Title: UniverseTBD: Democratising Science with AI & Why Stories Matter

Speakers: Ioana Ciuca

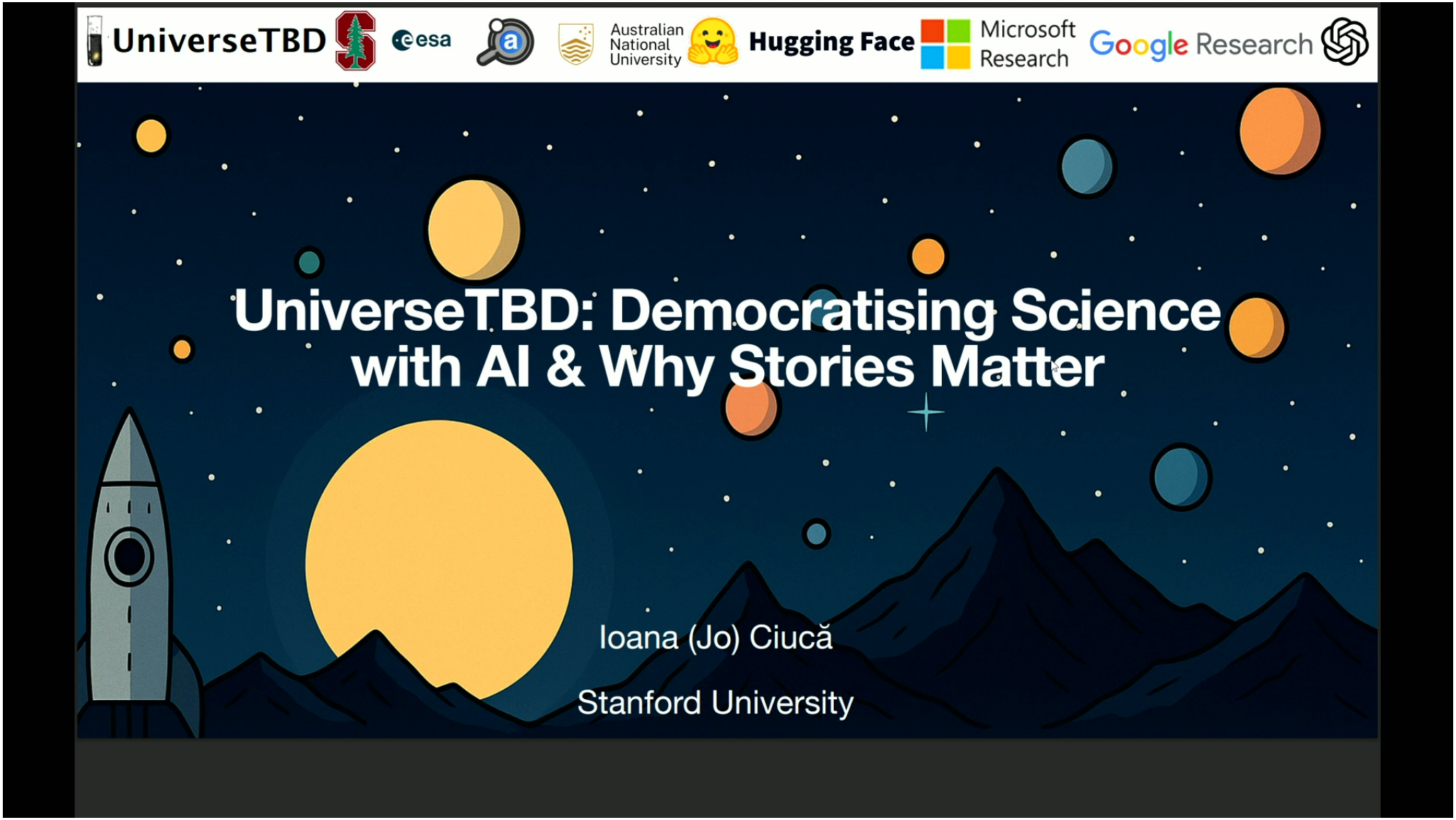
Collection/Series: Theory + AI Symposium

