



14 members from 11 countries

9 male,
5 female

- Eiichiro Komatsu



- Fabian Schmidt (W2)



- Chris Byrohl (PhD)
- Laura Herold (PhD)
- Leila Mirzaghali (PhD)
- Minh Nguyen (PhD)

- Alex Barreira (PD)
- Linda Blot (PD)
- Giovanni Cabass (PD)
- Elisa Ferreira (PD)
- Kaloian Lozanov (PD)
- Azadeh Maleknejad (PD)
- Ira Wolfson (PD)
- Samuel Young (PD)

14 members from 11 countries

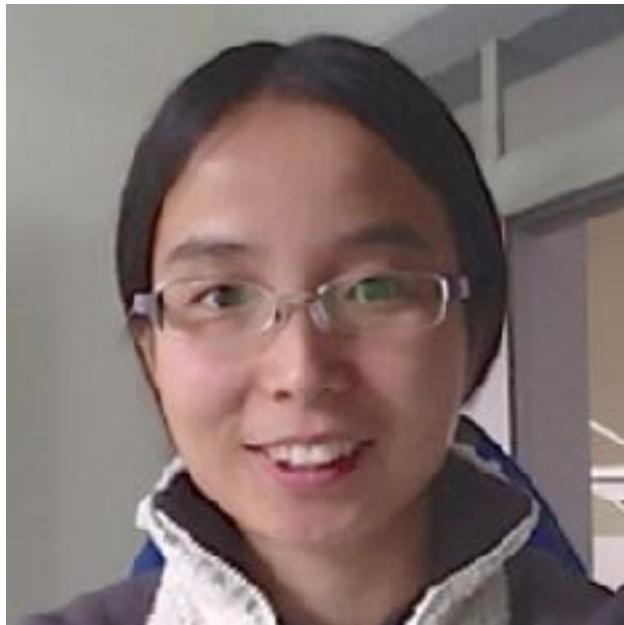
9 male,
5 female

Brazil (1), Bulgaria (1), France (0.5),
Germany (3), Iran (2), Israel (1),
Italy (1.5), Japan (1), Portugal (1),
UK (1), Vietnam (1)

- Laura Herold (PhD)
- Leila Mirzaghali (PhD)
- Minh Nguyen (PhD)
- Azadeh Maleknejad (PD)
- Ira Wolfson (PD)
- Samuel Young (PD)

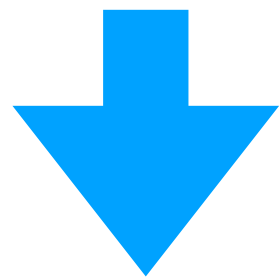
Since the 2016 Fachbeirat:

- Three postdocs went to faculty positions:



Xun Shi (2012–2018)

Physics of Galaxy Clusters

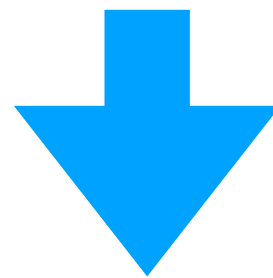


**Associate Professor,
Yunnan University**



Shun Saito (2016–2018)

Large-scale Structure

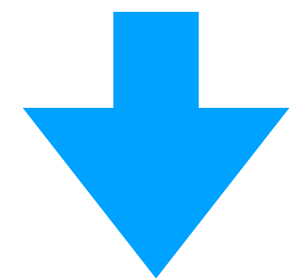


**Assistant Professor,
Missouri Univ. of S&T**



Marcello Musso (2015–2018)

Large-scale Structure



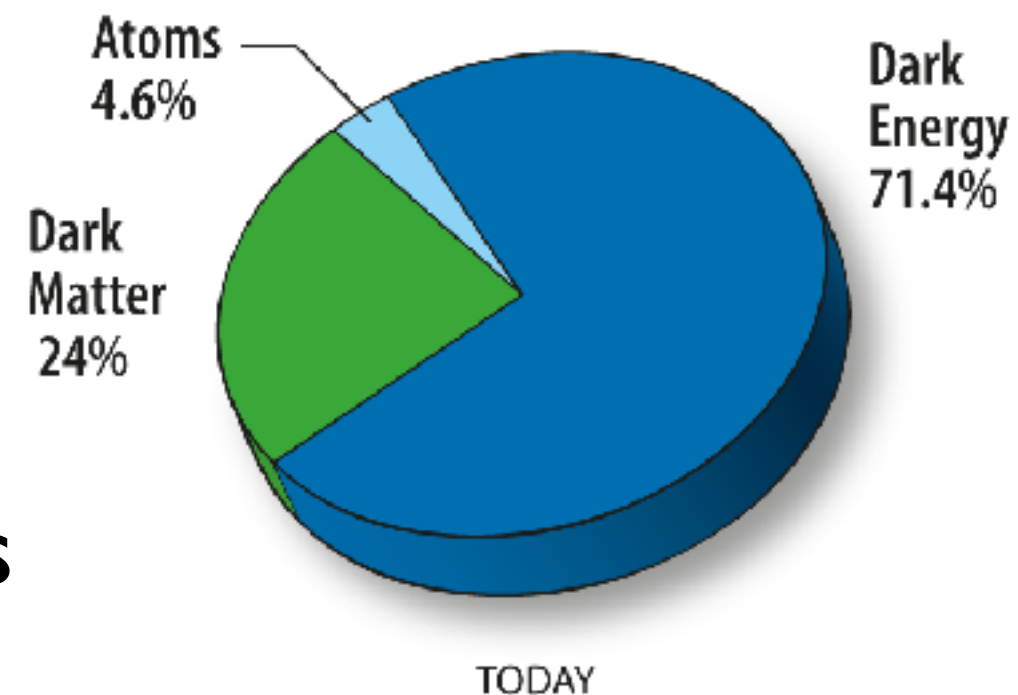
**Faculty Member,
ICTP, Rwanda**

Important Note:

- In this presentation, I do not include the achievements of Fabian Schmidt's ERC group
- See his presentation during the W2 interview for his achievements

Four Big Questions in Cosmology

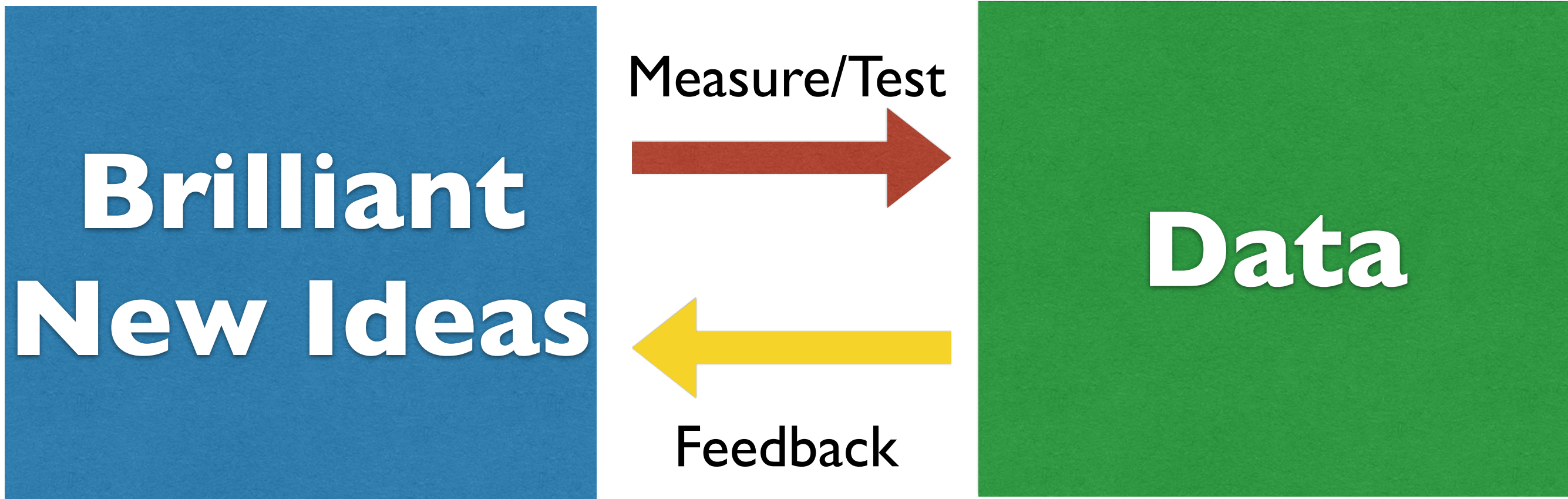
- **How did the Universe begin?**
[What is the physics of inflation?]
- **What is the origin of the cosmic acceleration?** [What is the nature of dark energy?]
- **What is the nature of dark matter?**
- **What is the mass of neutrinos?**



We use both **theory** and **observational data** to make progress

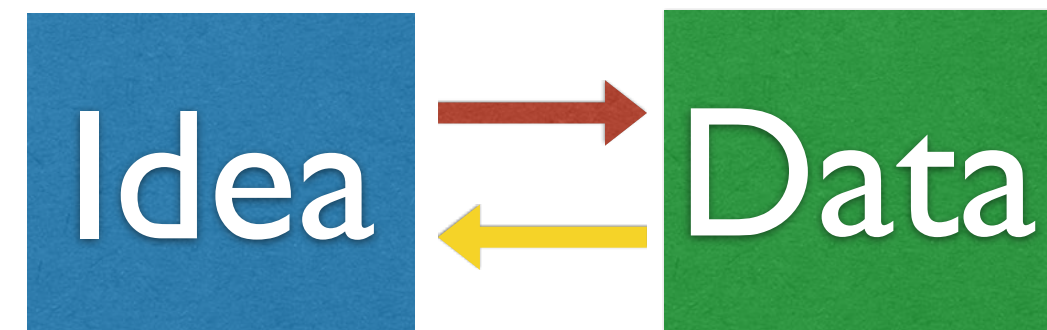
**And, do
whatever we
think are
interesting at
times**

Basic Routine



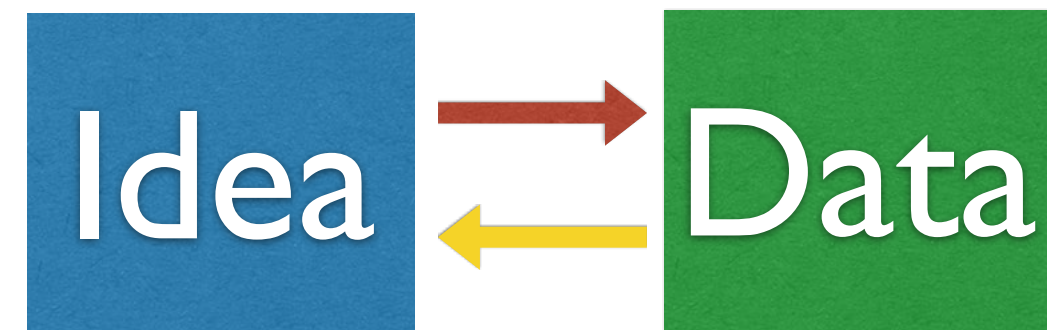
Research Style

1. Come up with new ideas (new tests; new methods; new observables), which will help make progress on the four questions
2. Write papers
3. Apply these ideas to extract new information from data; or collect new data if necessary
4. Write papers
5. Go back to #1



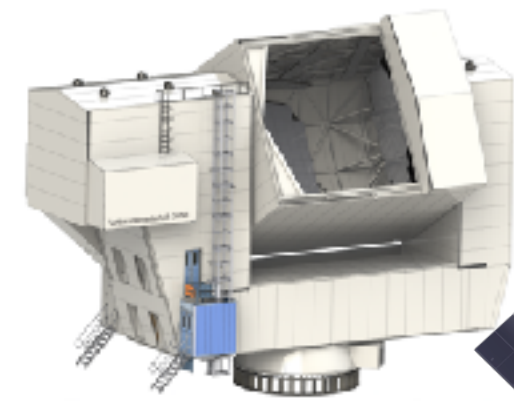
A Typical Thesis Structure

- Chapter 1: Introduction
- Chapter 2: Brilliant New Idea
- Chapter 3: Methodology and Tests
- Chapter 4: Application to Real Data
- Chapter 5: Exciting New Results
- Chapter 6: Conclusions

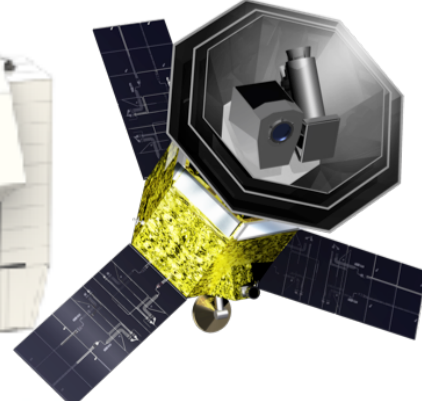


Main Tools

CCAT-prime

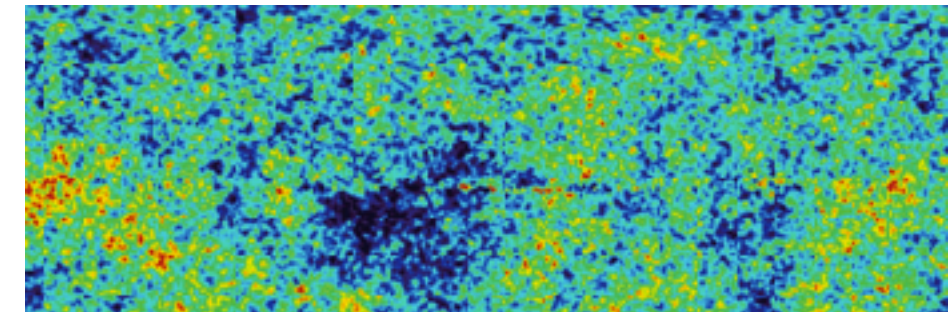


LiteBIRD



- **Cosmic Microwave Background (CMB)**

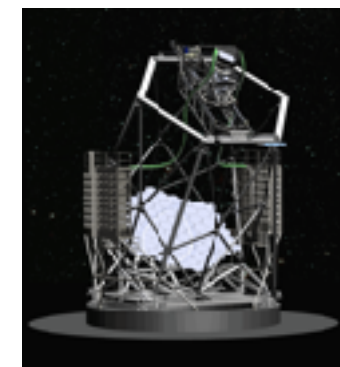
- Early universe probe: **Inflation**



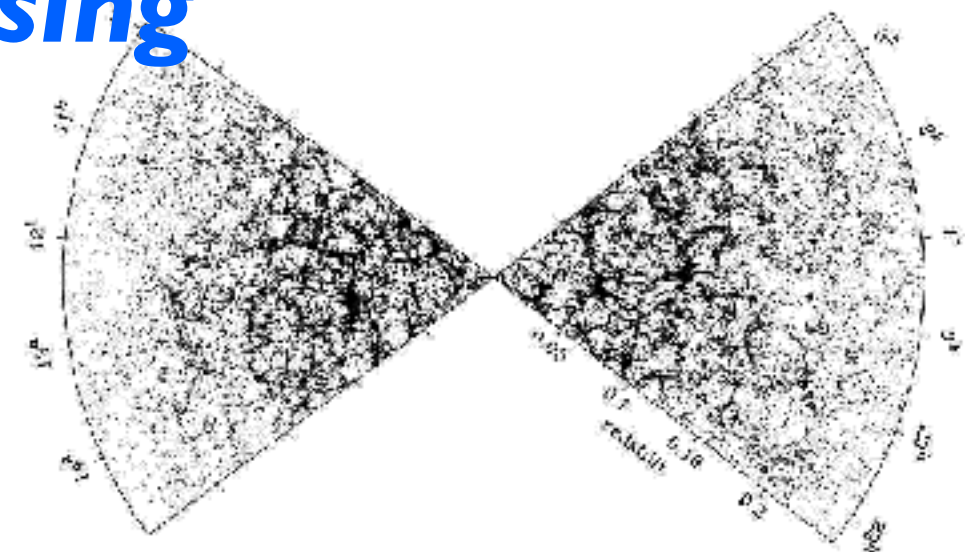
- **Large-scale structure (LSS): distribution of matter, galaxies, galaxy clusters, and strong lensing**

- Probing the late-time universe: **dark energy** and **mass of neutrinos**

HETDEX



PFS



Main Research Activities

Theory

- Early Universe
- Structure formation

Simulation

- CMB
- Structure formation

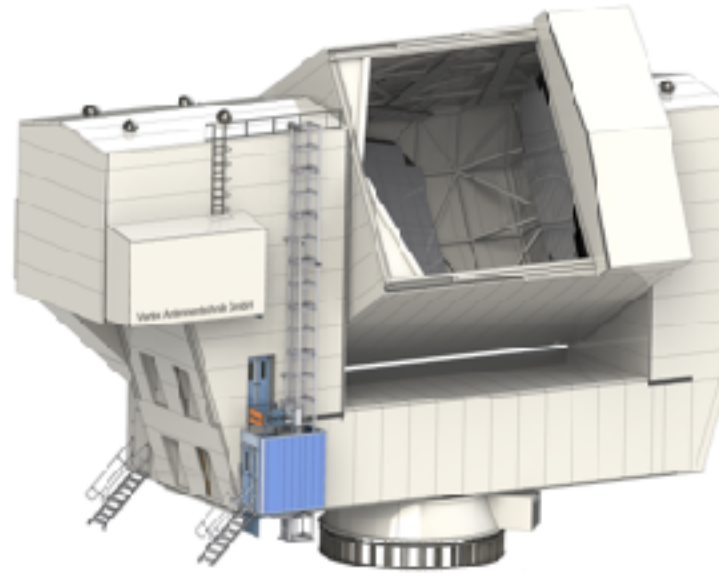
Data Analysis

- CMB
- Galaxy surveys

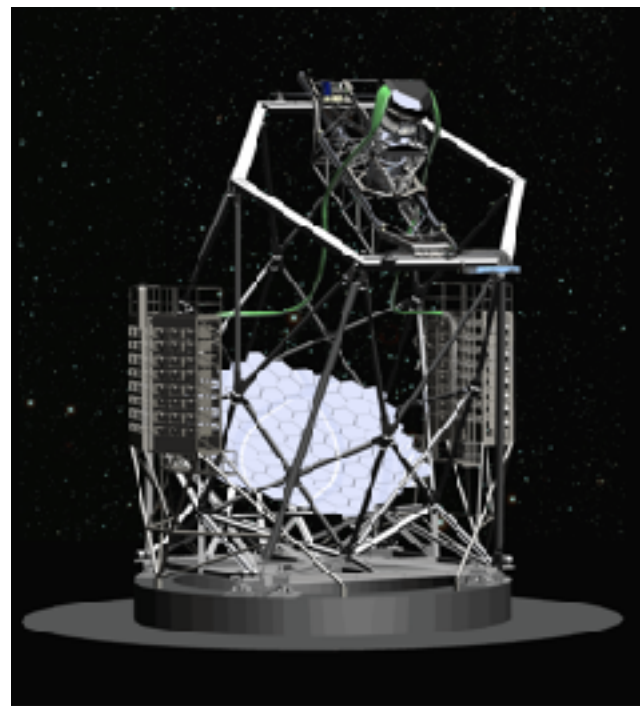
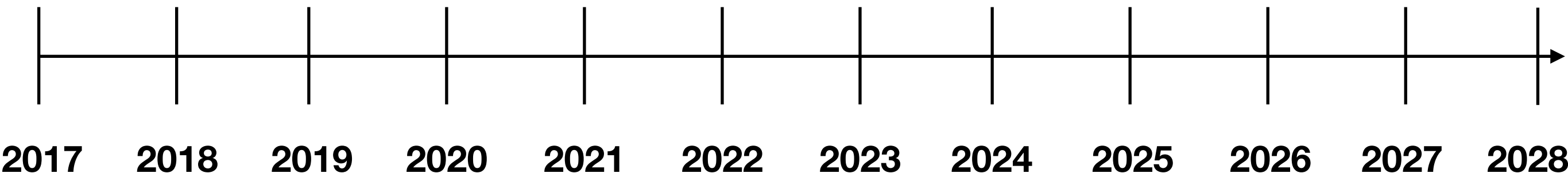
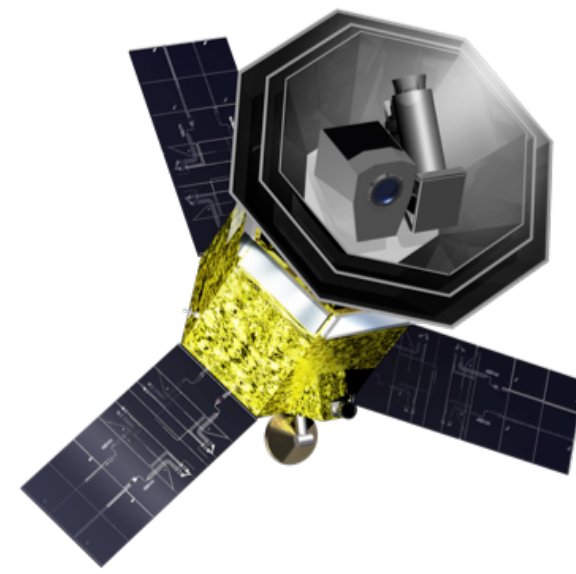
**Data available
to our group**

**CMB:
Early Universe
Probe**

**CCAT-prime
[2021–]**



**LiteBIRD
[2028–]**



**HETDEX
[2017–2023]**



**PFS
[2022–]**

**LSS:
Late Universe
Probe**

Three recommendations from the 2016 Fachbeirat

5.14: CMB

using Planck to constrain exotic early-universe models. It is also impressive to see Komatsu taking an energetic leadership role in future CMB missions, LiteBIRD and COrE+. To secure continued MPA leadership in this area, it is probably important that one of these missions be funded. In the near term, however, leadership in this field will probably pass to the USA with its ground-based collaborative stage-IV initiative. It would be much to the MPA's advantage if they were able to find some way of joining this work.

2.1 Directors

scientific productivity of his group. Looking ahead, we hope that he may raise his ambitions still further and explore innovative, bold ideas that may have wide and long-term repercussions. The personnel in his division, from students to postdocs, feel well

Three recommendations from the 2016 Fachbeirat

5.14: CMB

using Planck
Komatsu et al.
COrE+. To
one of these

**May 21, 2019: LiteBIRD has been selected
by JAXA. The launch date is 2028**

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Three recommendations from the 2016 Fachbeirat

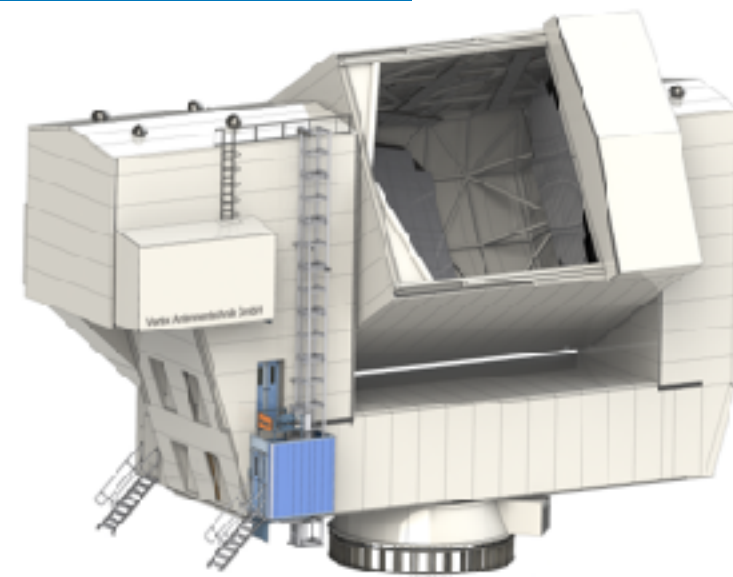
5.14: CMB

May 21, 2019: LiteBIRD has been selected by JAXA. The launch date is 2028

MPA joined the CCAT-prime telescope project in Chile (first light 2021). This will be the first CMB S-4 class observatory

2.1 Directors

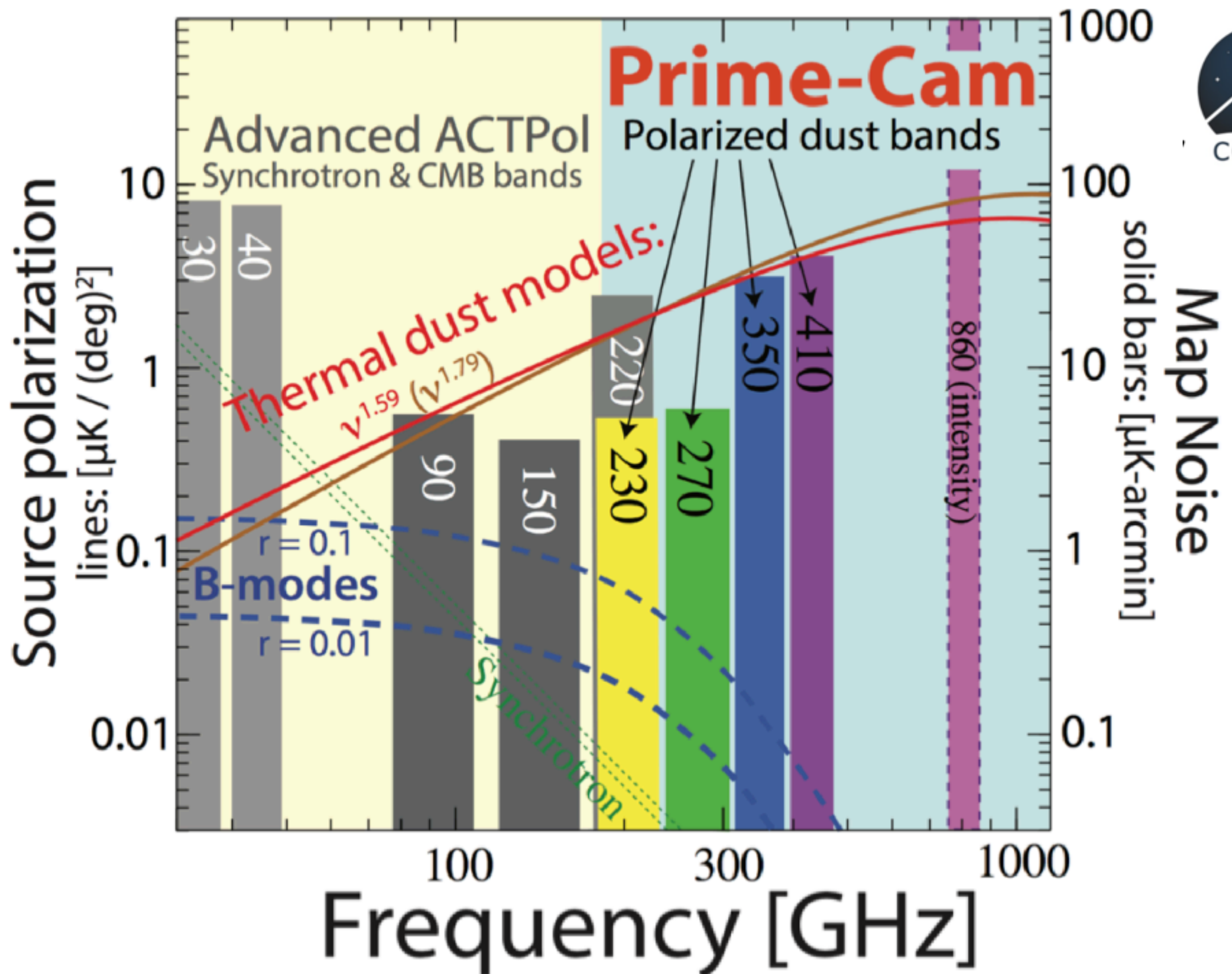
scientific productivity of his group. Looking ahead, we hope to have even more ambitious still further and explore innovative, bold ideas that have long-term repercussions. The personnel in his division, from students



Where is CCAT-p?

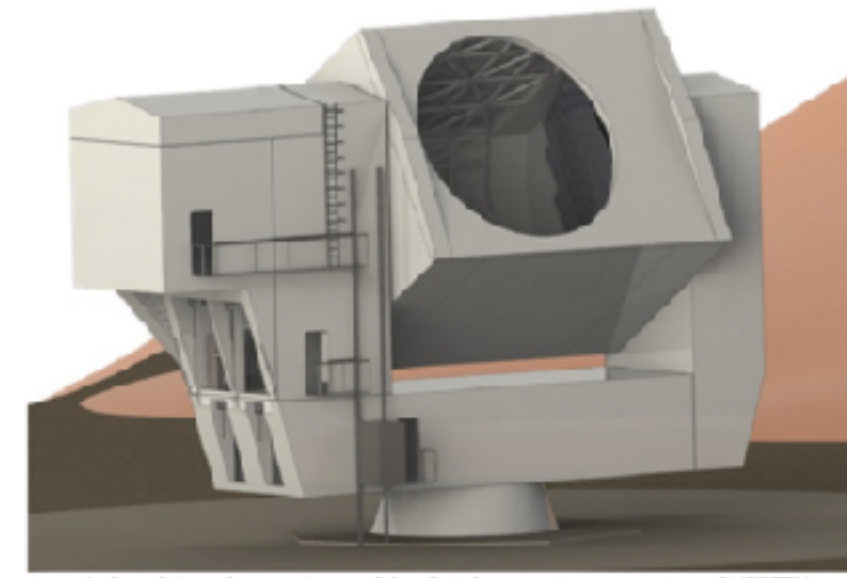
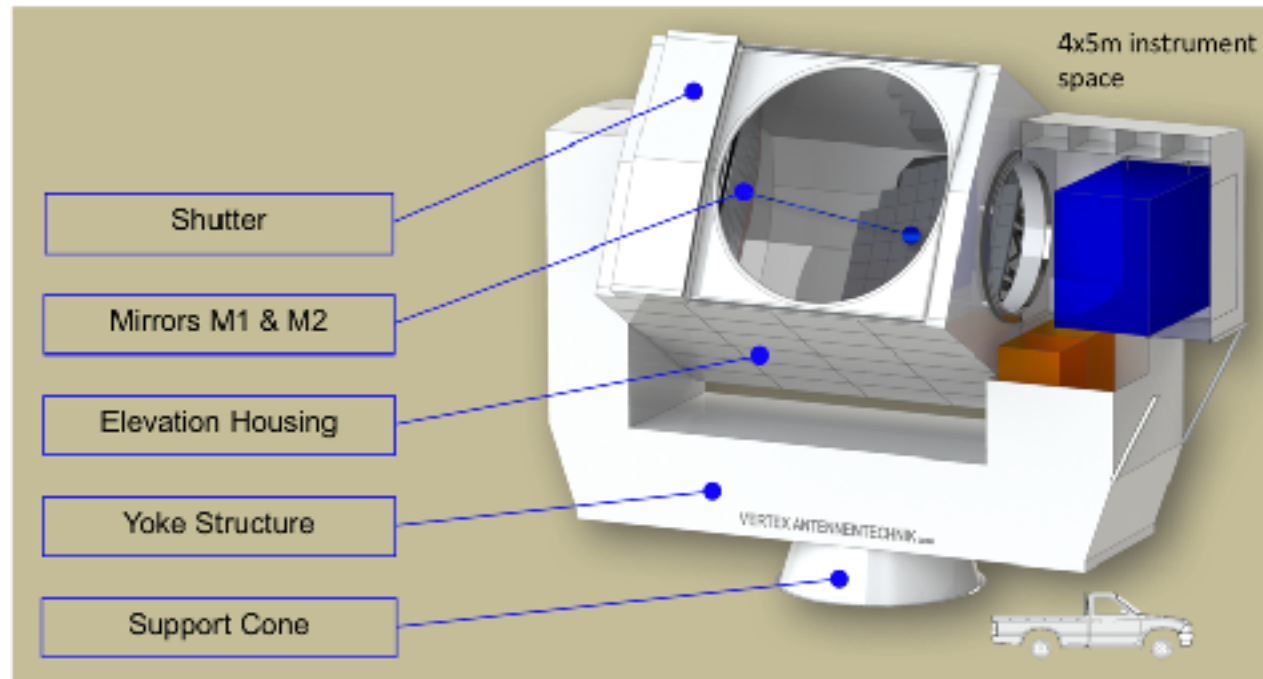
Cerro Chajnantor at 5600 m w/ TAO





CCAT-prime

designed and built by Vertex Antennentechnik GmbH, Duisburg



A rendering of the unique and powerful radio telescope. Image courtesy of VERTEX ANTENNENTECHNIK.

