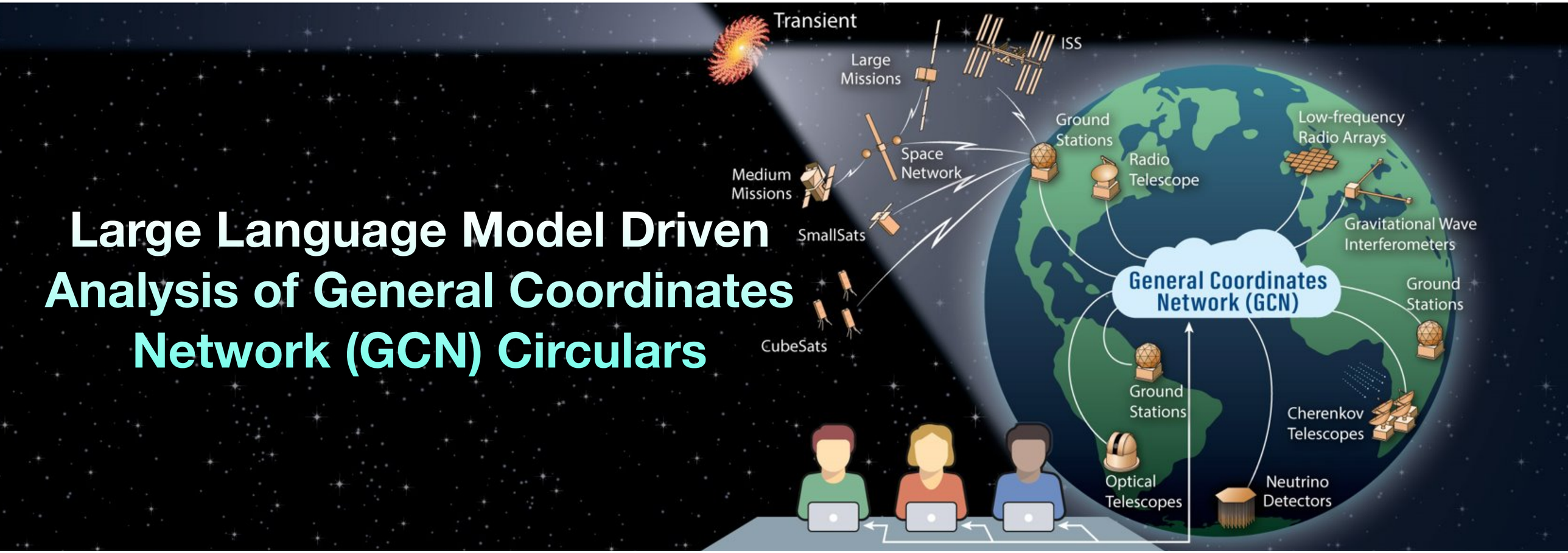
RAPID Response: Hot-wiring the Next Generation of Time-Domain Science

March 25th, 2026

Large Language Model Driven Analysis of General Coordinates Network (GCN) Circulars



Dr. Vidushi Sharma, Post-doc, NASA-GSFC/UMBC

Co-authors: Ronit Agarwala, Judith Racusin, Leo Singer, Tyler Barna, Eric Burns, Michael Coughlin, Dakota Dutko, Courey Elliott, Rahul Gupta, Ashish Mahabal, and Nikhil Mukund

Two Types of GCN data products:

Machine-Generated Alerts

GCN Notices

```
TITLE:            GCN/FERMI NOTICE
NOTICE_DATE:      Wed 26 Aug 20 22:10:07 UT
NOTICE_TYPE:      Fermi-GBM Flight Position
RECORD_NUM:       45
TRIGGER_NUM:      620172587
GRB_RA:           296.300d {+19h 45m 12s} (J2000),
                  296.250d {+19h 45m 00s} (current),
                  296.416d {+19h 45m 40s} (1950)
GRB_DEC:          +71.817d {+71d 49' 00"} (J2000),
                  +71.868d {+71d 52' 03"} (current),
                  +71.693d {+71d 41' 35"} (1950)
GRB_ERROR:        5.50 [deg radius, statistical plus systematic]
GRB_INTEN:        1078 [cnts/sec]
DATA_SIGNIF:      22.80 [sigma]
INTEG_TIME:       1.024 [sec]
GRB_DATE:         19087 TJD;   239 DOY;   20/08/26
GRB_TIME:         79782.72 SOD {22:09:42.72} UT
GRB_PHI:           20.00 [deg]
GRB_THETA:        150.00 [deg]
DATA_TIME_SCALE:  1.0240 [sec]
HARD_RATIO:       0.54
LOC_ALGORITHM:    3 (version number of)
MOST_LIKELY:       93%  GRB
2nd_MOST_LIKELY:    4%  Generic Transient
DETECTORS:        0,0,0, 0,1,1, 0,0,0, 0,0,0, 0,0,
SUN_POSTN:        156.00d {+10h 24m 01s}  +10.00d {+09d 59' 51"}
SUN_DIST:          94.05 [deg]   Sun_angle= -9.3 [hr] (East of Sun)
MOON_POSTN:       258.31d {+17h 13m 14s}  -22.27d {-22d 15' 56"}
MOON_DIST:         97.64 [deg]
MOON_ILLUM:       63 [%]
GAL_COORDS:       103.87, 21.63 [deg] galactic lon,lat of the burst (or transient)
ECL_COORDS:        41.25, 79.40 [deg] ecliptic lon,lat of the burst (or transient)
LC_URL:           http://heasarc.gsfc.nasa.gov/FTP/fermi/data/gbm/triggers/2020/bn200826923/
COMMENTS:         Fermi-GBM Flight-calculated Coordinates.
COMMENTS:         This trigger occurred at longitude,latitude = 209.65,1.28 [deg].
COMMENTS:         The LC_URL file will not be created until ~15 min after the trigger.
```

- By and for machines
- Fixed, predefined format
- Schema specific to each notice type

