Galapy: a fast API for modelling galaxy SEDs with Bayesian sampling

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Spoke 3 General Meeting, Elba 5-9 / 05, 2024

Scientific Rationale: Study Galaxies by Extracting (astro-)Physical Information from SED

Physical Emission Model

Spectral Energy Distribution (SED)

InfraRed

UltraViolet

→ **1 zettabyte** of data per year!

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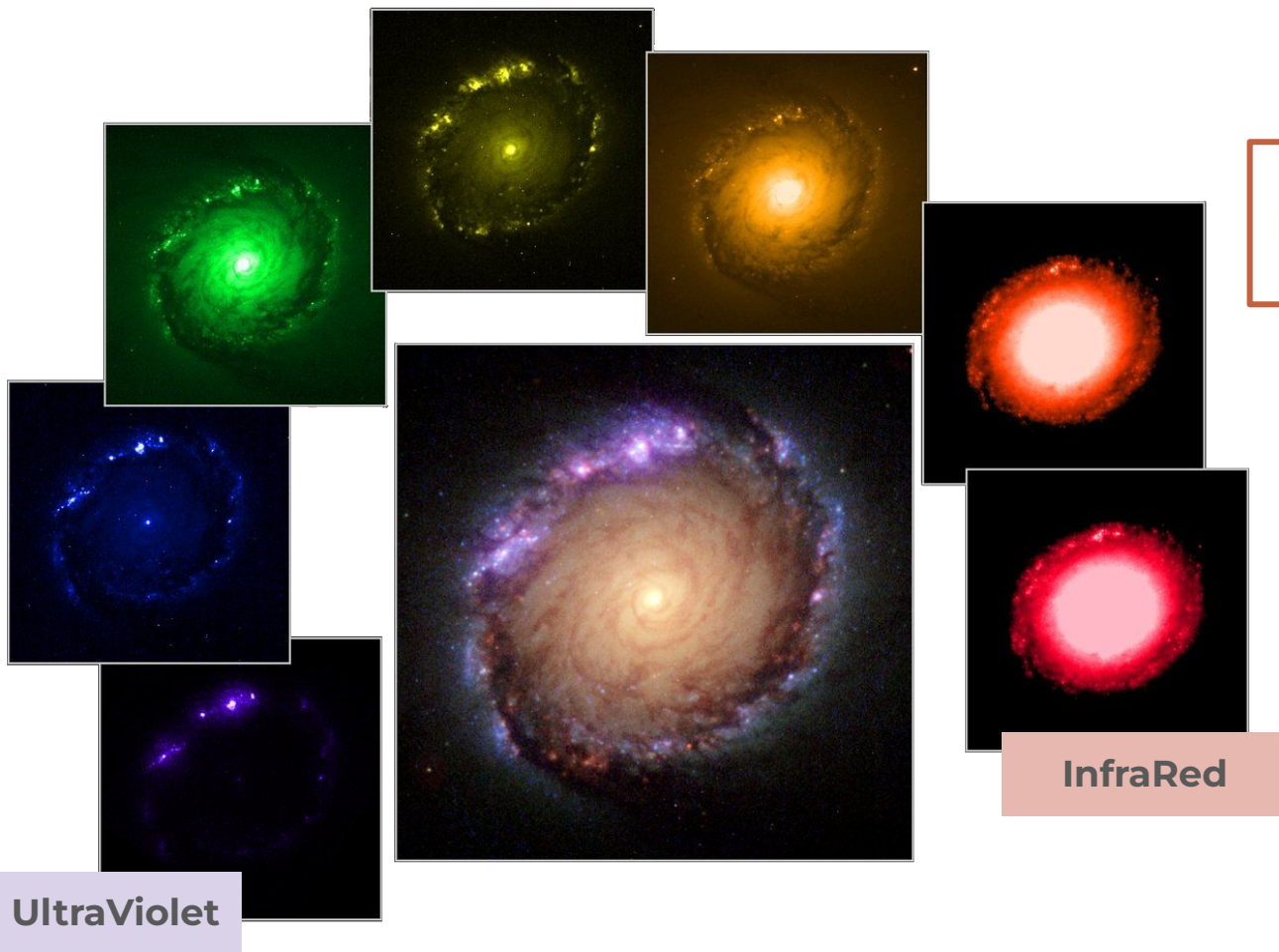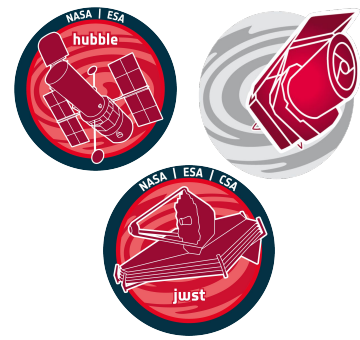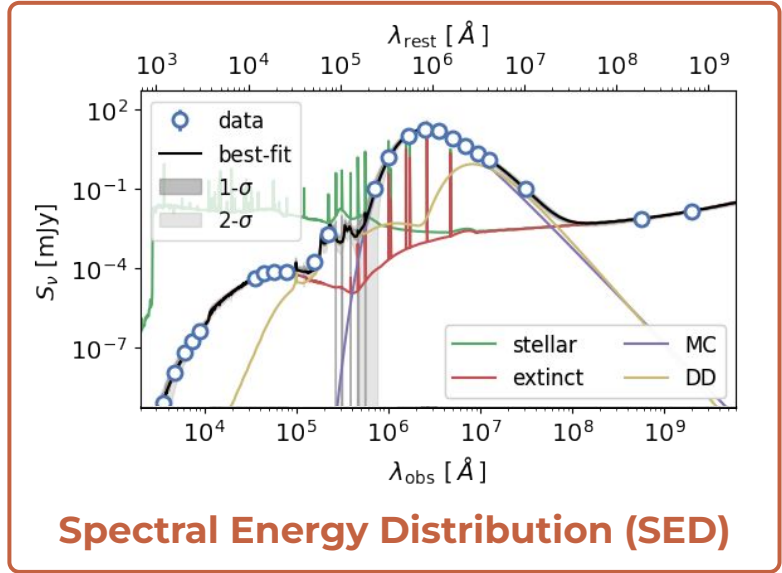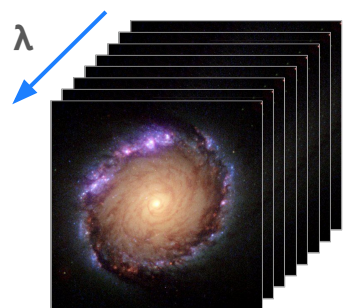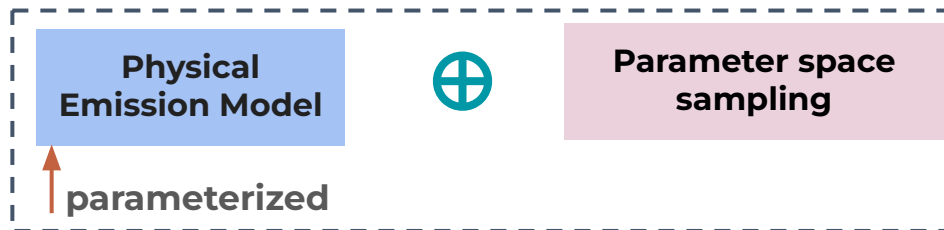
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Methods: SED Fitting 101 and desiderata

