

# Chatbots for Astrophysics

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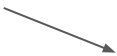
# A chatbot to help you learn



You're thinking of using a new tool or data source. You're not sure where to start.

- Read the documentation (can be tedious and hard to find what you need)
- Ask a colleague (you may not find someone with the needed knowledge and time)
- Ask ChatGPT (information can be hard to verify, links may not work)
- Ask the project's RAG chatbot

# Large Language Models (LLM)

**Language Model**: Predict the next word (or word-piece), based on the preceding context  
 (token)

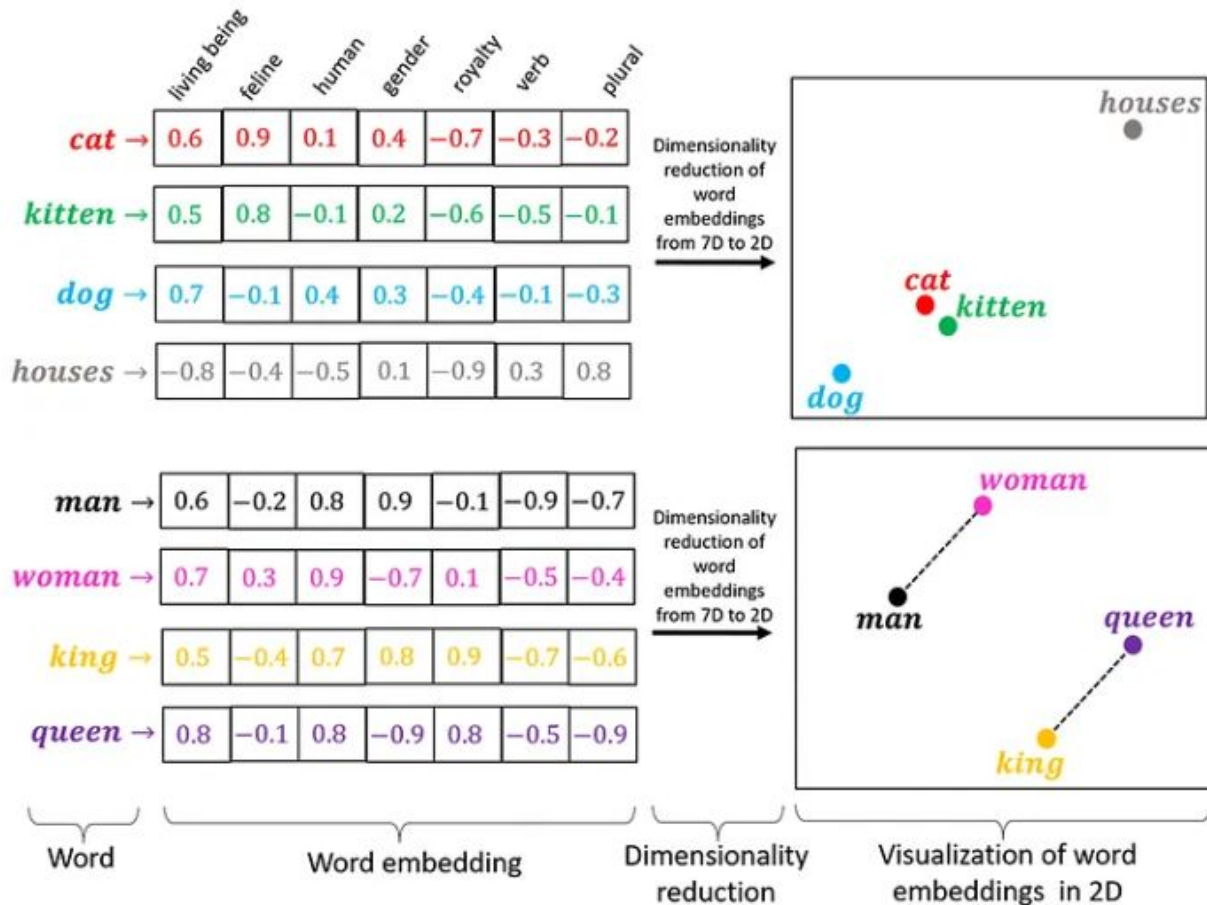
**Generative Model**: Can produce the kind of stuff that it was trained on (e.g. text, images)

**Large**:

- Large data: Pretrained on lots and lots of text (a lot of it from the internet)
- Large model: Deep learning model with billions of parameters

→ A modern LLM is a very sophisticated **next word prediction** machine, trained on a huge amount of text

# Word embeddings



Embeddings:

Vector representations in a high-dimensional space

Similar words get similar representations

# GPT: Generative Pre-trained Transformer

## Transformer:

- Efficient deep learning architecture
- Only left-to-right predictions, suitable for text generation
- Attention mechanism: learns which aspects of the context are most relevant

Made it possible to train a much larger model than before, making better use of context

→ Chat GPT (GPT 3.5 has 175 billion parameters)

- Initial training: Gets a sense of language and ‘What would the internet say?’
- Fine-tuning / Instruction tuning: additional training on more specific data (following instructions, answering questions, ...) ‘What is a good thing to say after this type of prompt?’
- Reinforcement learning with human feedback (RLHF): Learn what responses humans like (friendly, helpful style, etc)

Prompt: some text for the model to complete or instructions for the model to follow

## Use cases

- Brainstorming
- Spelling / grammar / editing
- Finding information
- Coding
- Drafting / writing text
- ...

## Challenges

- The model gets the gist of things, but does not memorize exact details
  - Text sounds plausible but contains incorrect information
  - Non-existing weblinks or references
- Biases in training data are reproduced and easily amplified
- The model has not seen the most recently published texts
- Computational costs

Many other but similar LLMs developed: LLaMa, Mistral, Claude, Olmo...(Some more open than others)

# Our Use Case

## Finding information and learning through natural dialog

LLM chatbot like ChatGPT:

- Free form query
- Answer tailored to user's needs (e.g. expertise level)
- Follow-up questions in natural dialog

Missing:

- Reliability
- Verifiable sources

# A custom chatbot with reliable sources

## Retrieval-Augmented Generation

- Collection of trusted documents (more easily updated than LLM)
- Relevant passages are retrieved (search)
- The language model is asked to respond to the user's query, using only the information from the retrieved passages
- Links to documents are provided along with the LLM's answer

## Advantages:

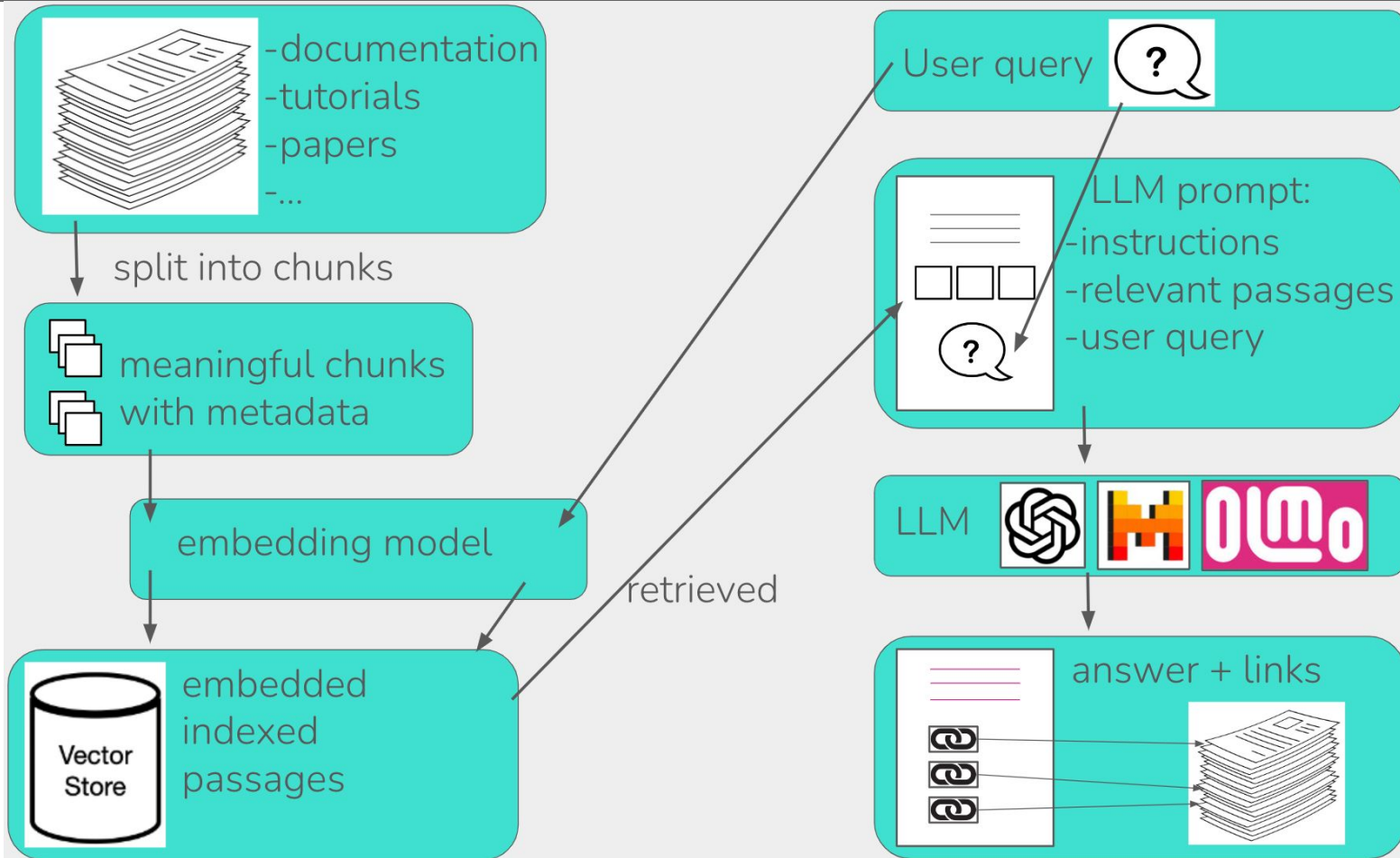
- Answer based on reliable sources
- Working links to original documents

