



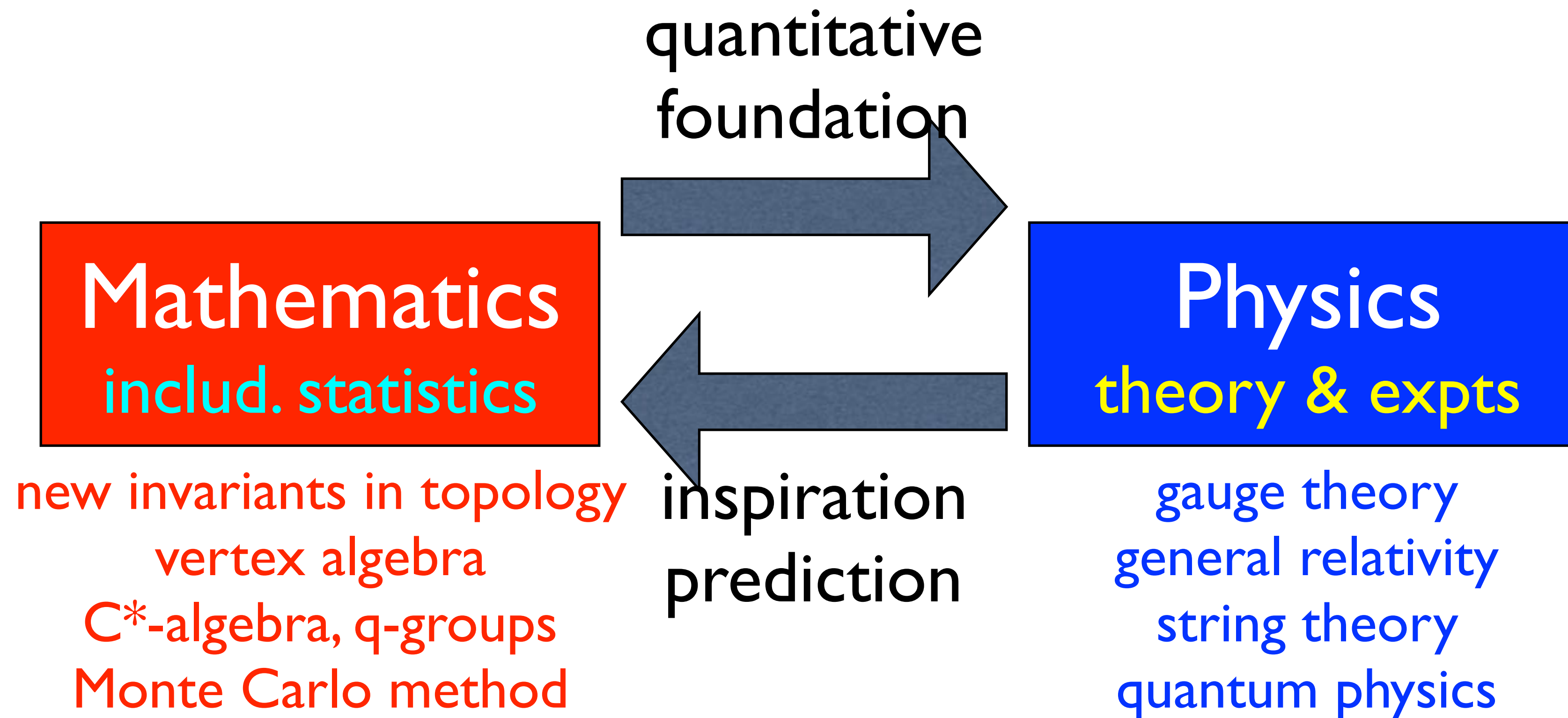
Opening Remarks

10th Anniversary Symposium

Hitoshi Murayama, October 16, 2017



Mathematics and Physics promote each other



7 out of 18 Fields Medals since 1990
were inspired by particle physics
Now 13 out of 26

growing field!

Nobel prizes in 1999, 2002, 2004, 2006

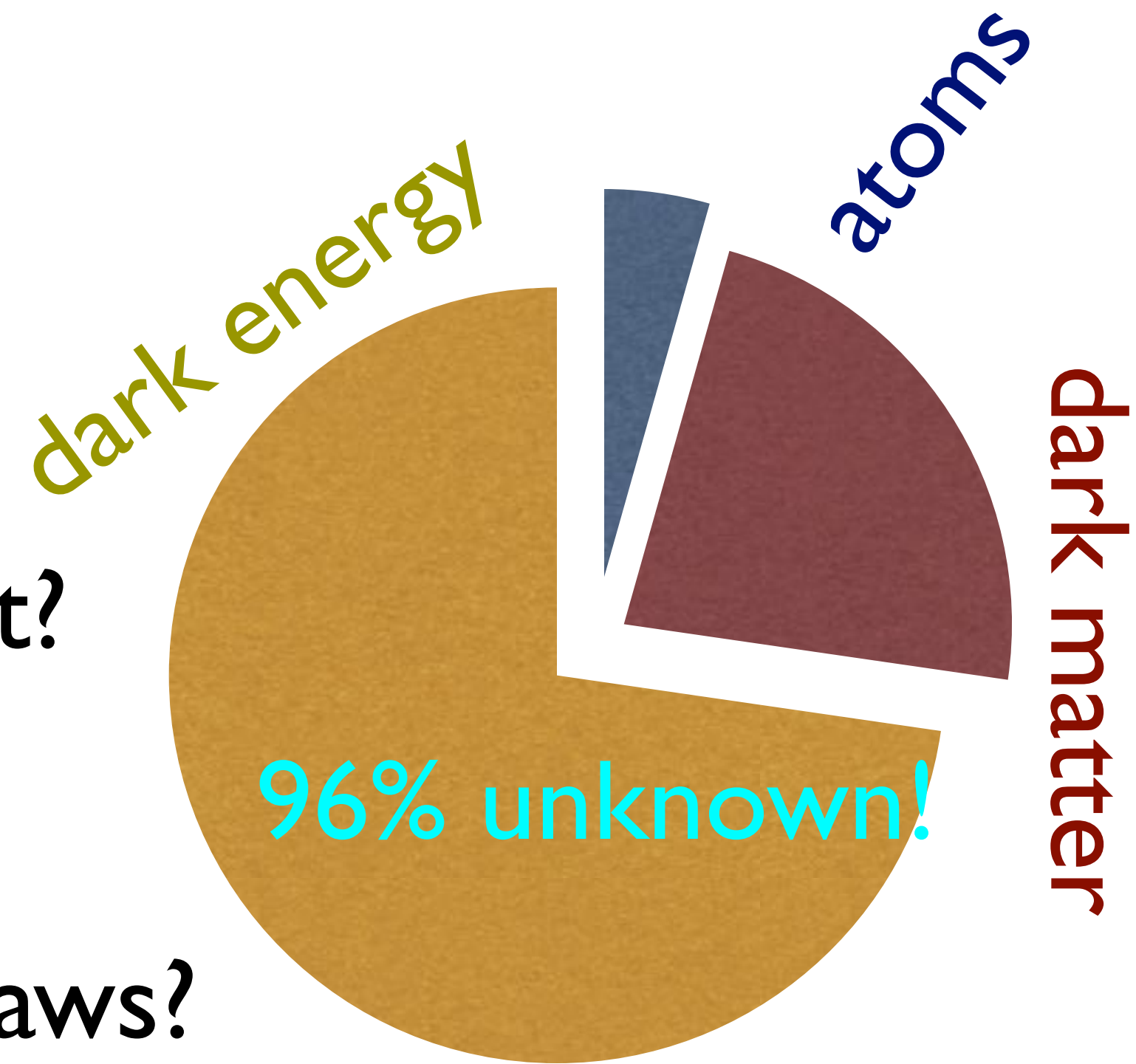
+2008, 2011, 2013, 2017

The Science

- How did the Universe start?
- What is it made of?
- What is its fate?
- What are its fundamental laws?
- Why do we exist?

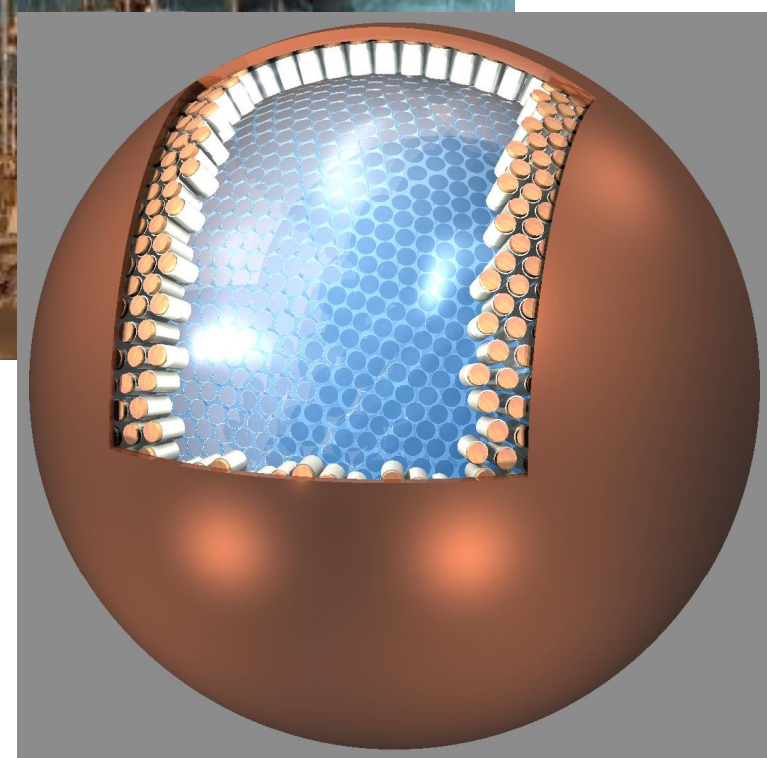
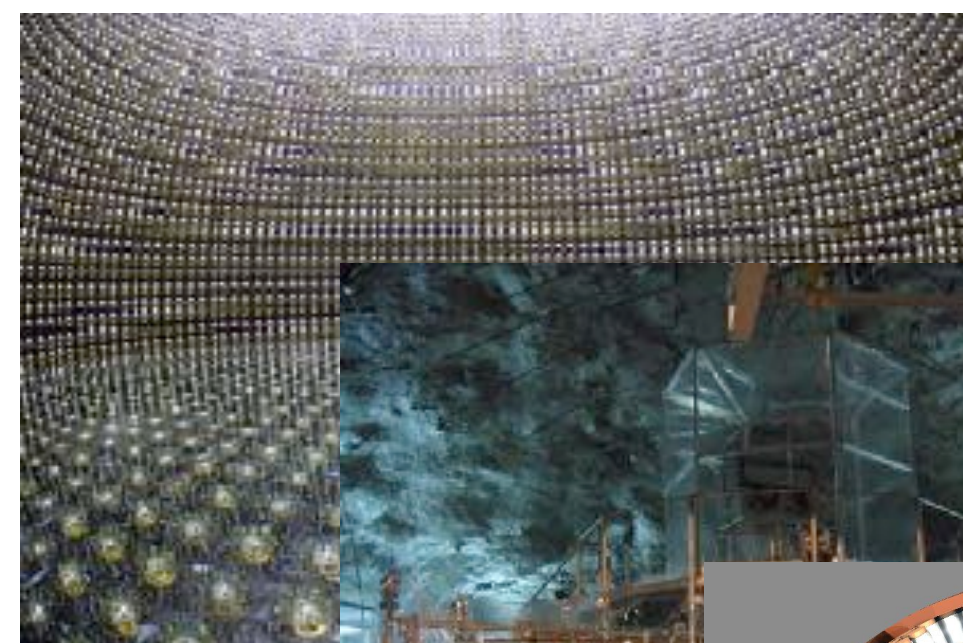
We need **new data** to address them

We need both **new mathematics** and **new physics** to describe them



Multi-faceted attack on the universe

Together with **math** and
theory, *unique*
combination in the
world!



ICRR/Tohoku

undergroun

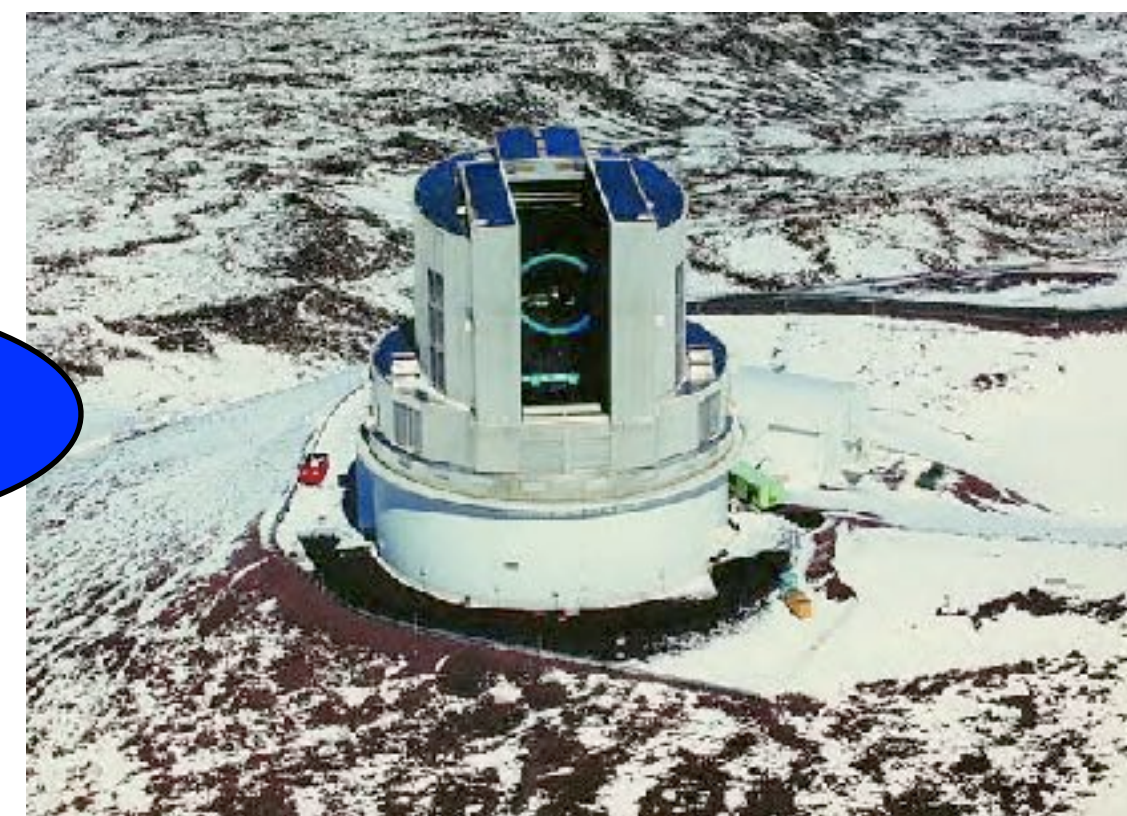
Universe

accelerator

sky



LHC
(CERN)



Subaru (NAOJ)

世界トップレベル国際研究拠点形成促進プログラム
東京大学数物連携宇宙研究機構発足
(Institute for the Physics and Mathematics of the Universe)

2007 October

The Institute for the Physics and Mathematics of the Universe (IPMU) established
Hitoshi Murayama appointed as Founding Director

