

CCAT-prime Science Team Activities and Surveys



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A Bit of History

- Science team efforts in existence since nearly the dawn of CCAT-prime in spring of 2016
- First Formal Science Teams
 - Galactic Ecology Science (Peter Schilke)
 - Cluster science (Frank Bertoldi)
 - Dusty Starforming Galaxies (Gordon Stacey)
 - EoR IM science (Dominic Riechers)
 - CMBR science (Mike Niemack)



Joint Science Telecoms

- Early days: biweekly telecoms
 1. Cluster science grouped with CMBR science
 2. DSFG science grouped with EoR IM science
 3. Galactic Ecology somewhat independent
- Evolved into “Joint Science Telecoms”
 - Group of 20 to 30 scientists from “1” and “2” meeting more-or-less once a week
- Holding these telecoms ever since



Products

- Science focus sharpened within each topic
 - Presentations of science expectations driving instrumentation requirements
 - Noise models produced and refined
 - Feedback to instrument design – some modifications!
- Science forecasts made driving the next ideas and feeding into proposal preparation
- Planned Science Workshop at U. Chile, April 2019
- New Science themes unfold...
 - Rayleigh Scattering
 - Transient Science
 - Dust polarization and star formation
- Planned this Collaboration Meeting...

Feedback: Science Products and Instrumentation



- Instrumentation constraints
 - Per Pixel Sensitivity
 - instrument throughput
 - Detector types/quantum efficiency.
 - thermal backgrounds
 - sky noise
 - Numbers of Pixels
 - fundamentally FoV
 - but... also budget... - in the sense of numbers of tubes
- Science constraints
 - Sensitivity requirements \Rightarrow RP of IM FPI: 300 \rightarrow 100
 - Availability of low frequency SO surveys \Rightarrow first light submm cameras will 280 GHz, then 350 GHz.



We are publishing!

Pre-Decadal Publications



First one to mention CCAT!

1. *Line-intensity Mapping: 2017 Status Report*, Ely Kovetz et al. 2017, arXiv170909066K

2018 SPIE Proceedings

2. *CCAT-prime: a novel telescope for sub-millimeter astronomy* (S. Parshley et al.)
3. *The optical design of the six-meter CCAT-prime and Simons Observatory telescopes* (S. Parshley et al.)
4. *Prime-Cam: a first-light instrument for the CCAT-prime telescope* (E. Vavagiakis et al.)
5. *Optimizing the Efficiency of Fabry-Perot Interferometers with Silicon-Substrate Mirrors* (N. Cothard et al.)
6. *CCAT-prime: Science with an Ultra-widefield Submillimeter Observatory at Cerro Chajnantor* (G. Stacey et al.)

Since SPIE 2018



8. *Planck's view on the spectrum of the Sunyaev-Zeldovich effect*, Jens Erler et al. 2018, MNRAS 476, 3360E
9. *Optimizing measurements of cluster velocities and temperatures for CCAT-prime and future surveys*, A. Mittal et al. 2018 JCAP, 2, 32M
10. *Introducing constrained matched filters for improved separation of point sources from galaxy clusters*, Jens Erler et al. 2019 MNRAS 484, 1988E
11. *Sensitivity of the Prime-Cam Instrument on the CCAT-prime Telescope*, Steve Choi et al. 2019, arXiv190810451C
12. *Coupling parsec and gigaparsec scales: primordial non-Gaussianity with multi-tracer intensity mapping*, R. Henry Lui and Patrick C. Breysse 2020 arXiv200210483L
13. *The Design of the CCAT-prime Epoch of Reionization Spectrometer Instrument*, Nick Cothard et al. 2020 JLT..tmp....4C
14. *Forecasting [CII] Line-intensity Mapping Measurements between the End of Reionization and the Epoch of Galaxy Assembly*, Chung, Dongwoo et al. 2020, ApJ 892, 51C

