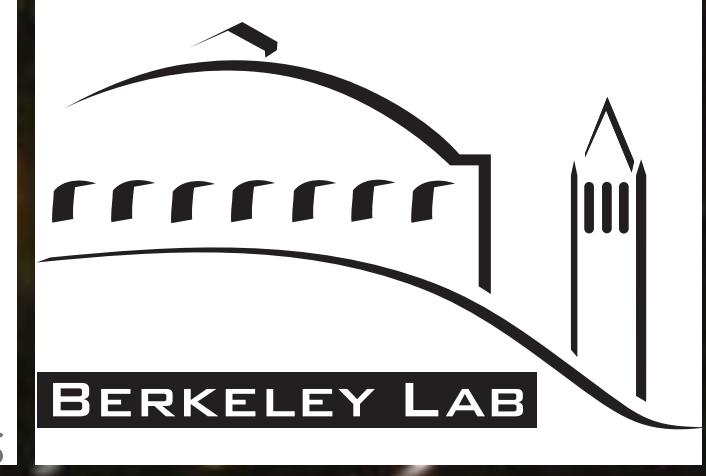
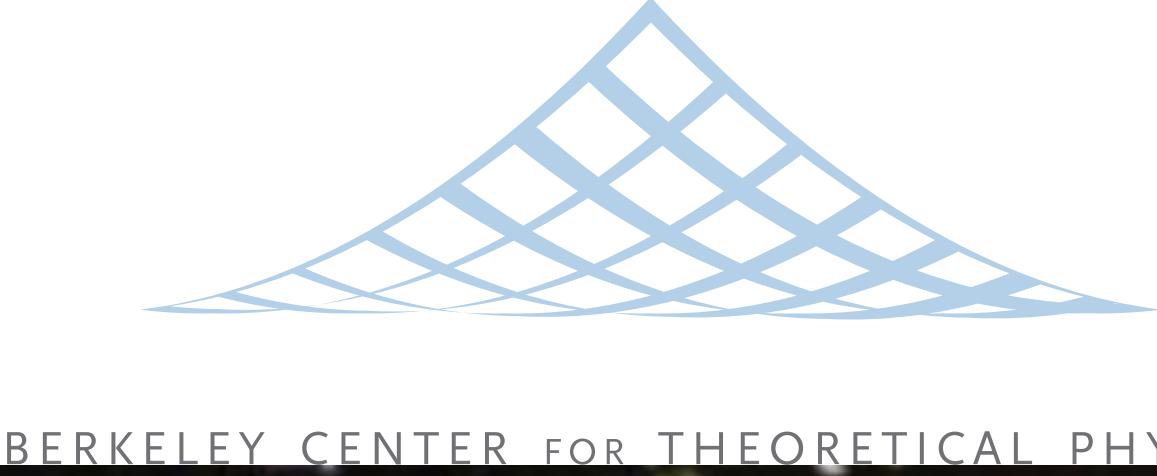




# Where do we come from? Perspectives from Physics

Hitoshi Murayama (Berkeley, Kavli IPMU Tokyo)  
ISCO2023, OIST, Feb 27, 2023



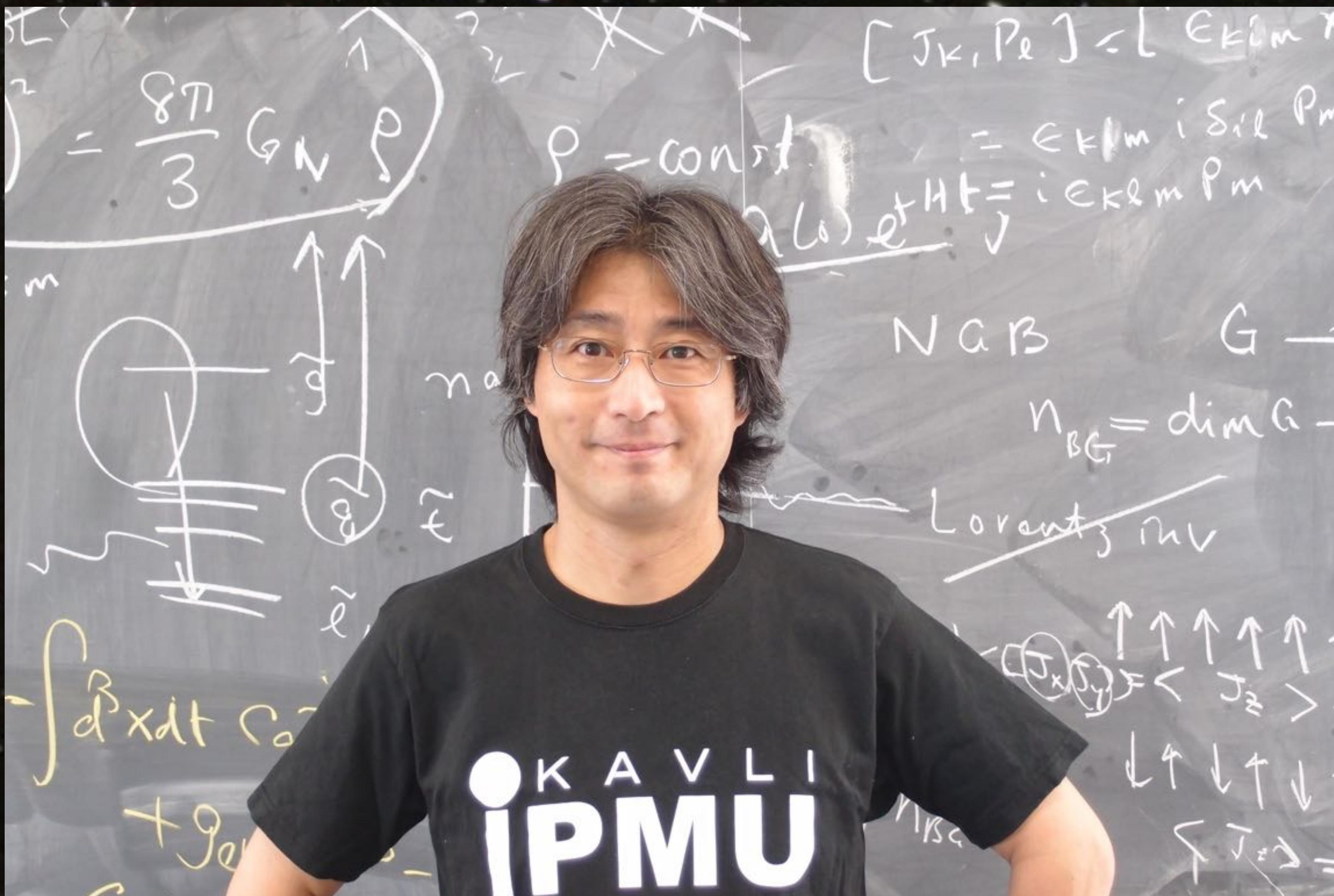
東京大学  
THE UNIVERSITY OF TOKYO

BERKELEY CENTER FOR THEORETICAL PHYSICS



Director of the Kavli Institute for the Physics  
and Mathematics of the Universe

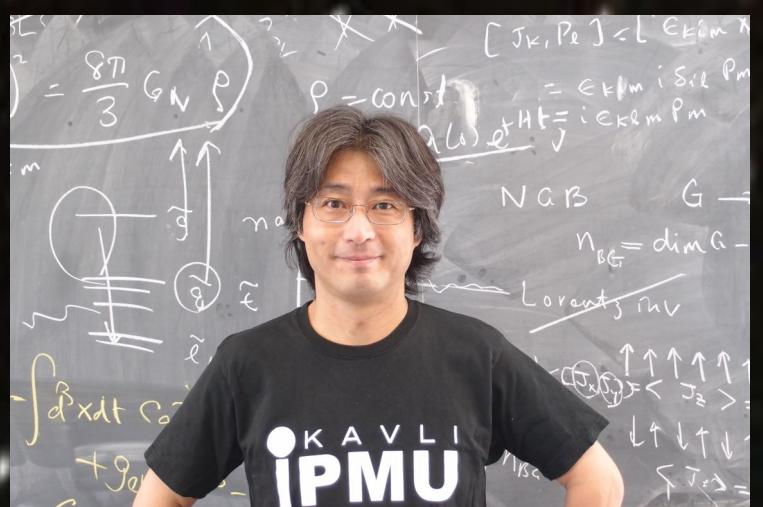
# huge responsibility!



Director of the Universe

# Not high enough authority

Voice of God

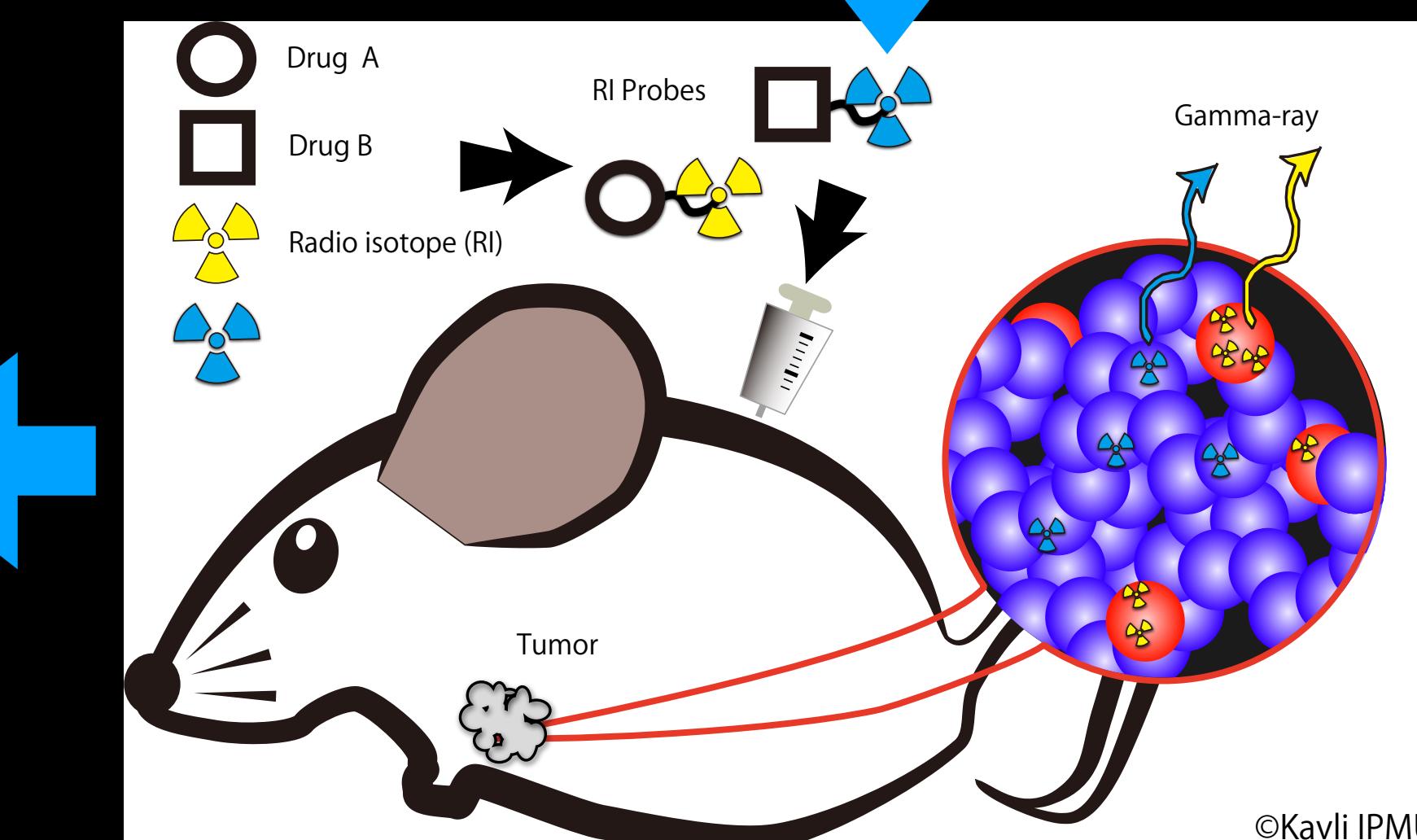
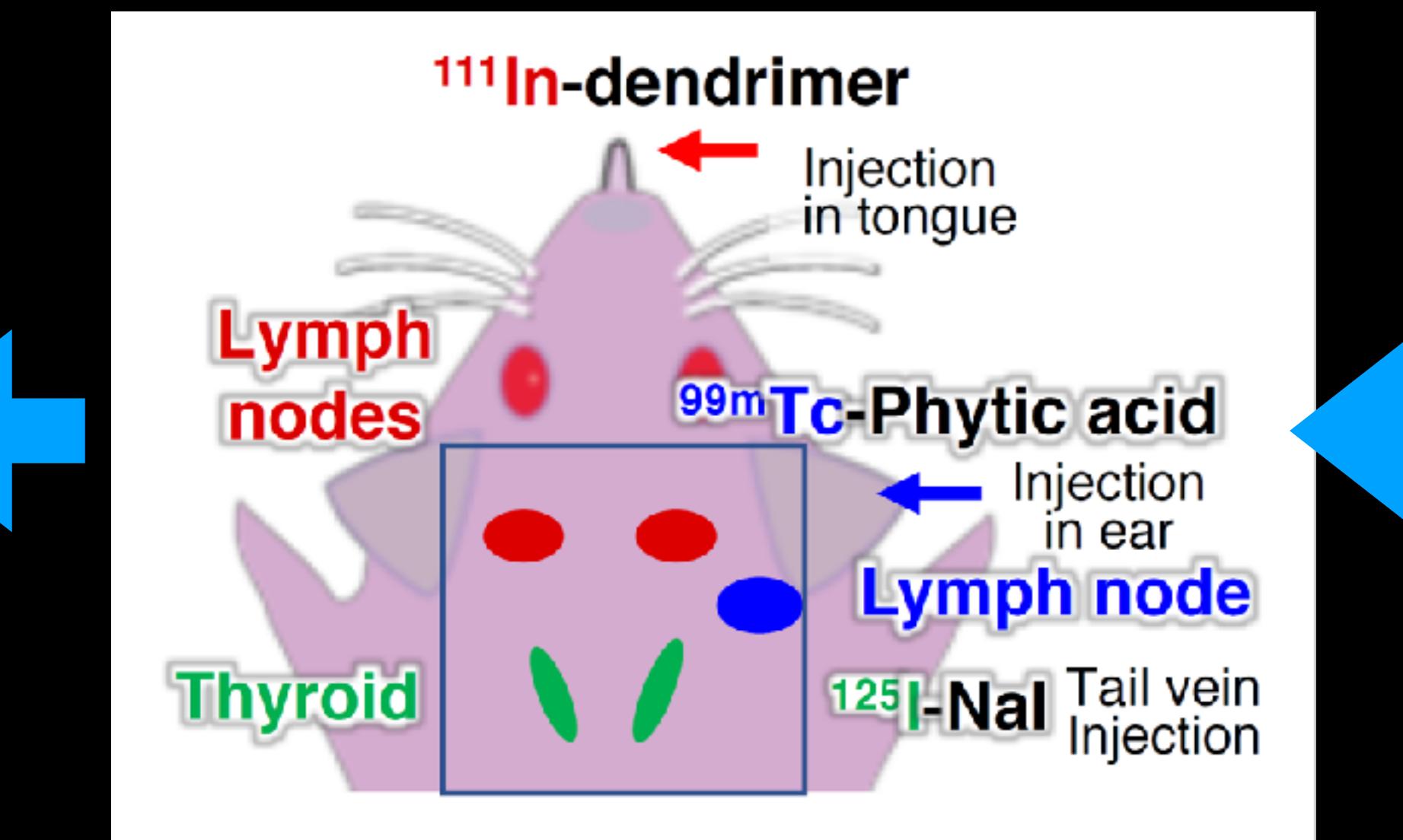
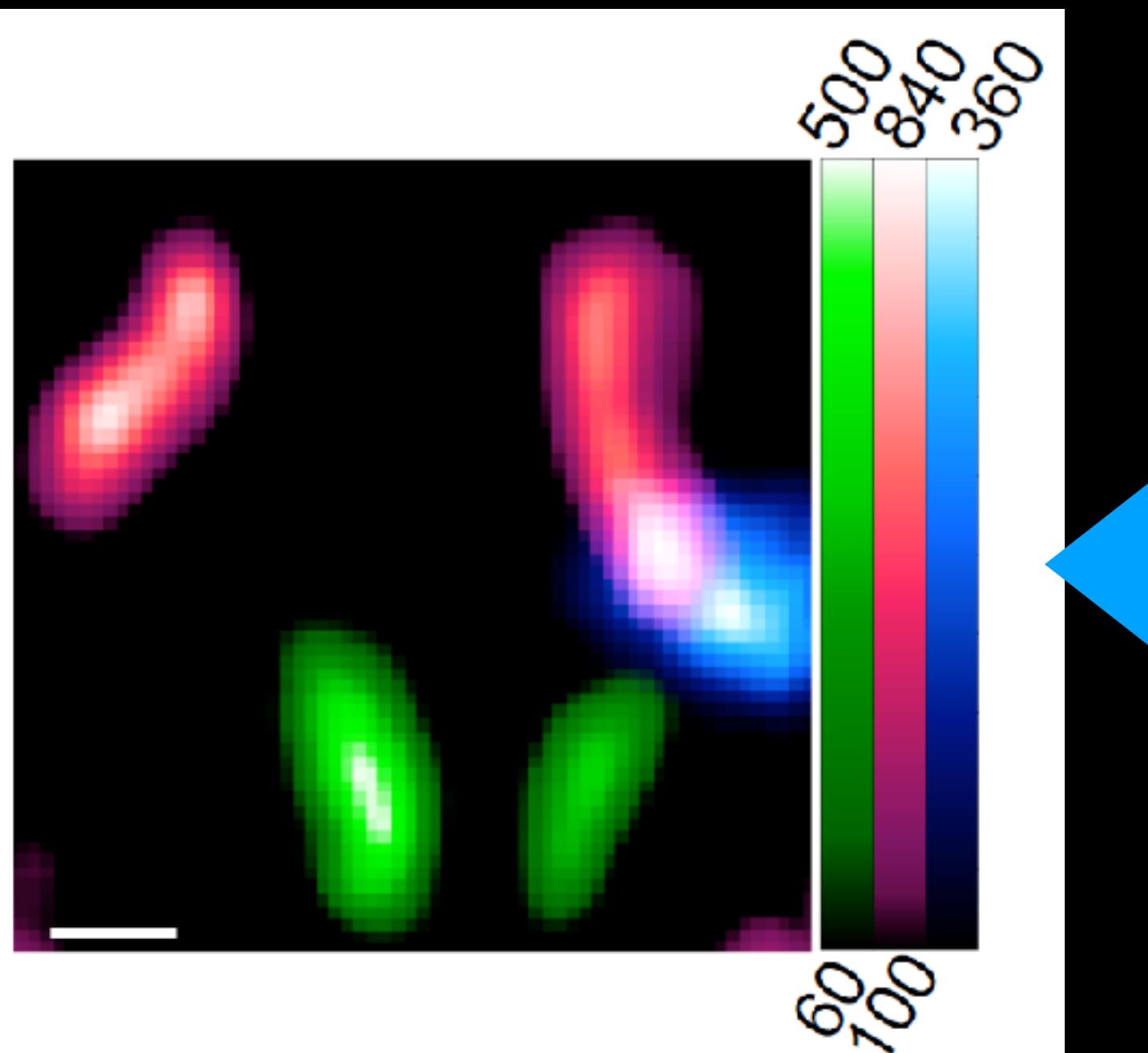
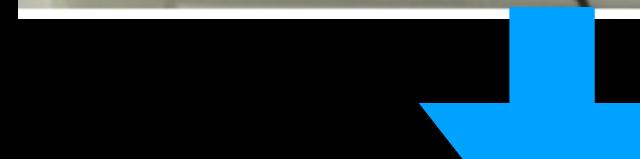
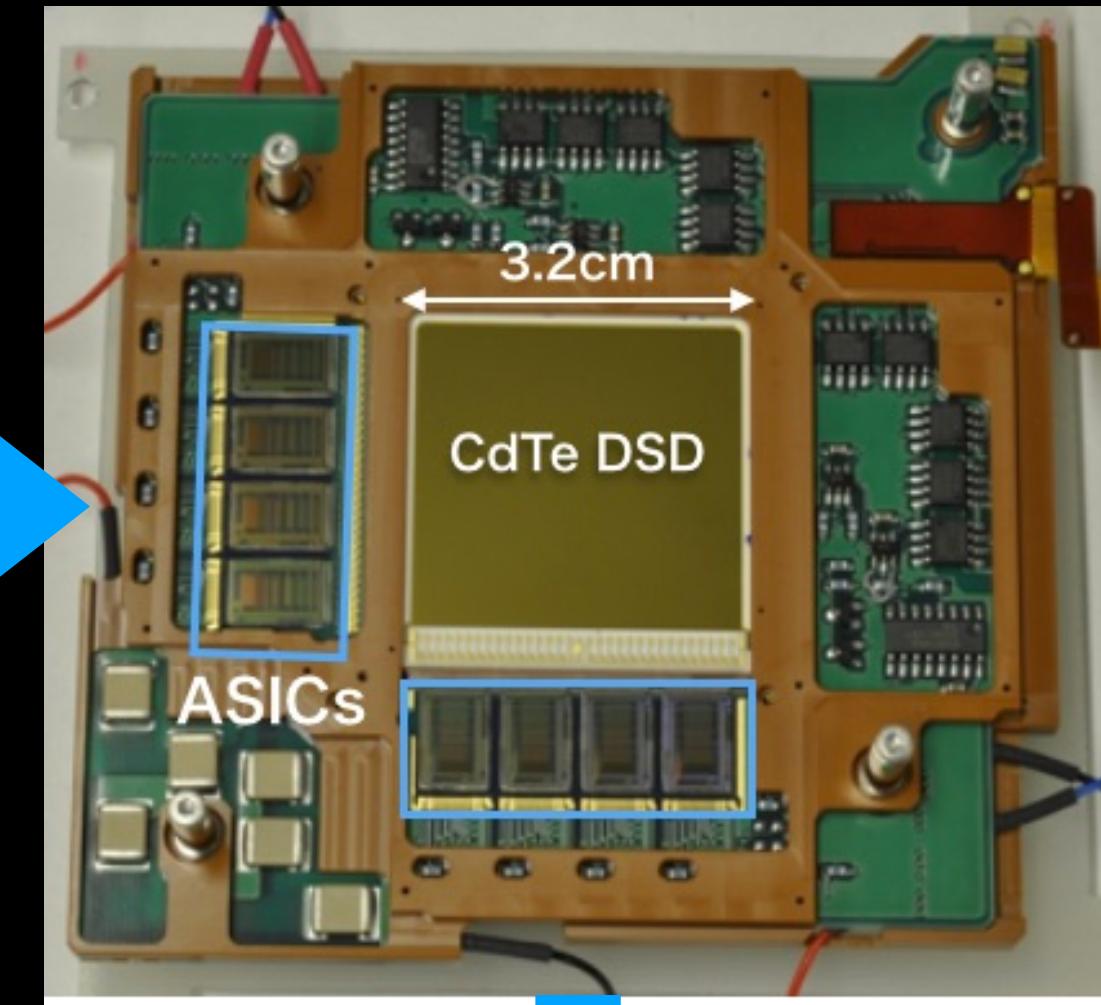
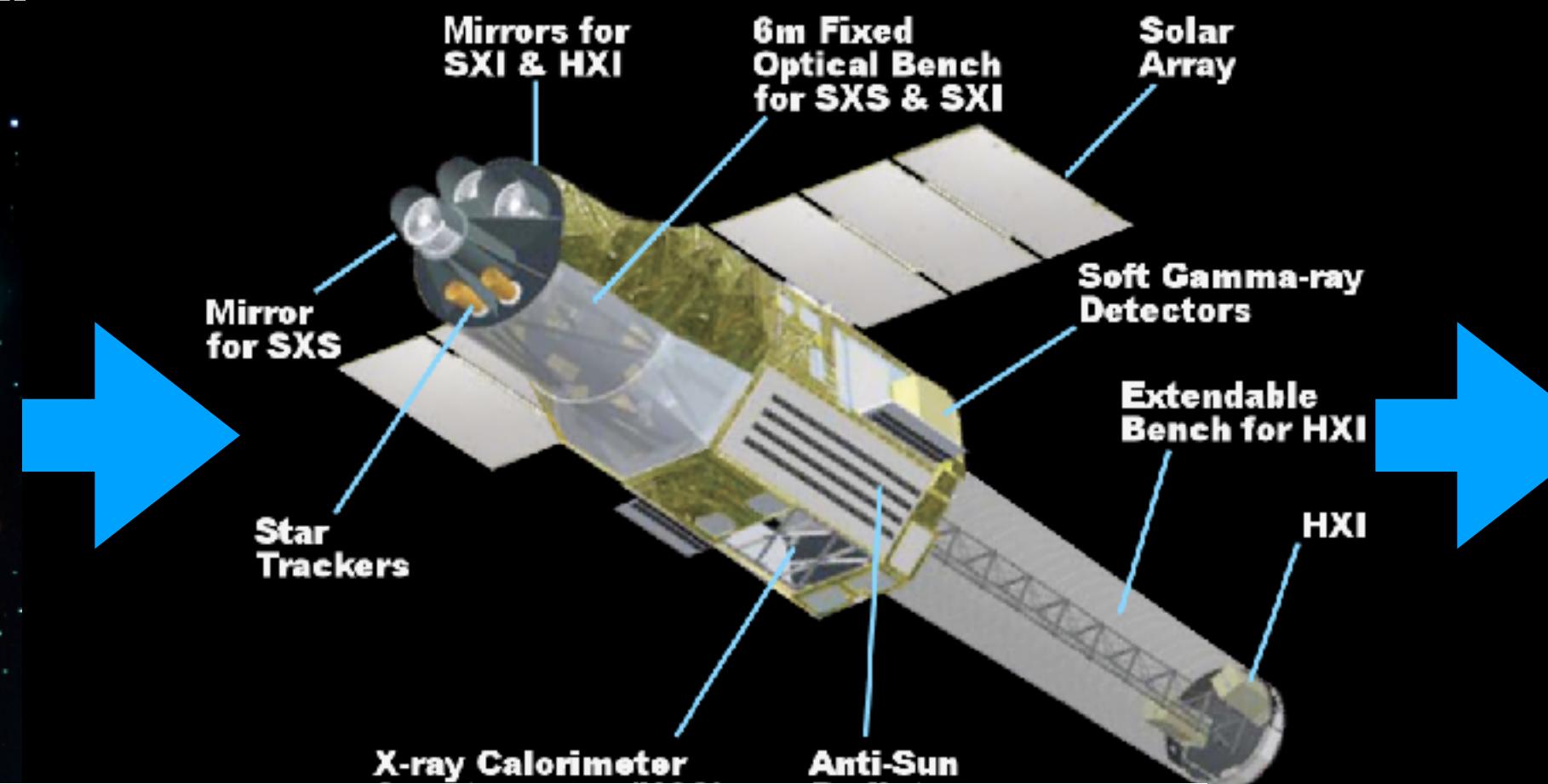
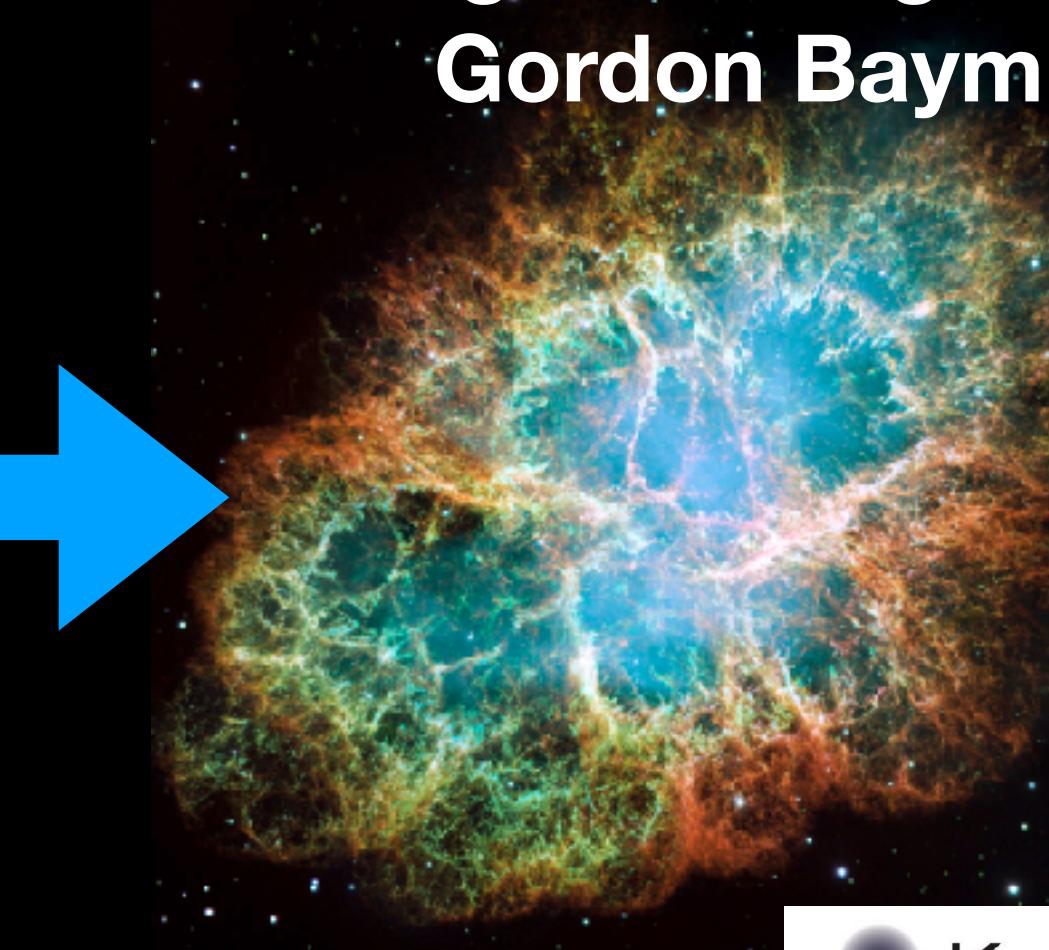
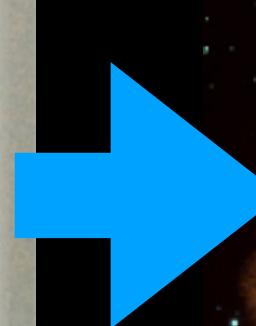


