The background image shows a massive iceberg floating in a deep blue ocean under a light blue sky with wispy clouds. The visible portion of the iceberg is white and jagged, while the submerged portion is a translucent blue, representing the dark matter that makes up most of the galaxy.

Dark matter:

a physicist's
perspective

Jennifer Siegal-Gaskins

What is dark matter?

What is dark matter?

(What isn't dark matter?)

What is dark matter?

(What isn't dark matter?)

How can you learn about something you
can't see?

First evidence for dark matter: the Coma cluster of galaxies

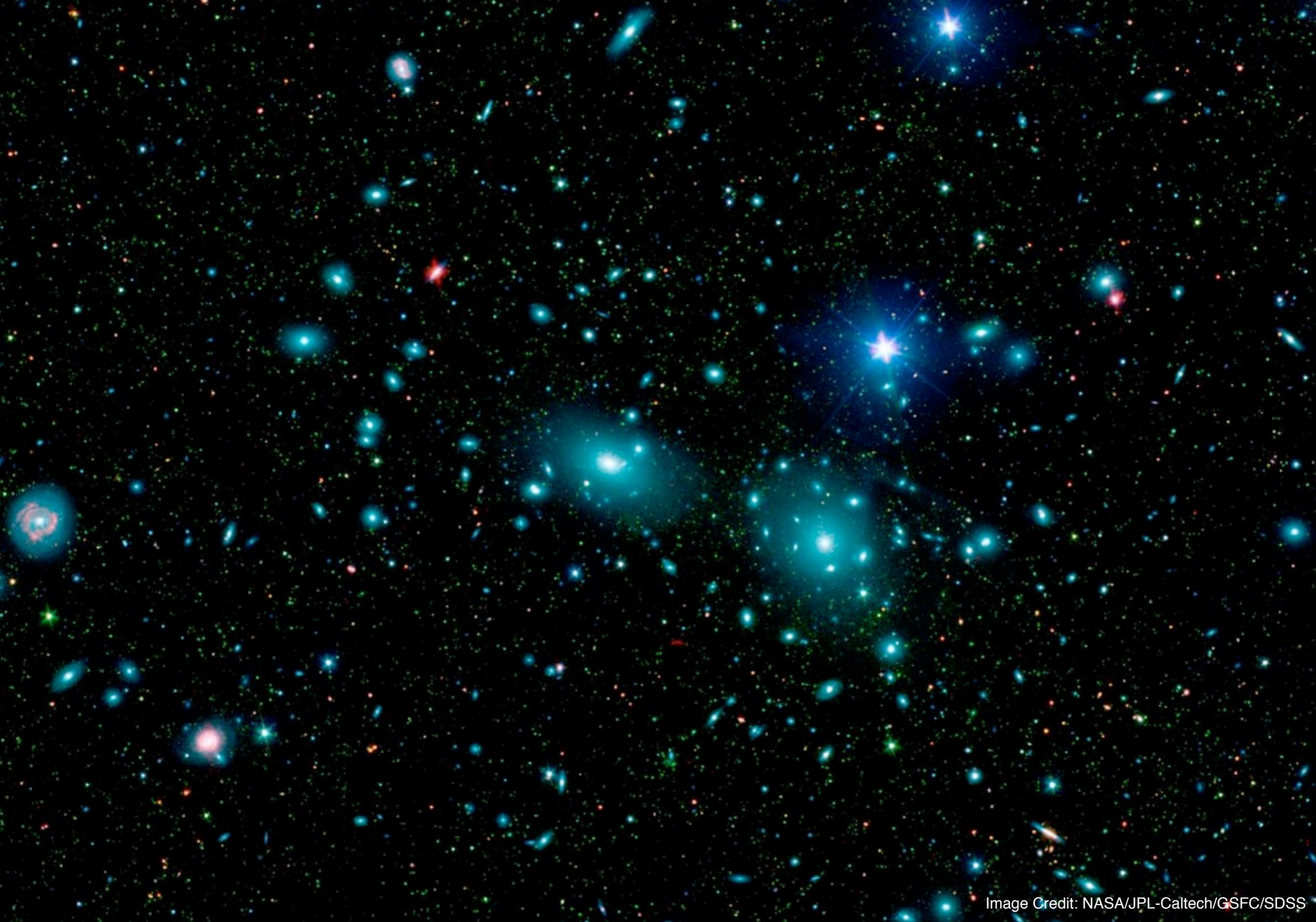


Image Credit: NASA/JPL-Caltech/GSFC/SDSS

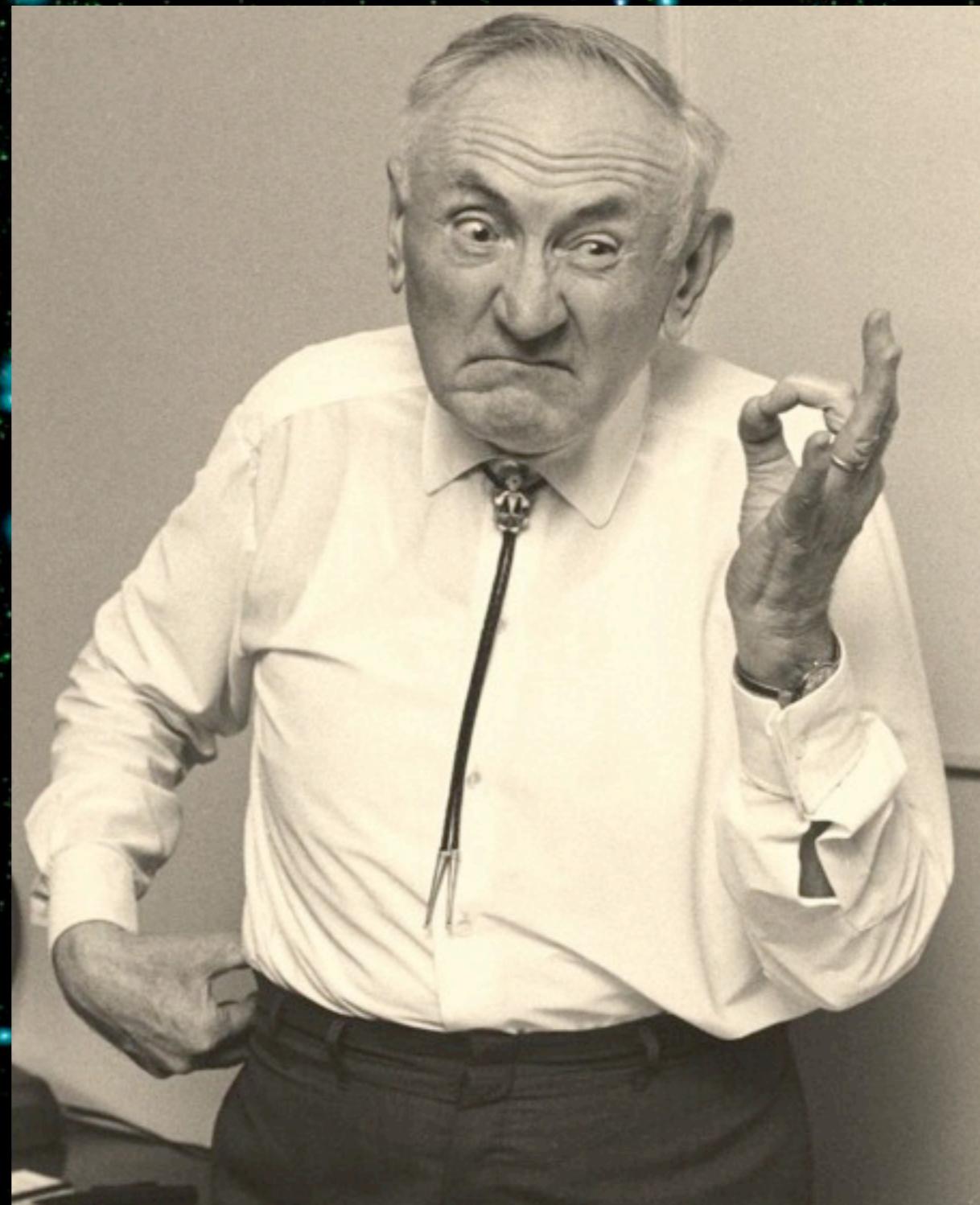
First evidence for dark matter: the Coma cluster of galaxies

In 1933 Fritz Zwicky observed the motion of galaxies in the Coma cluster...



