CMB-S4 Sources & Transients

Report Back

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CMB-S4 Collaboration Meeting @ SLAC

Joaquin Vieira (presenting)
Tom Maccarone (co-chair)
Anna Ho (outgoing co-chair and GRB guru)
Rachel Osten (star guru)

Sources and Transients Working Group Report Back

Topics:

- working group telecons
- The Transient and Variable Universe Conference held at NCSA
- Alert Time Scale Change Request?
- Science Book V2 planning

The last year of bi-weekly telecons

- Collaboration Meeting Planning
- Galactic Transient Science Case
- ExGal Transient Science Case
- Lessons from the SDSS Archive (Ani Thakur / JHU)
- Map making and Source finding from Chile (Sigurd Naess / Flatiron)
- CMB-S4 Observing Simulations (Reijo Keskitalo / LBL)
- proto-clusters (Allison Noble / ASU)
- blazar monitoring in the radio (Tony Readhead / Caltech)
- Transient Planning
- ACT+SO Transients (Adam Hincks / Toronto)
- optical transient surveys (Nick Law / UNC)
- mm transient follow up (Dave Wilner / SAO)
- Galactic Cold Clumps (Justin Clancy / Melbourne)
- blazars in the gamma ray and mm (Lizhong Zhang / UCSB)

The Transient and Variable Universe Conference

- Started conceptually as CMB-S4 Astrophysics Workshop edition 3
- Became generic Transient and Variability conference
- Held at NCSA for 3 days.
- ~150 people in attendance in person + virtual attendees
- Could possibly do something again in 2 years
- We should think about the best way of engaging the community going forward

The Transient and Variable Universe

June 20–22, 2023 | National Center for Supercomputing Applications at the University of Illinois Urbana-Champaign

Event program can be found at publish.illinois.edu/transient-variable-2023

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Measurement to Science — Transients

Science Goals:

- Open the mm-wave window onto the transient universe for multi-messenger astronomy.
- Explore the mm-wave transient sky.
- Measure the rate of mm-transients for the first time.
- Use the rate of mm-wave GRBs to constrain GRB mechanisms.
- Provide mm-wave variability and polarization measurements for stars and AGN.

Science Requirement 4.1: CMB-S4 shall detect GRB afterglows brighter than 30 mJy at 90 and 150 GHz over at least 50% of the sky and enable followup by issuing timely alerts to the community.

Science Requirement 4.2: CMB-S4 shall detect GRB afterglows brighter than 9 mJy at 90 and 150 GHz over at least 3% of the sky and enable followup by issuing timely alerts to the community.

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Note that it's just GRBs !

Measurement Requirement 4.1: During normal operations, CMB-S4 shall measure I, Q, and U at 90 and 150 GHz, over $\geq 25\%$ of the sky daily, with angular resolution $\leq$ 3.0 arcminutes and noise level ≤ 10 mJy/day. At least 90% of the time, the same $\geq 25\%$ of the sky shall be observed for ≥ 5 consecutive days.

Measurement Requirement 4.2: During normal operations, CMB-S4 shall measure I, Q, and U at 90 and 150 GHz, over 3% of the sky daily, with angular resolution ≤ 3.0 arcminutes and noise level ≤ 3 mJy/day.

Doesn't actually say anything about alerts or time scales !

Landscape

Timescales

fast (e.g. stellar flares ~10min) v. slow (e.g. GRBs ~2 days)

or even very fast (e.g. FRBs < 1s) v. very slow (e.g. novae >10 days)

We built the science case around GRBs. In the meantime we have realized that the stellar flares are the dominant foreground and interesting in their own right.

All things being equal, maximizing the sensitivity and time-scale phase space available for transients seems like the best way of allowing CMB-S4 to be impactful in this field.

There is a timescale of the event, and the time scale at which it's important to alert people about.

Site specific logistics

Pole v. Chile

there are differences

Current Baseline Plan:

Detect transients in each individual observation map

- Perform observation over field (~1 hr)
- make map (~1hr)
- difference and detect transients (at site for Pole in NA for Chile)
- send out alert (on ~1 hr time scale)

Pros

- least computational time
- least effort (these are the DQ maps)
- already demonstrated with SPT-3G
- DM is currently baselined to make these maps, so differencing and source finding is not that big of a deal
- much better for transients on time scales <1 day

Cons

- Still not optimal for fast things on minute time scales (e.g. stellar flares)
- waiting around for the entire observation before sending out alerts
- not good for fast things on <1 hour time scales

Potential Request:

Detect transients in each scan

- Scan across field
- make a sub-map
- difference and detect transients at site (Pole or Chile)
- send out alert (on 10 min time scale)

We can also separate/think of this in terms of:
- Goals v. Requirements
- Chile v. Pole

Pros

- After AGN variability, the only measured and assured transient signal from CMB surveys are stellar flares, which are ~10 minute time scales.
- This would increase sensitivity to stellar flares by a few.
- This would put us more in-line with other transient detection surveys (e.g. VRO/LSST with alerts within 60s)
- This is really just a few lines of code
- Building this in now will be relatively easy. Building this in later will be more difficult.

