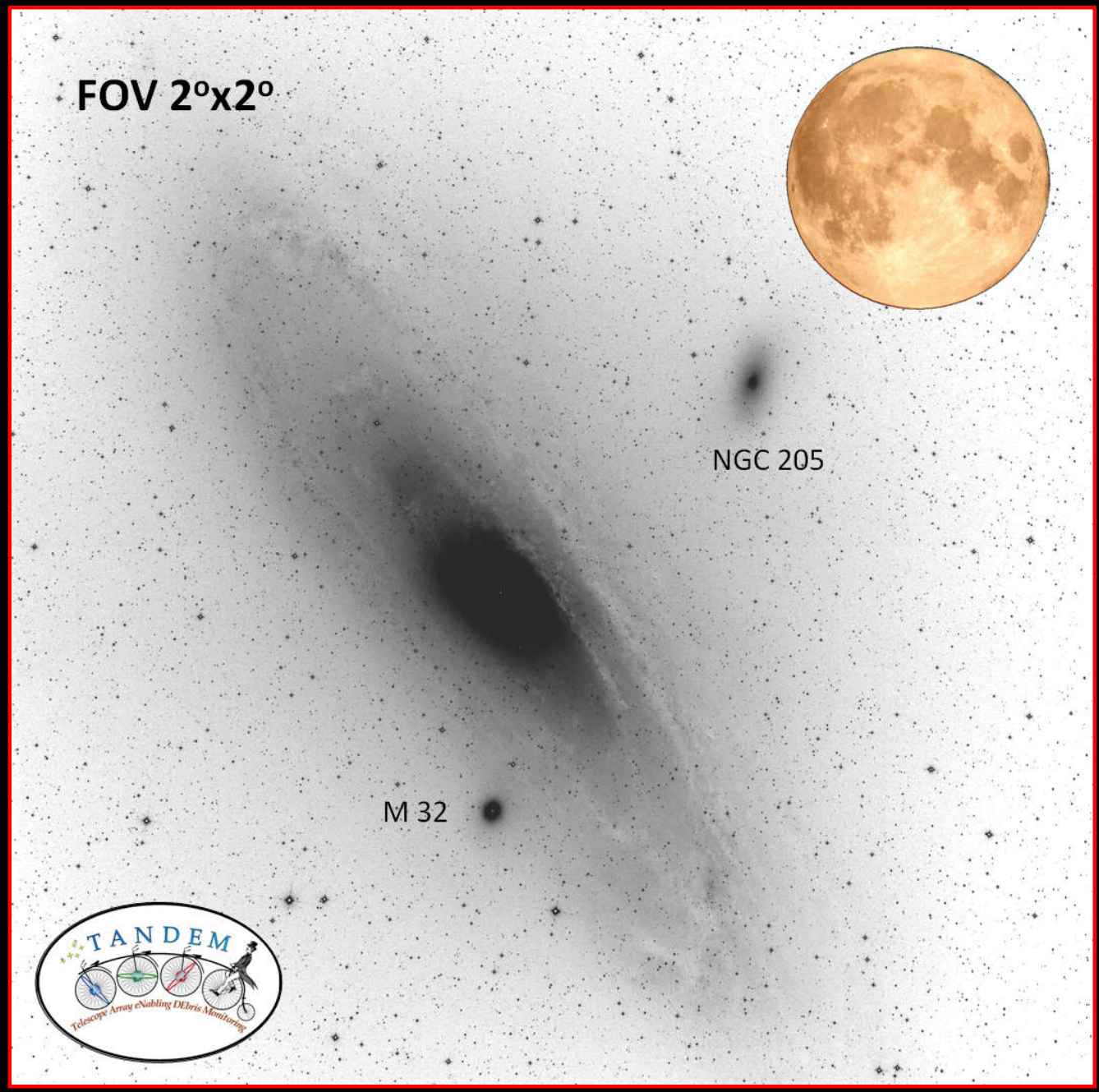
1 monolithic tel. Ø 70 cm f/1.5

