TipTop: a single tool for VLT-ELT instrument's AO-PSF support

26 Janvier 2026

TipTop Team

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TipTop Team

astro-tiptop

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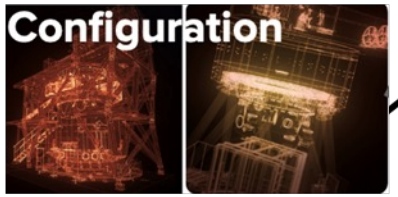
What is TipTop?

Target & Guide starts

Atmosphere

Instrument



Inputs

Analytical simulation tool developed in **Python**

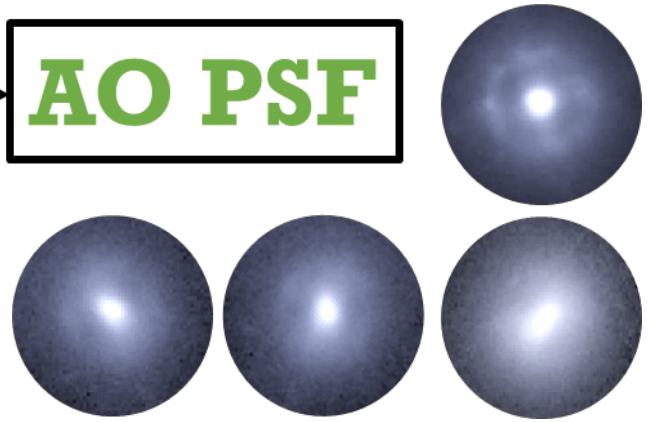
TipTop

GPU/CUDA acceleration supported

Outputs

- PSFs + all associated metrics (SR, EE, FWHM)
- Grid of PSFs over the field
- PSDs
- Radial Profiles

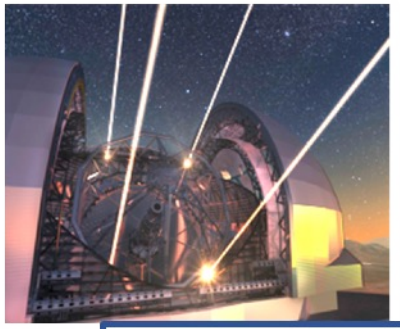
AO PSF

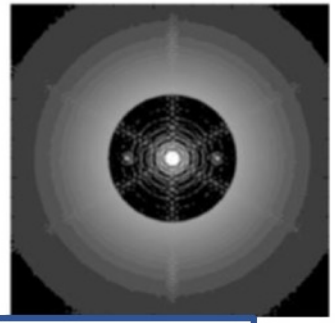


Works for all AO modes (SCAO, LTAO, GLAO, MCAO) and any atmospheric conditions

astro-tiptop

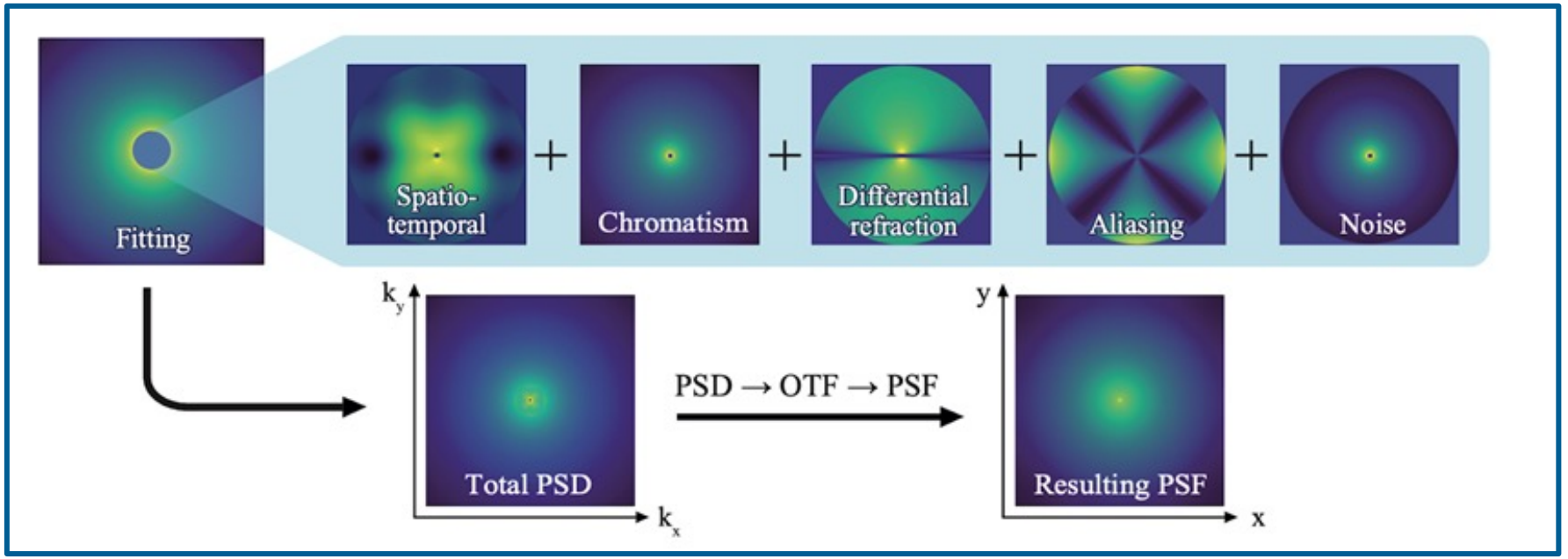
How does TipTop work?





High-Order contribution

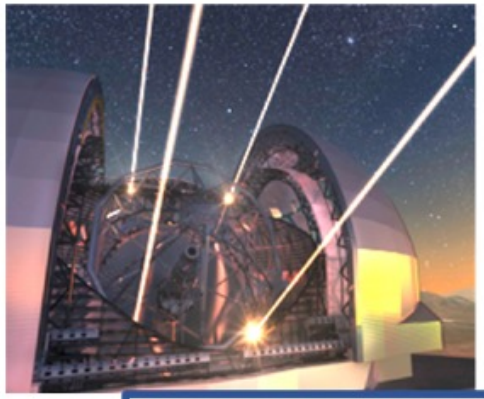
Fourier-Based

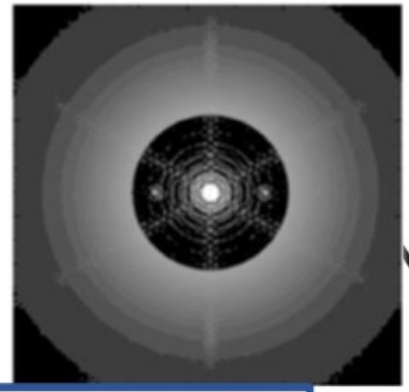


astro-tiptop

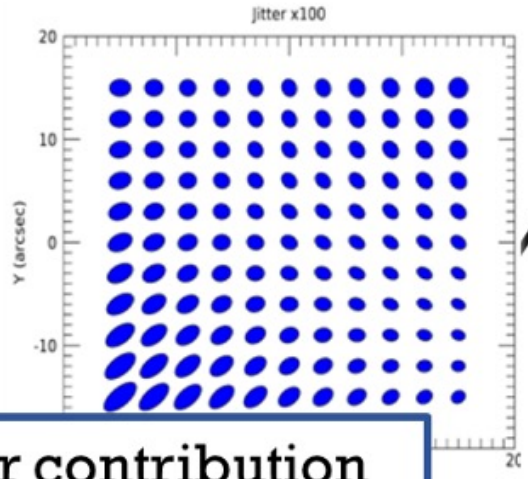
How does TipTop work?

Fourier-Based

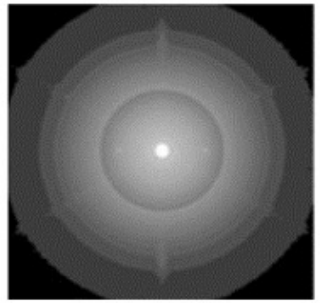




High-Order contribution

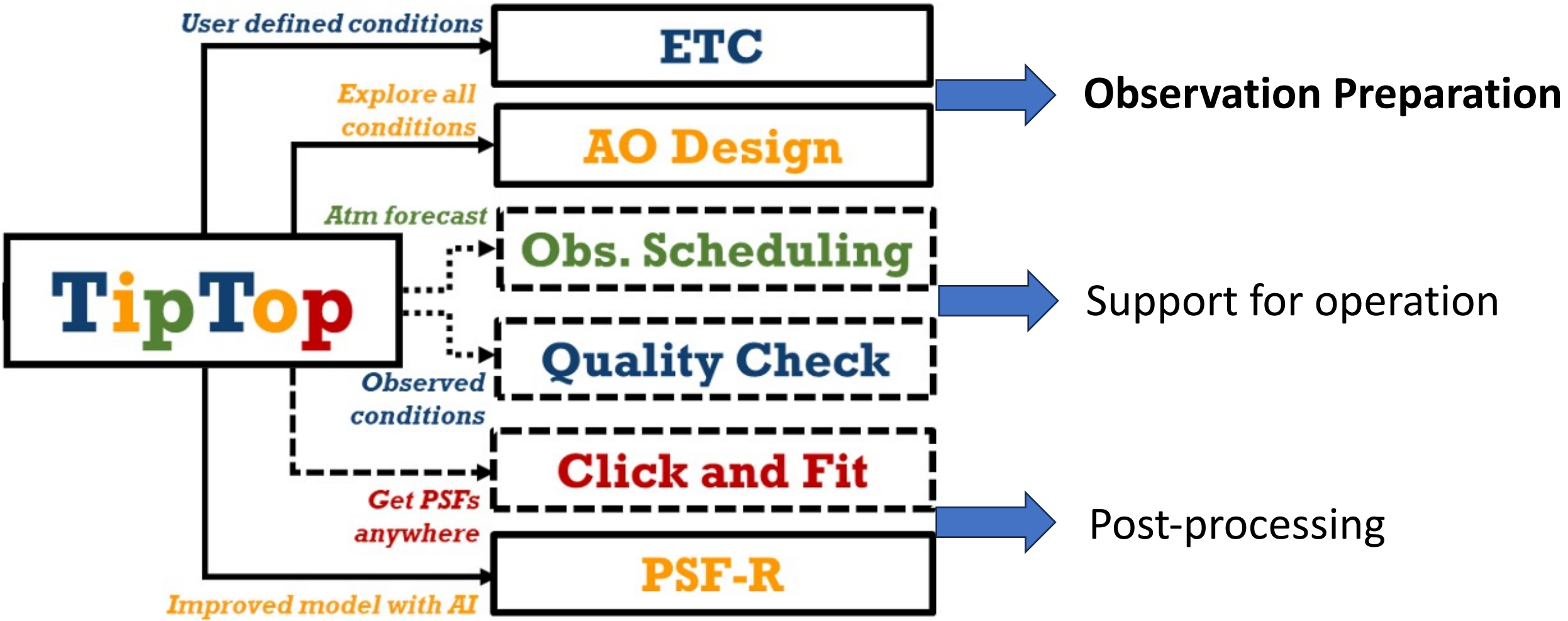


Low-Order contribution



$$PSF = PSF_{HO} * PSF_{LO}$$

What can TipTop be used for?



