TAOS Project

An Occultation Survey of the Outer Solar System

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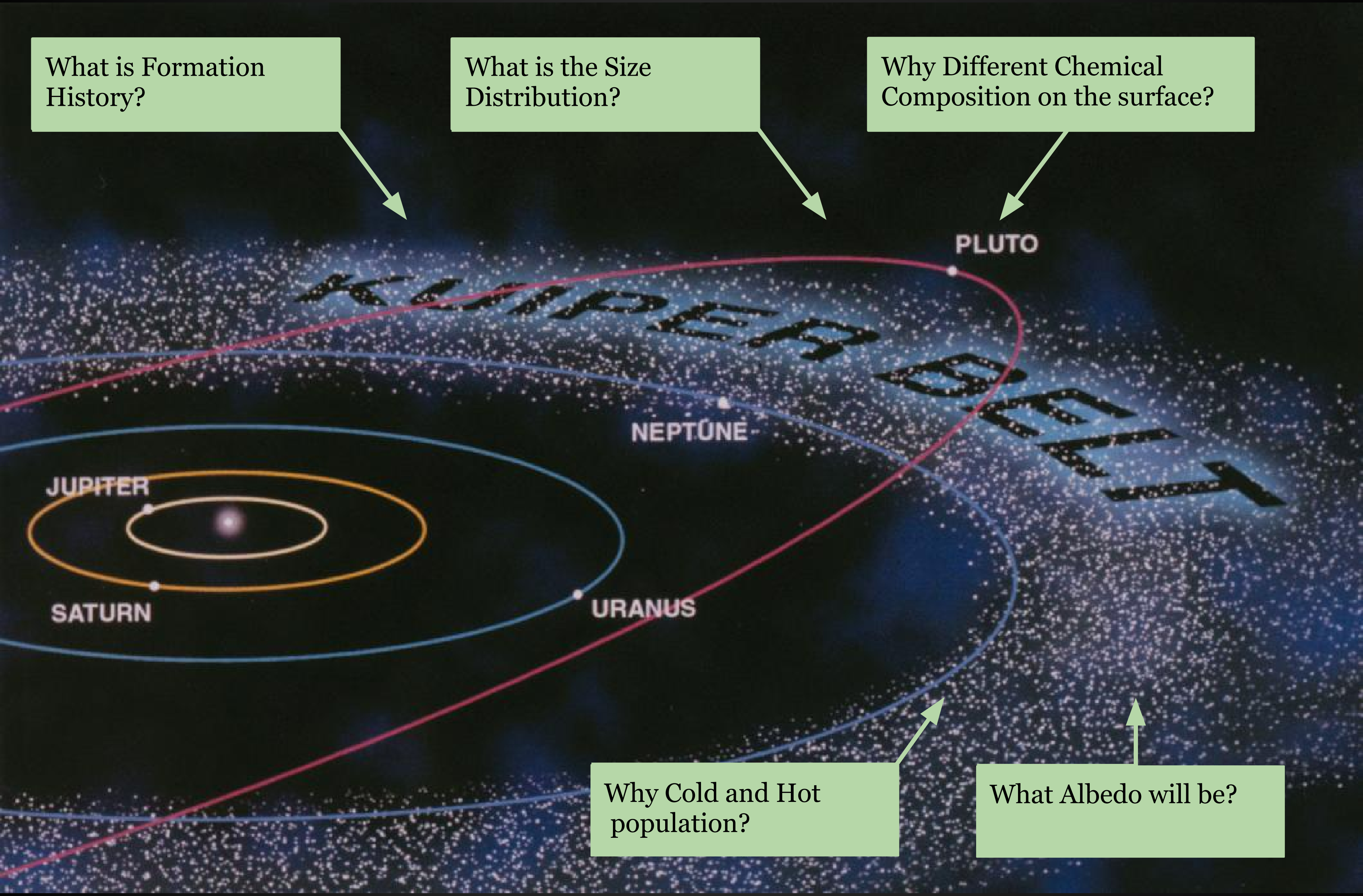
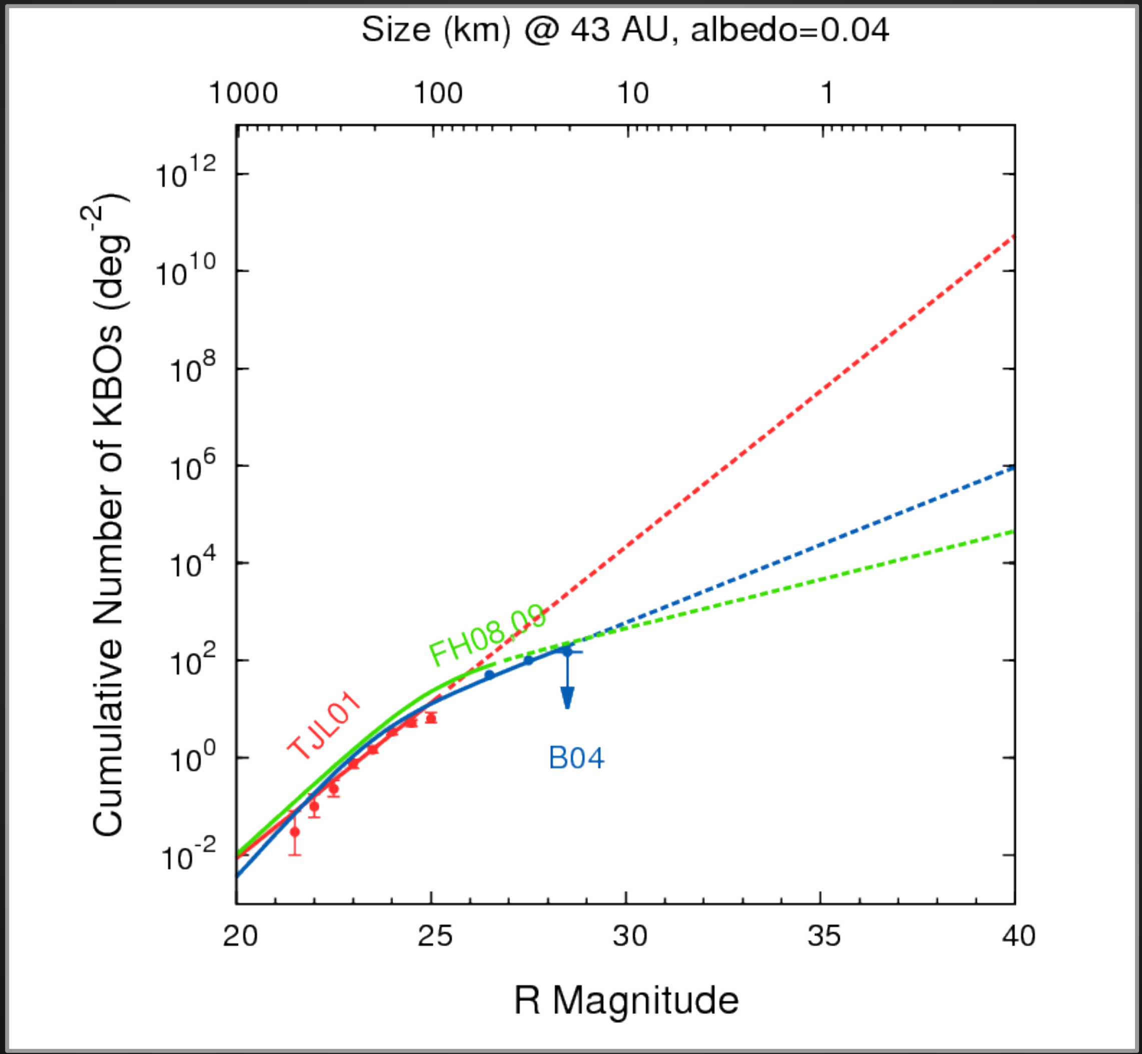
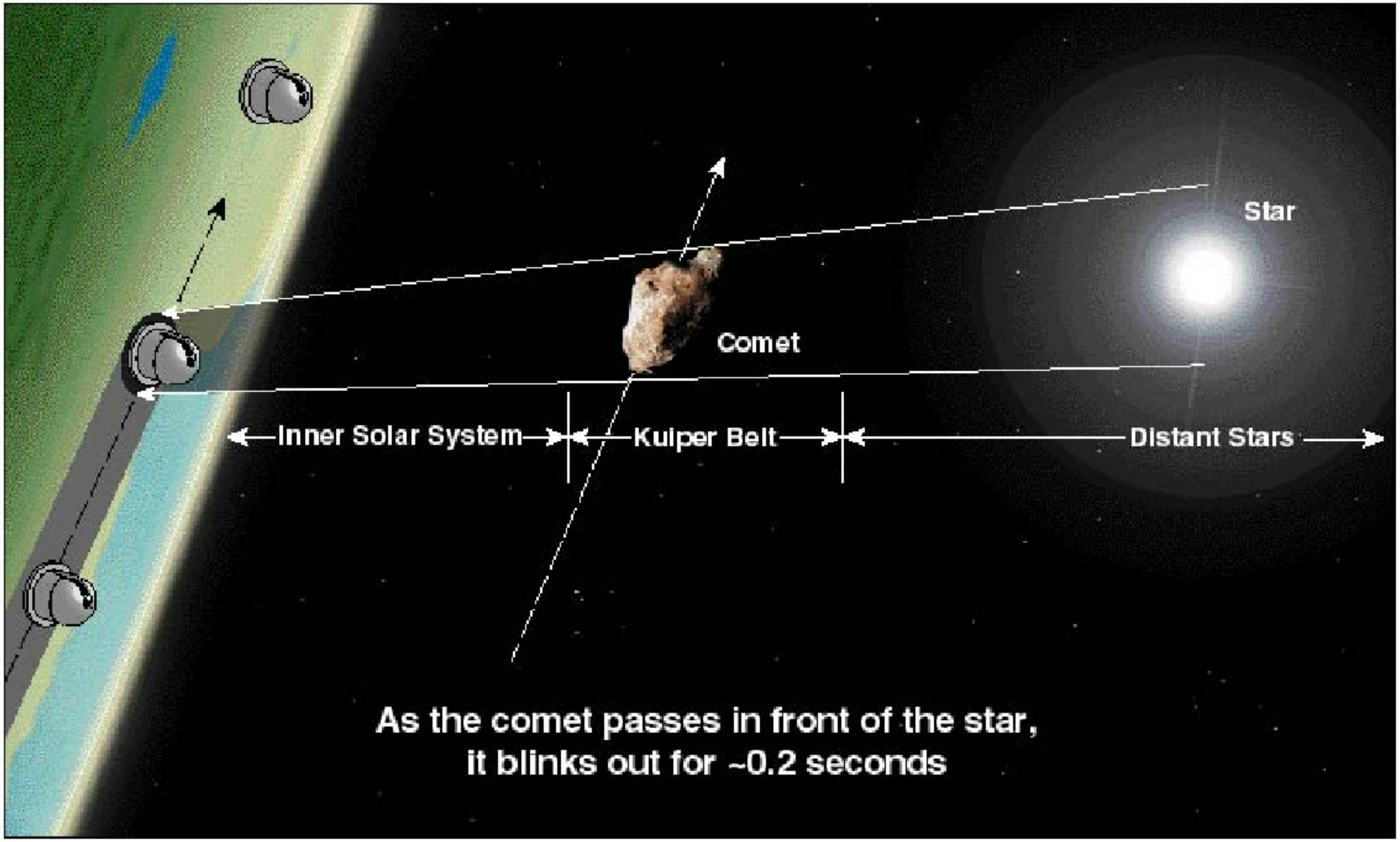
2012-09-03 @ Ensenada