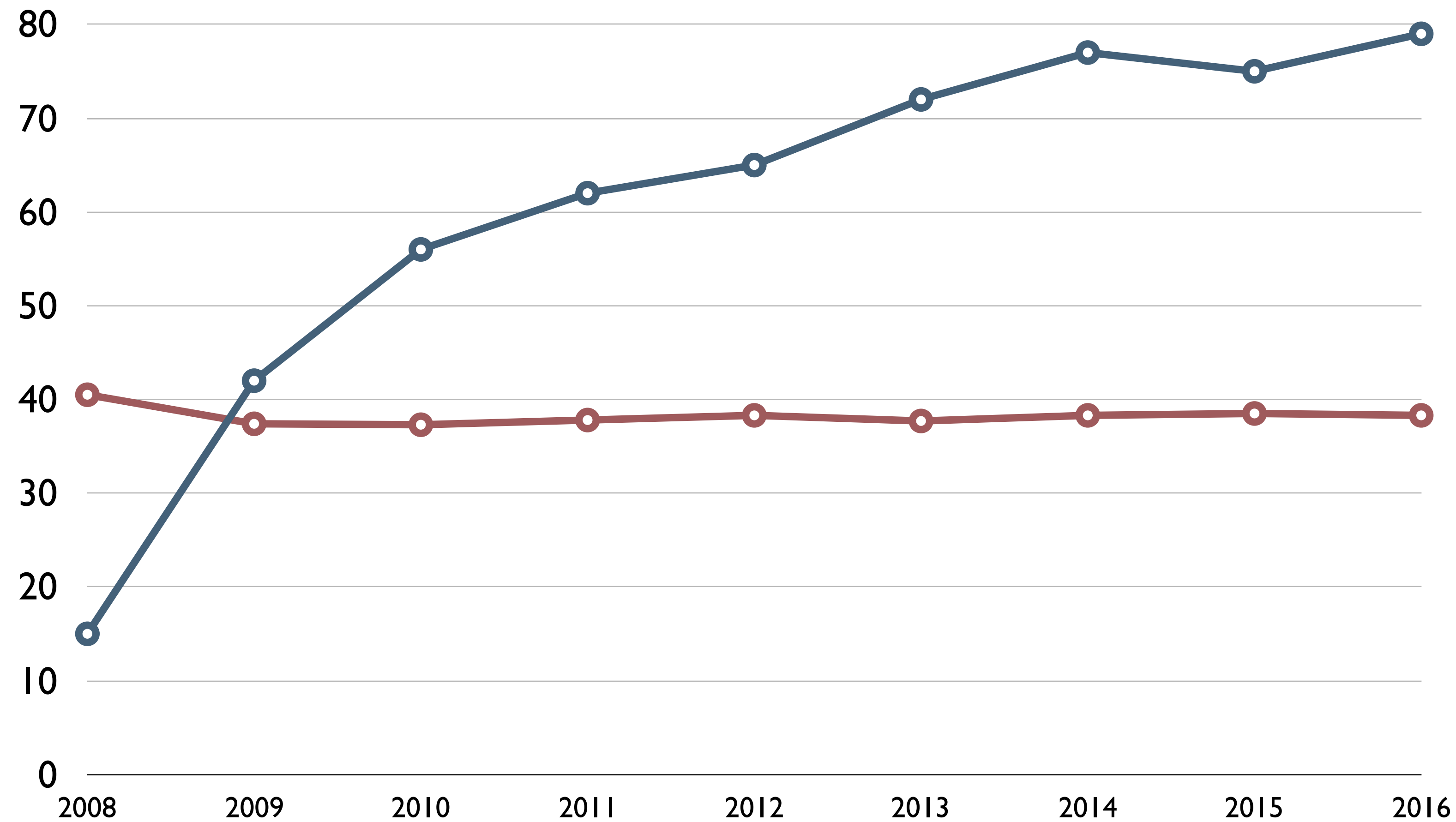




Credit:
Susanne Reffert

Young Institute

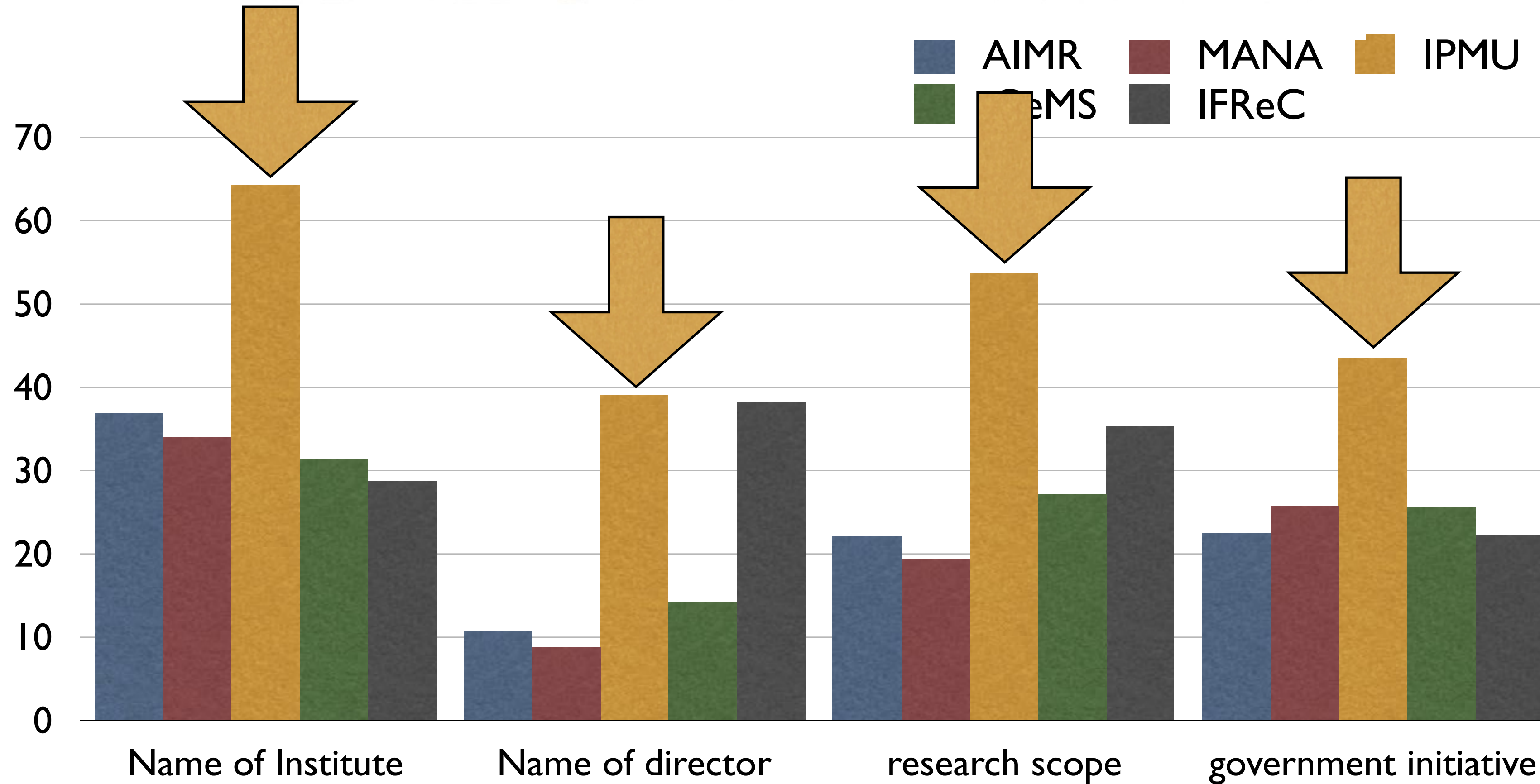
○ Number of Research Staff ○ Average Age



Ph.D. scientists only. Not including graduate students

International Visibility

KAVLI
IPMU INSTITUTE FOR THE PHYSICS AND
MATHEMATICS OF THE UNIVERSE



Mitsubishi Research Institute, November 2009
random sampling of authors in relevant journals

nurturing young scientists

- >700 applications every year
 - >80% from outside Japan
- hired 139 PDs so far, 107 left by Mar 2015
 - 44 already landed on faculty jobs (41%)!
 - 52 moved to next PD
- globalization spreads out
 - our international members go to faculty at Japanese institutions



Ph.D.
faculty



Berkeley
Tsukuba

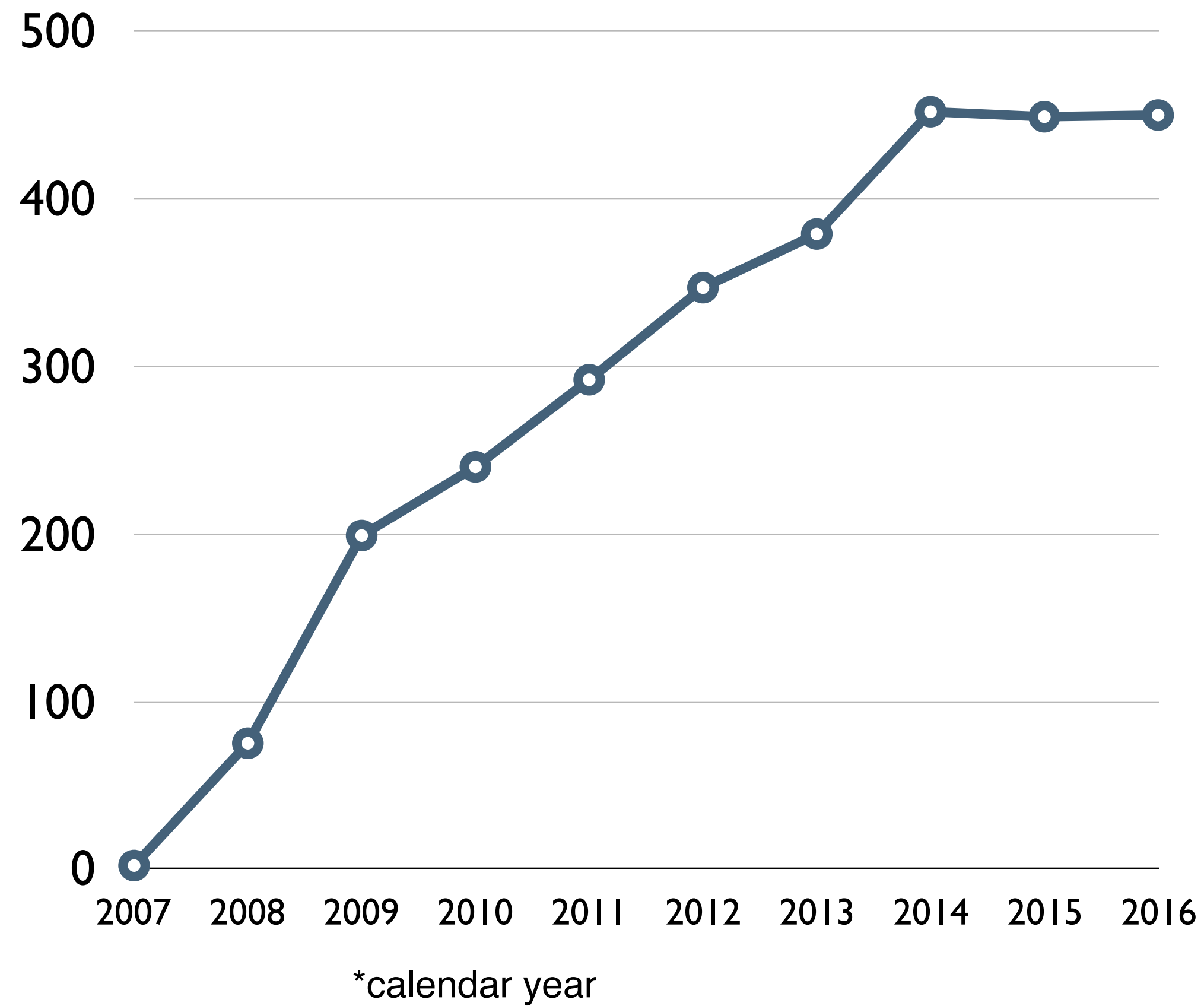


Cambridge
Kyoto

Yale
Kyoto

publications per year

○ refereed publications*



institute	citation/paper	#papers >50 citations
IPMU	24.7	293
IAS	28.1	254
KITP	31.8	131
YITP	18.0	100
Perimeter	25.3	243
ICTP	20.2	141

Jan 2008 - Dec. 2016

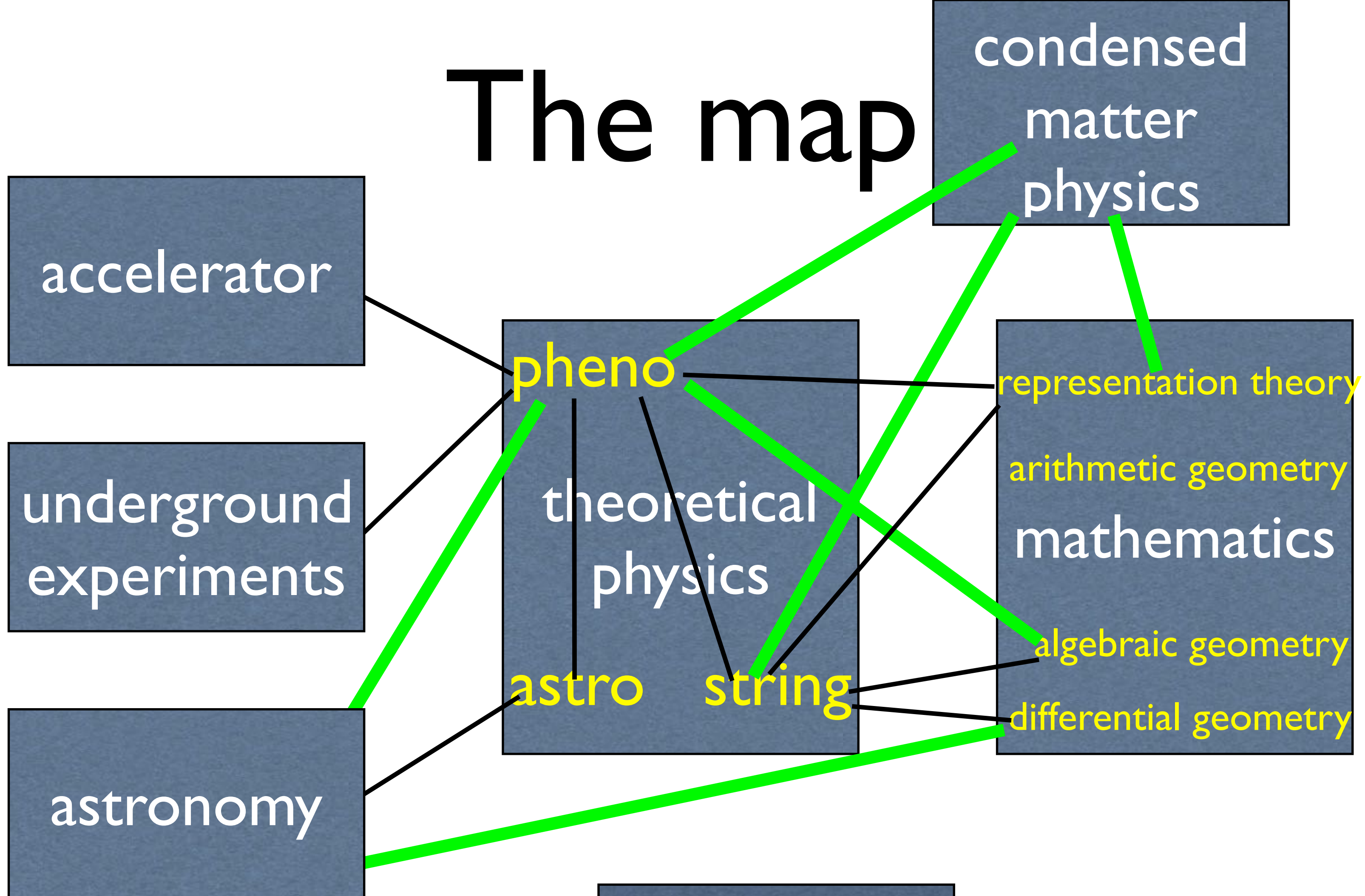
Web of Science (Thomson Reuters), excluding reviews
 fields: astronomy, astrophysics, particle and fields,
 multidisciplinary physics, mathematics, applied mathematics

