General Coordinates Network

NASA's Next Generation Time-Domain and Multimessenger Alert System

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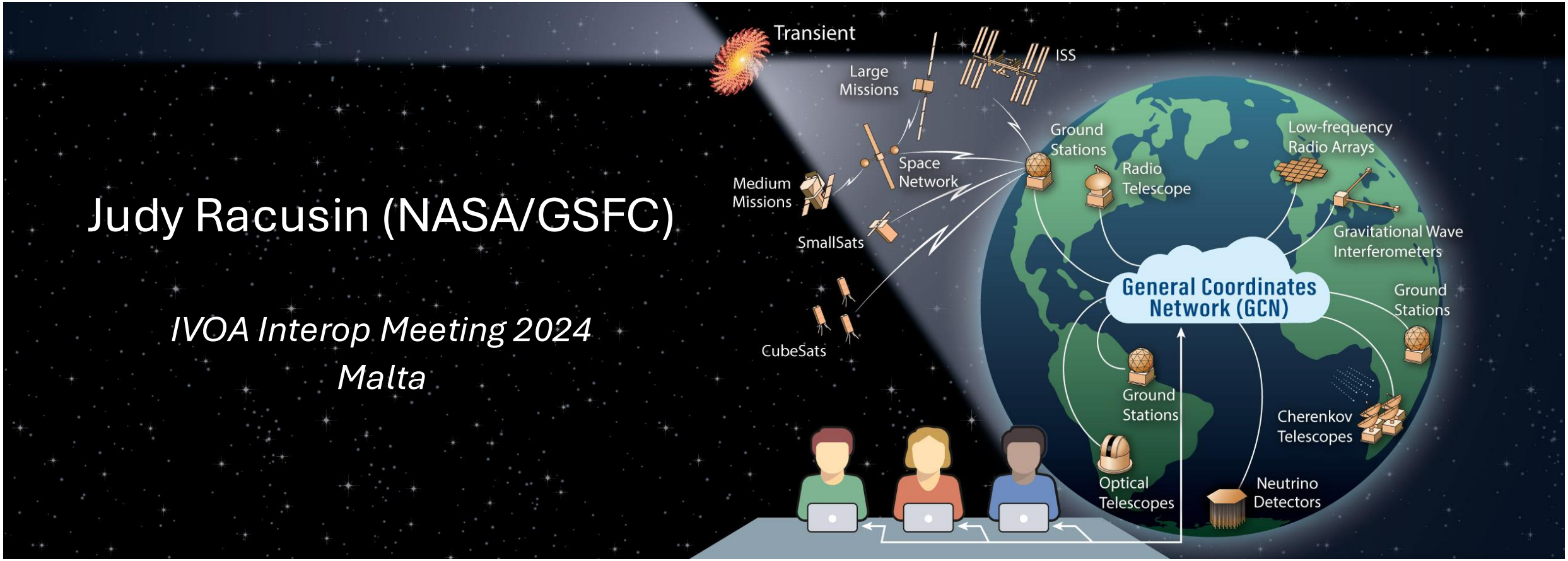
IVOA Interop Meeting 2024
Malta

