A Tool for Automated Identification and Reconstruction of Special Physical Phenomena

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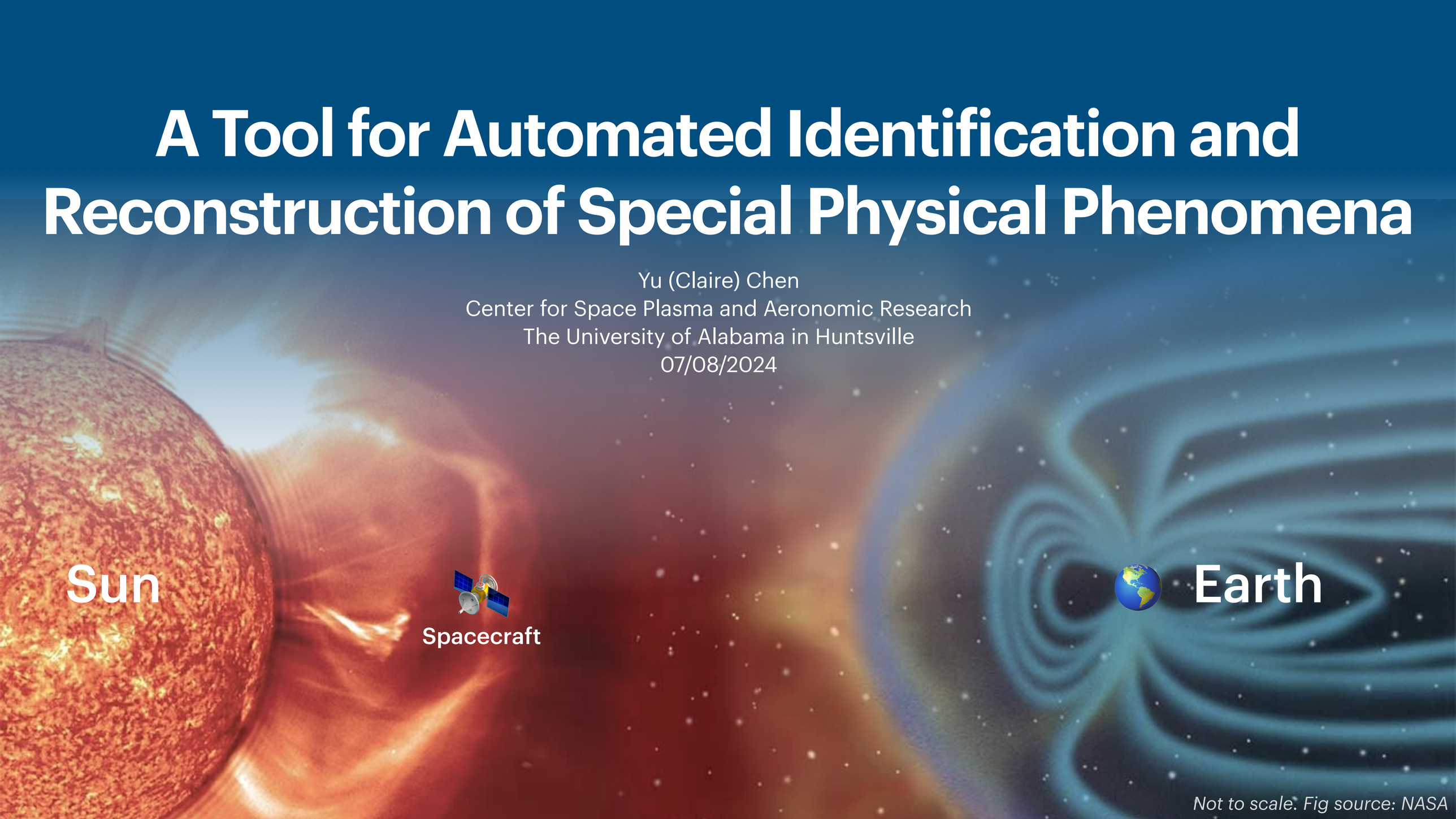


From Data to Event Identification

Daily Example

For a smoothie store without CCTV where we only have records of smoothie ingredient usages, how do we know if any strawberry smoothies were being made during a specific time period?