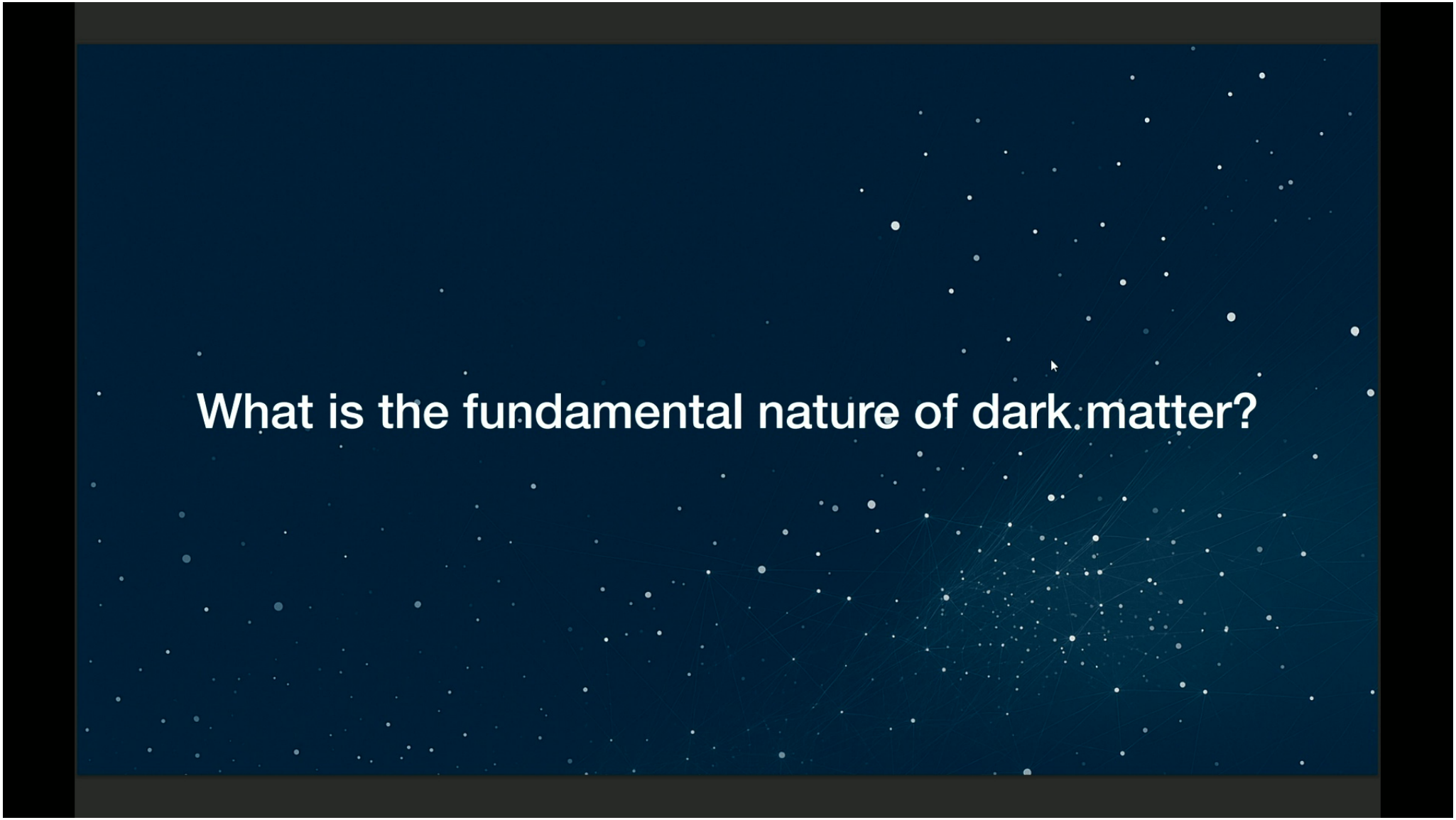
Date: April 08, 2025 - 9:50 AM

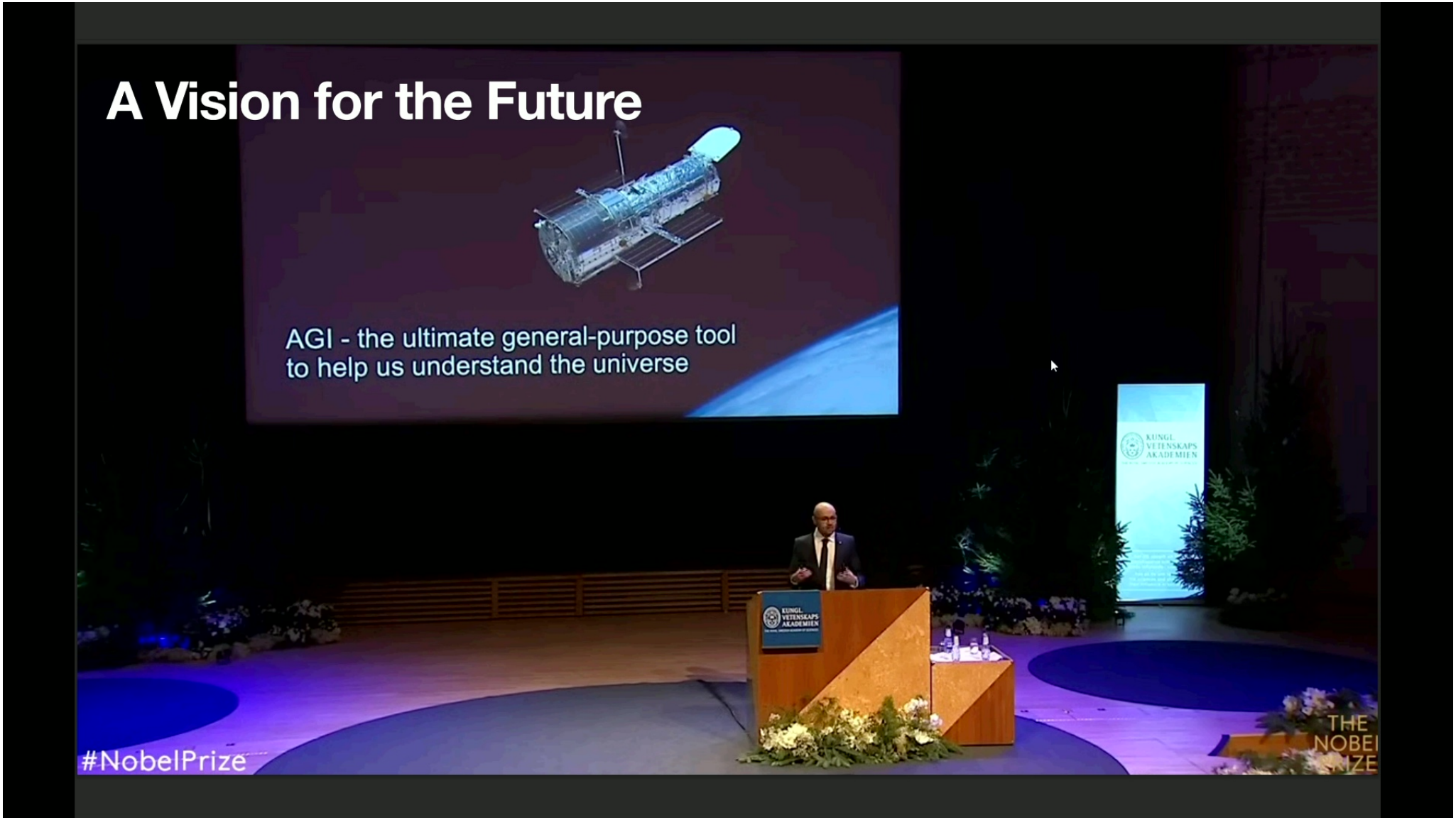
