Improving Astrometry and Photometry reduction for all-sky cameras

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Overview

- PRISMA project
- Astrometric reduction
  - ✓ Model and know issues
  - ✓ Proposed solutions
  - ✓ Results
- Photometry reduction
  - ✓ Calibration
  - ✓ Light pollution
  - ✓ Sensitivity calibration

PRISMA camera at Pino Torinese Observatory

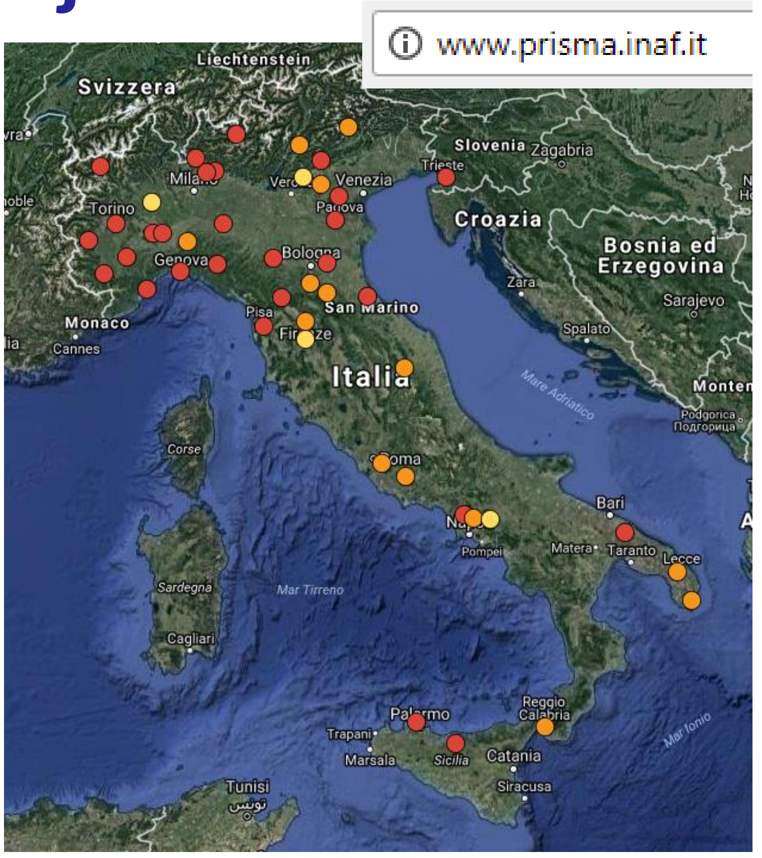
PRISMA project

Prima **R**ete **I**taliana per la **S**orveglianza **S**istematica di **M**eteore ed **A**tmosfera

- 27 operational cameras
- 18 cameras in purchase/installation phase

Participants:

- INAF observatories
- Universities & research institutes
- Amateur astronomical observatories and planetaria
- Schools (education – laboratories)



www.google.com/maps

Astrometry reduction model

Astrometry with fish-eye cameras: **Z. Ceplecha**[1] **(1987)**

Further developments in **J.Borovicka et al. (1992-1995)** [2-3]

$$\begin{cases} \begin{cases} b = a_0 - E + \operatorname{atan}\left(\dfrac{y - y_c}{x - x_c}\right) \\ u = Vr + S\left(e^{Dr} - 1\right) \end{cases} \\ r = \sqrt{(x - x_c)^2 + (y - y_c)^2} \end{cases} \rightarrow \begin{cases} a = E + \operatorname{atan}\left[\dfrac{\sin u \sin b}{\sin u \cos b \cos \epsilon + \cos u \sin \epsilon}\right] \\ z = \operatorname{acos}\left[\cos u \cos \epsilon - \sin u \cos b \sin \epsilon\right] \end{cases}$$

Known issues:

Many parameters to be determined
Strongly non-linear transformations

→

Sensitive to starting values of parameters
Non-optimal convergence

[1] Zdenek Ceplecha, Astronomical Institutes of Czechoslovakia Bulletin 38 222-234 (1987)
[2] J. Borovicka, Pub. Astron. Inst. Czech. Acad. Sci. 79 19
[3] J. Borovicka et al., Astron. Astrophys. Suppl. Ser. 112 173-178 (1995)

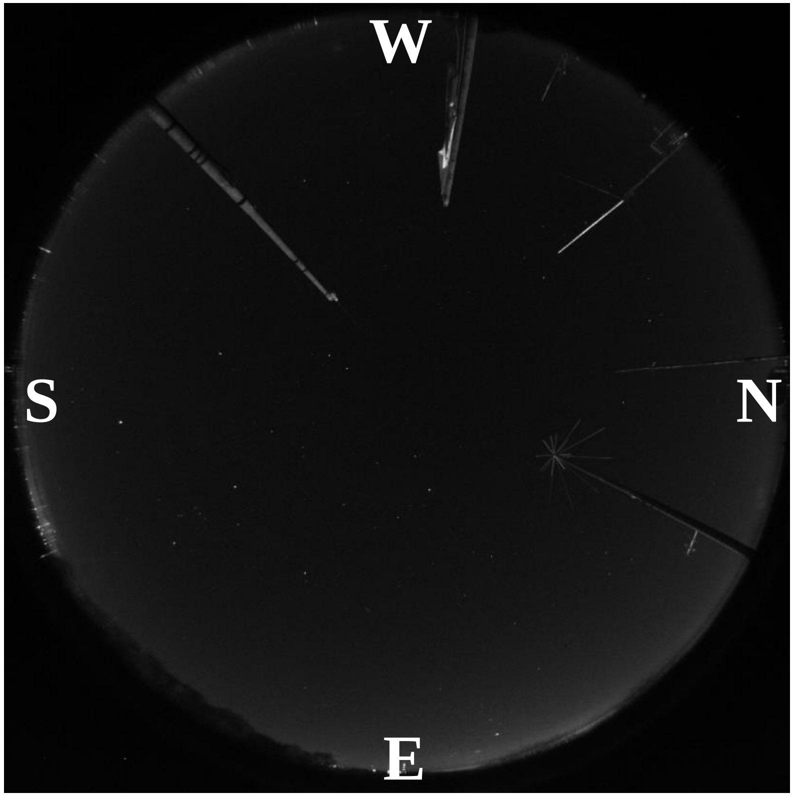
Implemented solutions (1)

Stepwise algorithm:

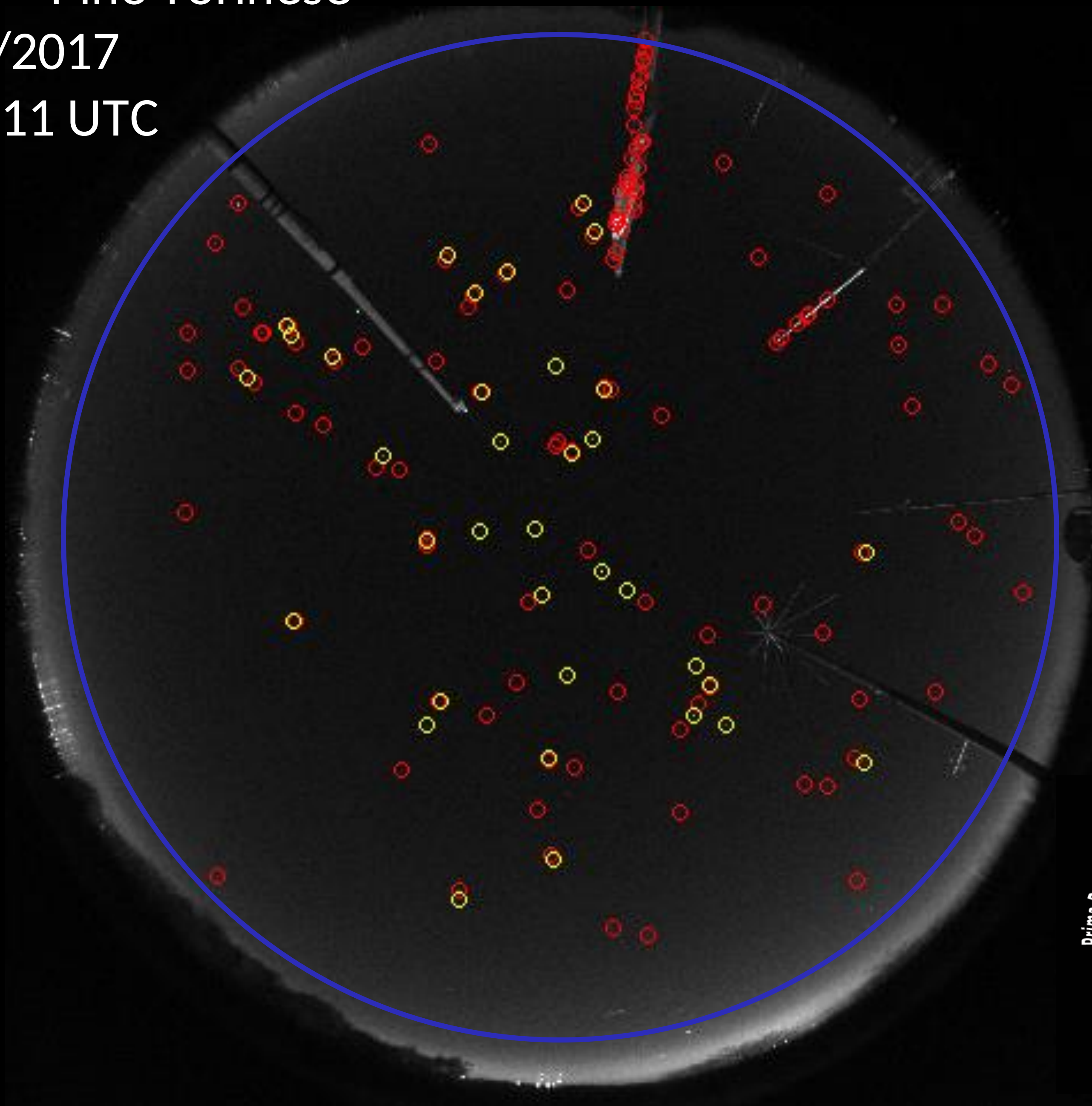
1. Determination of the star associations using simplified model (with known bias of ± 1-2°)

$$\begin{cases} \begin{cases} a = a_0 + \operatorname{atan}\left(\dfrac{y - y_c}{x - x_c}\right) \\ z = P_1 r + P_2 r^2 \end{cases} \\ r = \sqrt{(x - x_c)^2 + (y - y_c)^2} \end{cases}$$

About 4000-6000 associations in photometric nights, up to 75° of zenithal distance



ITPI01 – Pino Torinese
01/01/2017
20:45:11 UTC



Prima Rete Italiana Sorveglianza Sistematica Meteore & Atmosfera
PRISMA

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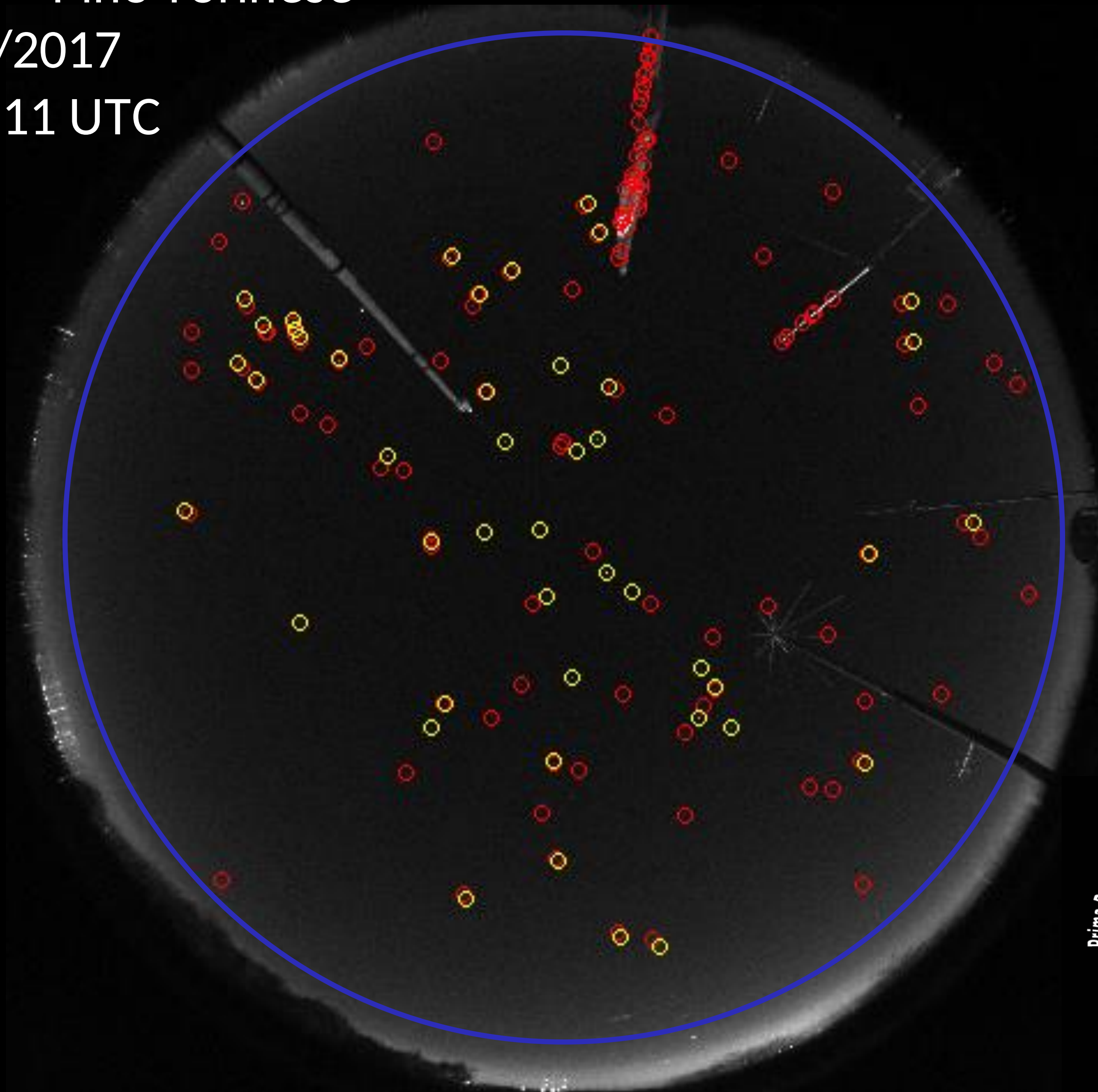

