A Review of the Data Analysis Pipeline of the PRISMA Network

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Network Infrastructure

FRIPON/PRISMA Network



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FRIPON server
(LAM/OSU Pythéas)

FRIPON processing & front end

Long-term archive
(INAF IA2 Trieste)

PRISMA server
(INAF OA Torino)

Data Analysis (on request)

Network Infrastructure

FRIPON/PRISMA Network



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FRIPON server
(LAM/OSU Pythéas)

FRIPON processing & front end

Long-term archive
(INAF IA2 Trieste)

Data Analysis Pipeline
- Calibration processing
- Fireball processing



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PRISMA Network

PRISMA server
(INAF OA Trieste)

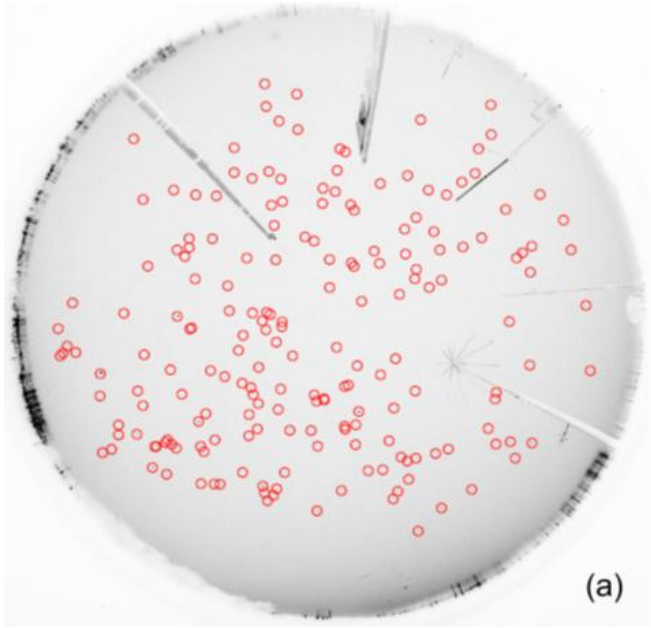
Front End

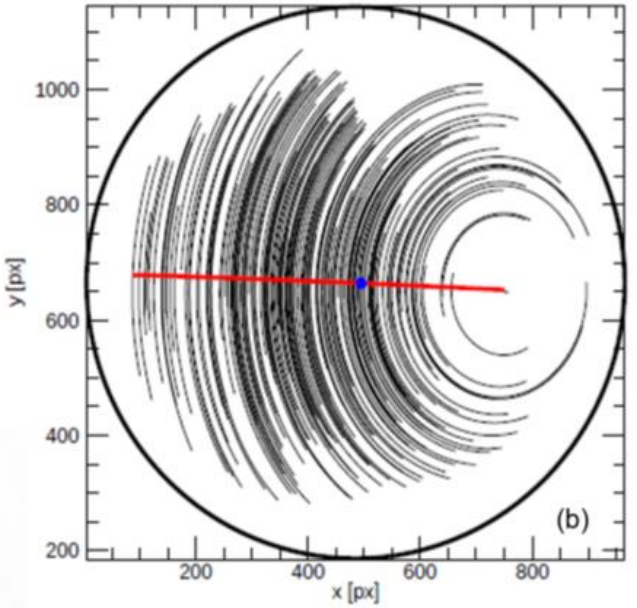


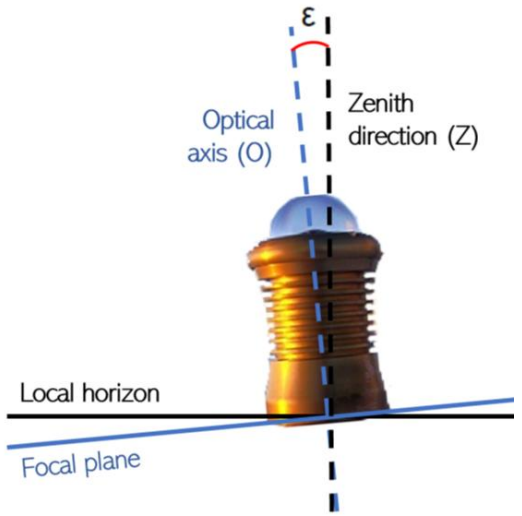
Calibration pipeline

Captures images used to perform **astrometric and photometric calibration** for each camera on a **daily and monthly basis**

- Automatic star identification and catalogue correlation
- 100 - 300 stars per image, down to **+4 / +5 limiting magnitude**
- Astrometry suffers from high **distortion** (fish-eye, 8+2 params)
- Photometry limited by sensor characteristics





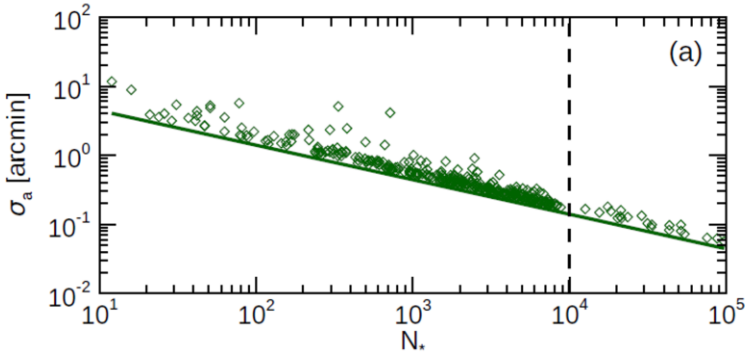


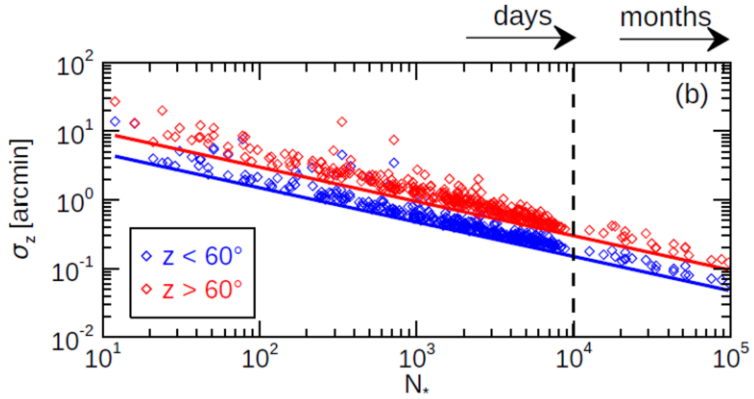
$$\begin{cases} b = a_0 - E + \text{atan}\left(\frac{y-y_O}{x-x_O}\right) \\ u = Vr + S(e^{Dr} - 1) \end{cases} \qquad \begin{cases} E = a_0 + \text{atan}\left(\frac{x_O-x_Z}{y_O-y_Z}\right) \\ \epsilon = Vr_\epsilon + S(e^{Dr_\epsilon} - 1) \end{cases}$$

$$r = [1 + K\sin(b + E - \phi)]\sqrt{(x - x_O)^2 + (y - y_O)^2}$$

$$\begin{cases} a = E + \text{atan}\left(\frac{\sin b \sin u}{\cos u \sin \epsilon + \cos b \sin u \cos \epsilon}\right) \\ z = \arccos(\cos u \cos \epsilon - \cos b \sin u \sin \epsilon) \end{cases}$$

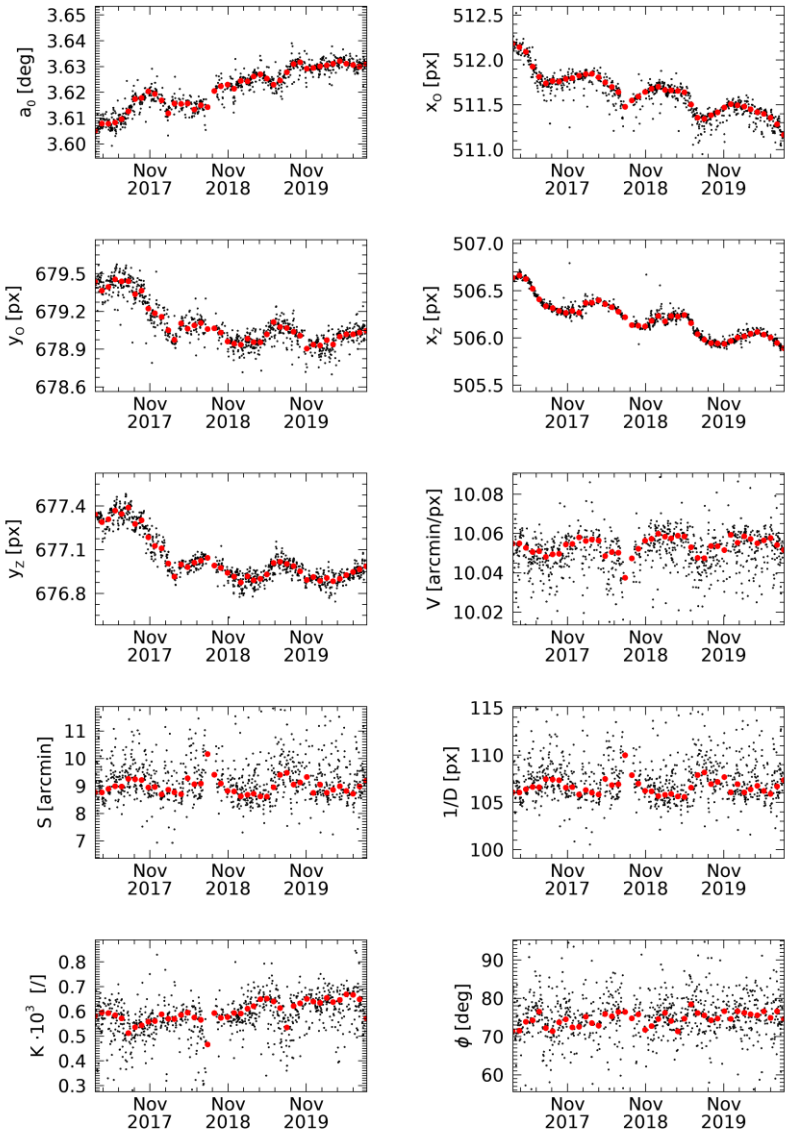
Calibration pipeline





Major challenges:

- Tracking and **managing station configuration** without physical access to it
- Handling configuration changes due to **hardware maintenance** operated from local personnel
- Photometry with **interlined CCDs** and low fill-factor
- Decreasing performance with **dome ageing**, affected by a **short lifecycle** (from 1 to 5 years)



