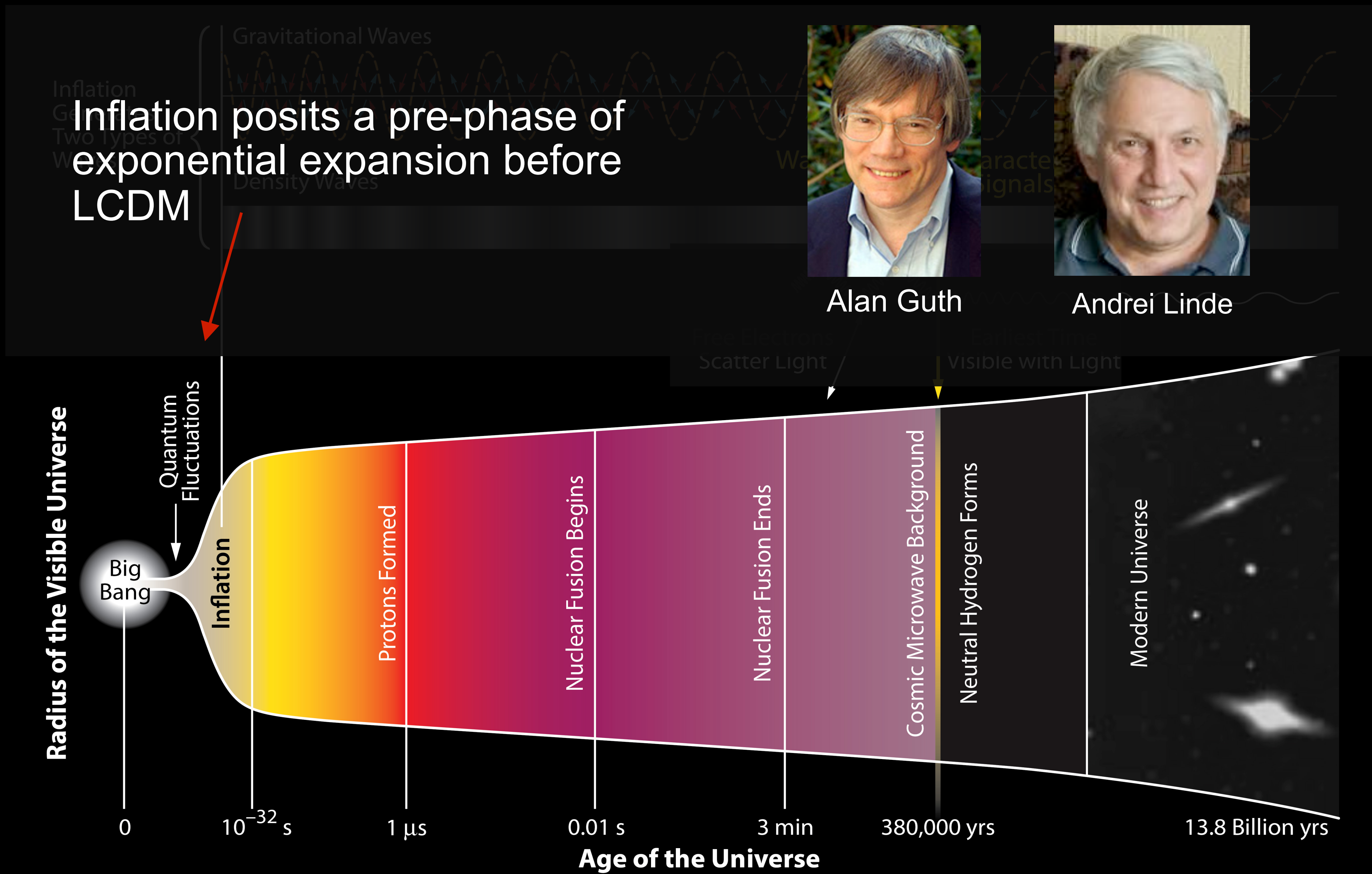
# Astro Summary
# 25th Anniversary
# Rencontres du Vietnam

Jonathan Sievers (McGill/UKZN)

## History of the Universe

Inflation posits a pre-phase of exponential expansion before LCDM



# What Does Inflation Do For Us?

Solves the horizon problem:
Why is the CMB nearly uniform?
How do apparently causally disconnected regions of space get set to the same temperature?
→ A volume much larger than our entire observable universe today was once a caussally connected sub atomic speck.

Solves the flatness problem:
Why is the net spatial curvature close to zero?
→ Any initial spatial curvature is diluted away to undetectabilty by the hyper expansion.

Explains the initial perturbations:
Why Gaussian with close to flat power law spectrum?
→ Equal amounts of perturbations are injected by quantum fluctuations at each step in the exponential expansion.

Solves the monopole problem:
Why do we not observe magnetic monopoles in the Universe today?
→ Monopoles are diluted away to undetectability.

Pryke

HEP at Higher Energies?

Collider Built by Nature?

What's needed as a "collider"?

What can be studied?

Mass: what's the resonance?

From resonance to interference

What's at the energy scale $H$?

How is the collider "built"?

Has inflation indeed happened?

SCIENTIFIC AMERICAN FEBRUARY 2017

## Cosmic Inflation Theory Faces Challenges

The latest astrophysical measurements, combined with theoretical problems, cast doubt on the long-cherished inflationary theory of the early cosmos and suggest we need new ideas

By Anna Ijjas, Paul J. Steinhardt, Abraham Loeb

VS

*Observations*

## A Cosmic Controversy

A *Scientific American* article about the theory of inflation prompted a reply from a group of 33 physicists, along with a response from the article's authors

Yi Wang

# Higgs-driven inflation

F.Bezrukov, M.Shaposhnikov (2007)

$$S^{JF} = \int d^4x \sqrt{-g} \left( -\frac{M_P^2}{2} R - \xi H^\dagger H R + \mathscr{L}_{SM} \right)$$

In a unitary gauge $H^T = \left(0\,, (h+v)/\sqrt{2}\right)$ (and neglecting $v = 246\,\text{GeV}$)

$$S = \int d^4x \sqrt{-g} \left( -\frac{M_P^2 + \xi h^2}{2} R + \frac{(\partial_\mu h)^2}{2} - \frac{\lambda h^4}{4} \right)$$

slow roll behavior due to modified kinetic term even for $\lambda \sim 1$

Go to the Einstein frame: $(M_P^2 + \xi h^2)\, R^{JR} \to M_P^2\, R^{EF}$

$$g_{\mu\nu}^{JF} = \Omega^{-2} \tilde{g}_{\mu\nu}^{EF}\,, \qquad \Omega^2 = 1 + \frac{\xi h^2}{M_P^2}$$

with canonically normalized $\chi$: interval $ds^2$ changes !

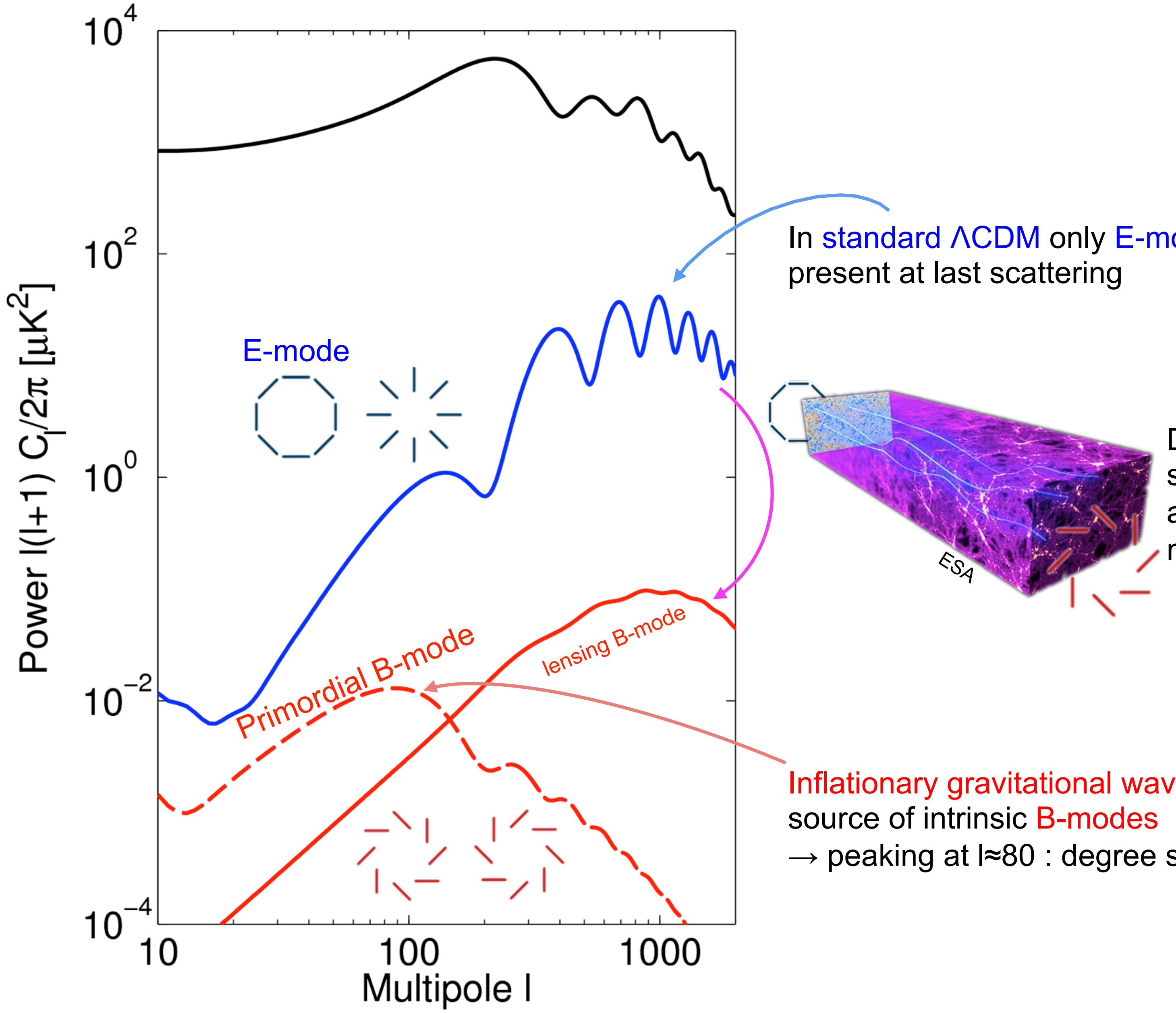
$$\frac{d\chi}{dh} = \frac{M_P \sqrt{M_P^2 + (6\xi + 1)\xi h^2}}{M_P^2 + \xi h^2}\,,\; U(\chi) = \frac{\lambda M_P^4 h^4(\chi)}{4(M_P^2 + \xi h^2(\chi))^2}\,.$$

we have a flat potential at large fields: $U(\chi) \to \text{const}$ @ $h \gg M_P/\sqrt{\xi}$



Gorbunov

# CMB Polarization power spectra




In standard ΛCDM only E-modes are present at last scattering

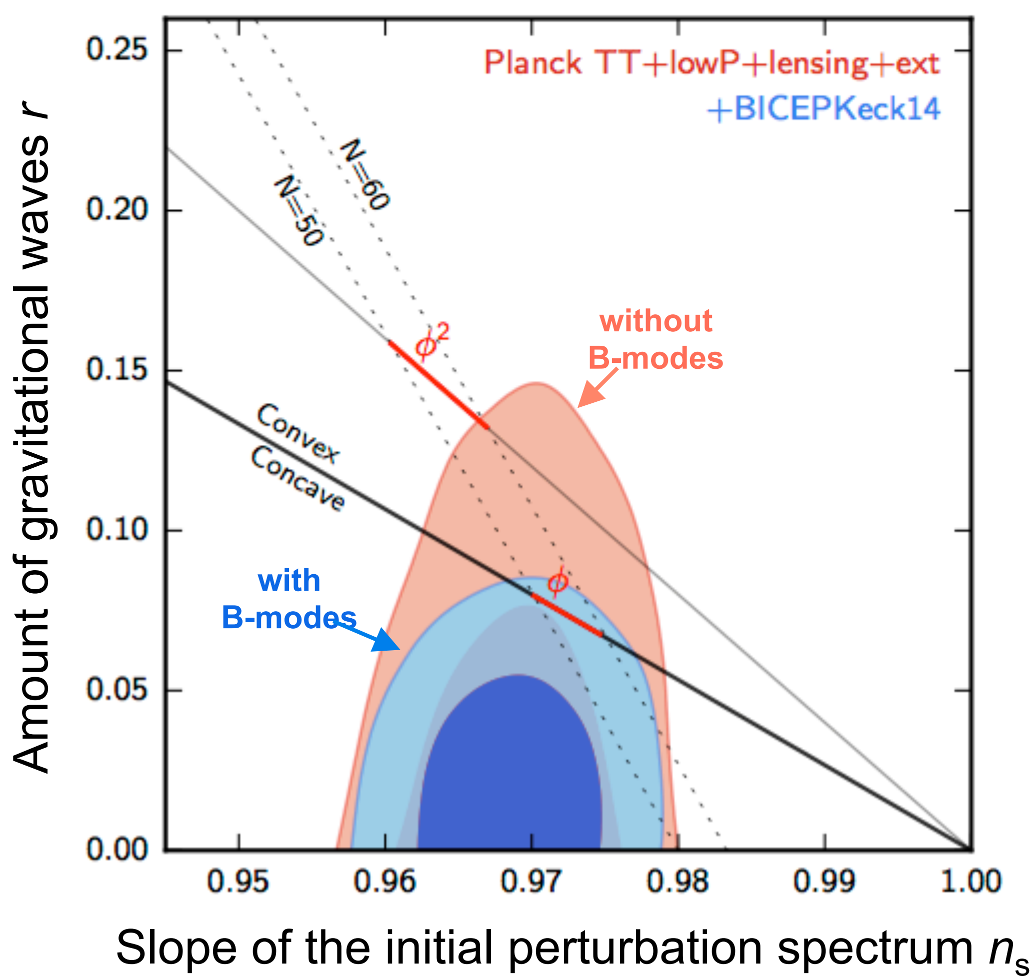
During propagation some of the E-modes are confused into B-modes by lensing

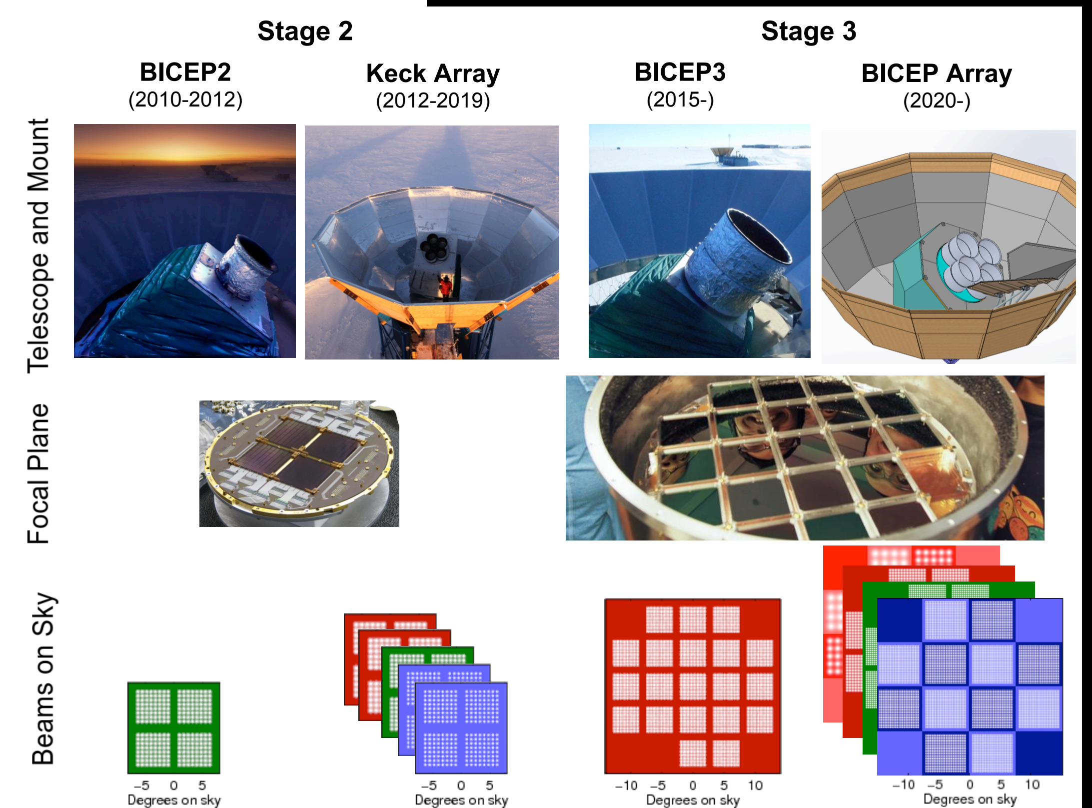
Inflationary gravitational waves are unique source of intrinsic B-modes
→ peaking at l≈80 : degree scales

The BICEP/Keck Collaboration

Pryke

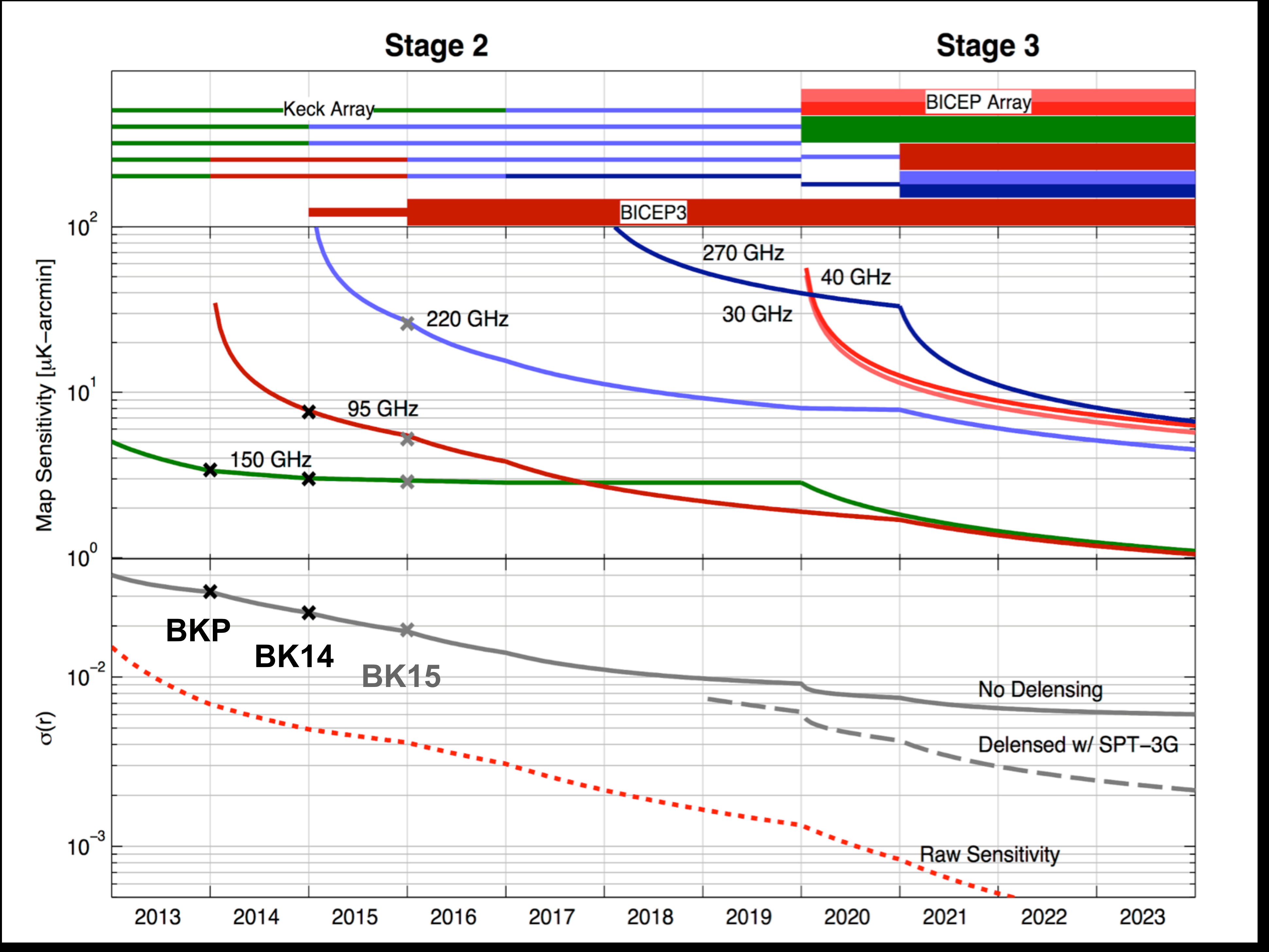
# Adding in Planck temperature measurements



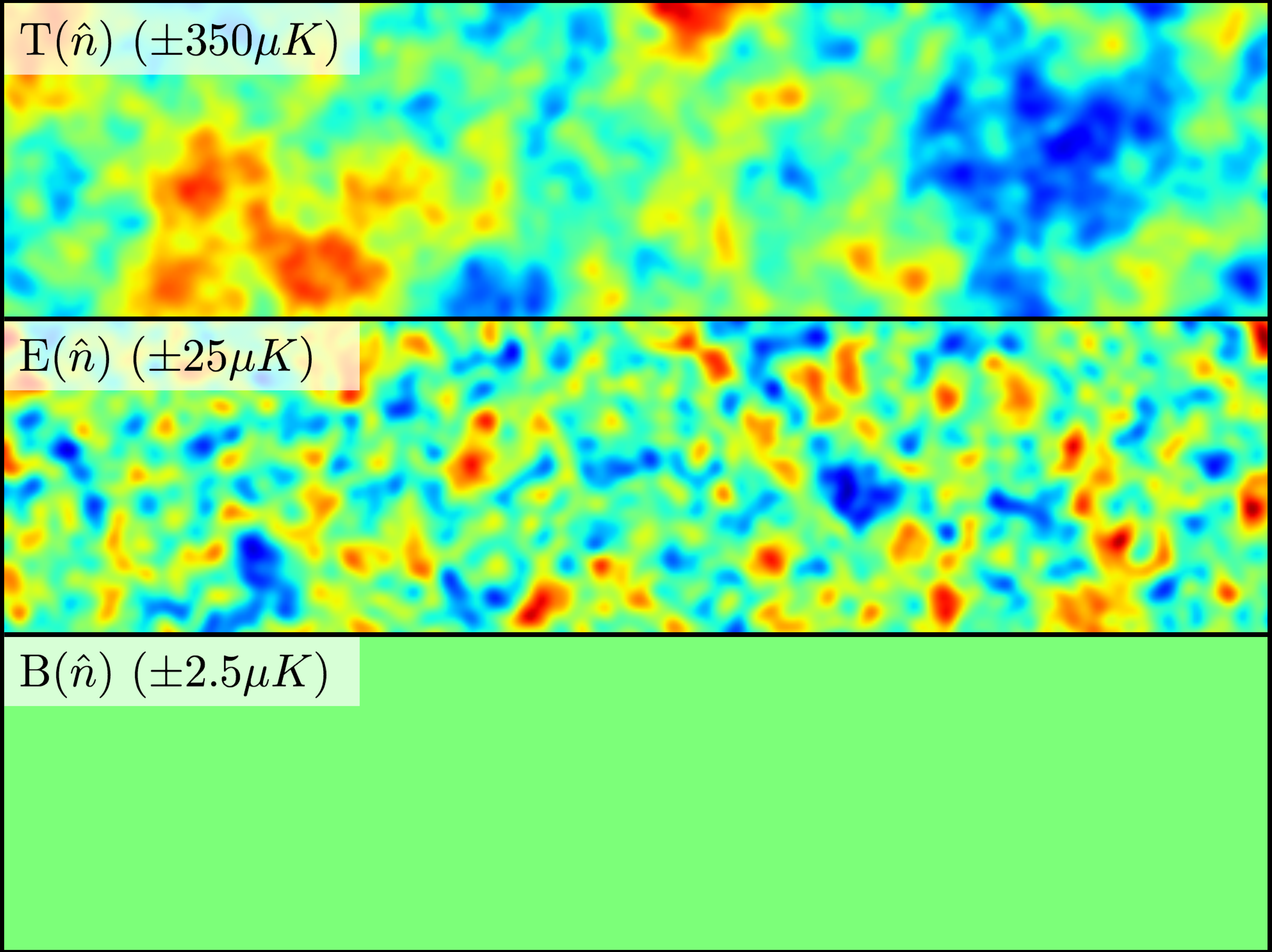

**Steadily tightening the constraints on inflationary models…**

**Pryke**

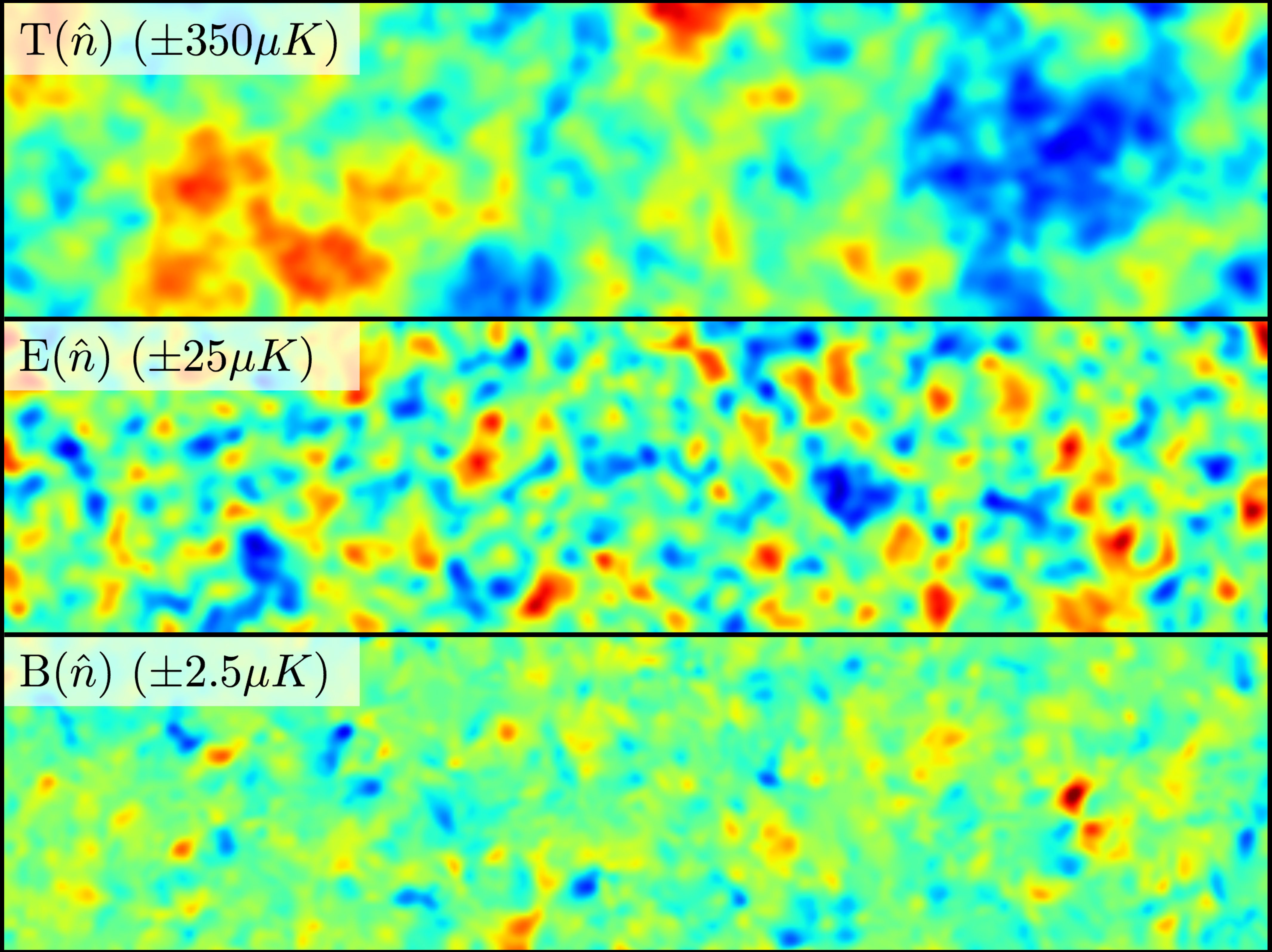


Stage 2
Stage 3
Keck Array
BICEP Array
BICEP3
Map Sensitivity [μK–arcmin]
270 GHz
40 GHz
30 GHz
220 GHz
95 GHz
150 GHz
σ(r)
BKP
BK14
BK15
No Delensing
Delensed w/ SPT–3G
Raw Sensitivity
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

