Why does the Universe speed up?– Comprehensive study and challenges to the future

Hitoshi Murayama（Kavli IPMU Tokyo, Berkeley）

Accelerating Universe Symposium, September 20, 2015

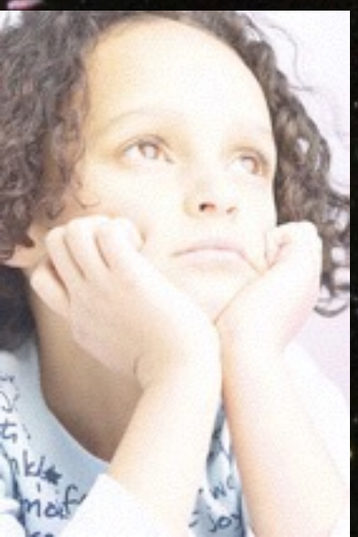
Welcome to Kavli IPMU!

東京大学
THE UNIVERSITY OF TOKYO

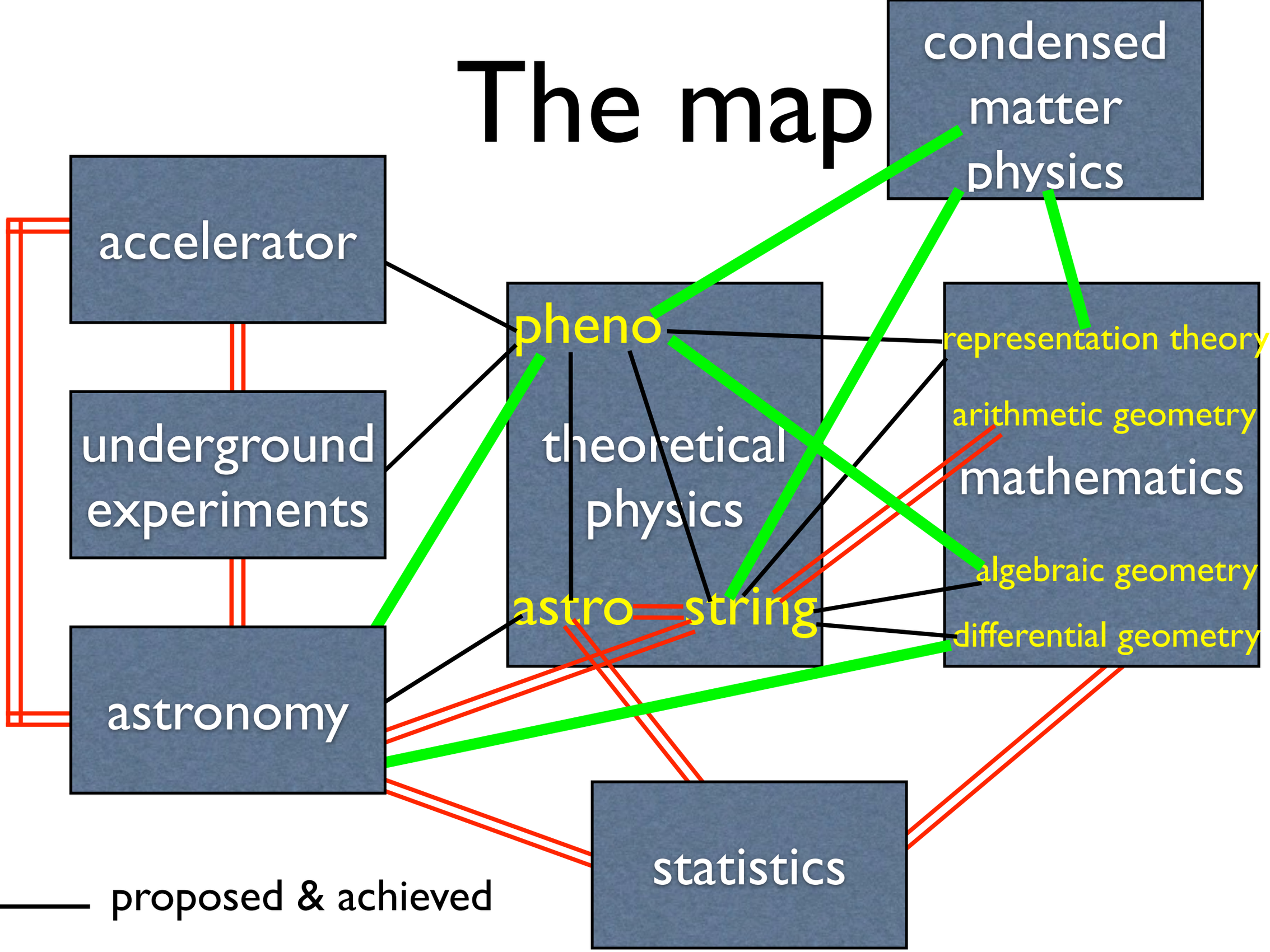
KAVLI IPMU
INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

Kavli Institute for the Physics and Mathematics of the Universe

How did the Universe begin?
What is its fate?
What is it made of?
What are its fundamental laws?
Why do we exist?
We need astronomers,
physicists, and mathematicians



The map



proposed & achieved

unanticipated & achieved

will be achieved

WPI: major program by MEXT, ~$13M/year, 5+5 years

Origins of Universe/ Earth/Life

KAVLI IPMU

U. Tokyo 2007

EARTH - LIFE SCIENCE INSTITUTE

Tokyo Tech 2012

Materials/ Energy

AIMR

Tohoku U. 2007

NIMS 2007

I^2CNER

Kyushu U. 2010

Life Science

wpi

WPI Osaka University iFReC

Osaka U. 2007

iCeMS KYOTO UNIVERSITY WPI Research Center

Kyoto U. 2007

IIIS INTERNATIONAL INSTITUTE FOR INTEGRATIVE SLEEP MEDICINE

U. Tsukuba 2012

ITbM Nagoya University

Nagoya U. 2012

world class, international, interdisciplinary, system reform

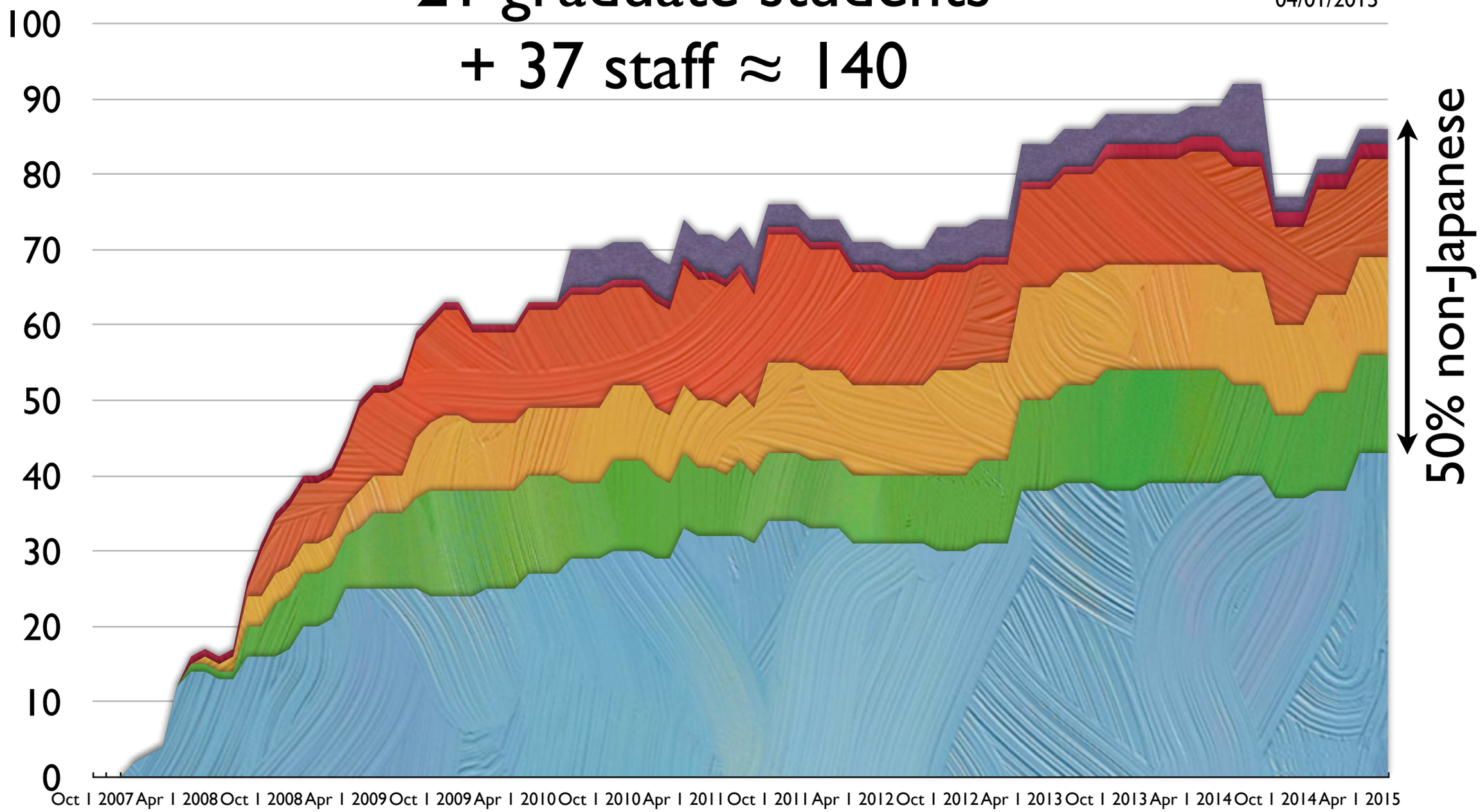
Oct 2007

Oct 2008

Oct 2010

Oct 2014

Full-time Scientists paid by IPMU
+21 graduate students
+ 37 staff ≈ 140



*Argentina, Canada, Chile

Name	Position	Ph.D.	Nationality	Field	fraction
Alexey Bondal	Professor	Stekov Institute	Russia	mathematics	50%
Masataka Fukugita	Professor	Tokyo	Japan	astrophysics	
Kantaro Hori	Professor	Tokyo	Japan	theoretical physics	
Mikhaill Kapranov	Professor	Stekov Institute	Russia	mathematics	
Nobuhiko Katayama	Professor	Tokyo	Japan	experiment	
Hitoshi Murayama	Professor	Tokyo	Japan	theoretical physics	50%
Ken'ichi Nomoto	Professor	Tokyo	Japan	astrophysics	
Yoichiro Suzuki	Professor	Kyoto	Japan	experiment	
Masahiro Takada	Professor	Tohoku	Japan	astrophysics	
Kyoji Saito	Professor	Göttingen	Japan	mathematics	
Mark Vagins	Professor	Yale	USA	experiment	
Tsutomu Yanagida	Professor	Hiroshima	Japan	theoretical physics	
Naoki Yasuda	Professor	Tokyo	Japan	astrophysics	
Naoki Yoshida	Professor	MPA Garching	Japan	astrophysics	40%
Simeon Hellerman	Assoc Prof	UC Santa Barbara	USA	theoretical physics	
Takeo Higuchi	Assoc Prof	Tokyo	Japan	experiment	
Kai Martens	Assoc Prof	Heidelberg	Germany	experiment	
Shigeki Matsumoto	Assoc Prof	Tohoku	Japan	theoretical physics	
Hajime Sugai	Assoc Prof	Tokyo	Japan	astrophysics	
Yukinobu Toda	Assoc Prof	Tokyo	Japan	mathematics	
Taizan Watari	Assoc Prof	Tokyo	Japan	theoretical physics	
Tomoyuki Abe	Assist Prof	Tokyo	Japan	mathematics	
Kevin Bundy	Assist Prof	Caltech	USA	astrophysics	
Mark Hartz	Assist Prof	Pittsburgh	USA	experiment	
Alexandre Kozlov	Assist Prof	Melbourne	Australia	experiment	
Todor Milanov	Assist Prof	Berkeley	Bulgaria	mathematics	
Surhud More	Assist Prof	MPA Heidelberg	India	astrophysics	
Alexie Leauthaud	Assist Prof	Marseille	France	astrophysics	
John Silverman	Assist Prof	Virginia	USA	astrophysics	
Nao Suzuki	Assist Prof	UC San Diego	Japan	astrophysics	
Naoyuki Tamura	Assist Prof	Kyoto	Japan	astrophysics	
Masahito Yamazaki	Assist Prof	Tokyo	Japan	theoretical physics	
Chiaki Hikage	Assist Prof	Tokyo	Japan	astrophysics	

33 on-site faculty members math 6, theory 7, expt 7, astro 13

36% international more than Berkeley, Harvard, MIT, or Yale

From Times Higher Education 2008 Ranking

postdoc stats

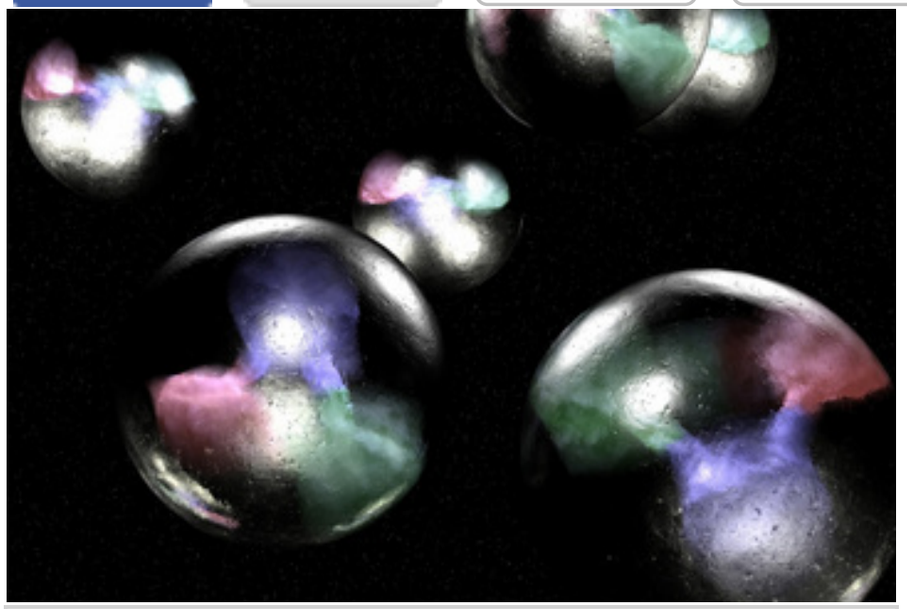
- >700 applications every year
  - >80% from outside Japan
  - appoint 10–15 every year
- hired 120 so far, 89 left by FY'14
  - <10% left the field
  - 40% already landed on faculty jobs!