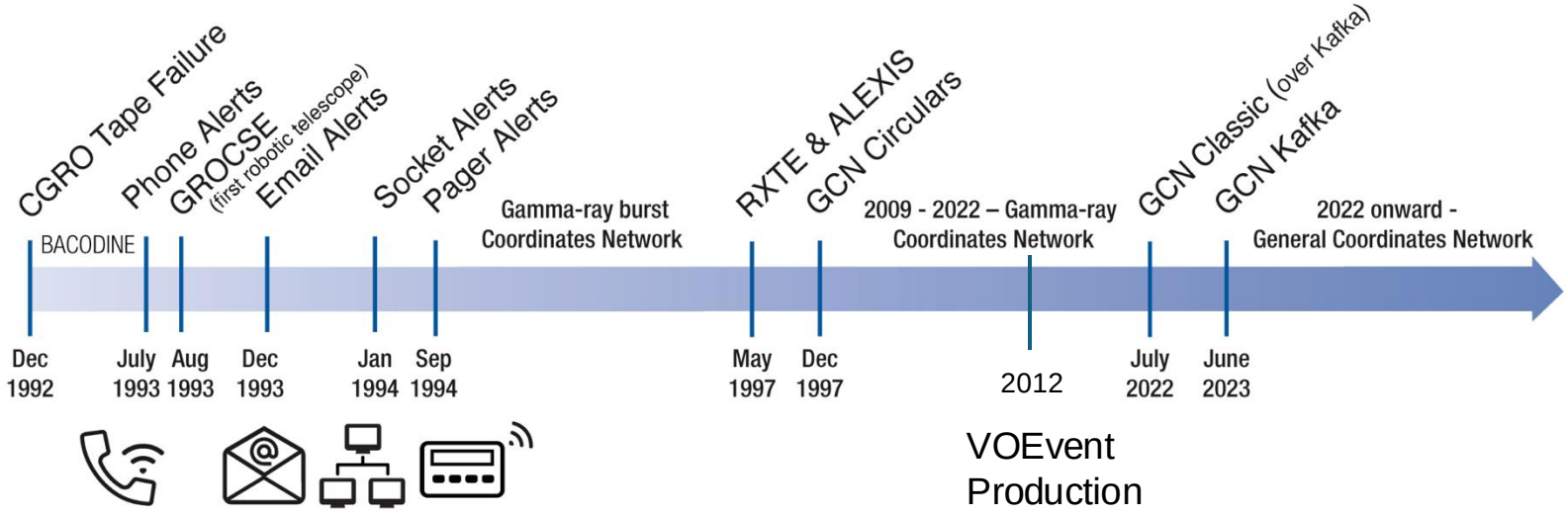


https://gcn.nasa.gov

GCN History and Background

The General Coordinates Network is the modernization of NASA's Astronomical transient alert system

- Legacy Gamma-ray Coordinates Network (https://gcn.gsfc.nasa.gov; now referred to as GCN Classic) has been the backbone of the high-energy transient astronomy community (especially gamma-ray bursts) since 1992
- Enabled seminal breakthroughs by rapidly connecting astronomers using public Internet infrastructure
- Rapid community growth in recent years has required significant implementation effort, especially given growth of multimessenger gravitational wave and neutrino astronomy



Two Types of GCN Data Products

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)
```

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

GCN Circulars

```
TITLE:   GCN CIRCULAR
NUMBER:  28298
SUBJECT: GRB 200826B: Fermi GBM detection
DATE:    20/08/27 21:10:30 GMT
FROM:

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:
```

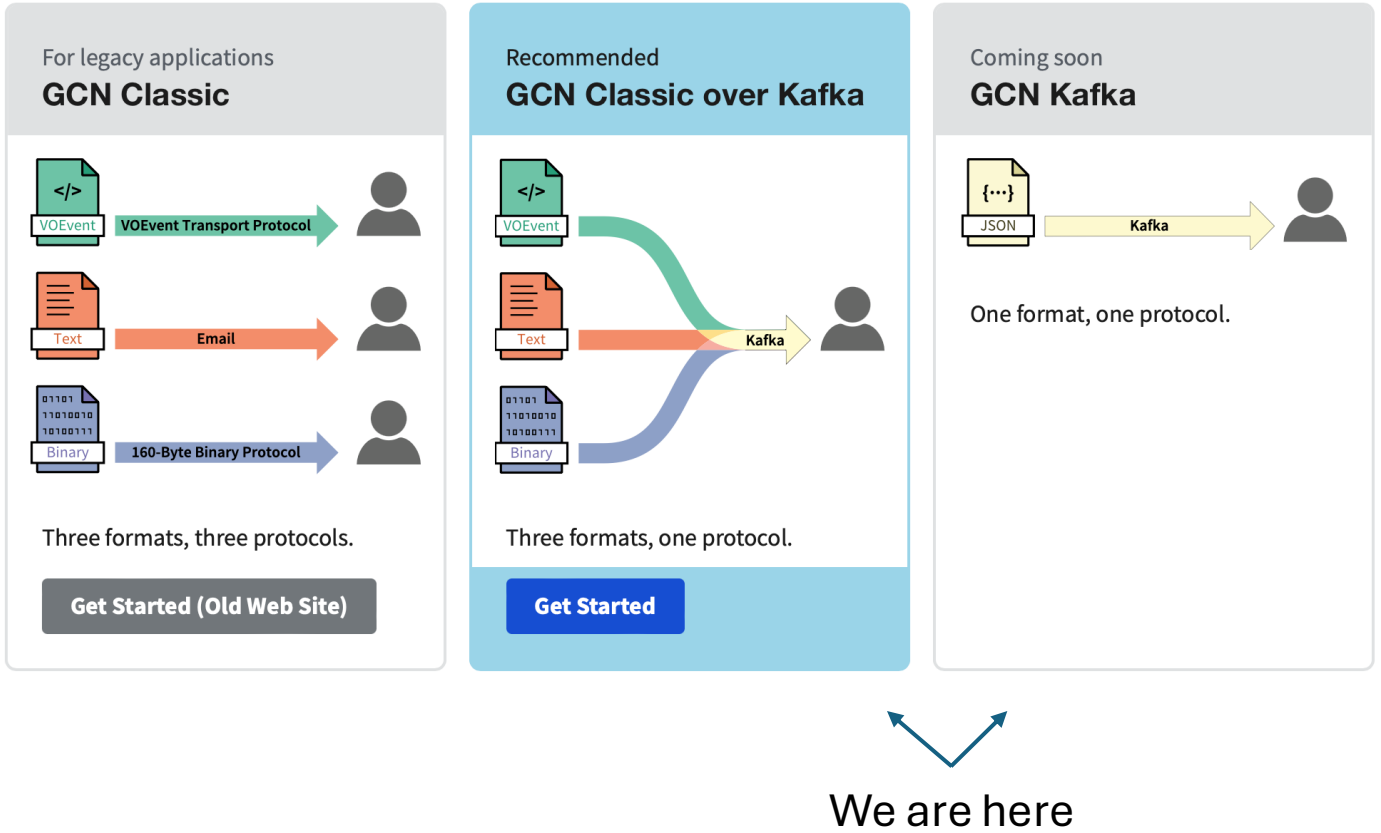
- By and for humans (some automated)
- Freeform text (with established style)
- Citable (but not peer-reviewed)

GCN Modernization Effort

- Funded by NASA to maintain role in time-domain and multimessenger (TDAMM) infrastructure
- Started in 2019 with aim at simplifying interfaces to GCN and making them self-service
- Created a GCN Notices/Circulars Archive (GCN Viewer)
  - No new development
  - Working on making new version integrated into the new system
- Became clear that we needed to build a new, modern, cloud-based system
- Maintaining GCN Classic
  - Developers are all retired
  - No new development
- Gradually transitioning services to the new system since 2022

The New GCN is Built on Kafka

- **GCN Classic** provides three formats over three custom protocols
- **GCN Classic over Kafka** provides all three formats over one standard protocol: Apache Kafka
- **GCN Kafka** will transition over the next few years to streaming all data in JSON format over Kafka (Notices and Circulars)

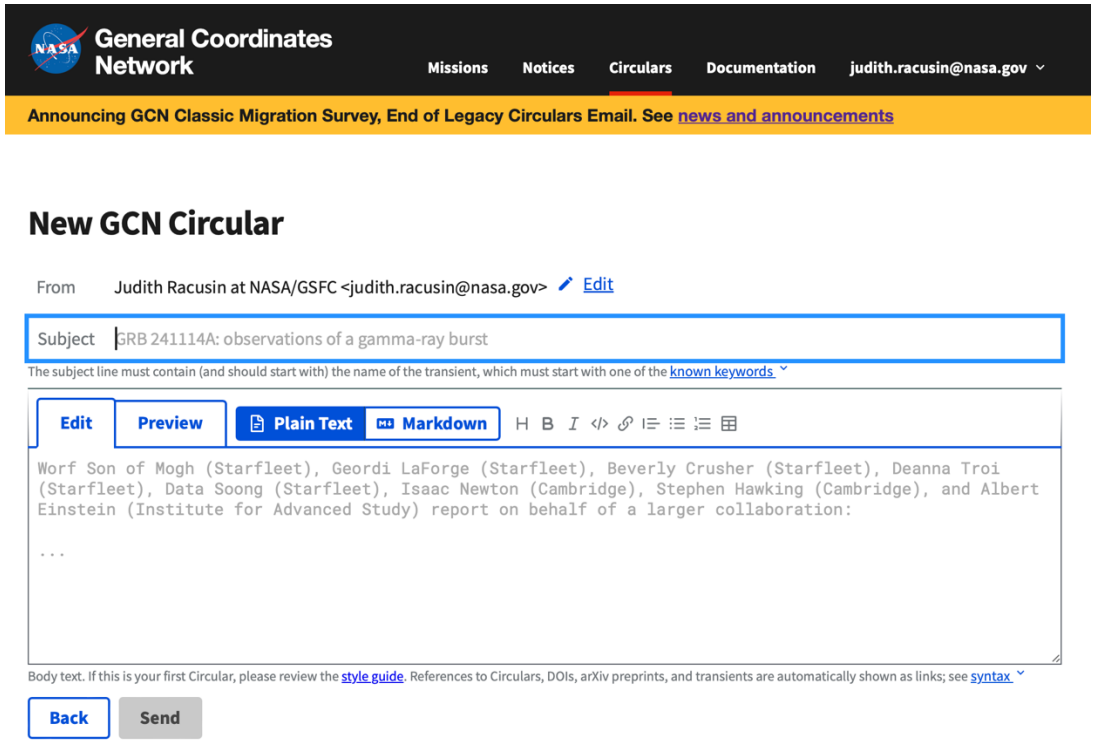


GCN Data Products and Transport Methods

GCN Data Products	Email	Socket	VOEvent Transport Protocol (VTP)	Kafka
Text Classic Notices	✓			✓
VOEvent Classic Notices			✓ Plan to eliminate or migrate	✓
Binary Classic Notices		✓		✓
JSON Notices	Plan to add			✓
Circulars	✓			✓

Circulars Complete Migration (April 2023)

- Complete migration of all legacy users on April 17, 2023 with relatively smooth transition
- Self service management of subscriptions and settings
- Peer endorsement system for new submitters (similar to ArXiv)
- Email notifications are distributed in parallel to all users within seconds
- Circulars run on highly available, distributed cloud services
- New Web Form for circular submission