URL: https://pirsa.org/25040062

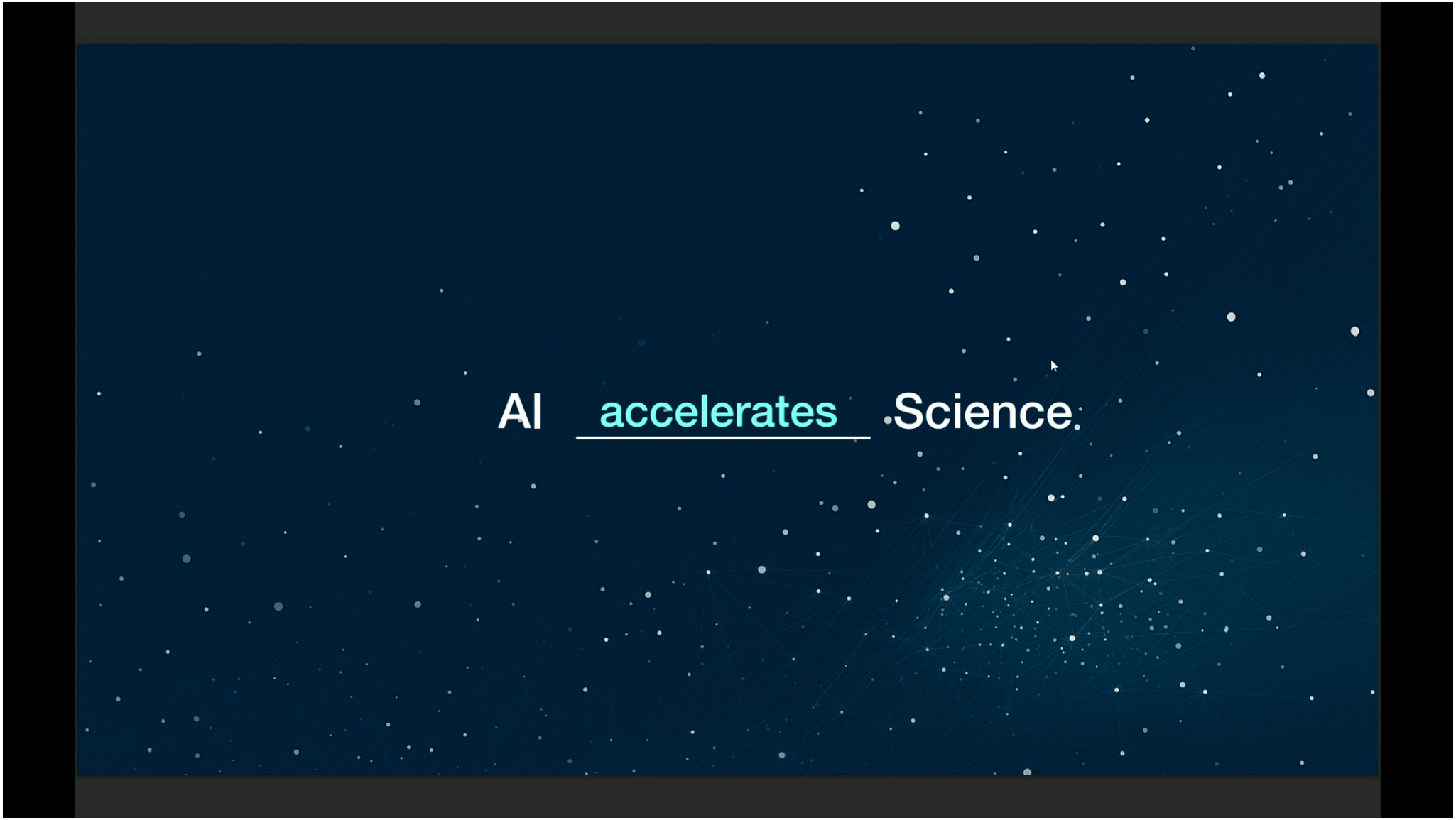
Abstract:

UniverseTBD is an interdisciplinary community of astronomers, AI researchers, engineers, artists and enthusiasts aligned on a bold mission to democratise Science for everyone. From releasing the first large language model in Astronomy, AstroLLaMA-1, to the AI-enabled literature discovery tool Pathfinder, and through our research with AstroPT and HypoGen, our team has pushed the boundaries of AI for Science for the past two years. In this talk, I discuss for the first time how UniverseTBD came to be, our vision, our values, and what drives us and has enabled us to scale our team projects in our commitment to share our learnings with the broader scientific community. I also briefly discuss our latest results with hypothesis generation (HypoGen), multimodal language models (AstroLlaVA-1) and agentic AI (AstroCoder). I conclude with a vision for the future where AI teams up with human researchers to "help us understand the Universe".


UniverseTBD
esa
Australian National University
Hugging Face
Microsoft Research
Google Research
UniverseTBD: Democratising Science with AI & Why Stories Matter
Ioana (Jo) Ciucă
Stanford University


What is the fundamental nature of dark matter?


A Vision for the Future
AGI - the ultimate general-purpose tool
to help us understand the universe
KUNGL VETENSKAPS AKADEMIEN
#NobelPrize


AI accelerates Science

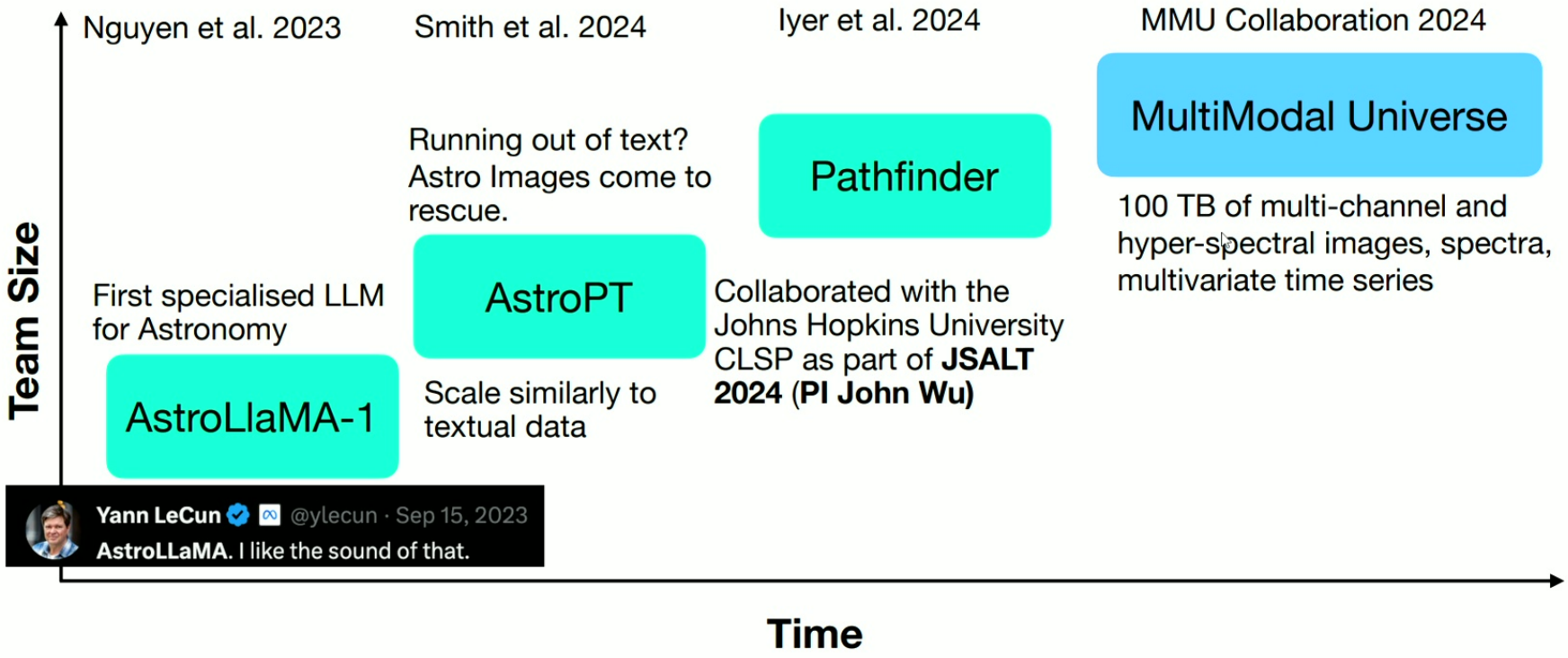
UniverseTBD: How to dream up an AI Research CoLab