Director of the Universe

# From space telescope to 4D microscope

Tad Takahashi

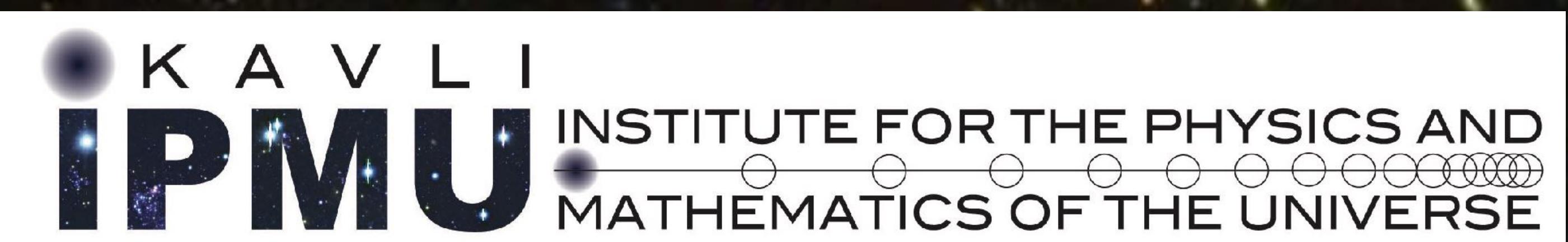
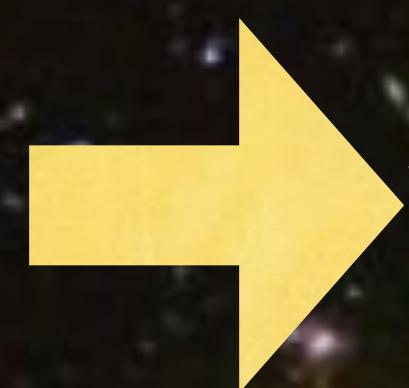
Shigehiro Nagataki  
Gordon Baym





We physicists ask  
very basic questions

How did the Universe begin?  
What is its fate?  
What is it made of?  
What are its basic laws?  
Why do we exist?  
Where do we come from?



# Where do we come from?



Credit: Reuters



<http://www.kamakura-burabura.com/meisyokamakuradaibutsu.htm>

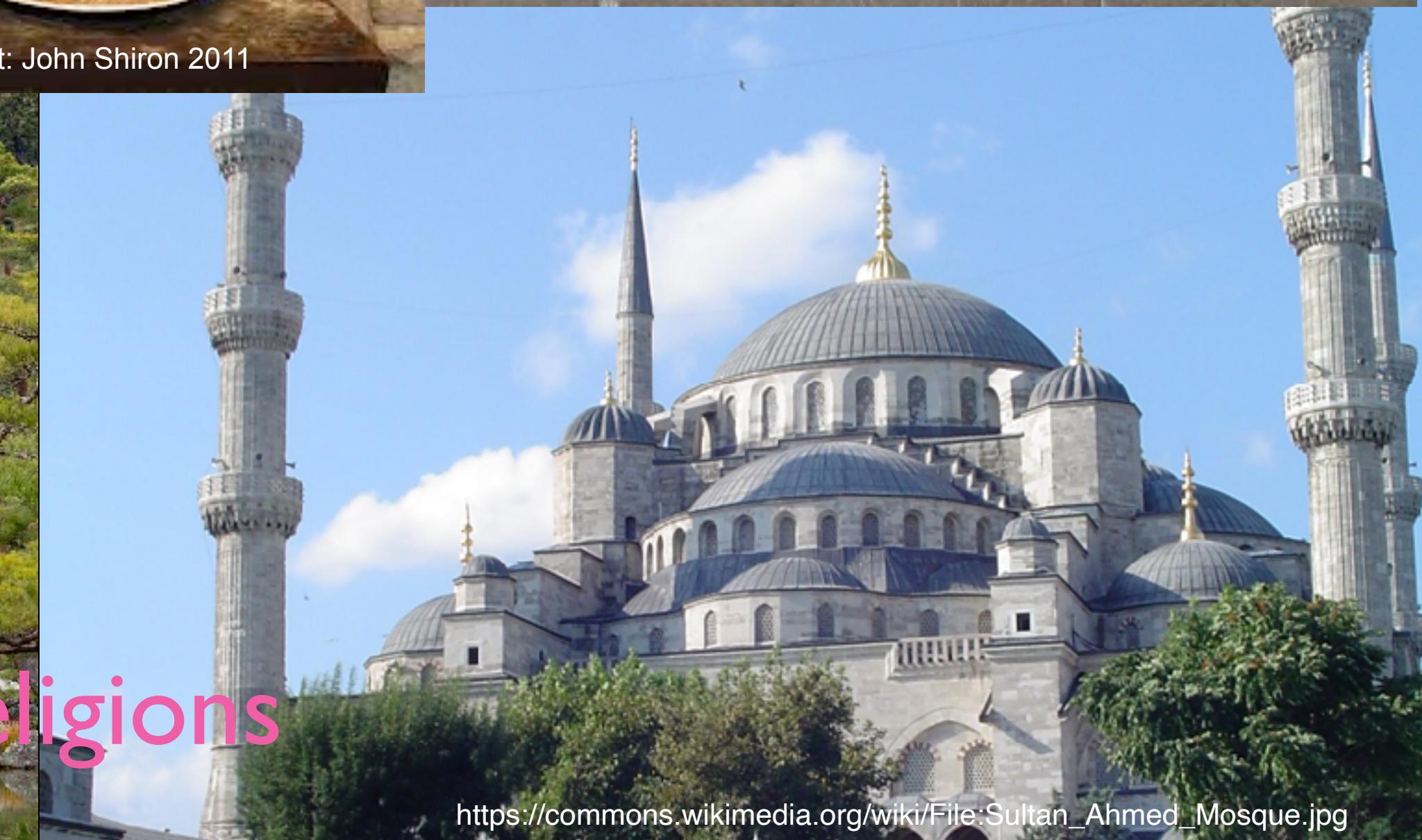


Credit: John Shiron 2011



<https://snapplace.jp/金閣寺（鹿苑寺）/>

## Religions



[https://commons.wikimedia.org/wiki/File:Sultan\\_Ahmed\\_Mosque.jpg](https://commons.wikimedia.org/wiki/File:Sultan_Ahmed_Mosque.jpg)

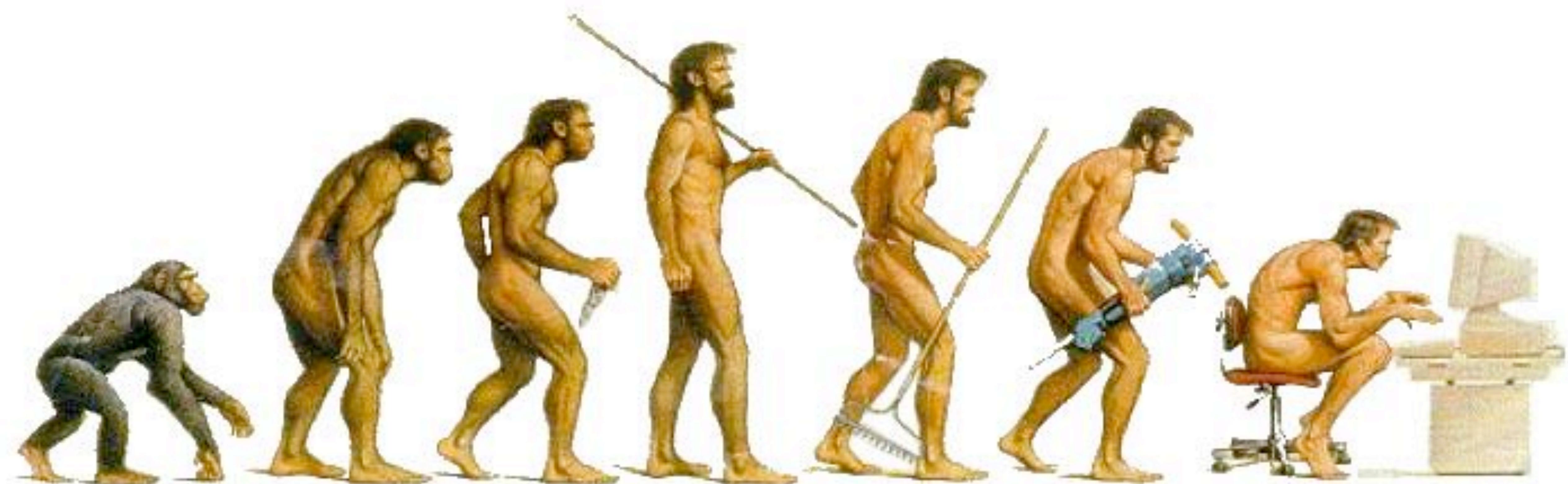
Where do we come from?



<https://www.metmuseum.org/art/collection/search/191811>

Philosophy

Where do we come from?