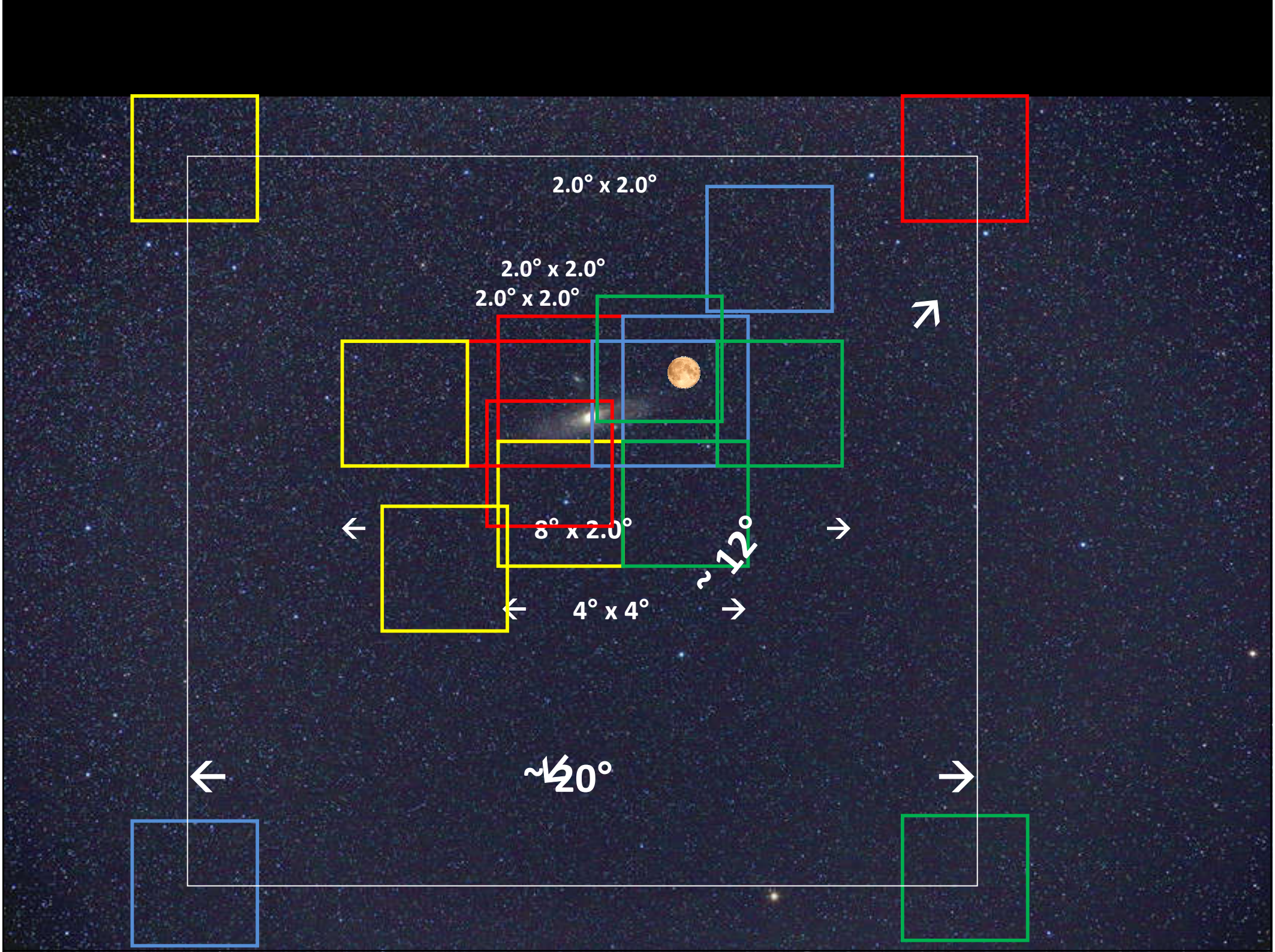
FOV = 2.0° x 2.0° V_{lim} ~ 20