First evidence for dark matter: the Coma cluster of galaxies

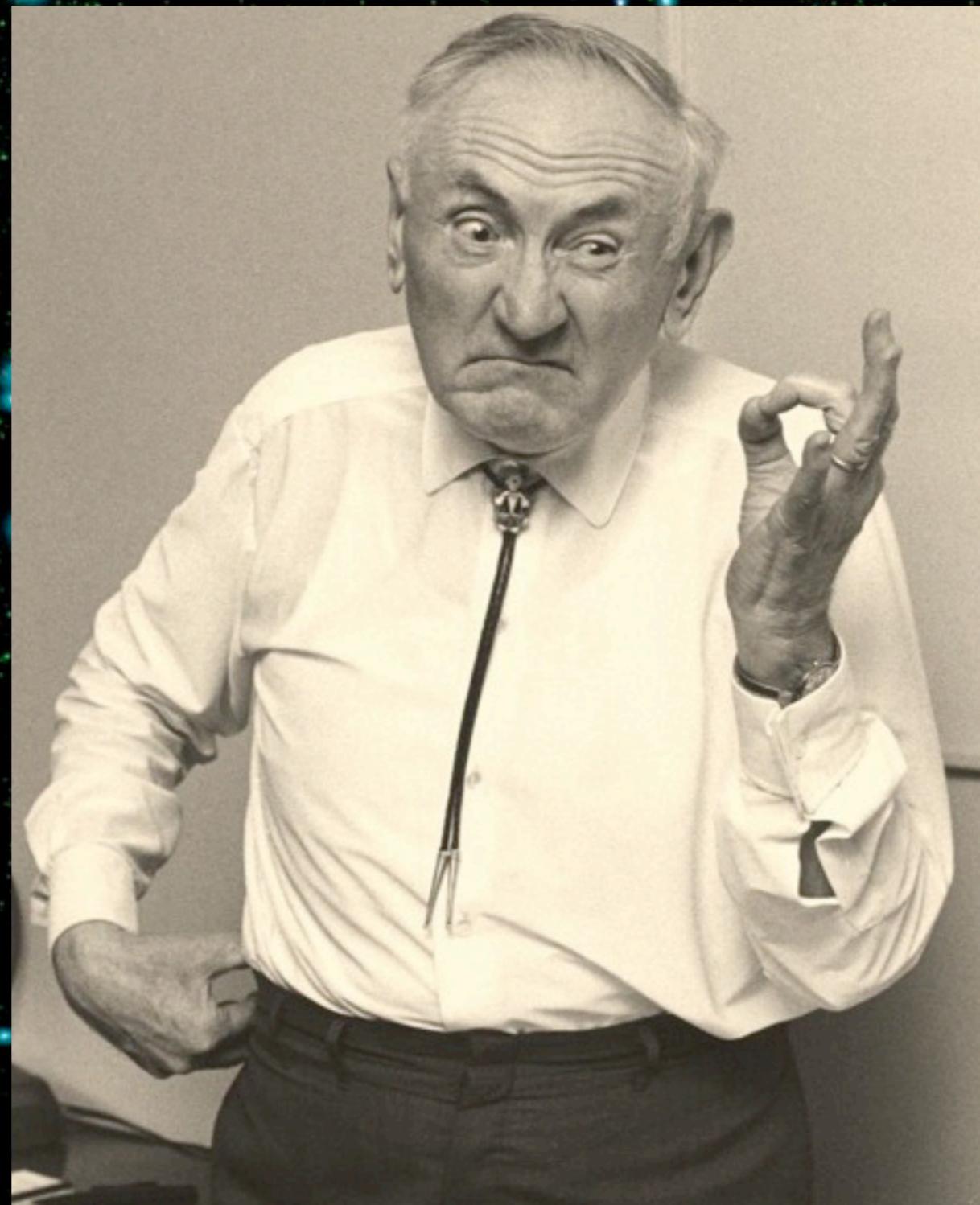
In 1933 Fritz Zwicky observed the motion of galaxies in the Coma cluster...