2020 Decadal Review White Papers



15. Mroczkowski

16. Cicone

17. Meerburg

18. Kovetz

19. Meerburg

20. Lis

21. Mroczkowski

22. Geach

23. Casey

24. Mantz

25. Chang

26. Battaglia

27. Basu

28. Ruszkowski

29. Orłowski-Scherer

30. Simon

31. La-Plante

32. Fischer

33. Burchett

34. Stanke

35. Johnstone

36. Herter



Studying high- z galaxies with [CII] intensity mapping

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ABSTRACT

We investigate the [CII] line intensity mapping (IM) signal from galaxies in the Epoch of Reionization (EoR) to assess its detectability, the possibility to constrain the $L_{\text{CII}} - \text{SFR}$ relation, and to recover the [CII] luminosity function (LF) from future experiments. By empirically assuming that $\log L_{\text{CII}} = \log A + \gamma \text{SFR} \pm \sigma_L$, we derive the [CII] LF from the observed UV LF, and the [CII] IM power spectrum. We study the shot-noise and the full power spectrum separately. Although, in general, the shot-noise component has a much higher signal-to-noise ratio than the clustering one, it cannot be used to put independent constraints on $\log A$ and γ . Full power spectrum measurements are crucial to break such degeneracy, and reconstruct the [CII] LF. In our fiducial survey S1 (inspired by CCAT-p/1000 hr) at $z \sim 6$, the shot-noise (clustering) signal is detectable for 2 (1) of the 5 considered $L_{\text{CII}} - \text{SFR}$ relations. The shot-noise is generally dominated by galaxies with $L_{\text{CII}} \gtrsim 10^{8-9} L_{\odot}$ ($M_{\text{UV}} \sim -20$ to -22), already at reach of ALMA pointed observations. However, given the small field of view of such telescope, an IM experiment would provide unique information on the bright-end of the LF. The detection depth of an IM experiment crucially depends on the (poorly constrained) $L_{\text{CII}} - \text{SFR}$ relation in the EoR. If the $L_{\text{CII}} - \text{SFR}$ relation varies in a wide $\log A - \gamma$ range, but still consistent with ALMA [CII] LF upper limits, even the signal from galaxies with L_{CII} as faint as $\sim 10^7 L_{\odot}$ could be detectable. Finally, we consider the contamination by continuum foregrounds (CIB, dust, CMB) and CO interloping lines, and derived the requirements on the residual contamination level to reliably extract the [CII] signal.

Key words: galaxies: high-redshift, dark ages, reionization, first stars, diffuse radiation, radio lines: galaxies

arXiv:1909.11656v1 [astro-ph.GA] 25 Sep 2019

SPIE 2020 Papers



- 37. *CCAT-prime: A status report on the ultra-widefield submillimeter observatory on Cerro Chajnantor*, Gordon Stacey et al.
- 38. *A 350 micron camera module for the Prime-Cam instrument on CCAT-prime*, Scott Chapman et al.
- 39. *CCAT-prime: Telescope final design*, Kayla Rossi et al.
- 40. *Observatory control software for CCAT-prime*, Mike Nolta et al.

We'll see if this happens this summer!



Groups Subdivide for Focus

- Tracing the Epoch of Ionization through Line Intensity Mapping (Coordinators: *Stacey, Riechers*)
- Galaxy and Cluster Formation (Coordinators: *Battaglia, Basu*)
- Tracing Dusty Star Formation over Cosmic Time (Coordinators: *Chapman, Aravena*)
- Characterizing foregrounds for CMB observations (Coordinators: *Niemack, Choi*)
- CMB Constraints on cosmological Rayleigh Scattering (Coordinator: *Meerburg*)
- New Windows into Time Domain Astrophysics (Coordinator: *Johnstone*)
- Tracing Star Formation in the Galaxy and Nearby Galaxies (Coordinators: *Simon, Stutz, Nikola*)
- Magnetic Fields and Galactic Science (Coordinator: *Fissel*)



Going Forward

- Plans are to continue full SWG telecoms biweekly
- Expectation is that subgroups will hold sub-telecoms (maybe shared) to progress:
 - Science motivation
 - Sensitivity requirements
 - Survey requirements
 - Instrumentation requirements beyond our first light modules

