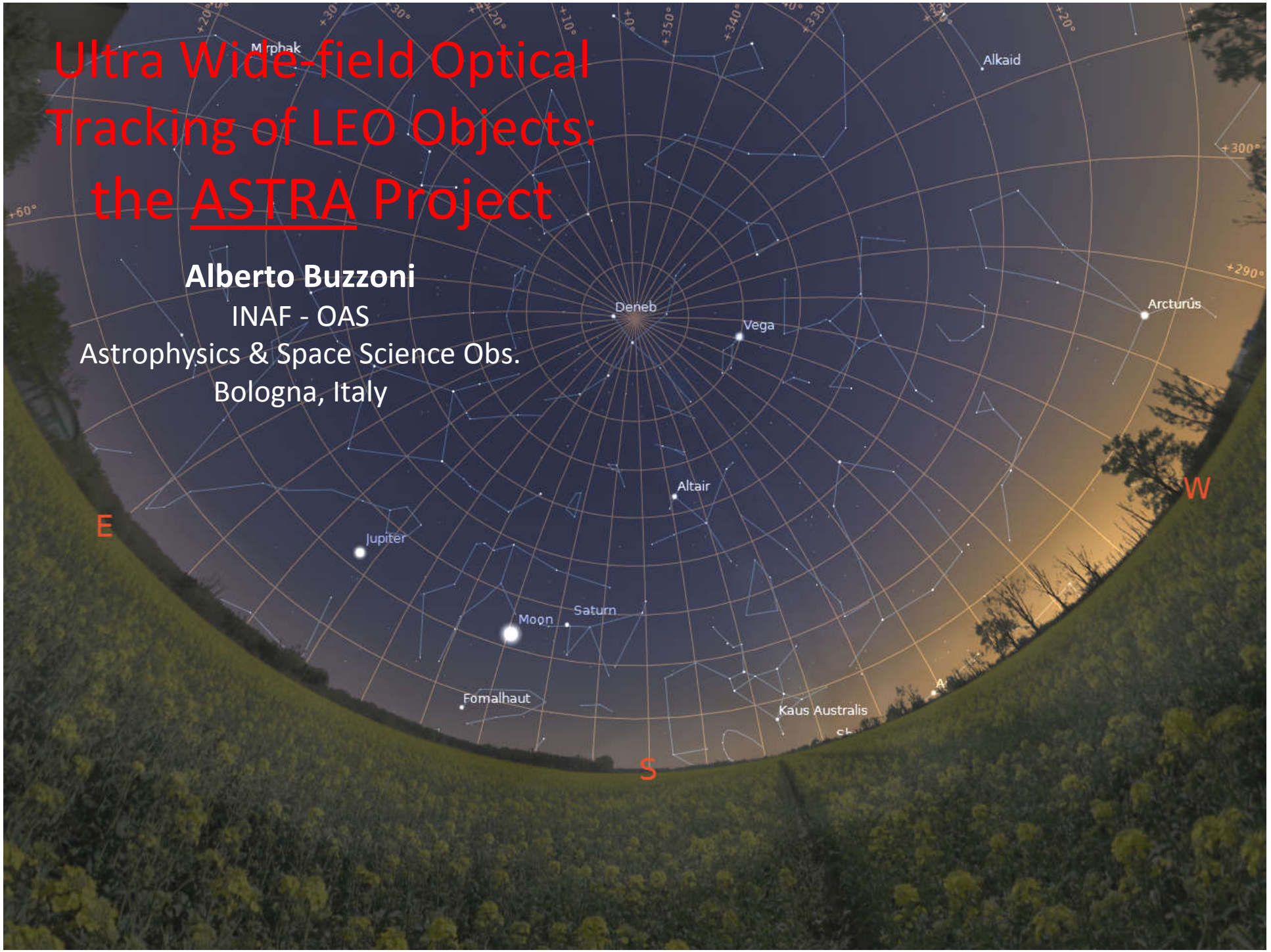
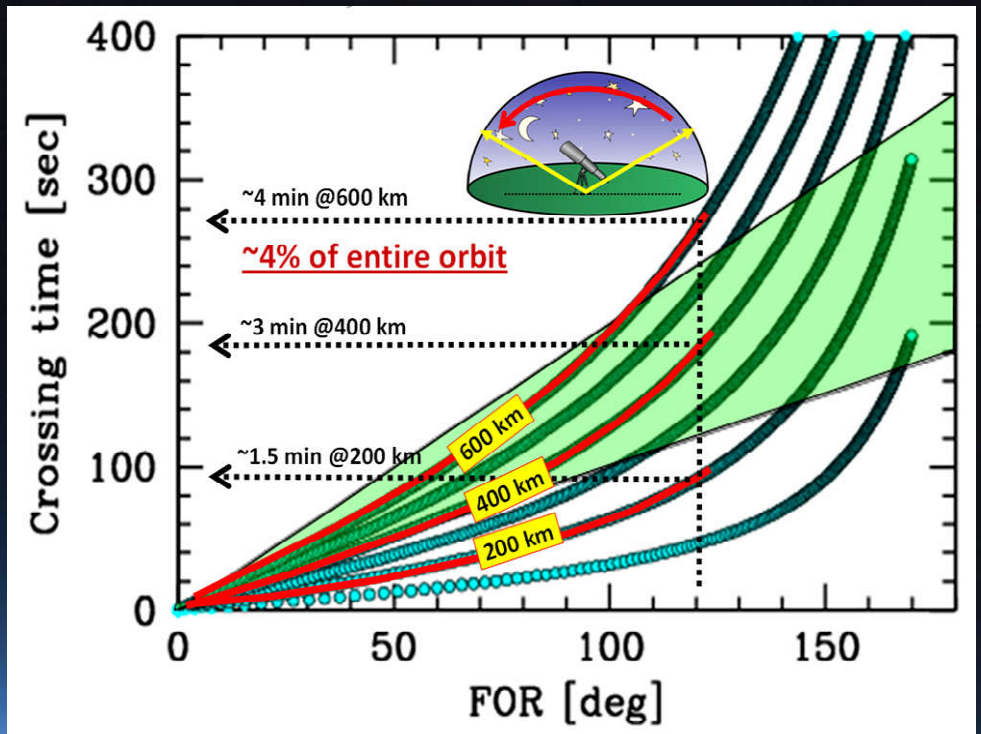
Ultra Wide-field Optical Tracking of LEO Objects: the ASTRA Project

