
The 11th International Conference on
Fuzzy Systems and Data Mining
(FSDM 2025)
Nov. 14-17, 2025
(Chaozhou, Guangdong, China)

FSDM
4681

# Visual Mining of Astrometric Solution: Let Numerics Meet Art in Astrometric Data Analysis

Presented by: **Konstantin Ryabinin**, Wolfgang Löffler, Michael Biermann

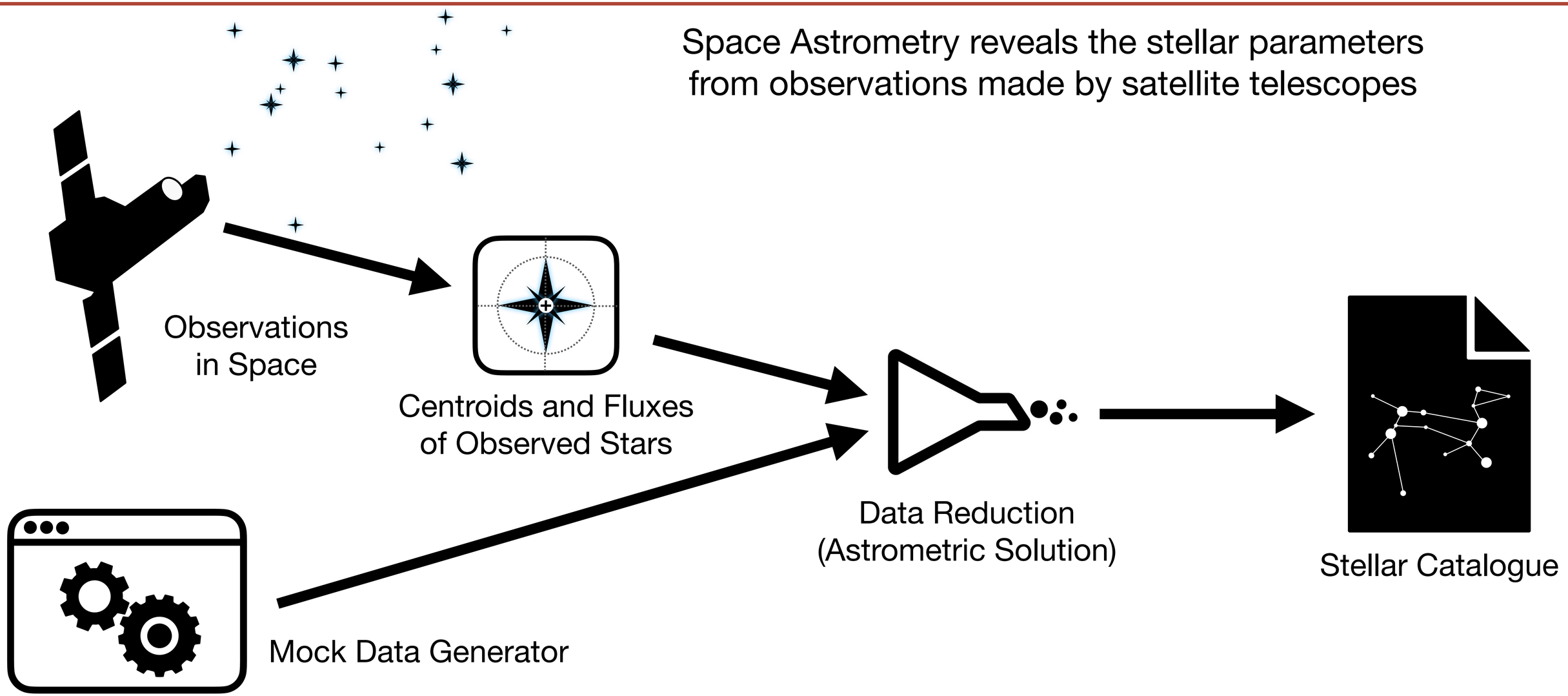
Affiliation: Astronomisches Rechen-Institut, Center for Astronomy of Heidelberg University

