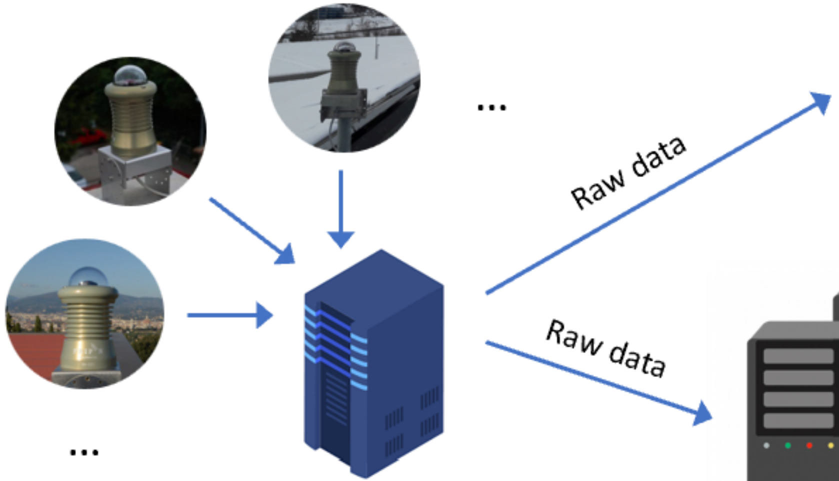
Verso la prima data release di PRISMA

D. Barghini et al.

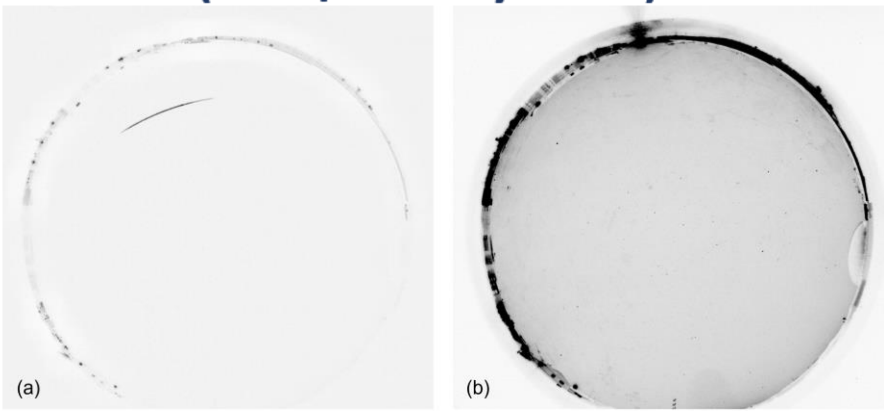
PRISMA Days 2023
Prato, 17-18 Novembre 2023

Data flow of PRISMA



Long-term data storage & Web access
at INAF-IA2 (OA Trieste)

FRIPON server
(LAM/OSU Pythéas)



Data processing pipeline
(INAF-OA Torino)

Calibration:
- Astrometry
- Photometry

Processed data

Events analysis:
- Video analysis (astrometry and photometry)
- Triangulation
- Dynamic model
- Orbit

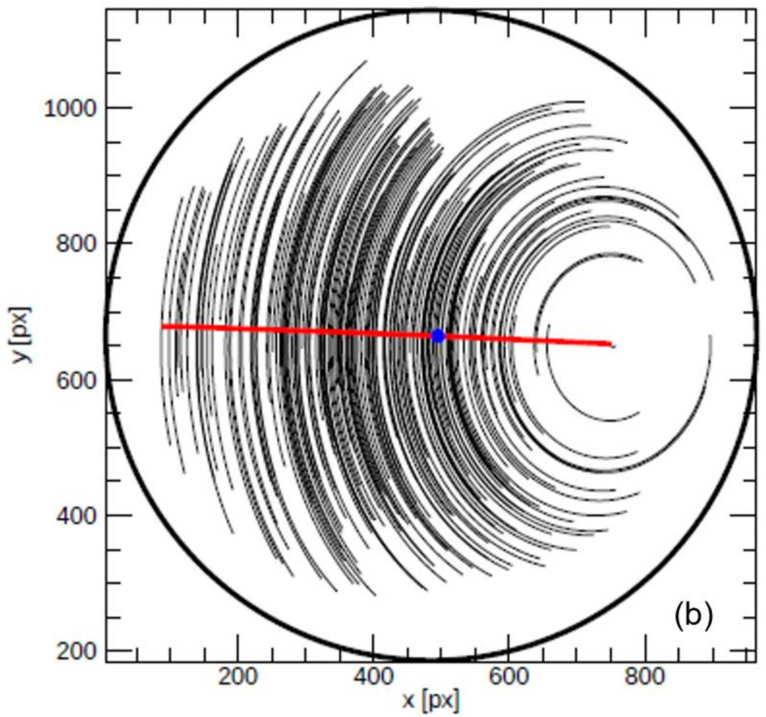
Processed data

Astrometric calibration

- Captures are used to deduce an **absolute astrometric and photometric calibration** of each PRISMA cameras
- Automatic **identification and catalogue's association** of stars
- Astrometry of fish-eye cameras has to deal with a lot of **distortion components in the FoV**
- **Final astrometric model** accounts for 8 (+2) parameters