Human-written Reports

GCN Circulars

```
TITLE:   GCN CIRCULAR
NUMBER:  28298
SUBJECT: GRB 200826B: Fermi GBM detection
DATE:    20/08/27 21:10:30 GMT
FROM:    Christian Malacaria at NASA-MSFC/USRA  <cmalacaria@usra.edu>

C. Malacaria (NASA-MSFC/USRA) and C.Meegan (UAH)
report on behalf of the Fermi GBM Team:

"At 22:09:42.72 UT on 26 August 2020, the Fermi Gamma-Ray Burst Monitor (GBM)
triggered and located GRB 200826B (trigger 620172587 / 200826923).

The on-ground calculated location, using the GBM trigger
data, was reported in GCN 28292.

The GBM light curve shows an exceptionally bright long GRB
with a duration (T90) of about 7.4 s (50-300 keV).
The time-averaged spectrum from T0-0.003 s to T0+ 12.544 s is
best fit by a Band function with Epeak = 410.3 +/- 5.6  keV,
alpha = -0.64 +/- 0.01, and beta = -2.52 +/- 0.04
The event fluence (10-1000 keV) in this time interval is
(1.414 +/- 0.006)E-04 erg/cm^2.
The 1.024-sec peak photon flux measured starting from T0+5.1 s in
the 10-1000 keV band is 110.1 +/- 0.7 ph/s/cm^2.

The spectral analysis results presented above are preliminary;
final results will be published in the GBM GRB Catalog:
https://heasarc.gsfc.nasa.gov/W3Browse/fermi/fermigbrst.html

For Fermi GBM data and info, please visit the official Fermi GBM Support Page:
https://fermi.gsfc.nasa.gov/ssc/data/access/gbm/"
```

- By and for humans (some automated)
- Freeform text (with established style)
- Citable (but not peer-reviewed)

GCN Circulars

Large-Language Models

Paper: Sharma et al 2026, ApJS
DOI: 10.3847/1538-4365/ae2e9c

https://github.com/nasa-gcn/circulars-nlp-paper

Why Language Model for Human-Written Text?

General Coordinates Network

Missions Notices Circulars Documentation

New Announcement Feature, Code of Conduct, Circular Revisions. See news and announcements

← Back | Text | JSON | Cite

GCN Circular 21520

Subject GRB 170817A: Fermi GBM detection
Date 2017-08-17T20:00:07Z (7 years ago)
From Andreas von Kienlin at MPE <azk@mpe.mpg.de>

A. von Kienlin (MPE), C. Meegan (UAH) and A. Goldstein (USRA)
report on behalf of the Fermi GBM Team:

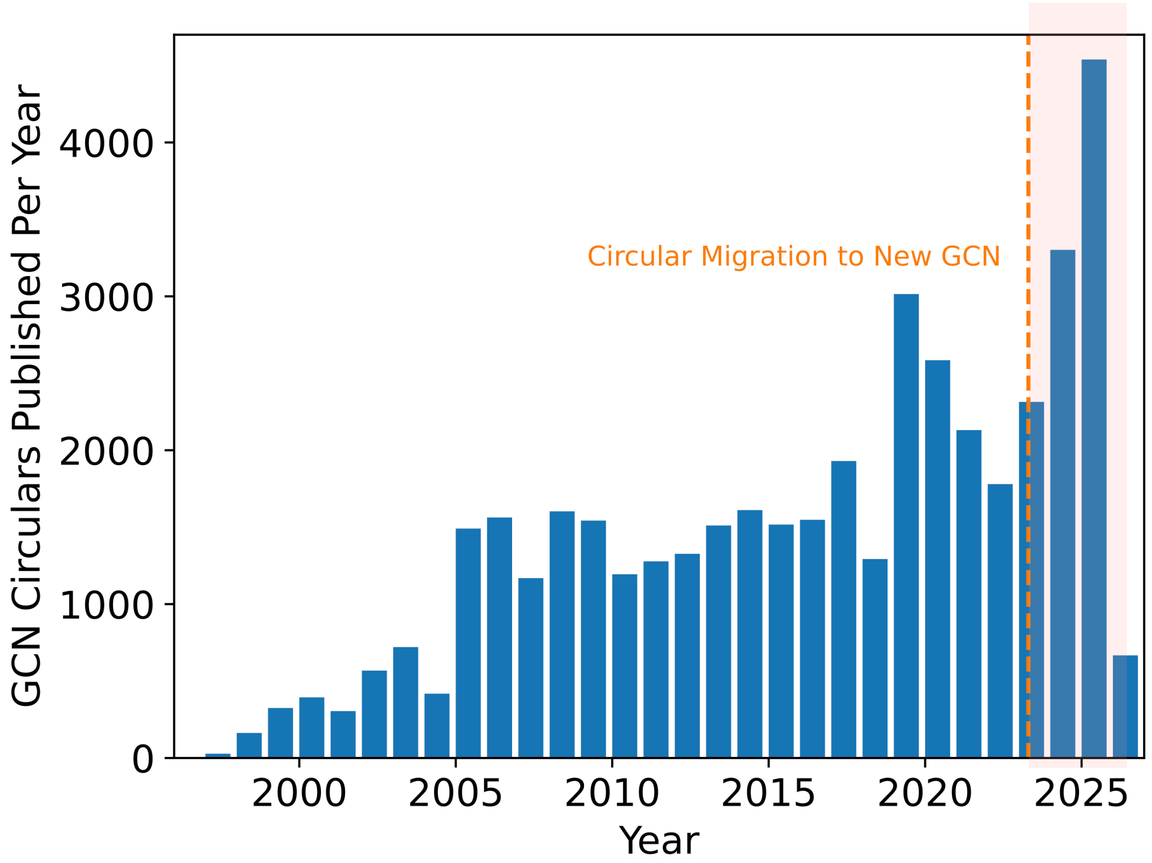
"At 12:41:06.47 UT on 17 August 2017, the Fermi Gamma-Ray Burst Monitor
triggered and located GRB 170817A (trigger 524666471 / 170817529).

The on-ground calculated location, using the GBM trigger
data, is RA = 176.8, DEC = -39.8 (J2000 degrees,
equivalent to 12 h 47 m, -39 d 48'), with an uncertainty
of 11.6 degrees (radius, 1-sigma containment,
statistical only; there is additionally a systematic
error which we have characterized as a core-plus-tail model, with 90% of
GRBs having a 3.7 deg error and a small tail suffering a larger than 10 deg
systematic error. [Connaughton et al. 2015, ApJS, 216, 32]).

The angle from the Fermi LAT boresight at the GBM trigger time is 91 degrees.

