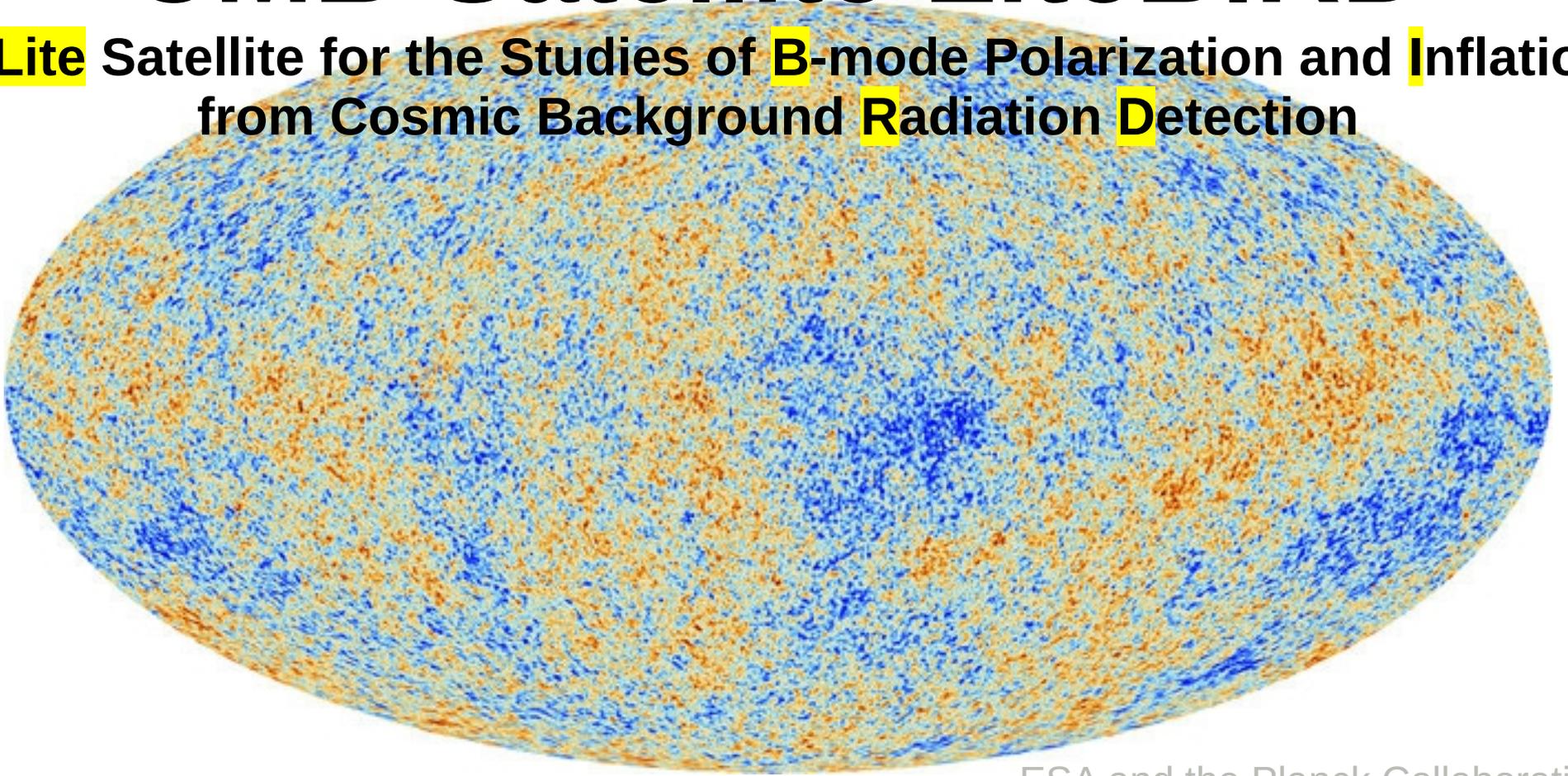


# Transient Search with CMB Satellite LiteBIRD

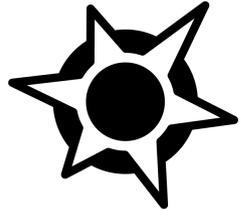
A **Lite** Satellite for the Studies of **B**-mode Polarization and **I**nflation  
from Cosmic Background **R**adiation **D**etection



ESA and the Planck Collaboration

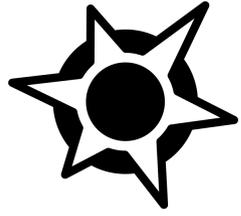


**M. Tsujimoto (JAXA ISAS), H. Ishino**  
(Okayama U.), Y. Inoue (RIKEN). et al.



# References

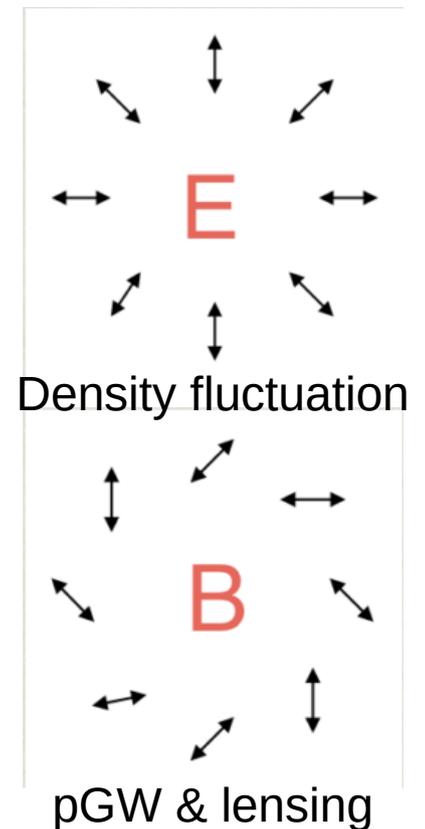
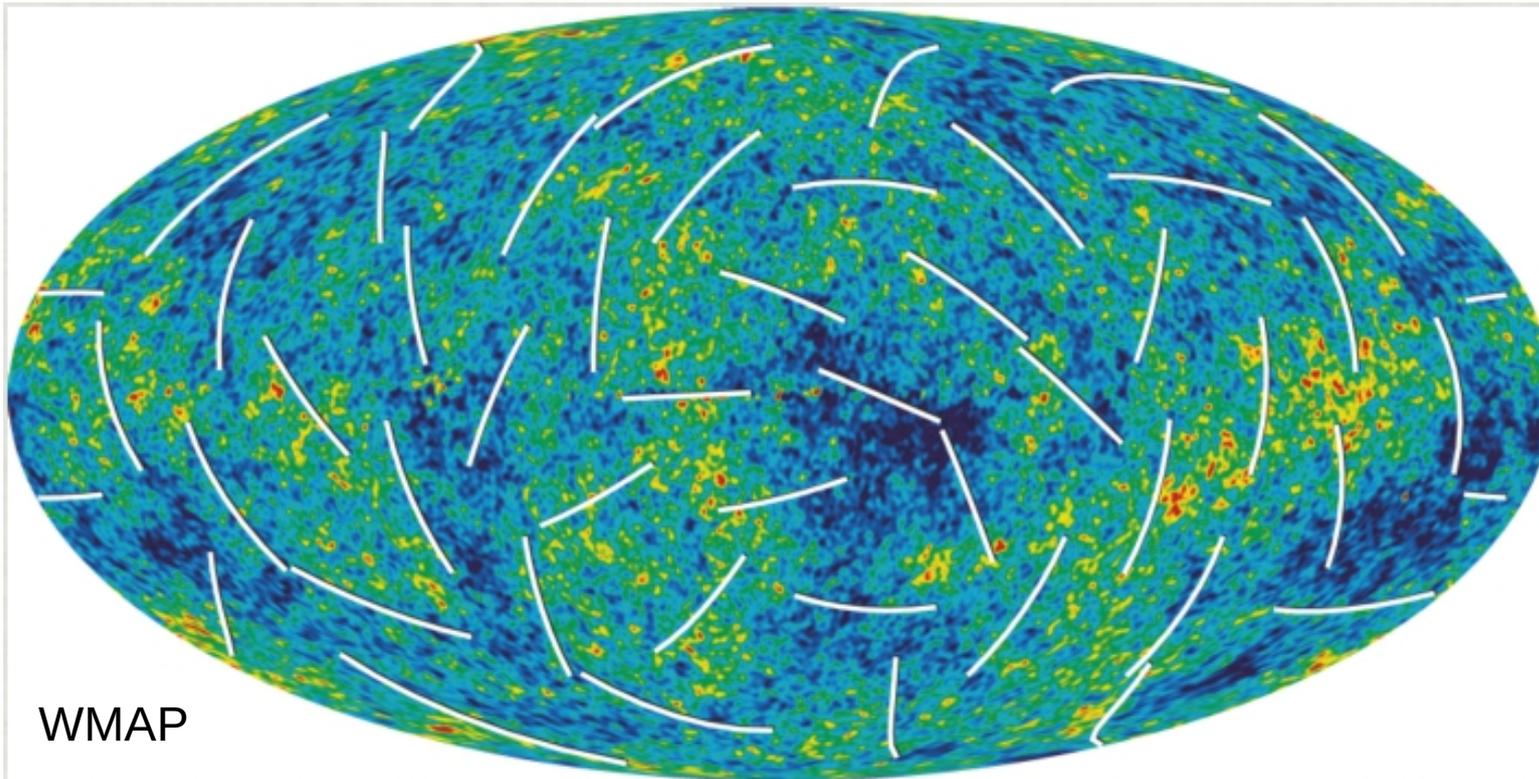
- “LiteBIRD”, M. Hazumi, 2nd B-mode from Space workshop, 2017
- “LiteBIRD as a Radio Transient Factory”, Y. Inoue, 1st B-mode from Space workshop, 2015
- “LiteBIRDにおける偏光変調器用連続回転機構の開発 II”, 桜井雄基+, 日本物理学会, 2017
- “CMB偏光観測実験 POLARBEARの最新の結果と今後の展望”, 長谷川雅也, 素粒子物理学シンポジウム, 2014
- “Delensing Cosmic Microwave Background B-modes with the Square Kilometre Array Radio Continuum Survey”, Namikawa, T. et al. arXiv:1511.04653