Recent Career Path

Atsushi Nishizawa	Postdoc	Lecturer	Nagoya University
Malte Schramm	Postdoc	Research Support Staff	NAOJ
Cornelius Schmidt-Colinet	Postdoc	Postdoc	Ludwig-Maximilians-Universitat
Yu-Chieh Chung	Postdoc		TBD
Chunshan Lin	Postdoc	Postdoc Fellow	Yukawa Institute for Theoretical Physics Kyoto University
Jing Liu	Postdoc	Assistant Professor	University of South Dakota
Jyotirmoy Bhattacharya	Postdoc	Postdoc Fellow	Durham University, Dept. of Mathematical Sciences
Biplob Bhattacherjee	Postdoc	Assistant Professor	Indian Institute of Science
Yefeng Shen	Postdoc	Postdoctoral Scholar	Stanford University
Changzhen Li	Postdoc	IBS Fellow	IBS Center for Geometry and Physics, POSTECH
Robert Quimby	Postdoc	Associate Professor / Director of Mount Laguna Observatory	San Diego State University
Satoshi Kondo	Project Assistant Professor	Assistant Professor	The National Research University - Higher School of Economics
Yu Nakayama	Postdoc	Senior Research Fellow	Caltech
John Kehayias	Postdoc	Postdoc	Vanderbilt University
Richard Eager	Postdoc	Postdoc Researcher	McGill University
Valentin Tonita	Postdoc	Postdoc Fellow	Fondation Sciences Mathematiques Paris
Melina Bersten	Postdoc	Scientific Researcher	CONICET (National Scientific and Technical Research Council - Argentina
Gaston Folattelli	Postdoc	Scientific Researcher	CONICET (National Scientific and Technical Research Council - Argentina
Myeonghun Park	Postdoc	Adjunct Professor	APCTP / POSTECH
Daniel Pomerleano	Postdoc	EPSRC Postdoc Research Fellow	Imperial College, London
Shinji Mukoyama	Project Associate Professor	Professor	Yukawa Institute for Theoretical Physics Kyoto University
Werner Marcus Christian	Postdoc	Assistant Professor	Yukawa Institute for Theoretical Physics Kyoto University
Bondal Alexey	Project Professor	Professor	Steklov Mathematical Institute
Nobuhiro Okabe	Postdoc	Assistant Professor	Hiroshima University

Dark Pion Particles May Explain Universe's Invisible Matter

by Jesse Emspak, Live Science Contributor | July 25, 2015 08:15am ET



Researchers propose that dark matter is a kind of invisible, intangible version of a pion, or a type of meson — a category of particles made up of quarks and antiquarks.

Credit: MichaelTaylor | Shutterstock.com

View full size image

Dark matter is the mysterious stuff that cosmologists think makes up some 85 percent of all the matter in the universe. A new theory says dark matter might resemble a known particle. If true, that would open up a window onto an invisible, dark matter version of physics.

The only way dark matter interacts with anything else is via gravity. I you poured dark matter into a bucket, it would go right through it because it doesn't react to electromagnetism (one reason you can stan on the ground is because the atoms in your feet are repelled by the atoms in the Earth). Nor does dark matter reflect or absorb light. It's therefore invisible and intangible.

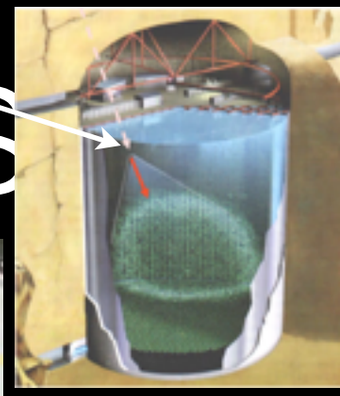
Scientists were clued into its existence by the way galaxies behaved. The mass of the galaxies calculated from the visible stuff they contained wasn't enough to keep them bound to each other. Later, observations of gravitational lensing, in which light bends in the presence of gravity fields, showed there was something that made galaxy clusters more massive that couldn't be seen. [The 9 Biggest Unsolved Mysteries in Physics]

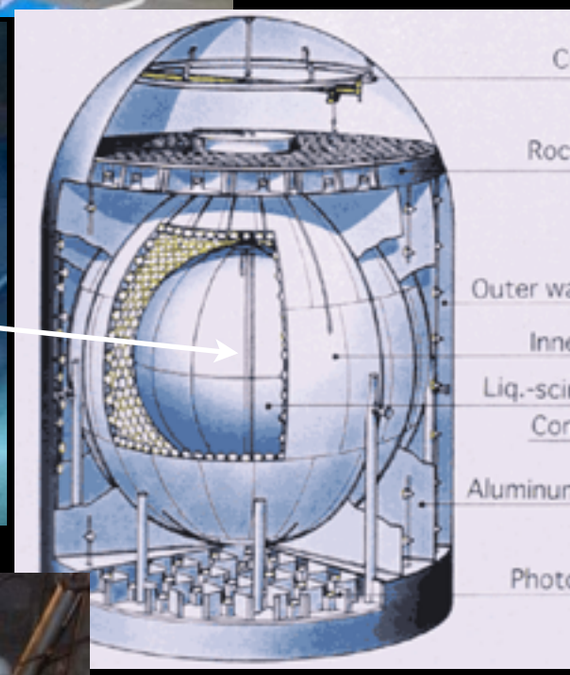
Clear leadership roles

- Vagins pioneered the concept to detect supernova relic neutrinos with Gd in SK

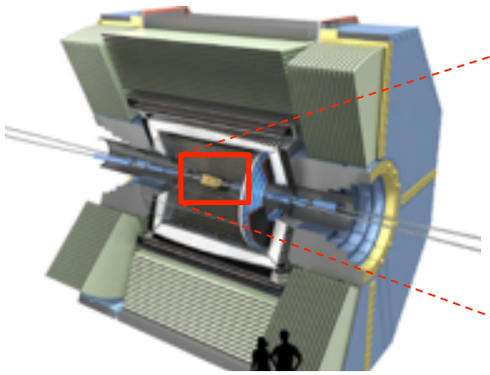
- Kozlov developed the concept to dissolve Xenon gas into KamLAND for 0νββ

- Suzuki proposed XMASS dark matter expt with single-phase scalable LXe detector

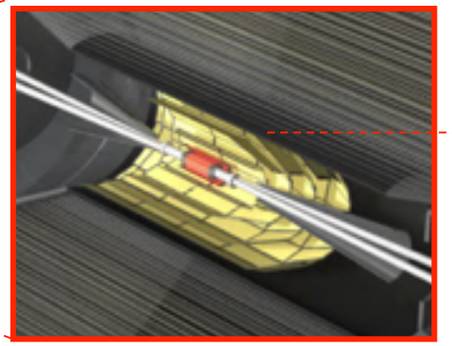




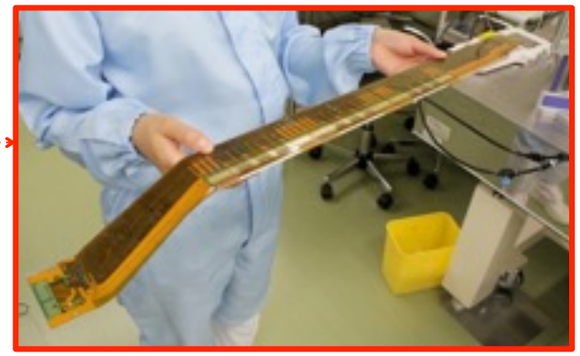
R&D of Belle II Silicon Vertex Detector (SVD)



Belle II Detector



SVD:
4 cylindrical layers



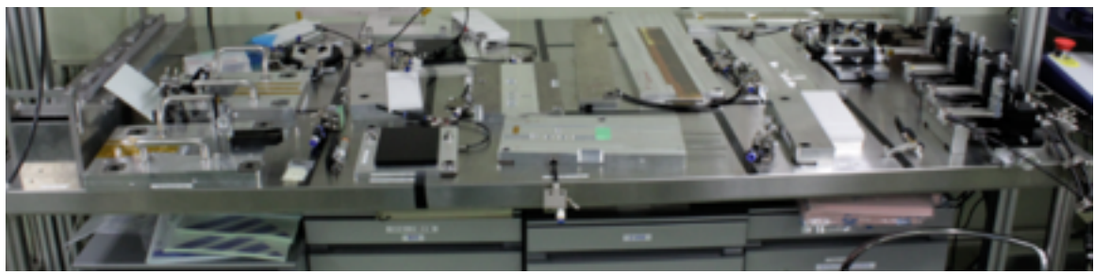
SVD "ladder":
7-16 ladders per layer

Outermost layer of SVD assembly downstairs

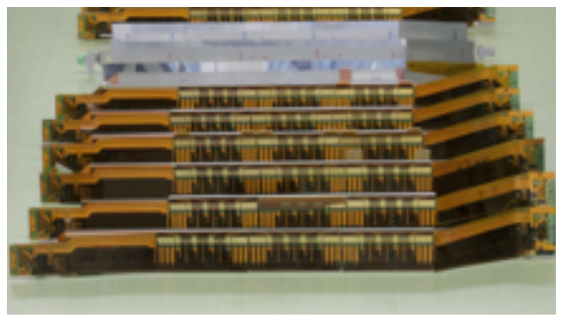
Pickups of Our Achievements

Assembly procedure and tools

- develop the assembly procedure from scratch
- design all assembly jigs



- compatibility fully confirmed by dozen assemblies of a mockup ladder.



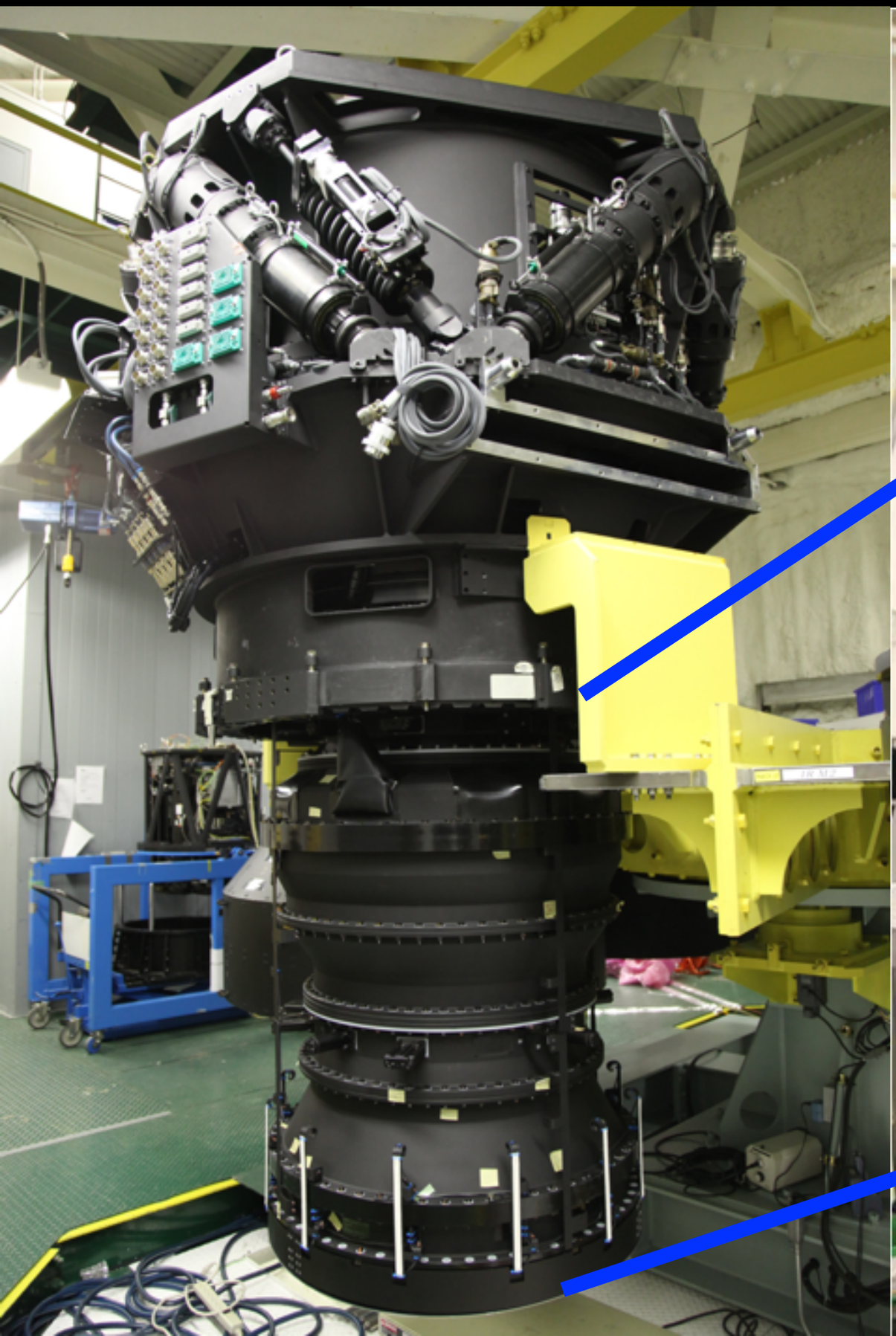
Assembly techniques

- high bonding efficiency
- high pull strength
- tested on mockup materials: $\varepsilon_{bond} \gtrsim 99\%$ and $F_{PS} \gtrsim 7$gw.

- success to control the epoxy-glue viscosity under the bonding pads, which subsequently provides stable pad base.

The Kavli IPMU is one of the most advanced institutes among the SVD collaborations. We are a *de facto* reference.