Evolutionary biology

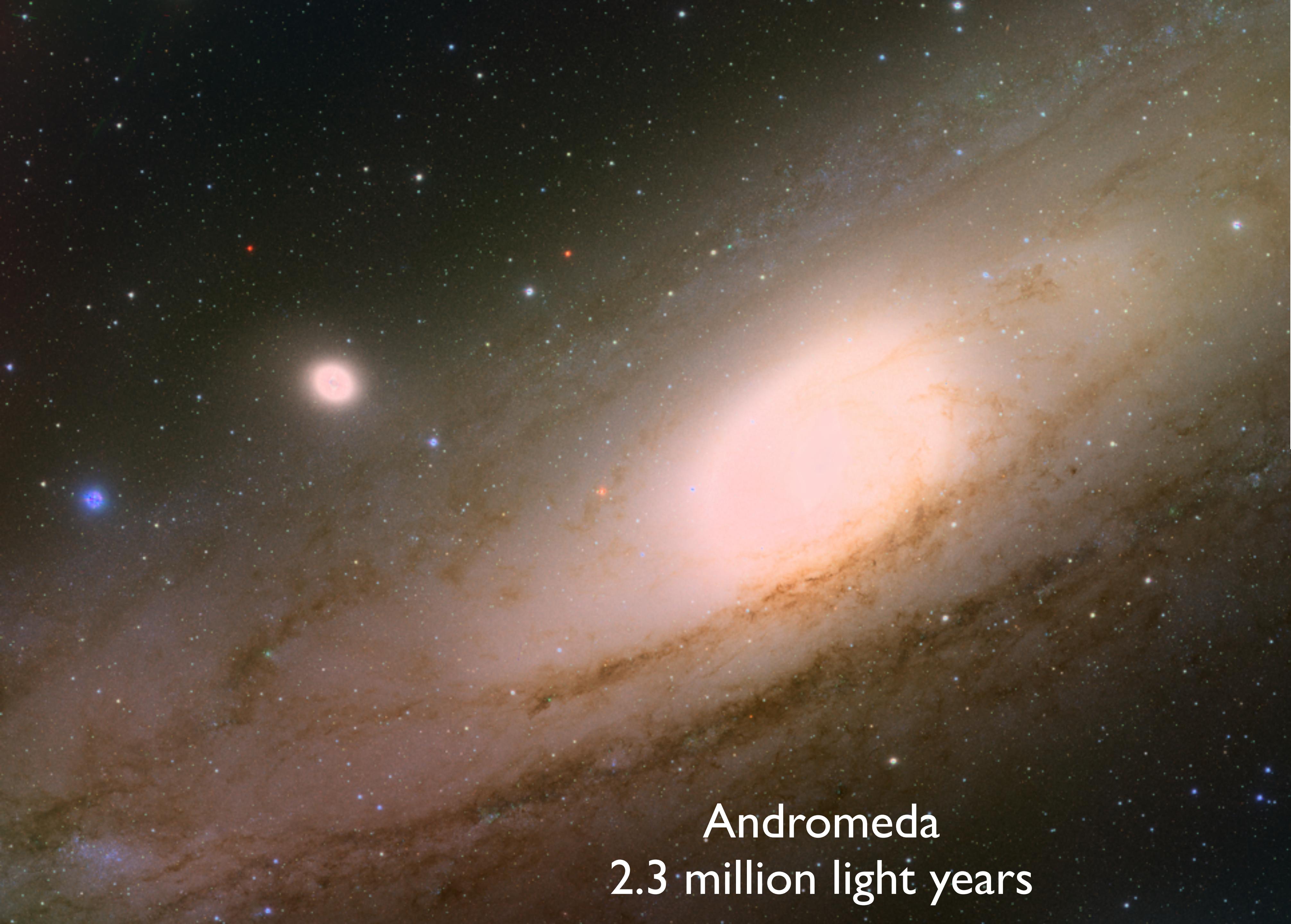
# Time machines



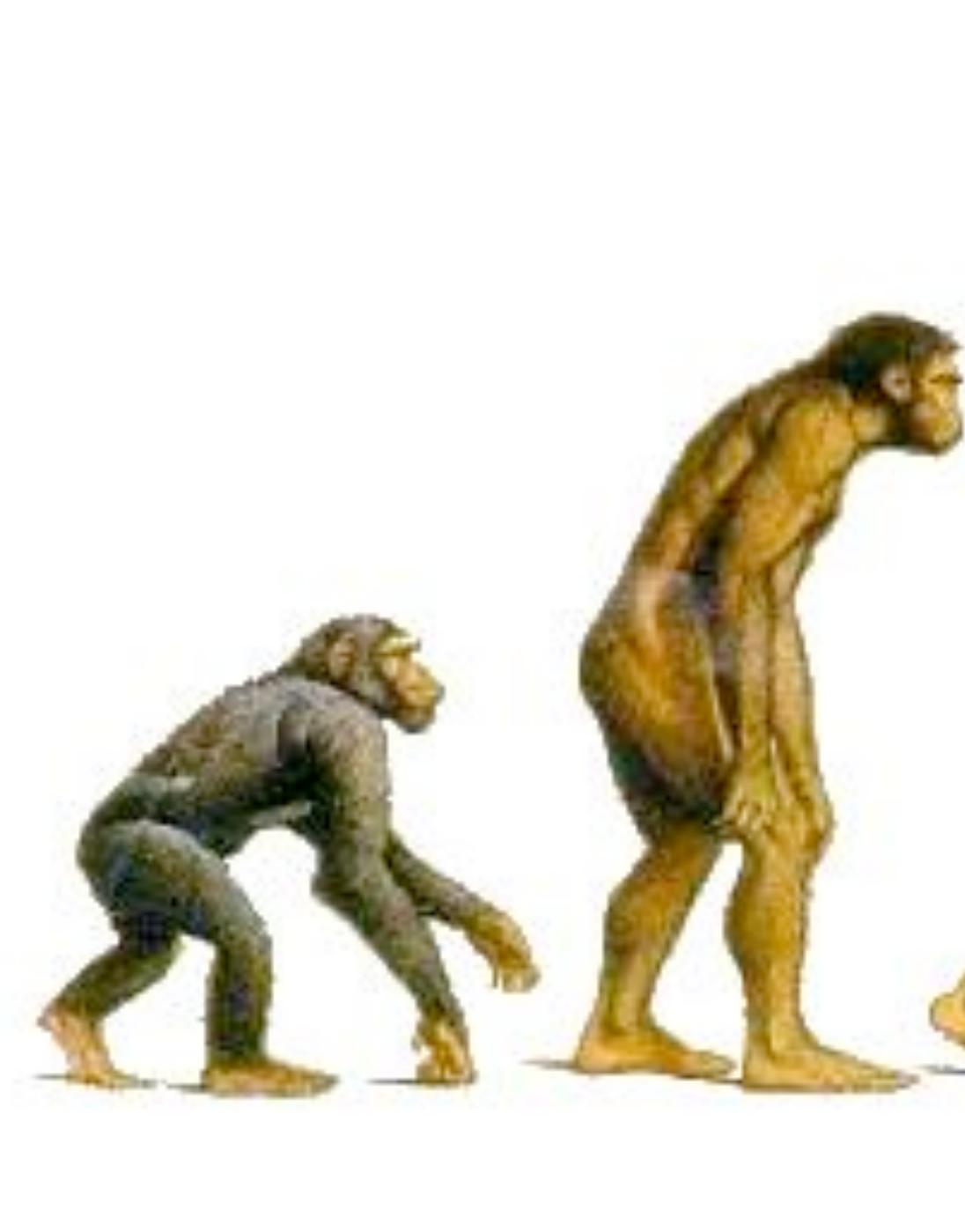
Credit: NAOJ



Credit: CERN

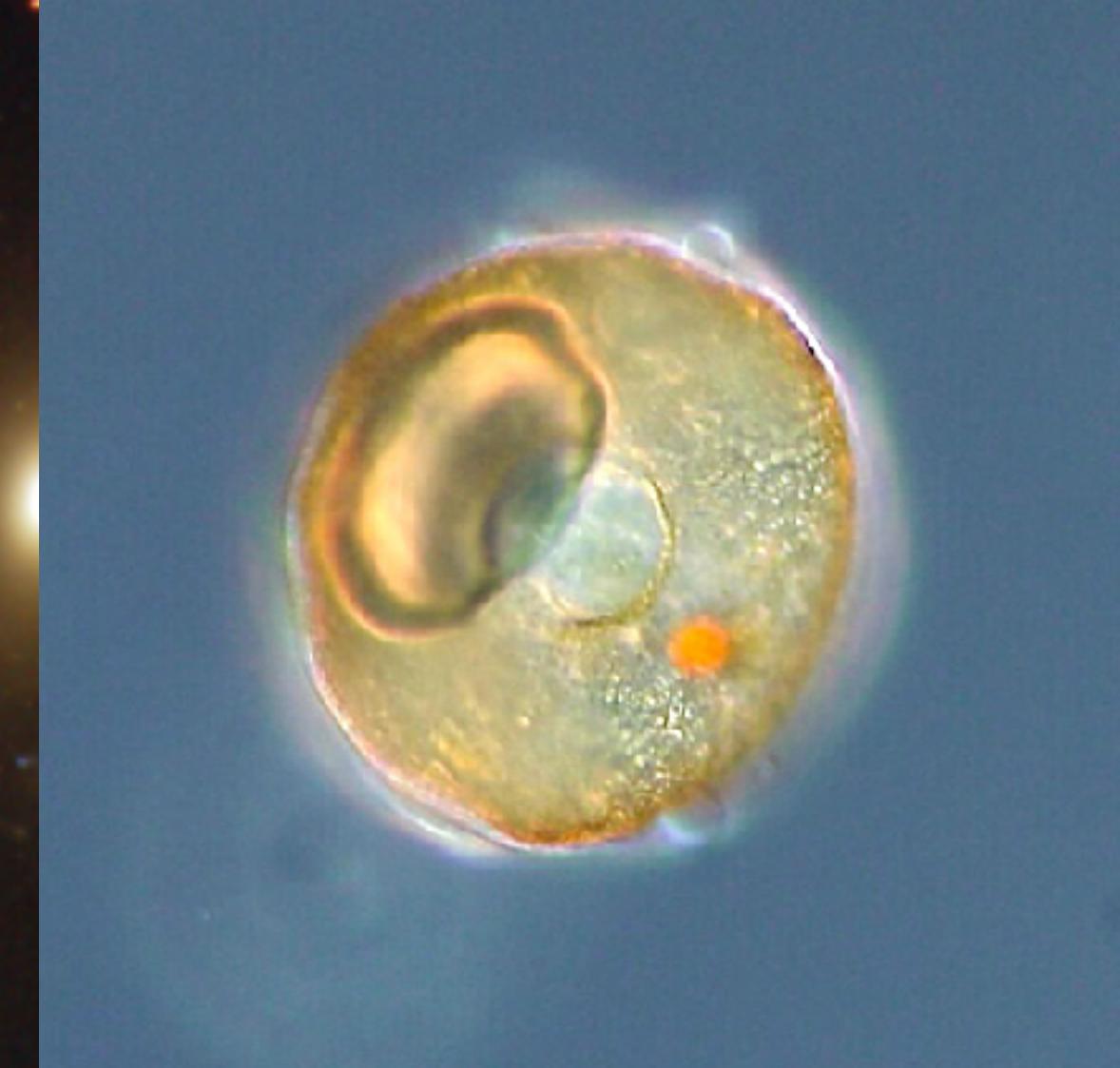


Andromeda  
2.3 million light years



HSC team  
Subaru  
telescope

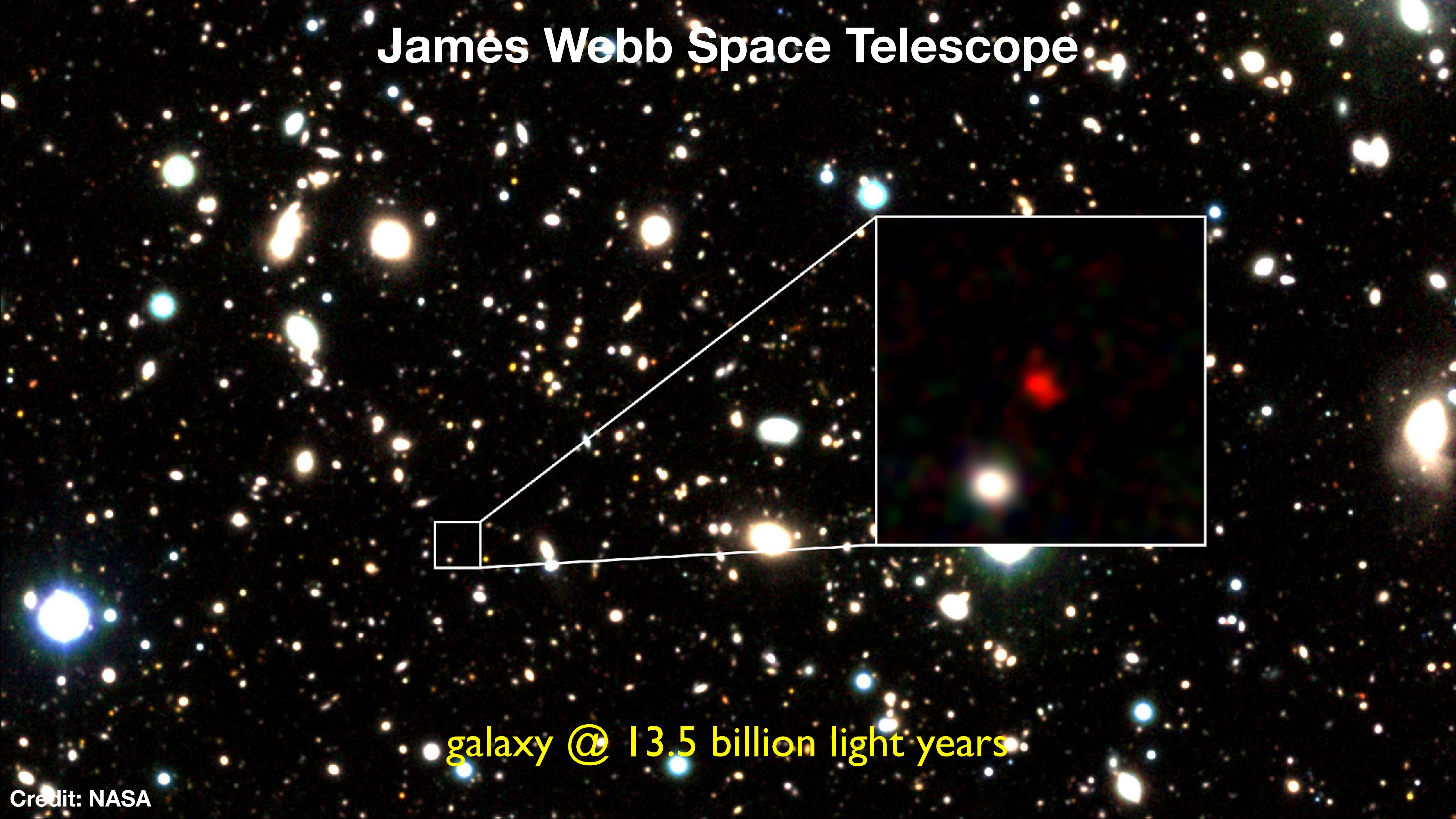
cluster of galaxies  
2.1 billion light years



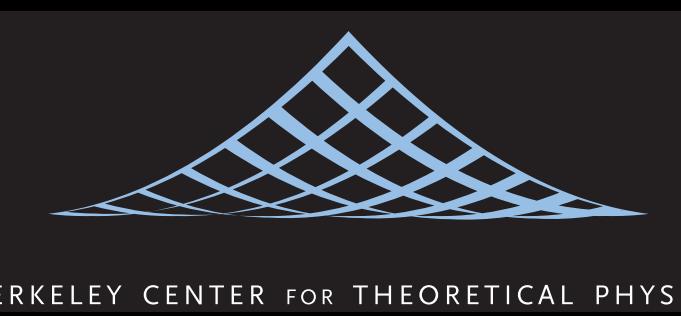
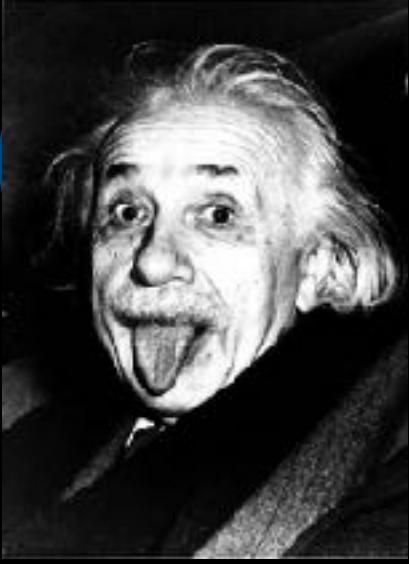
Credit: NASA

Abell 2218

# James Webb Space Telescope

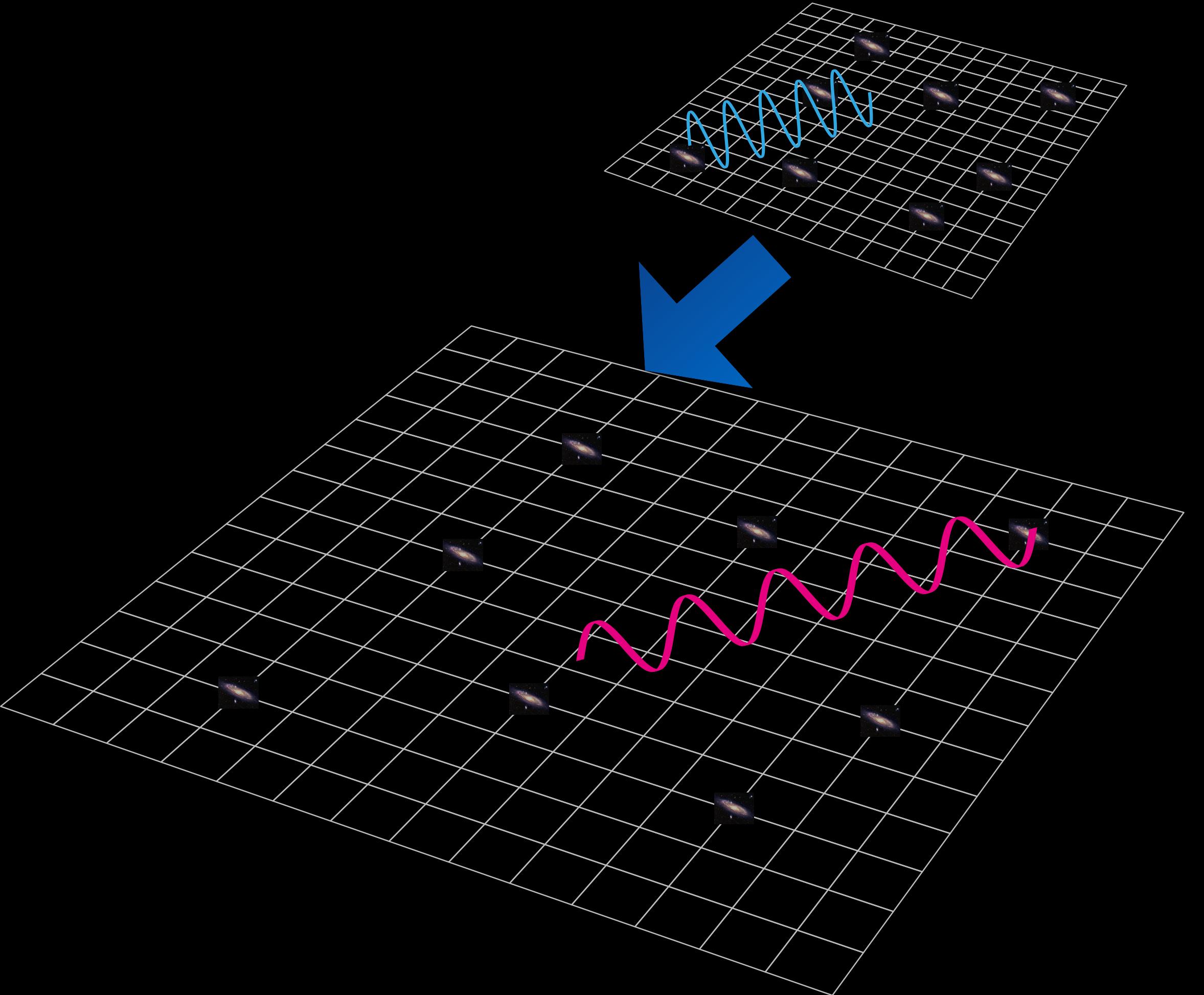


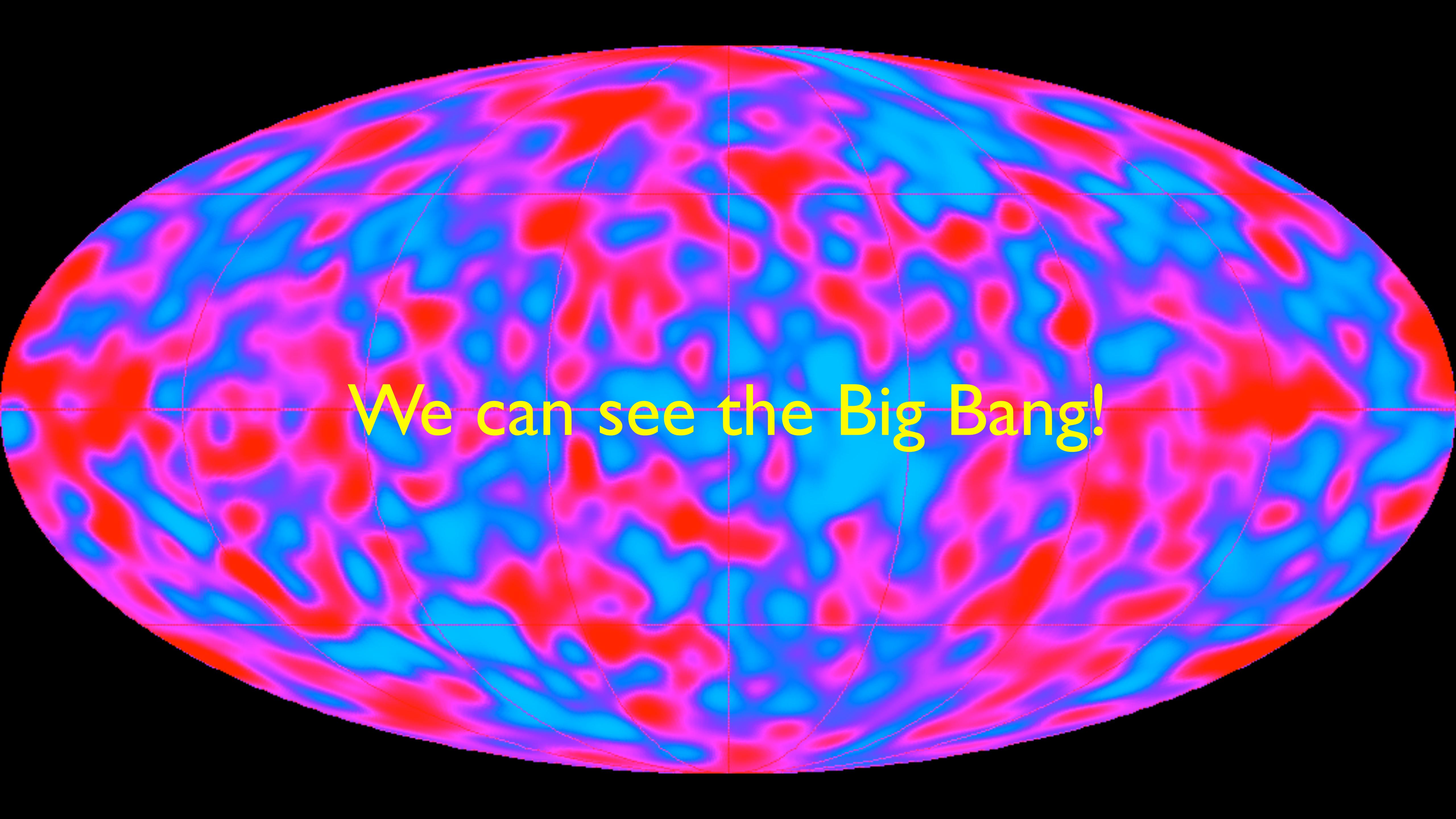
galaxy @ 13.5 billion light years



# Expanding Universe

- Einstein: Universe is not just a box
- It can **bend**, **twist**, **stretch**, and **collapse**
- Universe itself can become **bigger**
- Gets **colder** and **colder**
- It must have been small and **hot**
- ***Big Bang !***

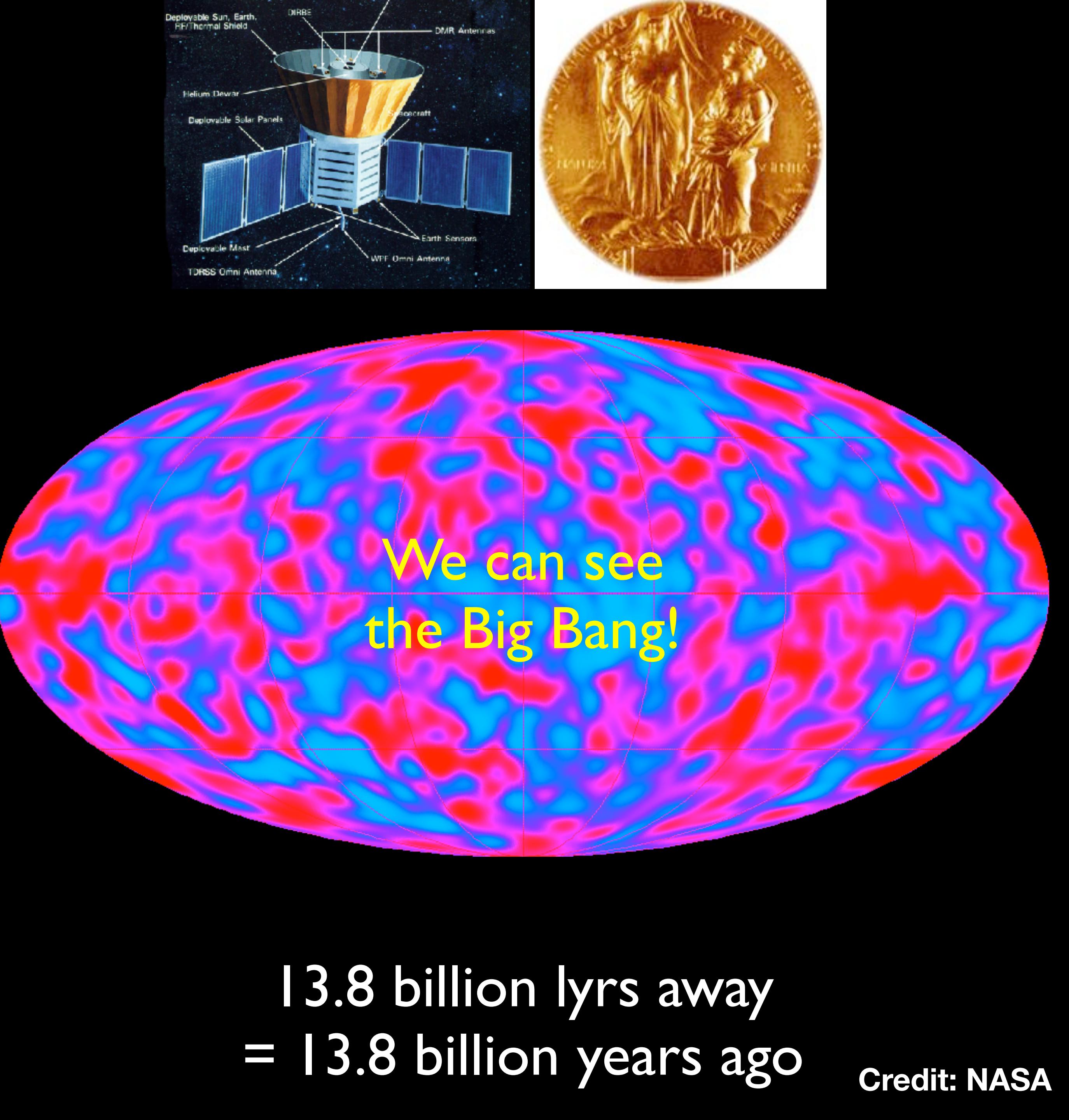




We can see the Big Bang!



