

DESTINY

A showcase for a FAIR data repository for stellar flyby simulations

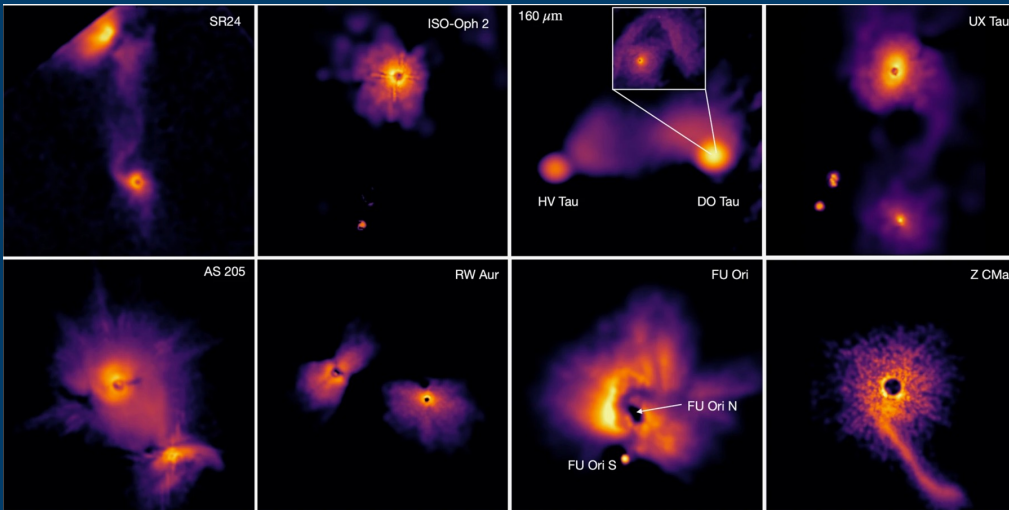
PUNCH4NFDI Annual Meeting 2024

Frank W. Wagner, Susanne Pfalzner, and Marco Bischoff

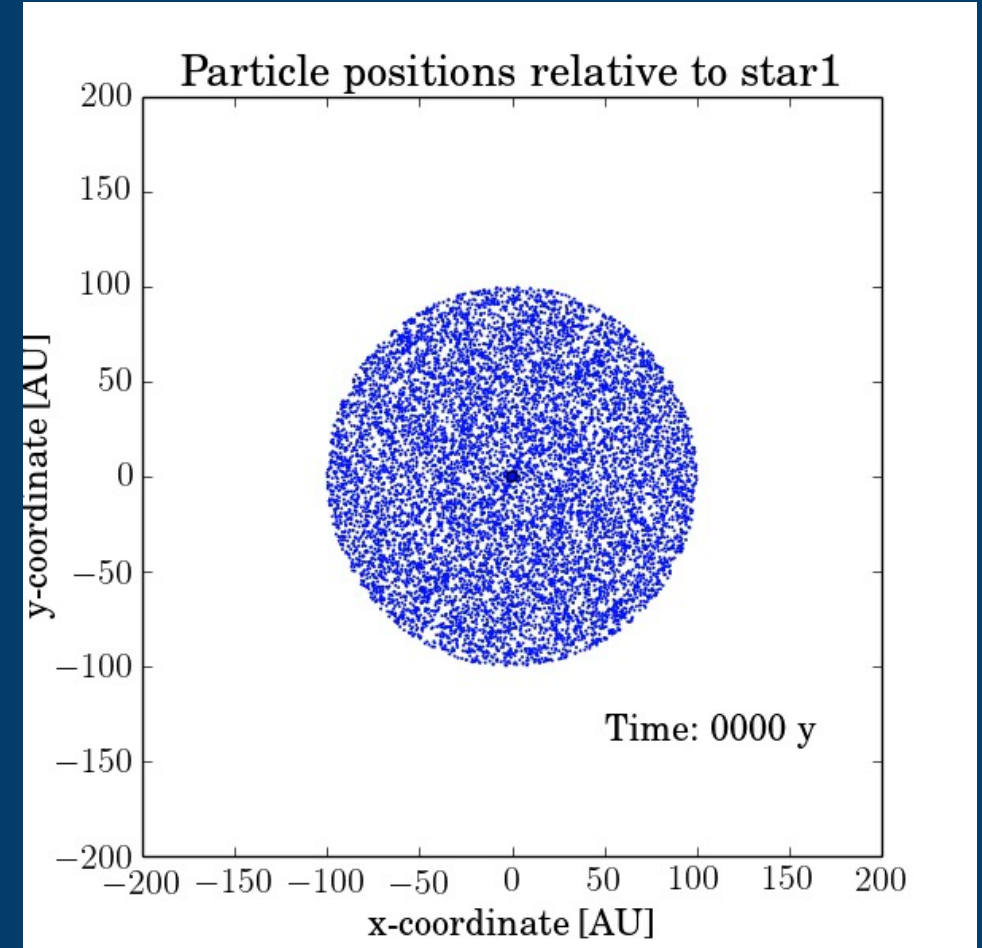
Jülich Supercomputing Centre, Forschungszentrum Jülich (FZJ), Jülich, Germany