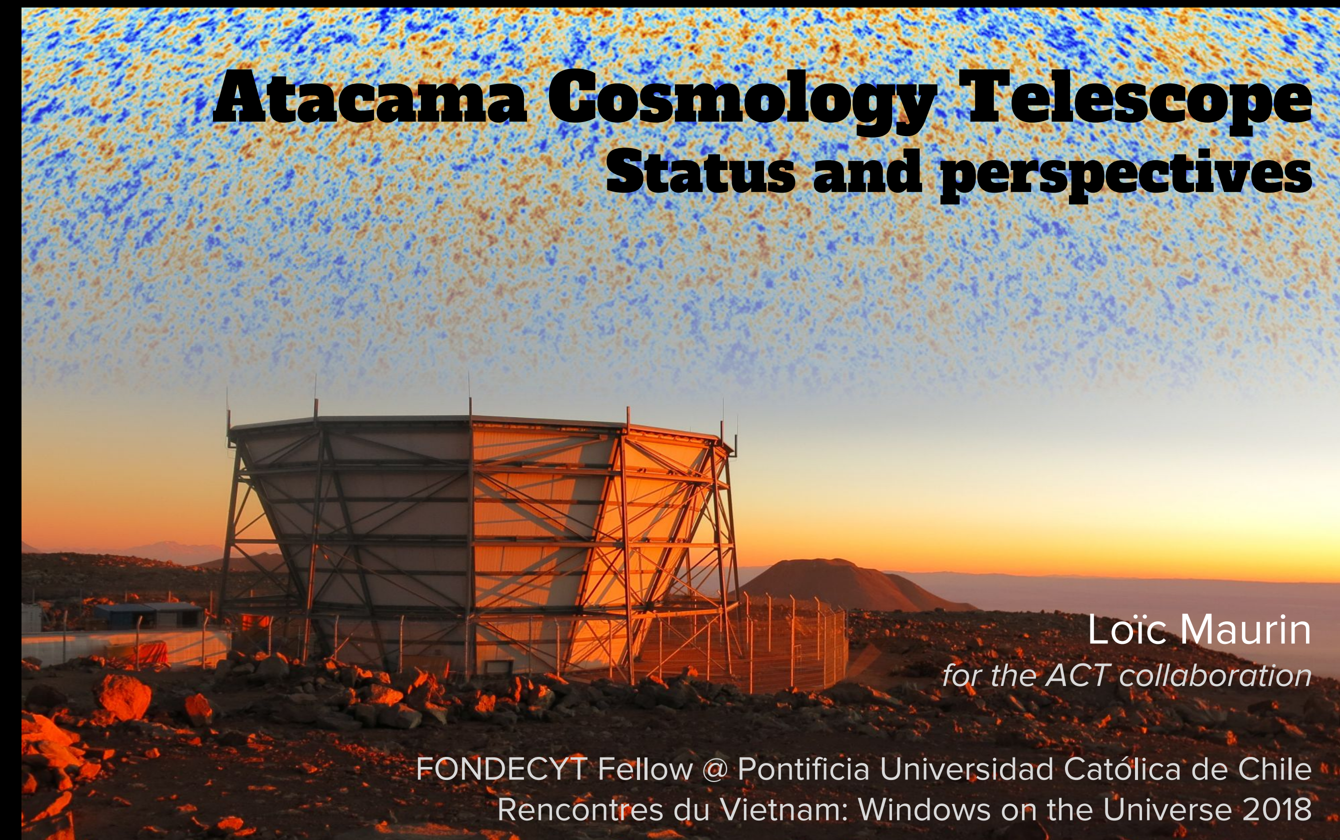

Pryke

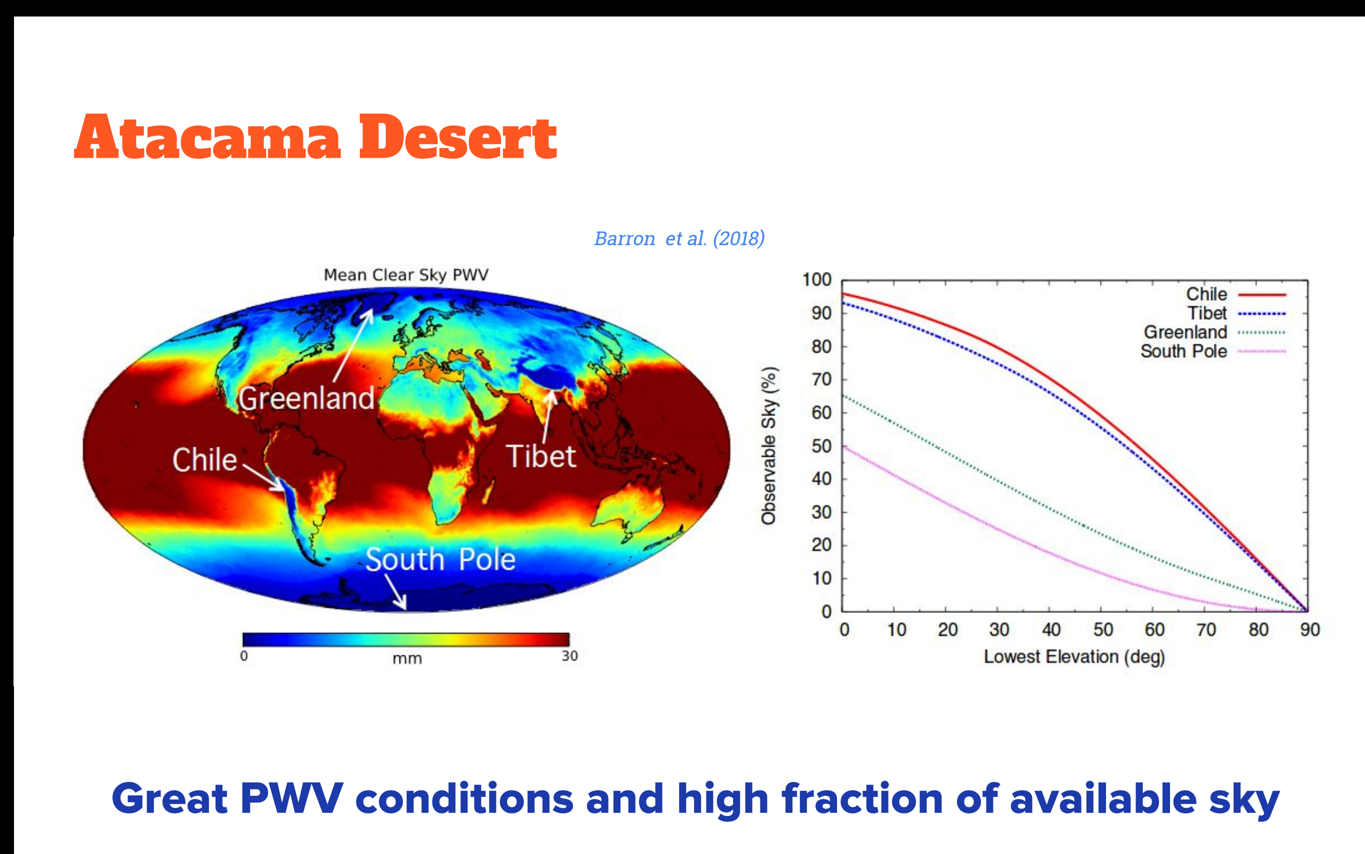



Gallicchio




**Gallicchio**

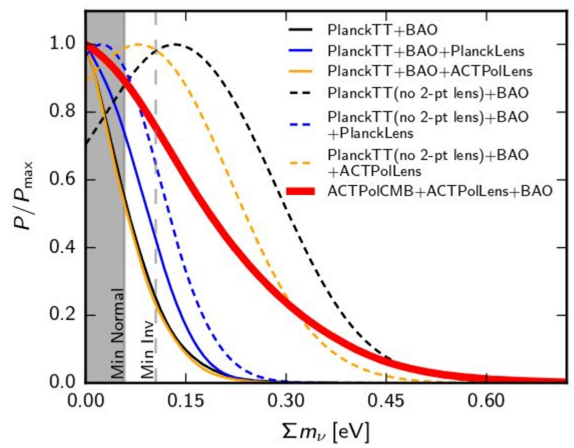




Gallicchio/Maurin

# Lensing





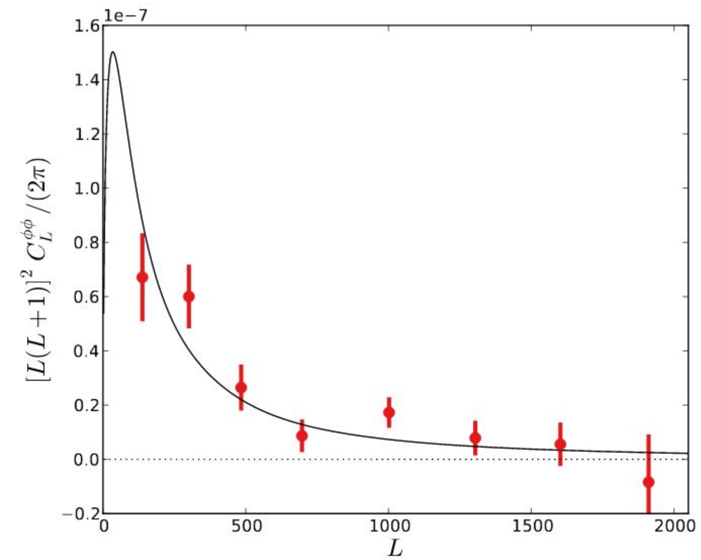
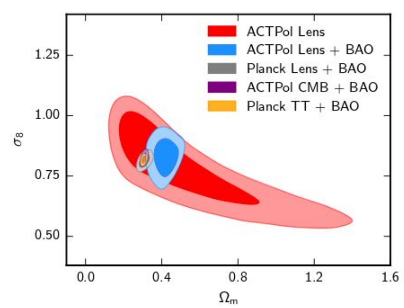
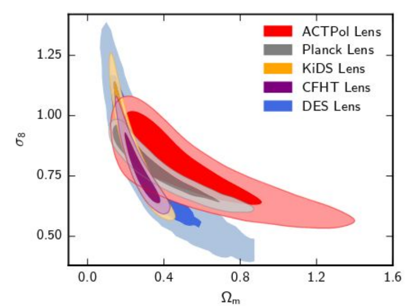




FIG. 2. Combined two-season ACTPol lensing power spectrum, coadded across all patches and estimators. The best-fit theory lensing power spectrum has an amplitude of $A_{\rm lens} = 1.06 \pm 0.15$ (stat.) $\pm 0.06$ (sys.) relative to the *Planck* best-fit ΛCDM cosmology from the *Planck* temperature and polarization power spectra (which we define to have $A_{\rm lens} = 1$). The ACTPol best-fit is indicated with a black solid line, and the error bars just include statistical uncertainty. The $\chi^2$ to the best-fit, scaled *Planck* ΛCDM theory model has a probability to exceed (PTE) of 0.32, suggesting a good fit to the standard ΛCDM cosmology.



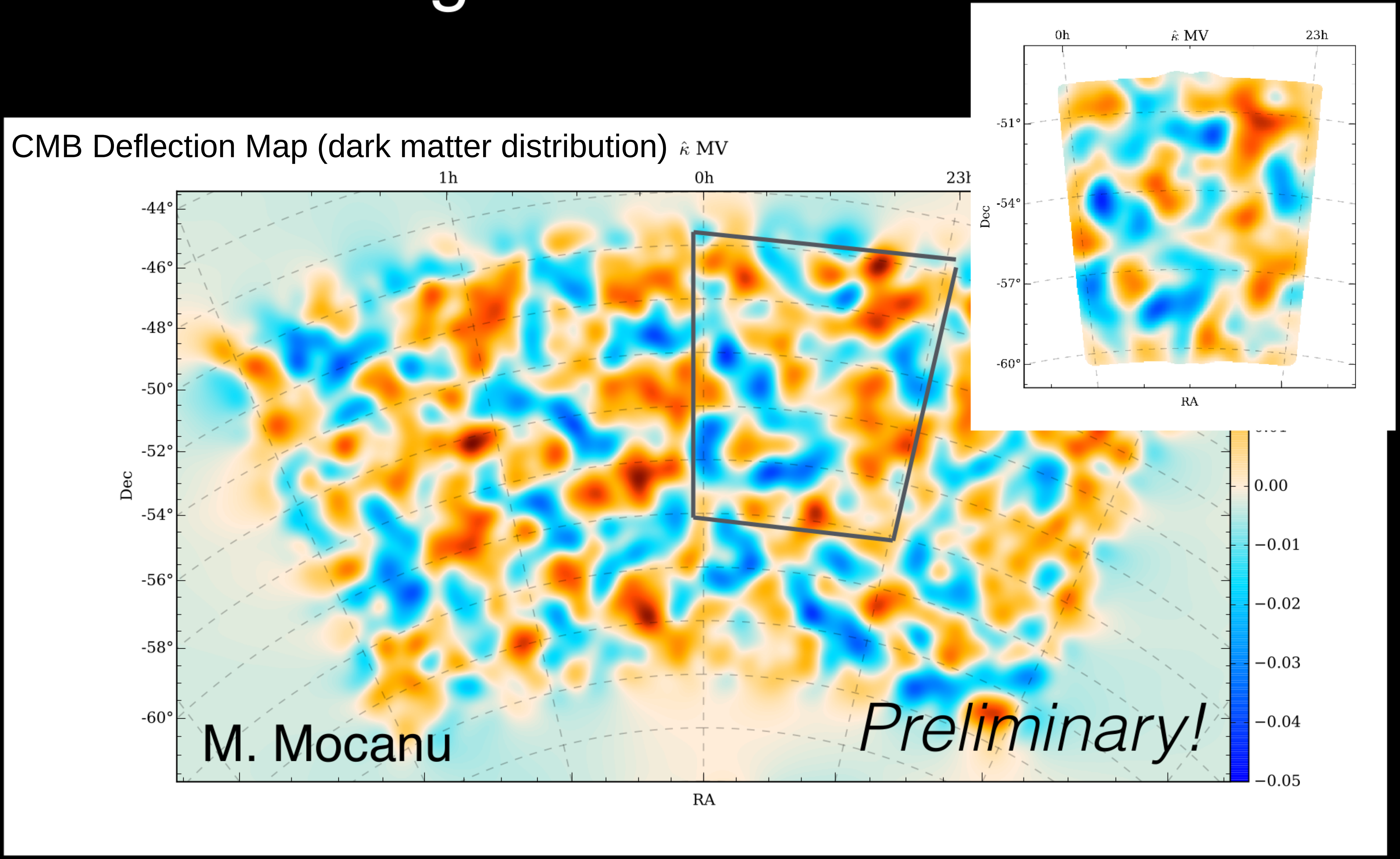

**Constraining power on $\Omega_m$, $\sigma_8$ and $\Sigma m_\nu$ combining with BAO**

*Sherwin et al. (2017)*

Maurin

# CMB Lensing

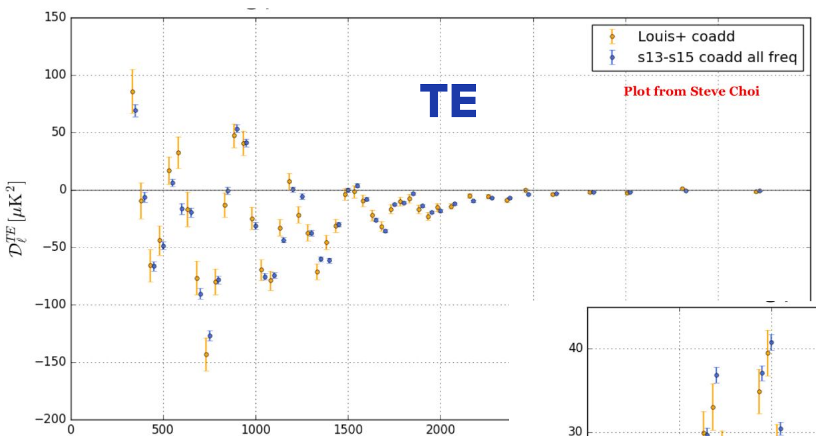
Story 2015



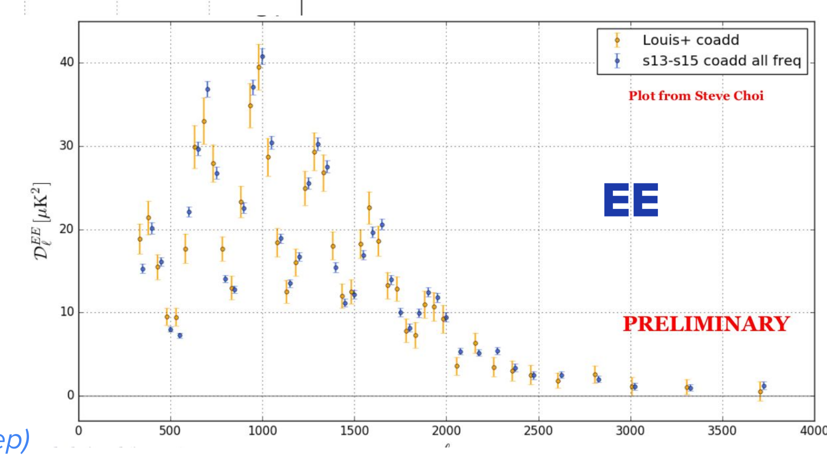

Gallicchio

# ACT/SPT E-Mode Spectra

## Preliminary results: Power Spectrum

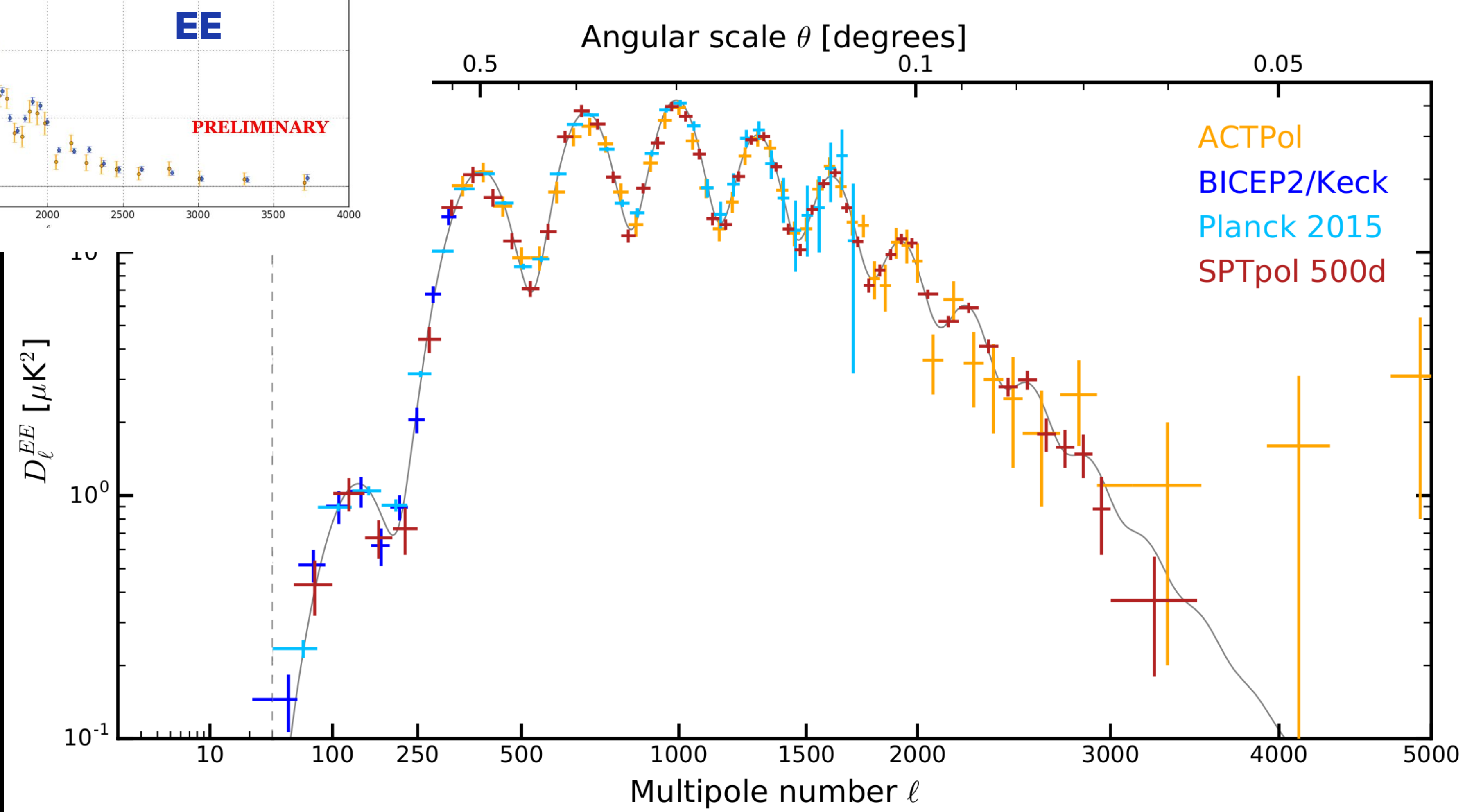



*Figures from Steve Choi*




*Aiola et al. (in prep) and Choi et al. (in prep)*

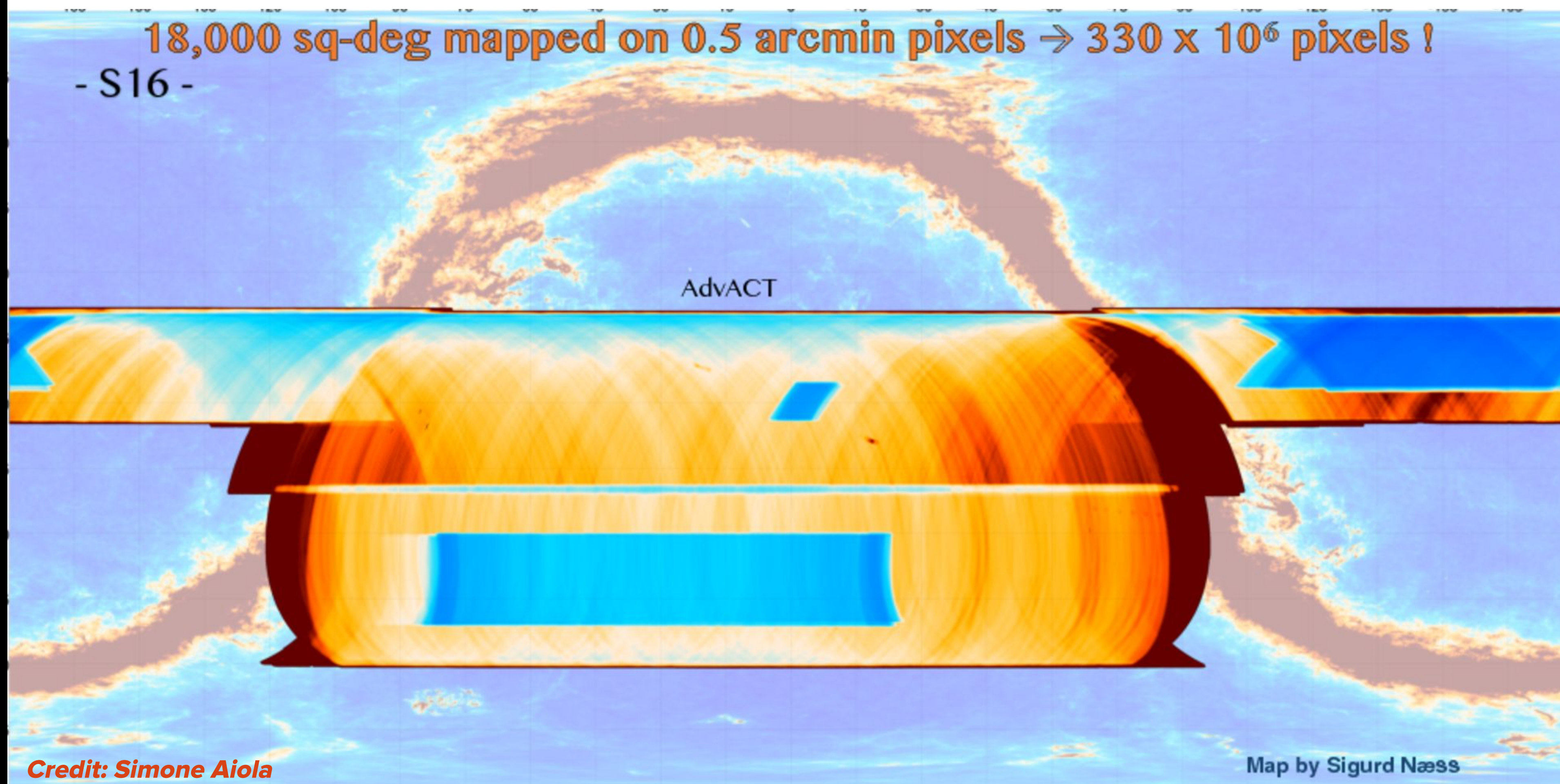
Ξ-Mode Spectrum
coustic peaks visible)




