



École Doctorale d'Astronomie & Astrophysique
d'Île-de-France

Multi-Messenger Astrophysics

time-domain astronomy

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**time-domain astronomy, alerts,
and multi-messenger networks**

what are multi-messenger alert systems?

- ▶ combine information from all messengers
- ▶ **main goal:** identify transient events (e.g., blazar flares, GRBs, NS mergers, etc)
- ▶ requires *rapid* global coordination
- ▶ **alerts** disseminate information quickly for follow-ups
- ▶ required information
 - ◆ event time
 - ◆ sky localisation
 - ◆ estimated significance
 - ◆ messenger type

multi-messenger networks: actors

sentinel (triggering)

- ▶ detect initial signal
- ▶ send out alerts
- ▶ **examples**
 - ◆ all air-shower experiments (e.g., KM3NeT, IceCube, Auger, LHAASO, HAWC, ...)
 - ◆ wide-field observatories (e.g., Fermi GBM, Fermi LAT)
- ▶ **requirements**
 - ◆ rapid processing times
 - ◆ angular resolution

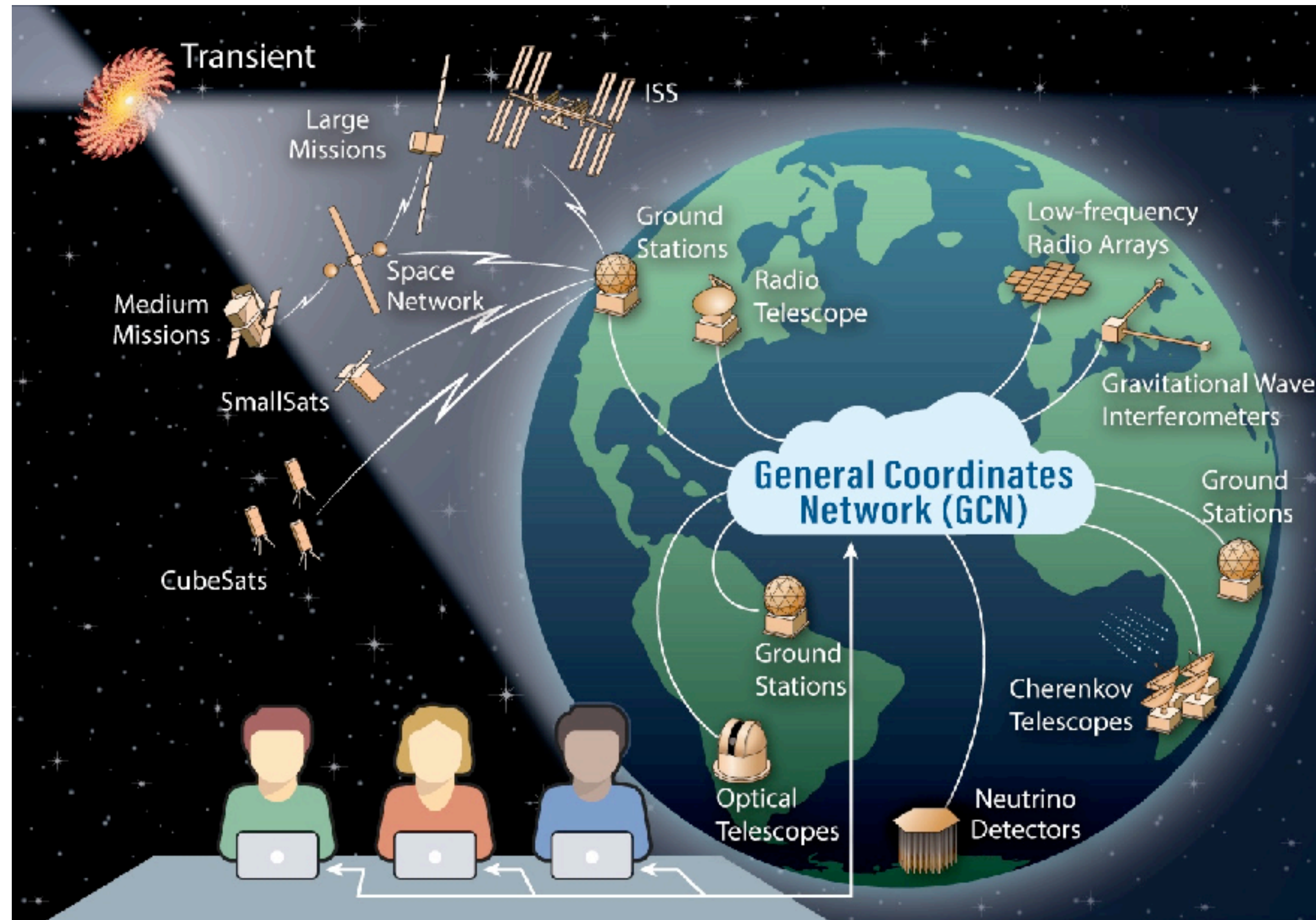
broker (coordinator)