Simons Observatory (USA)

in collaboration

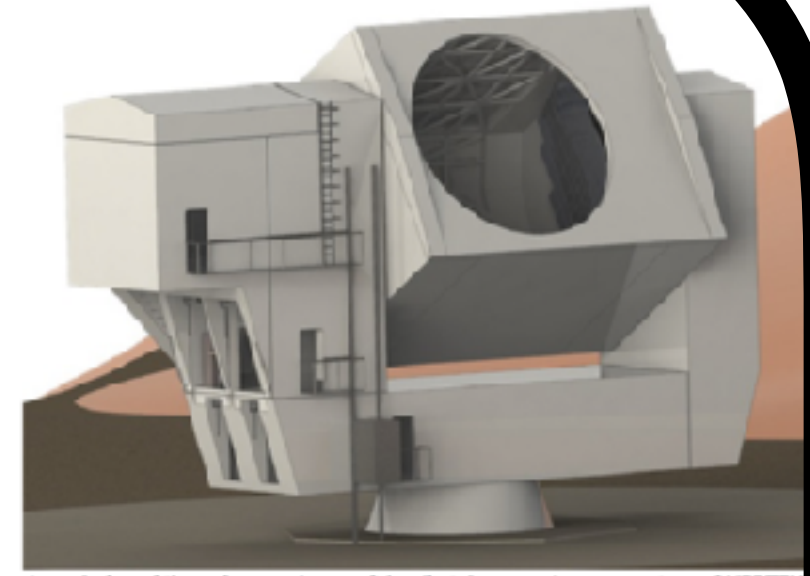
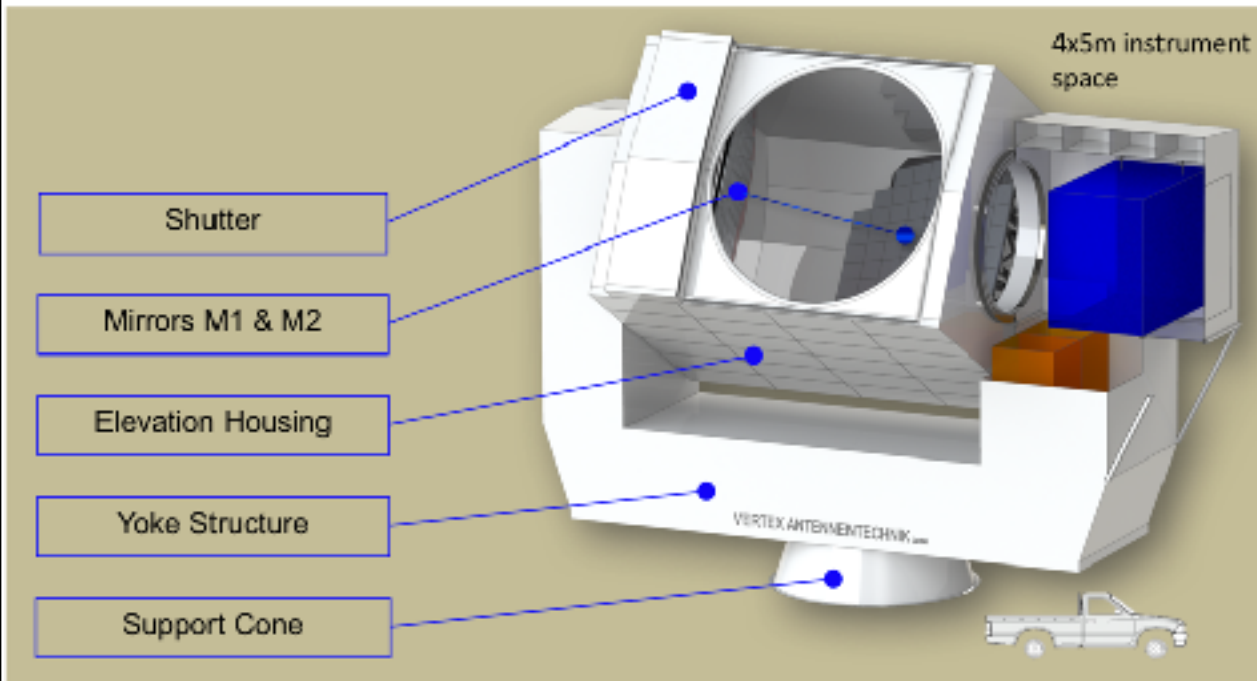


South Pole?

This could be “CMB-S4”

CCAT-prime

designed and built by Vertex Antennentechnik GmbH, Duisburg



A rendering of the unique and powerful radio telescope. Image courtesy of VERTEX ANTENNENTECHNIK.

**Simons Observatory
(USA)**

in collaboration

**Together with our European colleagues, we are
shaping European contributions to CMB S-4.**

**I am one of the German representatives
[another is Joe Mohr at LMU]**



South Pole?

Three recommendations from the 2016 Fachbeirat

5.14: CMB

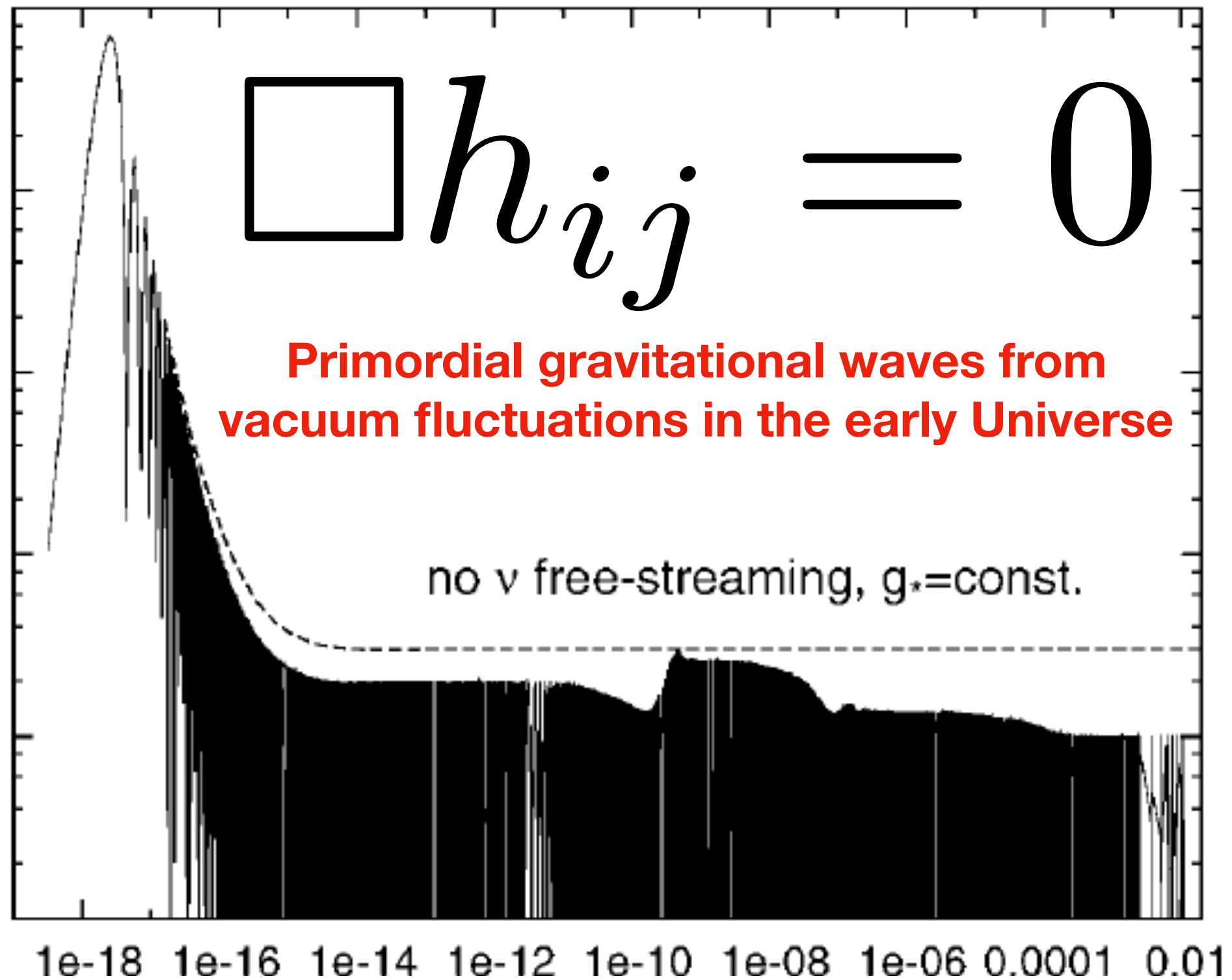
using Planck to constrain exotic early-universe models. It is also impressive to see Komatsu taking an energetic leadership role in future CMB missions, LiteBIRD and COrE+. To secure continued MPA leadership in this area, it is probably important that one of these missions be funded. In the near term, however, leadership in this field will probably pass to the USA with its ground-based collaborative stage-IV initiative. It would be much to the MPA's advantage if they were able to find some way of joining this work.

2.1 Directors

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Challenging the paradigm

Present-day energy density
spectrum of primordial
gravitational waves



Frequency of gravitational waves [Hz]

Are GWs from vacuum fluctuation in spacetime, or from sources?

$$\square h_{ij} = -16\pi G \pi_{ij}$$

- **Homogeneous solution:** “GWs from vacuum fluctuation”
- **Inhomogeneous solution:** “GWs from sources”

Are GWs from vacuum fluctuation in spacetime, or from sources?

$$\square h_{ij} = -16\pi G \pi_{ij}$$

- **Homogeneous solution:** “GWs from vacuum fluctuation”
- **Inhomogeneous solution:** “GWs from sources”
 - Scalar and vector fields cannot source tensor fluctuations at linear order (possible at non-linear level)
 - **SU(2) gauge field can!**

Aniket Agrawal**Kaloian Lozanov****Azadeh Maleknejad****Leila Mirzaghali**

Large tensor non-Gaussianity from axion-gauge field dynamics

Aniket Agrawal (Stanford U., Phys. Dept.), Tomohiro Fujita (Tokyo U., IPMU & Tokyo U., RESCEU), Eiichiro Komatsu (Tokyo U., ICRR). Jul 10, 2017. 6 pp.

Published in **Phys.Rev. D97 (2018) no.10, 103526**

DOI: [10.1103/PhysRevD.97.103526](https://doi.org/10.1103/PhysRevD.97.103526)

e-Print: [arXiv:1707.03023](https://arxiv.org/abs/1707.03023) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

[Detailed record](#) - [Cited by 46 records](#)

Tensor Non-Gaussianity from Axion-Gauge-Fields Dynamics : Parameter Search

Aniket Agrawal (Garching, Max Planck Inst.), Tomohiro Fujita (Kyoto U.), Eiichiro Komatsu (Tokyo U., IPMU). Feb 26, 2018. 34 pp.

Published in **JCAP 1806 (2018) 027**

DOI: [10.1088/1475-7516/2018/06/027](https://doi.org/10.1088/1475-7516/2018/06/027)

e-Print: [arXiv:1802.09284](https://arxiv.org/abs/1802.09284) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#); [Link to Fulltext](#)

[Detailed record](#) - [Cited by 23 records](#)

Finding the chiral gravitational wave background of an axion-SU(2) inflationary model using CMB observations and laser interferometers

Ben Thorne (Tokyo U., IPMU & Oxford U.), Tomohiro Fujita (Stanford U., ITP & Stanford U., Phys. Dept. & Kyoto U.), Masashi Hazumi (Tokyo U., IPMU & KEK, Tsukuba & Kanagawa, Graduate U. & JAXA, Sagami-hara), Nobuhiko Katayama (Tokyo U., IPMU), Eiichiro Komatsu (Tokyo U., IPMU & Garching, Max Planck Inst.), Maresuke Shiraishi (Tokyo U., IPMU & Kagawa U.). Jul 11, 2017. 18 pp.

Published in **Phys.Rev. D97 (2018) no.4, 043506**

DOI: [10.1103/PhysRevD.97.043506](https://doi.org/10.1103/PhysRevD.97.043506)

e-Print: [arXiv:1707.03240](https://arxiv.org/abs/1707.03240) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

[Detailed record](#) - [Cited by 33 records](#)

Particle Production by gauge field [like the Schwinger Effect, but by SU(2)]

Schwinger Effect by an $SU(2)$ Gauge Field during Inflation

Kaloian D. Lozanov, Azadeh Maleknejad (Garching, Max Planck Inst.), Eiichiro Komatsu (Garching, Max Planck Inst. & Tokyo U., IPMU). May 23, 2018. 31 pp.

Published in **JHEP 1902 (2019) 041**

DOI: [10.1007/JHEP02\(2019\)041](https://doi.org/10.1007/JHEP02(2019)041)

e-Print: [arXiv:1805.09318](https://arxiv.org/abs/1805.09318) [hep-th] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#); [Link to Article from SCOAP3](#)

[Detailed record](#) - [Cited by 15 records](#)

Production and Backreaction of Spin-2 Particles of $SU(2)$ Gauge Field during Inflation

A. Maleknejad (Garching, Max Planck Inst.), E. Komatsu (Garching, Max Planck Inst. & Tokyo U., IPMU). Aug 27, 2018. 46 pp.

Published in **JHEP 1905 (2019) 174**

DOI: [10.1007/JHEP05\(2019\)174](https://doi.org/10.1007/JHEP05(2019)174)

e-Print: [arXiv:1808.09076](https://arxiv.org/abs/1808.09076) [hep-ph] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#); [Link to Article from SCOAP3](#)

[Detailed record](#) - [Cited by 11 records](#)

Production and Backreaction of Fermions from Axion- $SU(2)$ Gauge Fields during Inflation

Leila Mirzaghali, Azadeh Maleknejad, Kaloian D. Lozanov (Garching, Max Planck Inst.). May 22, 2019.

e-Print: [arXiv:1905.09258](https://arxiv.org/abs/1905.09258) [hep-th] | [PDF](#)

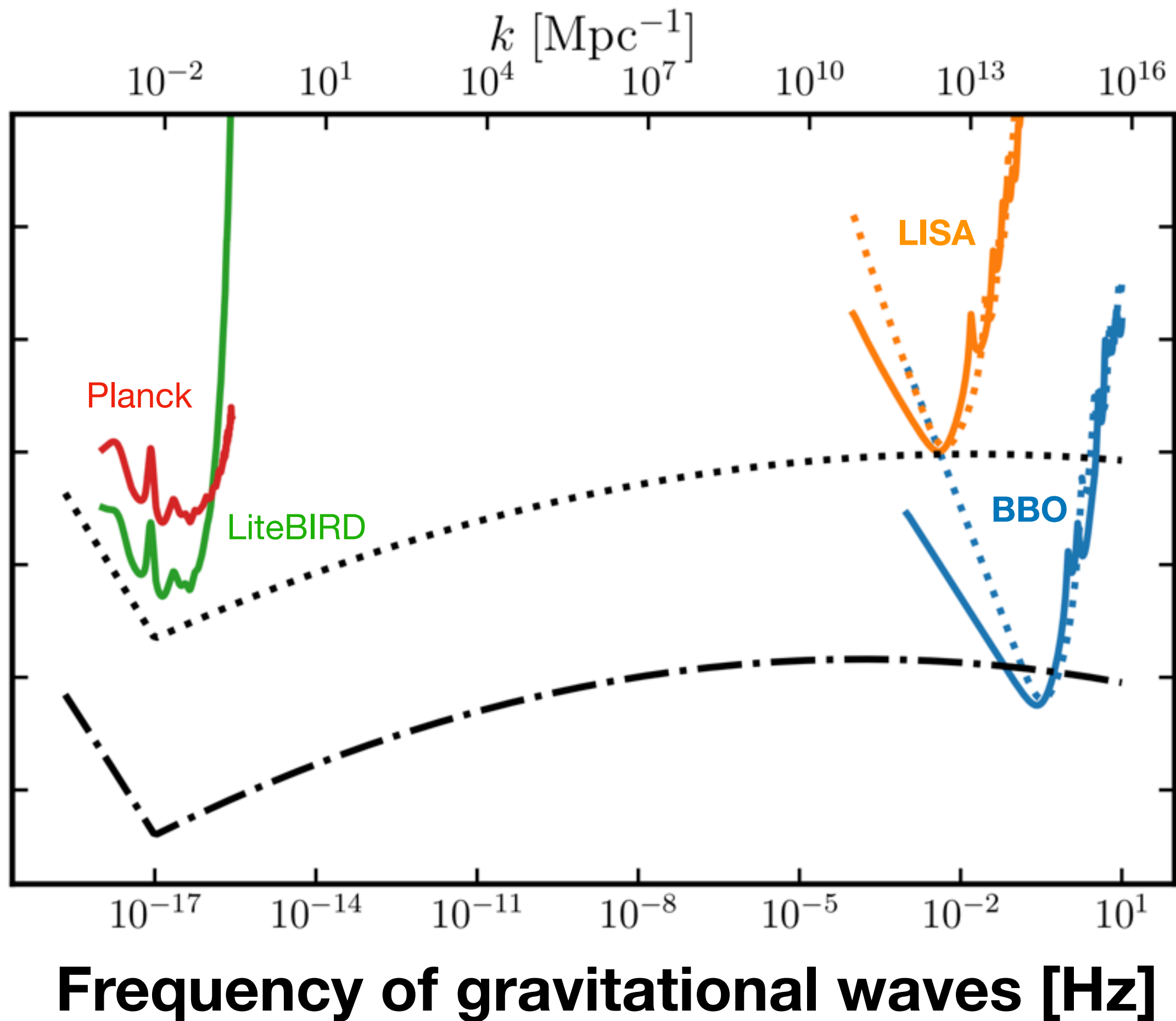
[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

New Paradigm

$$\square h_{ij} = -16\pi G \pi_{ij}$$

- **GW from vacuum**
 - Scale-invariant
 - Gaussian
 - Parity-conserving (no circular polarisation of GW)
- **GW from SU(2) gauge fields**
 - Non-scale-invariant
 - Non-Gaussian
 - Circularly polarised “Chiral” GW

Present-day energy density
spectrum of primordial
gravitational waves



Large bispectrum in GW from SU(2) fields

$$\frac{B_h^{RRR}(k, k, k)}{P_h^2(k)} \approx \frac{25}{\Omega_A}$$

$$\langle \hat{h}_R(\mathbf{k}_1) \hat{h}_R(\mathbf{k}_2) \hat{h}_R(\mathbf{k}_3) \rangle = (2\pi)^3 \delta \left(\sum_{i=1}^3 \mathbf{k}_i \right) B_h^{RRR}(k_1, k_2, k_3)$$

- $\Omega_A \ll 1$ is the energy density fraction of the gauge field
- **B_h/P_h^2 is of order unity for the vacuum contribution**
[Maldacena (2003); Maldacena & Pimentel (2011)]
- ***Gaussianity offers a powerful test of whether the detected GW comes from the vacuum or sources***

Experimental Strategy

Commonly Assumed So Far

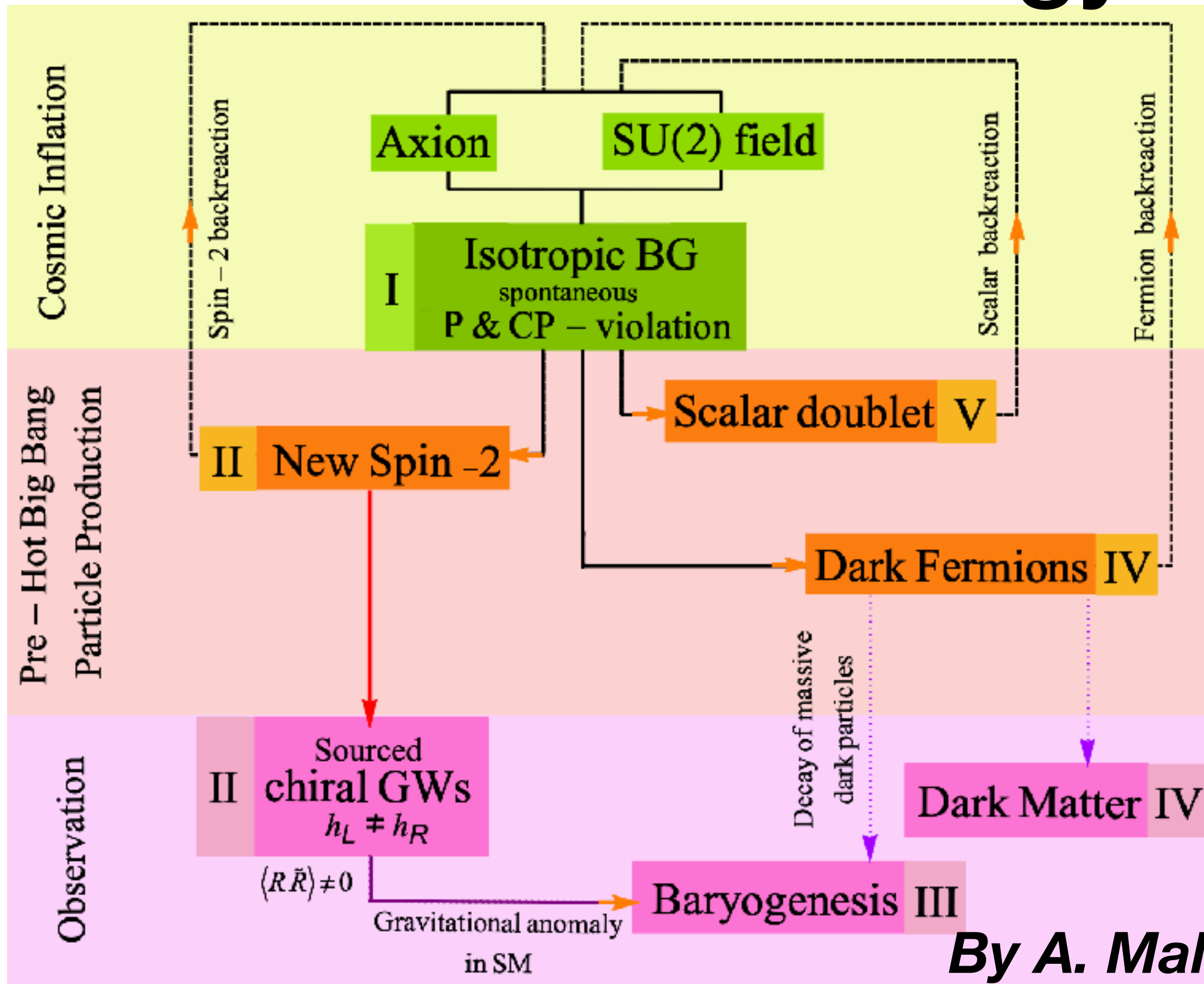
1. Detect CMB polarisation in multiple frequencies, to make sure that it is from the CMB (i.e., Planck spectrum)
2. Check for scale invariance: Consistent with a scale invariant spectrum?
 - Yes => Announce discovery of the vacuum fluctuation in spacetime
 - No => WTF?

New Experimental Strategy: New Standard!

1. Detect CMB polarisation in multiple frequencies, to make sure that it is from the CMB (i.e., Planck spectrum)
 2. Consistent with a scale invariant spectrum?
 3. Parity violating correlations consistent with zero?
 4. Consistent with Gaussianity?
- If, and **ONLY IF** Yes to **all** => Announce discovery of the vacuum fluctuation in spacetime

Particle Production!

Rich Phenomenology



By A. Maleknejad

Hubble Constant

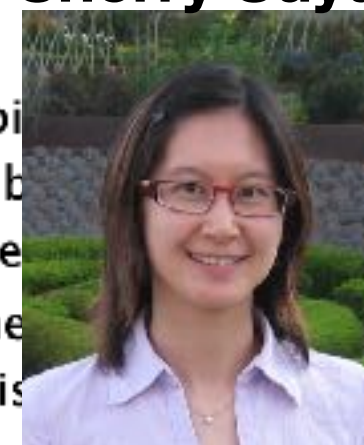
Astrophysics > Cosmology and Nongalactic Astrophysics

HOLICOW XIII. A 2.4% measurement of H_0 from lensed quasars: 5.3 σ tension between early and late-Universe probes

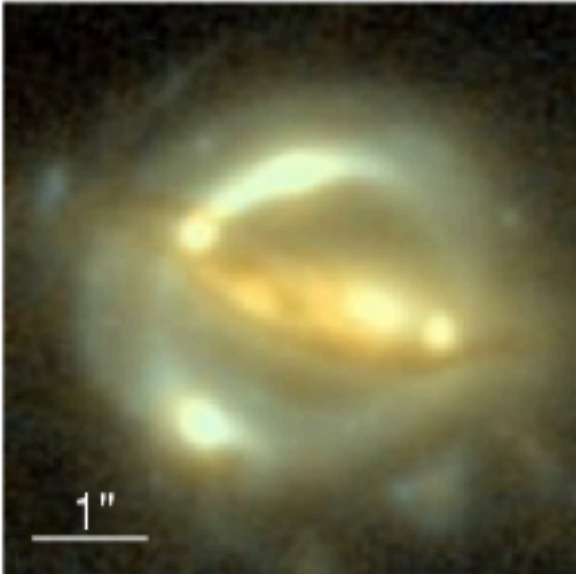
Kenneth C. Wong, Sherry H. Suyu, Geoff C.-F. Chen, Cristian E. Rusu, Martin Millon, Dominique Sluse, Vivien Bonvin, Christopher D. Fassnacht, Stefan Taubenberger, Matthew W. Auger, Simon Birrer, James H. H. Chan, Frederic Courbin, Stefan Hilbert, Olga Tihhonova, Tommaso Treu, Adriano Agnello, Xuheng Ding, Inh Jee, Eiichiro Komatsu, Anowar J. Shajib, Alessandro Sonnenfeld, Roger D. Blandford, Leon V. E. Koopmans, Philip J. Marshall, Georges Meylan

(Submitted on 10 Jul 2019)

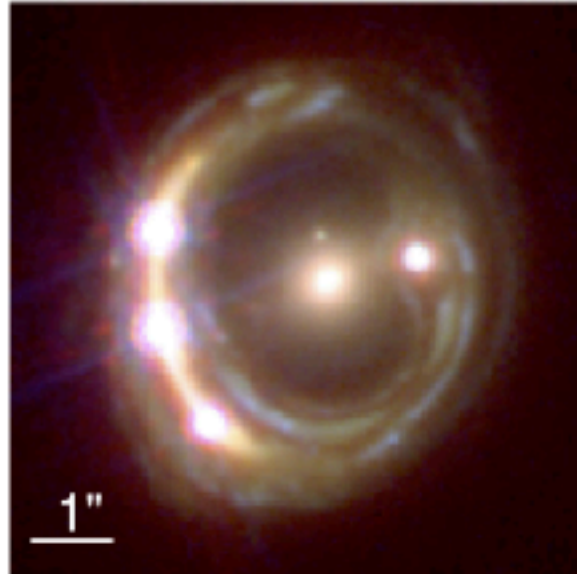
Sherry Suyu



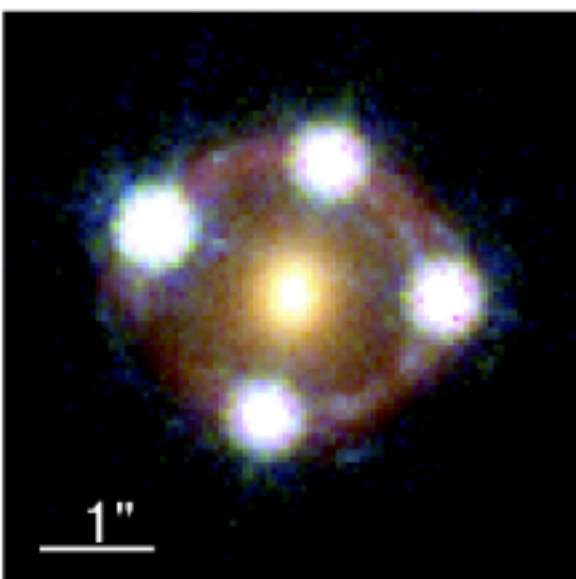
We present a measurement of the Hubble constant (H_0) and other cosmological parameters from a joint analysis of six gravitationally lensed quasars with measured time delays. All lenses except the first are analyzed with respect to the cosmological parameters. In a flat Λ CDM cosmology, we find $H_0 = 73.3^{+1.7}_{-1.8}$, a 2.4% precision measurement, in agreement with local measurements of H_0 from type Ia supernovae calibrated by the distance ladder, but in 3.1 σ tension with *Planck* observations of the cosmic microwave background (CMB). This result is completely independent of both the supernovae and CMB analyses. A combination of time-delay cosmography and the distance ladder results is in 5.3 σ tension with *Planck* CMB determinations of H_0 in flat Λ CDM. We compute Bayes factors to verify that all lenses give statistically consistent results, showing that we are not underestimating our uncertainties and are able to control our systematics. We explore extensions to flat Λ CDM using constraints from time-delay cosmography alone, as well as combinations with other cosmological probes, including CMB observations from *Planck*, baryon acoustic oscillations, and type Ia supernovae. Time-delay cosmography improves the precision of the other probes, demonstrating the strong complementarity. Using the distance constraints from time-delay cosmography to anchor the type Ia supernova distance scale, we reduce the sensitivity of our H_0 inference to cosmological model assumptions. For six different cosmological models, our combined inference on H_0 ranges from 73–78 km s⁻¹ Mpc⁻¹, which is consistent with the local distance ladder constraints.