Henning et. al., 2018, Planck 2016; BICEP/Keck 2015, Louis et al. 2017

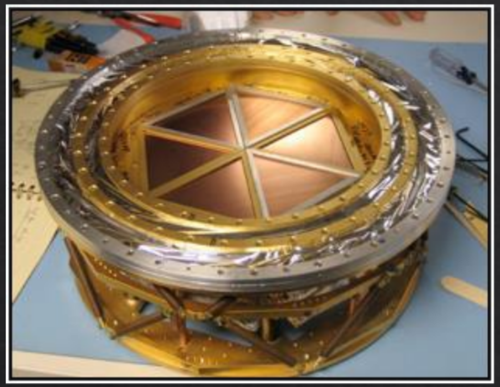
**Gallicchio/Maurin**

# Observations (s16) - 90/150/220 GHz



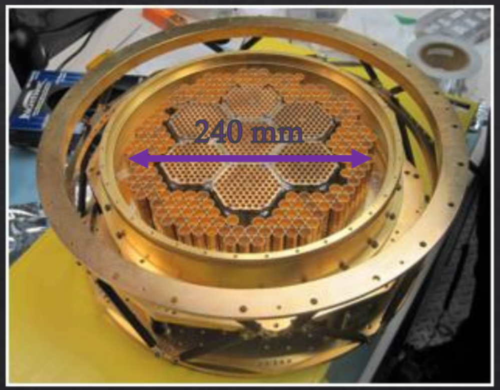
# SPT-3G

*2007*: SPT-SZ
960 Detectors



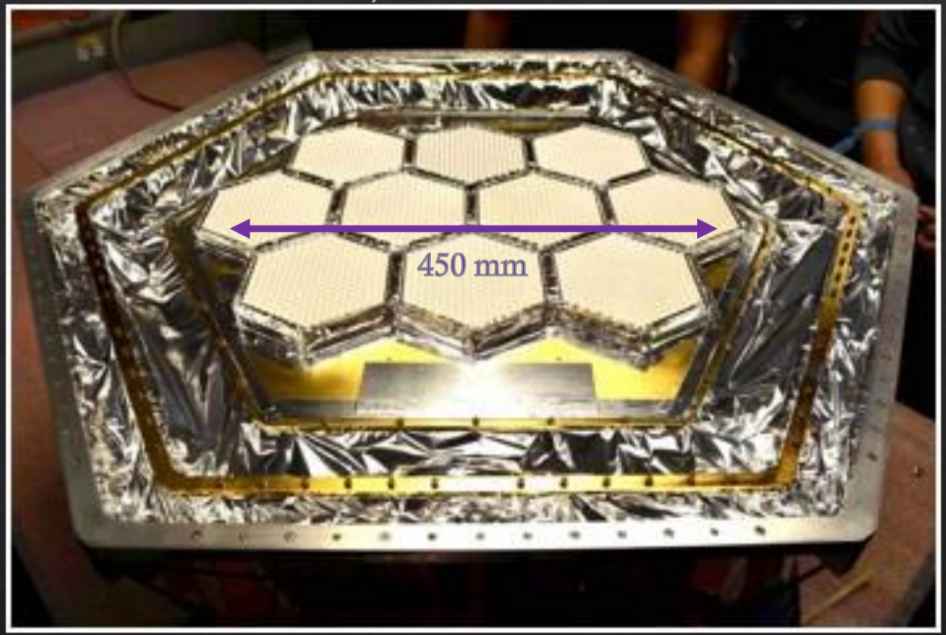
90, 150, 220 GHz

*2012*: SPTpol
1,500 Detectors




90, 150 GHz + Polarization

*2017*: SPT-3G
16,000 Detectors




90, 150, 220 GHz + Polarization
*(but in every pixel…)*

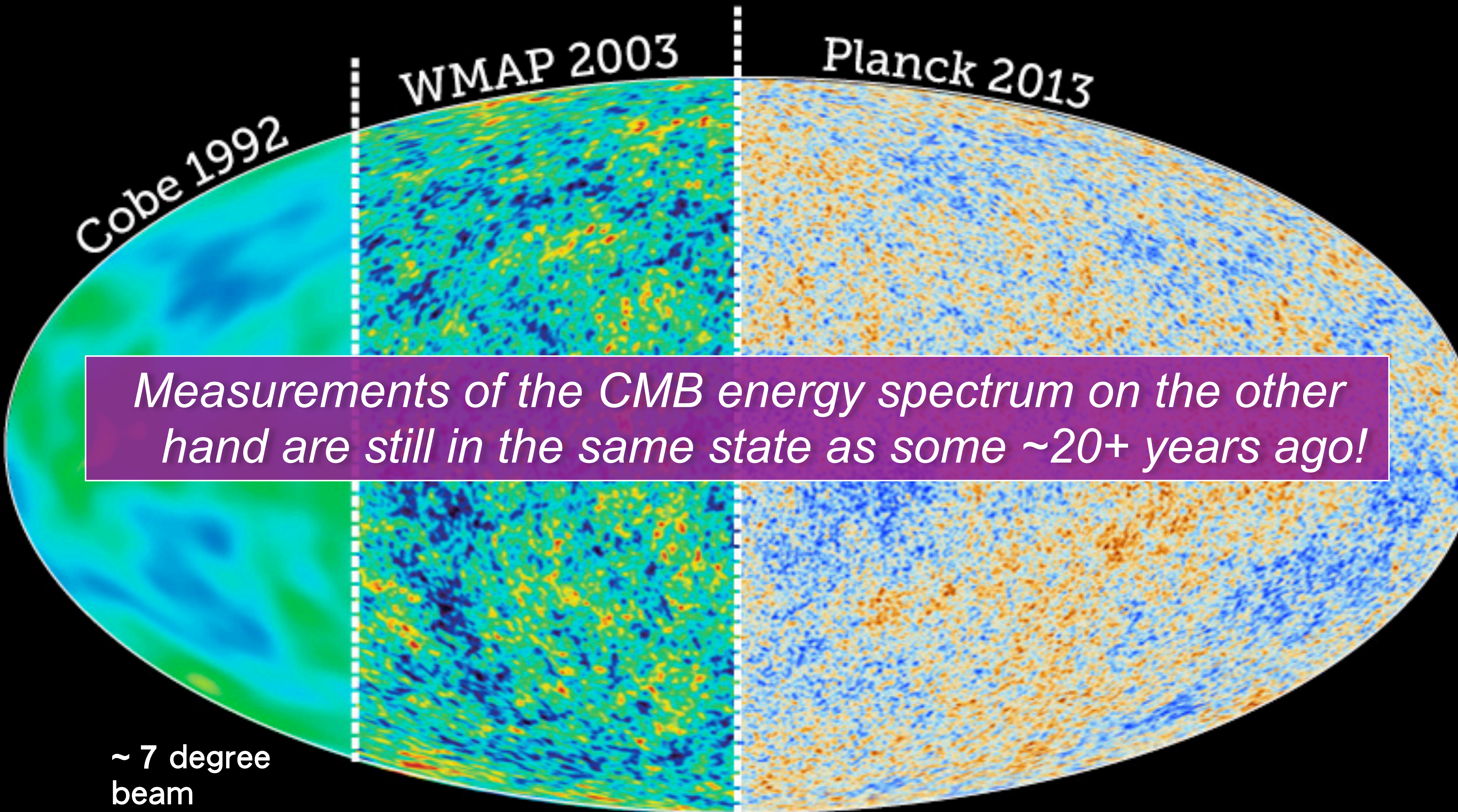
Shot Noise → More Detectors

Foregrounds → More Frequency Coverage

Credit: Joshua Sobrin

**Gallicchio**

# Dramatic improvements in angular resolution and sensitivity over the past decades!



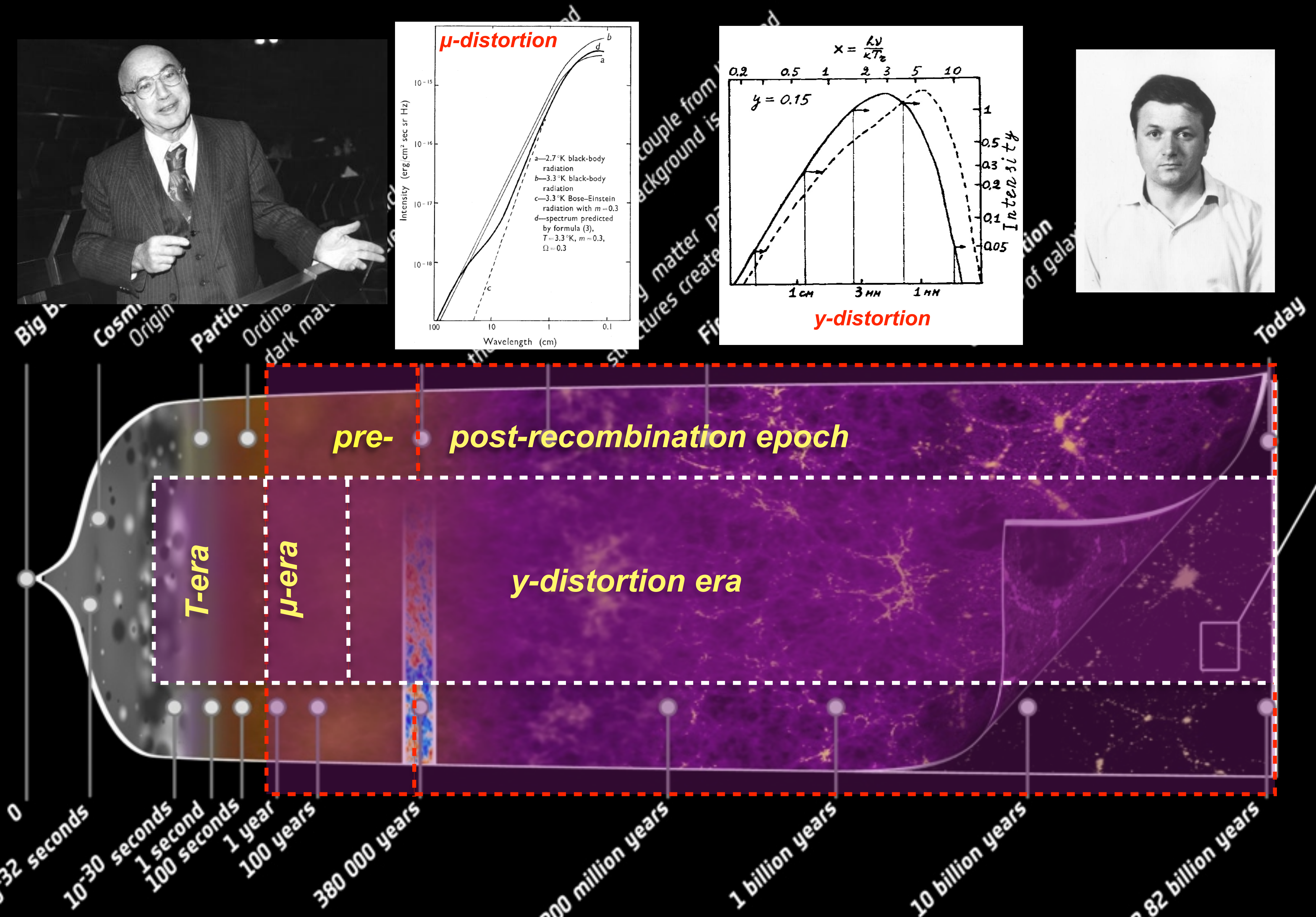

*Measurements of the CMB energy spectrum on the other hand are still in the same state as some ~20+ years ago!*

~ 7 degree beam

~ 0.3 degree beam

~ 0.08 degree beam

Chluba


μ-distortion
Intensity (erg/cm² sec sr Hz)
Wavelength (cm)
a—2.7 °K black-body radiation
b—3.3 °K black-body radiation
c—3.3 °K Bose–Einstein radiation with m = 0.3
d—spectrum predicted by formula (3), T = 3.3 °K, m = 0.3, Ω = 0.3
x = hν/kT_e
y = 0.15
Intensity
1 cm
3 mm
1 mm
y-distortion
Today
pre-
post-recombination epoch
T-era
μ-era
y-distortion era
0
10^-32 seconds
10^-30 seconds
1 second
100 seconds
1 year
100 years
380 000 years
200 million years
1 billion years
10 billion years
13.82 billion years

Chluba

# Physical mechanisms that lead to spectral distortions

*Standard sources of distortions*

- *Cooling by adiabatically expanding ordinary matter*
  **(JC, 2005; JC & Sunyaev 2011; Khatri, Sunyaev & JC, 2011)**
- Heating by *decaying* or *annihilating* relic particles
  **(Kawasaki et al., 1987; Hu & Silk, 1993; McDonald et al., 2001; JC, 2005; JC & Sunyaev, 2011; JC, 2013; JC & Jeong, 2013)**
- *Evaporation of primordial black holes & superconducting strings*
  **(Carr et al. 2010; Ostriker & Thompson, 1987; Tashiro et al. 2012; Pani & Loeb, 2013)**
- *Dissipation of primordial acoustic modes & magnetic fields*
  **(Sunyaev & Zeldovich, 1970; Daly 1991; Hu et al. 1994; JC & Sunyaev, 2011; JC et al. 2012 - Jedamzik et al. 2000; Kunze & Komatsu, 2013)**
- *Cosmological recombination radiation*
  **(Zeldovich et al., 1968; Peebles, 1968; Dubrovich, 1977; Rubino-Martin et al., 2006; JC & Sunyaev, 2006; Sunyaev & JC, 2009)**

***pre-recombination epoch***

„high“ redshifts

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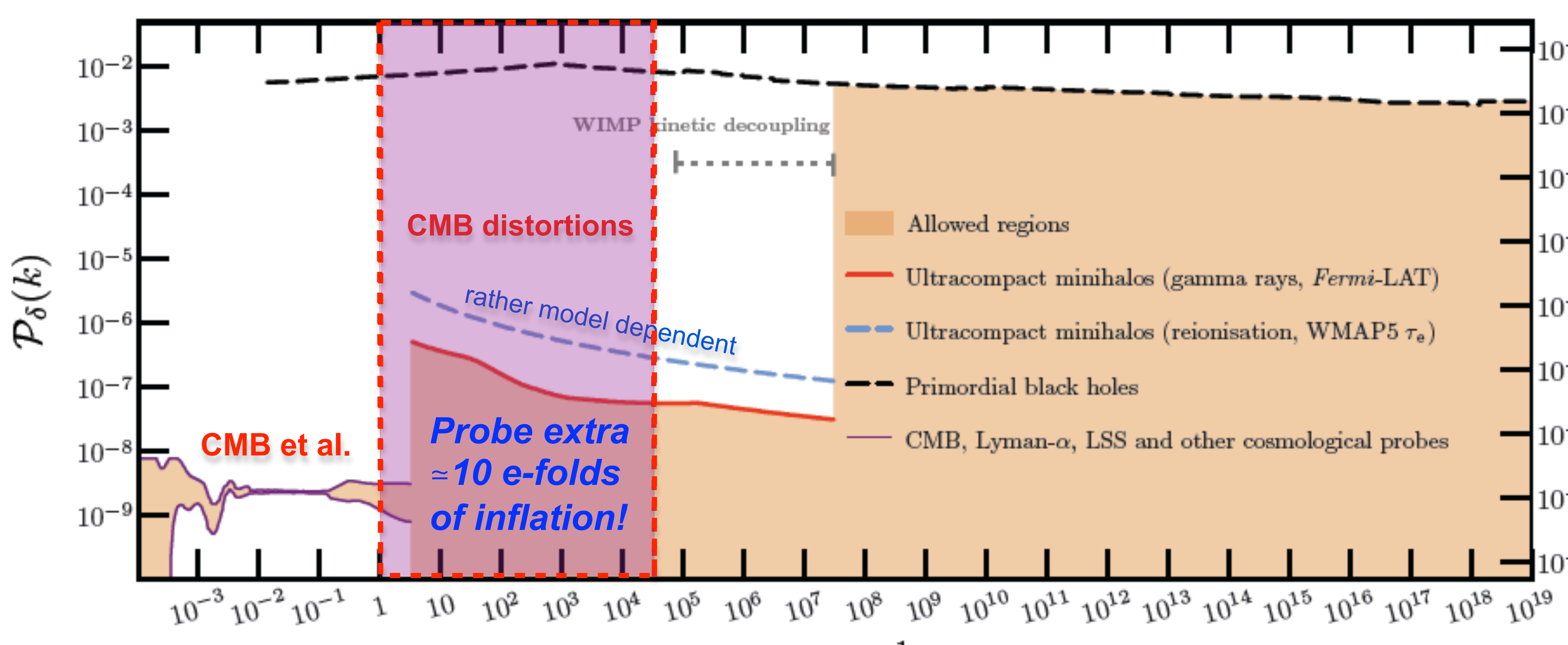
„low“ redshifts

***post-recombination***

- Signatures due to first supernovae and their remnants
  **(Oh, Cooray & Kamionkowski, 2003)**
- Shock waves arising due to large-scale structure formation
  **(Sunyaev & Zeldovich, 1972; Cen & Ostriker, 1999)**
- SZ-effect from clusters; effects of reionization
  **(Refregier et al., 2003; Zhang et al. 2004; Trac et al. 2008)**
- Additional exotic processes
  **(Lochan et al. 2012; Bull & Kamionkowski, 2013; Brax et al., 2013; Tashiro et al. 2013)**

# Distortions provide new power spectrum constraints!

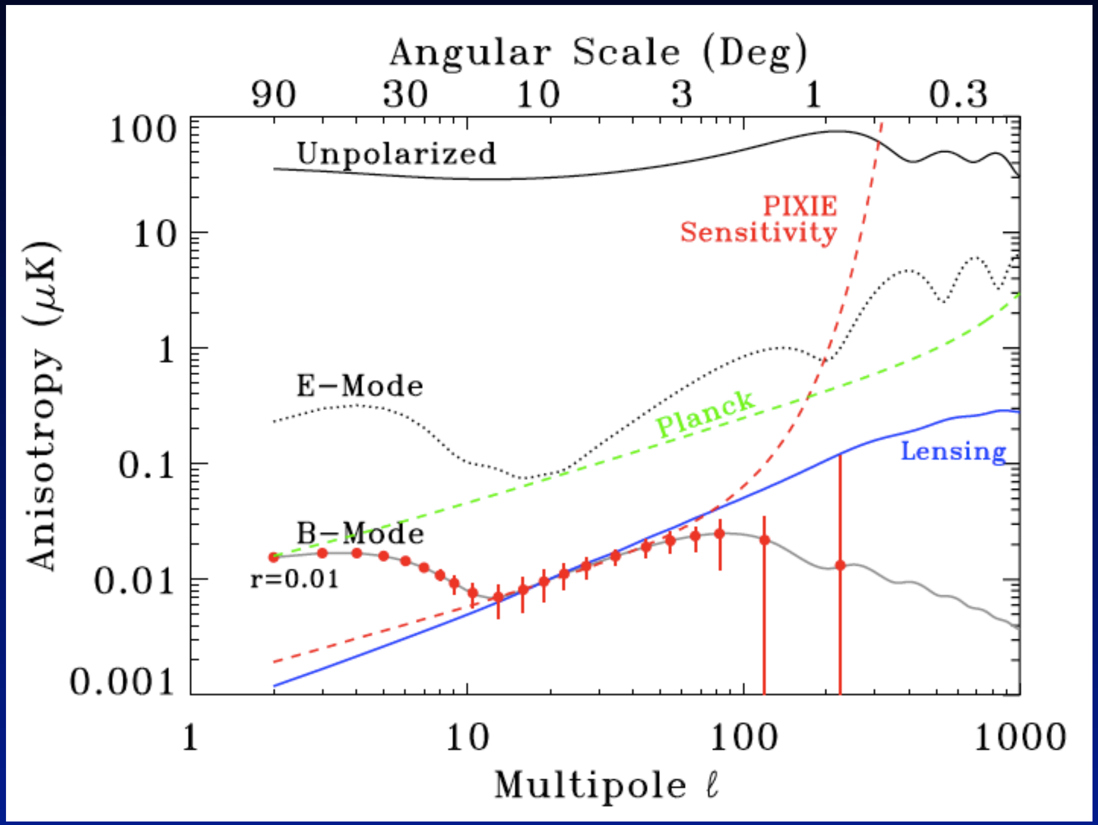



Bringmann, Scott & Akrami, 2011, ArXiv:1110.2484

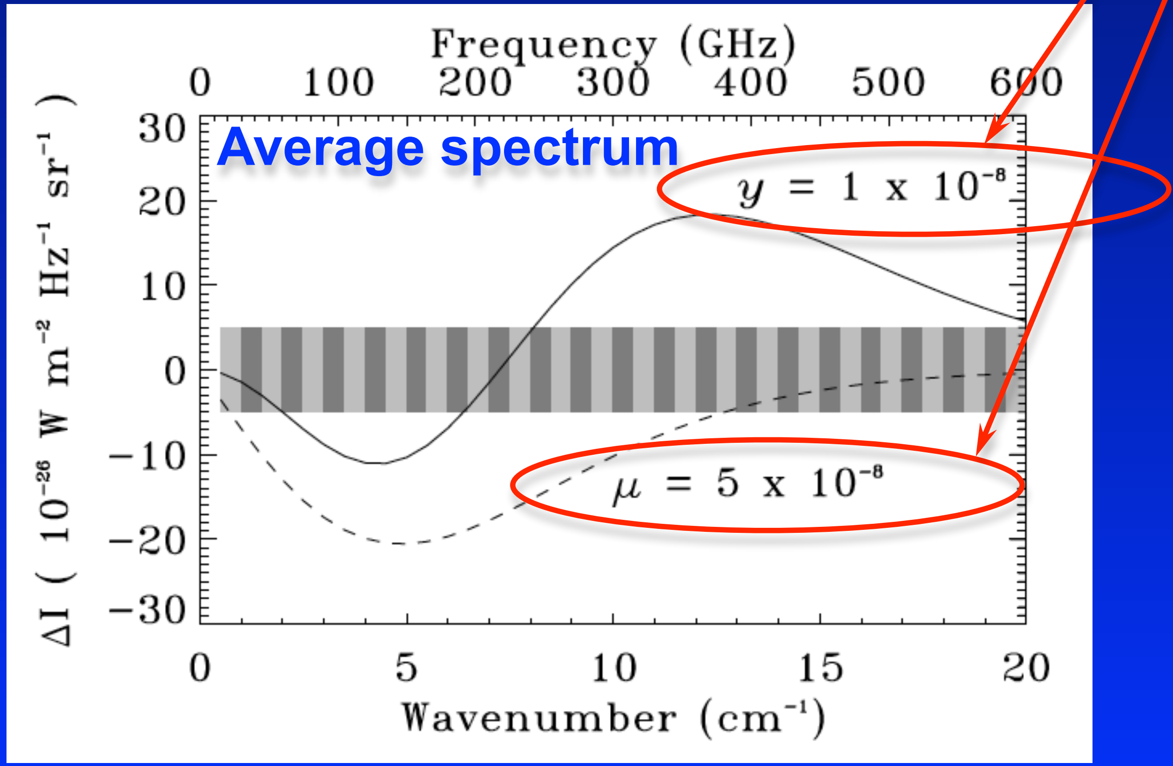
- Amplitude of power spectrum rather uncertain at $k > 3$ Mpc$^{-1}$
- improved limits at smaller scales can *rule out* many *inflationary models*
- CMB spectral distortions would *extend* our *lever arm* to $k \sim 10^4$ Mpc$^{-1}$
- very *complementary* piece of information about early-universe physics

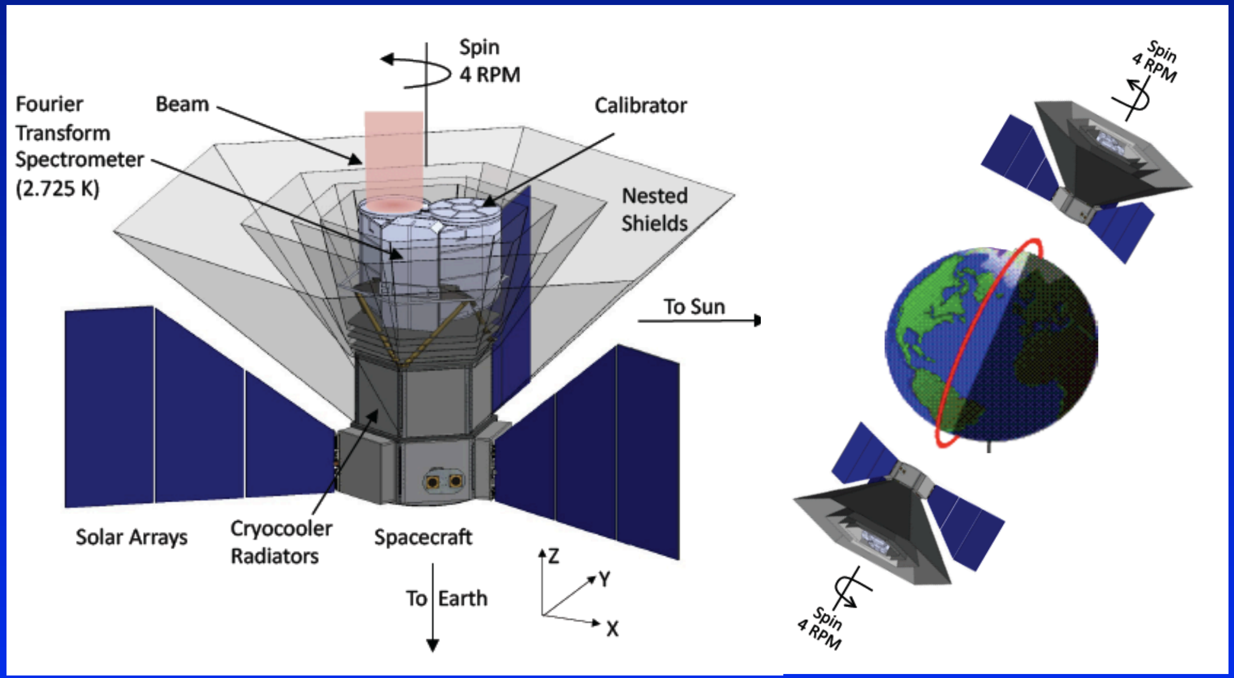
e.g., JC, Khatri & Sunyaev, 2012; JC, Erickcek & Ben-Dayan, 2012; JC & Jeong, 2013

# PIXIE: Primordial Inflation Explorer




- 400 spectral channel in the frequency range 30 GHz and 6THz (Δν ~ 15GHz)
- about 1000 (!!!) times more sensitive than COBE/FIRAS
- B-mode polarization from inflation ($r \approx 10^{-3}$)
- improved limits on $\mu$ and $y$
- was proposed 2011 & 2016 as NASA EX mission (i.e. cost ~ 200-250 M$)



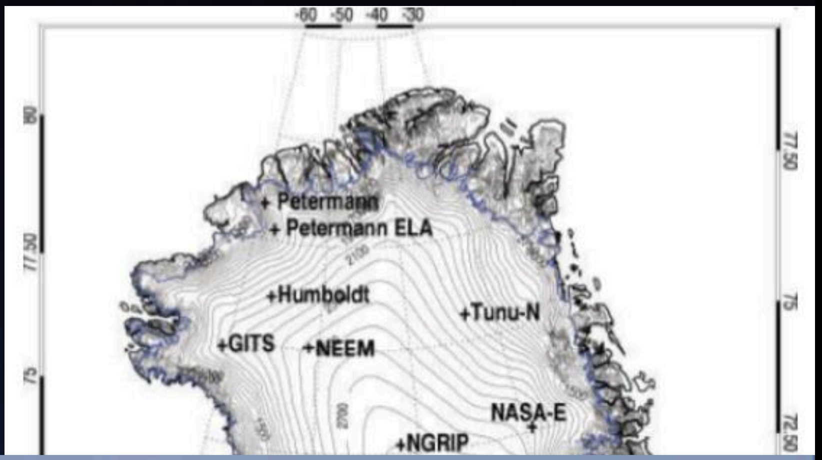




Kogut et al, JCAP, 2011, arXiv:1105.2044

Chluba

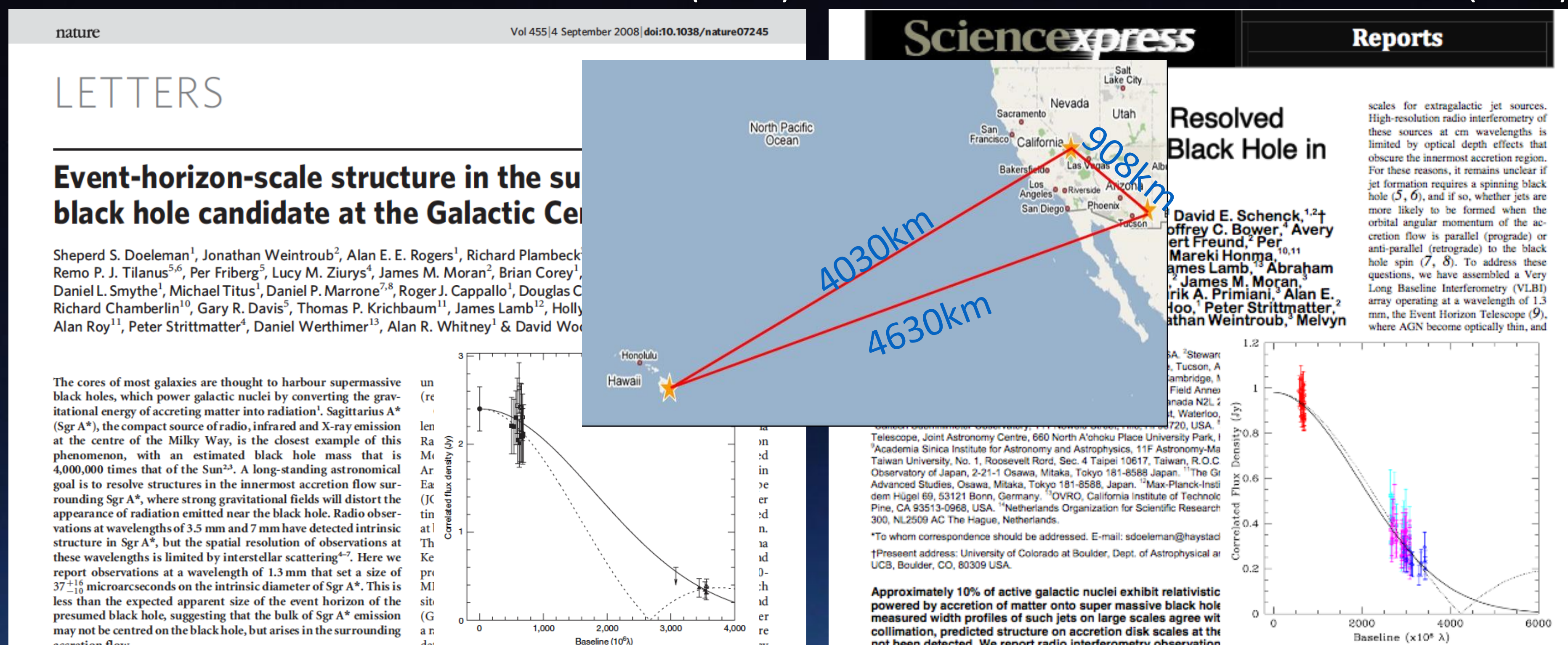
# Greenland - Summit Station

- Established/operated by US NSF & Greenland Government.
  - Established on 1989.
  - Atmospheric and weather researches are mainly ongoing.
  - N72.60°, W38.42°. Altitude: 3210m.
  - Summer: 45 people, Winter: 5 people (3 months shift)
  - Possible to carry things by flights with C-130, etc., or through land.




# Feasibility of Submillimeter VLBI

Doeleman et al. (2008) Doeleman et al. (2012)



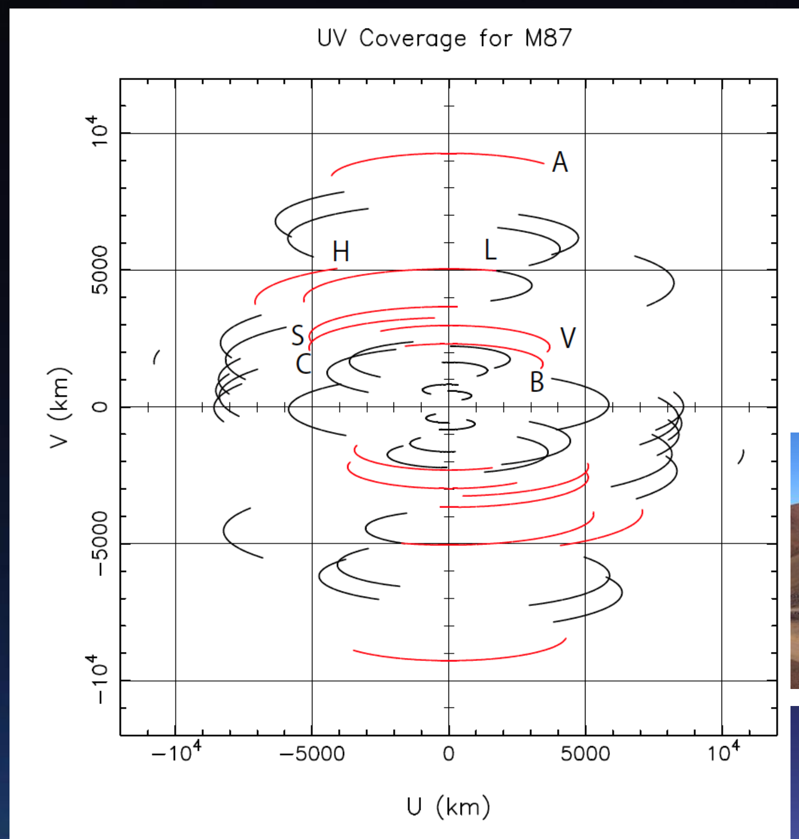

Sgr A*
Size ≈ 40 μas (≈ 4 $r_{sch}$)

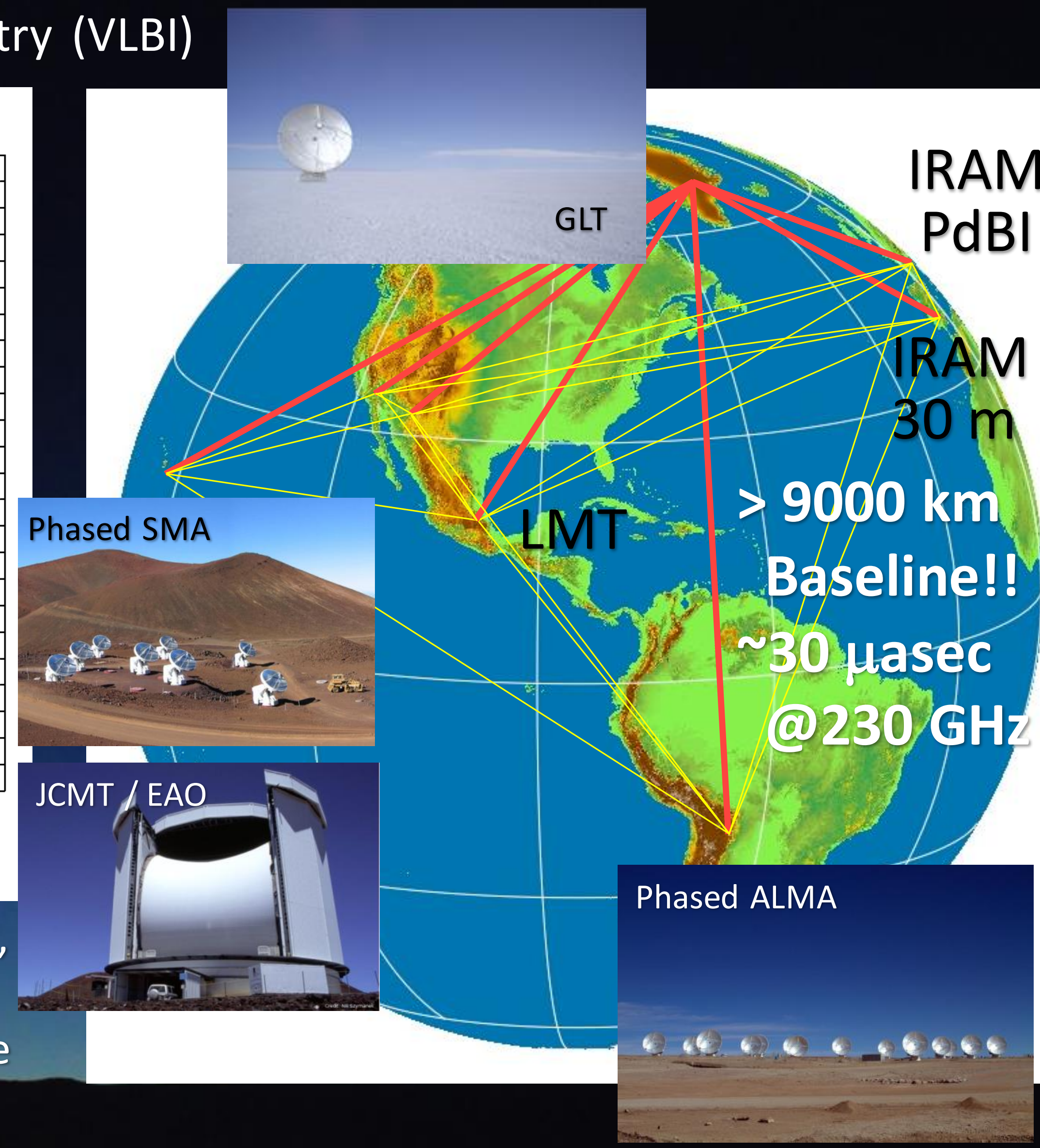
Vir A* (M 87)
Size ≈ 40 μas (≈ 5 $r_{sch}$)

Matsushita

# Expected uv Coverage with GLT

Very Long Baseline Interferometry (VLBI)




uv coverage for M 87 with GLT, ALMA, SMA/JCMT, LMT, SMT, CARMA, IRAM 30m, and PdBI. Baselines with GLT are shown in red.