Theoretically Amount Needed	🍓 Strawberries: 150g	🥛 Milk: 120 ml	🧊 Ice Cubes: 4-5 cubes
	🍌 Banana: 100g	🍯 Honey: 1-2 tsps	
	🥄 Yogurt: 125g	🌪️ Blender: Must have	
Recorded Usage 12:00-12:10 1/1/2024	🍓 Strawberries: 152g	🥛 Milk: 125 ml	🧊 Ice Cubes: 3 cubes
	🍌 Banana: 102g	🍯 Honey: 1 tsp	
	🥄 Yogurt: 123g	🌪️ Blender: Used	

Event Confirmation & Follow-up

- Recorded usage ≈ Theoretical amount needed
  - Very likely for a strawberry smoothie to be made during 12:00-12:10 on 1/1/2024
- Can derive additional/nutritional values as follow-up:
  - protein content, sweetness level, etc.

From Data to Event Identification

Automated Tool in This Project

Automatically extract & process data, identify special physical phenomena (events), conduct data analyses, derive event characteristics, and output files.

Theoretically Amount Needed

- 🍓 Strawberries: 150g
- 🍌 Banana: 100g
- ...

Targeted events follow theoretical patterns, which can be described by a series of complex formulas

Theoretical Prediction

Recorded Usage 12:00-12:10 1/1/2024

- 🍓 Strawberries: 152g
- 🍌 Banana: 102g
- ...

Raw Data 🛰️: few TB+, i.e., equivalent to databases.
Processing: Take segments only and transform to high-level data products

Processed Observational Data

Event Confirmation & Follow-up

- Recorded usage ≈ Theoretical...
  - Very likely for a strawberry...
- Can derive additional values...
  - protein content, etc.

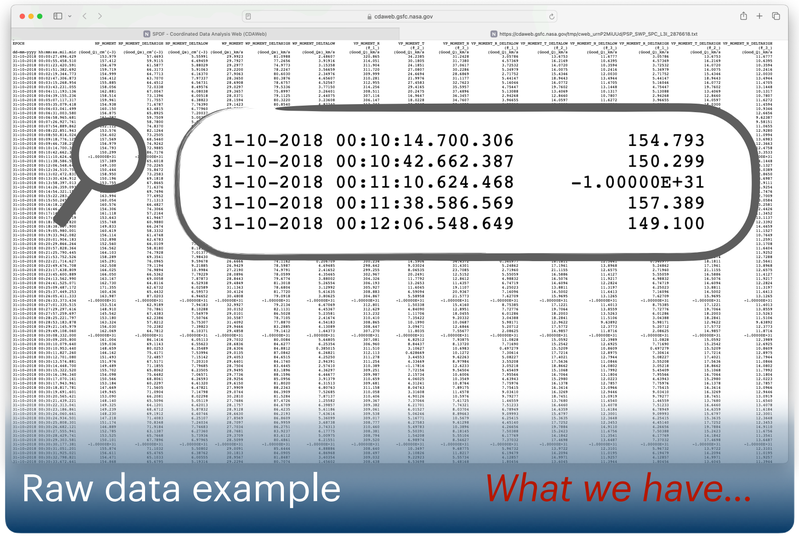
Event identification by checking Observation ≈ Theoretical prediction?
Derive parameters for each identified event & build **database**

Event Identification & Database

What can we get with this tool?

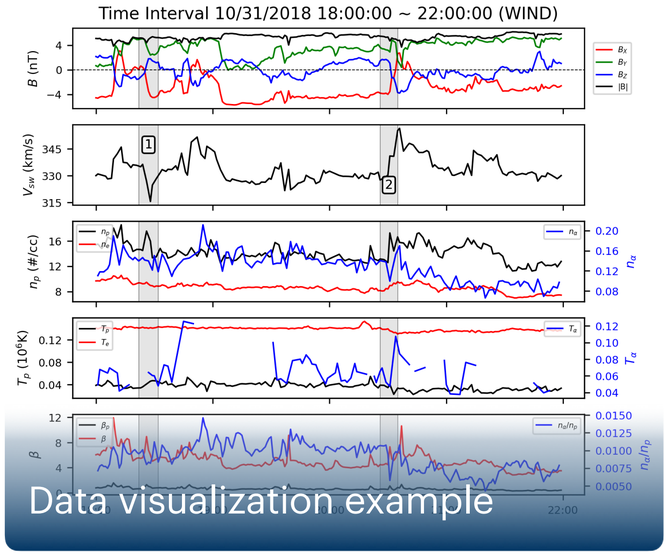
```
detection(rootDir, spacecraftID='WIND', timeStart=datetime(2018,10,31,18,0,0), timeEnd=datetime(2018,10,31,22,0,0),
duration=(10,30), includeTe=True, includeNe=False, Search=True, CombineRawResult=True, GetMoreInfo=True,
LabelFluxRope=True, B_mag_threshold=5.0, shockList_DF_path=shockList, allowIntvOverlap=False)
```

