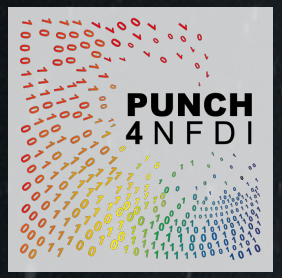

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Funded by
DFG Deutsche Forschungsgemeinschaft
German Research Foundation

DESTINY

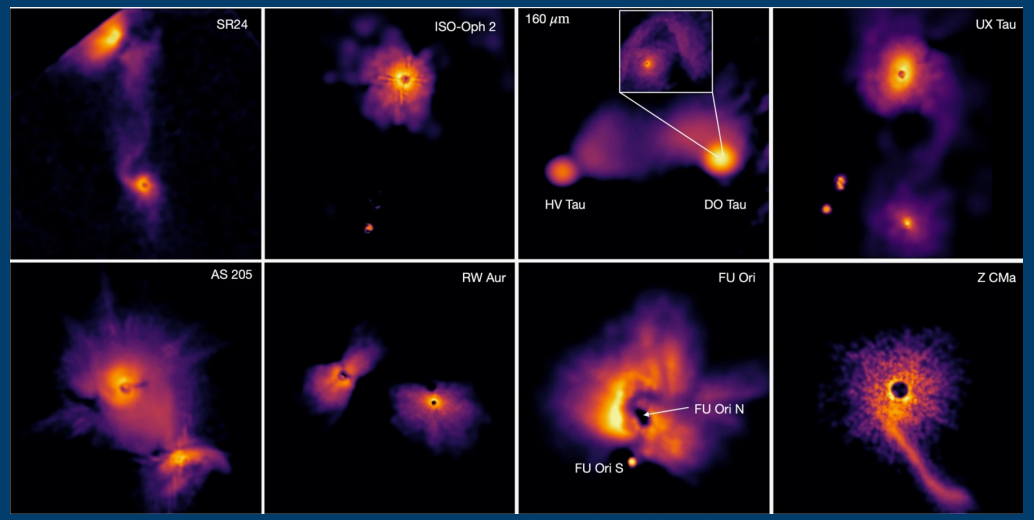
A showcase for a FAIR data repository for stellar flyby simulations

PUNCH4NFDI Annual Meeting 2024

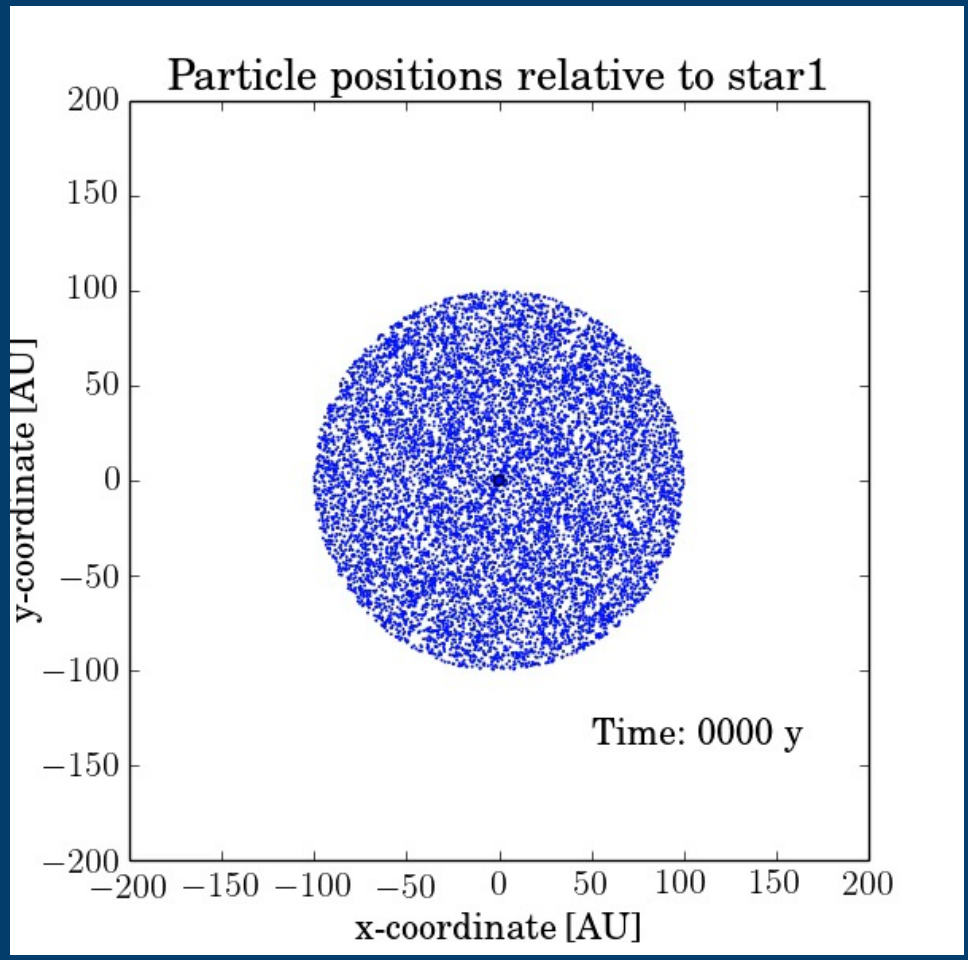
Frank W. Wagner, Susanne Pfalzner, and Marco Bischoff
Jülich Supercomputing Centre, Forschungszentrum Jülich (FZJ), Jülich, Germany