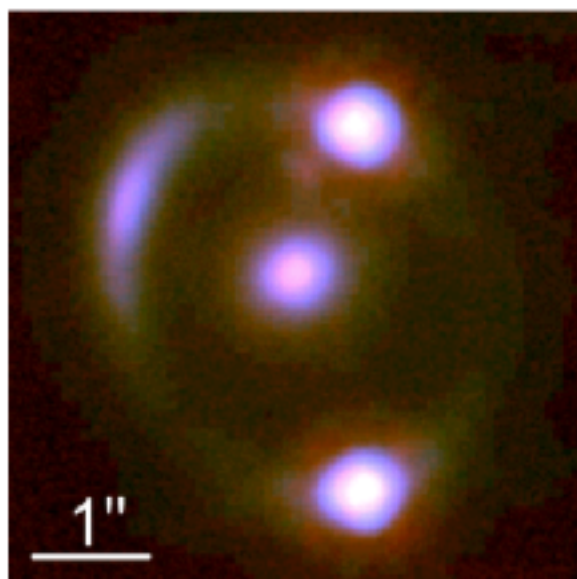
(a) B1608+656



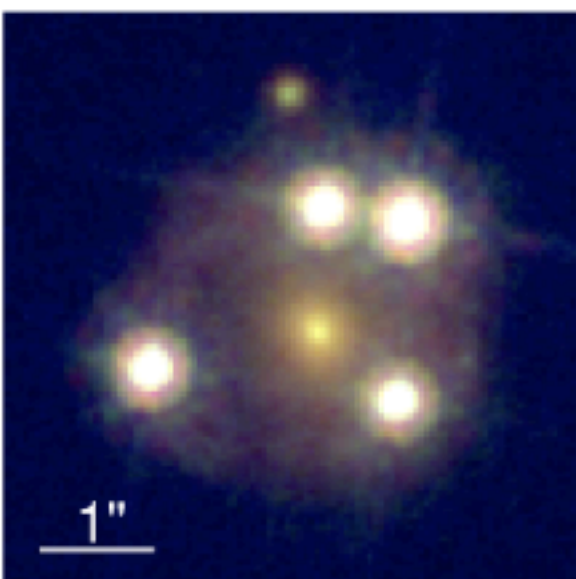
(b) RXJ1131-1231



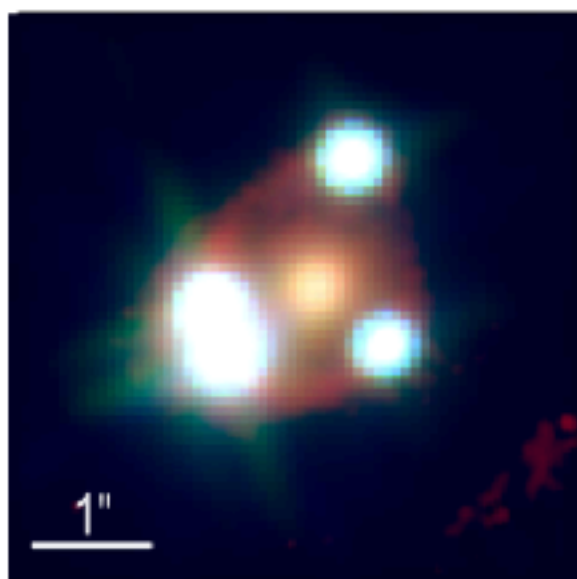
(c) HE 0435-1223



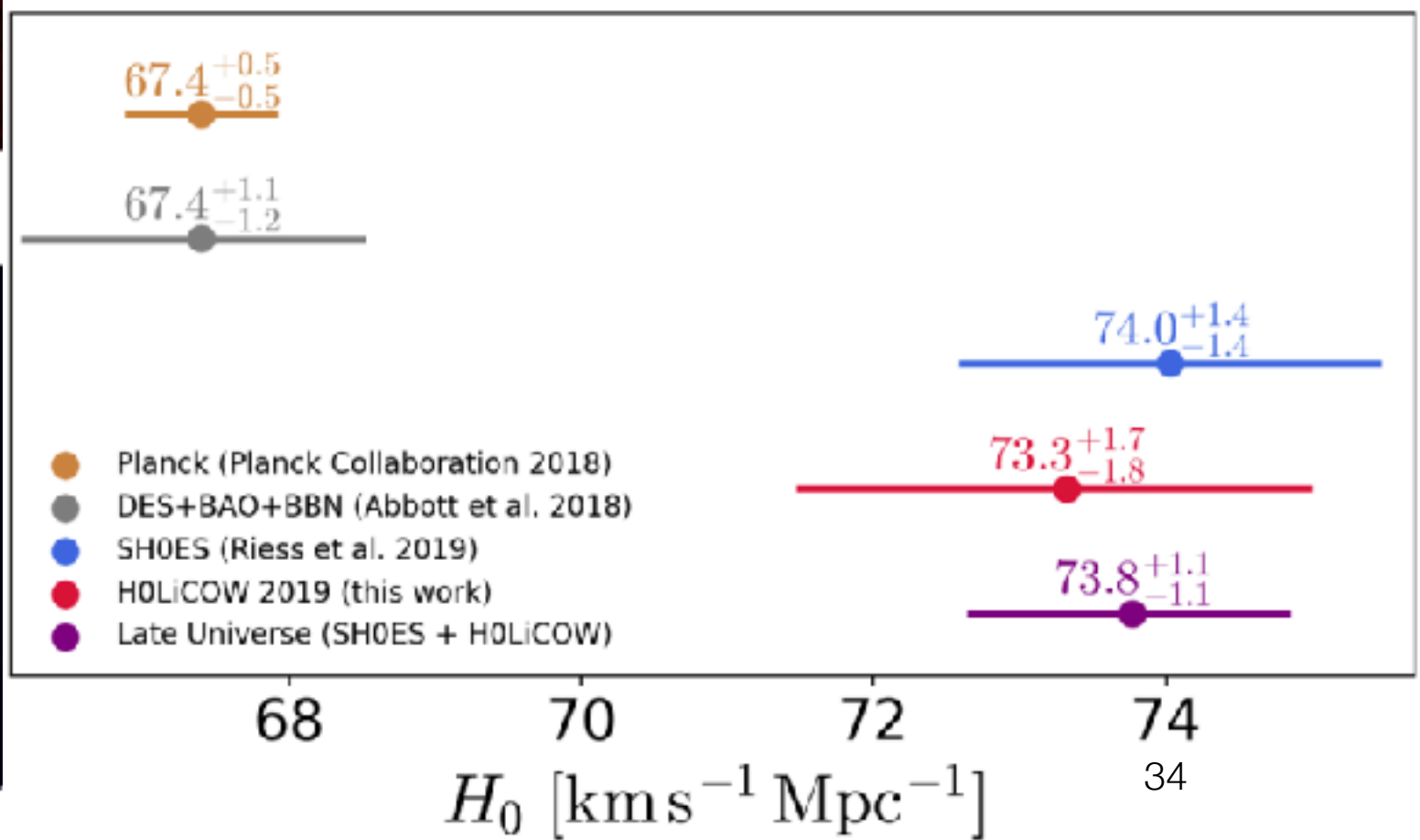
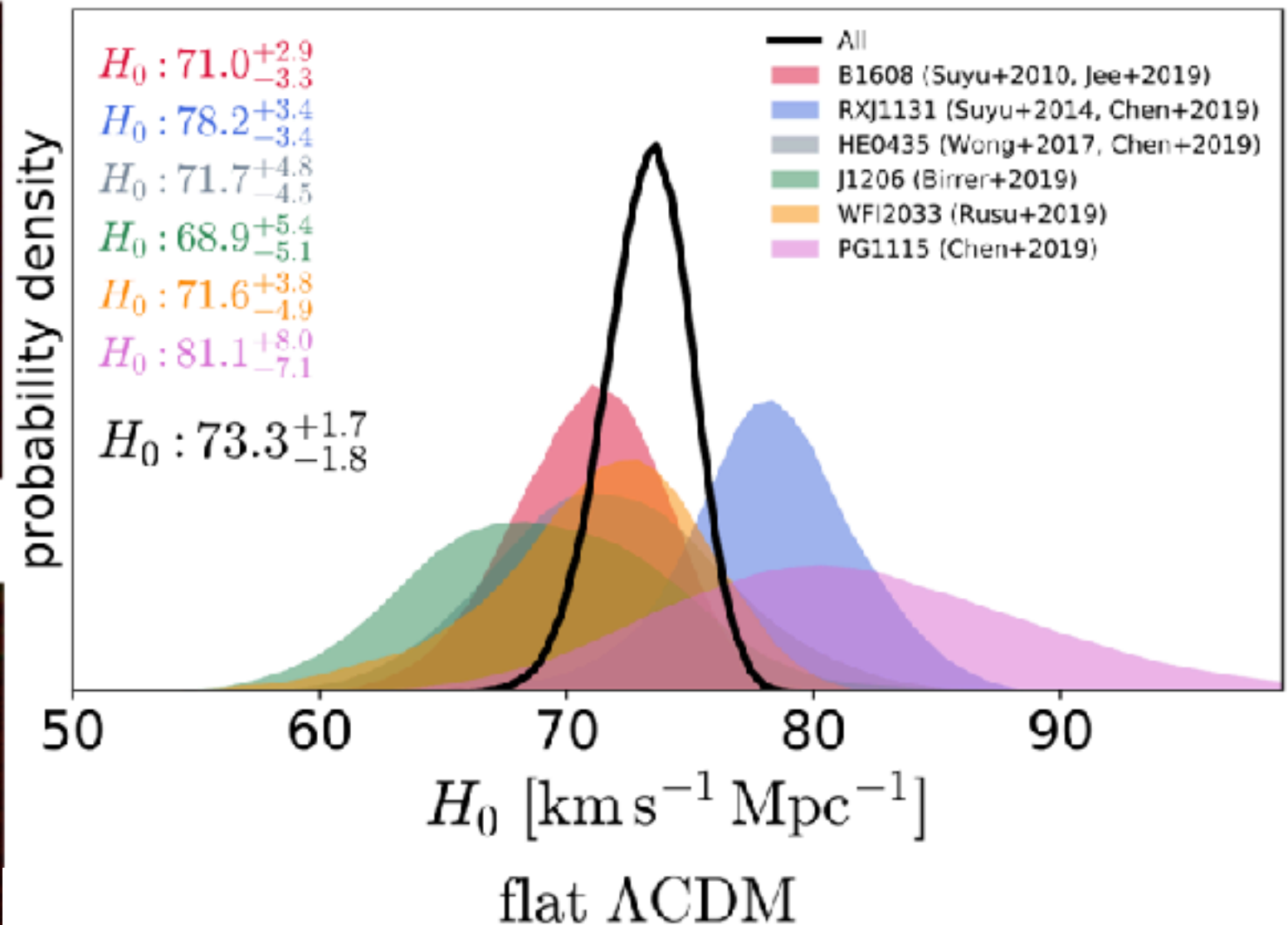
(d) SDSS 1206+4332



(e) WFI2033-4723



(f) PG 1115+080



Two innovations from our group

*Inh Jee's master (Texas)
and PhD work (MPA)*



Measuring angular diameter distances of strong gravitational lenses

Inh Jee, Eiichiro Komatsu, Sherry H. Suyu. Oct 28, 2014. 23 pp.

Published in **JCAP 1511 (2015) 033**

DOI: [10.1088/1475-7516/2015/11/033](https://doi.org/10.1088/1475-7516/2015/11/033)

e-Print: [arXiv:1410.7770](https://arxiv.org/abs/1410.7770) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

[Detailed record](#) - [Cited by 29 records](#)

Time-delay Cosmography: Increased Leverage with Angular Diameter Distances

Inh Jee, Eiichiro Komatsu, Sherry H. Suyu, Dragan Huterer. Sep 10, 2015. 18 pp.

Published in **JCAP 1604 (2016) 031**

DOI: [10.1088/1475-7516/2016/04/031](https://doi.org/10.1088/1475-7516/2016/04/031)

e-Print: [arXiv:1509.03310](https://arxiv.org/abs/1509.03310) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

[Detailed record](#) - [Cited by 25 records](#)

The Hubble Constant determined through an inverse distance ladder including quasar time delays and Type Ia supernovae

S. Taubenberger, S.H. Suyu, E. Komatsu, I. Jee, S. Birrer, V. Bonvin, F. Courbin, C.E. Rusu, A.J. Shajib, K.C. Wong. May 29, 2019. 5 pp.

Published in **Astron.Astrophys. 628 (2019) L7**

DOI: [10.1051/0004-6361/201935980](https://doi.org/10.1051/0004-6361/201935980)

e-Print: [arXiv:1905.12496](https://arxiv.org/abs/1905.12496) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

[Detailed record](#) - [Cited by 12 records](#)

RESEARCH ARTICLE

COSMOLOGY

A measurement of the Hubble constant from angular diameter distances to two gravitational lenses

Inh Jee^{1*}, Sherry H. Suyu^{1,2,3*}, Eiichiro Komatsu^{1,4}, Christopher D. Fassnacht⁵, Stefan Hilbert^{6,7}, Léon V. E. Koopmans⁸

The local expansion rate of the Universe is parametrized by the Hubble constant, H_0 , the ratio between recession velocity and distance. Different techniques lead to inconsistent estimates of H_0 . Observations of Type Ia supernovae (SNe) can be used to measure H_0 , but this requires an external calibrator to convert relative distances to absolute ones. We use the angular diameter distance to strong gravitational lenses as a suitable calibrator, which is only weakly sensitive to cosmological assumptions. We determine the angular diameter distances to two gravitational lenses, 810^{+160}_{-130} and 1230^{+180}_{-150} megaparsec, at redshifts $z = 0.295$ and 0.6304 . Using these absolute distances to calibrate 740 previously measured relative distances to SNe, we measure the Hubble constant to be $H_0 = 82.4^{+8.4}_{-8.3}$ kilometers per second per megaparsec.

**Science, 365, 1134
(2019)**

Innovation (1): Angular Diameter Distances

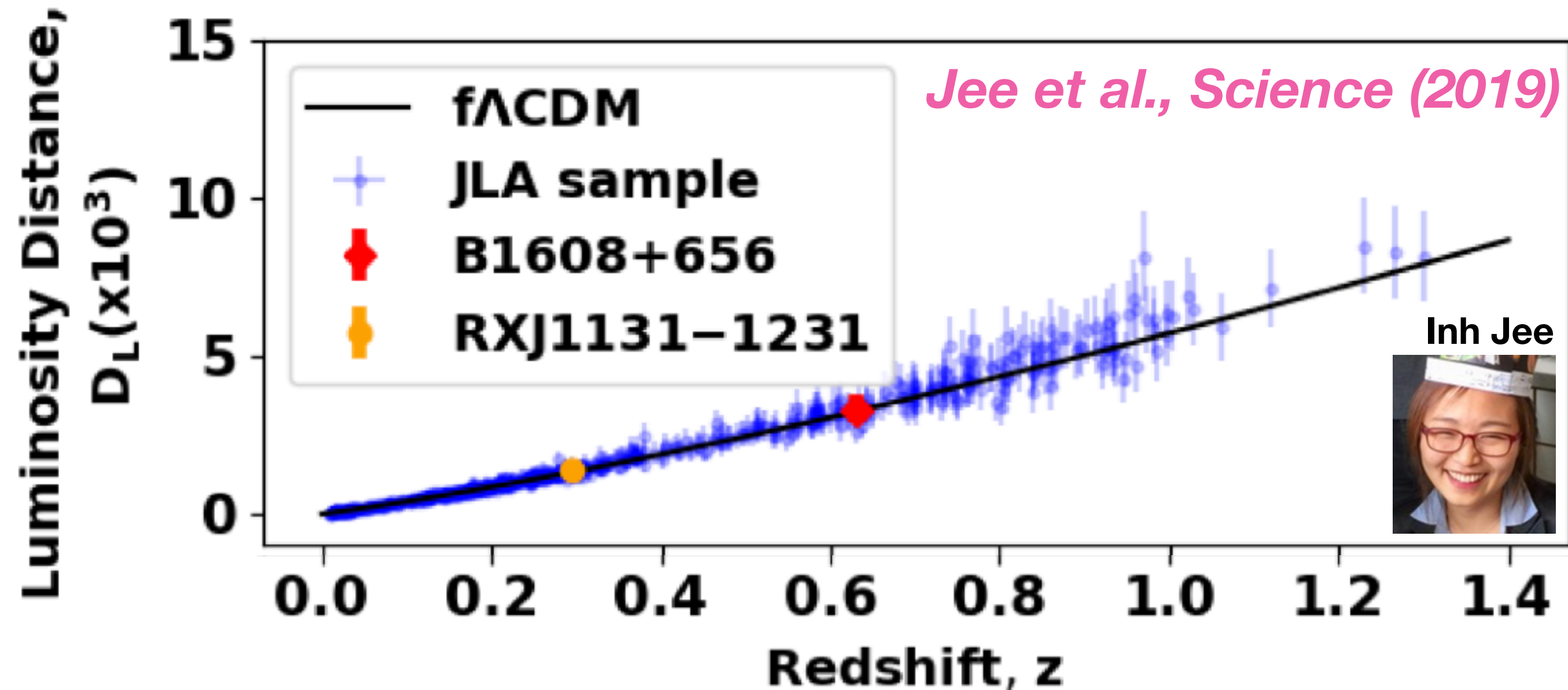
Table 2. $D_{\Delta t}$ and D_d constraints for H0LiCOW lenses. *H0LiCOW Collaboration*

arXiv:1907.04869

Lens name	$D_{\Delta t}$ (Mpc)	D_d (Mpc)	Blind analysis
B1608+656	5156^{+296}_{-236}	1228^{+177}_{-151}	no
RXJ1131–1231	2096^{+98}_{-83}	804^{+141}_{-112}	yes ^a
HE 0435–1223	2707^{+183}_{-168}	—	yes
SDSS 1206+4332	5769^{+589}_{-471}	1805^{+555}_{-398}	yes
WFI2033–4723	4784^{+399}_{-248}	—	yes
PG 1115+080	1470^{+137}_{-127}	697^{+186}_{-144}	yes

- Getting D_d from time-delay lenses is our innovation. It has become the standard practice of the field

Innovation (2): “Inverse Distance Ladder”

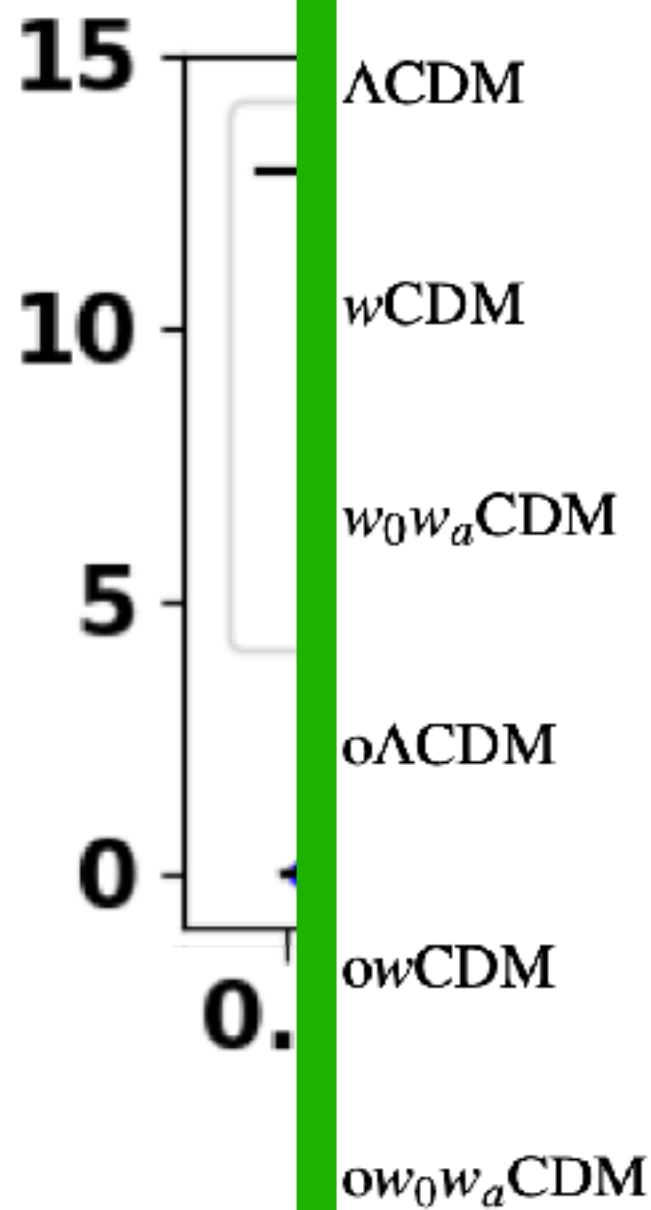


- We calibrate the absolute luminosity of Type Ia supernovae using strong lenses => Robust inference of H_0 , independent of assumed cosmological models

Luminosity Distance,

$D_L (\times 10^3)$

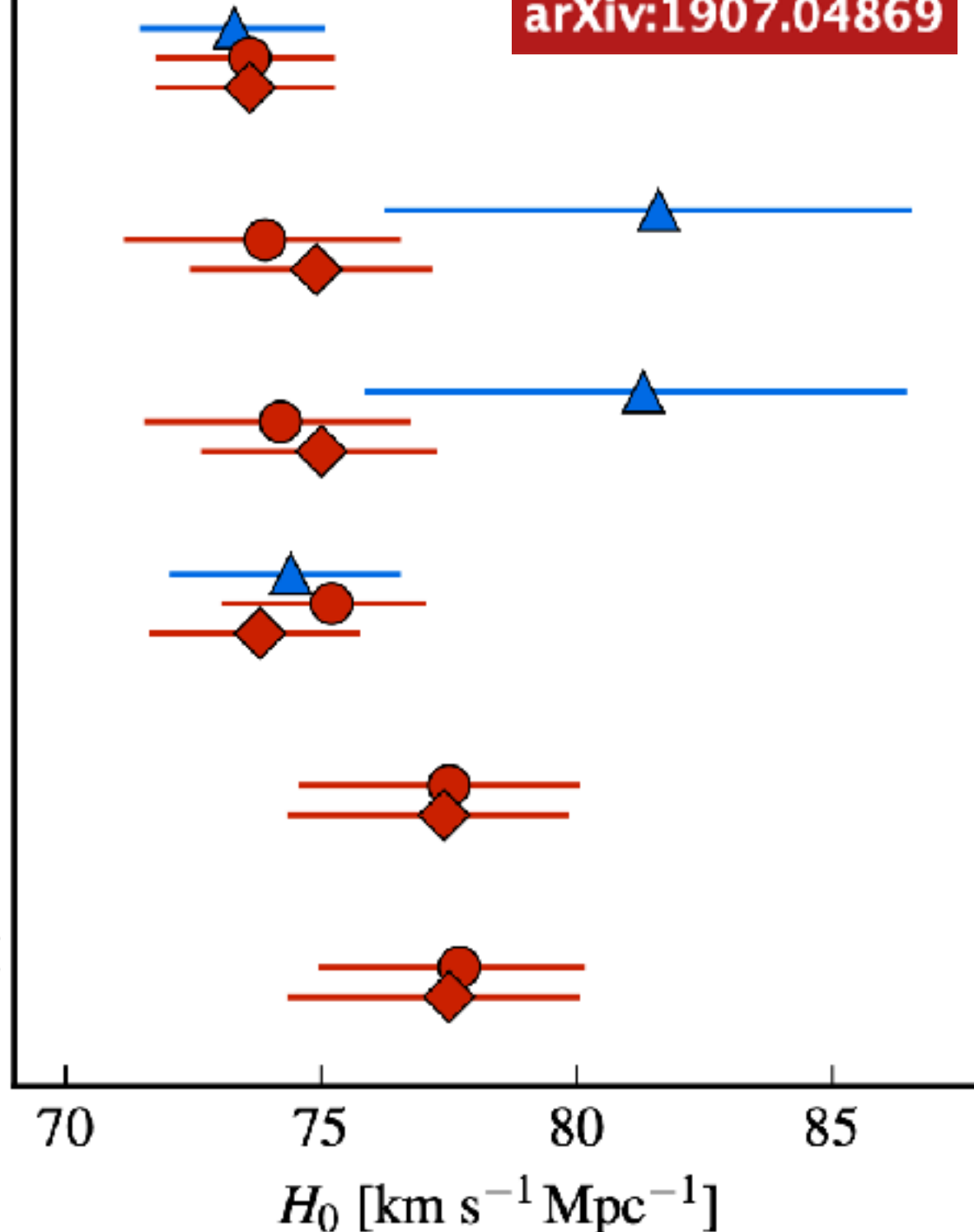
“Inv



- ▲ H0LiCOW
- H0LiCOW + JLA
- ◆ H0LiCOW + Pantheon

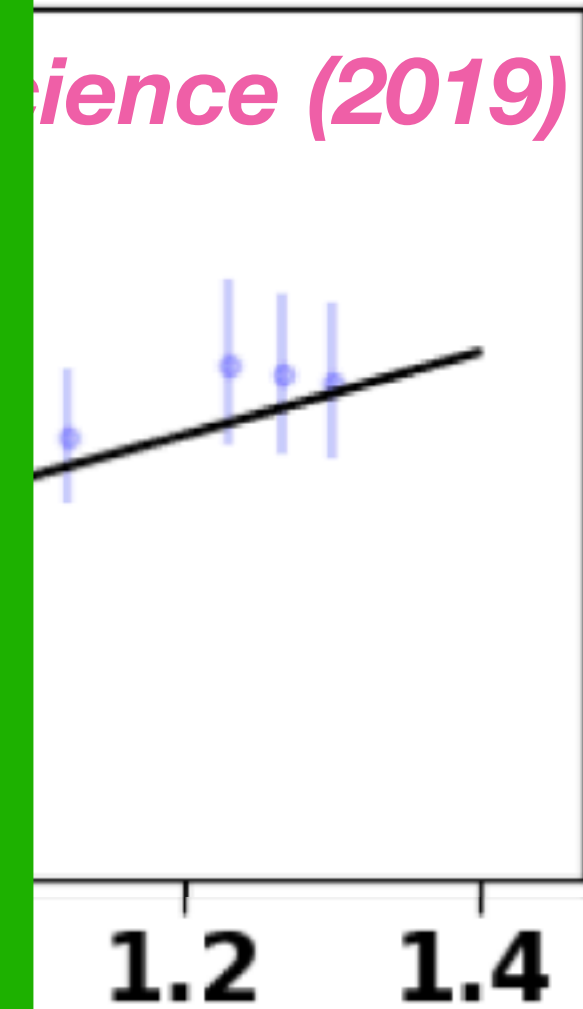
H0LiCOW Collaboration

arXiv:1907.04869



der”

science (2019)



Type Ia
most inference
logical models

Sunyaev-Zeldovich Effect

*Is there a tension in the amplitude of matter density
fluctuations?*

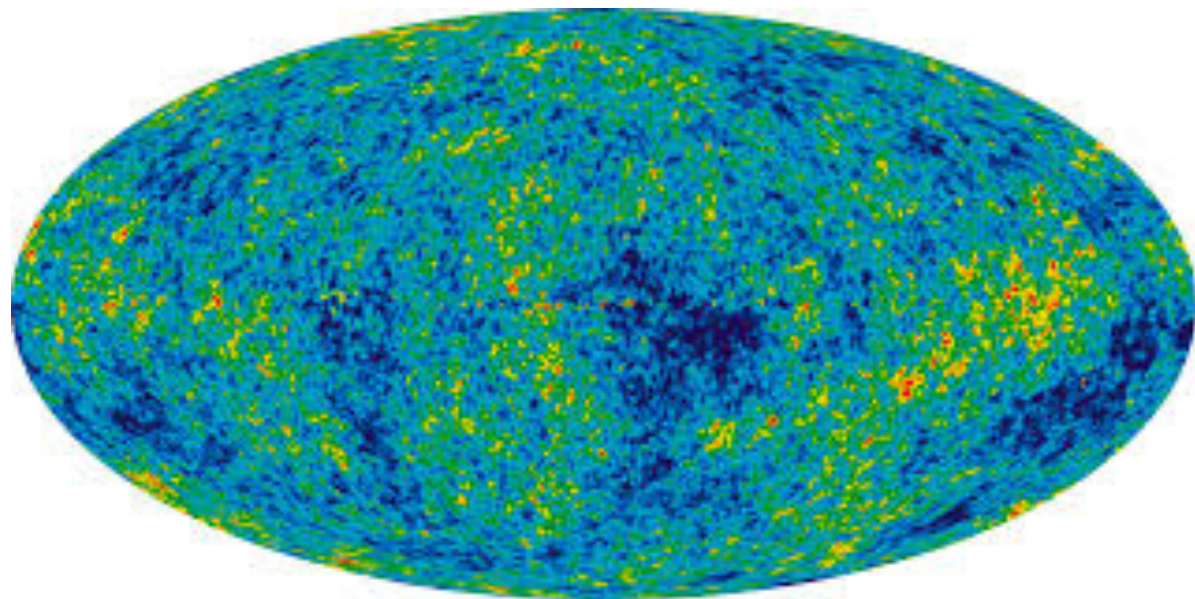
E2E Test of Cosmology

- H_0 offers an E2E test of the evolution of the cosmological background
- Amplitude of matter density fluctuations offers an E2E test of the evolution of the fluctuations
- Cosmology as an initial-value problem: given the initial condition given by the CMB, can we reproduce late-time observations?