Surveys



Table 2: Overview of baseline Prime-Cam survey performance^c [56, 15]

Survey	Field ID	LST range [h]	Area [deg ²]	Time [hr]	Sensitivity ^c (@ representative ν_{obs} [GHz])	Supporting Surveys ^b
EoR ^a	E-COSMOS	7.0-13.0	8	2000	0.02 MJy sr ⁻¹ bin ⁻¹ @ 220	1
	E-CDFS	23.5-7.0	8	2000	0.02 MJy sr ⁻¹ bin ⁻¹ @ 220	2
	HERA-Dark	13.0-23.5	8	(filler)	0.02 MJy sr ⁻¹ bin ⁻¹ @ 220	3
DSFG	Stripe 82	20.0-5.5	300	500	2.5 mJy beam ⁻¹ @ 860	4
	GAMA9/12/15	5.5-20.0	110	180	2.5 mJy beam ⁻¹ @ 860	5
SZ/CMB	AdvACT/SO	all	12,000	4000	11 μ K/arcmin ² (CMB) @ 270	6

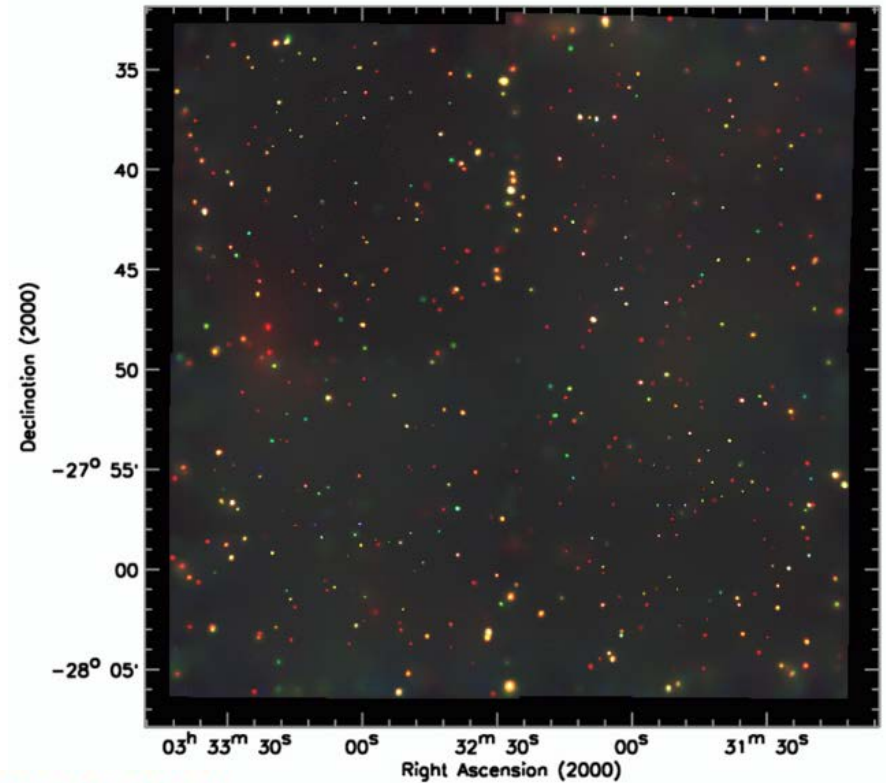