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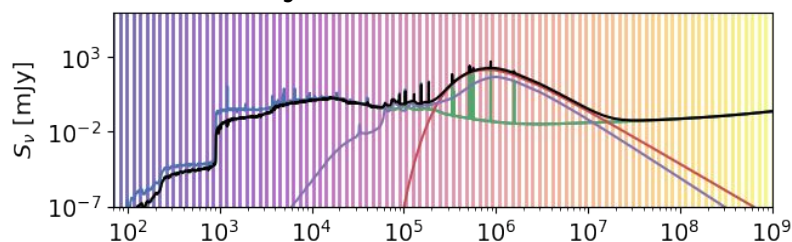| Spectrum Observation | ⊕ | Physical Emission Model | ⊕ | Parameter space sampling |

↑ **parameterized**

GalaPy

NOW **MCMC + Nested** sampling 1 source at a time (~10 minutes per source)

FUTURE (virtually) On-the-fly **posteriors** to handle up-coming data-fluxes from surveys
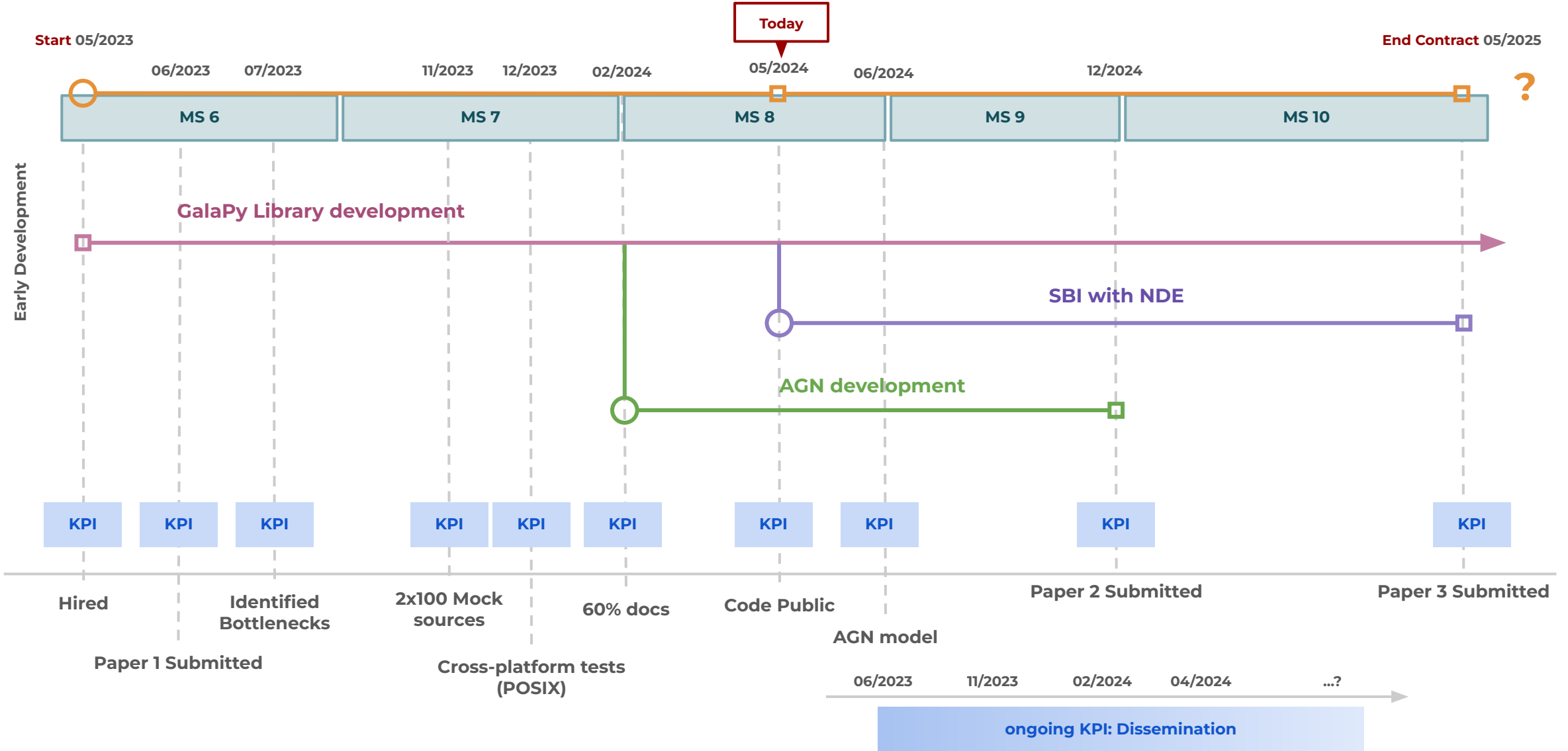
Main difficulty