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

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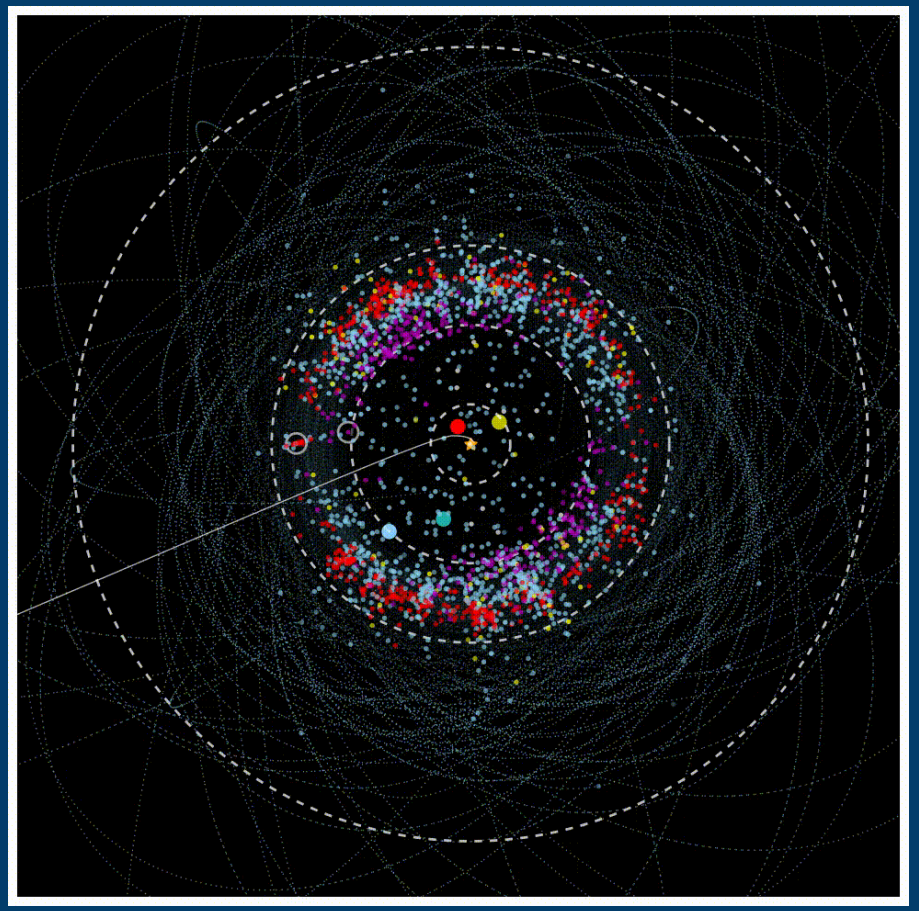
THE FLYBY THAT SHAPED THE SOLAR SYSTEM