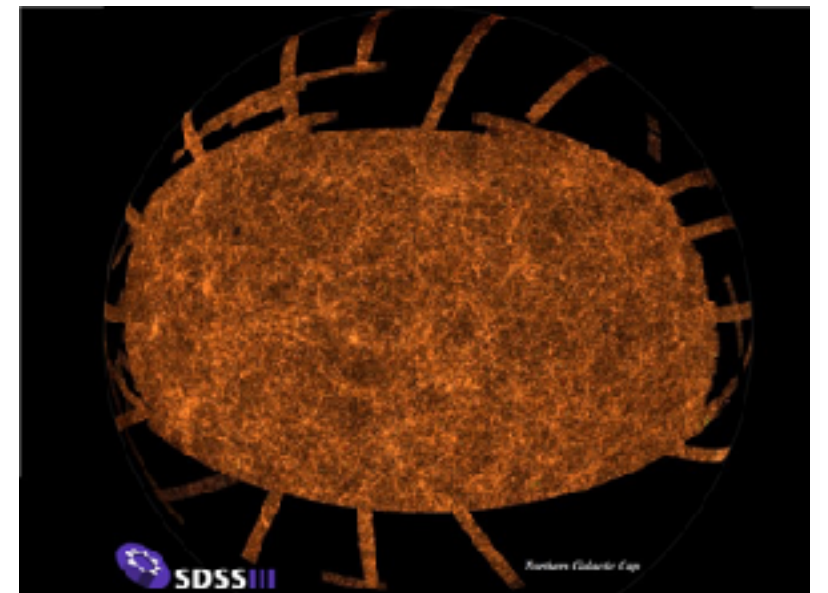
σ_8 Normalisation for the **linear** power spectrum of
matter density fluctuations **at present**

A_s $\longrightarrow$ σ_8

Primordial amplitude
constrained by the CMB



Present-day amplitude
constrained by late-time
observations

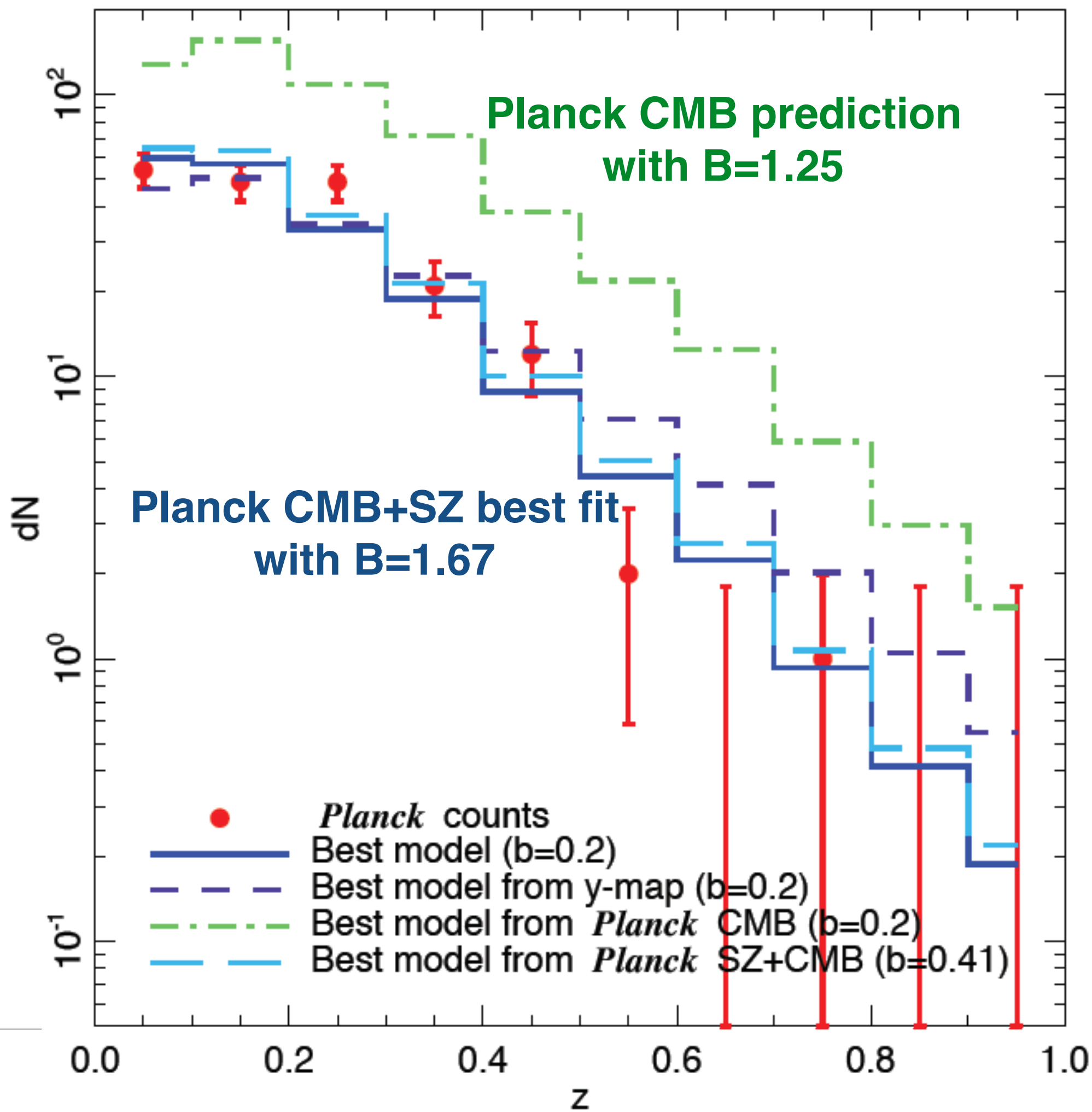


The Biggest Enemy: Mass Bias

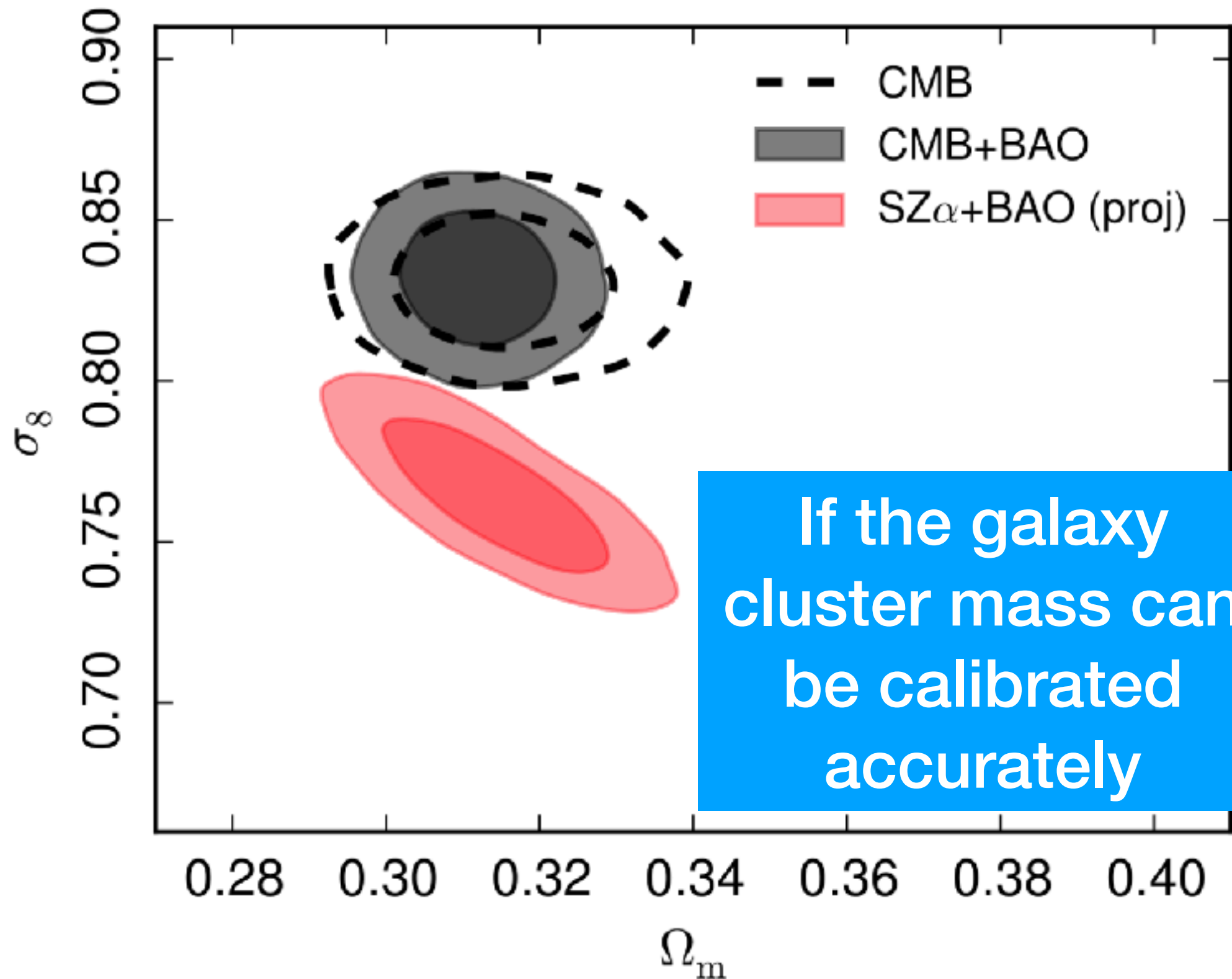
$$B = M_{\text{true}} / M_{\text{estimated}}$$

(People more often use $1-b = 1/B$)

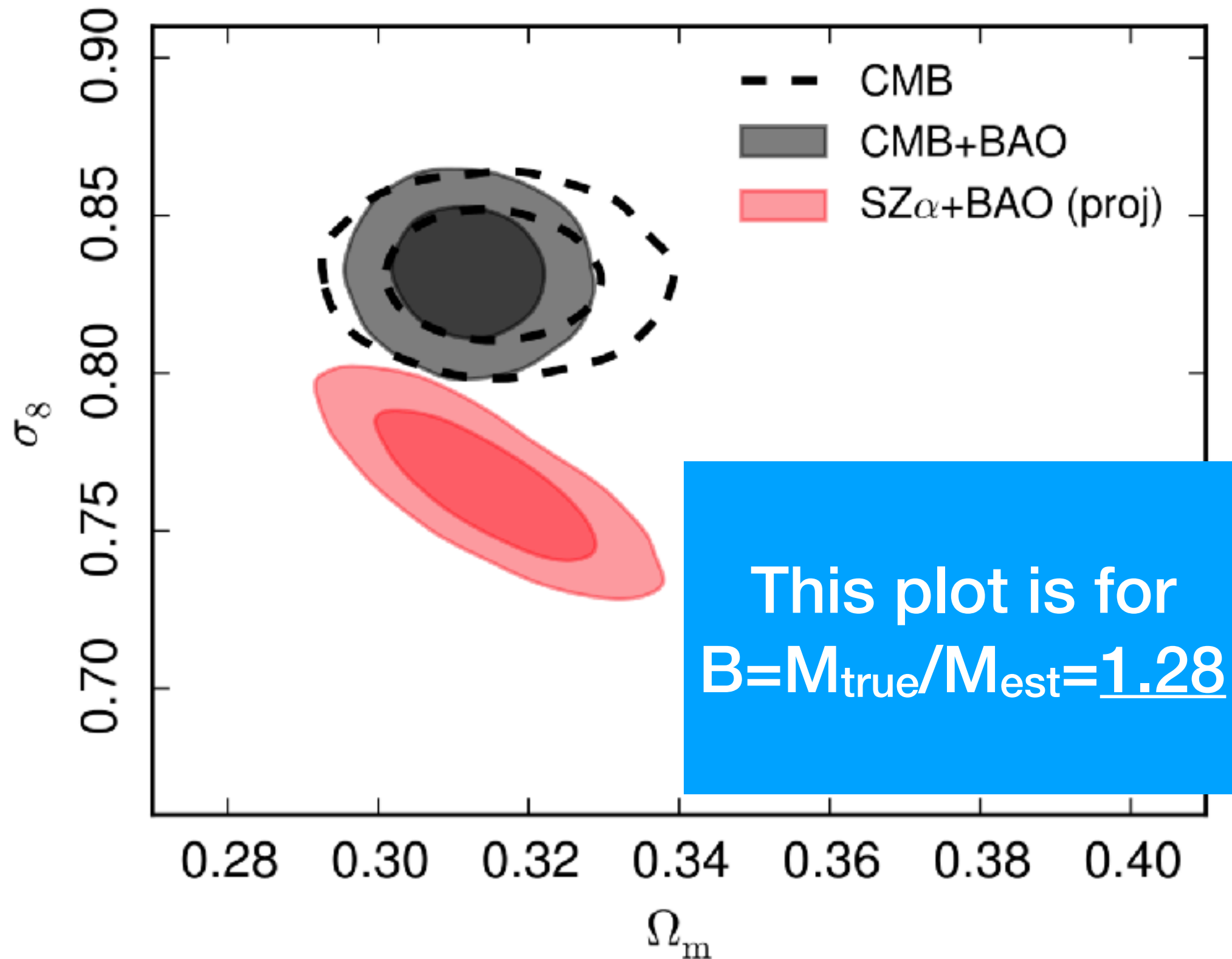
Planck SZ Cluster Count, $N(z)$

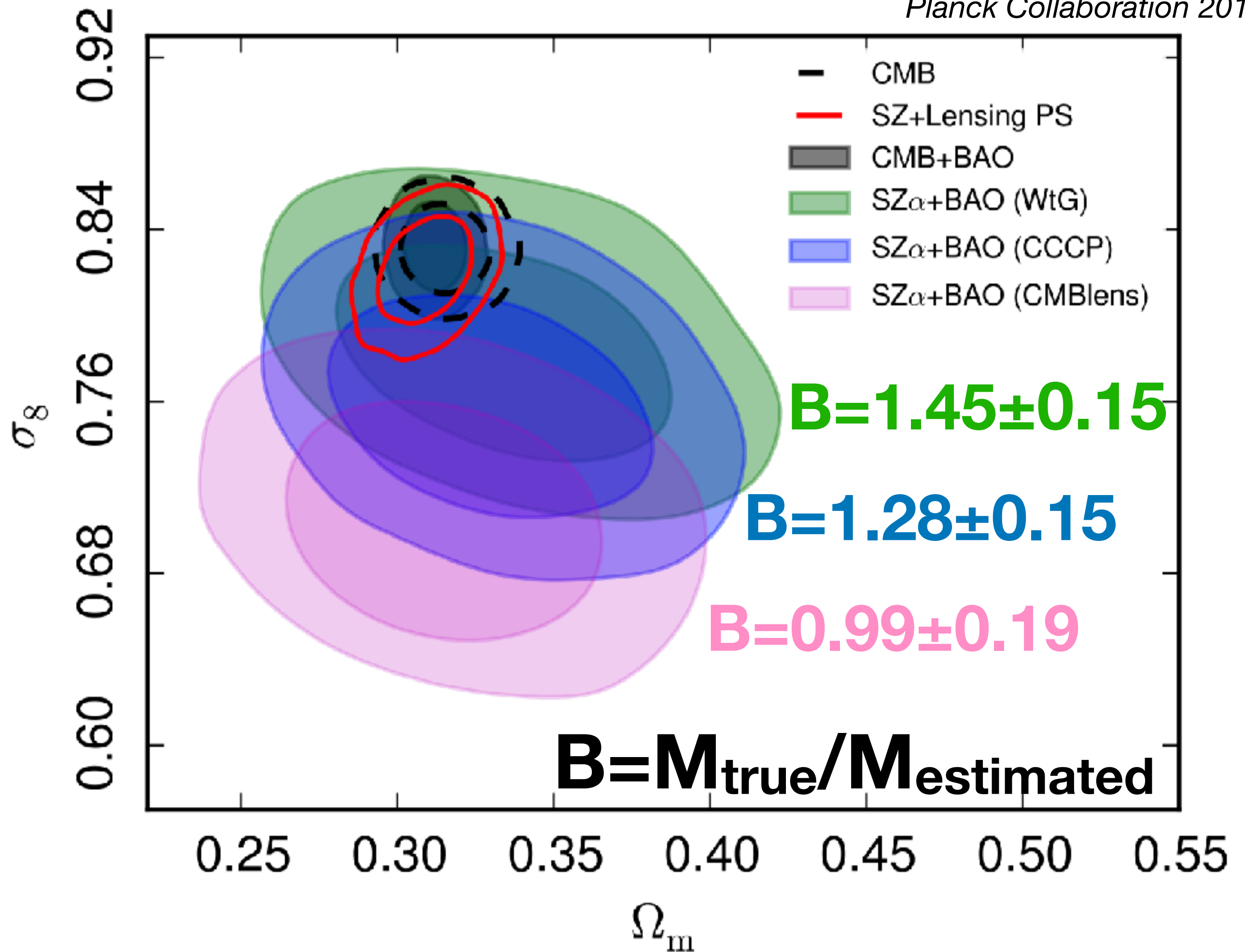


Galaxy Cluster Counts [SZ]



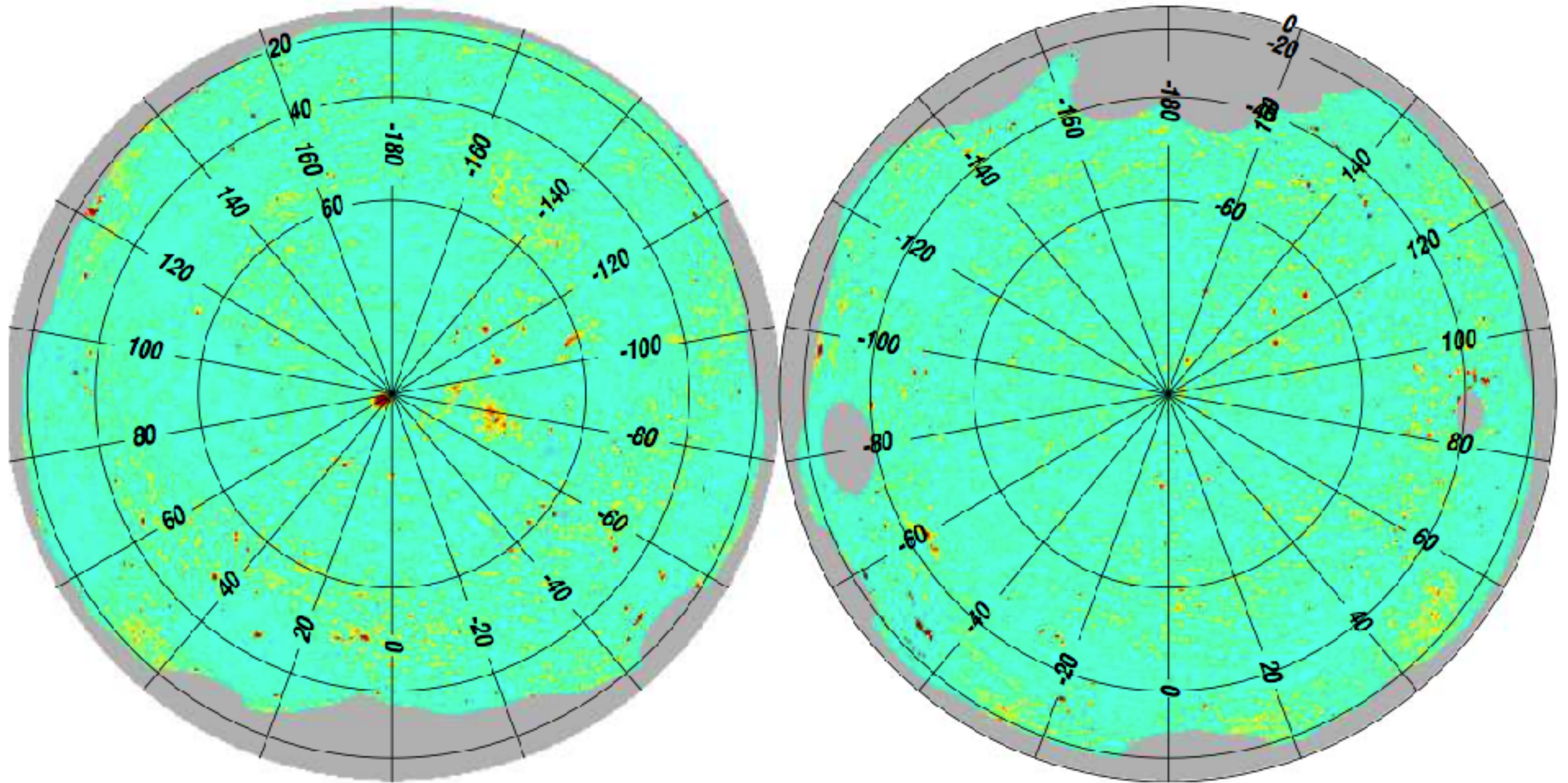
Galaxy Cluster Counts [SZ]





Full-sky Thermal Pressure Map

North Galactic Pole *MILCA tSZ map* South Galactic Pole



My favourite approach:
No number counts, but we model the map

*Planck
Collaboration*

State-of-the-art Model and Analysis

We have established the *definitive* model and analysis methods for analysing the power spectra and cross-power spectra of SZ and galaxy surveys

New constraints on the mass bias of galaxy clusters from the power spectra of the thermal Sunyaev-Zeldovich effect and cosmic shear

Ryu Makiya, Chiaki Hikage, Eiichiro Komatsu. Jul 18, 2019. 6 pp.

e-Print: [arXiv:1907.07870](#) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

[Detailed record](#) - [Cited by 4 records](#)

Joint analysis of the thermal Sunyaev-Zeldovich effect and 2MASS galaxies: probing gas physics in the local Universe and beyond

Ryu Makiya, Shin'ichiro Ando, Eiichiro Komatsu. Apr 13, 2018. 14 pp.

Published in *Mon.Not.Roy.Astron.Soc.* 480 (2018) no.3, 3928-3941

DOI: [10.1093/mnras/sty2031](#)

e-Print: [arXiv:1804.05008](#) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

[Detailed record](#) - [Cited by 11 records](#)

Dark energy constraints from the thermal Sunyaev-Zeldovich power spectrum

Boris Bolliet (LPSC, Grenoble & Garching, Max Planck Inst.), Barbara Comis (LPSC, Grenoble), Eiichiro Komatsu (Tokyo U., IPMU & Jodrell Bank), Juan Francisco Macías-Pérez (LPSC, Grenoble). Dec 3, 2017. 11 pp.

Published in *Mon.Not.Roy.Astron.Soc.* 477 (2018) no.4, 4957-4967

DOI: [10.1093/mnras/sty823](#)

e-Print: [arXiv:1712.00788](#) [astro-ph.CO] | [PDF](#)

[References](#) | [BibTeX](#) | [LaTeX\(US\)](#) | [LaTeX\(EU\)](#) | [Harvmac](#) | [EndNote](#)
[ADS Abstract Service](#)

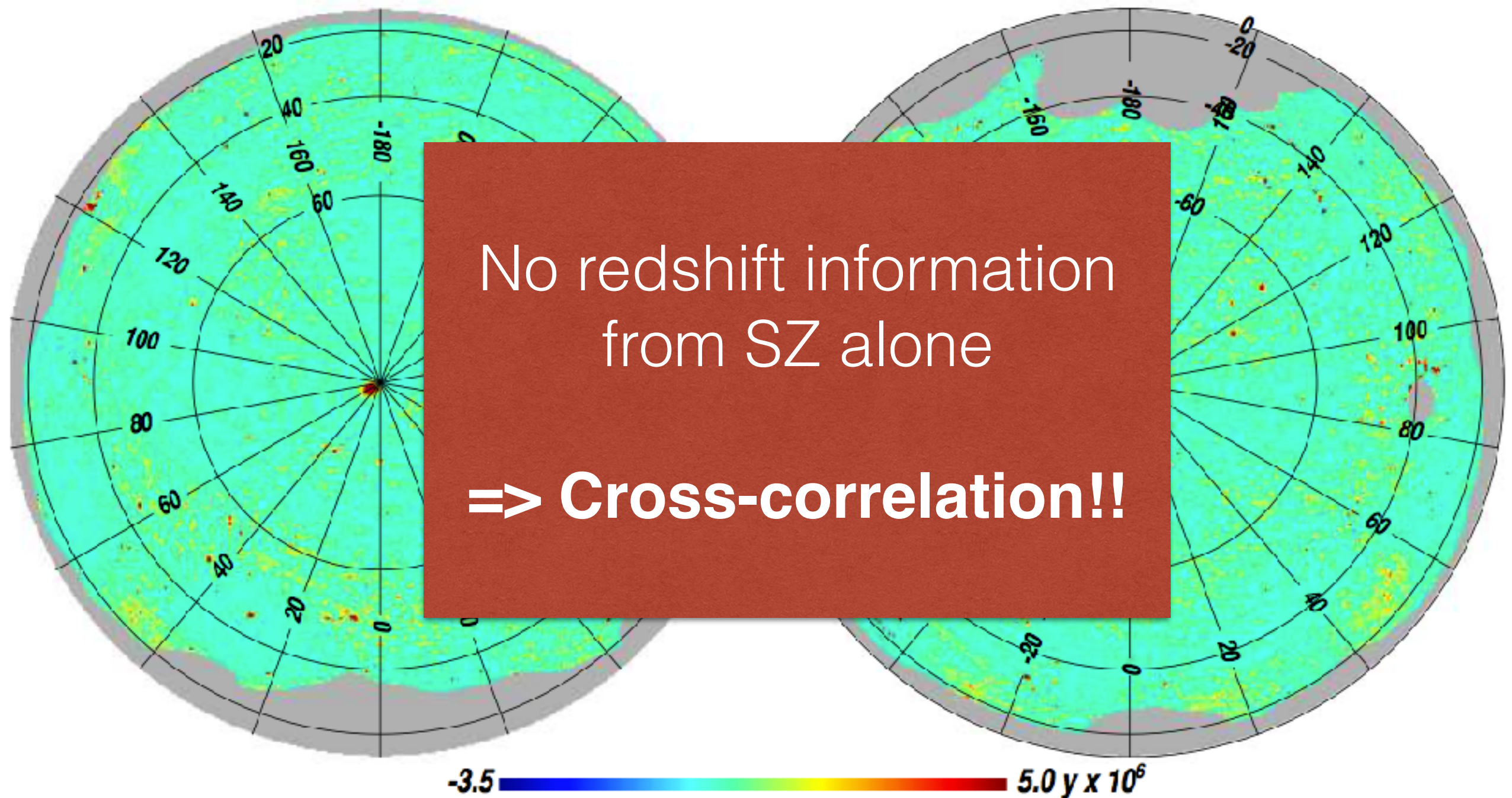
[Detailed record](#) - [Cited by 21 records](#)