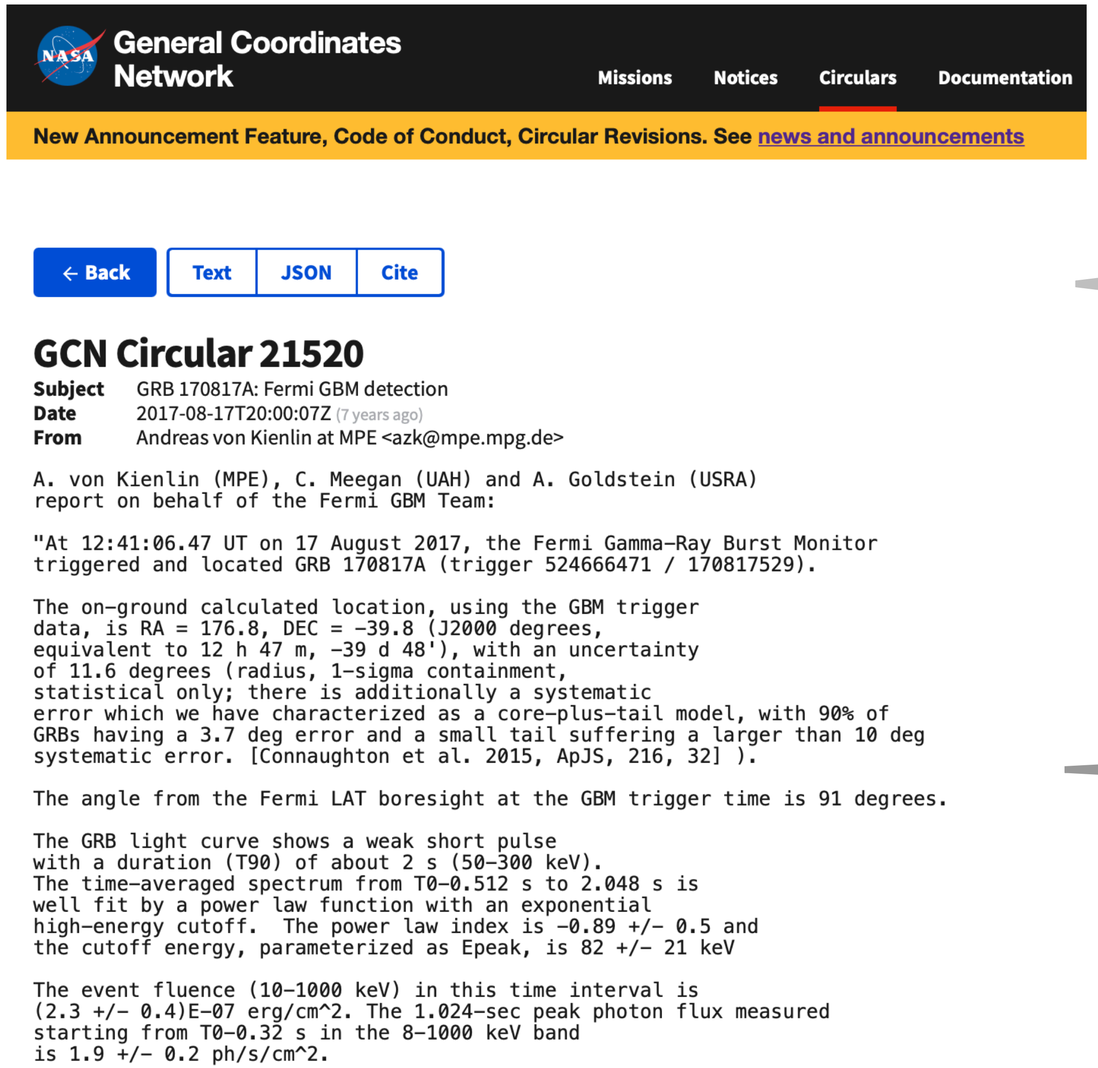
The GRB light curve shows a weak short pulse
with a duration (T90) of about 2 s (50-300 keV).
The time-averaged spectrum from T0-0.512 s to 2.048 s is
well fit by a power law function with an exponential
high-energy cutoff. The power law index is -0.89 +/- 0.5 and
the cutoff energy, parameterized as Epeak, is 82 +/- 21 keV

The event fluence (10-1000 keV) in this time interval is
(2.3 +/- 0.4)E-07 erg/cm^2. The 1.024-sec peak photon flux measured
starting from T0-0.32 s in the 8-1000 keV band
is 1.9 +/- 0.2 ph/s/cm^2.



- ✦ Human-written, Unstructured text
- ✦ Difficult to parse automatically
- ✦ Increasing Archive: >44K Circulars

From Unstructured Text To Scientific Knowledge



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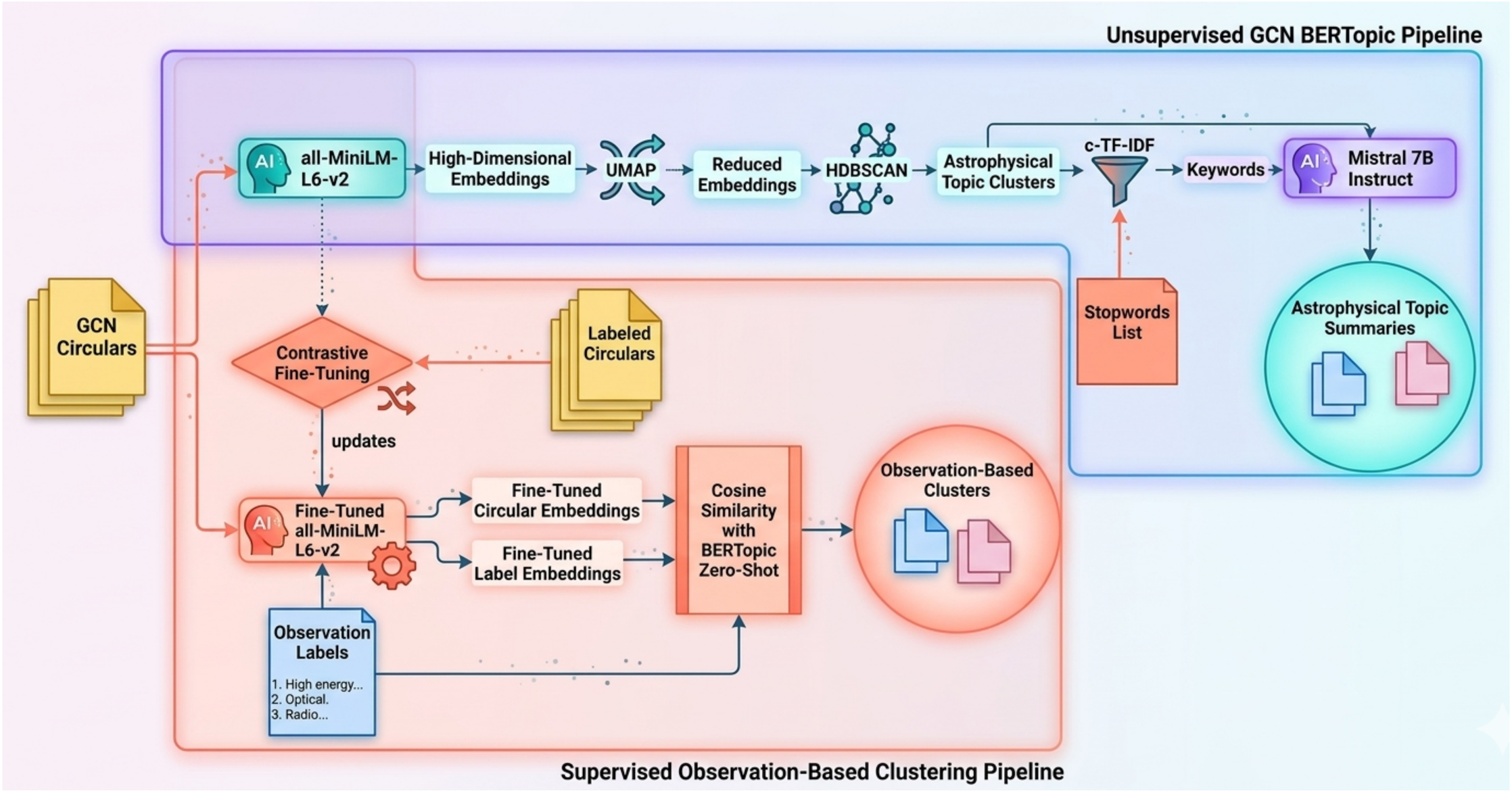
Topic Modeling