- **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**

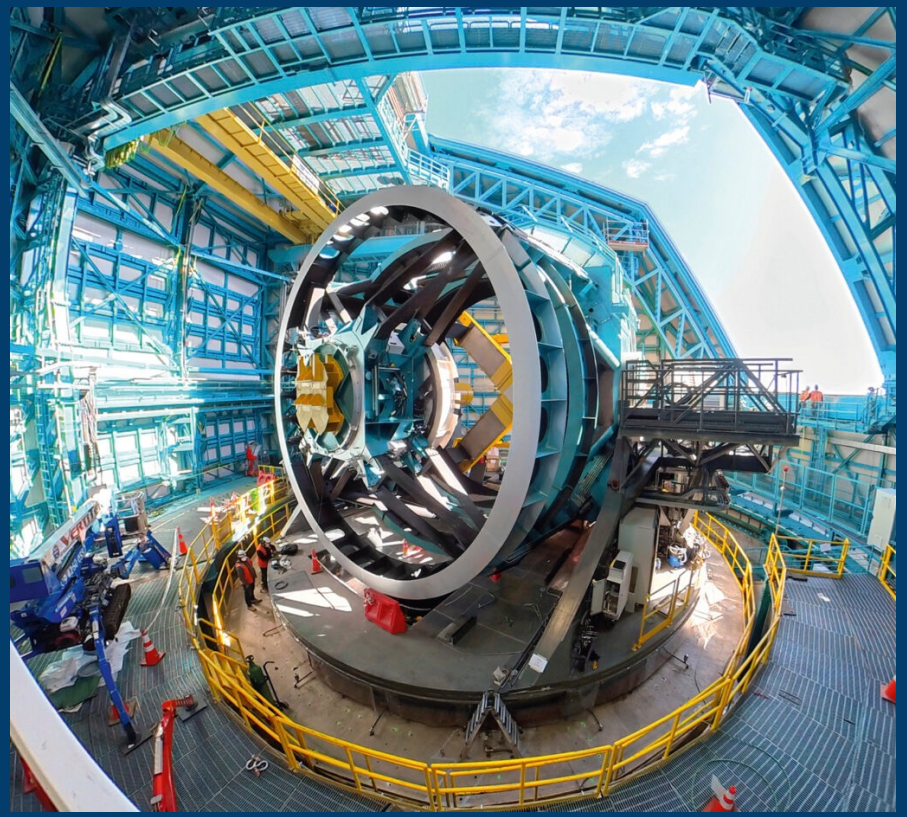
Perturber mass: 0.8 M_{sun}
Perihelion distance: 110 AU