Ryu Makiya

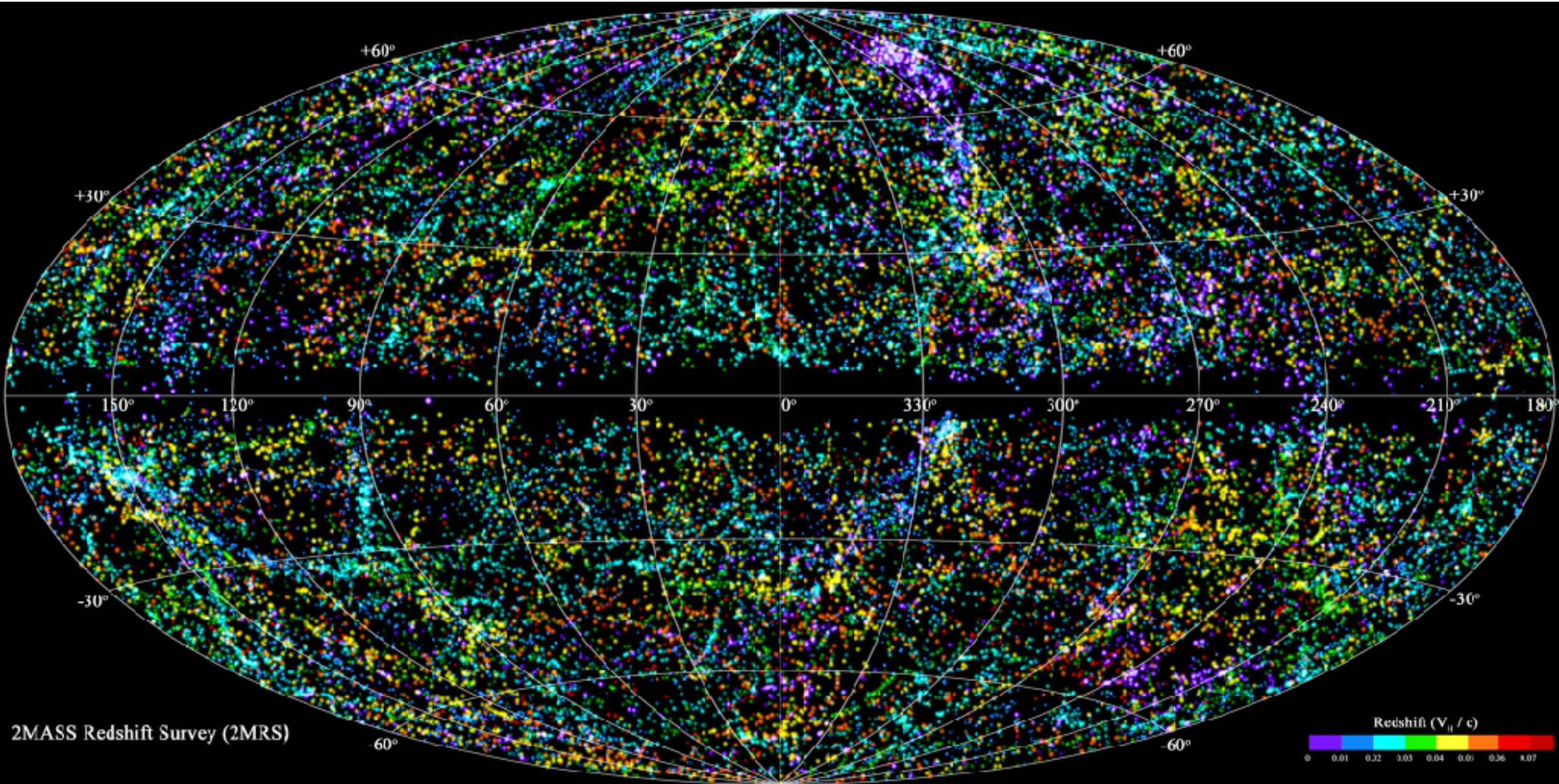


Full-sky Thermal Pressure Map

North Galactic Pole *MILCA tSZ map* South Galactic Pole

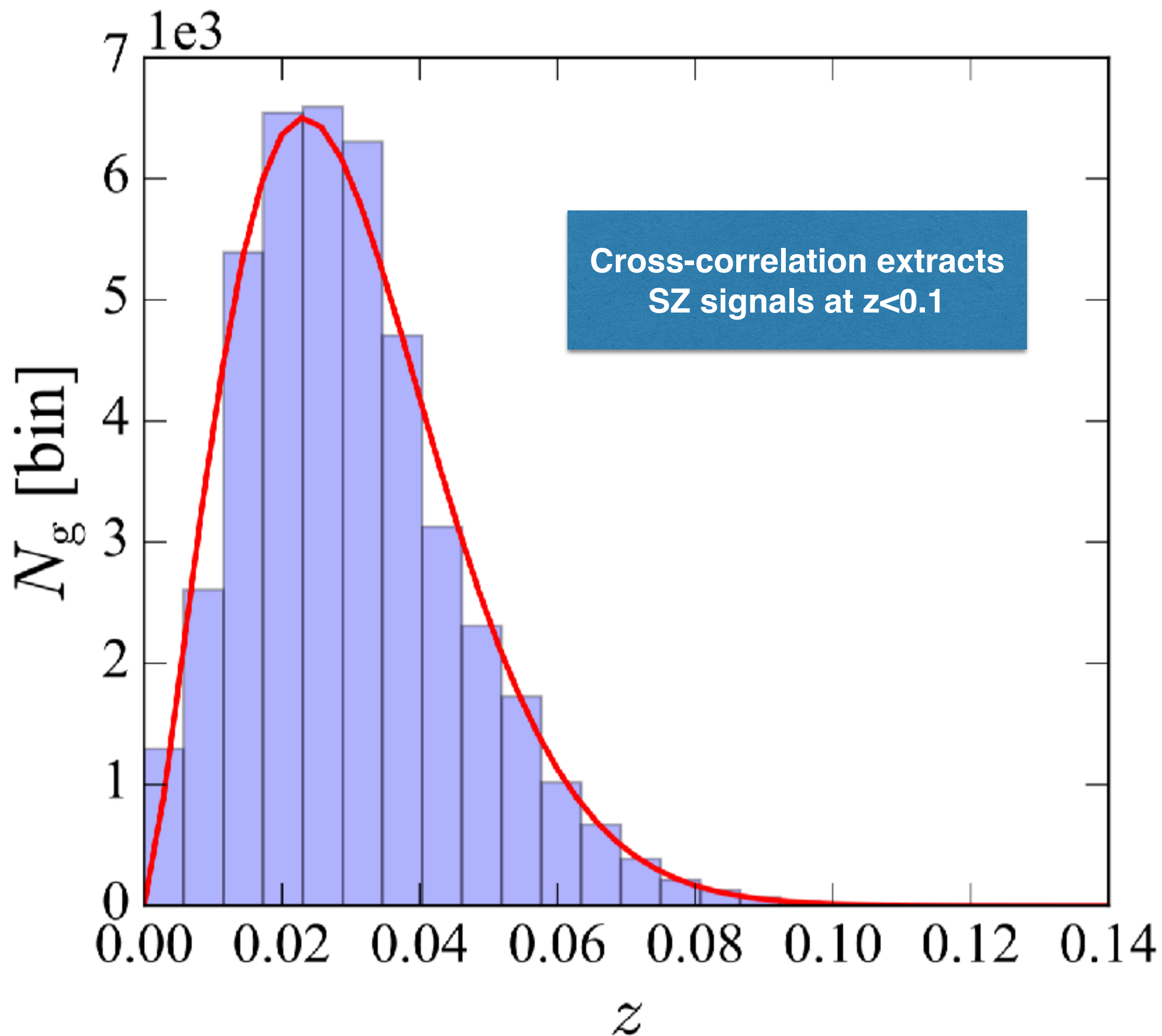
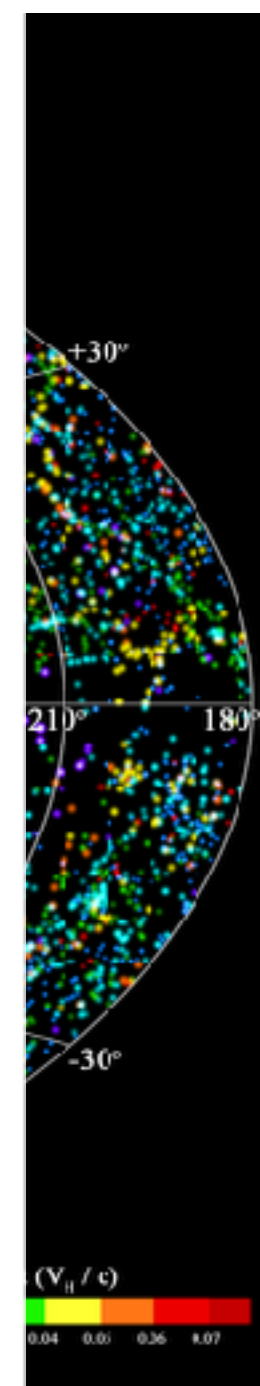
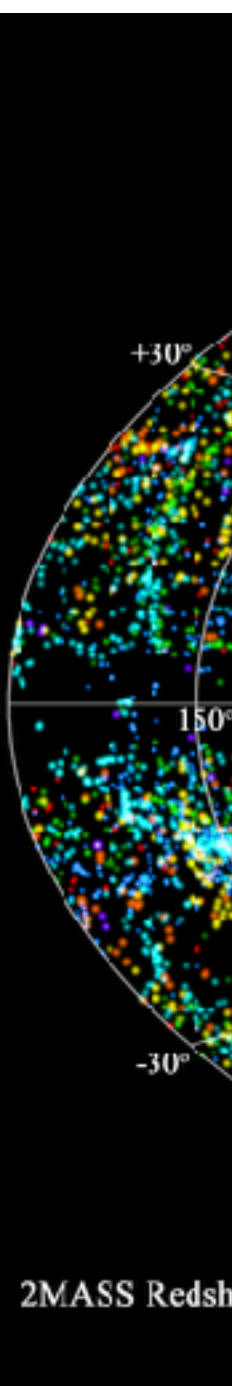


Planck Collaboration

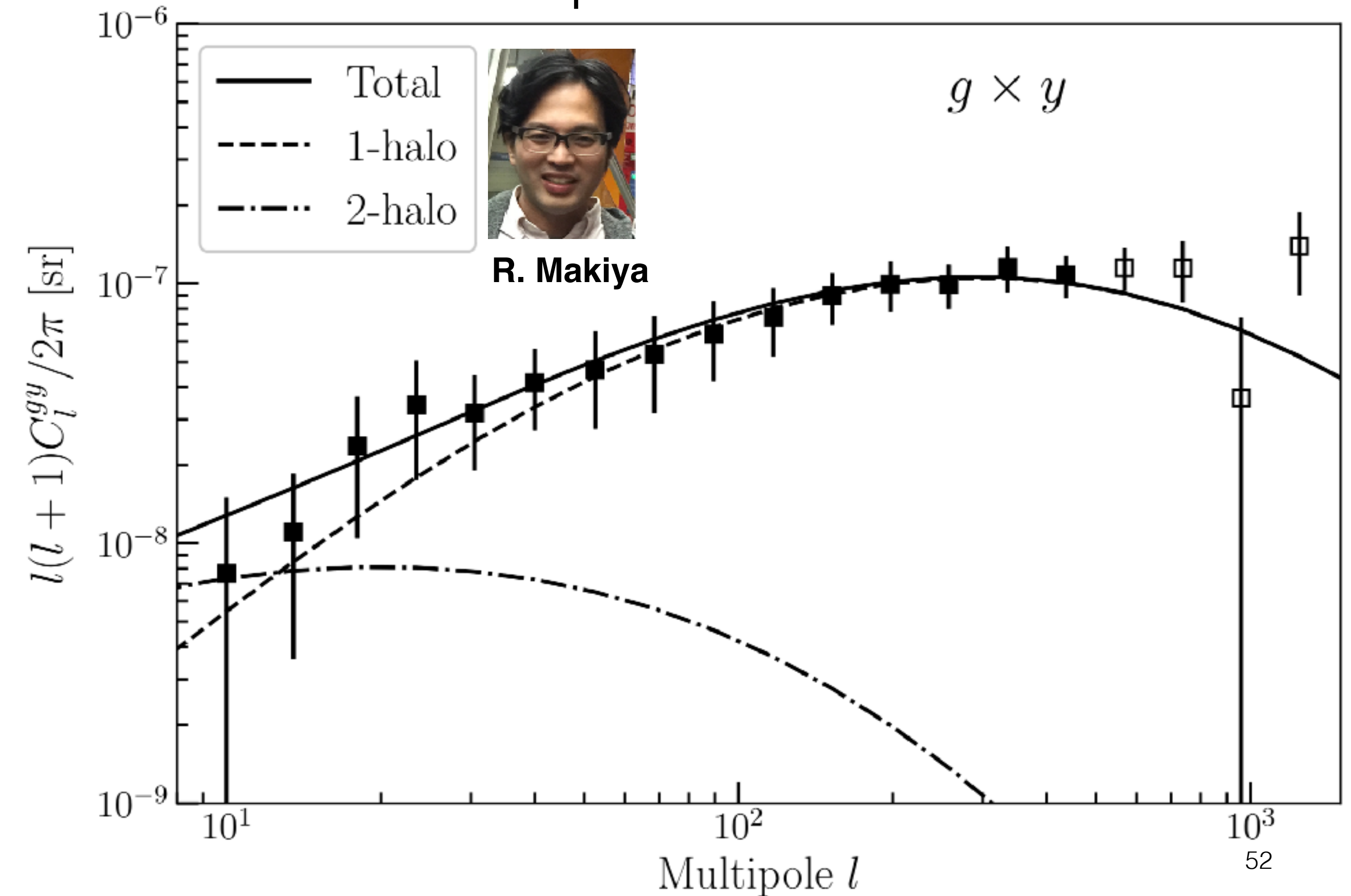


2MASS Redshift Survey

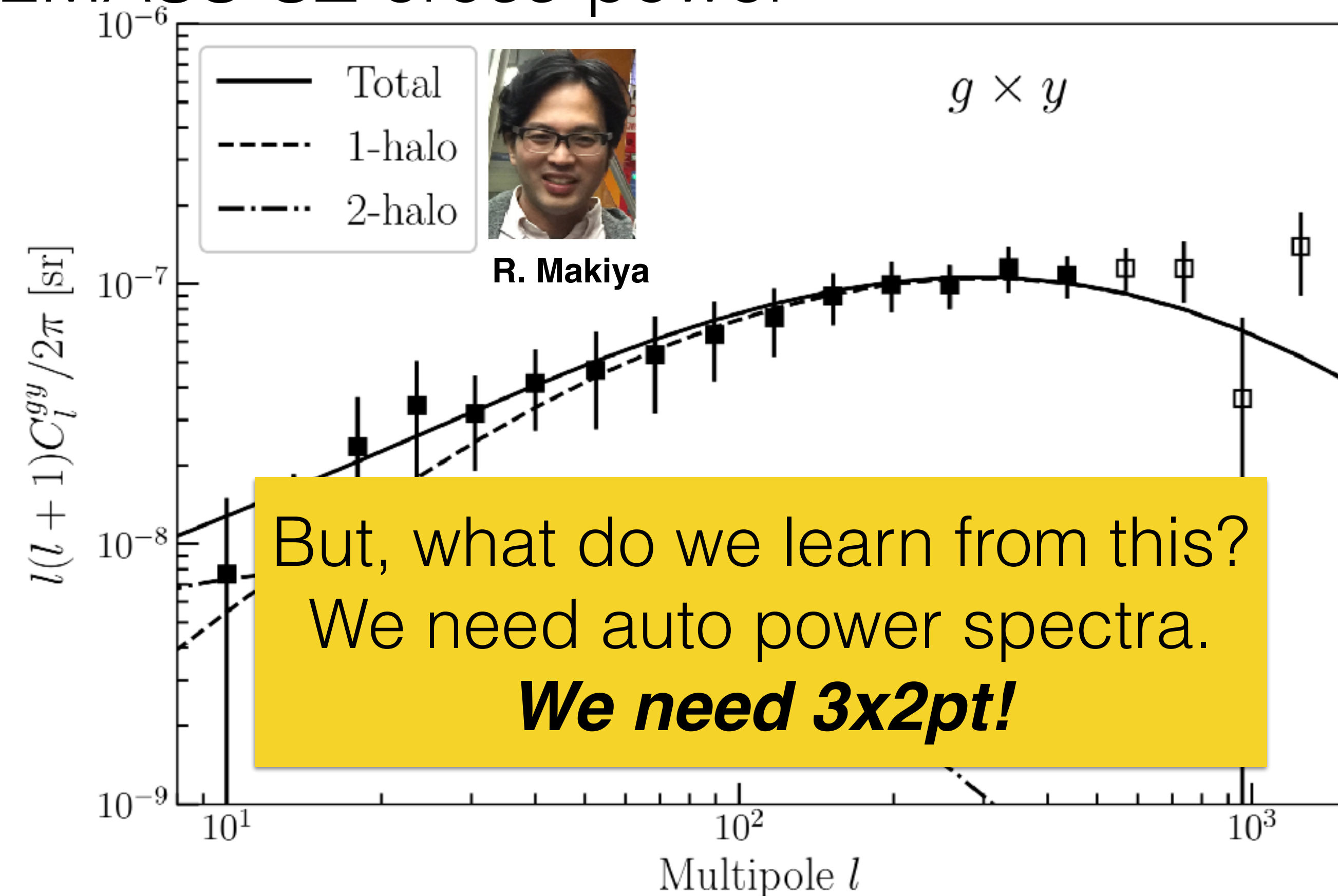
- ~40K galaxies with the median redshift of 0.02



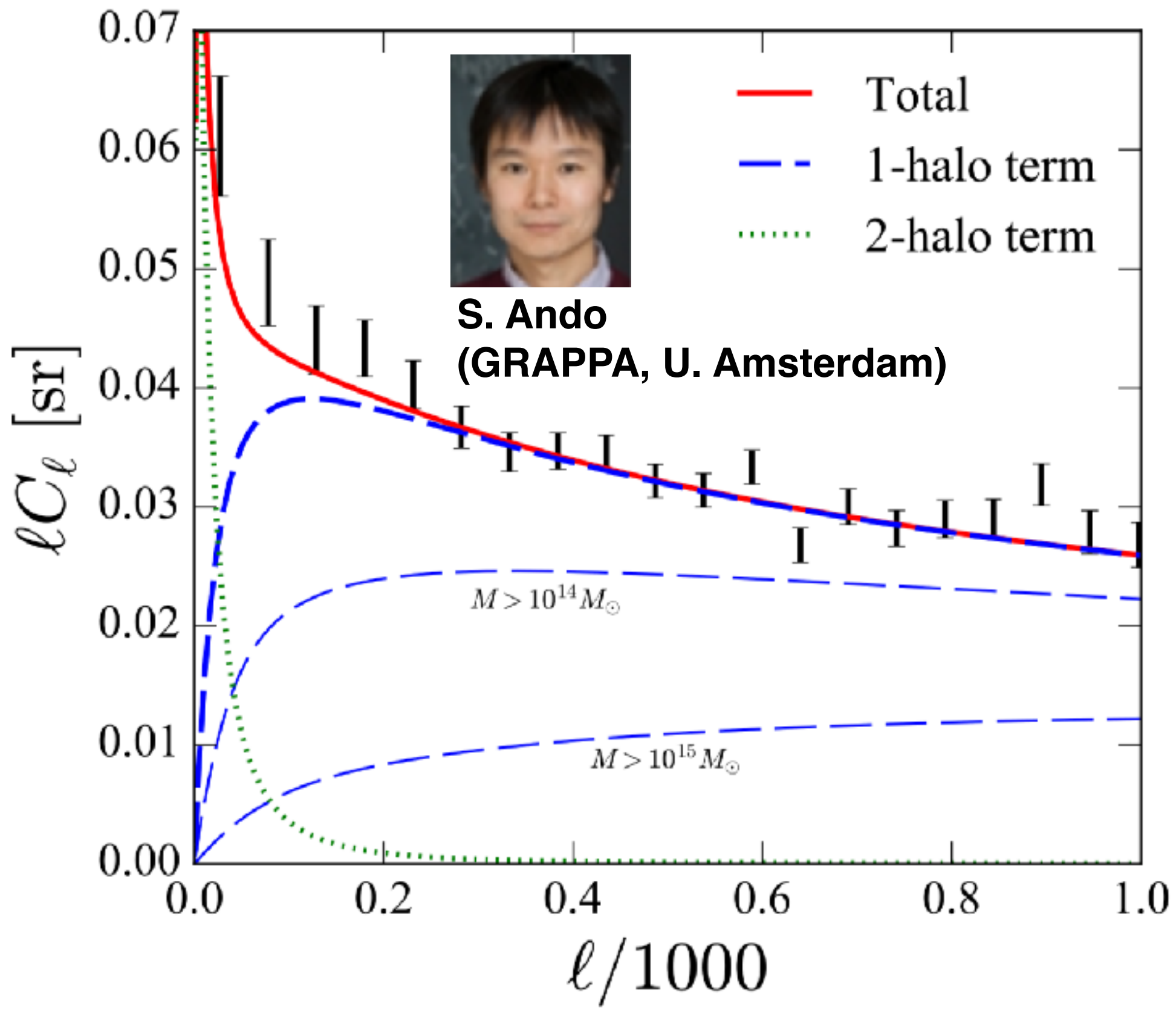
First measurement of the *Makiya, Ando & EK (2018)* 2MASS-SZ cross-power

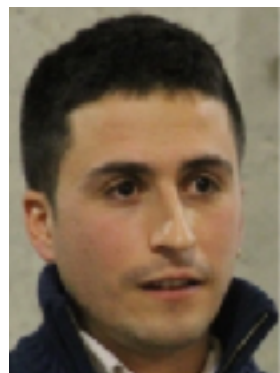


First measurement of the *Makiya, Ando & EK (2018)* 2MASS-SZ cross-power



2MRS Auto Power



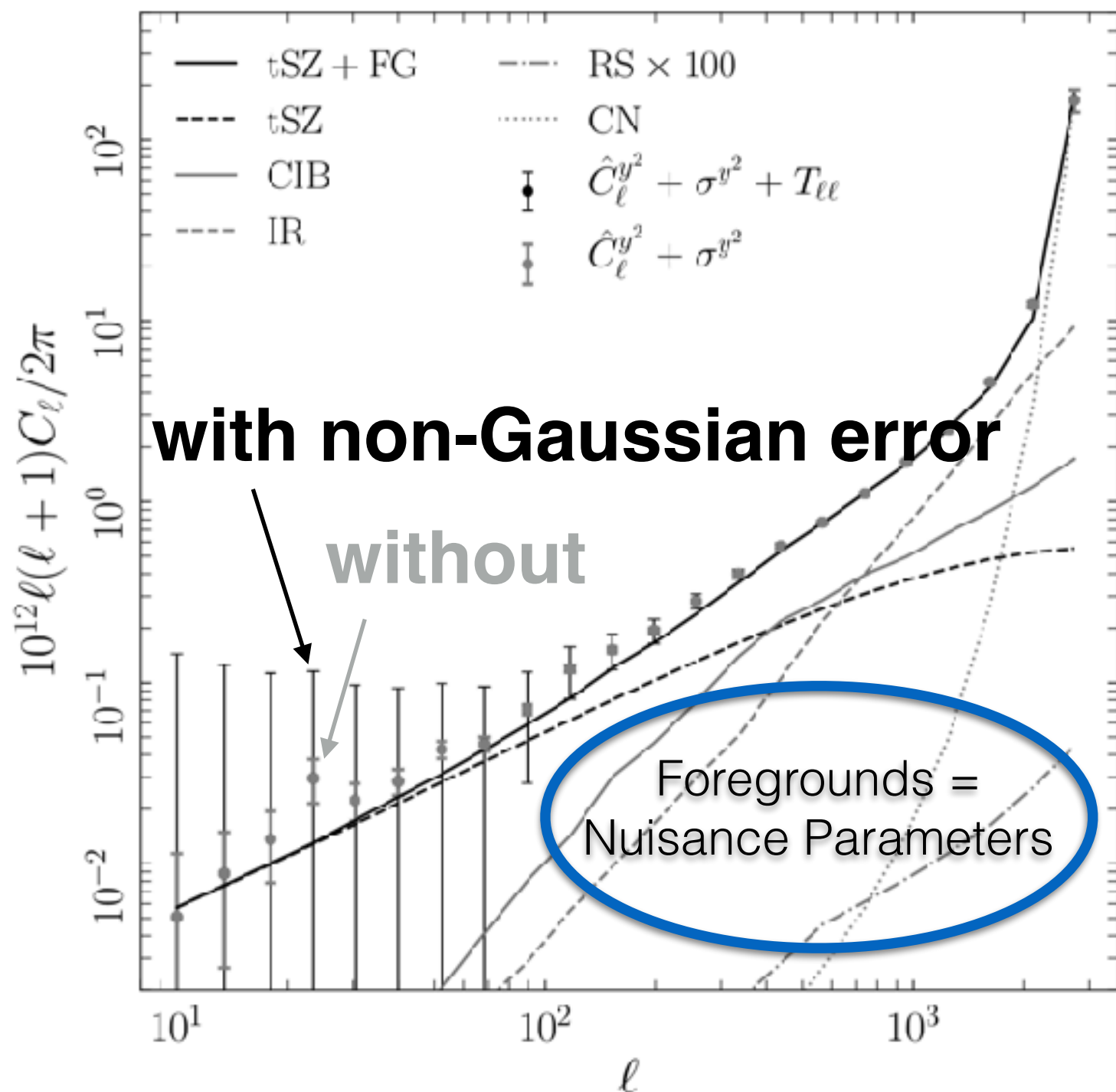


B. Bolliet
(U. Manchester)

Planck Collaboration (2016)
Bolliet, Comis, EK, Macias-Pérez (2018)

SZ Auto Power

- **Far** from Gaussian.
We need to include non-Gaussian error bars
[connected trispectrum]
- When fitting, the Planck team used Gaussian covariance ignoring the non-Gaussian term
- We also have a bunch of nuisance parameters

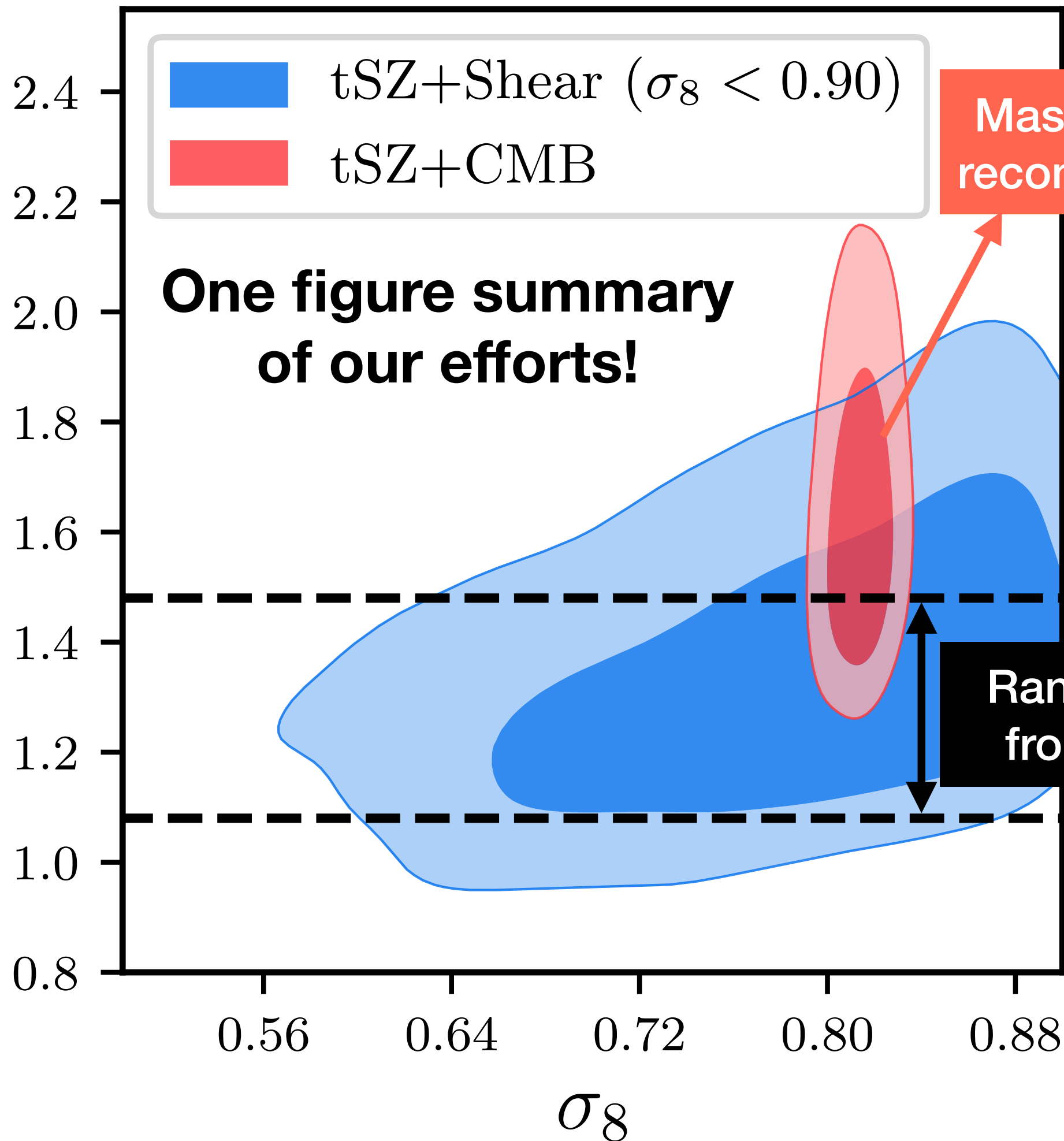


Key Quantity: Mass Bias

$$\tilde{M}_{500c} = M_{500c,\text{true}}/B$$

- **We have been working hard on measuring this quantity**
- Three approaches:
 - What is the value of B that is needed to reconcile the SZ data with the Planck CMB cosmology?
 - What is the value of B that is needed to reconcile the SZ data with weak lensing data without any reference to CMB?
 - What is the value of B that is expected from astrophysics of galaxy clusters?

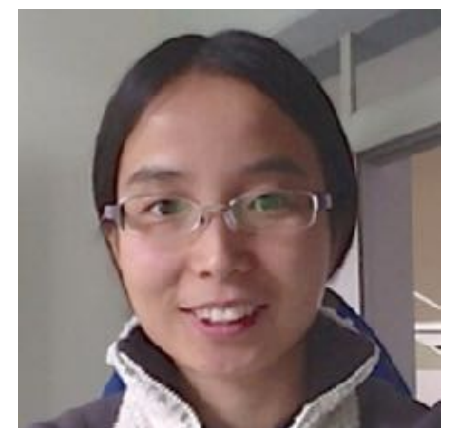
Mass bias B



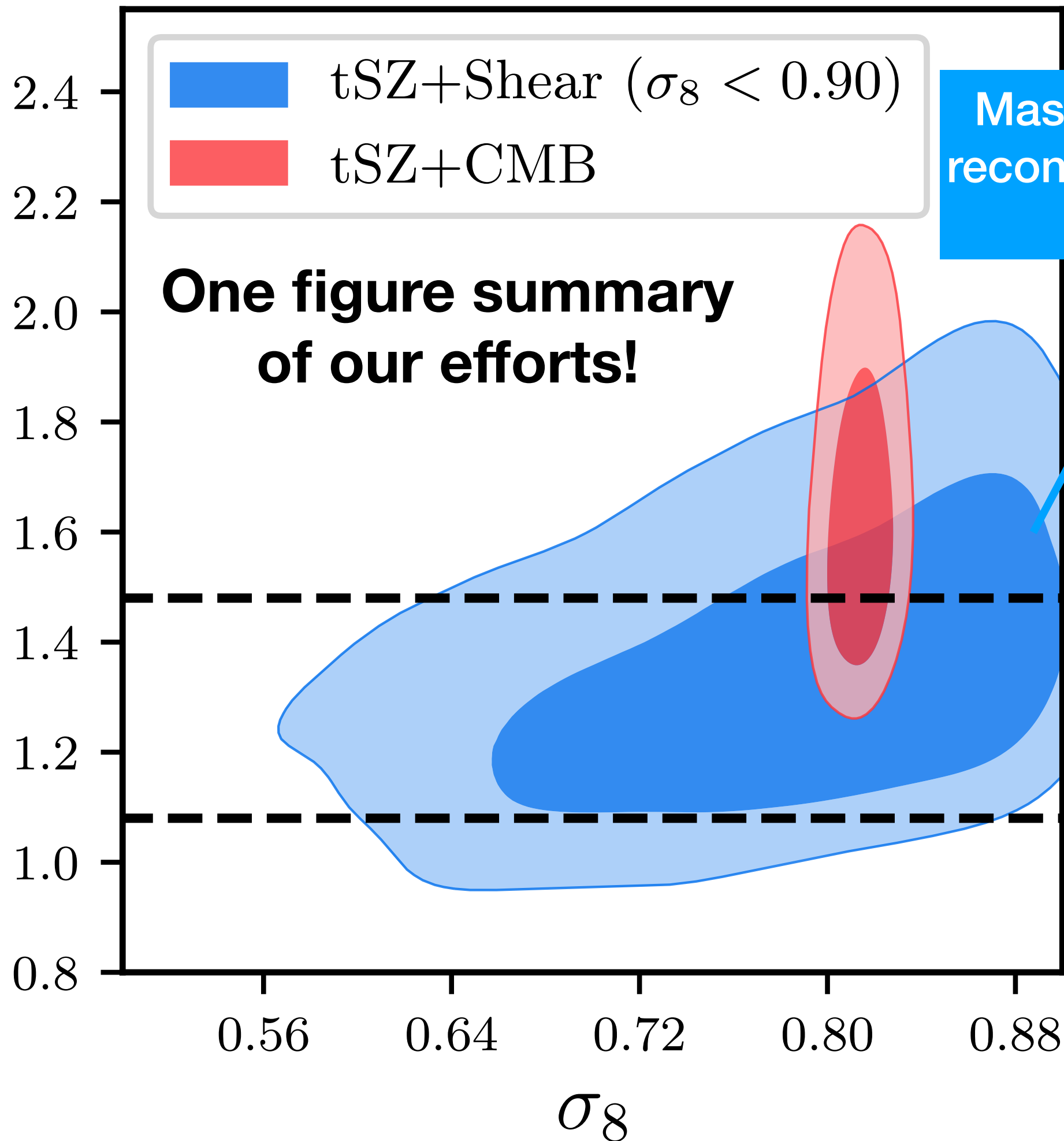
Makiya et al. (2018)
Bolliet et al. (2018)



Shi et al.
(2014,2015,2016)



Mass bias B



Mass bias needed to reconcile SZ and shear.
No CMB!