ZENTRUM FÜR ASTRONOMIE

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

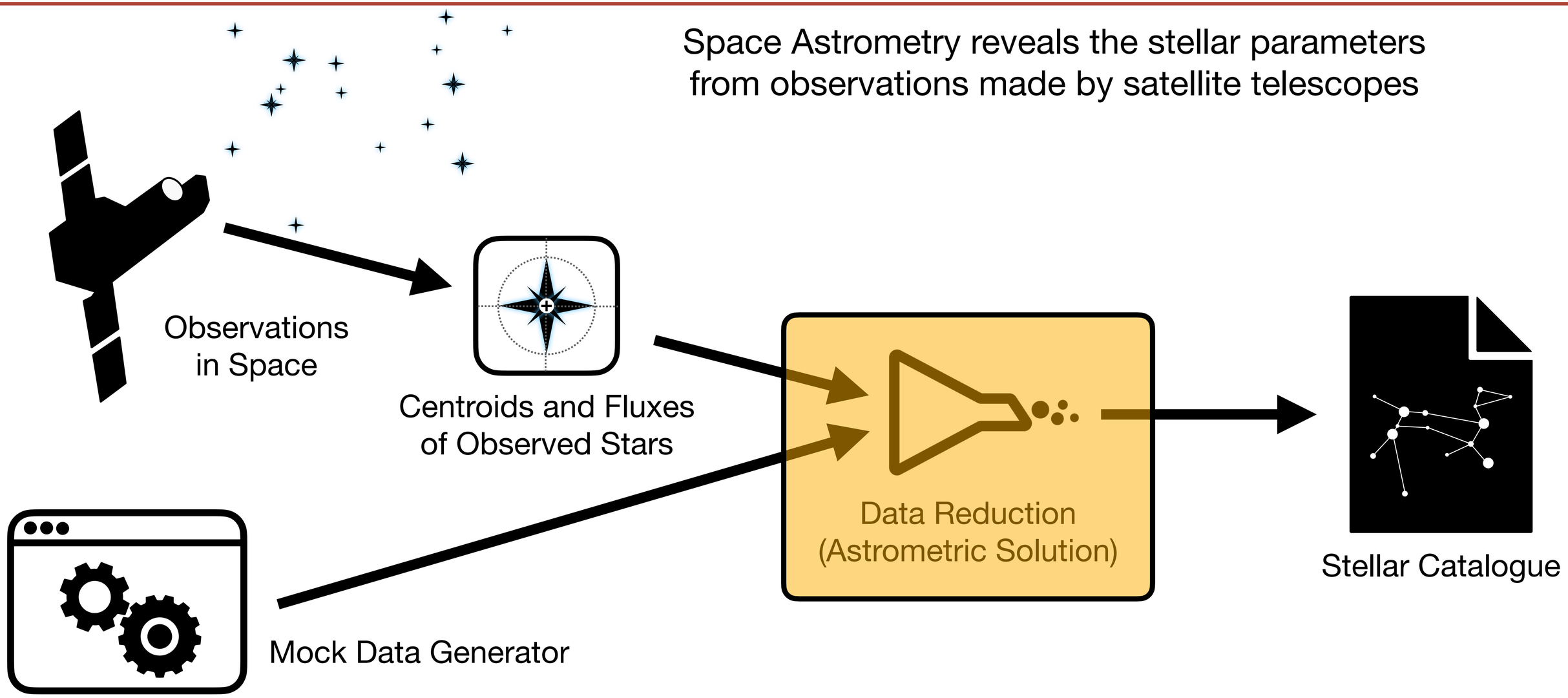
# Space Astrometry and Big Data

Space Astrometry reveals the stellar parameters from observations made by satellite telescopes



# Space Astrometry and Big Data

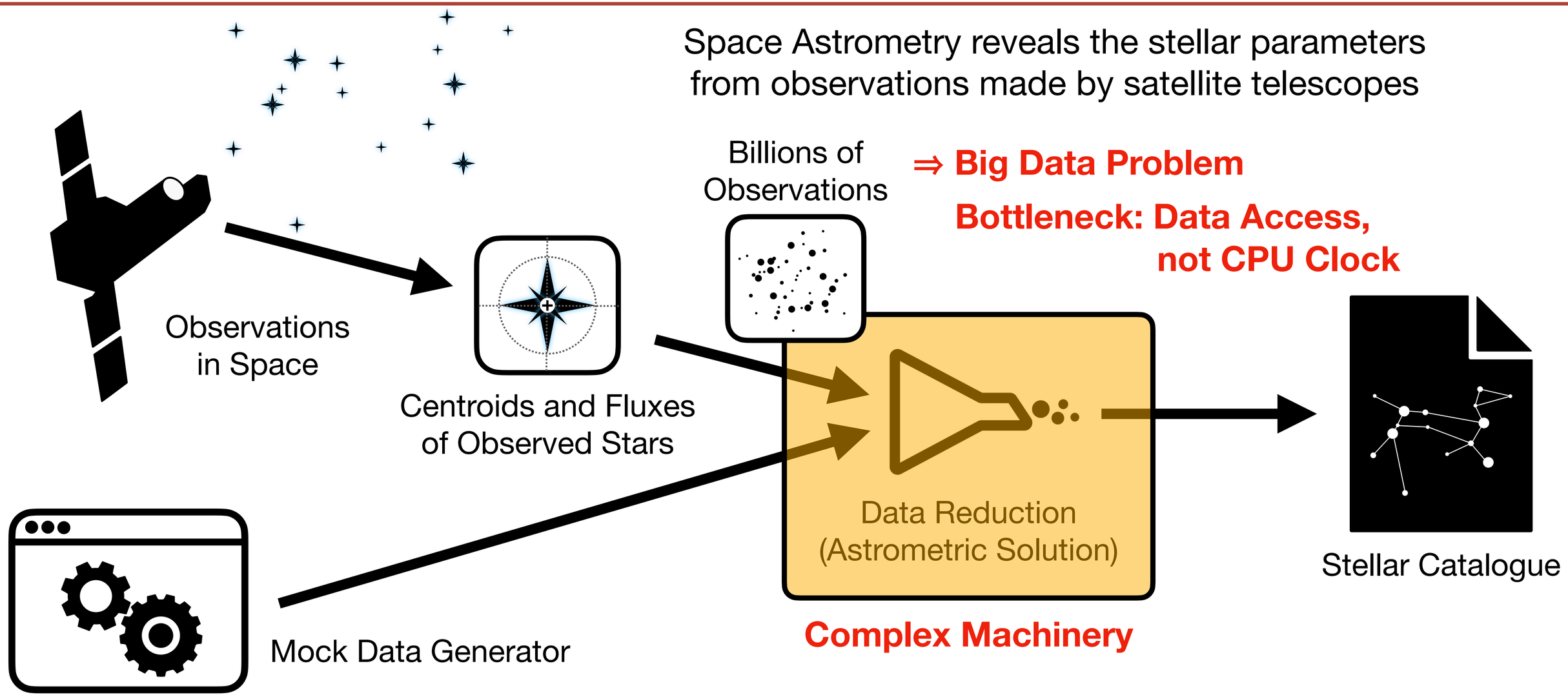
Space Astrometry reveals the stellar parameters from observations made by satellite telescopes