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

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

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.“

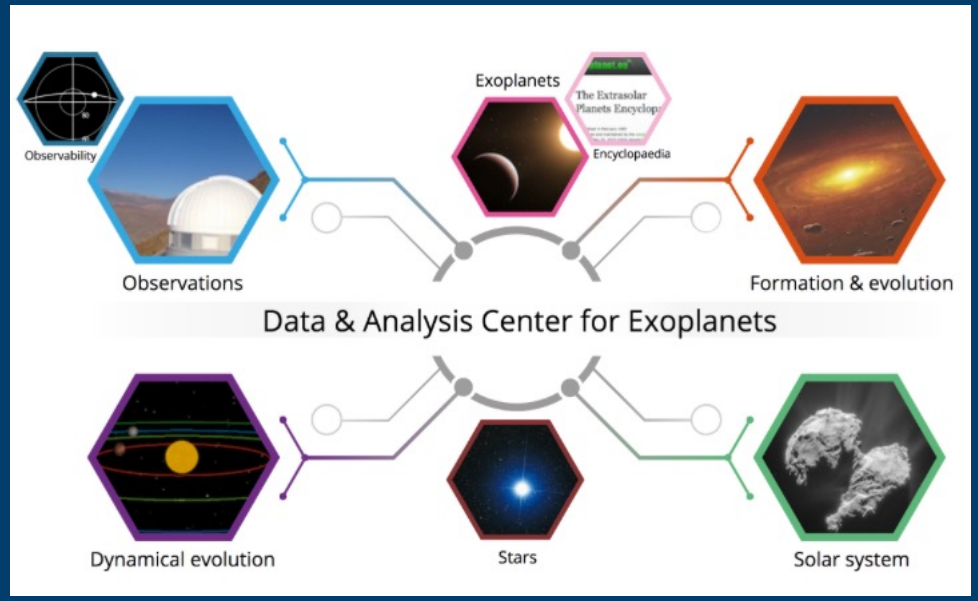
„Are they even serious, should I publish PBs of data?“

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

Current situation; a few lighthouse projects

zenodo

zenodo.org



dace.unige.ch

DESTINY

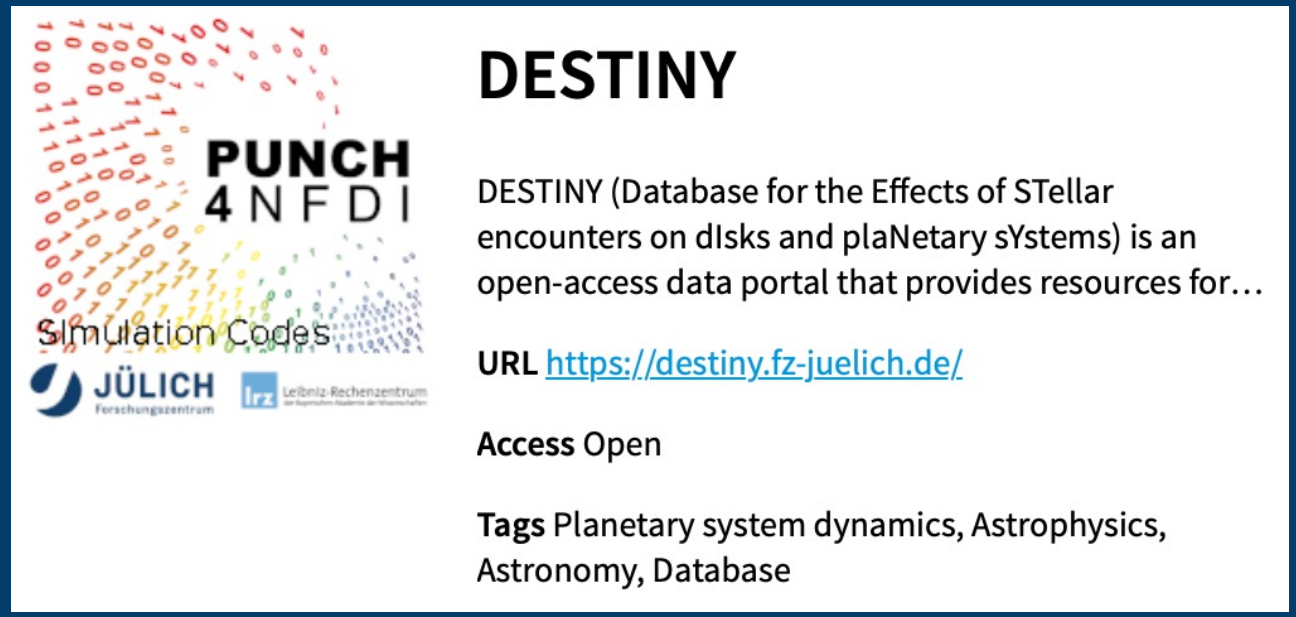
Database for the effects of stellar encounters on disks and planetary systems