First evidence for dark matter: the Coma cluster of galaxies

In 1933 Fritz Zwicky observed the motion of galaxies in the Coma cluster...

and discovered that a large amount of invisible matter must be present to prevent the cluster from flying apart.

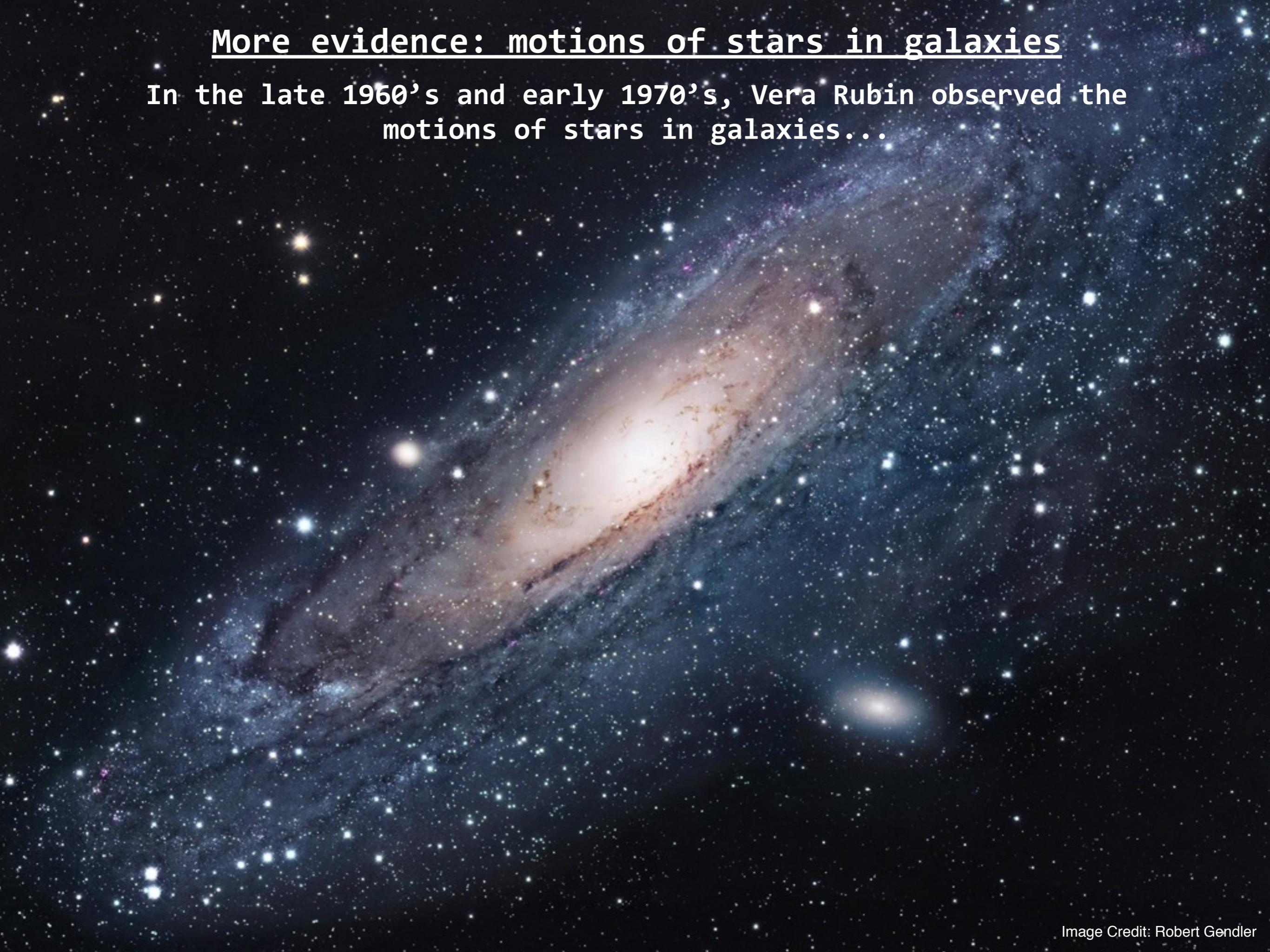


More evidence: motions of stars in galaxies



More evidence: motions of stars in galaxies

In the late 1960's and early 1970's, Vera Rubin observed the motions of stars in galaxies...