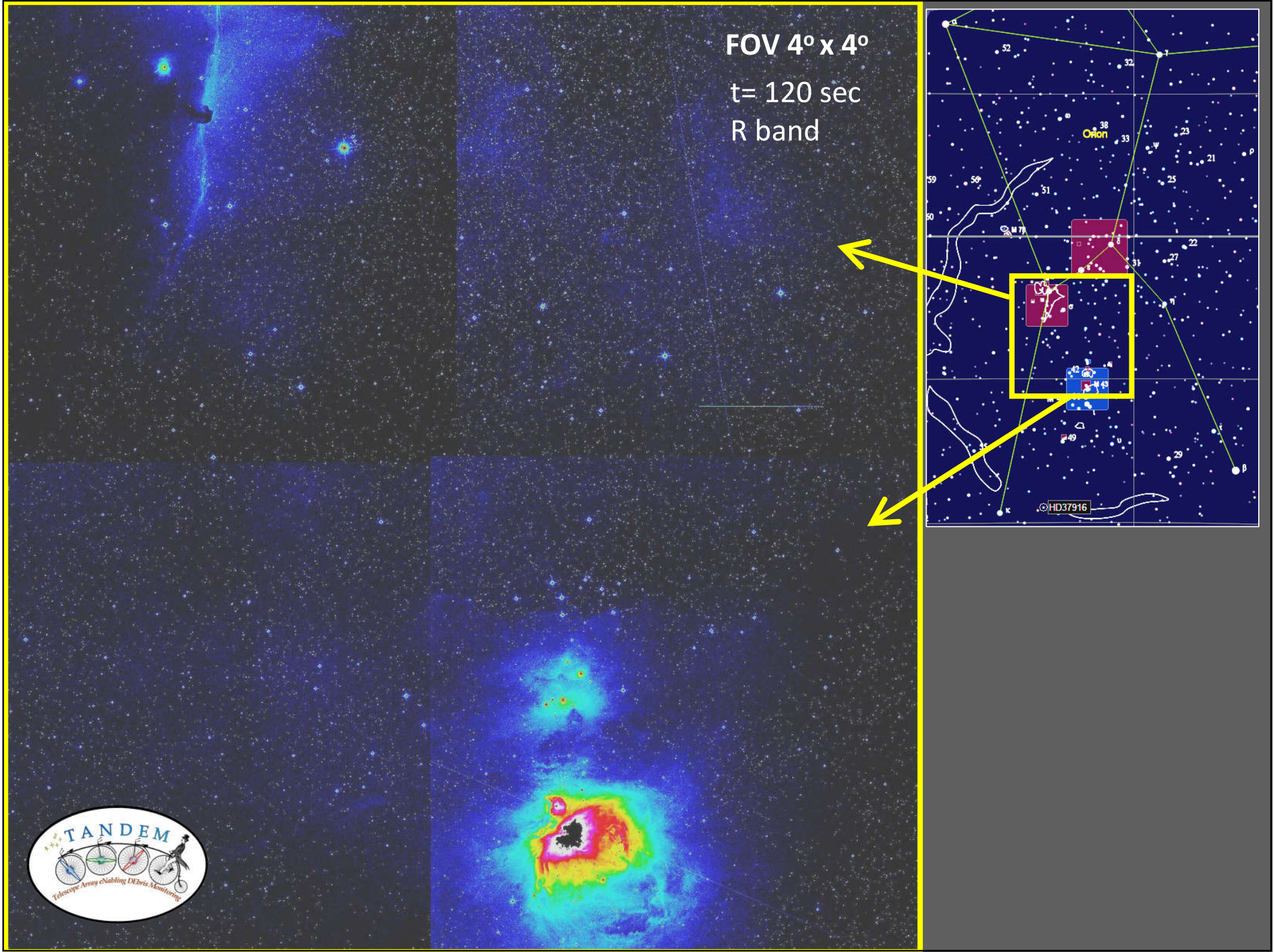




exp. time 20 microsec
(i.e. 0.00002 sec!!)