World-class

	Number of papers	Number of TOP10%	Ratio of TOP10%	Number of TOP1%	Ratio of TOP1%	Number of International joint authorship	Ratio of International joint authorship	Average of comparative citation counts
Kavli IPMU (Tokyo)	2,435	657	27.0%	85	3.5%	1,619	66.5%	2.37
KIPAC (Stanford)	1,529	515	33.7%	98	6.4%	1,227	80.2%	2.89
MPA (Munich)	2,491	751	30.1%	121	4.9%	2,219	89.1%	2.74
IAS (Princeton)	2,308	670	29.0%	121	5.2%	1,154	50.0%	2.56
KIAS (Seoul)	1,847	225	12.2%	30	1.6%	276	14.9%	1.35
IHES (Paris)	589	126	21.4%	13	2.2%	435	73.9%	2.39

Web of Science (Thomson Reuters) CY2007-2015

The map

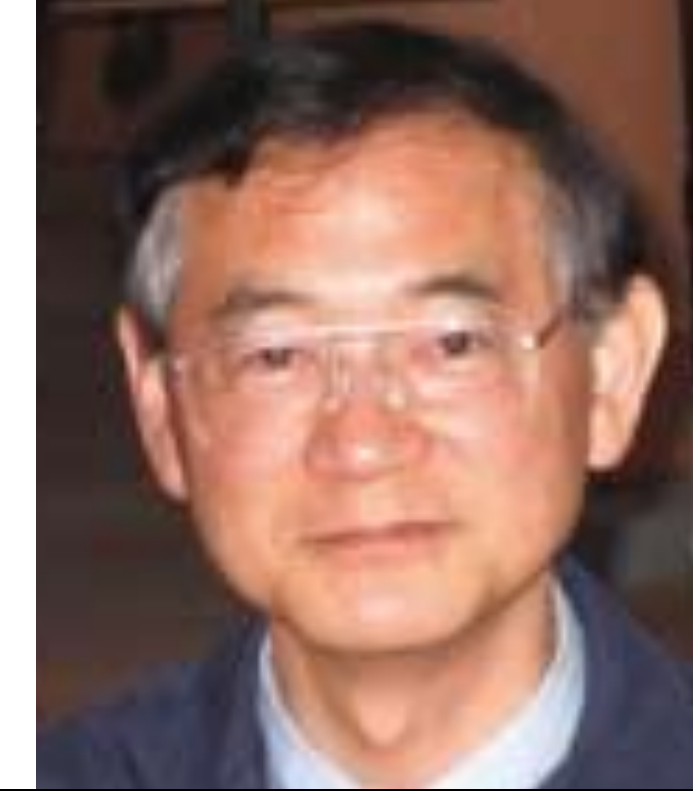


- proposed & achieved
- unanticipated & achieved

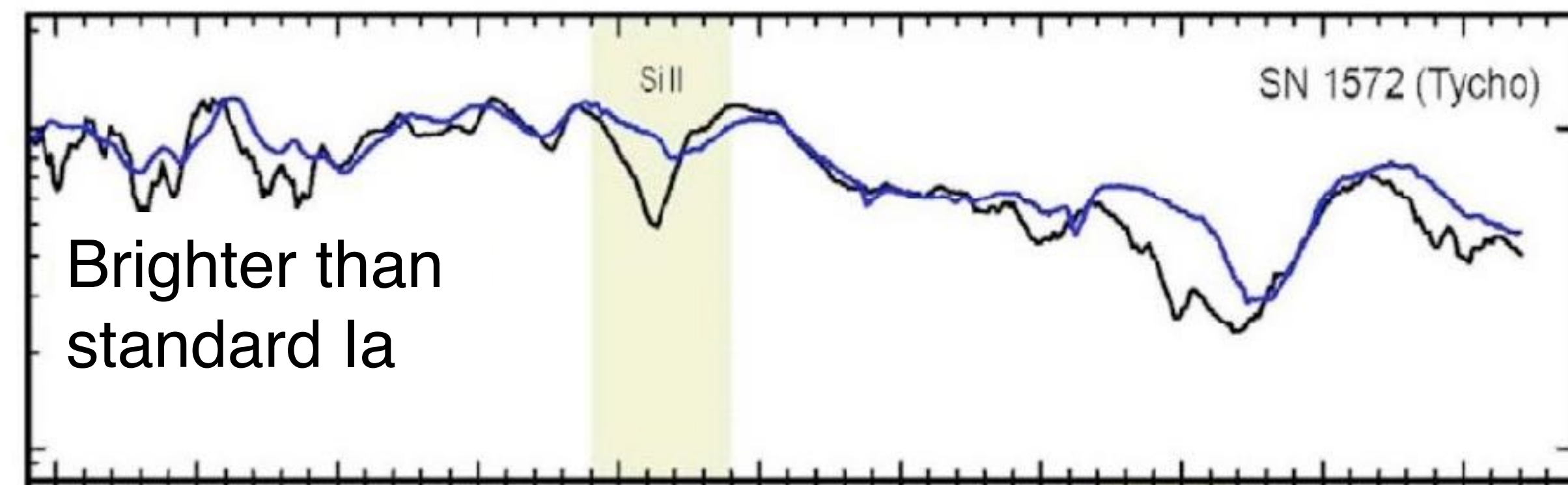
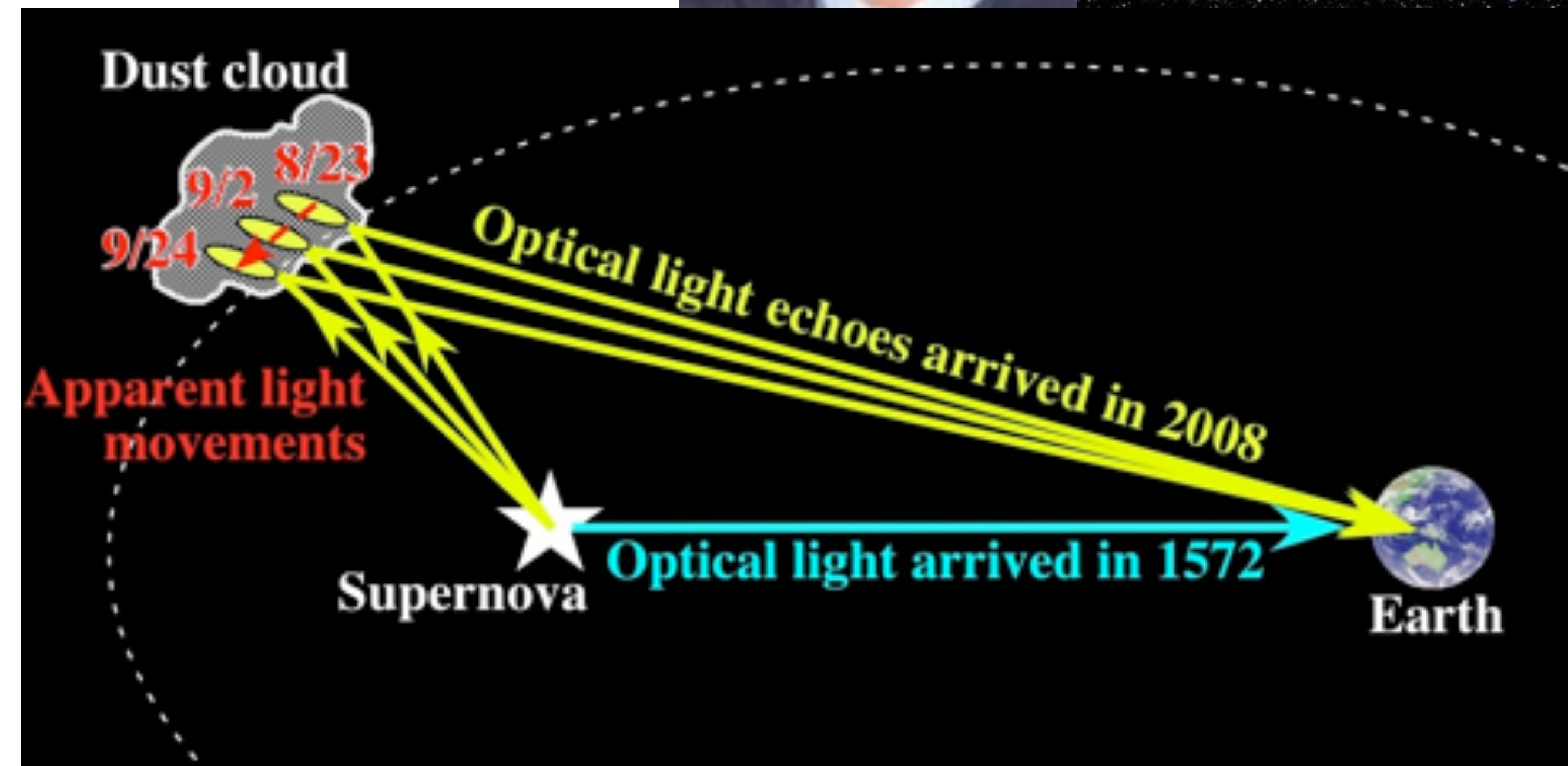


Echo of Tycho's supernova

Nature, 456 (2008) 617



- Tycho's supernova observed in 1572
- not known its type
- **Nomoto (PI)** and collaborators observed its *echo* due to reflection by dust cloud, spectral analysis by Subaru telescope
- **determined to be Type-Ia, the kind used to discover Dark Energy**



T2K Experiment

Y. Suzuki (IPMU Dep. Dir./PI)
M. Vagins (IPMU Prof)
M. Hartz (IPMU Asst. Prof)
C. Bronner (IPMU postdoc)
M. Nakahata (IPMU PI)
T. Kajita (IPMU PI)
K. Inoue (IPMU PI)
H. Sobel (IPMU PI)
+ 28 IPMU affiliate members

Super-Kamiokande
(ICRR, Univ. Tokyo)

J-PARC Main Ring
(KEK-JAEA, Tokai)



Discovered a new mode of neutrino oscillation $\nu_\mu \rightarrow \nu_e$
Most precise measurement of θ_{23} and Δm^2_{23}
CP Violation at 2σ ! (2017) announced by Hartz
Builds on Kajita's Nobel Prize





Werner
math
↓
Hakubi Prof
Kyoto

tea time!

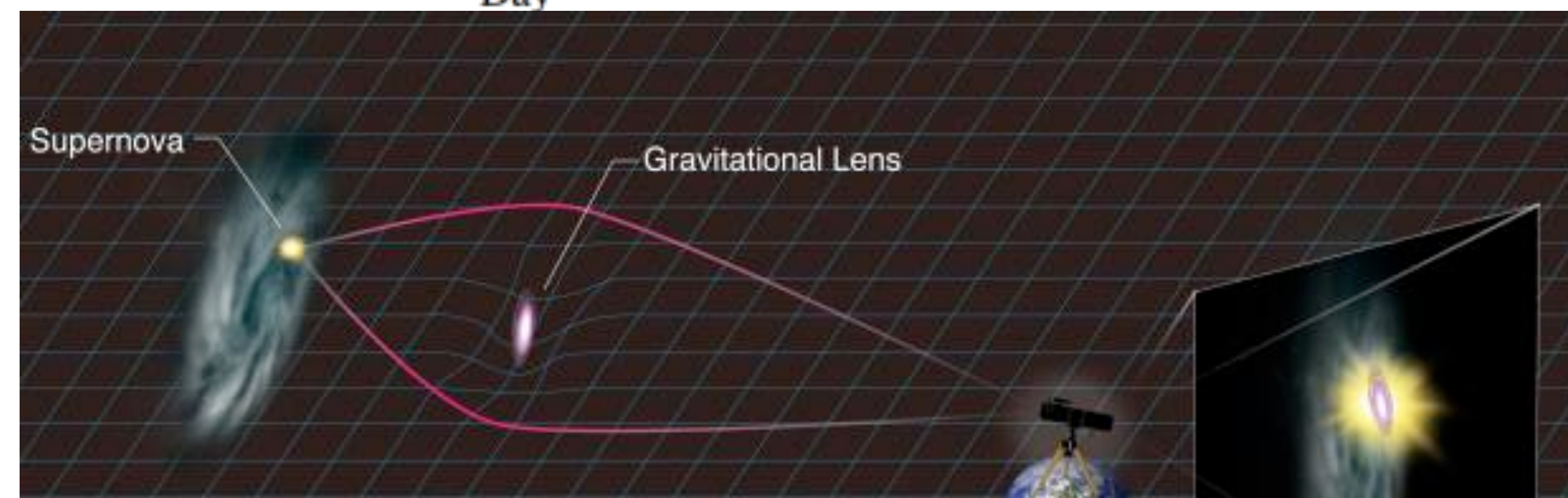
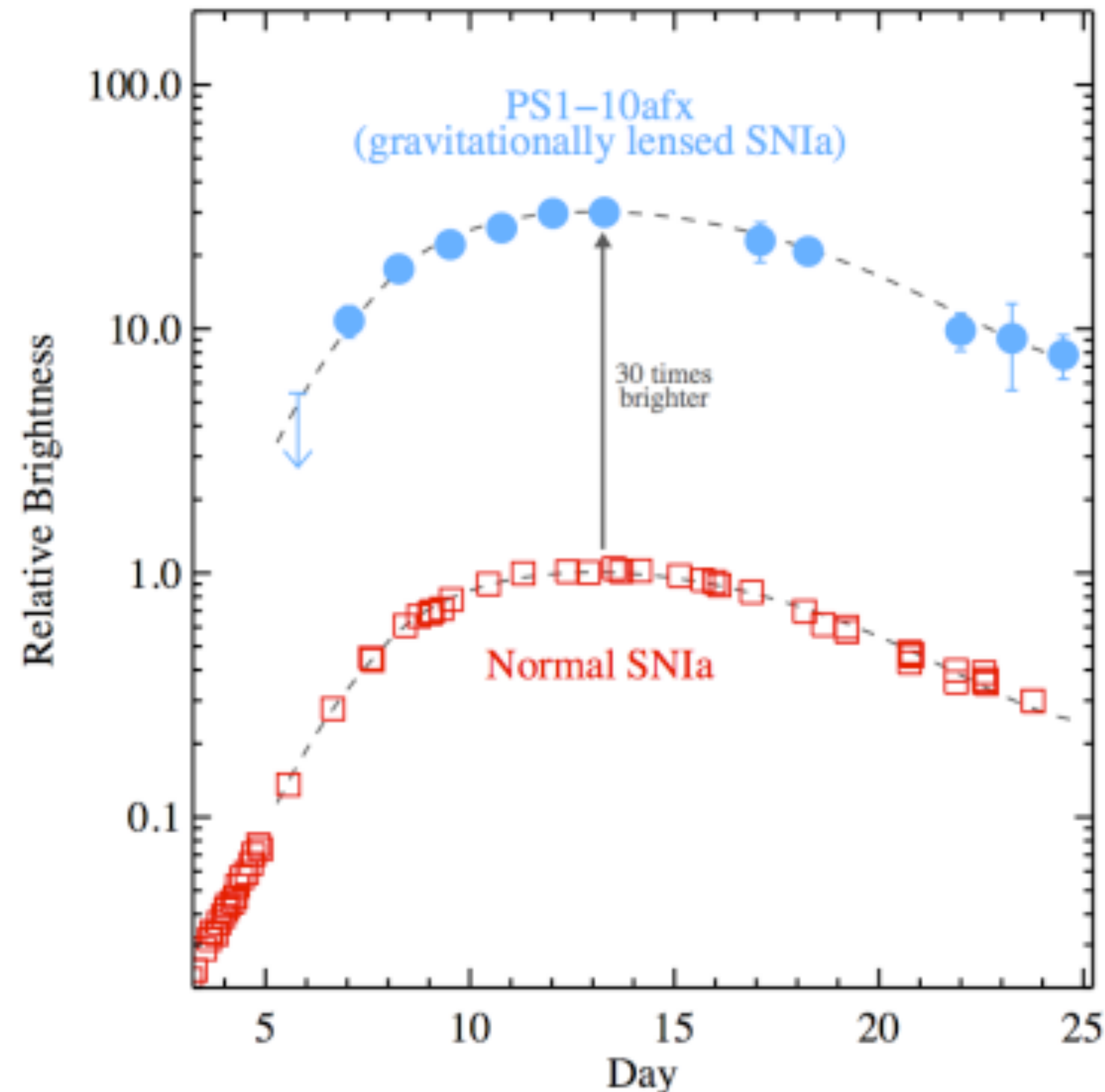