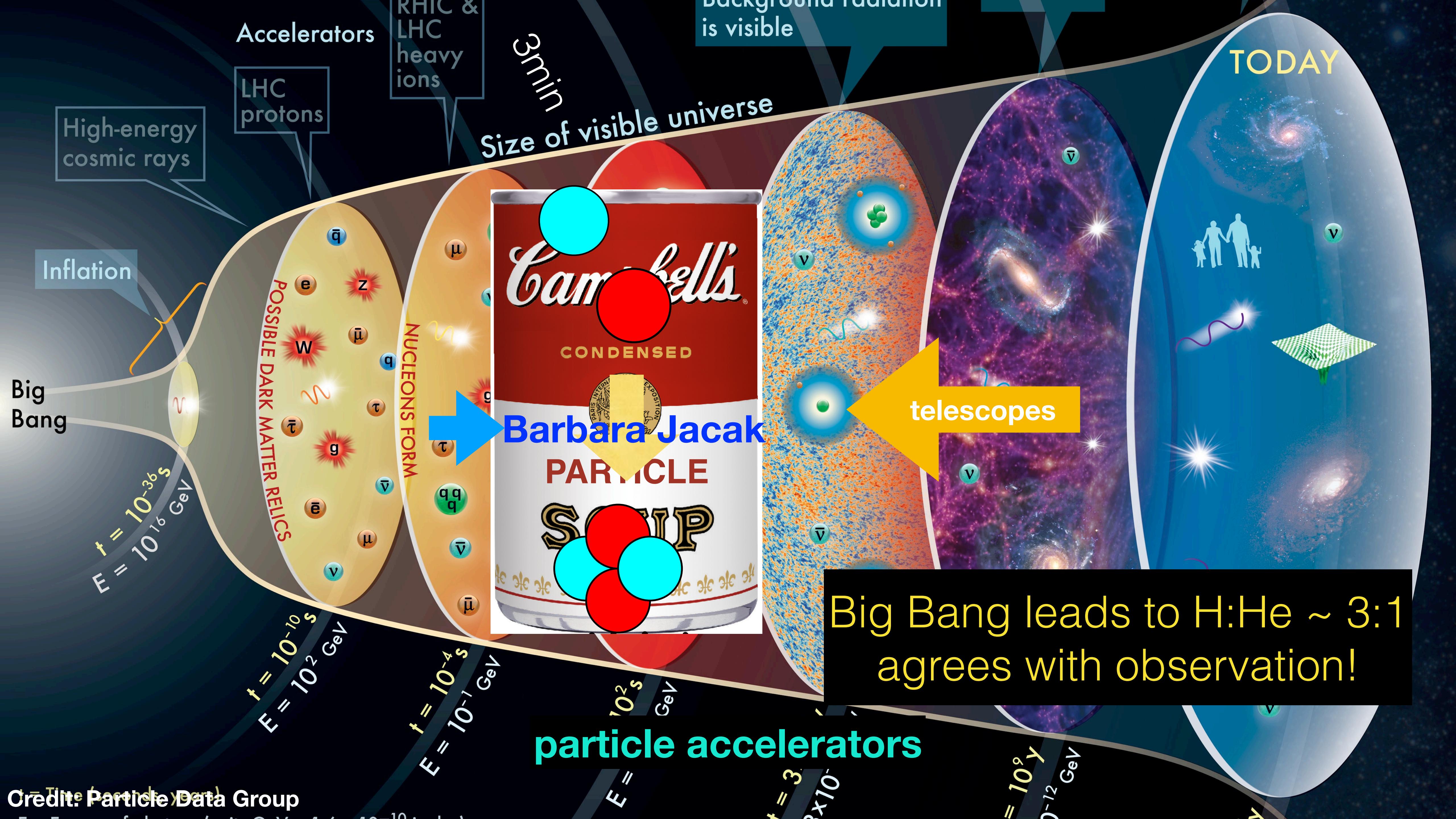
Credit: UC Berkeley



Credit: NASA



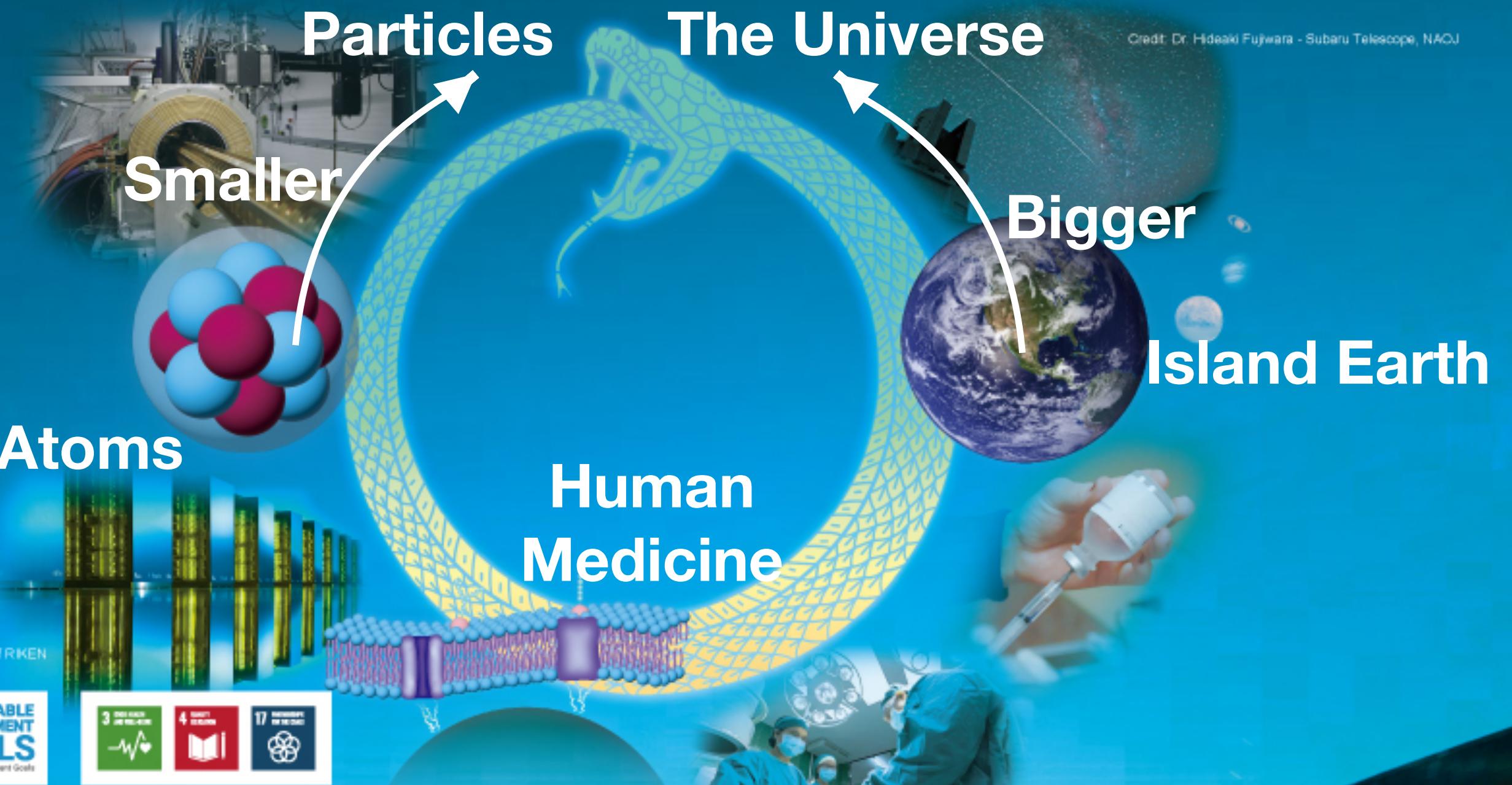
Credit: ESA



Interdisciplinary Science Conference in Okinawa

# ISCO 2023

Physics and Mathematics meet Medical Science



2023 Feb. 27<sup>th</sup> ▶ Mar. 3<sup>rd</sup>

**OIST** Okinawa Institute of  
Science and Technology

<https://indico.ipmu.jp/e/ISCO2023>

Deadline of Abstract Submission

30. Nov. 2022

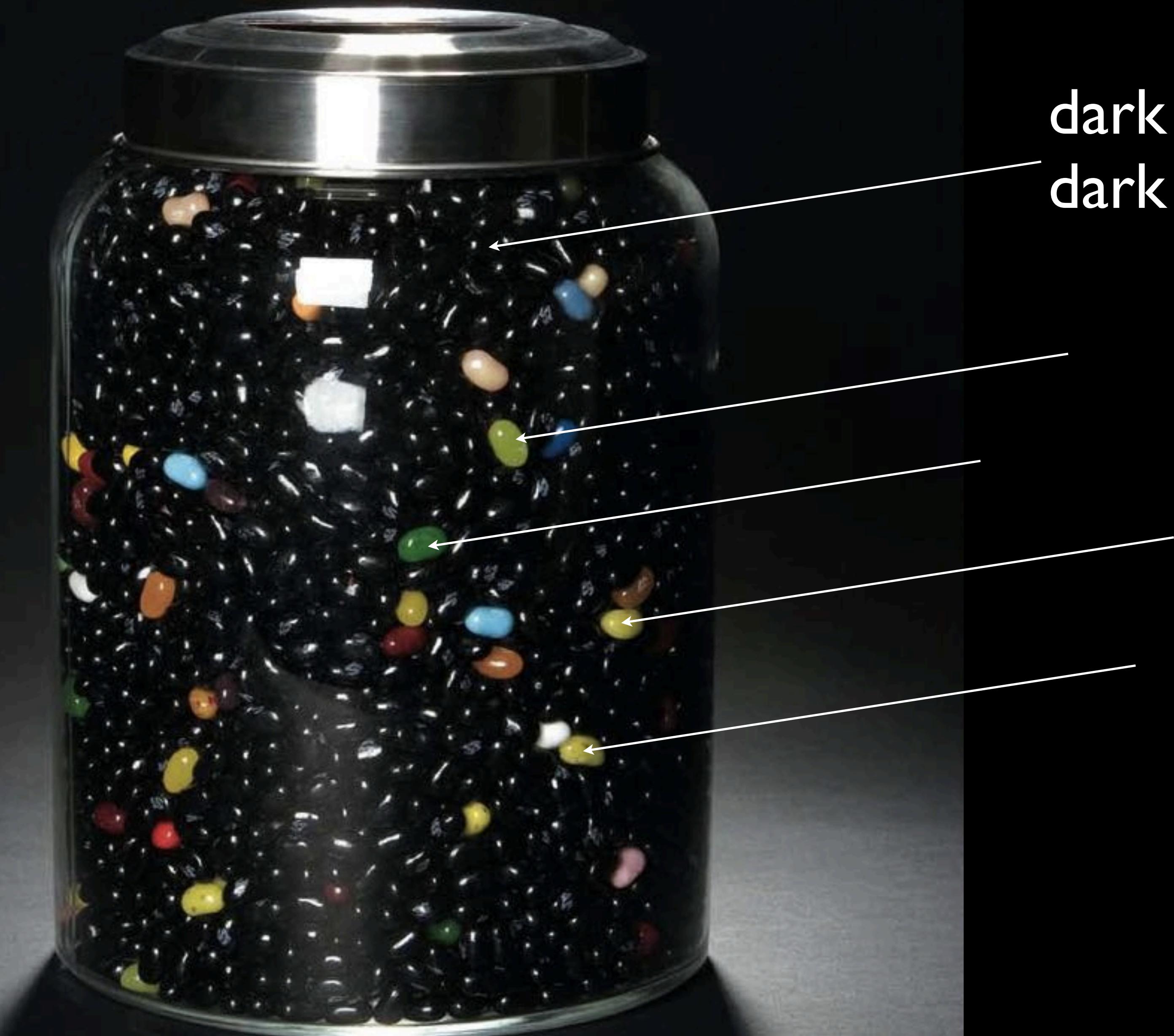
Deadline of Registration  
31. Jan. 2023

Scan this QR code  
for more information



The smallest = elementary particles  
meets  
The biggest = the Universe

The Universe



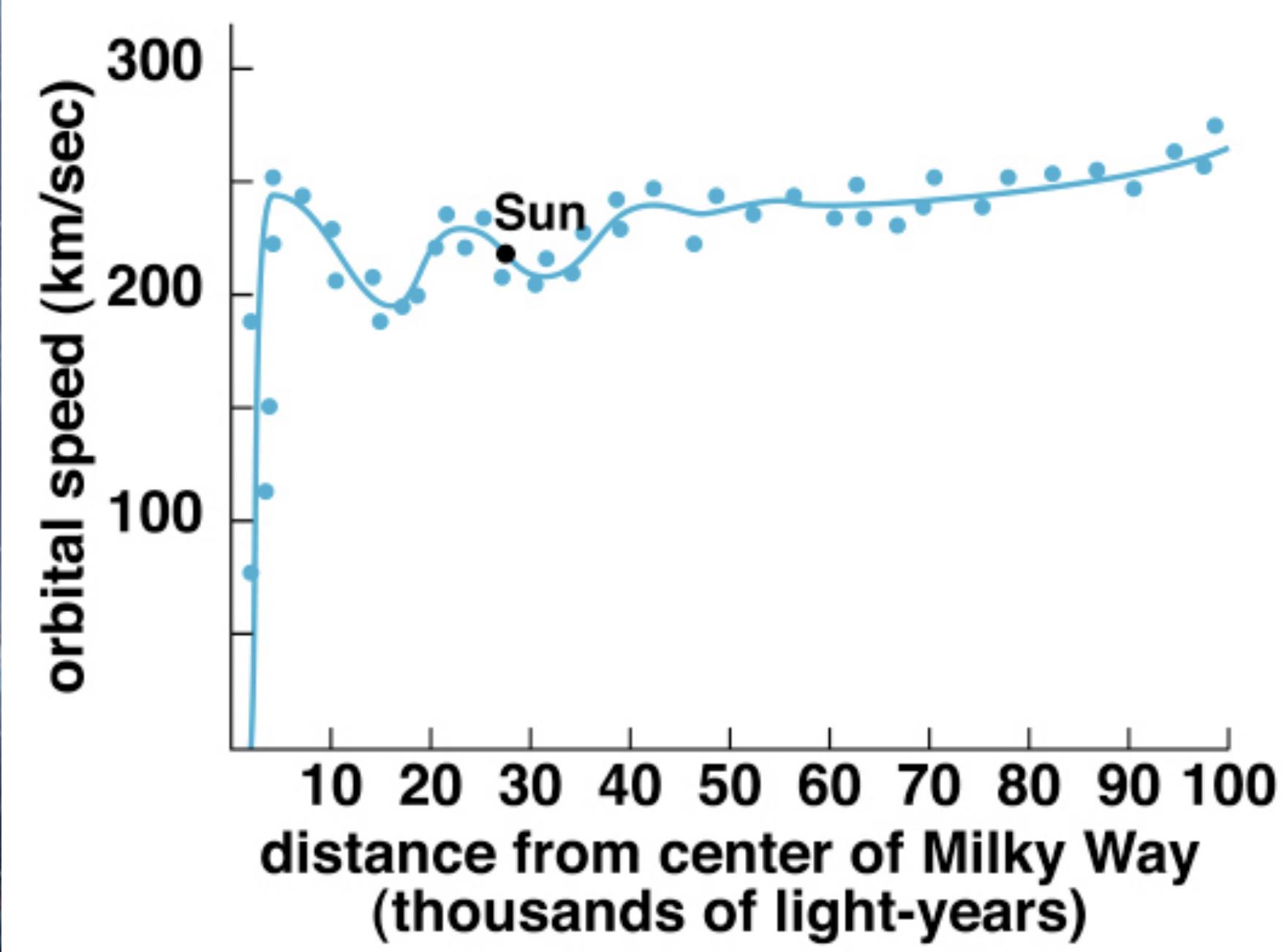
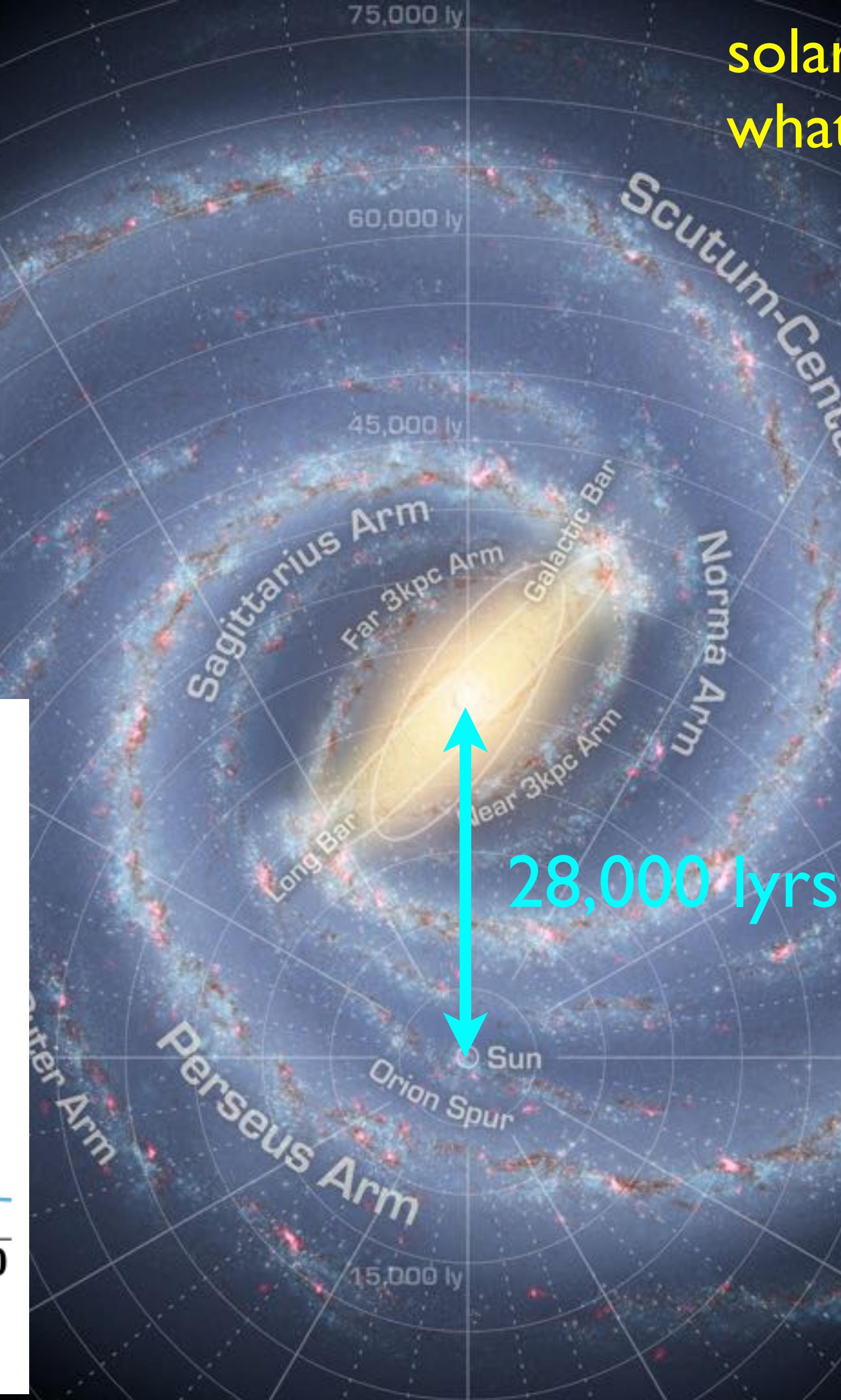
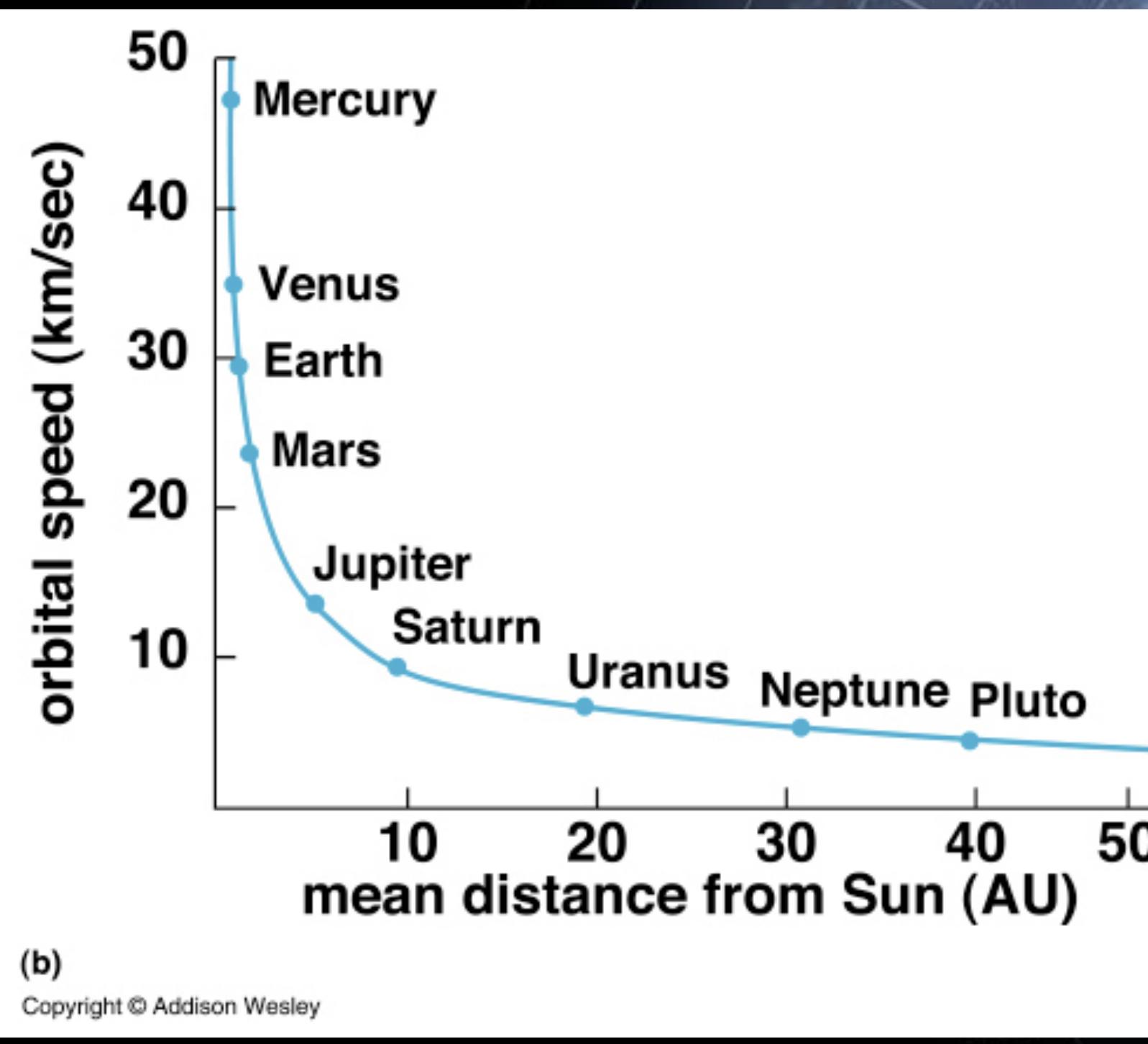
dark matter  
dark energy

atoms

# Dark Matter

a hundred billion stars

solar system revolves at 220 km/s  
what is pulling us inside?