  - Markdown support (May 2024)
  - Circulars over Kafka (July 2024)
- New Archive on https://gcn.nasa.gov/circulars including continued improvements to searching
- Maintained Legacy submission address (forwarding script) – plan to retire at end of 2024

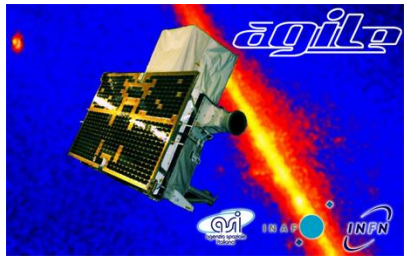


GCN Circular Web Form

Remaining GCN Migration/Development Tasks

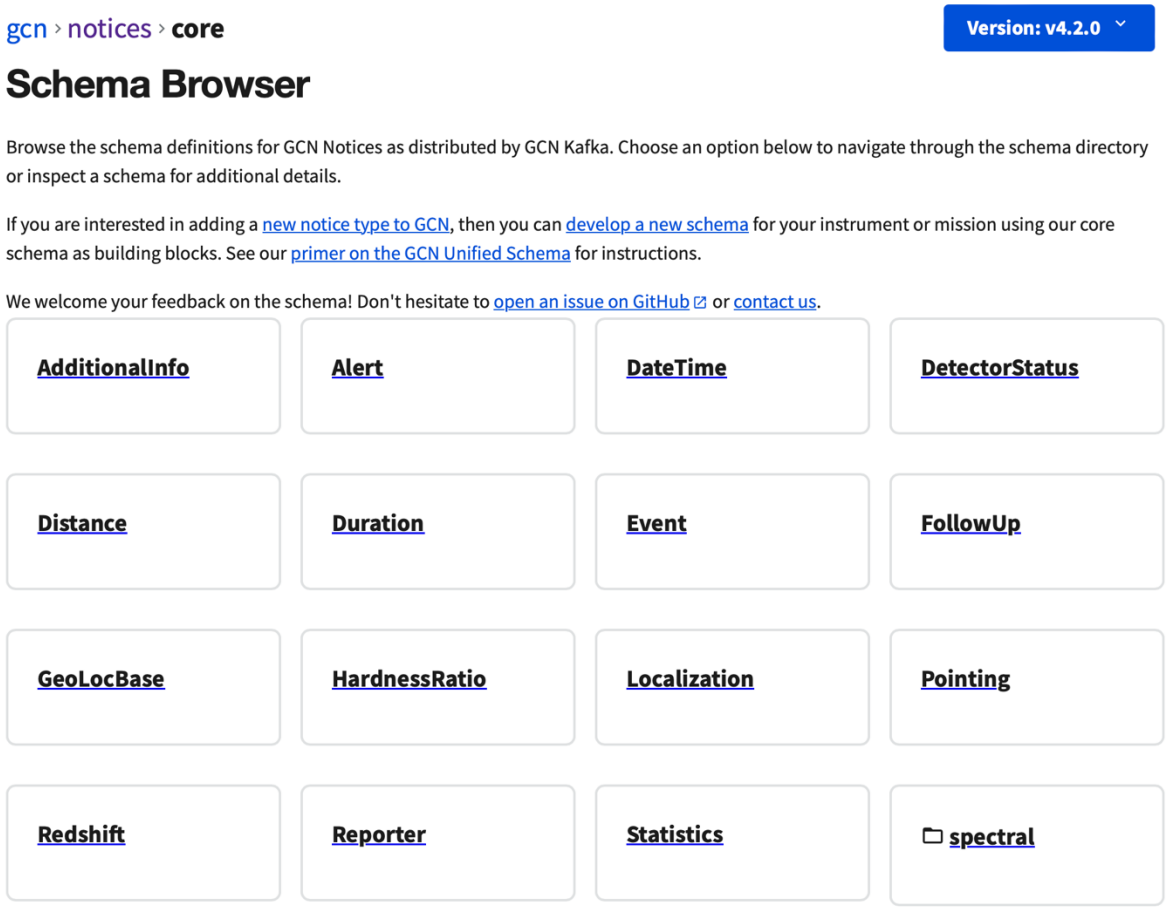
- Archive of GCN notices – all formats
  - Searchable database
  - Text format archive on GCN Classic website
  - Currently no JSON archive (beyond 2-week look back) of kafka notices
- Distribute JSON (pretty printed) without embedded attachments via email
- Add lots of improved search capability to Circulars archive (lucene syntax search, natural language model)
- Work with all legacy producers to generate JSON notices
- Migrate user community to receive notices via new GCN

GCN Notice Producer Missions/Observatories/Experiments



GCN Notices JSON Unified Schema

- Created our own new *core* schema as building blocks for producers
- Producers can utilize any subset of core schema and parameters
- Producers can add custom fields



https://gcn.nasa.gov/docs/schema/v4.2.0/gcn/notices/core

GCN JSON Over Kafka

- JSON Topics Available now
  - New GCN JSON notices
    - IceCube LVK Follow-up
    - Swift BAT GUANO
    - Einstein Probe
  - GCN Circulars
- In process of onboarding new notices for
  - Fermi-GBM
  - Swift
  - SVOM
  - Glowbug
  - AstroSAT
  - CHIME
  - KM3NET
  - Super-Kamiokande
- See https://github.com/nasa-gcn/gcn-schema

VOEvent in the New GCN

- GCN Classic still distributes VOEvent via VOEvent brokers (aka VOTANS)
  - Anonymous or manual subscriptions
  - You can contact the GCN Team (me) for changes
- VOEvent from GCN Classic available via Kafka (self-service)