Observation Preparation

Atmospheric Conditions

Instrument config.

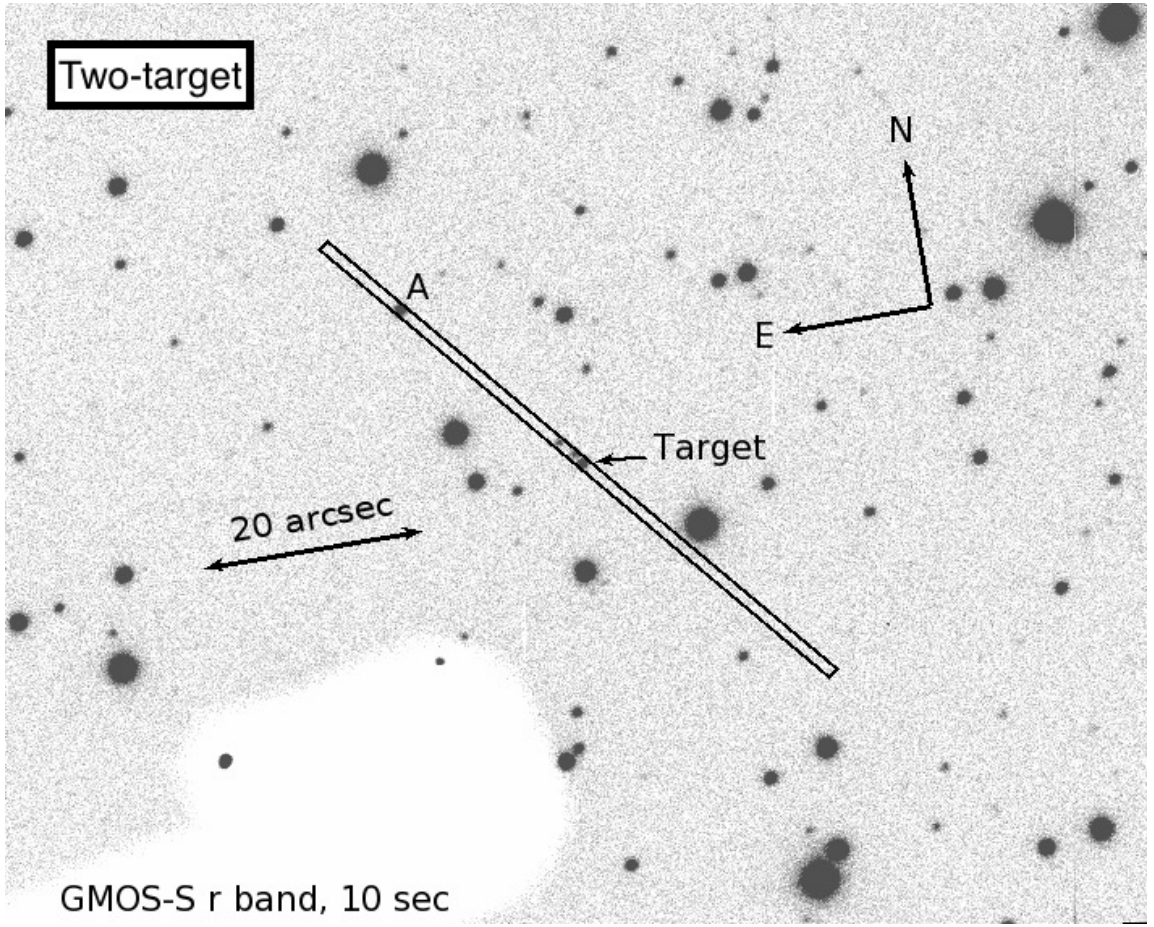
Guide/AO stars

Ini files

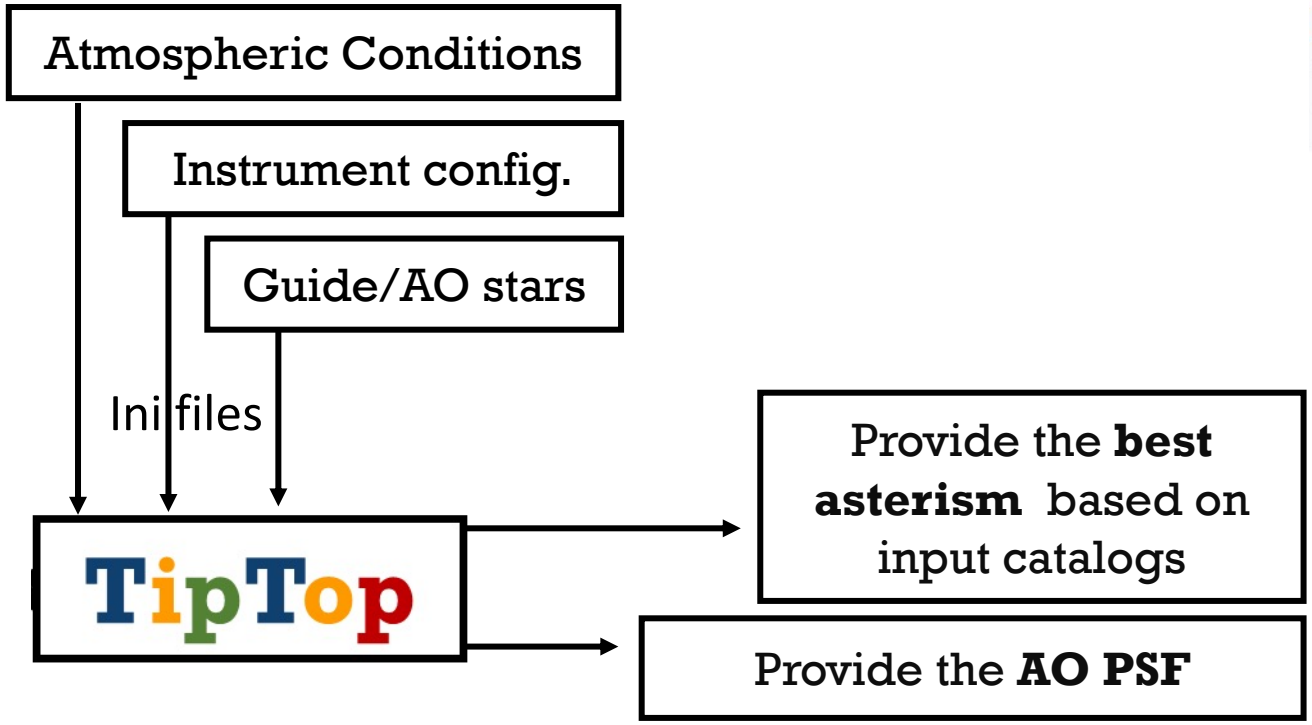
TipTop

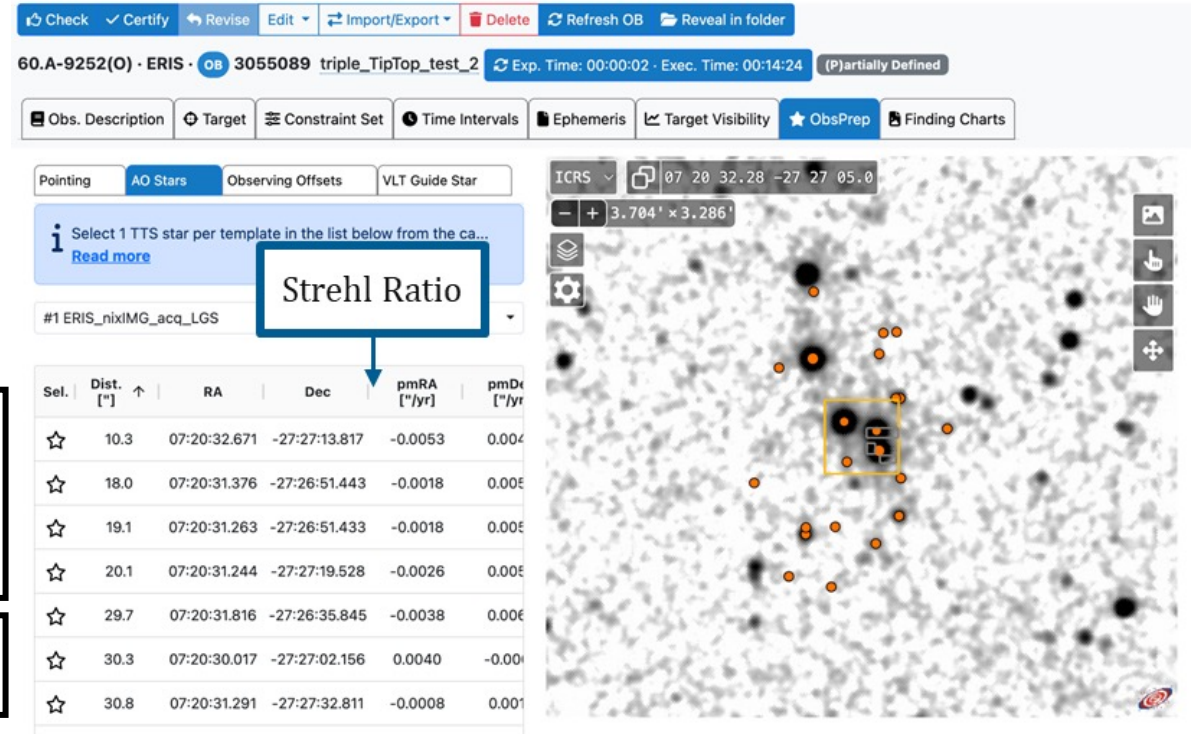
Provide the **best asterism** based on input catalogs