☜ *What we use...*



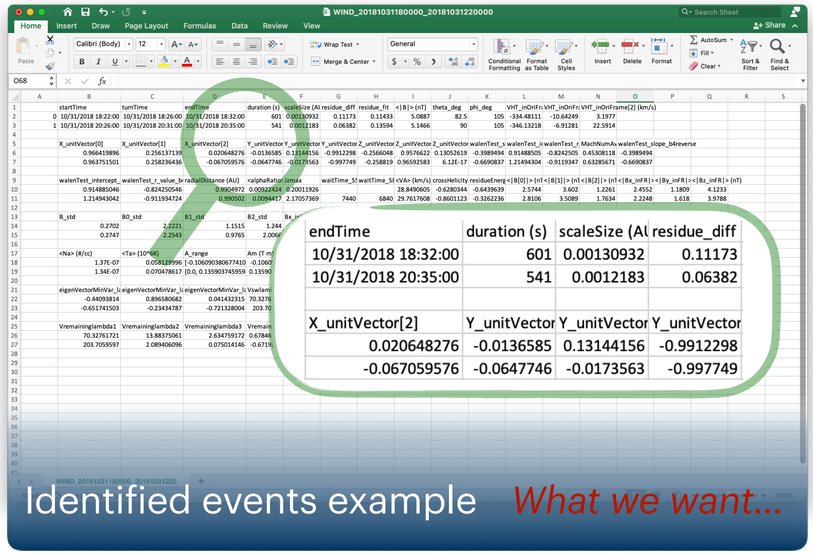
Raw data example *What we have...*

Time-series spacecraft data with outliers. Data volumes depend on length of time period and data resolution.



Data visualization example

Automatically generate **20+** different figures for comprehensive analysis.



endTime	duration (s)	scaleSize (Al	residue_diff
10/31/2018 18:32:00	601	0.00130932	0.11173
10/31/2018 20:35:00	541	0.0012183	0.06382

X_unitVector[2]	Y_unitVector	Y_unitVector	Y_unitVector
0.020648276	-0.0136585	0.13144156	-0.9912298
-0.067059576	-0.0647746	-0.0173563	-0.997749

Identified events example *What we want...*

The final list including 2 identified events. Proactive step: Each entry is supplied with **~100** derived parameters.

Automated Tool: Development

Major Functions: pull & process data, identify special events, extract characteristics, and output files.

Choices of Programming | Data Extract, Transform, & Load | Data Performance & Data Security | Automation Settings | Documentation | Version Control

1. Choices About Programming/Software:

Software/Programming	Pros	Cons
Python	Open source and free; resourceful community providing multiple tools	Requires learning and manual installation; not all tools are reliable
Matlab	Powerful for mathematical computations	License is not free; very slow for large-scale calculations
Excel	Widely used for daily tasks	Limited capacity and slow for large files; unable for complex 2D & 3D computations

Final Choices:

- Python: all data processing steps, calculations, analytics, and visualization
- Excel: share event lists per user requests
- SQL (PostgreSQL): for efficient data storage and database management (internal use)

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2. Data Extract, Transform, & Load (ETL) Pipelines:

- Data Extraction: extract data from sources (database, file, and online website, etc.)
  - This tool: Python + supported tool to extract data segments from data archives
- Data Transformation/Processing: prepare data for further analysis
  - This tool: Common transformations (1-4)

1. Convert Data Types	1.02 blender to 1 blender, convert float to integer
2. Drop Duplicates	One & only one record per timestamp, remove repeated
3. Identify & Clean Outliers	Beyond expected range... Data integrity issue
4. Derive New Products	E.g., Pressure = Density * Temperature * Factor