More evidence: motions of stars in galaxies

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More evidence: motions of stars in galaxies

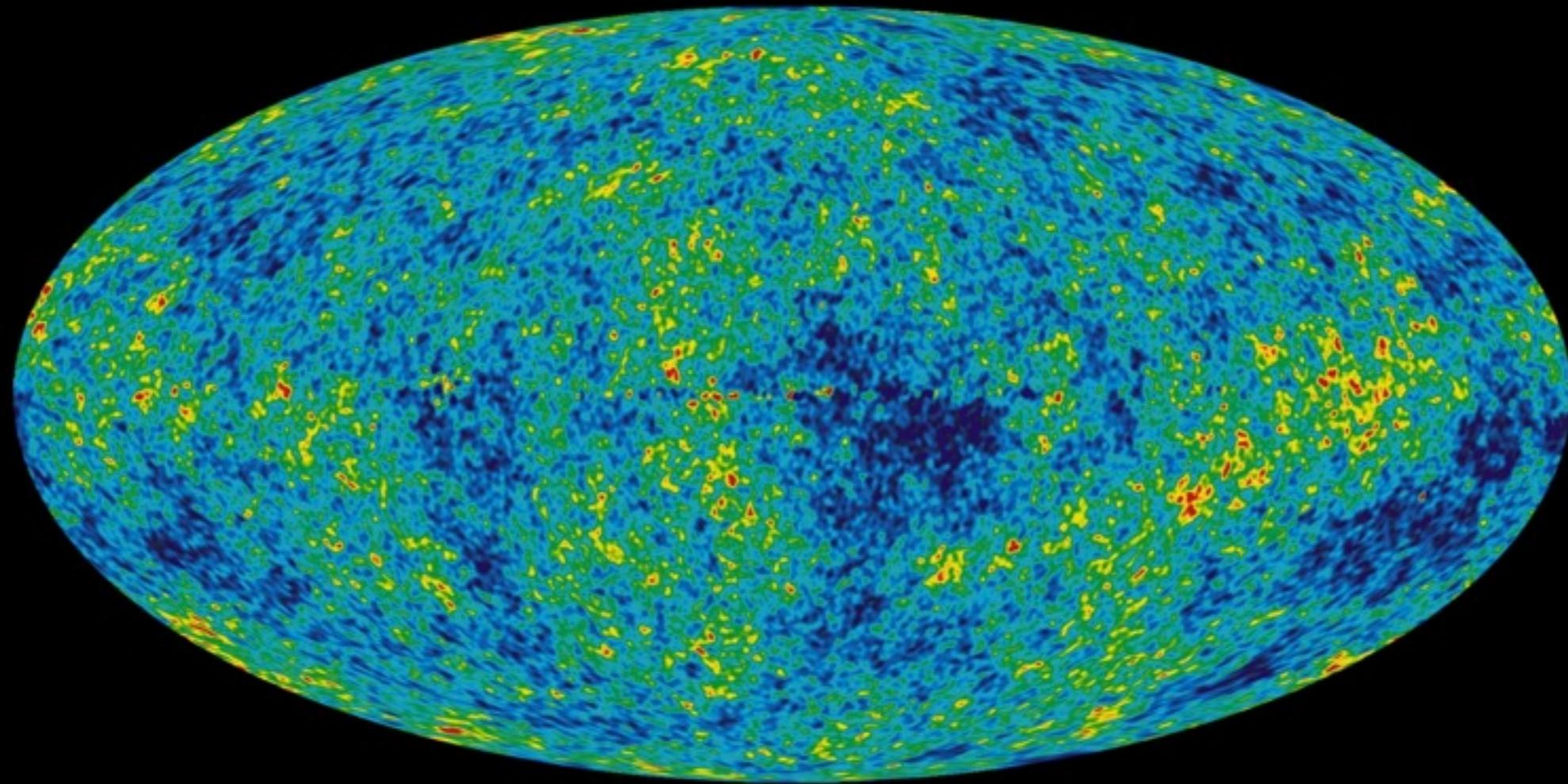
In the late 1960's and early 1970's, Vera Rubin observed the motions of stars in galaxies...

and again found that much more mass was needed to explain why the galaxies didn't fly apart.