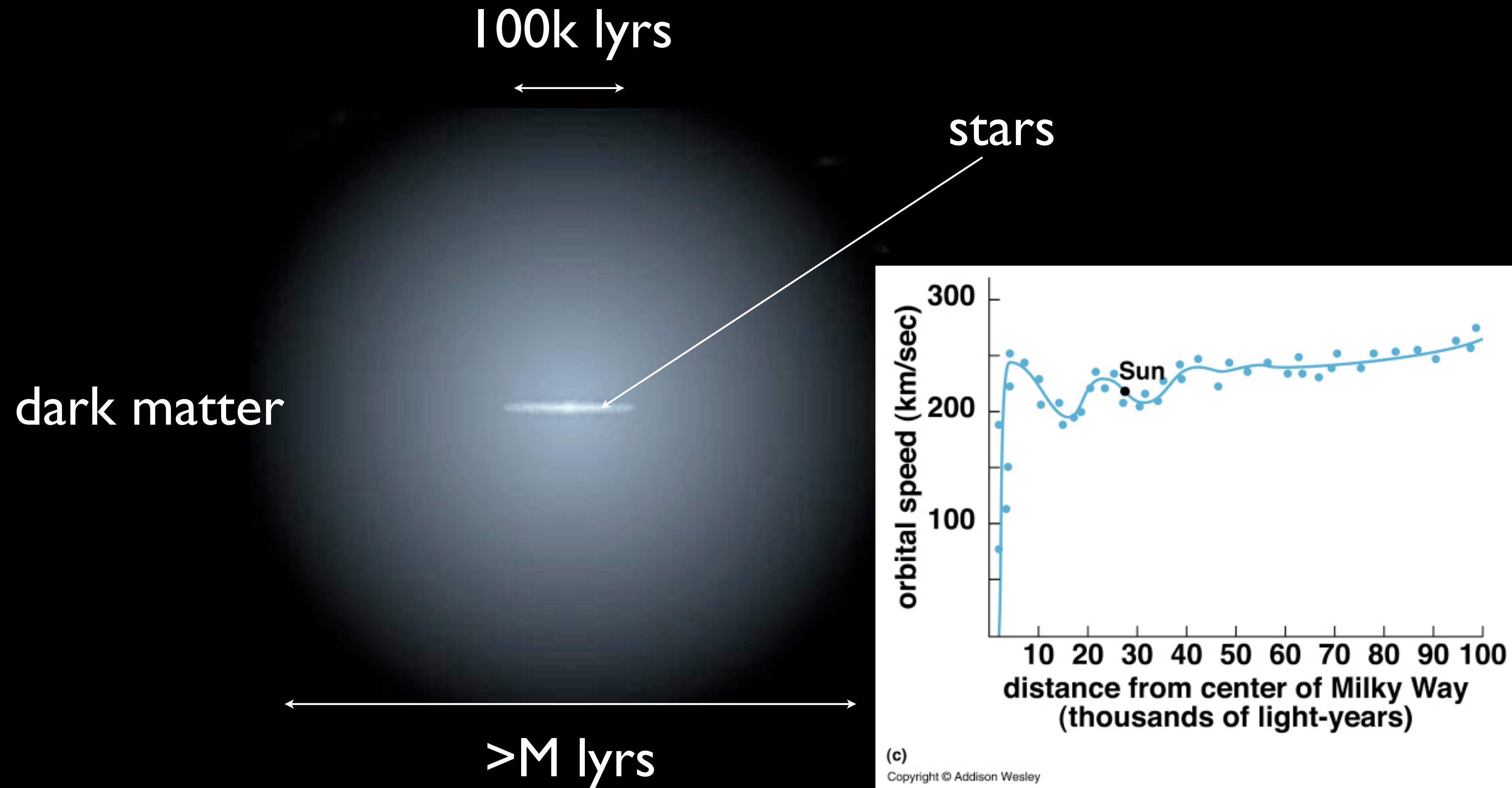
(b)

Copyright © Addison Wesley

(c)

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# true nature of galaxies

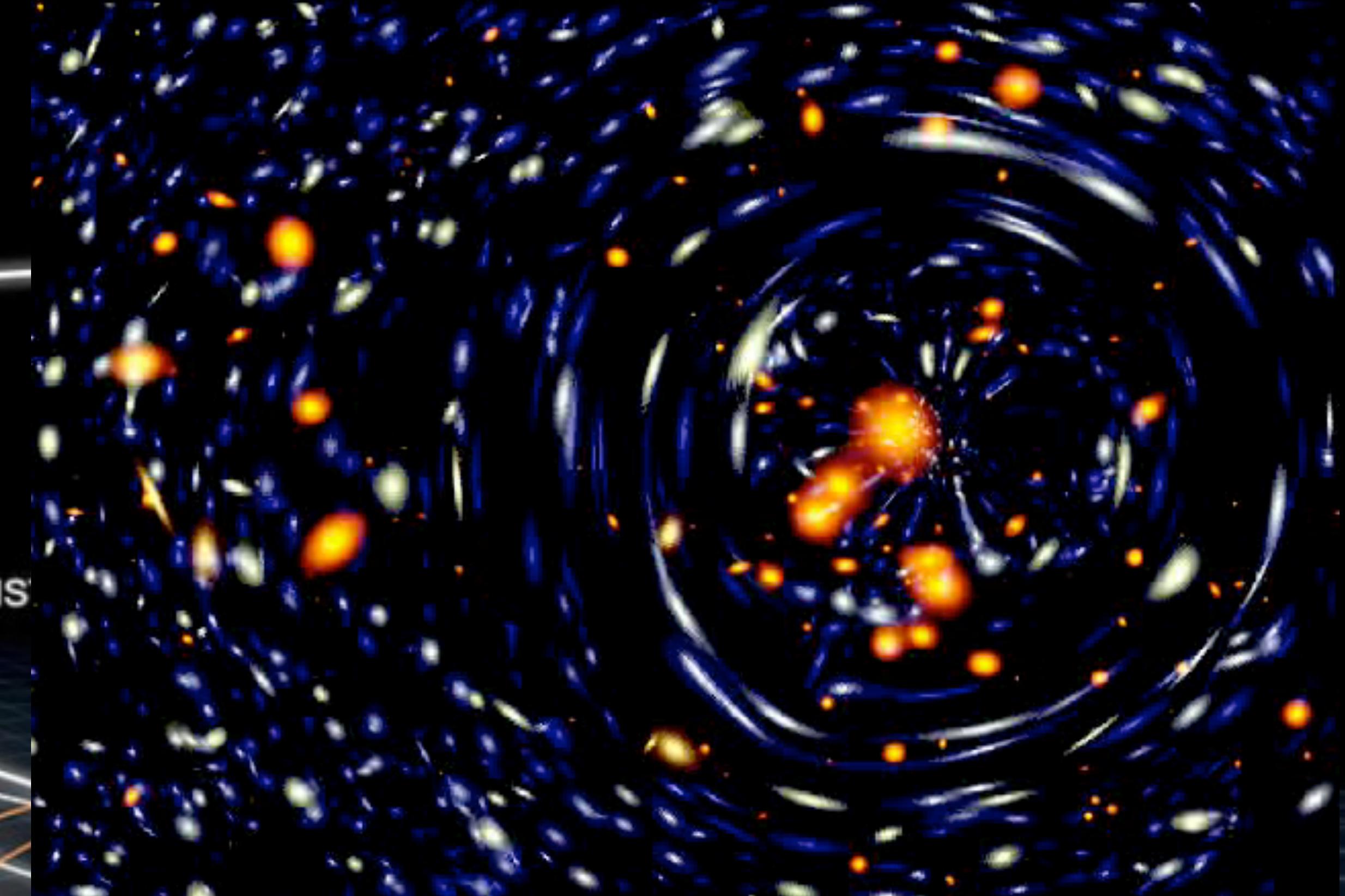
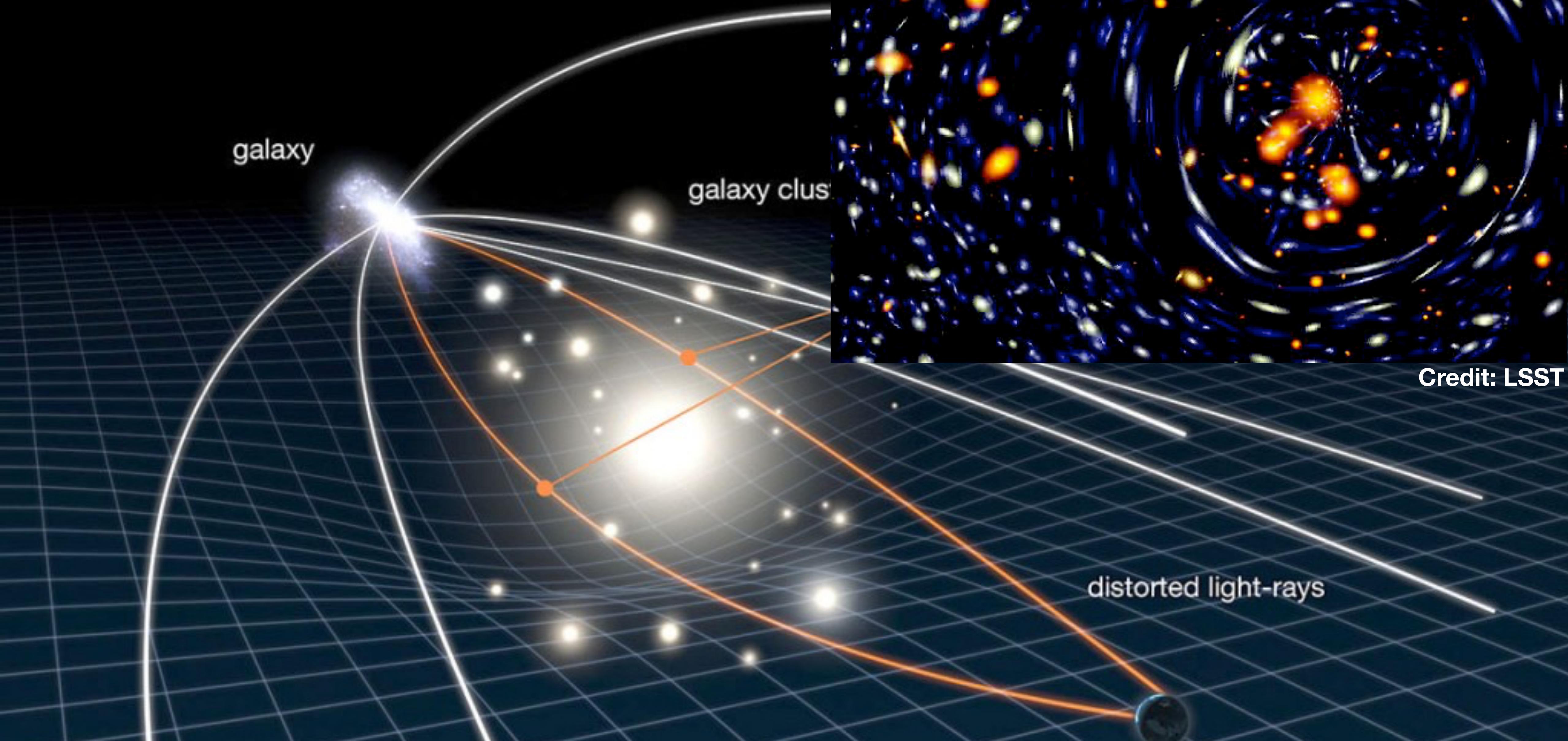