- Unsupervised Topic Classification
- Supervised Classification
  - Observation Type Clustering
  - Gravitational-wave Focused Cluster

Extracting Structured Information

Gamma-ray burst (GRB) Redshift (z)

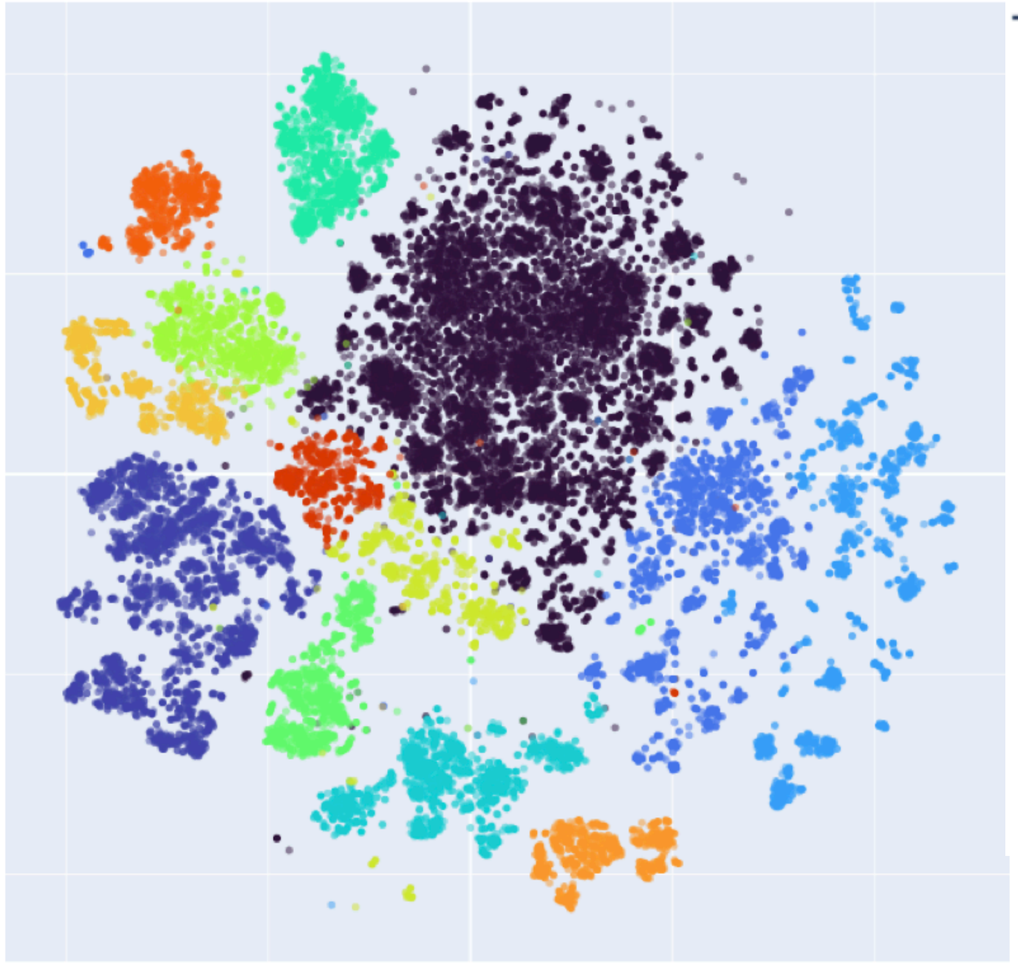
Topic Modeling Pipeline: Finding Pattern In Archive



Unsupervised Discovery of Astrophysical Topics

- BERT (Bidirectional Encoder Representations from Transformers)-based sentence transformer ‘all-MiniLM-L6-v2’
- Circulars are embedded and clustered based on semantic similarity
- Identify dominant topics, such as Optical afterglows, LIGO/Virgo GWs, Swift/BAT GRBs, Fermi/GBM events, Radio)
- Summarize each cluster using Mistral for concise, human-readable topic labels