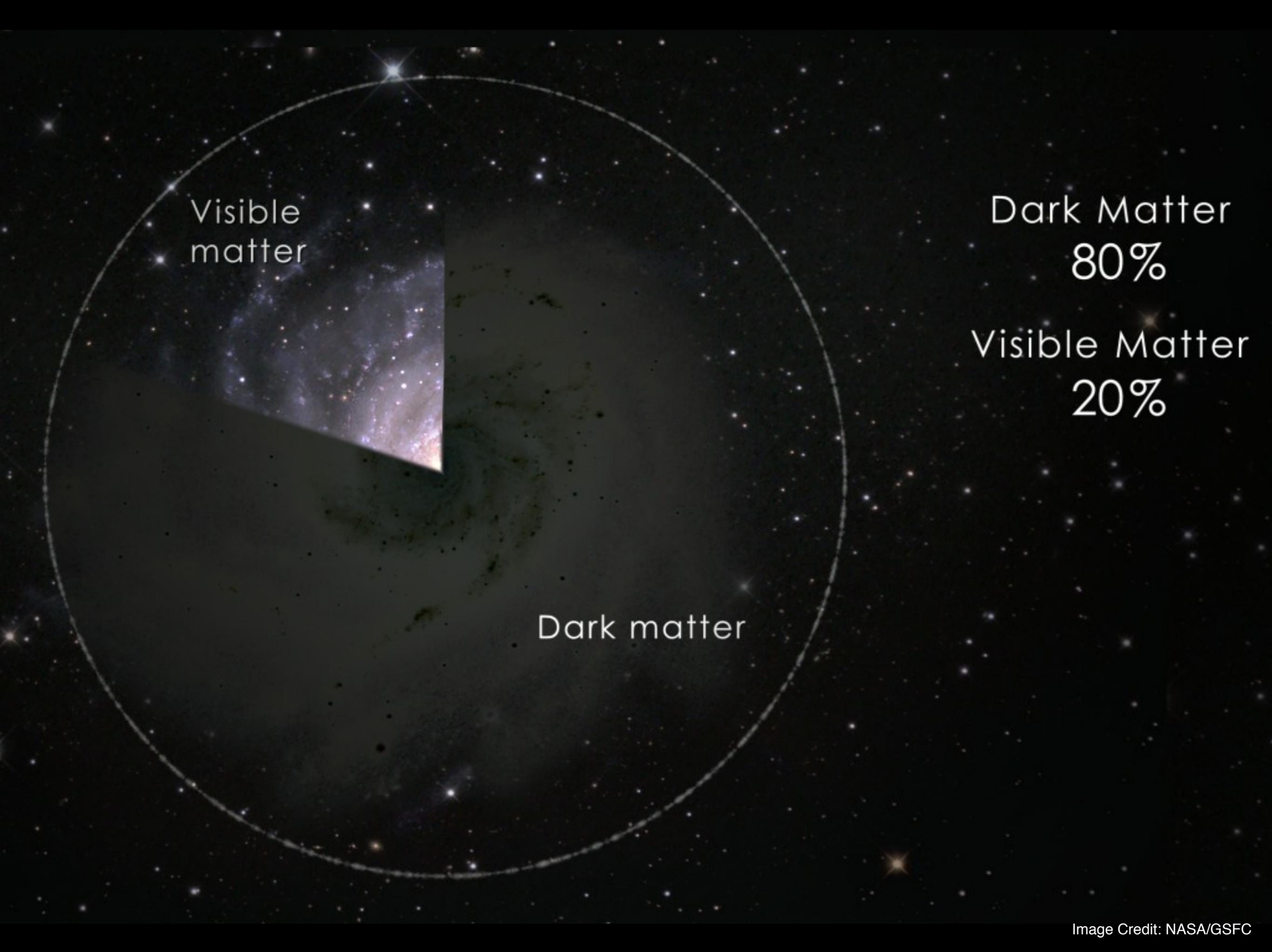
What does “dark” mean?