What is Formation History?
What is the Size Distribution?
Why Different Chemical Composition on the surface?
PLUTO
KUIPER BELT
NEPTUNE
JUPITER
SATURN
URANUS
Why Cold and Hot population?
What Albedo will be?

Cumulative Luminosity Function

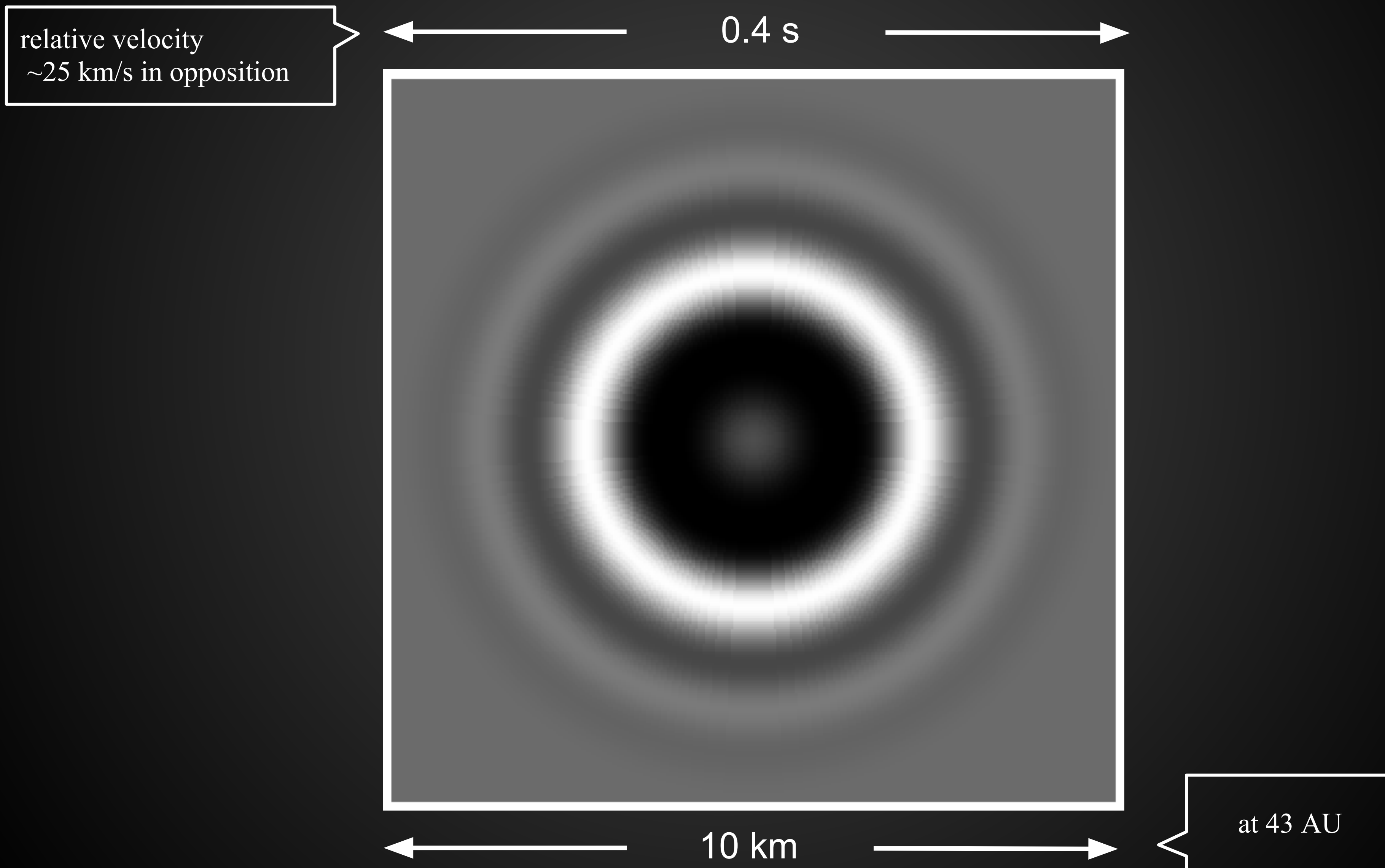


Counting Kuiper Belt objects using occultations

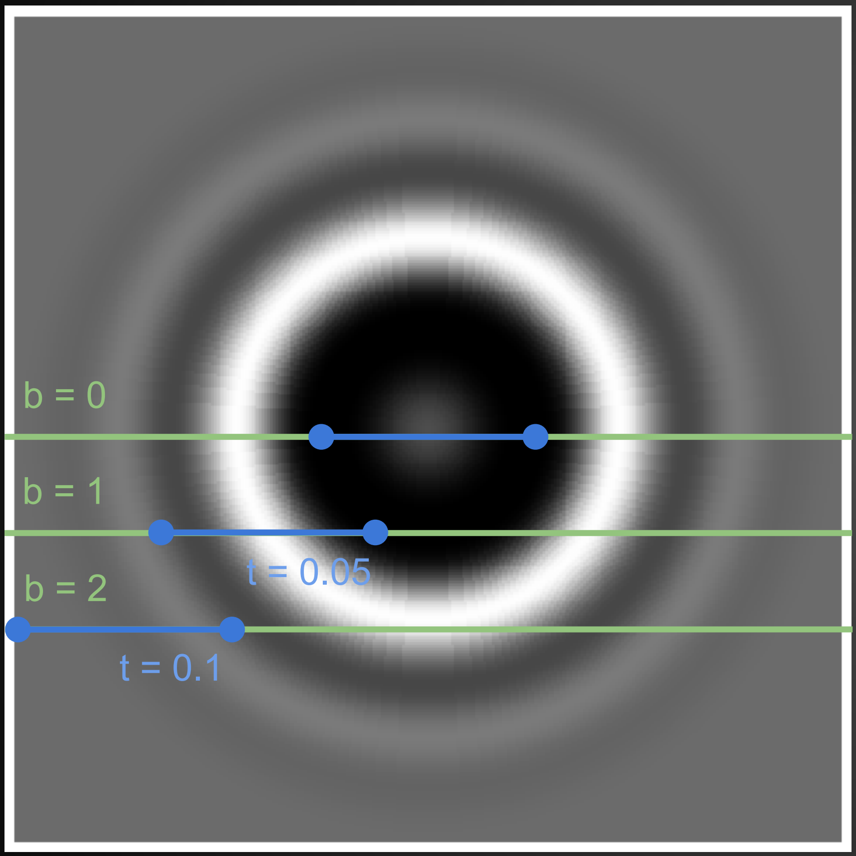


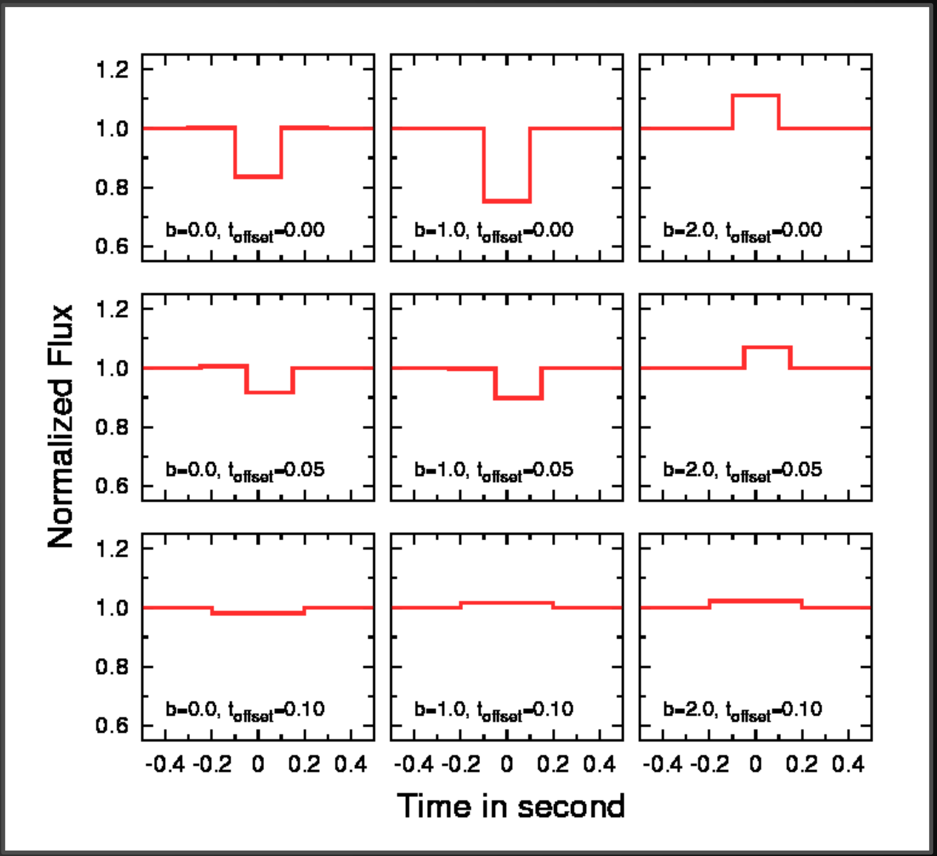
36723-K. Belt-001

Shadow of 1-km Object