Calibration pipeline

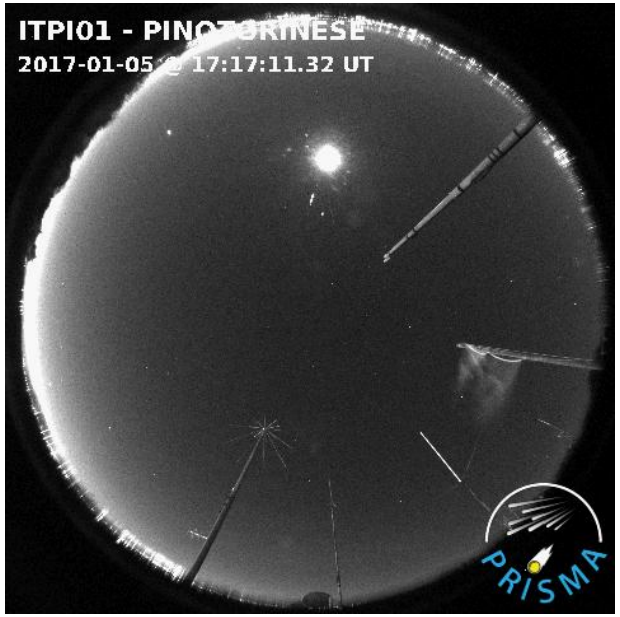
Captures

1 captures each 10’

Camera installation

Midnight UTC

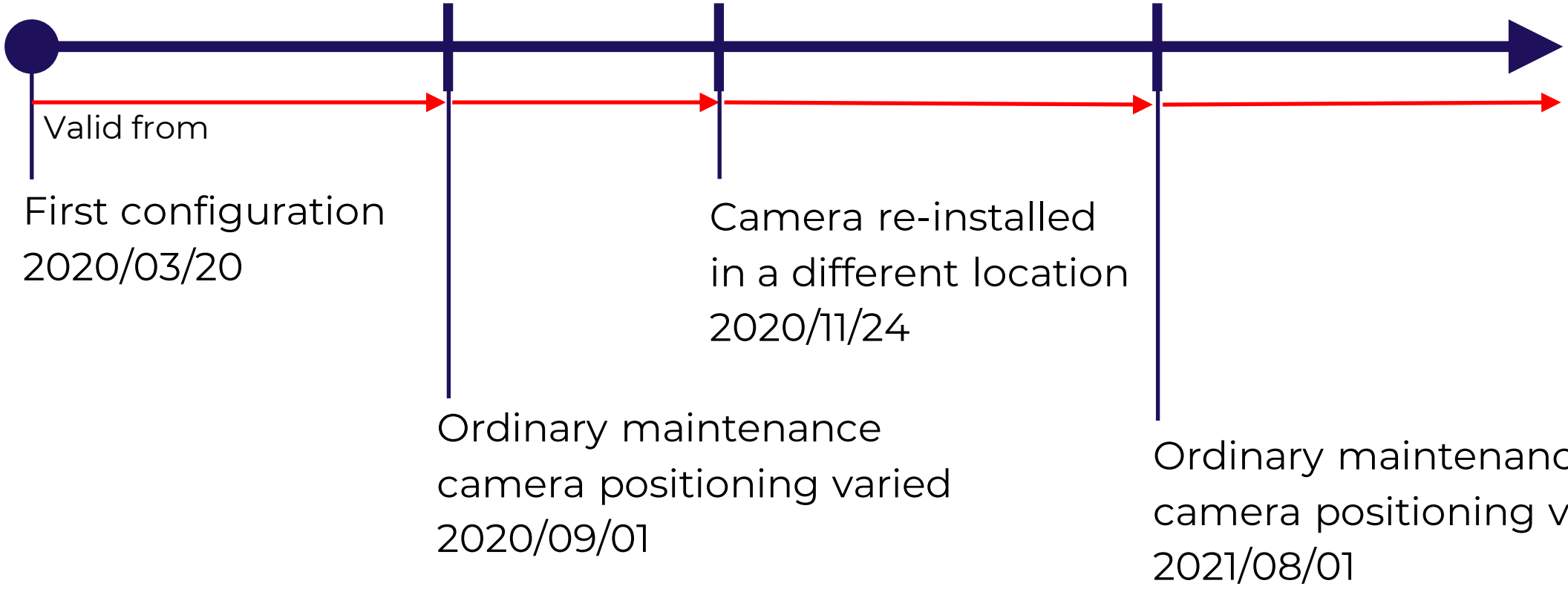
1 JD
e.g. from 2017-01-05 12:00 UTC
to 2017-01-06 12:00 UTC
(usually 144 captures/day)



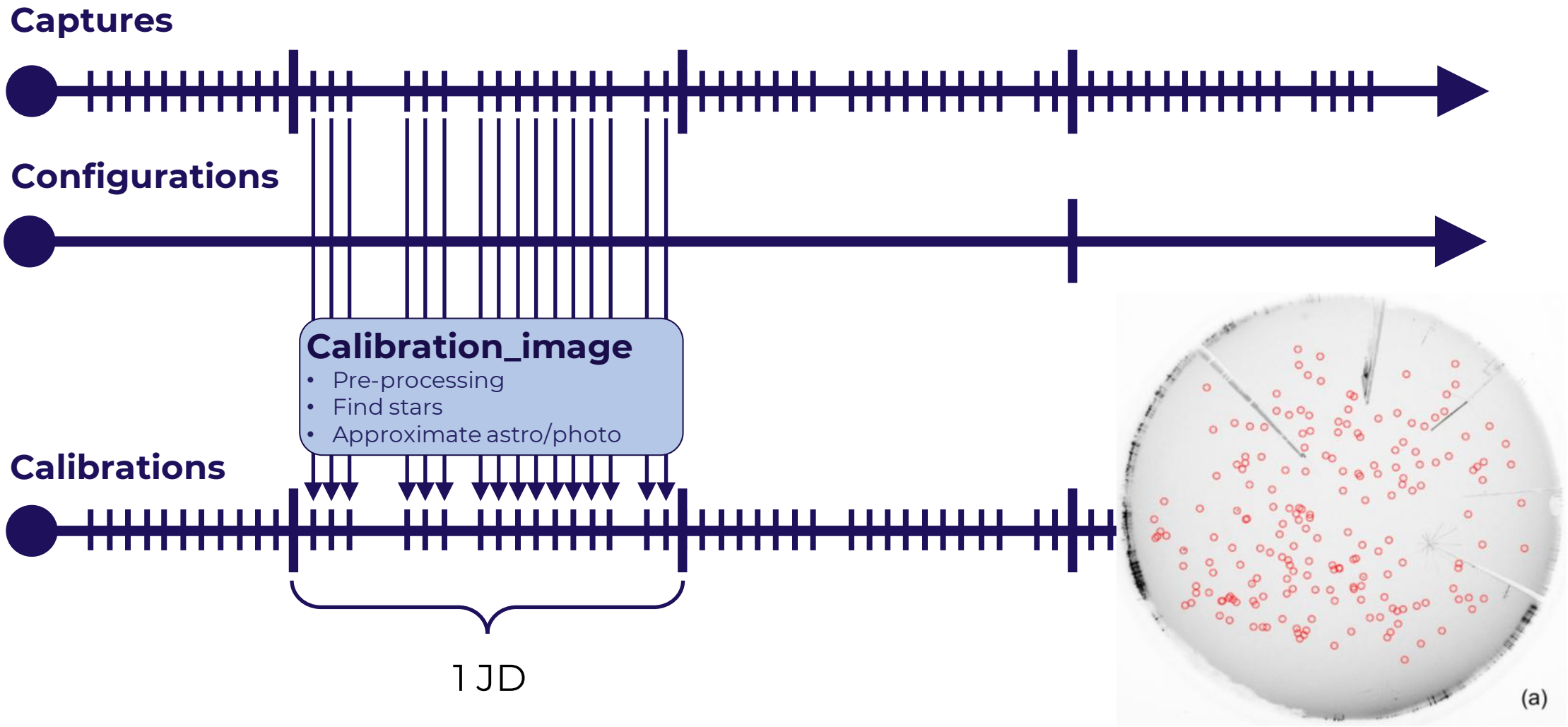
Calibration pipeline

Set of parameters to define:
- Image specifications
- Installation location
- Astrometry and photometry configuration
- Other relevant settings

Configurations

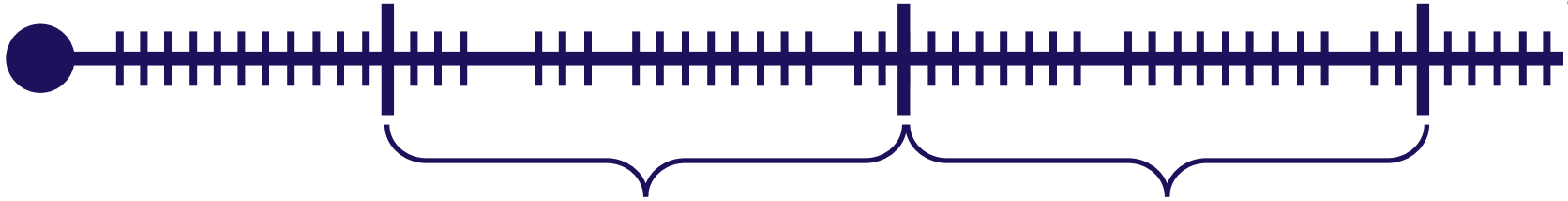


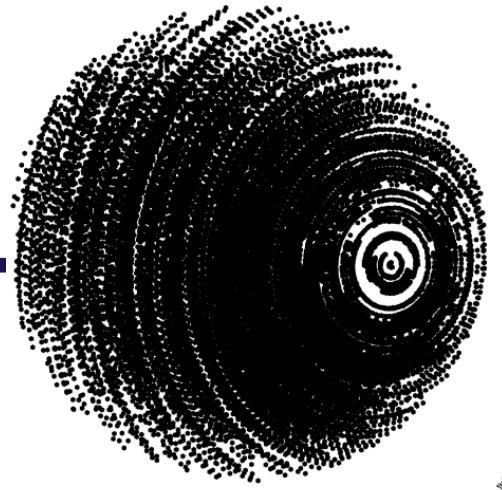
Calibration pipeline



Calibration pipeline

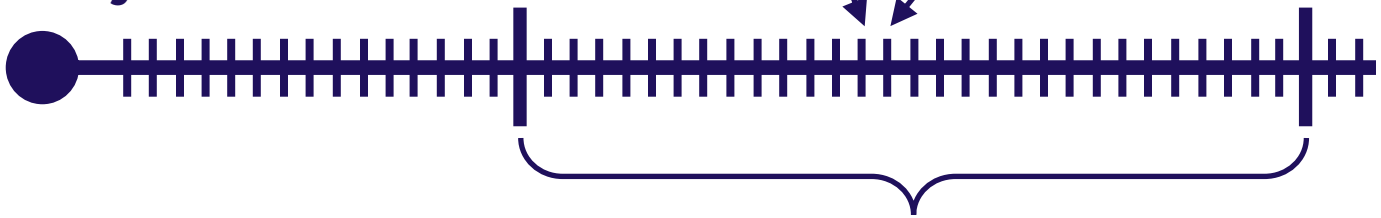
Image Calibrations



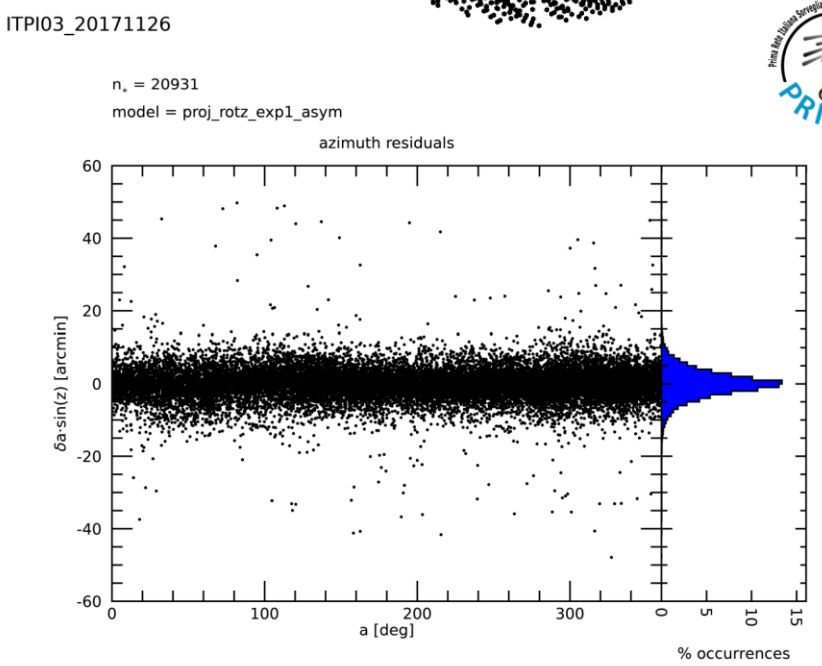


Calibration_day
- Full plate solving
- Photometry (and sky brightness)
- Statistics and reporting