Dark matter has since been detected in many other ways via the gravitational force it exerts on other things

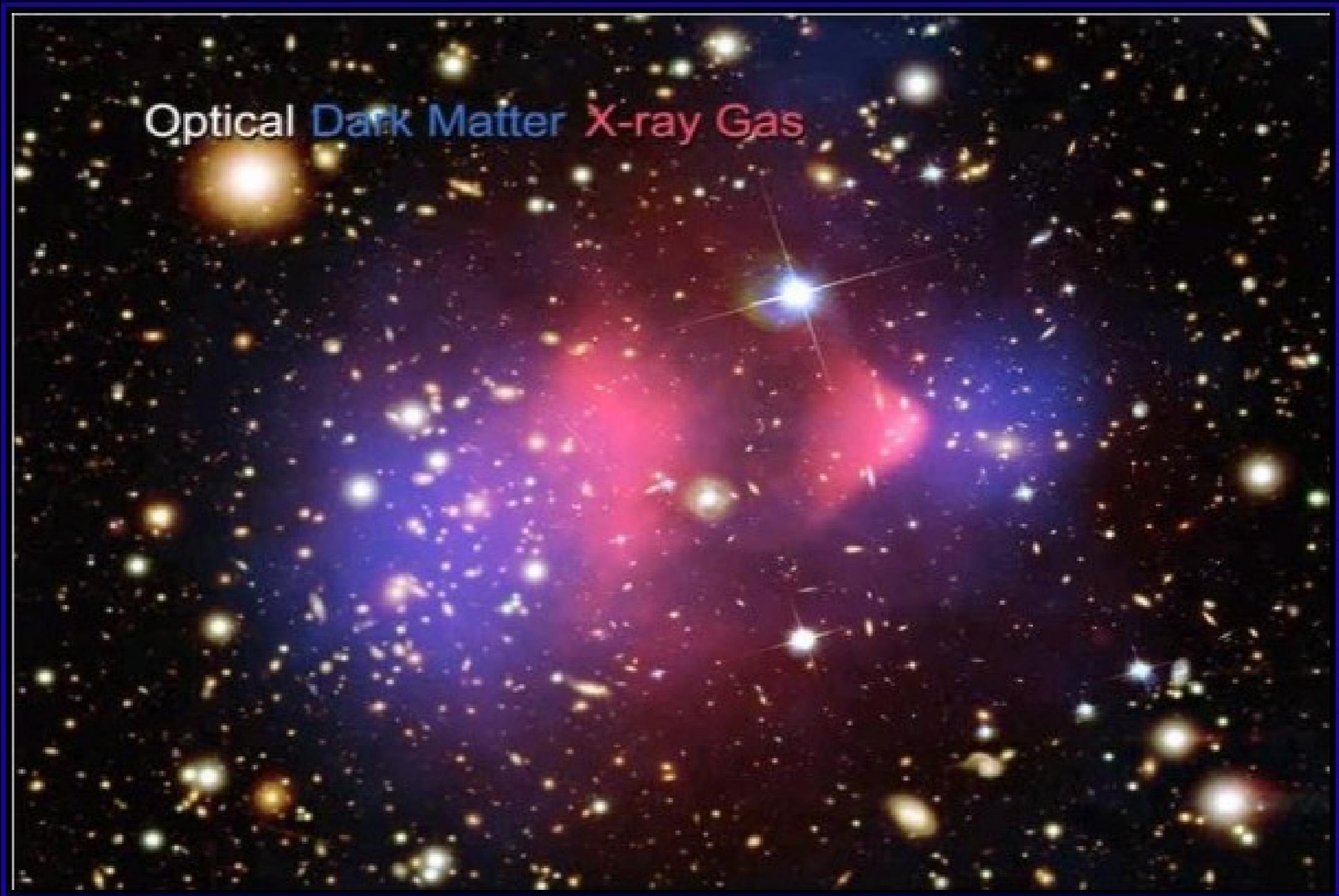


and from these observations we have been able to learn about some of the properties of dark matter and its role in the universe.

Dark matter is fundamentally different than the “ordinary” matter that we are made of.