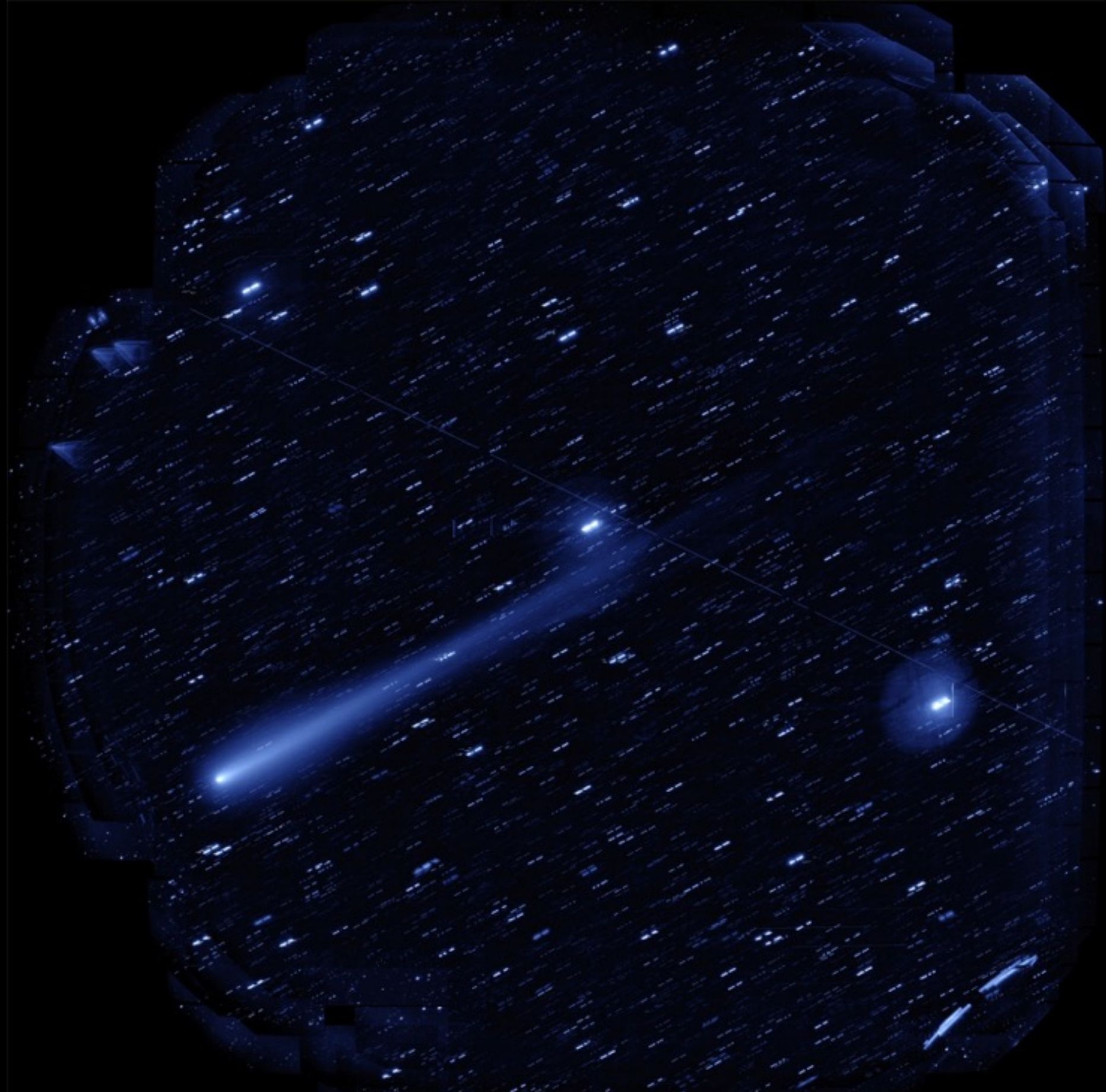

2014/07/29



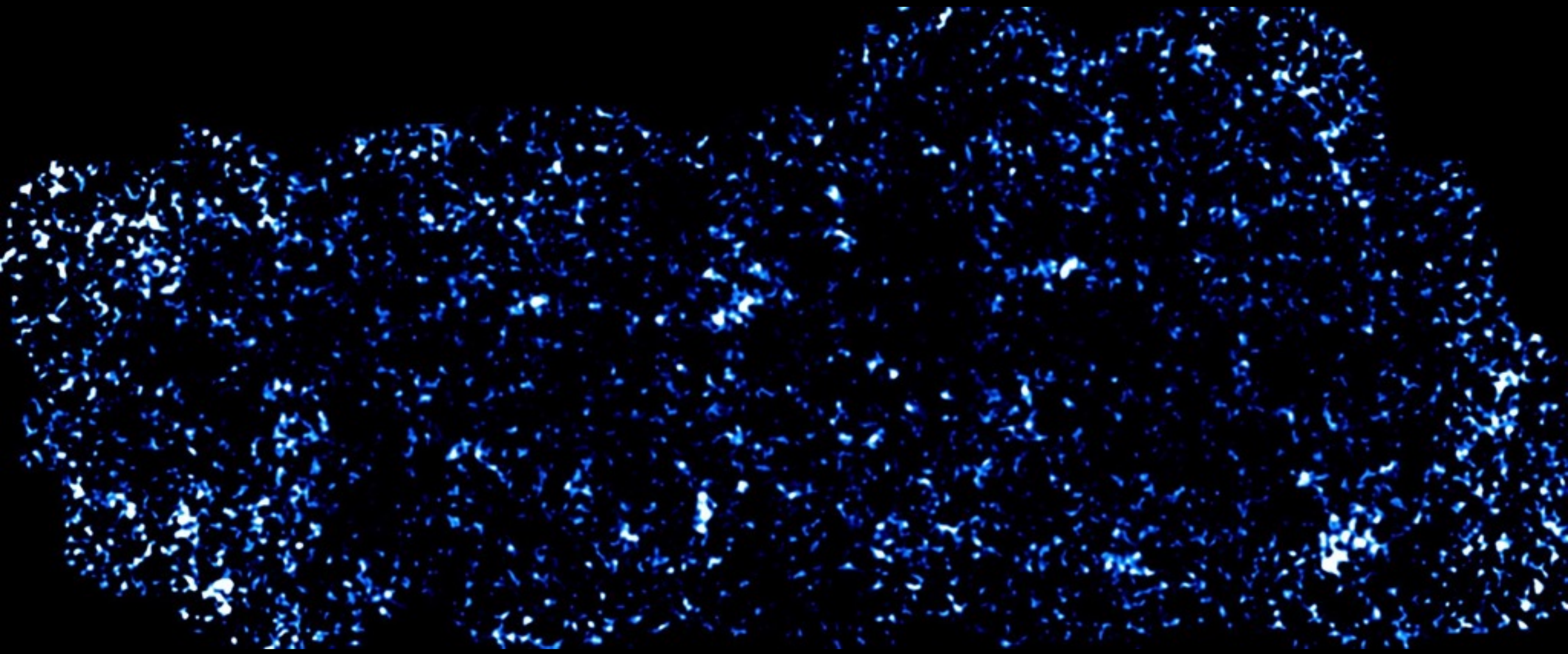
ISON comet

H15.11

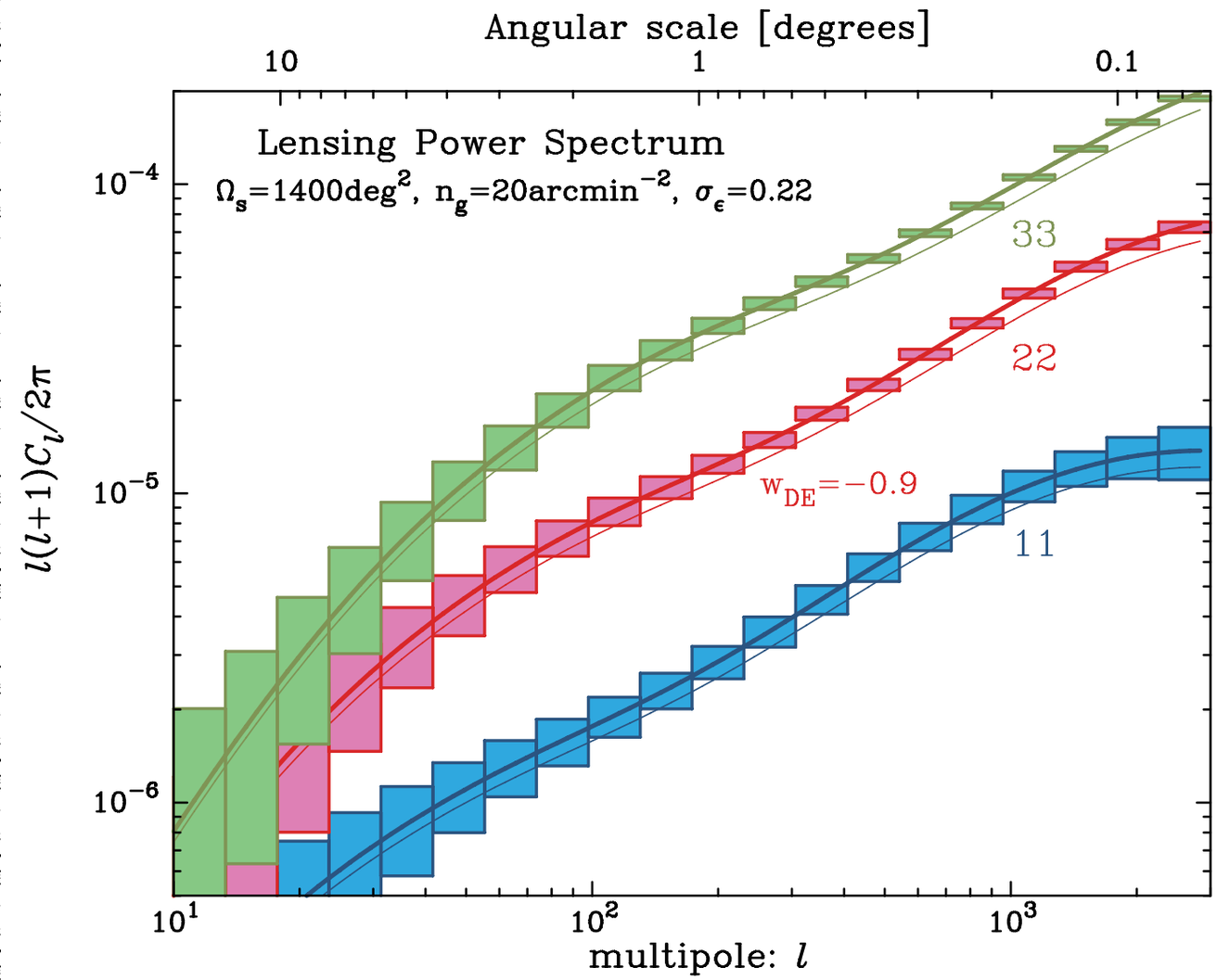
precision control thanks to Mitsubishi Electric

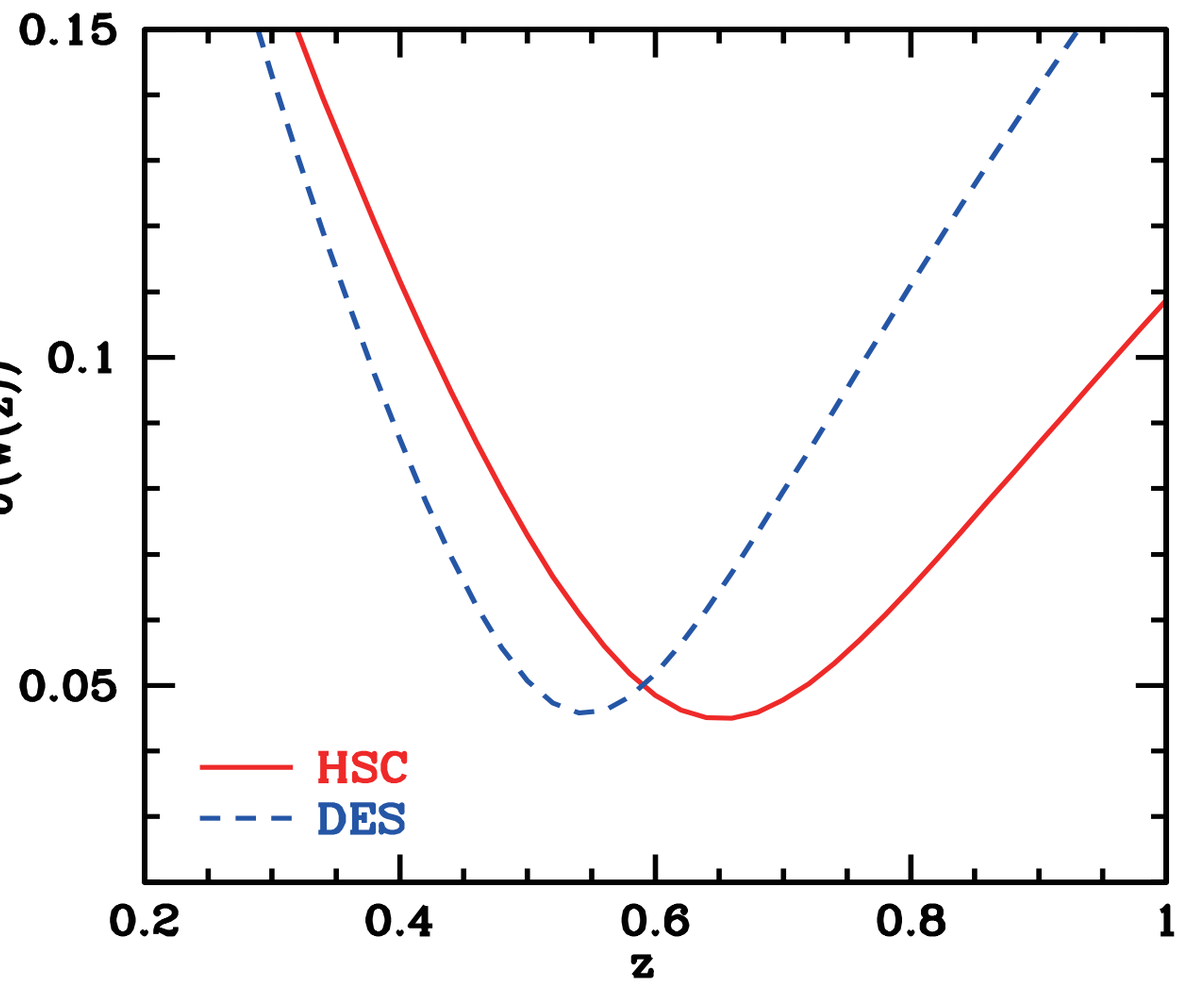


Weak lensing mass map for ~20 sq. degrees field (*2hrs data*)