- ▶ receive a signal
- ▶ send out alerts
- ▶ coordinates followers
 - ◆ avoid duplication
 - ◆ ensure coverage
- ▶ decides whether to send alert if sub-threshold
- ▶ **examples**
 - ◆ AMON, Lasair (optical), TOM, Astro-COLIBRI

follower

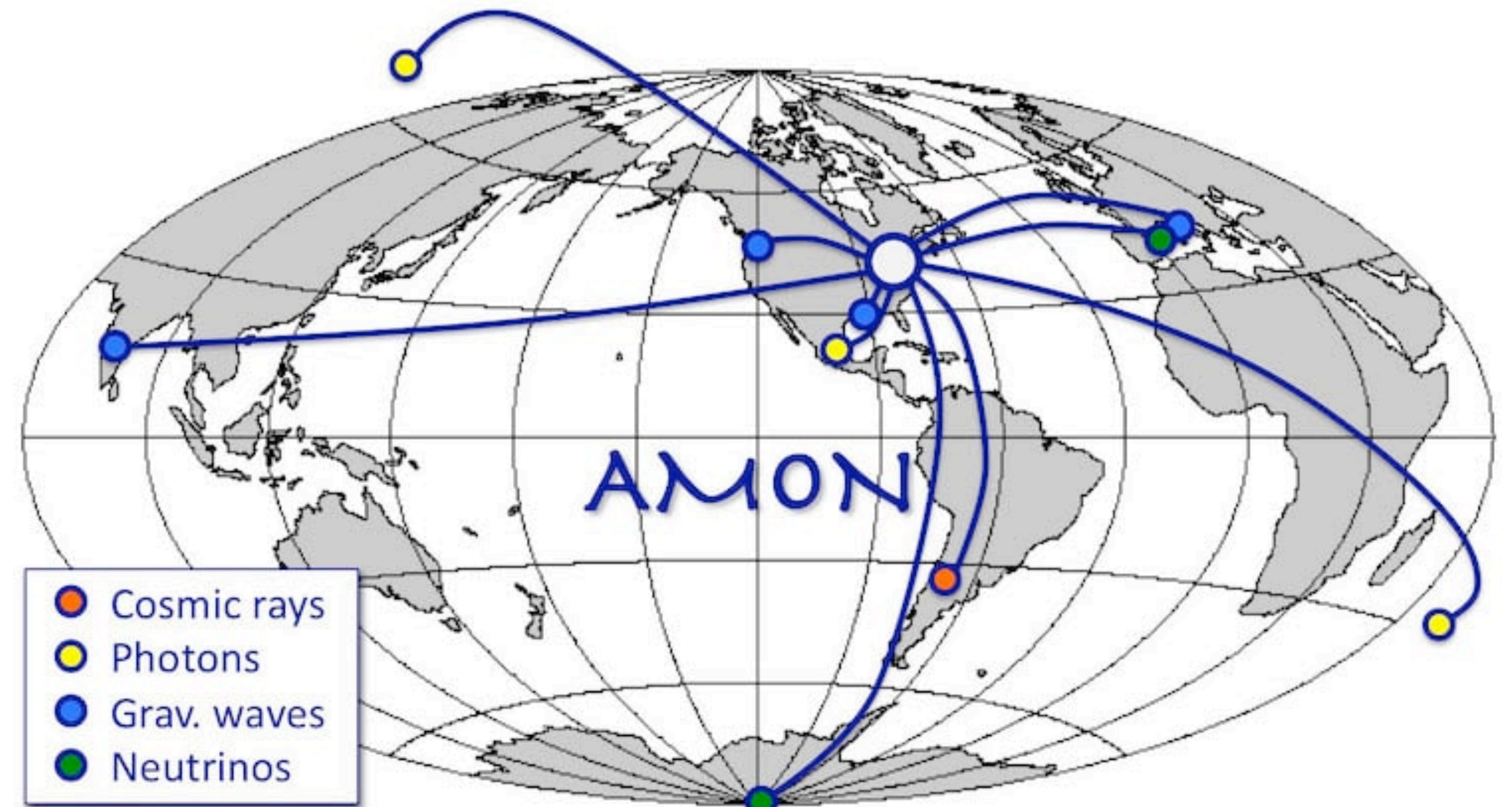
- ▶ receive a signal and point to specific coordinates
- ▶ **examples**
 - ◆ most small-field observatories (optical, IR, UV, some radio)
 - ◆ IACTs
- ▶ **requirements**
 - ◆ fast slew
 - ◆ rapid decision

alert systems. General Coordinates Network (GCN)



