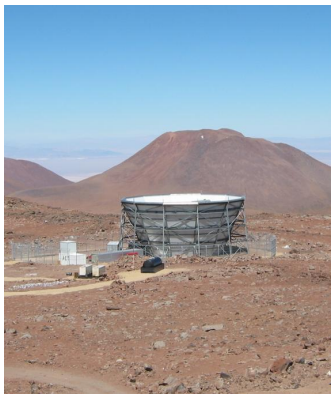
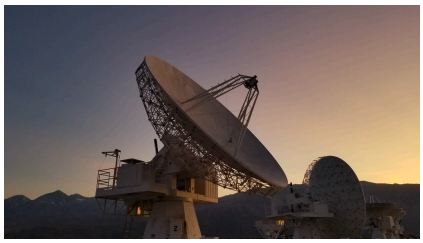
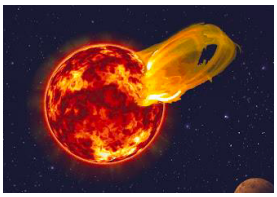
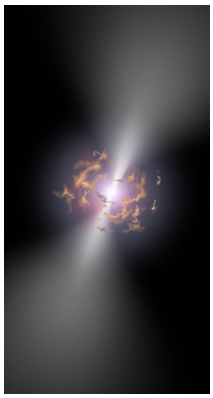
Millimeter-Wavelength Transient Searches: 2021

Virtual Workshop, 29 April 2021





Why This Workshop?

Although the sky is regularly monitored across many bands of the electromagnetic spectrum (as well as in gravitational waves and energetic particles) the dynamic sky at millimeter to sub-millimeter wavelengths (0.1-10 mm) remains poorly explored. Before last year, there had only been one blind transient survey specific to the millimeter band [1]. Millimeter facilities are usually only triggered after an initial discovery at another wavelength, but even when targeting known transients the success rate for detection is low.

We are now entering an era of wide-field millimeter transient surveys. Within the past few months, the Atacama Cosmology Telescope [2] and the South Pole Telescope [3] published blind discoveries of bright (mJy) transients. The highest-SNR events are stellar flares, but there are also two extragalactic transients of unknown origin. In the meantime, several projects are under development at Caltech for targeted follow-up of known classes of transients.

Anticipating that real-time discoveries of extragalactic transients will become routine in the next few years, the goal of this workshop is to bring together transient theorists and observers to review the status of current facilities and those under development, and discuss the science that will be made possible.

I would like to thank the representatives of the ACT and SPT collaborations (Sam Guns and Kevin Huffenberger), and Nitika Yadlapalli and Sunil Golwala (Caltech) for sharing their work with us. This booklet contains notes from the talks and discussion, as well as the PDF of each presentation.

Anna Y. Q. Ho

[1] Whitehorn, N., Natoli, T., Ade, P. A. R., et al. 2016, ApJ, 830, 143
[2] Naess, S., Battaglia, N., Bond, J. R., et al. 2020, arXiv:2012.14347
[3] Guns, S., Foster, A., Daley, C., et al. 2021, arXiv:2103.06166

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Notes: Transients from ACT

(Talk by Kevin Huffenberger)

- Scan strategy
  - Telescope moves side to side. Scans back and forth at constant elevation
  - Given source crosses FOV due to sky rotation, and is typically in the field for 6 minutes. So you get several passages over 6 minutes, then come back the next day (or later in the day if you shift to the west and catch a source setting).
  - Takes 40 seconds to scan 60 degrees in one direction
- Polarization capabilities: Linear polarization, but no circular polarization
- Sensitivity: depends on whether & where the source lands on the focal plane
  - Single one-way sweep, 1σ: 30-50 mJy (90 GHz), 60-80 mJy (150 GHz)
  - Steady source: integrating over the time it takes to traverse the focal plane, 1-σ is 10-20 mJy in 90 and 150 GHz and 50 mJy at 220 GHz
  - Across whole season: few mJy RMS, with variation across the sky
- Transient searches all at preliminary stages
  - Several different efforts (e.g., targeted archival SNe, Planet 9)
- Results so far
  - 3 bright transient events identified towards the end of last year (2020) as part of the Planet 9 search (not from a blind search)
    - Shift and stack optimized to look for moving sources
  - Each event spatially close to bright star
    - Stars are young, X-ray bright. Two are in known binaries.
    - Luminosities similar to mm-wave flares from young stars in the literature
    - Resolve rise over minutes, changes in spectral index, polarization limits
  - Search was not systematic, so could not establish a rate. However, these must be common, and might dominate searches at these wavebands.
- DF: The survey that found three transients: total sky coverage per epoch?
  - KH: 18000 sq deg total. Hard to answer question about epoch. Telescope scans 24 hours a day, but is not always covering that whole area.
- VR: could you tell us more about the search methods?
  - KH: 3-day shifting blocks depending on orbital parameters being checked at the time. We noticed these events because they were so bright. SPT search was much more systematic, so we're trying to implement similar methods.