Cons

- Would require some effort. (=$)
- Scope creep on project. Could have larger upstream complications.
- Potentially changes interface between DAQ and DM.
- No one has actually explicitly implemented and demonstrated this yet.
- By the time the stellar flares get detected and the alert sent out, the flare is already over. So … why not just wait a year for the raw data to arrive in the US and then do whatever detection you want, post-facto ?

Alert Time Scale Change Request

current text

Background:
When the initial science and measurement requirements were written (~4 years ago), CMB experiments had not yet detected any transient sources. In most of our minds, we were thinking about extragalactic transients (e.g. GRBs) on time scales of days. In the meantime, Stage 3 CMB experiments (ACT + SPT) have detected mm transients and shown them to be dominated by stellar flares in our galaxy. Another change that has happened is that CMB-S4 is now going to survey (as opposed to avoiding) the galactic plane.

Request:
The Sources and Transients Working Group thinks the project should investigate the possibility of detecting transient events at the scan-level and issuing alerts on a commensurate time scale (i.e. minutes, not hours). This will optimize our sensitivity to transient events occurring faster than hours.

Rationale:
The current language states “daily” measurements of the sky with a “timely” alert to the community. The current Data Management baseline plan, however, includes maps made from every observation, which means a roughly 2 hour cadence.

The one mm transient signal we know exists is from stellar flares in our galaxy. These are on time scales of ~10 minutes. Thus, we should optimize our detection and alerts for this known signal. Doing so will increase our phase space for discovery and put CMB-S4 more in-line with the contemporary transient surveys (e.g. 60 seconds with VRO/LSST). This shrinks the alert time scale from two orders of magnitude to one.

There was some discussion of the fact that we could go back into the data after the fact and detect faster transients, but the thinking was that in the coming era, timely alerts to the community will be increasingly important. An example was given of the old days of gamma-ray astronomy with BeppoSAX, where the alerts were not timely, and thus multi-wavelength association became very difficult and hampered the science.

There was also some discussion of having different goals or requirements for Pole versus Chile. At Pole, the power and bandwidth issues provide significant logistical challenges, particularly on computing. But also, the Pole survey will only be covering the extragalactic sky, not the galactic plane. So it was thought that this is more critical and easier to implement for Chile, but still important to investigate for Pole.

Alert Time Scale Change Request

current text

Science Case:

GRB Reverse shocks

There is still a case for fast alerts for GRB reverse shocks (as opposed to the slower forward shock)

Stellar Flares

physical time scales of ~15 minutes
CHLAT scans are ~2.6 min long. double that for processing. double that again for contingency. = 10 minutes
gives time for followup from optical, radio, x-ray

Alert Time Scale Change Request

Next Steps:

- The Science Working Group decides what we need to do science. (done)
- Science Working Group makes a request/recommendation to the Science Council (nearly finished)
- Science Council proposes an amendment to the Program Level Requirements to the Change Control Board.
- Demonstrate that this is feasible (we have started thinking about this)
- Magic happens, maybe.

Science Book V2

Outline and assignments

Static (Joaquin&Tom)

polarization (don't forget)

Extragalactic (Joaquin)

AGN (Greg&Joaquin)
DSFGs (Joaquin&Scott)
Lensed sources (Joaquin &???)
proto clusters (Joaquin & Scott)

Galactic (Tom)

stars
debris disks (Rachel + Doug)
proto stars (Doug J.)
planetary nebulae (Tom + ???)
AGB stars (
symbiotic stars (giant and a white dwarf)
SN remnants
pulsar wind nebulae

Magellanic clouds (don't forget)

Transient / Variable / moving (Tom & Joaquin)

Solar System (Paul Chichura ???)
Niburi
asteroids
+++

Galactic (Tom & Rachel)
stellar (magnetic reconnection) flares
protoplanetary & YSO variability
classical novae
x-ray binaries
magnetar outbursts
Sgr-A*
stellar mergers and common envelope
other classes

Extragalactic (Anna & Joaquin)

Explosive Transients (Anna & Tarraneh)
GRBs
TDEs

AGN (Greg and John)

SN
FRBs (?)
other sources (e.g. FRBs)
FRBs
MMA — LIGO, LISA, IceCube
???