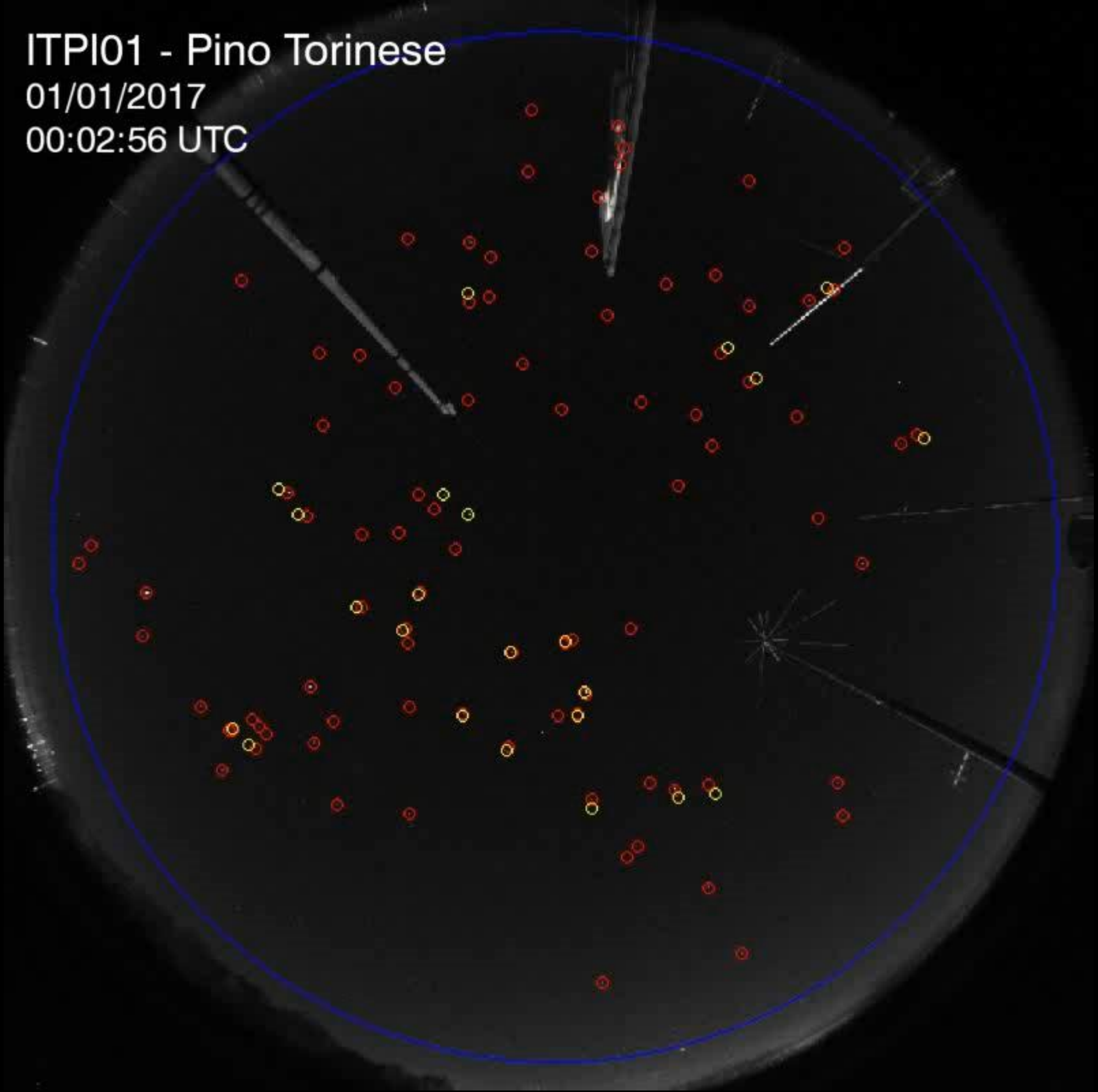
$$\begin{cases} b = a_0 - E + \text{atan}\left(\frac{y-y_O}{x-x_O}\right) \\ u = Vr + S(e^{Dr} - 1) \end{cases} \qquad \begin{cases} a = E + \text{atan}\left(\frac{\sin b \sin u}{\cos u \sin\epsilon + \cos b \sin u \cos\epsilon}\right) \\ z = \arccos(\cos u \cos\epsilon - \cos b \sin u \sin\epsilon) \end{cases}$$

$$r = [1 + K\sin(b + E - \phi)]\sqrt{(x - x_O)^2 + (y - y_O)^2} \qquad \begin{cases} E = a_0 + \text{atan}\left(\frac{x_O - x_Z}{y_O - y_Z}\right) \\ \epsilon = Vr_\epsilon + S(e^{Dr_\epsilon} - 1) \end{cases}$$



For details about PRISMA astrometric calibration:

Barghini D., Gardiol D., Carbognani A. and Mancuso S., "Astrometric calibration for all-sky cameras revisited", *Astron. Astrophys.*, **2019**, 626, A105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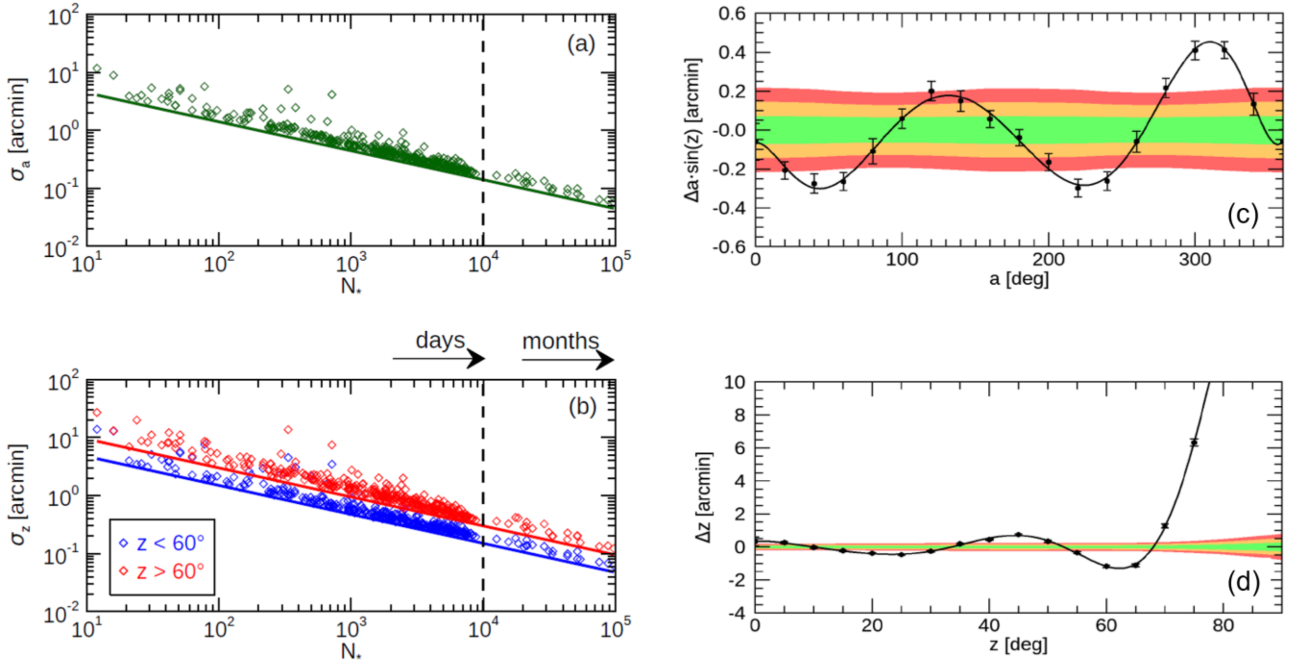
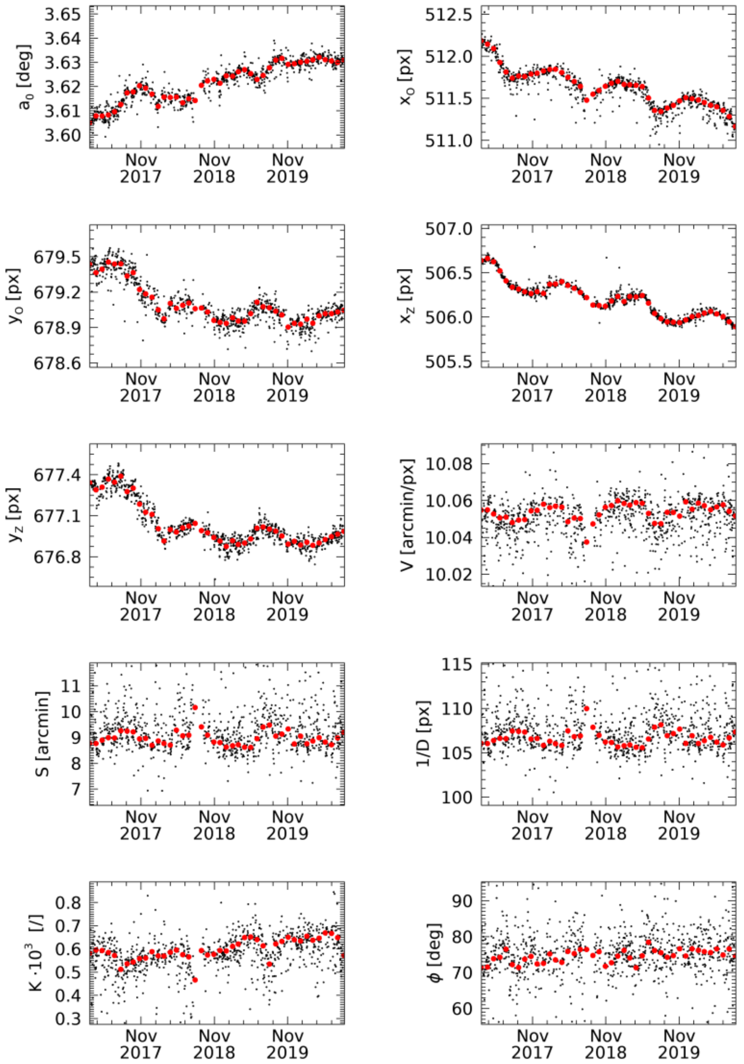
Results of the astrometric calibration

- Astrometric solution for daily and **monthly statistics** for each camera
- We are able to reach a **random projection error or ~ 0.2 arcsec** for a monthly calibration (10k-100k stars)
- The residuals show a **small systematic** (< 1 px) which is numerically corrected