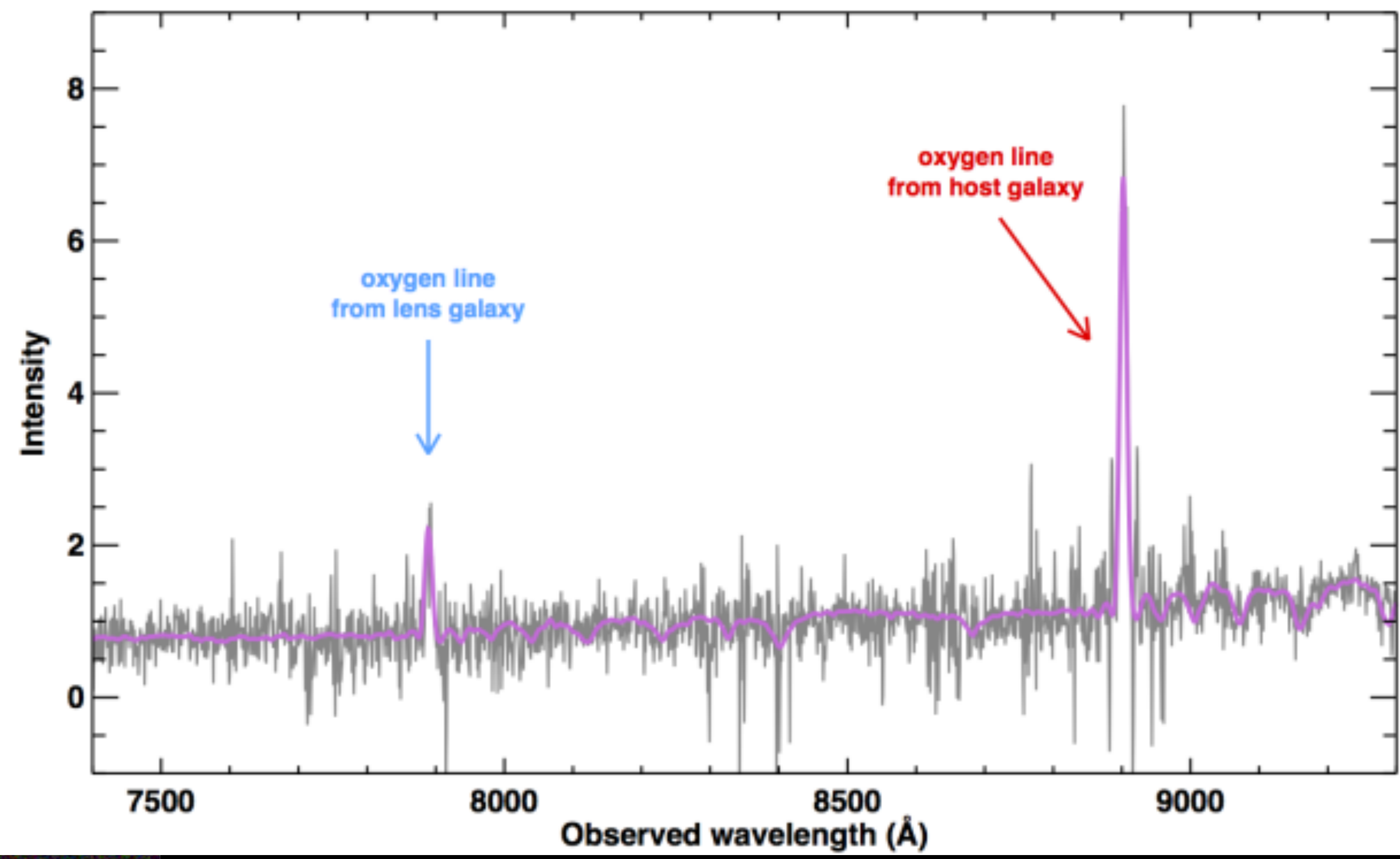
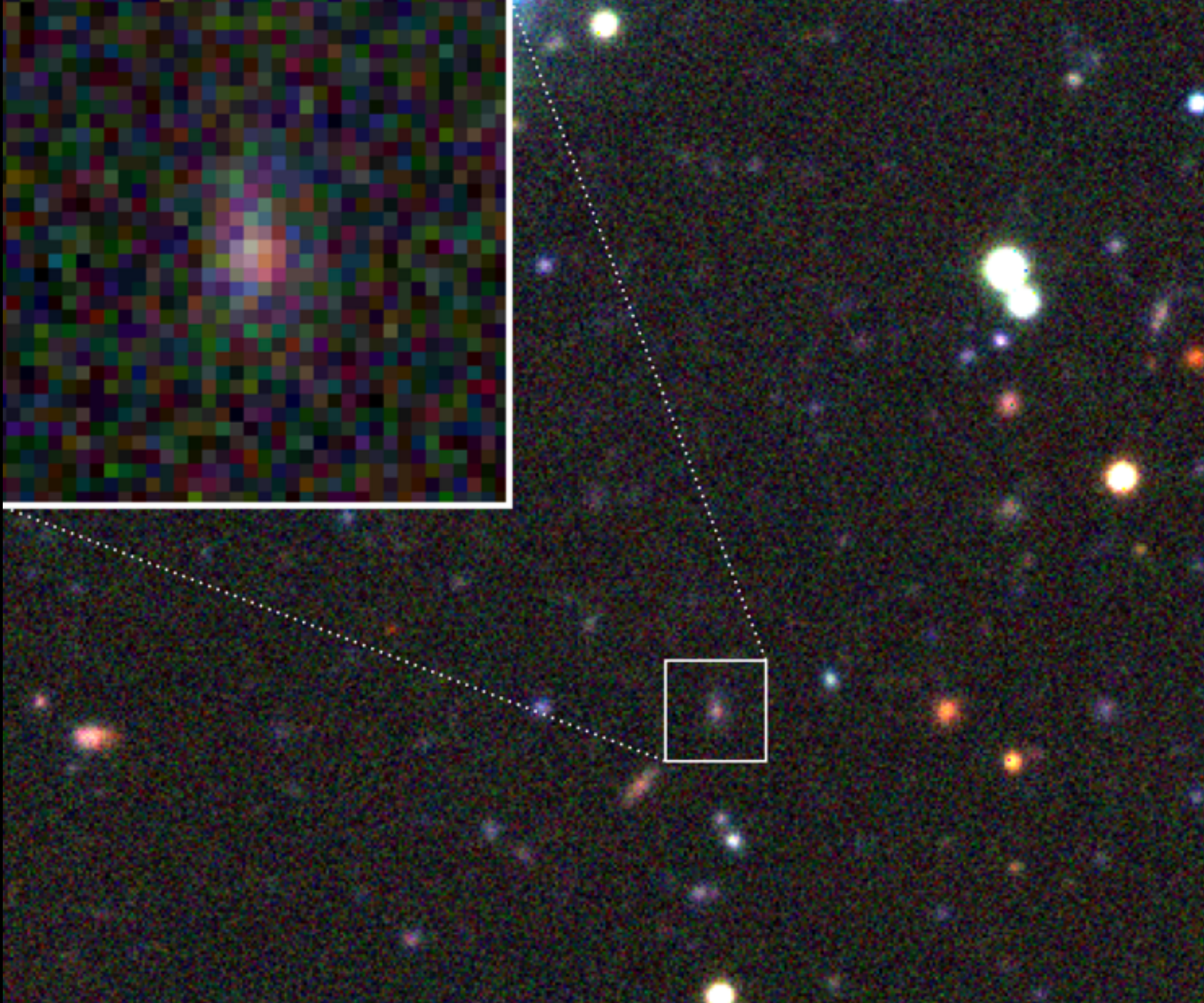
Oguri
physics
↓
Assist Prof
U Tokyo

Quimby
astronomer
↓
Director,
Mt Laguna
Obs
San Diego

- Harvard group claimed discovery of a new brightest supernova
- an astronomer puzzled; oddly familiar
- mathematician showed how it can be gravitational lensing
- physicist knew the probability of alignment
- a paper after the tea!

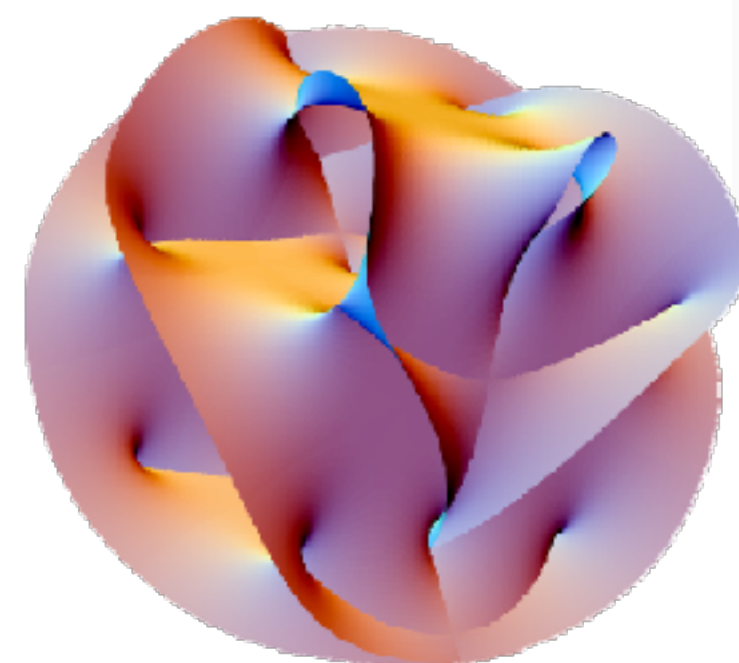
Proven true by an observation!