Diffraction Lightcurve of 1-km Object



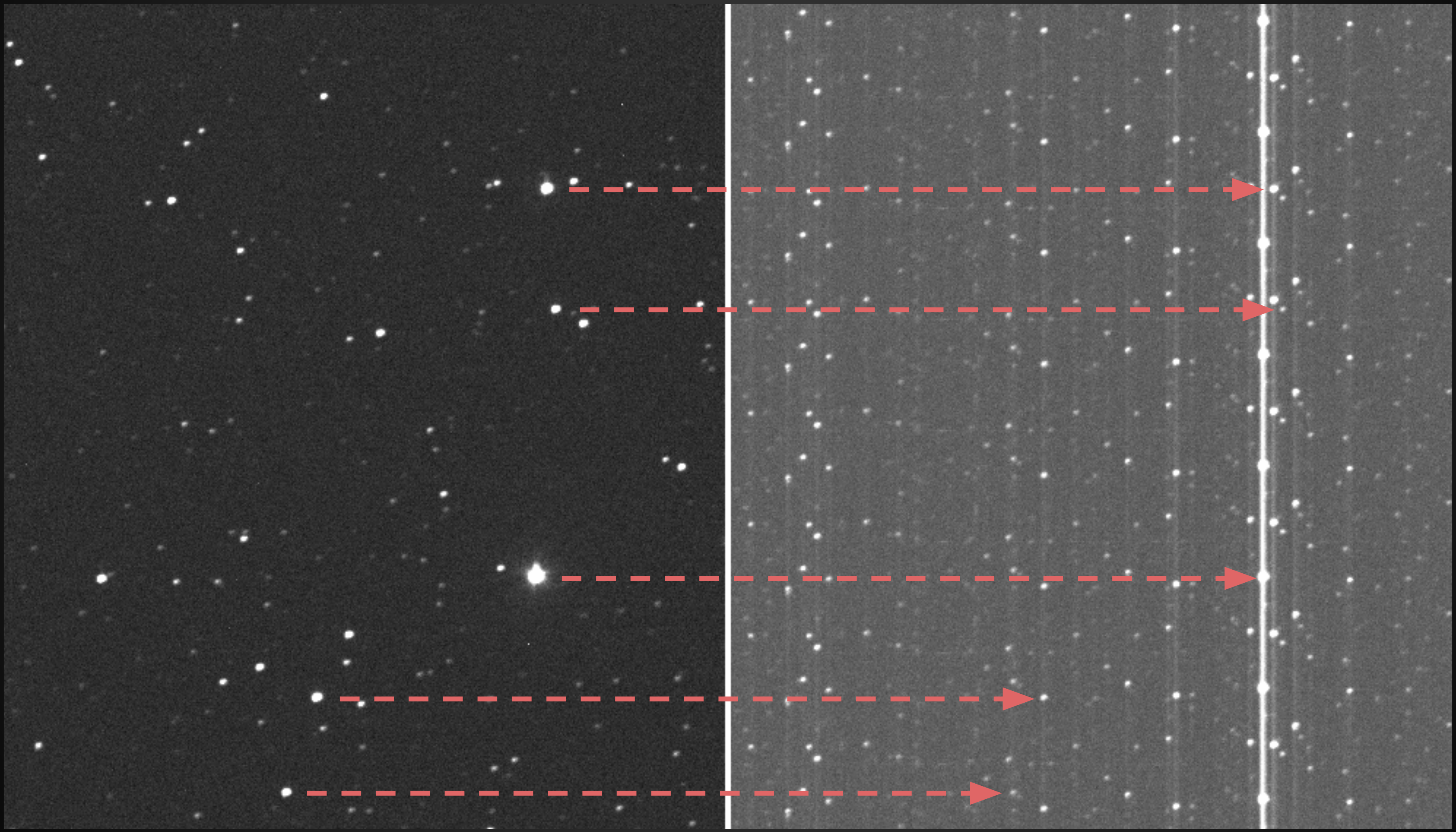


b is impact parameter in km

the duration is about 0.2 s and the flux drop is about 20%

t offset represents different start time

To Achieve 5 Hz --- Zipper mode



the drawback of zipper mode is (1) stars can easily interfere with others, (2) higher sky background

Four 0.5-m Telescopes with F/1.9

Observation Scheduler

Open Dome after Sunset (elevation < 0)
to cool down the telescope until elevation < -18