ITPI01 – Pino Torinese
01/01/2017
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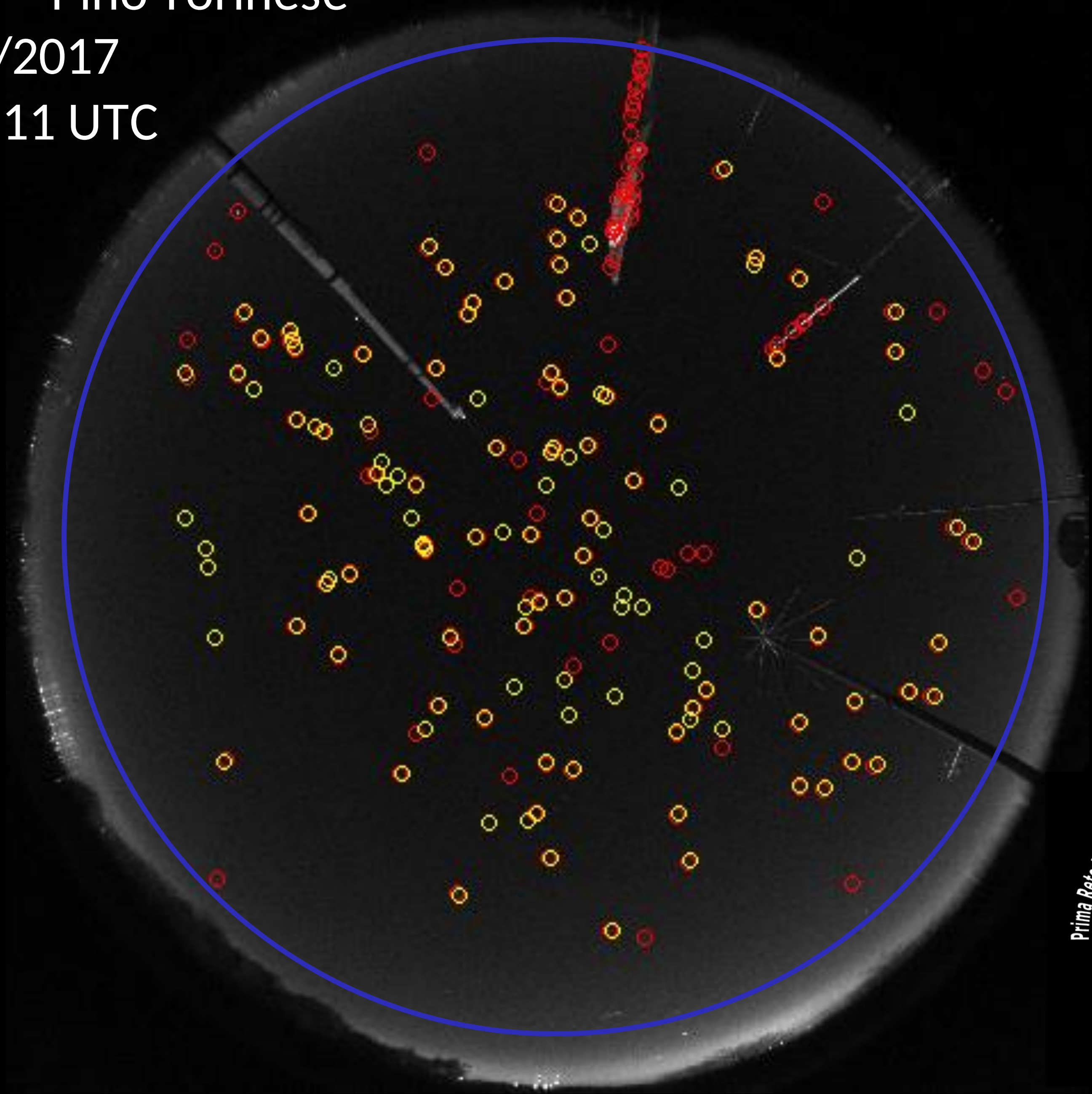
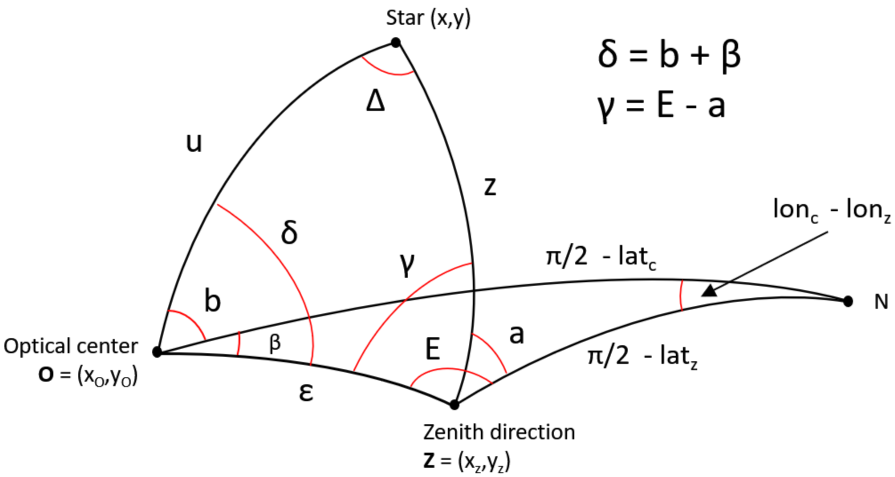


Implemented solutions (2)

Stepwise algorithm

2. Determination of the complete solution with a new parametrization for the (E, ε) correction

   - ✓ Easier initial estimates
   - ✓ Reduced crosstalk between parameters

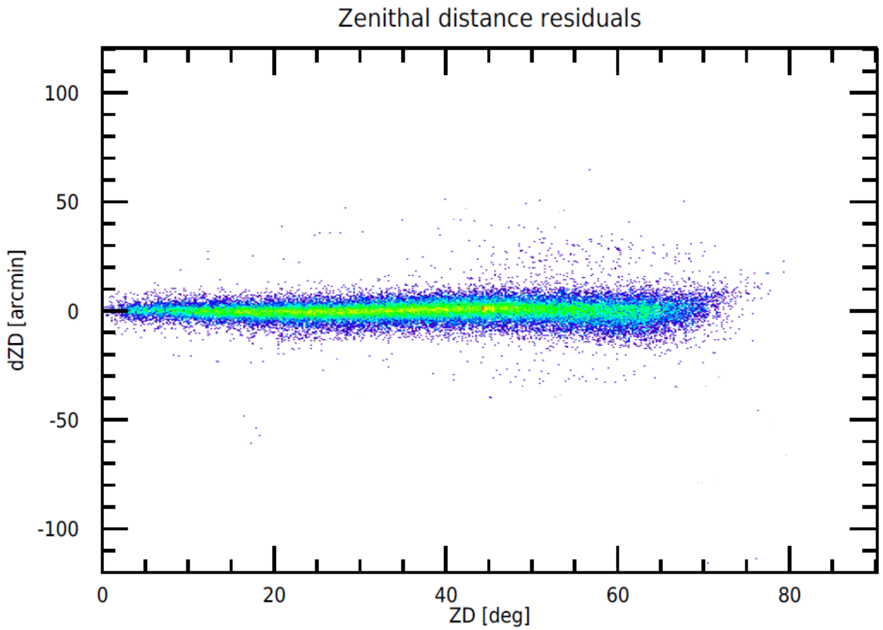


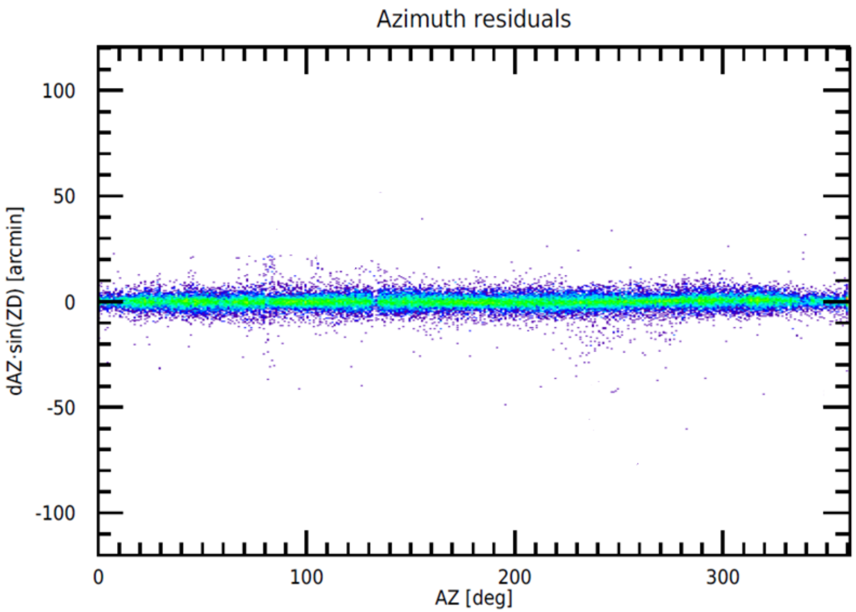
$$(a_0, x_o, y_o, V, S, D, E, \varepsilon) \rightarrow (a_0, x_o, y_o, V, S, D, x_z, y_z)$$