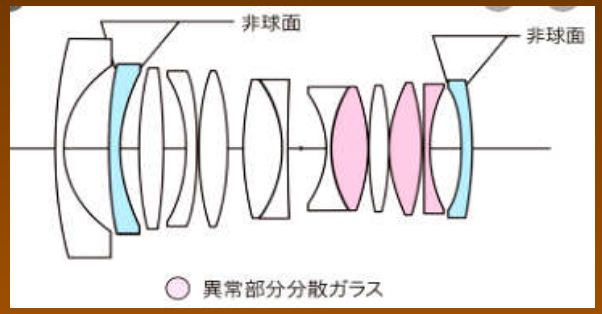



2.0° x 2.0°
2.0° x 2.0°
2.0° x 2.0°
8° x 2.0°
~ 12°
4° x 4°
~ 20°


FOV 4º x 4º
t= 120 sec
R band
Orion
HD37916
TANDEM
Telescope Array eNabling DEbris Monitoring

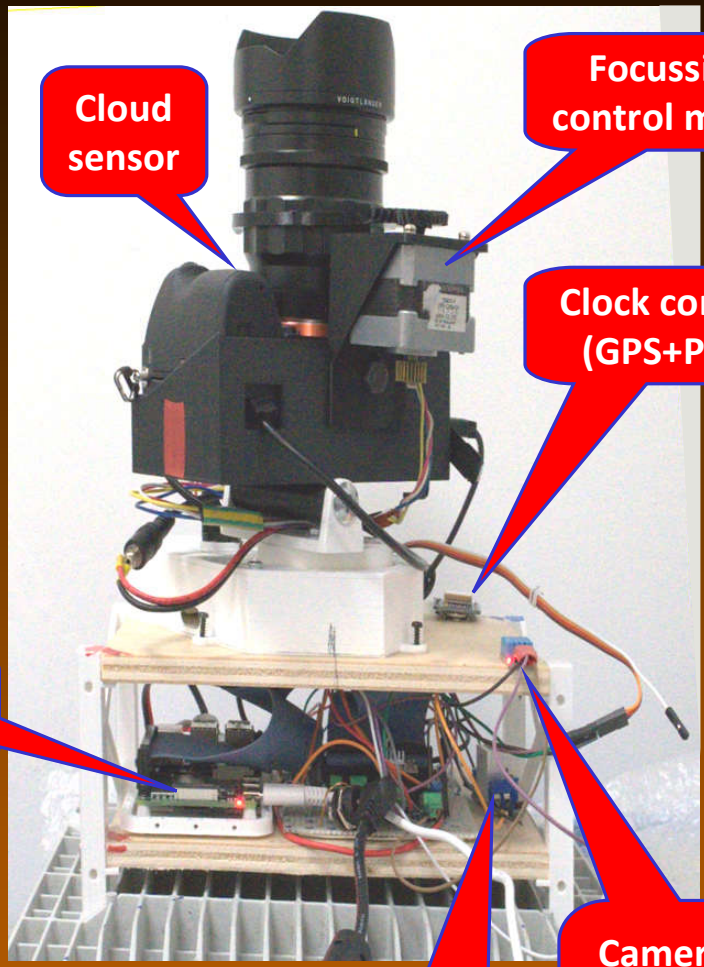
The ASTRA project