Select a TAOS field (close to the zenith)
to get best image quality

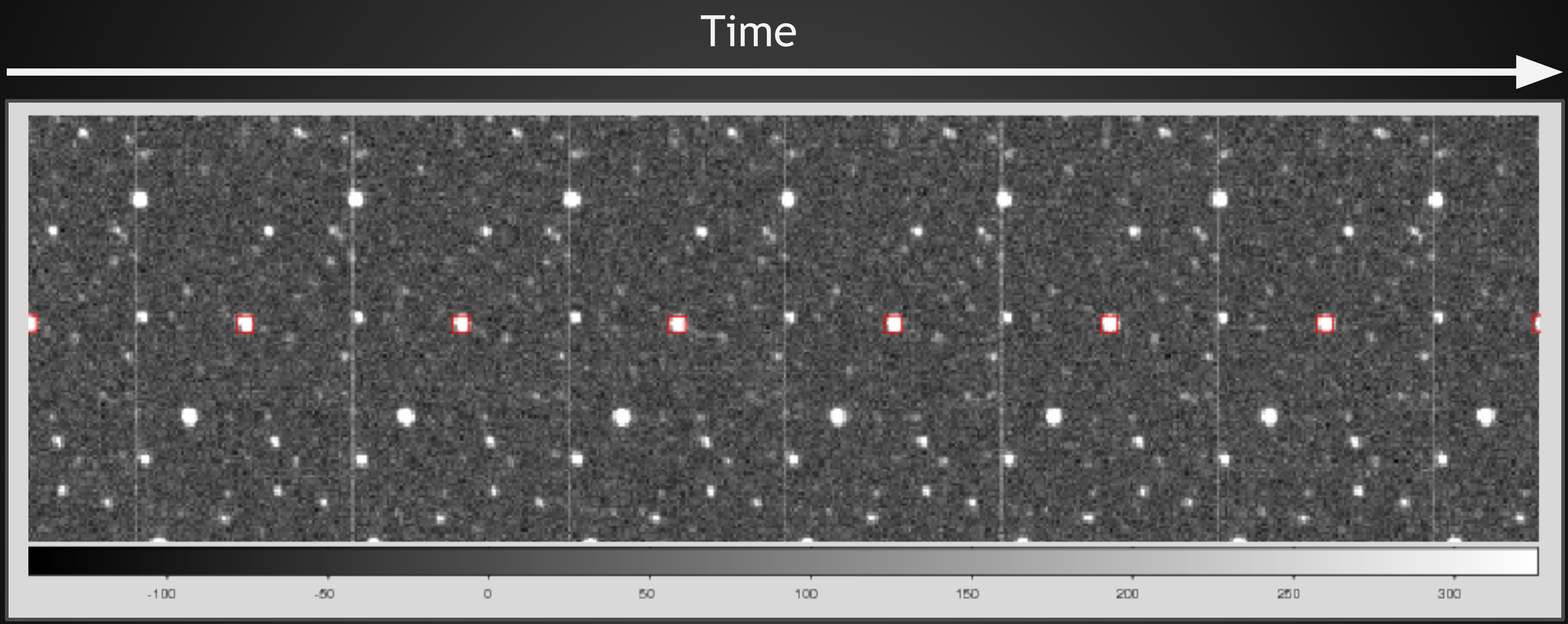
Slew and do Pointing Correction
to synchronize the pointing of all telescopes

Take 3 stares and Start zipper mode
zipper mode observation lasts 1.5 hr (27,000 for 5 Hz)

GRB alert

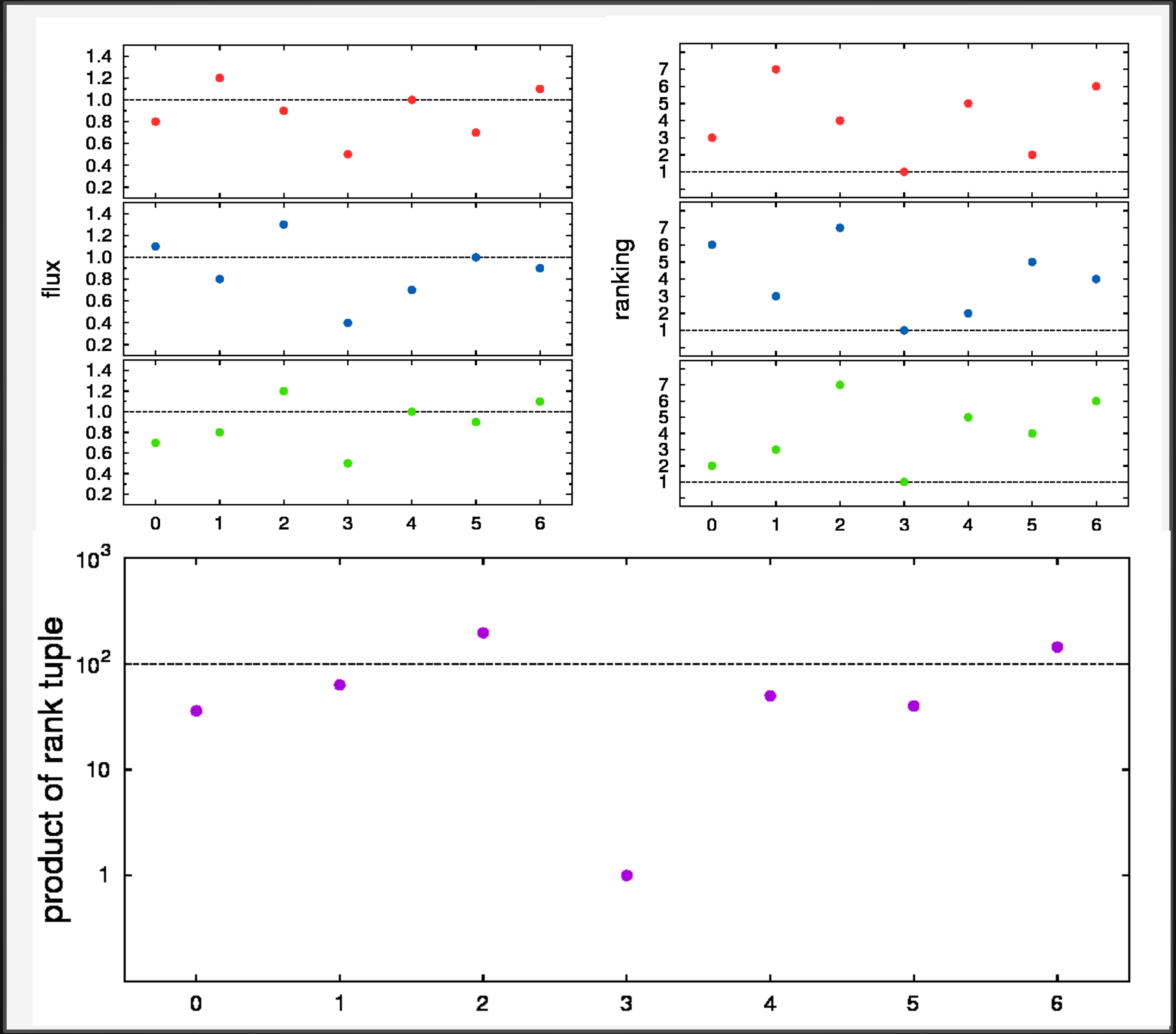
Stop KBO Observation when el. of Sun > -18
close dome until el. > 0

Data Reduction --- Aperture Photometry

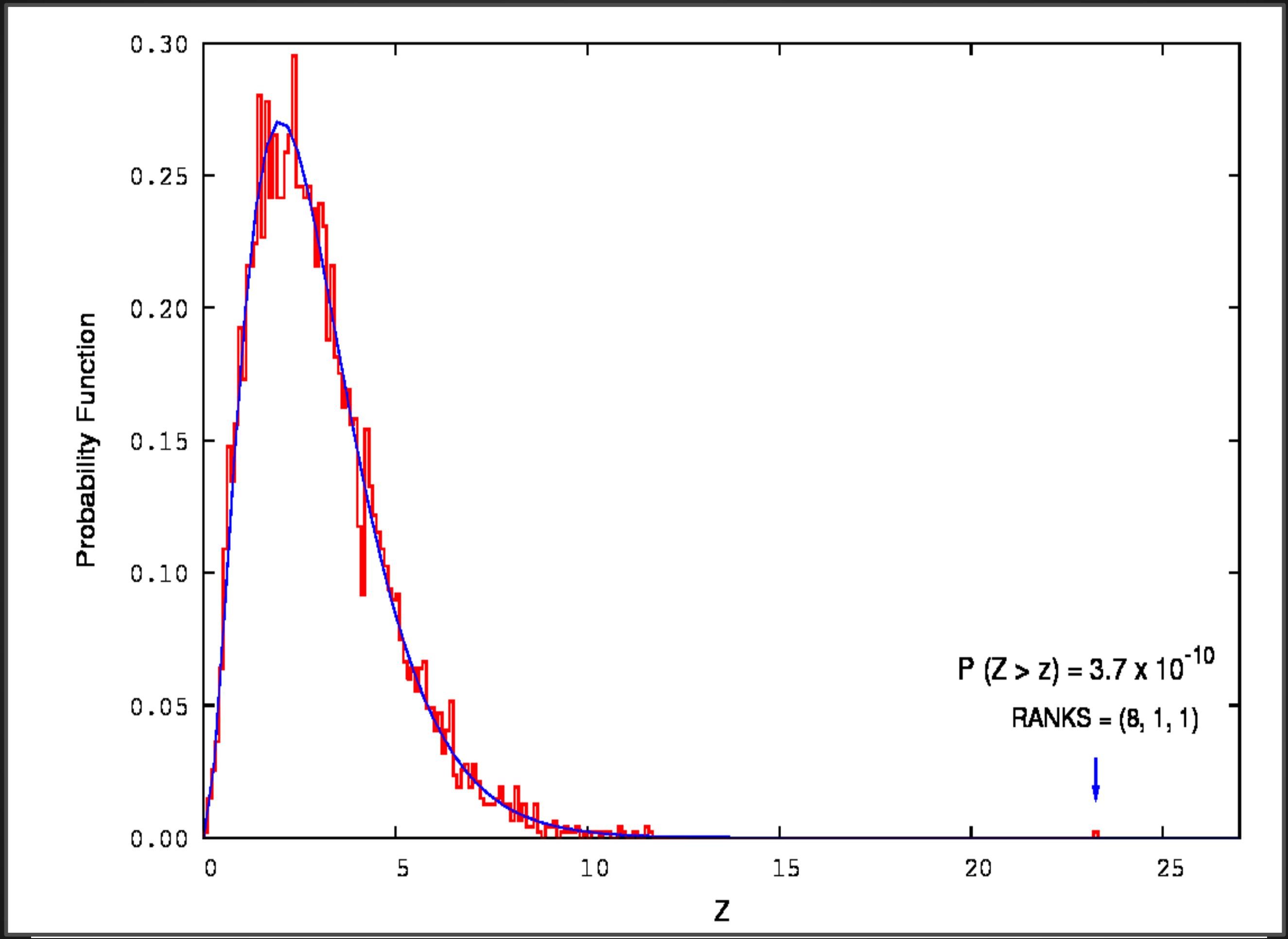


Photometry features: (1) optimal aperture size for the best SNR, (2) square aperture for minimizing the computing time.