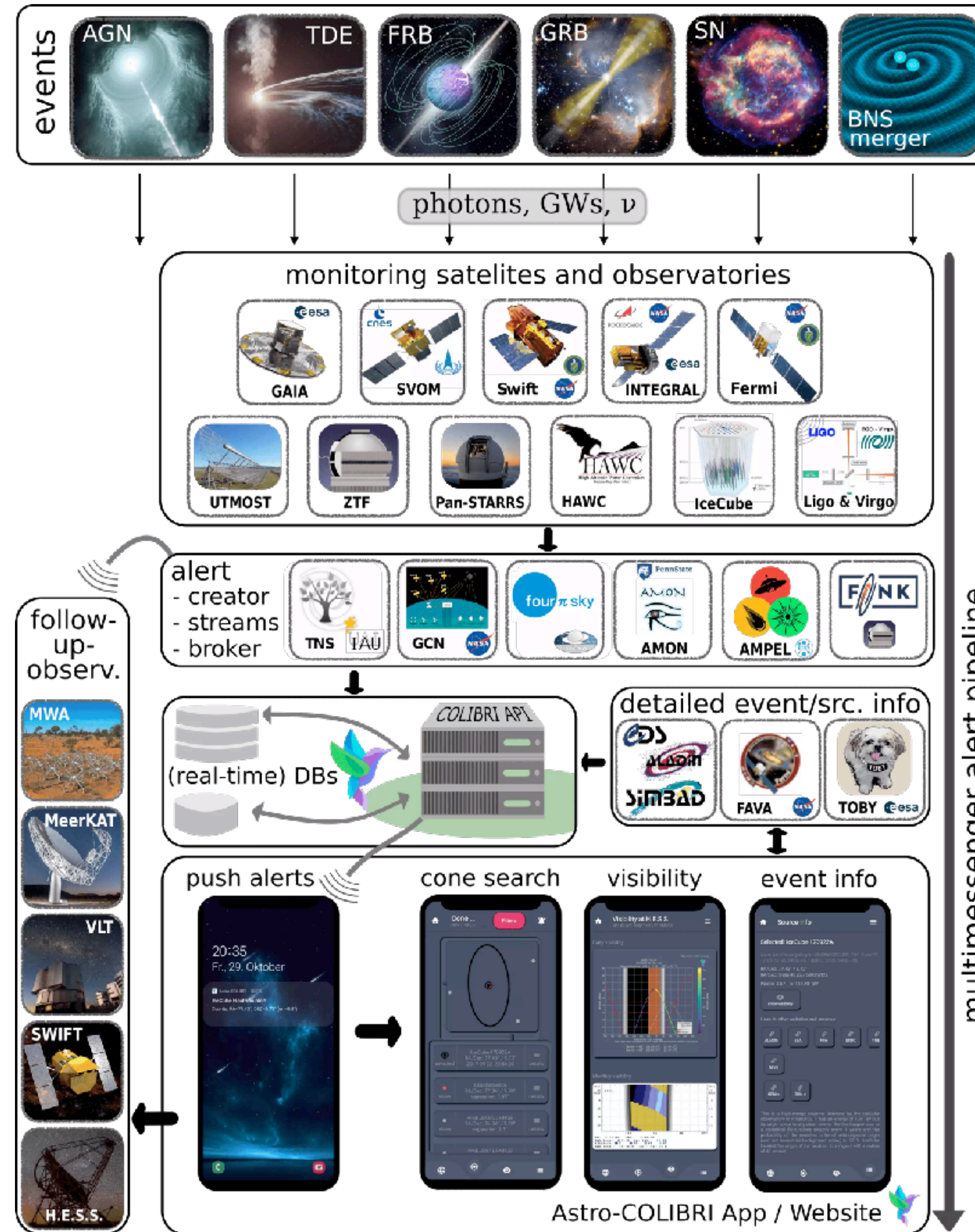
- ▶ by NASA, originally for GRBs
- ▶ evolved to a high-energy alert system for:
 - ◆ GWs
 - ◆ neutrinos
 - ◆ X and gamma rays
- ▶ alerts are distributed as circulars
- ▶ connected to observatories and brokers
- ▶ alerts are distributed as circulars
 - ◆ standardised **VOEVENT** → enables parsing and decision-making
 - ◆ real-time data feeds are created; **KAFKA** distributes the VOEvent