https://results.punch4nfdi.de

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

DESTINY …

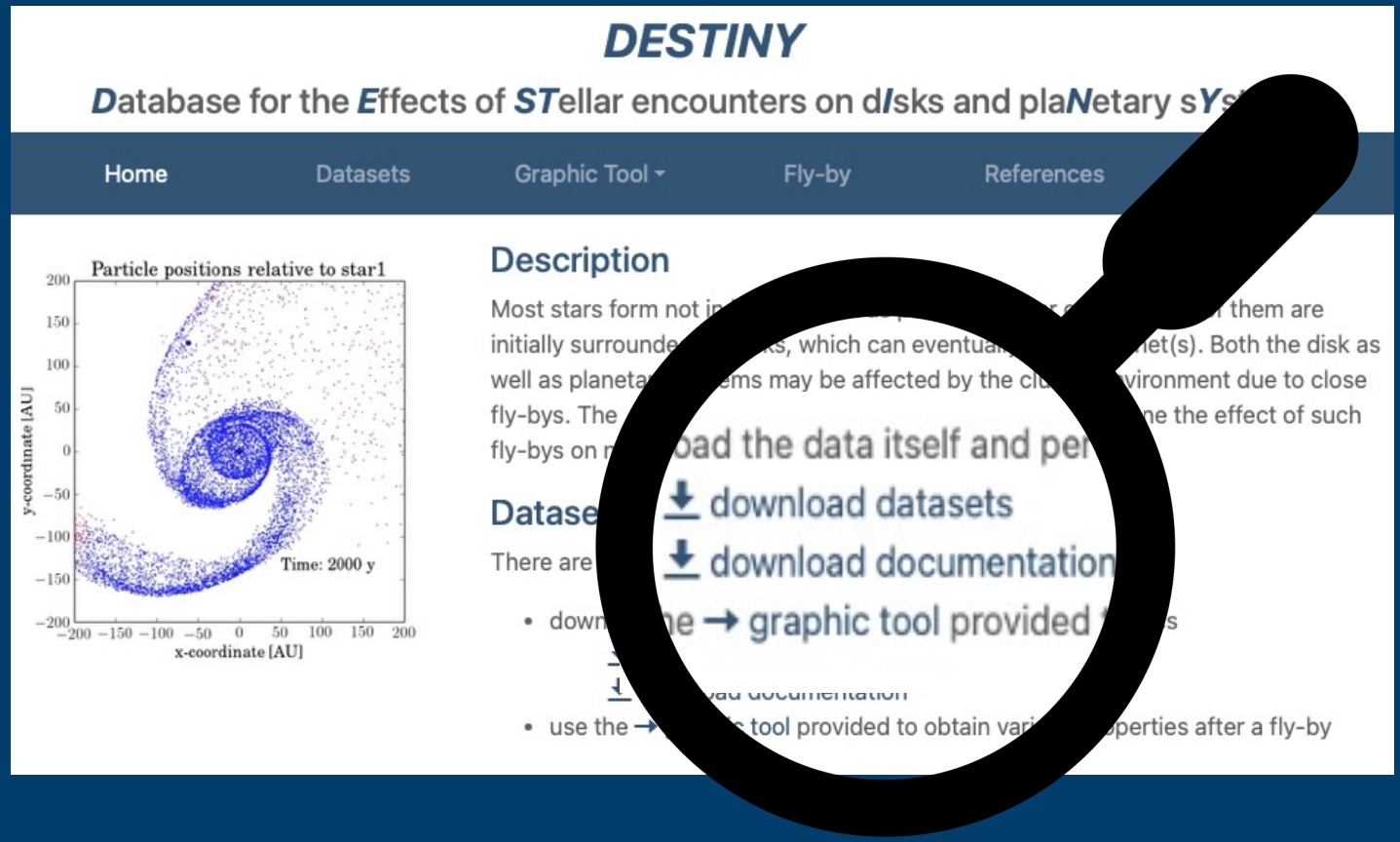
- **contains about 6000 simulations**
- **covers a wide parameter space**
- **provides visualisation tools for data analysis**