Matsushita

# Sizes of Black Holes

| | Shadow Size (μasec) | Mass ($10^6$ Mo) | Distance (Mpc) |
|---|---|---|---|
| Sgr A* | 50 | 4.1 +- 0.6 | 0.008 |
| M87 | 39 | 6600 +- 400 | 17.0 |
| M31 | 18 | 180 +- 80 | 0.80 |
| M60 | 12 | 2100 +- 600 | 16.5 |
| NGC 5128 (Cen A) | 7 | 310 +- 30 | 4.5 |

Note: Here we assume $R_{shadow} \sim 5 \times R_{sch}$

Gebhardt et al. (2011)

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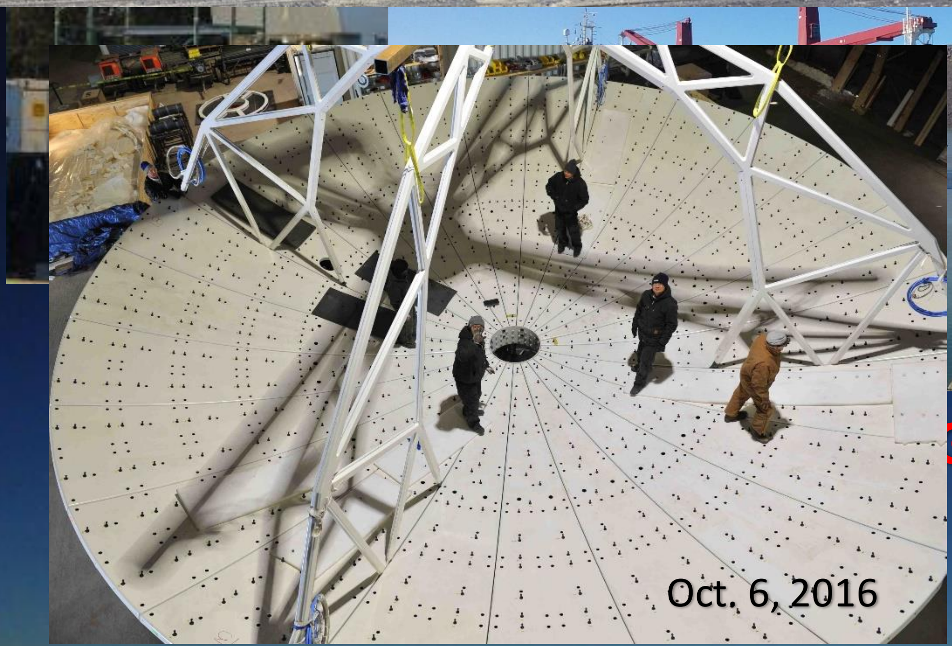
# GLT Antenna Shipping & Reassembly


Oct. 2, 2016

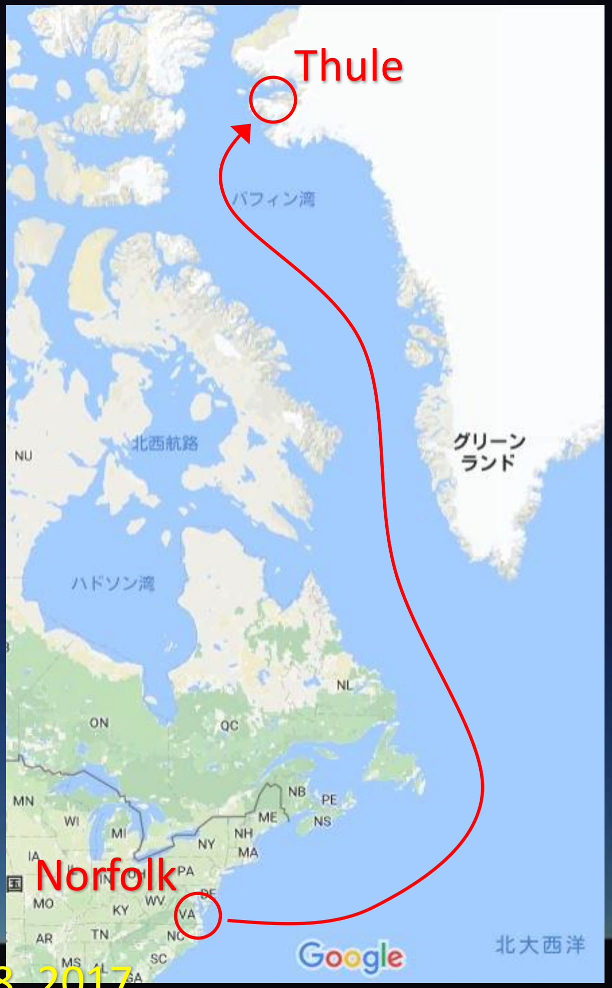
ade for Extreme Weather


2016/07

Greenland


Oct. 6, 2016

Thule Reassembly

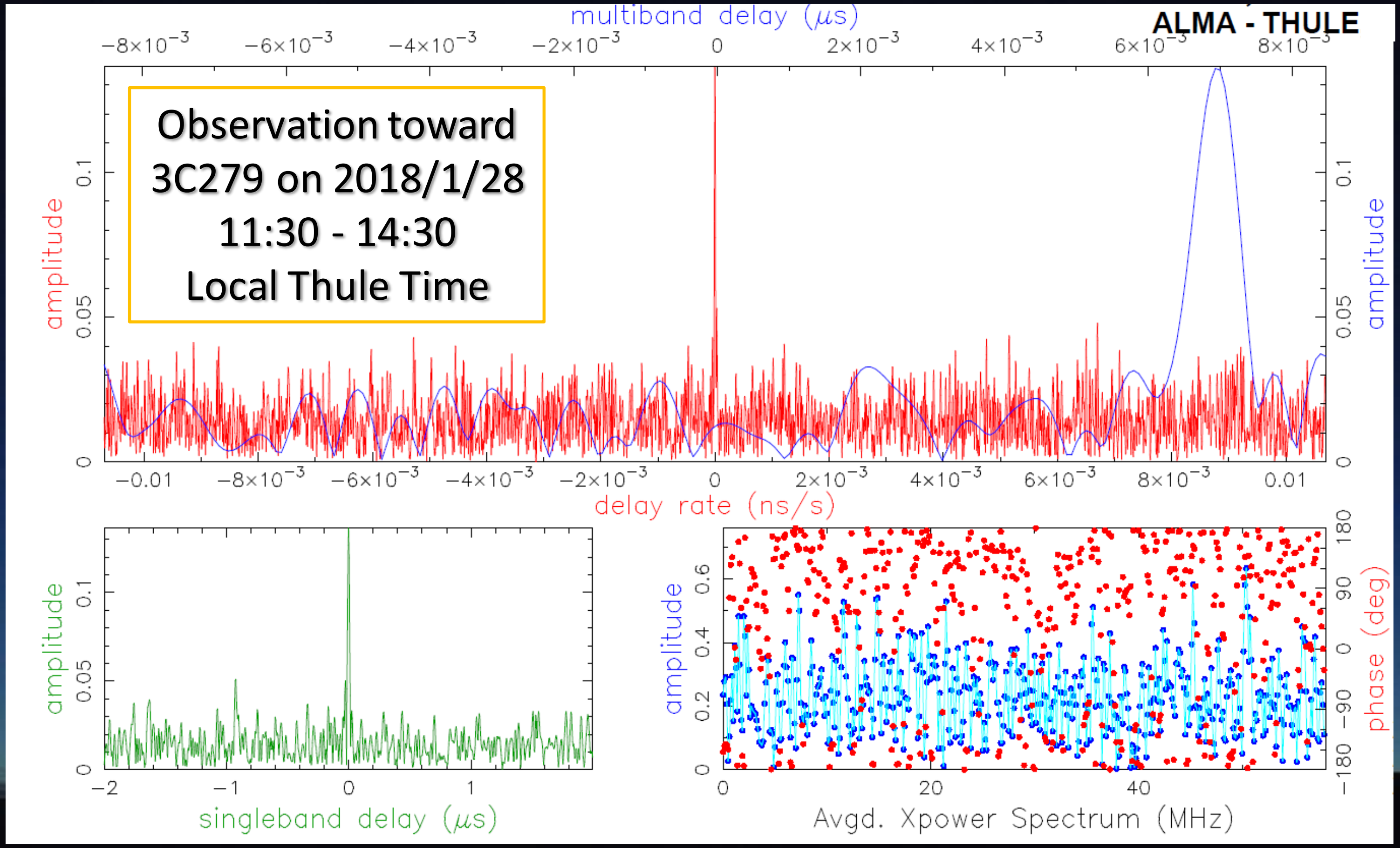



Feb. 18, 2017

Matsushita

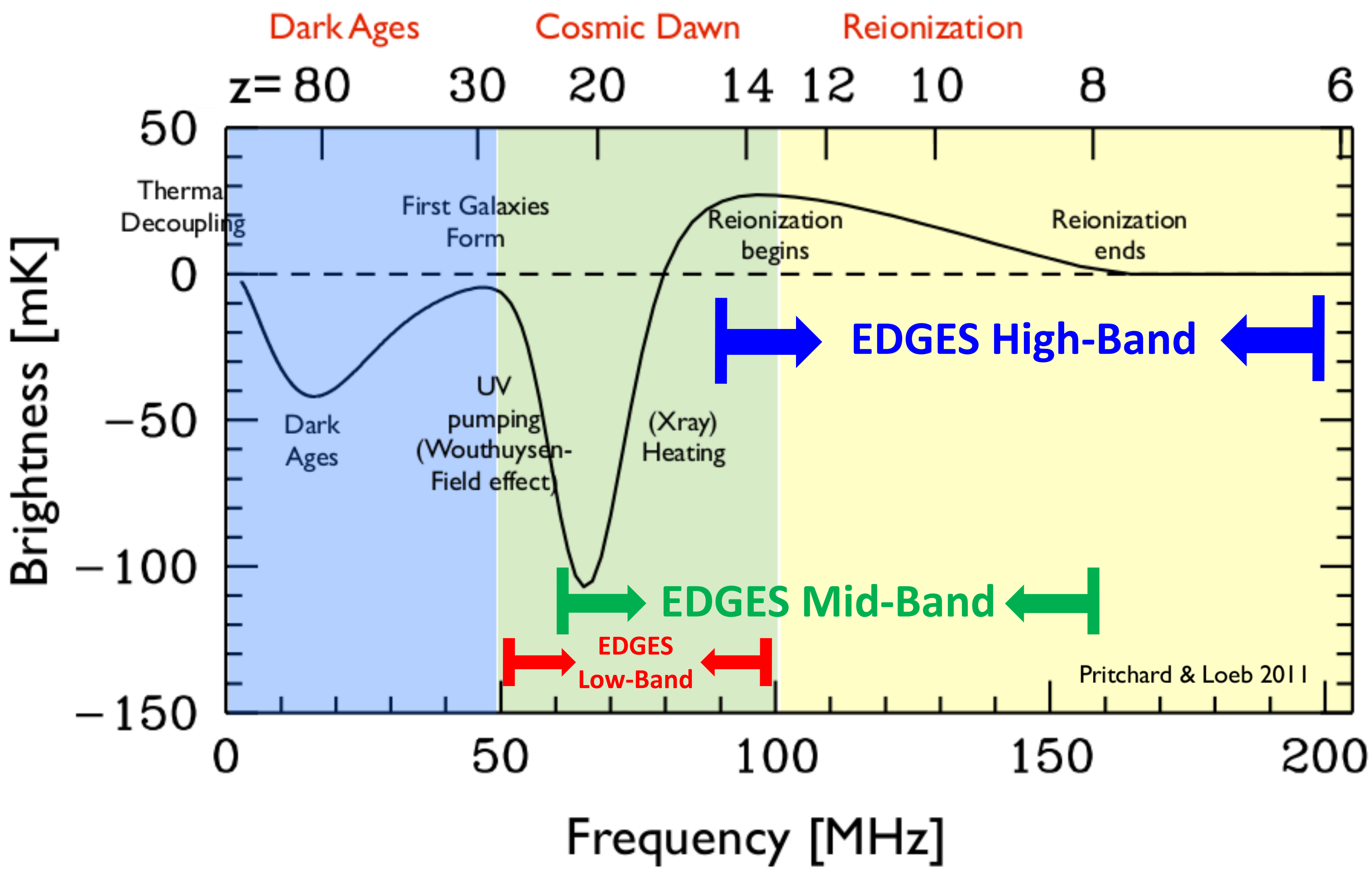
# 230 GHz VLBI First Fringe with ALMA!!!

- We got the first fringe with ALMA at 230 GHz!!!
- The data have been taken at the EHT Dress Rehearsal, namely within 2 months after the commissioning started.



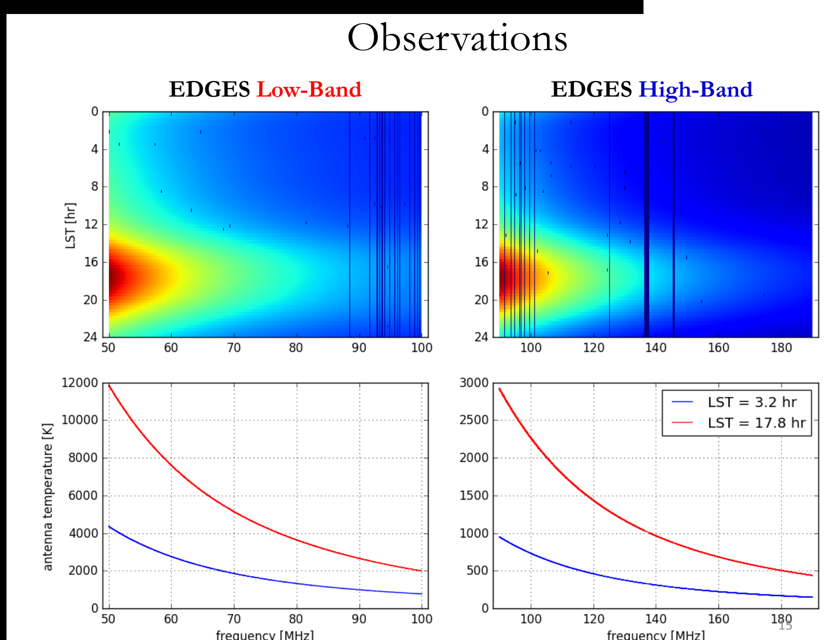

Matsushita

# EDGES Instruments

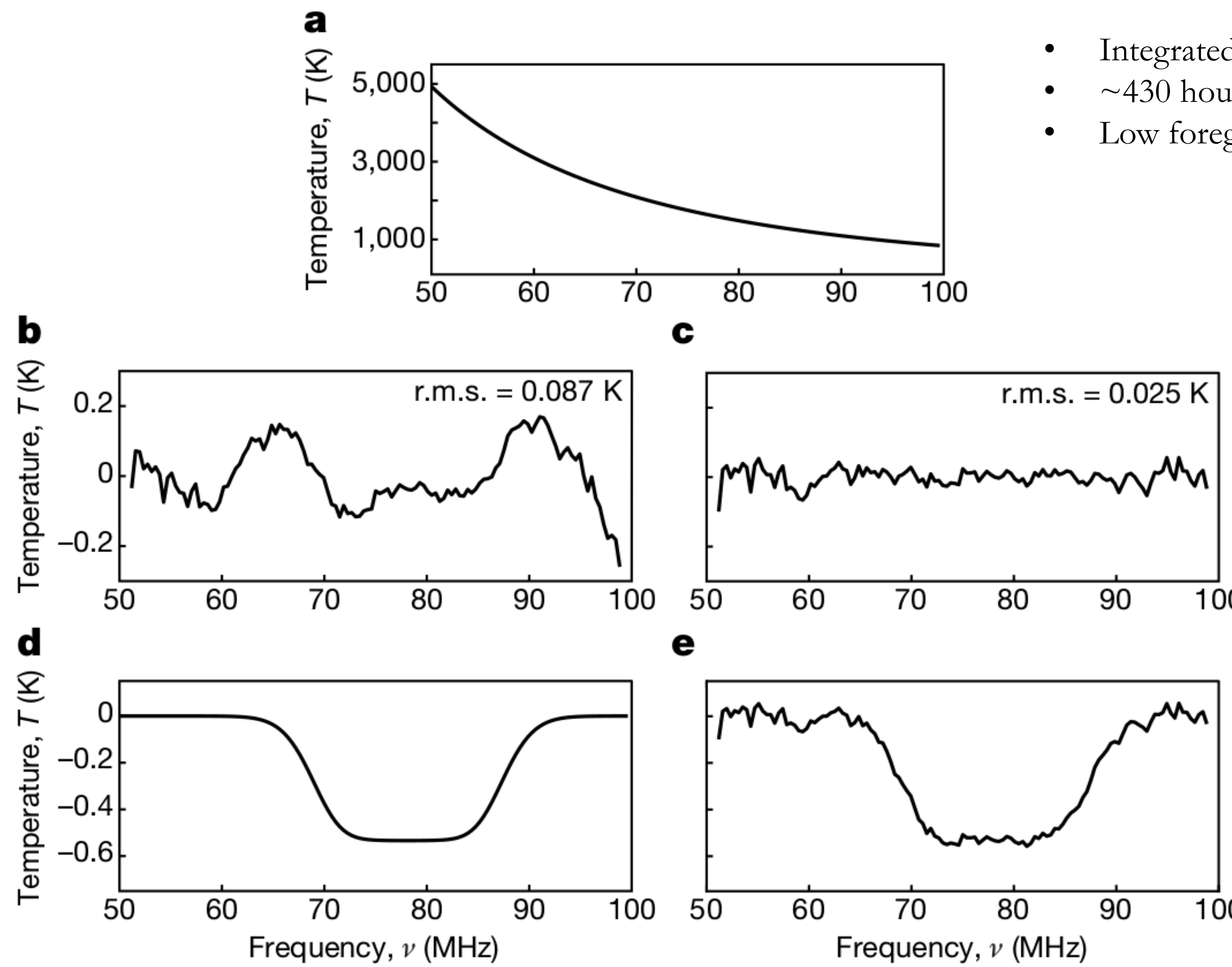





Monsalve


# Summary of the Detection



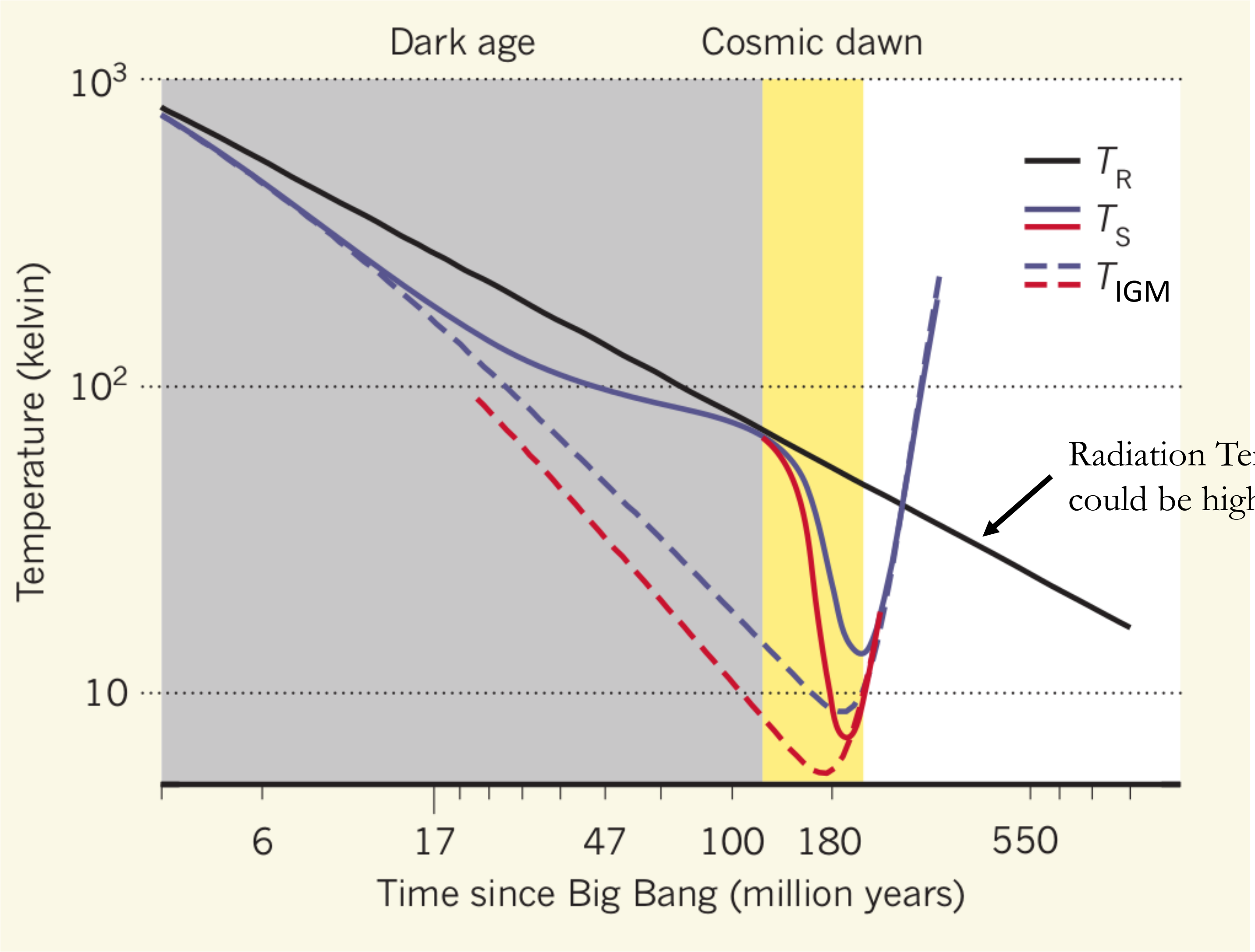

- Integrated spectrum
- ~430 hours
- Low foregrounds

Bowman, Rogers, Monsalve, Mozdzen, Mahesh 2018, **Nature**, 555, 67



Monsalve

# Producing a Deep Absorption




Radiation Temperature could be higher than CMB

Greenhill 2018, **Nature**, 555, 38

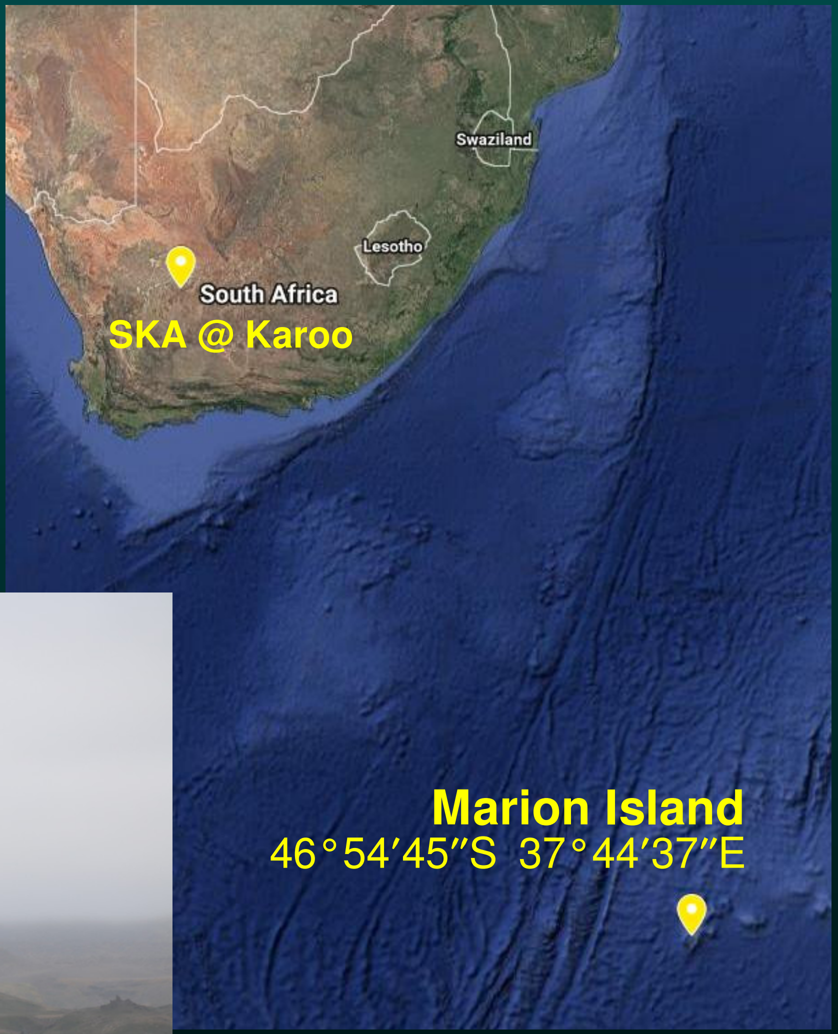
Monsalve

# *Marion Island*

Marion Island base is operated by the
South African National Antarctic Programme

2000 km from nearest continental landmass

PRI$^{Z}$M = first astro experiment on Marion!
2016 engineering run, science ops since 2017

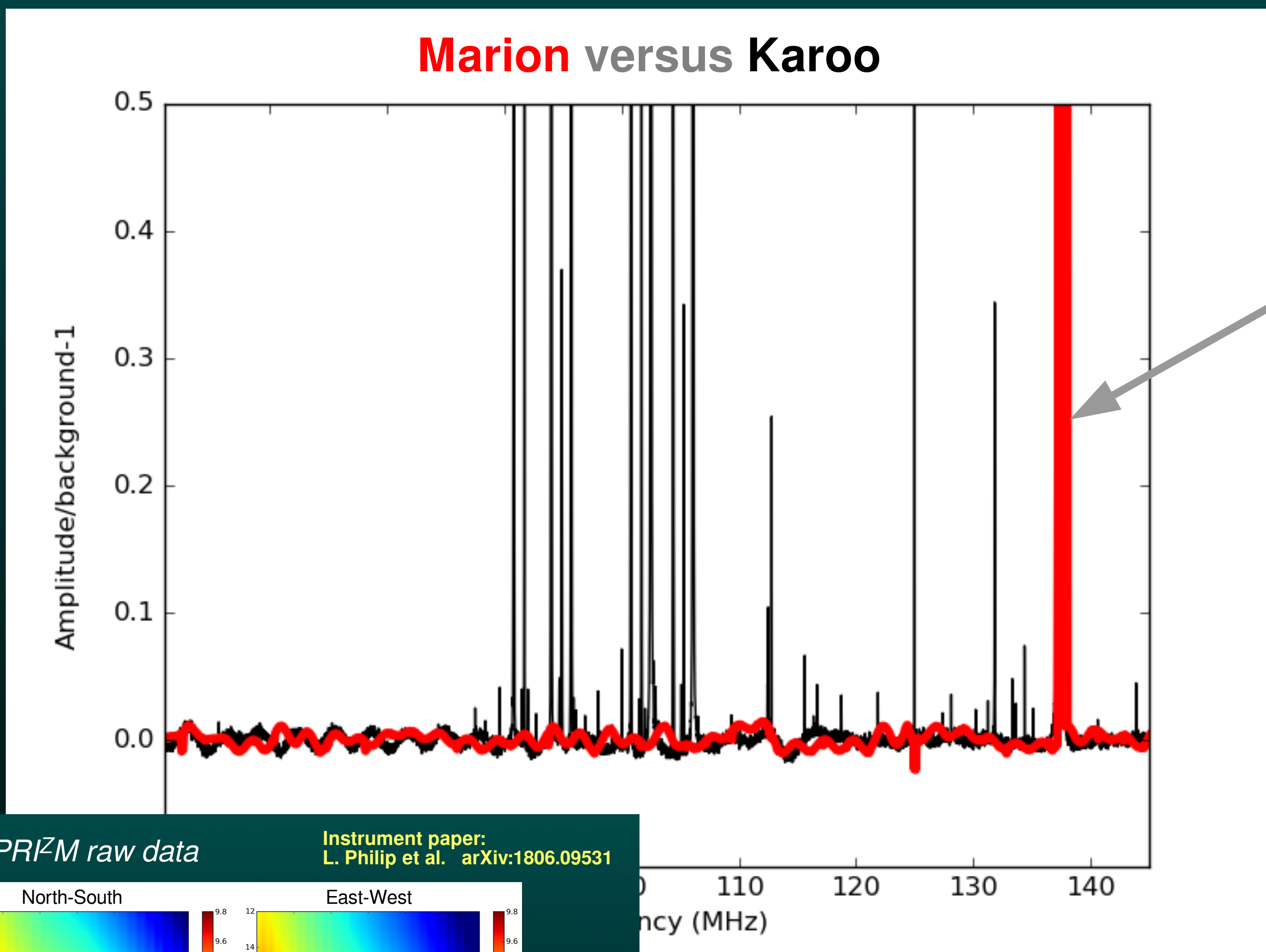



<u>Challenges:</u>
Access once per year
3 week deployment window
Roaring Forties weather
Mires and lava rocks
@#$% mice