Results (1)

One month processing (about 30000 associations)

2D residuals histograms

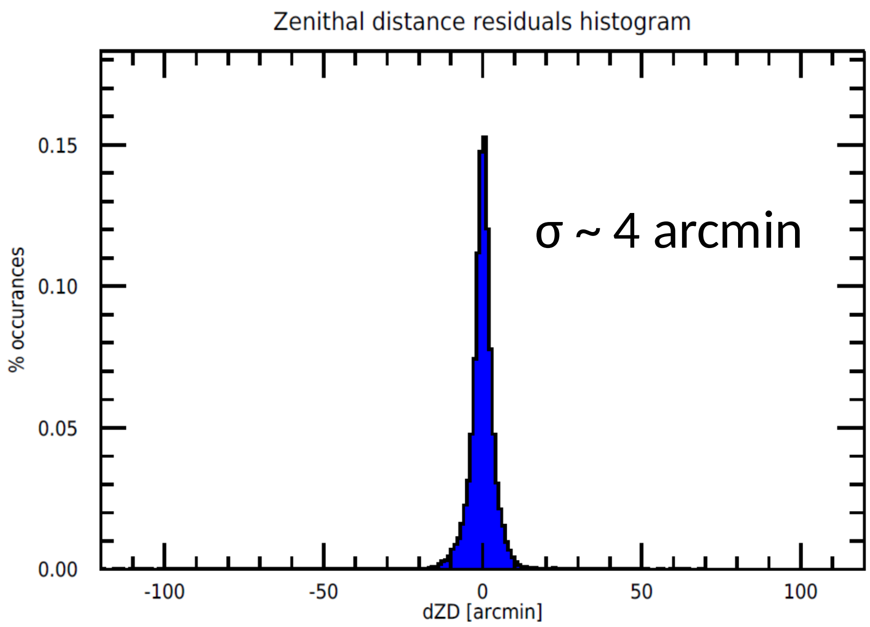


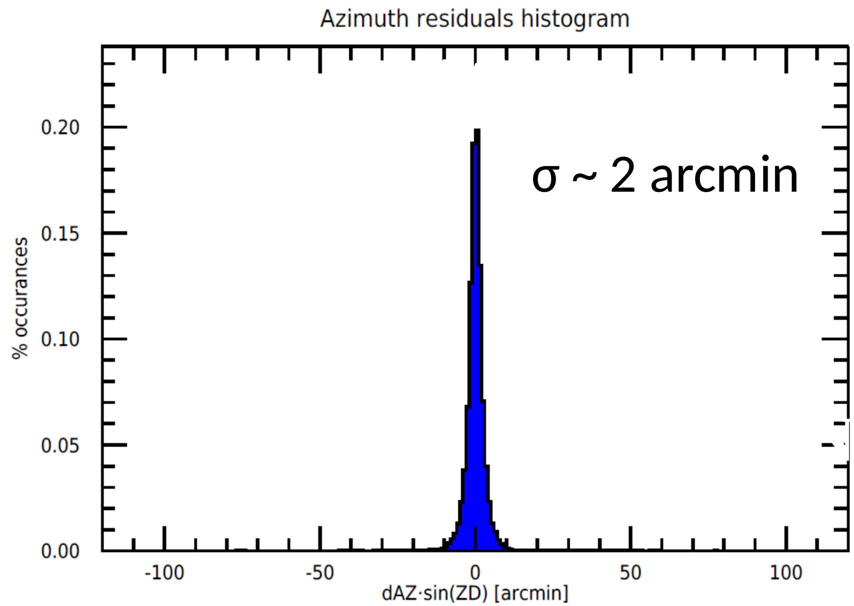


Results (2)

One month processing (about 30000 associations)

1D residuals histograms

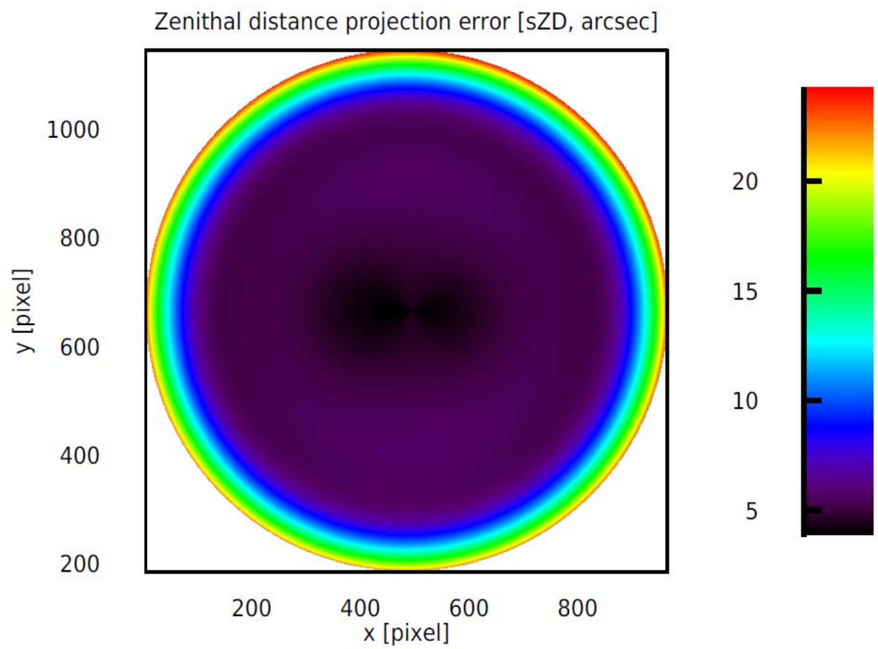


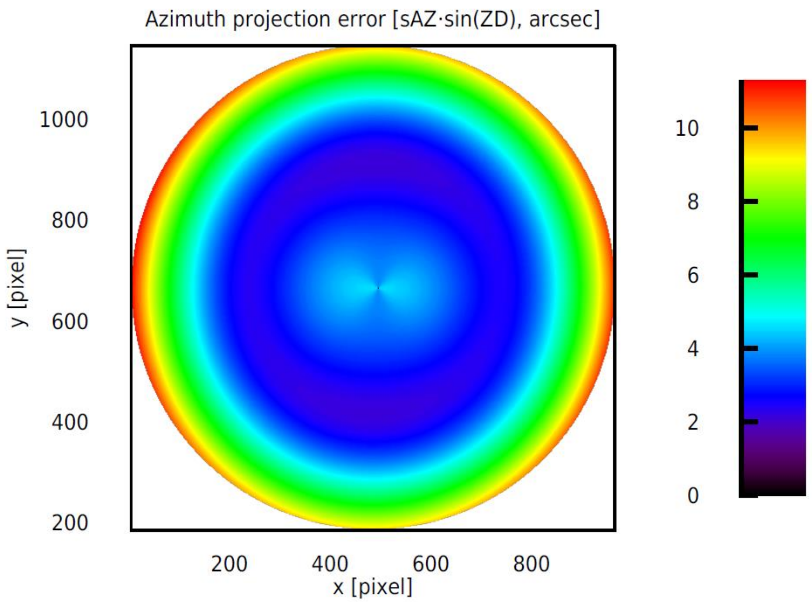


- ✓ 1 pix ~ 10 arcmin
- ✓ ~ 1/3 pixel of instrumental error

Results (3)