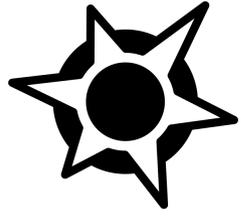


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# Mission Objective

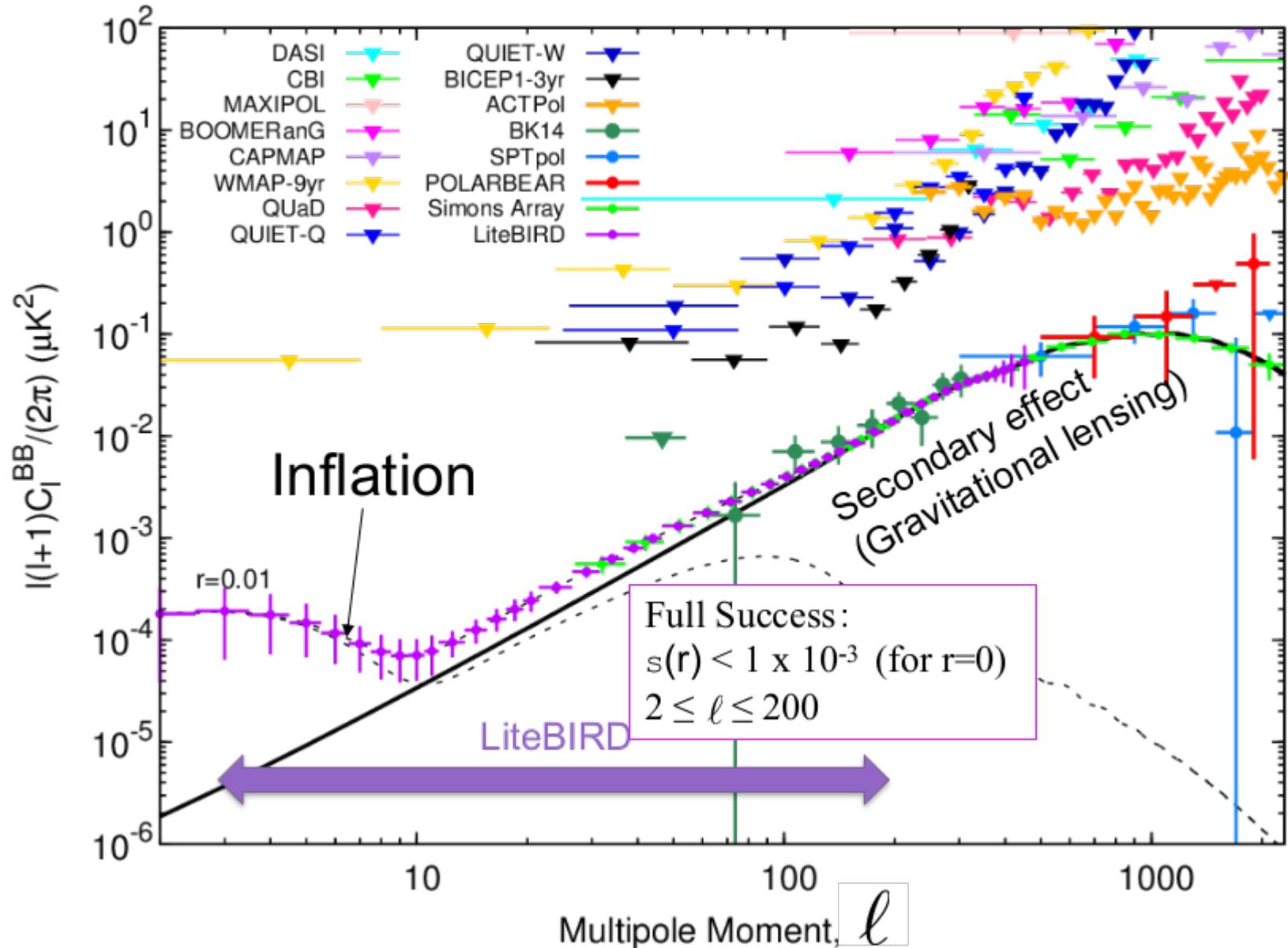
- Large-angle B-mode linear polarization.
  - Imprints of primordial GW.
  - Only currently feasible approach to access Inflation.
  - The Holy Grail of Cosmology

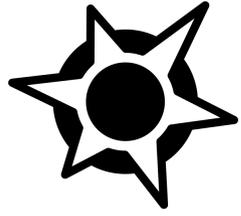




# 1. Project 2. Technology 3. Transient Search Mission Objective

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# Claim for detection

Created by JEREMIE SOMMET

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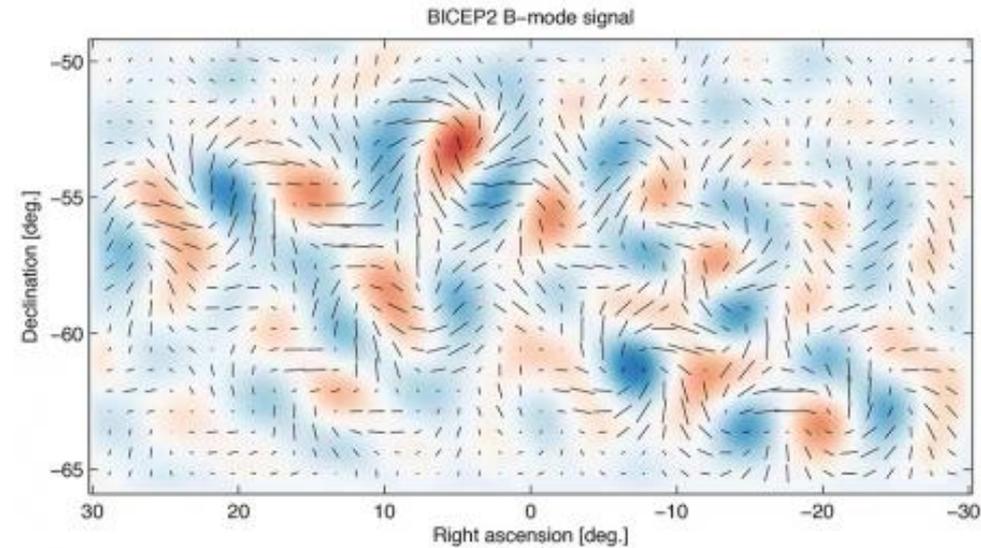
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03/17/2014

## BICEP2 Discovers First Direct Evidence of Inflation and Primordial Gravitational Waves

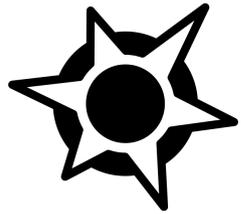
Astronomers announced today that they have acquired the first direct evidence that gravitational waves rippled through our infant universe during an explosive period of growth called inflation. This is the strongest confirmation yet of cosmic inflation theories, which say the universe expanded by 100 trillion trillion times in less than the blink of an eye.

"The implications for this detection stagger the mind," says **Jamie Bock**, professor of physics at Caltech, laboratory senior research scientist at the Jet Propulsion Laboratory (JPL) and project co-leader. "We are measuring a signal that comes from the dawn of



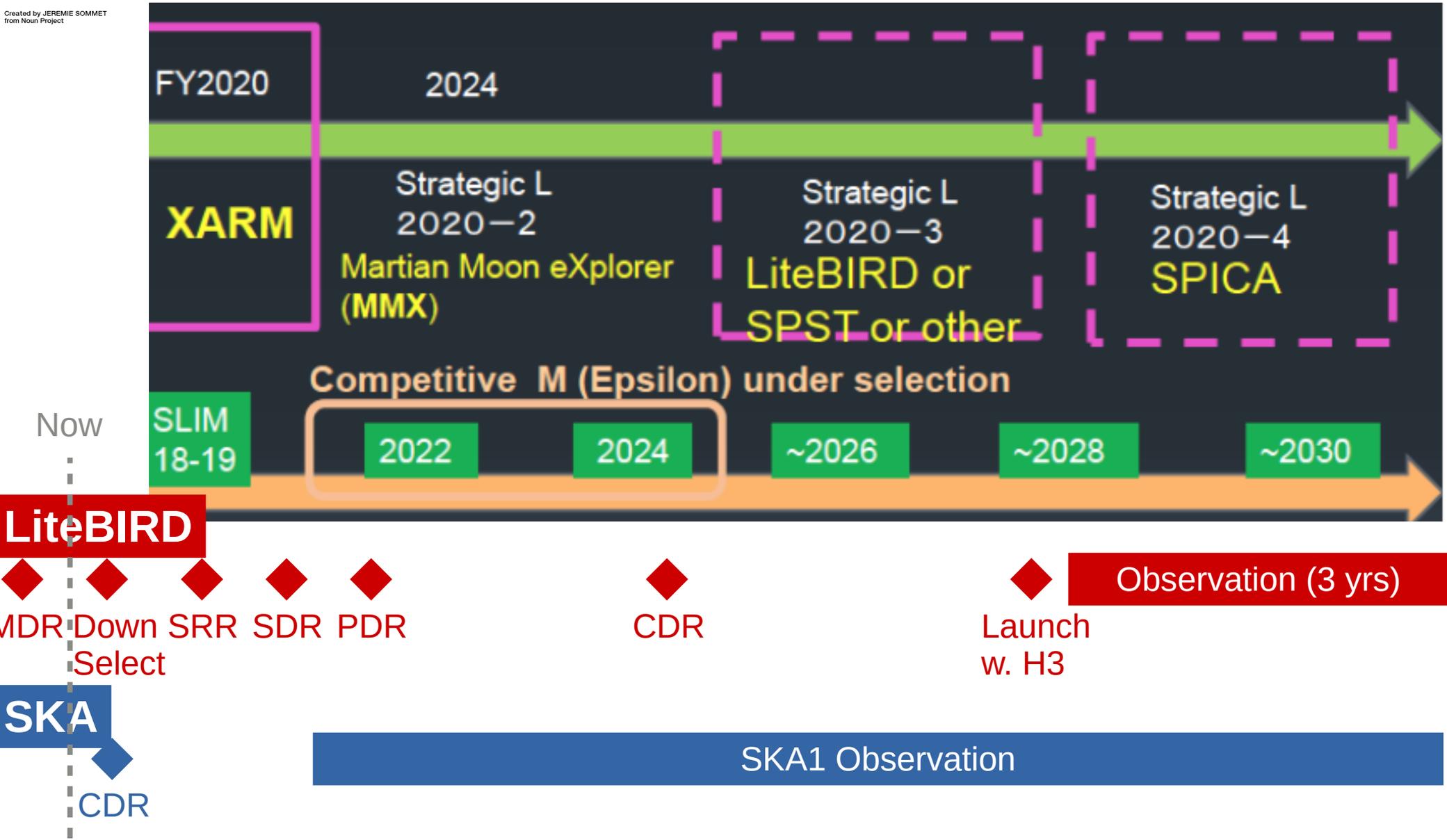
Gravitational waves from inflation generate a faint but distinctive twisting pattern in the polarization of the CMB, known as a "curl" or B-mode pattern. Shown here is the actual B-mode pattern observed with the BICEP2 telescope, with the line segments showing the polarization from different spots on the sky. The red and blue shading shows the degree of clockwise and anti-clockwise twisting of this B-mode pattern.