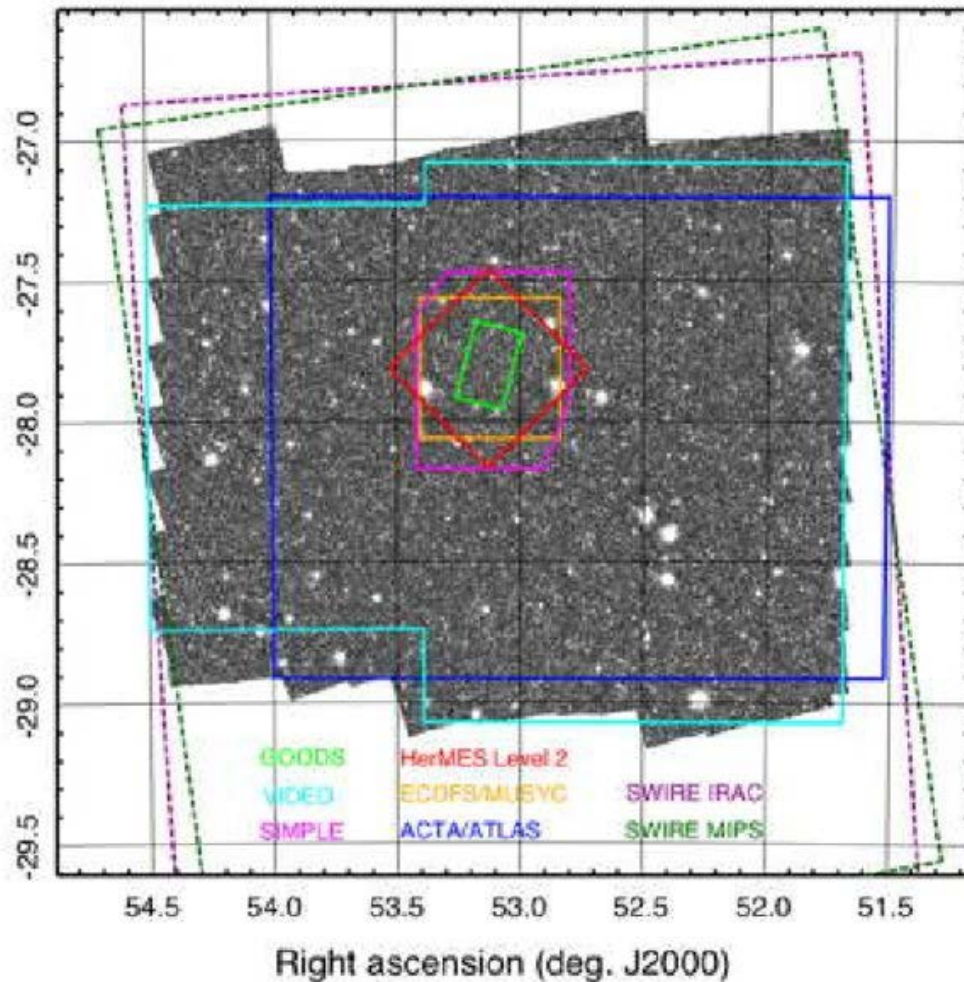
^aSpectroscopy; sensitivities provided for $R=100$. ^b(1) Deep Subaru HSC+PSF spectroscopy & COSMOS X-Ray-to-meter-wave multiwavelength survey; (2) deep Euclid grism spectroscopy (upcoming), HERA HI 21 cm (upcoming), & H-UDF/CDF-S multiwavelength surveys (incl. JWST GTO); (3) HERA HI 21 cm (upcoming), VLASS; (4) SDSS, HeLMS/HeRS Herschel/SPIRE, VLASS; (5) GAMA, H-ATLAS Herschel/SPIRE, ACT, VLASS; (6) Planck, SDSS, DES, ACT, SO, DESI, LSST, eROSITA (upcoming).

^cPreliminary sensitivity model; a more advanced model is now available in Choi et al. (2019) [15].