Event Detection --- Rank Statistics

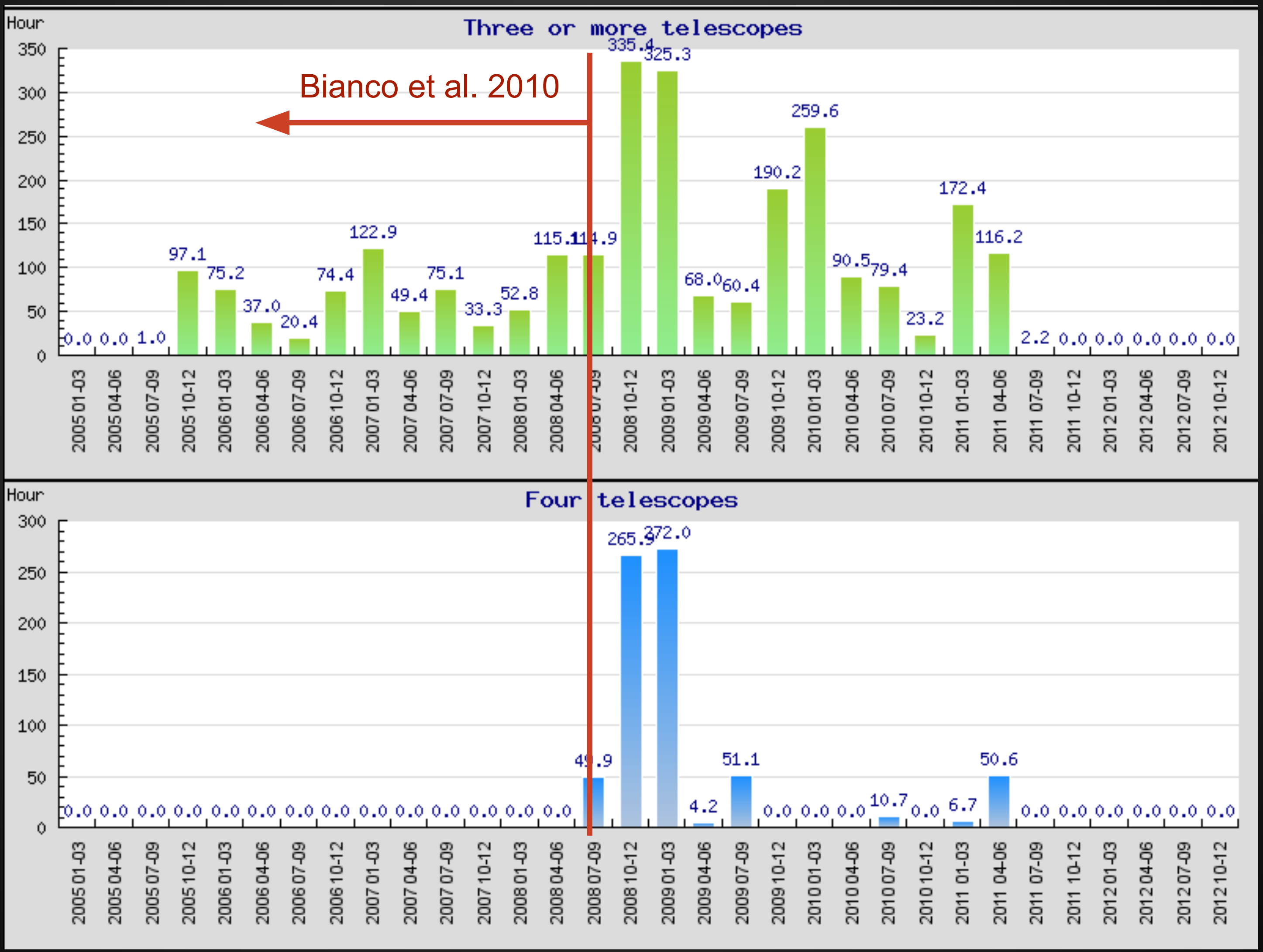


Event Detection --- Rank Statistics



Z = - log (r_1 * r_2 * r_3 / N^3), e.g. N = 27,000
the probability of P(Z > z') can be easily computed.
for small Z, the histogram approximately follows Gamma dist.

Summary of Data Runs



Summary of Data Runs

Start Date	2005 February	
End Date	2008 July	2011 September
Number of Data Runs	443	2,016
Total Exposure in star-hour	500,761	1,383,052
Number of Photometry Points (or Rank tuples)	8.516×10^{9}	2.024×10^{10}

Bianco et al. (2010) used 2005 to 2008 data
This work is the whole data set (2005 to 2011)

Result

No statistically significant events found

Efficiency Test

1. implant an occultation event into a lightcurve set with a certain size of KBO

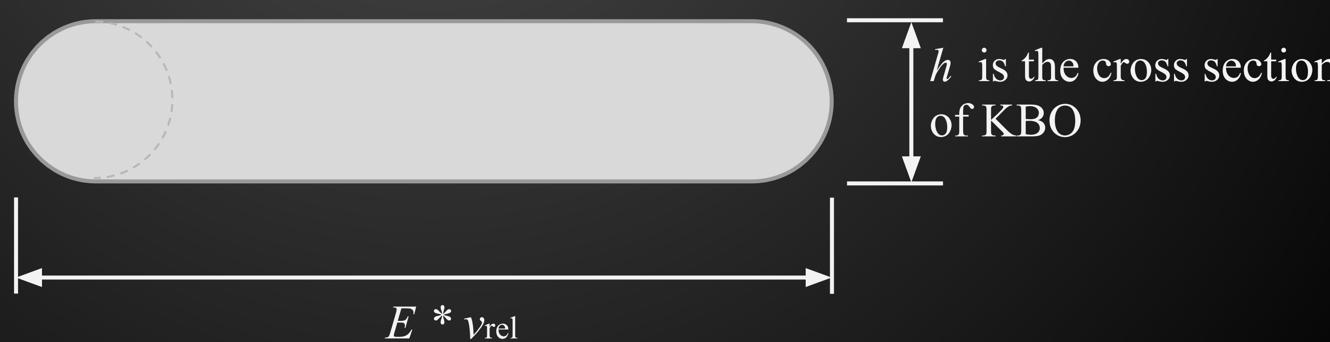
2. sizes of KBO in km: D = [0.5, 0.6, 0.7, 1.0, 1.3, 2.0, 3.0, 5.0, 8.0, 15, 30]