Provide the **AO PSF**



Observation Preparation



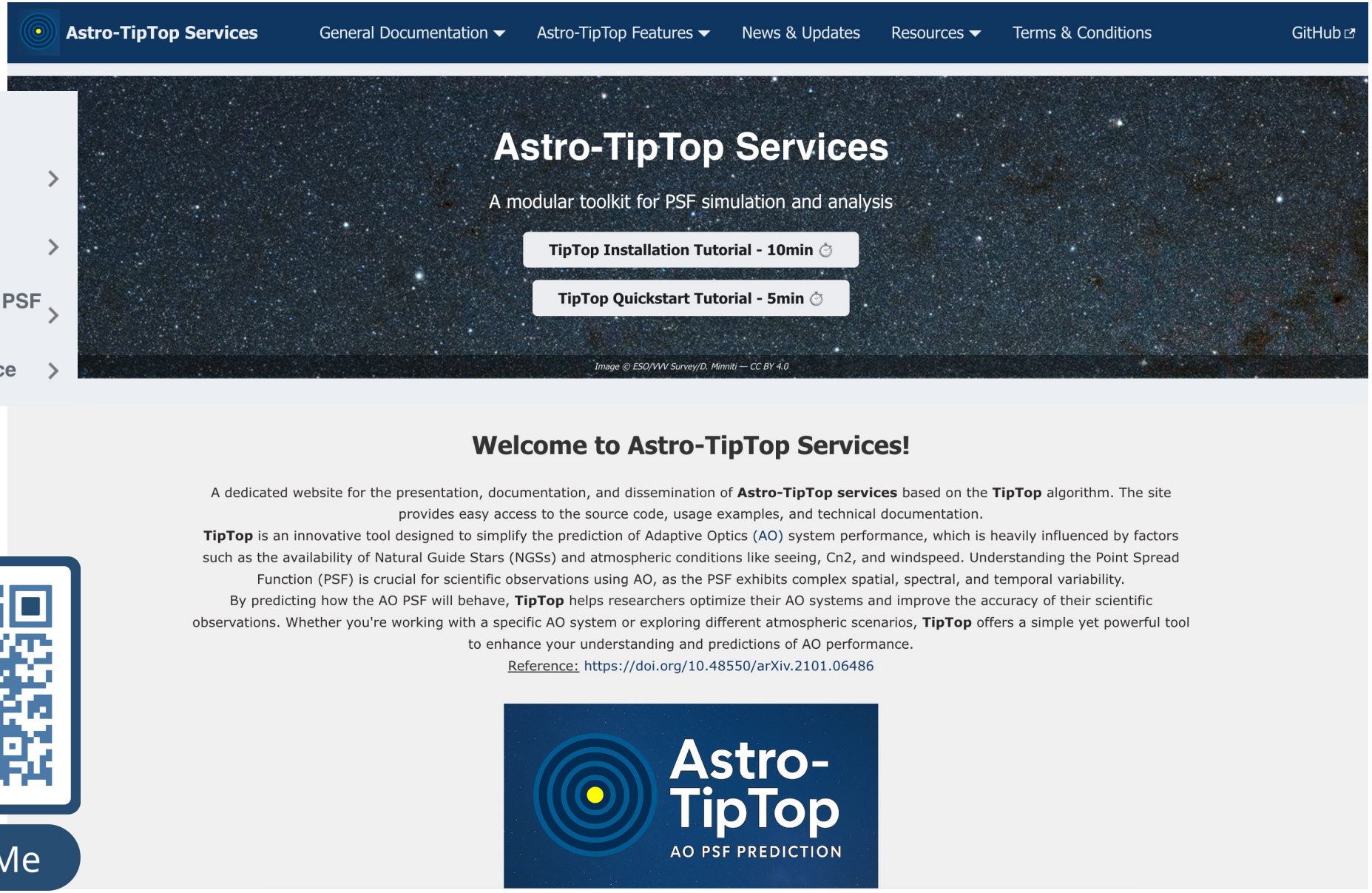


TipTop into **ESO tools ETC, ObsPrep, P2**

This mode has been extensively compared / validated vs. E2E simulations

This mode is operational and ready to support instruments

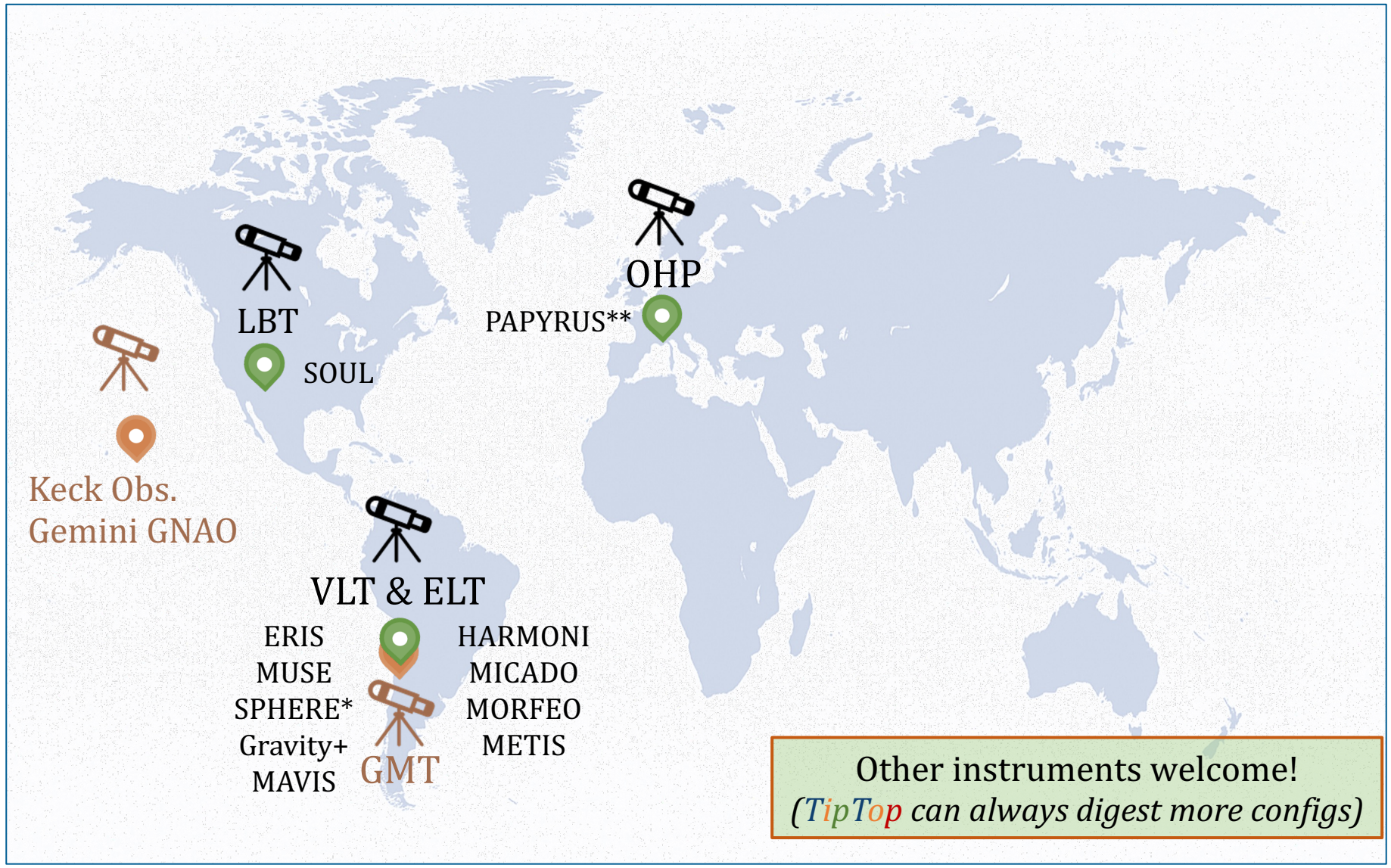
A lot of available documentation



Scan Me

Feel free to contact Lisa-Marie

More than 12 instruments already available



** Coronagraphic mode not supported yet. This is WIP (best effort)*

*** Pyramid WFS model currently updated*

A lot of available documentation

Set Up a Launch Script for TipTop and Display Results

📍 Run a TipTop simulation and display PSFs

Simplest way

As explained in the Quickstart section, to run a simulation with TipTop, you need:

➡️ a launch script which:

- Loads the simulation parameters from a .ini file (e.g., minimalPar.ini)
- Initializes the necessary modules
- Starts the simulation using the **overallSimulation** function

The simplest file to launch a simulation looks like this (`TIPTOP-EXAMPLE.py`, available in the `examples/` folder of our GitHub repository):

```
from tiptop.tiptop import *

overallSimulation("./", "minimalPar", './', 'test')
```

where:

- The first and second arguments of `overallSimulation` are the path to the folder containing the input `.ini` file and the name of that file (without the extension).
- The third and fourth arguments specify where to save the output results (in `.fits` format) and and the name of the resulting `.fits` file.

A detailed documentation on the `overallSimulation` function is available **below**.

More complete launch script

Below is an example of a more advanced launch script (suitable for a single science source). It **runs a simulation** for the **ERIS instrument** and **extracts key outputs**, including **PSFs** and **performance metrics** (e.g., Strehl Ratio (SR), Full Width at Half Maximum (FWHM)) from the output FITS file (see **Simulation Output** below). It also generates log-scaled intensity plots of the **AO PSF**, **diffraction limited PSF**, and **seeing limited PSF**, as well as a log-scaled **radial profile plot**.
✅ You can adapt this script by changing the input/output paths and filenames to match your configuration.
The full example script is available for download **here**🗳️.

▸ **Example run and display script for a single science source:** `TIPTOP_RUN_DISPLAY.py`

More complete display script

Below is an example of a more complete display script (suitable for multiple science sources). It **loads the generated FITS file** obtained after running TipTop — in this case, for the **MORFEO instrument**. It extracts the **PSFs** and **performance metrics** such as Strehl Ratio (SR) and Full Width at Half Maximum (FWHM), for each science source. It also recomputes SR and FWHM from the PSF data to enable consistency checks with the stored header values.
This script then displays the **AO PSFs** in a log-scaled **grid layout**, annotated with zenith/azimuth coordinates and performance metrics, allowing for quick visual assessment of PSF quality across the field. In addition, it plots the normalized **radial PSF profiles** in log-log scale for all sources.
✅ You can adapt this script to your own simulation results by modifying the file names and paths.
The full example script is available for download **here**🗳️.