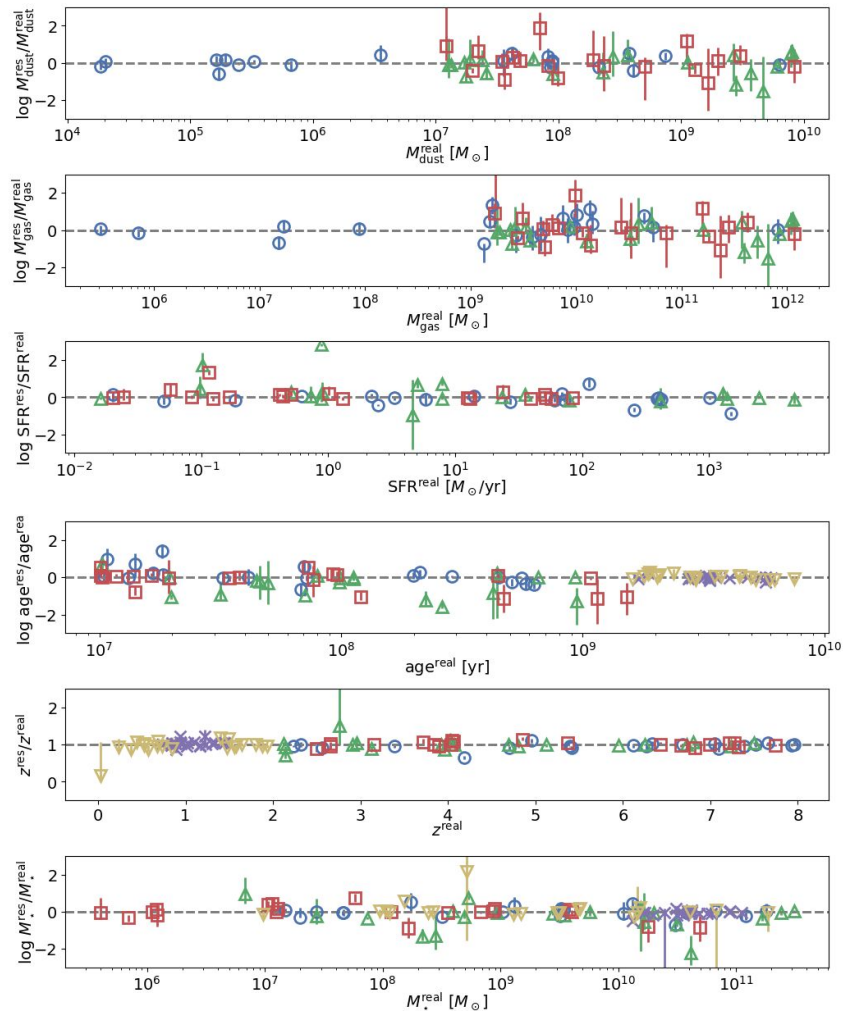**Ideally:**

Realistically:
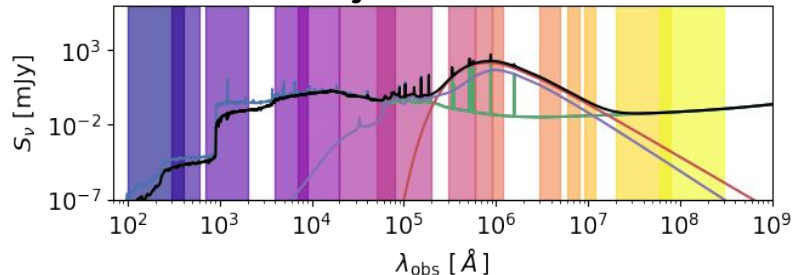
- **Optimisation strategies/parallelisation** Hybrid implementation approach: C++/Python currently investigating on parallelization strategies

- **Simulation Based Inference** with **Neural Density Estimators**
  - **SBI package** (Tejero-Cantero et al., 2020)
  - **PyDELFI** (Alsing et al., 2019)

Start 05/2023

Today

End Contract 05/2025

06/2023   07/2023   11/2023   12/2023   02/2024   05/2024   06/2024   12/2024

?

| MS 6 | MS 7 | MS 8 | MS 9 | MS 10 |

Early Development

GalaPy Library development

SBI with NDE

AGN development

| KPI | KPI | KPI | KPI | KPI | KPI | KPI | KPI | KPI | KPI |

Hired

Identified Bottlenecks

2x100 Mock sources

60% docs

Code Public

Paper 2 Submitted

Paper 3 Submitted

AGN model

Paper 1 Submitted

Cross-platform tests (POSIX)

06/2023   11/2023   02/2024   04/2024   ...?