# Space Astrometry and Big Data



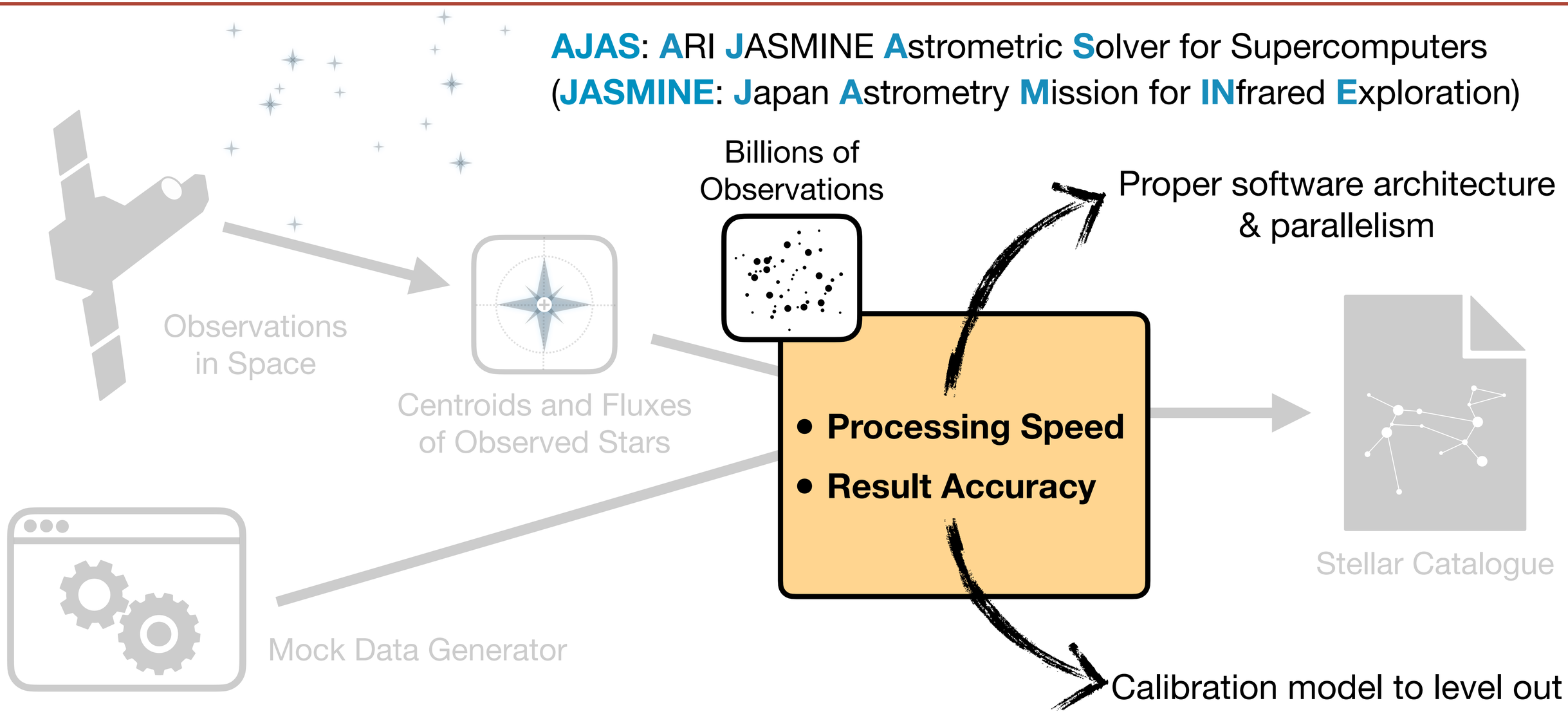
Space Astrometry reveals the stellar parameters from observations made by satellite telescopes



# Previous Work



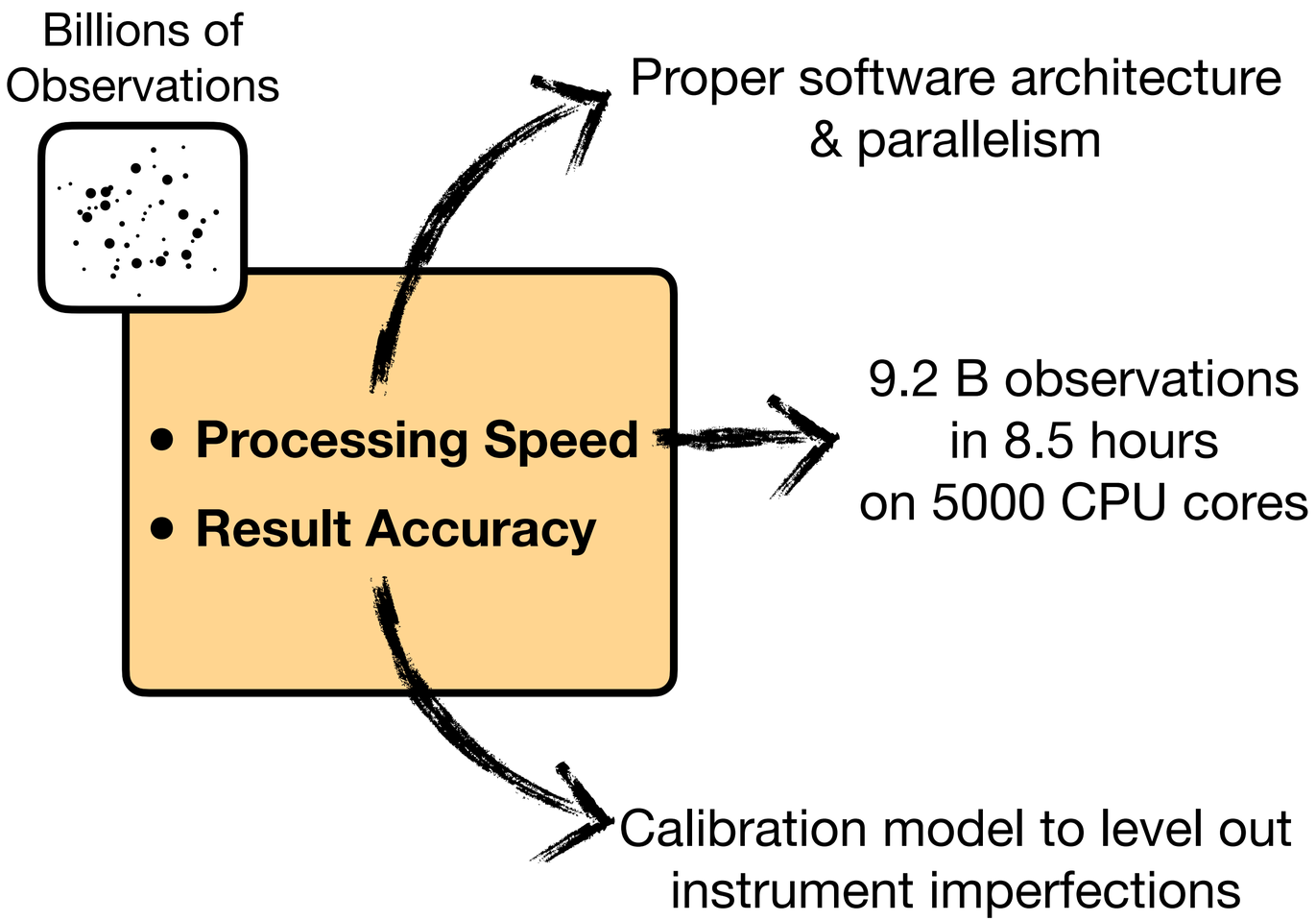
**AJAS**: **A**RI **J**ASMINE **A**strometric **S**olver for Supercomputers
(**JASMINE**: **J**apan **A**strometry **M**ission for **IN**frared **E**xploration)