cluster of galaxies

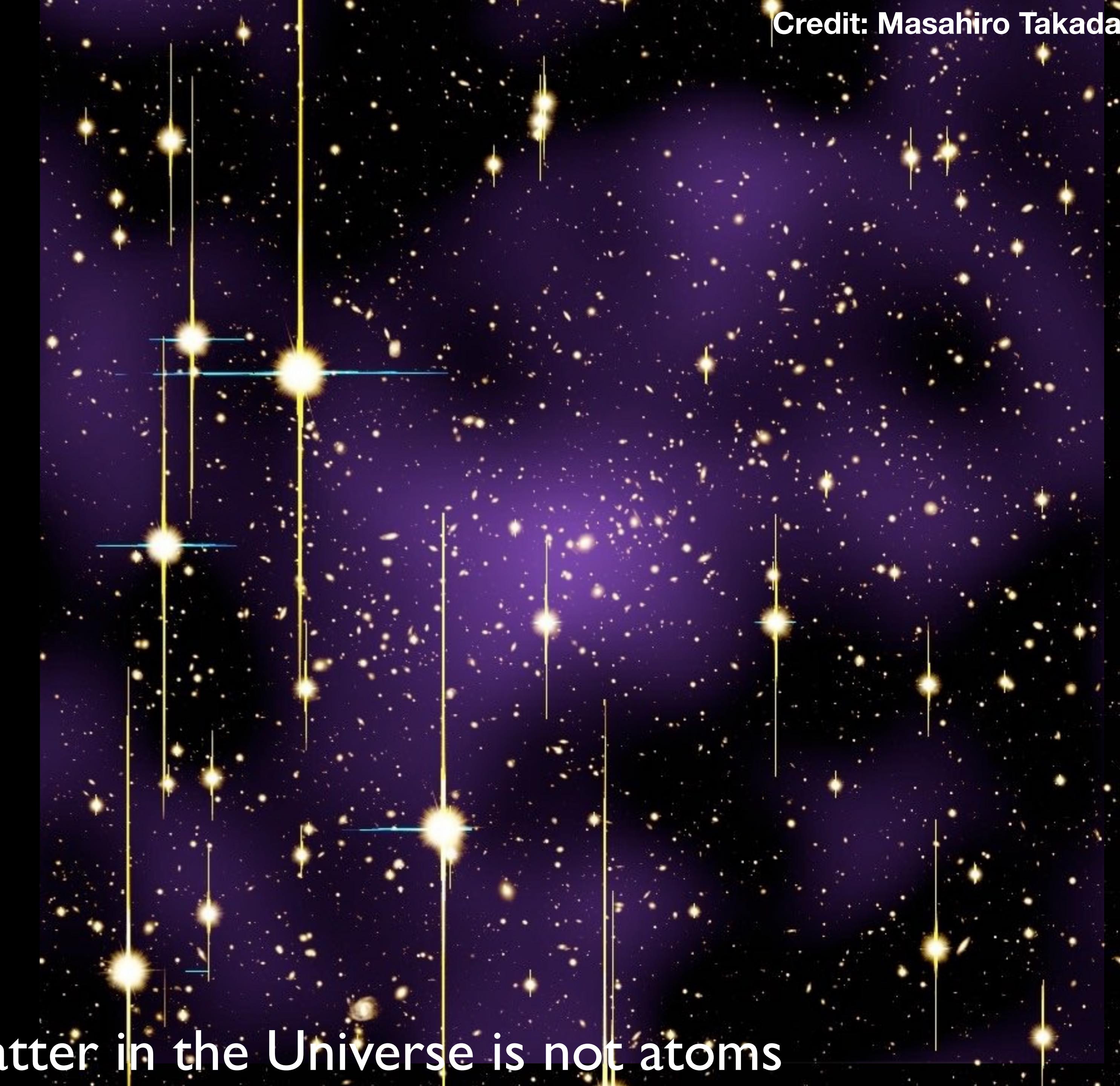
Abell 2218  
2.1B lyrs

Credit: NASA/ESA

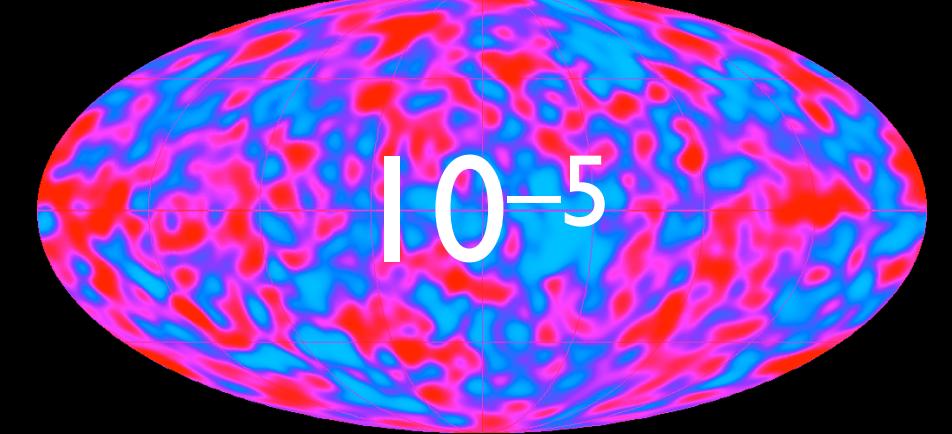


Credit: LSST

image invisible  
dark matter

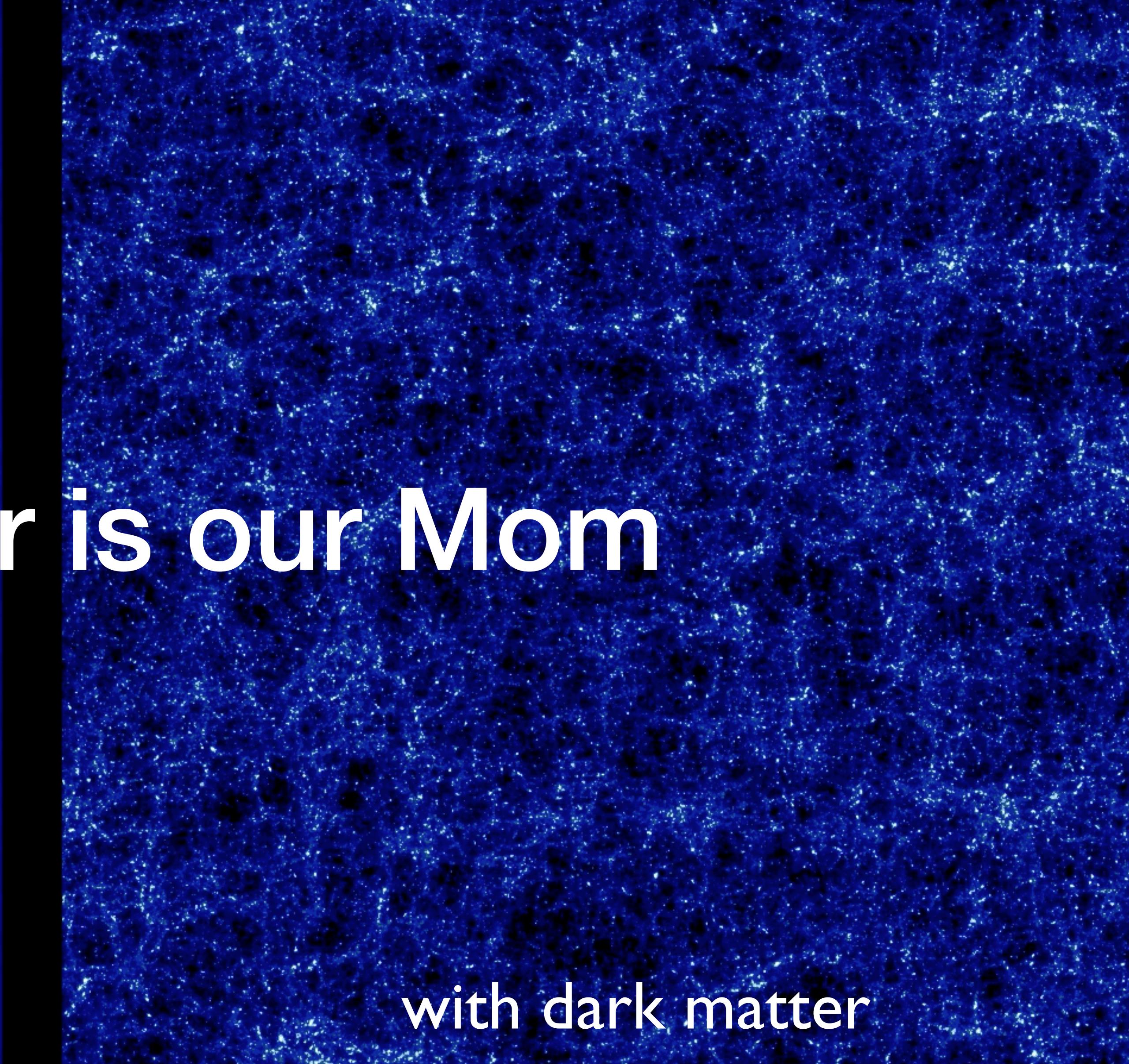


more than 80% of matter in the Universe is not atoms



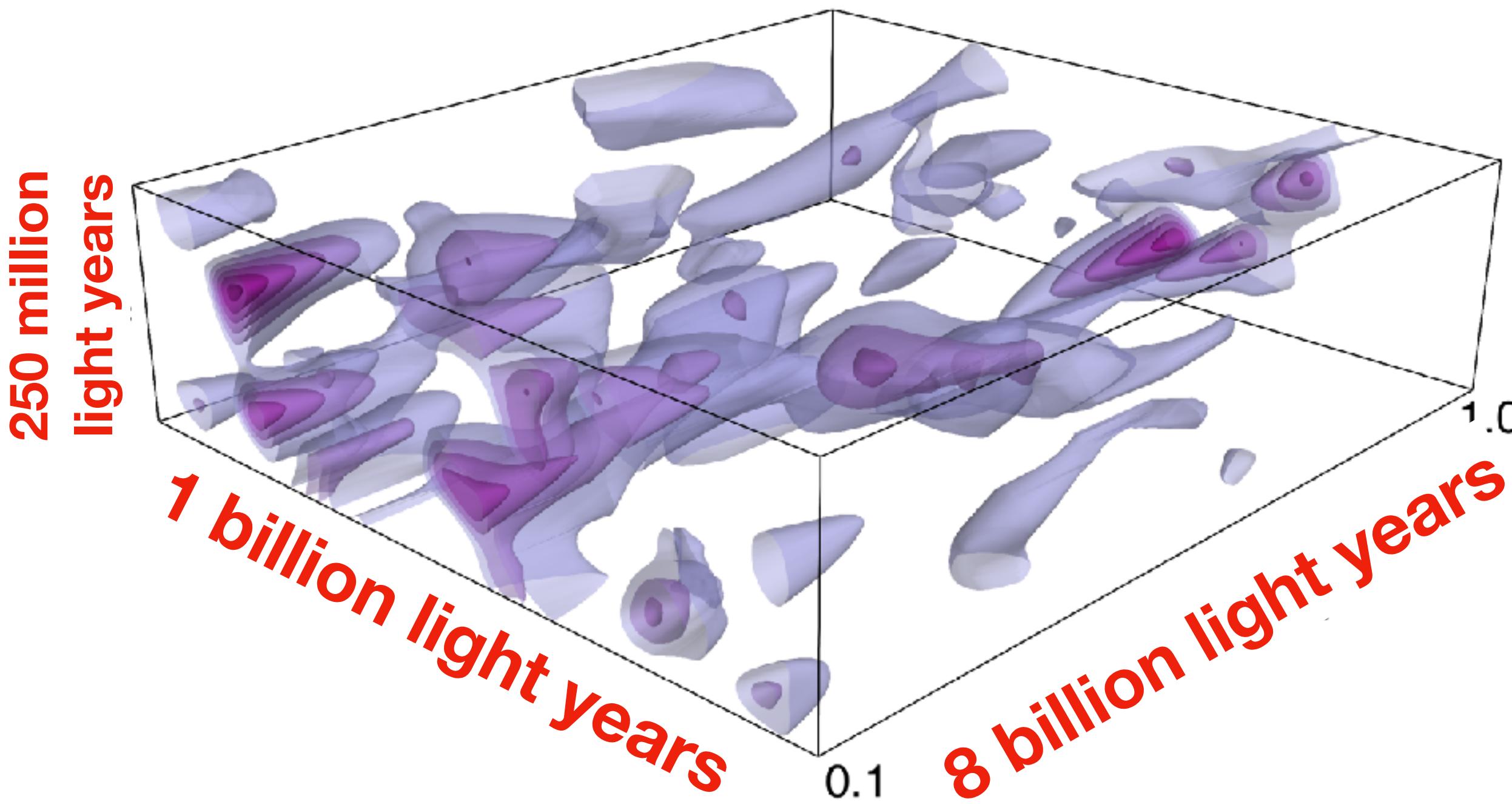
Dark Matter is our Mom

without dark matter

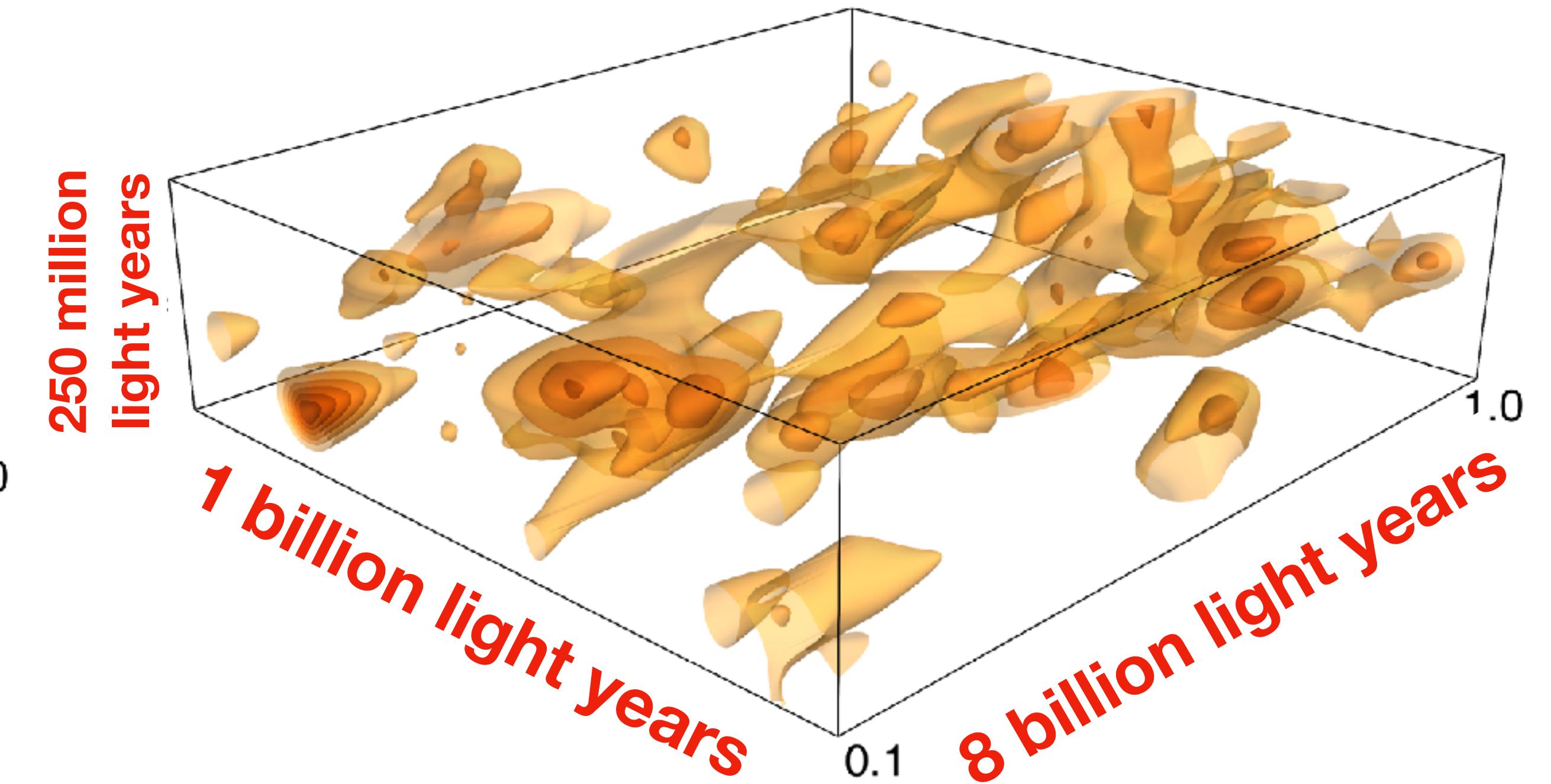


with dark matter

# 3D maps

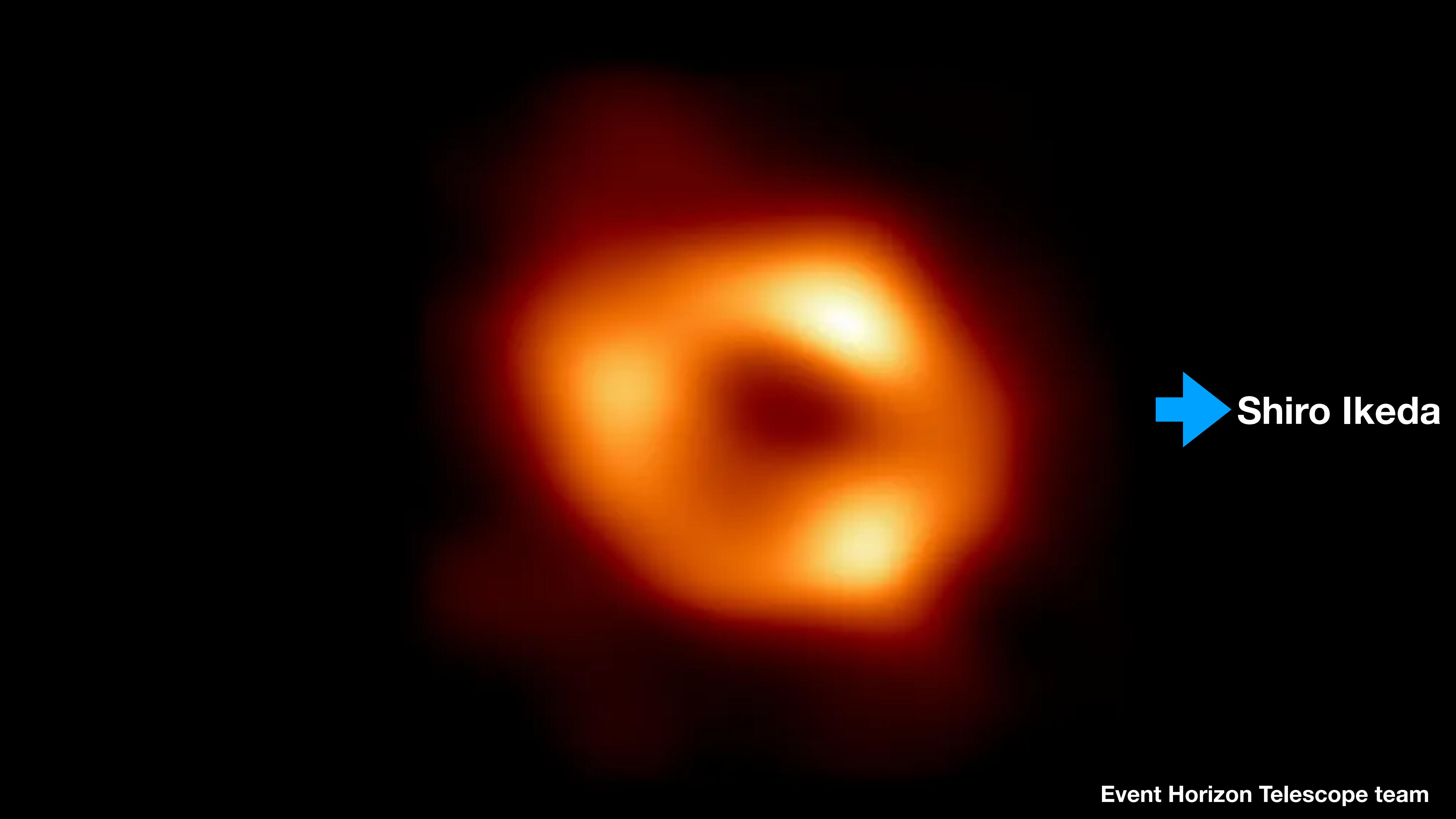


Dark matter



Galaxies

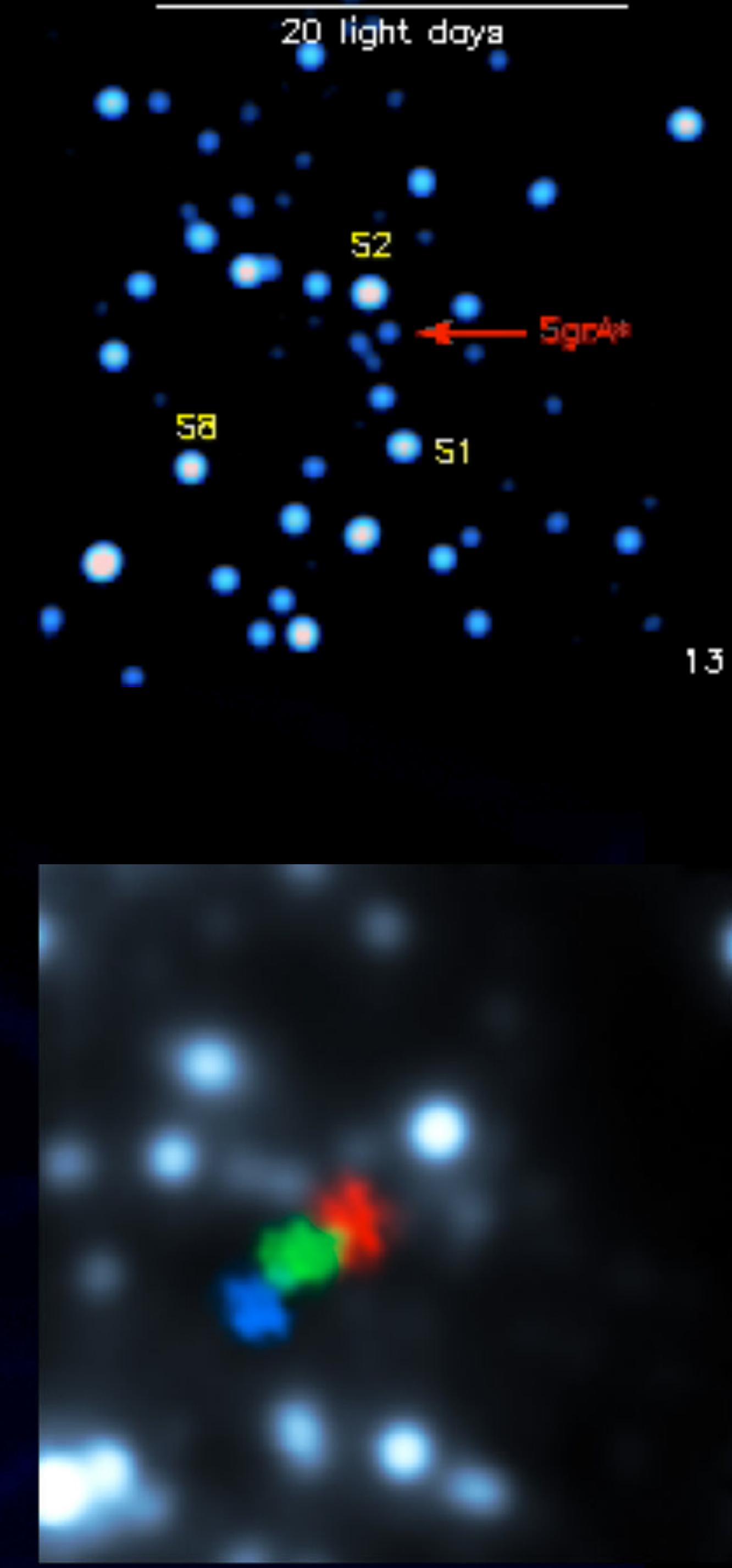
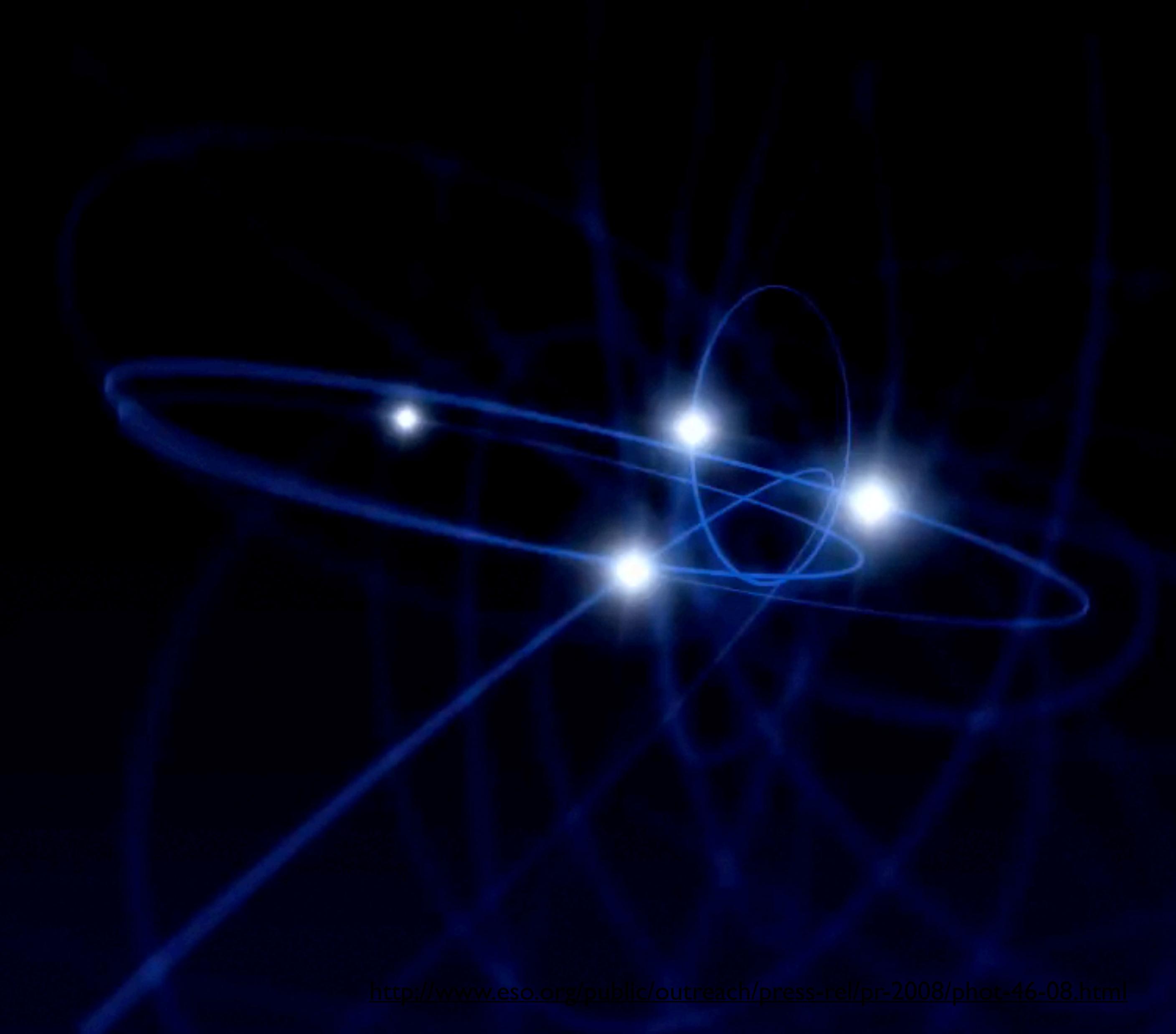
Credit: Subaru HSC collaboration



**→ Shiro Ikeda**

**weighs only 4 million times the Sun**

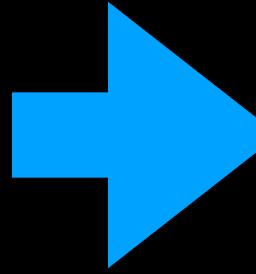
20 light days





# What is dark matter?

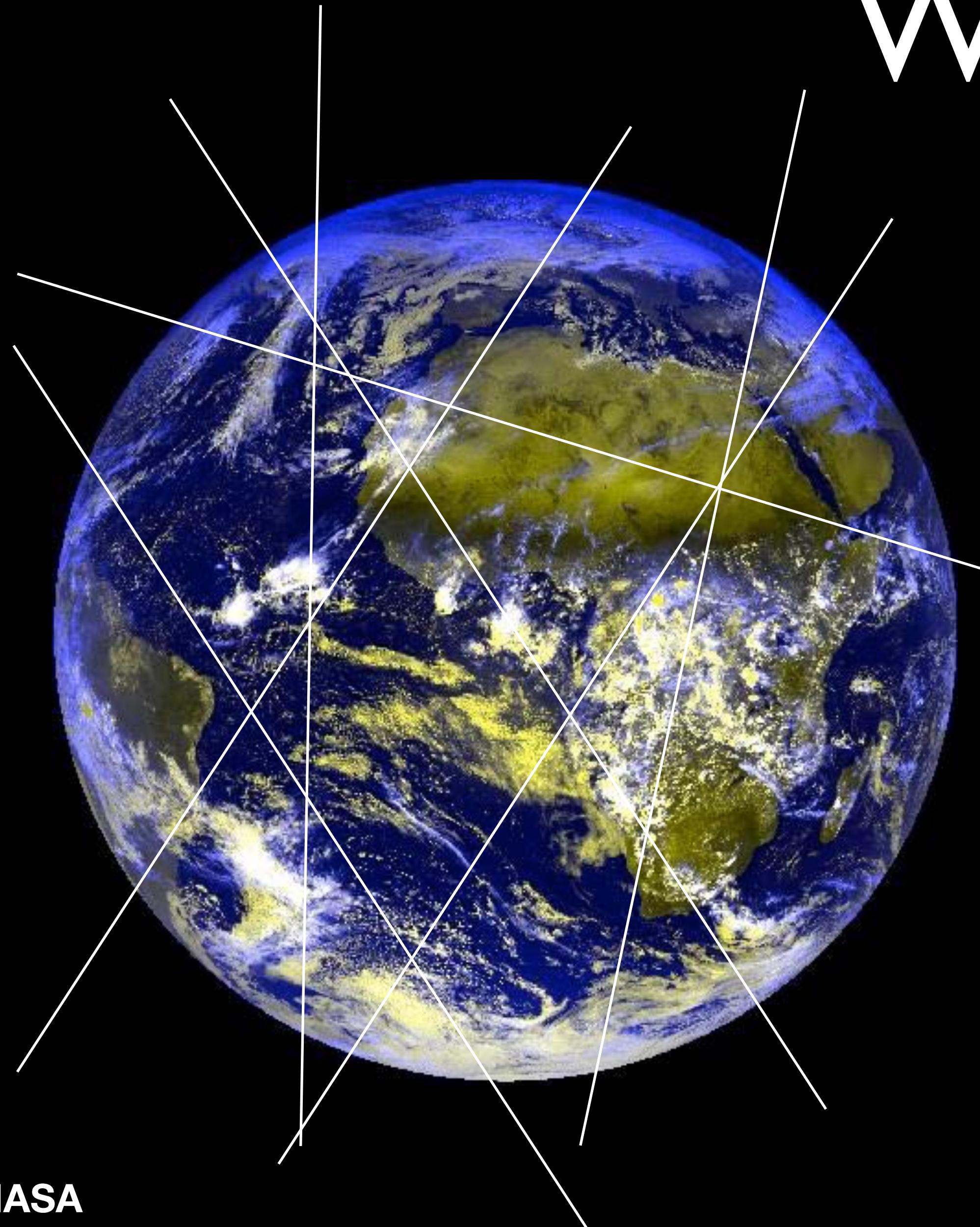
- Not black holes
  - except for ~nm size
- Not dim stars
- Not neutrinos
- Nothing we know of
- New particles?