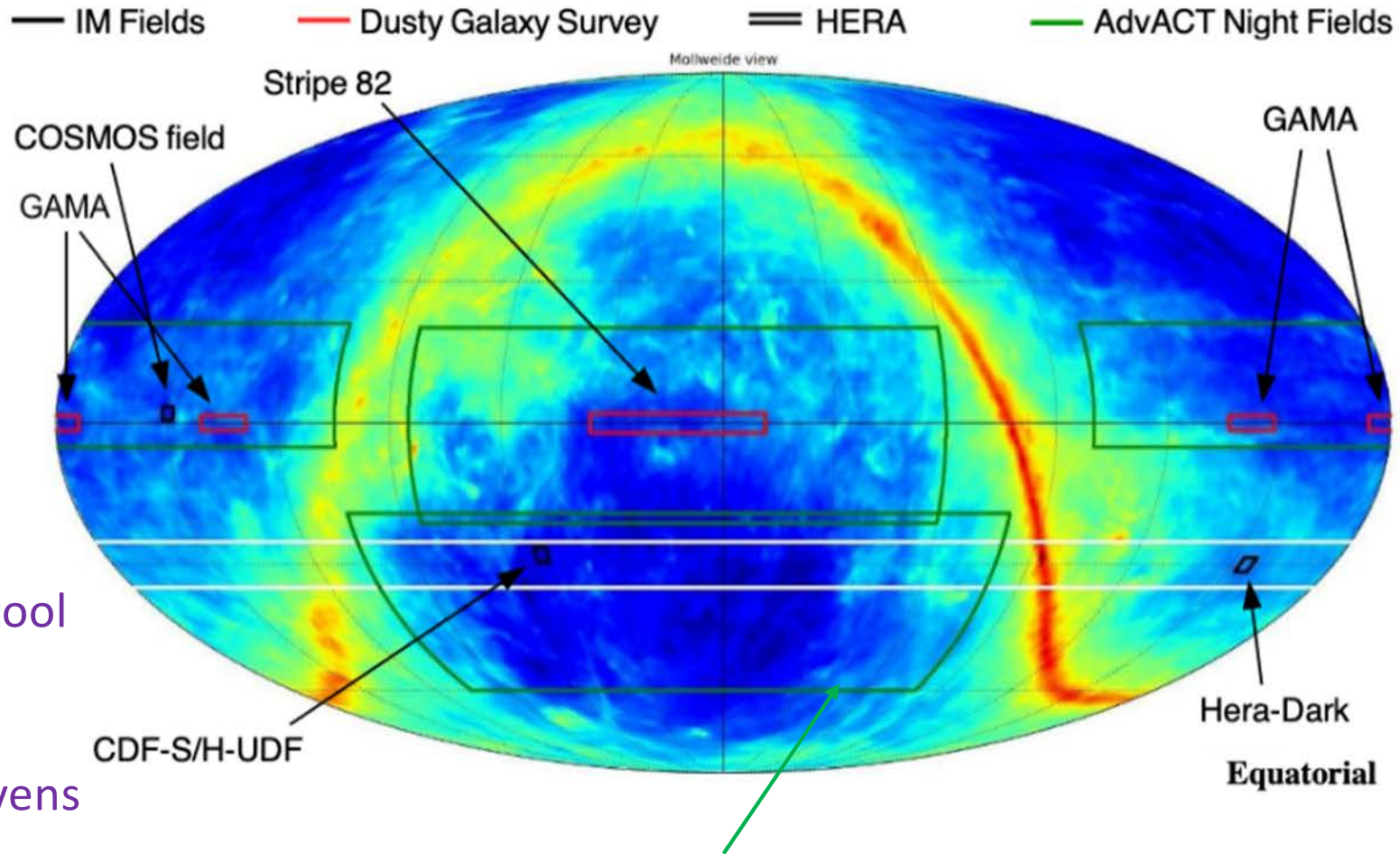
Fields chose to overlap with existing/planned surveys

Herter et al. 2020 Decadal white paper (arXiv:1909.02587)

Extended-CDFS (Chandra Deep Field South)