# Previous Work



**AJAS**: **A**RI **J**ASMINE **A**strometric **S**olver for Supercomputers
(**JASMINE**: **J**apan **A**strometry **M**ission for **IN**frared **E**xploration)



# Previous Work



**AJAS**: **A**RI **J**ASMINE **A**strometric **S**olver for Supercomputers
(**JASMINE**: **J**apan **A**strometry **M**ission for **IN**frared **E**xploration)

Billions of Observations

Proper software architecture & parallelism

- **Processing Speed**
- **Result Accuracy**

9.2 B observations in 8.5 hours on 5000 CPU cores

Tools are needed to track both directions during the development, debug, and operation

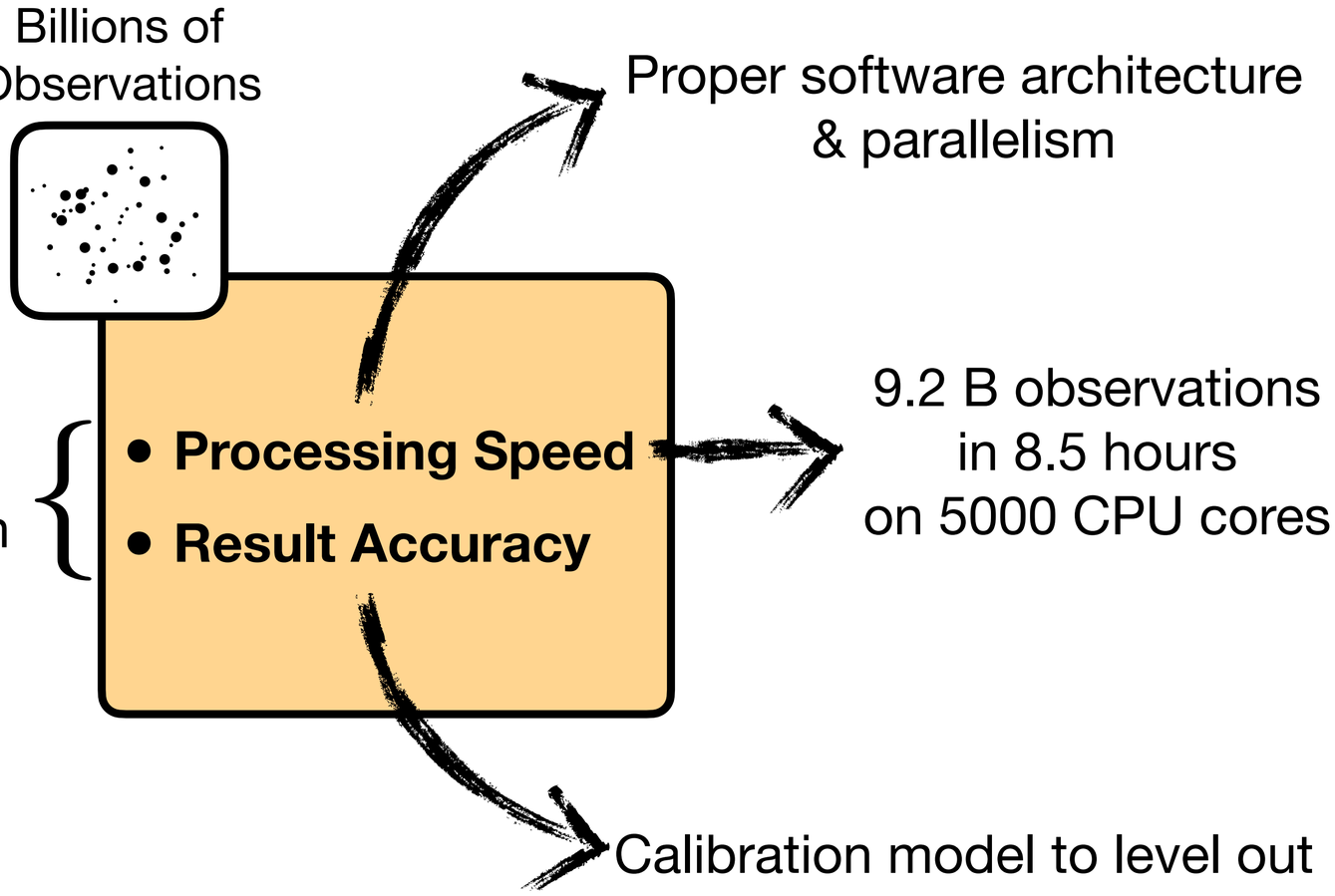
Calibration model to level out instrument imperfections

# Previous Work

**AJAS**: **A**RI **J**ASMINE **A**strometric **S**olver for Supercomputers
(**JASMINE**: **J**apan **A**strometry **M**ission for **IN**frared **E**xploration)

Again, **Big Data Problem**:
Access to input and output data is needed

Tools are needed to track both directions
during the development, debug, and operation



# Present Work



Tools are needed to track both directions during the development, debug, and operation