Alex Kusenko



# WIMPs



- It may be **WIMP** (Weakly Interacting Massive Particle)
- Stable heavy **point-like particle** produced in early Universe
- millions of them going through our body every second

An aerial photograph showing the Large Hadron Collider (LHC) ring, a massive circular structure composed of many smaller arcs, winding through the green fields and towns of the Franco-Swiss border. The sky above is blue with scattered white clouds.

LHC

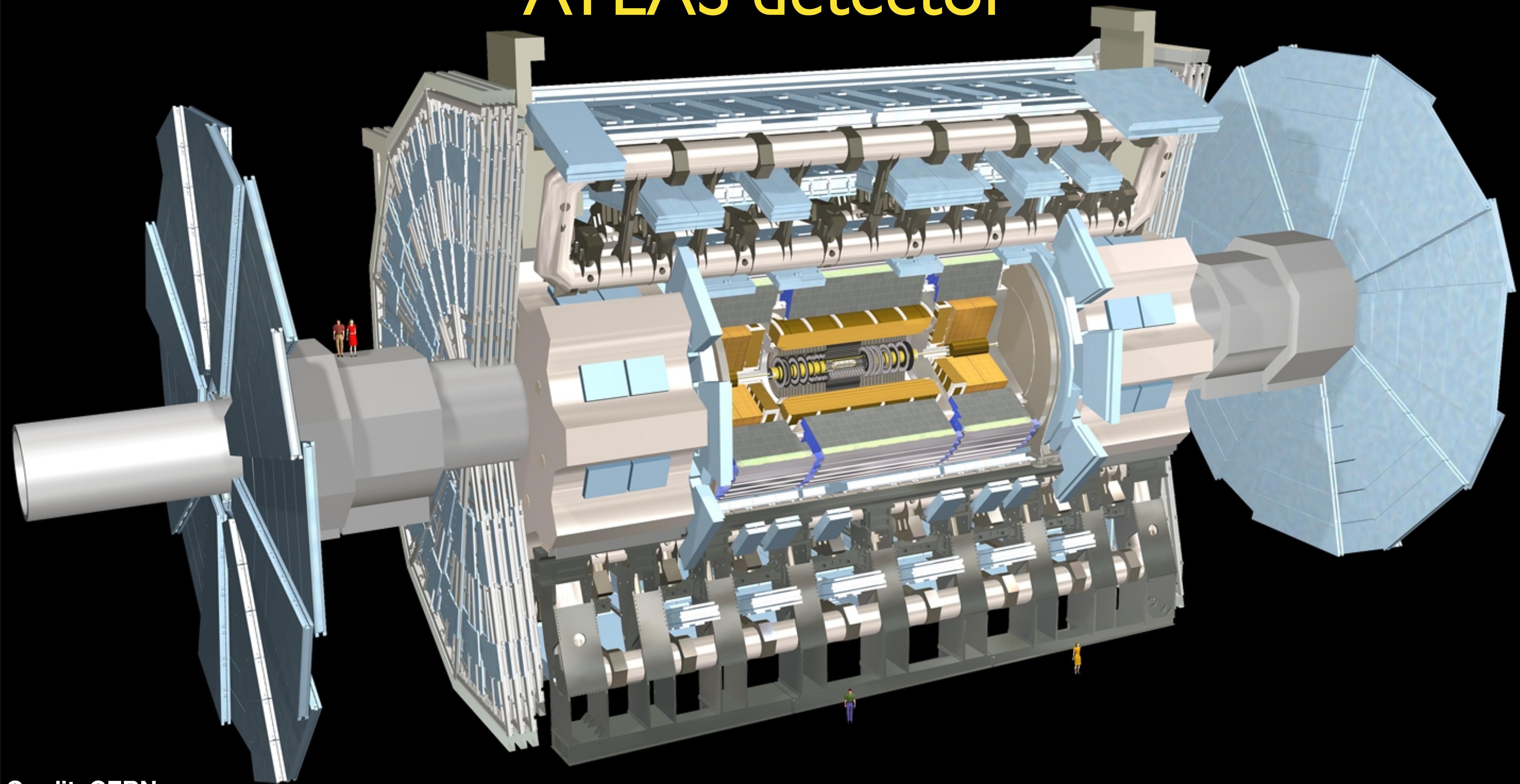
*Redo the Big Bang!*





Credit: CERN

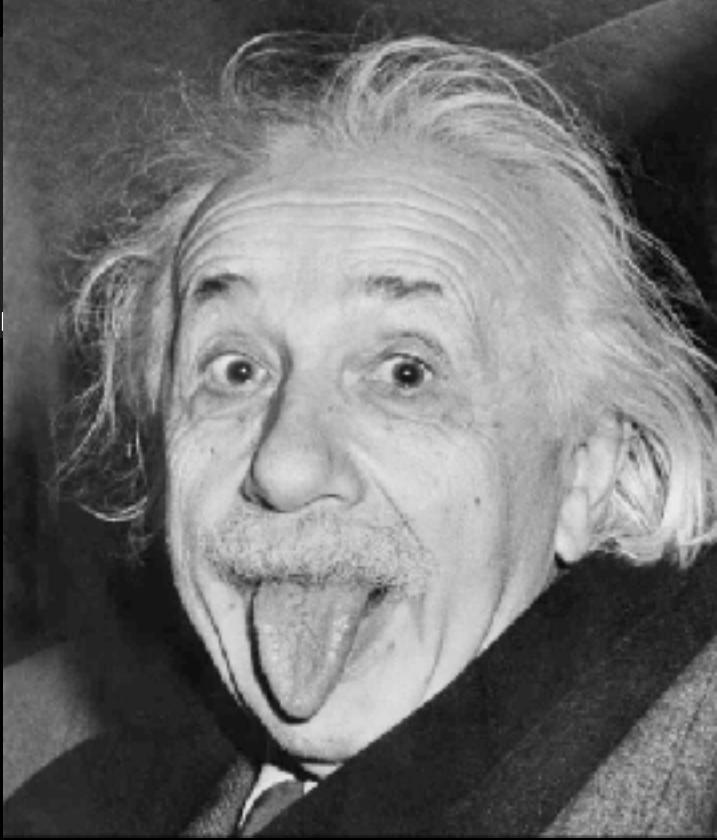
# ATLAS detector



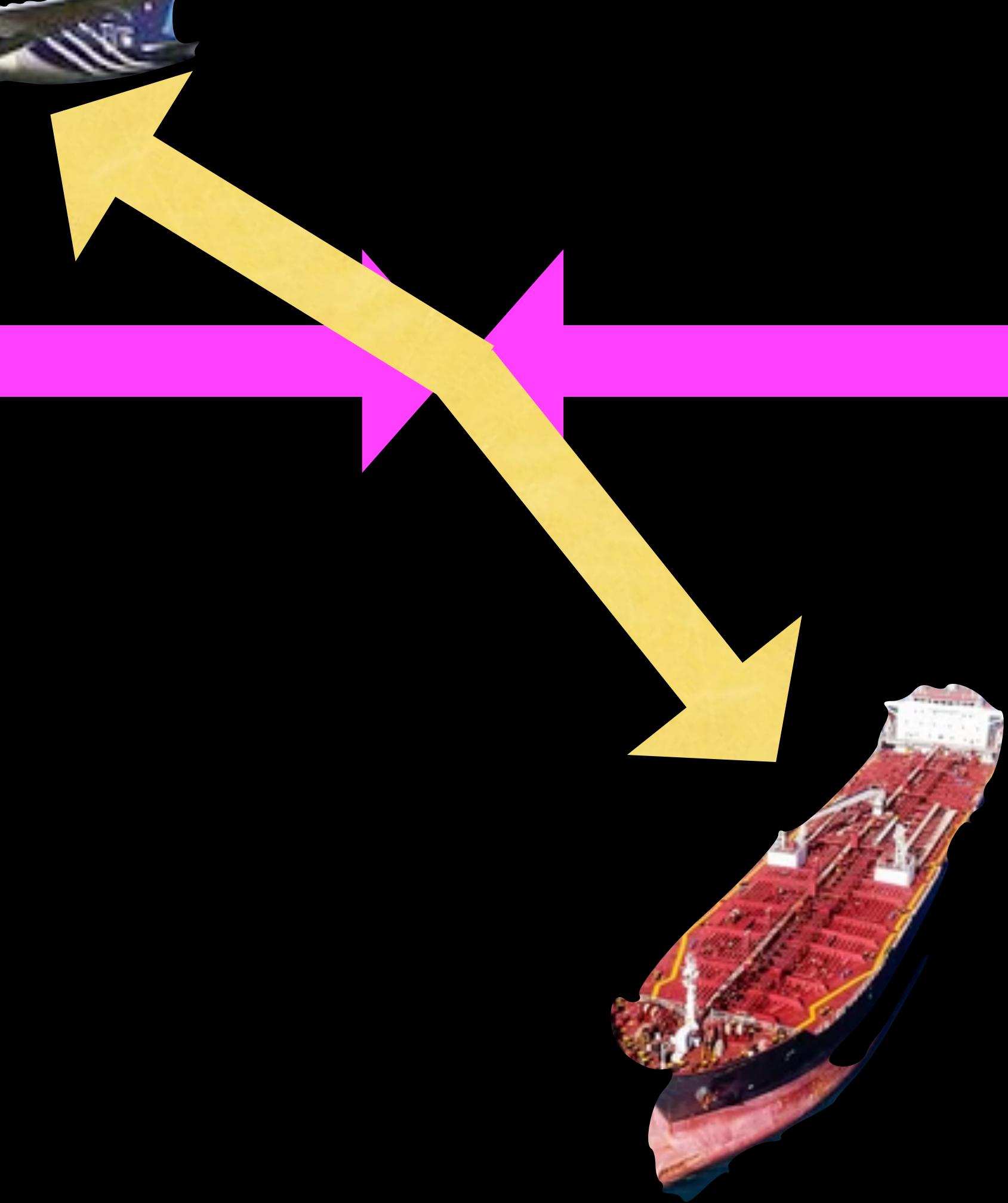
Credit: CERN



# Can we make dark matter?



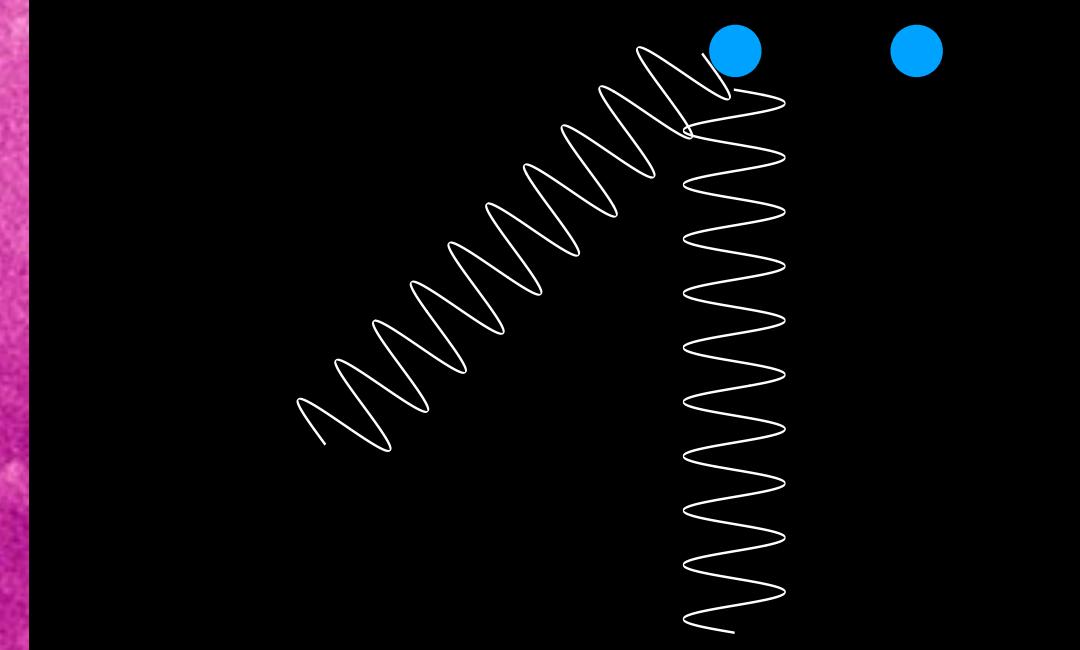
$$E=mc^2$$



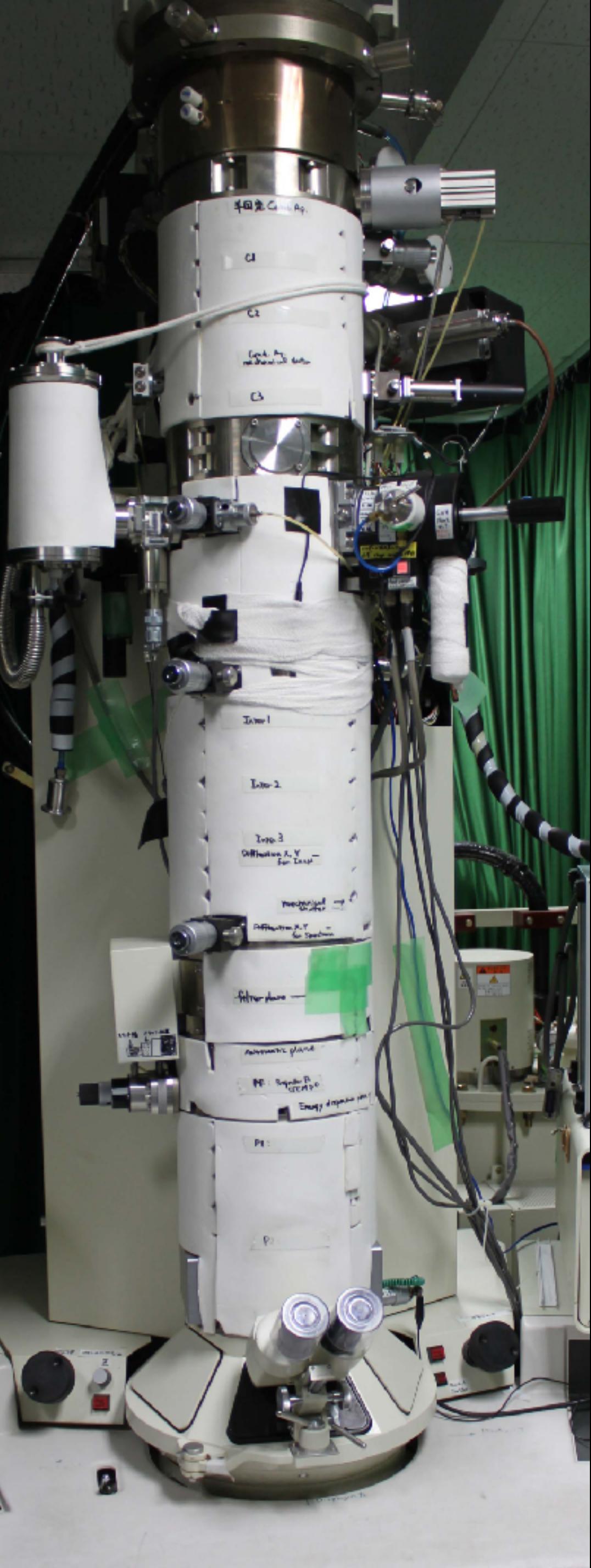
# accelerator=microscope



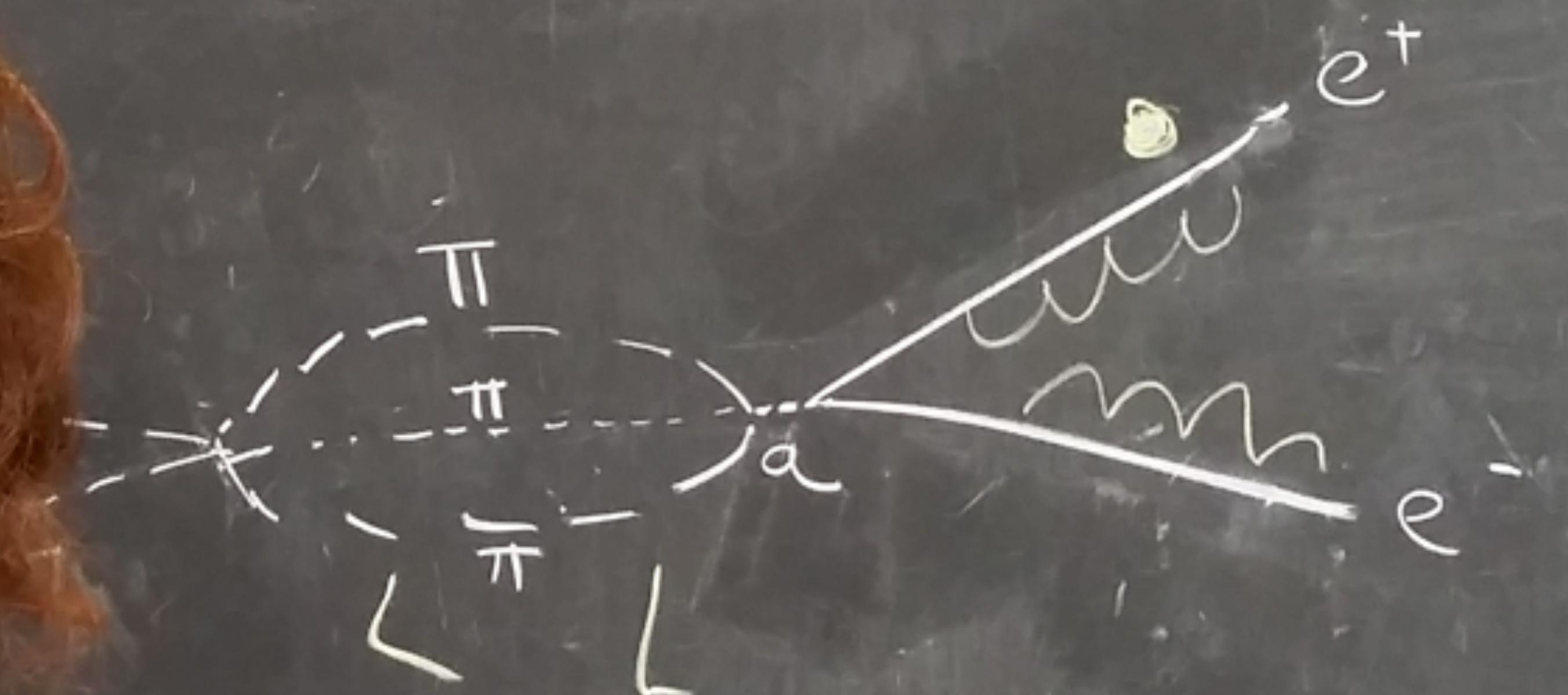
- can't see things smaller than the wavelength
- short wavelength=high energy