Daily Calibrations

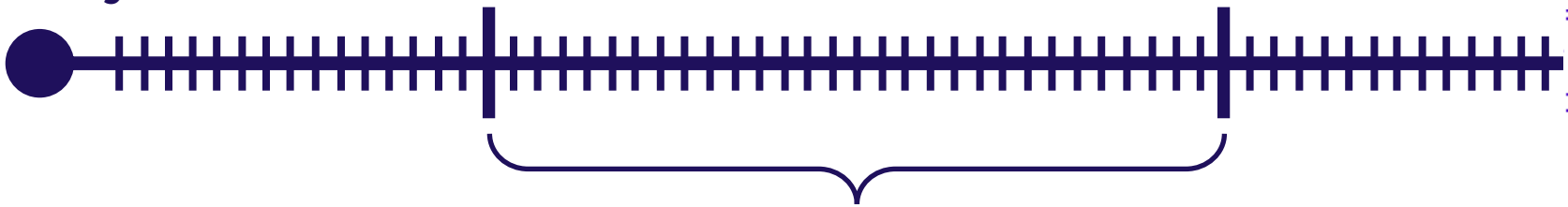


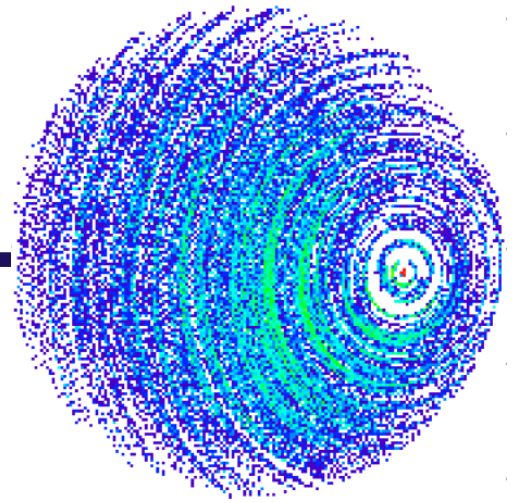
1 month



Calibration pipeline

Daily Calibrations



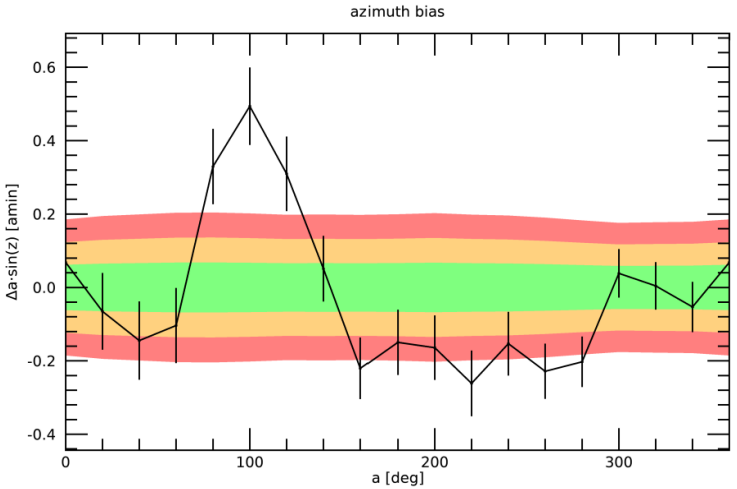


Calibration_month
- Full plate solving
- Better accuracy and precision
- Statistics and reporting

Monthly Calibrations



Quality checks
- Total number of identified stars
- Std. deviation of az/zd residuals

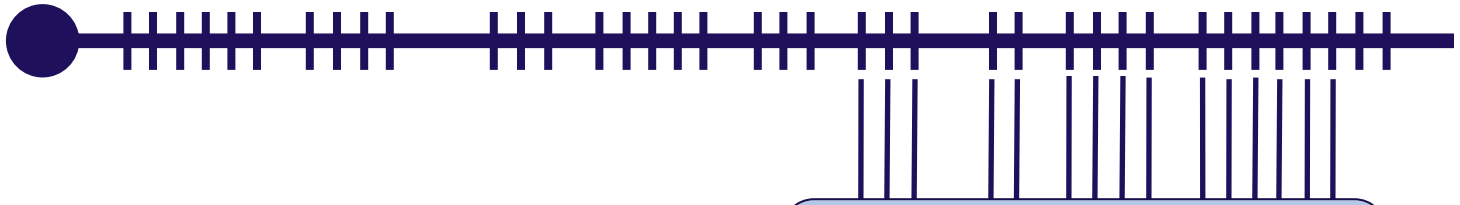


Solutions



Calibration pipeline

Solutions

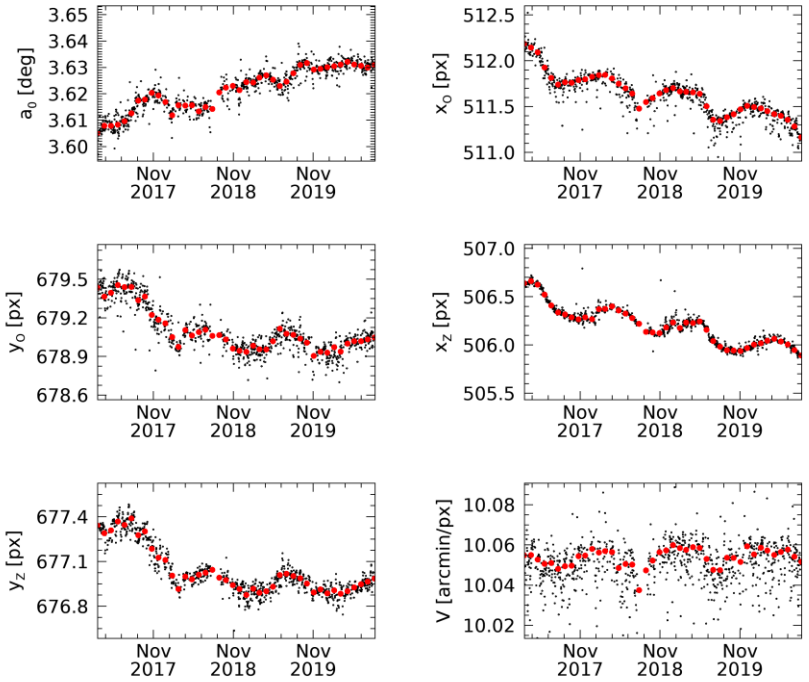


Config Feedback

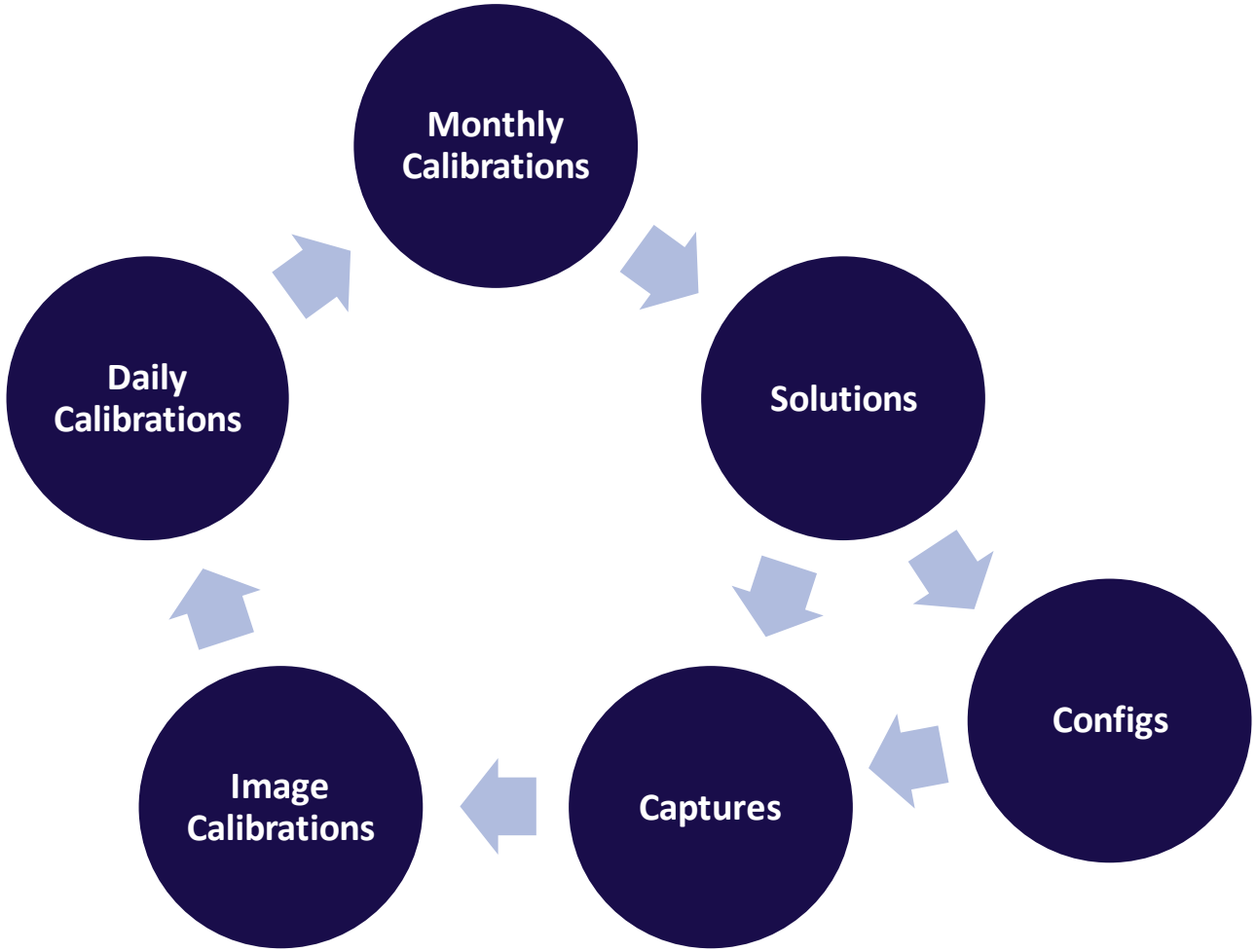
- Checking significant differences in astro/photo params
- Updating config if needed