Notes: Transients from SPT-3G

(Talk by Sam Guns)

- Hardware: 10m dish in Antarctica, third-iteration camera on SPT
  - 16000 polarization-sensitive bolometers
  - Same bands as ACT (95, 150, 220 GHz)
- Scan strategy: observe a 1500 sq deg field (FOV is 3 sq deg)
  - Use raster-scan strategy: revisit strip several times (averages out to twice daily) then move onto the next one, with a day-long gap before revisiting
  - For a given point in the sky, have 20 minutes of semi-continuous coverage, where every 100s have a 2-sec pass over the same source. So for bright flares can see high-resolution time evolution from individual scans.
- Sensitivity: 6 mJy in 95 and 150 GHz, 27 mJy at 220 GHz (1-sigma)
- Results from a systematic search of the 2020 dataset
  - Made a difference map to subtract the 2019 average
  - Apply point-source filter, fit Gaussian flare model at 95 and 150 GHz
  - Focused on events above 10-sigma, found 15 above this threshold
    - Majority: bright (brighter > 2 Jy) short-lived (down to 20 min) stellar flares
    - DD: what % of the year were you observing the star that flared 4x? SG: 20%
    - VR: were the multiple flares found in a sub-threshold search? SG: no.
    - Simultaneous optical coverage: contemporaneous TESS light curve
  - Two extragalactic events
    - Both had secondary flare, each lasted two months
    - No Galactic association, plausible associations in WISE
    - Both sources were detectable in the 2019 average map
    - Leading hypothesis: AGN flares
    - Plan to analyze AGN data to understand statistics of low-luminosity flares
      - VR: AGN data will be useful for gravitational lensing studies. Should reach out to Tim Pearson and Tony Readhead at Caltech.
  - Outlook for 2021-2023: Online alert system running since October
    - Search running automatically at SP right now
    - Working to increase sensitivity, reduce systematics, lower threshold to 6-7σ
    - Expect to find other classes of extragalactic transients
      - VR: with SPT-3G, or first discovered by other instruments?
      - SG: Both. For example, off-axis GRBs will not have GRB trigger.

Notes: Sub/mm Transients with the Leighton Chajnantor Telescope

(Talk by Sunil Golwala)

- CSO is being decommissioned (will be decommissioned in 2022). Plan is to get LCT off the mountain in the next year, and move to site inside ALMA
- 12m class telescope
- Will be a facility focused on large (1000-hour level) surveys, not possible with existing facilities like ALMA
- Focus is continuum-imaging
- Can be used for technology demonstrations, new instruments
  - MUSIC: simultaneous coverage in 6 bands
  - SHARC II: coverage up to 850 GHz
- Science ideas
  - Cow-like transients will be difficult because of the low rate.
  - Stellar flares could be a good target: pick 100 deg2 patches and do shallow integrations. Additional high-frequency bands would help constrain spectrum, look for dust.
  - Episodic accretion onto protostars. Good match for broad LCT spectral coverage.
- ESP: Could you do time gating (sub-second timescales) for magnetar observations? Pulses are ~1/10 sec long every 3 seconds. Typical sensitivity at 100 GHz is at level of 10 mJy-second.
  - SG: Would be marginal.
  - JZ: You could just stare at it and then the time-gating is straightforward. The fact that it's fast in the time-domain eliminates all those considerations.
- KH: Do you have a time constant in the detectors?
  - SG: Sub-millisecond

Commissioning and Observing Plans for SPRITE

(Talk by Nitika Yadlapalli)

- Upcycling old 10m dishes currently left unused after CARMA decommissioned. Will take 3 of these dishes and turn them into instrument for SPRITE.
- 1' FOV
- 1hr integration: 1 mJy RMS (100 GHz; also have 30 and 230 GHz receivers)
- Initially not going to do any calibration for polarization
- Two types of observing plans
  - Follow up triggers from other telescopes (e.g., reverse shocks from LGRBs)
    - Nearby GRBs
      - DP: suggest triggering off alerts, because that's unexplored territory. Have never seen rise of GRB in the millimeter. With CARMA the typical delay was 15 min. Will not know redshift for hours, so will lose early phase
    - Promising ZTF candidate sources
  - Monitor ongoing classes (AGN, XRB, EHT, nearby stars)
- Rate estimates based on 5-sigma sensitivity
  - Expect two stripped-envelope SNe per year
  - SRK: Suggest early phases of core-collapse SNe. According to Chevalier models peak flux is same across frequencies. Directly detect ff signature.
  - GH: 2009ip-like events, target Type IIn SNe with pre-explosion outbursts
  - ESP: should add TDEs to the list
- Plan to get on sky by Winter 2021
  - Building correlator for SPRITE, refinements to control software
  - Have antennas, receivers, IF in signal chain, recently had fiber installed, connecting telescope to computers
- KH: how far south in declination can you comfortably observe sources?
  - NY: Telescopes go to 20 deg above horizon, and OVRO is at 37 deg lat.
- GH: Anticipating SPT ATels for stellar flares, will you have circular polarization capabilities straightaway?
  - VR: not straightaway.

CMB-S4

We did not have a dedicated talk about CMB-S4. However, it came up several times during the Q&A, so I have included notes on the subject here.

- Large survey with Chilean telescopes and 3% of the sky survey from South Pole with the large-aperture SPT
- Cadence numbers still TBD. If you have opinions on what they should be, tell us. At least once a day for the wide survey, and for SPT surveying the field every eight hours. Some revisit within observations on minute timescales like what SPT and ACT are doing now.
- Wide-field survey will scan right through the galaxy, primary purpose is to do de-lensing for B-mode search. That has to be in the cleanest part of the sky, well away from the plane.
- CMB-S4 and SPT-3G have same daily sensitivity (~40 mJy for 6-sigma detection)

Participants

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