## Challenges:

- Retrieval needs to be good
- LLM will still occasionally produce inaccuracies



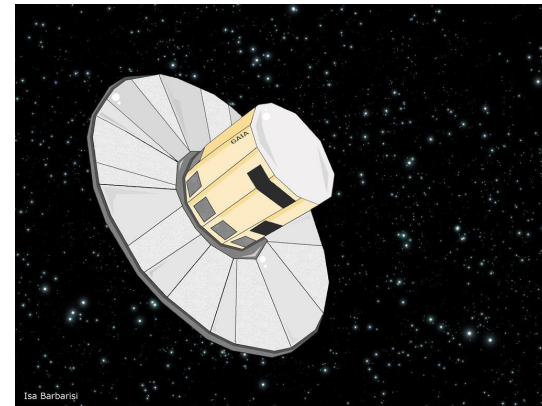
# Retrieval-Augmented Generation (RAG)



# Examples for Astrophysics

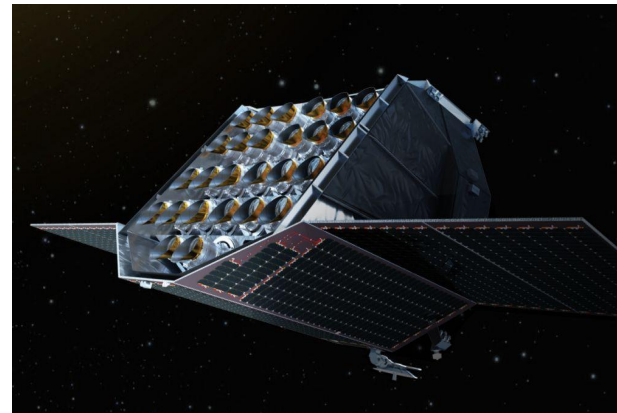
Gaia <https://gaiachat.streamlit.app/>

- Long-running ESA mission
- ETA final data release: 2030
- Complex data products
- Helpdesk available for limited time
- Data relevant well beyond mission end date
- Prototype with DR3 documentation and release papers



PLATO <https://platochat.streamlit.app/>

- Upcoming ESA mission
- Launch: end of 2026
- Prototype with PLATOpub papers



# Smart Portal for internship opportunities

Students:

- What opportunities exist?
- How to find something that is a good fit?

Companies:

- Who to reach out to to find interested students?

Smart portal:

- Central sign-up for companies
- Companies provide descriptions of possible projects and expectations
- Students talk to chatbot to discover opportunities and refine their search

# Related work

Fine-tuning models on Astrophysics papers:

- AstroLLaMa (Nguyen et al. 2023): LLaMa 2 fine-tuned on astrophysics abstracts

Studying use of LLMs in Astrophysics writing:

- Evidence of use of LLM in papers (Astarita et al. 2024)
- Writing and evaluation of observing proposals (Jerabkova et al. 2024)

Chatbots and knowledge systems for Astrophysicists:

- Evaluation framework for RAG in astrophysics (Wu et al. 2024)
- Pathfinder (Iyer et al. 2024): Literature review and knowledge discovery

# Conclusions

LLMs are powerful next word prediction machines with many potential use cases in text processing and generation

Growing body of work exploring usefulness of LLMs in Astrophysics

LLM chatbot allows for free form dialogue and responses tailored to the user

RAG provides the LLM with reliable up-to-date information to base responses on

RAG provides links that work for the user to check the information

**A RAG chatbot has the potential to boost learning  
and minimize the need to read boring documentation**