Alberto Buzzoni
INAF - OAS
Astrophysics & Space Science Obs.
Bologna, Italy



Crossing time



Inclination (i) (through the Heading angle)

$$d\,i \le \frac{dH}{\sin\ i} \approx \frac{}{\sin\ i}\left(\frac{5\ \ arc\,\sec}{30\ \ \deg}\right) \approx 0.005\ \ \deg$$

Semi-major axis (a) (through arclet timing)

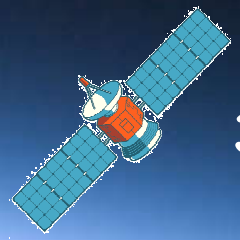
$$\frac{d\,a}{a} \equiv \left(\frac{2}{3}\right)\frac{d\,P}{P} \le \left(\frac{2}{3}\right)\frac{dt}{t} \approx \left(\frac{2}{3}\right)\frac{1.4\ \ px}{30\ \ \deg\ \ arc} \approx \left(\frac{2}{3}\right)\frac{70\ \ arc\,\sec}{30\ \ \deg} \approx 1/2000$$

e.g. Macko (1962)

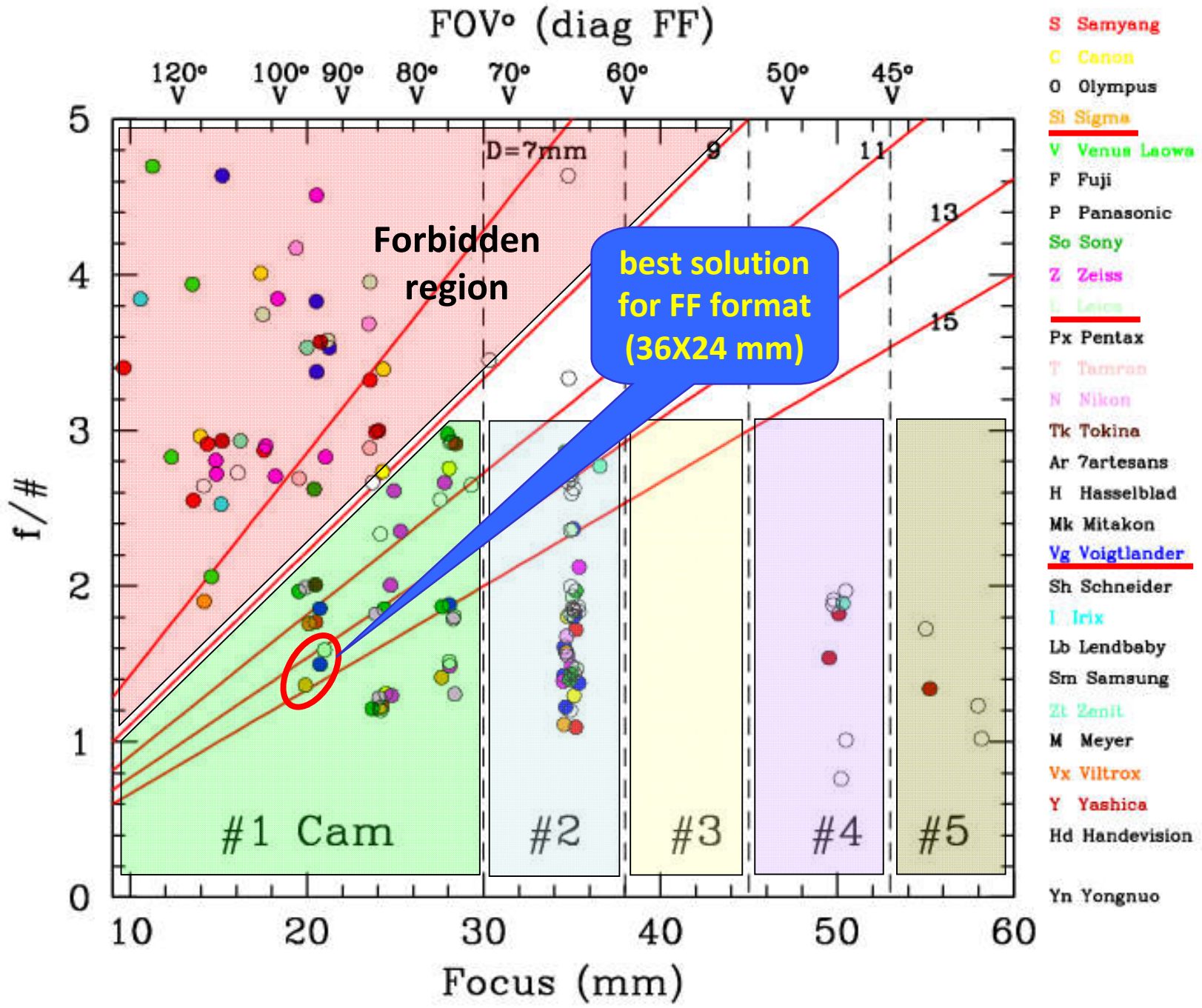
2000 km → 0.2°/sec

1000 km → 0.4°/sec

600 km → 0.7°/sec

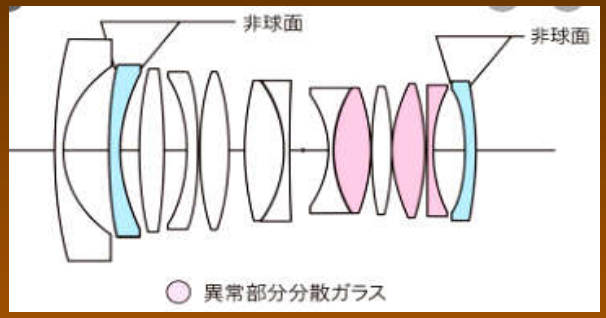


300 km → 1.5°/sec


FOV° (diag FF)
120° V
100° V
90° V
80° V
70° V
60° V
50° V
45° V
D=7mm
9
11
13
15
Forbidden region
best solution for FF format (36X24 mm)
#1 Cam
#2
#3
#4
#5
f/#
Focus (mm)
0
1
2
3
4
5
10
20
30
40
50
60
S Samyang
C Canon
O Olympus
Si Sigma
V Venus Laowa
F Fuji
P Panasonic
So Sony
Z Zeiss
L Leica
Px Pentax
T Tamron
N Nikon
Tk Tokina
Ar 7artesans
H Hasselblad
Mk Mitakon
Vg Voigtlander
Sh Schneider
I Irix
Lb Lendbaby
Sm Samsung
Zt Zenit
M Meyer
Vx Viltrox
Y Yashica
Hd Handevision
Yn Yongnuo