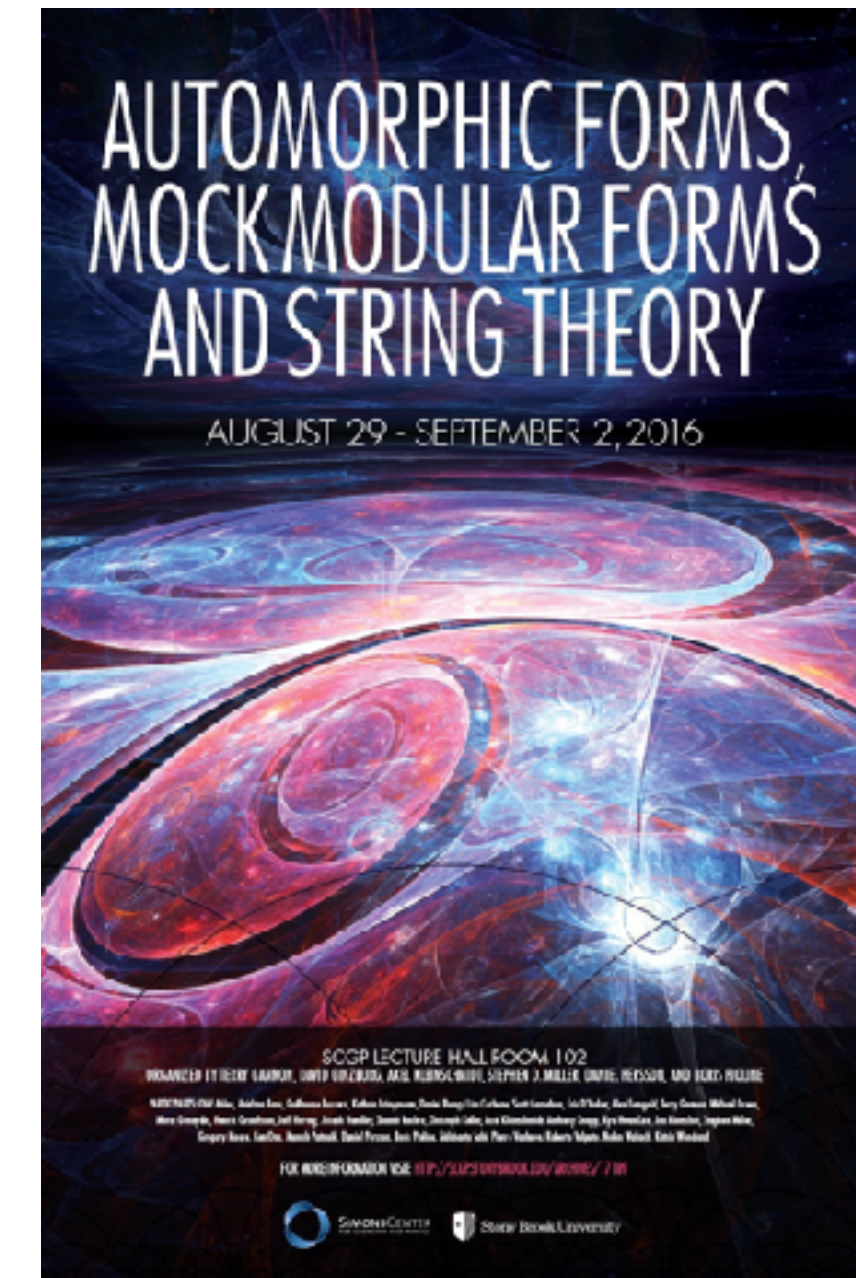
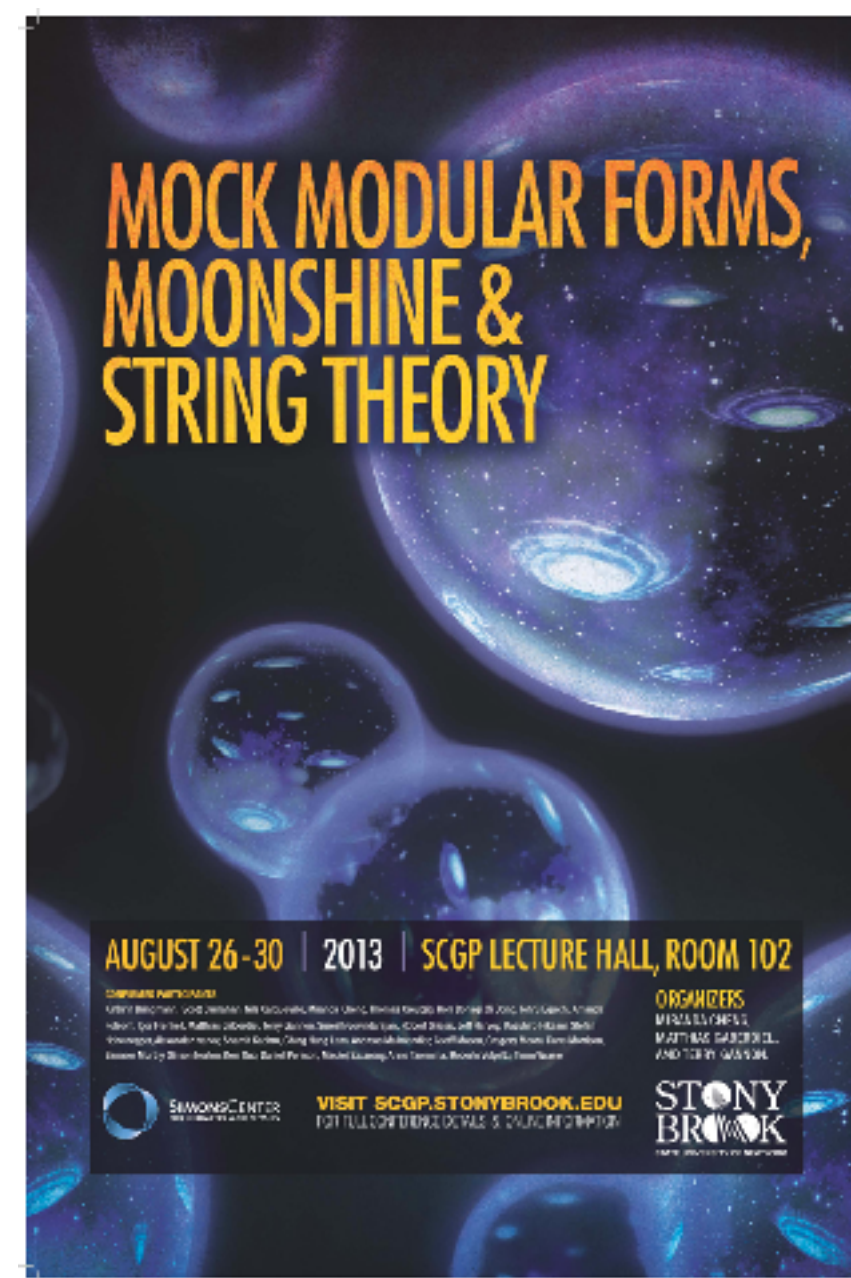
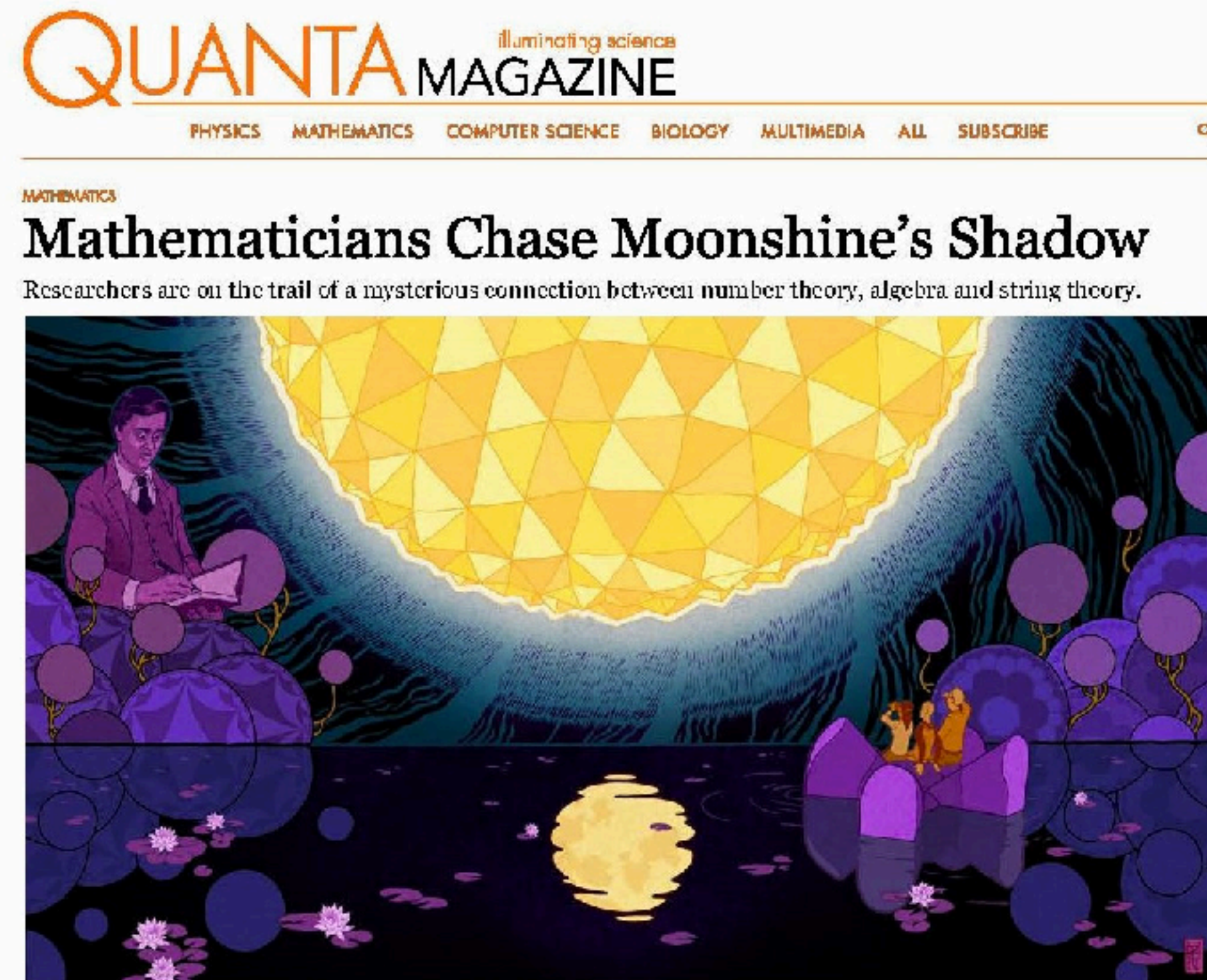


Matthieu Moonshine

- discovered a surprising connection between the **K3 surface** and the largest Mathieu group **M_{24}** using **string theory**
- connects **physics**, **algebra**, **geometry**, & **number theory**
- spawned new area of research in mathematics (*umbral moonshine*)



Eguchi, Ooguri, Tachikawa
Experimental Mathematics
20 (2011) 91





condensed matter physicist

2016 Yukawa Commemoration Prize



PRL 108, 251602 (2012)

PHYSICAL REVIEW LETTERS

week ending 22 JUNE 2012



Unified Description of Nambu-Goldstone Bosons without Lorentz Invariance

Haruki Watanabe^{1,2,*} and Hitoshi Murayama^{1,3,4,†}

¹Department of Physics, University of California, Berkeley, California 94720, USA

²Department of Physics, University of Tokyo, Hongo, Tokyo 113-0033, Japan

³Theoretical Physics Group, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

⁴Kavli Institute for the Physics and Mathematics of the Universe (WPI), Todai Institutes for Advanced Study, University of Tokyo, Kashiwa 277-8583, Japan

(Received 3 March 2012; published 21 June 2012)

Using the effective Lagrangian approach, we clarify general issues about Nambu-Goldstone bosons without Lorentz invariance. We show how to count their number and study their dispersion relations. Their number is less than the number of broken generators when some of them form canonically conjugate pairs. The pairing occurs when the generators have a nonzero expectation value of their commutator. For non-semi-simple algebras, central extensions are possible. The underlying geometry of the coset space in general is partially symplectic.

Solved 50-Year Old Mystery

Generalized theory of spontaneous symmetry breaking that works for magnets, neutron stars, to Higgs boson relies on pre-symplectic structure of homogeneous spaces helped by mathematicians Scott Carnahan, Todor Milanov, ...



Yoichiro Nambu 2008 Nobel



mathematician

Available online at www.sciencedirect.com



Nuclear Physics B 806 (2009) 224–299

www.elsevier.com/locate

NUCL
PHYS



mathematician helped physicists

New aspects of Heterotic–F-theory duality

Hiroataka Hayashi^a, Radu Tatar^b, Yukinobu Toda^c, Taizan Watari^{a,c,*},
Masahito Yamazaki^a

^a Department of Physics, University of Tokyo, Tokyo 113-0033, Japan

^b Division of Theoretical Physics, Department of Mathematical Sciences, The University of Liverpool,
Liverpool, L69 3BX, England, UK

^c Institute for the Physics and Mathematics of the Universe, University of Tokyo, Kashiwano-ha 5-1-5, 277-

Received 26 June 2008; accepted 23 July 2008

Available online 26 August 2008



DETERMINANT FORMULA FOR PARABOLIC VERMA MODULES OF LIE SUPERALGEBRAS

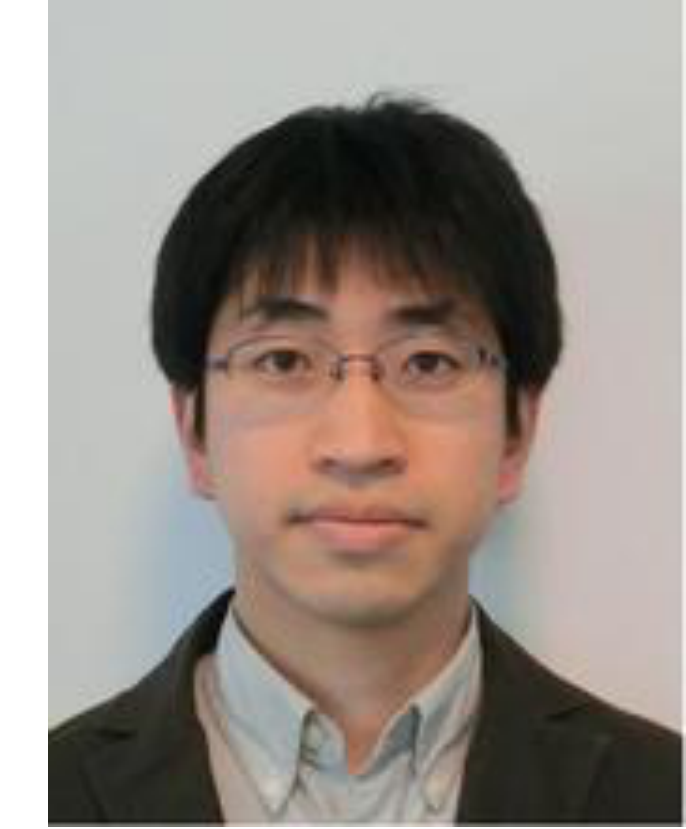
mathematician YOSHIKI OSHIMA (大島芳樹) AND MASAHIITO YAMAZAKI (山崎雅人) **physicist**

ABSTRACT. We prove a determinant formula for a parabolic Verma module of a Lie superalgebra, previously conjectured by the second author. Our determinant formula generalizes the previous results of Jantzen for a parabolic Verma module of a (non-super) Lie algebra, and of Kac concerning a (non-parabolic) Verma module for a Lie superalgebra. The resulting formula is expected to have a variety of applications in the study of higher-dimensional supersymmetric conformal field theories. We also discuss irreducibility criteria for the Verma module.

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**first paper where
physicist collaborated
proving math theorems!**



**Kavli IPMU PD ⇒
Assoc Prof Osaka**

arXiv:1603.06705v1 [math.RT] 22 Mar 2016



**Kavli IPMU student ⇒
Kavli IPMU Assist Prof**

Subaru Measurement of Images and Redshifts

- What is the *fate* of the Universe?
- need *cosmic census*
- 8.2 m, excellent seeing 0.6''
- FOV 1.5° ~1000x Hubble

HyperSuprimeCam

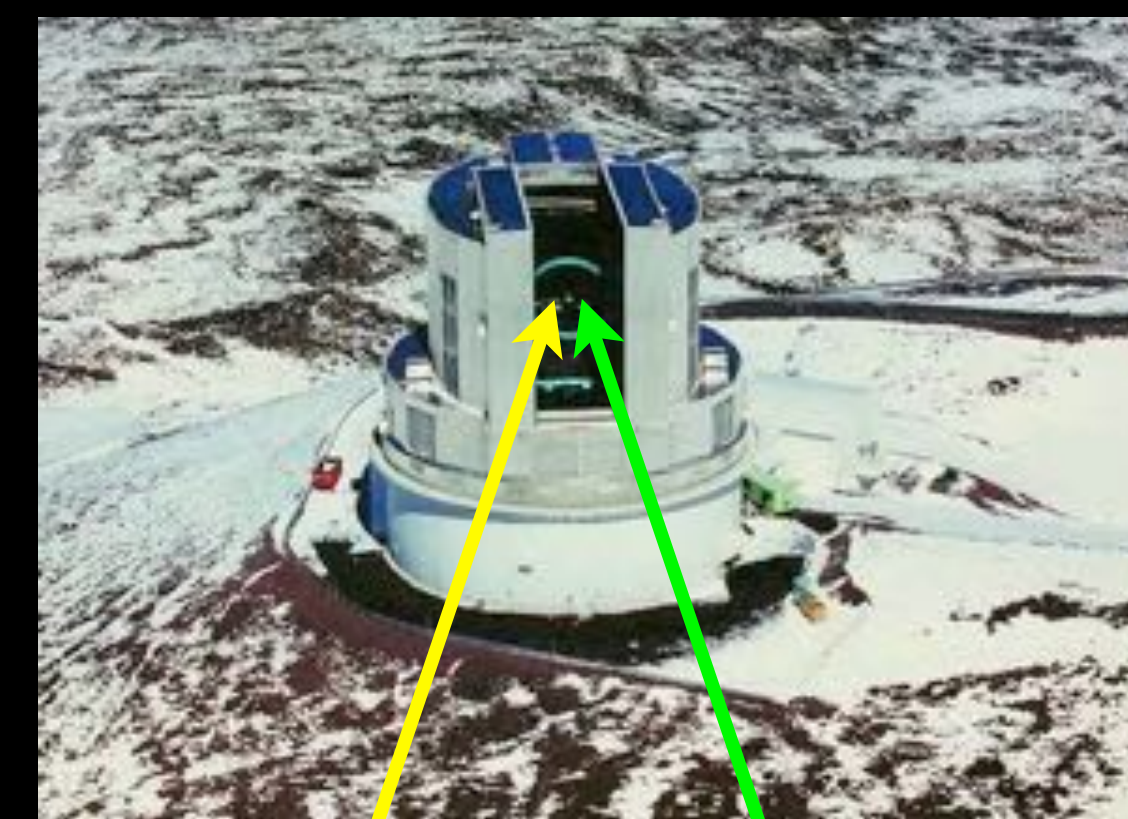
- 0.9 B pixels, 3 ton camera
- hundreds of millions of galaxies