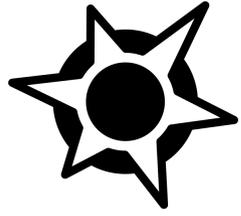
*Credit: The BICEP2 Collaboration*



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1. Project 2. Technology 3. Transient Search

# World-wide Joint Effort

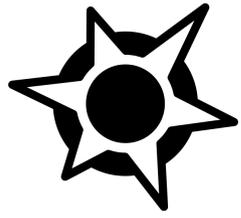
- Countries: Japan, US, Canada, many Europeans.
- Lead by M. Hazumi (KEK), A. Lee (UC Berkeley)



**B-MODE FROM SPACE WORKSHOP**

SECOND MEETING AT THE UNIVERSITY OF CALIFORNIA, BERKELEY

December 4th 2017 - December 6th 2017



1. Project 2. Technology 3. Transient Search

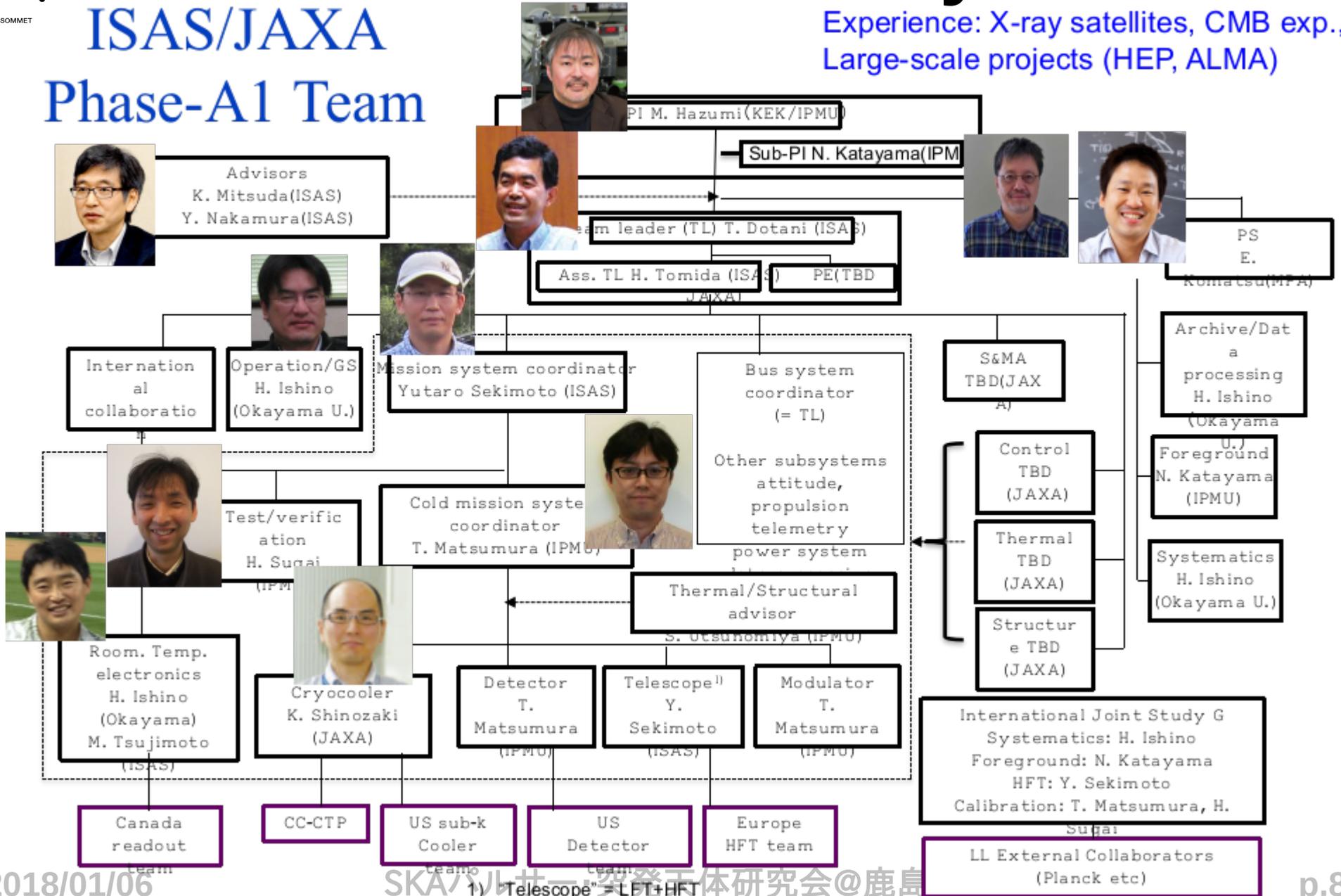
# Domestic Community

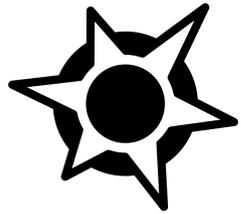
ver. 2017.11.02

## ISAS/JAXA

Experience: X-ray satellites, CMB exp., Large-scale projects (HEP, ALMA)

### Phase-A1 Team



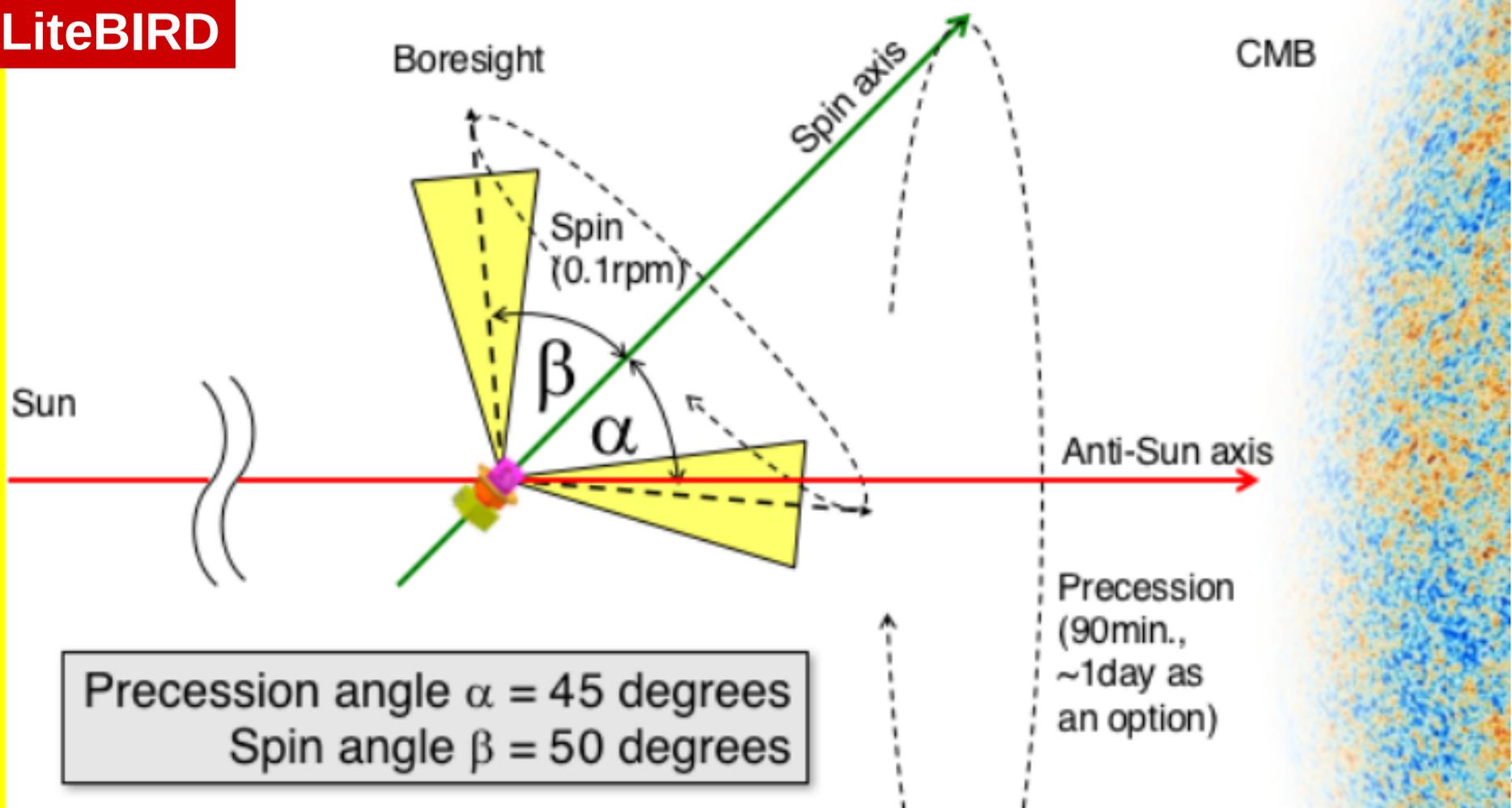


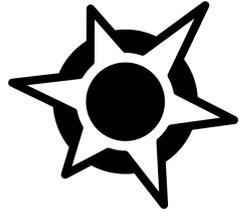
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# Orbit & Scan Strategy

- L2 orbit
- Large precession angle.