t-SNE representation of GCN Topic Clusters



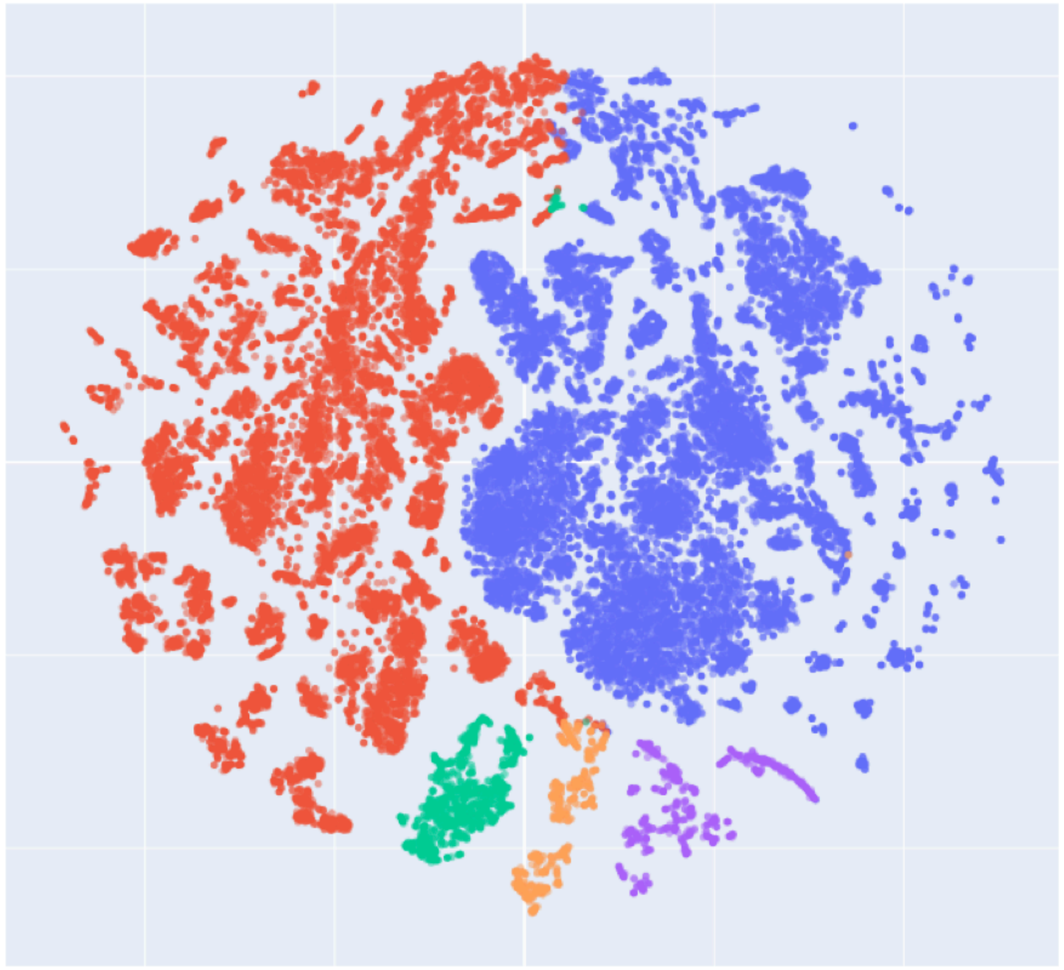
Topics (Circular Counts)

- grb_optical_afterglow_images (12384)
- bat_swift_burst_raj2000 (4355)
- icecube_ligovirgo_neutrino_ligo (3476)
- mastersaao_masteroafa_masterkislovodsk_mastertunka (2923)
- gbm_fermi_lat_degrees (2175)
- swiftuvot_uvot_exposures_reddening (1782)
- konuswind_chi2_peak_grb (1449)
- swiftxrt_xrt_cm2_s1 (1409)
- calet_burst_gammaray_ibas (1296)
- cm2_swiftxrt_powerlaw_unabsorbed (1156)
- gbm_fermi_degrees_localizationthe (1090)
- swiftxrt_uvot_xrtuvot_alignment (988)
- radio_vla_grb_nrao (971)

Supervised Classification by Observation Type

- Embed Circulars using the BERT-based sentence transformer all-MiniLM-L6-v2
- Fine-tune the embedding model using **contrastive learning**
- Classify Circulars into 5 observation clusters: **High-energy, Optical, Radio, Gravitational-Wave, Neutrino**

t-SNE representation: observation-based clusters



Topics (Circular Counts)

- Optical Observations (19637)
- High Energy Observations (17489)
- Radio Observations (1368)
- Neutrinos (1170)
- Gravitational Wave (842)

Evolution of Multimessenger Astronomy

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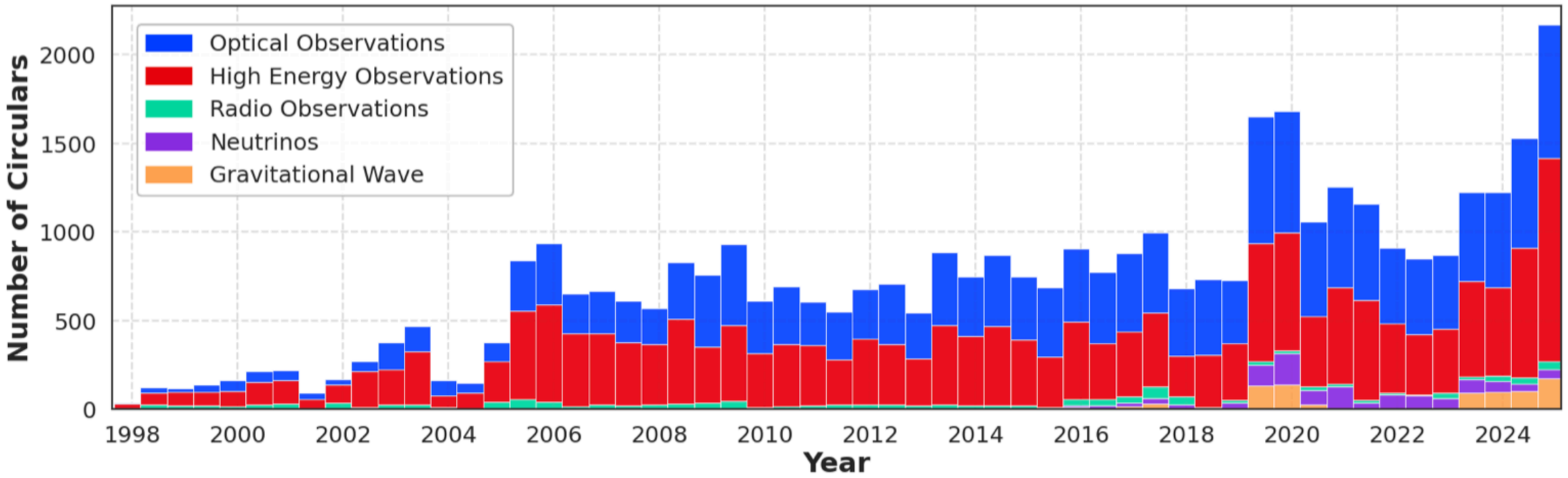
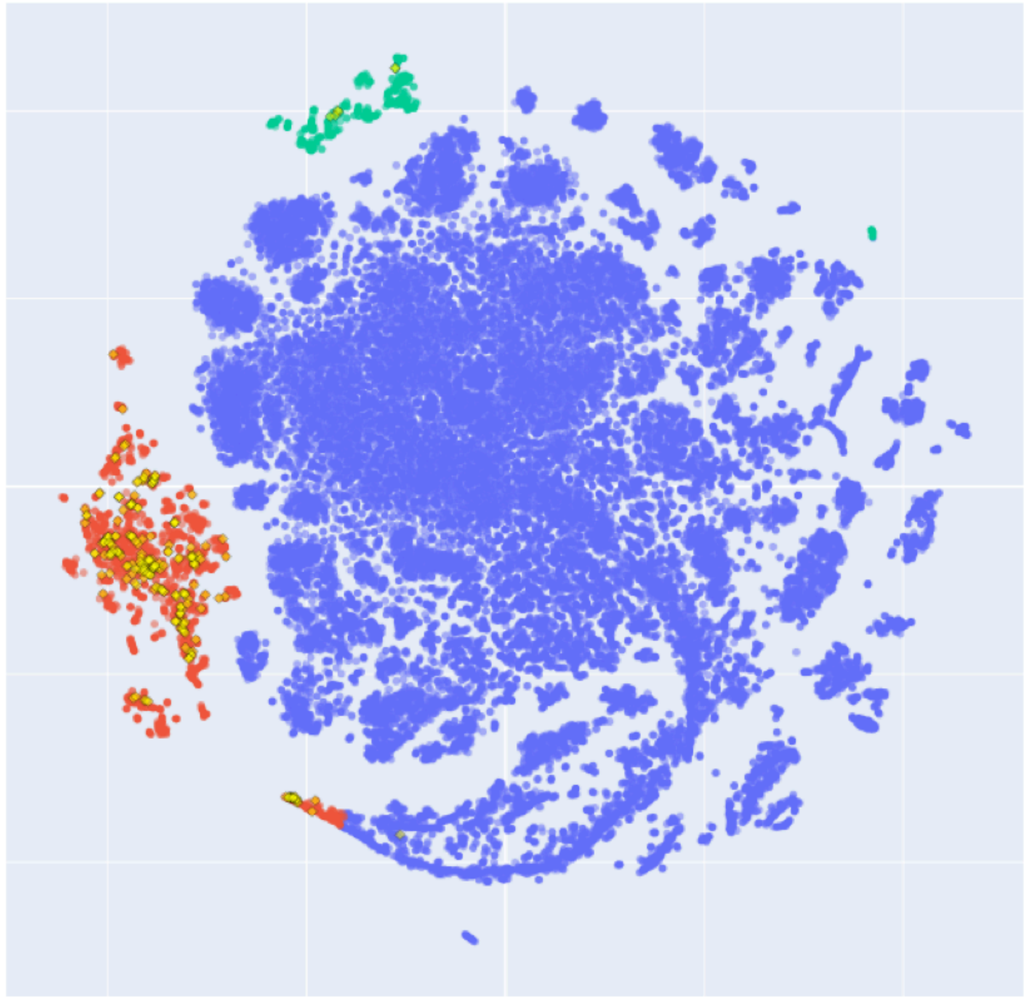