The ASTRA project

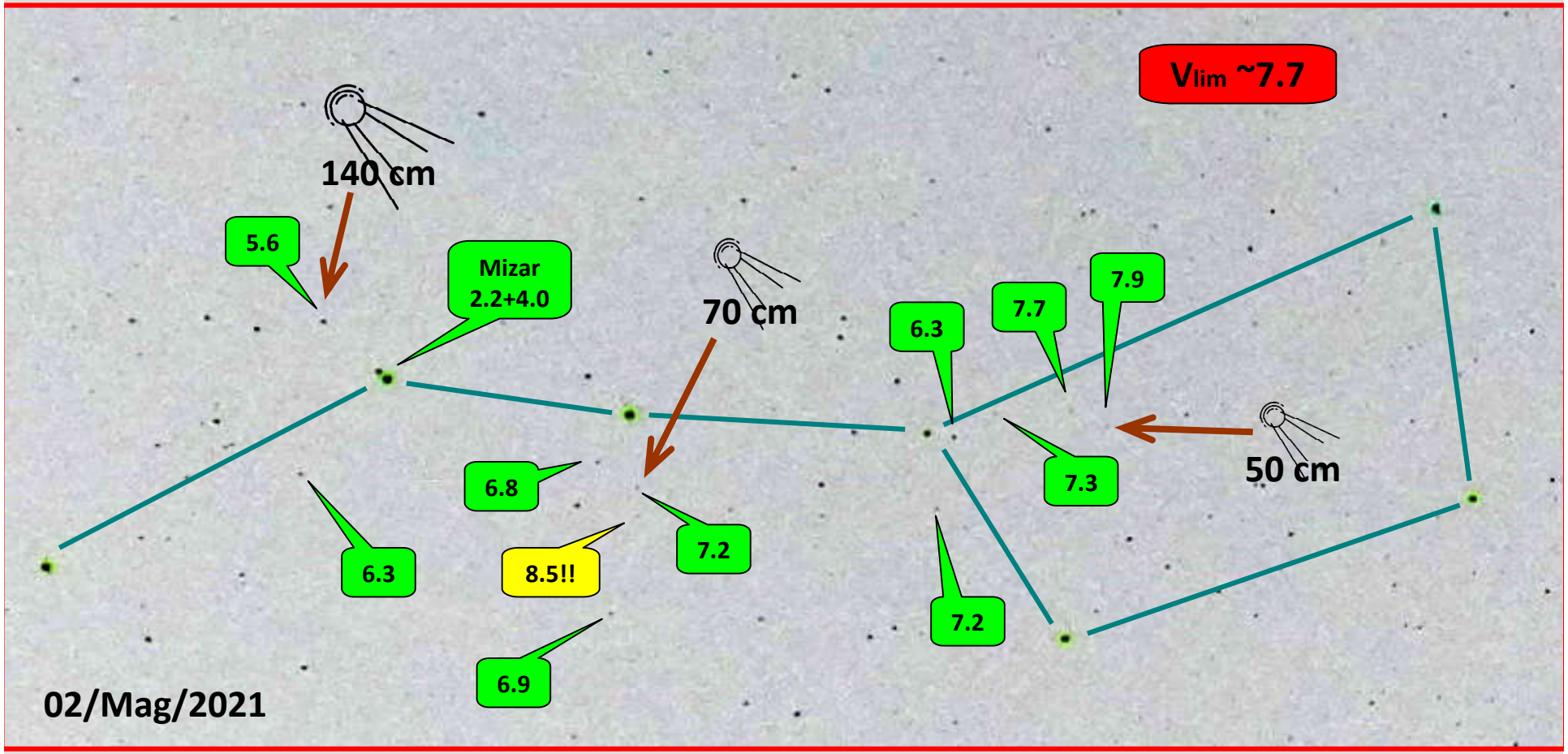
Voigtlander E 21mm f/1.4 Nokton



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

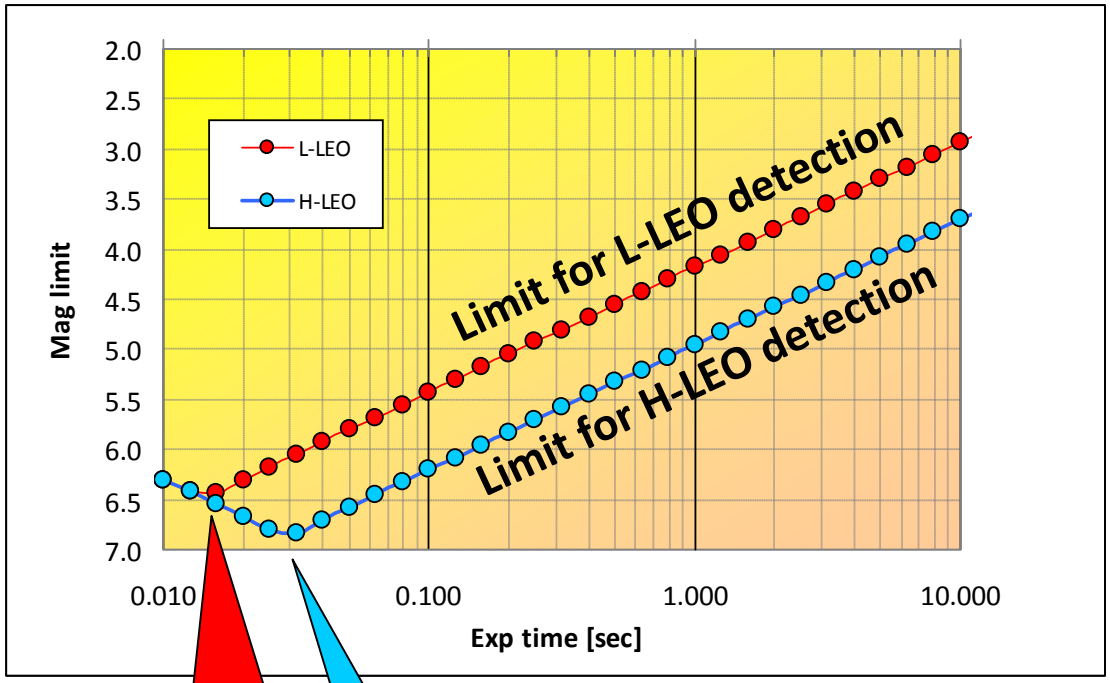
FOV: 82° x 59° (100° diag)
Full Frame format:
6000 x 4000 px back-illuminated CMOS
Platescale: 50 arcsec/px
Latency: 0.01 sec (LEO)

Voigtlander E 21mm f/1.4
Nokton



t_{exp} = 0.1 sec (ISO 25000)

How deep can we see?