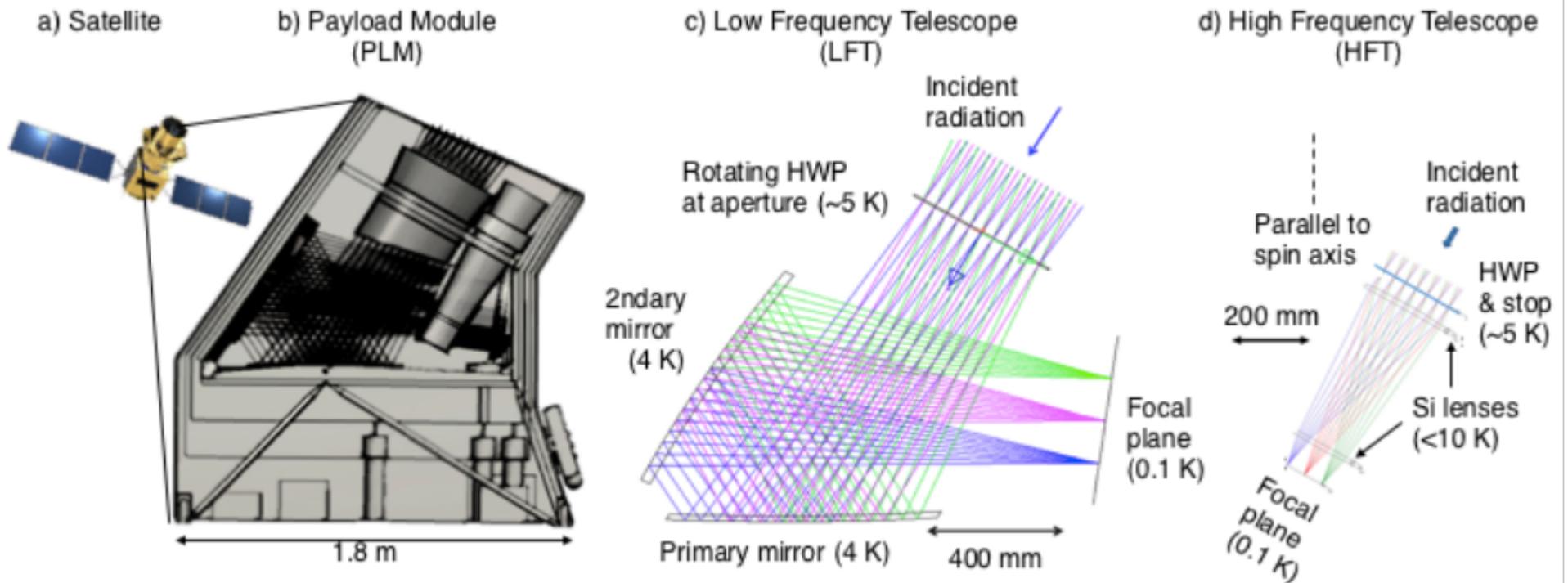
**LiteBIRD**

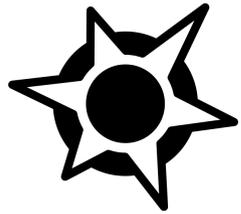




# Telescopes

- Two telescopes.
  - LFT : aperture  $\sim 400\text{mm}$ ,  $\nu=40\text{-}235\text{ GHz}$
  - HFT : aperture  $\sim 300\text{mm}$ ,  $\nu=280\text{-}400\text{ GHz}$

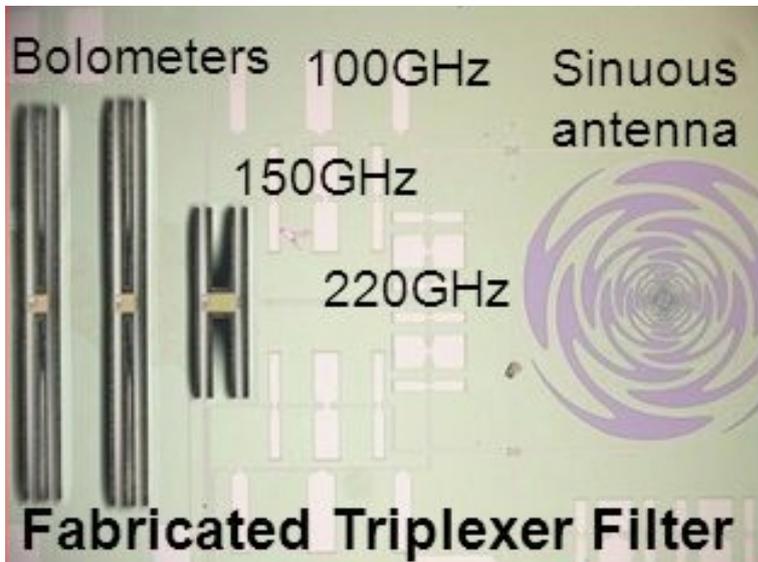
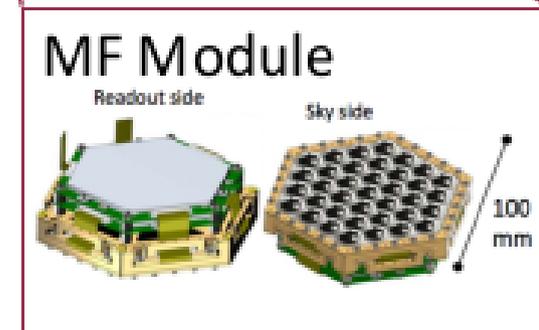
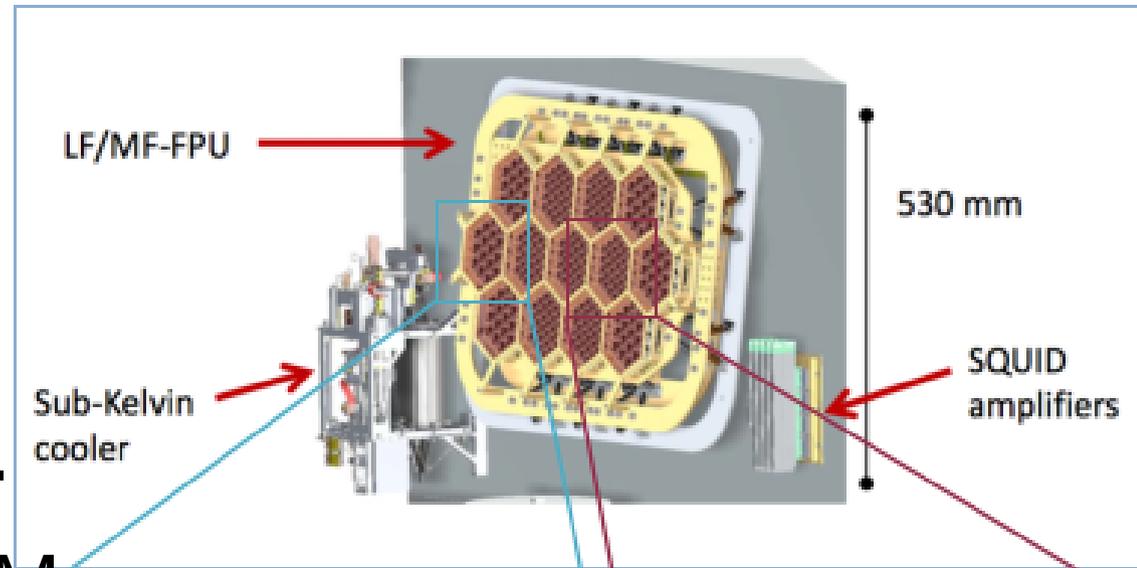


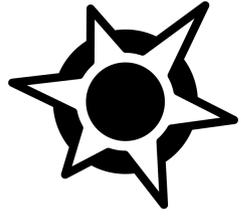


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# Focal Plane Detectors

- Sinuous antenna.
  - Multi-chroic.
  - Two linear pols.
- ~3k TES bolometers.
- Read by SQUID+FDM.