3.1 Inserting NaN/Null	Have records at 12:00 & 12:10 only >> Insert NaN/Null at 12:05
3.2 Interpolation	Used 2 🍌 from 12:00 to 12:10 >> Possibly 1 🍌 by the middle at 12:05
3.3 Downsampling	Have records at 12:00 & 12:10 only >> Analyze broader intervals > 10 mins
3.4 Replacement	Honey is out of stock, replace it with sweetener

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- Data Loading: load transformed/processed data into databases or saved as files
  - This tool: output final event lists as CSV files to share with the others and/or load into databases

3. Data Performance:

- This tool: establish checkpoints to check efficiency, accuracy, etc. & show warnings in execution window

4. Data Security:

- This tool: N/A since files and results are intended to be public, e.g., publish identified events to online database
- Feasible if needs to be confidential: add access limit, require users to login, etc.

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5. Automation Settings:

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```

- **With an automated tool:** only need to run 1~3 lines to get final results & figures
- **Optional automation settings**
  - Controller: syntax like Search=True
    - Setting it to be True: activate the corresponding modules
    - Setting it to be False: skip the corresponding modules or finish this round
  - Different combinations result in different outputs — ensuring flexible usage to meet different needs
  - Users also opt to edit pre-written script files — customizing adjustments and extending

Automated Tool: Development

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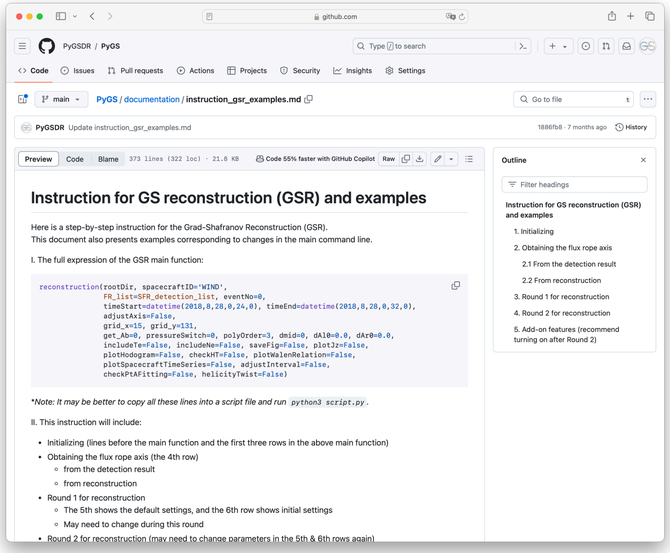
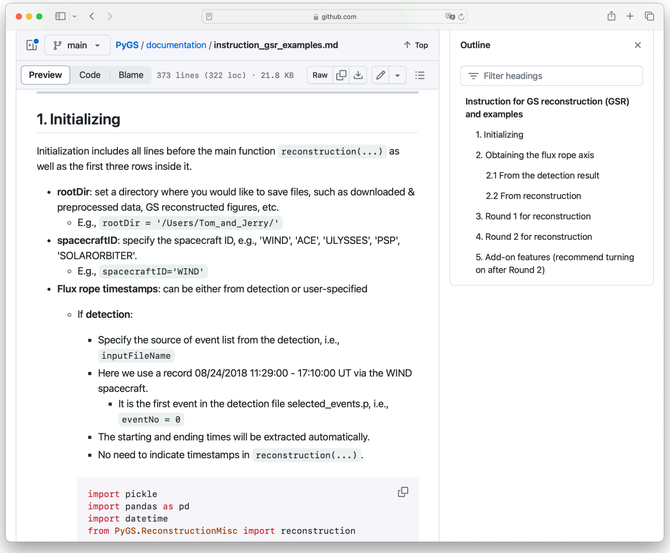
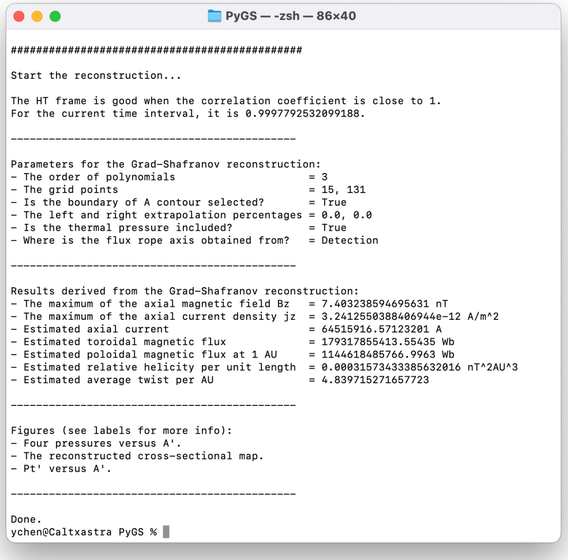
6. Documentation: guide users on how to use the tool and understand its functions