Surveys as Currently Planned



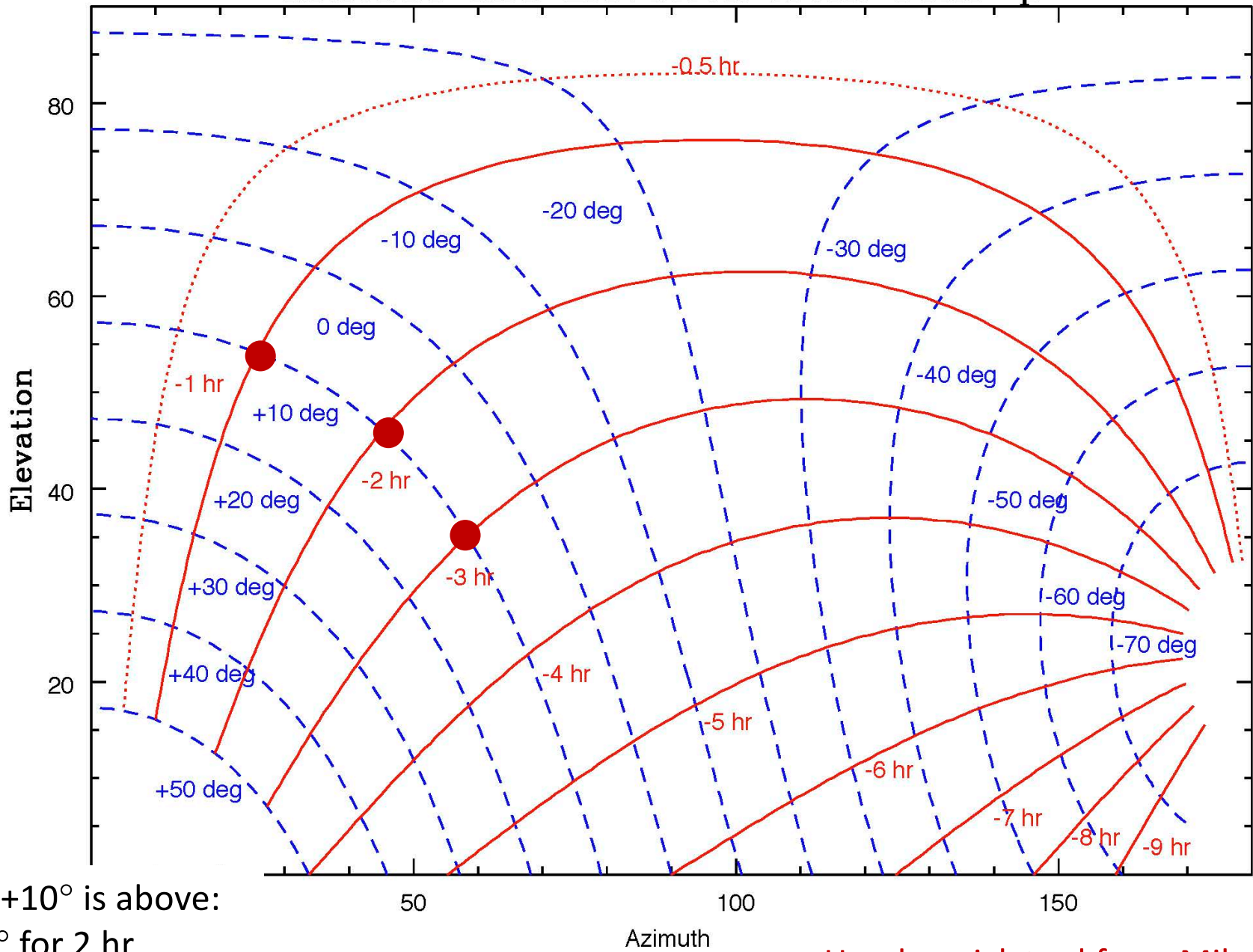
ACT-Pol
planning tool

Figure by
Jason Stevens

*“cosmology” survey (green boxes)
expandable to include Galactic regions*

Stacey et al. 2018 (arXiv:1807.04354)

Altitude and Elevation from CCAT-p



Dec. of $+10^\circ$ is above:
 El. = 55° for 2 hr
 El. = 48° for 4 hrs
 El. = 35° for 6 hrs

Handy quick tool from Mike Fich

Collaboration Meeting Goals



- Foster:
 - collaborations between scientists within areas of scientific expertise
 - collaborations between scientists across areas of scientific expertise
- Communicate data and survey requirements to technical team (who are often fellow scientists)
- Look for:
 - exciting first light science
 - synergies in survey fields – more than one science tube can operate at the same time!
 - Brings in questions of field size and integration time, i.e. scan strategies



CCAT-p