Also PET  
Radiation therapy



# Or SIMP?

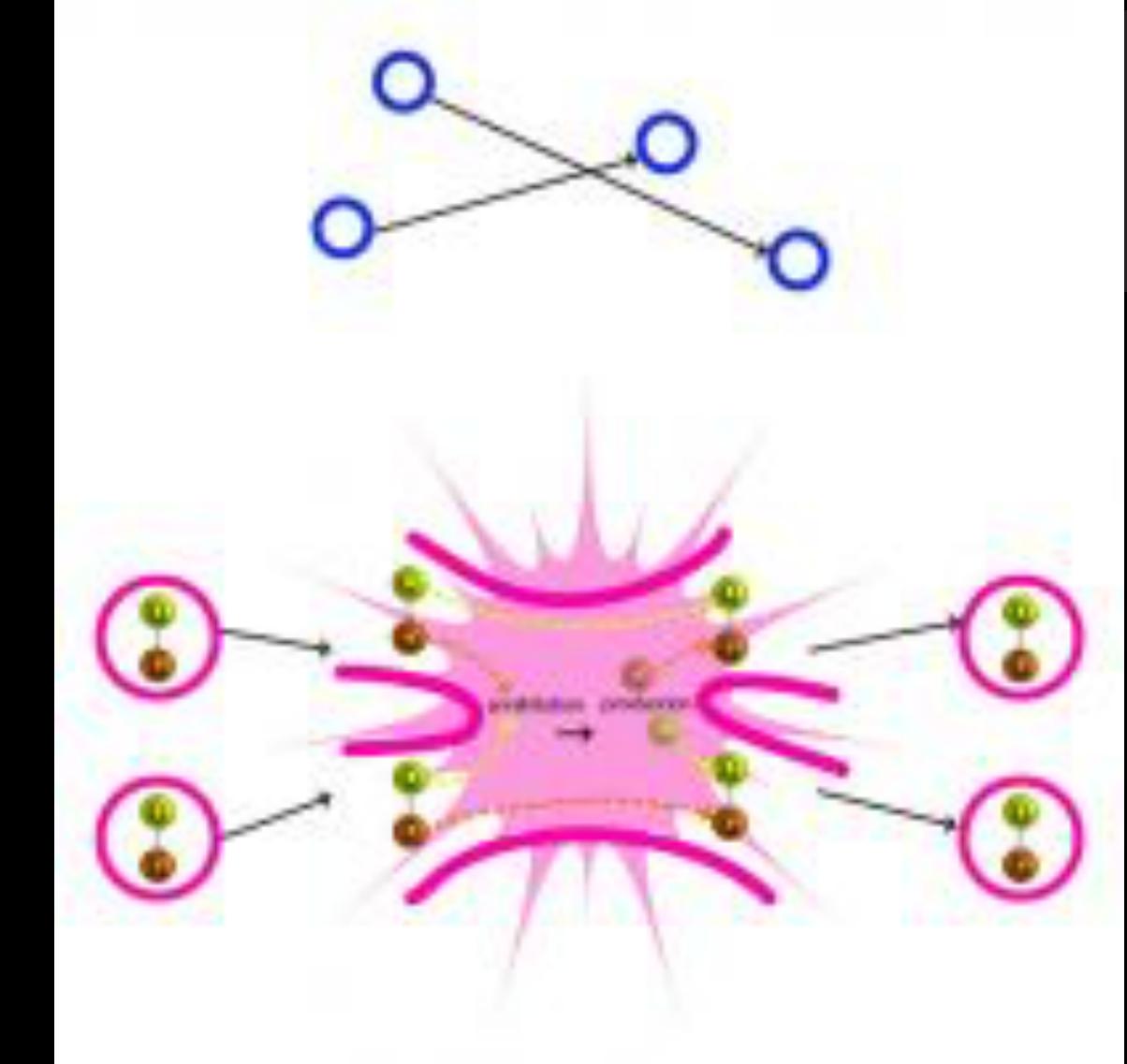


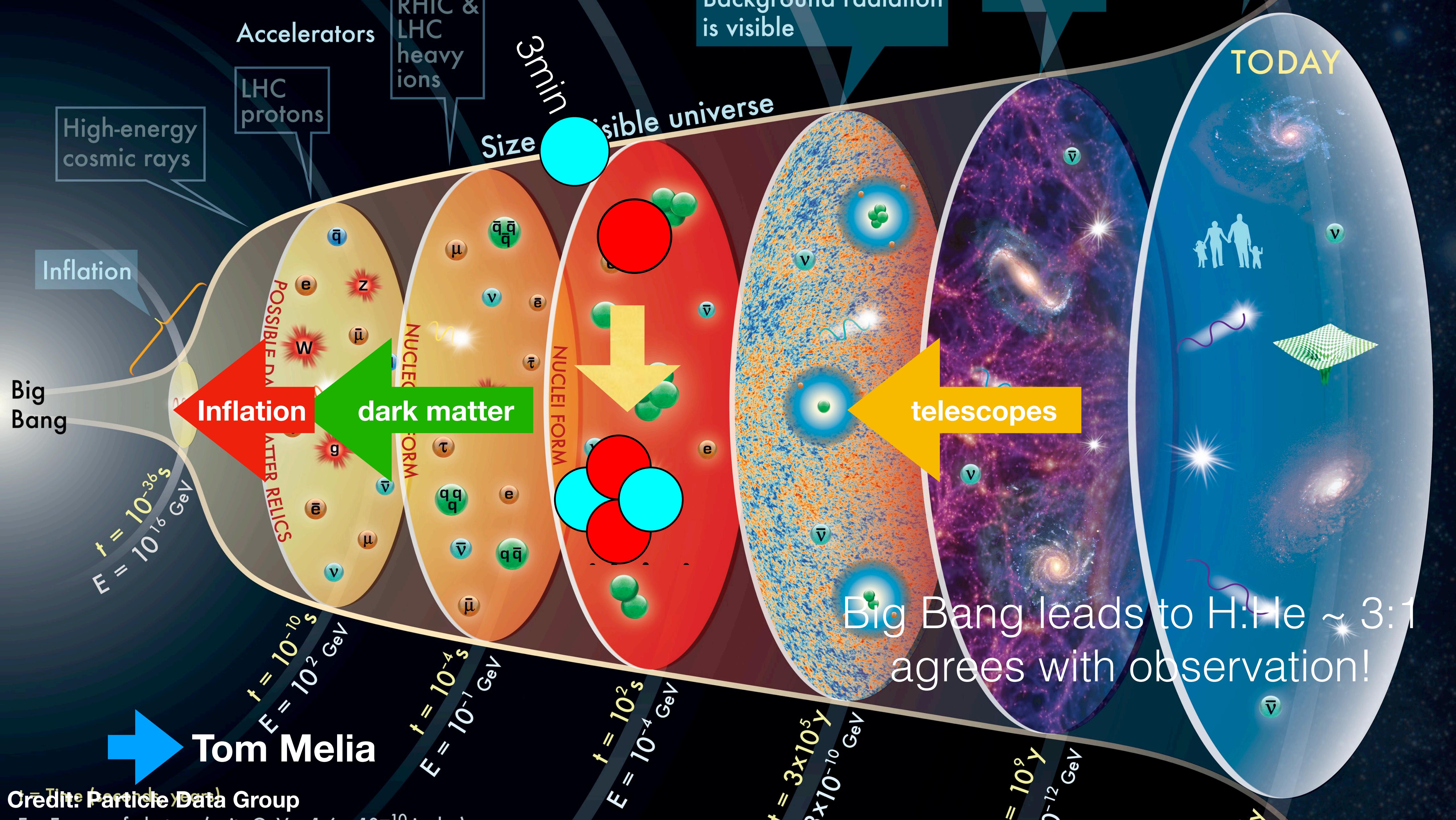
Yonit Hochberg



# size matters

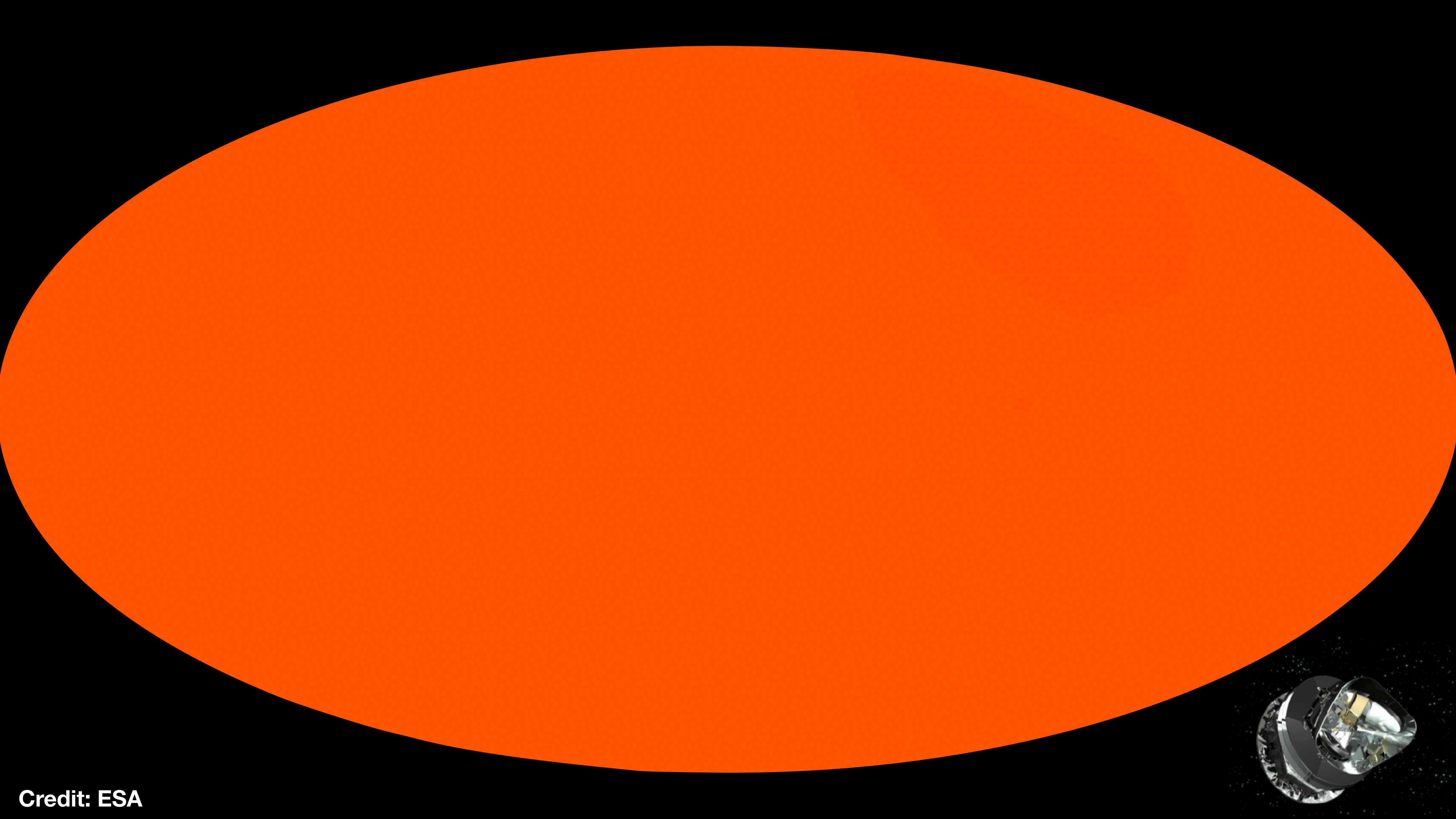
- Perhaps dark matter is not elementary but *composite*?
- Then it has a *finite size*
- flattens the spikes in dark matter density profile
- actually desirable for dwarf galaxies?



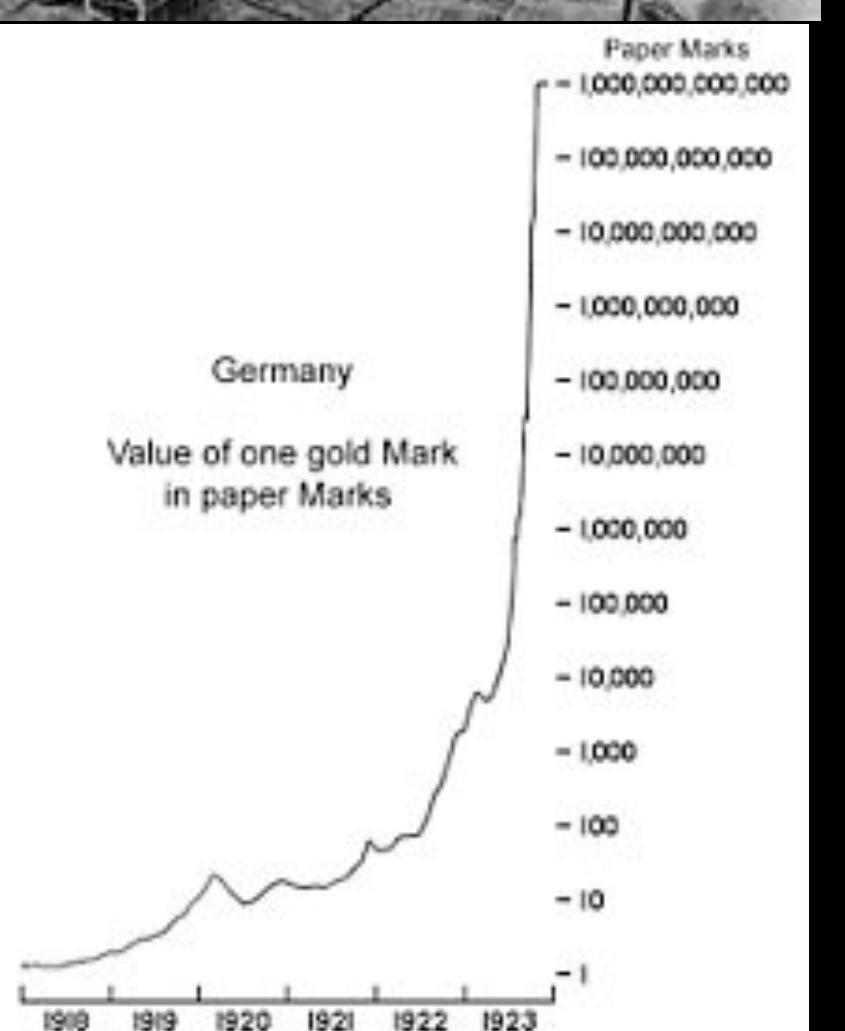


# Inflation

→ Misao Sasaki

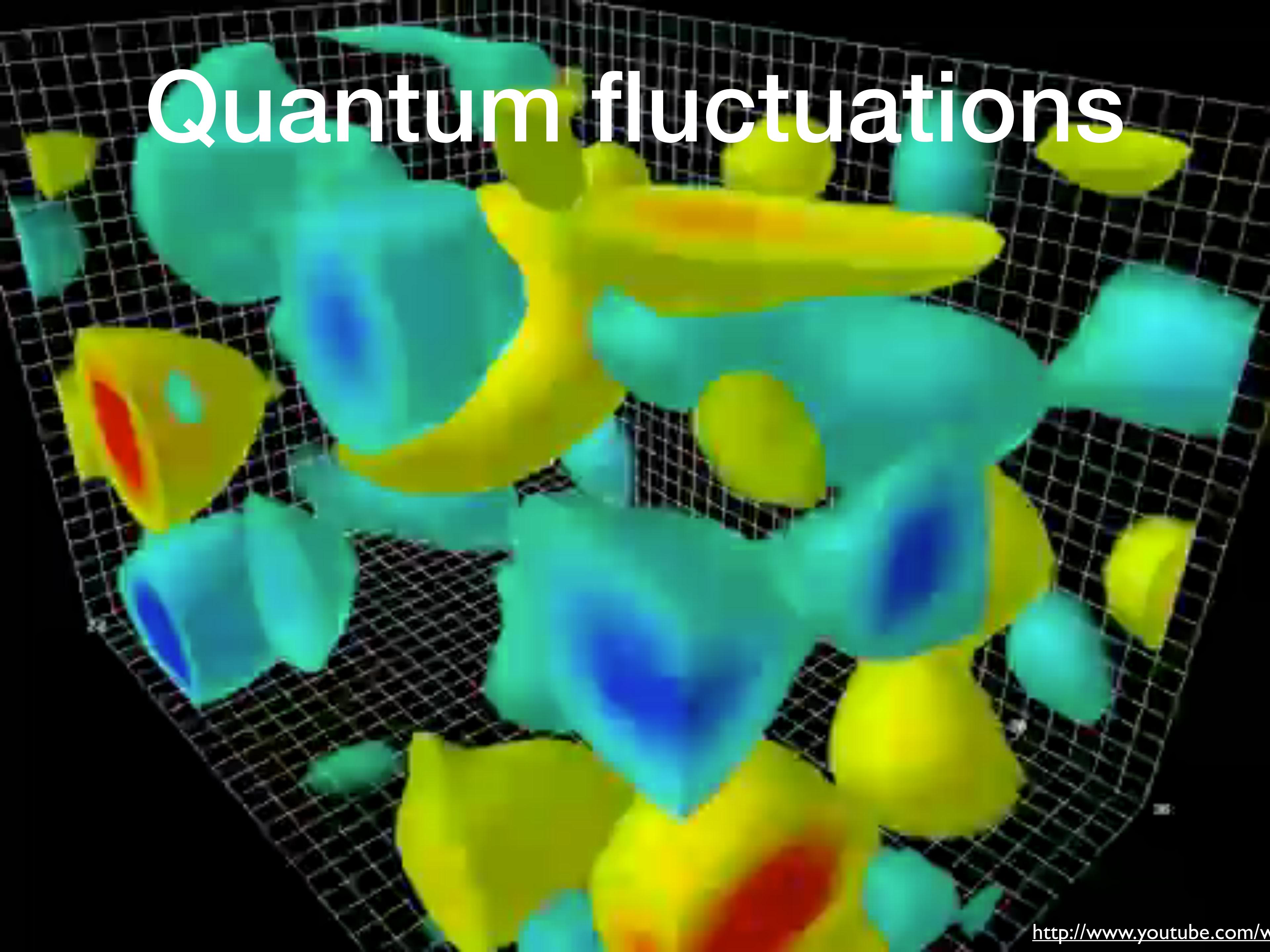


Credit: ESA

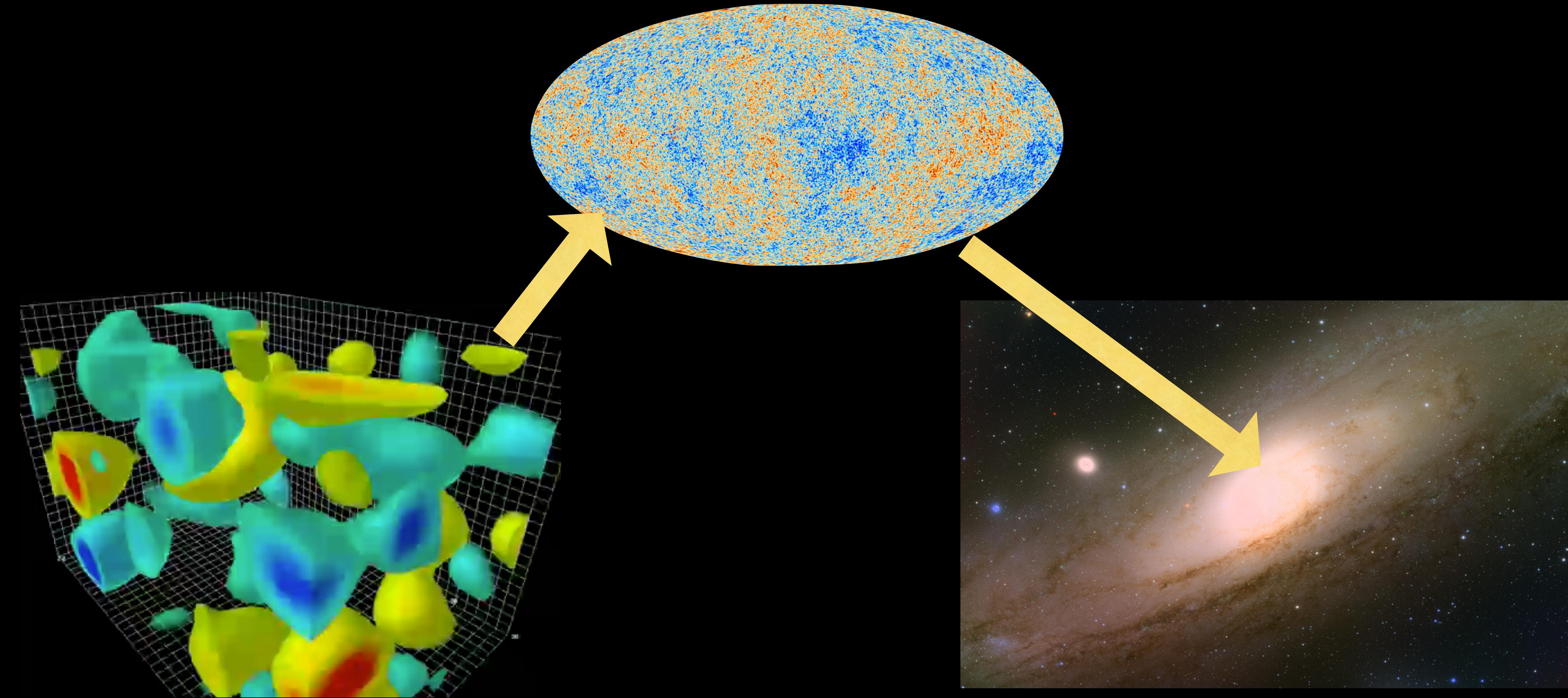


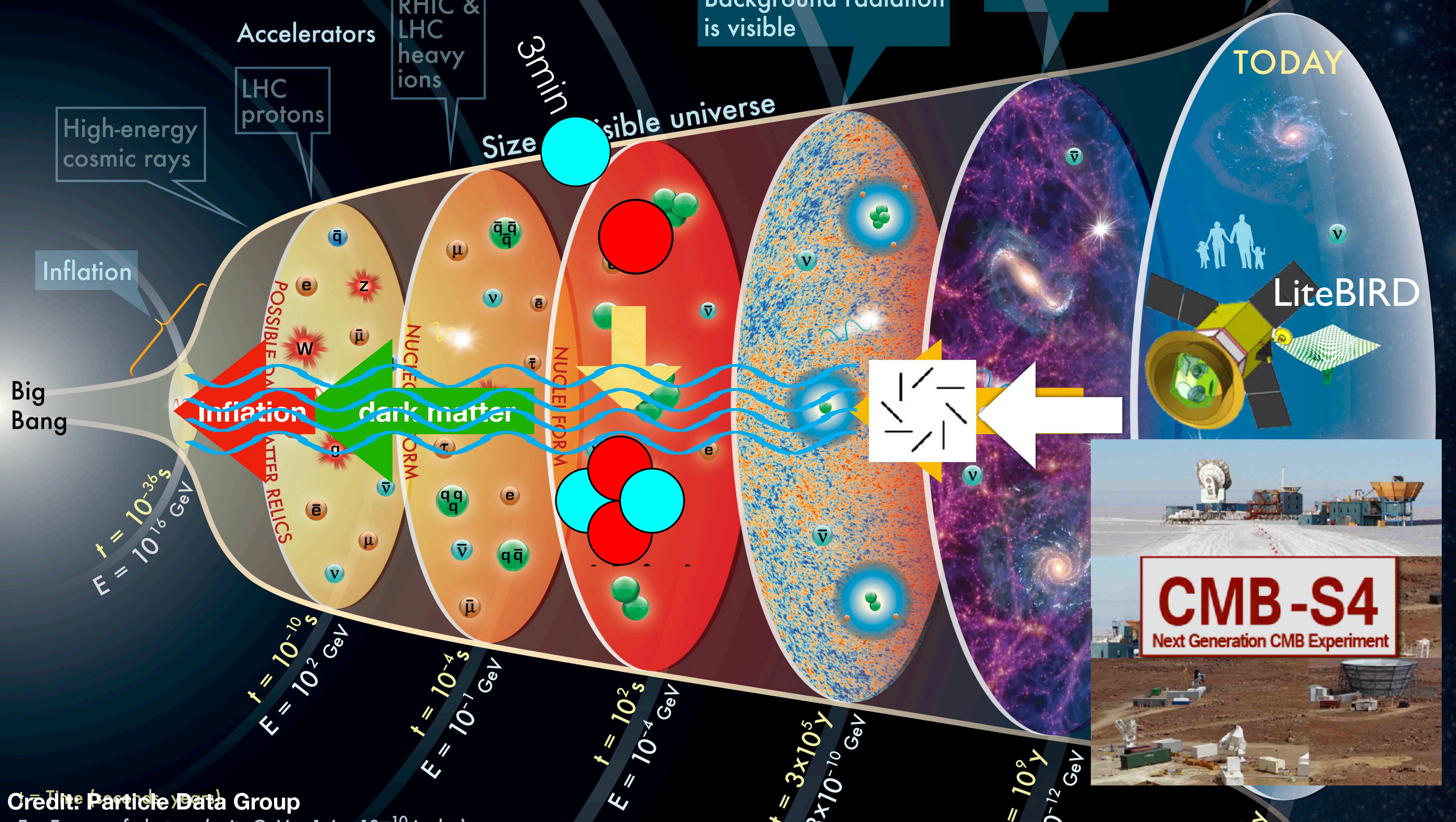


# Quantum fluctuations



# Inflation is our Dad







# Reenacting the Big Bang with Cal Marching Band





# Where do we come from?

Dark Side:  
Inflation  
Dark Matter

physicists



UNITED NATIONS

Science for Peace  
And Development  
2014/10/20

UN Headquarters  
In New York



<https://www.ipmu.jp/ja/node/2050>

KAVLI  
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MATHEMATICS OF THE UNIVERSE



Sep 30, 2008  
Kaguya



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*The world can work together!*

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