Configurations

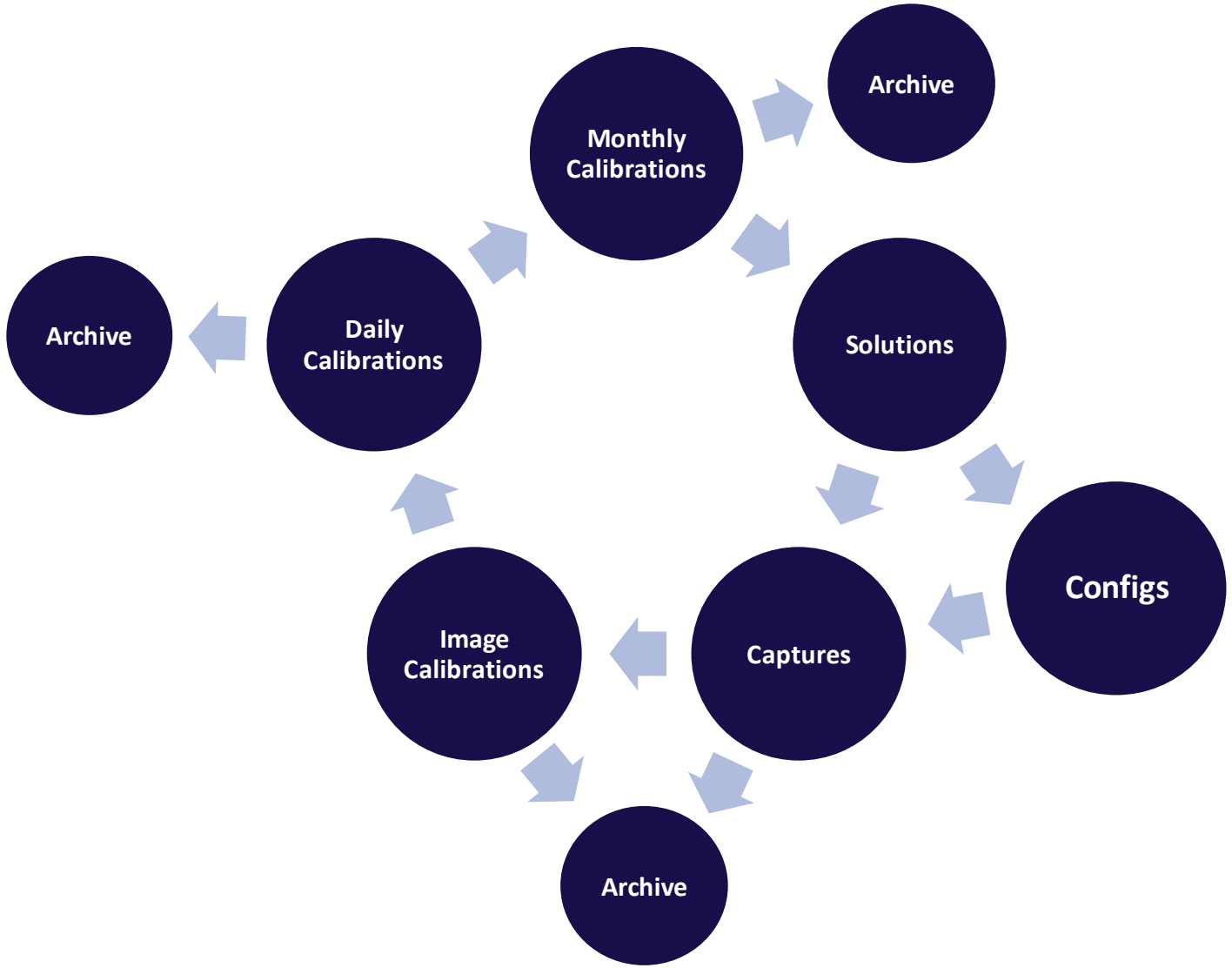




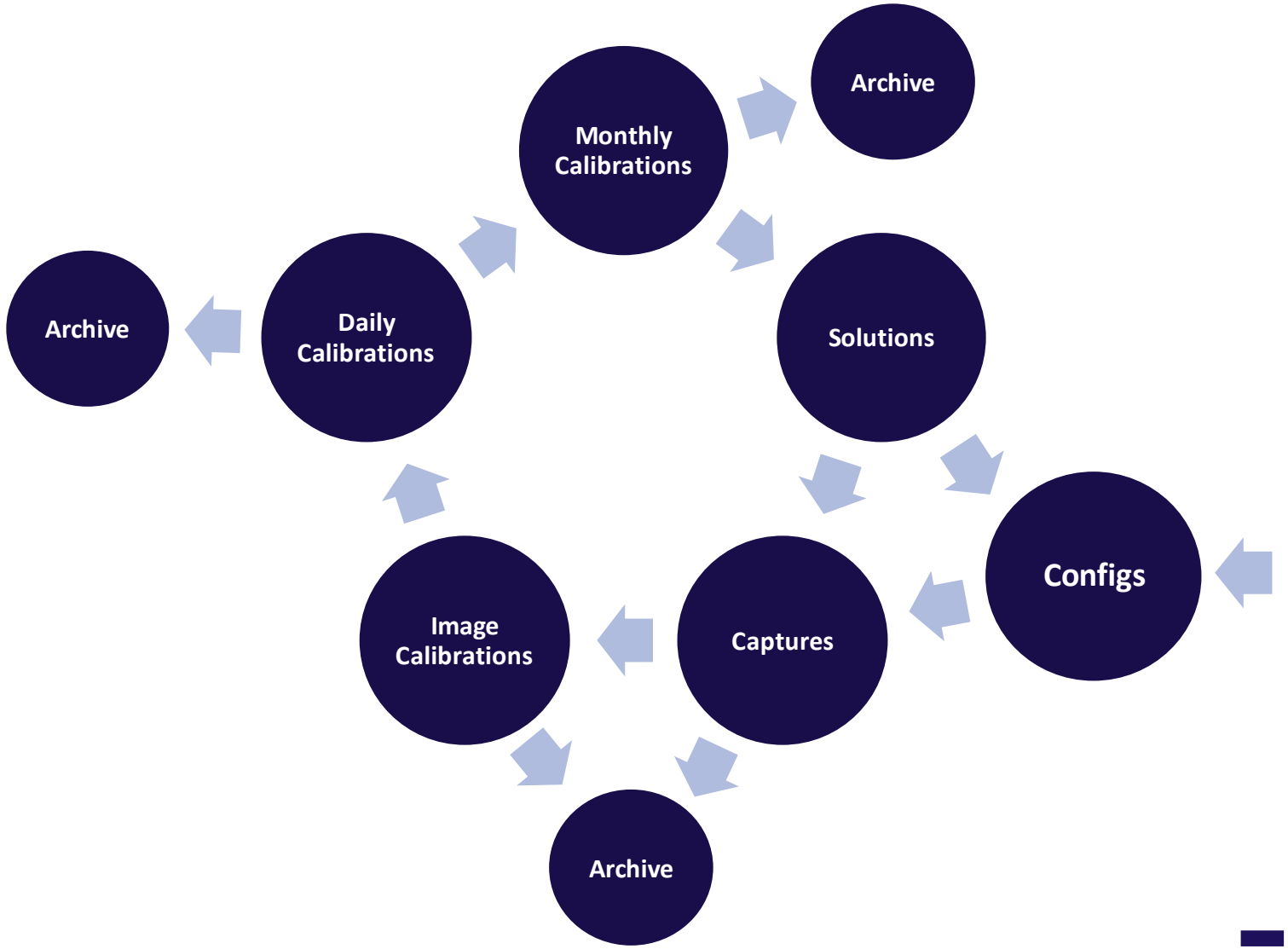
Calibration pipeline



Calibration pipeline



Calibration pipeline



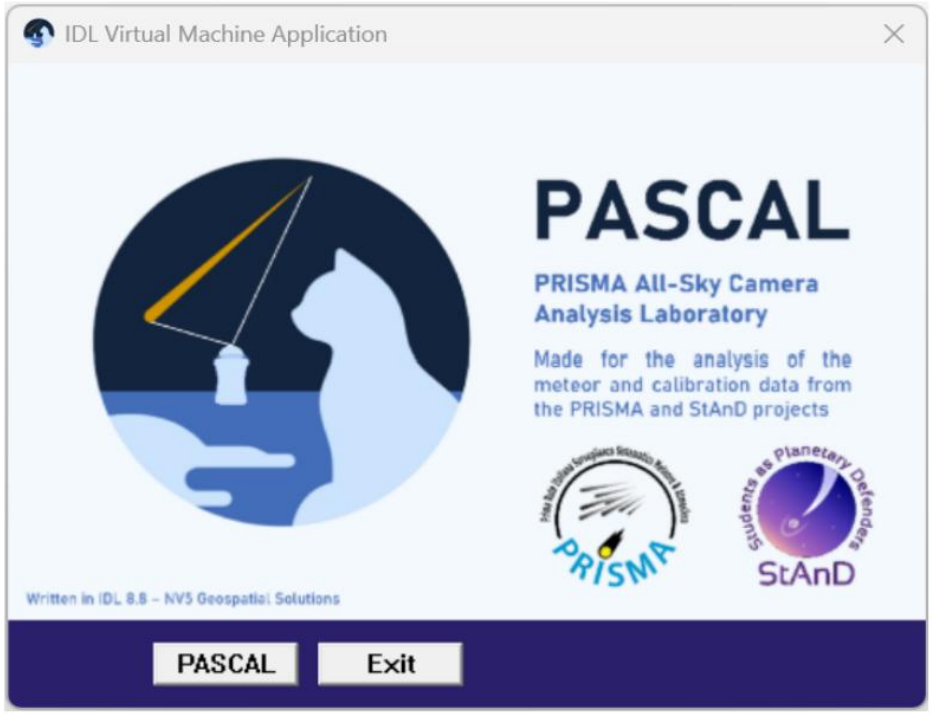


User input

- Updating coordinates or sensor parameters
- Updating initial astro/photo param estimates
- Updating mask
- […]