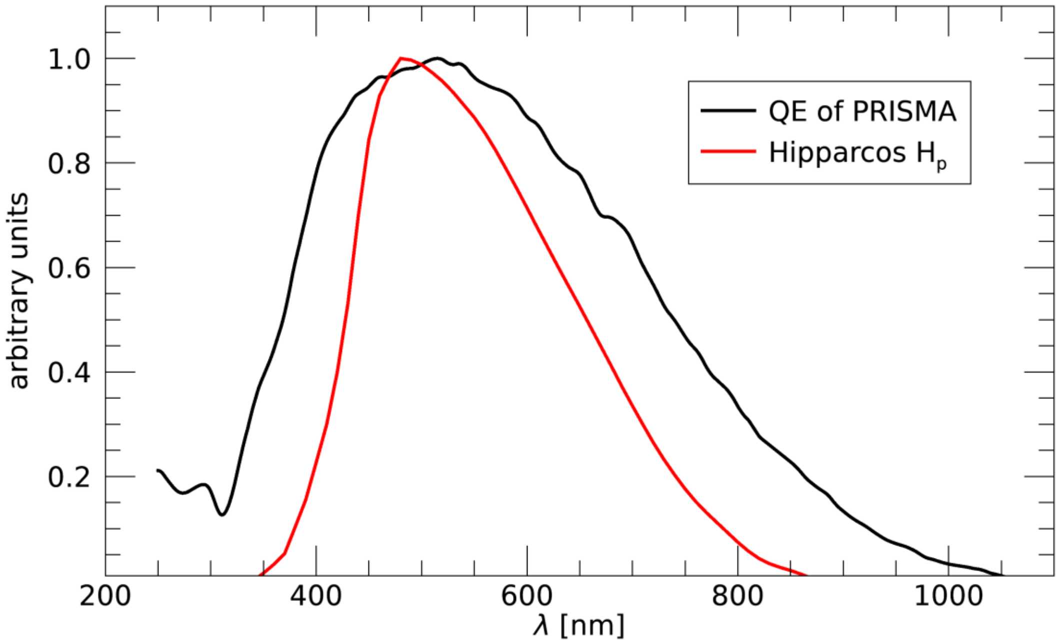


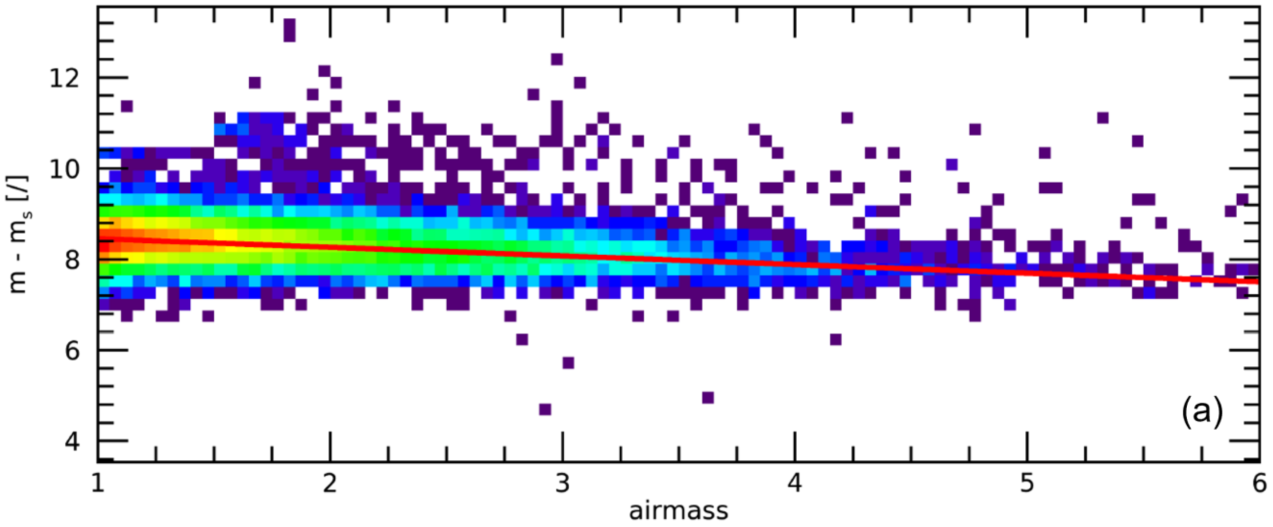


Photometric calibration

We perform **aperture photometry** on each identified star and compare experimental and catalogue (apparent) magnitudes to perform the photometric calibration