WHAT ARE STELLAR FLYBYS?

- gravitational encounters between two stars, where one star passes close to another star, perturbing the orbits of the surrounding disk of minor bodies
- can be modelled using numerical N -body simulations
- observational evidence that stellar flybys do occur



Cuello, Menard, & Price: EPJP, 2023



Source: DESTINY.fz-juelich.de

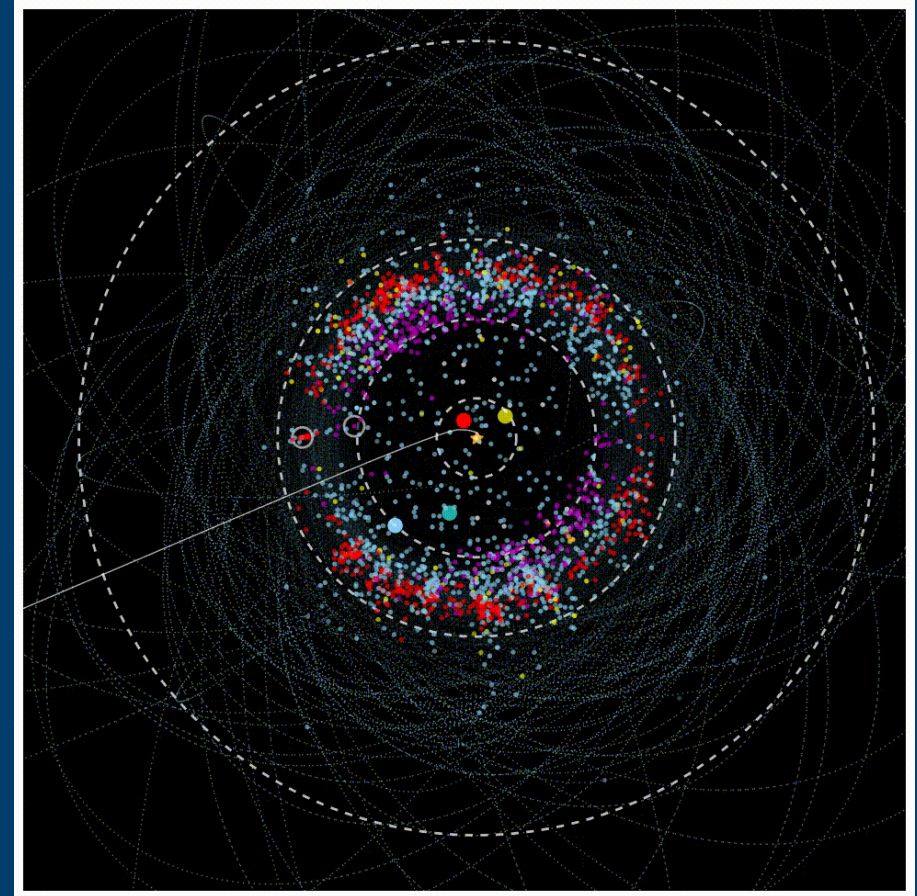
THE FLYBY THAT SHAPED THE SOLAR SYSTEM

- extensive parameter study:
- 6000 N -body simulations on supercomputers
- varying periastron distance, mass of perturber, inclination, and angle of periastron
- looking for the perfect match to observed TNO

Perturber mass: $0.8 M_{\text{sun}}$

Perihelion distance: 110 AU

Pfalzner, Govind, & Portegies Zwart: Nature Astronomy, 2024



Credit: W. Fraser, National Research Council of Canada

THIS SPECIFIC FLYBY PREDICTS ...



Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA

- More objects beyond 60 AU
- More high inclination objects
- More retrogrades
- Clustering in certain areas

Rubin Observatory, conducting sky surveys starting from August 2025, will provide almost immediate tests

Essential to preserve simulation data

SIMULATION DATA IN ASTROPHYSICS

Findable



Accessible



Large simulations collaborations sometimes fulfil these criteria already, but often you hear:

„I have to get my paper out, not my data for others to scoop me.“

Interoperable



Reusable



„Are they even serious, should I publish PBs of data?“

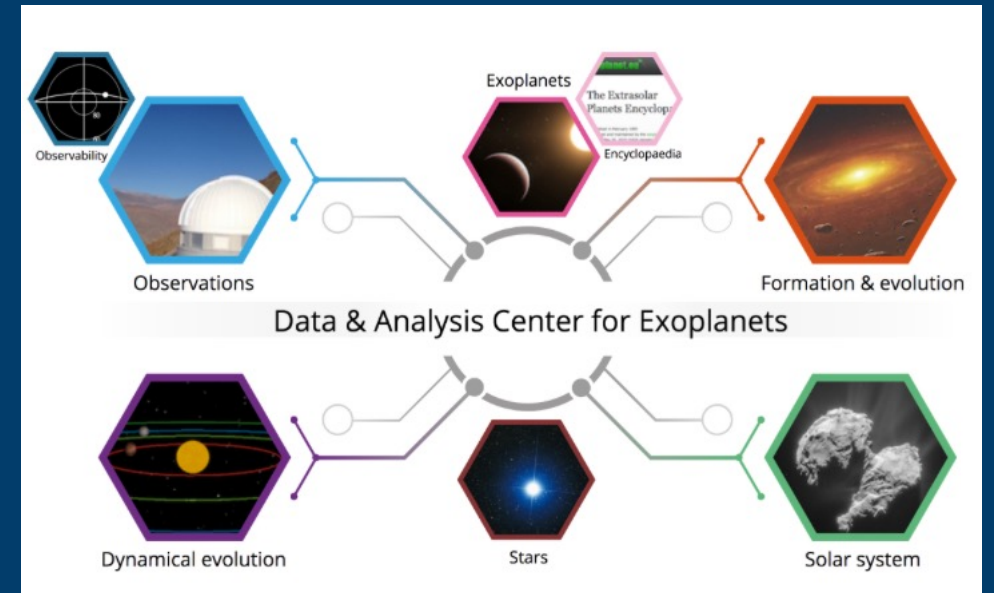
Wilkinson et al. (2016) – Scientific Data 3, 160018

„I have no time for this nonsense, I need to work.“

Current situation; a few lighthouse projects

The logo for Zenodo, featuring the word "zenodo" in a white, lowercase, sans-serif font on a blue background.

zenodo.org



dace.unige.ch

The IllustrisTNG Project

The next generation of cosmological hydrodynamical simulations.

www.tng-project.org

DESTINY


Database for the effects of stellar encounters on disks and planetary systems

<https://results.punch4nfdi.de>

- open-data initiative for astrophysical N -body simulations of stellar flybys

DESTINY ...

- contains about 6000 simulations
- covers a wide parameter space
- provides visualisation tools for data analysis



DESTINY

DESTINY (Database for the Effects of STellar encounters on disks and plaNetary sYstems) is an open-access data portal that provides resources for...