PASCAL

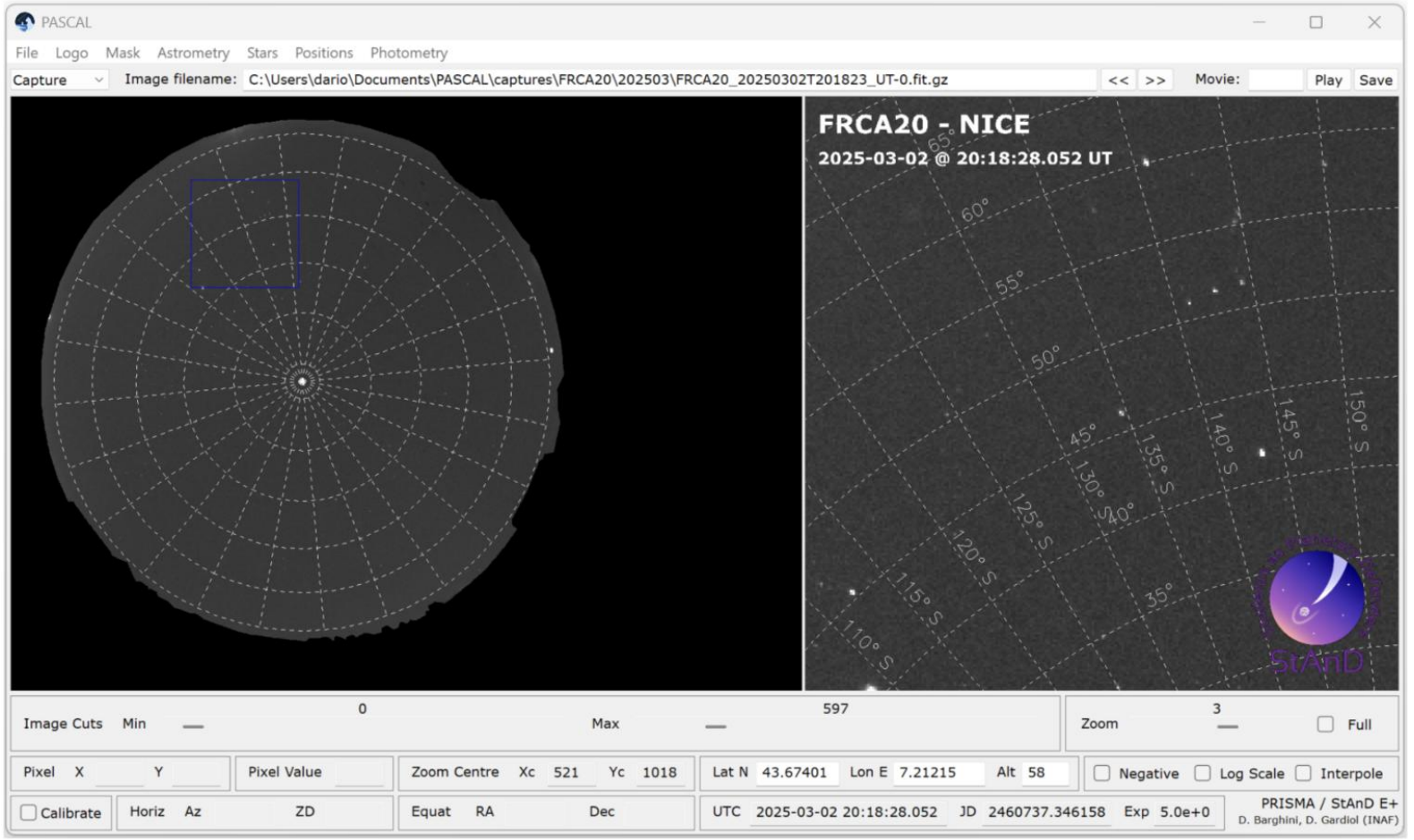
PRISMA All-Sky Camera Analysis Laboratory





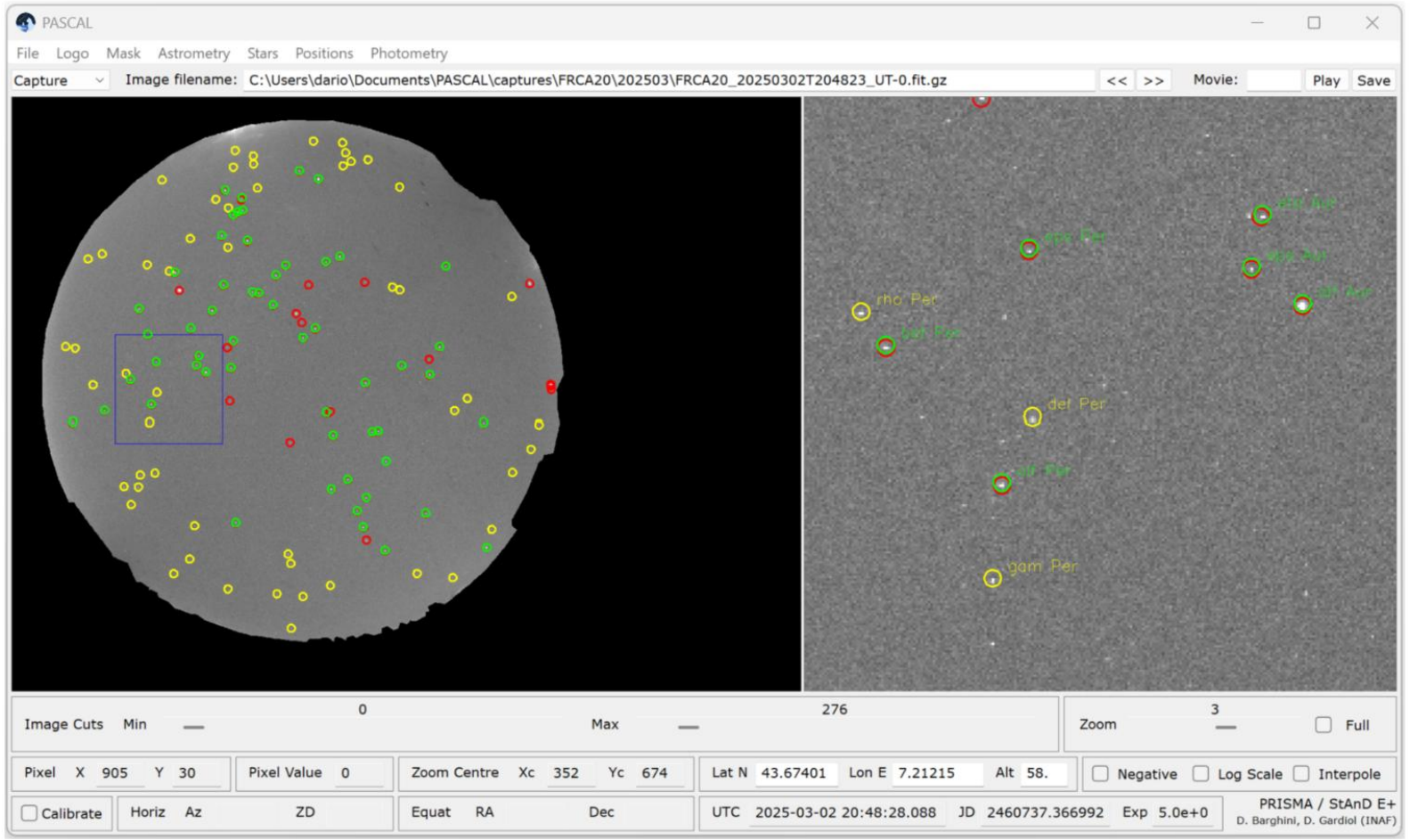
PASCAL

PRISMA All-Sky Camera Analysis Laboratory



PASCAL

PRISMA All-Sky Camera Analysis Laboratory



PASCAL

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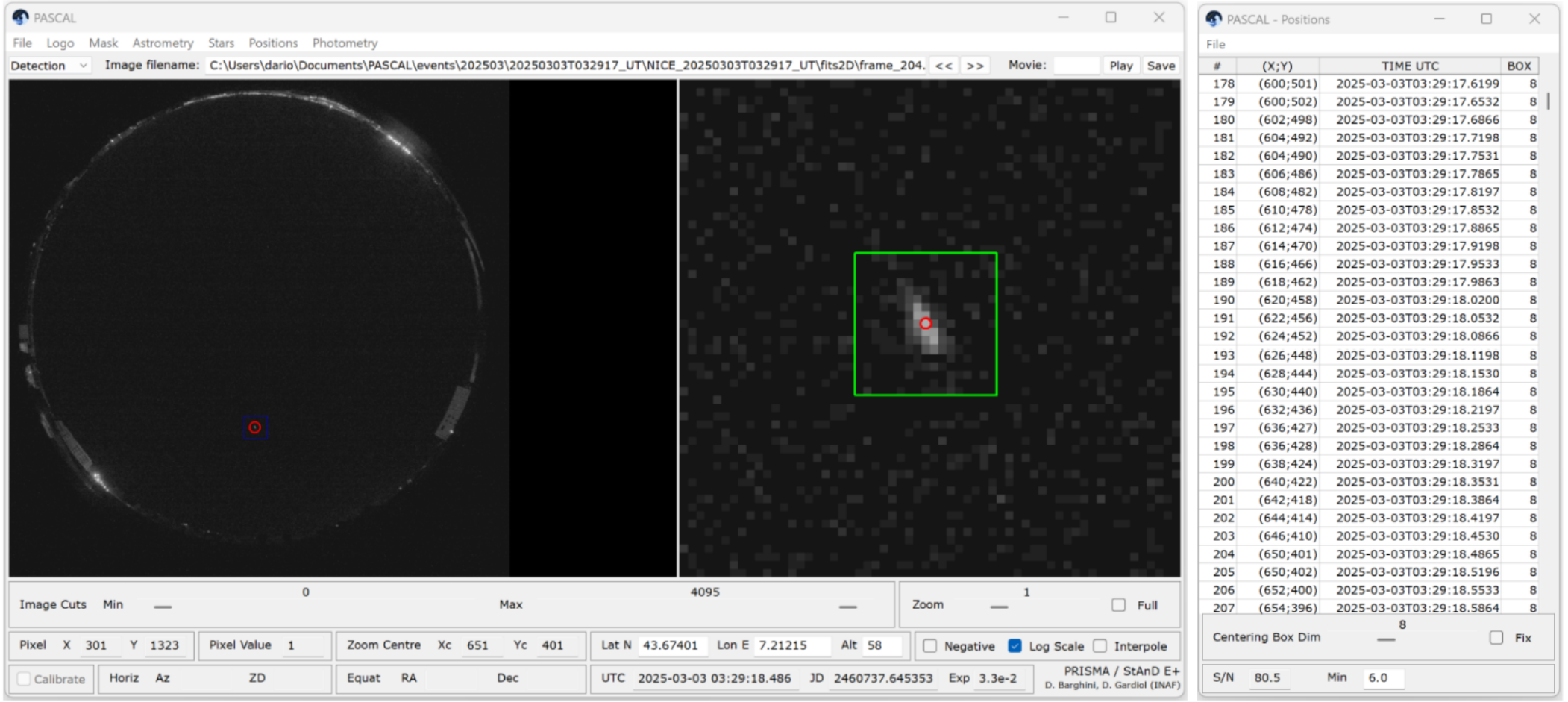