- The New GCN is trying to get out of the business of conversions between formats of notices (e.g. text->VOEvent)
- Some new producers (e.g. SVOM) still want to distribute VOEvent
  - GCN is happy to do this, but mission teams must provide alerts
  - Distribute via Kafka

VOEvent – 3 Separate Discussions

VOEvent Transport Protocol - Method of distributing data

Data Serialization - e.g. XML vs JSON

Schema – Standards for contents of the alerts

VOEvent Transport Protocol

- GCN Classic runs 3 cloud brokers offering anonymous and manually maintained subscriptions (by me)
- We need to either eliminate or migrate those brokers to meet NASA security standards
- On Nov 8 - Announced 3 Options and community survey
  - https://gcn.nasa.gov/docs/vtp
  - Survey responses due Nov 30 https://forms.gle/8tVRkmQd2v99FqYYA

Option 1:
Replace GCN VTP Broker with VOEvents over Kafka

- ✓ Service already exists and is available for use
- ✓ Self service subscription
- ✓ Open source
- ✓ Secure
- ✓ Broker is the server, minimal firewall configuration
- ✓ Client-side filtering
- ! Requires users to modify their client code to stream notices via Kafka using GCN Kafka Client

Option 2:
Replace GCN VTP Broker with Comet

- ! Requires new development from GCN
- ✓ Self service subscription
- ✓ Open source
- ✗ Not secure
- ✓ Broker is the server, minimal firewall configuration
- ✓ User programmable server-side filtering
- ! Requires update to broker hostname and client

Option 3:
Migrate GCN VTP Broker to AWS

- ✗ Requires significant development effort by GCN team
- ✗ Subscription changes require submitting support tickets to GCN team
- ✗ Closed source
- ✗ Not secure
- ✗ Broker is the client, consumers require firewall rules
- ! Requires update to broker hostname
- ✗ Optional server-side filtering configured via support tickets to GCN team

VOEvent Data Serialization

XML