Voigtlander E 21mm f/1.4
Nokton



5 x

Sony α 7 III Full Frame 24.2 MP
CMOS back-illuminated



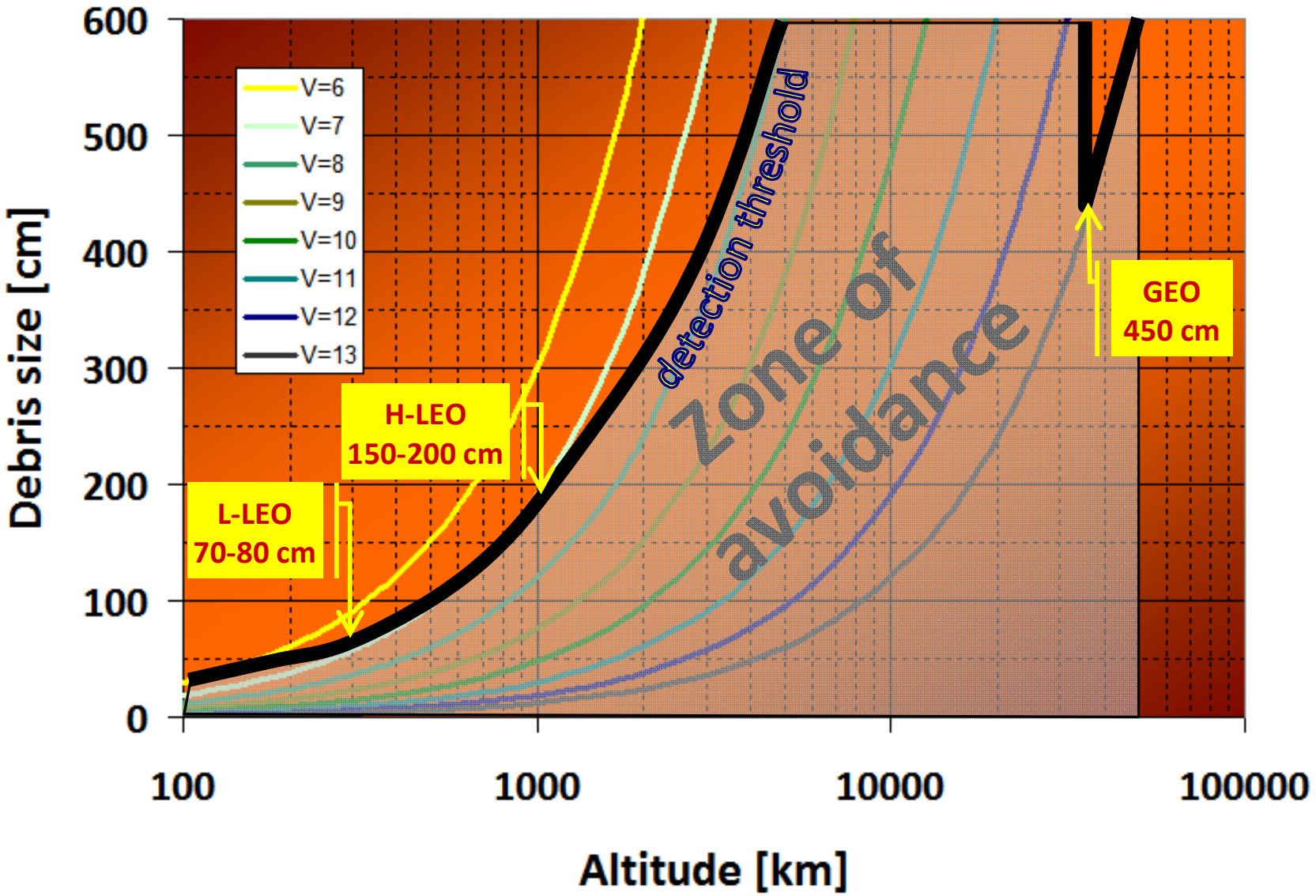
FOV: 82° x 59° (100° diag)
Full Frame format:
6000 x 4000 px CMOS
Platescale: 50 arcsec/px
Latency: 0.02 sec (LEO)