- Founded **April 6 2023** over coffee on Level 11 at Flatiron Institute by Kartheik Iyer (Columbia) and Ioana
- **TBD** originally a placeholder next to the **Universe**, which we **really** wanted to have
- Over 30+ astronomers, computer scientists, engineers, artists and enthusiasts spread over **four continents**
- **Values**: **Openness**, **Excellence** with Purpose, Fearless **Experimentation**, **Junior Leadership**, **Integrity, Transparency** and a **Behaviour beyond Reproach**
- **Approach**:
  - Team first.
  - Move slowly, grow things.

Maja Jablonska (ANU)

Pranav Khetarpal (IIT Delhi)

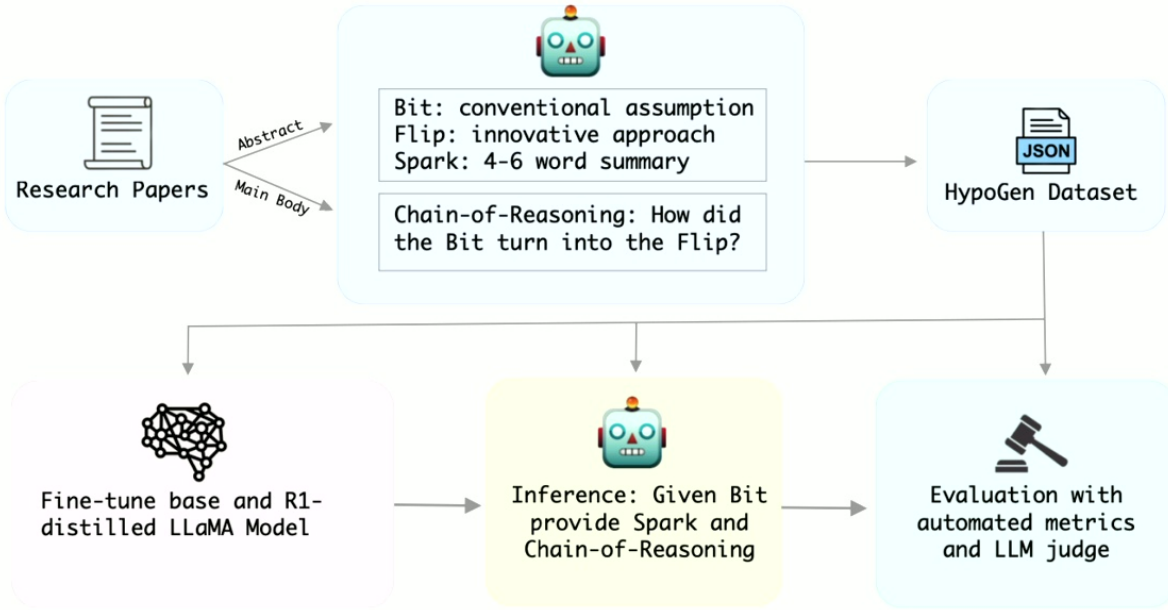
Spotlight on UTBD Projects and Collaborations



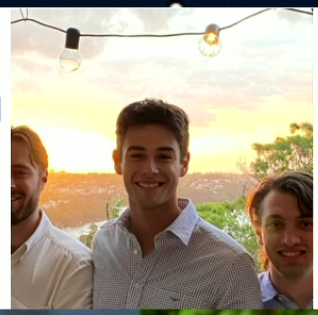
We've been busy for the past year.

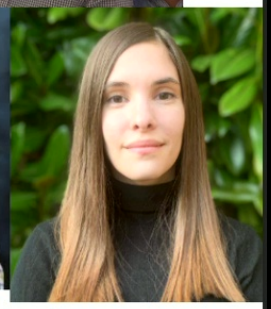
- Clear focus on getting our **structure** right.
- Currently experimenting with a hybrid structure: **delegate executive team** with **autonomous research pods** and **service teams**.
- After a lot of doubt, it seems to work!
- Spotlight on three+ projects from Q1 (on arXiv this week):
  - Ideation: PI Charlie O'Neill (Oxford) **HypoGen**, PI Atilla Alkan (Université Paris-Saclay)
  - Multimodality: PI Sharaf Zaman (ANU) **AstroLlaVA**, PI Dimitrios Tanoglidis (WBA)
  - Agents: PI Nolan Koblischke (UoT, *in the audience**) ***Surprise special project**

HypoGen: Can AI generate viable scientific hypotheses?