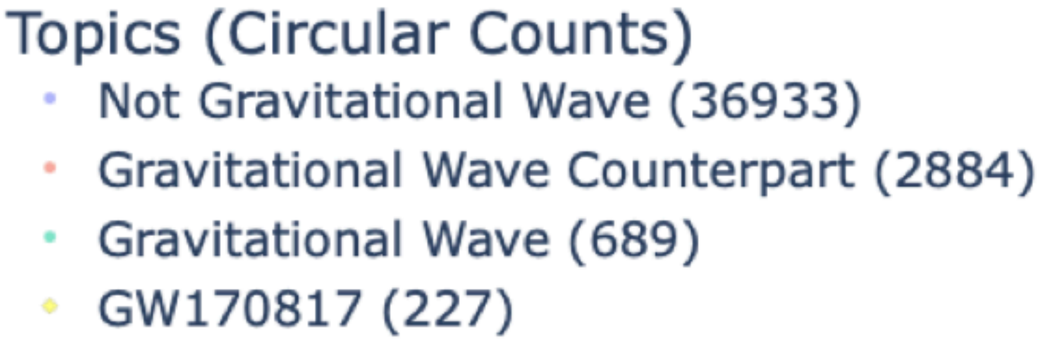
Observation-type Clustering Diagram: Fantasy-Inspired Land

Supervised Clusters: Gravitational-Wave Events & Counterparts

- Contrastive fine-tuning trains the model to recognize GW-related text
- Classified: GW, GW-Counterpart & non-GW clusters. **170817A Circulars manually marked!**

