AstroAKD

An MCP-Based Agent for Natural-Language Search of Astronomical Archives



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WHY THIS MATTERS

The bottleneck is not archive access — it is orchestration

> “Find archival UV and X-ray observations of this target, then identify related papers.”

That request hides multiple coordination tasks.

1 Resolve the target

Name, aliases, coordinates



2 Choose the right service

MAST? HEASARC? ADS?



3 Translate constraints

Radius, instrument, dates



4 Reconcile outputs

Observations, tables, metadata



SIMBAD · MAST · HEASARC · IRSA · Gaia · ADS · VizieR

Meet the AstroAKD Team

NASA Accelerated Knowledge Discovery • IMPACT • ODSI

ACCELERATED KNOWLEDGE DISCOVERY | IMPACT Interagency Implementation and Advanced Concepts Team | NASA | Office of Data Science and Informatics | THE UNIVERSITY OF ALABAMA IN HUNTSVILLE | USRA



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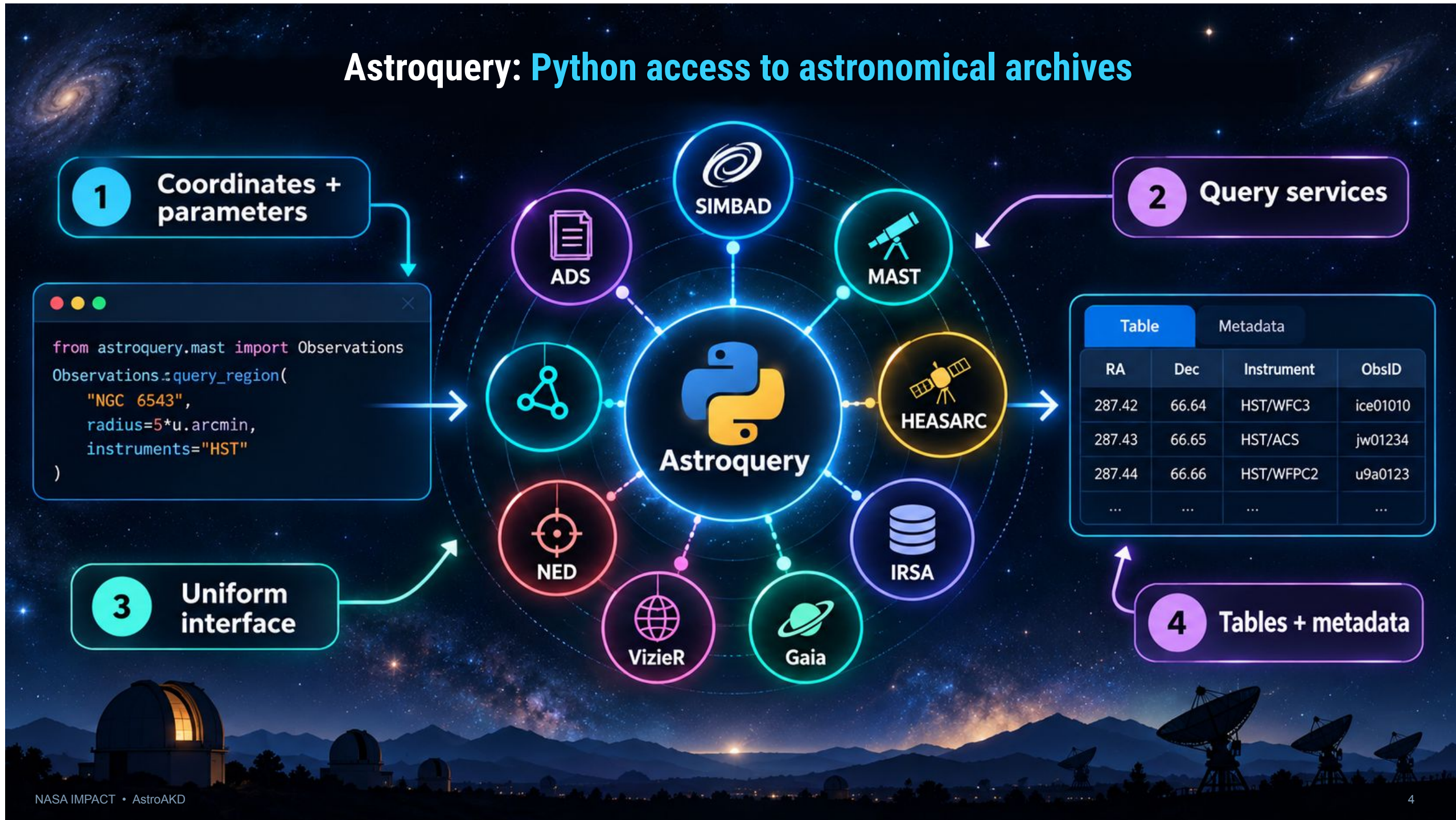