Statistical error due to uncertainties of projection parameters (variance-covariance propagation)

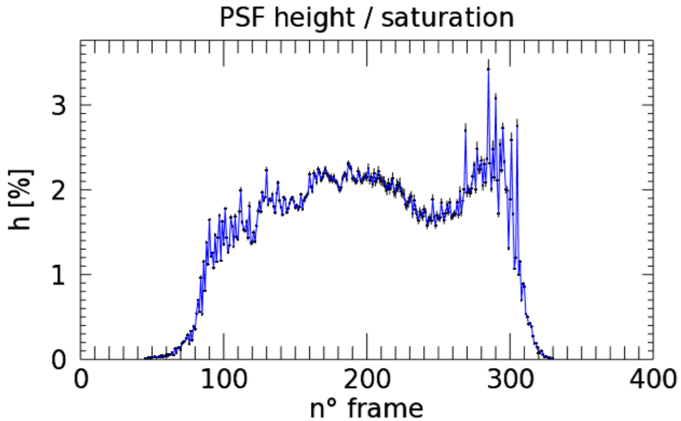


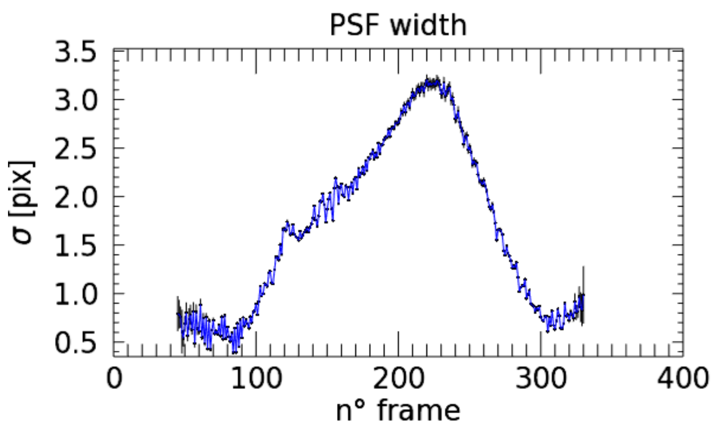


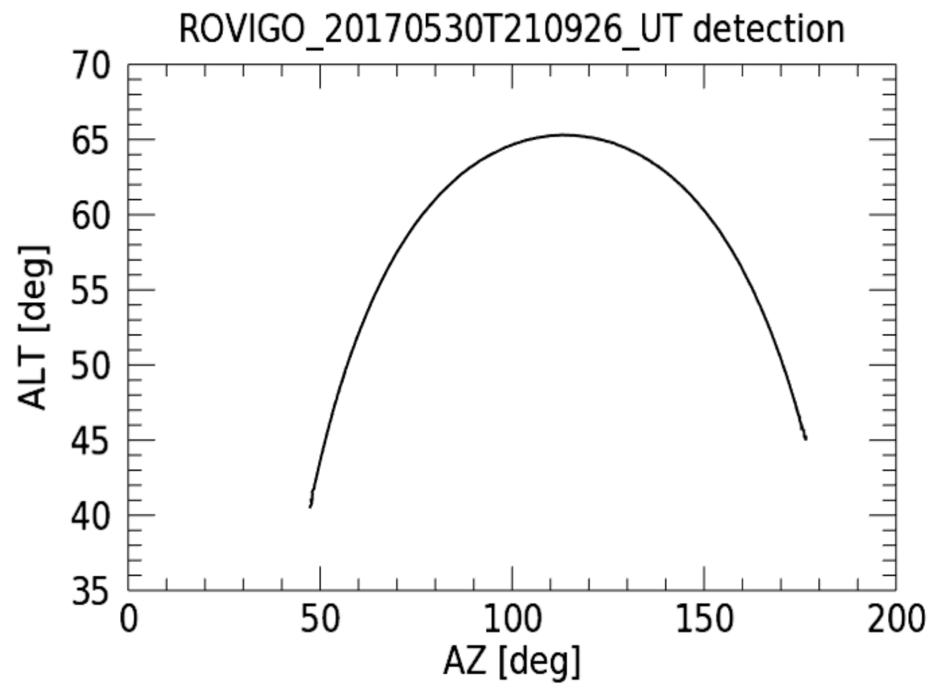
- ✓ order of 10 arcsec
- ✓ negligible with respect to instrumental error (up to 75°)


Bolide of 30.05.2017
30 maggio 2017
Share
Un grande bolide verde illumina i cieli del Nord Italia
Le immagini, le testimonianze e le analisi dell'accaduto
2017-05-30
21h09m UTC
Rovigo
Piacenza
Navacchio
PRISMA
www.coelum.com
29

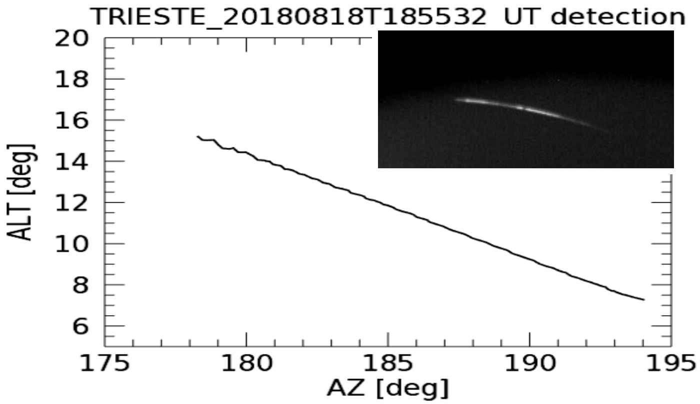
Examples (1)

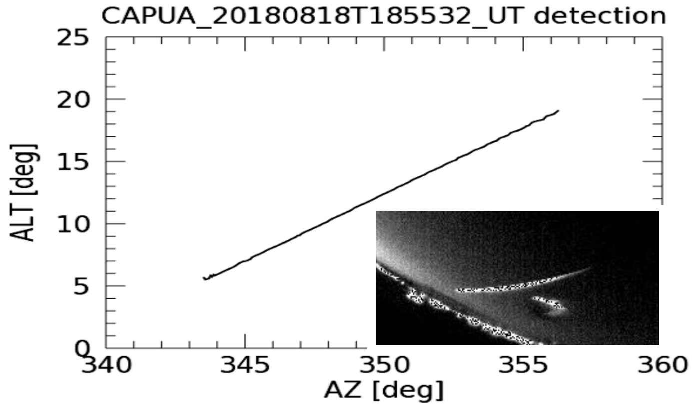

PSF height / saturation
h [%]
0
1
2
3
0
100
200
300
400
n° frame


PSF width
σ [pix]
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
100
200
300
400
n° frame