- Documentation & instructions within code files & on GitHub (left two figures); video introduction available
- Built-in real-time tips & guidance on Python execution window (right figure)







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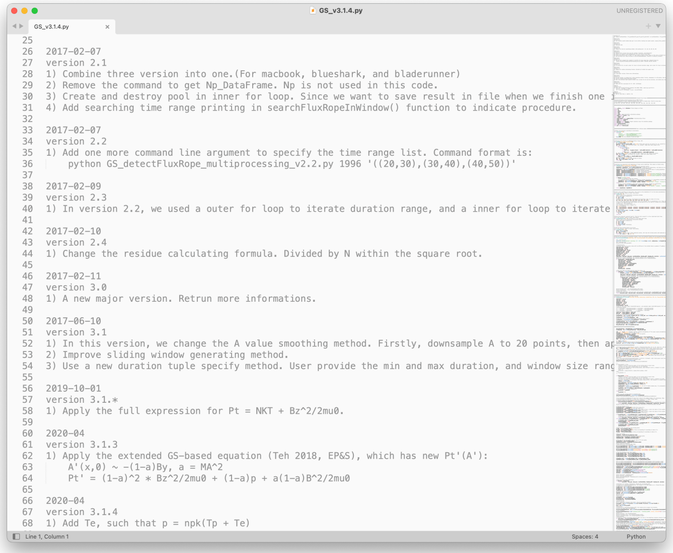
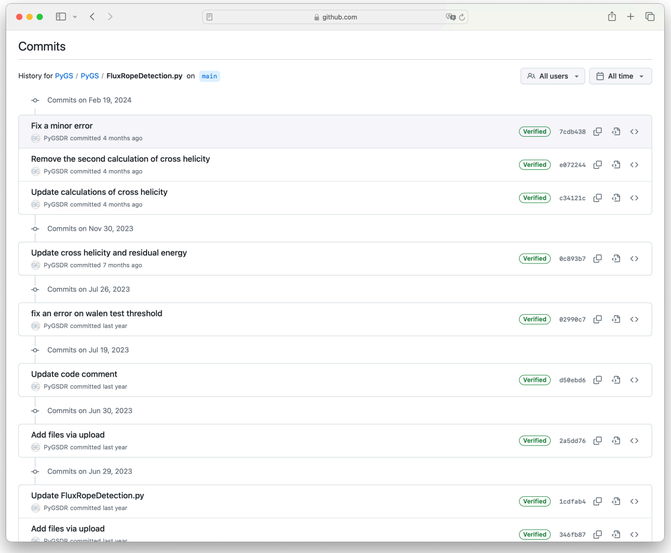
7. Version Control: Track changes, allow reversion to previous states, and backup

- Before launching: manage local files & document each version change with a brief description (middle figure)
- After launching: from 0.0.1 (beta/public test) to 1.0.0 (official); changes are available on GitHub (right figure)

Software Version "x.y.z"

- x: major update
- y: minor update
  - e.g., adding new features
- z: fix bugs
  - generally do not impact the major use