➡️MAVIS (MCAO-Assisted Visible Imager and Spectrograph)

MAVIS is intended to be installed at the Nasmyth A focus of the VLT UT4 (replacing Hawk-I/GRAAL) with the AOF and is made of two main parts: an Adaptive Optics (AO) system that cancels the image blurring induced by atmospheric turbulence and its post focal instrumentation, an imager and an IFU spectrograph, both covering the visible part of the light spectrum.
(Text sourced from: https://www.eso.org/sci/facilities/develop/instruments/MAVIS.html#BasSpec)

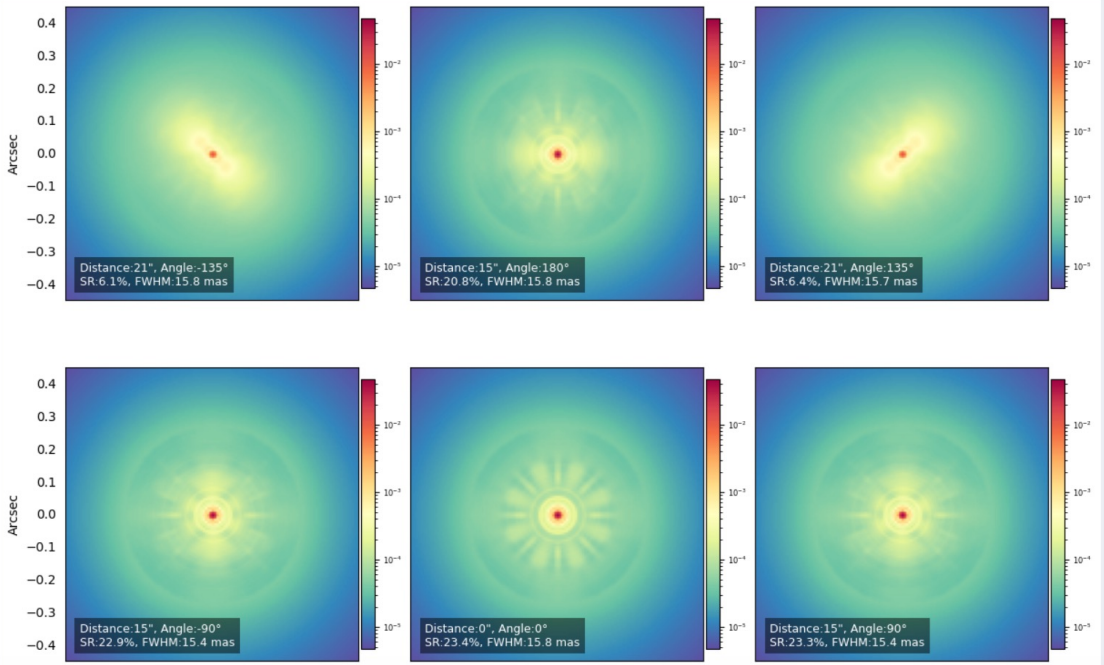
AO mode used:

🟣 **Multi Conjugate Adaptive Optics (MCAO)**

Parameter file (.ini format) - 🟣MCAO✨

▸ **View parameter file contents (.ini)**

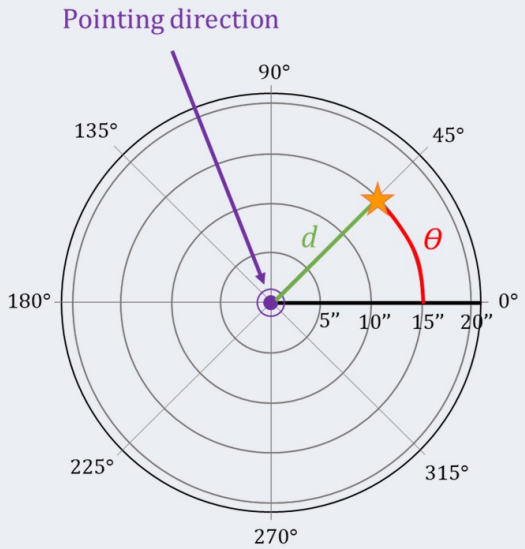
MAVIS MCAO - AO PSFs - $\lambda_{science} = 550nm$

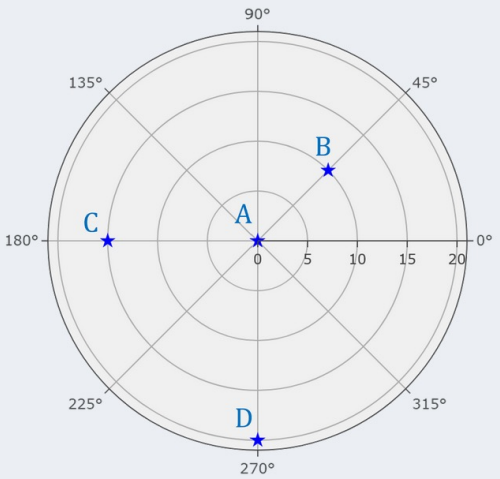


A lot of available documentation

Detailed descriptions of each section are provided below.

Explanation of `Zenith` and `Azimuth` parameters in the `[sources_science]`, `[sources_HO]`, `[sources_LO]` sections





d ↔ *Zenith parameter [arcsec]*
θ ↔ *Azimuth parameter [degree]*

A: Zenith = [0.0], Azimuth = [0.0] (on-axis)
B: Zenith = [10.0], Azimuth = [45.0]
C: Zenith = [15.0], Azimuth = [180.0]
D: Zenith = [20.0], Azimuth = [270.0]

Parameter Sections in Detail

`[telescope]`

▸ [telescope] parameters

[sources_science]

Band: -- Select Band --

Number of science sources: 9

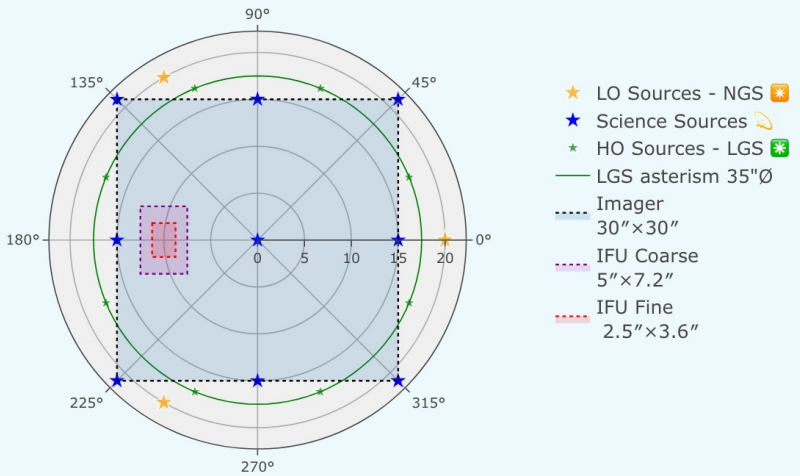
▸ Show details

[sources_LO] & [sensor_LO] - NGS(s)

NGS(s) Wavelength set at 1650 nm | Band: H

Number of NGS: 3

	Distance(1):	Angle(2):	V-Magnitude(3):	NumberPhotons:
NGS #1	20 (arcsec)	0 (degree)	13.76 H-Magnitude: 10.73 (spectral class: M0V)	1900 (nph/subap/frame)
NGS #2	20 (arcsec)	120 (degree)	13.76 H-Magnitude: 10.73 (spectral class: M0V)	1900 (nph/subap/frame)
NGS #3	20 (arcsec)	240 (degree)	13.76 H-Magnitude: 10.73 (spectral class: M0V)	1900 (nph/subap/frame)



A lot of available documentation

3. Static aberrations (`PathStaticOn`, `zCoefStaticOn`)

Static aberrations correspond to wavefront errors that are fixed in time and do not evolve during the simulation.
In **TipTop**, to introduce such static terms you can define:

- a user-provided OPD map (`PathStaticOn`)
- a set of Zernike coefficients (`zCoefStaticOn`)

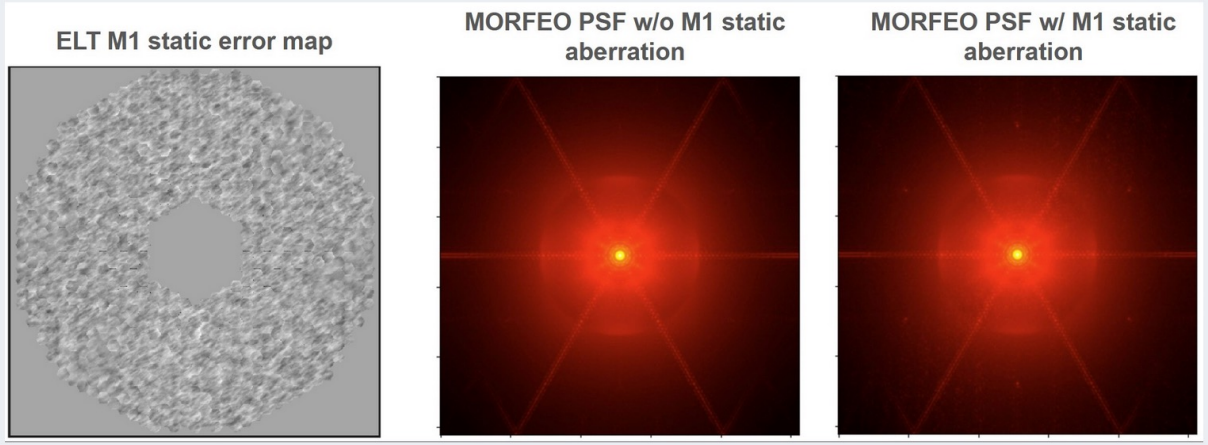
> ✏️ ***Implementation note:***
> Both contributions are combined into an on-axis OPD map (in *nm*) inside the `telescope` class (attribute `tel.opdMap_on`). This OPD map is then applied in the pupil plane when computing the final PSFs, on top of the AO residual wavefront error.

3.1 Using an OPD map (PathStaticOn)

`PathStaticOn` allows you to load a static optical path difference map (in *nm*) from a `FITS` file.
It adds a static aberration (it can be used to add any kind of static aberrations).

This is the recommended approach when you have a measured or simulated aberration map.
The OPD map is rescaled/rotated to match the telescope pupil resolution and geometry and is then used as an additional OPD term during PSF computation.

One example is the static aberration given by ELT M1 (available here).



TipTop Asterism Selection — Hands-on Tutorial (VS Code / Jupyter)

This page walks you through a Jupyter Notebook shows how to run `asterismSelection` with **TipTop**, inspecting and save metrics, reload results later without recomputing, and (optionally) train a **heuristic model** for fast ranking.