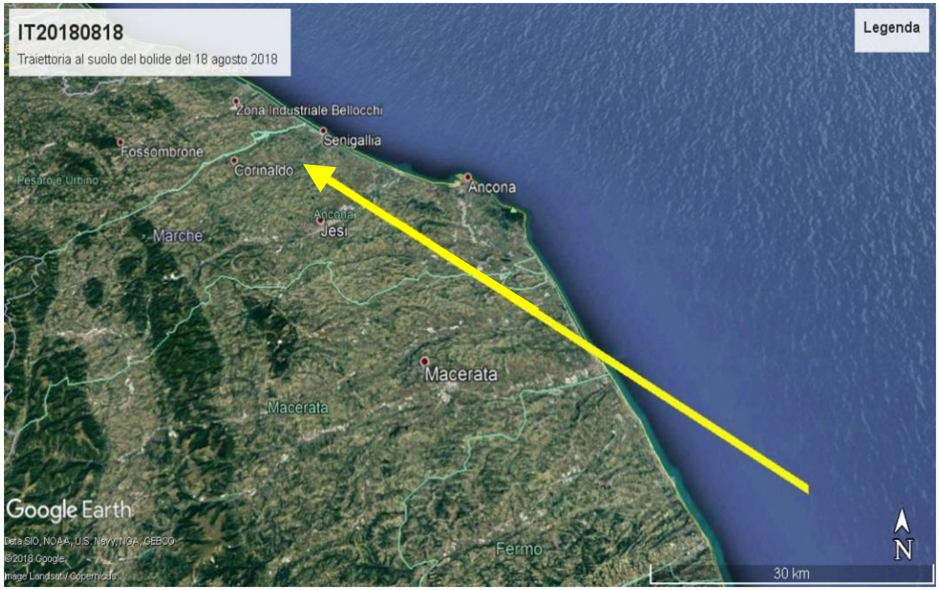

ROVIGO_20170530T210926_UT detection
ALT [deg]
35
40
45
50
55
60
65
70
0
50
100
150
200
AZ [deg]

Examples (2)





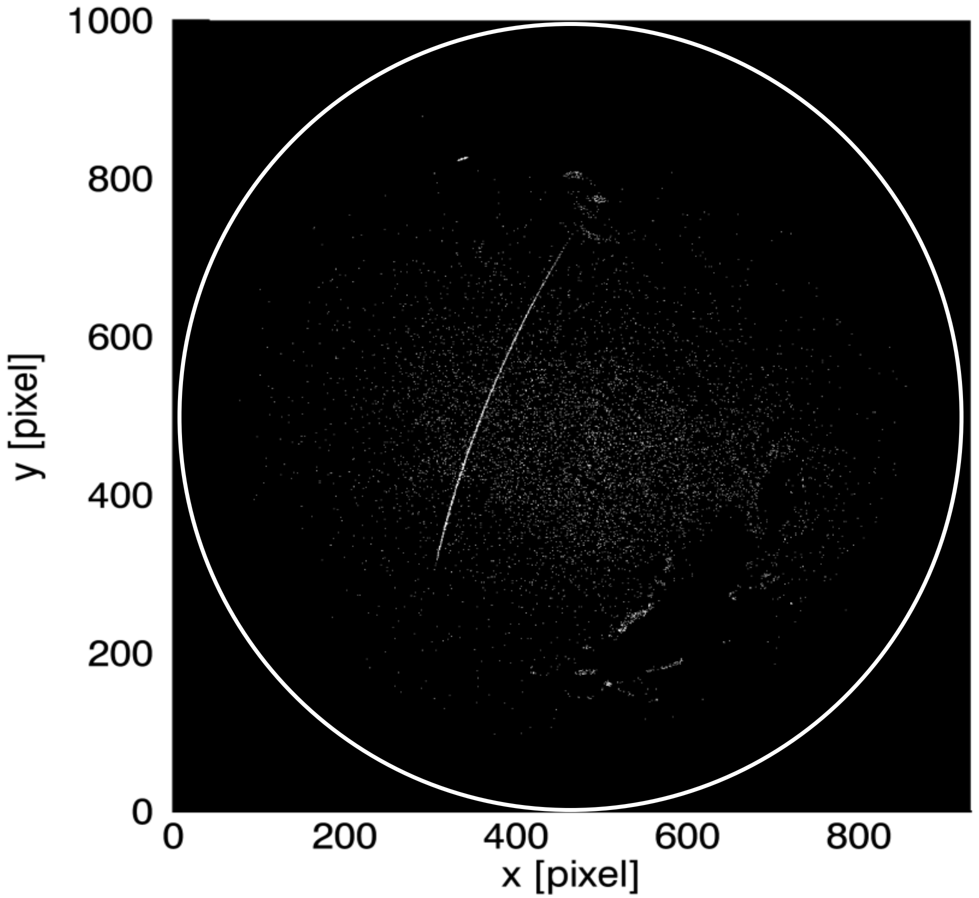
Bolide of 18.08.2018



Examples (3)

PRISMA deployed four cameras (Alessandria, Genova, Loiano, Navacchio) to monitor the chinese spatial station Tiangong-1

Detection – Navacchio
13/02/2018
05:06:29 - 05:07:28 UTC



Examples (3)

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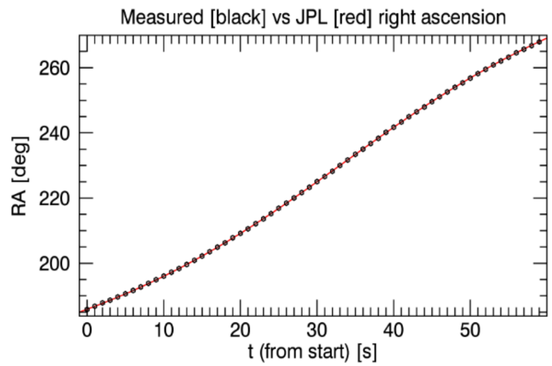

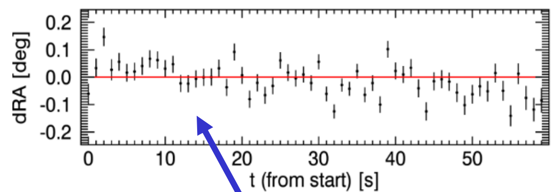

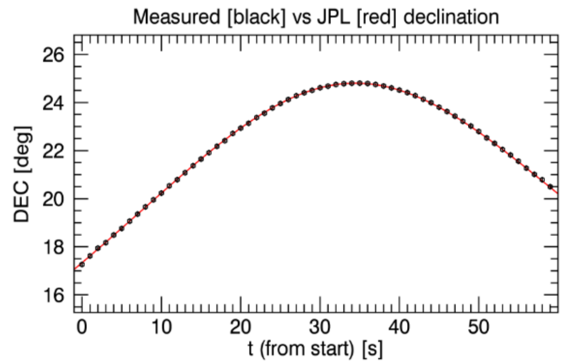

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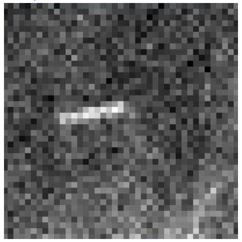
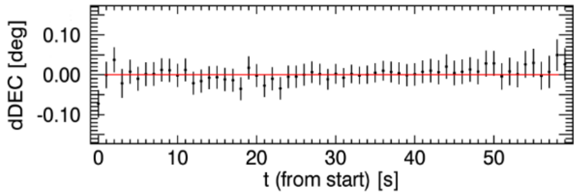
13/02/2018
05:06:29 - 05:07:28 UTC



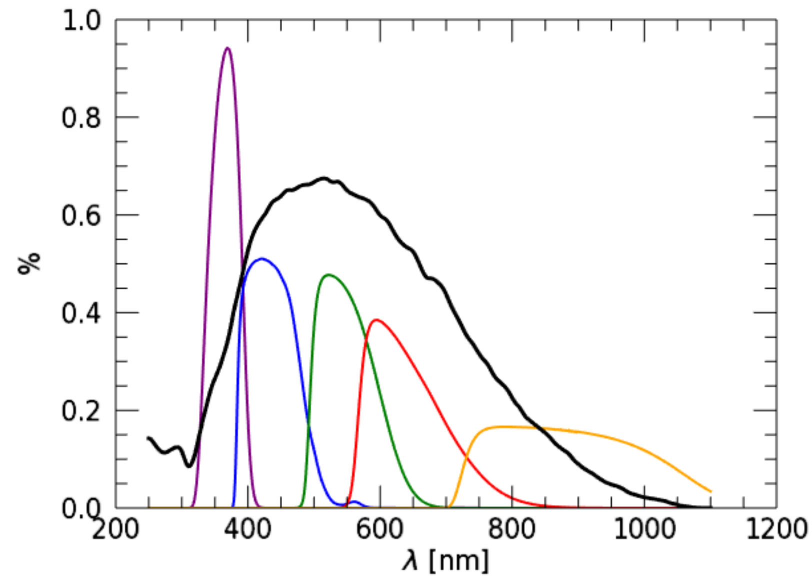


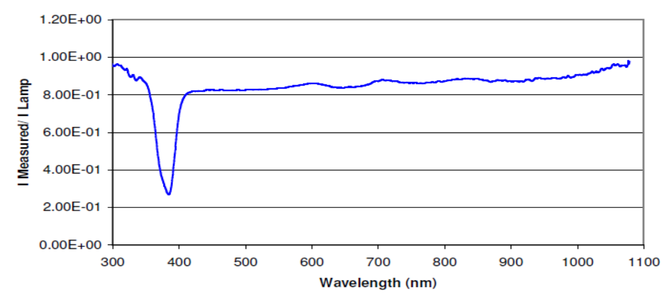
Photometric reduction (1)