Makiya et al. (2019)



Conclusion:
Non-CMB data agree with astrophysical expectation!

Another indication of a tension between CMB and low-z data?

Hobby-Eberly Telescope Dark Energy Experiment

Location

McDonald Observatory
(West Texas)

Primary Mirror Size

10 m

Wavelength Coverage

350–550 nm ($\Delta\lambda=6.2\text{\AA}$)

Spectrograph Type

Integral Field Unit (IFU)

Field of View

0.1 deg² (22' diam.)
~20 Mpc in one go!

Survey Volume

2.8 (Gpc/h)³

of fibers

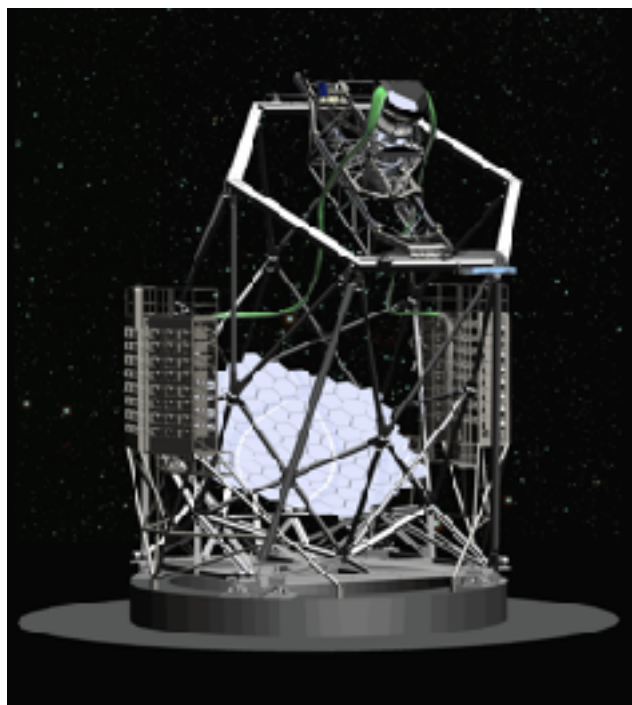
34,944

Fiber Diameter

1.5 arcsec

Survey Type

Blind



Prime Focus
Spectrograph

PFS

Location

Subaru Telescope
(Hawaii)

Primary Mirror Size

8.2 m

Wavelength Coverage

Blue: 380–650 nm ($\Delta\lambda=2.1\text{\AA}$)
Red(LR): 630–970 nm ($\Delta\lambda=2.7\text{\AA}$)
Red(HR): 710–885 nm ($\Delta\lambda=1.6\text{\AA}$)
NIR: 940–1260 nm ($\Delta\lambda=2.4\text{\AA}$)

Spectrograph Type

Robotic Multi Object Fiber-fed

Field of View

1.25 deg² (1.38 deg diam.)

Survey Volume

8.2 (Gpc/h)³

Redshift ([OII])

z=0.02–0.74
z=0.69–1.60
z=0.90–1.37
z=1.52–2.38

of fibers

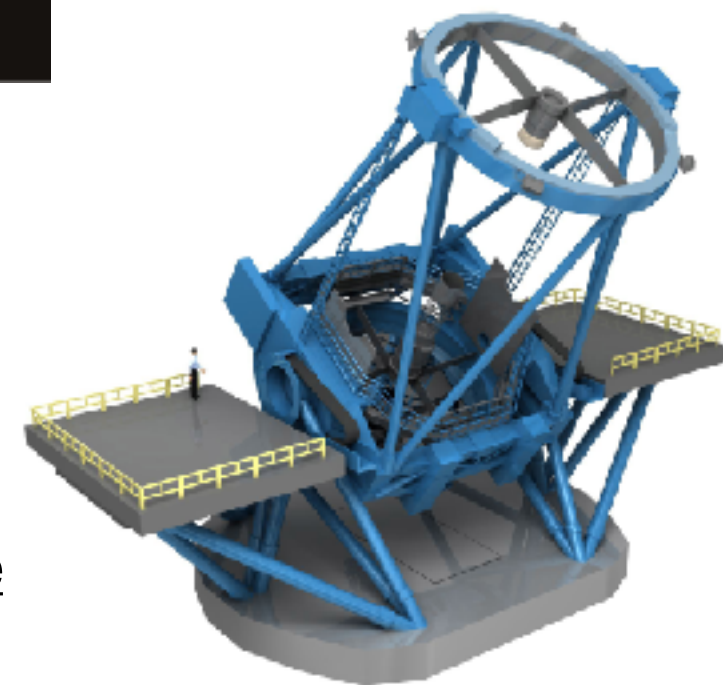
2,394 + 96

Fiber Diameter

1.2 arcsec

Survey Type

Traditional

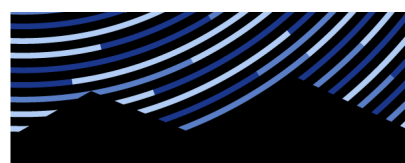


HETDEX
Hobby-Eberly Telescope Dark Energy Experiment

Illuminating the Darkness

Hobby-Eberly Telescope Dark Energy Experiment

**Texas-led
\$42M experiment**



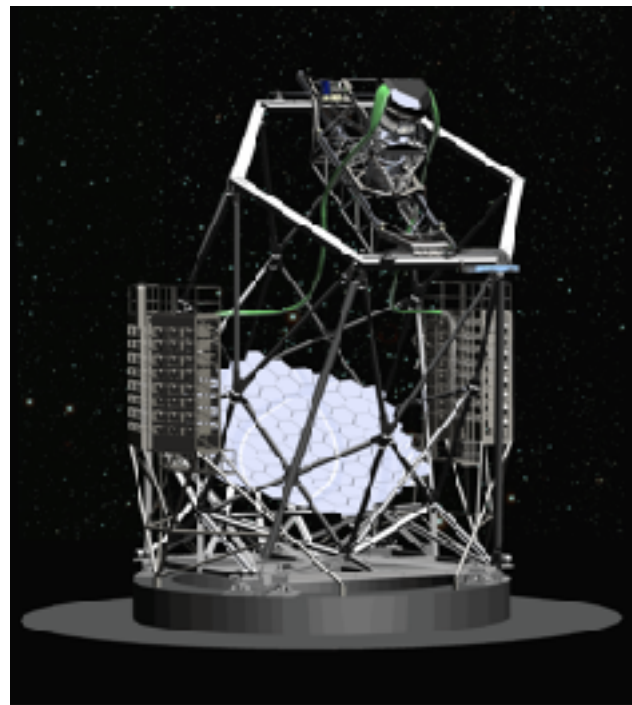
McDonald Observatory
THE UNIVERSITY OF TEXAS AT AUSTIN



Main Objective:
Cosmology

But, we can do:

- Properties of Lyman-alpha emitting galaxies
- **Blind survey:** Unbiased survey of everything



Prime Focus
Spectrograph

PFS

**Japan-led
\$85M instrument**

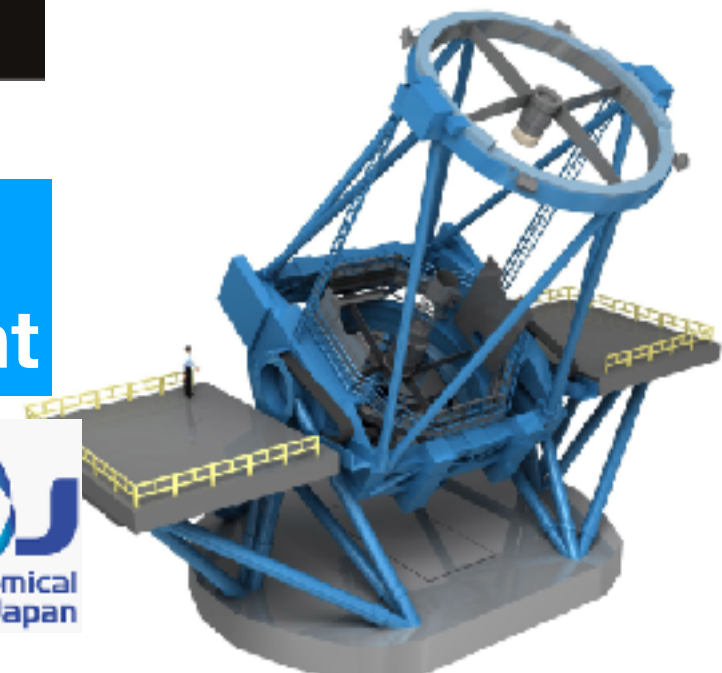


Main Objective:

Spectroscopic follow-up of targets detected
by the imaging survey of Hyper Suprime Cam

Three major science programs:

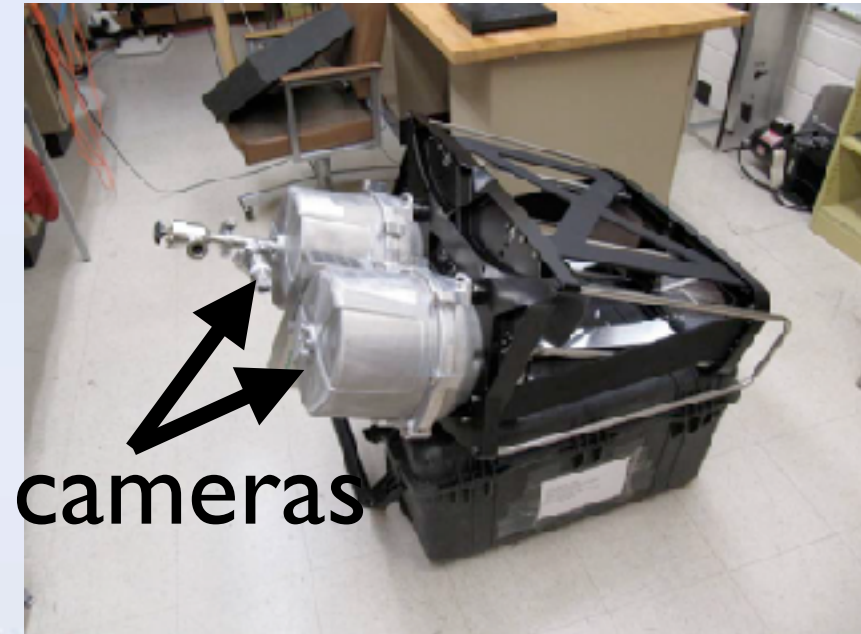
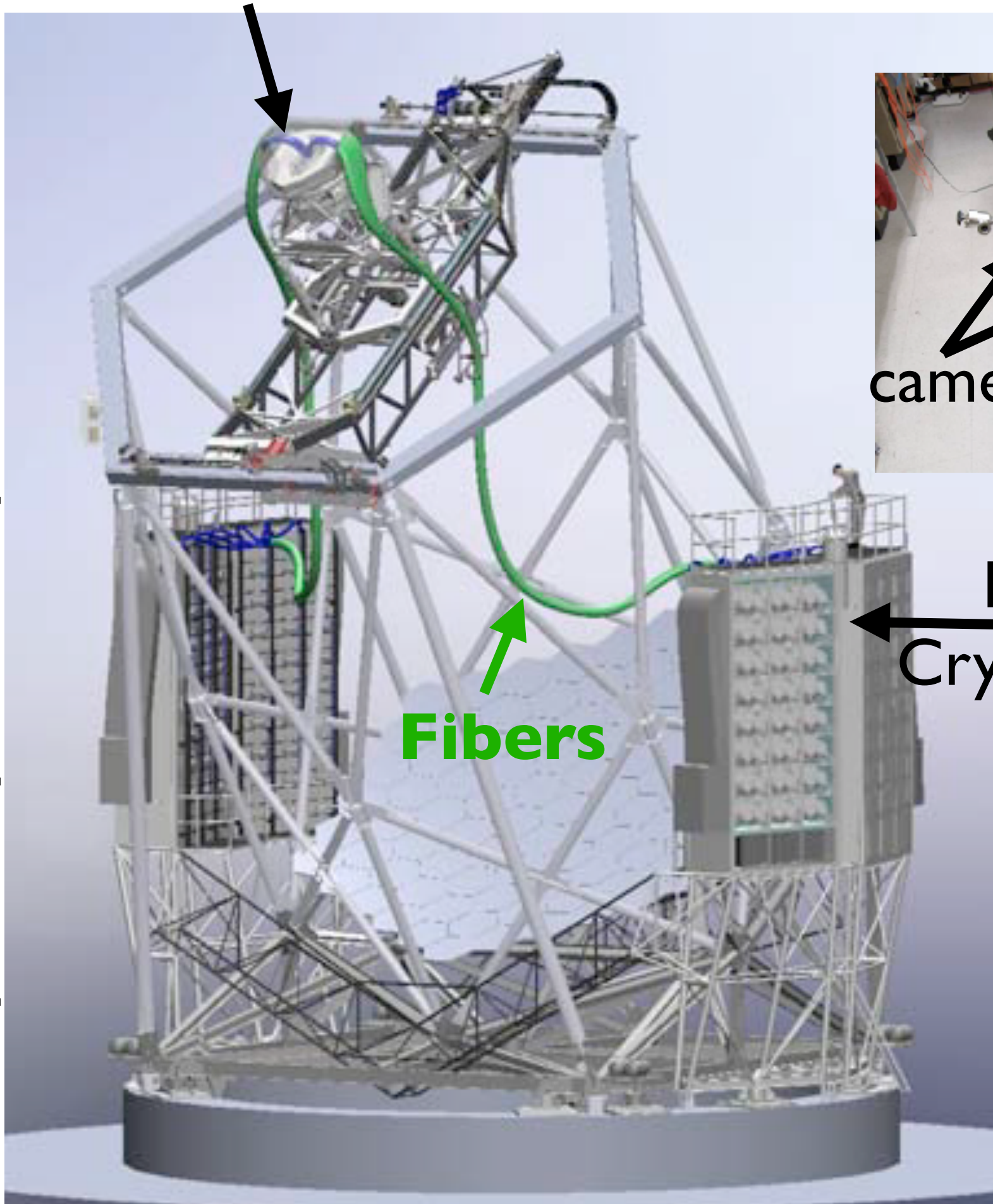
- Cosmology
- Galaxy Evolution
- Galactic Archeology



Hobby-Eberly Telescope with VIRUS

Prime Focus Instrument (2 tons!)

One *VIRUS*
Detector Unit



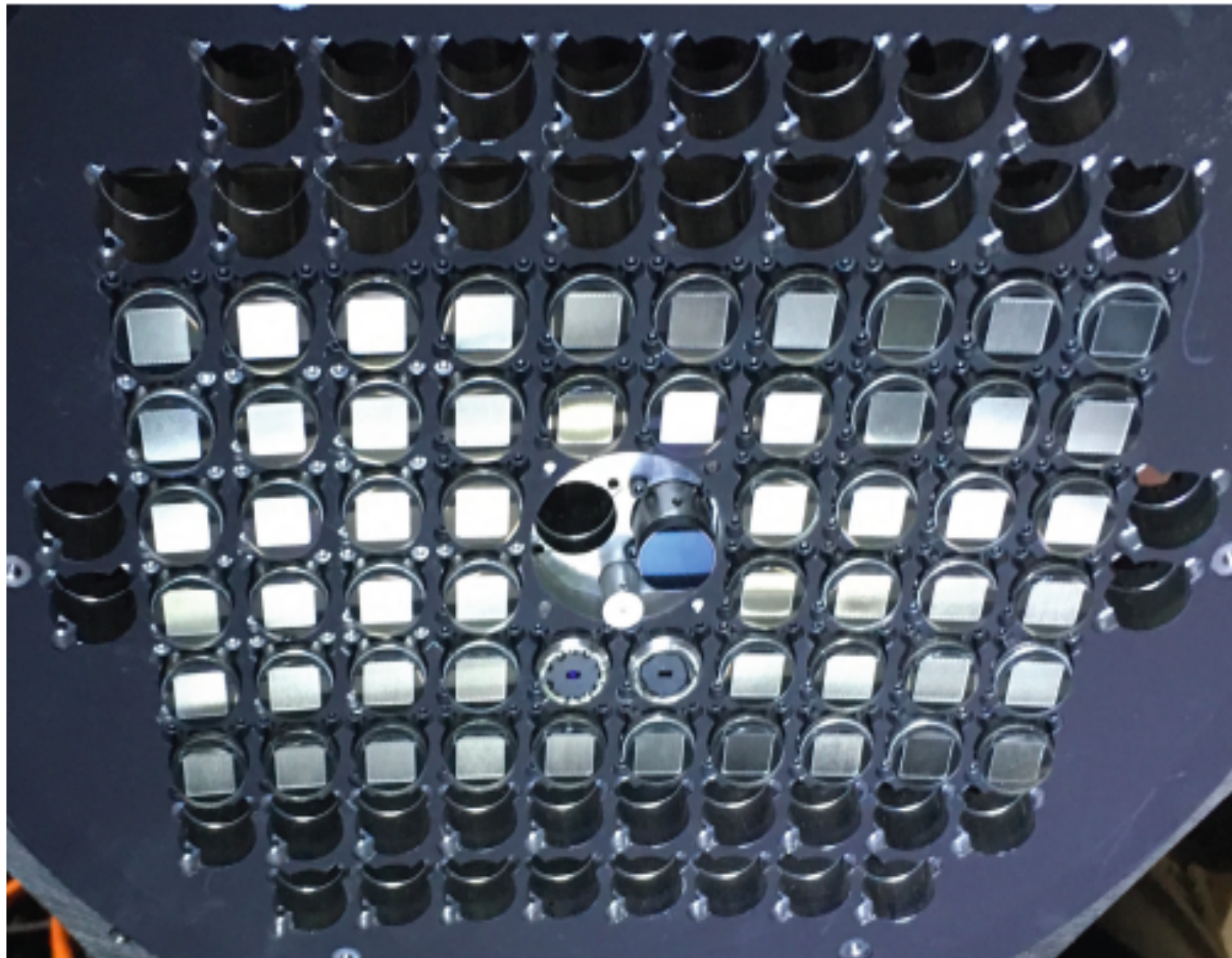
Detectors /
Cryogenic system



HETDEX Started!

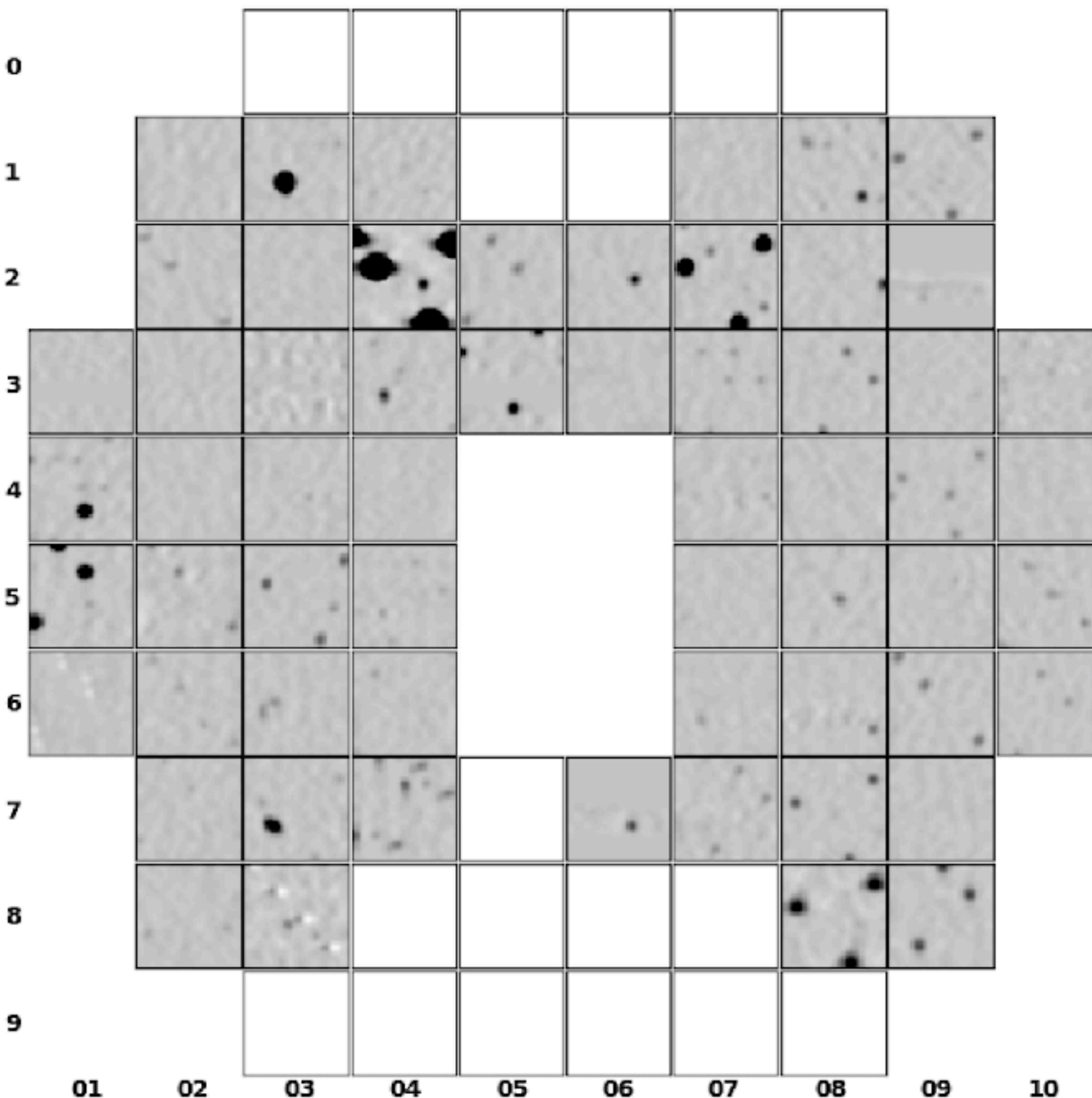
- We have been taking HETDEX data since March 2017
- As of October 28, 2019: *133 million* calibrated spectra!
 - 74,411 IFUs on the sky
 - $74,411 \times 448$ (# of fibers per IFU) $\times 3$ (dither) = 133M
- And this is only 16% of the full survey data!
 - Goal: 468,000 IFUs on the sky
- ***629M* calibrated spectra. This is the big data!**

VIRUS = World's Largest IFS



- 59 IFUs (out of 78) are active now. More IFUs will be installed as they are built (at the rate of 3 units per month)
- $59 \times 448 = \mathbf{26,432}$ fibers! And this is the open-use instrument

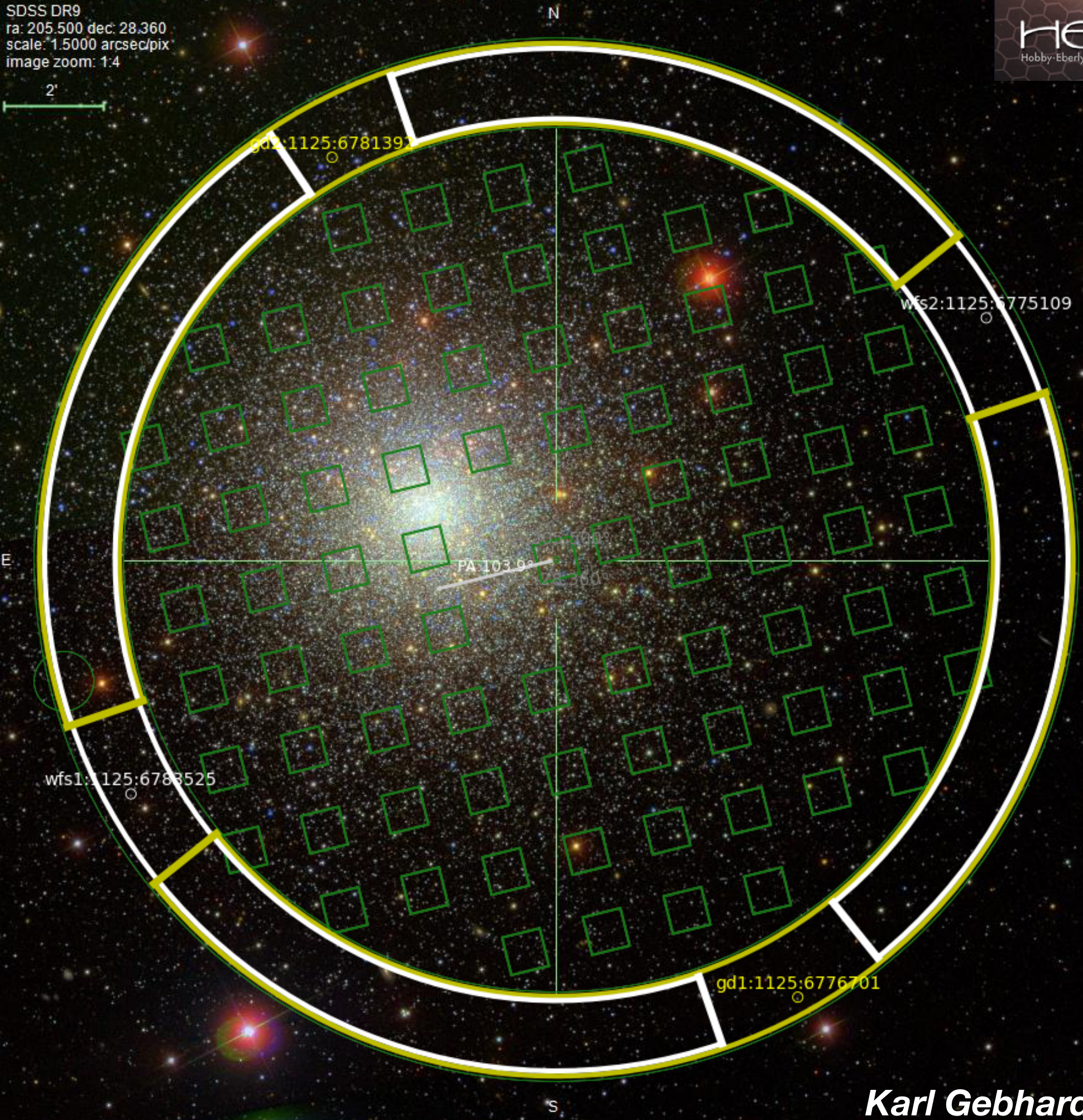
A typical hetdex field



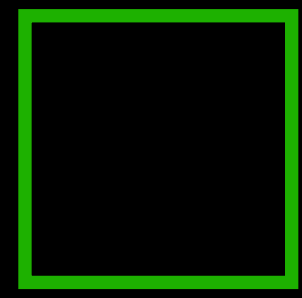
Reconstructed image of the **26k** fibers. Filled squares are active IFUs, open squares are those remaining.

In this frame, we would use about 15 of the stars for astrometry and throughput measures.

SDSS DR9
ra: 205.500 dec: 28.360
scale: 1.5000 arcsec/pix
image zoom: 1.4

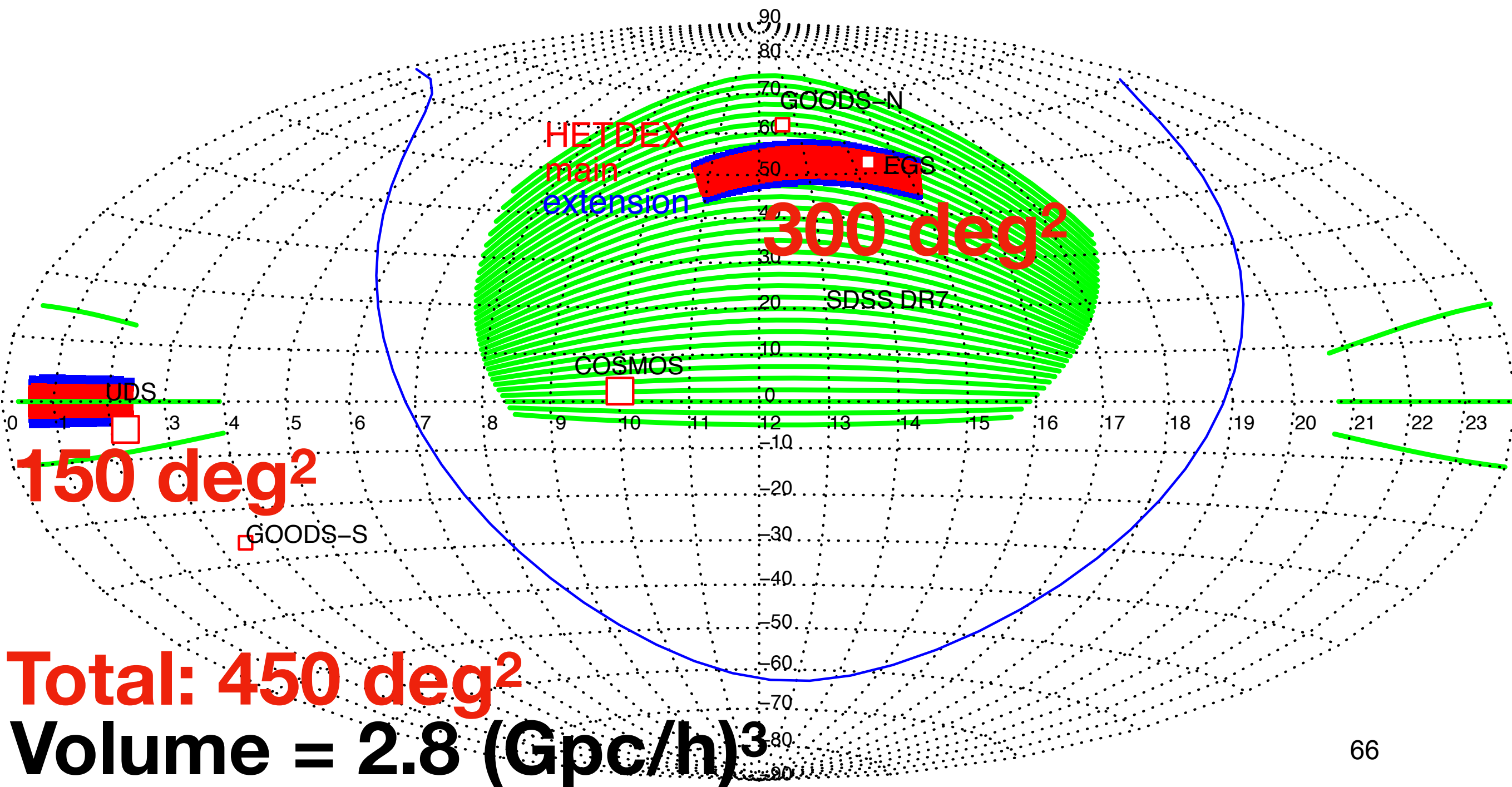


Example of full field on M3. Green boxes are the IFU locations.