3. do the analysis again on this event implanted lightcurve set

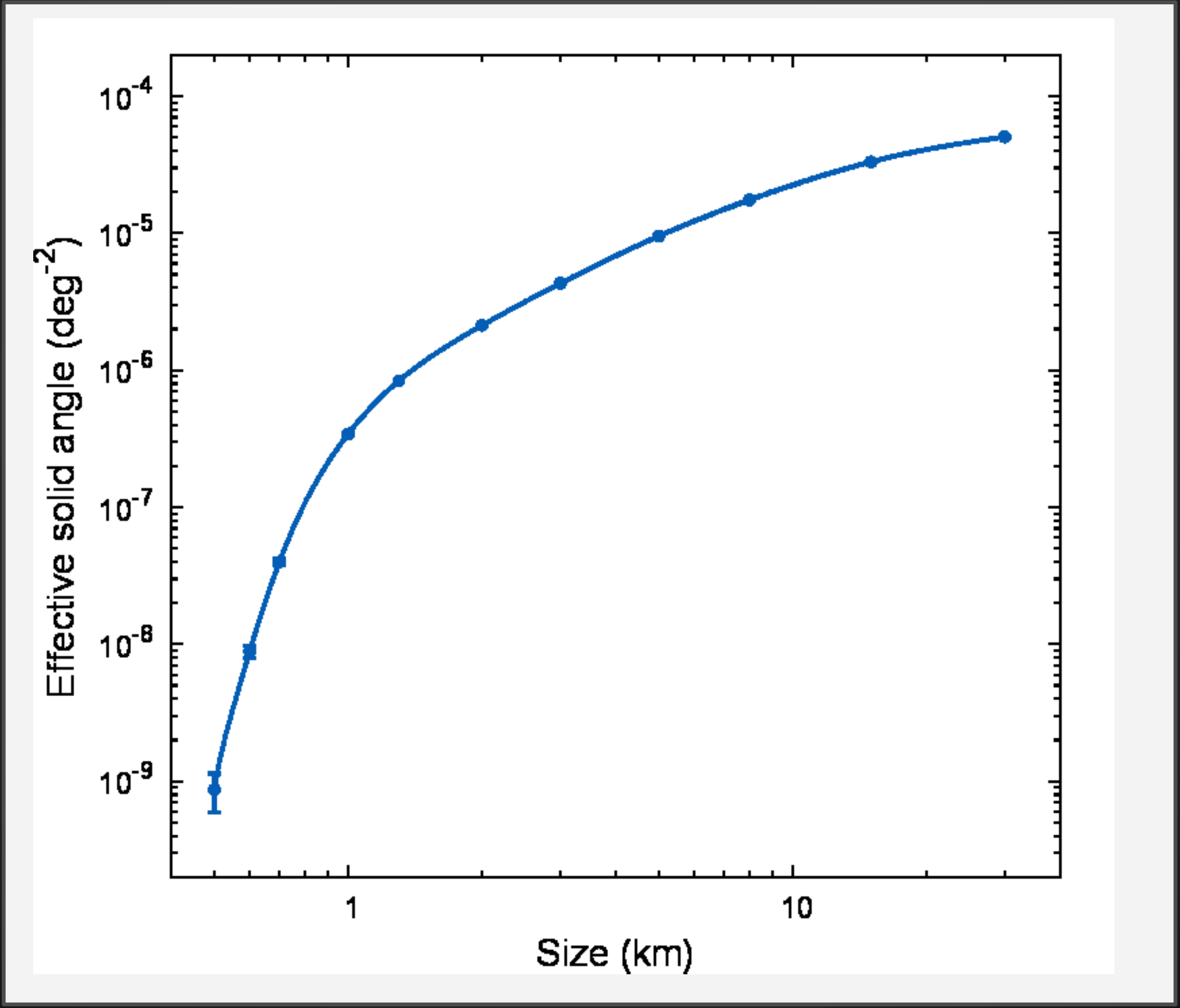
4. count how many lightcurve sets with recovered events and then

5. sum those usable lightcurve sets up to derive the <u>effective solid angle</u>

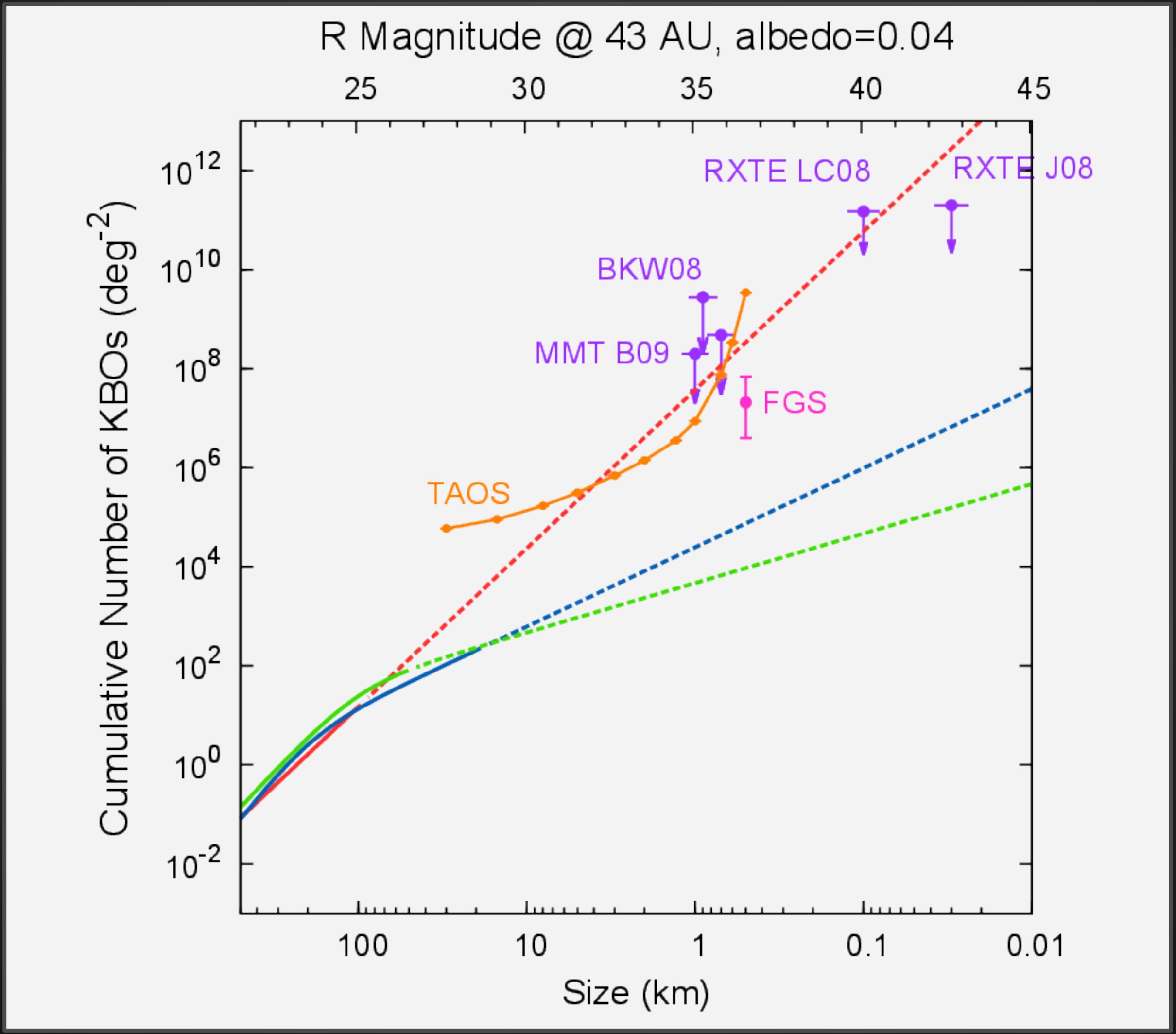
$$\Omega_e(D) = \sum_j E_j \, v_{rel} \, h_j(D),$$