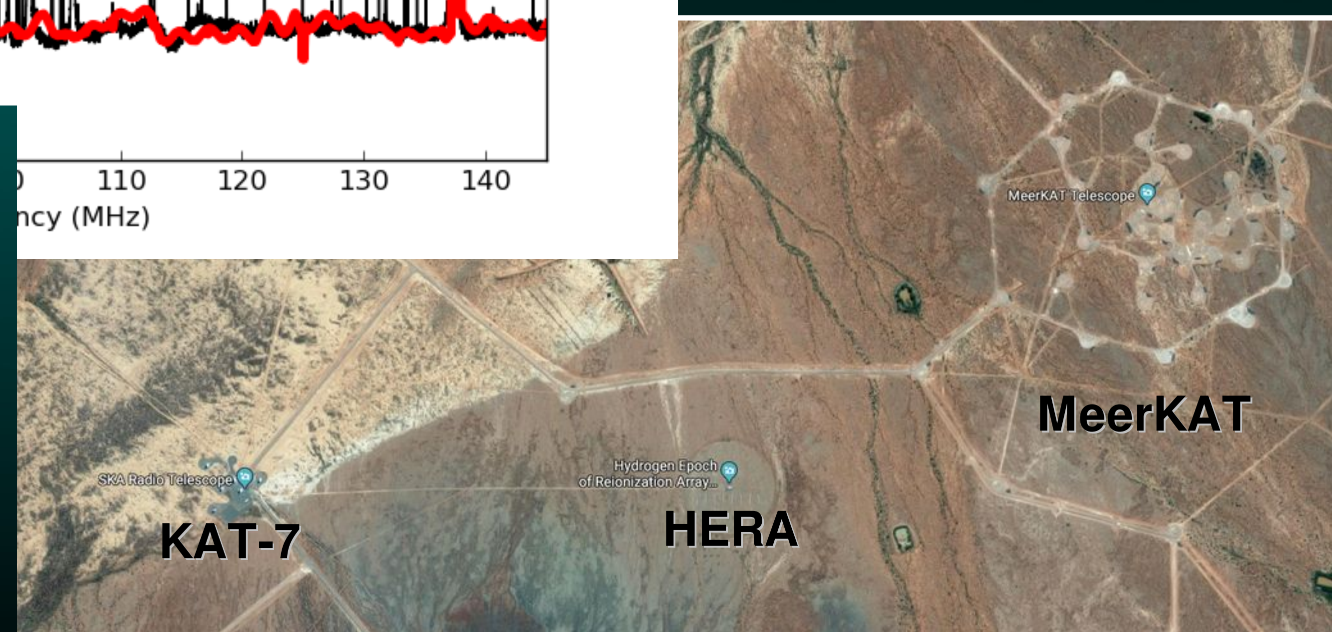
Chiang

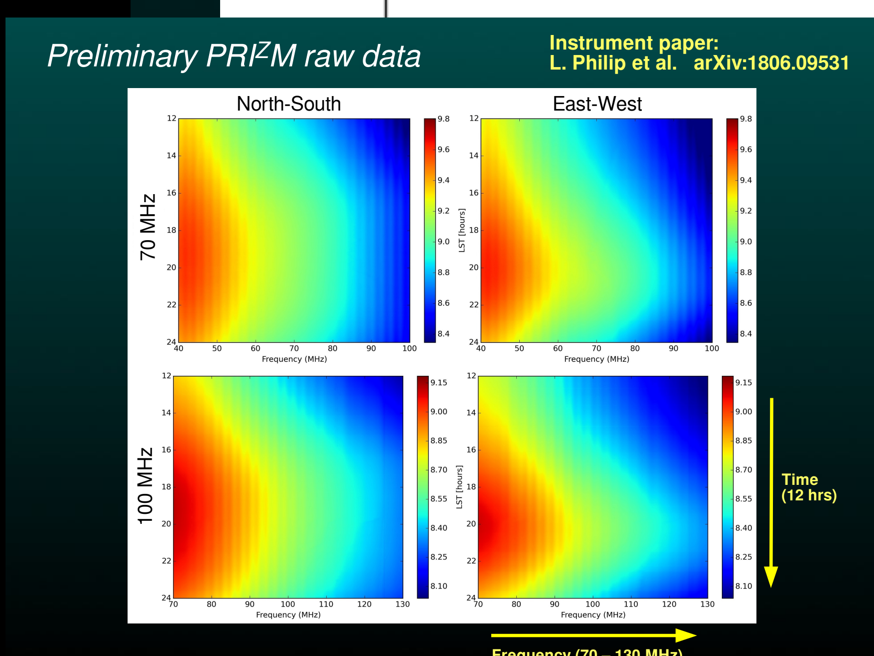
# *RFI comparison with Karoo*

**Instrument paper:**
**L. Philip et al. arXiv:1806.09531**



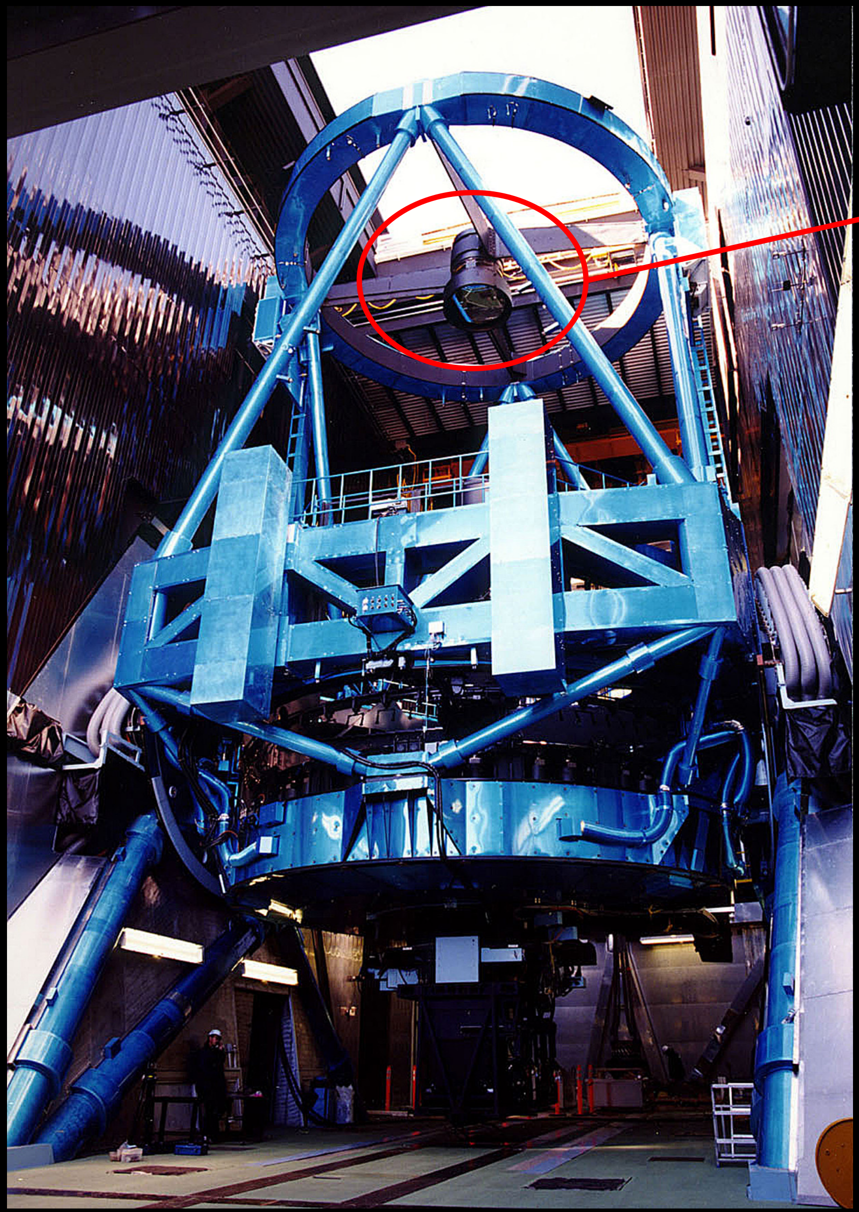

Only detectable feature at Marion is Orbcomm satellites (137–138 MHz)



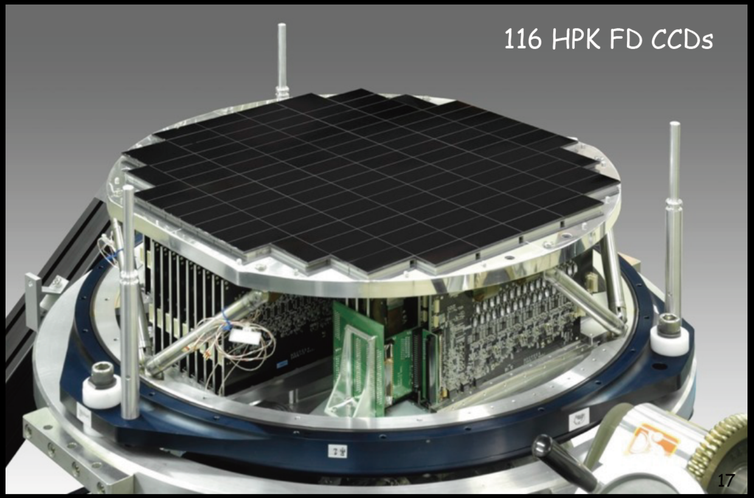




**Chiang**

# Hyper Suprime-Cam (HSC)



- largest camera
- 3m high
- weigh 3 ton
- 104 CCDs (~0.9G pixels)




Takada

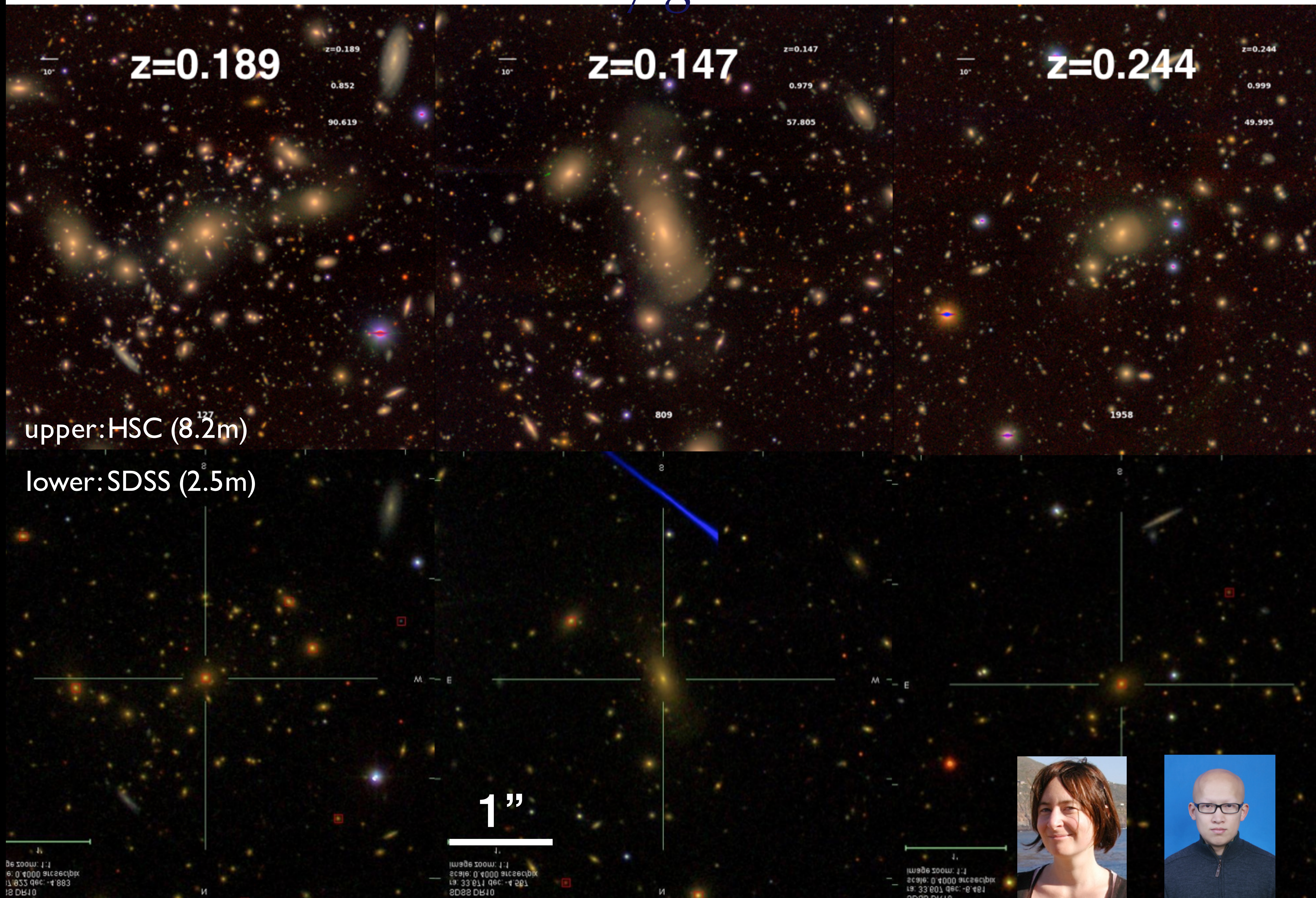
**wi**

- **Fas**
- a cos

## Hyper Suprime-Cam FoV


Takada

# Nearby galaxies




*All data reduced by the HSC pipeline*

A. Leauthaud S. Huang

Takada

# Unprecedented wide and deep 3D DM map

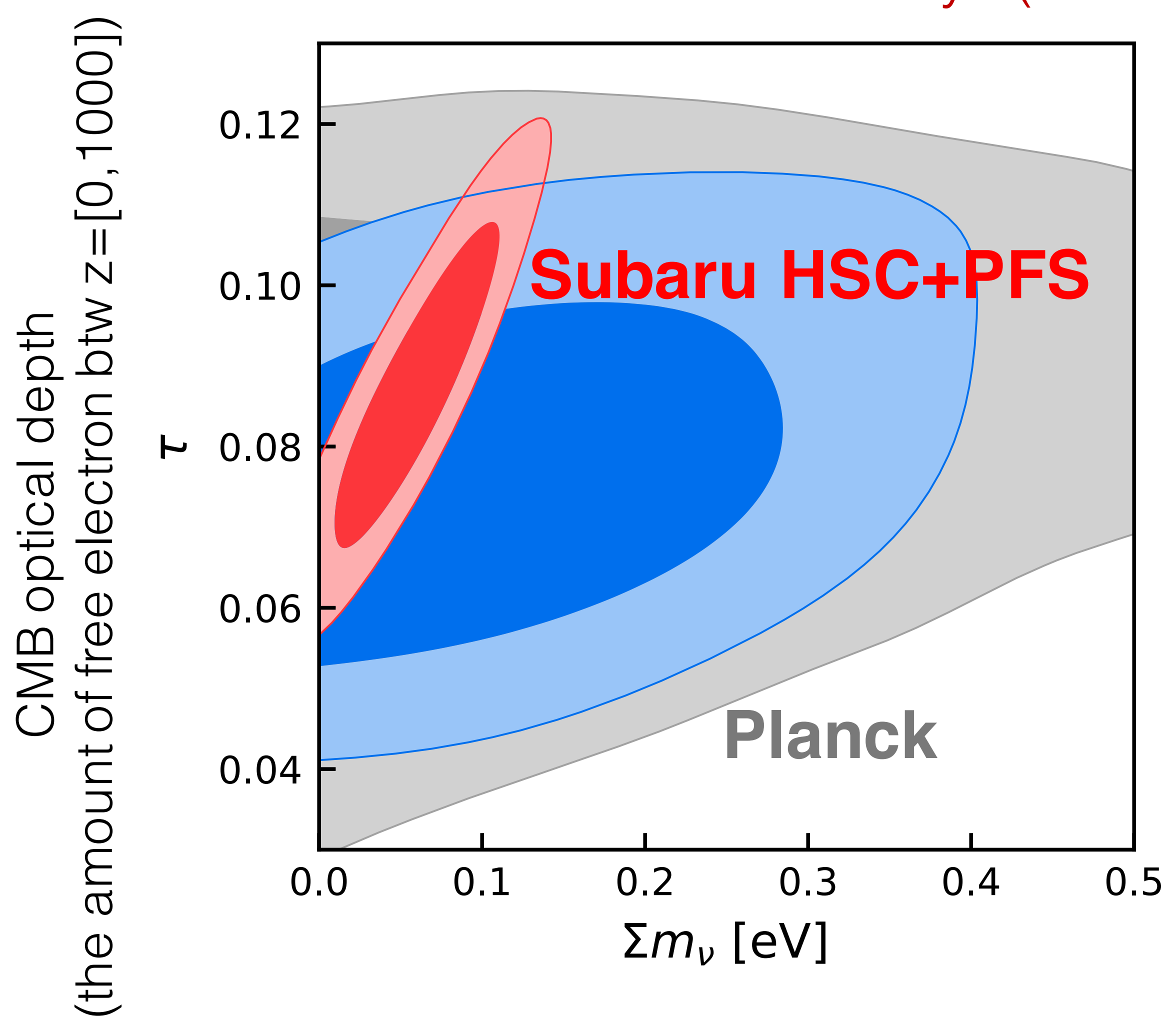
Oguri et al. 2018

(~7Gyr light years away)

one particular field (VVDS field)

# Cosmology goal for neutrino mass

- Forecasts for Subaru surveys (aimed at achieving by 2025)




**$m_{\nu,\,tot}$<0.1eV (95%CL)**
with Subaru

Note: limited by an accuracy of CMB optical depth (stat. + sys.~0.02)

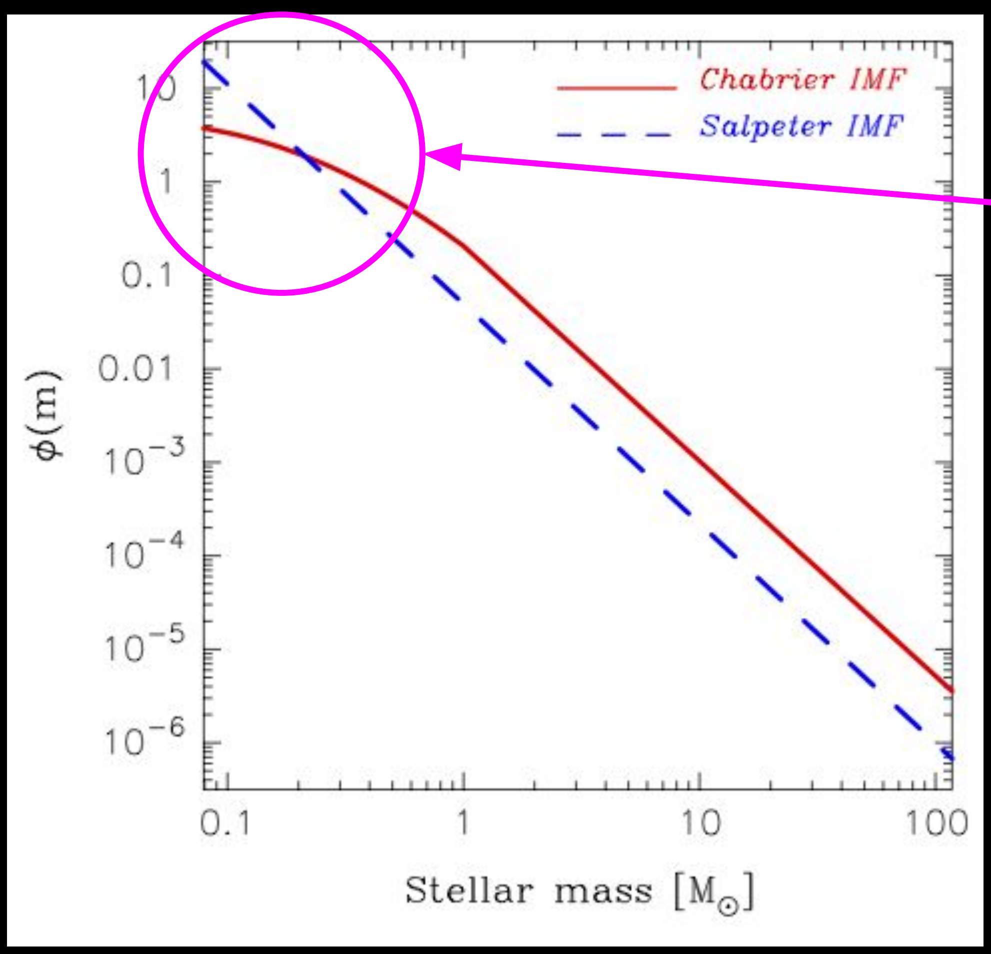
Future (till 2030):
$m_{\nu,\,tot}$<0.03eV (95CL) with CMB exp.
⇔ HK/DUNE (till 2030, after 5-years operation.)

$\sigma(N_{eff})$~0.027

**Takada**

# Weak+Strong lensing to understand galaxies

The stellar initial mass function (IMF)

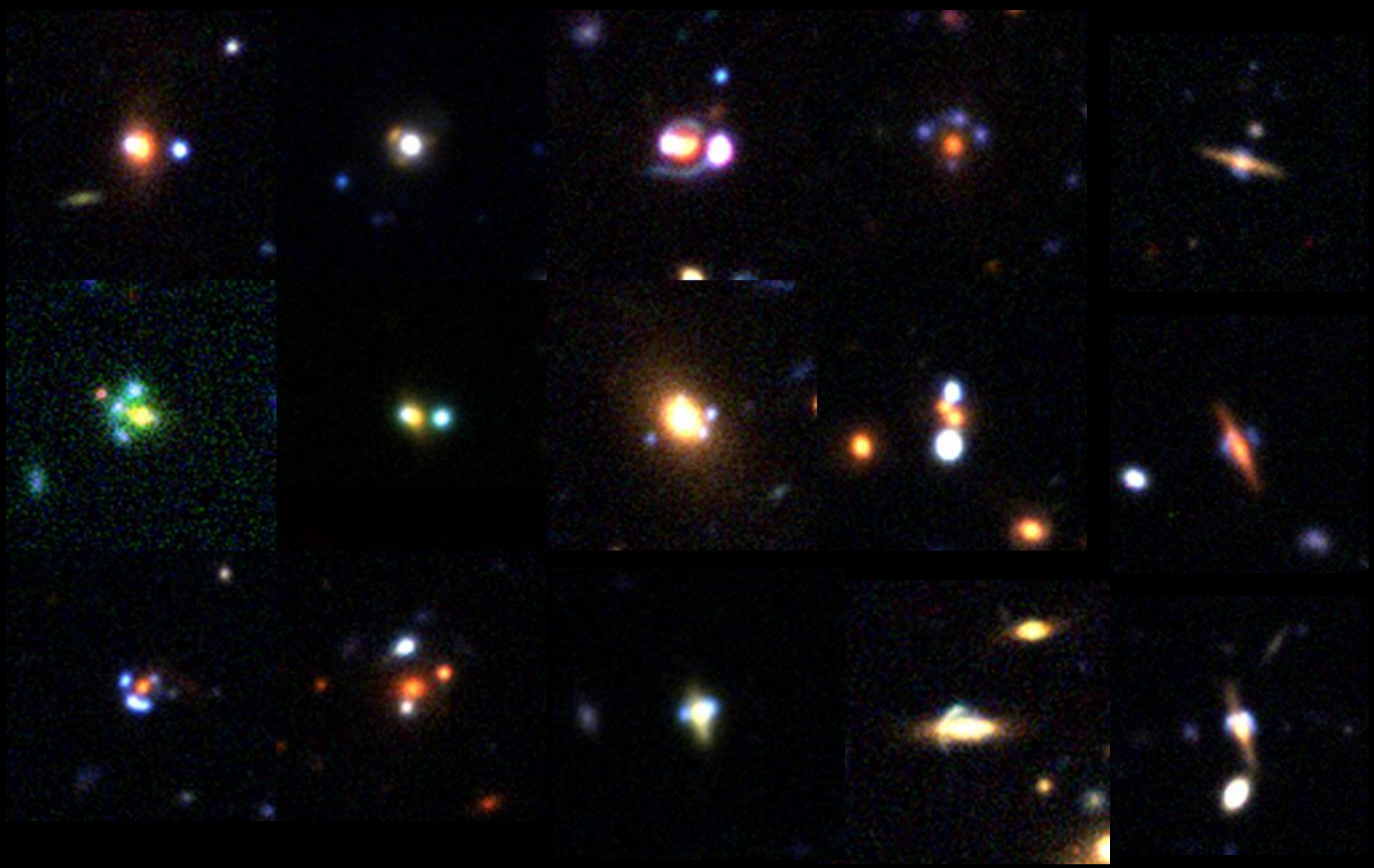



These stars contribute very little to the light of a galaxy, but contribute a lot to the mass: uncertainty in M/L of up to a factor of 2!