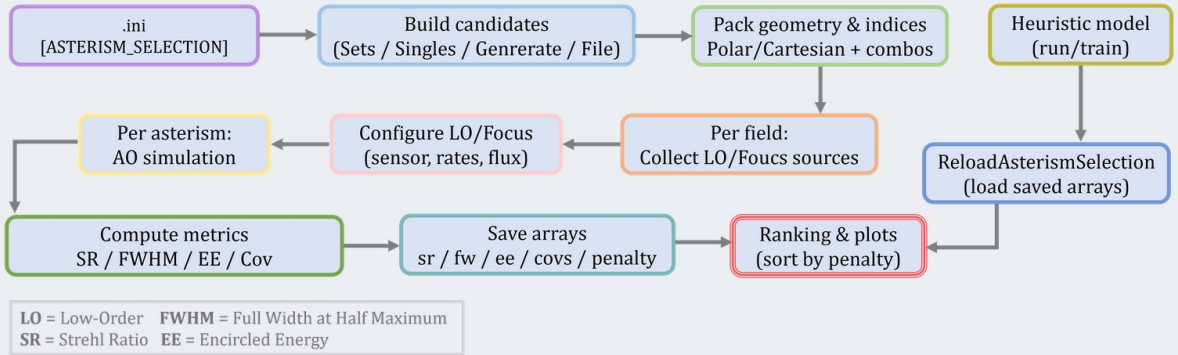
It's meant as a practical guide: pick the parts you need—no need to follow every step end-to-end.

Download the full Notebook: here📥.

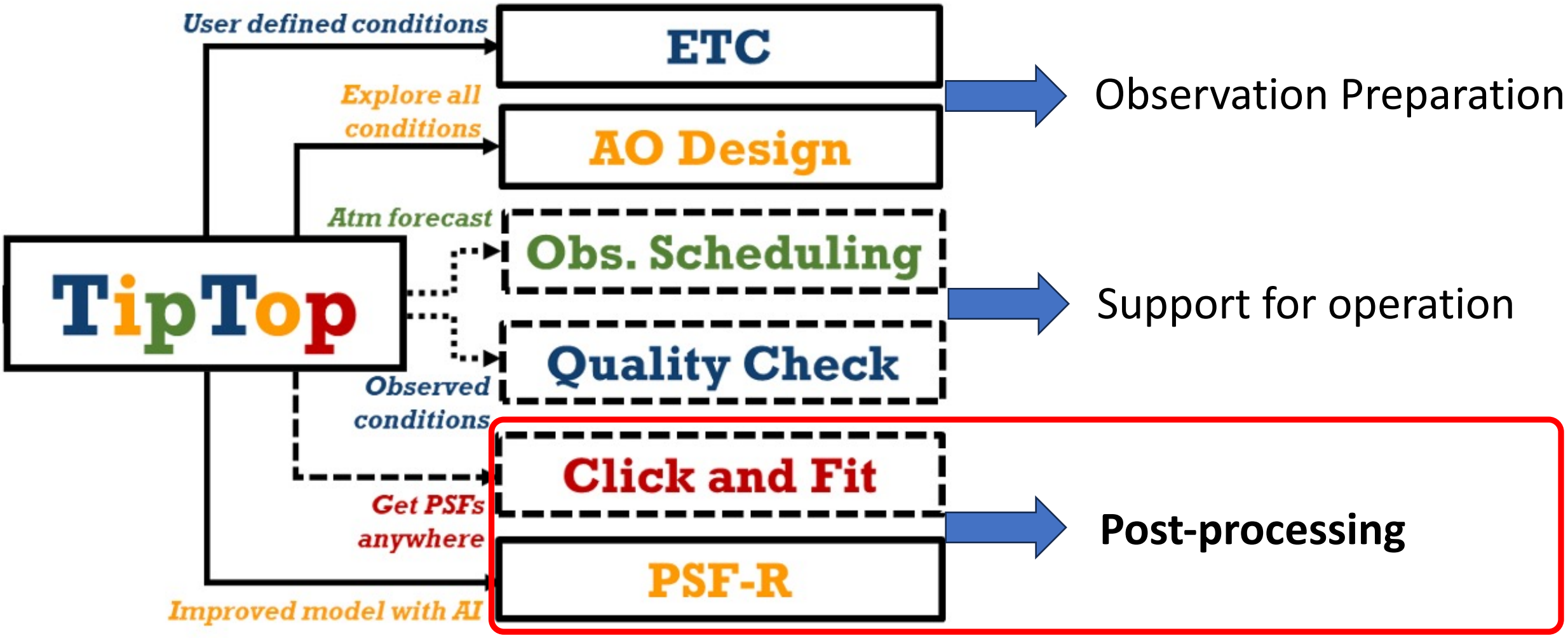
Running asterism selections

🛠️ Pipeline

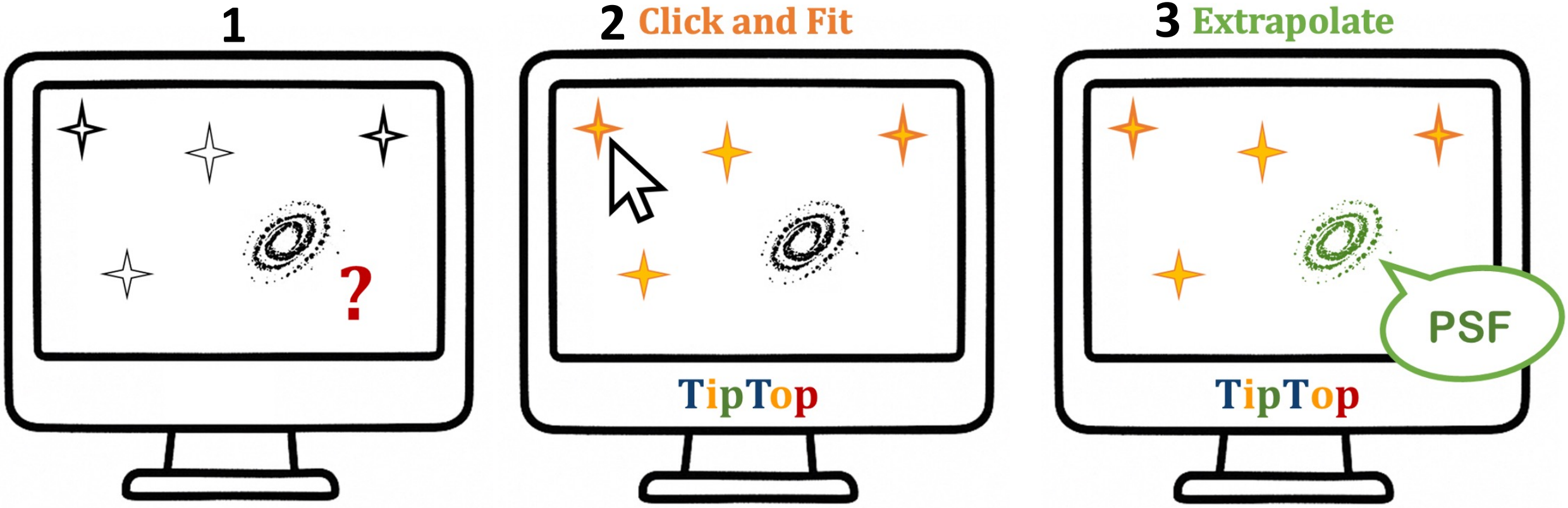
TipTop Asterism Selection – Pipeline Overview



What can TipTop be used for?

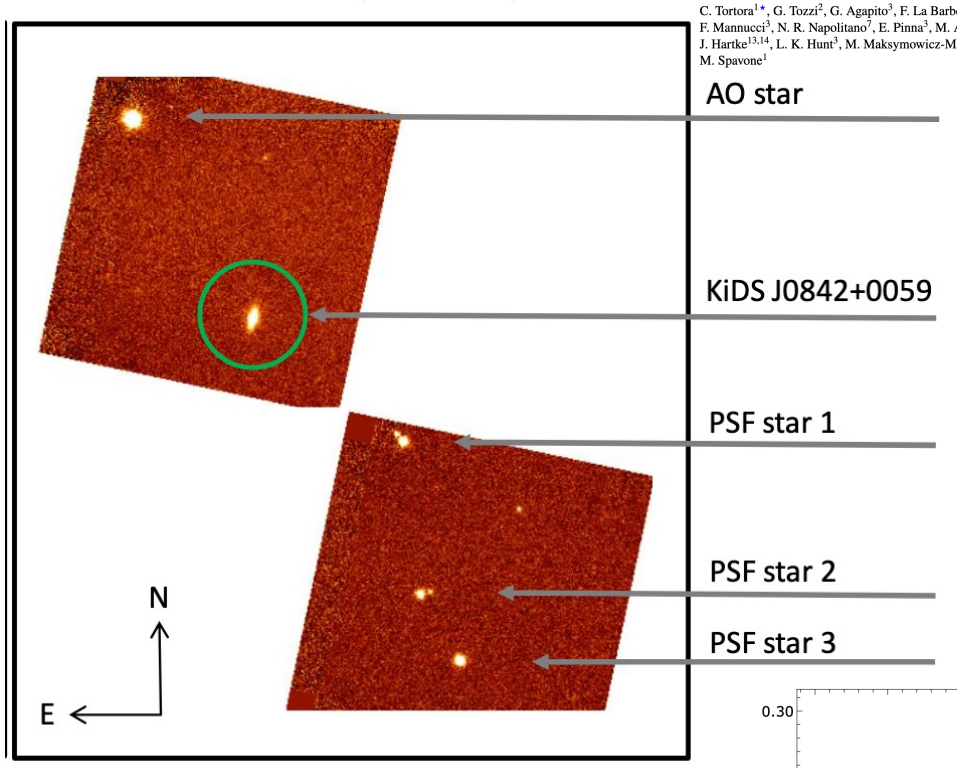


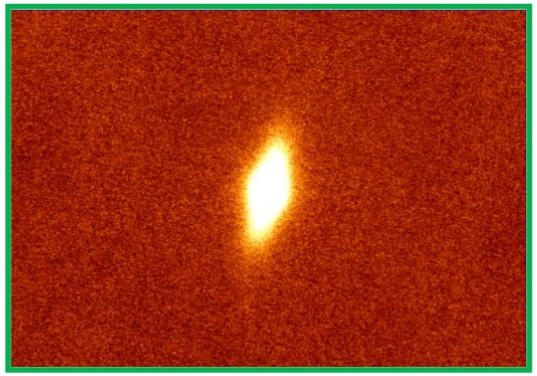
Get the PSF anywhere in the field, from your science data