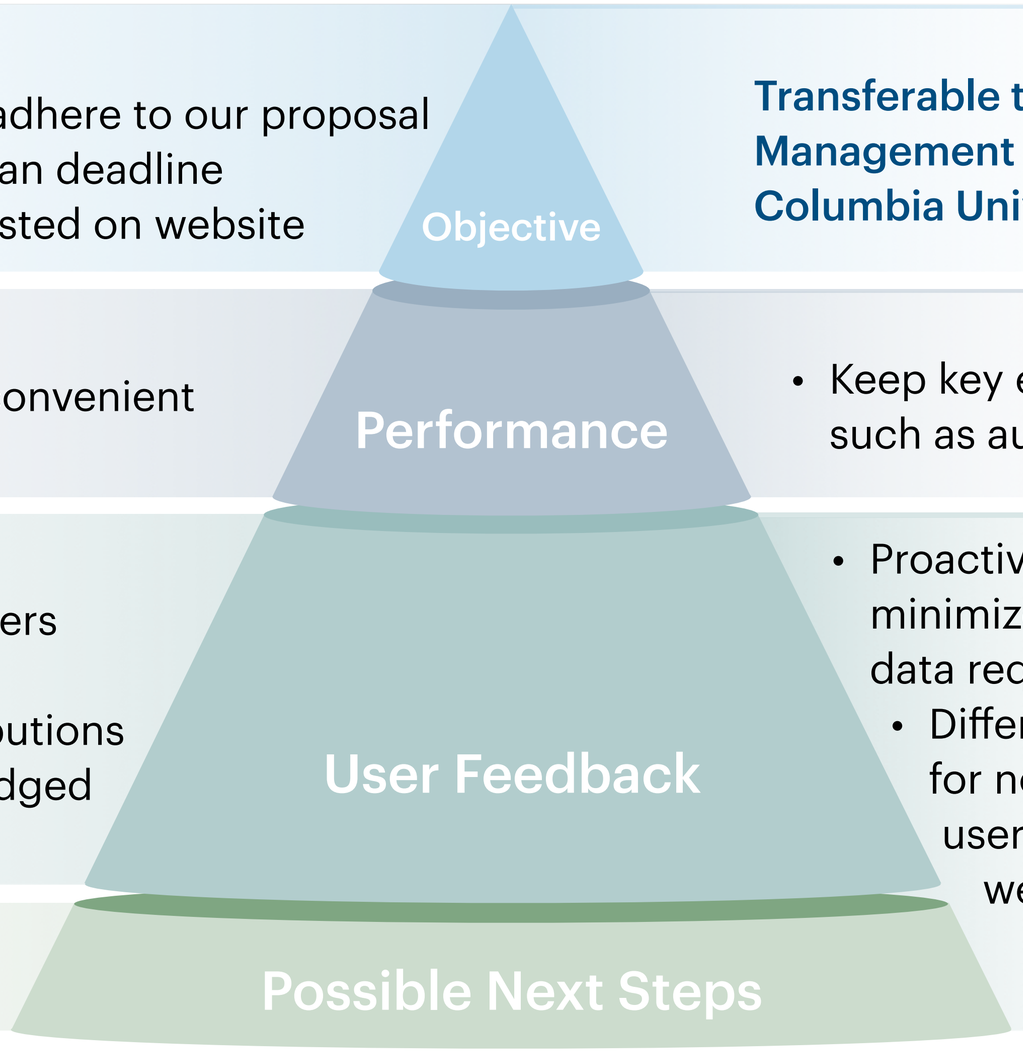
Automated Tool: Post Evaluation & Future Work

Did we meet our objectives?
- This is a NASA-funded project, and thus needs to adhere to our proposal
- We delivered the tool/package 5 months earlier than deadline
- Met the community's evaluating criteria and was listed on website

Does the tool perform well?
- All-in-one package to conduct various analyses - convenient
- Successfully run on different OS/environments