- Stellar IMF is the biggest systematic in stellar mass measurements
- Challenge for the measurement of dark matter distribution

Sonnenfeld

Lenses found by citizens



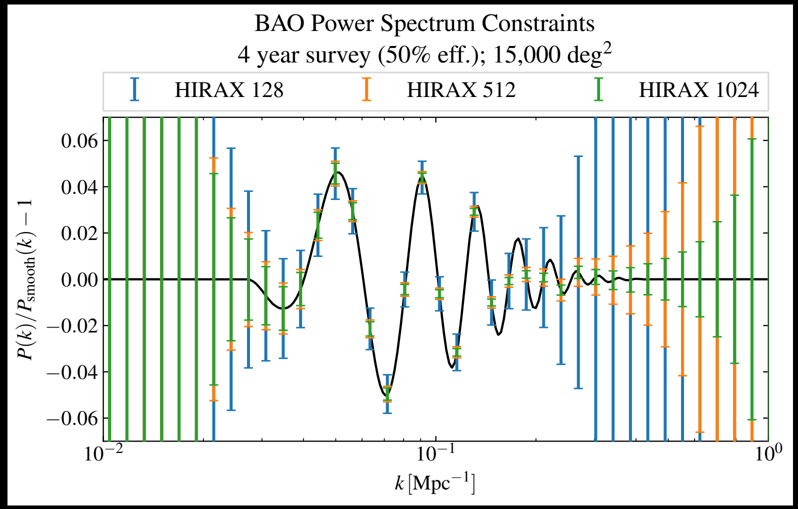
Sonnenfeld

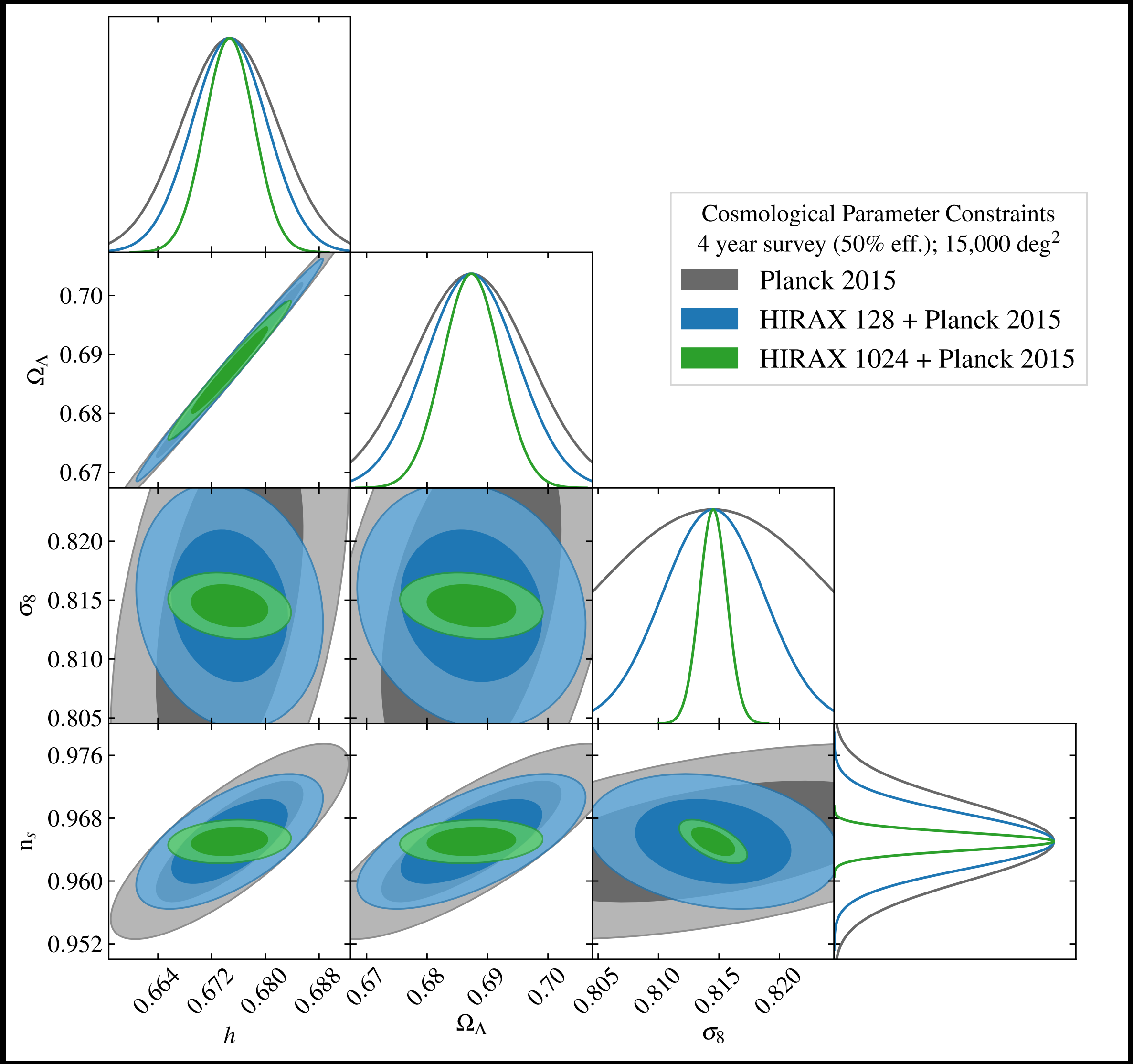
# Design Plan

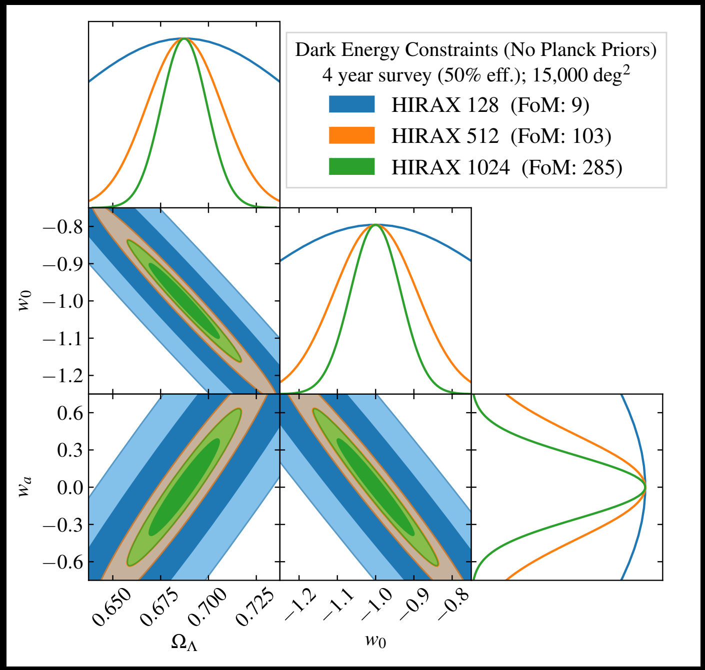
- Order $10^3$ close-packed 6m dishes.
- Operate between 400-800 MHz
- Channelizing on FPGA ICE boards
- Correlation on GPUs
- Dishes tilt N/S: when "deep enough" on a strip, tilt over to increase $f_{sky}$.
- Will beamform in correlator, for FRBs, kick out small

JLS

# Forecast (Devin Crichton. See also Amadeus Witzemann results)




JLS

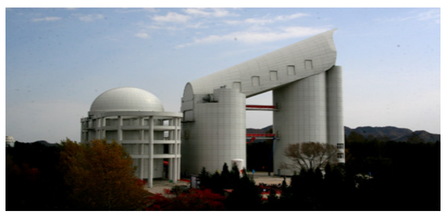
# Asian Astrophysics

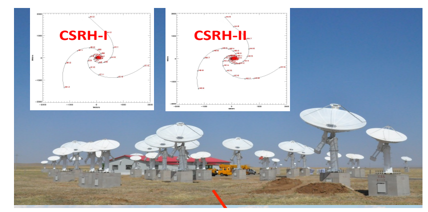
- Well Developed in East Asia during the last 30 years
- Key Players:  Japan, China, Korea, Taiwan
  - Strong Theory Tradition:  e.g. Hayashi
  - Strong Facilities Development:  In-Country, Abroad
- Resources in East Asia:
  - Fast Economic Growth
  - Large Population
  - Industrial Infrastructures
- Resources in South East Asia:
  - Thailand, Vietnam, Malaysia, Indonesia

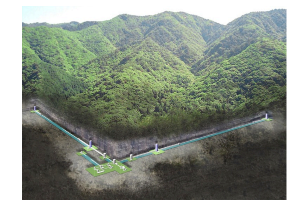
- Main Problems:  Coordination, Organization, Competitiveness

Ho

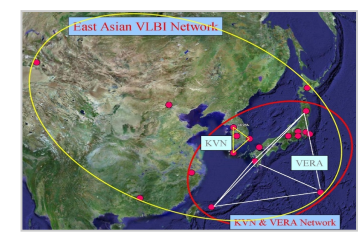
# East Asia already has Regional Facilities (10~100M USD)





- **China: LAMOST, FAST, 21CMA, CSRH, Silk Road, ...**

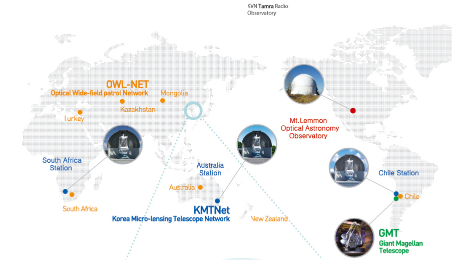



- **Japan: Subaru, Hinode, VERA, KAGRA, Nobeyama, Okayama, Kyoto NTT, TAO, ....**
- **Korea: Bohyunsan OAO, Sobaeksan OAO, KVN, KMTNet, Space Weather, CIBER, OWL, ....**

- **Taiwan: SMA, AMiBA, TAOS, TAOS-2, GLT, LOT**







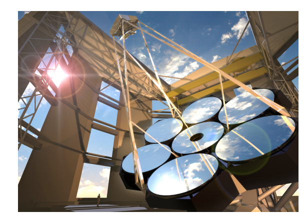

Ho

# and Regional Large Scale Projects

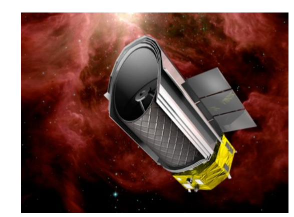
# (> 1B USD)


- ALMA: Japan, Taiwan, Korea

- TMT: Japan, China



- GMT: Korea



- SPICA: Japan (Korea, Taiwan)
- SKA: China, Japan, Korea (Taiwan)

**However, Better Coordination Needed**

Ho

# EAO Status:  2015-2018

- Operate JCMT more efficiently than ever
- Built EA JCMT Submm community (~350 PIs)
- Introduced new JCMT Polarization Capabilities (POL-2)
- JCMT is now part of Event Horizon Telescope consortium
- JCMT Large Programs lead to New Science Initiatives
- By 2017, EA Community leads ~50% of JCMT Partners 1st Author papers
- JCMT operations extended to 2024
- EAO Access to SMA, UKIRT, Subaru
- EAO working with Southeast Asian countries
- Vietnam and Thailand are now Observers: Access to all of EAO facilities — Accelerate regional developments

Ho

# MASTER IN SPACE

**EARTH OBSERVATION, ASTROPHYSICS, SATELLITE TECHNOLOGIES**

*The only master degree in space sciences & technologies in Vietnam*

*********

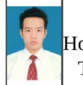
Two specialties:

- Science from Space
- Satellite technologies


Nuss

# USTH-SPACE PhD students

VIETNAM FRANCE UNIVERSITY

| No | Photo | Name | Title | Advisor | Laboratory | University | Country | Funding | French ED |
|---|---|---|---|---|---|---|---|---|---|
| 1 |  | Hoàng Đức Thường | Optimization of the next generation CMB satellite missions | Guillaume Patanchon, Yannick Giraud-Héraud | APC | Université Paris Diderot | France | Vietnam 911 | 560 |
| 3 |  | Lê Mai Sơn | The surface heat fluxes estimation using remote sensing data | Yuei-An Liou, Hwa Chien | Hydrology Remote Sensing Laboratory | National Central University | Taiwan | Taiwan National Central University | |
| 5 |  | Phan Thanh Hiền | Design, development and inflight exploitation of IGOSAT satellite payloads for measuring the radiative content of low-earth orbit and in the ionosphere. | Hubert Halloin, Philippe Laurent | APC | Université Paris Diderot | France | Vietnam 911 | 560 |
| 6 |  | Phan Thị Hoa | Rice monitoring using radar remote sensing. From research to applications. | Thuy Le Toan, Mehrez Zribi | CESBIO | Université Paul Sabatier (Toulouse) | France | CIFRE Telespazio | 173 |
| 7 |  | Bùi Văn Tuấn | Galaxy cluster detection and photometric redshifts for cosmology in the context of the Esa's Euclid mission | Cyrille Rosset, Volker Beckmann | APC | Université Paris Diderot | France | Vietnam 911 | 560 |
| 8 |  | Jasinghege Don Prasanna Deshapriya | Etude comparée de la composition des surfaces des palnètes naines, des objets transneptuniens, et des comètes à partir des données recueillies in situ. | Antonella Barucci | LESIA | Université Paris Diderot | France | CD UPD | 127 |
| 9 |  | Nguyễn Hoàng Phương Thanh | Chemical origin of N2 and CO differential depletion in prestellar cores | Laurent Pagani, François Dulieu | LERMA | Université de Cergy-Pontoise | France | French Labex Michem | 127 |
| 10 |  | Hoàng Quốc Nam | Analysis on Mekong delta's soil (10N provinces) under climate change and measures proposal | Luu The Anh | VAST/Institute of Geography | VAST/GUST | Vietnam | VAST/Institute of Geography | |
| 11 |  | Trần Đức Dũng | Etude du spectre d'absorption de l'oxygène en infrarouge proche et application à la télédétection des gaz à effet de serre dans l'atmosphère. | Ha Tran, Juan Cuesta | LMD | Université Pierre et Marie Curie | France | CD UPMC | 129 |
| 12 |  | Nguyễn Trần Hoàng | Weakened cell phenomenon modelling and simulation | Alain Michez, Frédéric Wrobel | IES | Université de Montpellier | France | CNES - TRAD | 166 |
| 13 |  | Nguyễn Tùng Lâm | Etudier les super-amas d'étoiles dans les galaxies à flambées à l'époque de JWST | Damien Gratadour, Daniel Rouan | LESIA | Université Pierre et Marie Curie | France | CD UPMC | 127 |

Nuss

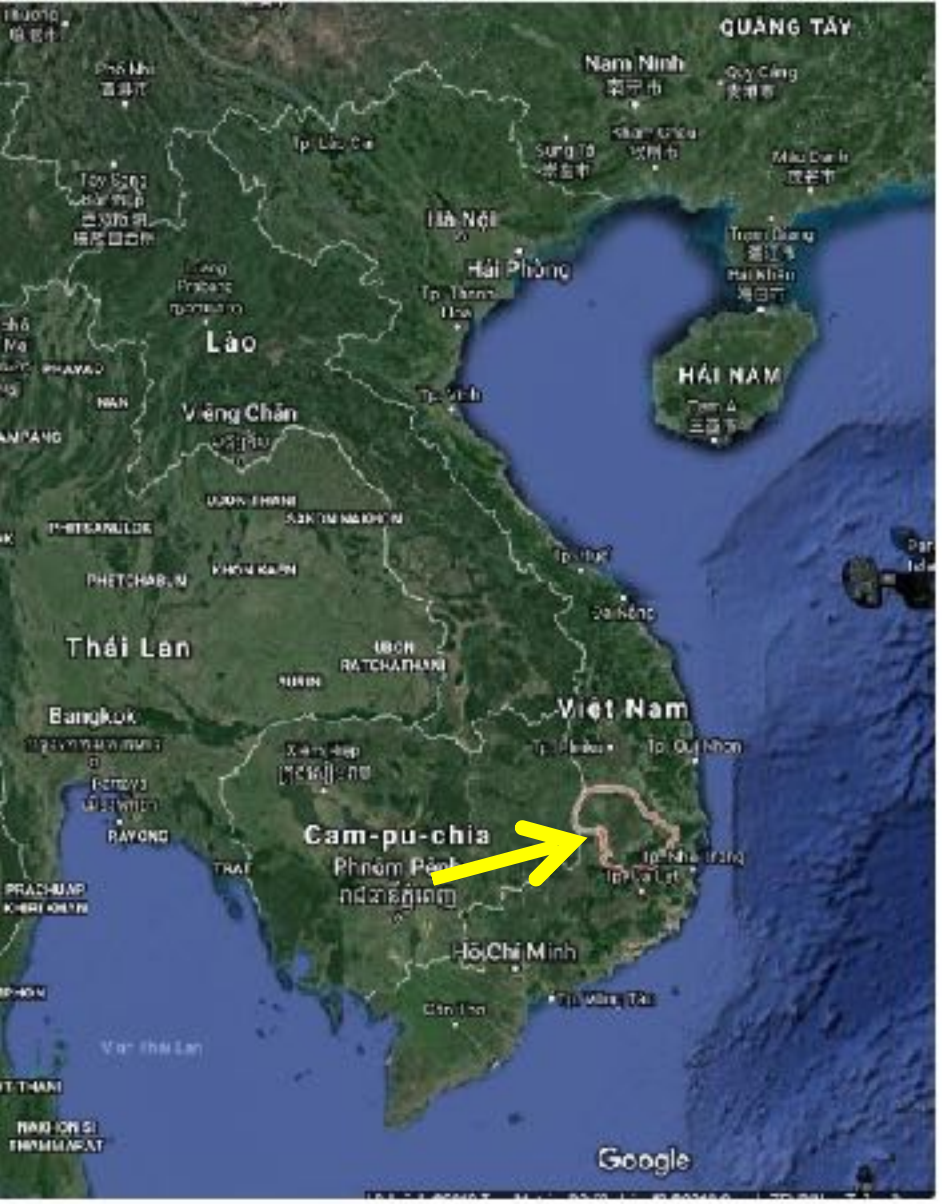
# 3. Proposal for the development of Space Science in Viet Nam

So far, what have we done?

- ✓ Created an undergraduate program for Viet Nam.
- ✓ Established an internship program with ASIAA (Taiwan), Sokendai (Japan).
- ✓ Created a research group at VNUHCM.
- ✓ Created a linkage with East Asian Observatory.
- ✓ Established a foundation for basic science VNUHCM-Rencontres du Viet Nam.

However, we have not received any support from the central government!

Phan Bảo Ngọc





http://gody.vn/diadiem/dak-lak/vuon-quoc-gia-chu-yang-sin

Dak Lak province: The largest province in the HighLand region in Vietnam (~ 400 - 800 m high above sea level)

Has high mountain: Chu Yang Sin (2442 m high)

Dak Lak is ~200 km far from the sea

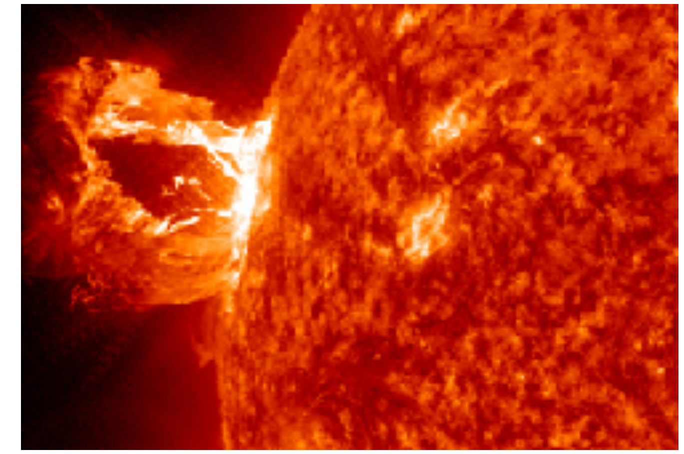
Largest university in the region: Tay Nguyen university (TNU).

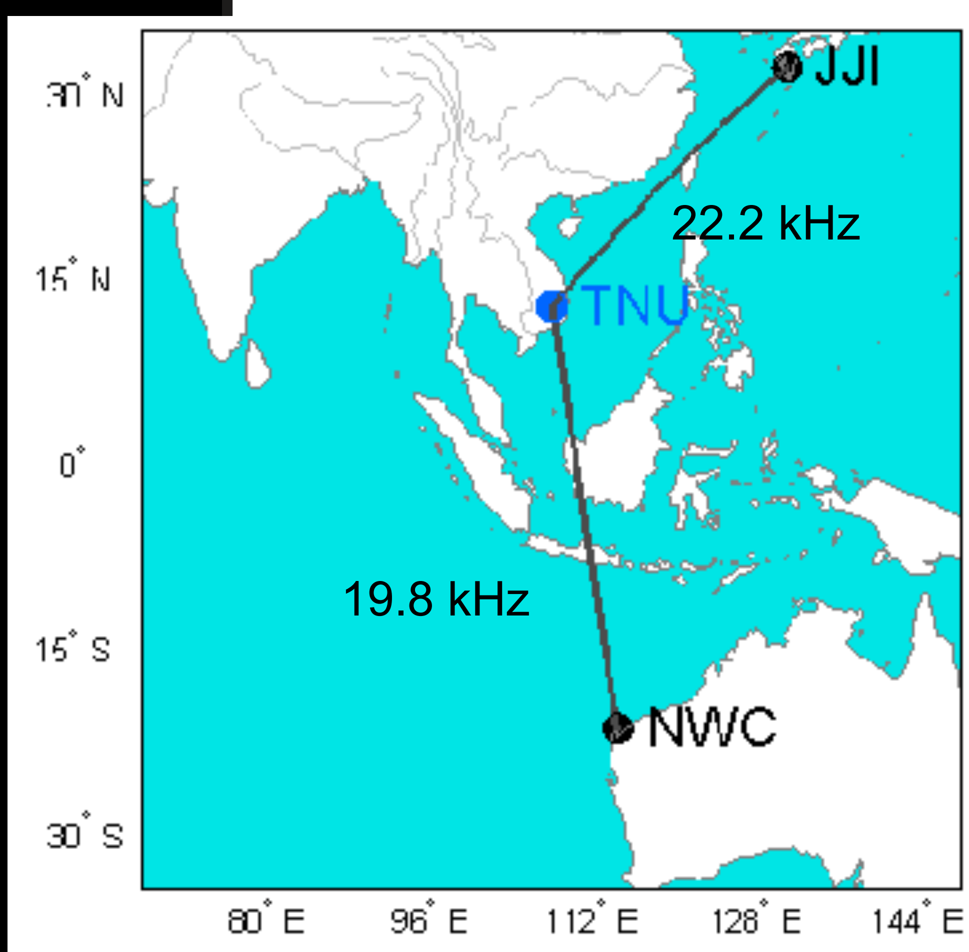
TNU has ~ 17000 students (1200 students are in Faculty of Natural Science and Technology and ~160 students in Physics at Department of Physics).

**Tan**

ow Frequency Telescope

Standford SuperSID

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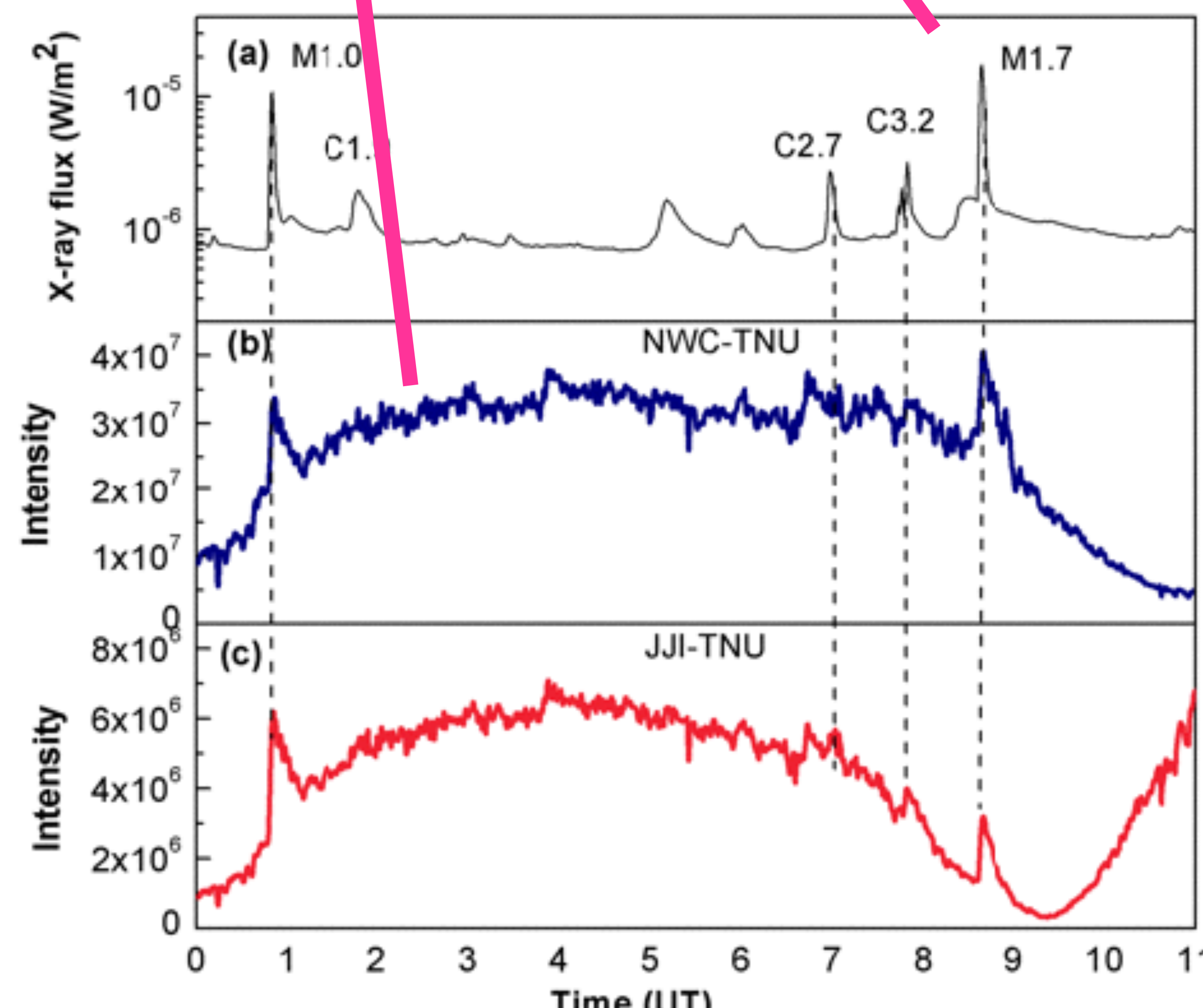


# Astronomical observatory: telescopes and equipment

- We signed an MOU with NAOJ to ask for support in constructing the observatory
- The new telescope tube design is led and donated by the astronomy lab from Kyoto university, CCD is supported by NHAO
- A staff of TNU, Tran Quoc Lam, is joining the NARIT Optical Design Summer School 2018 at Chiang Mai, Thai Land
- He will join a scientific group at Kyoto University to design a new telescope
- We are actively looking for financial supports for other parts of the observatory (dome, rotator, mount)


Tan

# KASI: Facilities abroad and in space

## Abroad

**Optical Patrol System (OWL-Net)**

**Mt. Lemmon Observatory**

**Giant Magellan Telescope (GMT)**

**Korea Microlensing Telescopes (KMTNet)**

## Space

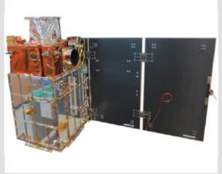
**Far-UV Imagin Spectrometer (FIMS)**

2003

**Multi-purpose Infrares Imaging Spectometer(MIRIS)**

2013

**Near Infrared spectroscopic surveyor**

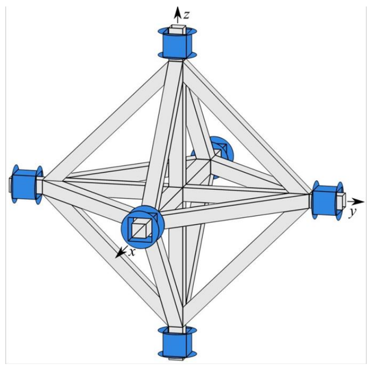


To be launched soon (2018)



Lee

# Superconducting tensor GW Detector (Paik et al. 2016, CQG, 33, 075003)



- Superconducting Omni-directional Gravitational Radiation Observatory (SOGRO)

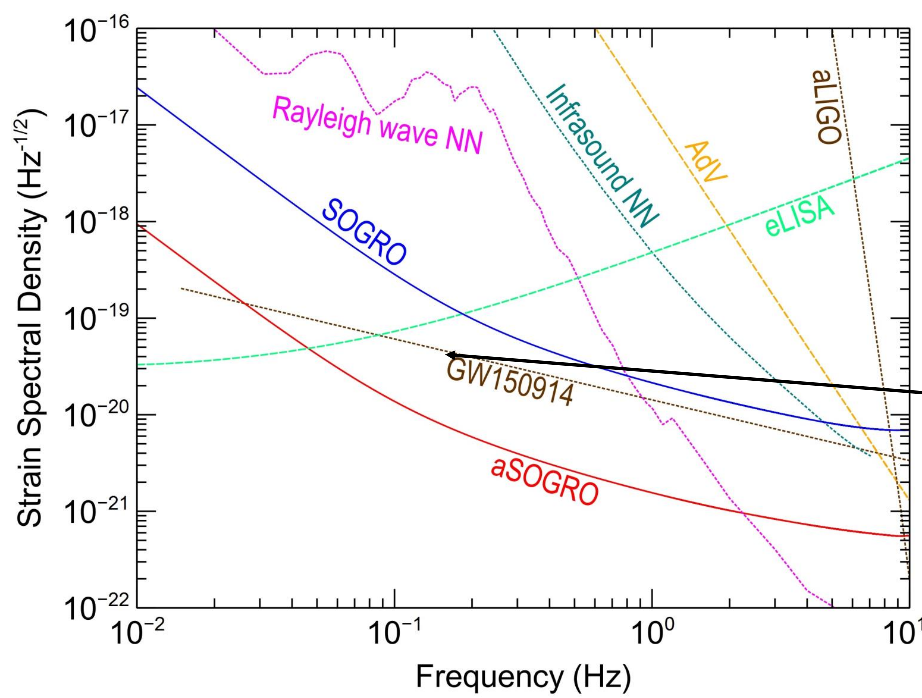
$$h_{ii}(t) = \frac{1}{L}[x_{+ii}(t) - x_{-ii}(t)]$$
$$h_{ij}(t) = \frac{1}{L}\{[x_{+ij}(t) - x_{-ij}(t)] - [x_{-ji}(t) - x_{+ji}(t)]\}$$

- By detecting all six components of Riemann tensor, the source direction and the polarization can be determined.