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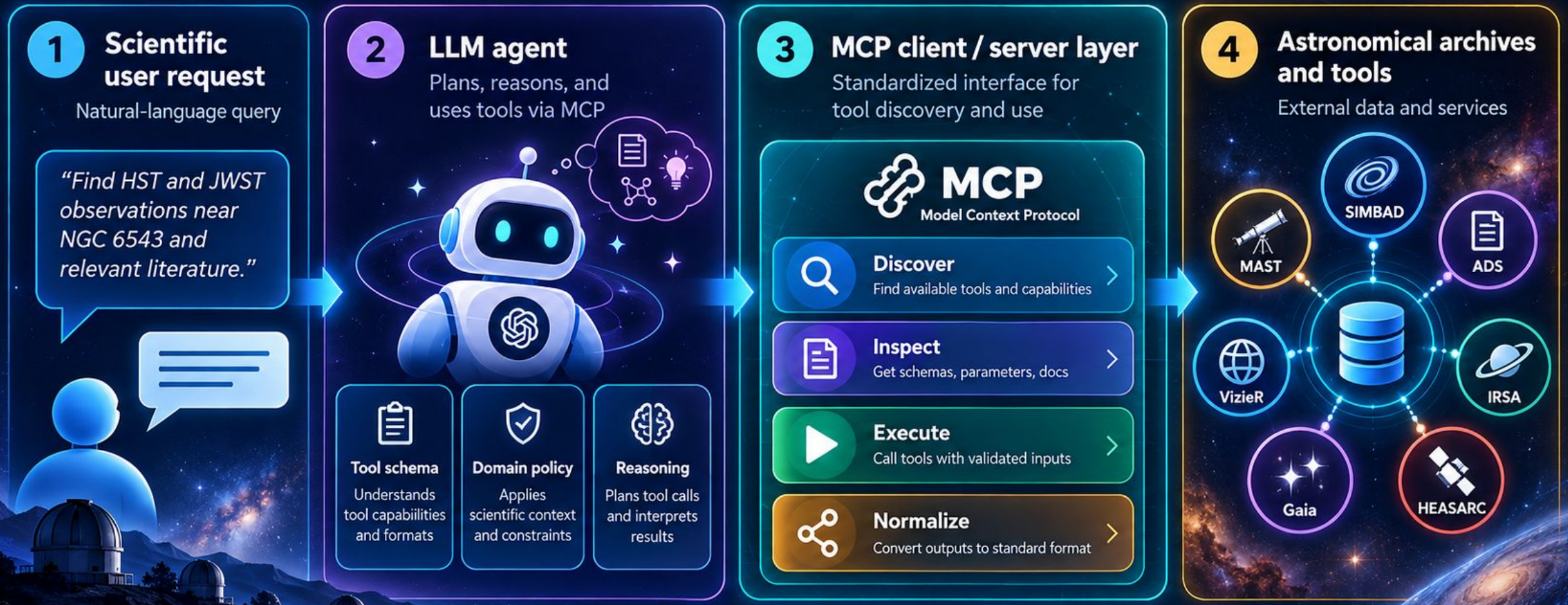
Rahul Ramachandran
IMPACT Lead (NASA MSFC)