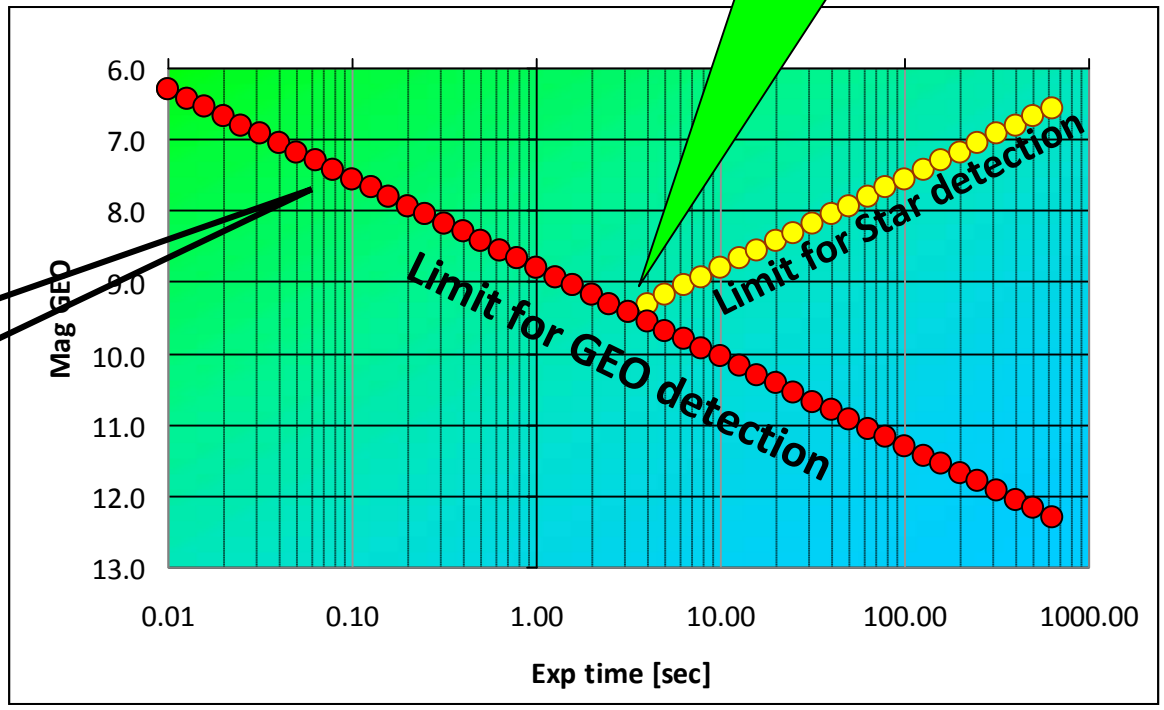


L-LEO Latency
~0.015 sec/px

H-LEO Latency
~0.03 sec/px

Sideral Min Latency
~3.5 sec/px

$$V_{lim} \approx 1.25 \log(t''_{exp}) + 8.8$$