URL <https://destiny.fz-juelich.de/>

Access Open

Tags Planetary system dynamics, Astrophysics, Astronomy, Database

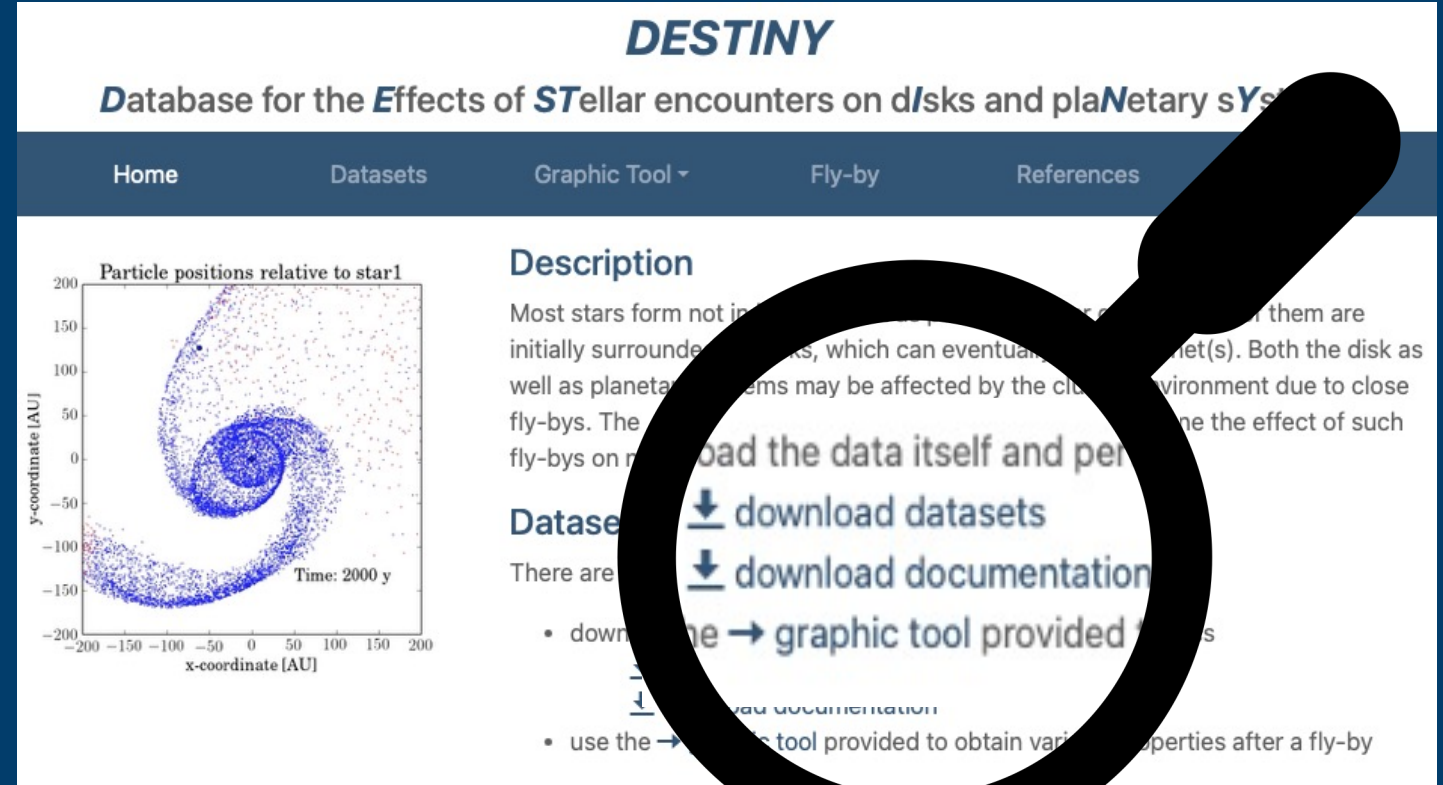
Simulation Codes

JÜLICH Forschungszentrum lrz Leibniz-Rechenzentrum der Europäischen Akademie der Wissenschaften

Result data

- raw simulation data available for download
- HDF5 hierarchical data format
- thoroughly documented
- tools for plot generation available

<https://destiny.fz-juelich.de/datasets>



The screenshot displays the DESTINY website interface. At the top, the title "DESTINY" is followed by the subtitle "Database for the Effects of STellar encounters on dIsks and plaNetary sYstems". A navigation bar includes links for Home, Datasets, Graphic Tool, Fly-by, and References. On the left, a plot titled "Particle positions relative to star1" shows a spiral distribution of points in a 2D coordinate system (x and y in AU) at "Time: 2000 y". On the right, the "Description" section explains that most stars form in disks and can be affected by close fly-bys. A large magnifying glass is positioned over the "Datasets" section, highlighting the links "download datasets" and "download documentation". Below these, a list of actions includes "download the data itself and perform analysis" and "use the graphic tool provided to obtain various properties after a fly-by".

DESTINY
Database for the **E**ffects of **S**Tellar encounters on **d**Isks and **pl**a**N**etary **s**Ystems

Home Datasets Graphic Tool Fly-by References

Description
Most stars form not in isolation, but in the environment of a molecular cloud. They are initially surrounded by disks, which can eventually form planets. Both the disk as well as planetary systems may be affected by the close environment due to close fly-bys. The effect of such fly-bys on the system can be studied by using the data itself and performing analysis.