Astroquery: Python access to astronomical archives



MCP: a standard bridge between AI agents and tools

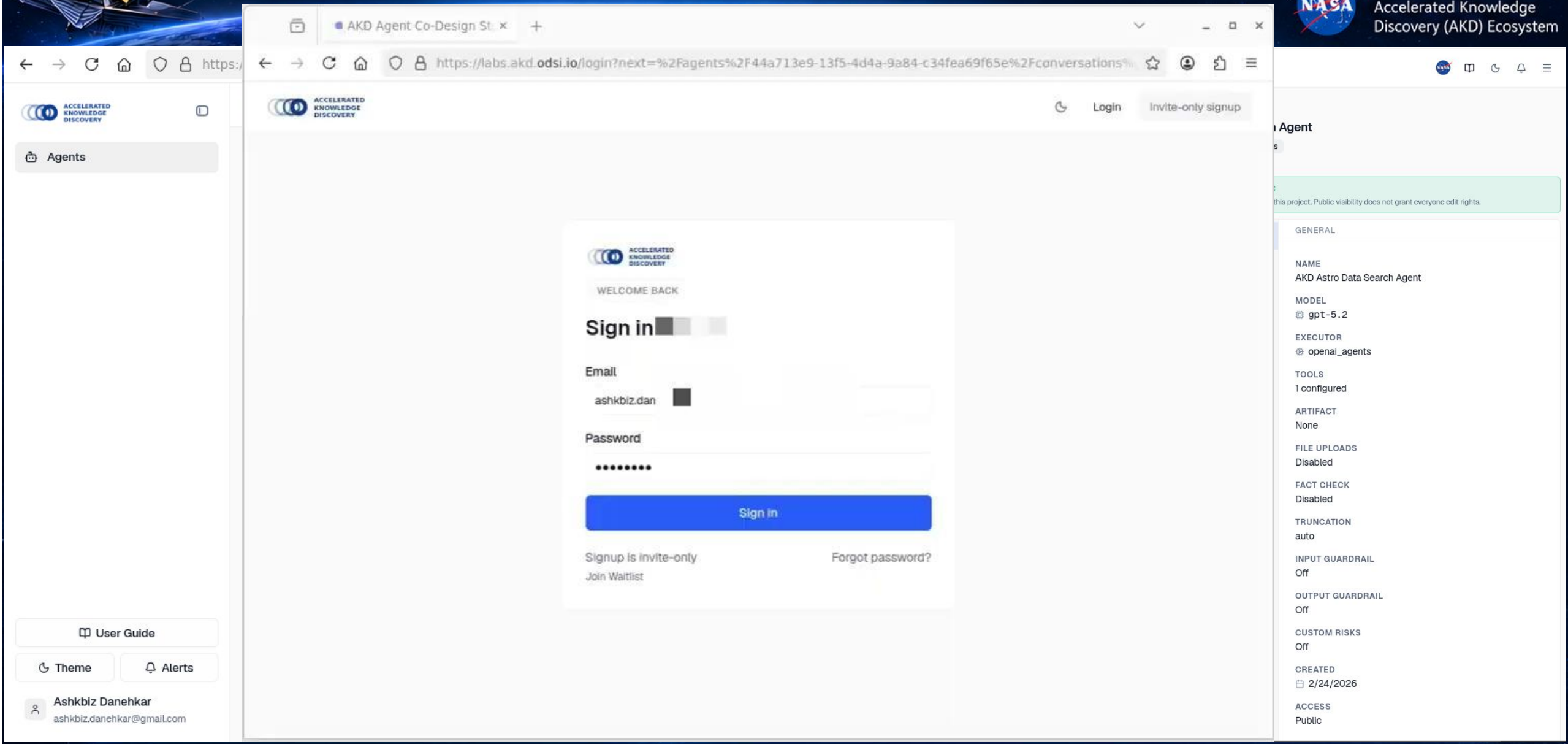
Standardized tool interface for external data services



AstroAKD in the AKD ecosystem

A MODULAR SCIENTIFIC-AGENT STACK FOR ASTRONOMICAL DISCOVERY

NASA IMPACT
Accelerated Knowledge Discovery (AKD) Ecosystem



https://youtu.be/qaCzvAGtL2I

AstroAKD architecture

An MCP-based agent for natural-language search of astronomical archives

1 Scientific request

Natural-language question

> *"Find HST and JWST observations near NGC 6543 and relevant literature."*



2 AstroAKD agent

Plan and orchestrate



AstroAKD

- Resolve targets
- Select tools & archives
- Compose and execute queries

3 MCP tool layer

Standardized interface

MCP server

- **discover** — Find available tools
- **inspect** — View parameters
- **execute** — Run archive queries
- **normalize** — Harmonize results

4 Astroquery

Archive access layer

Astroquery



- Convert parameters
- Handle coordinates and units
- Return structured tables and metadata

5 Astronomical archives

Distributed data and services



6 Evidence, provenance, and outputs

Results retained for validation and reuse

Retrieved data products



Images, spectra, catalogs, and observations

Structured tables and metadata

RA (deg)	Dec (deg)	Instrument	ObsID
287.42	66.64	HST/WFC3	icxe01010
287.42	66.64	JWST/NIRCam	jw012340
287.41	66.65	GALEX	gA100021
…	…	…	…

Reproducible tool traces

```
[1/4]  discover    ✓  2.3s
[2/4]  inspect     ✓  1.1s
[3/4]  execute     ✓  4.8s
[4/4]  normalize   ✓  0.9s
```

Retrieved 12 datasets, 8 papers
Full trace of tool calls and responses

INSIDE THE MCP SERVER

astroquery-mcp turns a Python package into a discoverable tool surface

1 List modules

What services exist?

```
{
  "modules": [
    "simbad",
    "vizier",
    "nasa_ads",
    "mast",
    "..."
  ]
}
```

2 List functions

What can this service do?

```
{
  "module": "simbad",
  "functions": [
    "query_object",
    "query_region",
    "query_objects",
    "..."
  ]
}
```

3 Inspect function

What arguments are required?

```
{
  "name": "query_object",
  "description": "...",
  "parameters": [
    {
      "name": "object",
      "type": "str",
      "description": "Target name"
    },
  }
```

4 Execute

Run the selected archive call

```
{
  "module": "simbad",
  "function": "query_object",
  "arguments": {
    "object": "M31"
  }
}
```

Structured input

JSON-like request

```
{
  "module": "simbad",
  "function": "query_object",
  "arguments": { ... }
}
```