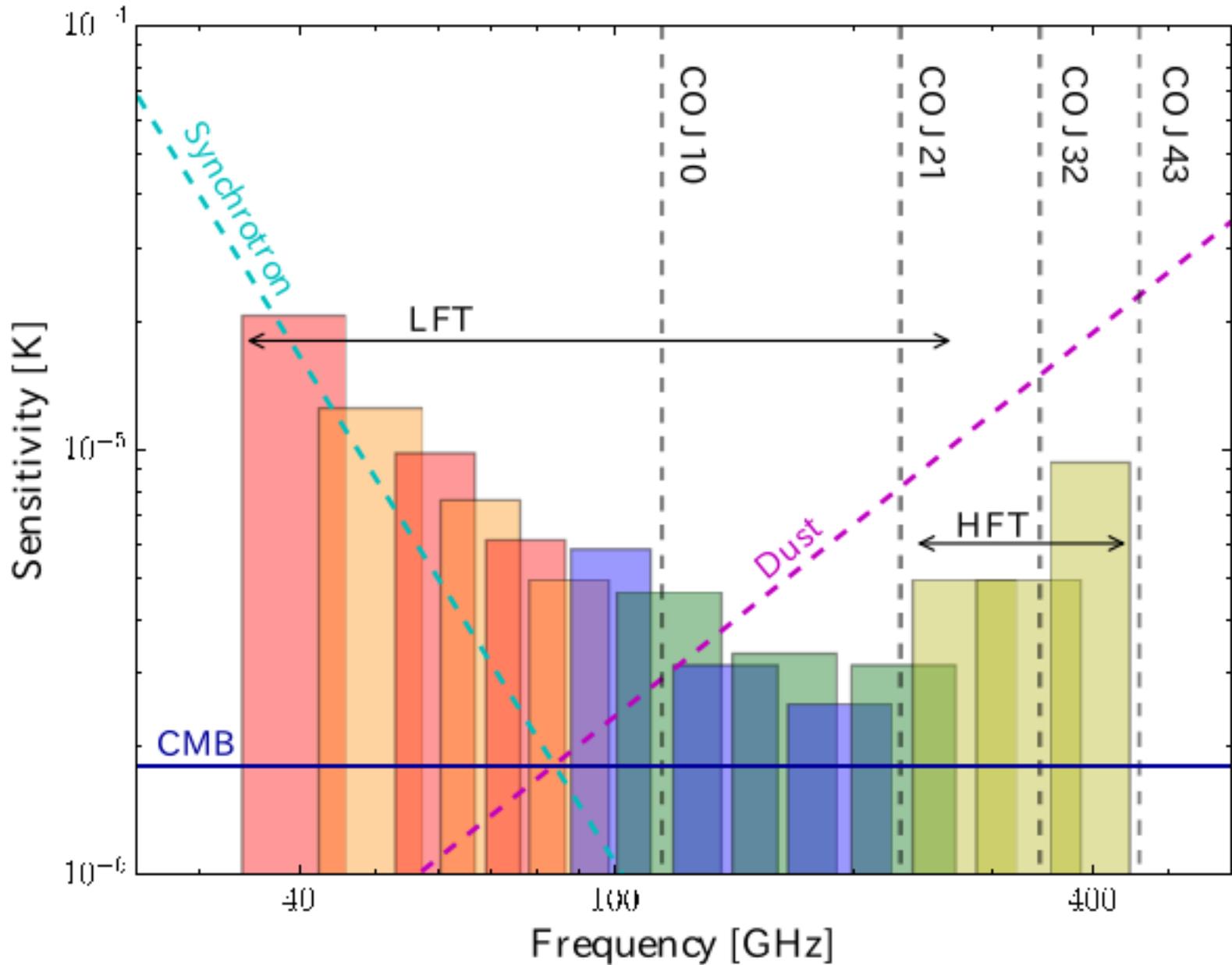


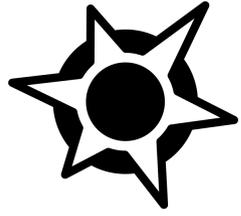


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# Multi-Chroic Coverage

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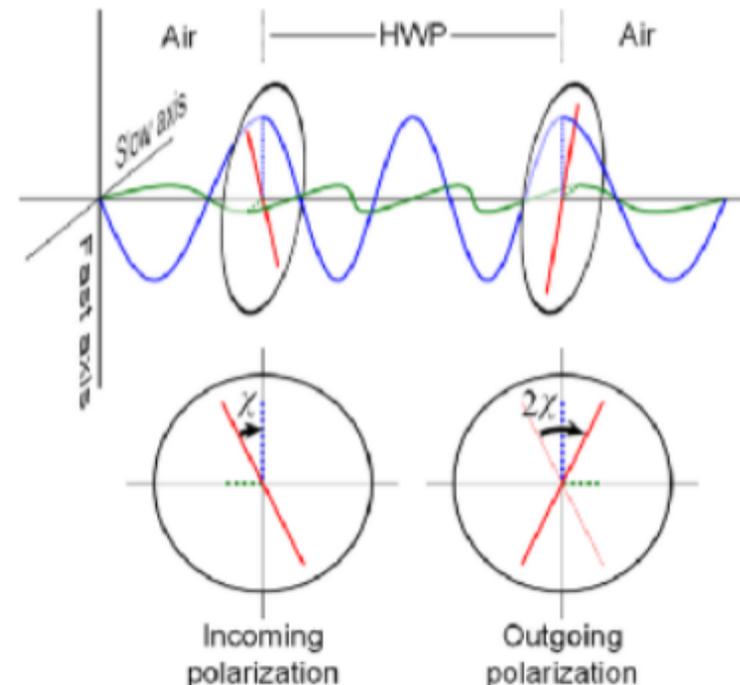
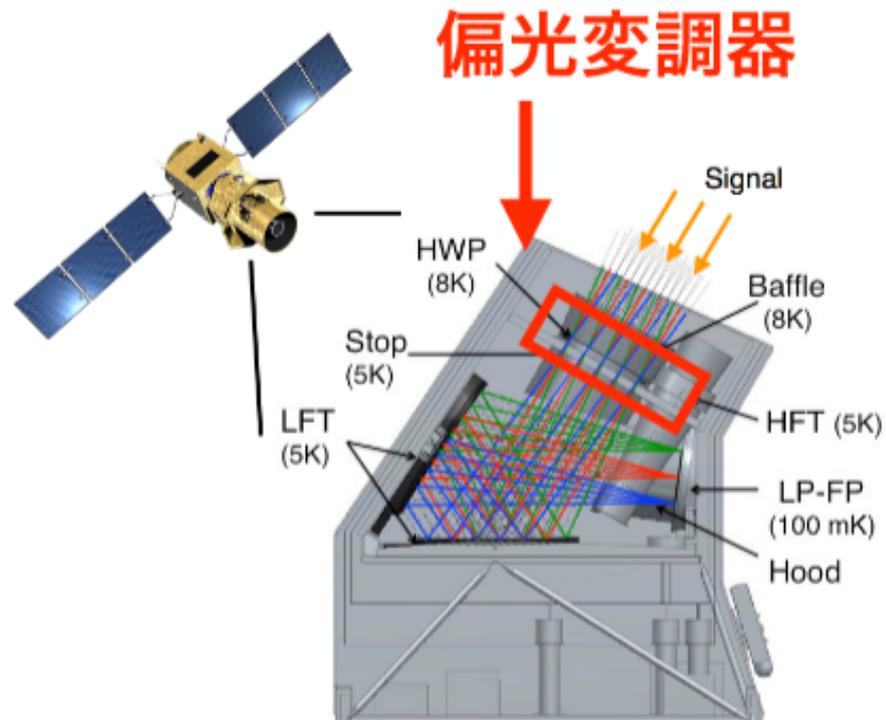




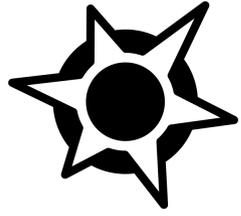
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# Polarization Modulator

- Continuously rotating ( $\sim 100$  rpm) half-wave plate.
  - Modulate (up-convert) signal against  $1/f$  noise.
  - Reduce systematics due to det gain mismatch.



Kusaka et. al., Rev. Sci. Instrum., 85, 024501 (2014)



# 1. Project 2. Technology 3. Transient Search

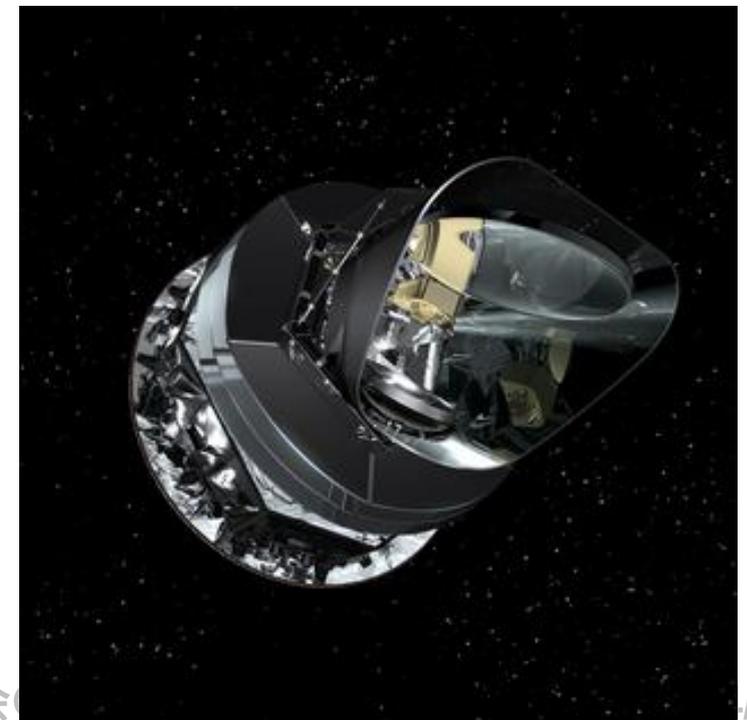
## (1) Comparison w. Planck HFI

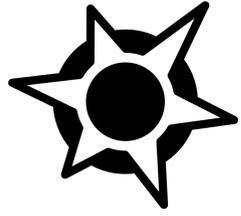
表 1: LiteBIRD と Planck 衛星の比較

名前	— 打上げ —		— 軌道・スキャン —			— 偏光 —		— 検出器・読出し —		
	国	年	軌道	自転速度	歳差角	変調器	帯域	数	Sampling	多重化
Planck <sup>a</sup>	欧州	2009	L2	1 rpm	7.5°	なし	4	32	180 Hz	1
LiteBIRD <sup>b</sup>	日本	2027	L2	0.1 rpm	45°	あり	13	2622	23.8 Hz	64