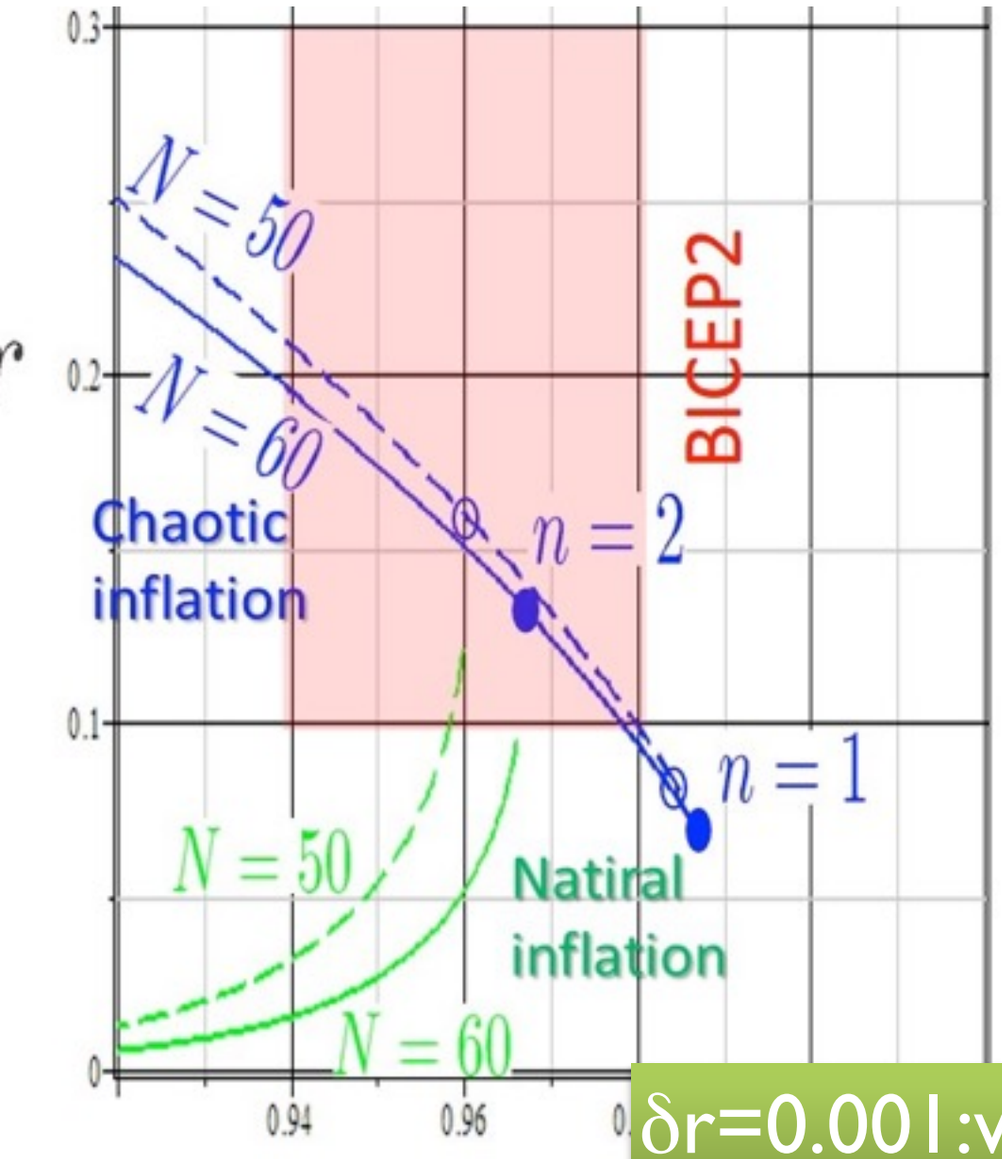
Cosmic Shear

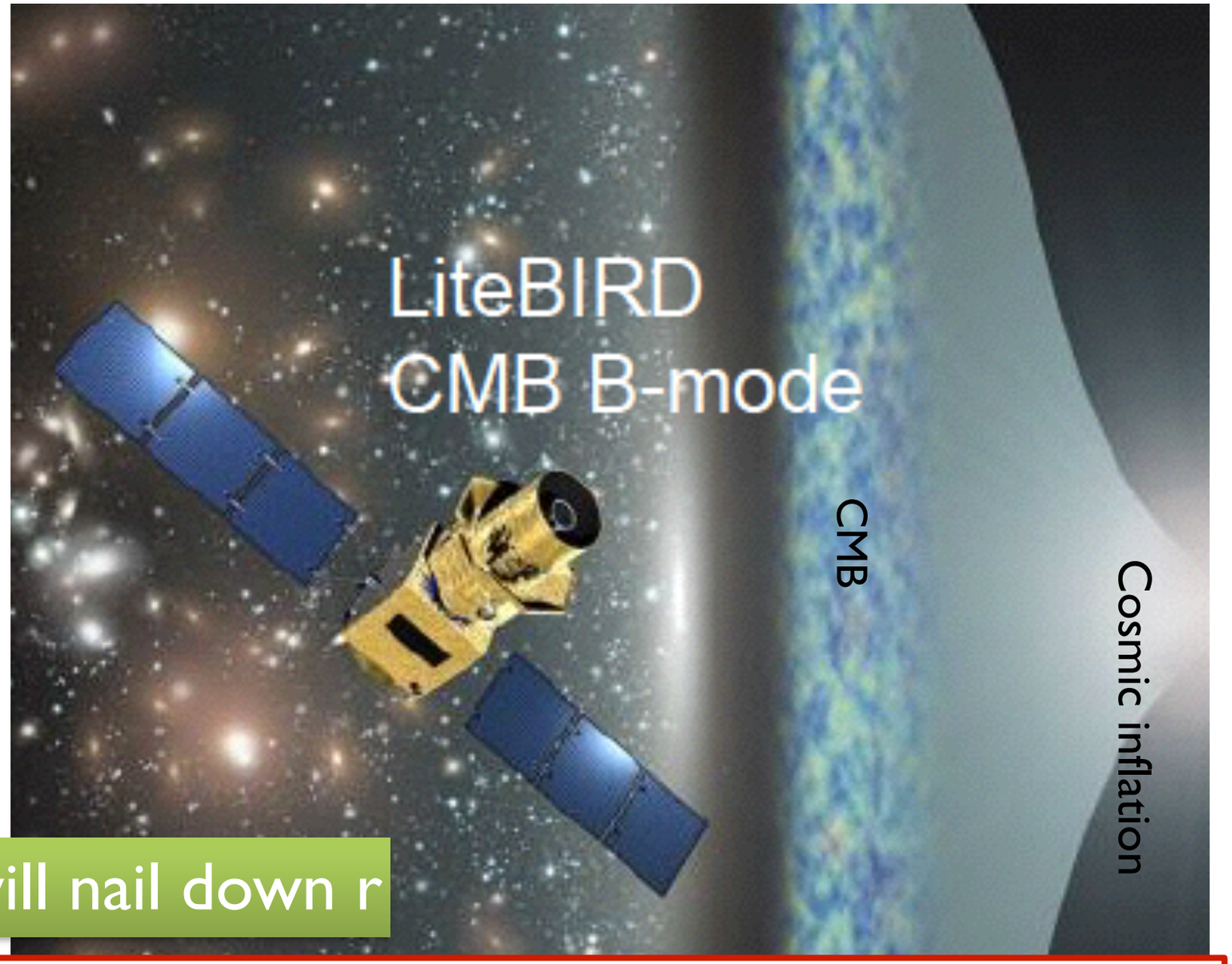




LiteBIRD

A satellite for measurements of the cosmic microwave background polarization to explore the universe before the hot Big Bang





δr=0.001:will nail down r

WG | Pre-proj | Project

2014 | 2015 | 2016 | 2017 | 2018 | 2018 | 2019 | 2020 | 2021 | 2022

Prototype Model

Flight Model

Launch

Mission Design Review

System Specification Review

Systems Design Review

Critical reviews are coming

Will take four years to harvest the science after launch

Future?

- Current funding is good till March 2017
- *Will we disappear from the map?*
- WPI funding is for 10 years, and 5-year extension is possible for institutes “with outstanding results”
- The program committee reviewed the initial five institutes last year

FY 2014 Follow-up of WPI Program

By Program Committee

February 2015

(This report deals with progress made under the WPI Program in FY 2013.)

Summary 2

A. Outline of WPI program 4

B. WPI Centers 5

C. Follow up 6

D. Follow-up of 5 WPI centers launched in 2007 6

E. Follow up of WPI center launched in 2010 (Interim evaluation of I^2CNER) 9

F. Future plans of WPI program 9

Sustainability of WPI centers

A condition upon the host institutions' acceptance to establish a WPI center was that they would sustain the center with their own and other resources after the WPI grant ended. Furthermore, the presidents of the host institutions have repeatedly declared and confirmed their support for their centers.

Follow up of 5 WPI centers launched in 2007

The WPI Program supports the centers for a period of 10 years. A possible extension for another 5 years is applicable to those with outstanding results. Afterwards, these centers are to be sustained under the auspices of their host institutions.

All five of the WPI centers launched in 2007 applied for a possible 5-year extension after their initial supporting period for 10 years. These centers are AIMR, Kavli IPMU, iCeMS, IFReC and MANA.

The WPI Program Committee examined carefully their achievements and concluded that all 5 centers have achieved a "World Premier Status," fully meeting the goal of the WPI program. After extensive discussion on the definition and implications of "outstanding" as the level of achievement needed to warrant a 5-year extension, the committee members agreed to apply it to only highly exceptional case(s) whose achievements are far beyond the very high WPI standard. As a result, among the five centers under consideration, Kavli IPMU was nominated for a 5-year extension.

Summary

Sep '14 site visit

- Kavli IPMU is *our treasure*
  - –Should become a *national treasure*
- Kavli IPMU started from scratch and has already achieved the "world premier" status
- Kavli IPMU has become a career path in the world's brain circulation, is highly visible and bears the prestigious Kavli name
- I support the initiative for a new graduate school
- UTokyo will permanently support Kavli IPMU
  - –We have secured $7M/yr beyond WPI
    - including 15 tenure pos. April 2015
  - –We commit the rest if given the highest evaluation

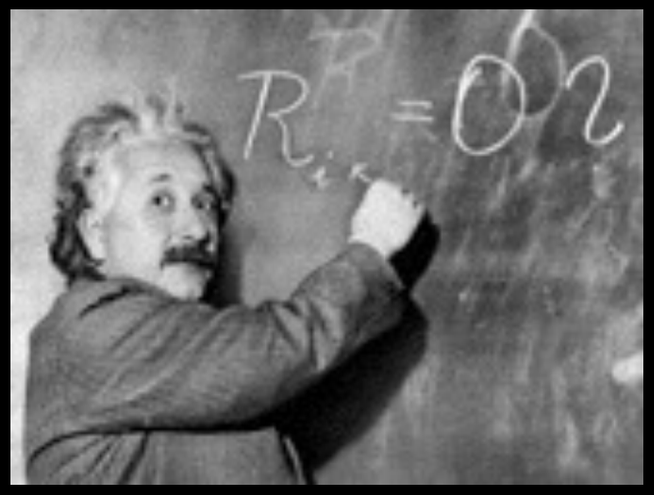
We are here to stay!

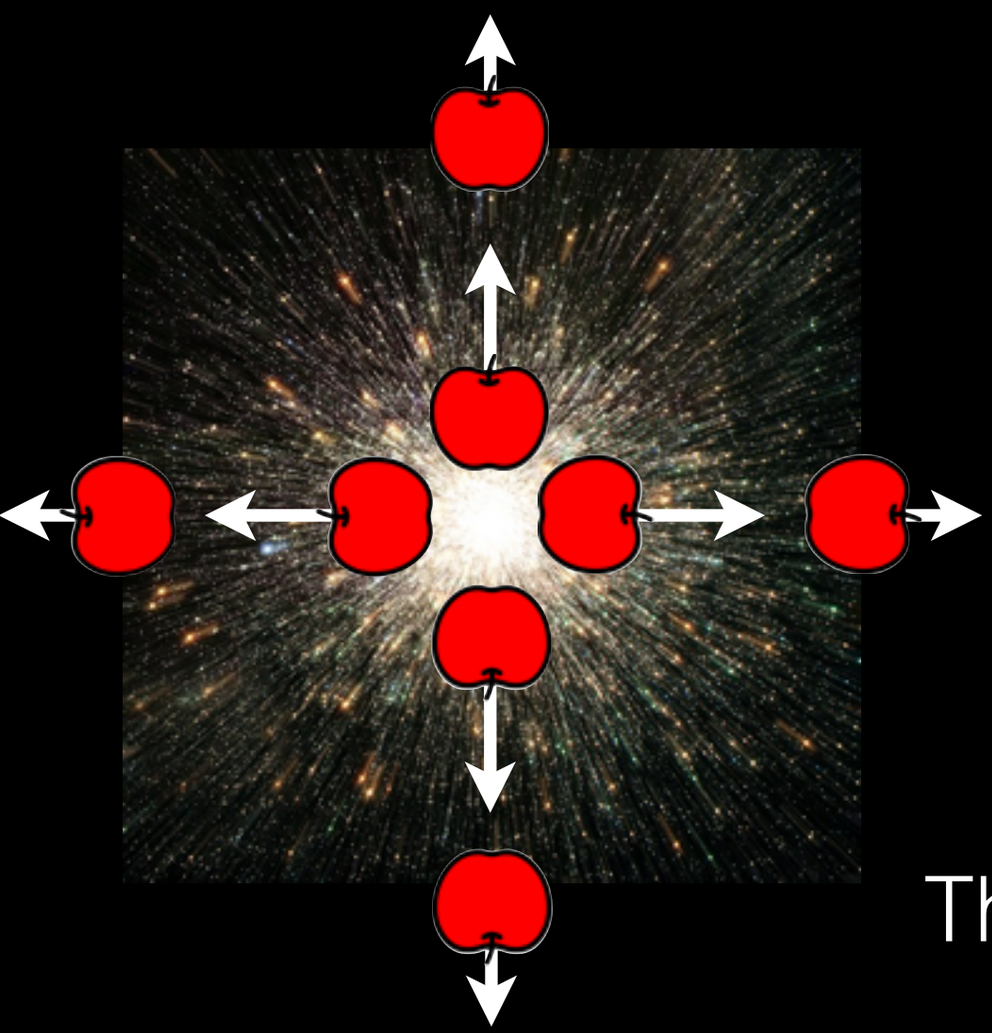
Why does the Universe speed up?– Comprehensive study and challenges to the future

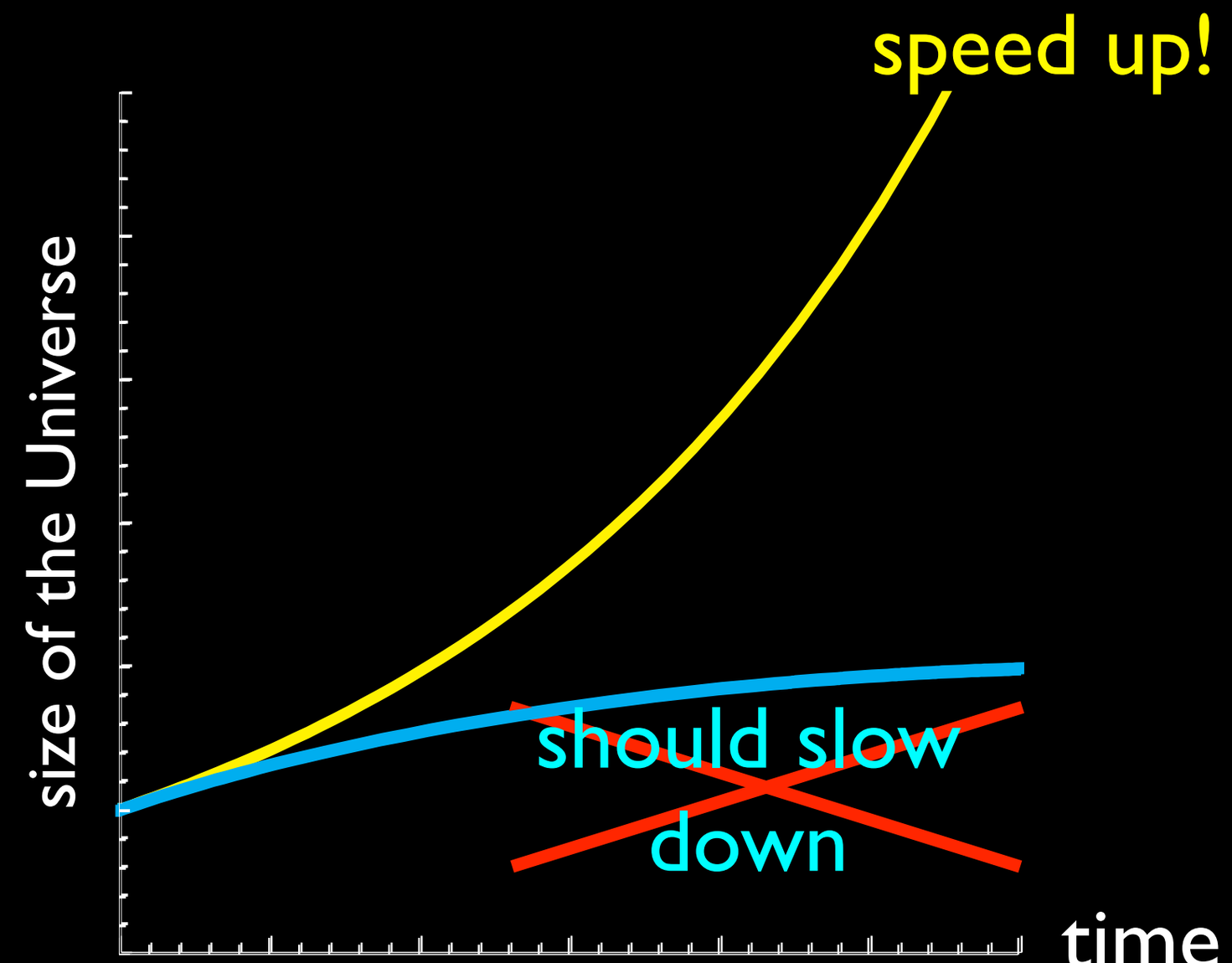
PI：Hitoshi Murayama（Kavli IPMU Tokyo, Berkeley）

June 4, 2015

Cosmic Expansion







Gravity only pulls
Something is pushing the expansion
The biggest mystery in modern physics!