PrimeFocusSpectrograph

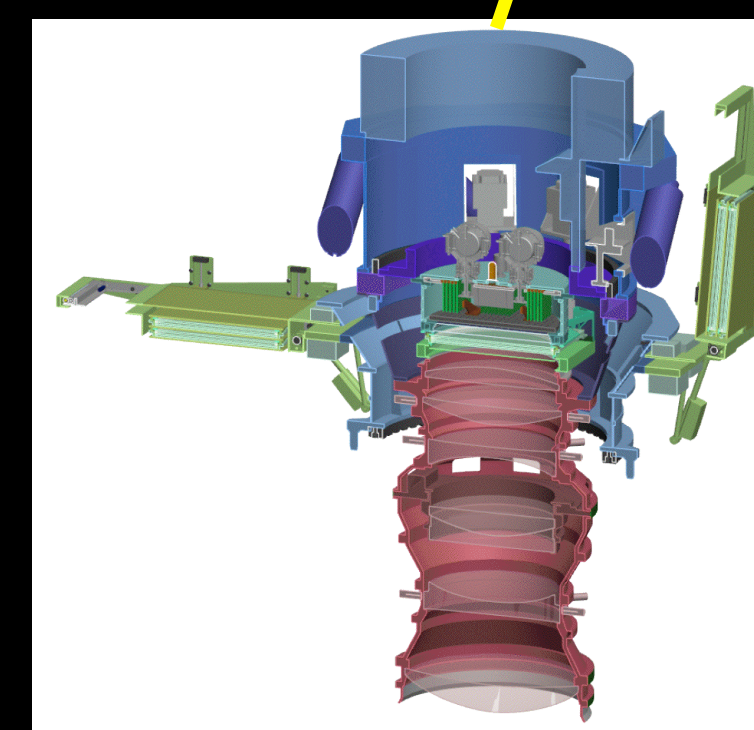
- 2400 fibers, ~2000 sq. dg.
- > 1 M redshifts

imaging & **spectroscopy** on the same telescope

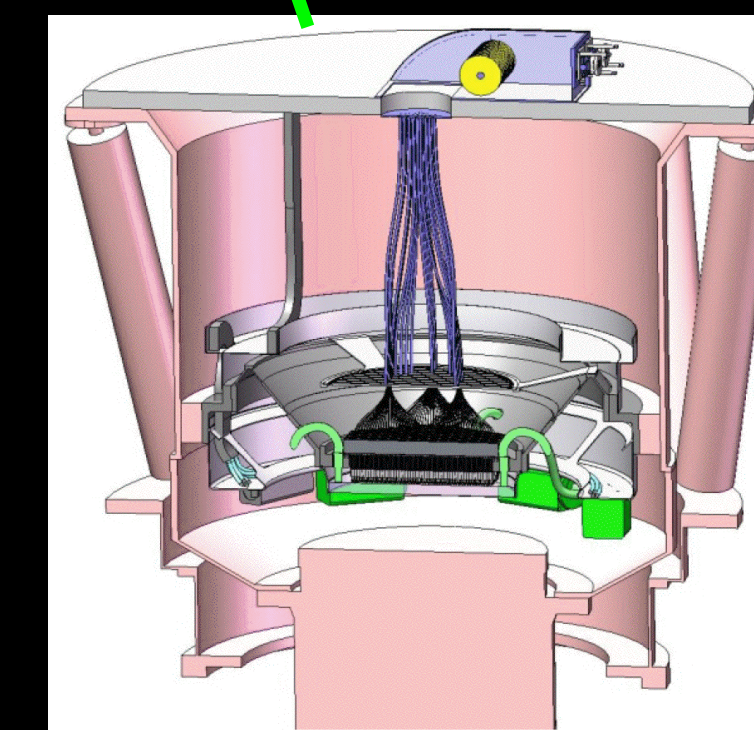
- world-leading project
- PI: HM



Subaru



HSC



PFS



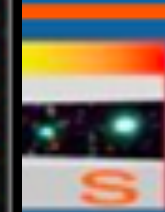
HSC performance

HSC: riz in 2.5 hours

4.0)

COSMOS HST (640 orbits: ~500hrs)

Conducting a major survey for 300 nights! First data release Feb 2017



The COSMOS Skywalker is based

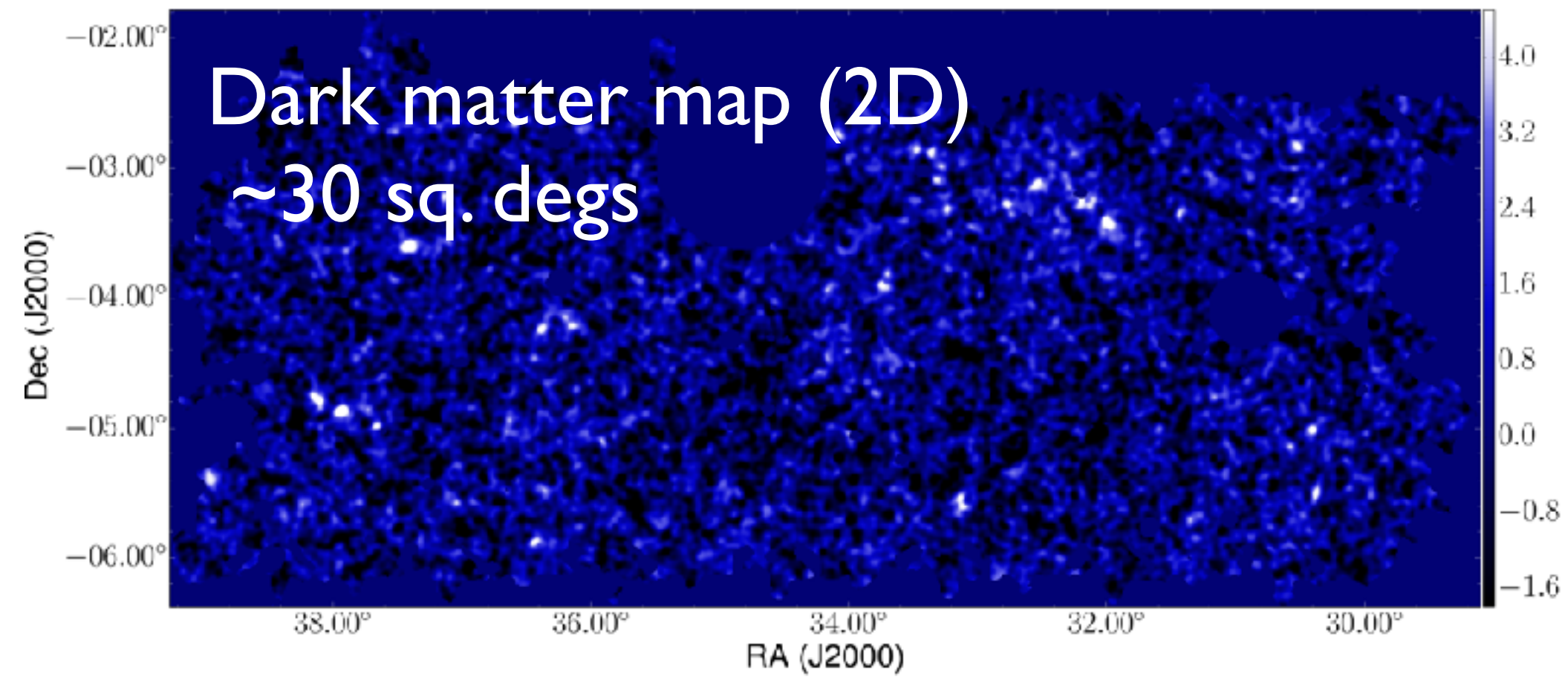
2D & 3D Dark Matter Map



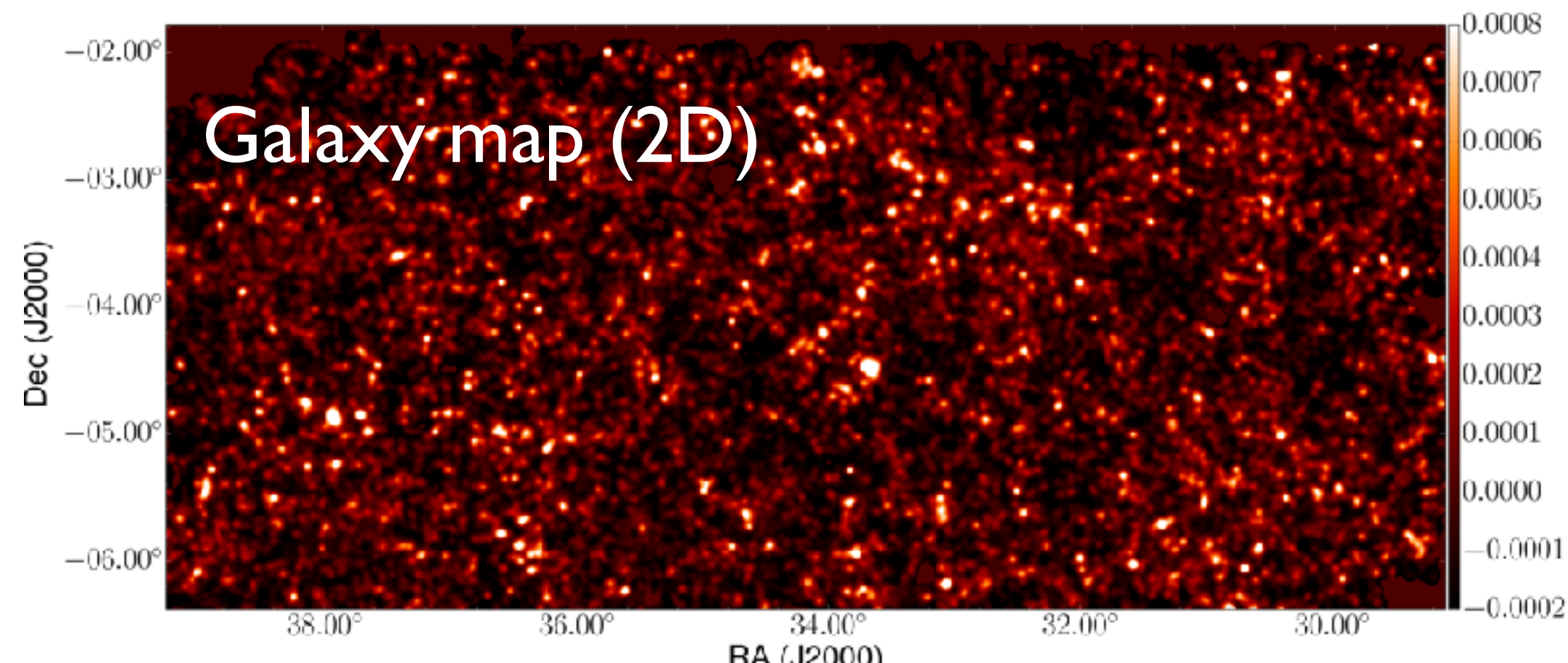
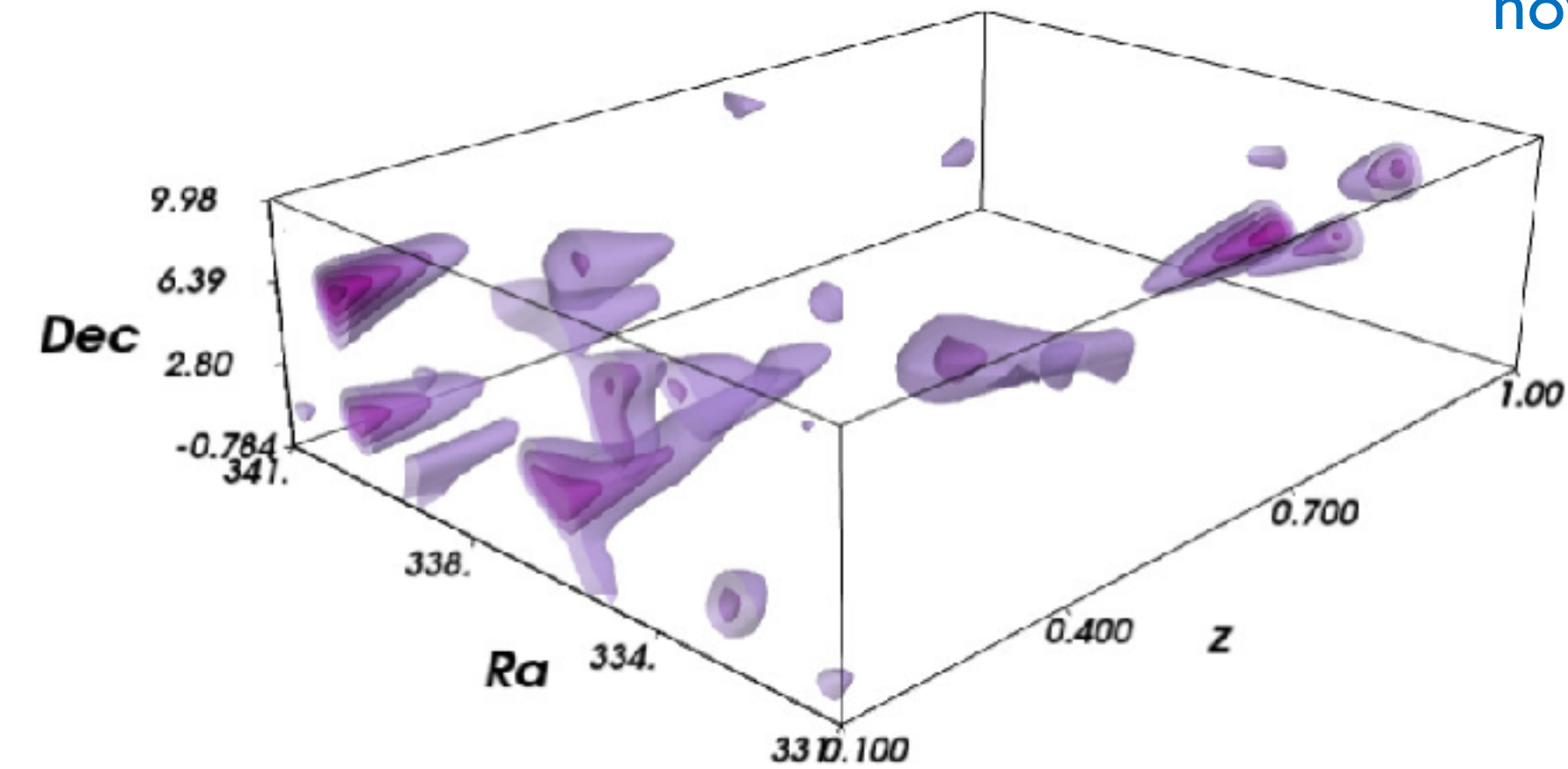
Masamune Oguri
(former assist. Prof.
now a joint member)

- Galaxy shape catalog now fixed (Mandelbaum, Miyatake + 17)
- Galaxy shapes + Photoz of gals → 3D mass & galaxy maps
- Strong correlations between DM and galaxy distributions