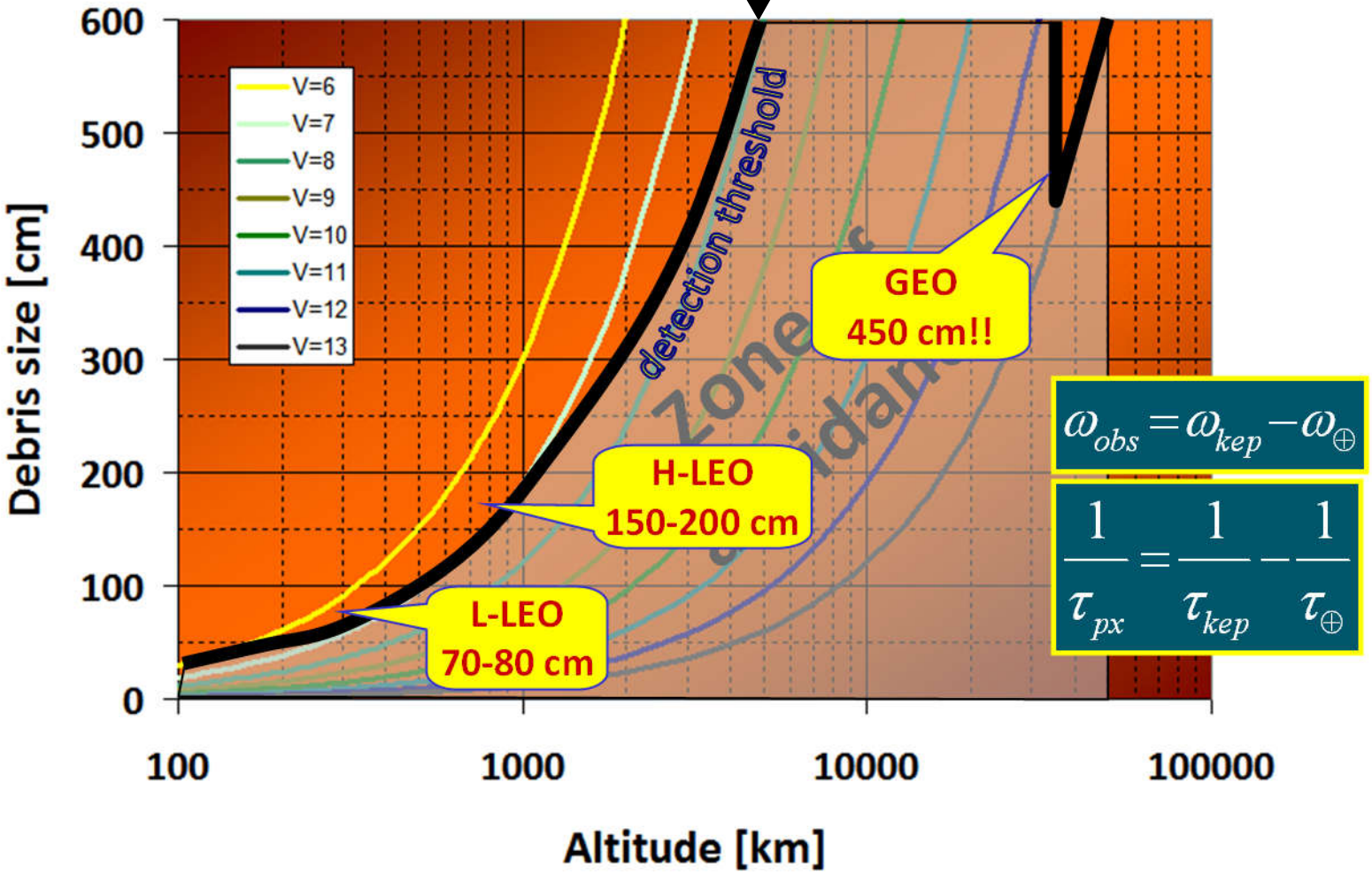
(Buzzoni et al. 2014)

Magnitude vs. Size

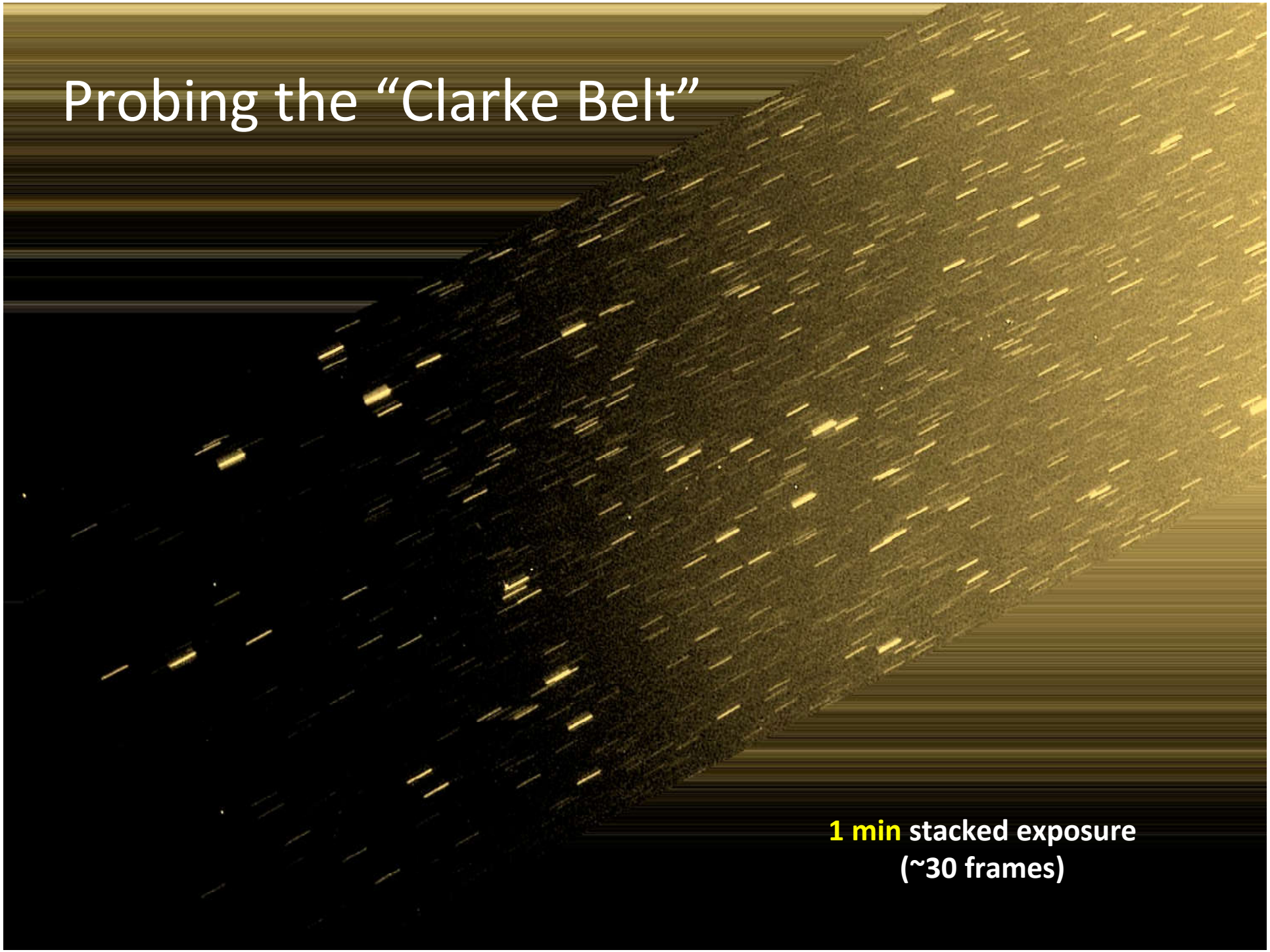
$$V \cong -5\log(s_{cm}) + 5\log h_{km} - 2.5\log(\alpha/0.1) + 3.40$$