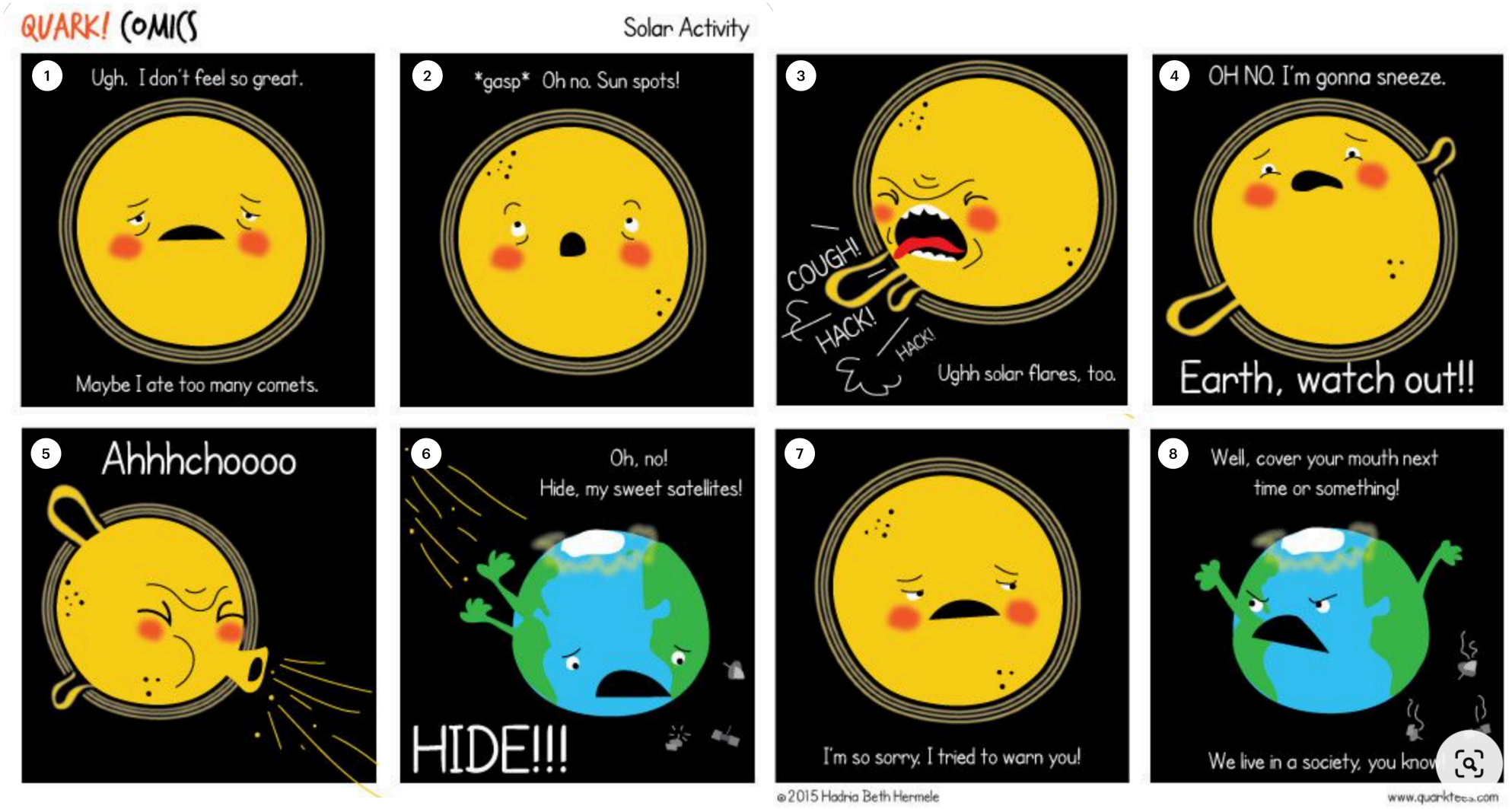
What has the user feedback been like?
- Before the public testing: tested by the internal users whose feedbacks helped refine the tool
- User-friendly features, flexibility, & support contributions
- Positive feedbacks & our work has been acknowledged in several journal publications

Possible Next Steps
- Maintenance & Add new features if time permits



Transferable to Data Management Role at Columbia University

- Keep key elements such as automated ETL
- Proactive approach to minimize frequent data requests
  - Different strategies for non-technical users such as website request


QUARK! COMICS
Solar Activity
1
Ugh. I don't feel so great.
Maybe I ate too many comets.
2
gasp Oh no. Sun spots!
3
COUGH!
HACK!
HACK!
Ughh solar flares, too.
4
OH NO. I'm gonna sneeze.
Earth, watch out!!
5
Ahhhchoooo
6
Oh, no!
Hide, my sweet satellites!
HIDE!!!
7
I'm so sorry. I tried to warn you!
8
Well, cover your mouth next time or something!
We live in a society, you know
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www.quarktees.com

Thanks!