<sup>a</sup> Planck は HFI 装置で偏波感度があるものの数値を列挙。

<sup>b</sup> LiteBIRD は現時点での値。最適化の詳細検討を進めている。



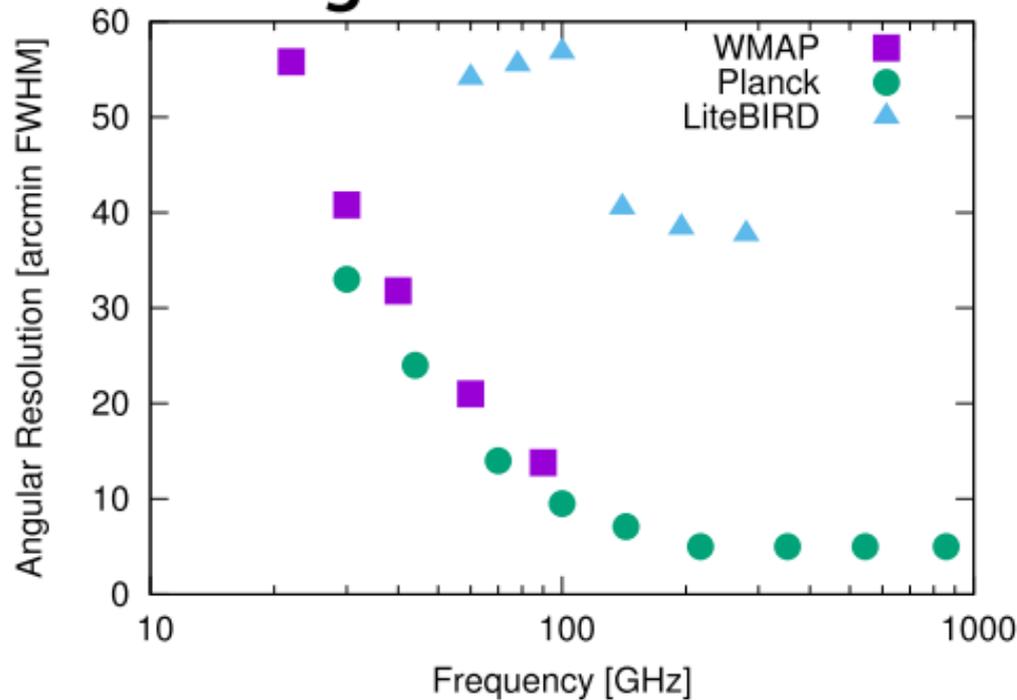


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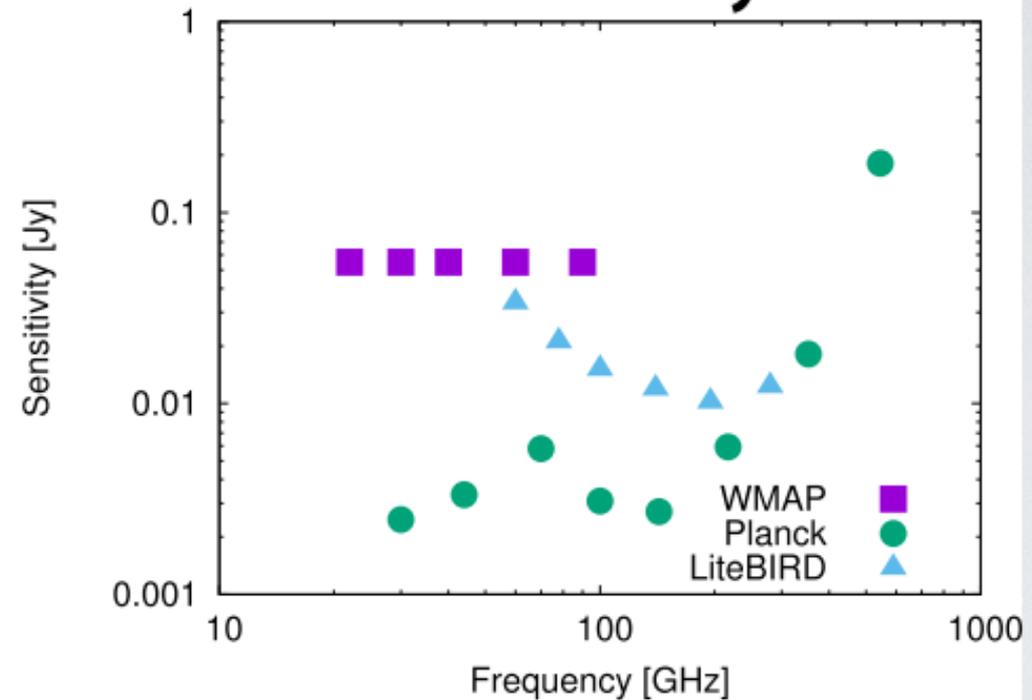
# (2) Point Src Sensitivity

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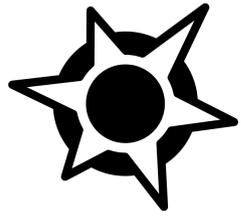
## Angular Resolution



## Sensitivity



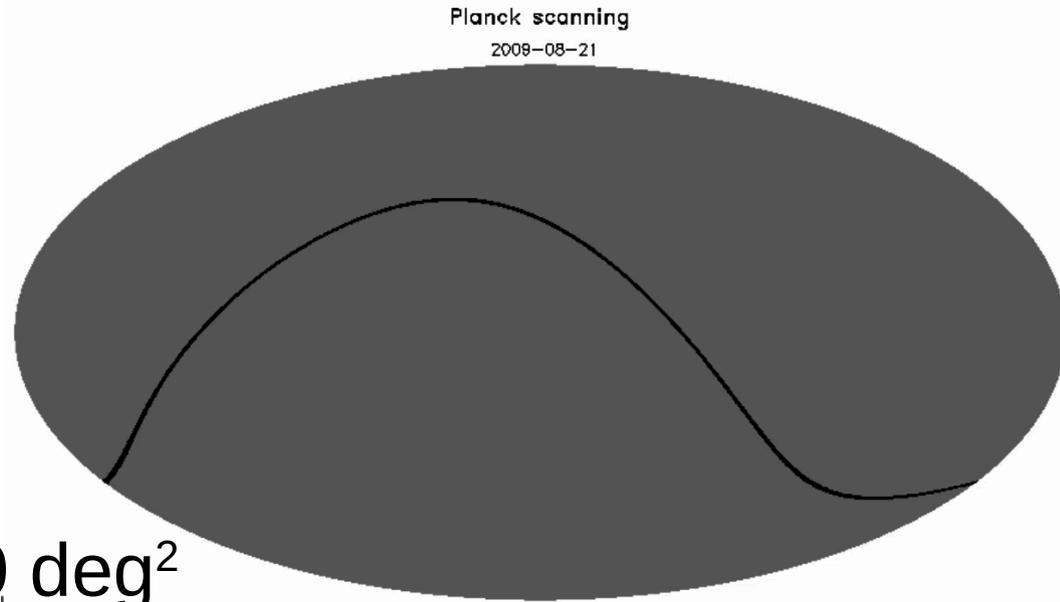
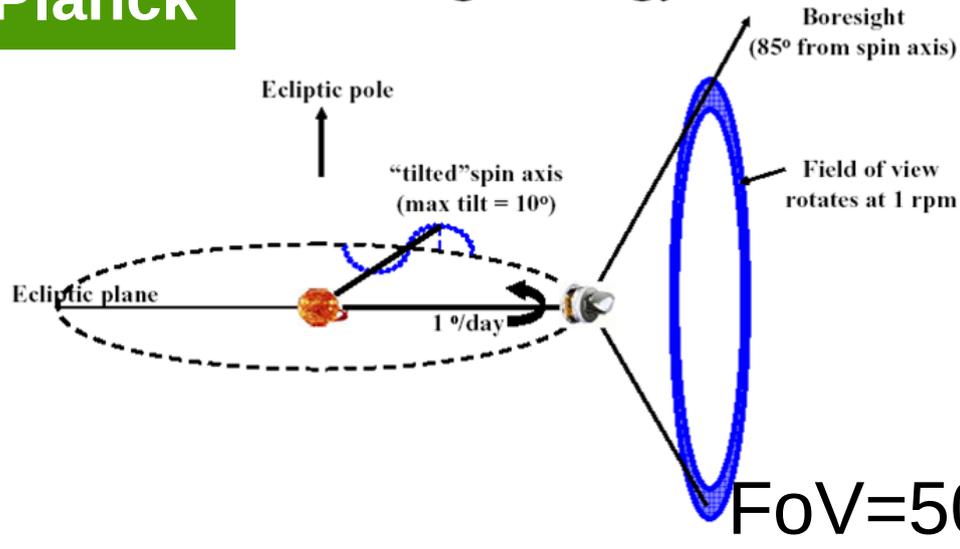
\* Based on design in 2015 “LiteBIRD as a Radio Transient Factory”, Y. Inoue



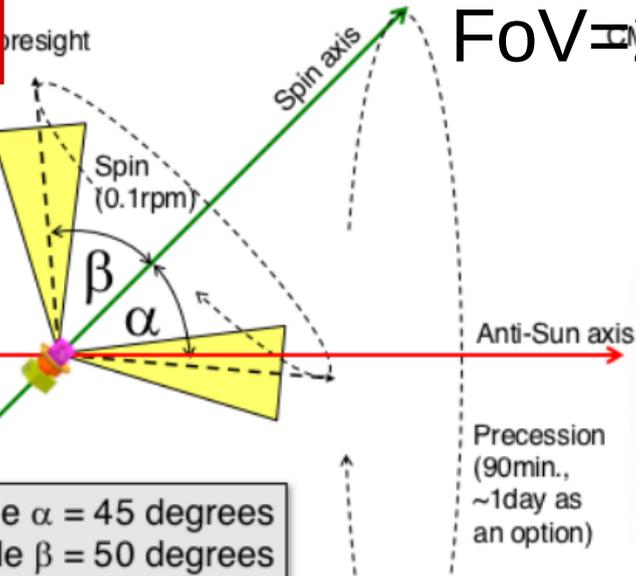
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# (3) Survey area