```
<?xml version = '1.0' encoding = 'UTF-8'?>
<voe:VOEvent ivorn="ivo://nasa.gsfc.tan/vo-gcn.gsfc/SWIFT#BAT_GRB_Position_279494-123"
     role="observation" version="1.1"
     xmlns:voe="http://www.ivoa.net/xml/VOEvent/v1.1"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xmlns:xlink="http://www.w3.org/1999/xlink"
     xsi:schemaLocation="http://www.ivoa.net/xml/VOEvent/v1.1
http://www.ivoa.net/xml/VOEvent/VOEvent-v1.1.xsd" >
  <Who>
    <AuthorIVORN>ivo://nasa.gsfc.tan/organization</AuthorIVORN>
    <Author>
      <shortName>VO-GCN</shortName>
      <contactName>Scott Barthelmy</contactName>
      <contactPhone>+1-301-286-3106</contactPhone>
      <contactEmail>scott@milkyway.gsfc.nasa.gov</contactEmail>
    </Author>
    <Date>2007-07-04T19:42:03</Date>
  </Who>
  <What>
    <Param name="Packet_Type"  value="61" />
    <Param name="Pkt_Ser_Num"  value="1" />
    <Param name="TrigID"       value="279494" ucd="meta.id" />
    <Param name="Segment_Num"  value="0" ucd="meta.id" />
    <Param name="Burst_TJD"    value="14237" unit="days" />
    <Param name="Burst_SOD"    value="40858.39" unit="sec" />
    <Param name="Burst_Inten"  value="15607" unit="cts" ucd="phot.count" />
    <Param name="Burst_Peak"   value="370" unit="cts" ucd="phot.count" />
    <Param name="Integ_Time"   value="3.072" unit="sec" ucd="time.duration" />
    <Param name="Phi"          value="-100.53" unit="deg" ucd="pos.az.azi" />
    <Param name="Theta"        value="22.03" unit="deg" ucd="pos.az.zd" />
    <Param name="Trig_Index"   value="474" />
    <Param name="Soln_Status"  value="0x2003" />
    <Param name="Misc_flags"   value="0x1002000" />
    <Param name="Rate_Signif"  value="11.26" unit="sigma" ucd="stat.snr" />
    <Param name="Image_Signif" value="8.00" unit="sigma" ucd="stat.snr" />
    <Param name="Bkg_Inten"    value="147063" unit="cts" ucd="phot.count" />
    <Param name="Bkg_Time"     value="11:20:14.03" />
    <Param name="Bkg_Dur"      value="32.00" unit="sec" ucd="time.duration" />
    <Param name="SC_Long"      value="196.43" unit="deg" ucd="pos.earth.lon" />
    <Param name="SC_Lat"       value="644.94" unit="deg" ucd="pos.earth.lat" />
```

https://gcn.gsfc.nasa.gov/vo_examples.html

JSON