Phases of cosmic expansion

3 pillars of science

A01
Inflation

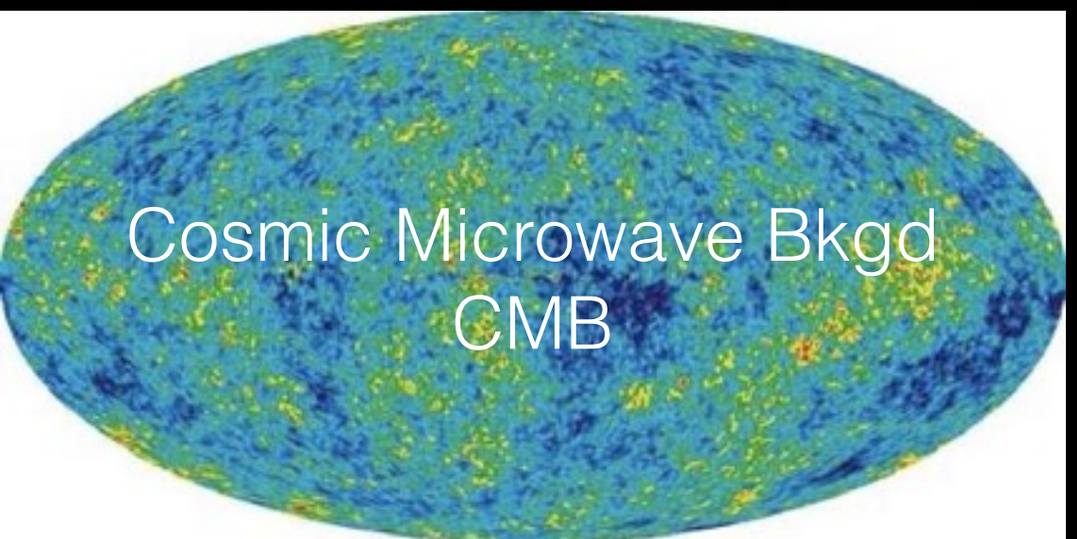
A02 dark matter
deceleration

A03
dark energy
acceleration

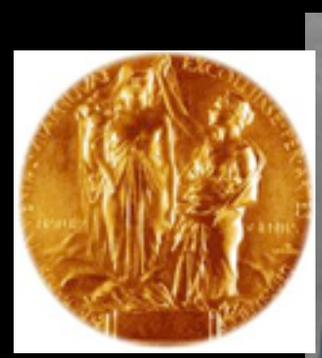
acceleration

size of the Universe

time



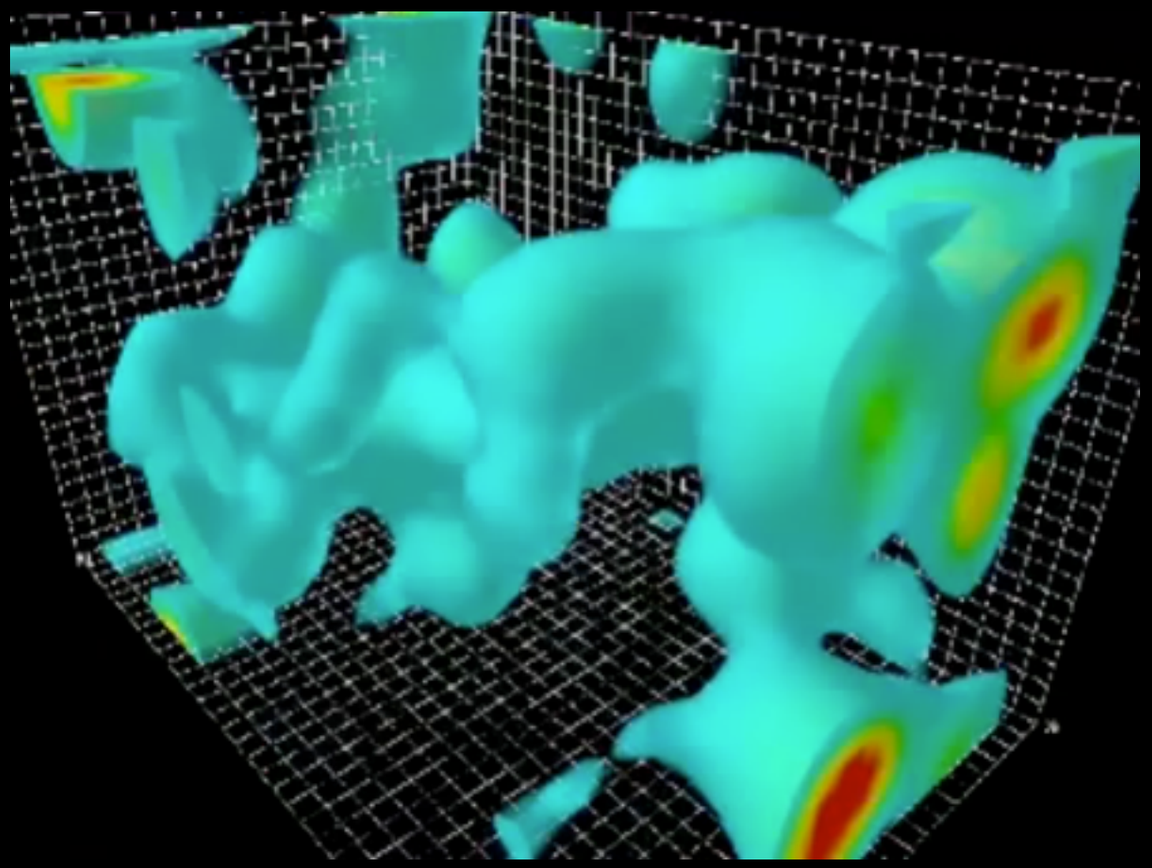
2011 Nobel Prize in Physics



Theory Team A01

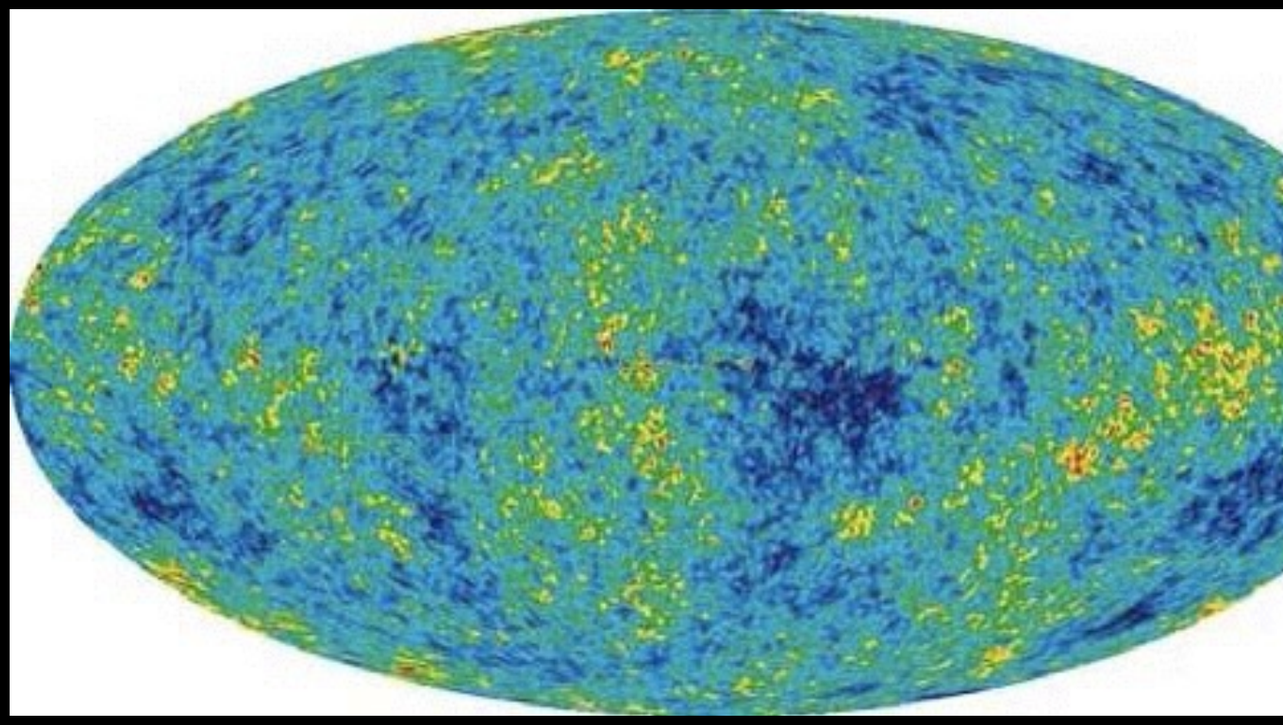
We are born from quantum flucutation

Universe < 10^{-26} cm



borrow & lend energy within uncertainty principle

stretched to a macroscopic Universe

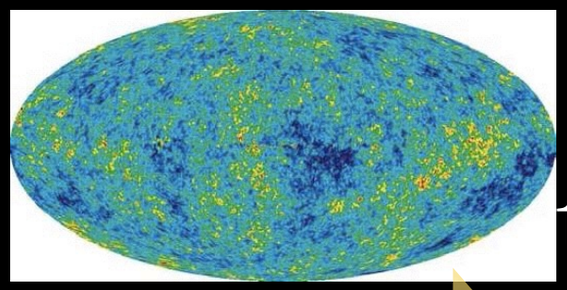


stuck with the energy borrowed or lent fluctuation of10^{-5}

Why, when did it accelerate?
How did it end acceleration and become hot?
quantum gravity?

Theory Team A02

Dark Matter is our Mom



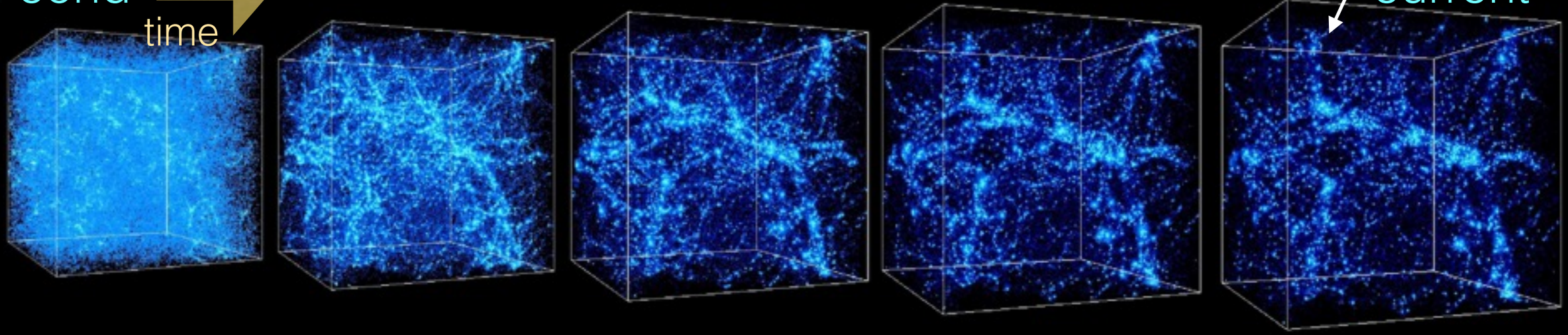
10^{-5}
1mm ripples on
100m deep ocean

stars, galaxies,
clusters
amplified by 10^{6}

intl cond

time

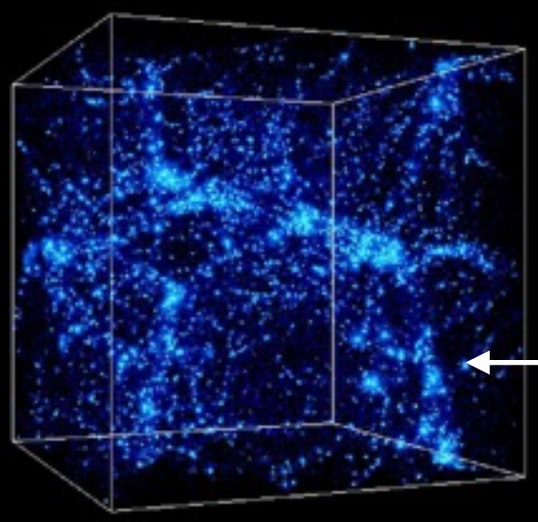
current



Did dark matter really make stars & galaxies?
What is dark matter? Where did it come from?
Any relationship between dark matter & dark energy?

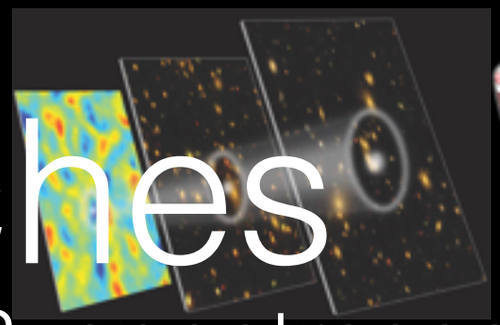
Theory Team A03

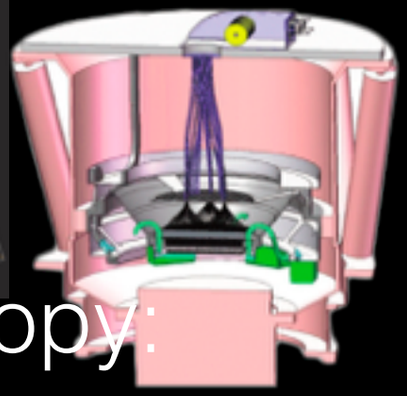
Universe being ripped apart



Why accelerate again? Was Einstein wrong?
Will the Universe end completely ripped apart?
Why “just right”? Multiverse?