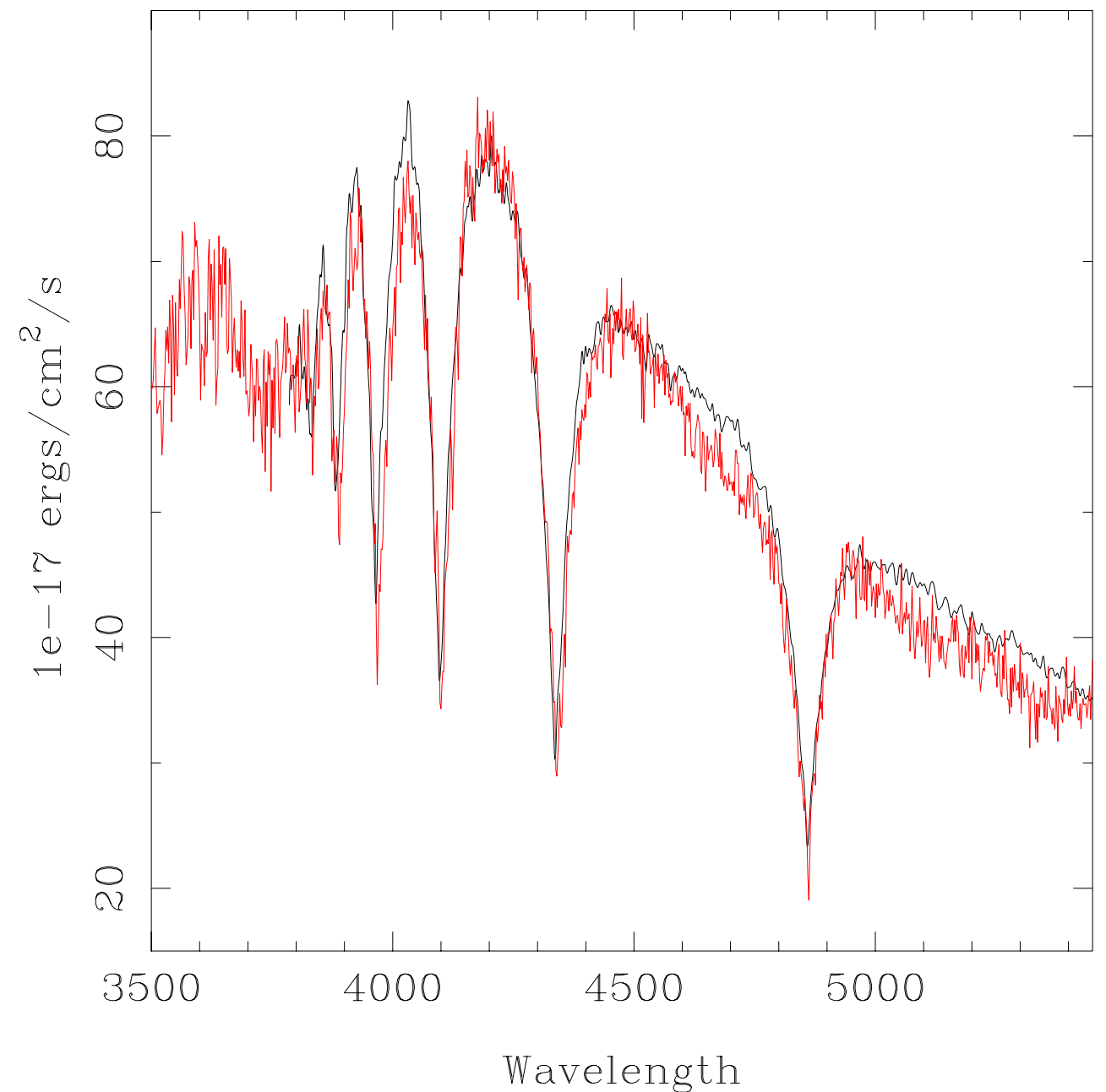
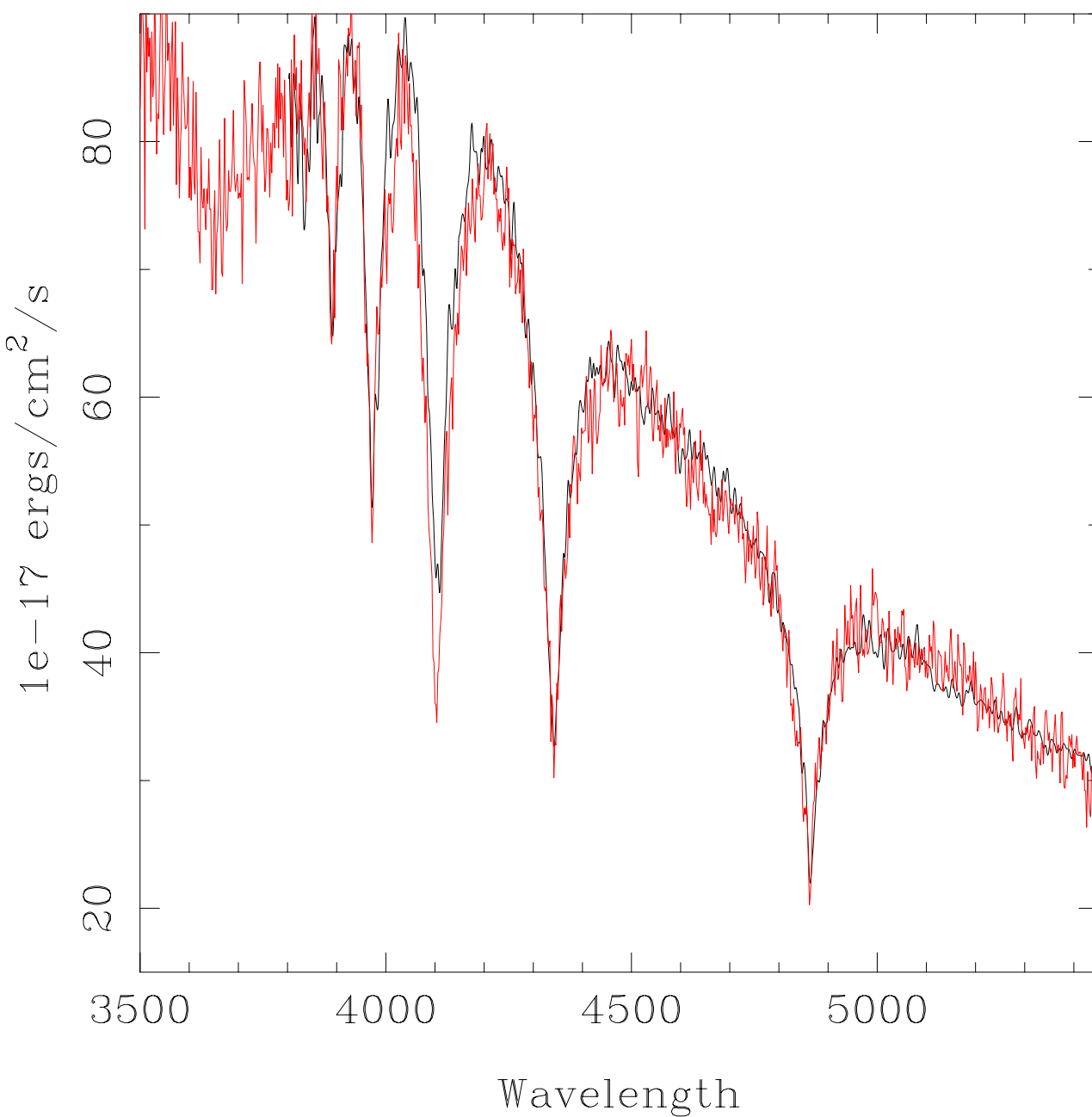


**~1 arcmin,
completely filled
by fibers
(after 3 dither)**

HETDEX Foot-print (in RA-DEC coordinates)



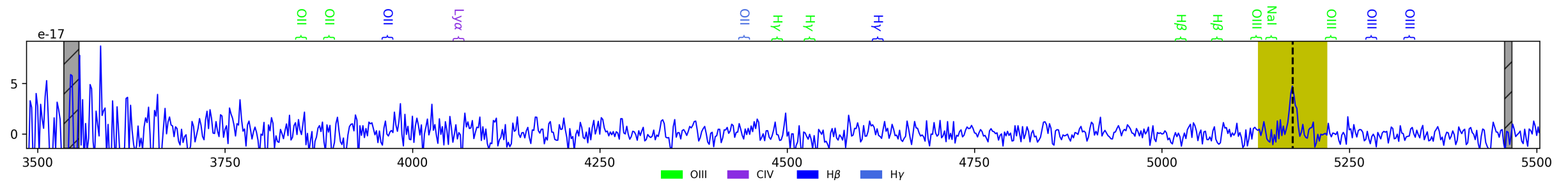
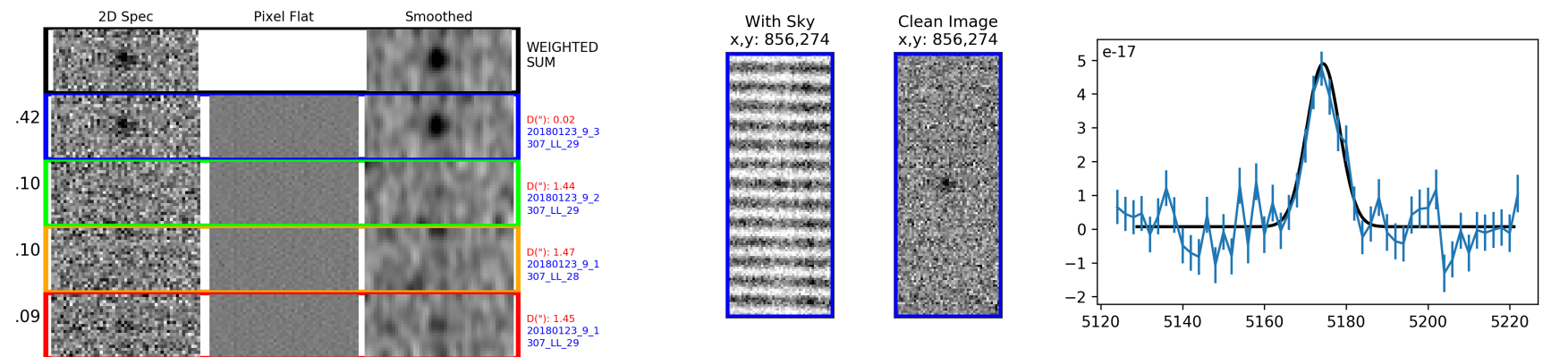
Example calibration check, using 2 white dwarfs from SDSS (virus in red, SDSS in black)



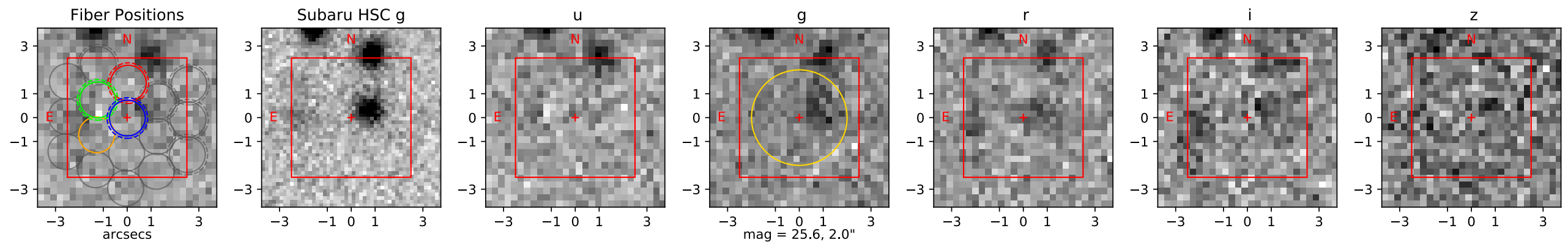
Examples from one field

2018-10-23 13:09:51 Version 1.5.0a

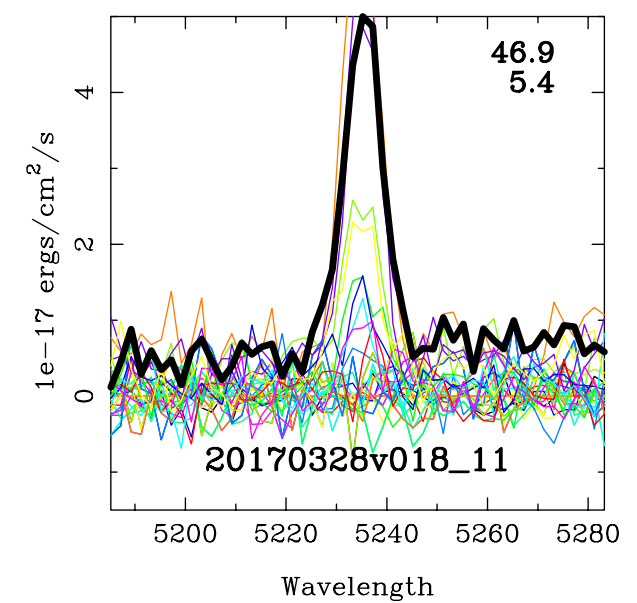
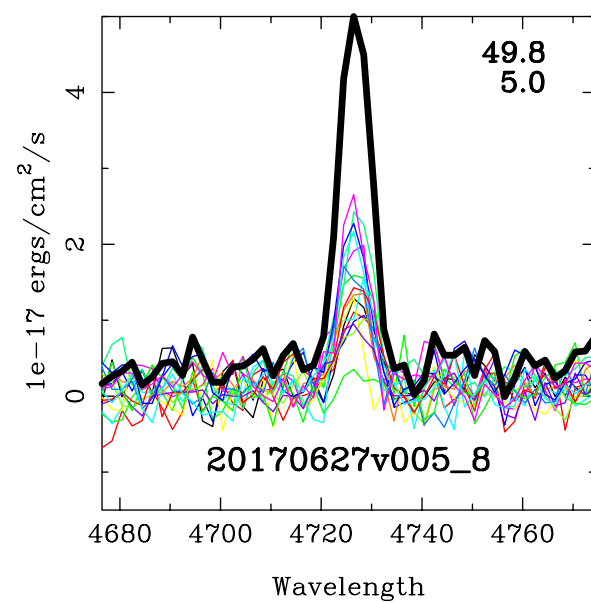
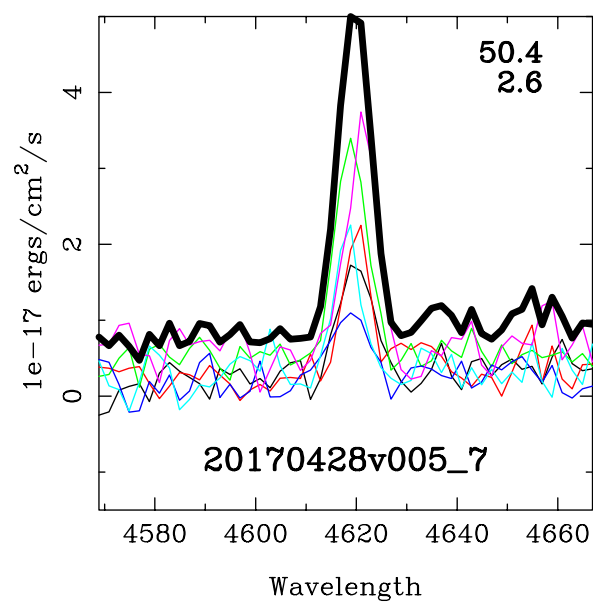
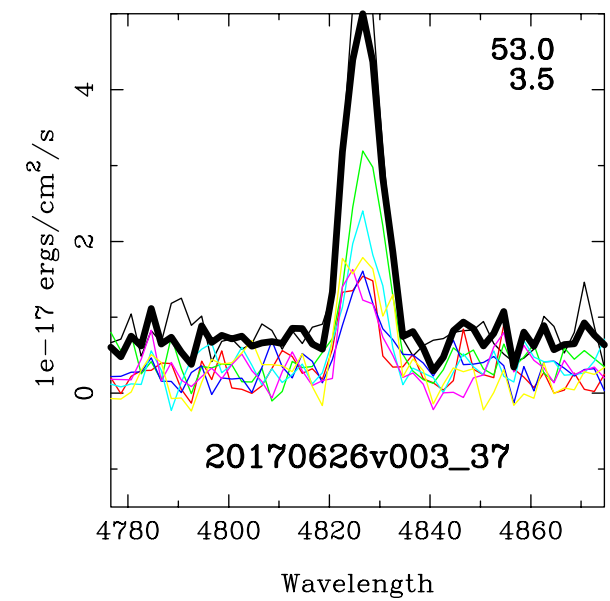
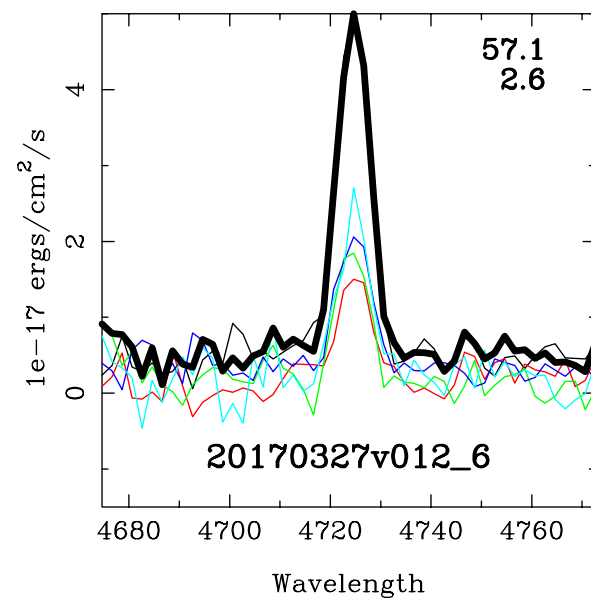
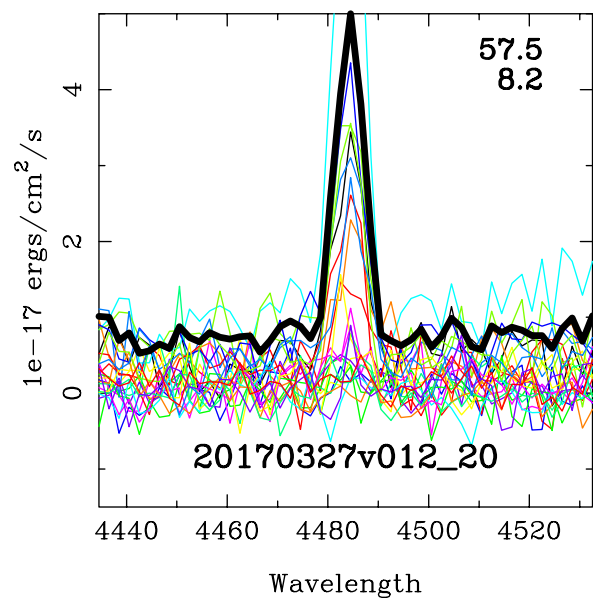
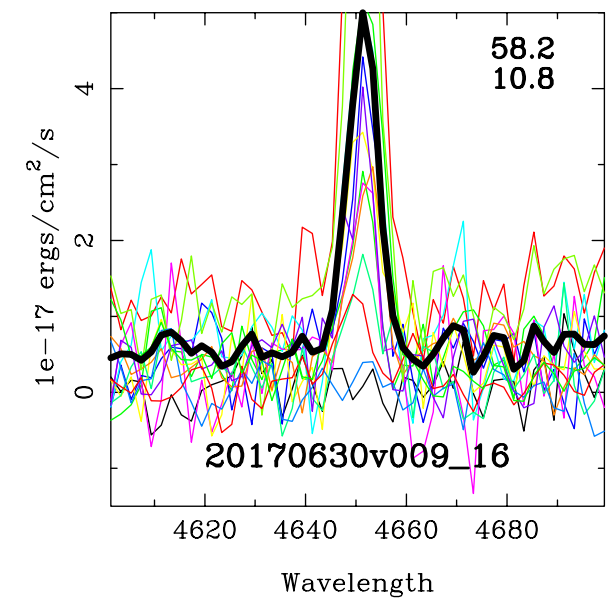
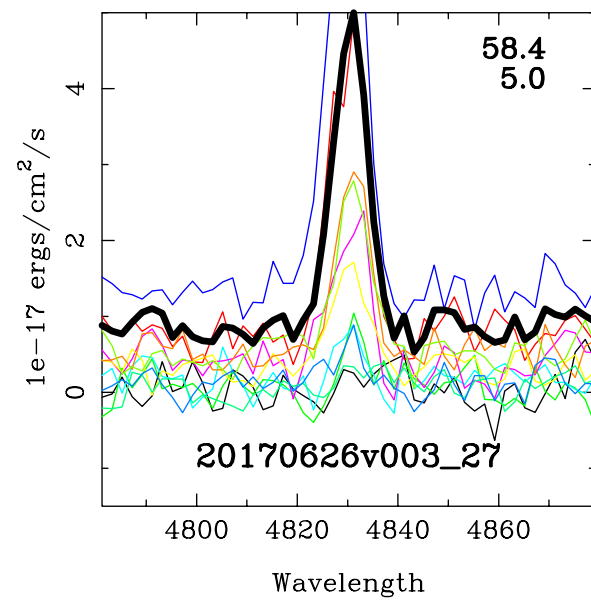
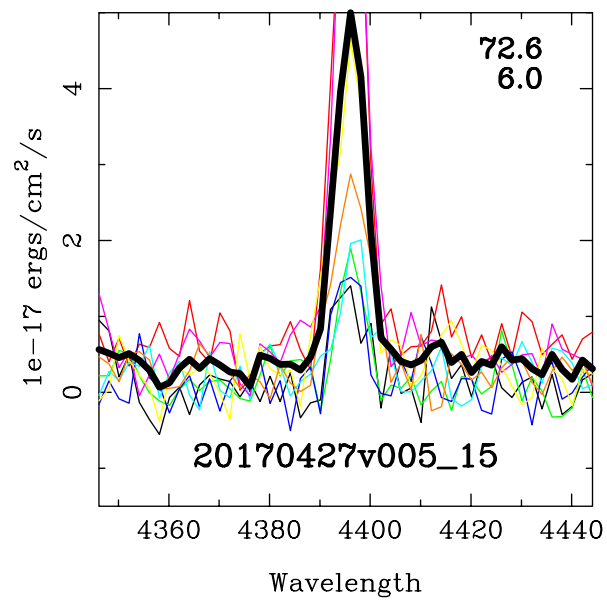
20180123v009_1269.pdf
 Obs: 20180123v09_1
 Entry# (1269), Detect ID (1)
 Primary IFU Slot 074
 RA,Dec (150.038250,2.127700)
 $\lambda = 5174.44\text{\AA}$ FWHM = 9.447 $\text{\AA}$
 EstFlux = 4.58e-16
 EstCont = 5e-19
 EW_r(LyA) = 215 $\text{\AA}$
 S/N = 20.82
 P(LAE)/P(OII) = 999
 LyA z = 3.2553 OII z = 0.3884

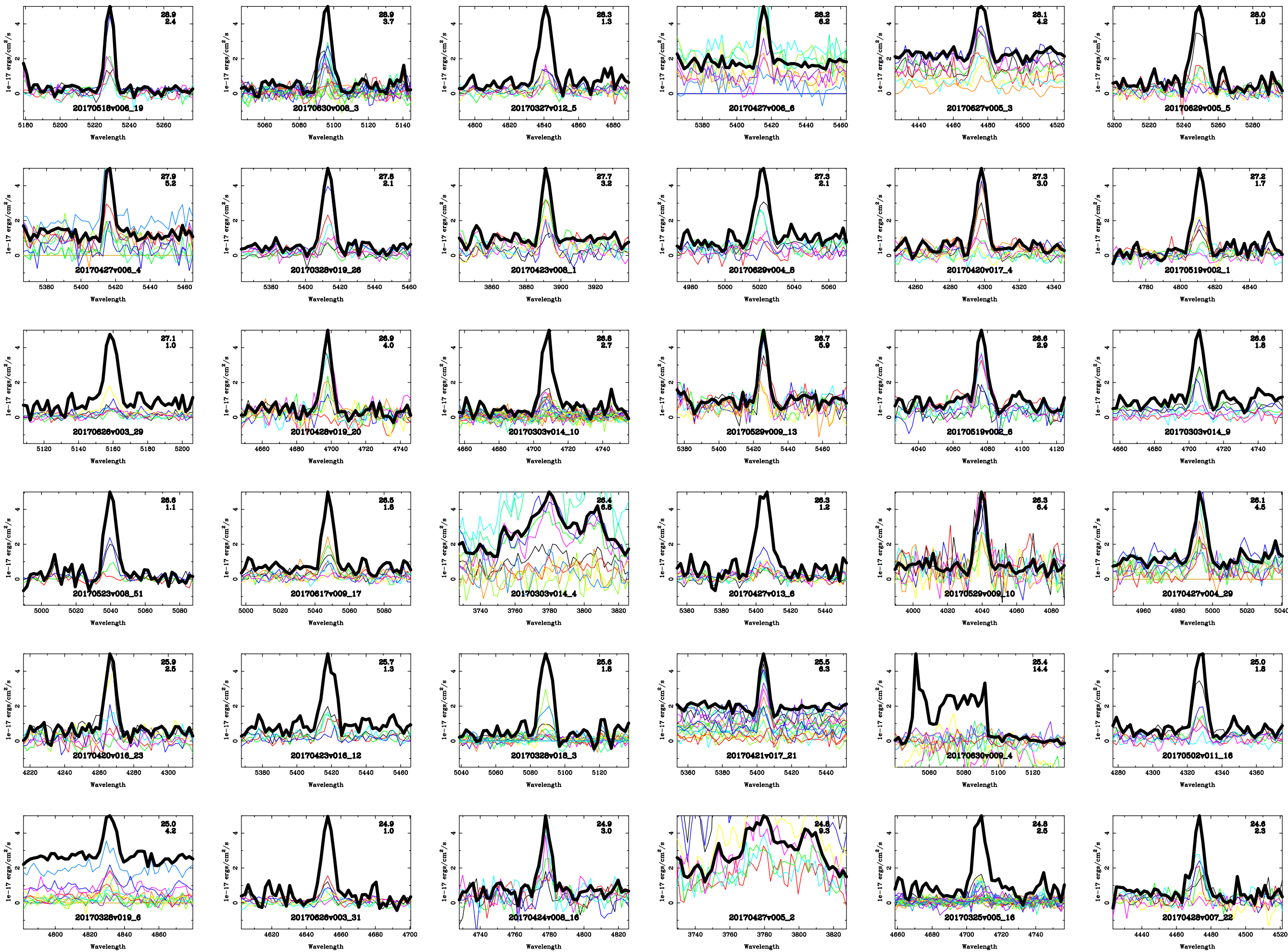


STACK_COSMOS : Possible Matches = 0 (within +/- 2.5") No continuum floor baseline defined.



No matching targets in catalog.
 Row intentionally blank.

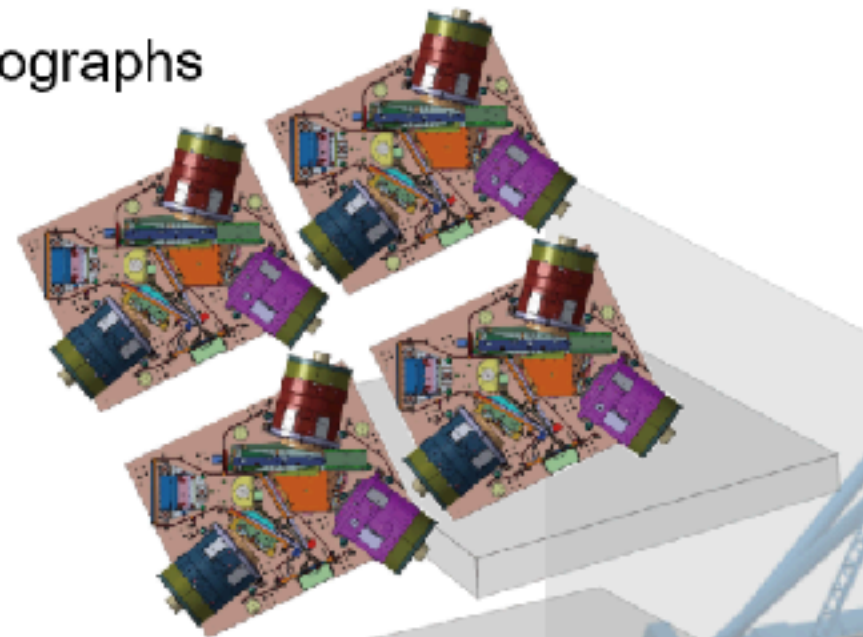




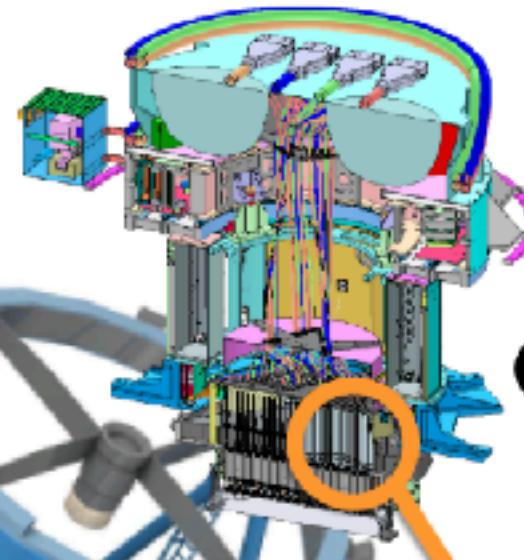
Analysis well underway

- We plan the first “paper splash” next year!