t-SNE representation: GW-based clusters





Code: https://github.com/nasa-gcn/circulars-nlp-paper

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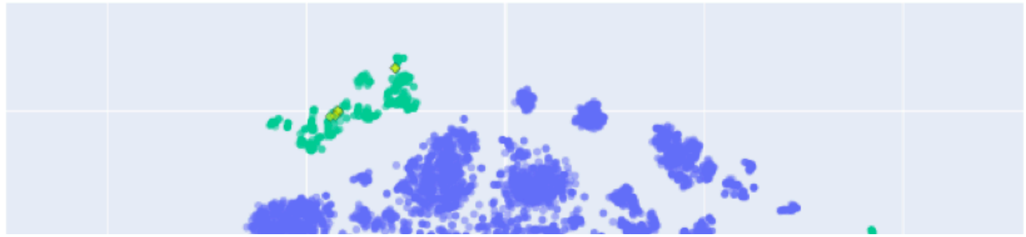
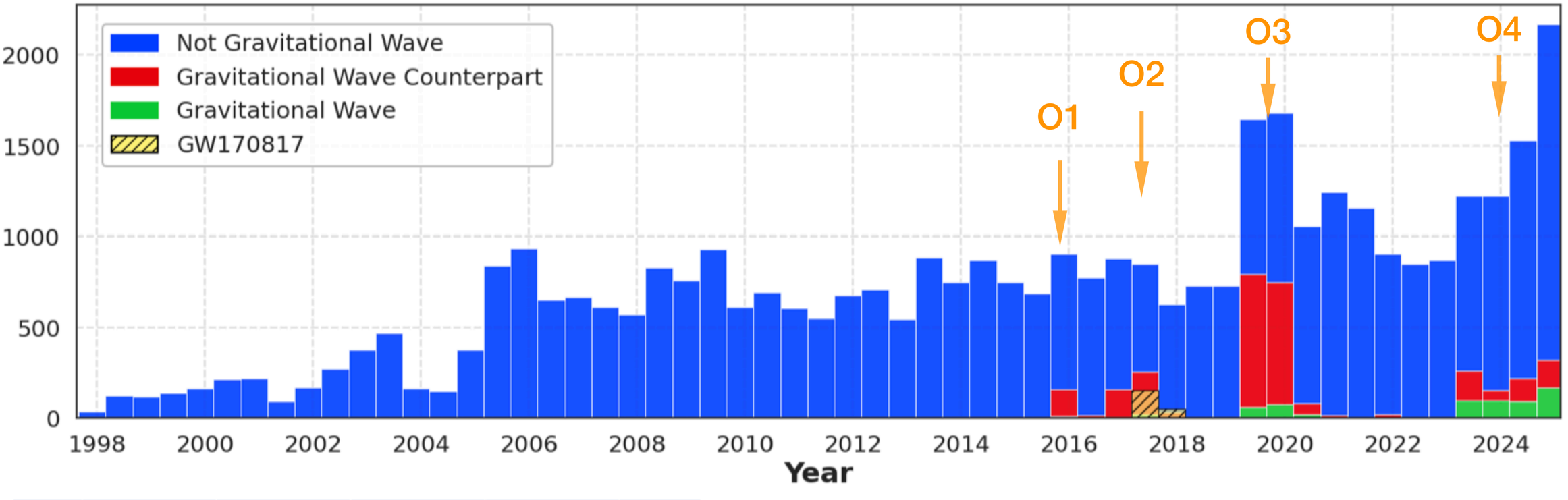
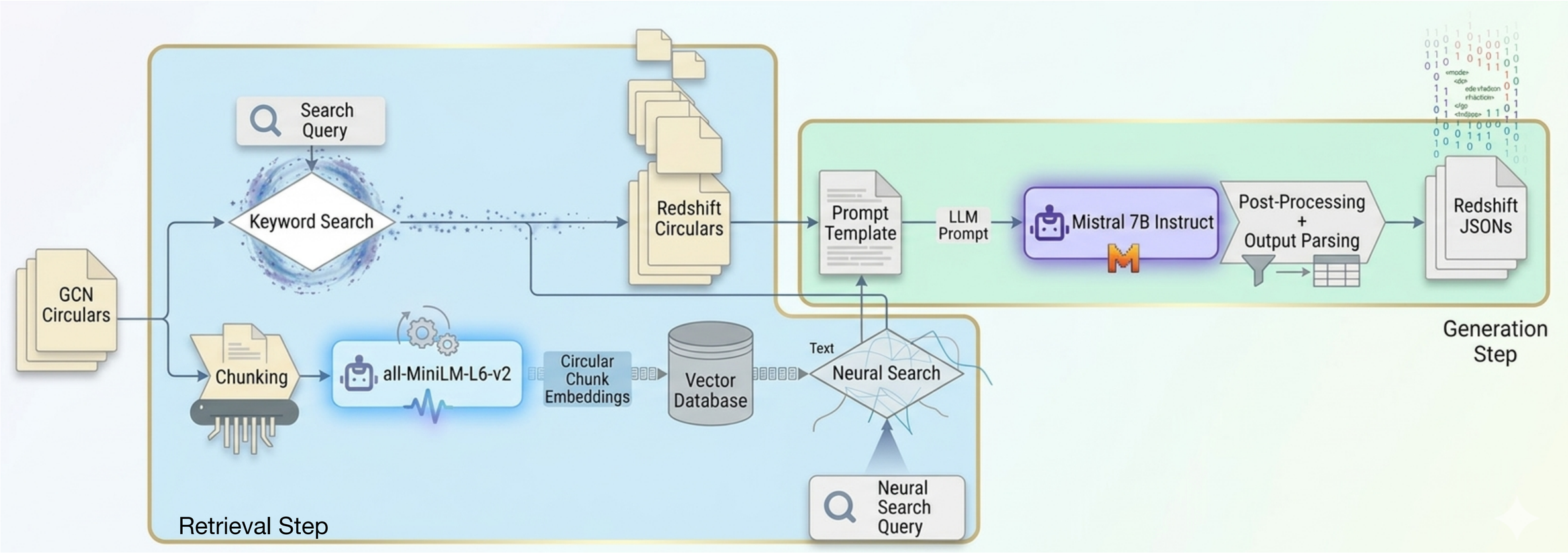




Information Extraction: Turning Text Into Data

Mistral-7B-Instruct (Open source!)

- Open-source instruction-tuned model
- Automatically Extracts: Redshift, Event name, Instrument, & Redshift-Type
- Accuracy measured on Swift GRB table is 96.6%



Unstructured Text to JSON Data

Prompt Template

```
GRB 151027A: Keck/HIRES redshiftD. A. Perley (DARK/NBI), L. Hillenbrand (Caltech), and J. X. Prochaska
(UCO/Lick) report:

We obtained a 900s spectrum of the optical afterglow of GRB 151027A
(Maselli et al., GCN 18478) with Keck/HIRES starting at UT 06:54 on
2015-10-27.  In the preliminary reduction, we identify a series of
strong absorption lines including the MgII doublet at z=0.81. Associated
MgI, FeII, and (likely) FeII* are also present, indicating that this is
the redshift of the GRB.  Analysis is ongoing.

For the given circular, can you extract the following information:

Redshift Value: Extract the redshift value observed for the GRB, if any. If not, answer No Redshift.If multiple measurements are present, only pick the most
likely one.
Telescope: What was the name of the telescope used for observation? Event: Extract the GRB Number of the event. Redshift Type: How was the redshift
determined? Answer Photometric if it was photometric. Answer Spectroscopic if it was spectroscopic or had absorption or emission features or lines. If
there's no redshift value, answer No Redshift. If there's no information on the type, answer No Information.

The output should be a markdown code snippet formatted in the following schema, including the leading and trailing "```json" and "```":