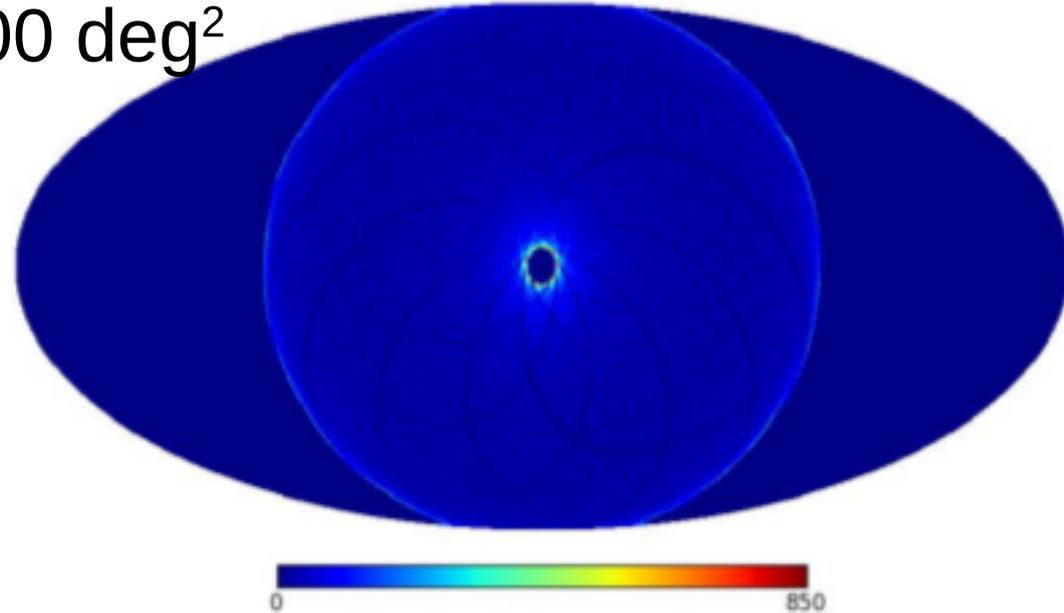
## Planck Observing strategy

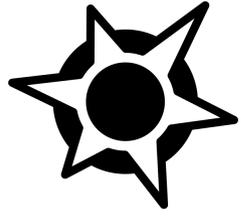


## LiteBIRD



FoV=200 deg<sup>2</sup>



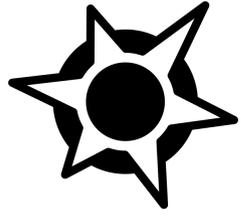


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## (4) Prospective targets

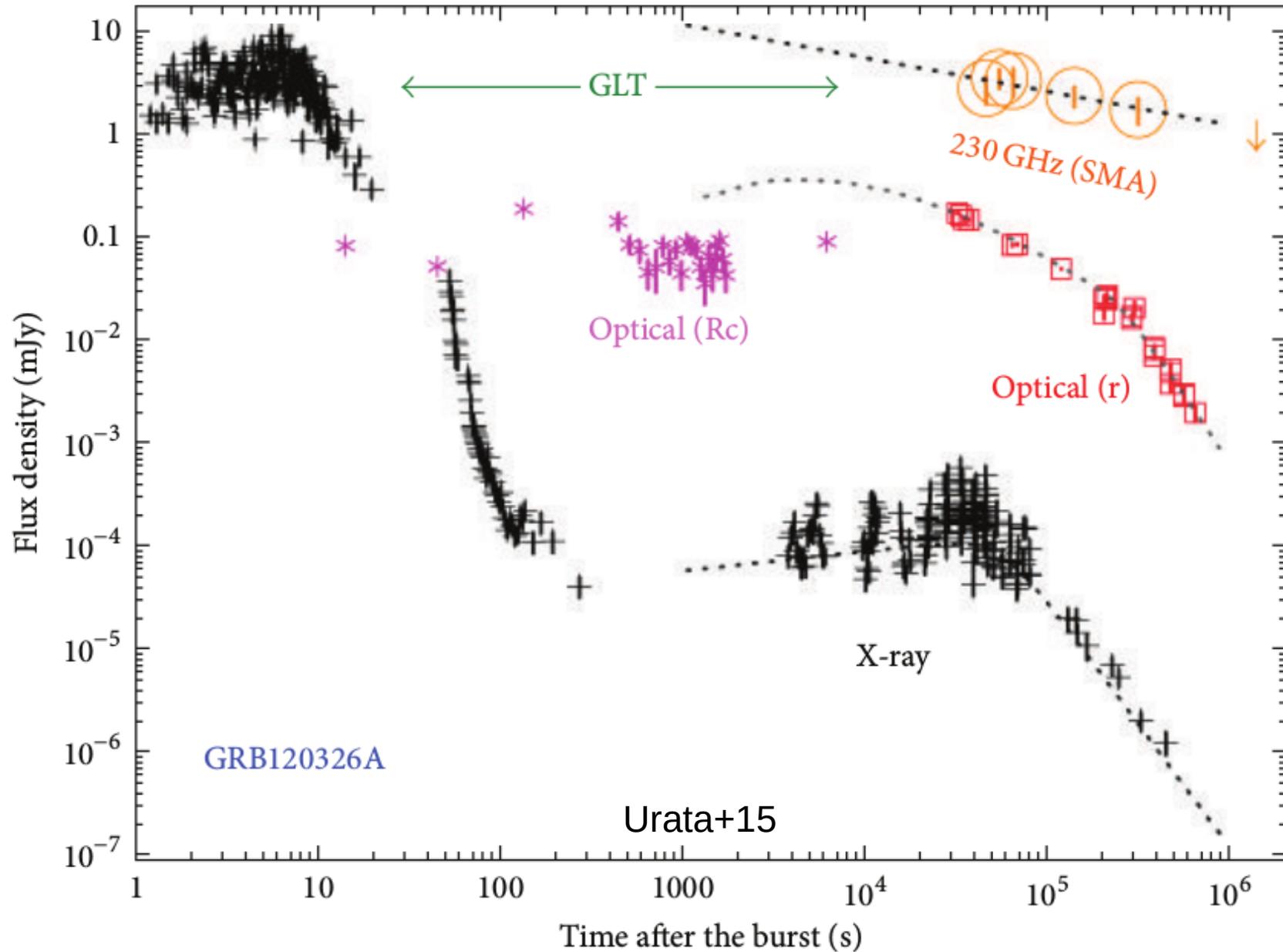
- LB suited for rare, extremely bright, short events.
  - Capability for DM and RM measurements.
  - Multi-chroic observation.
- Prospective targets are:
  - GRBs.
  - FRBs

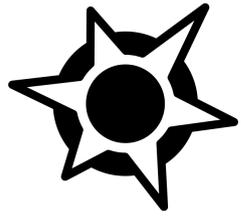




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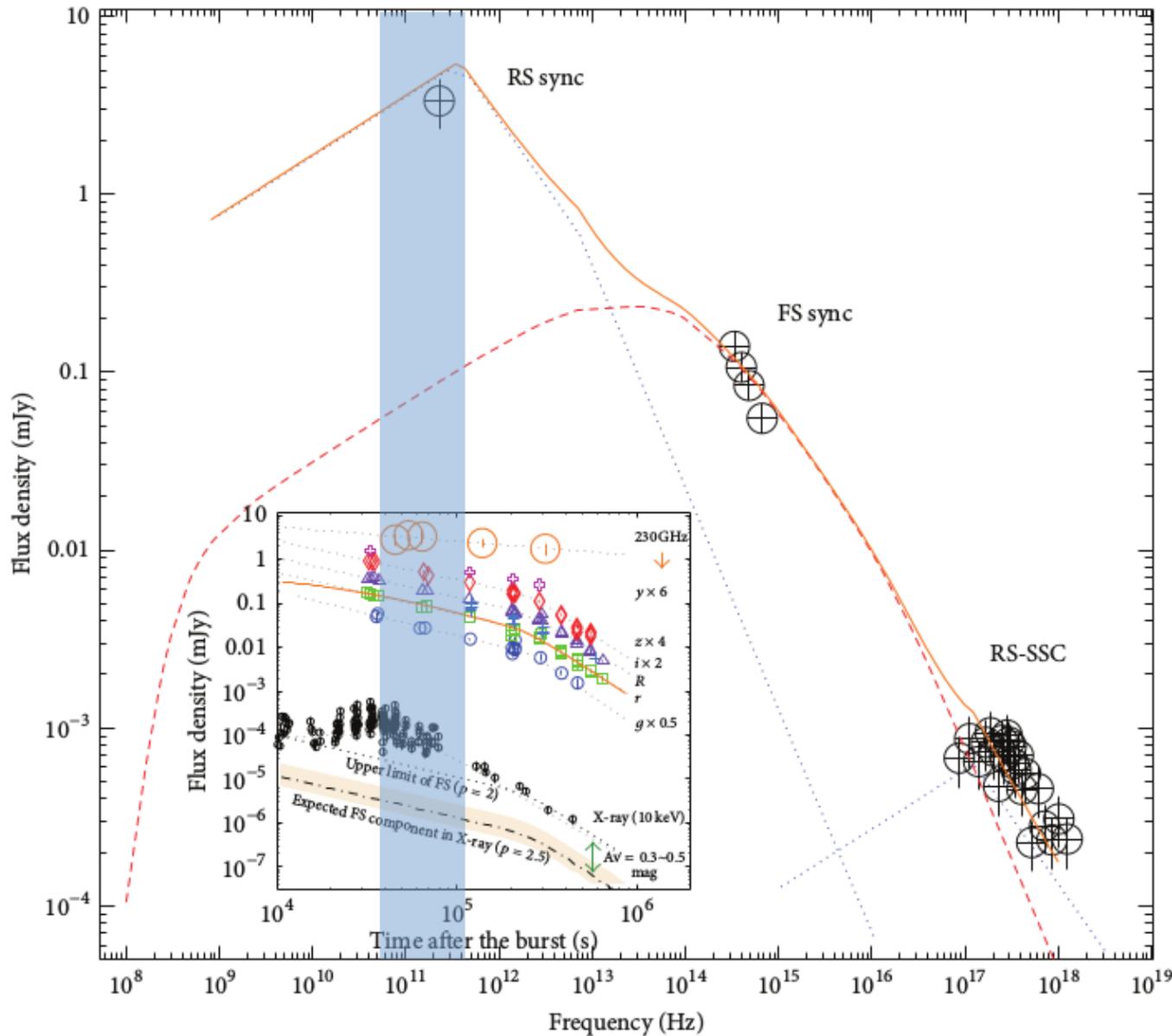
# (5) GRB – afterglow