→

Astronomy types

SkyCoord • quantities • units

```
from astropy import units as u
from astropy.coordinates import SkyCoord

coord = SkyCoord("M31", unit=u.deg)
```

→

Archive call

Astroquery method

```
from astroquery.simbad import Simbad

result = Simbad.query_object("M31")
```

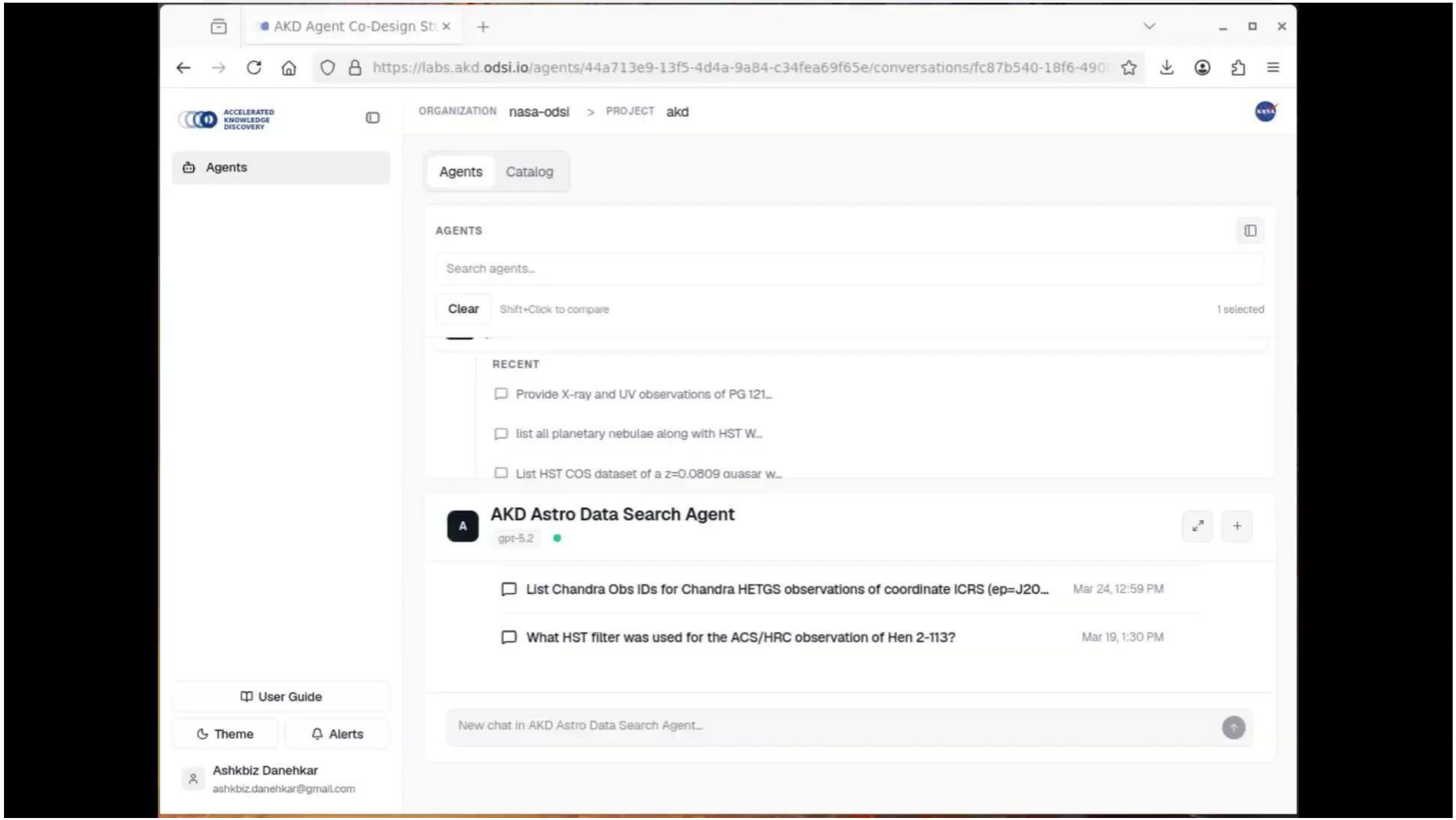
→

Normalized result

Astropy tables → machine-readable data

MAIN_ID	RA	DEC	...
M31	10.6847	41.2688	...
M31*	10.6850	41.2691	...

Example workflow



https://youtu.be/CzJxKnIsogc

Example multi-archive workflow

for a natural-language request using target data, metadata, and literature

1 User request
Natural-language query

"Find HST and JWST observations near NGC 6543 and relevant literature."