- **Processing Speed**
- **Result Accuracy**

**Solving Process Visual Mining**

**Solution Visual Mining**

Logo by Google Gemini

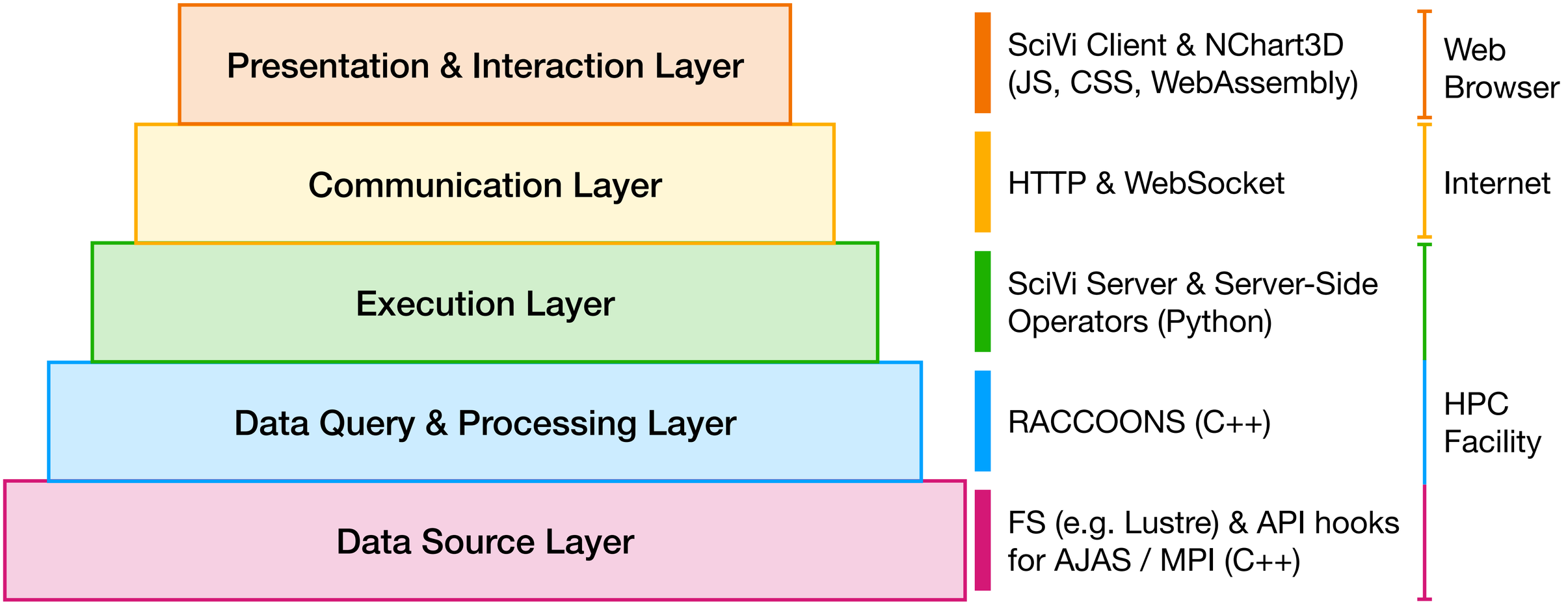
**Cognitive Clarity**

**Visual Aesthetics**

**LORIS**: **L**ayered **O**nline **R**eduction **I**nspection **S**ystem

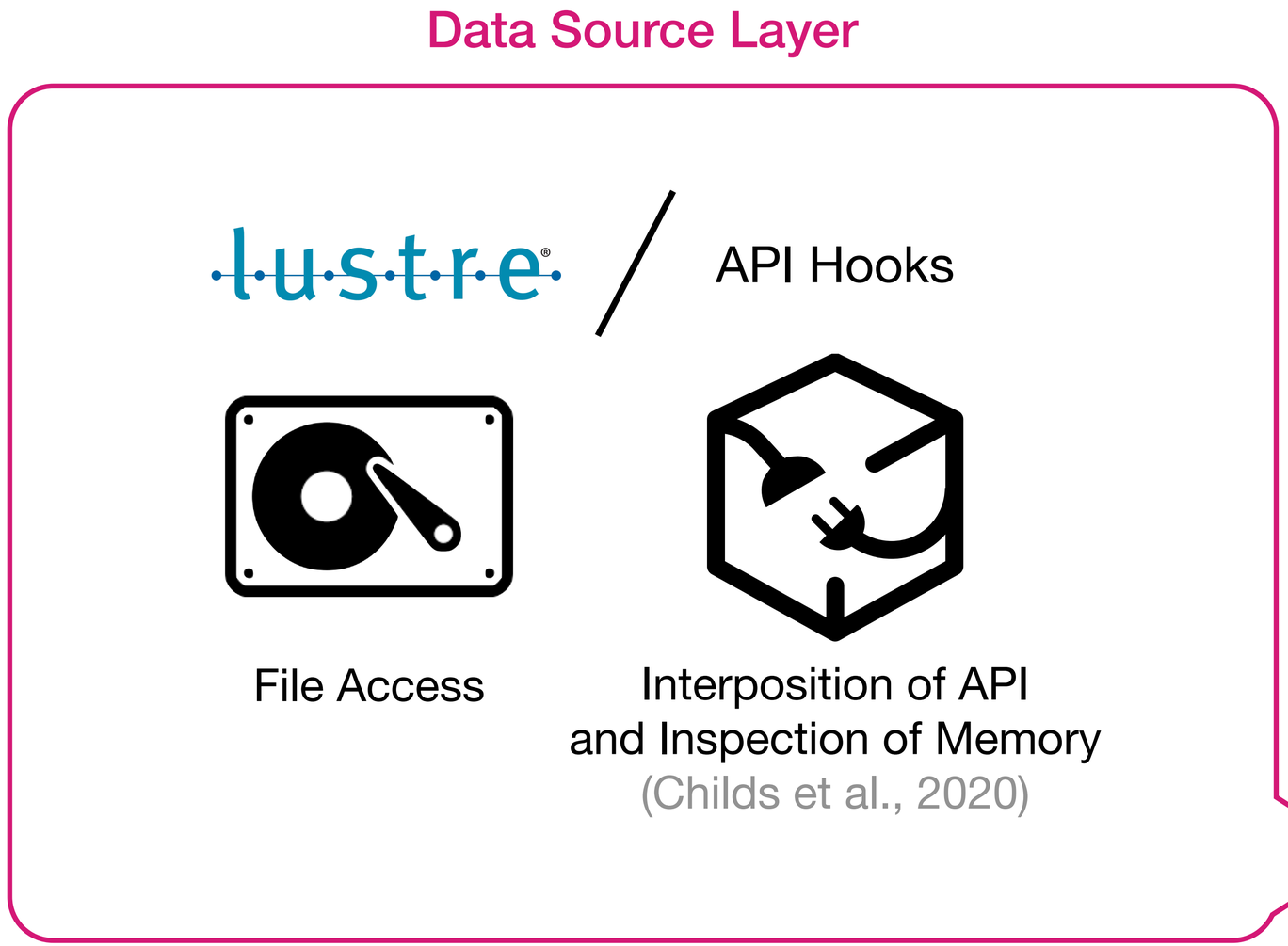
# LORIS Architecture





# LORIS: Data Source Layer






SciVi Client & NChart3D
(JS, CSS, WebAssembly)