Get the PSF anywhere in the field, from your science data

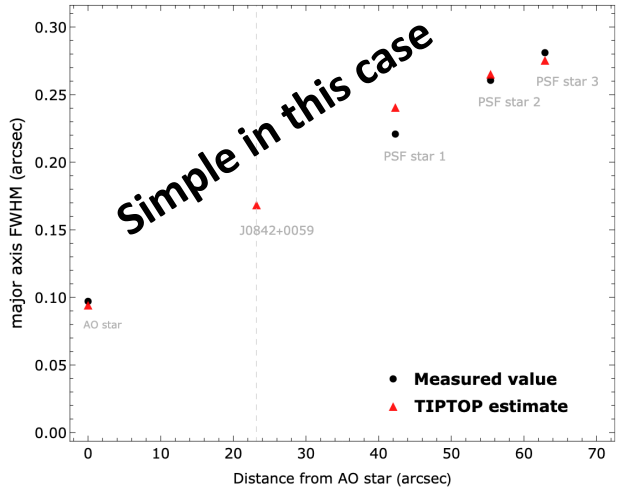
SOUL@LBT (Ks-band)





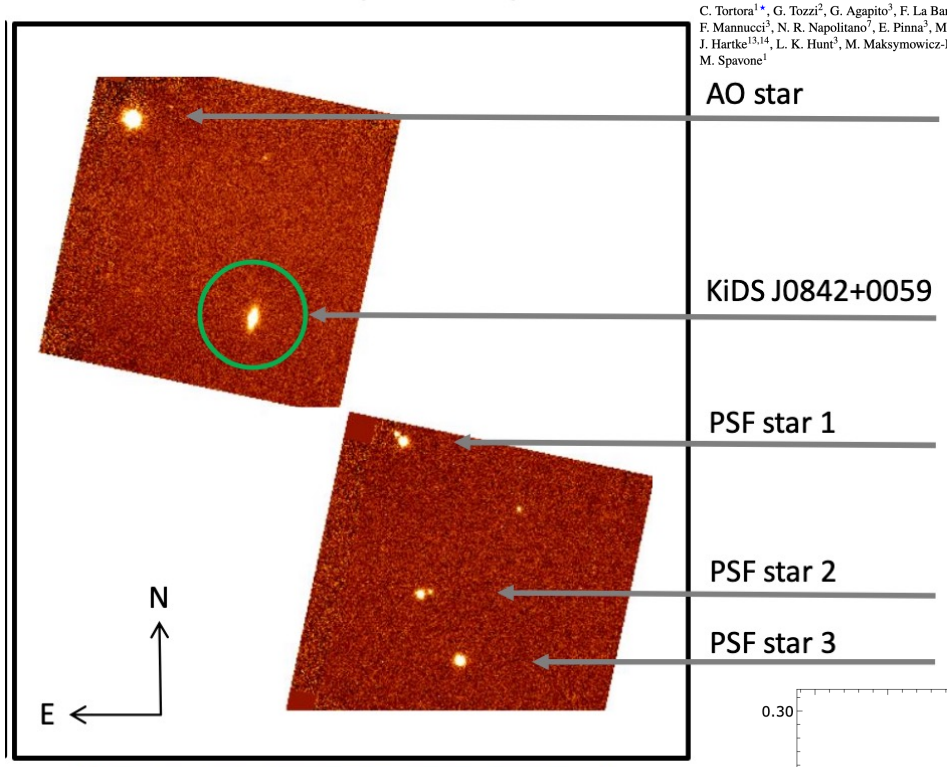
INSPIRE: INvestigating Stellar Populations In RElics. IX.
KiDS J0842+0059: the first fully confirmed relic beyond the local Universe

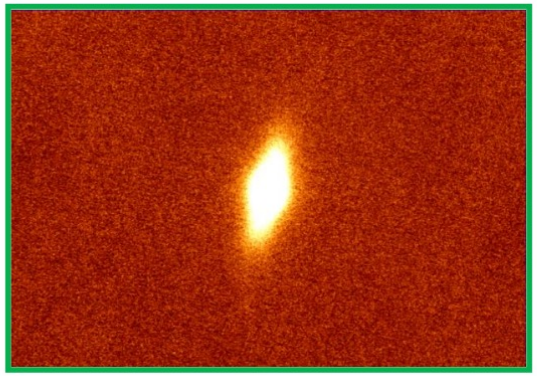
C. Tortora[1]*, G. Tozzi[2], G. Agapito[3], F. La Barbera[1], C. Spiniello[5,1]†, R. Li[4], G. Carlà[3], G. D'Ago[6], E. Ghose[3], F. Mannucci[3], N. R. Napolitano[7], E. Pinna[3], M. Arnaboldi[8], D. Bevacqua[9,10], A. Ferré-Mateu[11,12], A. Gallazzi[3], J. Hartke[13,14], L. K. Hunt[3], M. Maksymowicz-Maciata[17,5], C. Pulsoni[15], P. Saracco[9], D. Scognamiglio[16], M. Spavone[1]



Get the PSF anywhere in the field, from your science data

SOUL@LBT (Ks-band)





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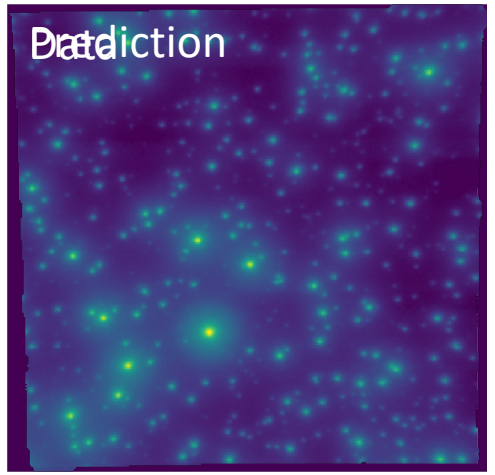
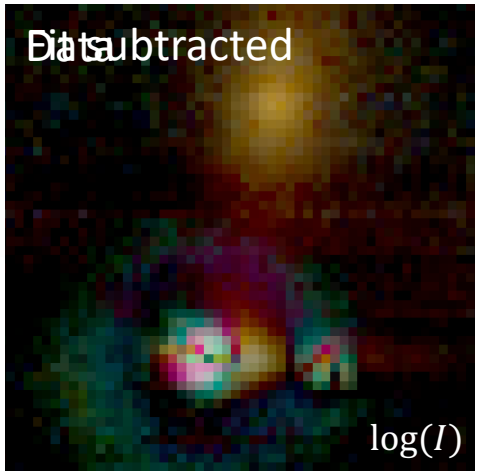
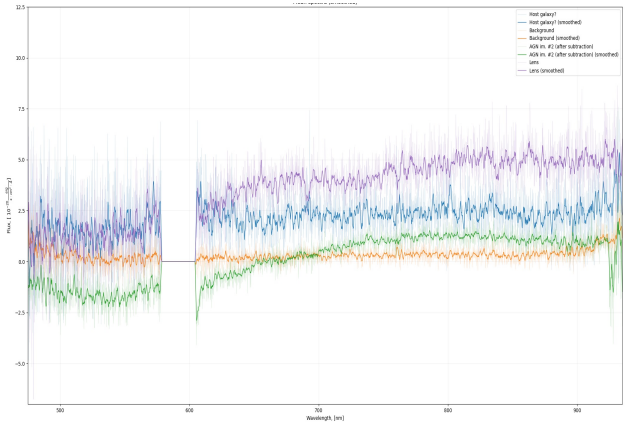
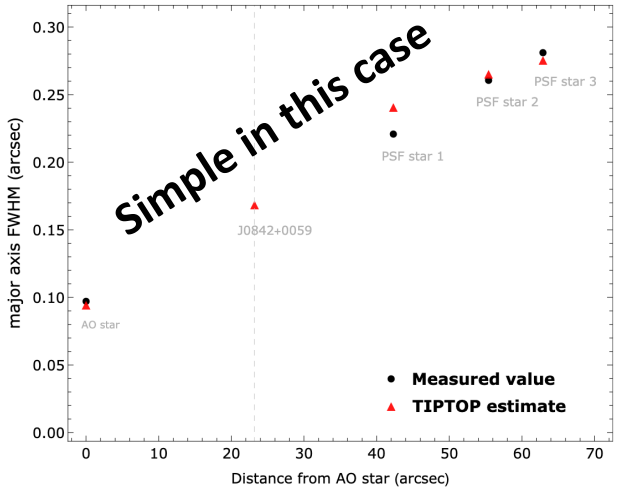
More complex for multiple sources



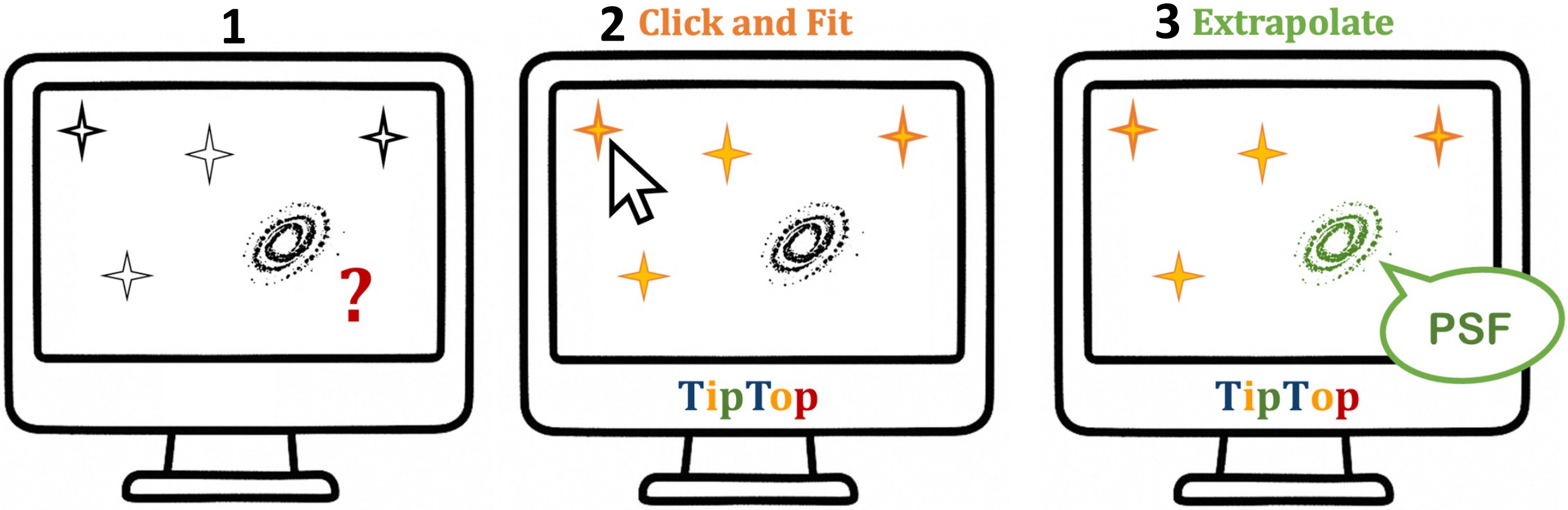






Global fit of multiple PSFs
-> TipTorch

Get the PSF anywhere in the field, from your science data



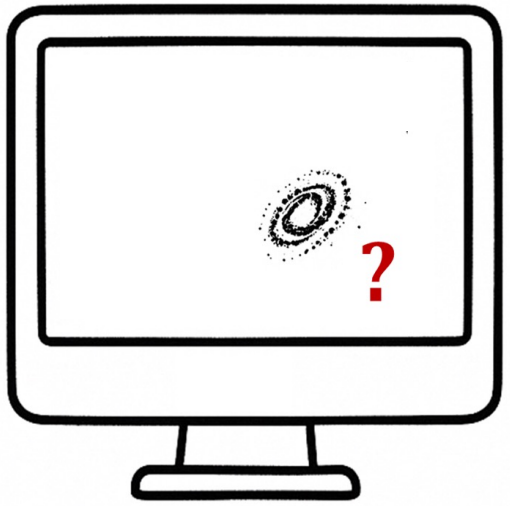
Currently under development

Plan is to get it by end of 2026.