Charlie O'Neill (Oxford)



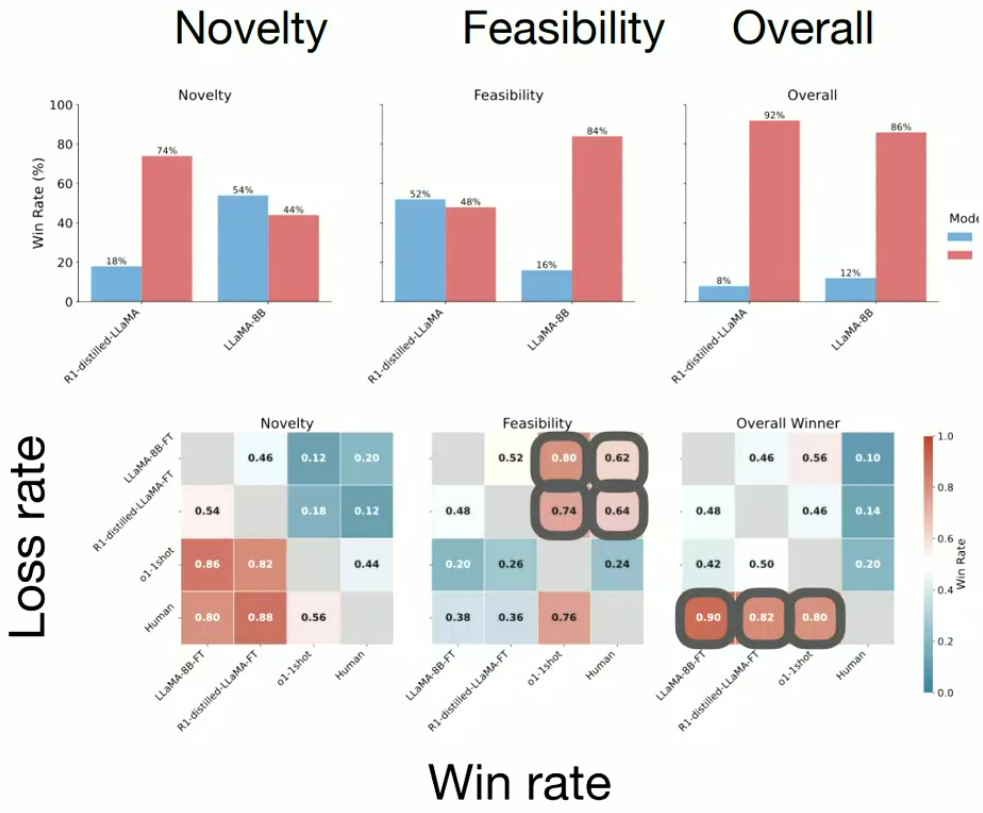


Tirthankar Ghosal (ORNL)

Roberta Raileanu (UCL)

O'Neill et al. 2025, submitted

HypoGen: Can AI generate viable scientific hypotheses?



Sparks of Science: Hypothesis Generation Using Structured Paper Data

Charles O'Neill
University of Oxford
cponeill@cs.ox.ac.uk

Tirthankar Ghosal
Oak Ridge National Laboratory
ghosalt@ornl.gov

Roberta Răileanu
University College London
r.raileanu@ucl.ac.uk

Mike Walmsley
University of Toronto
mwalmsley@utoronto.ca

Thang Bui
Australian National University
thang.bui@anu.edu.au

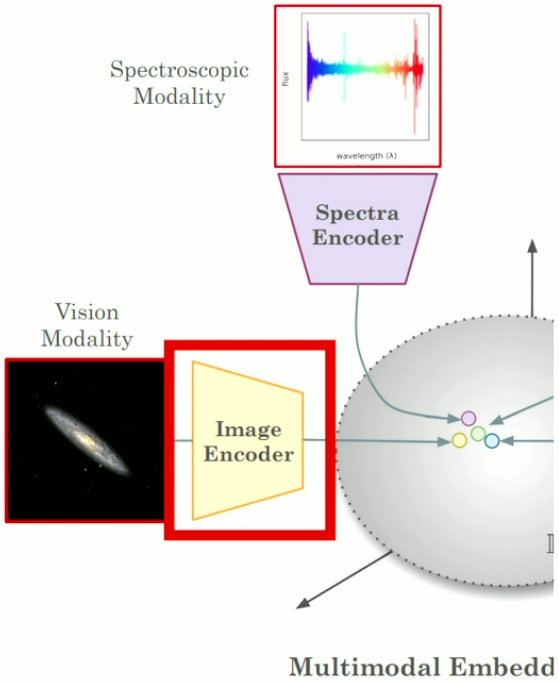
Kevin Schawinski
Modulos AG
kschawinski@modulos.ai

Ioana Ciucă
Stanford University
iciuca@stanford.edu

Abstract

Generating novel and creative scientific hypotheses is a cornerstone in achieving Artificial General Intelligence. Large language and reasoning models have the potential to aid in the systematic creation, selection, and validation of scientifically informed hypotheses. However, current foundation models often struggle to produce scientific ideas that are both novel and feasible. One reason is the lack of a dedicated dataset that frames Scientific Hypothesis Generation (SHG) as a Natural Language Generation (NLG) task. In this paper, we introduce *HypoGen*, the first data set of approximately 5500 structured problem-hypothesis pairs extracted from top-tier computer science conferences structured with a **Bit-Flip-Spark** schema, where the **Bit** is the conventional assumption, the **Spark** is the key insight or conceptual leap, and the **Flip** is the resulting counterproposal. *HypoGen* uniquely integrates an explicit **Chain-of-Reasoning** component that reflects the intellectual process from **Bit** to **Flip**. We demonstrate that framing hypothesis generation as conditional language modelling, with the model fine-tuned on **Bit-Flip-Spark** and the **Chain-of-Reasoning** (and where, at inference, we only provide the **Bit**), leads to improvements in the overall quality of the hypotheses. Our evaluation employs automated metrics and LLM judge rankings for overall quality assessment. The timing of this work is critical as AI systems increasingly participate in scientific discovery processes, requiring structured approaches to hypothesis generation. We release *HypoGen* under an MIT license.