2 SIMBAD
Resolve target

SIMBAD
Astronomical database

Resolve object name
NGC 6543

Resolved target
NGC 6543
RA 287.42°
Dec 66.64°
Object type: Planetary nebula



3 MAST
Search HST & JWST

MAST
Mikulski Archive for Space Telescopes

Search archival observations
HST and JWST around target coordinates

Retrieve observations
Find datasets with instrument, filters, dates, metadata

4 ADS
Find related literature

ADS
Astrophysics Data System

Search papers
NGC 6543, HST, JWST, planetary nebula

Retrieve metadata
Titles, authors, years, citations

5 AstroAKD
Synthesize and answer

AstroAKD
Multi-archive synthesis

- **Merge multi-archive results** — Cross-match, deduplicate
- **Harmonize metadata** — Common schema and units
- **Synthesize evidence** — Combine datasets and literature
- **Return answer** — Ranked datasets and papers with inspection-ready outputs

Example results
Target data, metadata, and literature from each archive

SIMBAD – Target resolution
1 result

Preview	Object	RA (deg)	Dec (deg)	Type
	NGC 6543	287.42	66.64	Planetary nebula

MAST – Archival observations
3 datasets

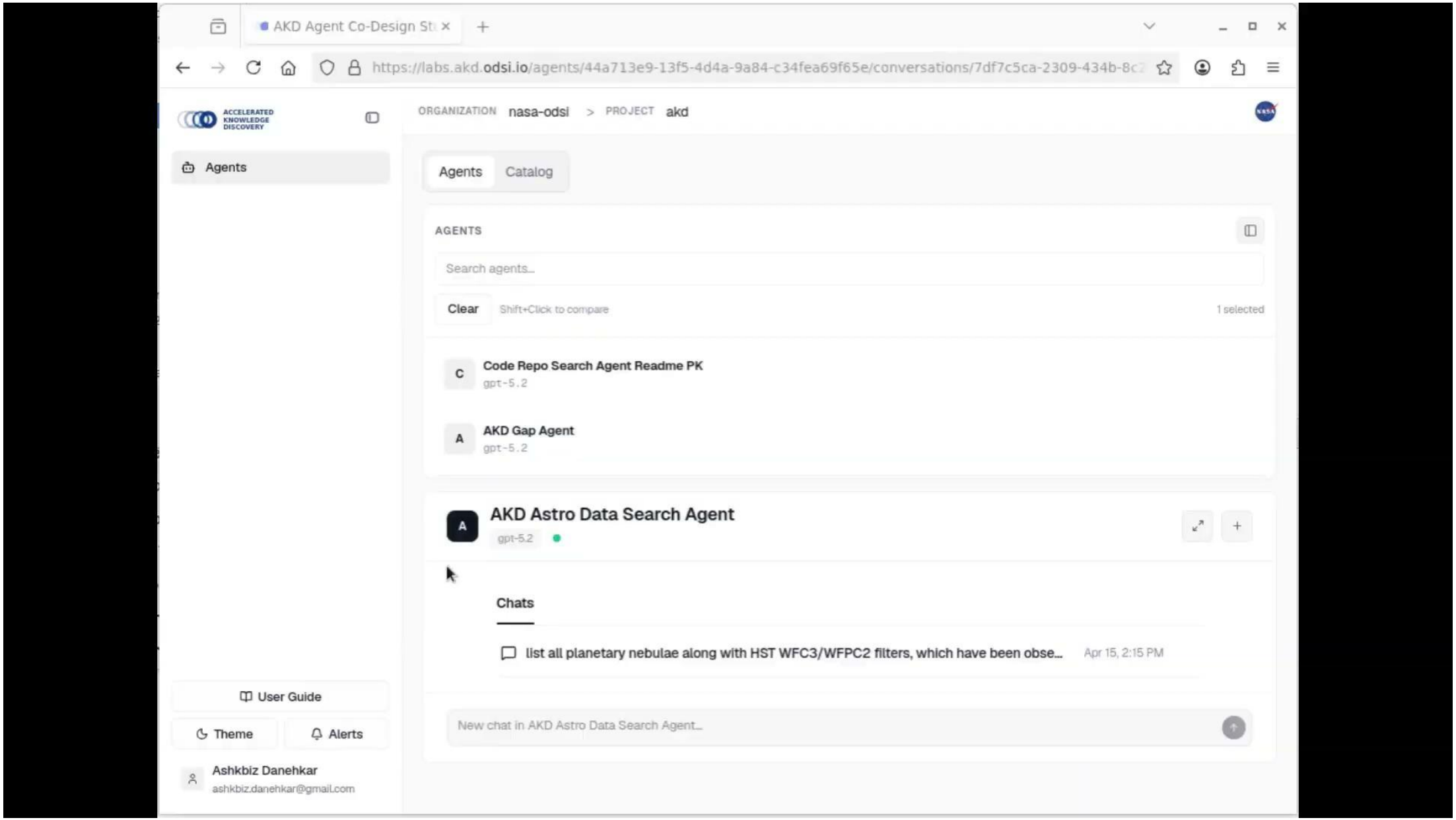
Preview	ObsID	Instrument	Filter(s)	RA (deg)	Dec (deg)
	jw012340	NIRCam	F200W, F300M	287.42	66.64
	jw015670	MIRI	F770W, F1130W	287.42	66.64
...	...	...	...	...	...