HTTP & WebSocket

SciVi Server & Server-Side
Operators (Python)

RACCOONS (C++)

FS (e.g. Lustre) & API Hooks
for AJAS / MPI (C++)

Web
Browser

Internet

HPC
Facility

# LORIS: Data Query & Processing Layer

**FSDM 4681**

## Data Query & Processing Layer

**RACCOONS**: **R**apid **ACC**ess **O**perations
**O**n **N**umerical **S**olutions

Multithreaded Data Queries and Processing Engine
(Ryabinin et al., 2025)

- SciVi Client & NChart3D (JS, CSS, WebAssembly) — Web Browser
- HTTP & WebSocket — Internet
- SciVi Server & Server-Side Operators (Python) — HPC Facility
- **RACCOONS (C++)** — HPC Facility
- FS (e.g. Lustre) & API hooks for AJAS / MPI (C++) — HPC Facility

# LORIS: Data Query & Processing Layer

**FSDM 4681**

## Data Query & Processing Layer


Inspired by the wild neighbours who created their nest in the roof truss of the ARI building

- SciVi Client & NChart3D (JS, CSS, WebAssembly) — Web Browser
- HTTP & WebSocket — Internet
- SciVi Server & Server-Side Operators (Python) — HPC Facility
- RACCOONS (C++) — HPC Facility
- FS (e.g. Lustre) & API hooks for AJAS / MPI (C++) — HPC Facility

# LORIS: Execution Layer



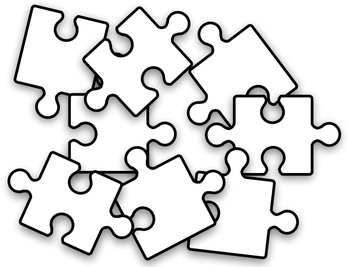
## Execution Layer

SciVi Ontology-Driven
Semantic Visual Data Mining Platform

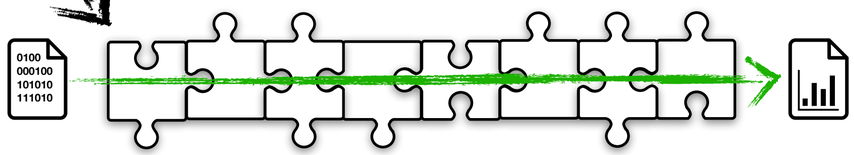
SciVi = ∑ Control Modules + ∑ Operators

Operator = Implementation + Lightweight Ontology

In-House  Third-Party  $O = \{ R, T \}$



SciVi allows building pipelines of operators
and automatically generates corresponding GUI



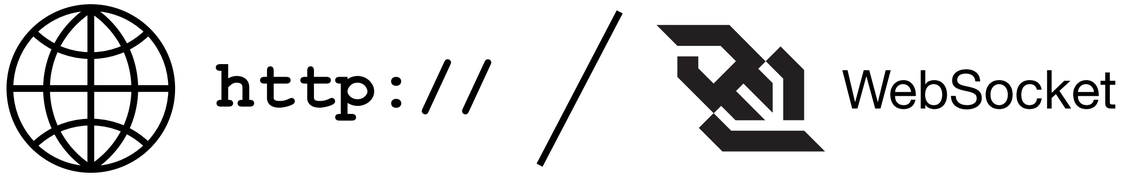

(Ryabinin et al.,
2013–2023)

- SciVi Client & NChart3D (JS, CSS, WebAssembly) — Web Browser
- HTTP & WebSocket — Internet
- SciVi Server & Server-Side Operators (Python) — HPC Facility
- RACCOONS (C++) — HPC Facility
- FS (e.g. Lustre) & API hooks for AJAS / MPI (C++) — HPC Facility

# LORIS: Communication Layer



## Communication Layer




Communication based on TCP/IP stack

- SciVi Client & NChart3D (JS, CSS, WebAssembly) — Web Browser
- HTTP & WebSocket — Internet
- SciVi Server & Server-Side Operators (Python) — HPC Facility
- RACCOONS (C++) — HPC Facility
- FS (e.g. Lustre) & API hooks for AJAS / MPI (C++) — HPC Facility

# LORIS: Presentation & Interaction Layer

**FSDM 4681**

## Presentation & Interaction Layer

SciVi Client

/

NChart3D

JavaScript

CSS

- Written in C++
- Compiled with Emscripten for Web
- Uses GPU for rendering
- Can handle 1M+ data points and remains interactive

SciVi Client & NChart3D (JS, CSS, WebAssembly) — Web Browser

HTTP & WebSocket — Internet

SciVi Server & Server-Side Operators (Python)

RACCOONS (C++)