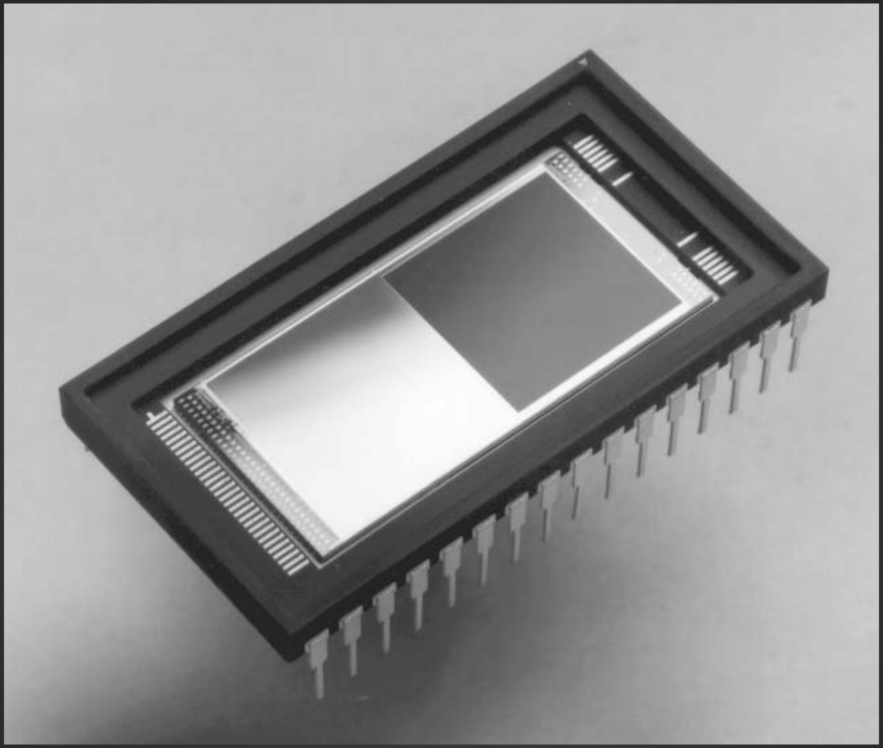
Effective Solid Angle



Upper Limit on the Size Distribution



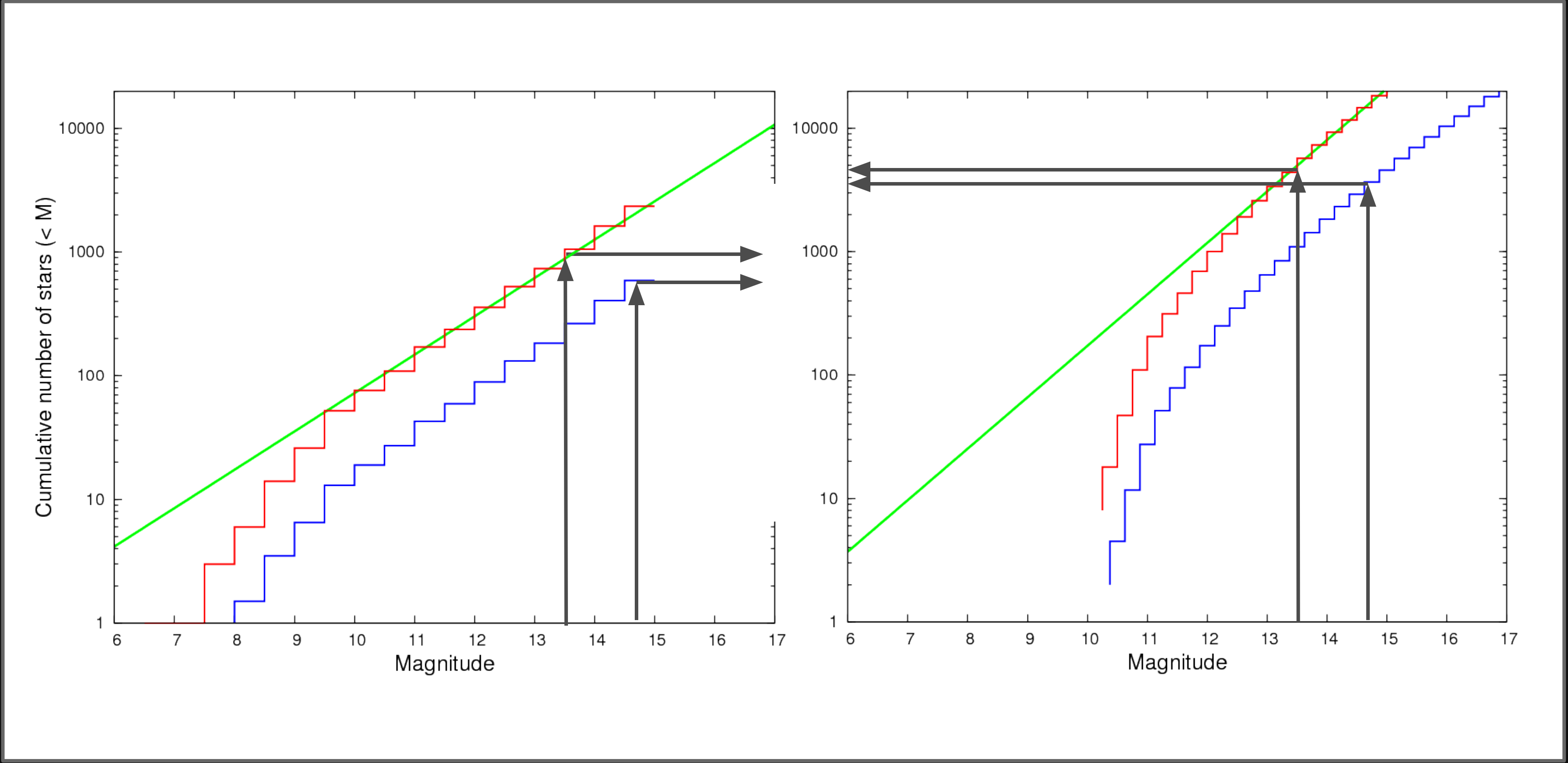
TAOS 1.5 --- Frame Transfer Camera



Good: 10 Hz sampling rate, no zipper mode
(e.g. lower sky background, limiting magnitude down to 14.5 mag, etc.)

Bad: FOV is one fourth of the original camera

Cumulative Luminosity Function



Thanks for listening

TAOS II

Trans-Neptunian Automated Occultation Survey

TAOS 2 Design Goal --- A factor of 100

<u>Higher quality site (a factor of 7)</u>

- 250 observable nights per year

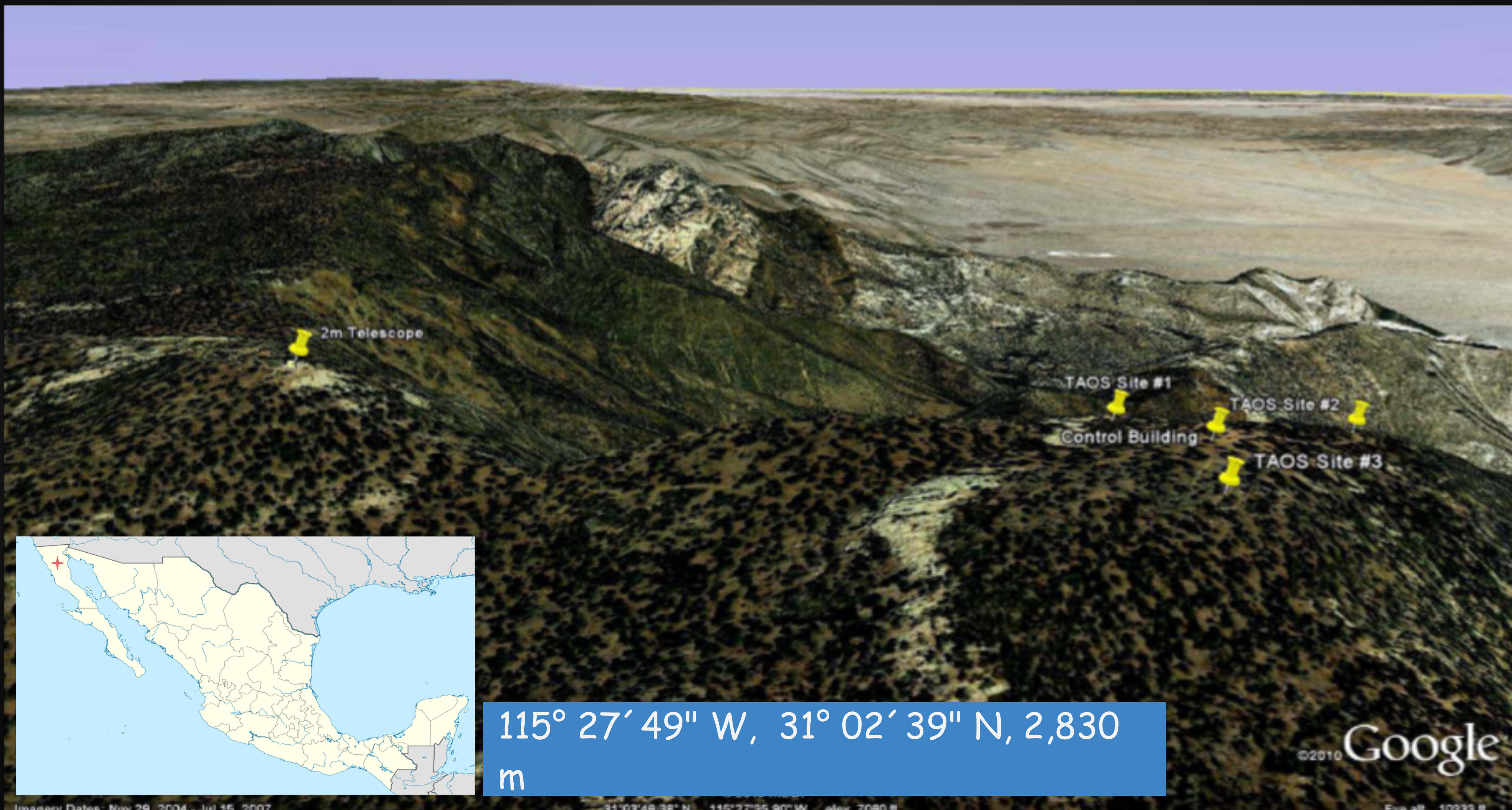
<u>Higher signal-to-noise data (a factor of 10)</u>

- larger aperture telescope (0.5 m to 1.3 m)
- better seeing (~0.6 arcsec)

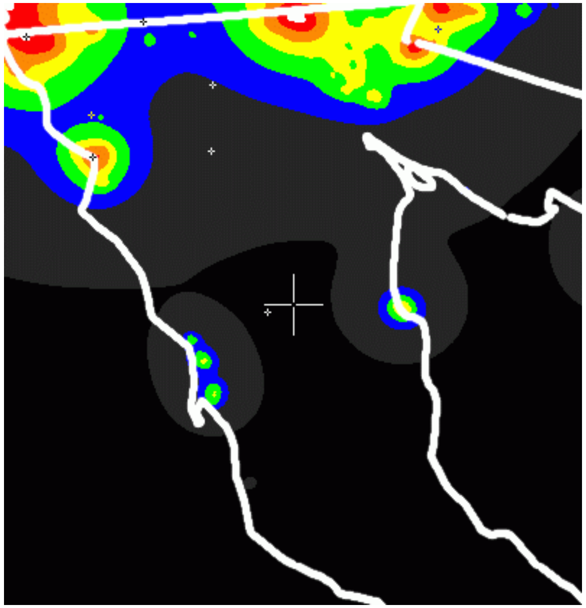
<u>Higher sample cadence (a factor of 1 to 10)</u>