Datasets
There are two main ways to access the data:

- download the data itself and perform analysis
- use the graphic tool provided to obtain various properties after a fly-by

[download datasets](#)
[download documentation](#)

Visualisation and analysis

<https://destiny.fz-juelich.de/plot-finestudy>

Model Parameters

Mass ratio

(perturber mass / host mass)

0.5

Angle of periastron

(degrees)

70

Orbital inclination

(degrees)

55

Periastron distance

(au)

100

Disk size

(au)

150

Plot Settings

Property X-Axis

semimajoraxis

☒ Logarithmic

Property Y-Axis

eccentricity

☐ Logarithmic

Property Color-Axis

inclination

☐ Logarithmic

Limits X-Axis

(leave empty for auto)

min

- max

✕

Limits Y-Axis

(leave empty for auto)

min

- max

✕

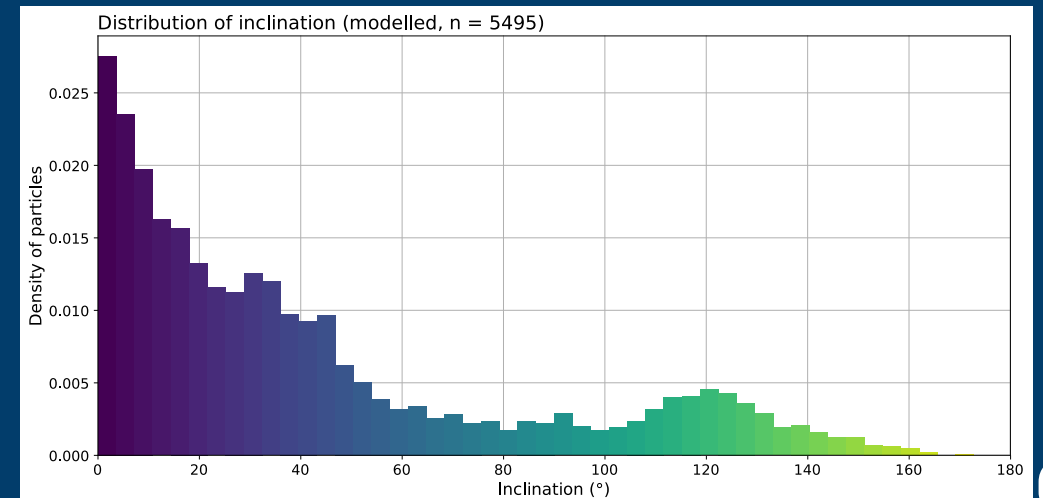
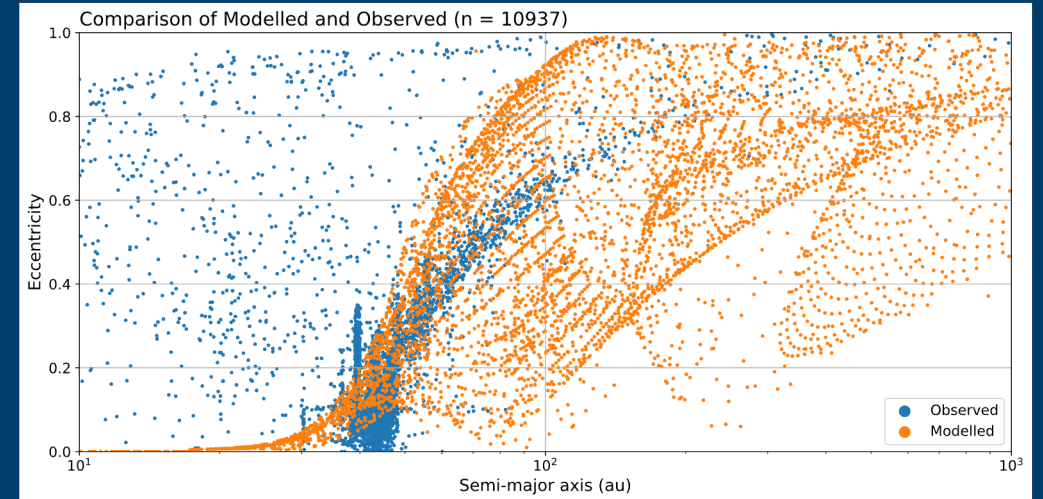
Limits Color-Axis