4 Approaches

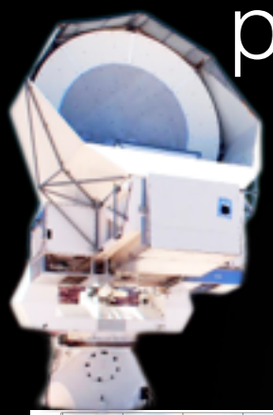


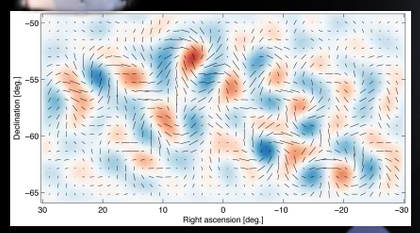


B03: spectroscopy:
3D

10 yrs later

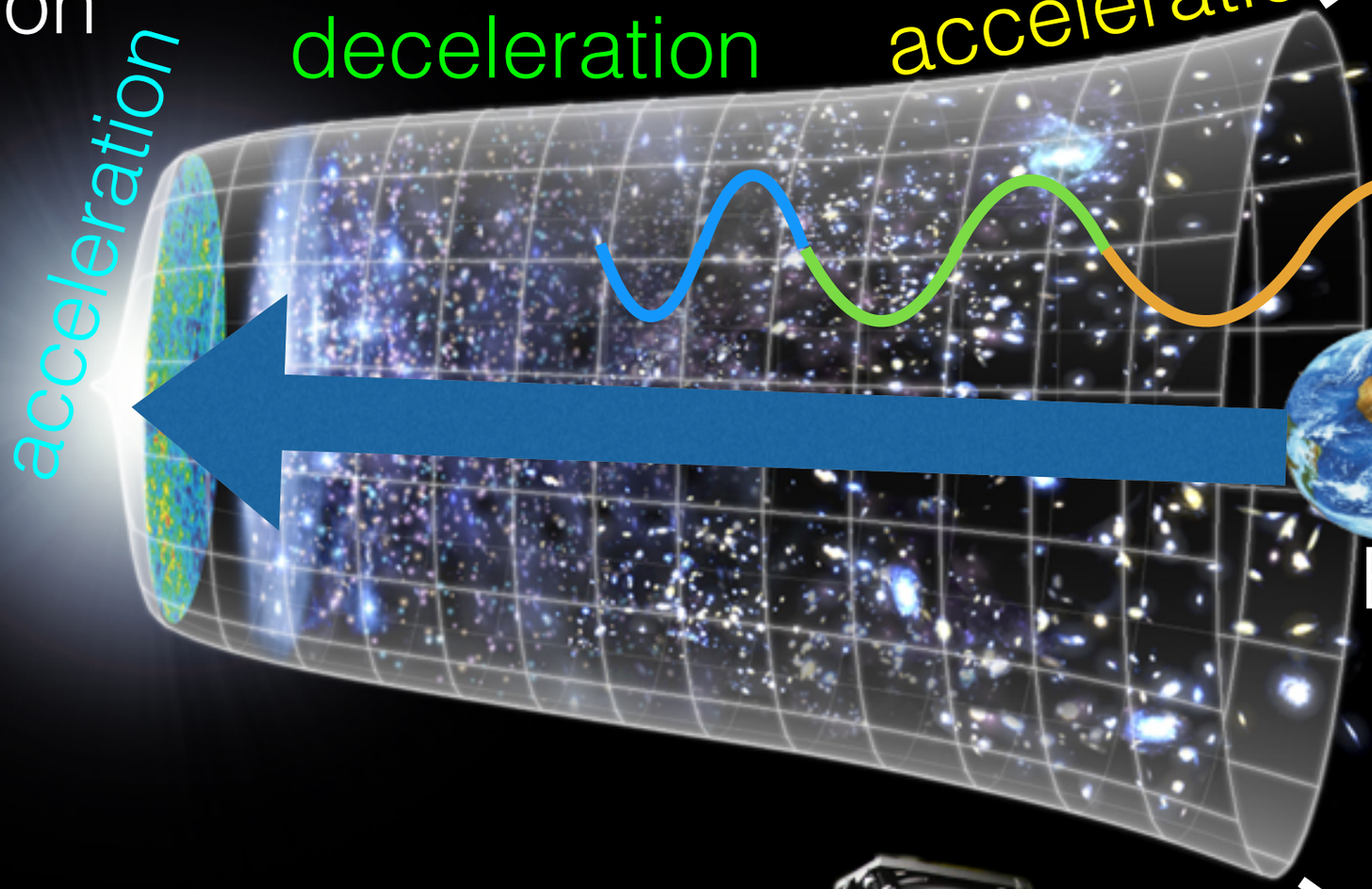
B01:CMB
polarization

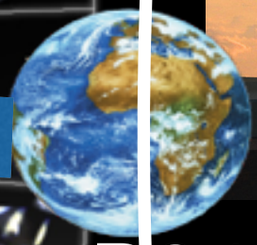


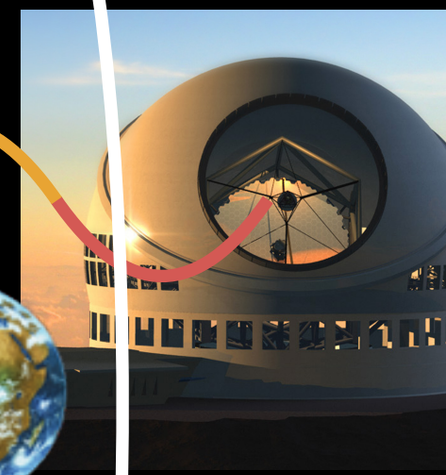


deceleration

acceleration

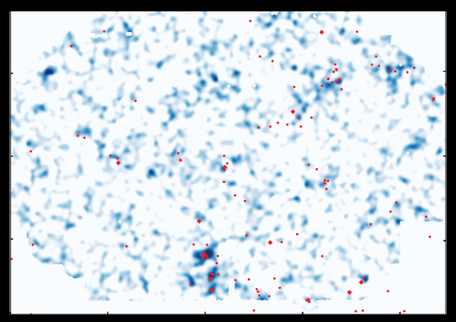


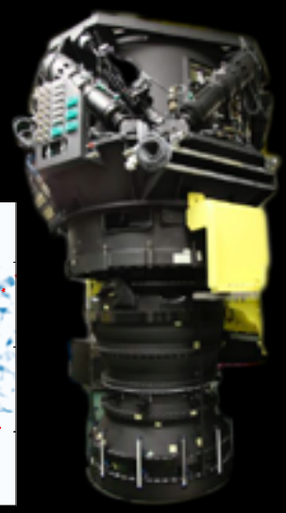




B04:measure
this change
directly

B02: imaging：2D





3 pillars of science (theory)

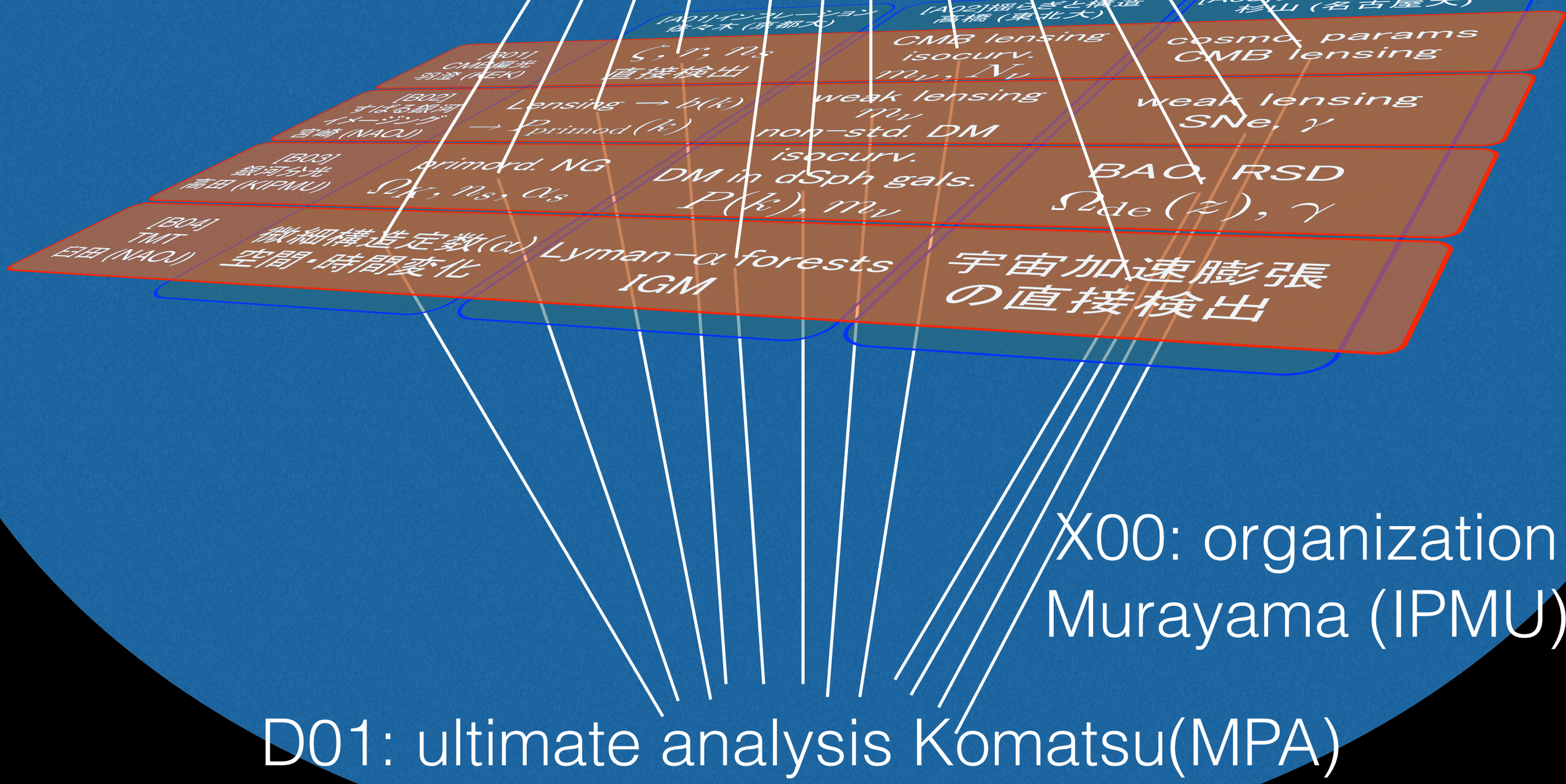
4 approaches (expt, obs)

	[A01] Inflation Sasaki (Kyoto)	[A02] fluent. & struct. Takahashi (Tohoku)	[A03] Dark Energy Sugiyama (Nagoya)
[B01] CMB polariz. Hazumi (KEK)	ζ, r, n_s direct evidence	CMB lensing isocurv. m_ν, N_ν	cosmo. params CMB lensing
[B02] Subaru galaxy imaging Miyazaki(NAOJ)	Lensing → $b(k)$ $\rightarrow P_{\rm primod}(k)$	weak lensing m_ν non-std. DM	weak lensing SNe, γ
[B03] galaxy spectroscopy Takada(KIPMU)	primord. NG Ω_K, n_s, α_s	isocurv. DM in dSph gals. $P(k), m_\nu$	BAO, RSD $\Omega_{\rm de}(z), \gamma$
[B04] TMT Usuda (NAOJ)	QED coupling (α) space time var.	Lyman-α forests IGM	direct detection of acceleration

important observables at each intersection

C01: ultimate theory Ooguri(Caltech)

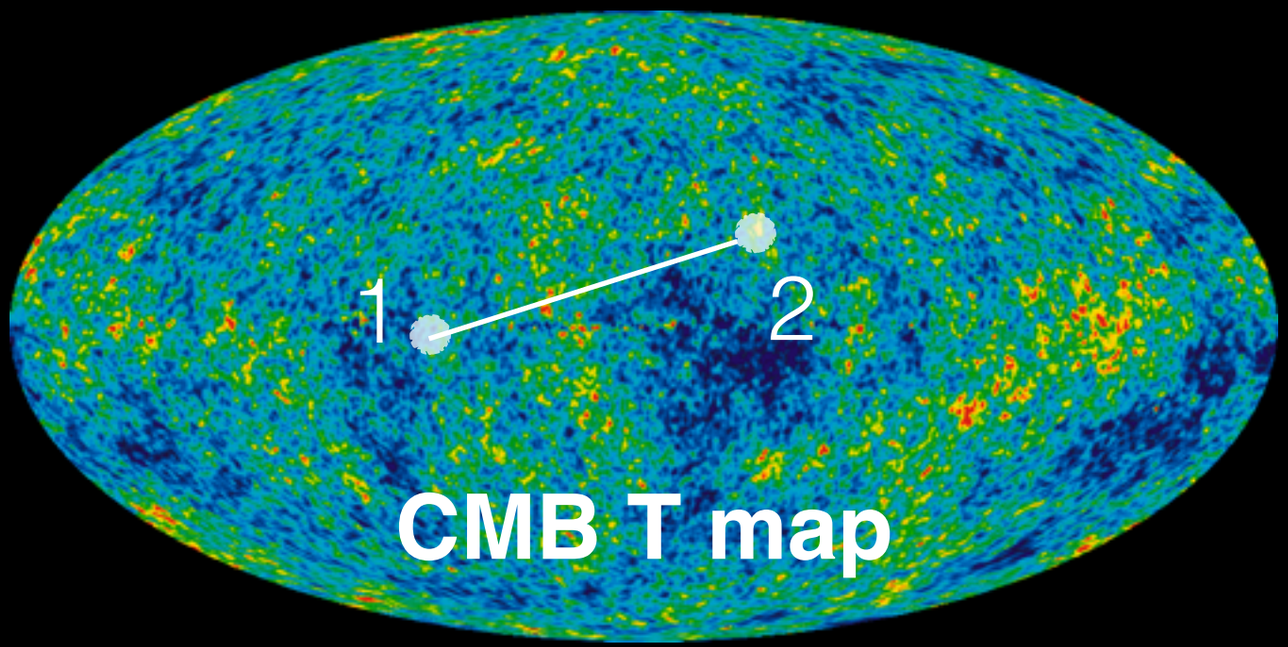
Universe before inflation?
Birth of time?
quantum gravity? string?
other dims? end of Universe?
Multiverse?

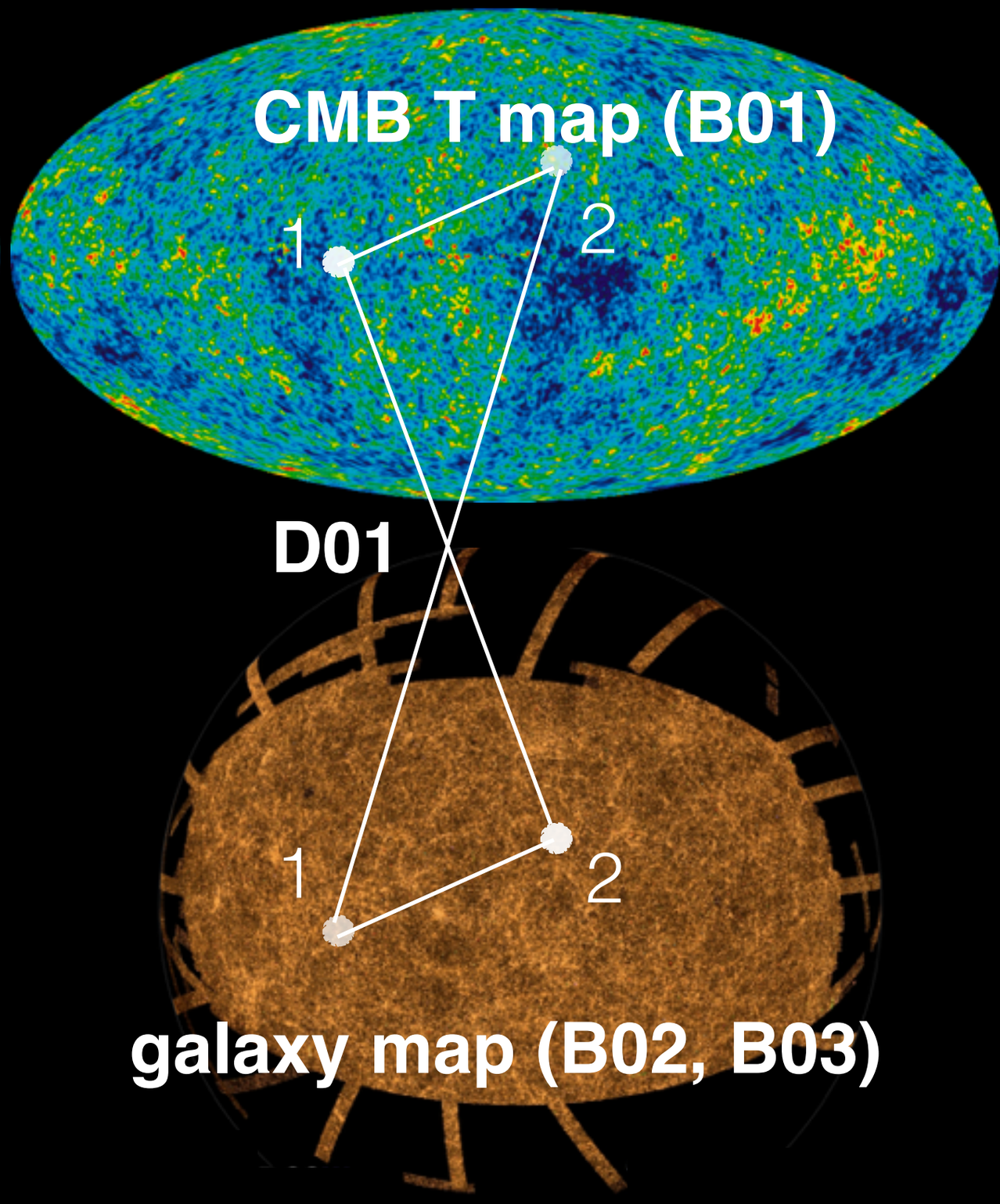


X00: organization
Murayama (IPMU)