- Newtonian noises could be modeled and subtracted  from the signal



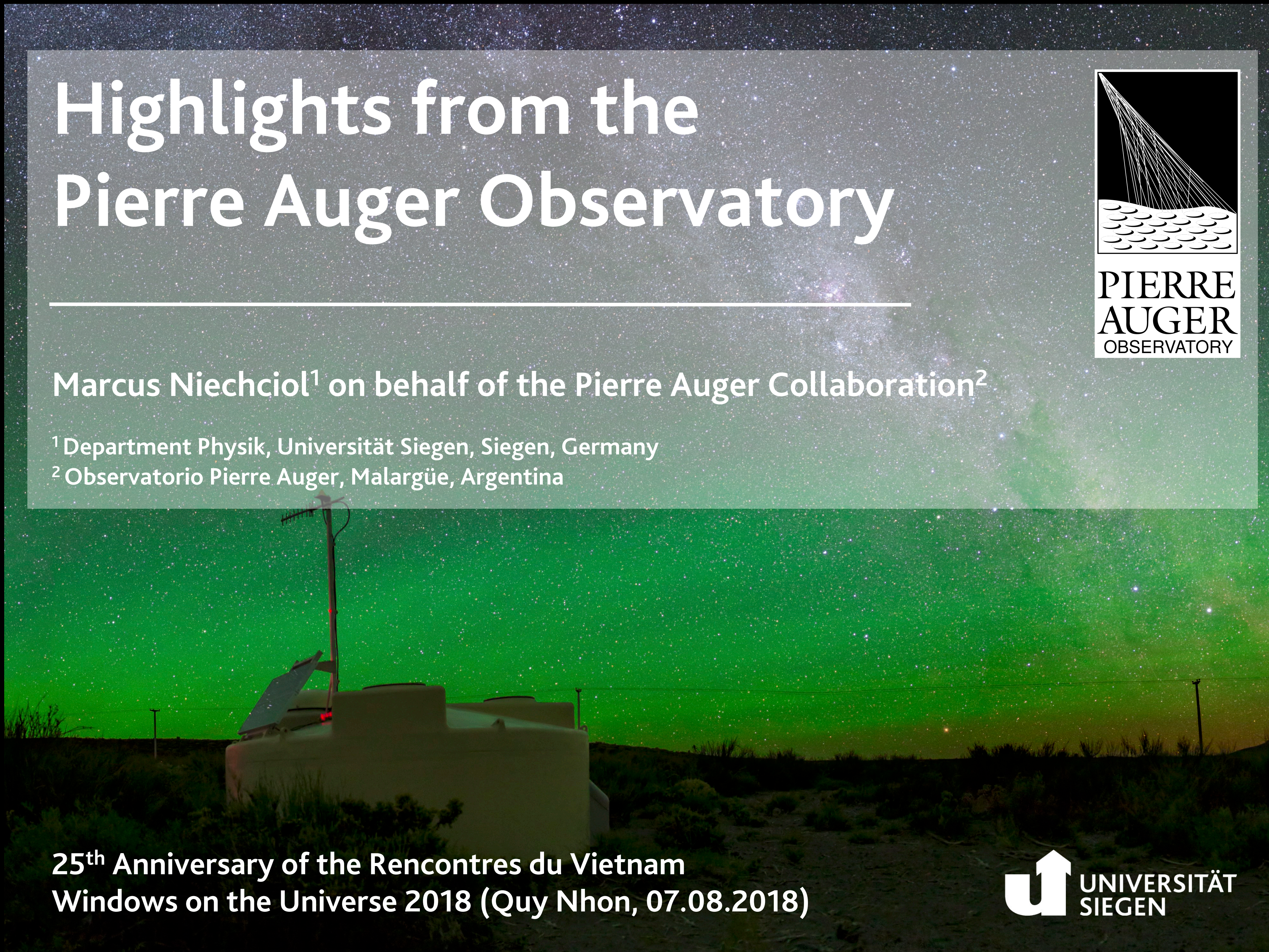
# Predicted SOGRO Sensitivity Curves




~1 week before September 14, 2015

Paik et al. 2016

Lee



# Highlights from the Pierre Auger Observatory

Marcus Niechciol[1] on behalf of the Pierre Auger Collaboration[2]

[1] Department Physik, Universität Siegen, Siegen, Germany
[2] Observatorio Pierre Auger, Malargüe, Argentina

PIERRE AUGER OBSERVATORY

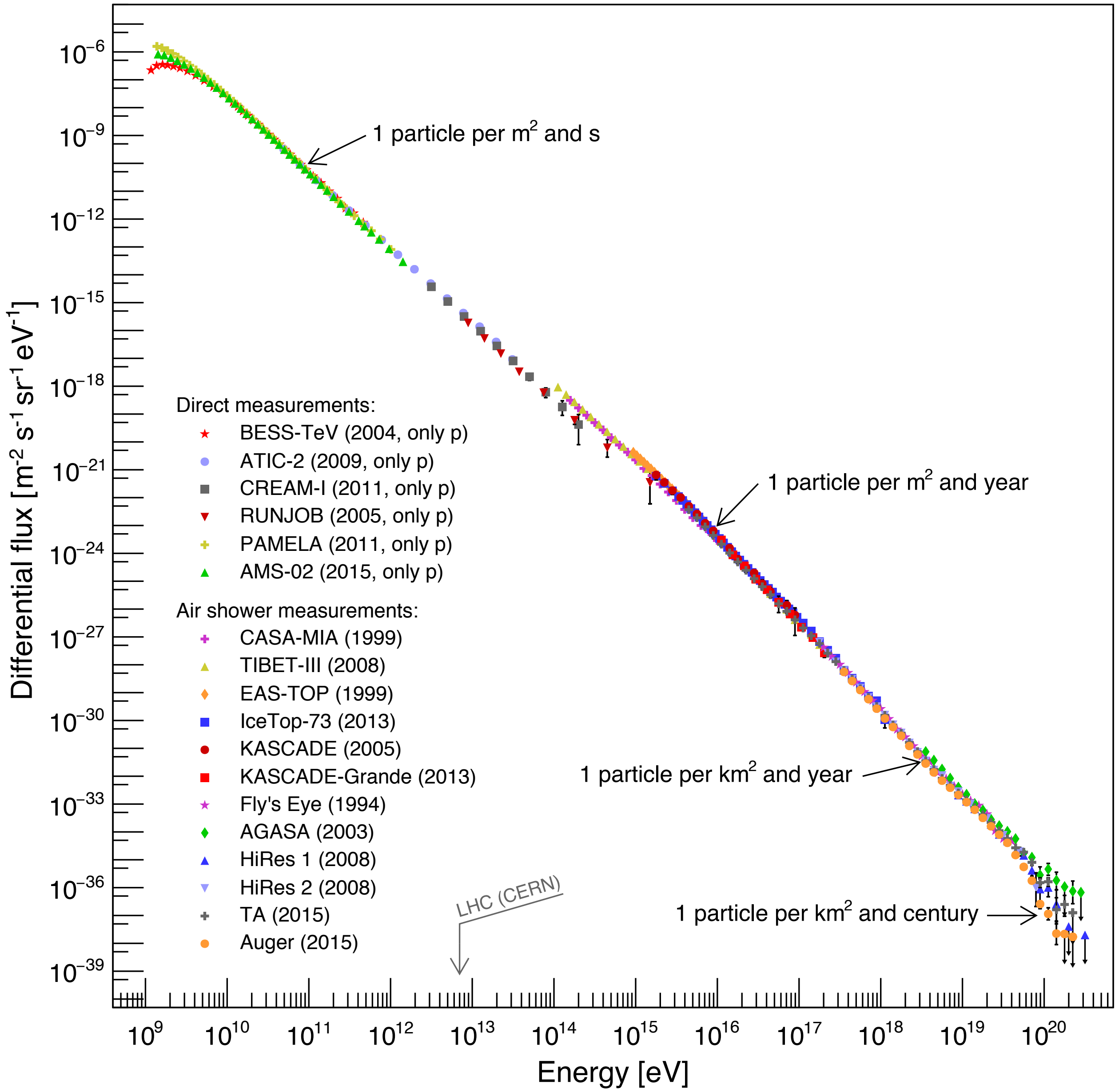
25th Anniversary of the Rencontres du Vietnam
Windows on the Universe 2018 (Quy Nhon, 07.08.2018)

UNIVERSITÄT SIEGEN

# Cosmic Ray Energies

## Cosmic rays

UNIVERSITÄT SIEGEN






**Energy spectrum covers ~12 orders of magnitude, 30 orders of magnitude in event rate**

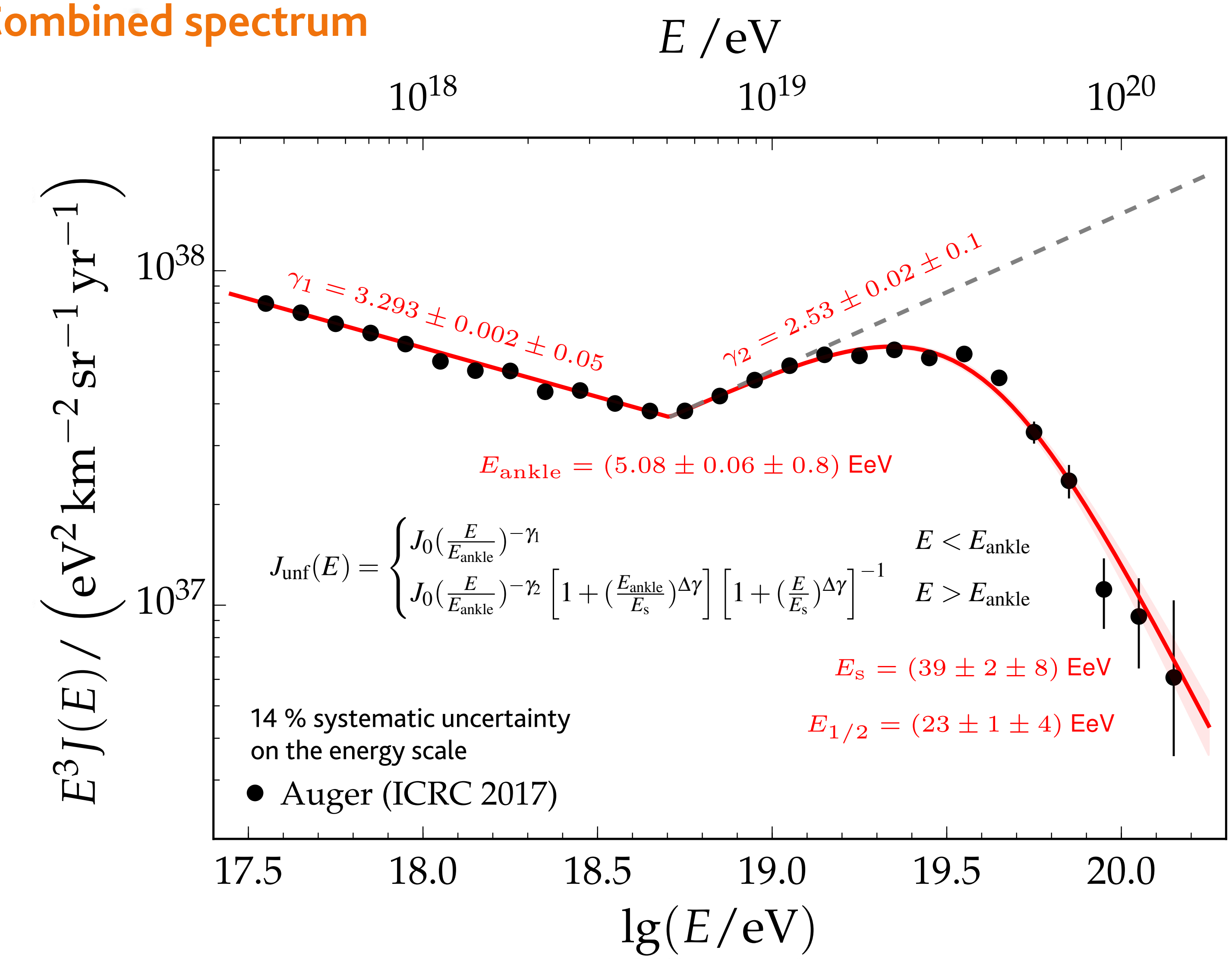
**Niechciol**

# Auger Pushing at high E

## Energy spectrum (III)

UNIVERSITÄT SIEGEN

- Combined spectrum




[F. Fenu for the Pierre Auger Collaboration, PoS(ICRC2017)486]



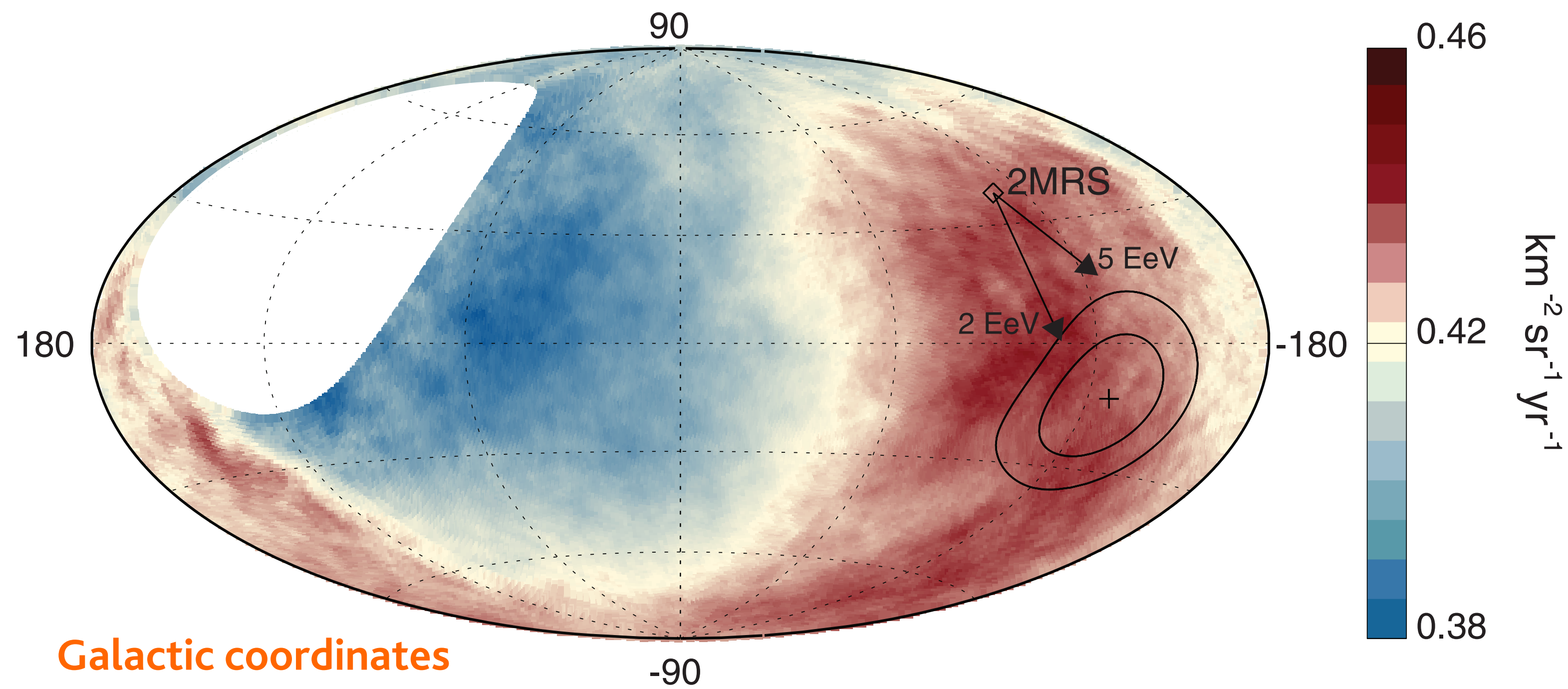
Niechciol

- Suppression of the flux of cosmic rays at the highest energies firmly established, …but the origin of the suppression not yet clear (propagation effect? maximum energy at the source? both?)

# Large-scale anisotropy (II)

- Reconstruction of the **dipole structure:**

| Energy (EeV) | Dipole component $d_z$ | Dipole component $d_\perp$ | Dipole amplitude $d$ | Dipole declination $\delta_d$ (°) | Dipole right ascension $\alpha_d$ (°) |
|---|---|---|---|---|---|
| ≥8 | −0.026 ± 0.015 | $0.060^{+0.011}_{-0.010}$ | $0.065^{+0.013}_{-0.009}$ | $-24^{+12}_{-13}$ | 100 ± 10 |




Galactic coordinates

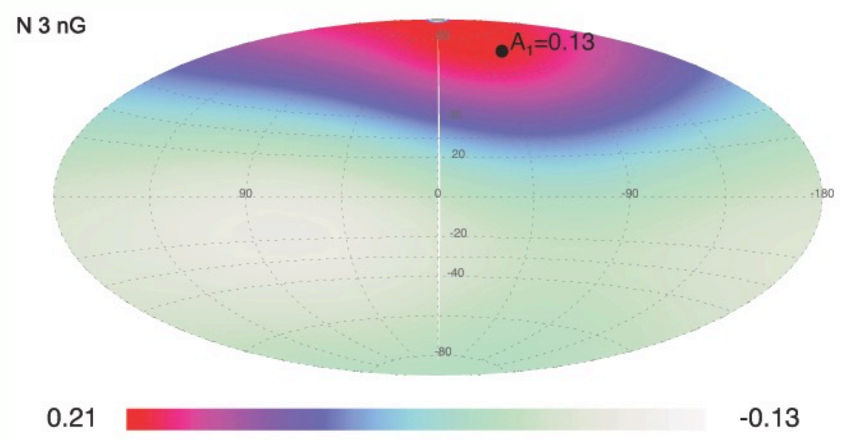
- Dipole structure is **expected** if cosmic rays diffuse to the Galaxy from sources distributed similar to **nearby galaxies** (take e.g. the **2MRS catalog**)
  - Deflection of the dipole pattern due to the **Galactic magnetic field**
- Strong indication for an **extragalactic origin** of UHECR above 8 EeV

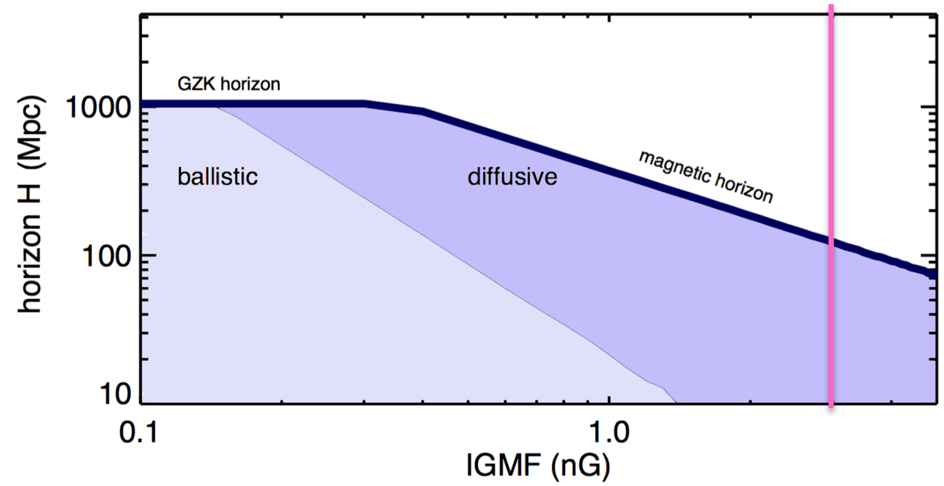
[The Pierre Auger Collaboration, Science 357 (2017) 1266]

# Large scale structure induced UHECR anisotropy

*Globus, Piran, Hoffman, Carlesi & Pomarède submitted*
**eprint arXiv:1808.02048**

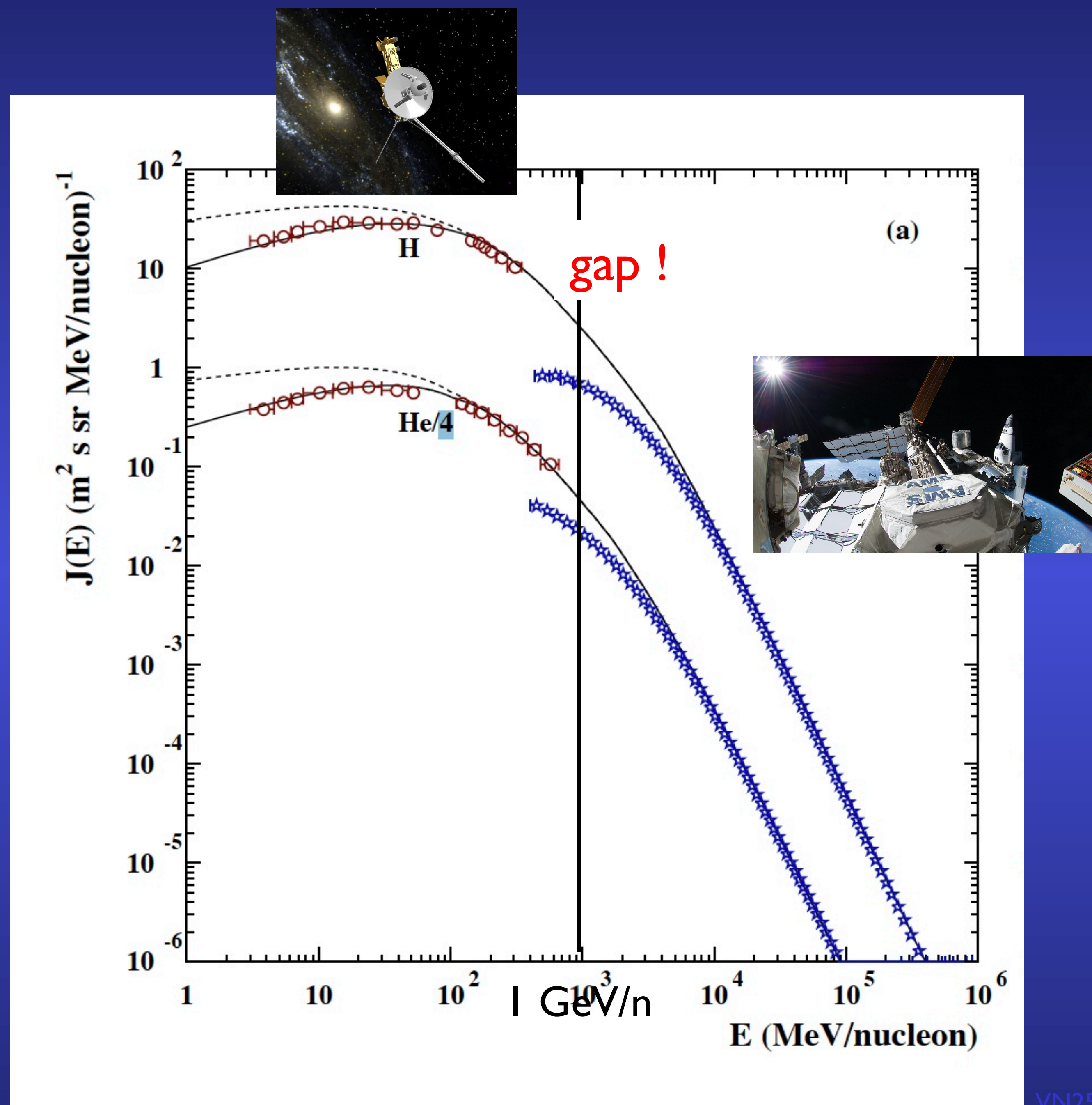
nitrogen @11.5 EeV






Globus


(a)
H
He/4
gap !
J(E) (m2 s sr MeV/nucleon)-1
E (MeV/nucleon)
1 GeV/n
10 2
10
1
10 -1
10 -2
10 -3
10 -4
10 -5
10 -6
1
10
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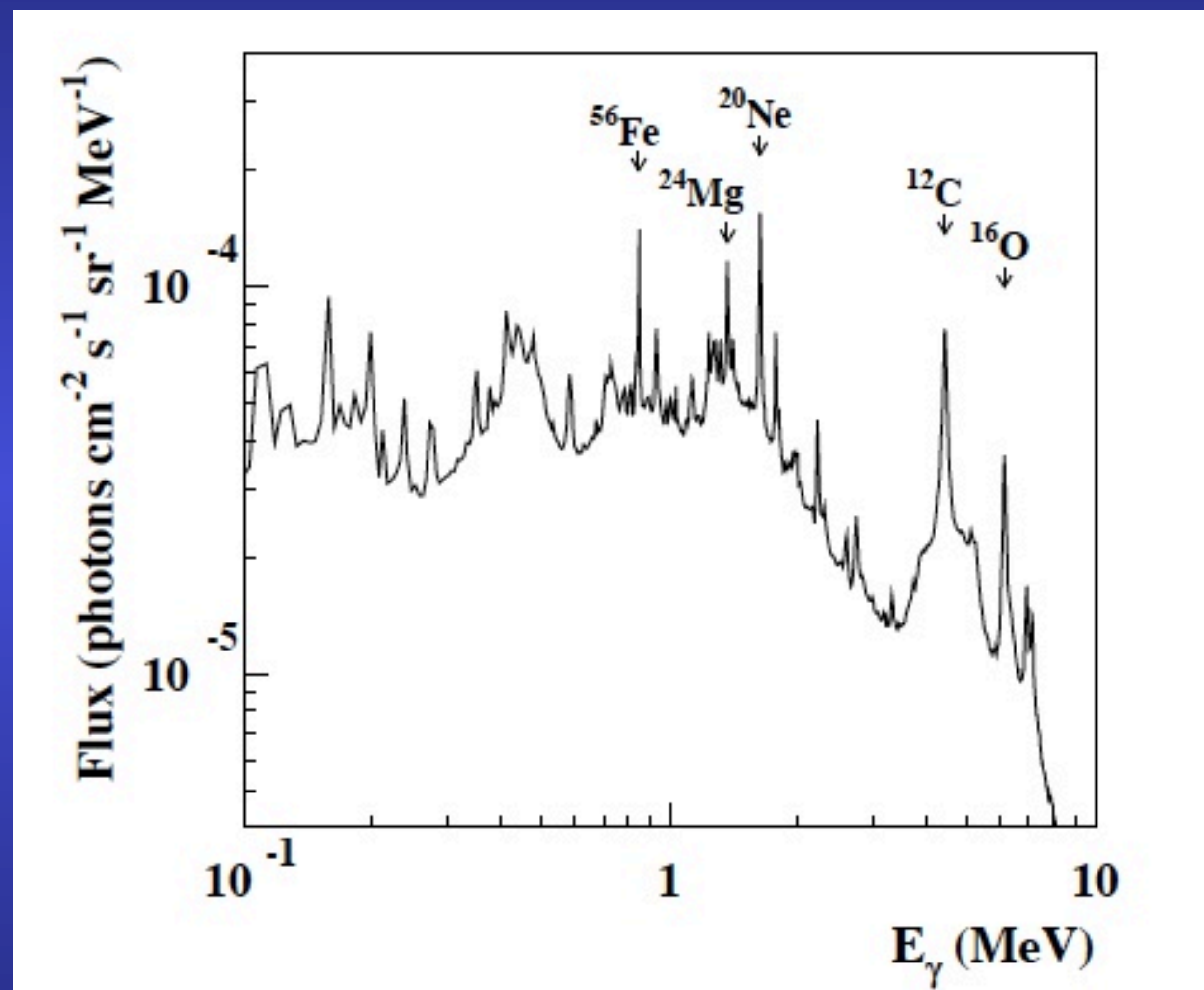
10 4
10 5
10 6



**Montmerle**

## *Predicted nuclear γ-lines towards the center of the Galaxy*




*(Tatischeff+ 2012)*



**Montmerle**

# THE MAGIC TELESCOPES

- At Roque de los Muchachos Observatory in La Palma (Spain)
- System of two Imaging Atmospheric Cherenkov Telescopes (IACTs)
- 17 m diameter reflector, fast imaging camera with field of view of 3.5 deg
- Sensitive to γ-rays between 50 GeV and 50 TeV
- Detectors (PMTs) sensitive to Cherenkov photons in the U-band (365 nm)



Hoang

# THE FRB STORY SO FAR: FRB121102 breakthrough

## A Repeating Fast Radio Burst

L. G. Spitler[1], P. Scholz[2], J. W. T. Hessel
J. M. Cordes[6], F. Crawford[9], J. Deneva[10]
R. Lynch[11,12], E. C. Madsen[2], M. A. M
I. H. Stairs[15,2], B. W. Stappers[16], J. van

Published online by *Nature* on 2016 Ma

## FRB 121102: Detection at 4 - 8 GHz band with Breakthrough Listen backend at Green Bank

ATel #10675; *Gajjar, Vishal (University of California, Berkeley, USA), Andrew P. V. Siemion (University of California, Berkeley, USA), David H. E. MacMahon (University of California, Berkeley, USA), Steve Croft (University of California, Berkeley, USA), Gregory Hellbourg (University of California, Berkeley, USA), Howard Isaacson (University of California, Berkeley, USA), J. Emilio Enriquez (University of California, Berkeley, USA), Danny C. Price (University of California, Berkeley, USA), Matthew Lebofsky (University of California, Berkeley, USA), David DeBoer (University of California, Berkeley, USA), Dan Werthimer (University of California, Berkeley, USA), Jack Hickish (University of California, Berkeley, USA), Casey Brinkman (University of Vermont, Burlington, USA), Shami Chatterjee (University of Cornell, Ithaca, USA), Scott Ransom (University of Virginia, Charlottesville, USA)*
on ***29 Aug 2017; 03:11 UT***
*Distributed as an Instant Email Notice Transients*
*Credential Certification: Steve Croft (scroft@astro.berkeley.edu)*

Subjects: Radio, Transient, Fast Radio Burst

Referred to by ATel #: 10693, 11376



On Saturday, August 26 at 13:51:44 UTC we initiated observations of the well-known repeating fast radio burst FRB 121102 [Spitler et al., Nature, 531, 7593 202-205, 2016] using the Breakthrough Listen Digital Backend with the C-band receiver at the Green Bank Telescope. We

## The direct localization of a fast radio burst and its host

S. Chatterjee[1], C. J. Law[2], R. S. Wharton[1], S. Burke-Spolaor[3,4,5], J. W. T. Hessels[6,7], G. C. Bower[8], J. M. Cordes[1], S. P. Tendulkar[9], C. G. Bassa[6], P. Demorest[3], B. J. Butler[3], A. Seymour[10], P. Scholz[11], M. W. Abruzzo[12], S. Bogdanov[13], V. M. Kaspi[9], A. Keimpema[14], T. J. W. Lazio[15], B. Marcote[14] M. A. McLaughlin[4,5], Z. Paragi[14], S. M. Ransom[16], M. Rupen[11], L. G. Spitler[17], & H. J. van Langevelde[14,18]

Published online by *Nature* on 4 Jan 2017. DOI: 10.1038/nature20797

[1]*Cornell Center for Astrophysics and Planetary Science and Department of Astronomy, Cornell University, Ithaca, NY 14853, USA*
[2]*Departme*
*94720, US*
[3]*National*
[4]*Departme*

## An extreme magneto-ionic environment associated with the fast radio burst source FRB 121102

D. Michilli[1,2,*], A. Seymour[3,*], J. W. T. Hessels[1,2,*], L. G. Spitler[4], V. Gajjar[5,6,7], A. M. Archibald[2,1], G. C. Bower[8], S. Chatterjee[9], J. M. Cordes[9], K. Gourdji[2], G. H. Heald[10], V. M. Kaspi[11], C. J. Law[12], C. Sobey[13,10], E. A. K. Adams[1,14], C. G. Bassa[1], S. Bogdanov[15], C. Brinkman[16], P. Demorest[17], F. Fernandez[3], G. Hellbourg[12], T. J. W. Lazio[18], R. S. Lynch[19,20], N. Maddox[1], B. Marcote[21], M. A. McLaughlin[22,20], Z. Paragi[21], S. M. Ransom[23], P. Scholz[24], A. P. V. Siemion[12,25,26], S. P. Tendulkar[11], P. Van Rooy[27], R. S. Wharton[4], D. Whitlow[3]