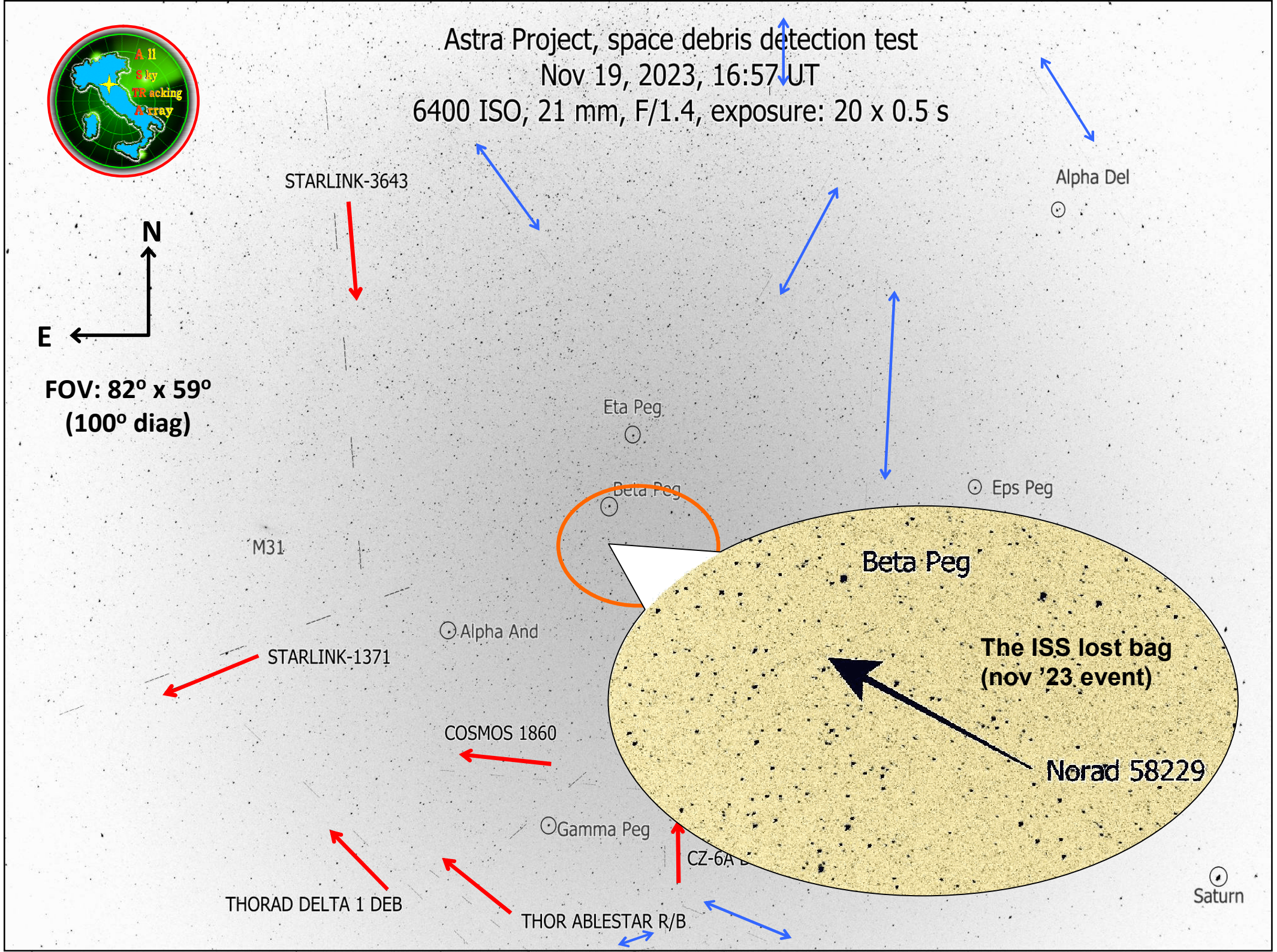
Buzzoni et al. (2022)