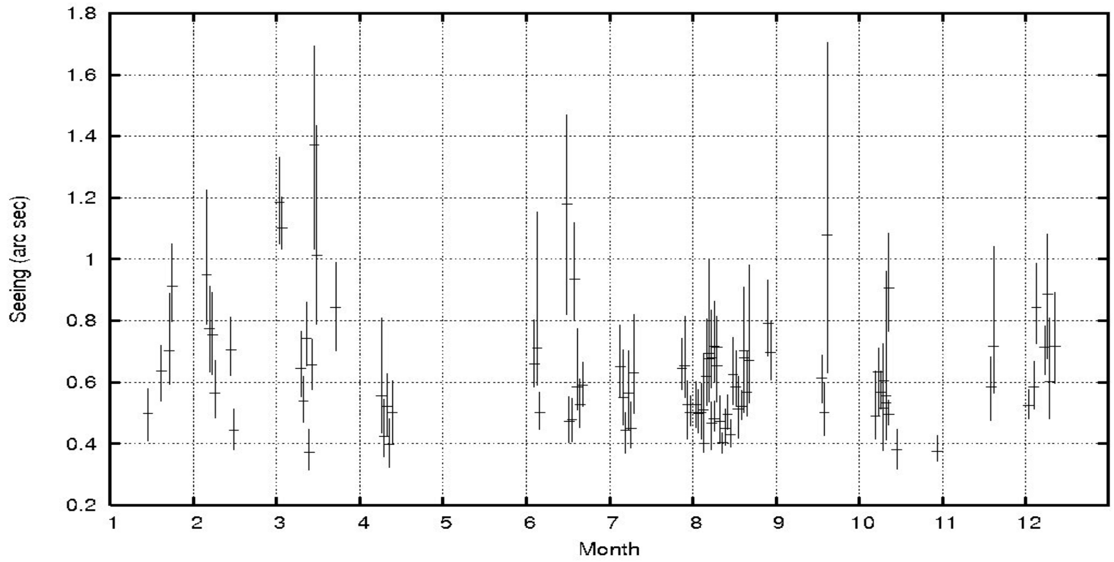
- 20 Hz sampling rate
- sensitive to smaller objects (model dependent)

San Pedro Martir Observatory



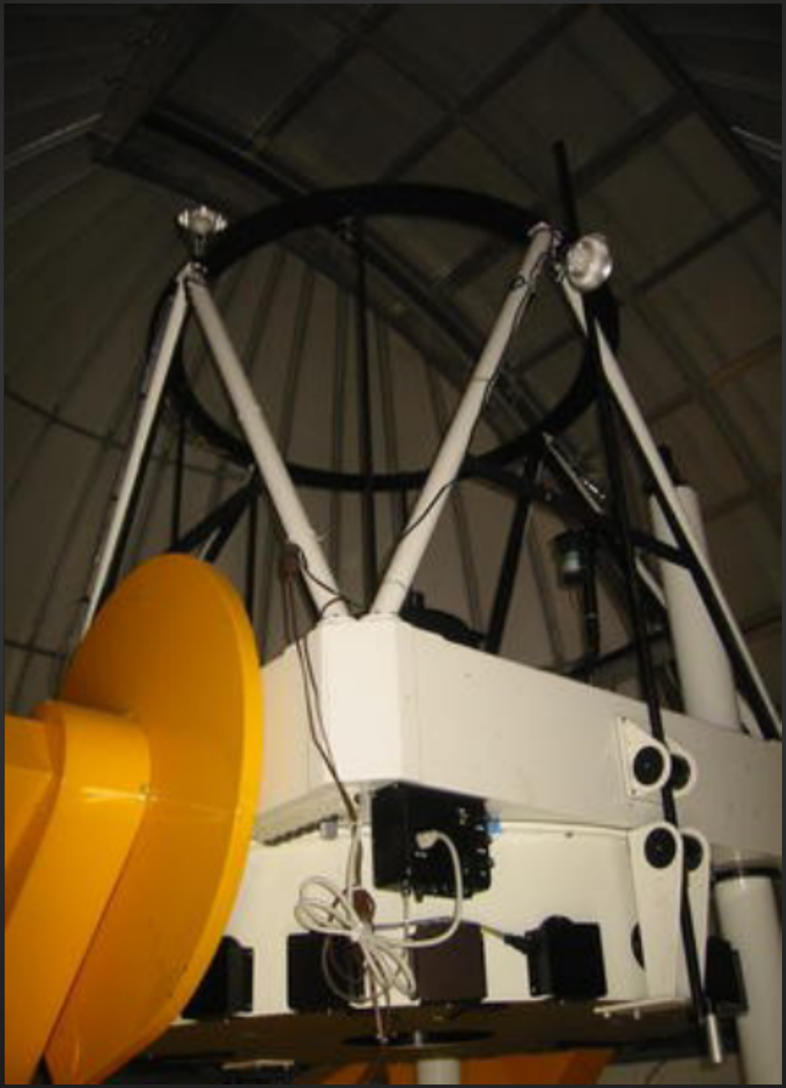
Dark Sky and Stable Seeing



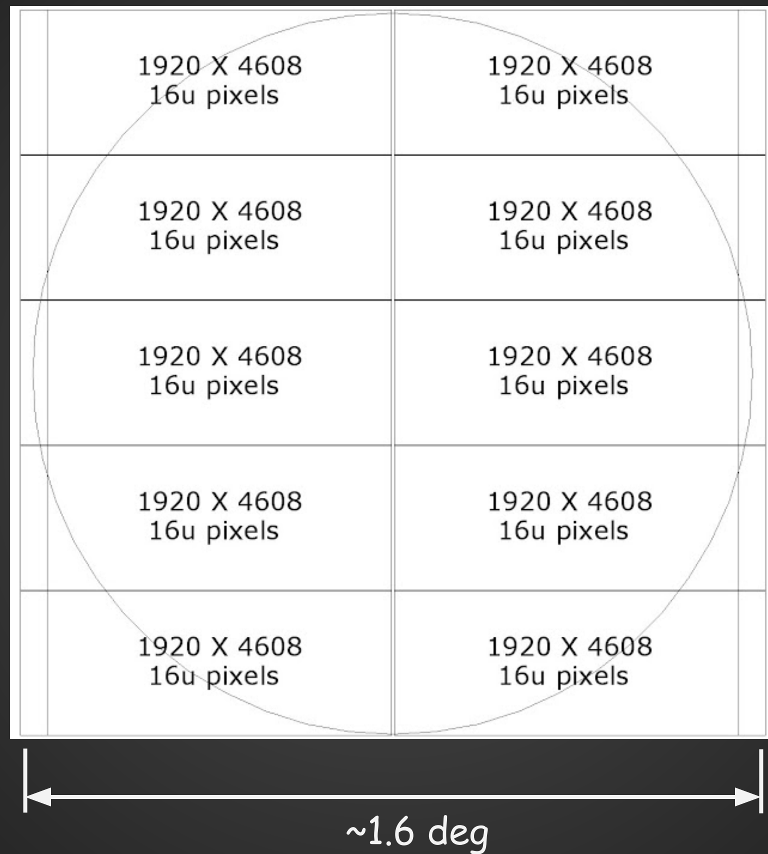


Seeing data measured by a DIMM monitor on 2002

1.3 m F/4 by DFM Engineering



CMOS Image Sensors



A custom 1920 x 4608 CMOS imager from e2v technologies plc.

Why do not use CCD? The circuit will be too complicated for 20 Hz readout (EM CCD may be doable).

Data Rates

- 100 Mpixel camera (3 of them) + 20 Hz readout
  = ~300 TB of raw image data per night

- sub-aperture readout (10 x 10 pixels)
  - reduce data rate to 3 TB per night, assume 10,000 stars monitored.
    (maybe it won't be too bad in 4 years later)

The TAOS II Schedule

Site preparation to begin in late 2011

weather monitors, enclosures, domes

Telescopes delivered throughout 2012

telescope #3 ready, telescope #1 primary mirror ready

Prototype camera late 2011/early 2012

camera development is the bottleneck

Completed system operation late 2013

The TAOS II Partners

Academia Sinica Institute of Astronomy and Astrophysics, Taiwan

Universidad Nacional Autónoma de México, México

Harvard-Smithsonian Center for Astrophysics, USA

Yonsei University, Korea