Currently 2 master students working on it (INAF, LAM), more support is welcomed !

Automatization is necessary for “calibrating” TipTop for PSF-R

PSF-Reconstruction

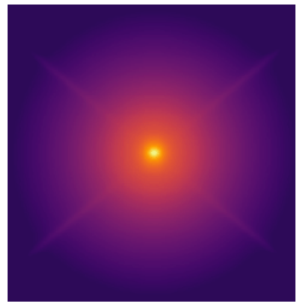


See Arseniy Kuznetsov PhD

External data associated with science obs.

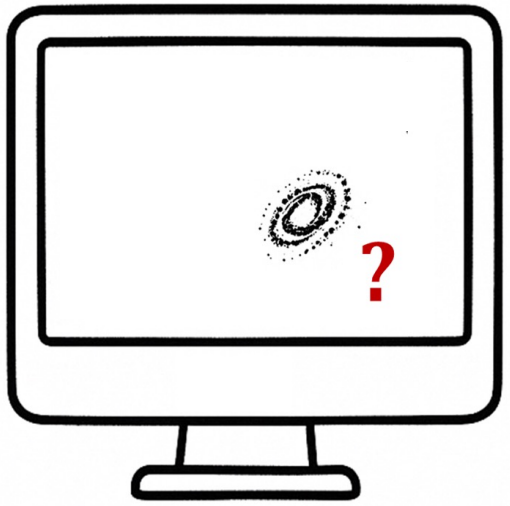
PSF model

Model infers the PSF shape



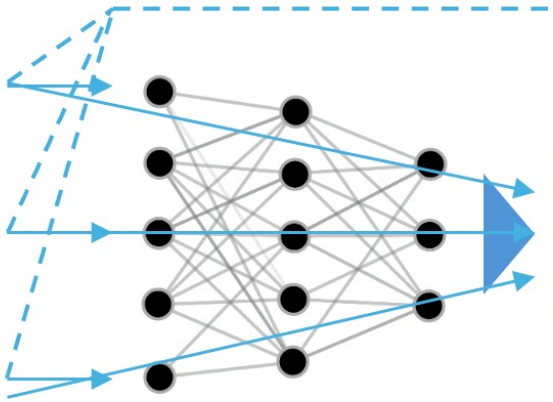
Predicted PSF

PSF-Reconstruction



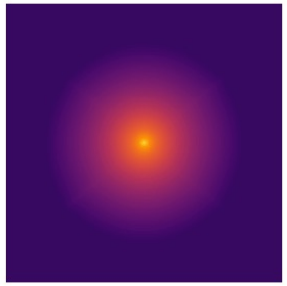
Integrated inputs

- Seeing / r_0
- C_n^2
- WFS(s) flux
- AO loop rate
- AO loop gain
- Wind speed
- Exp. time
- Tel. pointing
- Airmass
- Slopes RMS
- ...



Neural Network (NN) calibrator

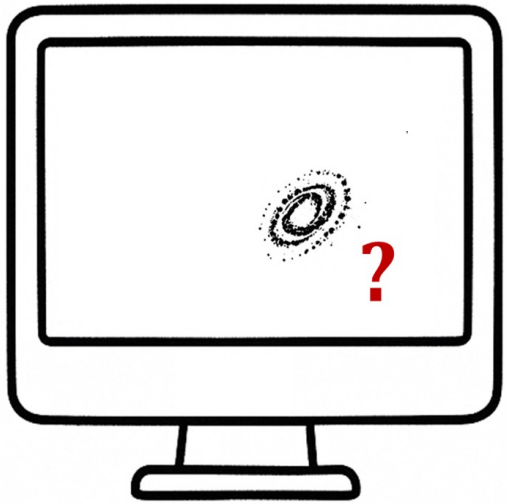
PSF model



Predicted PSFs

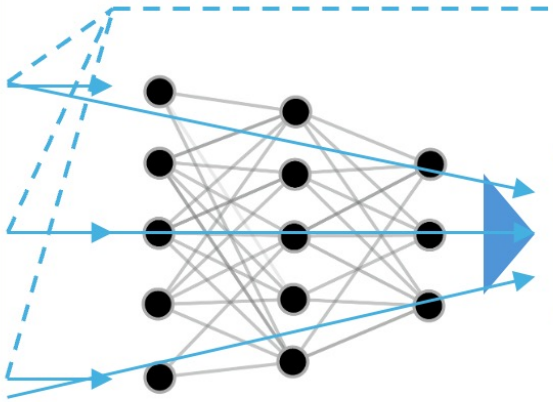
See Arseniy Kuznetsov PhD

PSF-Reconstruction



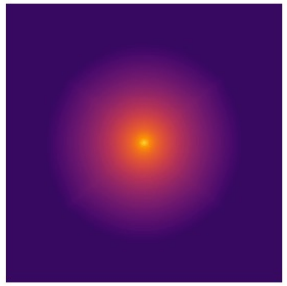
Integrated inputs

- Seeing / r_0
- C_n^2
- WFS(s) flux
- AO loop rate
- AO loop gain
- Wind speed
- Exp. time
- Tel. pointing
- Airmass
- Slopes RMS
- ...