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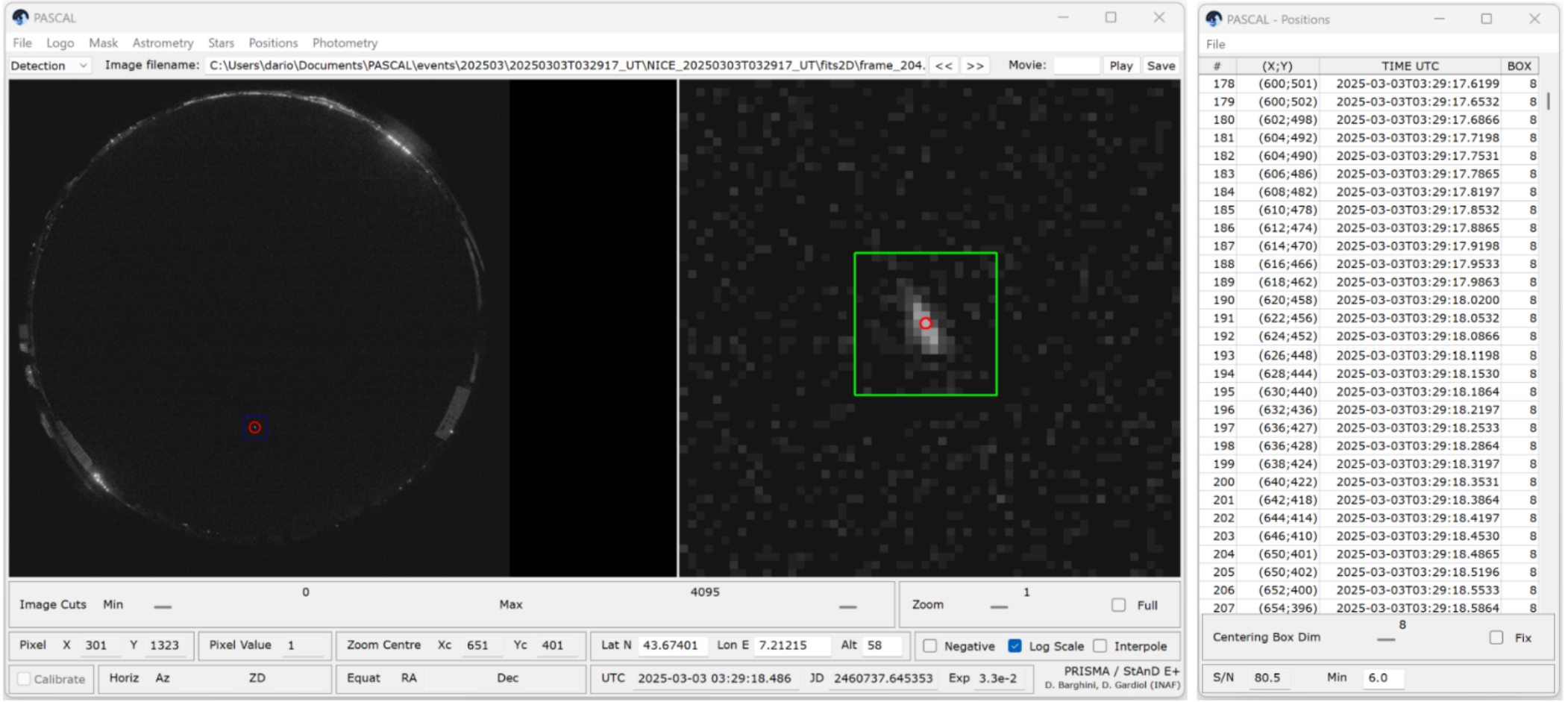
PRISMA All-Sky Camera Analysis Laboratory



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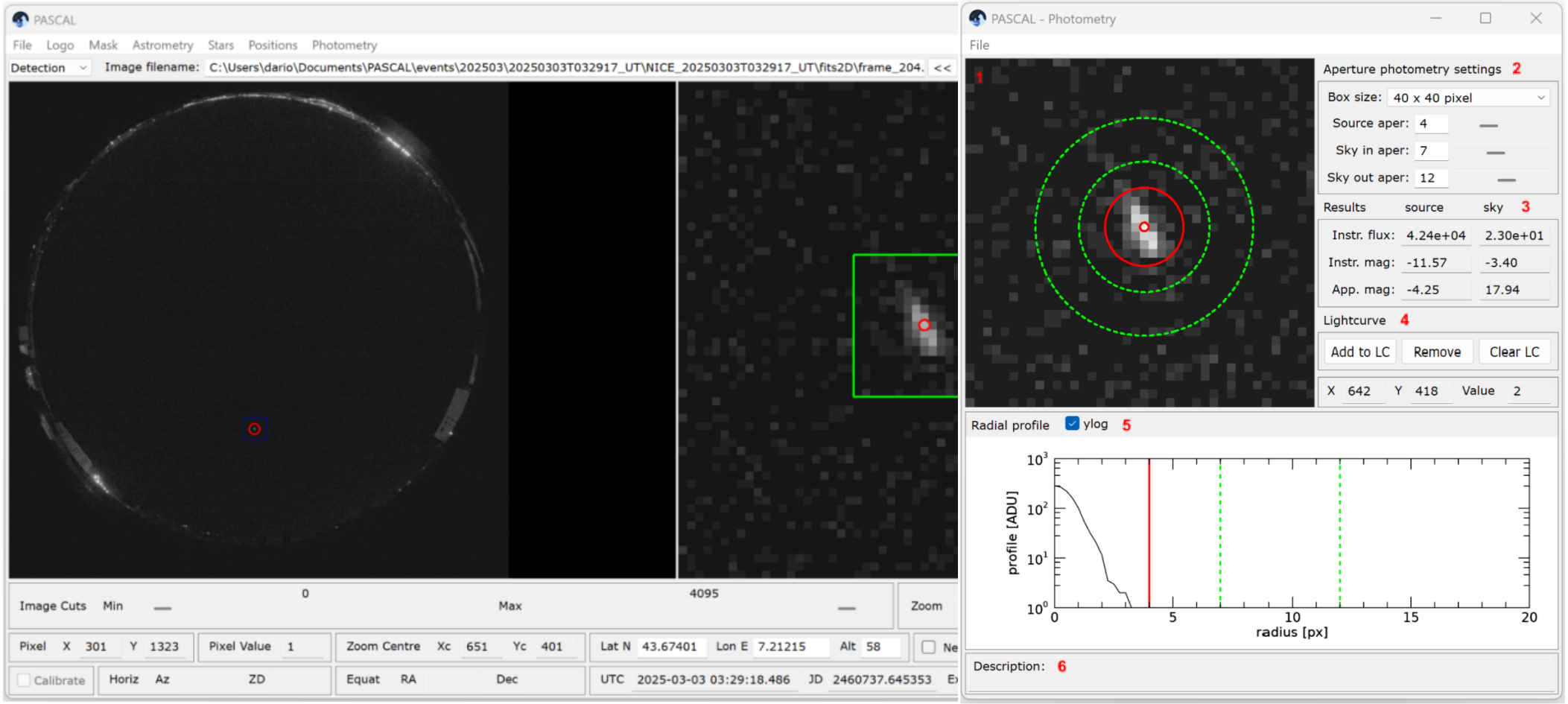
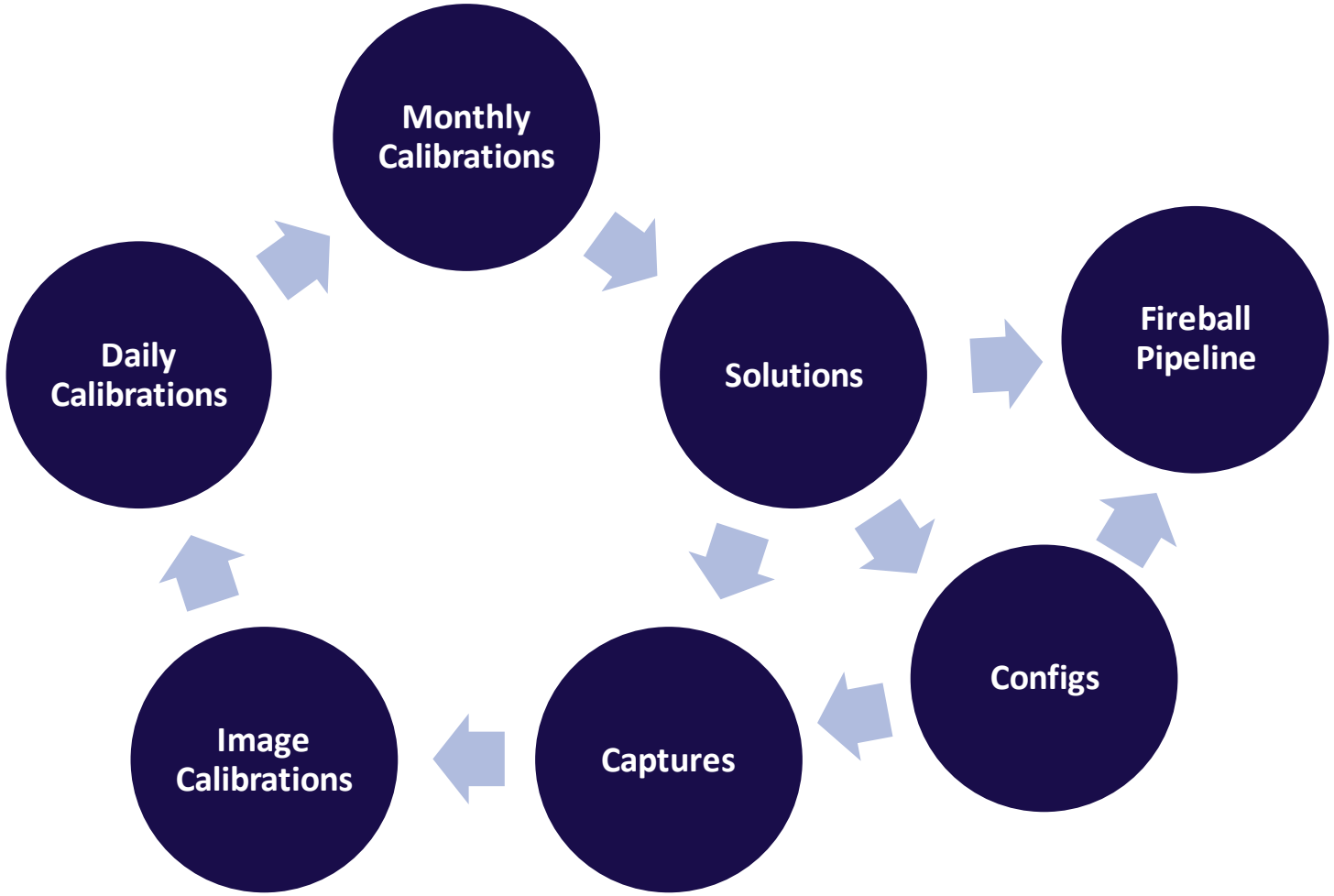
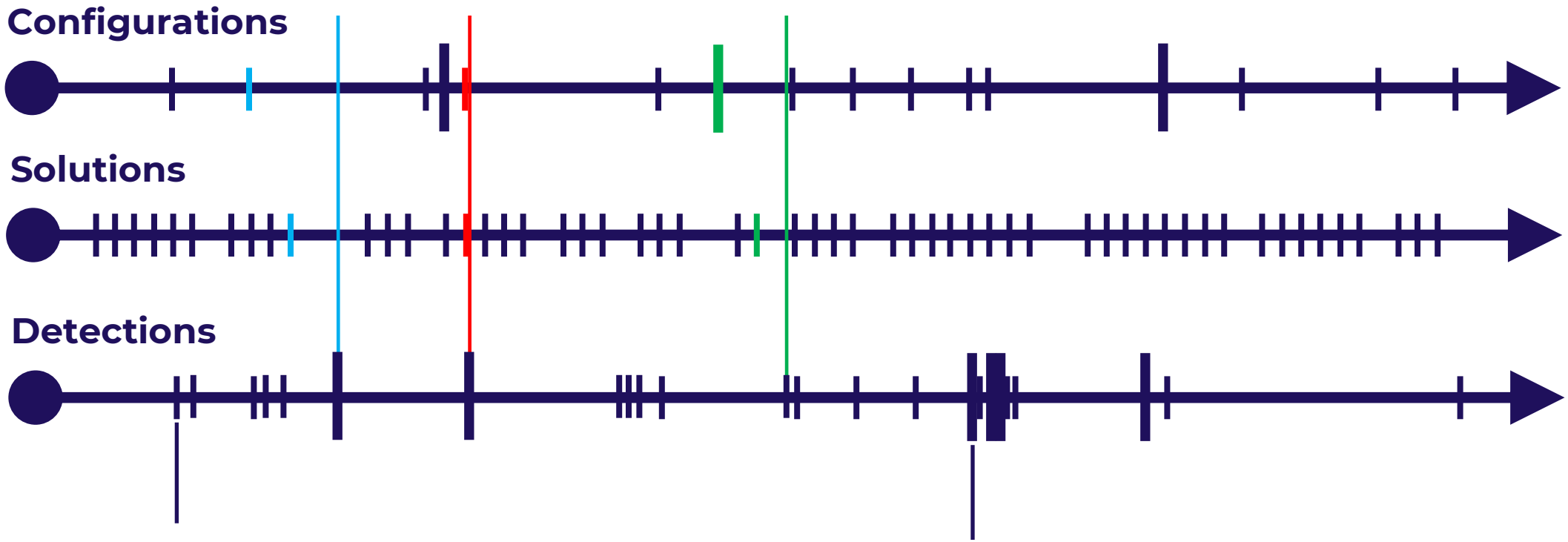