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



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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

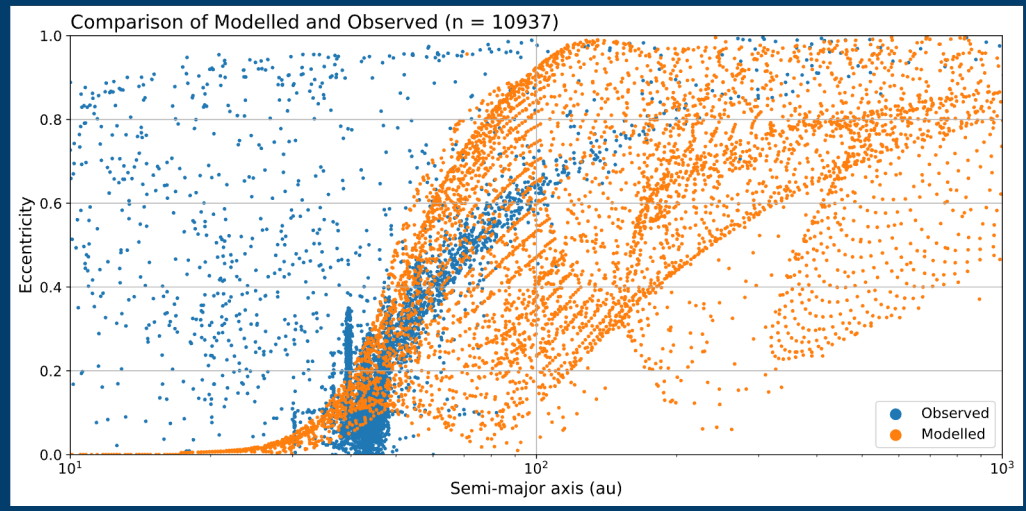
Property Y-Axis: eccentricity — Logarithmic

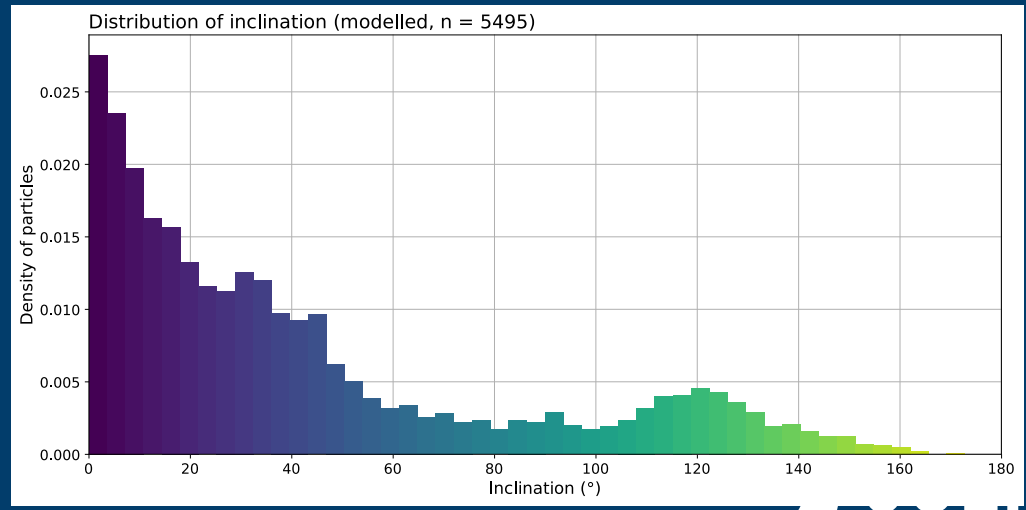
Property Color-Axis: inclination — Logarithmic