Neural Network (NN) calibrator

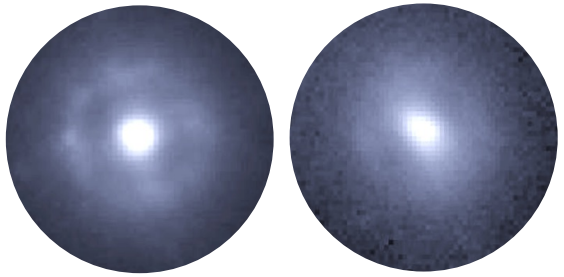
PSF model



Predicted PSFs

See Arseniy Kuznetsov PhD

PSF Archive



Fit PSFs with TipTop

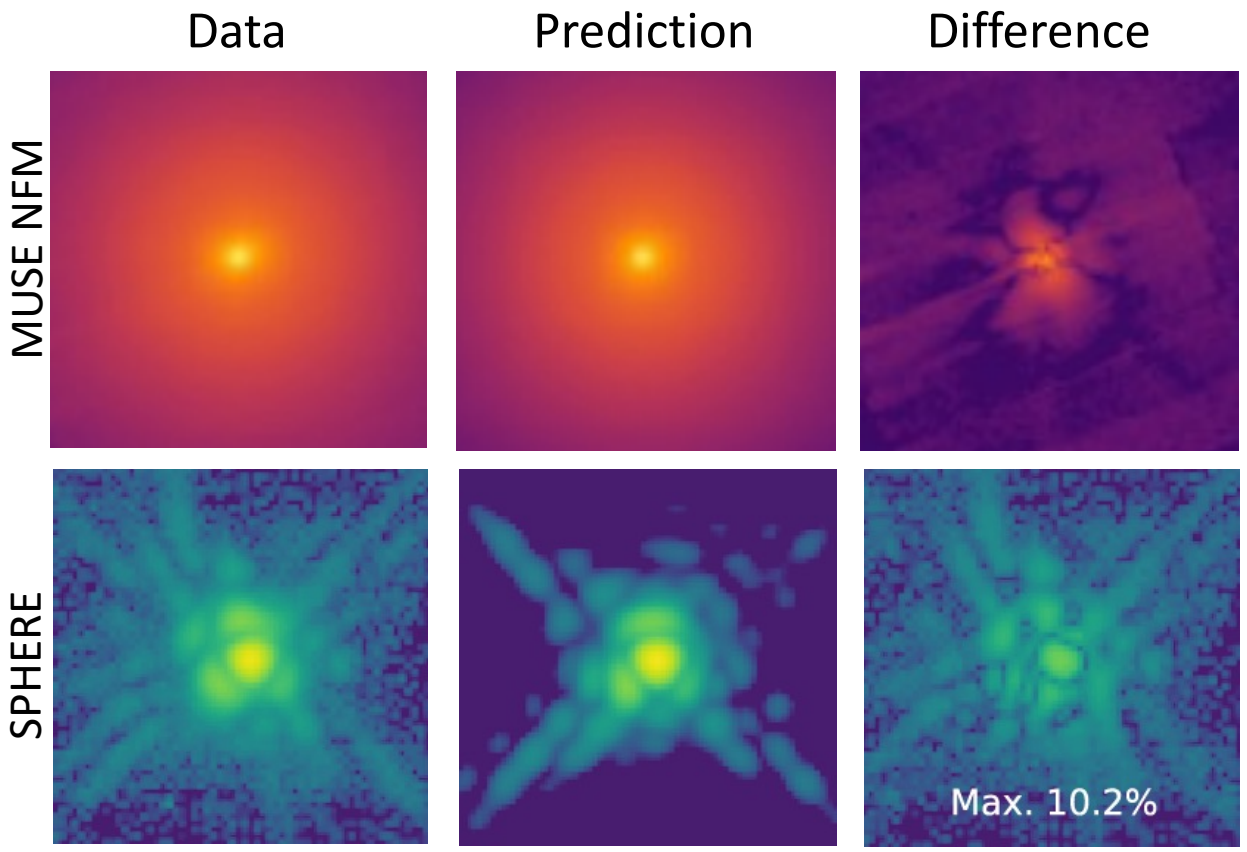
Cf. above

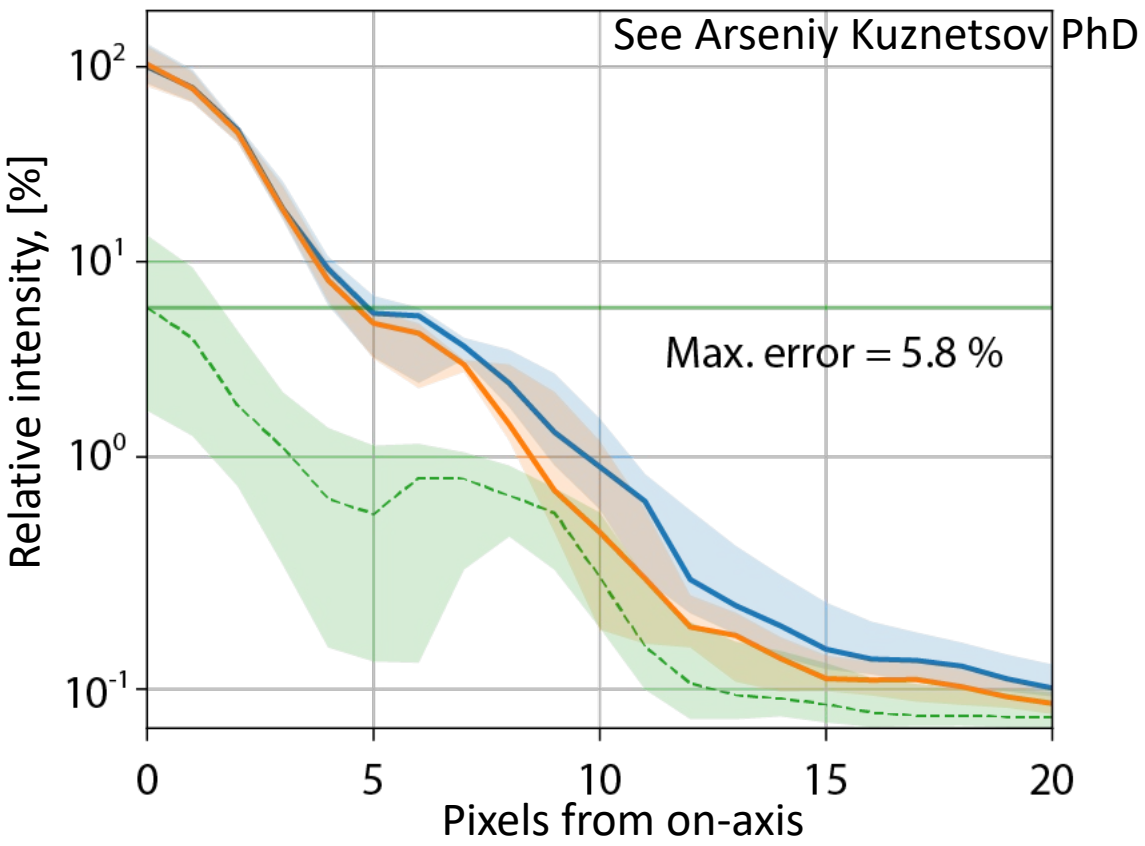
Get TipTop parameters

Use fit to "calibrate" TipTop inputs

Validate on Test sample

PSF-Reconstruction: MUSE-NFM, SPHERE

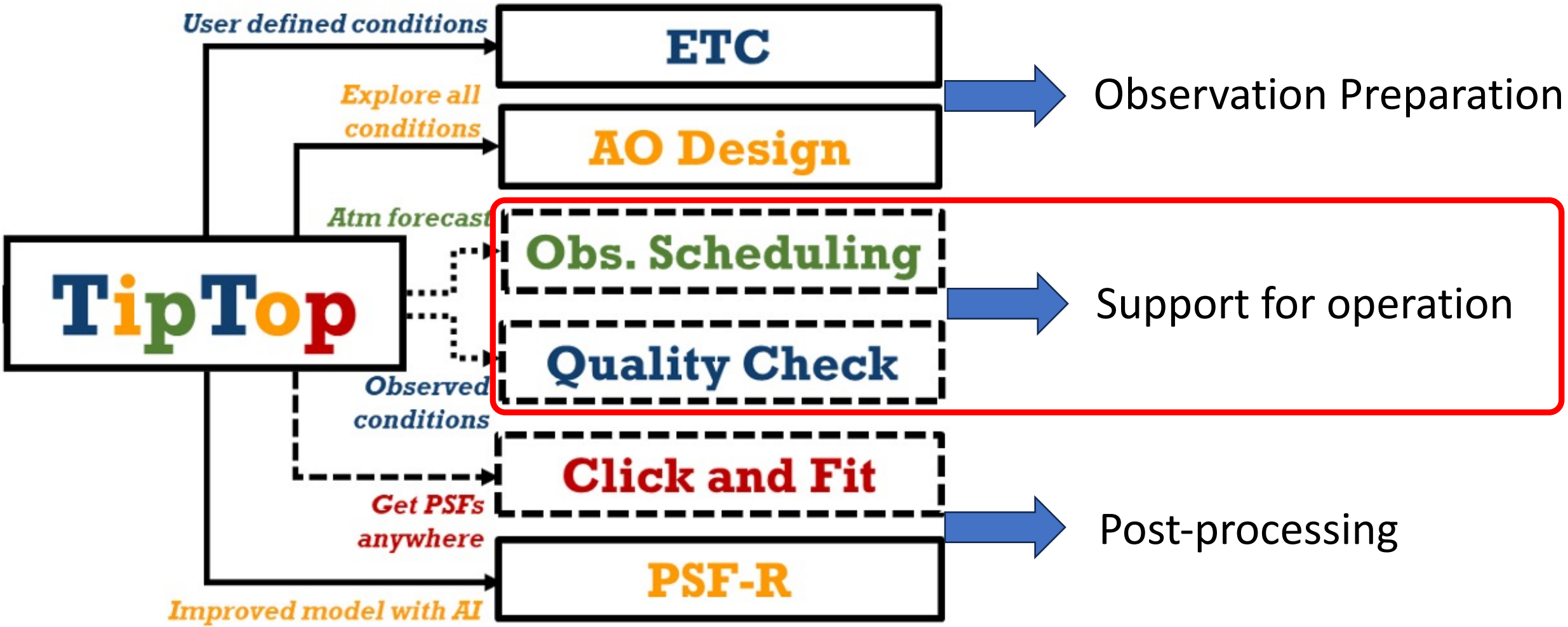




Feedback from SPHERE and MUSE-NFM so far:

- Works well ! Could reach 5% accuracy for very large sample of observations (>1000)
- Need enough (> few hundreds) **clean** data to get accurate results. Data Set must be PSF images + AO system parameters (first list available, but TB confirmed) + atmospheric parameters (first list available, but TB confirmed).
- Instrument configuration need to be stable (NCPA, vignetting, mis-alignements, …)
- Very specific effects can be accounted for, if data set is good: ex with LWE for SPHERE, and “sausage effect” for MUSE-NFM

What can TipTop be used for?



Queue scheduling / QC0-1

Bunch of external data (seeing, windspeed, Cn2, guide star fluxes, ...)

Empirical formulas

To be translated into

Instrument Performance

Queue scheduling / QC0-1

Bunch of external data (seeing, windspeed, Cn2, guide star fluxes, ...)

Empirical formulas

To be translated into

TIPTOP

Instrument Performance

Queue scheduling / QC0-1

Could be same scheme as PSF-R: once a model is calibrated, it could be used for queue planning /QC0-1

Bunch of external data (seeing, windspeed, Cn2, guide star fluxes, ...)

Empirical formulas

Pros: simple
Cons: less accurate & TBD

To be translated into

TIPTOP

Pros: accurate & does exists
Cons: maybe more prone to glitches

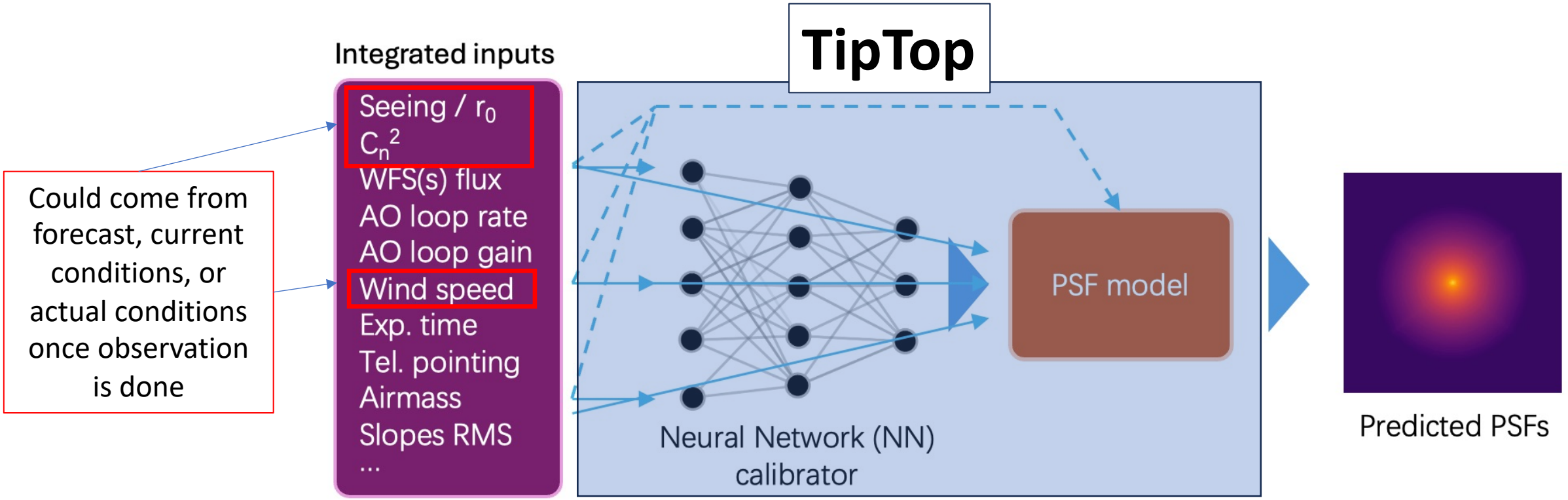
Instrument Performance

This can be replaced by a mix of:

- **Weather forecast** for queue planning
- **Current conditions** for OB execution
- **Observed conditions** for Quality Check / Diagnosis & PSF-R (level0)

Queue scheduling / QC0-1

Could be same scheme as PSF-R: once a model is calibrated, it could be used for queue planning /QC0-1



Conclusions

Plenty of opportunities to get TipTop everywhere !

How do we effectively work together ?
What should be the priorities ? P2, ObsPrep, ETC, Queue scheduling, QC0-1, PSF-R
How can we get more resources ? (best effort vs. industrial development)