ADS – Related literature
3 papers

Title	Authors	Year	Citations
The Hubble Space Telescope view of NGC 6543	Balick et al.	2013	245
JWST mid-infrared observations of NGC 6543	Santander-García et al.	2023	98
Physical structure and evolution of the Cat's Eye Nebula	Guerrero et al.	2021	76
...	...	...	...

Target: NGC 6543 (SIMBAD) | MAST queries: HST + JWST around target | ADS query: NGC 6543, HST, JWST | Merged and ranked by AstroAKD

Example multi-archive workflow



https://youtu.be/jBOJXP3x1IA

AstroAKD-Bench

Benchmarking AstroAKD for natural-language search of astronomical archives

Synthetic astronomy queries, MCP tool traces, and repeatable agent evaluation

1 Benchmark Construction

Independent Astroquery MCP Server

SIMBAD · ADS · MAST · HEASARC

IRSA · Gaia · VizieR · NED/VO

Synthetic Query Generation

Reference answers + traces

Question mix
(100 default questions)

- Archive-driven (60)
- Coordinate-driven (20)
- ADS literature (8)
- Multi-archive (12)

Uses the Astroquery MCP server to generate benchmark tasks and collect reference evidence.

2 Agent Under Test



User Request

"Find HST observations of M31 and related literature."



AstroAKD
LLM agent + CARE instructions

Astroquery MCP tools
(built from the Astroquery MCP server)

3 Evaluation & Reporting

- Archive selection
- Function selection
- Parameter correctness
- Task completion
- Recovery from ambiguous IDs
- Recovery from empty results / unavailable services
- Inspectable traces
- Repeatability

Benchmark outputs:
scores, traces, and evaluation reports

AstroAKD-Bench provides a transparent, repeatable benchmark for AstroAKD data search agent.

A/B/C: MCP only vs AstroAKD vs Web only

A controlled three-arm comparison with the same synthetic astronomical questions

100 frozen questions → Same GPT-5.2 model Same baseline limits

The evaluated agents receive the same frozen question set; hidden references are not shown to them.

A MCP only

General-purpose agent

Astroquery MCP tools

No domain-specific instruction

- **LLM** — general purpose
- **Astroquery MCP** — archive tools
- **Astronomical archives**

Tests the value of MCP tool access

B AstroAKD

Domain-guided agent

Astroquery MCP tools

AstroAKD / CARE instructions

- **LLM + AstroAKD** — frozen specialist instruction, CARE-derived
- **Astroquery MCP** — archive tools
- **Astronomical archives**

Tests the value of domain guidance

C Web only

Web-search baseline

Web search tools

No Astroquery MCP access

- **LLM** — general purpose
- **Web search** — general web tools
- **Web sources**

Tests web-based discovery alone

Compare answers with independently collected Astroquery MCP reference snapshots

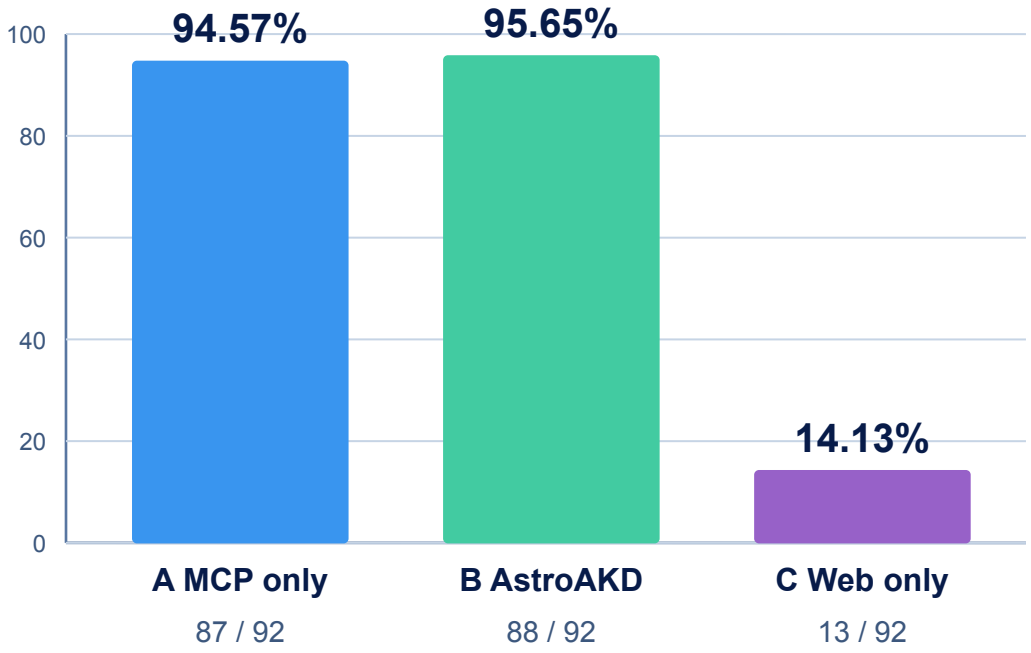
Automated match rate • Completion • Runtime • Token use • Traces