- ▶ can perform archival studies
- ▶ alerts are sent to GCN
- ▶ *sub-threshold* events
- ▶ members
 - ◆ Auger,
 - ◆ IceCube
 - ◆ ANTARES (no longer operating),
 - ◆ Fermi
 - ◆ MAGIC
 - ◆ H.E.S.S.
 - ◆ VERITAS
 - ◆ Swift
 - ◆ HAWC
 - ◆ LIGO
 - ◆ LMT,
 - ◆ LCOGT
 - ◆ Palomar Transient Factory
 - ◆ MASTER
 - ◆ ASTRON
 - ◆ FACT

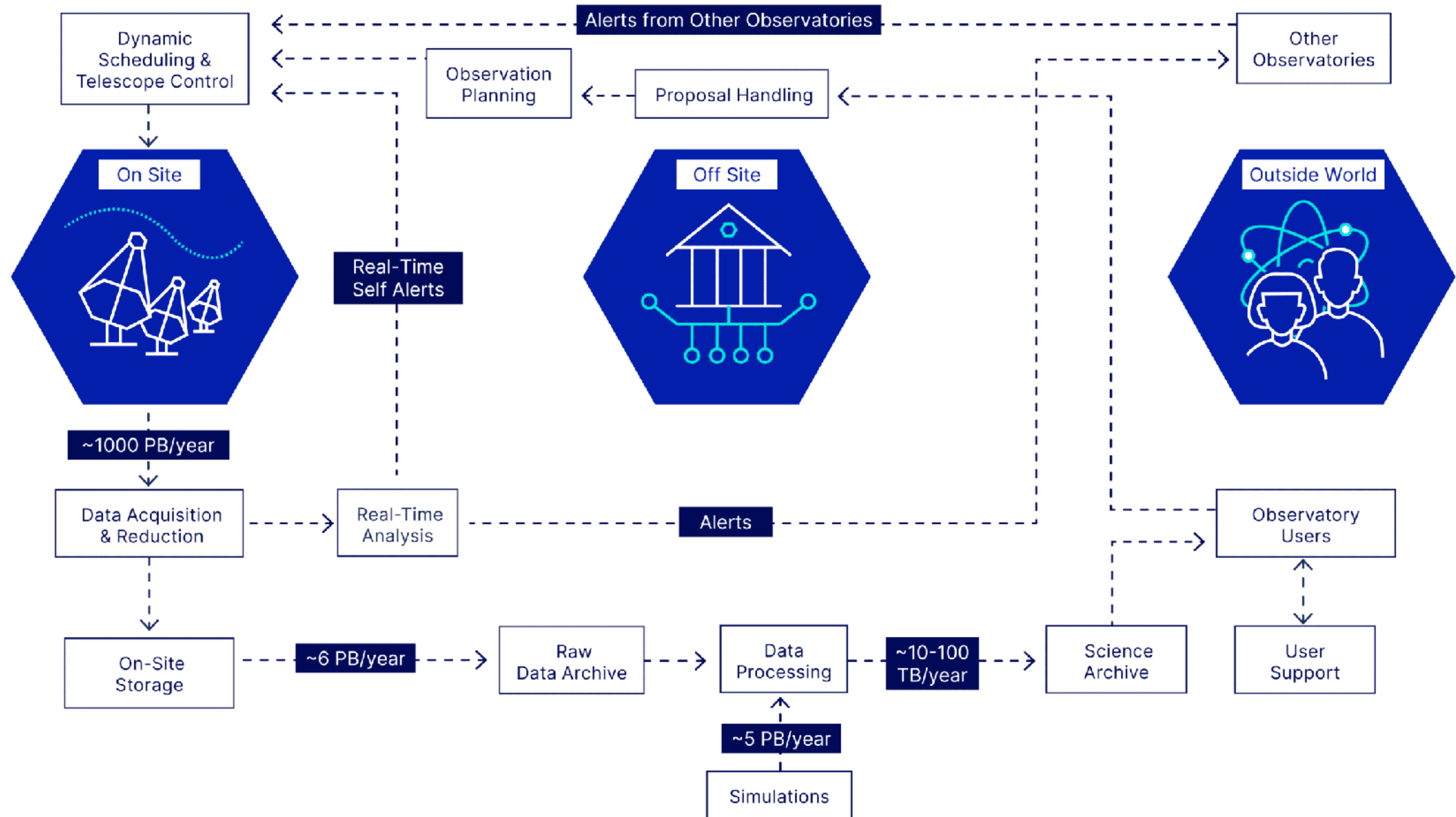




multi-messenger coordinators. Astro-COLIBRI



an example: CTA0



SNEWS: the SuperNova Early Warning System

- ▶ neutrinos from SNe precede EM signal (~hours)
- ▶ latency: ~tens of seconds
- ▶ it sends out alerts for EM follow-ups when the SN neutrinos arrive
- ▶ many (low-energy) neutrino detectors have poor resolution → temporal reconstruction with multiple detectors