$$\Delta m = m - m_s = C - kX$$

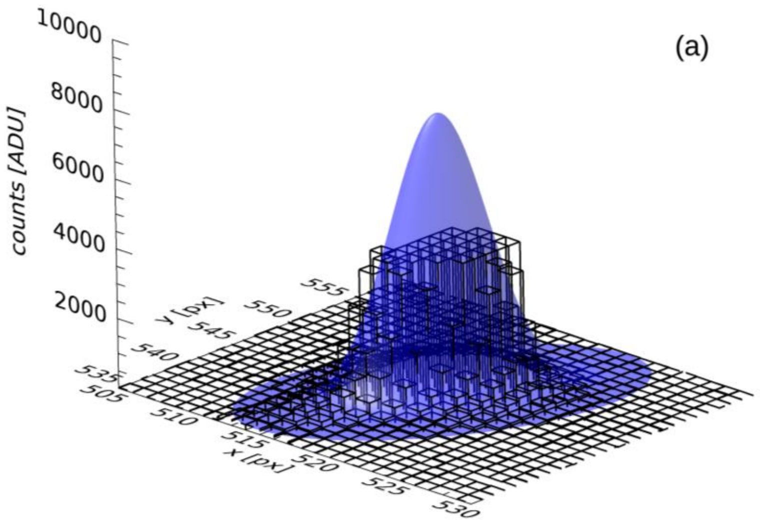


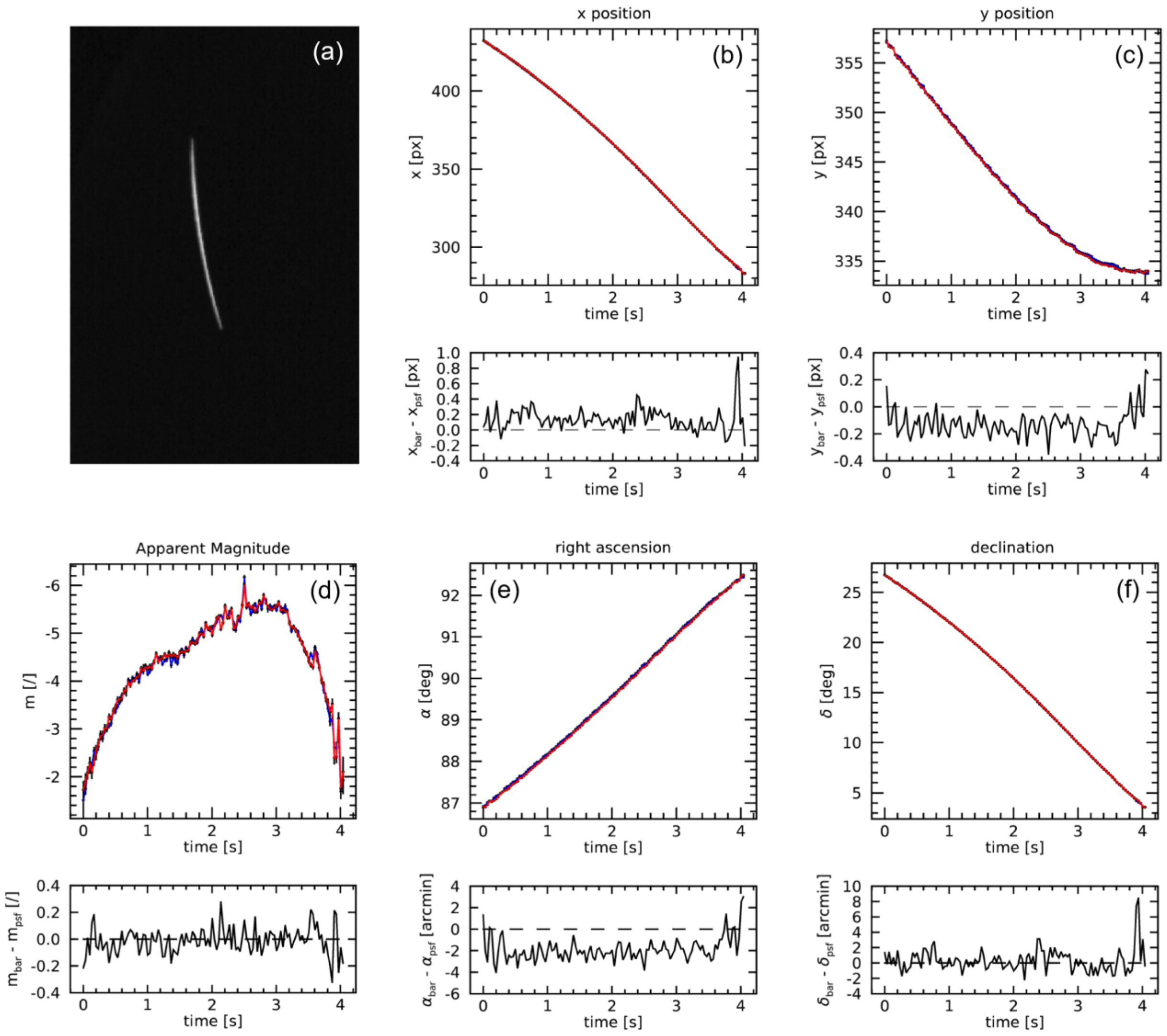


The best match with the PRISMA QE curve was found to be the **H_p bandpass of Hipparcos**

Analysis of events detected by PRISMA

- The astrometric and photometric calibration is then used to reduce each detection video
- **Centring precision of the order of 0.1 px** (few arcmins)
- Bright bolides often saturates
- We apply a tentative correction by the analysis of the **shape of the unsaturated portion of the PSF**





Triangulation

Two approaches:

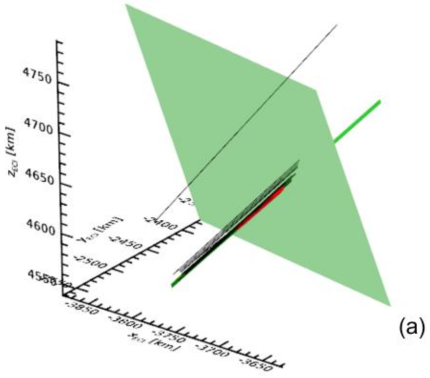
a) **Plane intersection** from couples of cameras

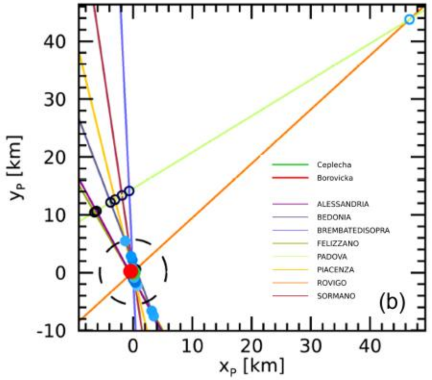
b) **Lines of Sight** distance minimization

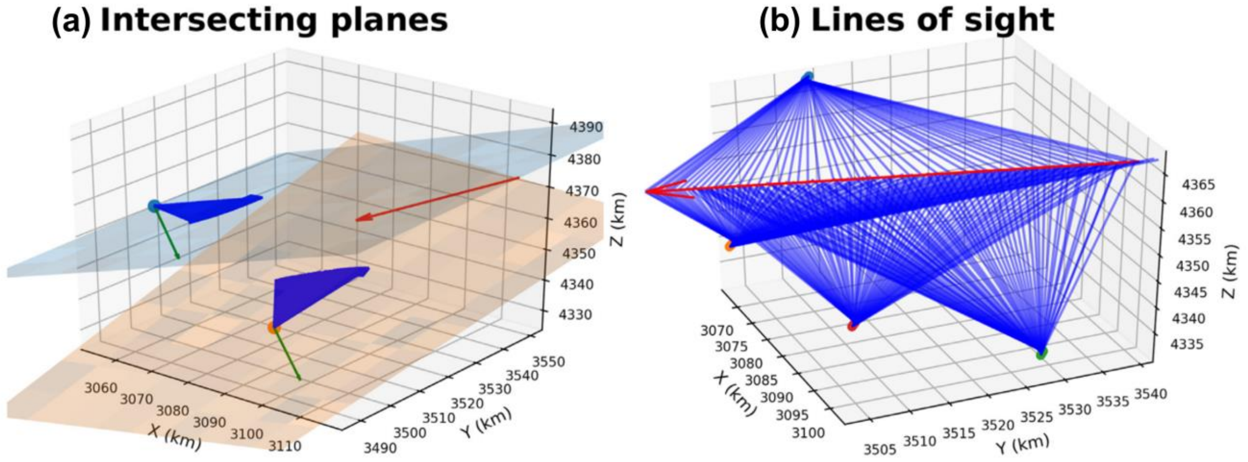
We implemented and combined both approaches in a unique solution