Measured A/B/C results

astroakd_100 | 100 questions | GPT-5.2 | original, common 8-turn budget

Automated reference-answer agreement

92 evaluable questions



Operational metrics

Metric	A	B	C
Completed	98/100	100/100	100/100
Mean time (s)	21.20	21.33	16.19
Tokens (M)	0.80	1.47	1.72

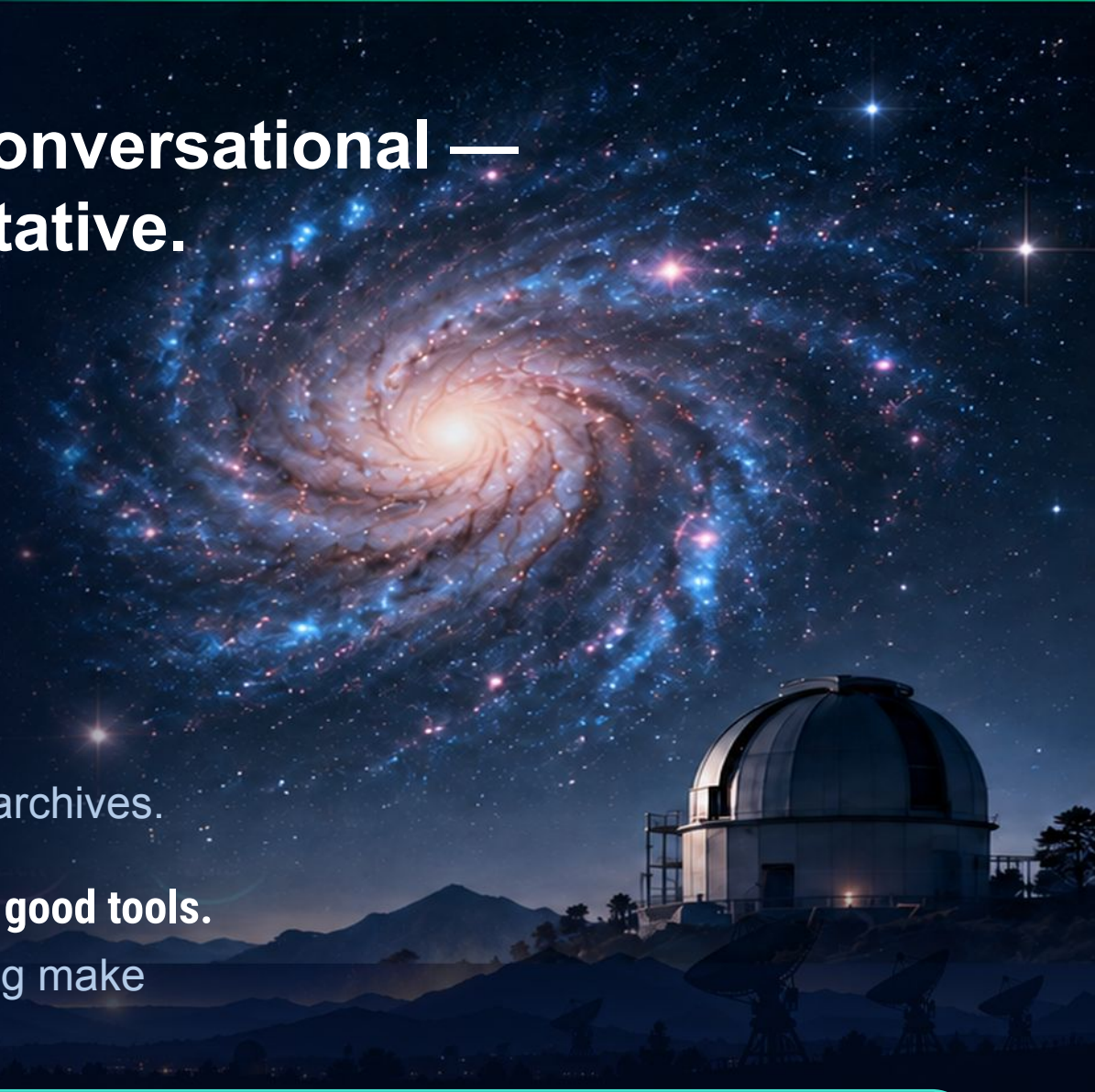
Original common 8-turn run shown here; A's two errors were resolved only in a separate diagnostic.