Size vs. Altitude

$$\log(s_{cm}) = 0.75\log(h_{km}/300) - 2.5\log(\alpha/0.1) + 1.9$$



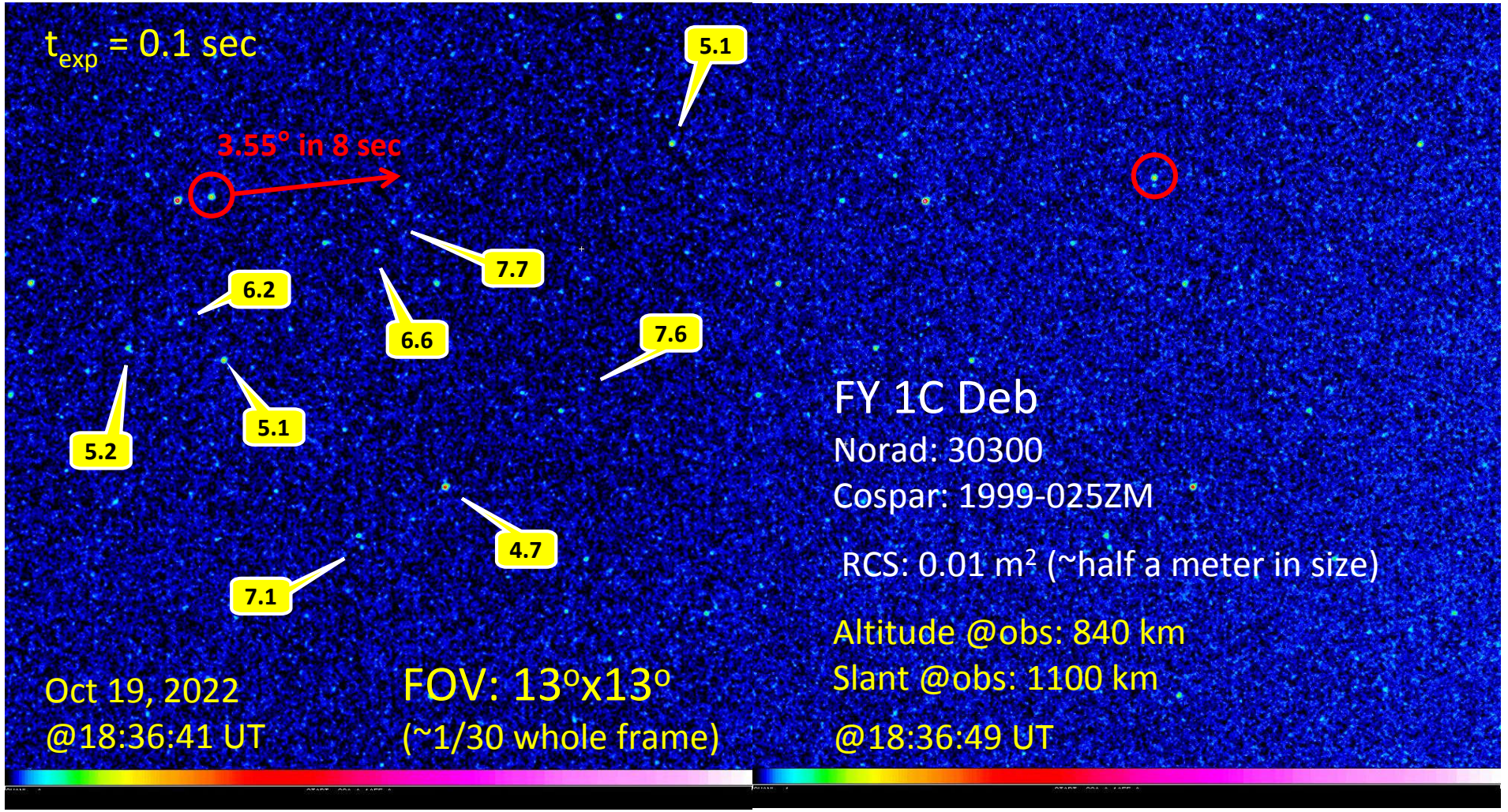
Probing the “Clarke Belt”