(leave empty for auto)

min

- max

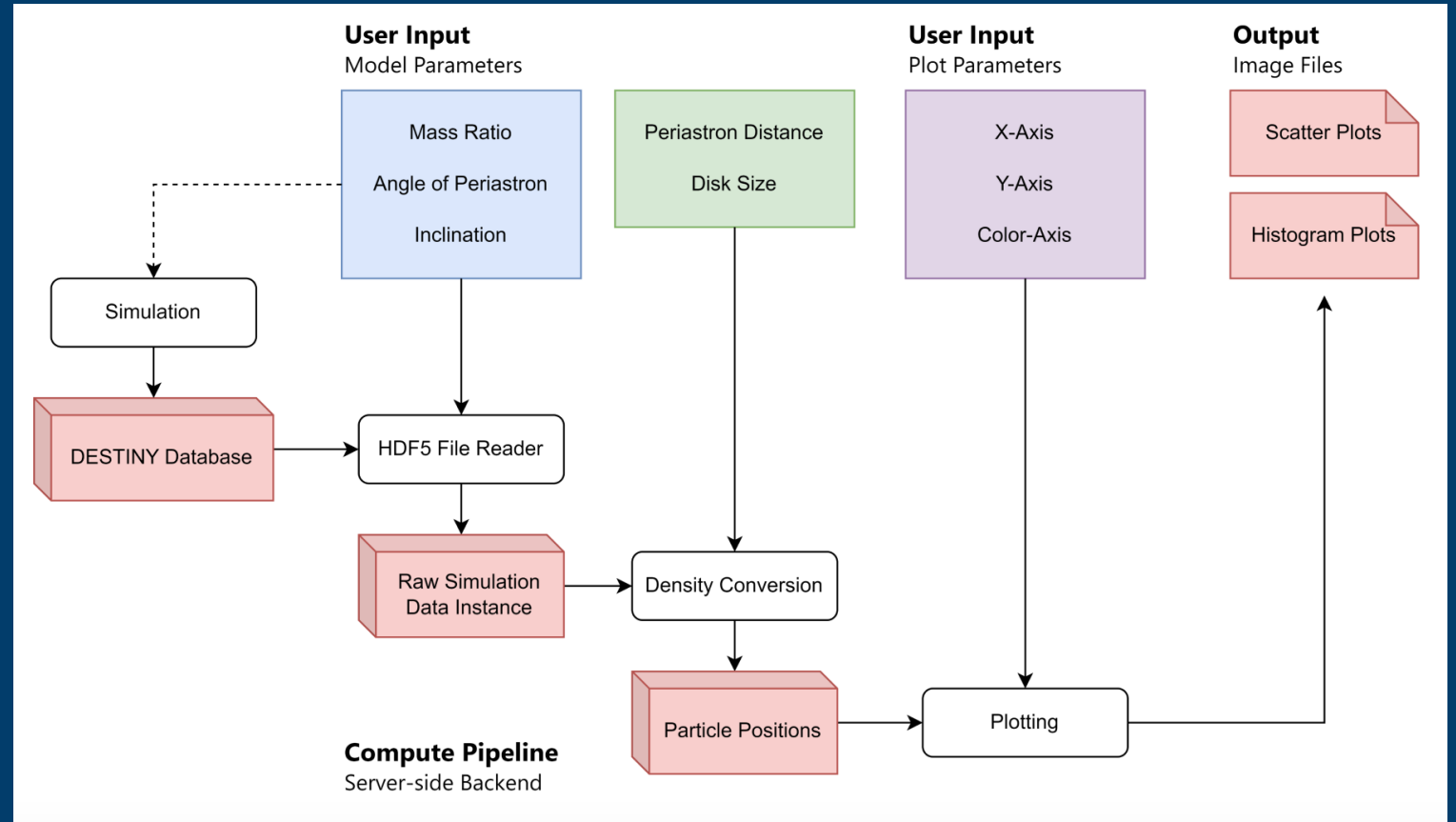
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DESTINY

Database for the effects of stellar encounters on disks and planetary systems

- Flask-based frontend
- Pandas for data processing
- Matplotlib for data visualisation
- student project



Credit: M. Bischoff

SUMMARY AND OUTLOOK

- **DESTINY: a FAIR data repository for stellar flyby simulations**
- **Doable, even for small teams**

To do:

- **Publish source code of N -body integrator**
- **Persistent identifier (PID) for shared datasets**
- **Integration of further databases**



THANK YOU FOR LISTENING