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

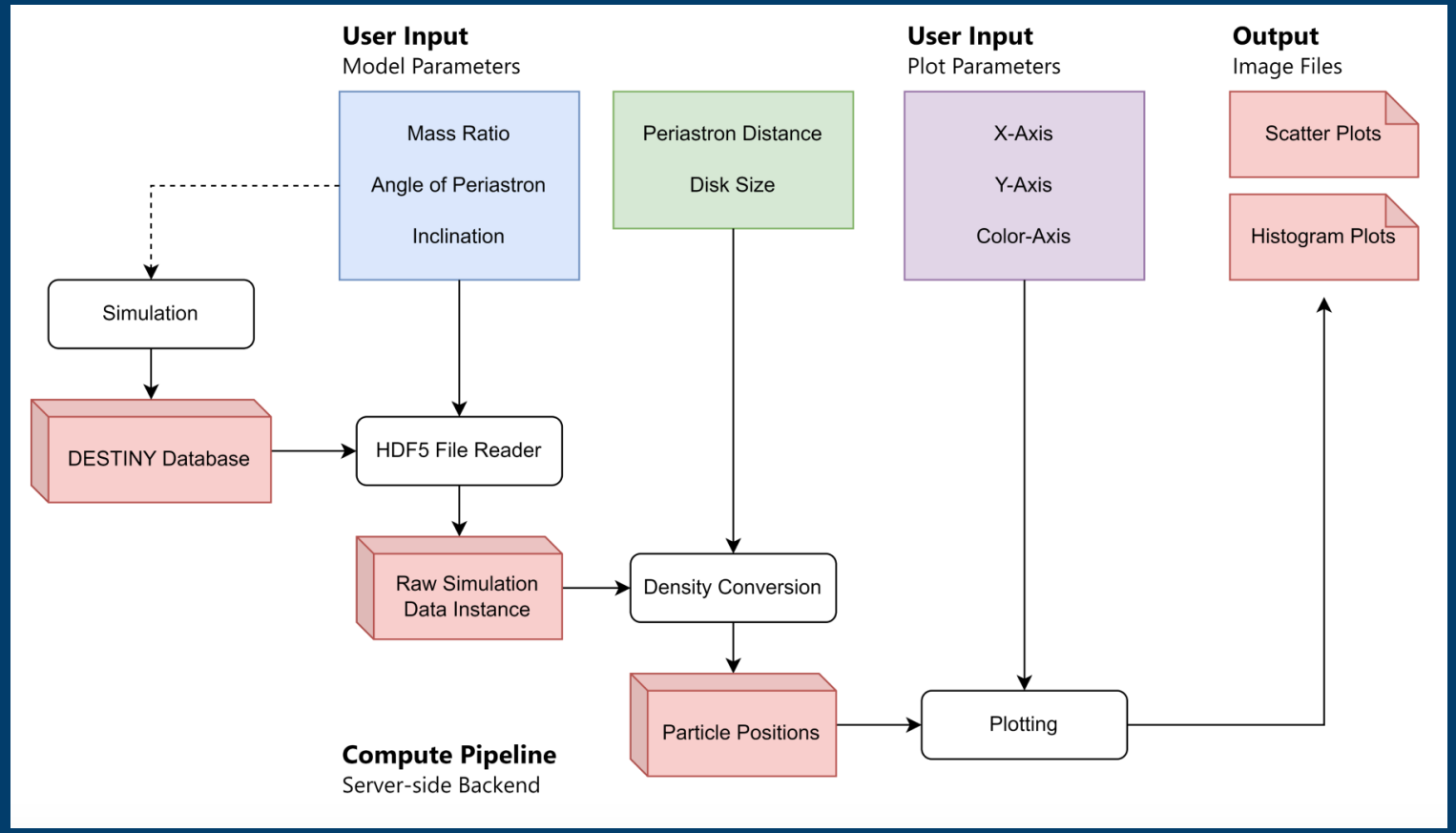




DESTINY

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

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