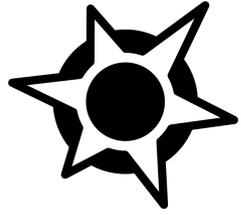


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# (6) GRB – afterglow



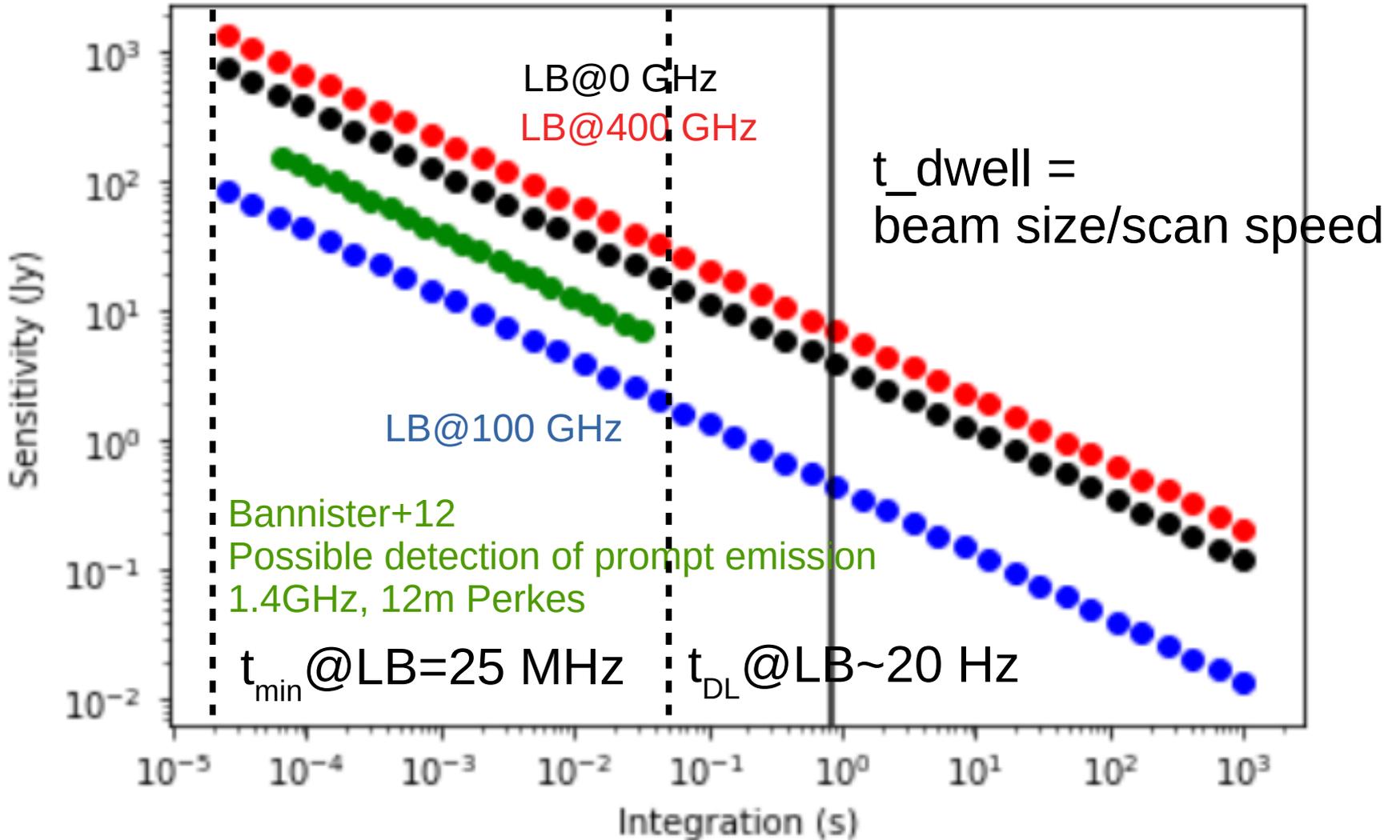
Urata+15

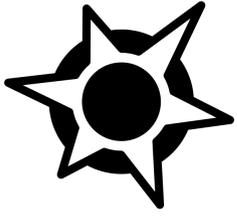


# 1. Project 2. Technology 3. Transient Search (7) GRB – prompt emission

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5  $\sigma$  detection sensitivity of point source.

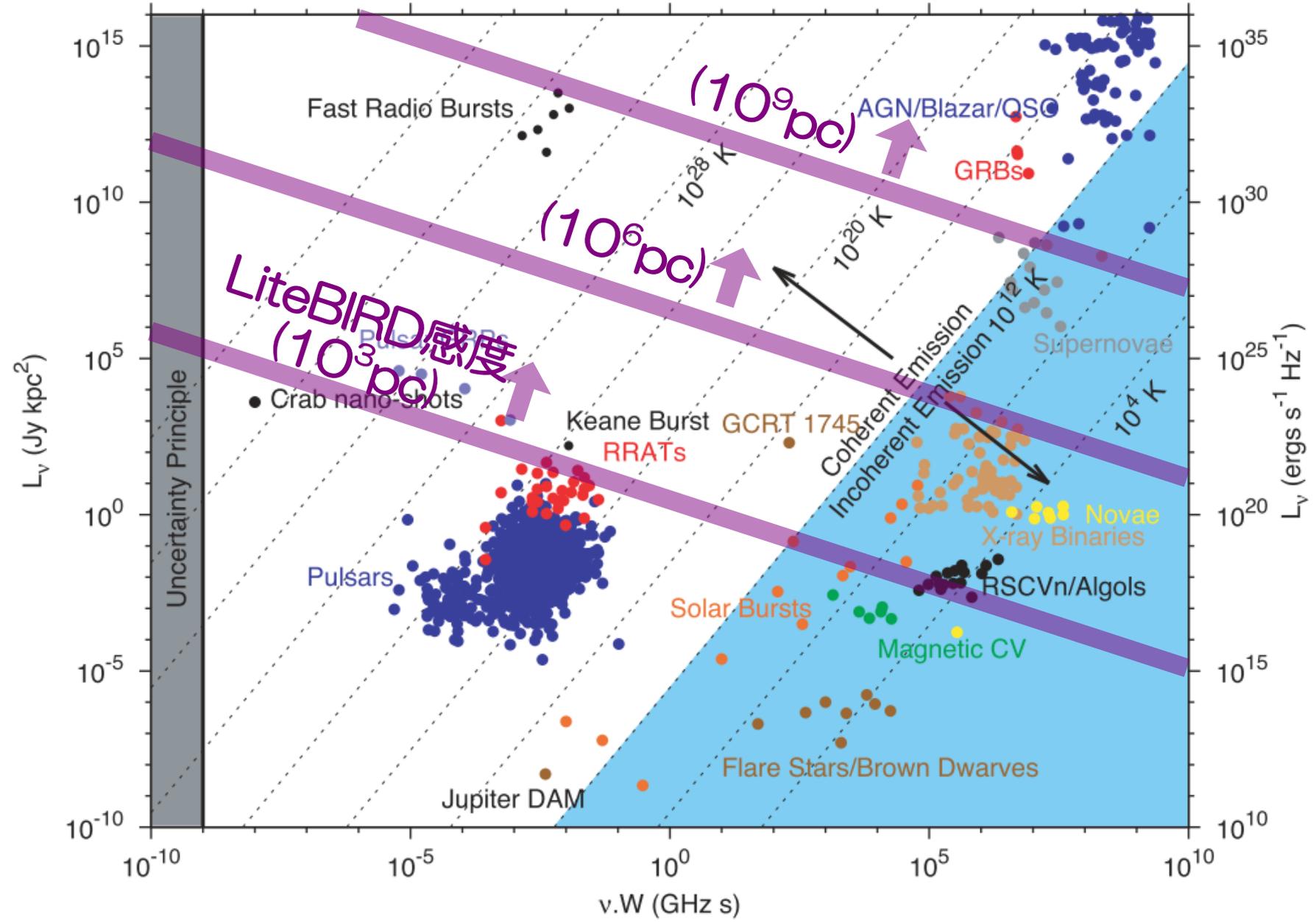


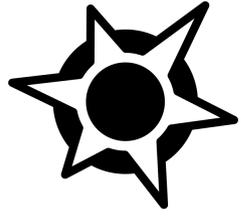


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## (8) FRBs

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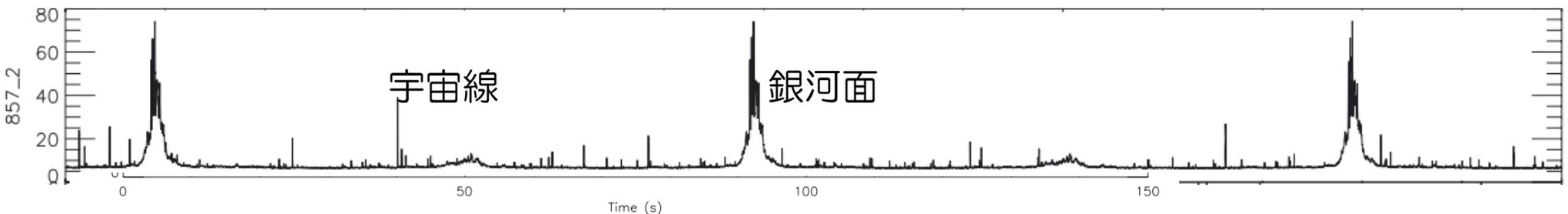
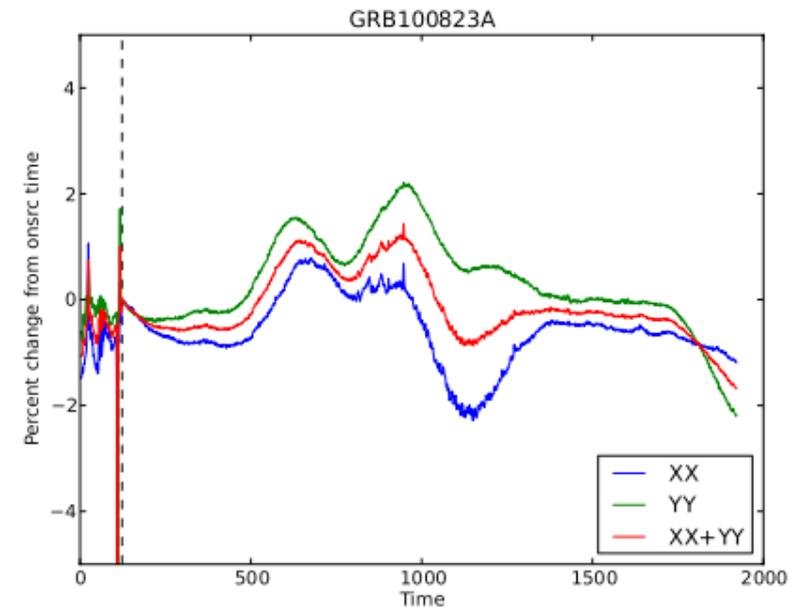


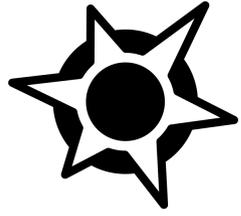
# (9) Chance coincidence

- On ground, noise by RFI.
  - Peritons due to Microwave oven (Petroff+15)
  - Beidou (Bannister+12)

<sup>6</sup> Refereed, English information about the *Beidou* global satellite system is non-existent. The only information available in English is on general news and satellite navigation Web sites. Perhaps the best source of information can be found at [http://en.wikipedia.org/wiki/Beidou\\_navigation\\_system](http://en.wikipedia.org/wiki/Beidou_navigation_system). The official Chinese Web site is <http://www.beidou.gov.cn>. *Beidou* satellite ephemerides are provided by the US Space Command and the real time position was computed using data provided at <http://www.n2yo.com/>.

- At L2, noise by CRs.



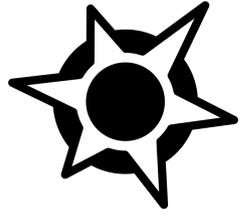


# 1. Project 2. Technology 3. Transient Search (10) Onboard processing

- DCE : Data Compression Electronics
- Required functions:
  - Data compression.
  - Trigger & characterize CRs.
  - Dump high- $\Delta t$  waveform for diagnosis.
- Can be utilized to detect and dump transients.
  - FPGA coding has just begun.
  - “Template” of transients needed.

Equivalent of DCE for ASTRO-H/SXS





# Summary

- LiteBIRD aims the detection of B-mode pol of CMB.
- As a by-product, it can be used for transient search.
- Unique capabilities:
  - High-cadance all-sky survey.
  - Multi-chroic, linear polarization.
  - 40-400 GHz band.
- Onboard det & characterization of CRs needed.
  - May be used for transient search.