FS (e.g. Lustre) & API hooks for AJAS / MPI (C++) — HPC Facility

# AJAS: Data Reduction Process

$$N \cdot \vec{x} = \vec{b}$$

Normal matrix of the astrometric system

Astrometric unknowns

Transformed observational residuals

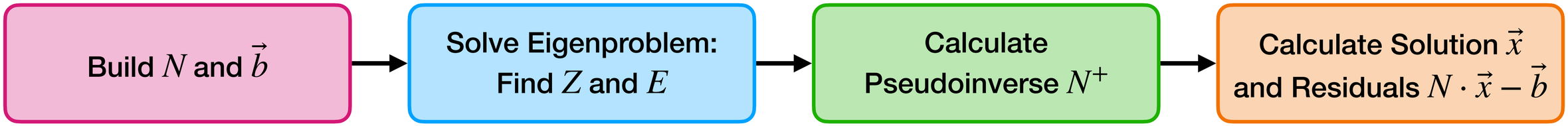
$$\vec{x} = N^{+} \cdot \vec{b}$$

$$\vec{x} = Z \cdot E^{-1} \cdot Z^{\top} \cdot \vec{b}$$

Matrix of eigenvectors of $N$

Diagonal matrix of eigenvalues of $N$

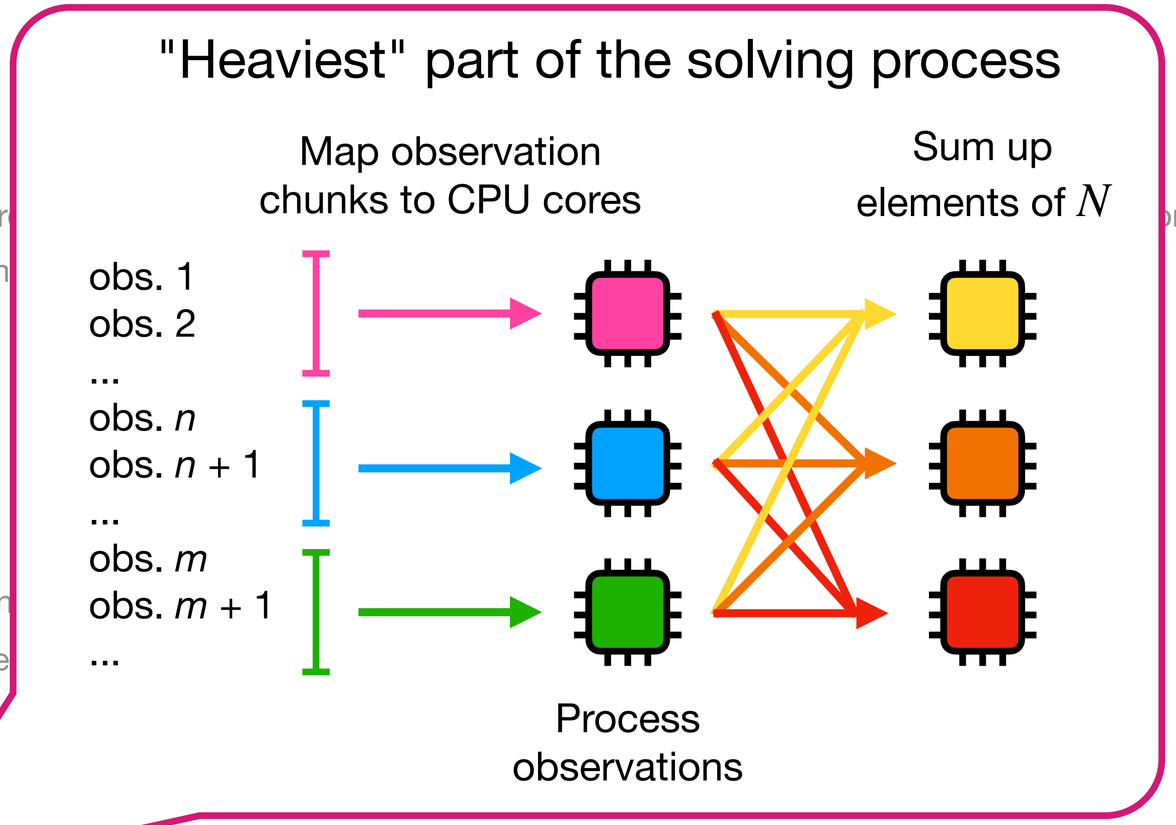
Solving Process:




(Ryabinin et al., 2025)

# AJAS: Data Reduction Process





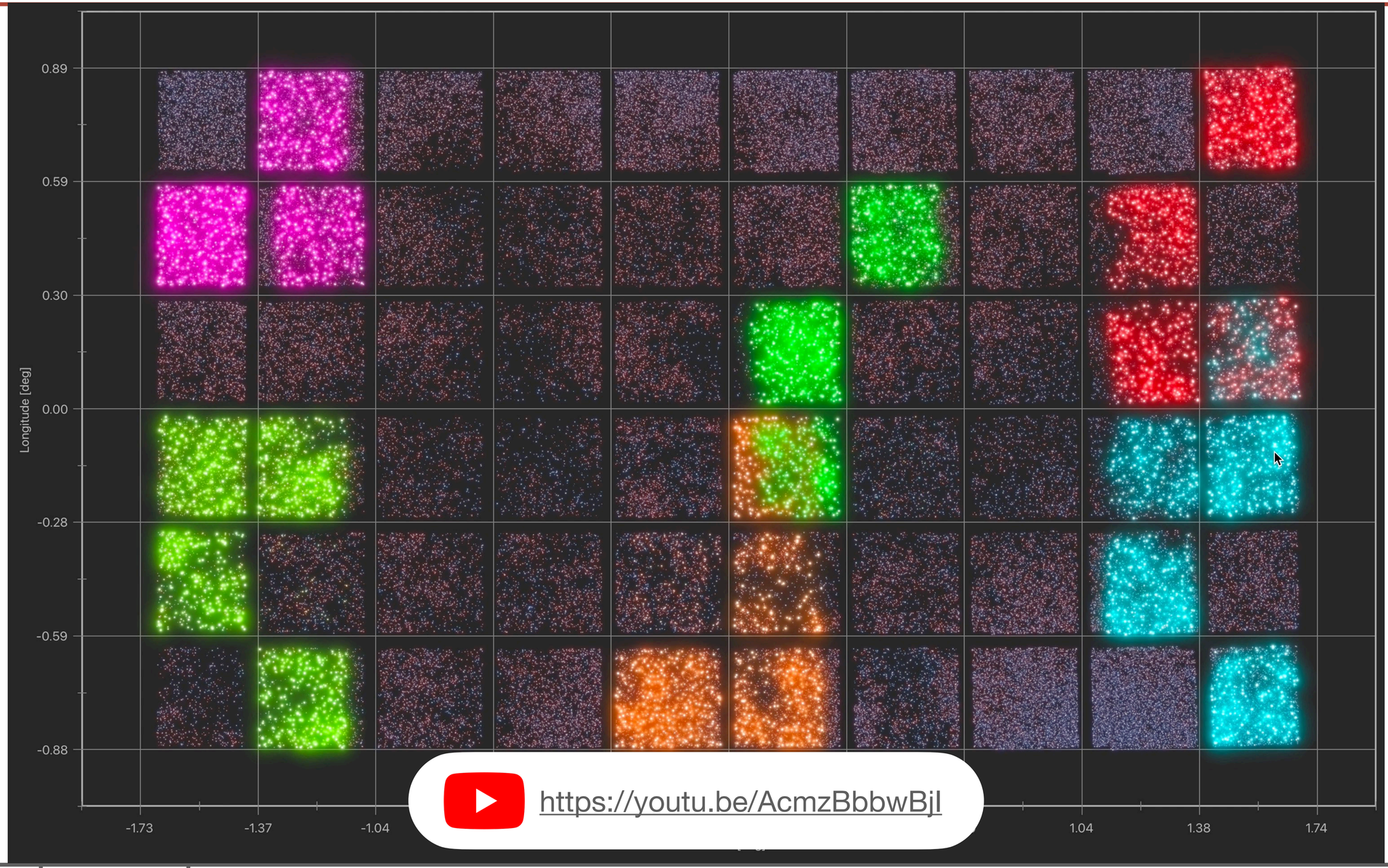

Solving Process:

**Build $N$ and $\vec{b}$** → **Solve Eigenproblem: Find $Z$ and $E$** → **Calculate Pseudoinverse $N^+$** → **Calculate Solution $\vec{x}$ and Residuals $N \cdot \vec{x} - \vec{b}$**

(Ryabinin et al., 2025)

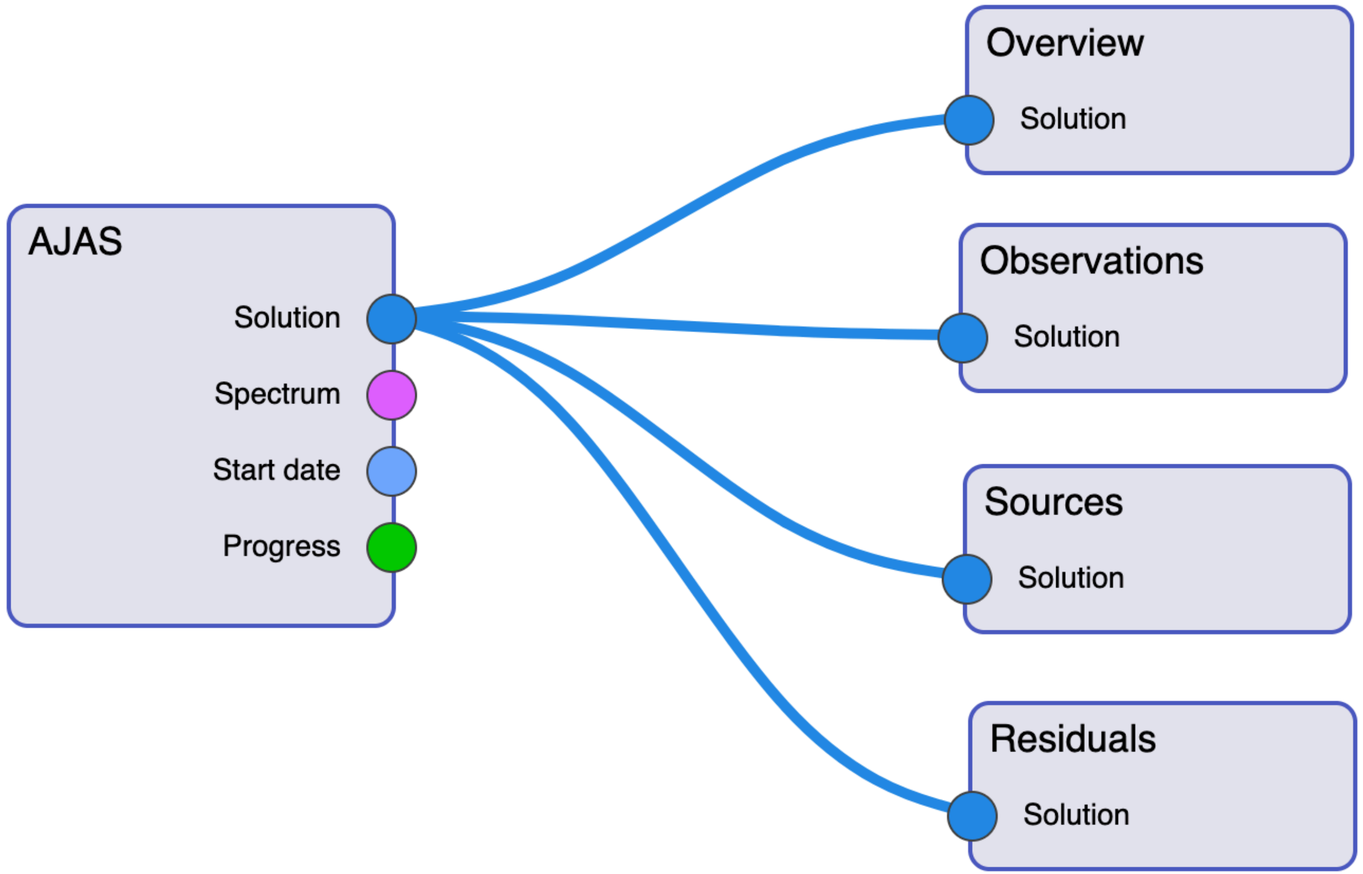
# Visual Mining of Solving Process

**FSDM 4681**



# Visual Mining of Solution






https://youtu.be/kZbfdeHcdhQ

# Conclusions



## Key Contributions:

1. LORIS: cognitive clarity & visual aesthetics for the in-situ semantic visual data mining in astrometry
2. Identifying key bottlenecks in the matrix building process of AJAS
3. Presenting the AJAS solving process in an artistic way for broader audience promoting the JASMINE mission
4. Comprehensive visual analysis of the AJAS solution

## Future Work:

1. Building up more visual mining operators for LORIS
2. Optimising the data access routines
3. Addressing the fault tolerance issues

## Acknowledgments:

Supported by the German Aerospace Agency (DLR) through grant 50OD2201


# The 11th International Conference on Fuzzy Systems and Data Mining (FSDM 2025) Nov. 14-17, 2025 (Chaozhou, Guangdong, China)

FSDM 4681

# Thank you for your attention!

Presented by: **Konstantin Ryabinin**, Wolfgang Löffler, Michael Biermann

Affiliation: Astronomisches Rechen-Institut, Center for Astronomy of Heidelberg University

ZENTRUM FÜR ASTRONOMIE

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386