ongoing KPI: Dissemination
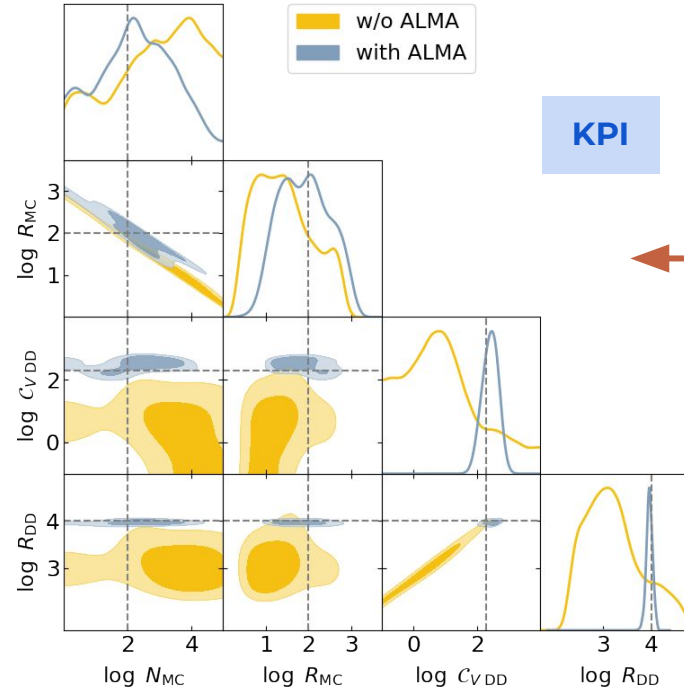
Accomplished Work:

➜ Extensive **VALIDATION** over all the parameter space

KPI

Sampling
- ○ mock sources (models/parameter space)
- ○ real sources (peculiar science cases)

w/o ALMA
with ALMA

KPI

Modelling
- ○ N-body simulated sources
- ○ forecasting constraining power

Accomplished Work:

➔ **We went PUBLIC**

KPI Extensive online docs (~80% coverage)

KPI **paper 1 accepted**
on A&A: 15 - Numerical methods and codes

KPI **cross platform** deployment

- Linux
- Unix
- Windows

galapy-fit 0.5.3

`pip install galapy-fit`

Bonus

KPI Interaction with the **community**

- **4 releases** from publication (bugs+features)
- Users growing in number

GalaPy

GalaPy: Spectral modelling tool for Galaxies in Python — View page source

GalaPy: Spectral modelling tool for Galaxies in Python

test passing build passing docs passing

GalaPy is an open source, extensible API for modelling and fitting the Spectral Energy Distribution (SED) of galaxies from the X-ray to the radio band, as well as the evolution of their components and dust attenuation/reradiation. It provides functions, classes and terminal commands for Bayesian inference of galaxy properties from panchromatic photometric data, as well as for the analysis and simulation of galaxies spectral properties.

GENERAL
Quickstart
Installation Guide
Physical Units (used in functions Input/Output)
Free Parameters of the Galaxy model

GUIDES
Fit a model to photometric data
Build and modify the parameter file
Results Analysis
Choose the Simple Stellar Population library

TUTORIALS
Load an ASCII catalogue
Build a galaxy model from an interpolated SFH
Modelling the different physical components