Wide band photometry

- ✓ **QE of the CCD**
- ✓ **UBVRI Jonhson-Cousins filters**
- ✓ **Glass dome trasmission**

Need to compute 'equivalent' wide-band magnitude for calibration (close correlated with V band)





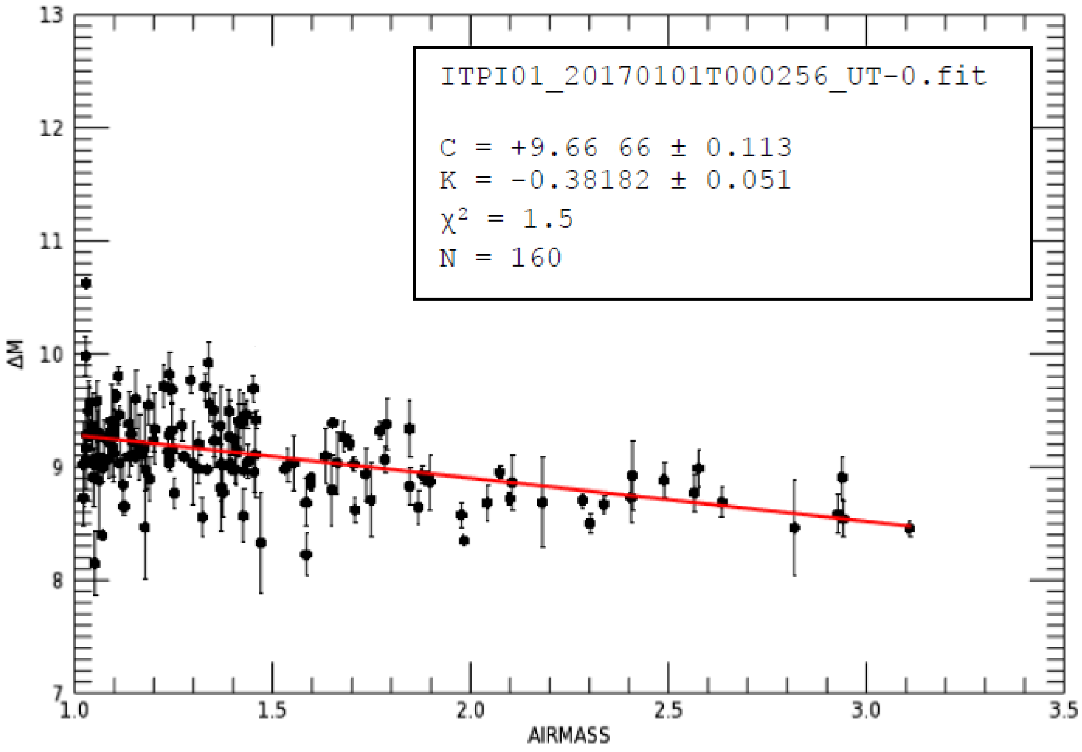
Photometric reduction (2)

Calibration of the magnitude zero point (C) and atmospheric extinction coefficient (k)