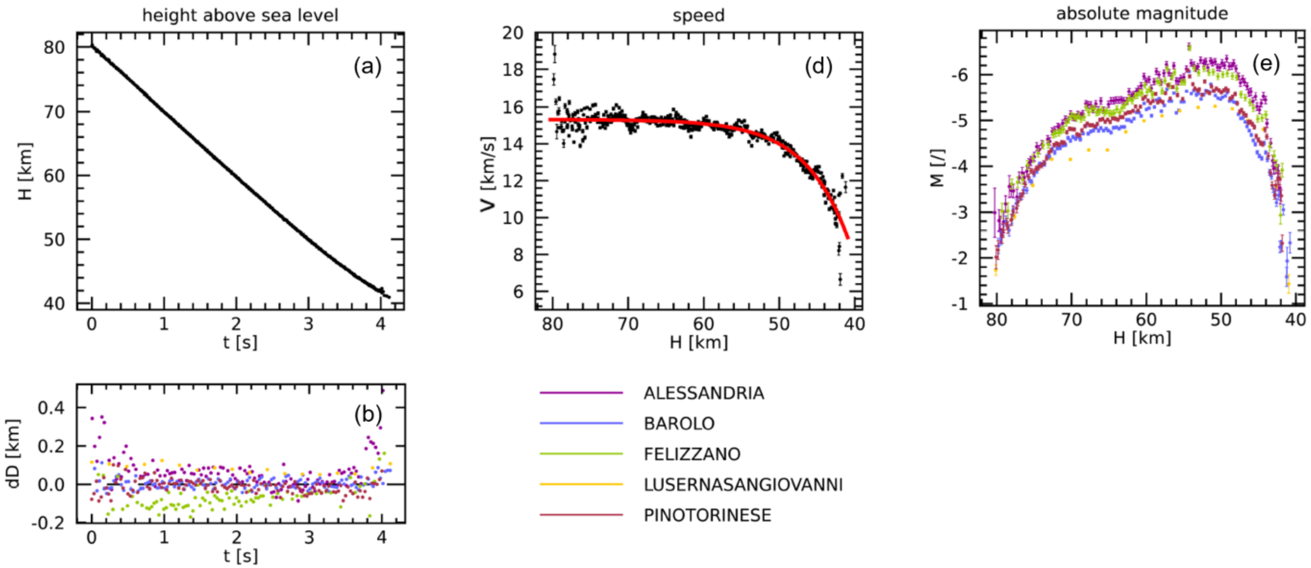
- We use (a) to detect outliers
- and then used (b) to give the final solution

Positioning precision of ~ 100 m









Dynamic model

Solution and fitting of the dynamic model over observed data (height, speed, magnitude).

$$
\begin{cases}
\frac{\mathrm{d}H}{\mathrm{d}t} = -V \sin\gamma \\
M\frac{\mathrm{d}V}{\mathrm{d}t} = -\Gamma S \rho_a V^2 \\
M = M_\infty \exp\left\{\frac{1}{2}\sigma\left(V^2 - V_\infty^2\right)\right\} \\
I = -\tau M V\left(1 + \frac{\sigma V^2}{2}\right)\frac{\mathrm{d}V}{\mathrm{d}t}
\end{cases}
$$

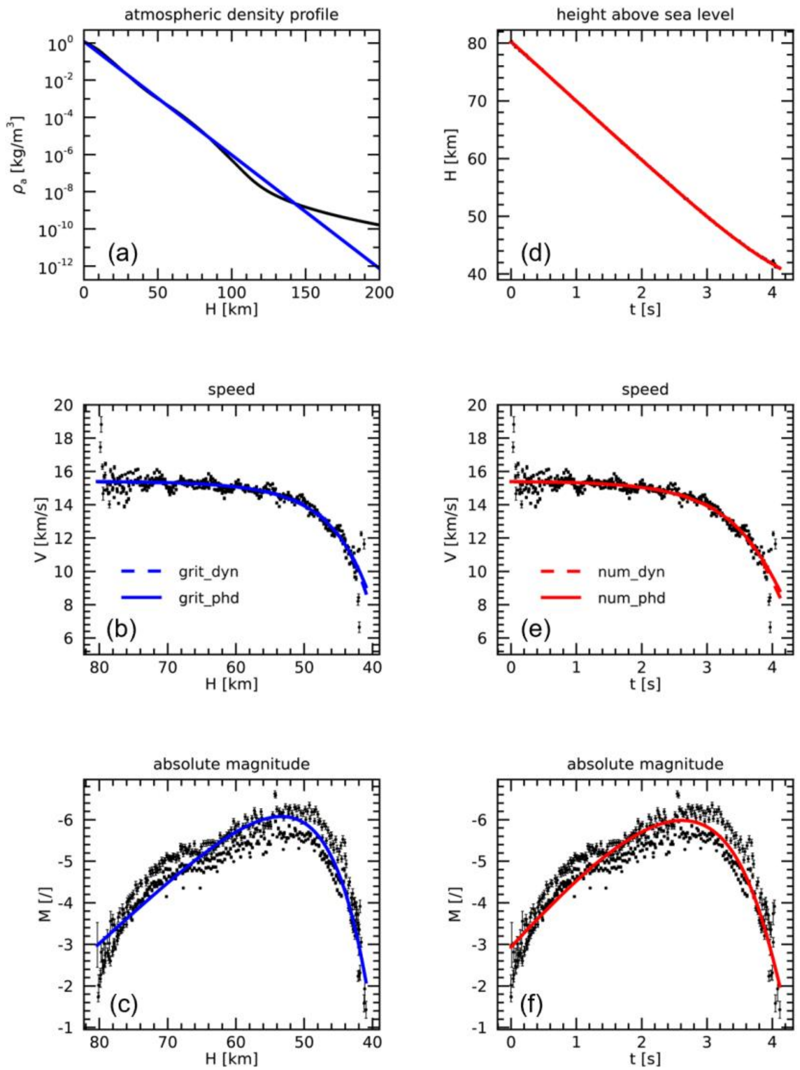
Two approaches:

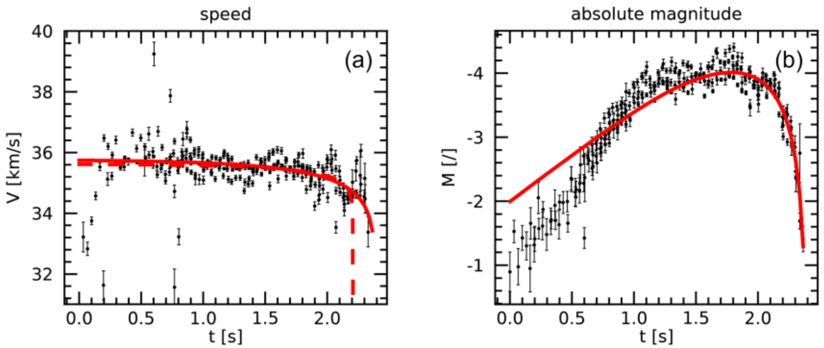
a) **Analytical solution**

b) **Numerical solution**

Usually speed and magnitude data are considered separately.
We implemented a novel approach with a **simultaneous fitting of the deceleration and intensity data**

1. **Purely dynamical model** (only deceleration)
2. **Photo-dynamic model** (deceleration + intensity)



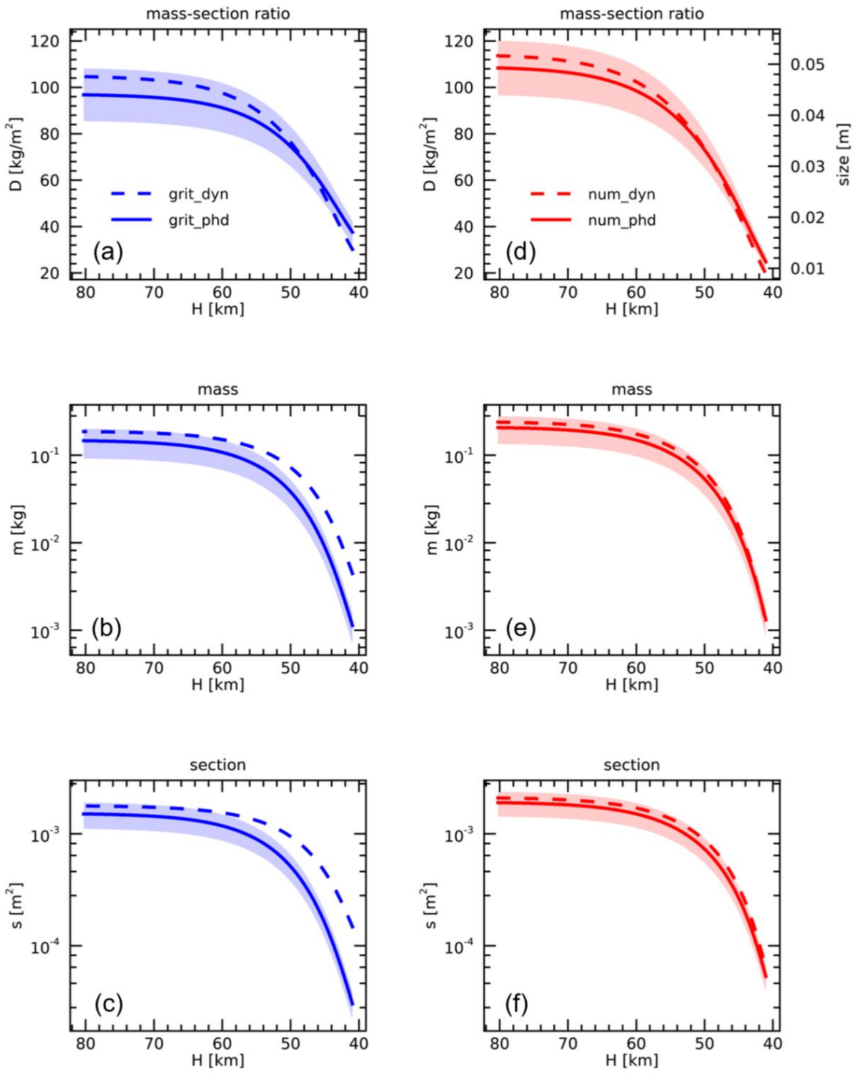


The photodynamical approach is particularly useful when dealing with events which showed **negligible deceleration**

Physical parameters of the meteoroid

From **reasonable assumptions on the geometry of the body**, we can retrieve the physical parameters of the body, such as the **pre-atmospheric and final mass** and typical dimensions