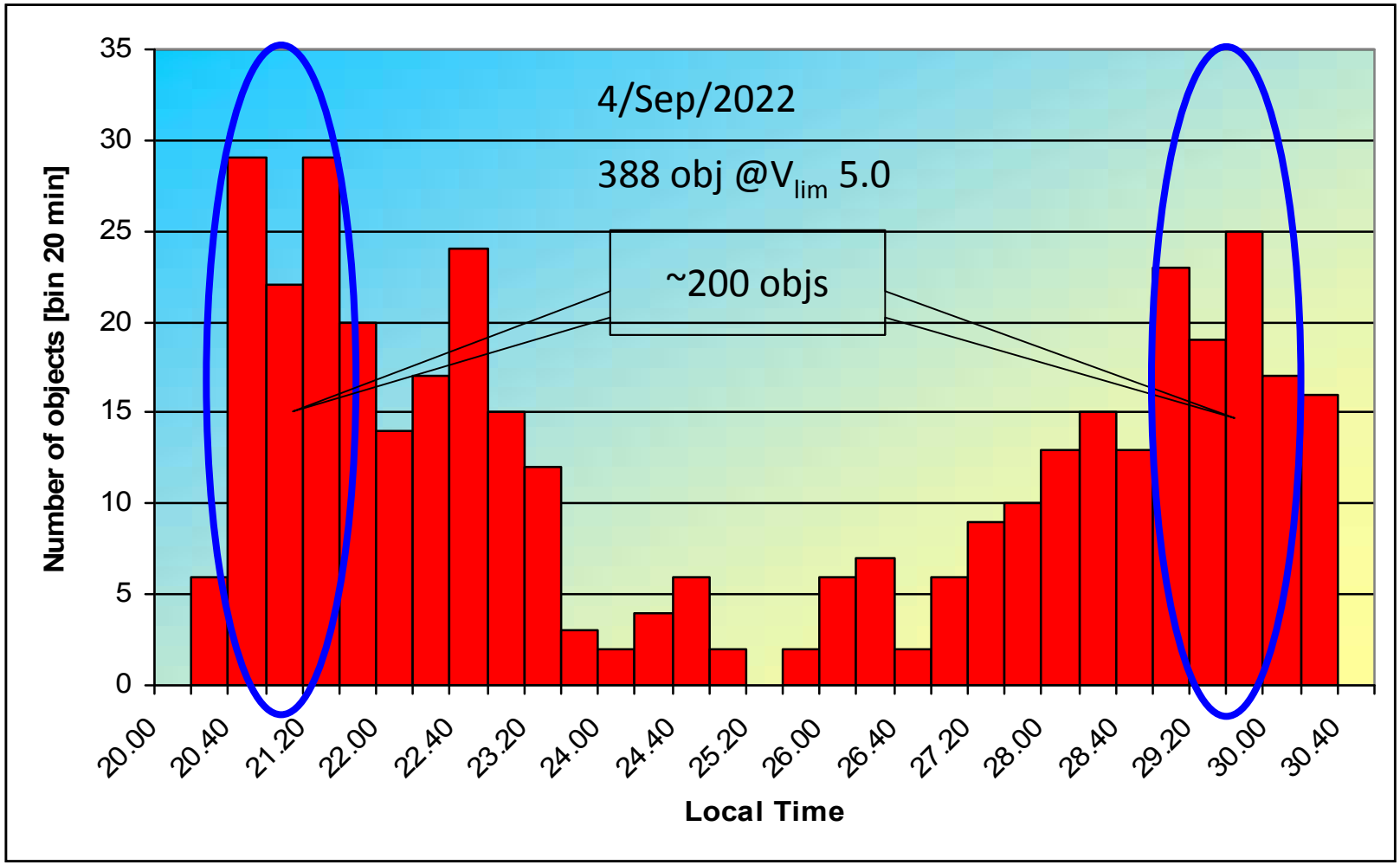
1 min stacked exposure
(~30 frames)

Intercepting the LEO debris population

the FengYun 1C ASAT event (Jan 2007)



Surveying the LEO population



@latency time V_{lim} ~ 6.5
namely a factor of 4 more targets

Orbit determination (TLE) for (nominally)
~ 800 obj/night

Timeliness!

(astronomers never sleep)