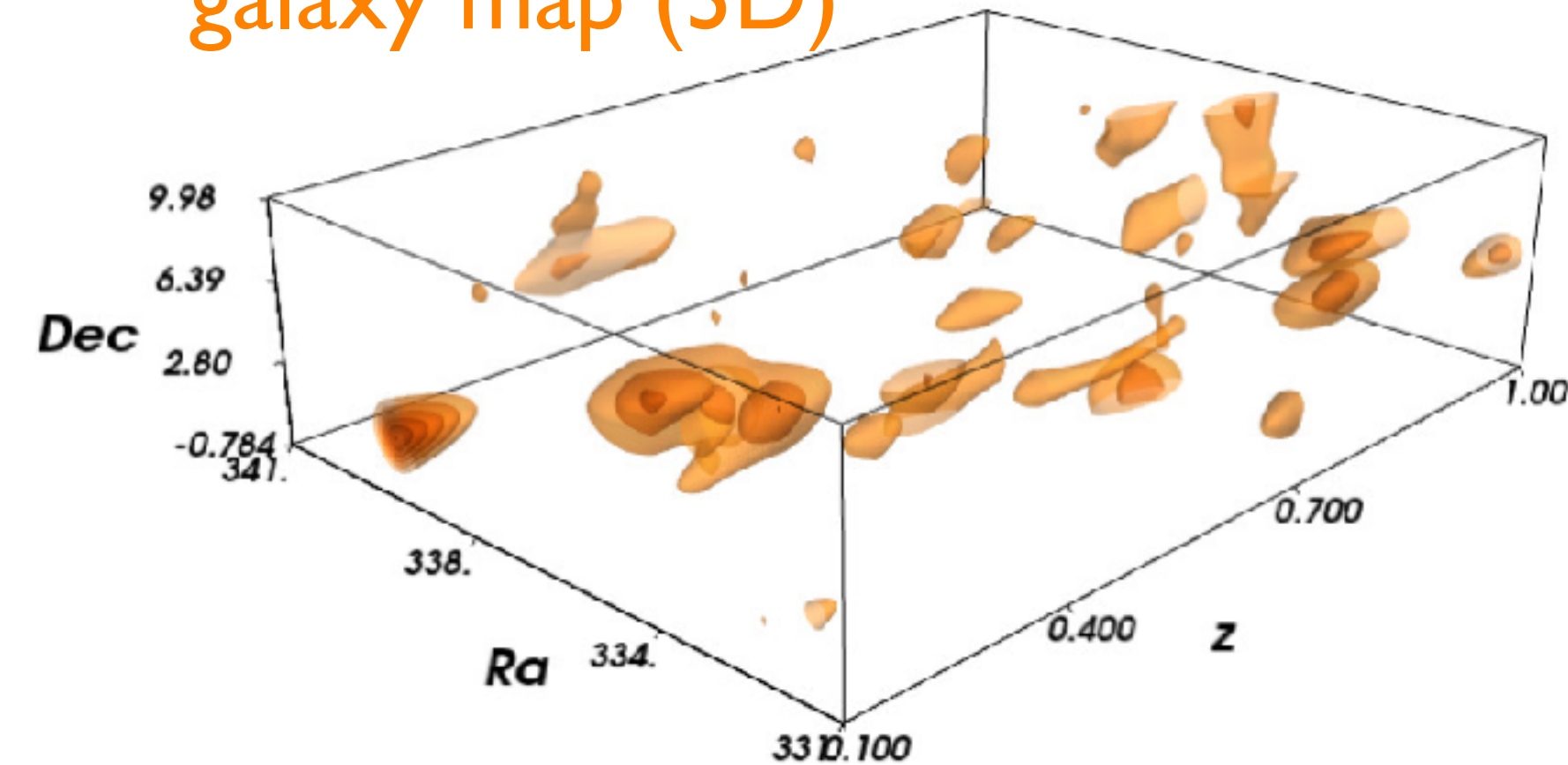
Oguri et al. arXiv:1705.06792



Dark matter map (3D)

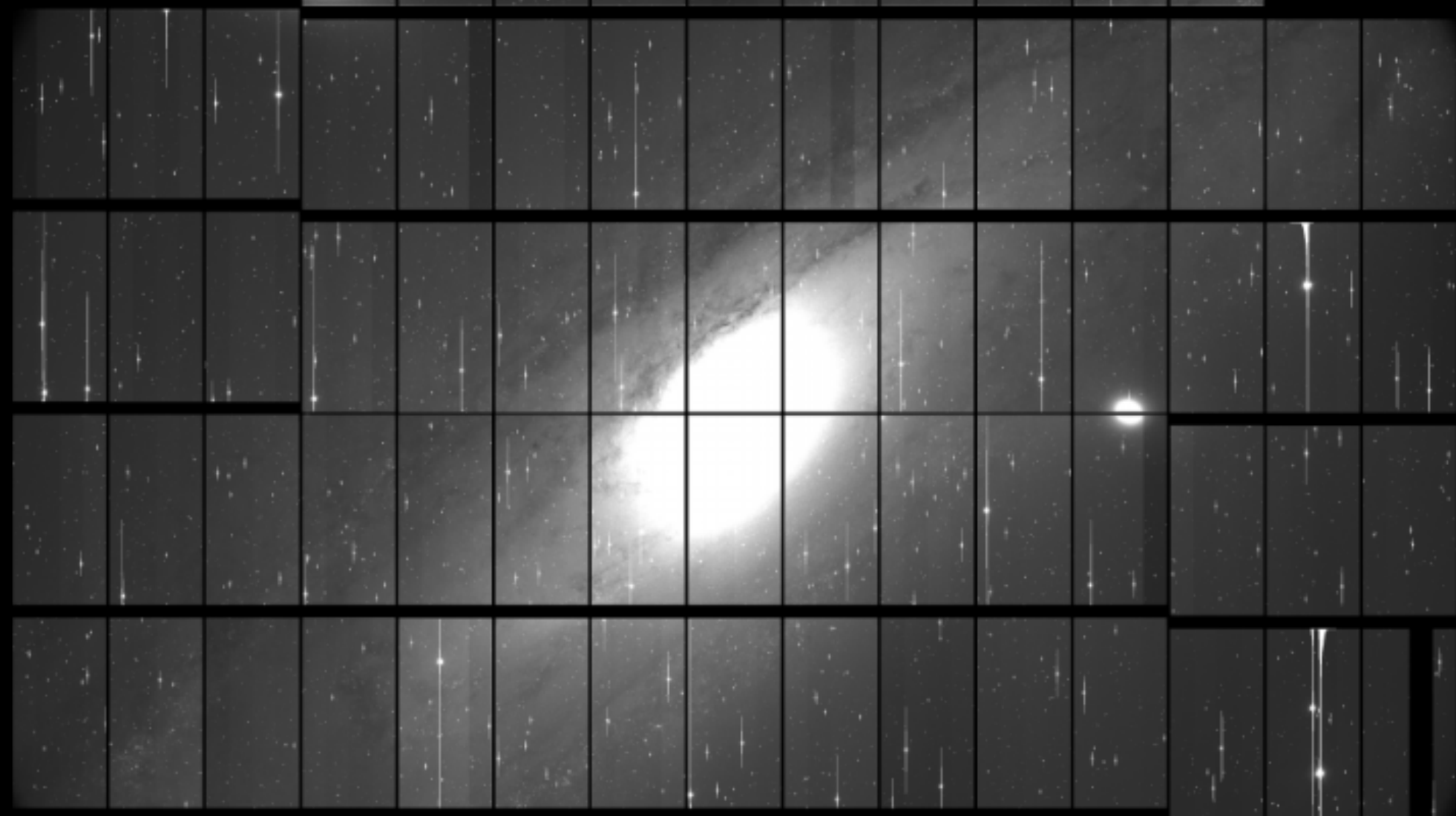


galaxy map (3D)



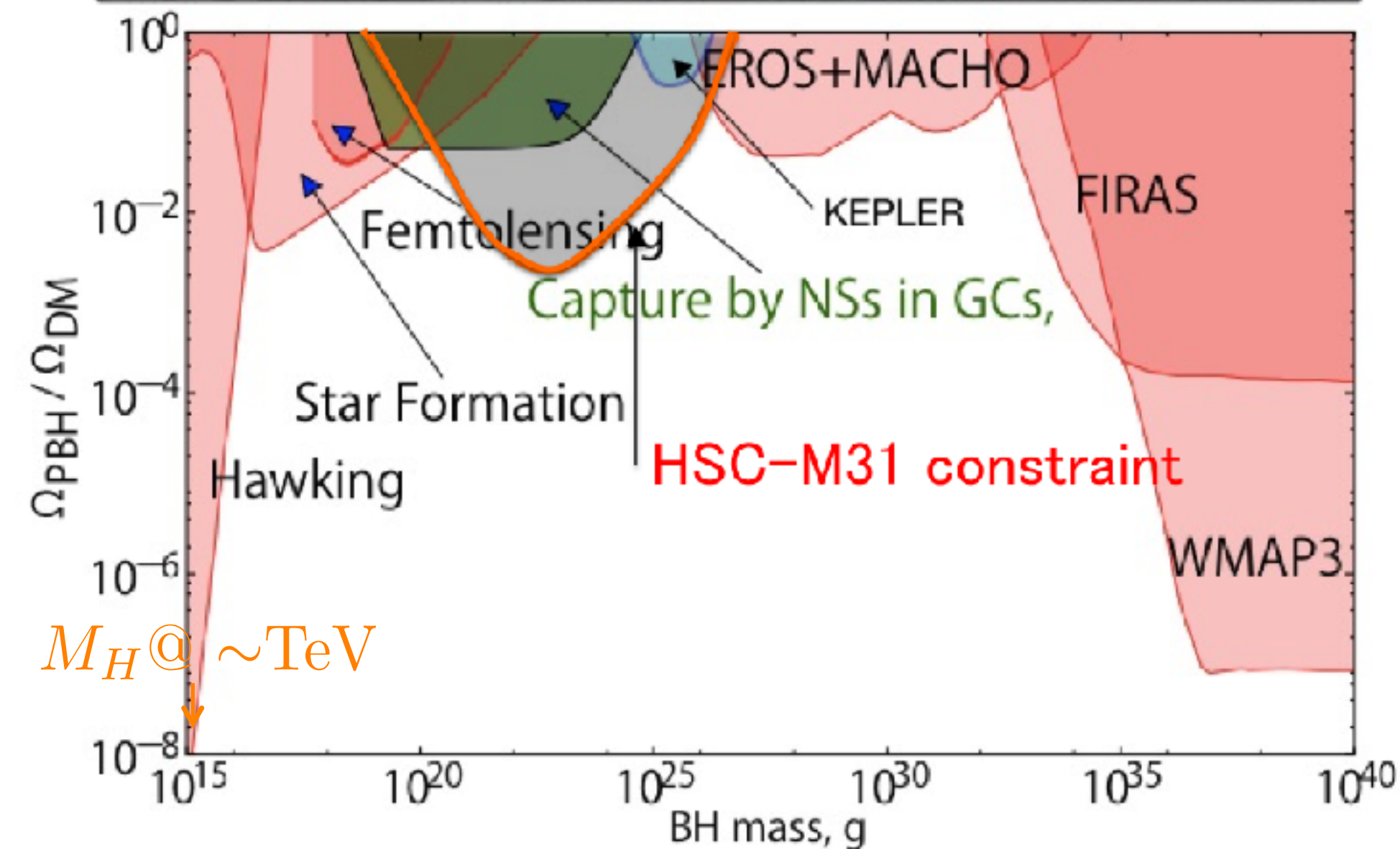
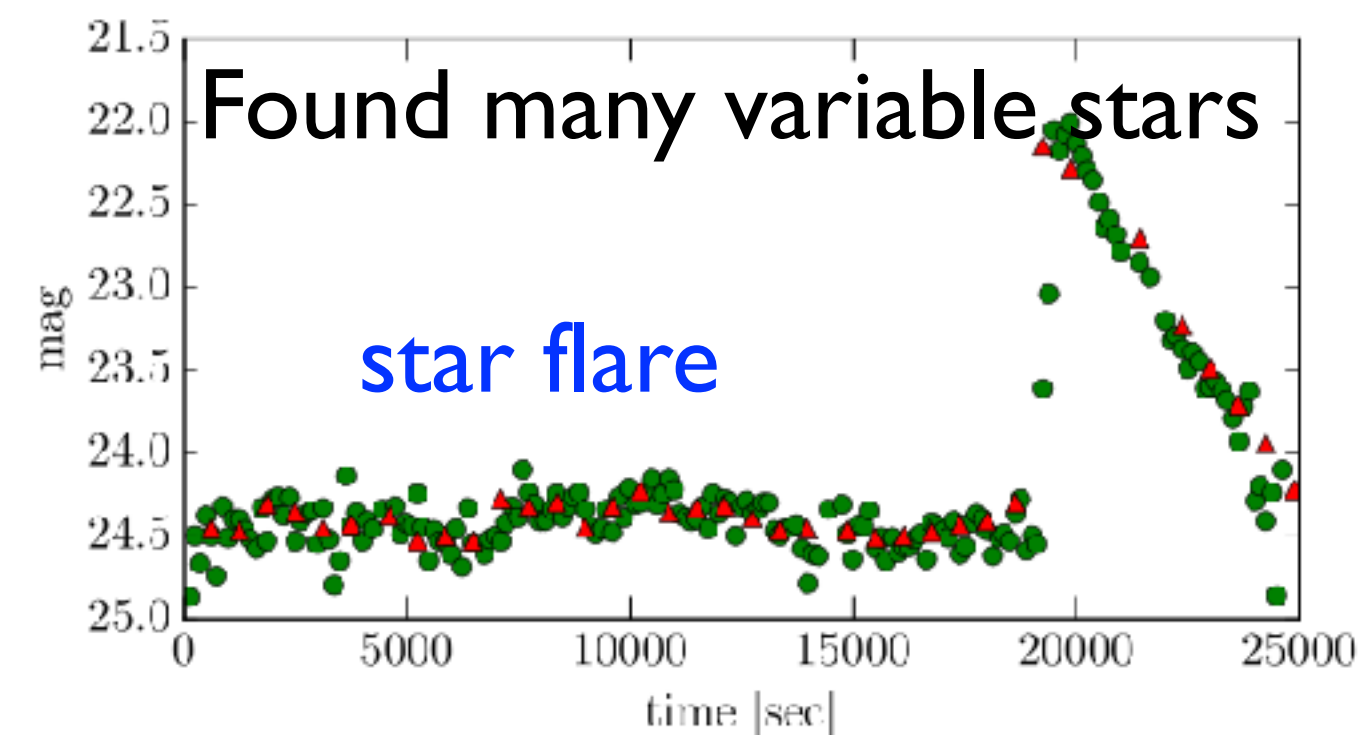
Best limit on Black Hole dark matter

Niikura, Takada et al.,
*started from conversation between
 astronomers and particle physicists*



A dense cadence HSC obs. of M31 to
 search for microlensing due to PBHs
 (just *one* night in Nov, 2015)

*No detection ⇒ more stringent upper bound,
 than 2yr Kepler data (Griest et al.)*







International Award on planetarium movie



Ooguri



**The Best Educational Production Award
sponsored by the IPS-Eugenides Foundation**



Keynote Speech
Science for Peace
and Development
2014/10/20



<http://www.ipmu.jp/node/2049>



United Nations
Headquarters
New York



HM



Kofi
Annan



Carlo
Rubbia

External Advisory Committee



It is fair to say that Kavli IPMU has been **remarkably successful**, within the context of the WPI institutes, at achieving the goals it established for itself at the initial outset. In particular, the Institute has developed a **truly international reputation** as one of the leading centers in the world in the fields that it represents. It is especially **unique** in the degree to which it has coupled pure mathematics to the topics of physics, cosmology, and astronomy.

As expected for WPI institutes, Kavli IPMU has also **led the way toward system reform**, challenging the standard norms in Japanese academia. This has had a dramatic effect on the University of Tokyo, resulting in the creation of UTIAS among other innovations. It remains to be seen whether those reforms will also be reflected at other Japanese universities, but the demonstrable success of Kavli IPMU will clearly help to make the case.