11 Jan 2018

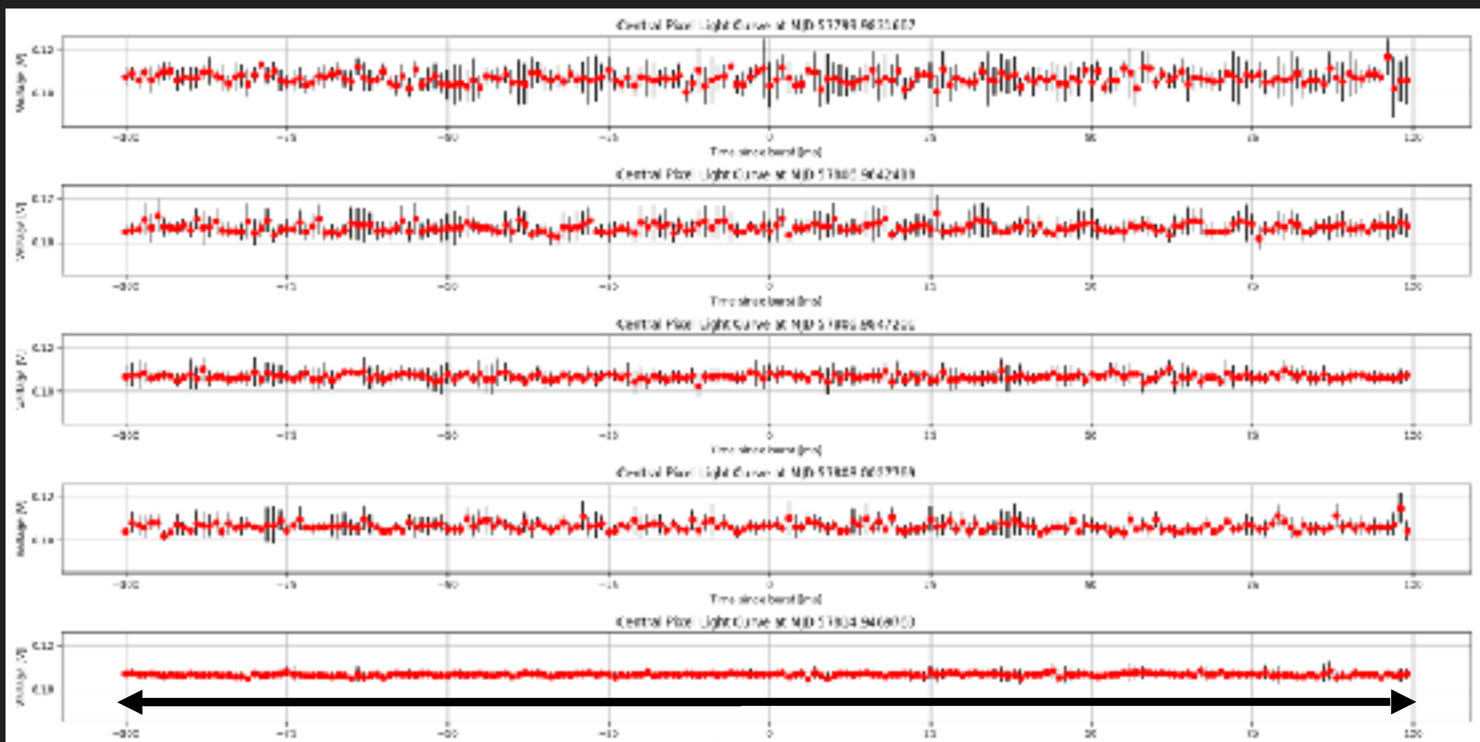
Published online by *Nature* on 10 Jan 2018. DOI: 10.1038/nature25149

[1]*ASTRON, Netherlands Institute for Radio Astronomy, Postbus 2, 7990 AA, Dwingeloo, The Netherlands*
[2]*Anton Pannekoek Institute for Astronomy, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands*

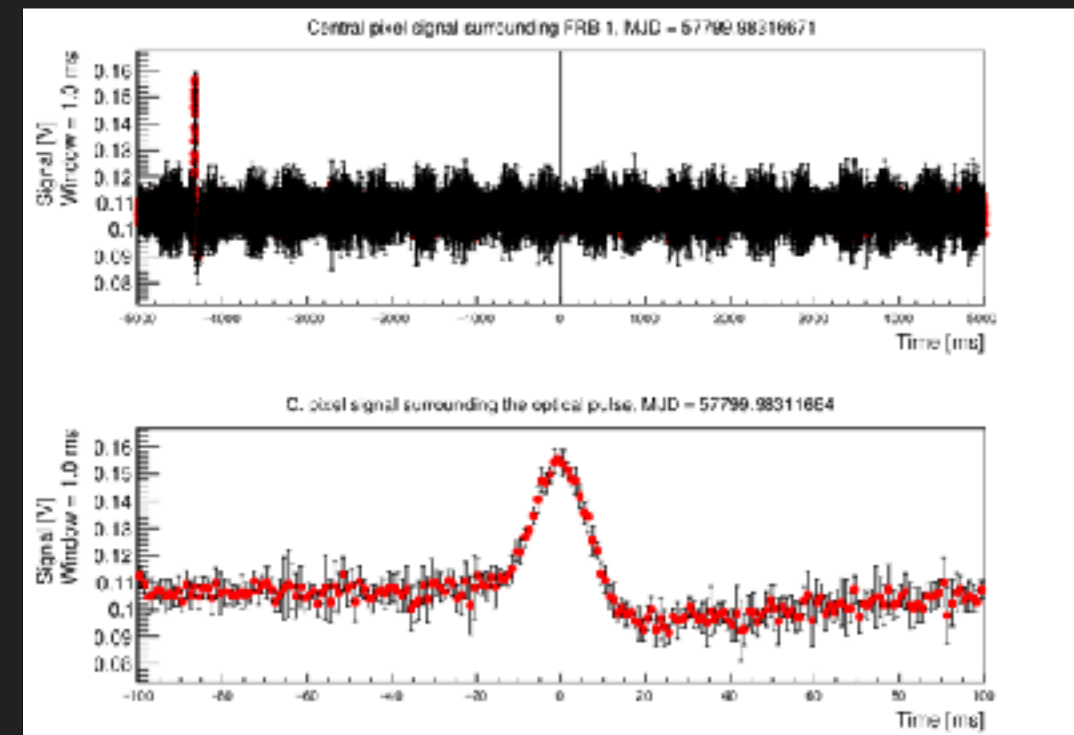


Hoang

# RESULTS: Optical



200ms

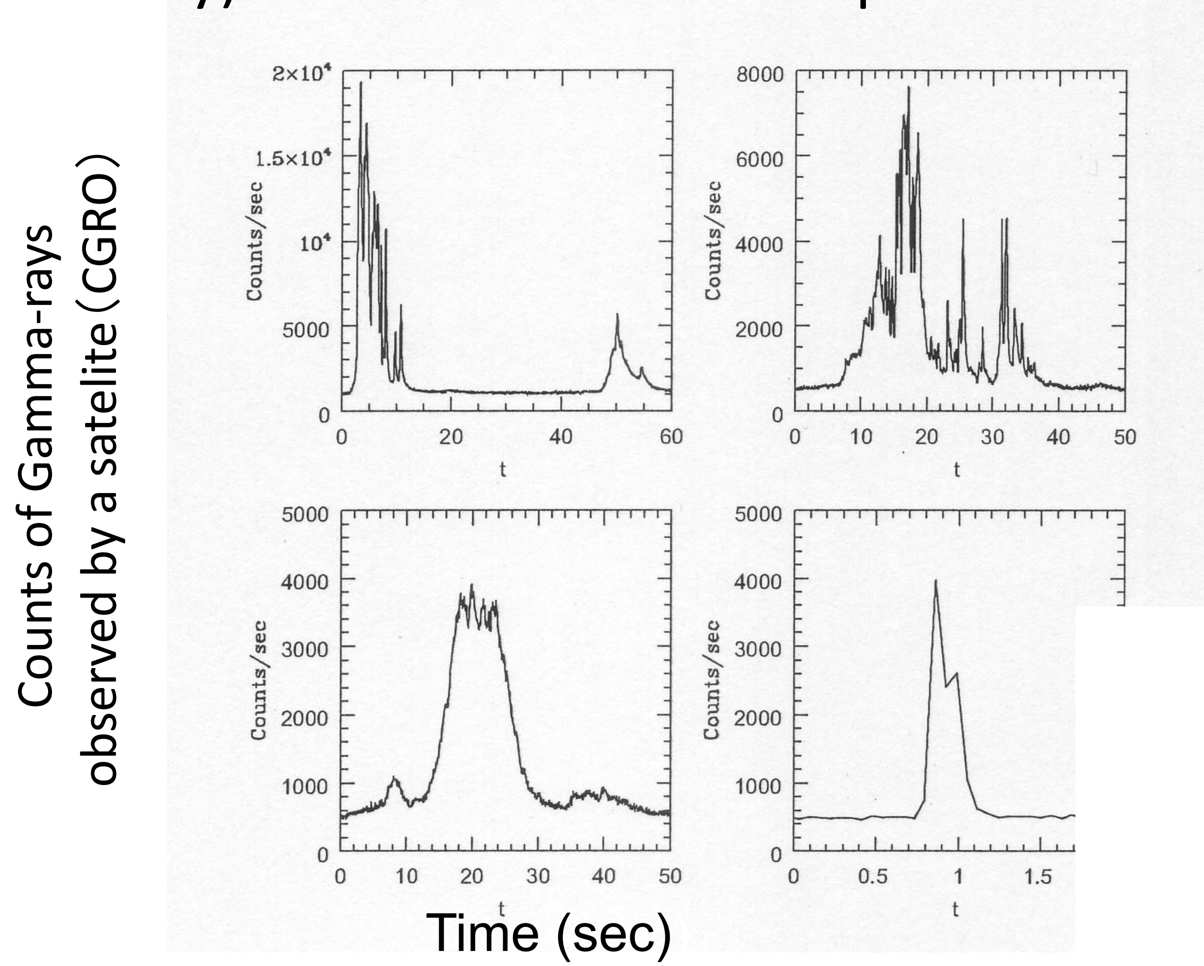



Credit: T. Hassan et al 2018

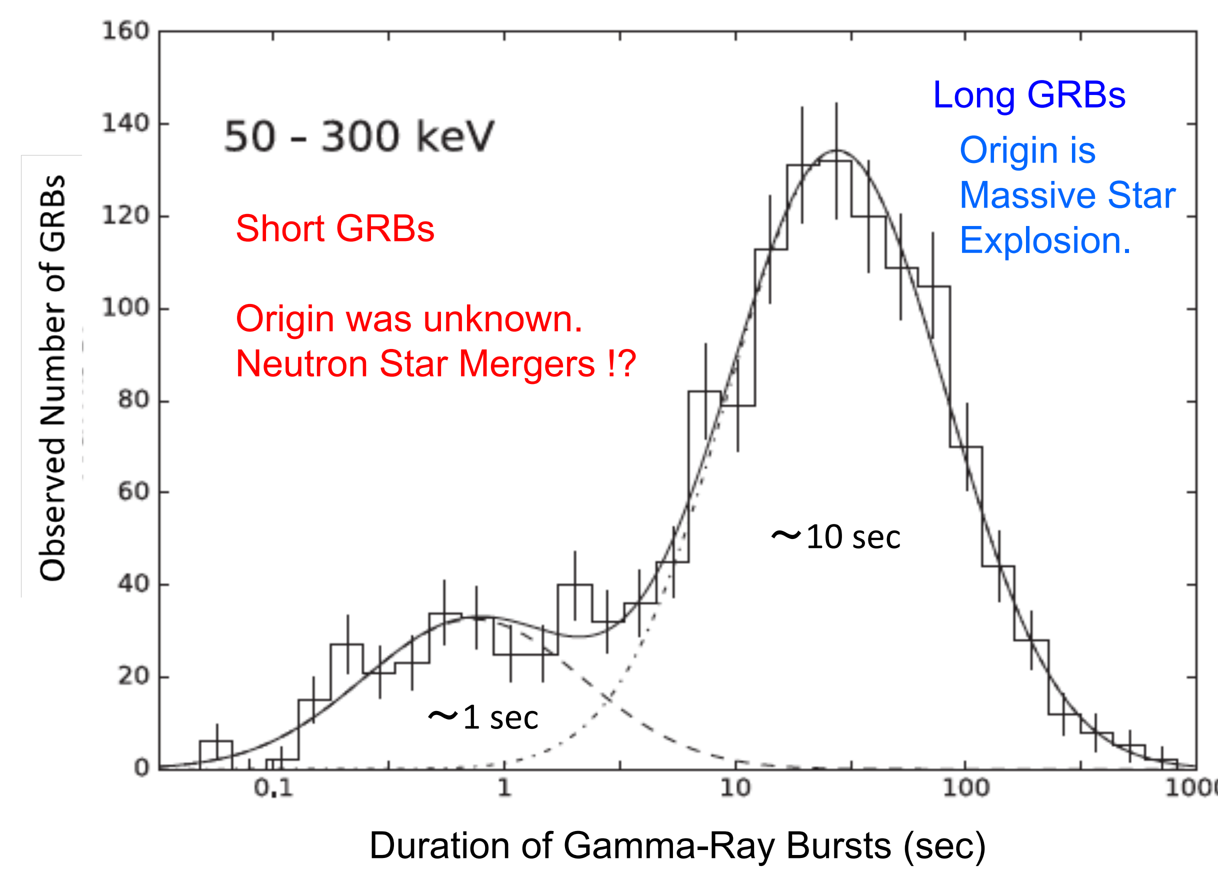
- No optical bursts detected 100 ms before & after the 5 FRBs
- During the first radio burst, there was 1 optical flash ~4 s before the radio burst
  - Most likely a background event due to meteor within FoV

# Gamma-Ray Bursts

## (Probably) The Most Powerful Explosion in the Universe

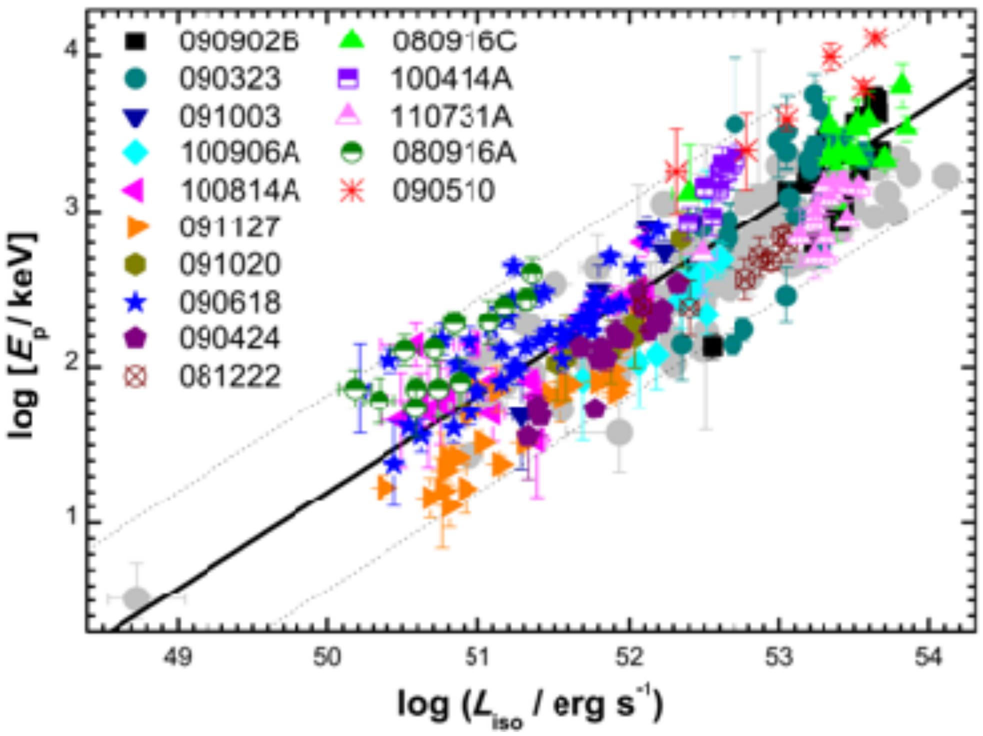



# Distribution of Duration of GRBs

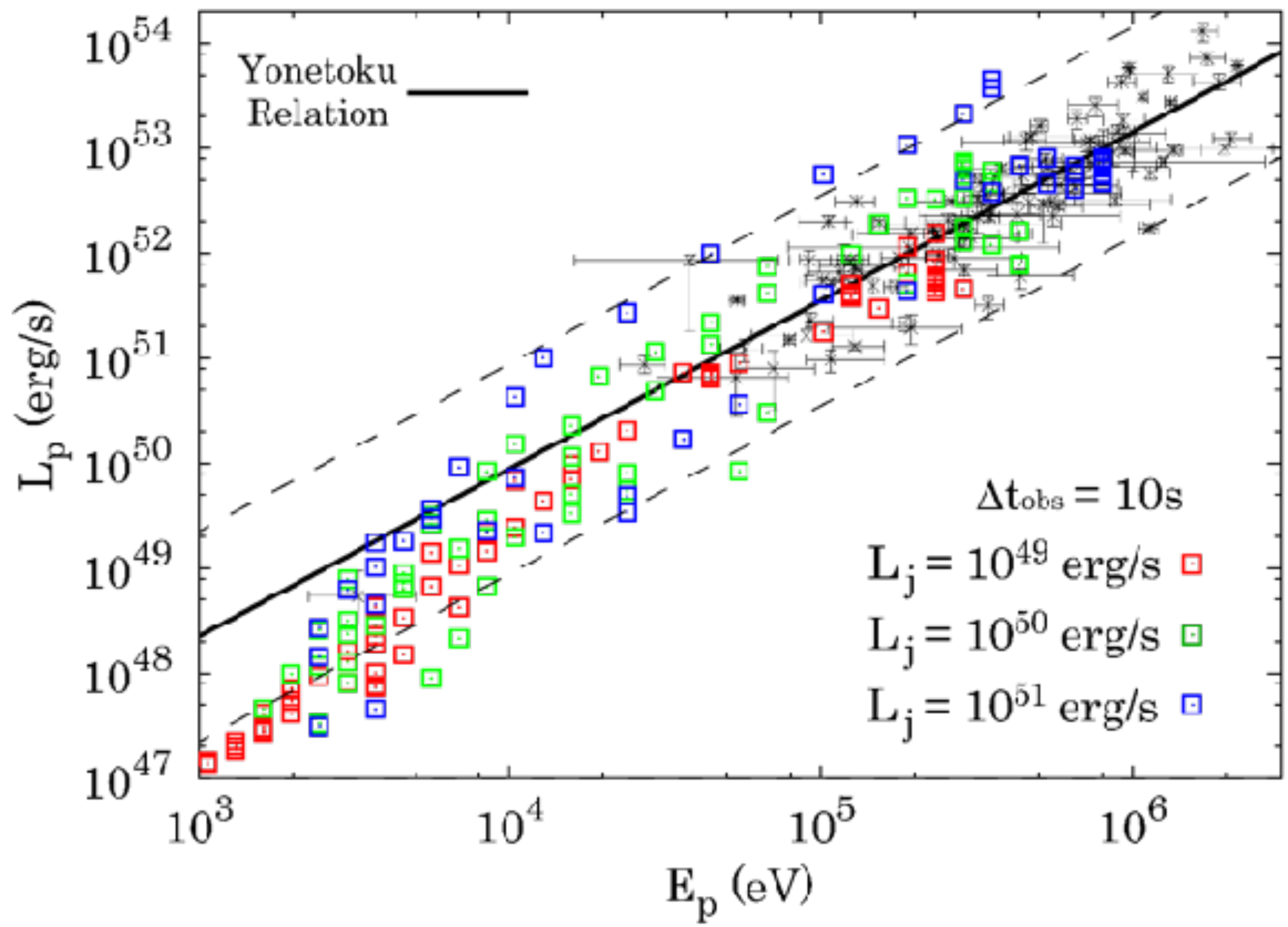



**Nagataki/Ito**

# Time resolved Yonetoku relation




Lu + 2012
15 GRBs with time resolved
Ep and redshift




Yonetoku Relation holds *regardless* of the time interval

**Nagataki/Ito**

# Remaining Main Differences between the CB and FB Models

| | CB | FB |
|---|---|---|
| Power Source: | jet of plasmoids (CBs) fired by MSP in SNeIc, n*n* mergers, n*→q* PT | jet fired by bh/magnetar in hypernovae and macronova |
| Jet Geometry: | discrete plasmoids (CBs) | conical flow/shells |
| Radiations: | | |
| *Prompt* $\gamma$ | *Inverse* Compton scattering of glory light by CB electrons | Synchrotron radiation from shell collisions/internal shocks |
| Afterglow | SR from Fermi Accelerated e's within the CBs | SR from Fermi Accelerated e's in the shocked ISM |
| HE $\gamma, \nu$ | SSC + hadronic meson prod. | SSC + photo meson prod. |
| ~~XRFs, LLGRBs~~ | ~~Ordinary GRBs viewed far-off axis~~ | ~~Different classes of GRBs~~ |

**Dar**

# Test #1 : Polarization

Dar

**Prompt Emission Mechanism** | **Afterglow Mechanism**

**CB**: ICS of glory light by jet electrons

$$\Pi \approx \frac{2\ {}^{2}\ {}^{2}_{0}}{1+\ {}^{4}\ {}^{4}_{0}} \sim 1 \ \text{if} \quad \approx \quad {}_{0}$$

**(Shaviv & Dar 1994)**

SR from Fermi accelerated swept in ISM electrons*

$$\Pi << 1$$

**(Dar 1998)**

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**FB**: SR from shocked jet

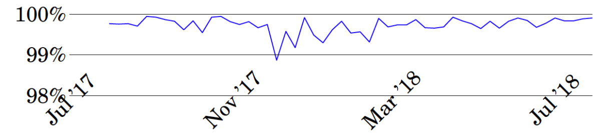
$$\Pi \ll 1$$

SR from shocked ISM

$$\Pi \ll 1$$

*Turbulent magnetic fields are required for shock acceleration of the HE e's emitting the SR.
All the a posteriori attempts to explain a large polarization of the prompt emission in the FB model (after measurements) cannot explain why almost all GRBs have large

Uptime




99.91%



# MISSION: SEARCH AND STUDY THE COSMIC ACCELERATORS

Resconi

*Credit: IceCube/NSF*

# ICECUBE-170922A: POINTING TO THE BLAZAR (TXS 0506+056)

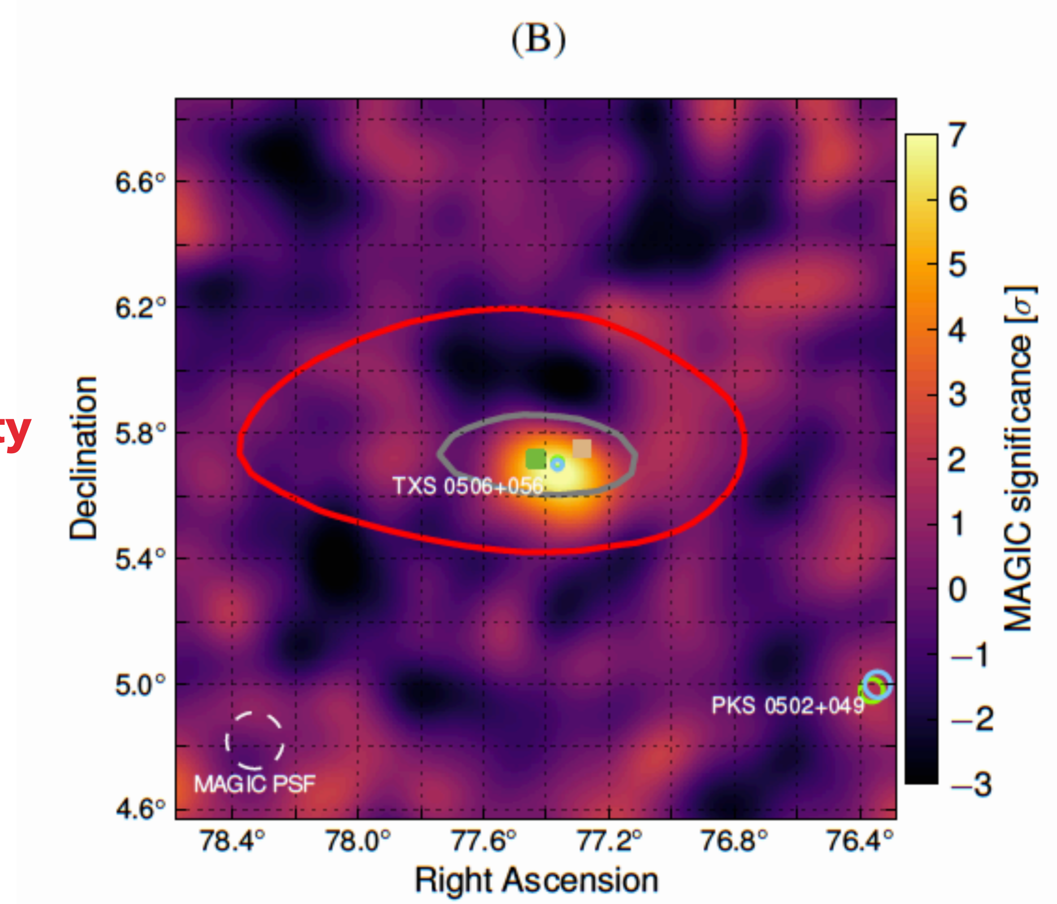
"Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A," The IceCube, Fermi-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S, INTEGRAL, Kanata, Kiso, Kapteyn, Liverpool telescope, Subaru, Swift/NuSTAR, VERITAS, and VLA/17B-403 teams. *Science* 361, 2018

Event occurred on the 22nd Sept 2017, 20:54:30 UTC
First notice sent **43s later**!

Revised coordinates sent 4 hours later

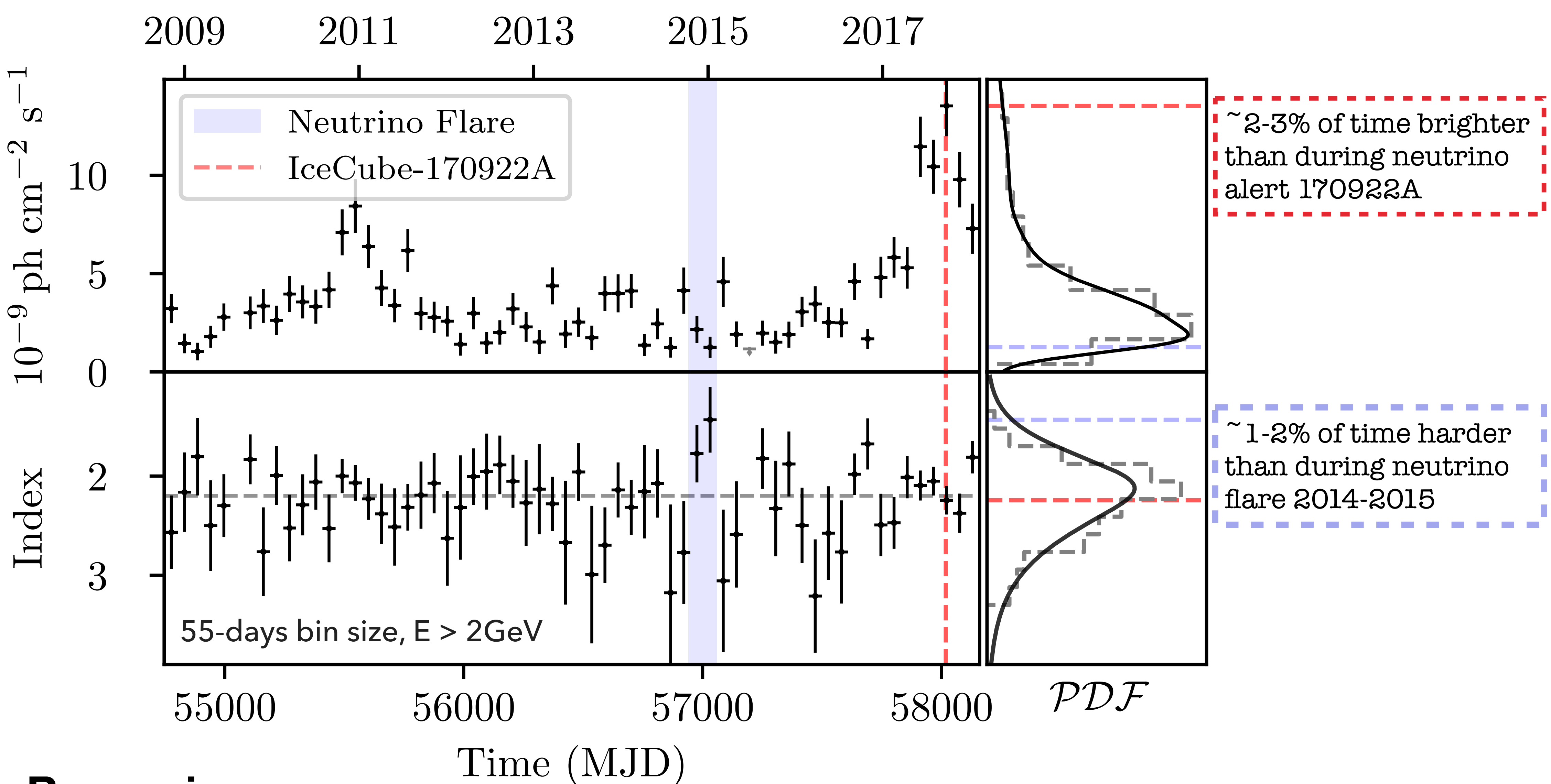
- Follow-up responses
  GCN 21917 - Integral - No detection [...]
- ATel 10791 - **Fermi - increased gamma-ray activity of TXS 0506+056** (RA 77.36 deg, Dec +5.69 deg)
- ATel 10817 – The First-time **detection of VHE gamma rays by MAGIC**

....and observations and reports by many more telescopes: AGILE, ASAS-SN, Kapteyn, Kanata, Kiso, Liverpool, Subaru, VERITAS, VLT




**Resconi**

# GAMMA-RAY LIGHT CURVES: TXS 0506+056




Resconi

# Cám ơn rất nhiều


**Wishing you another 25 years of successful conferences, and continued growth in physics and astronomy in Vietnam**

**And, of course, thank you for all the delicious food!**