UniverseTBD is going MultiModal



Credit: Dimitrios Tanoglidis

AstroLLaVA: Towards the Unification of Astronomical Data and Natural Language

Sharaf Zaman[1,*] **Michael J. Smith**[1,†] **Pranav Khetarpal**[1,2]
Rishabh Chakrabarty[1,3] **Michele Ginolfi**[1,4] **Marc Huertas-Company**
Maja Jabłońska[1,5] **Sandor Kruk**[6] **Matthieu Le Lain**[7,8]
Sergio José Rodríguez Méndez[1,9] **Dimitrios Tanoglidis**

*sharaf.email †mike@mjjsmith.com

[1]UniverseTBD [2]Indian Institute of Technology Delhi [3]Intelligent Internet Inc.
[4]University of Florence [5]ANU RSAA [6]European Space Agency [7]IRISA
[8]Université Bretagne Sud [9]ANU School of Computing

Abstract

We present AstroLLaVA, a vision language model for astronomy that enables interaction with astronomical imagery through natural dialogue. By fine-tuning the LLaVA model on a diverse dataset of ∼30k images with captions and question-answer pairs sourced from NASA's 'Astronomy Picture of the Day', the European Southern Observatory, and ESA/Hubble Space Telescope, we create a model capable of answering open-ended questions about astronomical concepts depicted visually. Our two-stage fine-tuning process adapts the model to both image captioning and visual question answering in the astronomy domain. We demonstrate AstroLLaVA's performance on an astronomical visual question answering benchmark and release the model weights, code, and training set to encourage further open source work in this space. Finally, we suggest a roadmap towards general astronomical data alignment with pre-trained language models, and provide an open space for collaboration towards this end for interested researchers.

Accepted to ICLR 2025 FMSci W

Sharaf Zaman (ANU)

Mike Smith (Aspia)

UniverseTBD is going MultiModal: sharing our learnings

Dimitrios Tanoglidis (WBA)

Multimodality and Multimodal Models in Astrophysics: A Tutorial, *Early-Stage* Review, and the Road Ahead