$$m_s = -2.5\log(F_s)$$

$$\Delta m = m - m_s$$
$$= C + kx$$

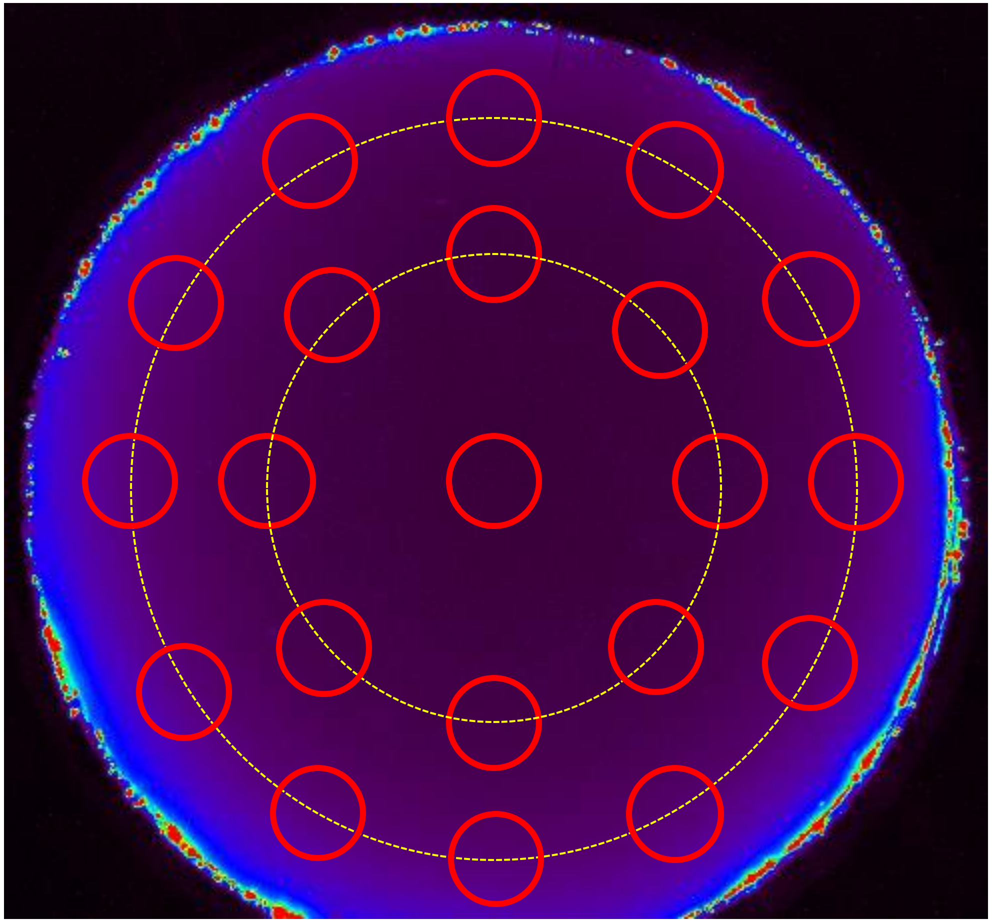
airmass



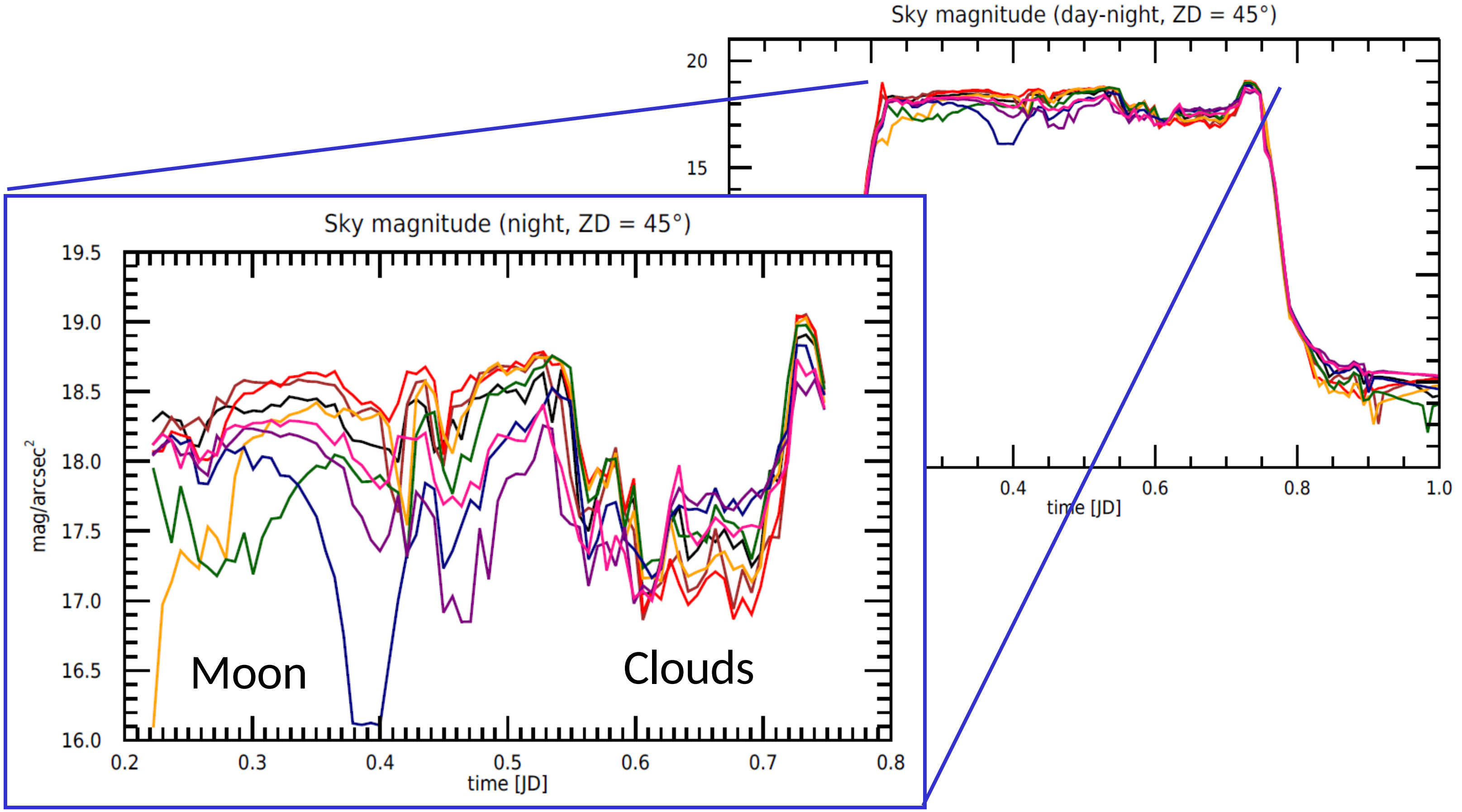
Application – Light pollution monitoring

Measurement of the sky magnitude using the calibration images (5s exposure each 10 minutes)

- ✓ Zenith
- ✓ 8 points at 45° altitude
- ✓ 12 points at 20° altitude



Application – Light pollution monitoring



Sensitivity calibration vs zenith distance (1)

We mounted an all-sky camera in alt-az configuration

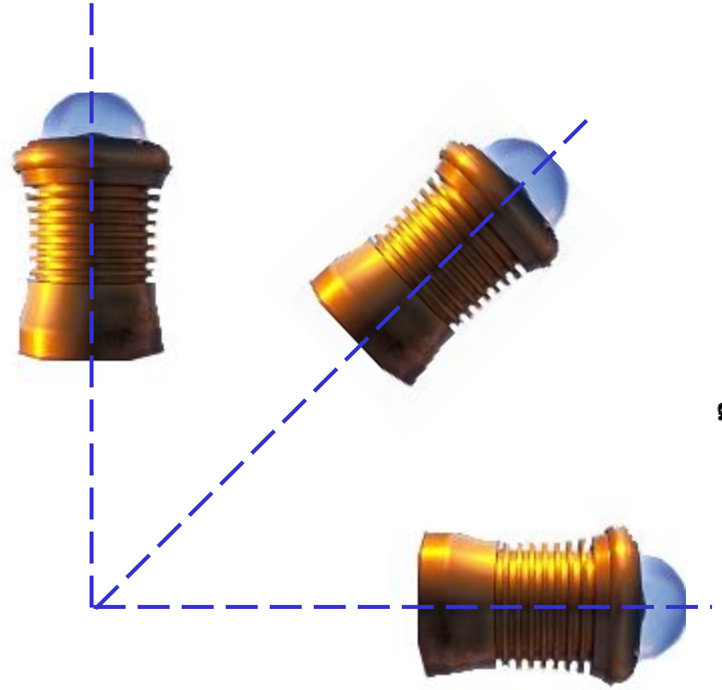
↓

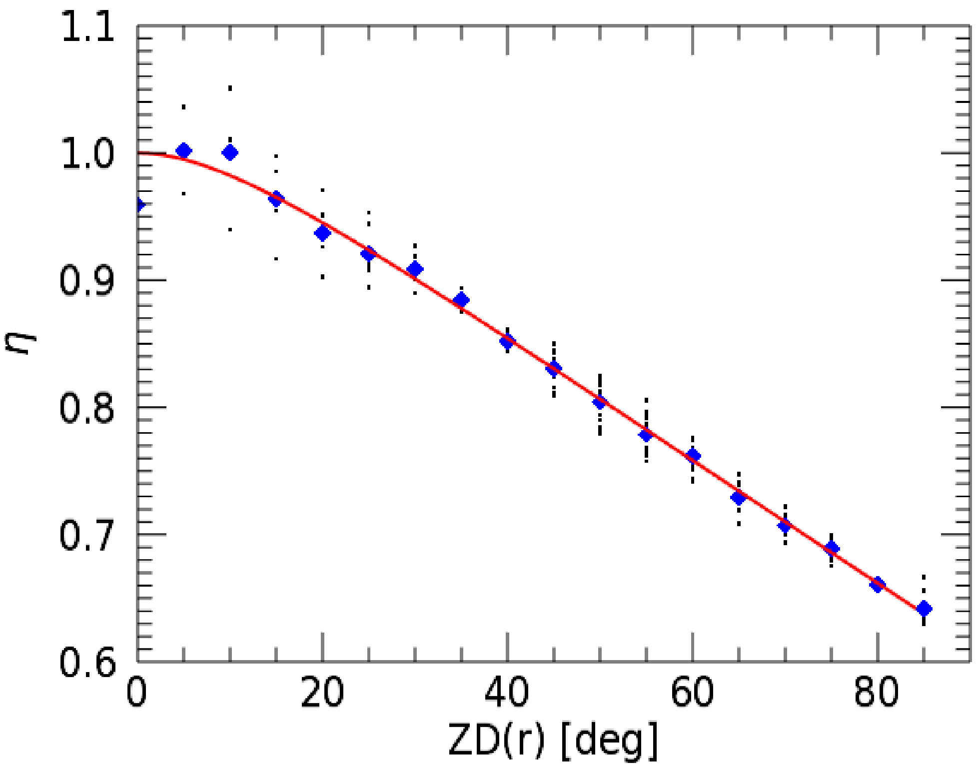
Observing the same portion of sky with different pointing directions

↓

Sensitivity of the whole system as a function of zenith distance (~ radius) ?

Sensitivity calibration vs zenith distance (2)





Thanks for your attention!