		GRIT_DYN	GRIT_PHD	NUM_DYN	NUM_PHD
V_∞	[km/s]	15.39 ± 0.08	15.41 ± 0.08	15.41 ± 0.05	15.40 ± 0.05
γ	[deg]	42.00 ± 0.20	42.00 ± 0.20	42.02 ± 0.04	42.09 ± 0.04
α	[/]	92 ± 11	100 ± 12	85 ± 10	89 ± 10
β	[/]	1.8 ± 0.1	1.5 ± 0.1	2.50 ± 0.07	2.21 ± 0.07
Ω	[/]	5.5 ± 0.4	7.5 ± 0.2	7.5 ± 0.2	7.6 ± 0.1
$\sigma\ (\cdot 10^2)$	[s^2/km^2]	4.6 ± 0.4	6.3 ± 0.2	6.3 ± 0.2	6.4 ± 0.1
μ	[/]	2/3	0.80 ± 0.01	2/3	0.71 ± 0.01
τ	[%]	–	4.5 ± 1.7	–	3.1 ± 1.1
D_∞	[kg/m^2]	105 ± 12	97 ± 11	114 ± 12	109 ± 12
D_{fin}	[kg/m^2]	30 ± 4	38 ± 5	20 ± 2	25 ± 3
M_∞	[g]	190 ± 70	150 ± 60	240 ± 80	210 ± 70
M_{fin}	[g]	4 ± 2	1.1 ± 0.4	1.3 ± 0.5	1.3 ± 0.5
S_∞	[cm^2]	18 ± 5	15 ± 4	21 ± 5	19 ± 5
S_{fin}	[cm^2]	1.5 ± 0.4	3.0 ± 0.9	0.7 ± 0.2	0.5 ± 0.2
$2r_\infty$	[cm]	4.8 ± 0.6	4.4 ± 0.6	5.2 ± 0.6	5.0 ± 0.6
$2r_{fin}$	[cm]	1.4 ± 0.2	1.7 ± 0.2	0.9 ± 0.1	1.1 ± 0.1



Pre-atmospheric orbit

The deduced **pre-atmospheric speed** (from the dynamic model) and **3D orientation** of the trajectory in ECI coordinates (from the triangulation) are then used to estimate the pre-atmospheric orbit of the meteoroid

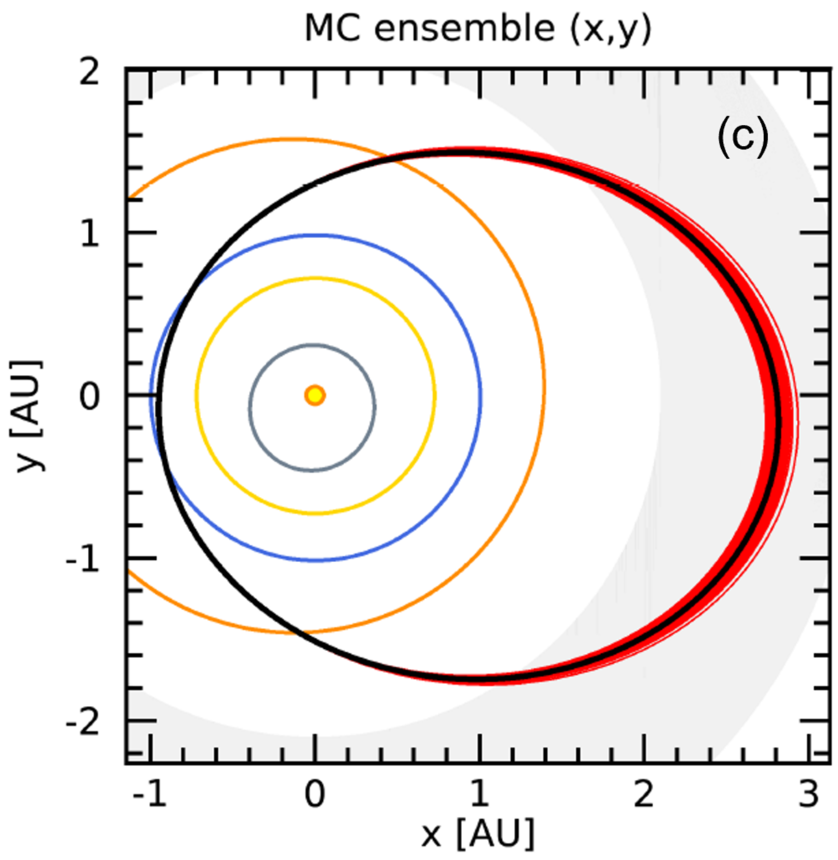
1. Correction for the **zenithal attraction effect**
2. Conversion to **heliocentric ecliptic reference system**
3. Computation of the **orbital elements**

Speed and radiant

V_a	[km/s]	15.40 ± 0.05			
α_a	[deg]	64.98 ± 0.05	δ_a	[deg]	63.73 ± 0.04
V_g	[km/s]	10.67 ± 0.07			
α_g	[deg]	47.45 ± 0.15	δ_g	[deg]	59.68 ± 0.06
V_h	[km/s]	36.06 ± 0.06			
α_h	[deg]	106.65 ± 0.03	δ_h	[deg]	33.61 ± 0.06
λ_h	[deg]	104.07 ± 0.03	ϕ_h	[deg]	10.99 ± 0.06

Orbital elements

h	[AU^2/yr]	7.49 ± 0.01	a	[AU]	1.89 ± 0.02
e	[/]	0.500 ± 0.004	q	[AU]	0.9477
i	[deg]	11.19 ± 0.06	Q	[AU]	2.84 ± 0.03
Ω	[deg]	25.28251 ± 0.00008	T	[yr]	2.61 ± 0.03
ω	[deg]	146.5 ± 0.1	T_J	[/]	3.77 ± 0.02
ν	[deg]	33.5 ± 0.1	M_ν	[deg]	10.1 ± 0.2



Database structure

The PRISMA database will be divided in two main parts:

Calibration data:

- Captures: daily tarball with (~144) captures from each camera
- Calibrations: daily and monthly tarball with results of calibration from captures analysis

Events data:

- Events: tarball for each event with detections tarballs within it
- Results: results of the event processing (astrometry, triangulation, dynamic, orbit)

Each tarball will be given with a **FITS header** with all relevant metadata, and a preview image.
A selection of them (i.e., the most important ones) will be searchable within the database