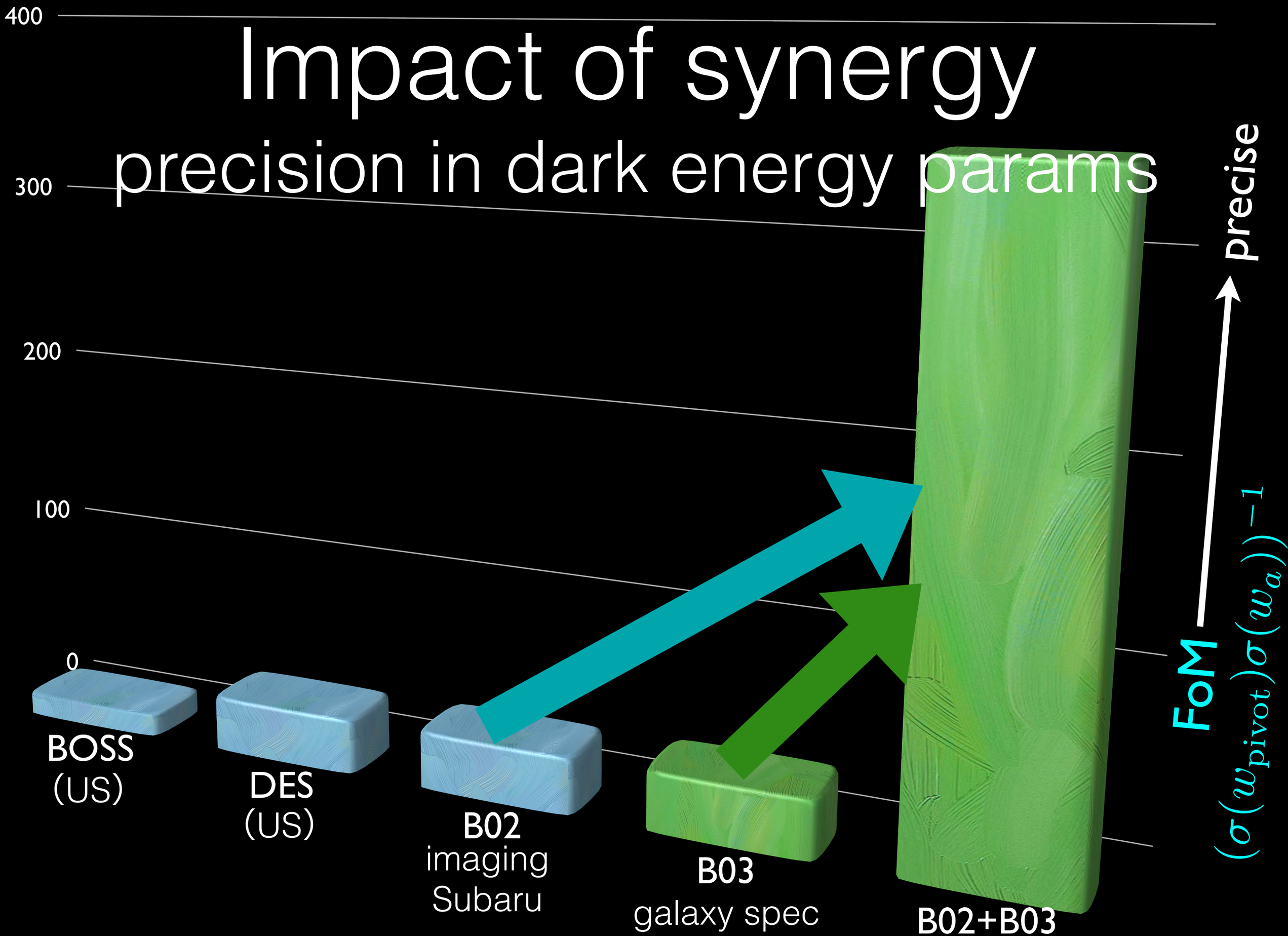
D01: ultimate analysis Komatsu(MPA)

D01:combination⇒synergy





Impact of synergy
precision in dark energy params

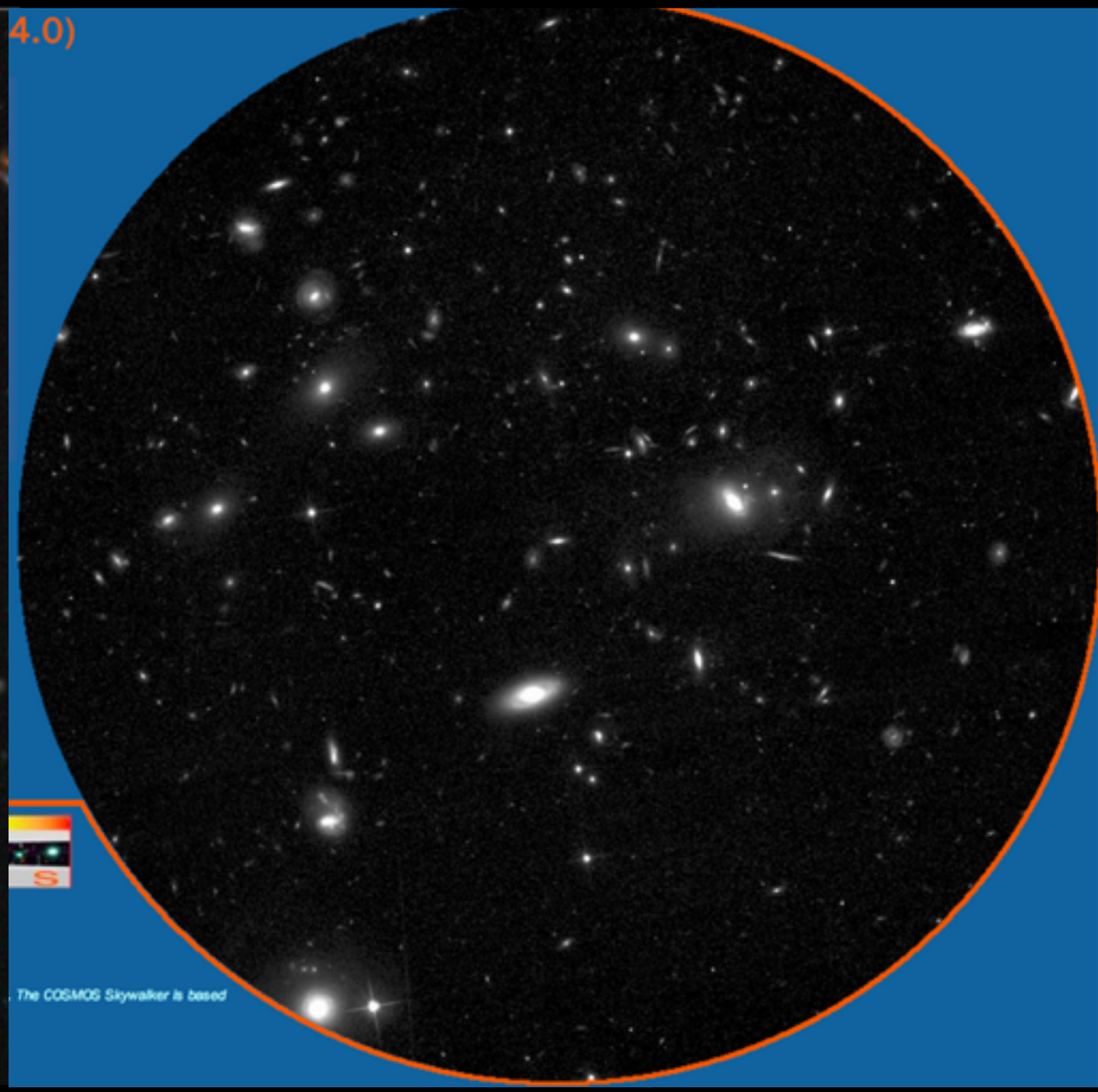


HSC WFC

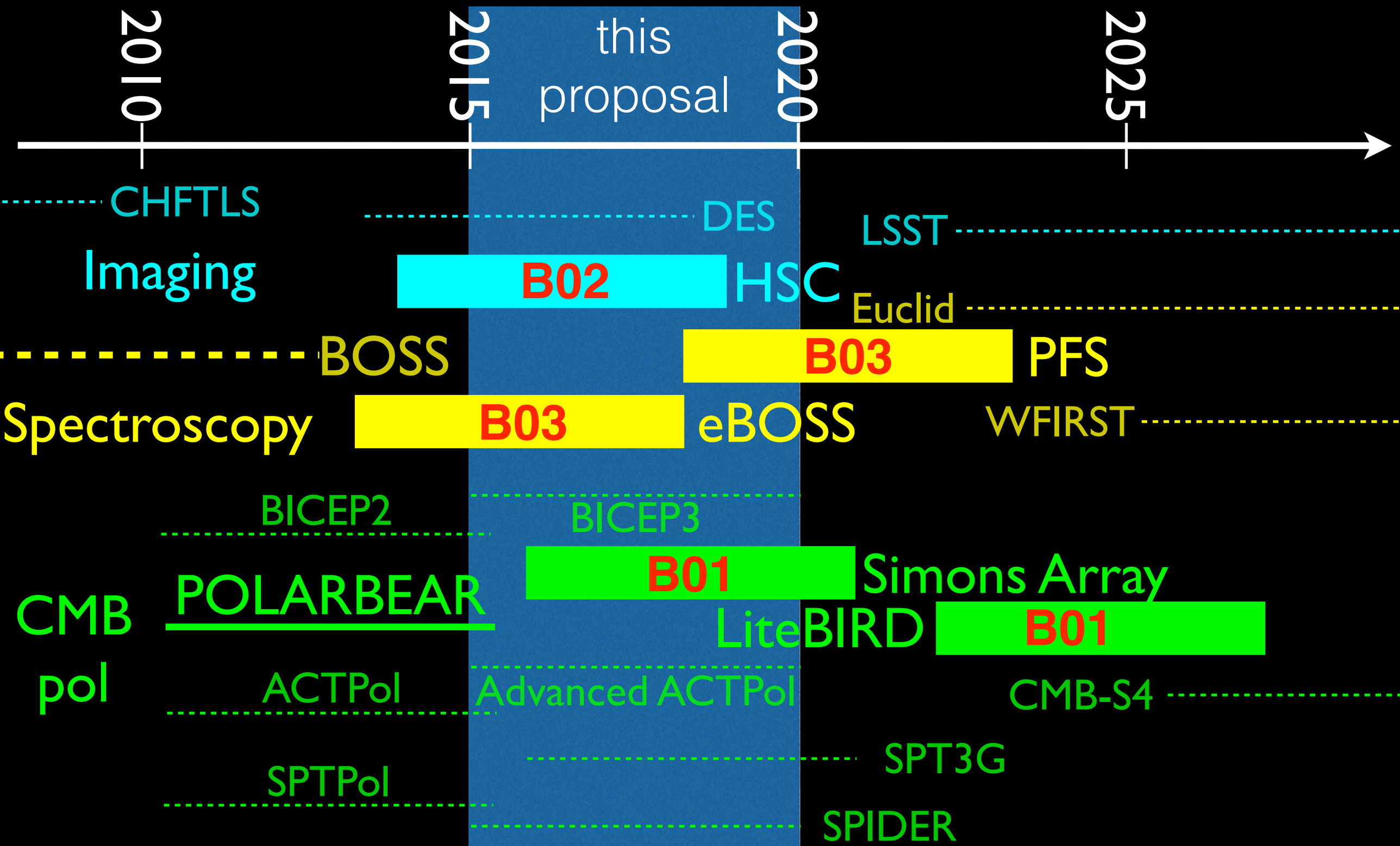
Example of readiness: B02

new camera on Subaru
2.5 hours in 3 colors

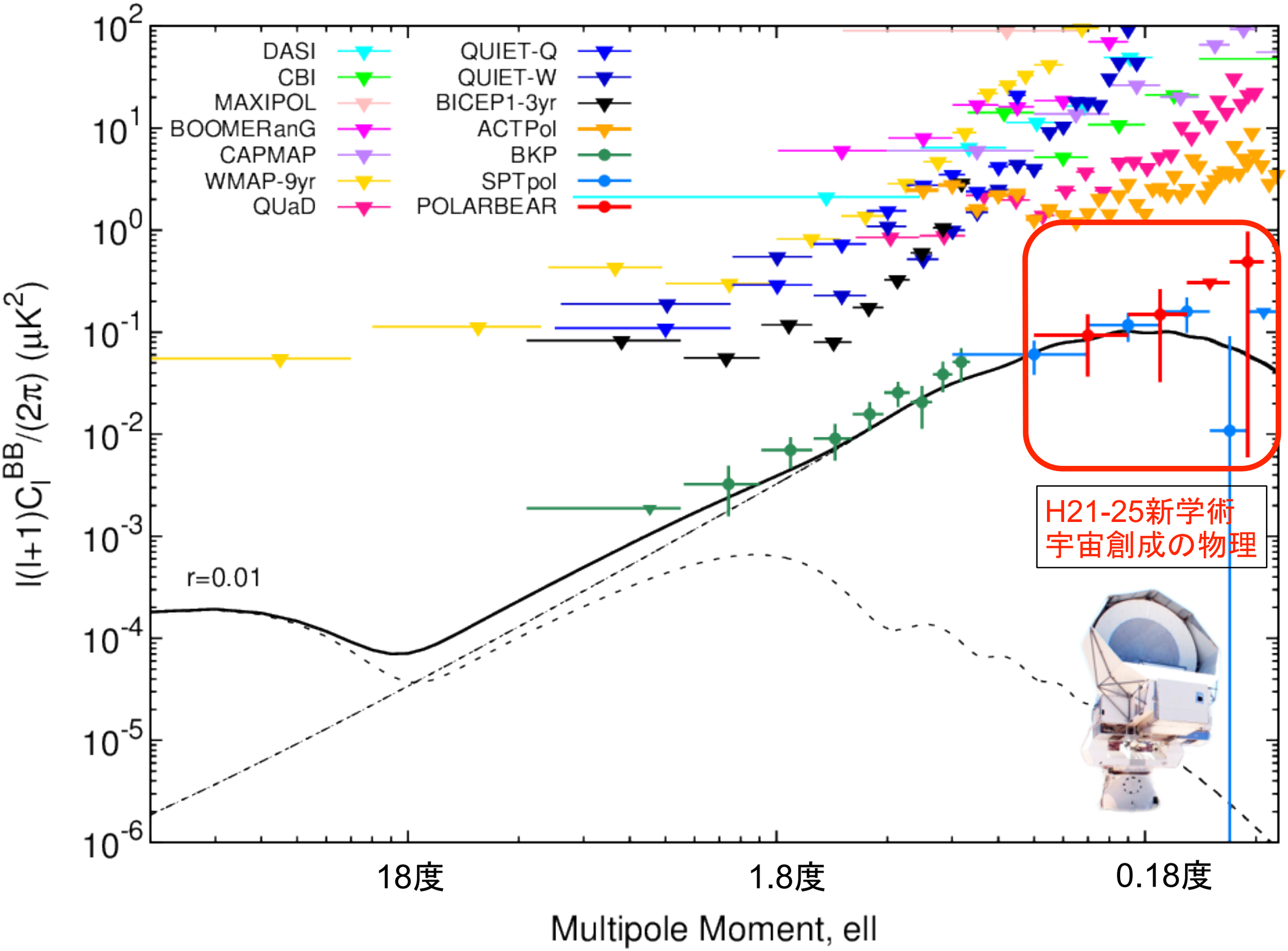
Hubble Space Telescope
500 hours in 1 color