Coverage: 80 single-call + 12 multistep references = 92 evaluable | 8 excluded (need independent archive query plan)

Agreement means automatic comparison to archive-derived reference answers; it is not independently verified scientific accuracy.

TAKEAWAYS

AstroAKD makes archive search conversational — while keeping the archives authoritative.



1. **MCP access matters for astronomy search.**
   On 92 evaluable questions,
   A = 94.57% and B = 95.65% agreement,
   versus 14.13% for web-only.

2. **Domain guidance shows a modest improvement in overall reference agreement.**
   AstroAKD (B) slightly outperforms MCP-only (A),
   especially when combining evidence from several archives.

3. **Reliable agents need structured evaluation as well as good tools.**
   Reference collection, traces, and automated scoring make benchmark-driven iteration possible.

Next: resolve remaining literature-plan cases and continue strengthening AstroAKD + astroquery-mcp.

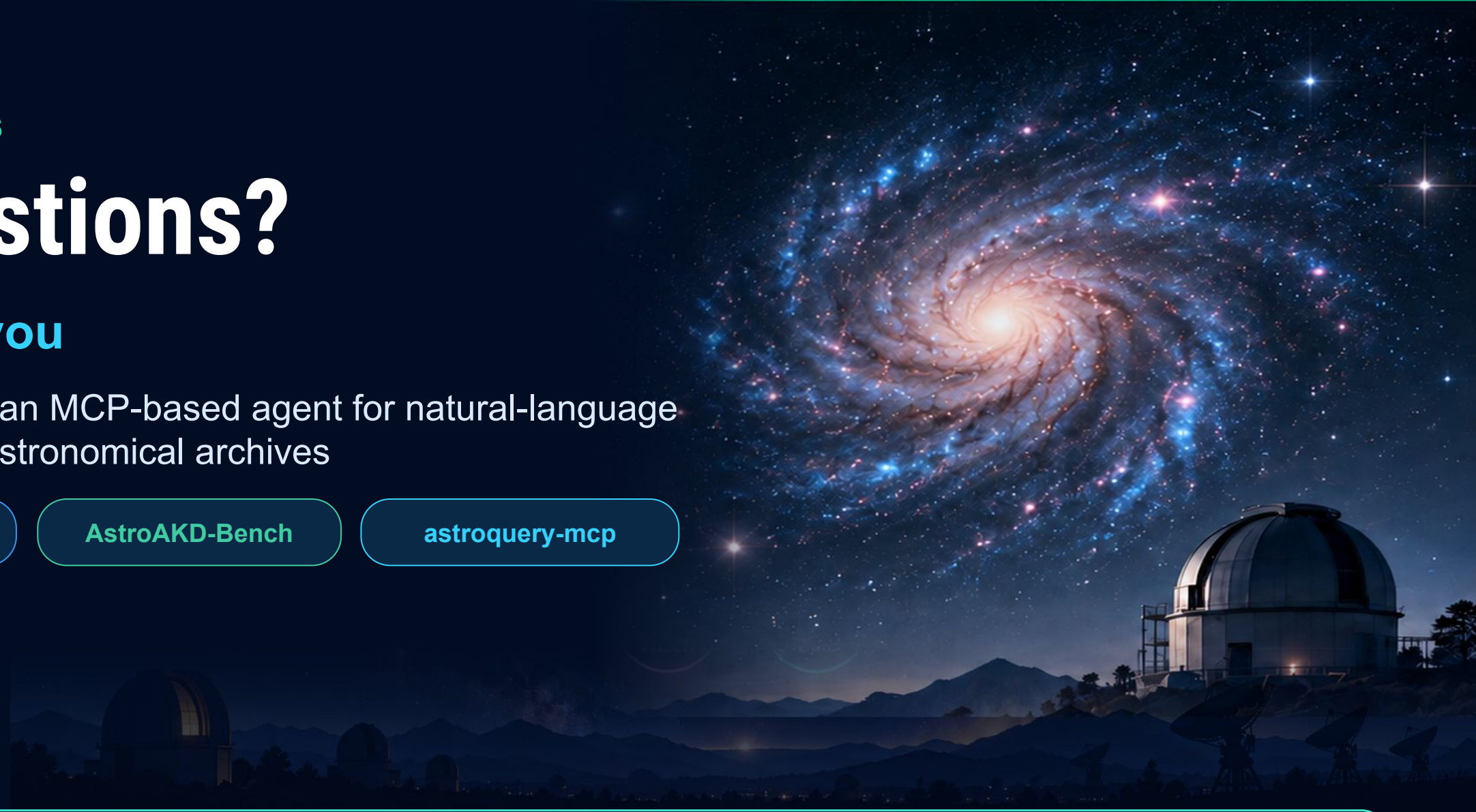
QUESTIONS

Questions?

Thank you

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AstroAKD | AstroAKD-Bench | astroquery-mcp



github.com/NASA-IMPACT/astroquery-mcp • github.com/NASA-IMPACT/astroakd-bench