Fireball pipeline



Fireball pipeline



Detection

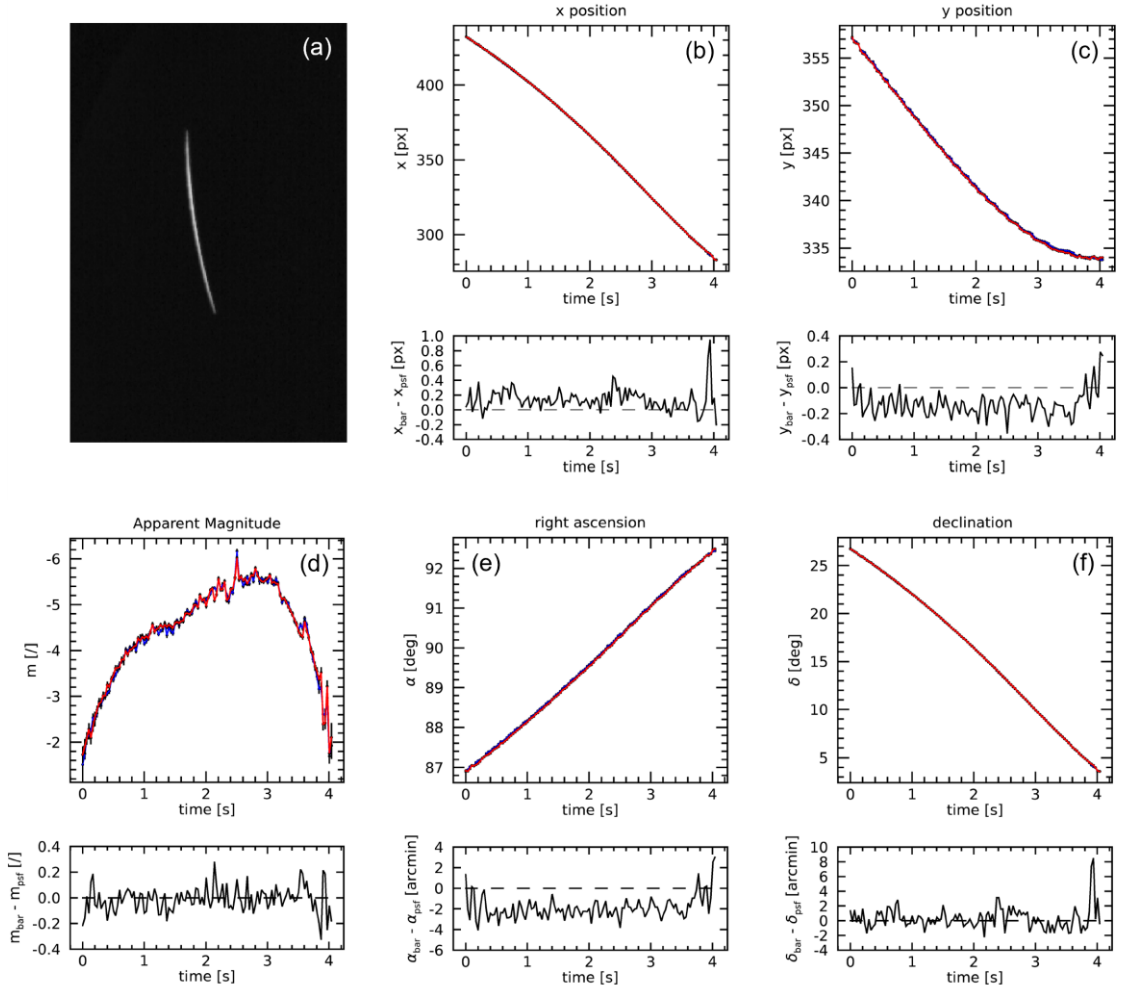
Recording of a fireball seen by one camera

Event

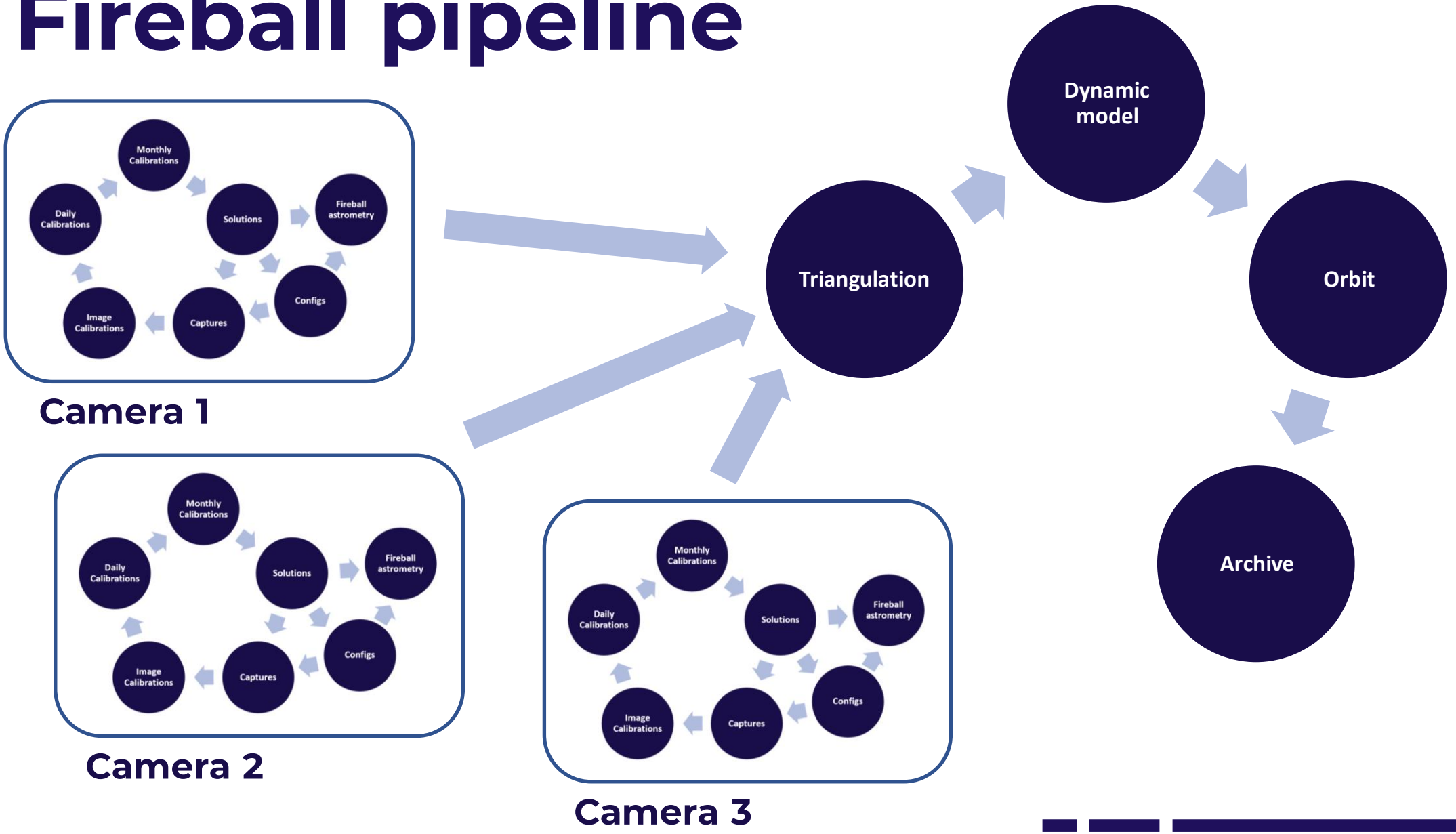
Collection of N > 2 detections of the same fireball seen by different cameras

Fireball pipeline / Astrometry

- 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
  - ➢ Analysis of the **shape of the unsaturated PSF portion**
- **Major challenges** for automation:
  - Faint beginning and final portion of the trajectory **sentitive to image noise**
  - Automated centering subject to **stray light** (moon / neighbouring lights)
  - **Greatly variable aperture** radius



Fireball pipeline



Fireball pipeline / Triangulation

Combination of two of the most common approaches, to provide a unique solution:

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

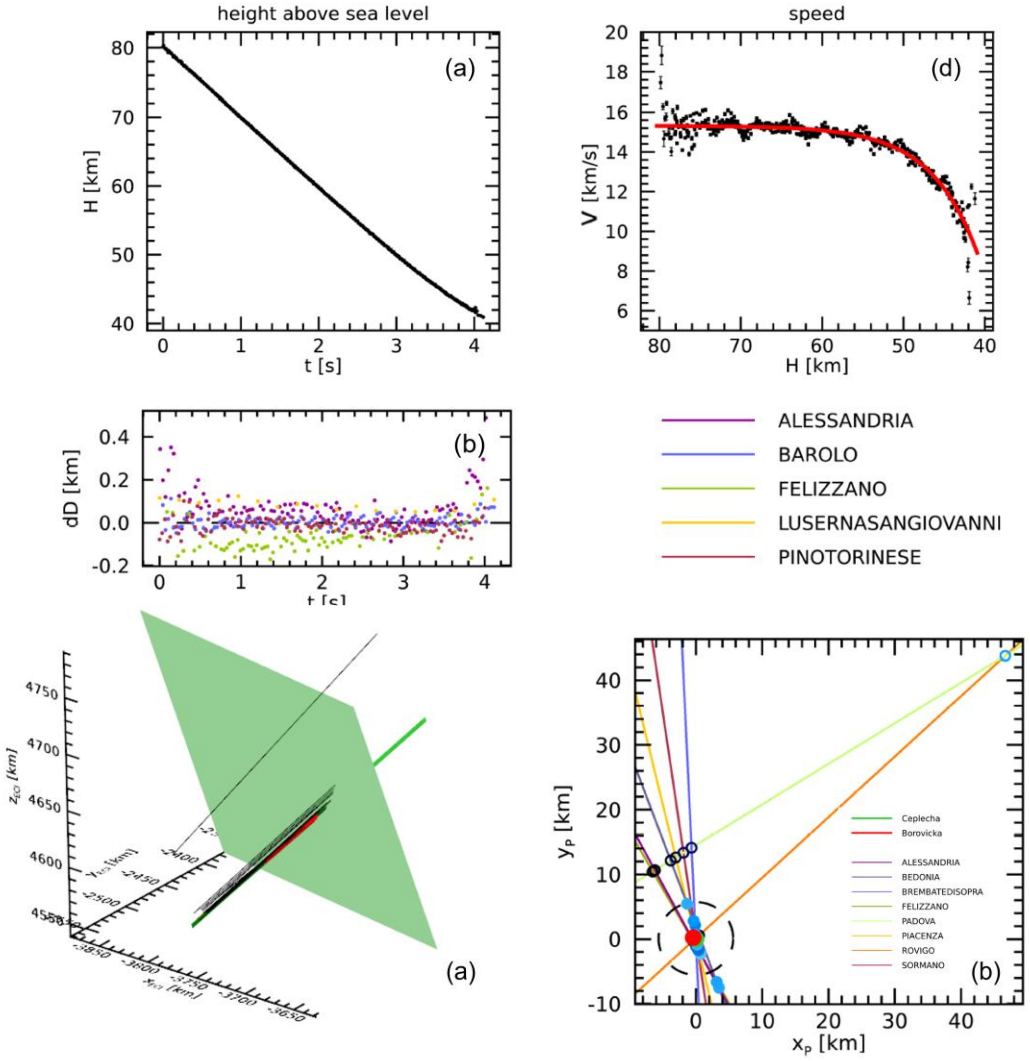
b) **Lines of Sight** distance minimization

Typical **positioning precision of 100 m**

Major challenges for automation:

- Identifying and **excluding outliers** among observations from different stations
- Providing **meaningful estimation of uncertainties**

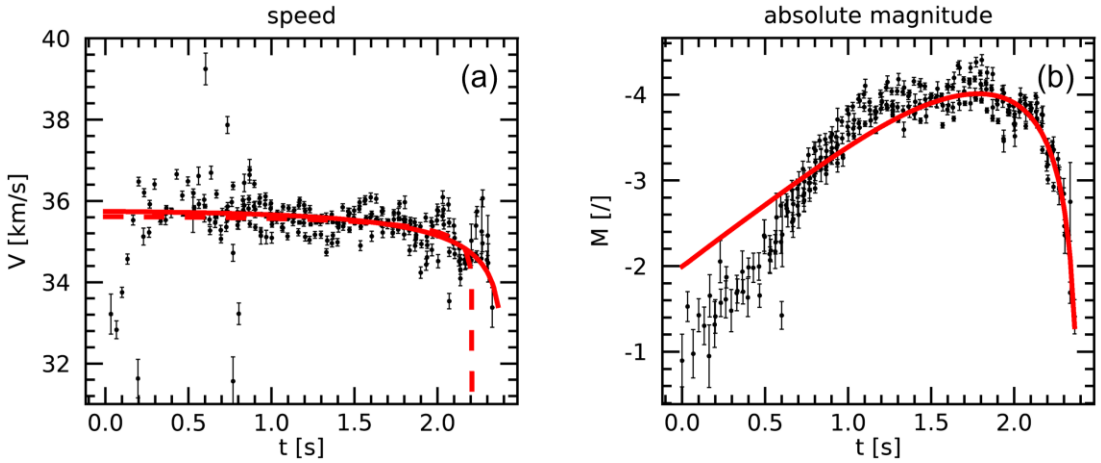
Both addressed by inspecting results of **plane intersections** with respect to average trajectory weighted for parallax angle.



Fireball pipeline / Dynamics (1)

- **Solution and fitting of the dynamic model** over observed data (height, speed, magnitude)
  - **a) Analytical solution**
  - **b) Numerical solution**
- We implemented a novel approach with a **simultaneous fitting** of the **deceleration and lightcurve data**
  - **1) Purely dynamical model** (only deceleration)
  - **2) Photo-dynamic model** (deceleration + lightcurve)

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

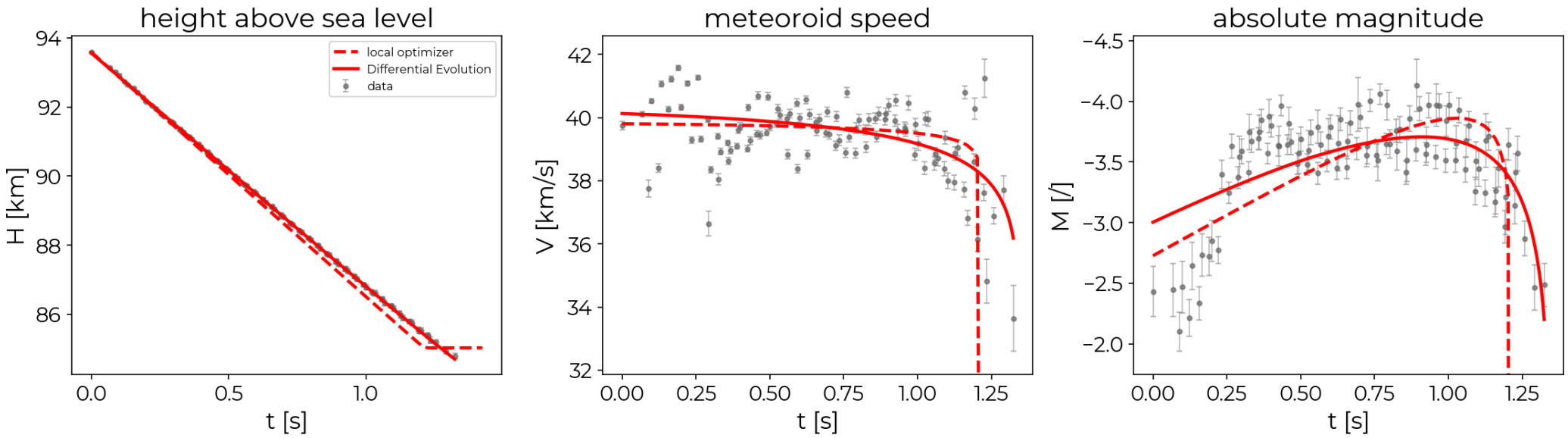


Particularly useful when dealing with events showing **small deceleration**

Fireball pipeline / Dynamics (2)

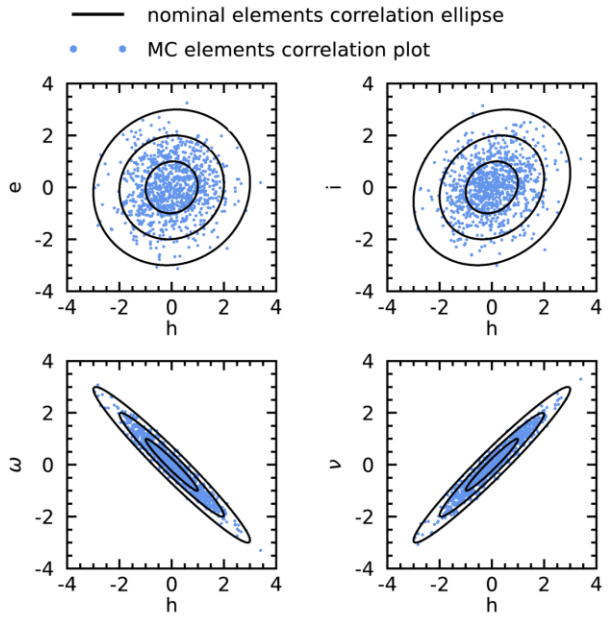
Major challenge for automation:

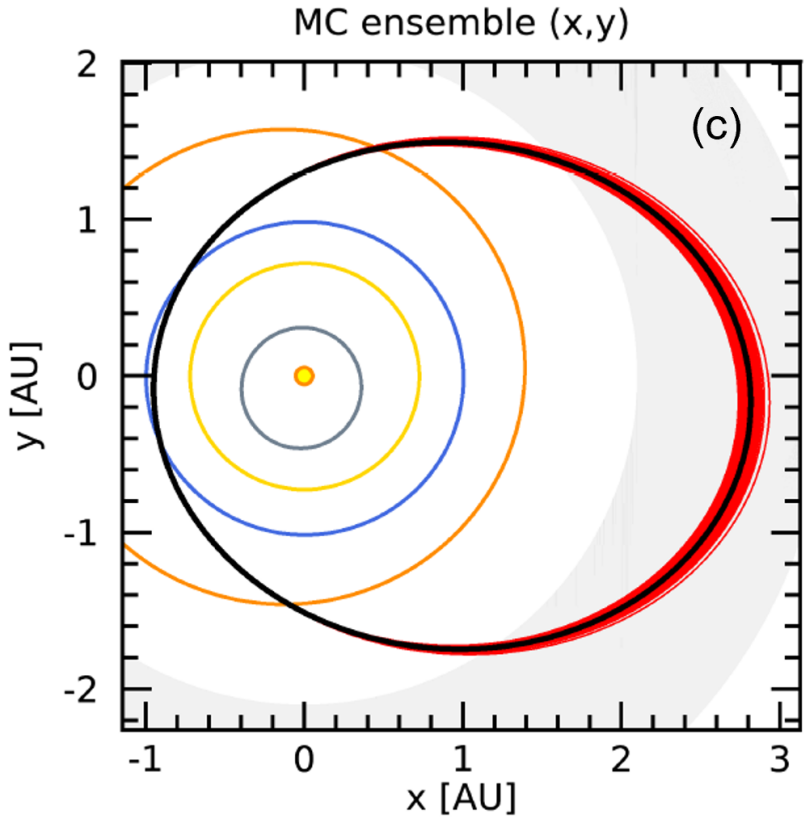
- **Convergence of dynamic model fitting**: a small but significant fraction of events (< 5%) shows diverging results, with biased estimates of meteoroid parameters
  - ➢ Currently testing **Differential Evolution**, a global optimiser that requires no initial guess, with promising preliminary results



Fireball pipeline / Orbit

Retrieving **pre-atmospheric orbit** from trajectory versor (after **zenith attraction** correction) and pre-atmospheric speed module from dynamic model fit





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

Thank you for your attention!

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