PYTHON DOCUMENTATION
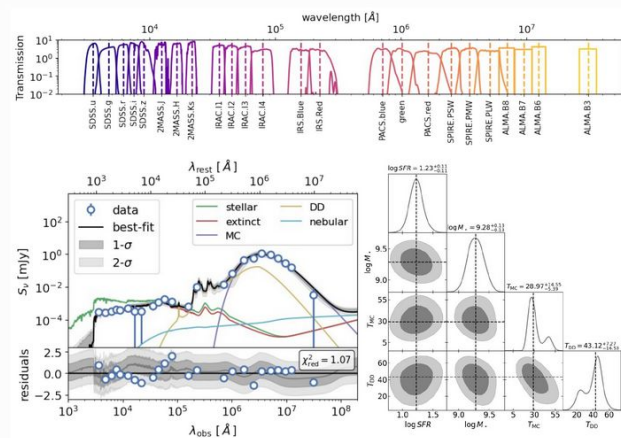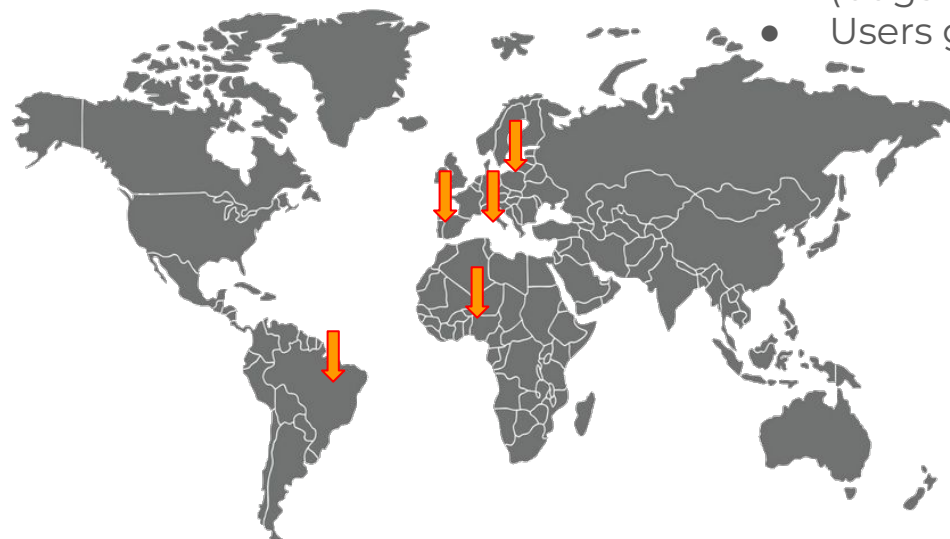GalaPy API Documentation

GalaPy provides an easy-to-use Python user interface while the number-crunching is done with compiled, high-performance, object-oriented C++.

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Next Steps and Expected Results

→ (~science) Implementation + validation + deployment
   Panchromatic Active Galactic Nucleus model

   ◆ theoretical parameterized **model ready**
   ◆ coding started

   NOTE: currently, no other parameter-space sampling
   SED-fitting code implements this in a consistent,
   non-templated approach along with the Star Formation
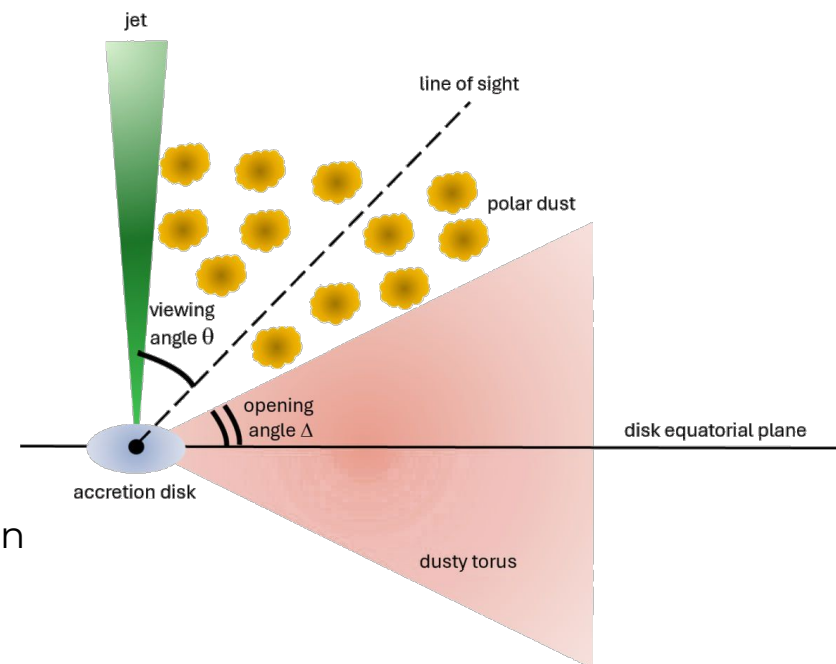
→ Simulation Based Inference with Neural Density Estimators (**SBI with NDE**)

   ◆ identified expertise (Dr.Pacilio @ UniMiB) and relevant codes (SBI + PyDELFI)
   ◆ started investigating on the main difficulties:
     ● construction of training sets
     ● Combining data from different experiments

   NOTE: it is an **enabling feature** besides being a development per-se:
   acceleration + differentiability