Spectrographs



Prime Focus Instrument



Wide Field Corrector

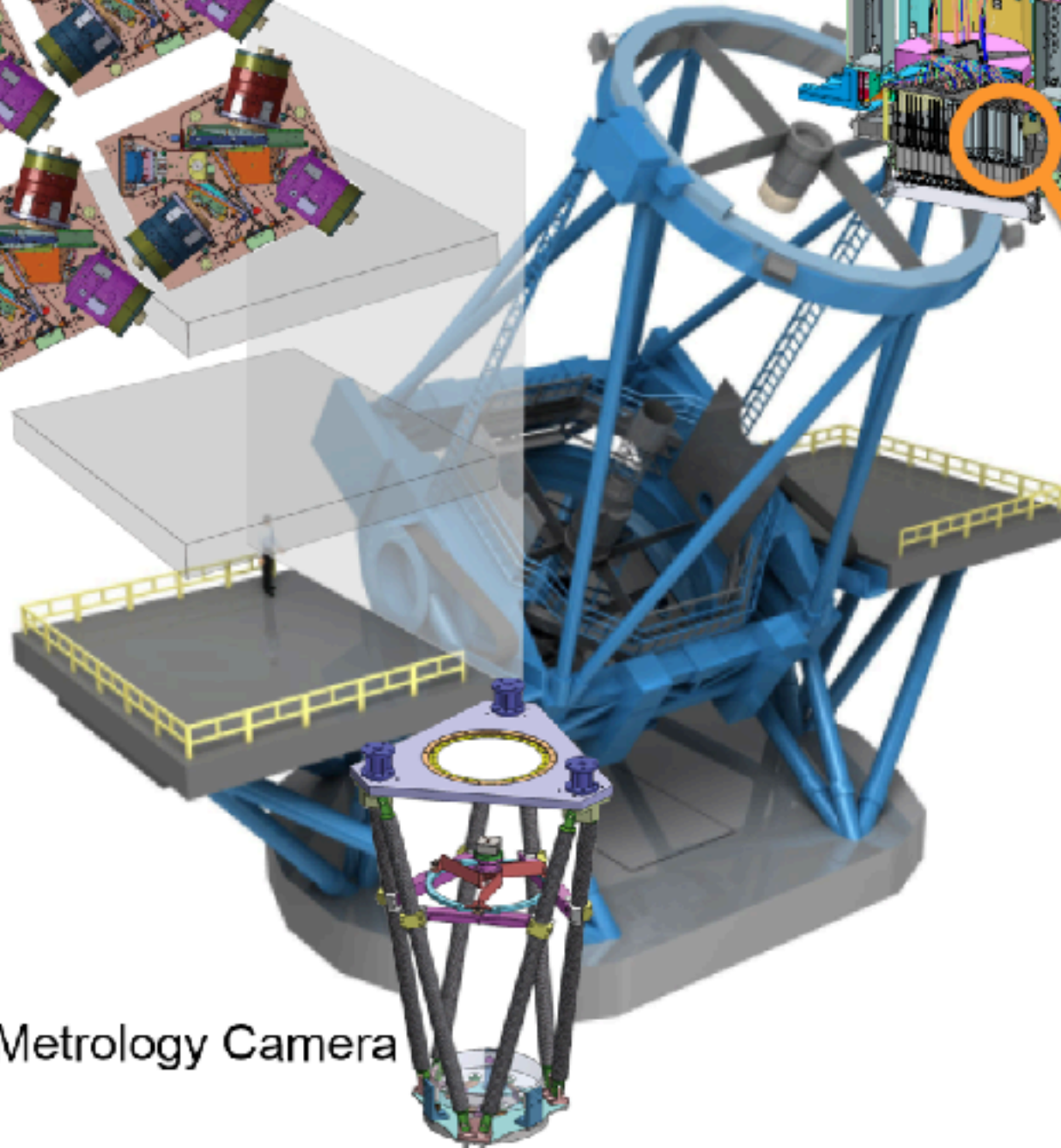


&

Fiber Positioner "Cobra"

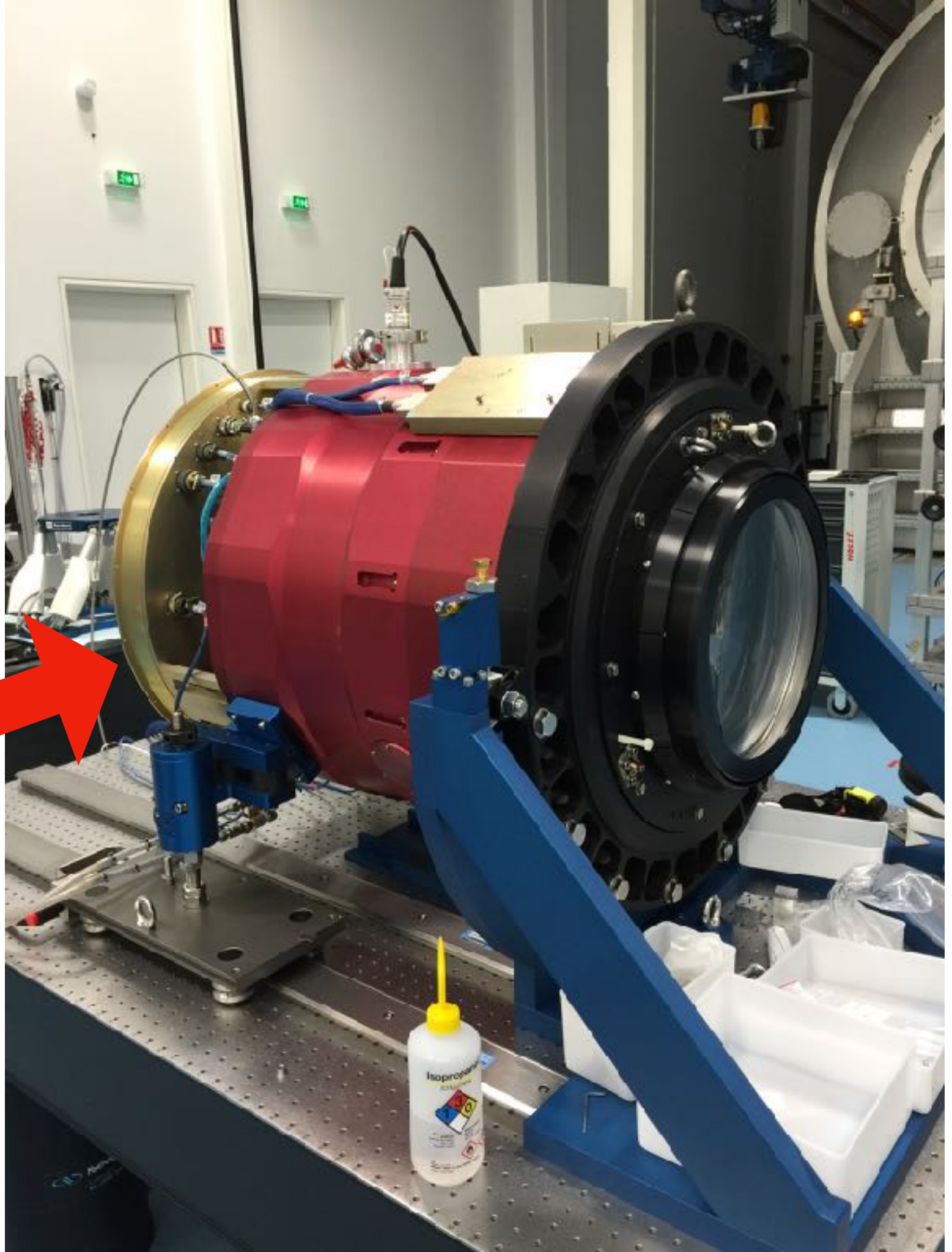
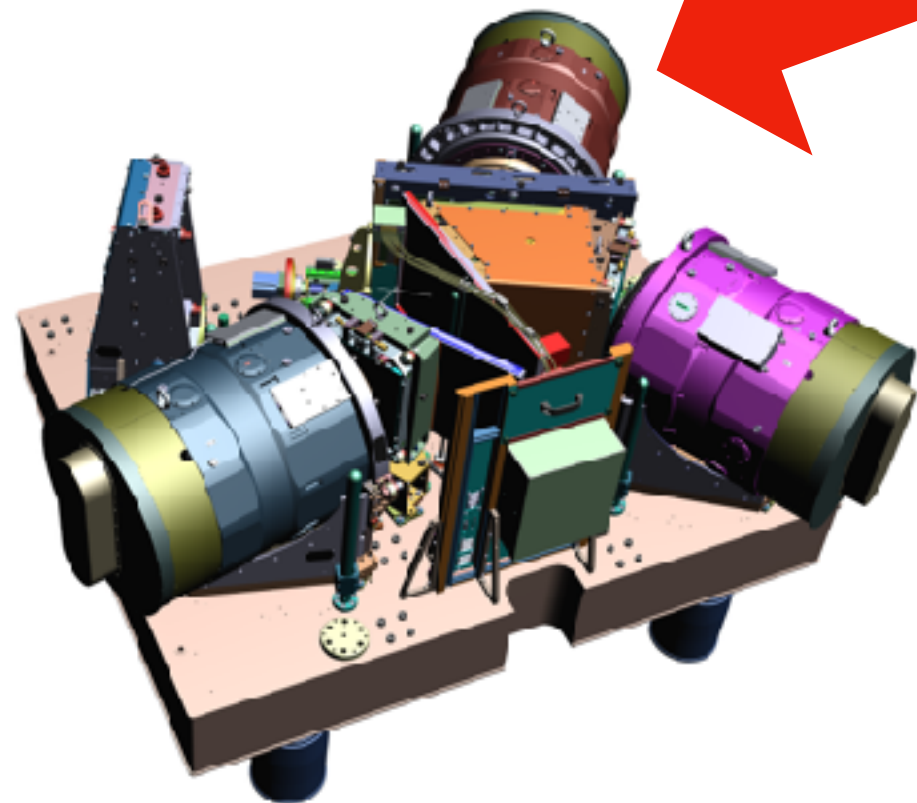


Metrology Camera



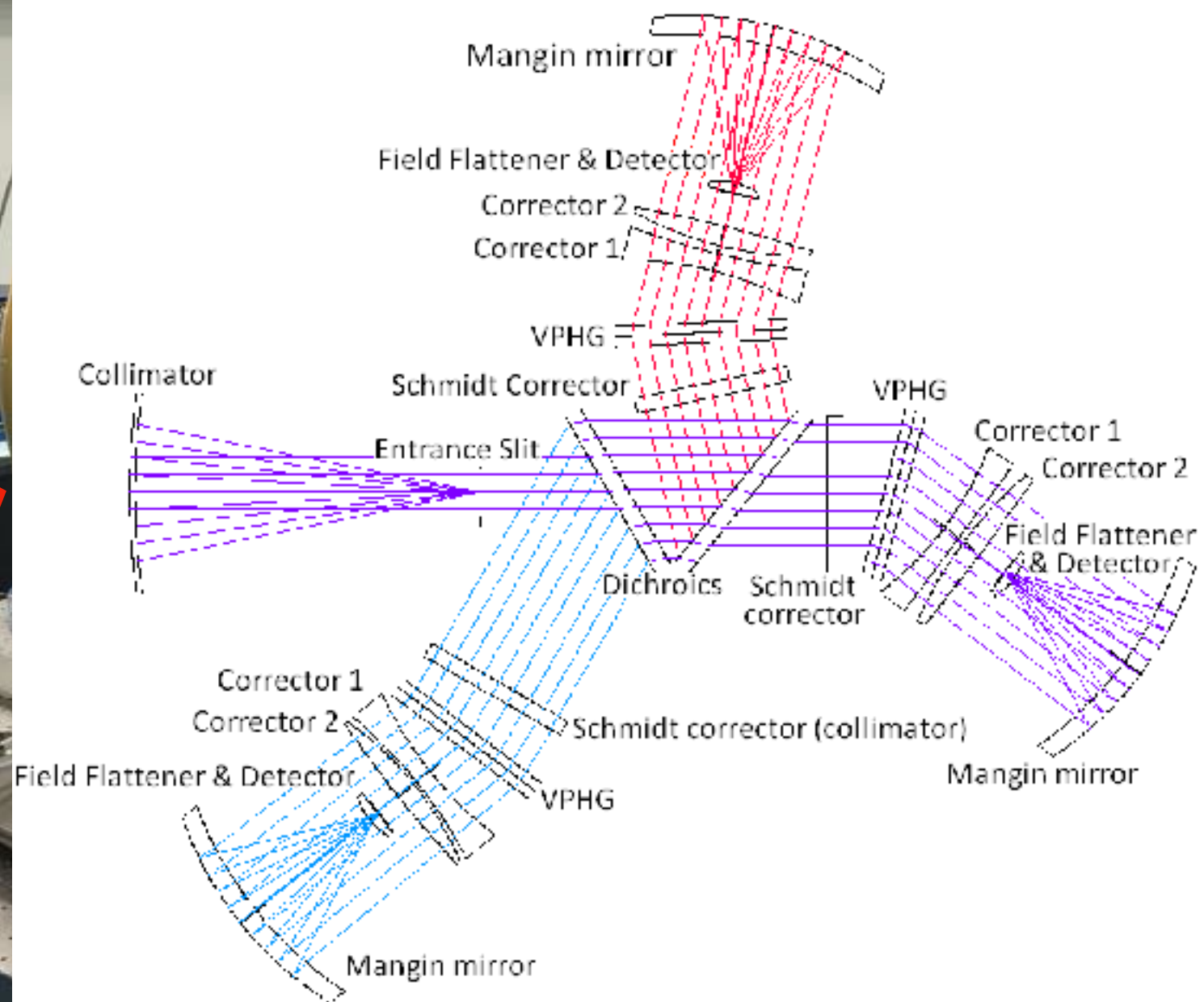
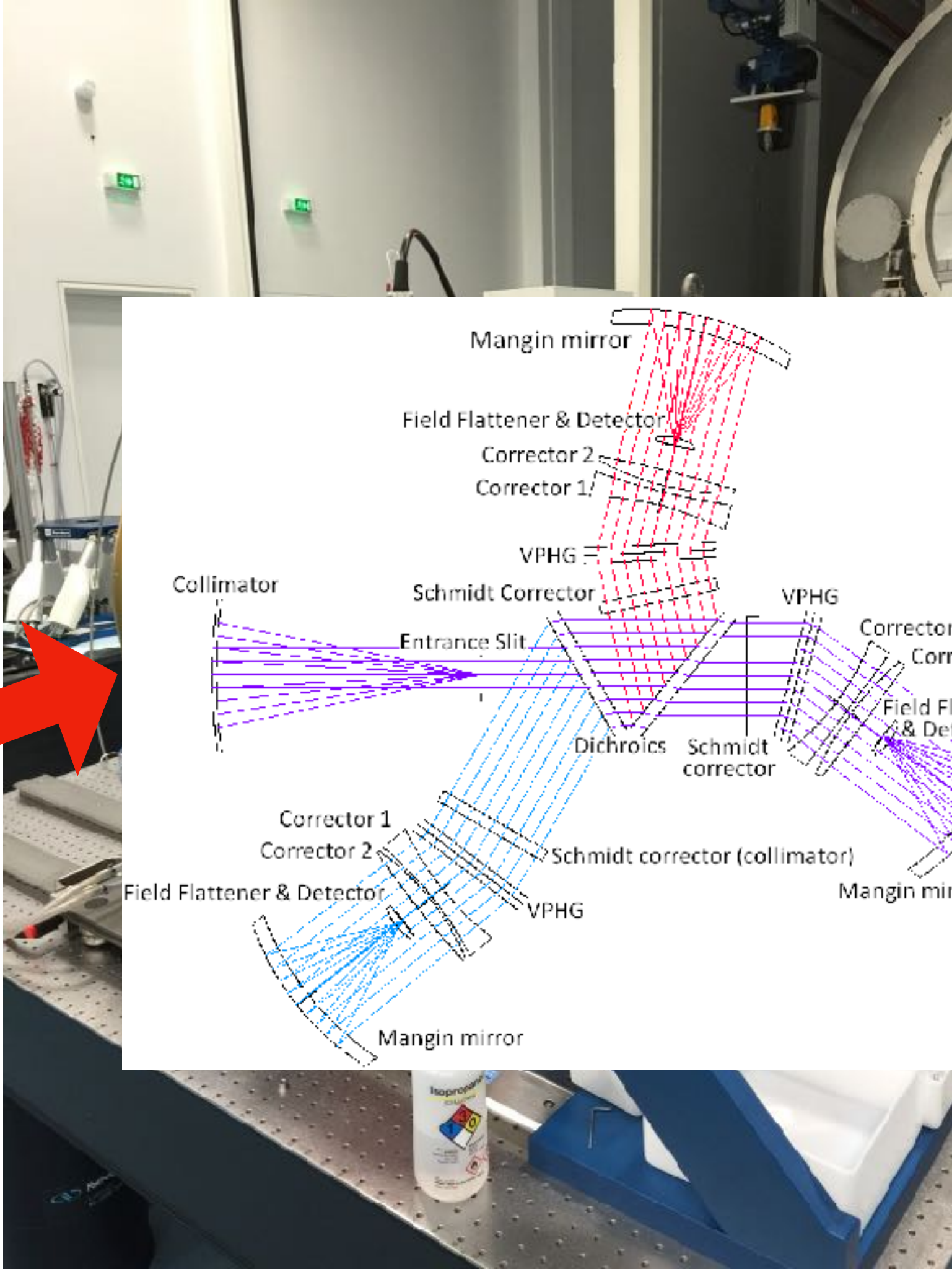
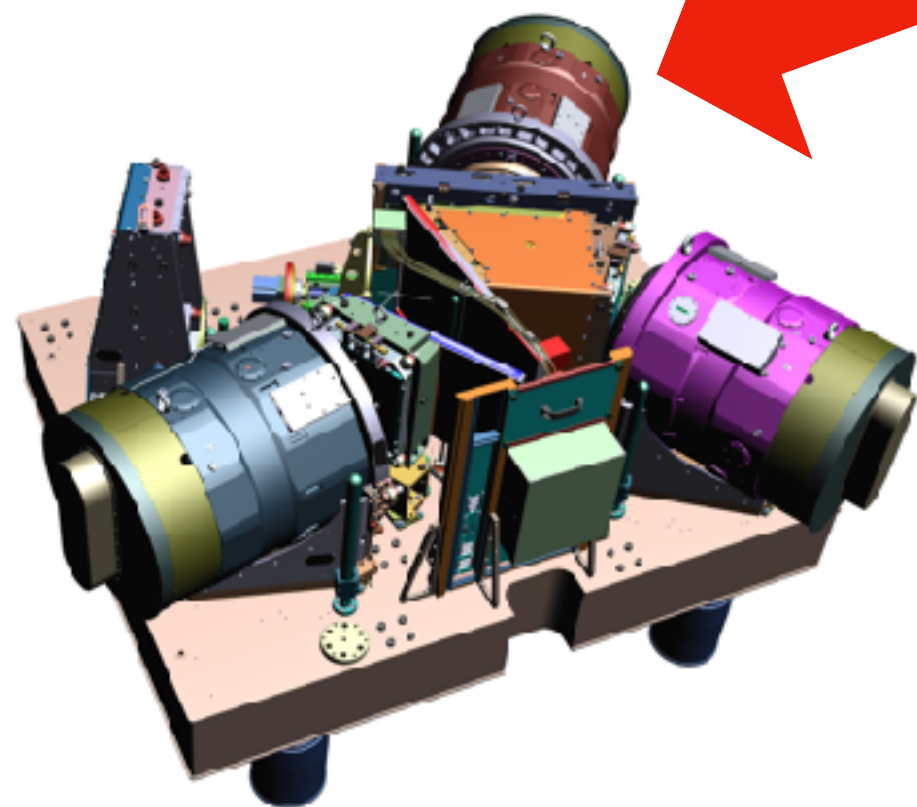


One of the “Red” Spectrograph Modules being tested at LAM

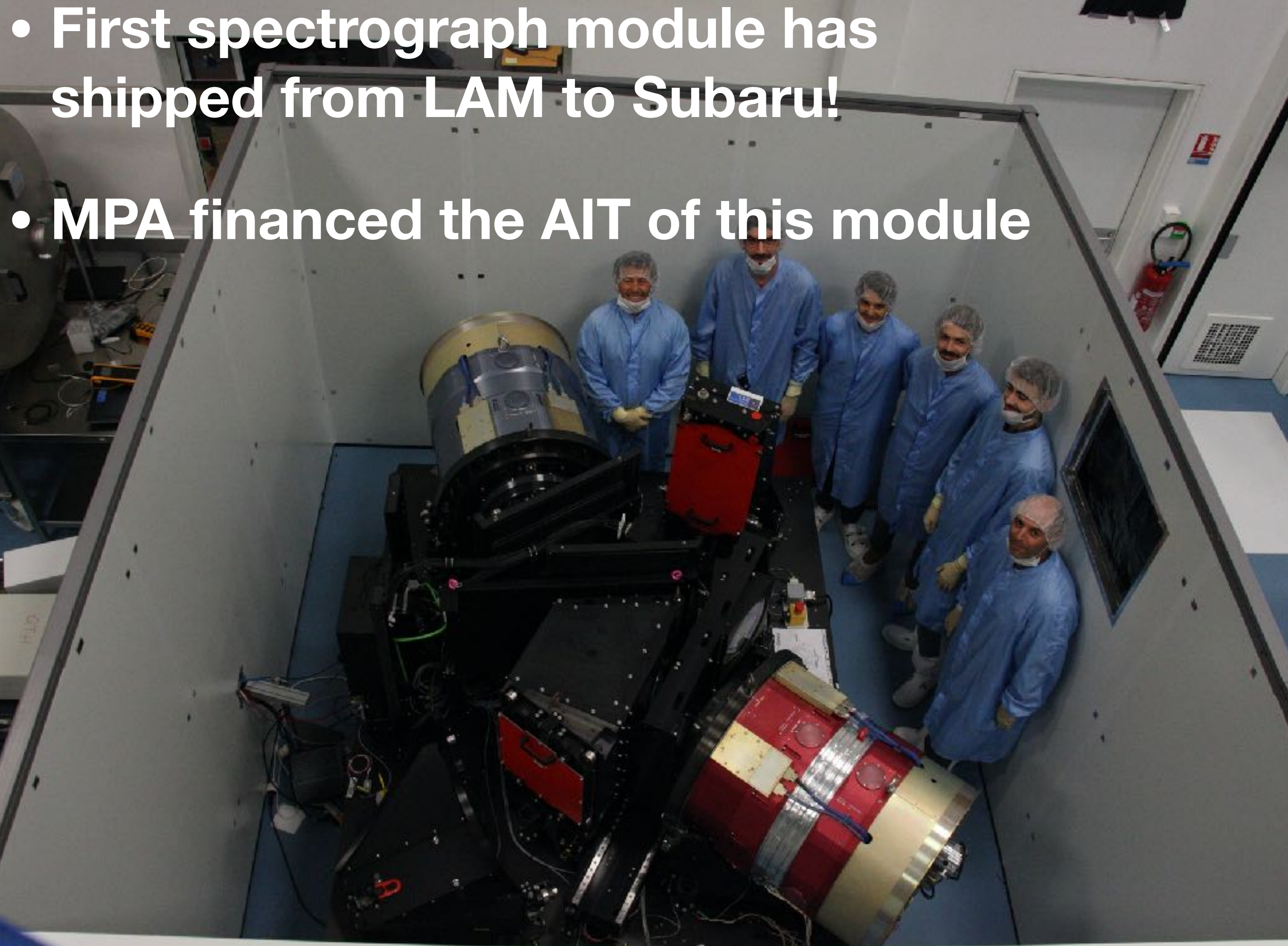




One of the “Red” Spectrograph Modules being tested at LAM



- First spectrograph module has shipped from LAM to Subaru!
- MPA financed the AIT of this module



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Ryu Makiya



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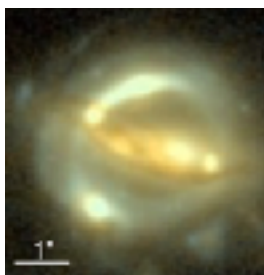
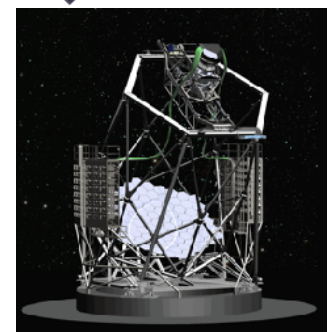
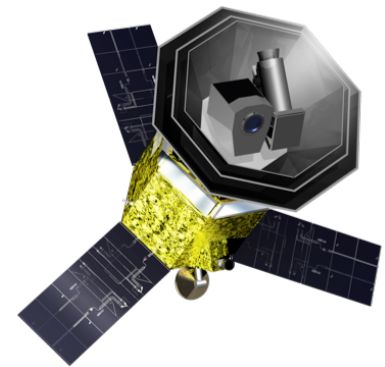
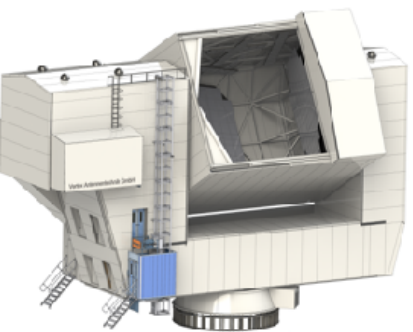


(Dated: November 17, 2017)

**Major contributions from MPA scientists
to shaping PFS's cosmology program**

Vision: Summary

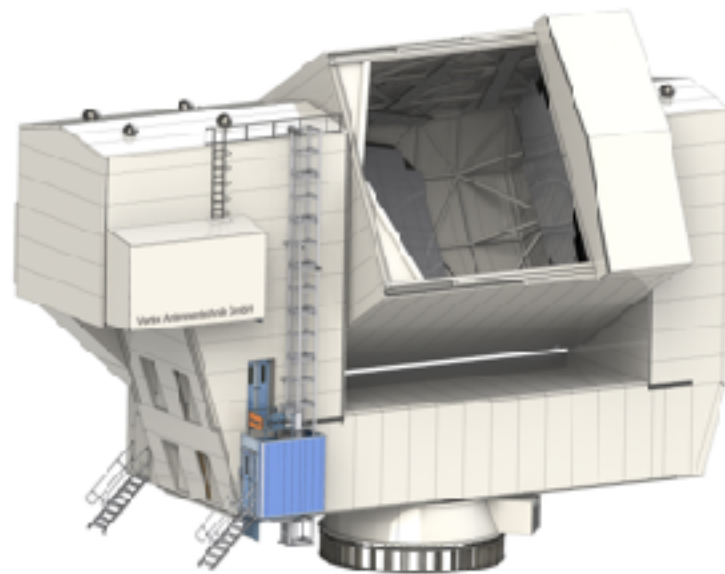
- Over the coming decade, I wish to make significant contributions to:
 - detect **primordial gravitational waves** [LiteBIRD, CCAT-prime]
 - maybe we discover the effect of gauge fields during inflation!
 - **rule out Λ CDM** (or map out the universe out to $z=3.5$) [HETDEX, PFS, time-delay lenses]
 - determine **the neutrino mass** (PFS)



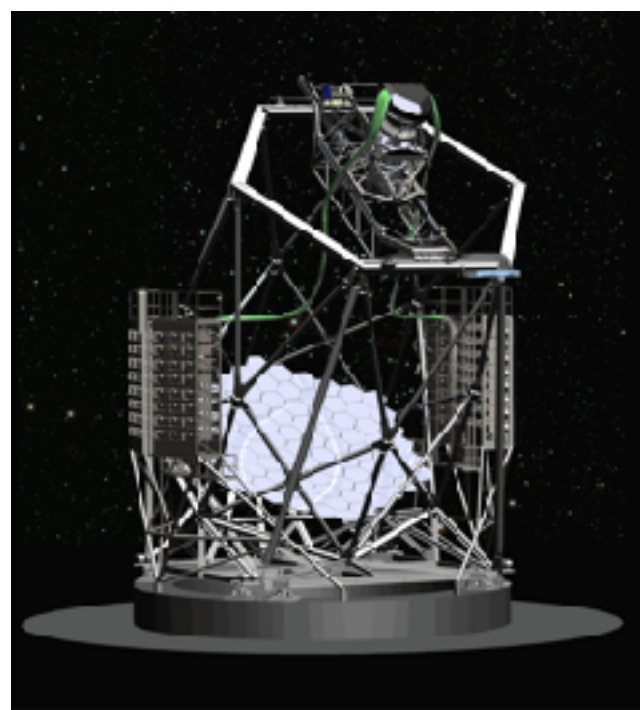
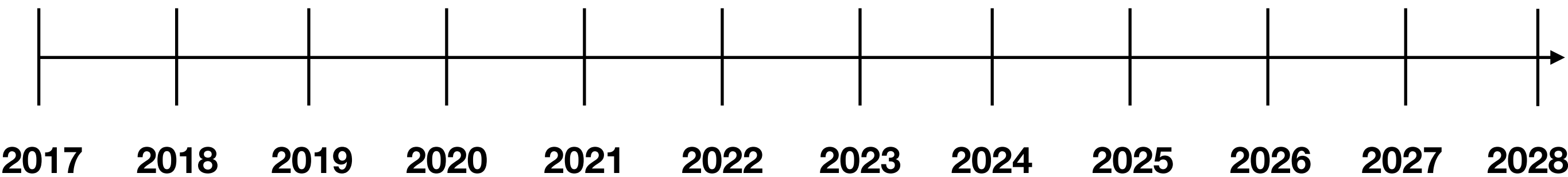
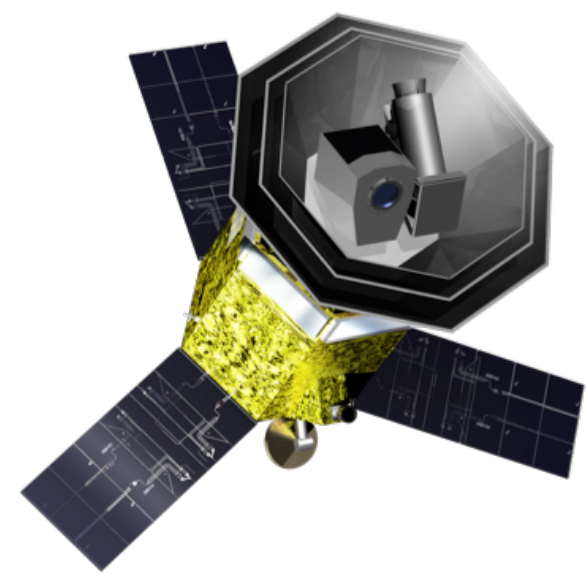
Coming Decade

CMB:
Early Universe
Probe

CCAT-prime
[2021–]



LiteBIRD
[2028–]



HETDEX
[2017–2023]



PFS
[2022–]

LSS:
Late Universe
Probe