```
{ "$schema":
"https://gcn.nasa.gov/schema/v4.2.0/gcn/notices/swift/bat/Guano.schema.json",
 "mission": "Swift",
"instrument": "BAT-GUANO",
"messenger": "EM",
"record_number": 1,
"alert_datetime": "2023-01-01T03:24:36.0Z",
"alert_tense": "current",
"alert_type": "initial",
"trigger_time": "2022-12-31T21:46:05.13Z",
"rate_snr": 15.8, "rate_duration": 0.256,
"rate_energy_range": [ 15, 350 ],
"classification": { "GRB": 1 },
"far": 0.00001,
"follow_up_event": "Fermi 694215970",
"follow_up_type": "GRB",
"data_archive_page": "https://guano.swift.psu.edu/trigger_report?id=694215995",
"id": [ "694215995" ] }
```


https://gcn.nasa.gov/docs/schema/v4.2.0/gcn/notices/swift/bat/Guano.schema.json

VOEvent Schema

- *Who* they are;
- *What* they have observed;
- *Where and when* the observed it;
- *How* the observations were made;
- *Why* they think it is of general interest to the community.

Big Question:
Why hasn't this continued to serve the needs of various transient astrophysics communities?

https://voevent.readthedocs.io/en/latest/intro.html#the-voevent-standard

What can IVOA do?

- Currently various transient astronomy communities use
  - Rubin/LSST + other optical time-domain surveys – AVRO custom schema
  - SCiMMA – custom AVRO with embedded schema + flexible on other formats
  - CHIME/FRB – VOEvent, but working on GCN JSON Schema
  - GCN – moving towards GCN JSON Unified Schema
  - IGWN – their own JSON (GCN working on translation to GCN JSON)
  - Radio transient community - ?
- Is it still possible to create new modern JSON-based standard that everyone will adopt?
  - Let’s discuss