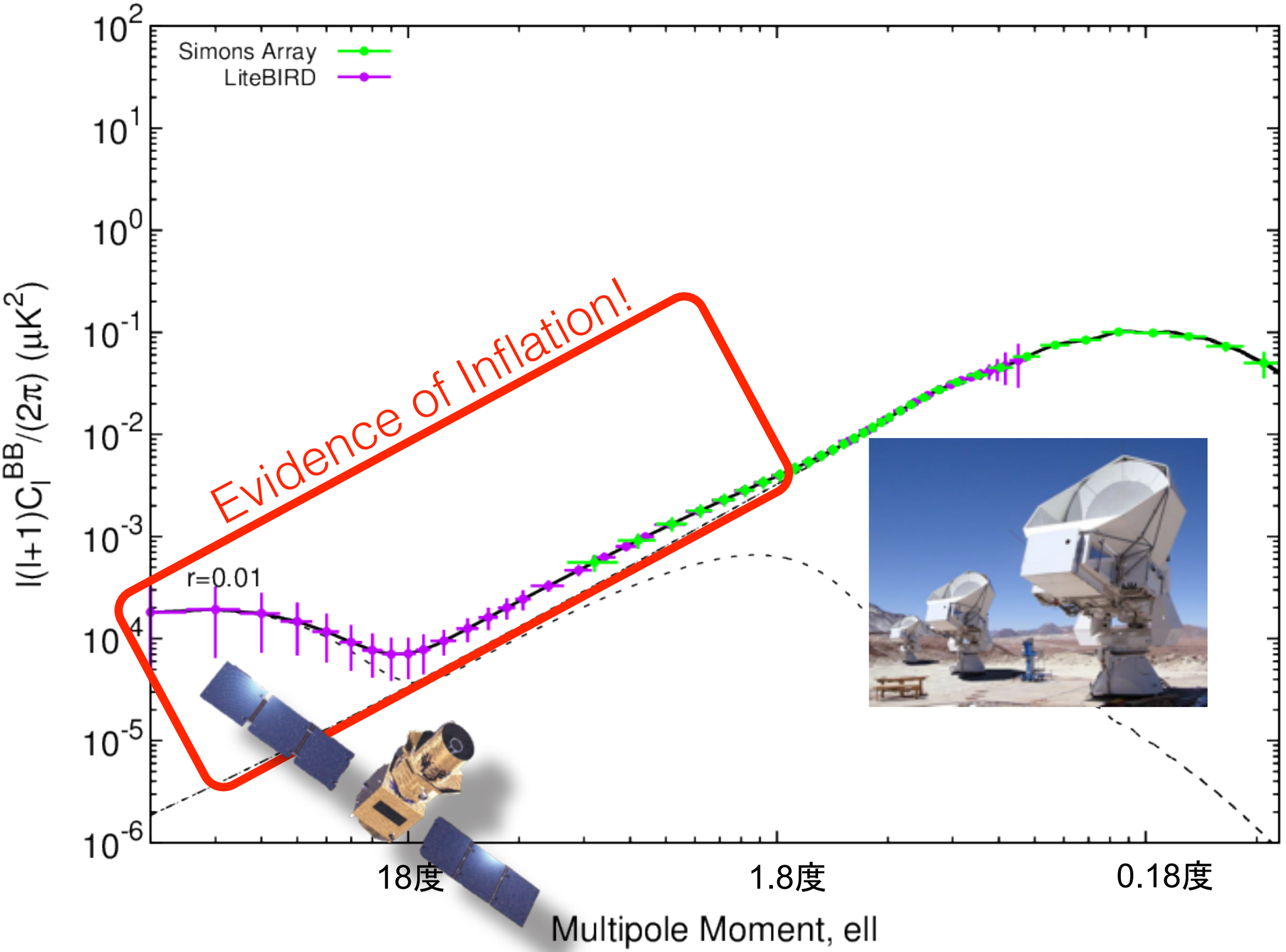
Intense Competition



Example of readiness: B01



And into the future: B01



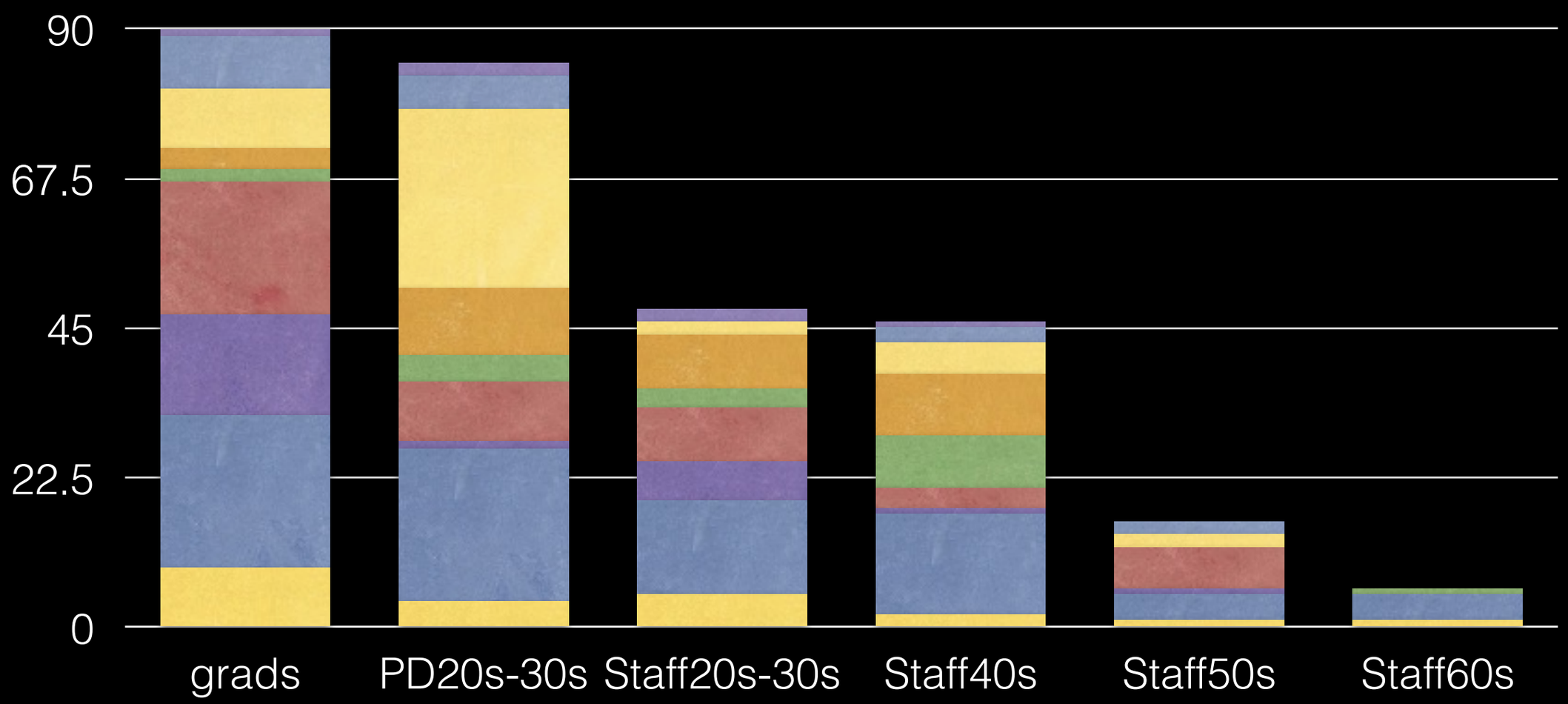
What result may come out

- *Possible within 5 years*
  - B01 detects primordial grav wave and proves inflation → Big challenge for string theory
    - B02 shows dark energy changes → Big Rip
  - Preparation for future big discoveries
    - B03 measures curvature of space → Multiverse?
    - B04 detects variation in natl constants → strongly supports string
- evidence & new development in ultimate theory

All Star Team

Team	Name	Affiliation	Expertise
PI, organization	Murayama	Tokyo/Berkeley	particle theory
administration	Katayama	Tokyo	particle expt
A01	Sasaki	Kyoto	relativity
A02	Takahashi	Tohoku	particle theory
A03	Sugiyama	Nagoya	cosmology
B01	Hazumi	KEK	particle expt
B02	Miyazaki	NAOJ	observation, instrument
B03	Takada	Tokyo	cosmology
B04	Usuda	NAOJ	observation, instrument
C01	Ooguri	Tokyo/Caltech	particle
D01	Komatsu	Tokyo/MPA	cosmology

Age population

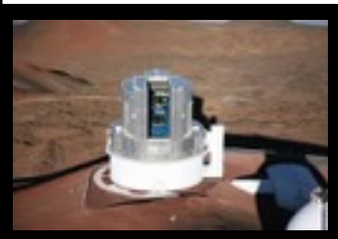


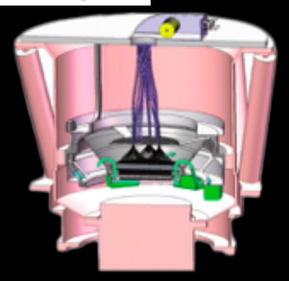
research led by grad students and researchers in 30s-40s

Japan

overseas

Intl collab





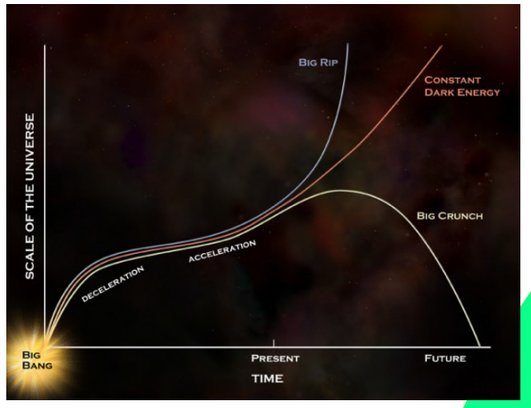
TMT
THIRTY METER TELESCOPE

Strong Community Support

Comprehensive study of accelerating Universe

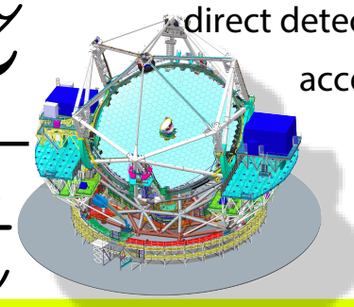
Ultimate Theory

Ultimate Analysis



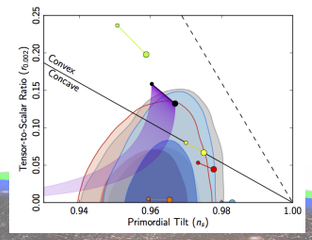
Dark Energy

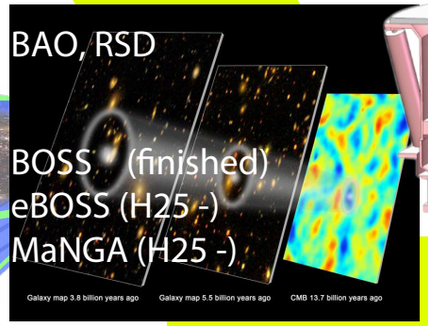
$$\frac{dz}{dt}$$

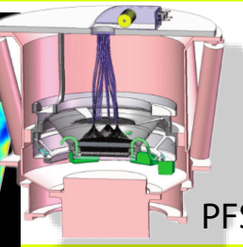


direct detection of acceleration (future)

TMT

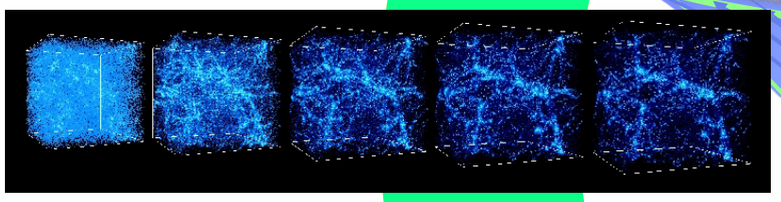






PFS(future)

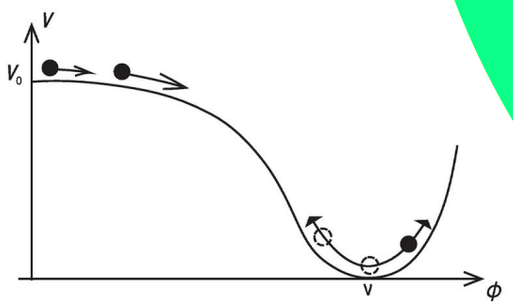
spectroscopy



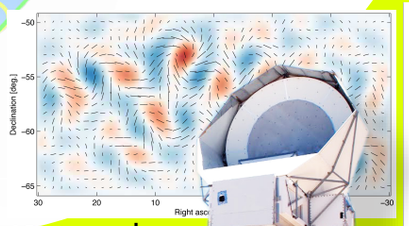
Fluctuation & Structure

(H26-30)

Subaru HSC

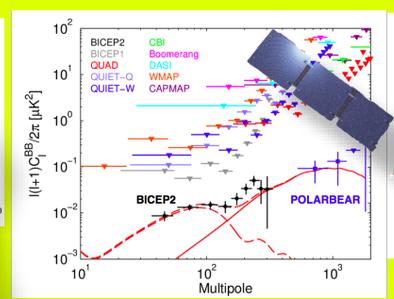


Inflation



CMB B-mode

Simons Array (H27-)



LiteBIRD (future)

CMB E-mode

primordial spectrum

primordial non-Gaussianity

CMB Pol.

Open Solicitation

- This project comes with opportunities for 14 participating proposals in JFY2015! ~9 <¥1M, ~2 <¥2M, ~2 < ¥4M
- E01: Theoretical and/or numerical study related to the evolution and structure of the Universe
- E02: Experimental and observational study related to the evolution and structure of the Universe
- E03: Study that can bridge between theoretical, numerical and experimental/observational studies related to the evolution and structure of the Universe

複数ウィンドウ（複数タブ）を開いて利用すると、システムが正常に動作しない場合があります。複数ウィンドウでのご利用は控えてください。

➡ 一時保存をして次へ進む　一時保存　保存せずに戻る

平成28年度（2016年度）新学術領域研究（研究領域提案型）　（継続の研究領域・終了研究領域）
研究計画調書

研究区分	公募研究	
研究課題番号		
研究領域 一覧	領域番号	領域略称名
	2705	加速宇宙
研究項目番号	E01	
各年度の上限金額	2000 （千円）	

領域選択に戻る

Consider applying!