August 22, 2016

New faculty

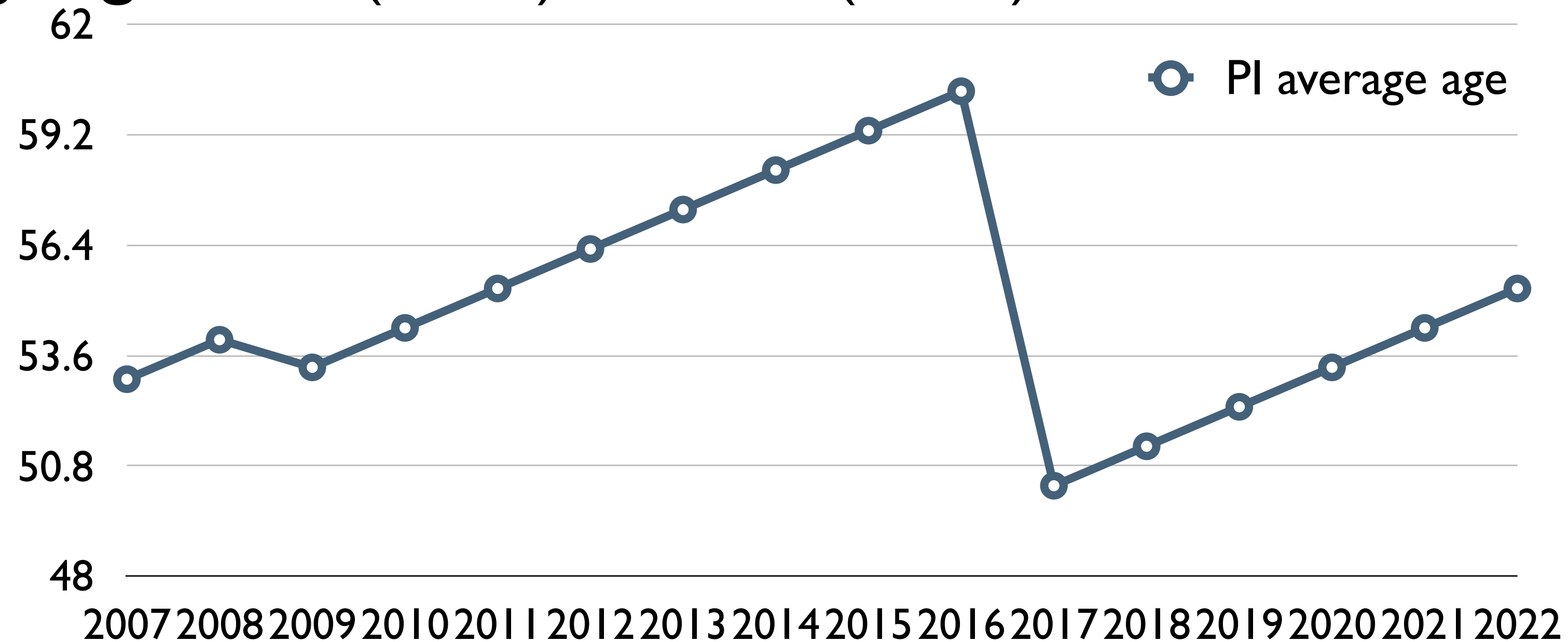


- Hiromi Yokoyama (Tokyo), science policy & communication (April 1, 2017)
- Tom Melia (Berkeley), Particle phenomenology with strong connection to math (on Sept 16, 2017)
- Yukari Ito (Nagoya), mathematics with strong connection to physics on 40:60 appointment (Sep 1, 2017), and becomes full-time in April 2019
- Hiraku Nakajima (RIMS, Kyoto), mathematics with strong connection to physics will join April 2018



new PIs

- **on-site:** K. Hori, M. Kapranov, K. Martens, S. Matsumoto, M. Takada, Y. Toda, M. Vagins, N. Yoshida
- CMB: E. Komatsu (Director MPA)
- Phenomenology: Y. Nomura (Berkeley)
- LHC: YK Kim (Chicago, former Fermilab deputy director)
- DM: S. Moriyama (ICRR) 50.1
- average age: 53.0 (2007) \Rightarrow ~~50.3~~ (2017)



Future

Up to 2017

- Thanks to the effort by the University, we secured approx. 9 oku-yen
 - 10 permanent positions
 - 5.2 oku-yen (including 13 positions)
 - 9 University administrative staff
 - building use (2 oku-yen worth)

And from 2018

- Additional ~4 oku-yen budget request
 - University budget committee ranked it #1



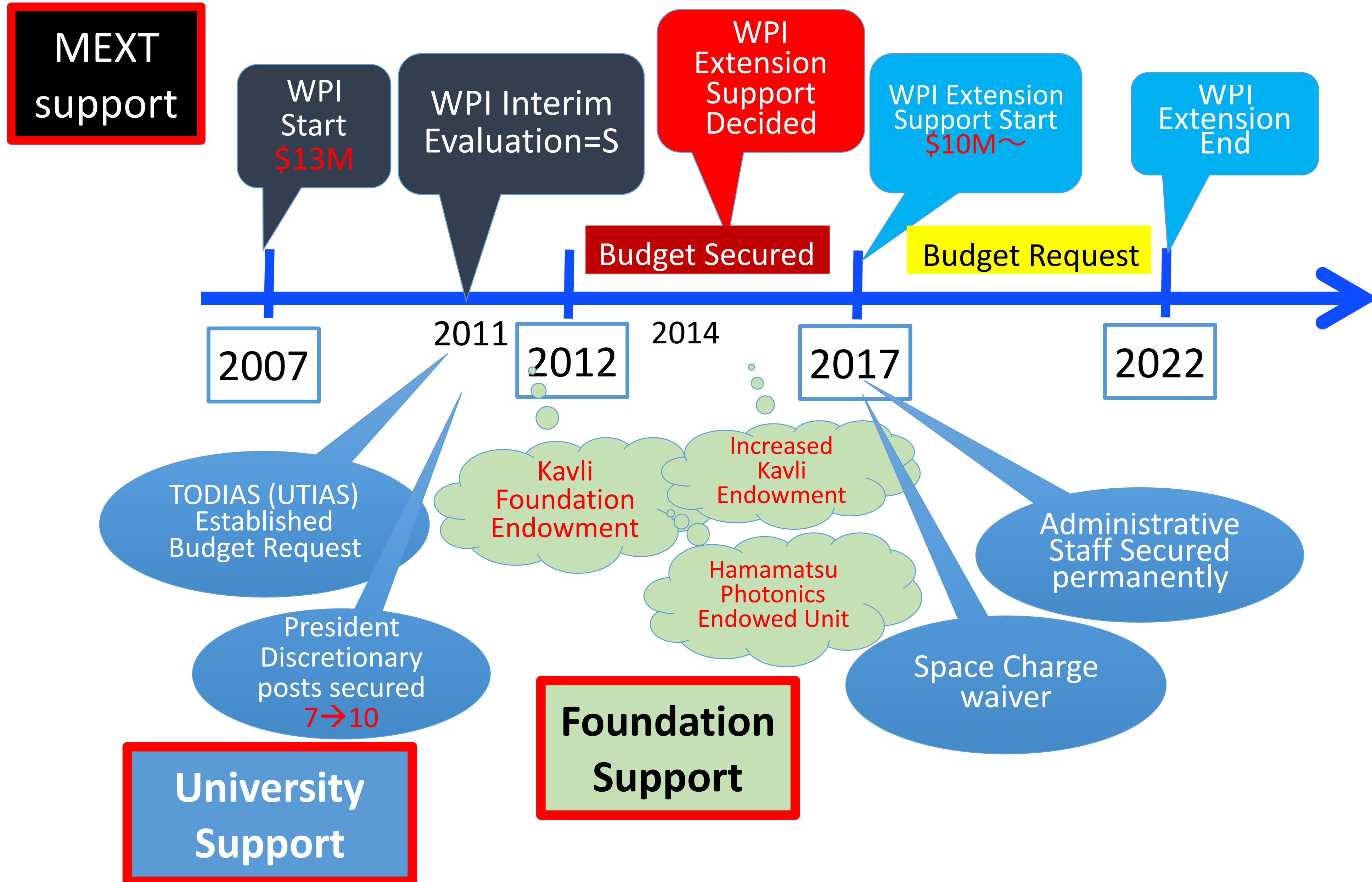
Vision for the University and Support for Kavli IPMU

Toshihiko Koseki, Executive Vice President
WPI Program Committee, September 14, 2017



東京大学
THE UNIVERSITY OF TOKYO

“3-way” Budget support for Kavli IPMU since 2007



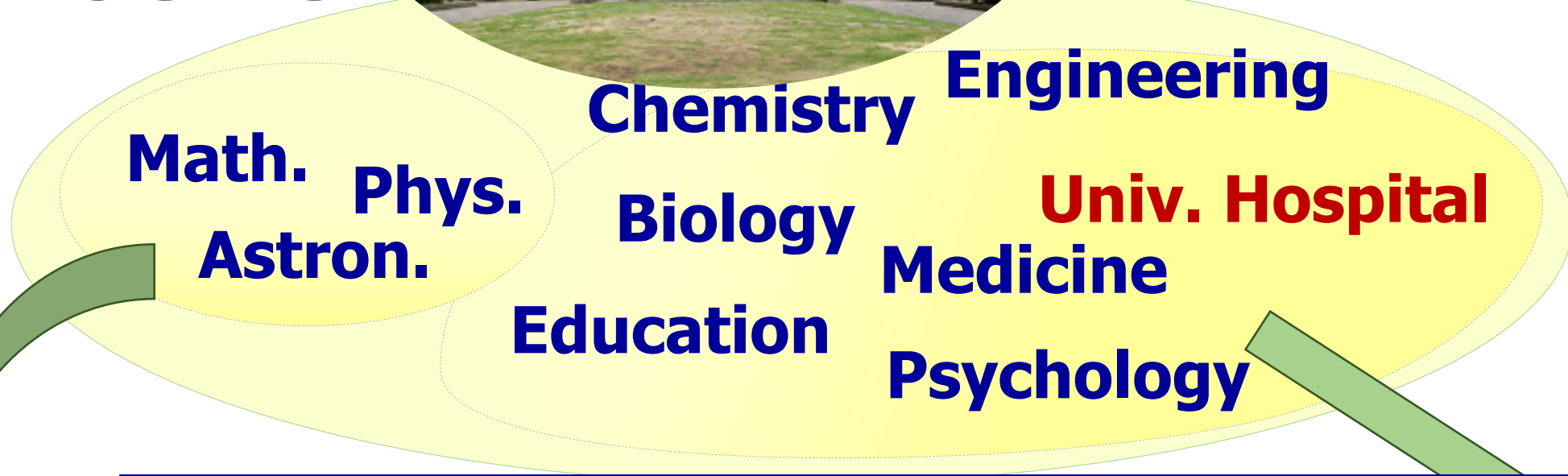
- Plan for FY 2018-2021 new budget request to MEXT (Gaisan)
 - “To make Kavli IPMU permanent as an international institute of excellence”
 - 10 tenure-track assistant professors
 - 35 field interactive young researcher
 - 10 bilinguals as support staff
 - Travel support and research funds for brain circulation
- Best **model** for establishing a new type of excellent international institute
- This budget plan is evaluated as the **highest one** in the university budget request ranking process
- **Kavli IPMU** is supported by **3-way** financial sources: **MEXT, Kavli Foundation and University**
- **University** can provide **further resources** as long as Kavli IPMU keeps top performance and presents convincing case

Conclusion:

We'd like to capitalize
on the amazing success of Kavli IPMU!

- Kavli IPMU perfectly matches our **vision for UTokyo**
→ A role model for the rest of the University
- We will maintain and hopefully **expand** Kavli IPMU even after WPI support is ended
- **System reform** spearheaded by Kavli IPMU
→ to the rest of the University, other Universities
- UTokyo, **now** a Designated Natl. Univ., strengthens **the University's financial base**
→ We can support Kavli IPMU with no problems!

International Research Institutes of Excellence

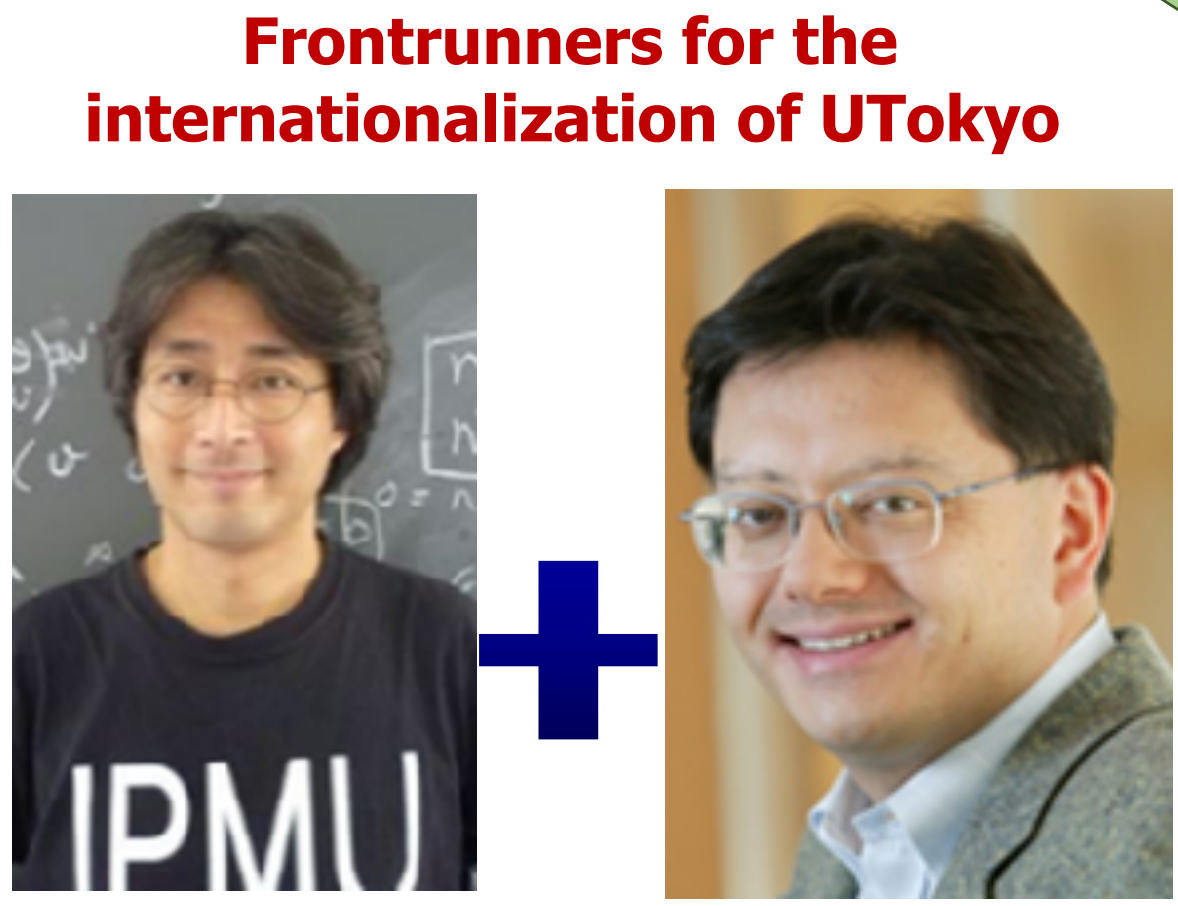


Global Base for Knowledge Collaboration

UTokyo Institutes for Advanced Study (UTIAS)

Kavli IPMU
(Established by WPI in 2007)

- World-class institute fusing physics, math and astronomy
- Approx. 40% international researchers
- 700 applications/year for scientific positions (80% from outside Japan)



International Research Center for Neurointelligence (IRCN)

- Fusion of science, engineering, clinical studies and psychology
- Close collaboration with the University Hospital
- Expected to become a research institute that attracts international researchers

“Special area” leading internationalization of UTokyo as a whole



Looking forward to
exciting next ten years!