```json
{
        "Redshift Value": string  // Extract the redshift value observed for the GRB, if any. If not, answer No Redshift. If multiple measurements are
present, only pick the most likely one.
        "Telescope": string  // What was the name of the telescope used for observation? If not provided, answer No Information.
        "Event": string  // Extract the GRB Number of the event. If not provided, answer No Information.
        "Redshift Type": string  // How was the redshift determined? Answer Photometric if it was photometric. Answer Spectroscopic if it was spectroscopic
or had absorption or emission features or lines. If there's no redshift value, answer No Redshift. If there's no information on the redshift type, answer No
Information.
}
```

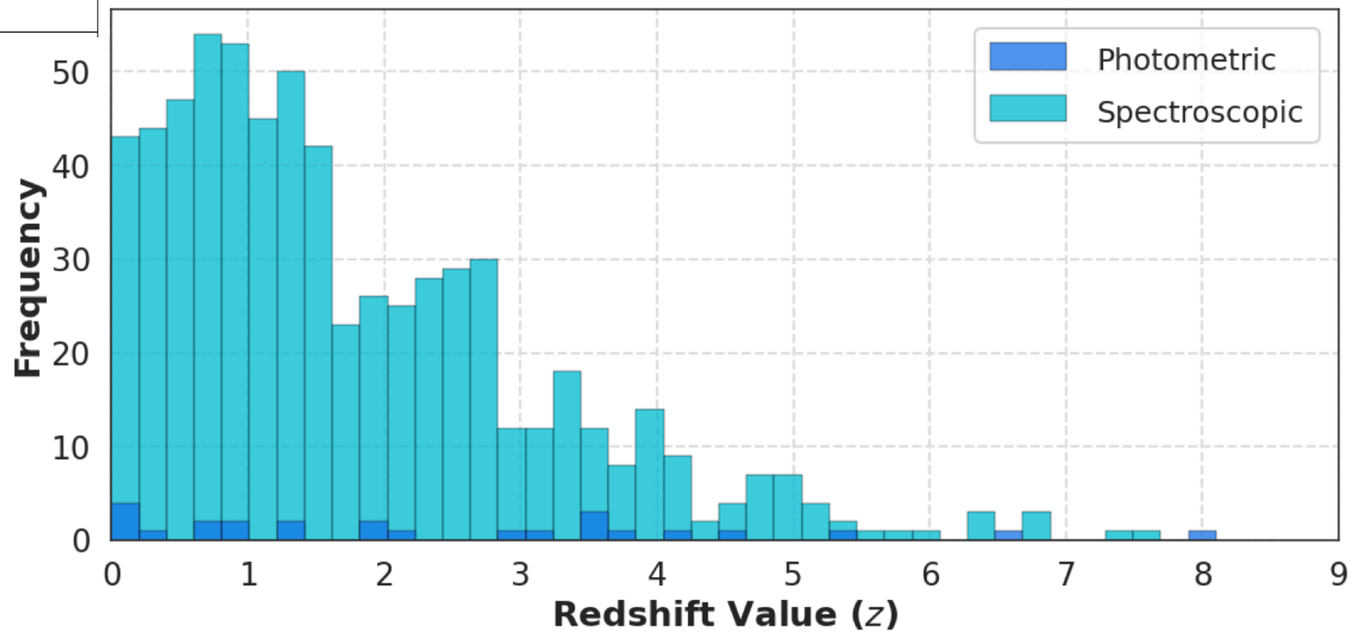
A:
```

JSON O/p

```
```json
{
        "Redshift Value": "0.81",
        "Telescope": "Keck/HIRES",
        "Event": "GRB 151027A",
        "Redshift Type": "Spectroscopic"
}
```
```

Information Extraction: Turning Text Into Data!

GCN	Predicted / Actual GRB	Predicted / Actual Redshift	Predicted / Actual Telescope	Predicted / Actual Redshift Type
9712	GRB090726 / 090726	2.71 / 2.71	SAO RAS 6-m telescope in Caucasus using SCORPIO / SAO RAS	Spectroscopic / Spectroscopic
12867	GRB 120119A / 120119A	z=1.728 / 1.728	MMT 6.5-m telescope / MMT	Spectroscopic / Spectroscopic
4591	GRB 060124 / 060124	0.82 / 2.30	MDM 2.4m telescope / MDM	Spectroscopic / Spectroscopic
18969	GRB 160131A / 160131A	0.97 / 0.97	Xinglong 2.16m telescope / Xinglong	Spectroscopic / Spectroscopic
33110	GRB 221226B / 221226B	2.694 / 2.694	ESO VLT UT3 (Melipal) / VLT	Spectroscopic / Spectroscopic
7601	GRB 080413B / 080413B	1.10 / 1.10	ESO VLT / VLT	Spectroscopic / Spectroscopic
12761	GRB 111228A / 111228A	0.716 / 0.716	Gemini-South 8-m telescope / Gemini-South	Spectroscopic / Spectroscopic
7615	GRB 080413B / 080413B	1.10 / 1.10	Gemini South / Gemini-South	Spectroscopic / Spectroscopic
11708	GRB 110213A / 110213A	z = 1.46 / 1.46	2.3-m Bok telescope / Bok	Spectroscopic / Spectroscopic

Side by side comparison of redshift
Accuracy ≈ 97%

GRBs redshift database



Summary:

- We demonstrate the potential of LLM for transient alert system to enable rapid and scalable astrophysical text mining.
- In the era of Rubin and Roman, the growing volume of heterogeneous, unstructured data across multiple platforms can benefit from scalable, ML-based infrastructure capable of unified analysis.

Thanks for listening!

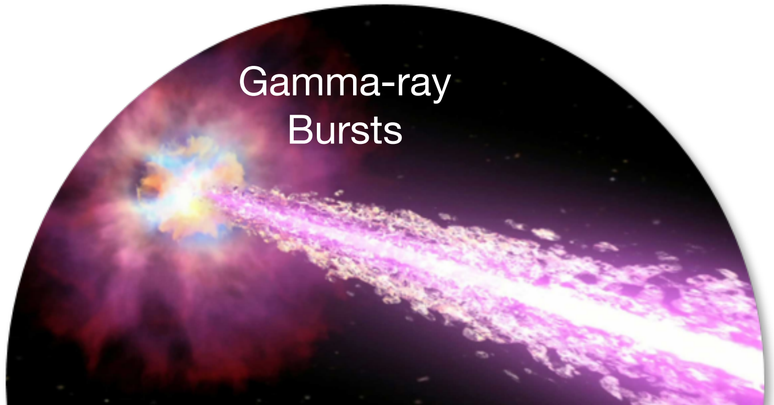
Web site: https://gcn.nasa.gov
arXiv Print: 2511.14858
GitHub: nasa-gcn/circulars-nlp-paper

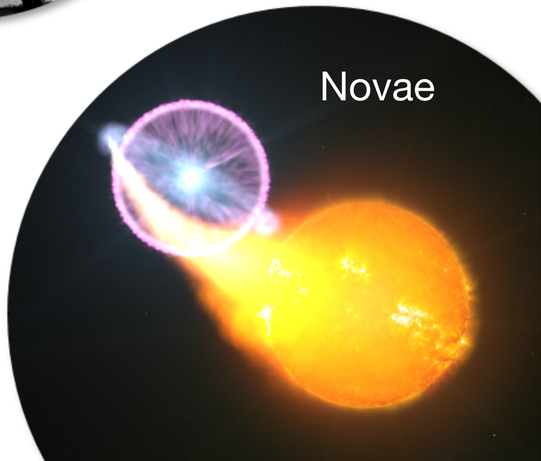
Fast Astronomical Transients

- Initially outburst on timescales of milliseconds to days
- Detection and follow-up observations across electromagnetic spectrum (radio to very high-energy gamma-ray) and multi-messenger

GCN is constantly evolving to serve new transients, messengers, and observatories:

- Gravitational wave events (GW150914, GW170817)
- High-energy neutrinos (IC170922A)
- Tidal disruption events (Swift J1644+57)
- Magnetar giant flares (200415A)





Topic Modeling Pipeline