Magnitude vs. Size

$$V \cong -5\log(s_{cm}) + 5\log h_{km} - 2.5\log(\alpha / 0.1) + 3.40$$

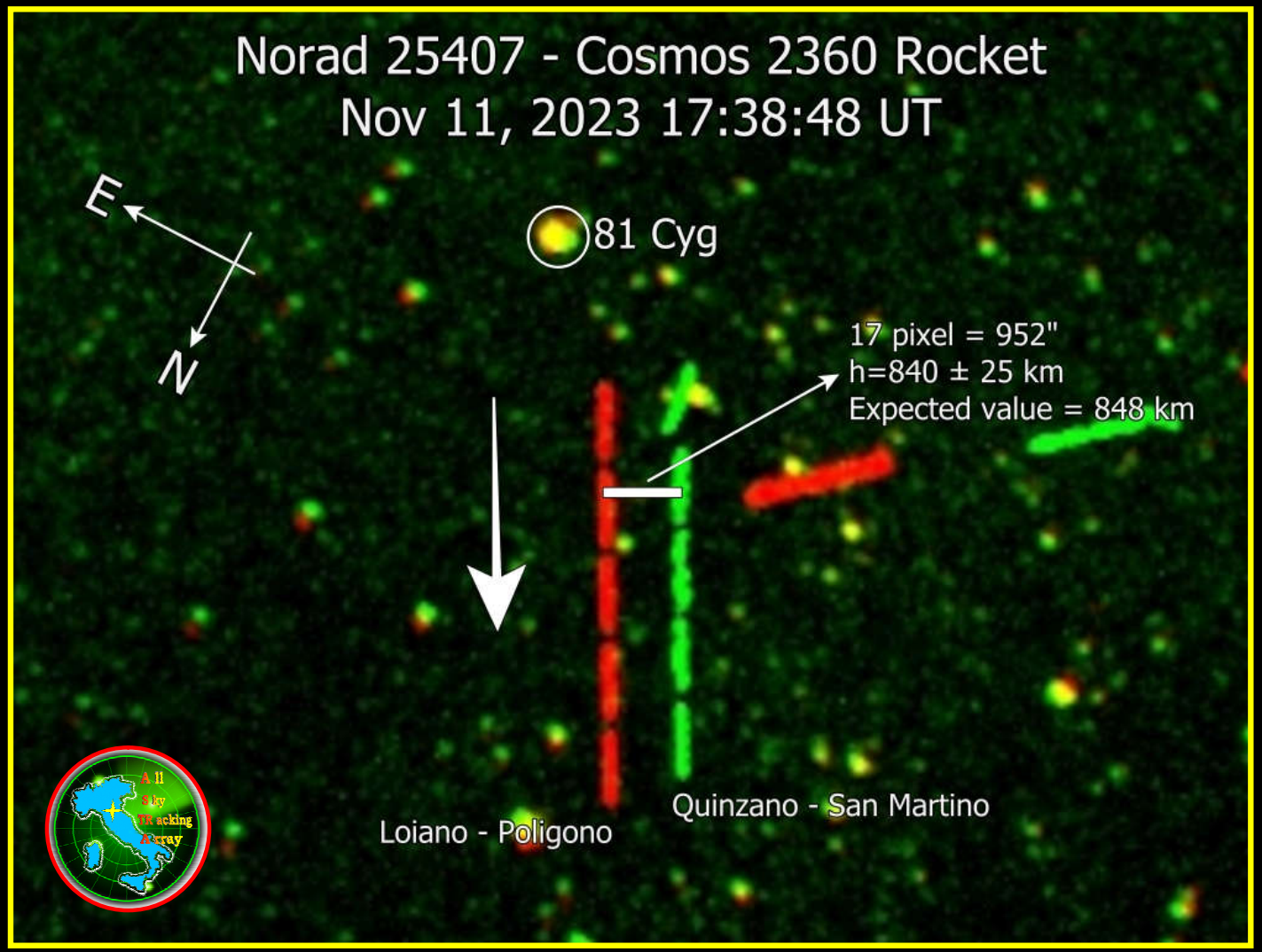
(Buzzoni et al. 2014)




Astra Project, space debris detection test
Nov 19, 2023, 16:57 UT
6400 ISO, 21 mm, F/1.4, exposure: 20 x 0.5 s
STARLINK-3643
Alpha Del
N
E
FOV: 82° x 59°
(100° diag)
Eta Peg
Beta Peg
Eps Peg
M31
Alpha And
STARLINK-1371
COSMOS 1860
Gamma Peg
CZ-6A
THORAD DELTA 1 DEB
THOR ABLESTAR R/B
Saturn
Beta Peg
The ISS lost bag
(nov '23 event)
Norad 58229


All Sky TRacking Array
Probing the
“Clarke Belt”
1 min stacked exposure
(~30 frames)


Loiano
A. Carbognani
(green track)
3.86 km
R. Gualandi
(red track)
Cà di Balloni
Antico Stradello 1810
Casa di Federico
Scuola Media
PP Baldassarri
T.S.N - Loiano
Stele di Scanello
Chiesa San Martino
Antennista Connolly
Sebastiano
Quinzano
La Corte dei Celti
Azienda Agricola
La Torre
Gnazzano
STRADELLA
Stazione astronomica
e Parco delle Stelle di...


Norad 25407 - Cosmos 2360 Rocket
Nov 11, 2023 17:38:48 UT
E
N
81 Cyg
17 pixel = 952"
h=840 ± 25 km
Expected value = 848 km
Loiano - Poligono
Quinzano - San Martino