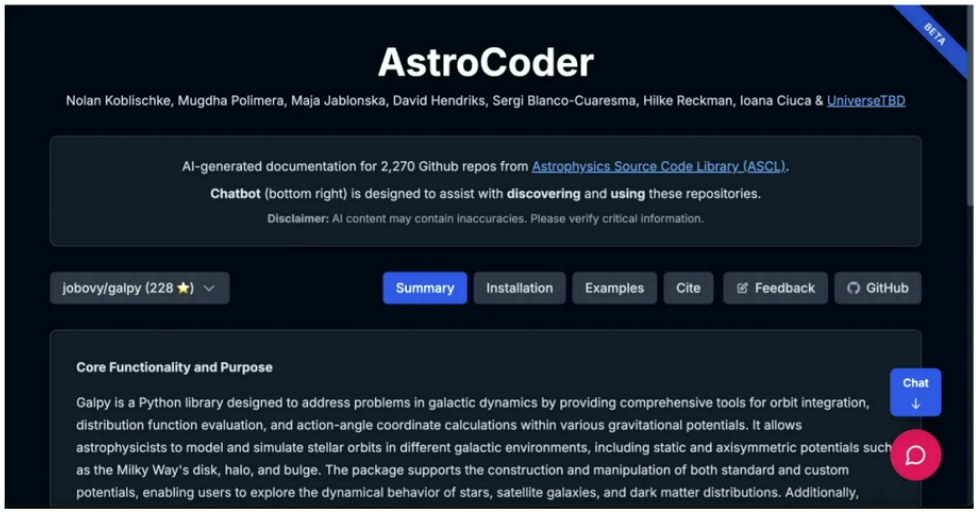
DIMITRIOS TANOGLIDIS AND UNIVERSETBD

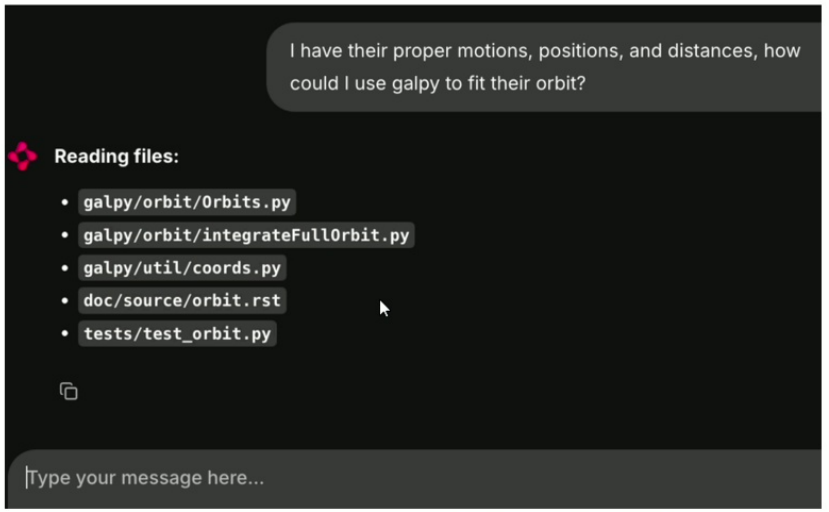
ABSTRACT

Astrophysics has always been a multimodal science, drawing insights from the integration of diverse data types, such as images, spectra, and time-series (photometry), both observed and simulated. With the growing volume and complexity of data coming from current and upcoming astronomical surveys, machine learning methods capable of handling and aligning multiple modalities are becoming increasingly important. This paper serves as a hybrid tutorial, an early-stage review, and a white paper on the emerging role of multimodal AI in astrophysics. We clarify terminology - distinguishing between traditional, foundation, and generative multimodal models. We explain the core technical ideas behind modern approaches such as contrastive representation learning and generative vision-language models. We discuss how these models can be trained or fine-tuned for astrophysical use cases, and survey the relatively limited but growing body of work applying them to astronomical data. We also highlight useful tools (e.g. agents, and retrieval-augmented generation) and available datasets. We conclude by discussing potential future directions and open challenges, emphasizing the immense promise of multimodal AI in opening new paths for discovery in astrophysics.

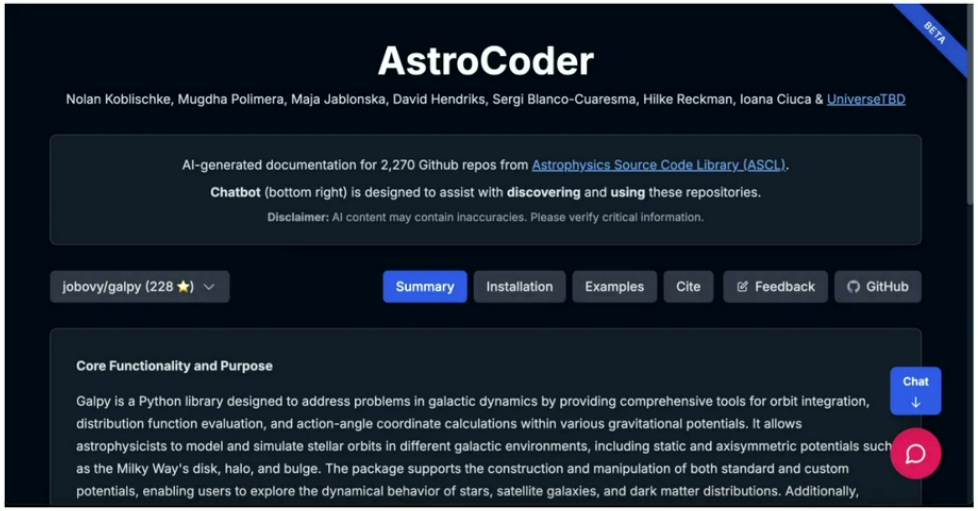
Tanoglidis et al., in prep

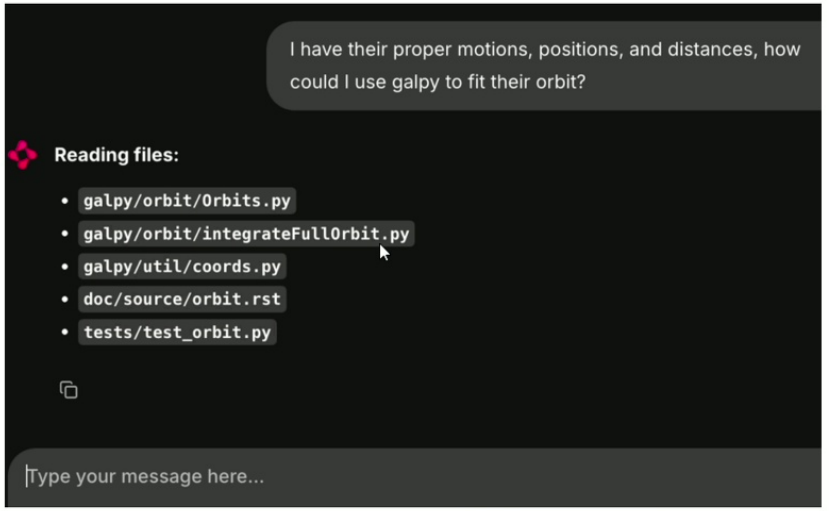
UniverseTBD is going agentic with AstroCoder





UniverseTBD is going agentic with AstroCoder





- AI summaries and code examples for 2,270 astro repos
- Search and coding agents help users **discover** and **work** with these tools