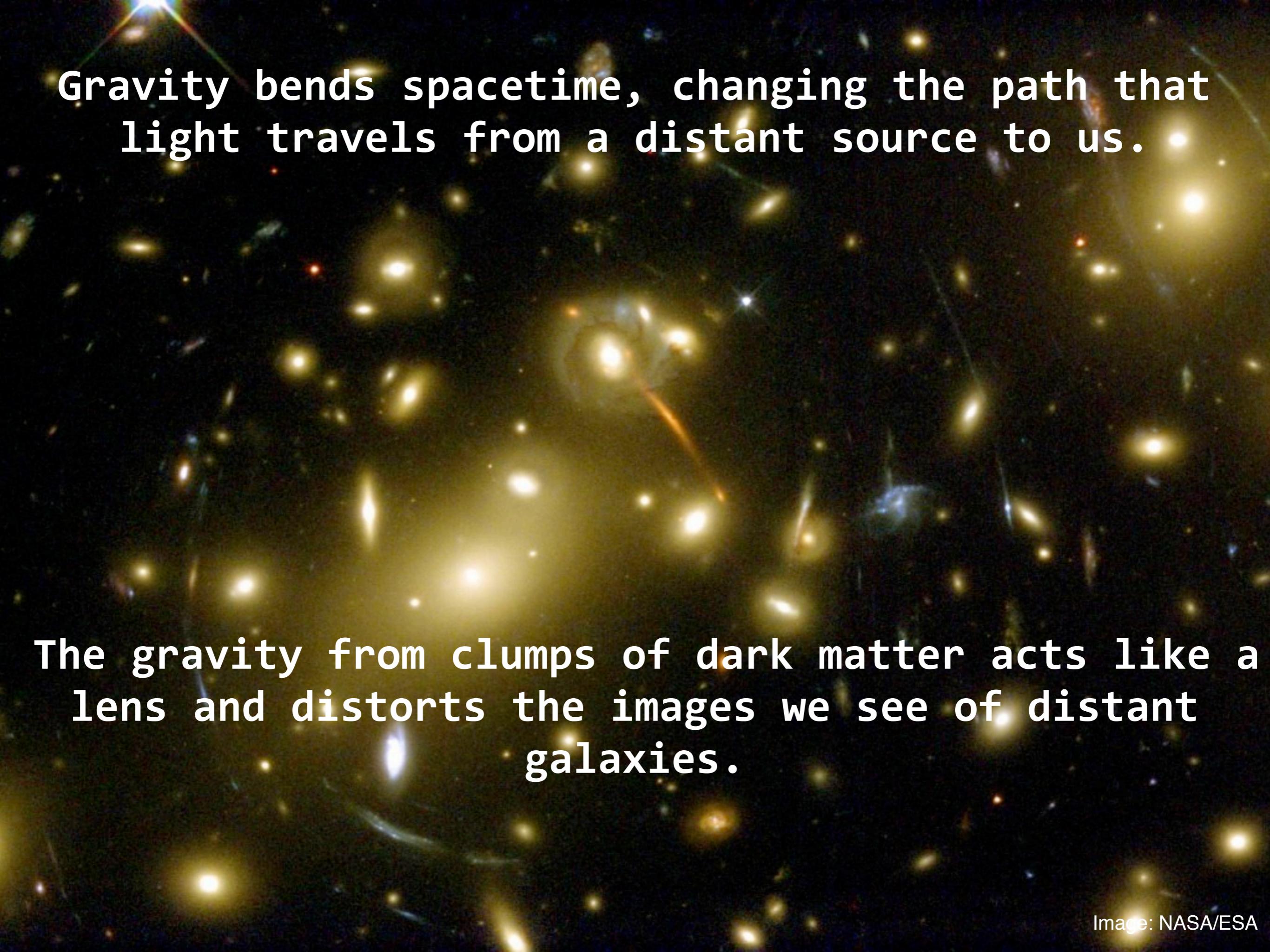


It interacts with other matter (almost?)
exclusively through gravity.



DARK MATTER

Most of the universe can't even be bothered to interact with you.



Gravity bends spacetime, changing the path that light travels from a distant source to us.

The gravity from clumps of dark matter acts like a lens and distorts the images we see of distant galaxies.

To date, dark matter has only been robustly detected via its gravitational pull on other objects in the universe.

How do you learn about something in the universe
that you cannot see?

**How do you learn about something in the universe
that you cannot see?**

- 1. Simulate its distribution in the Universe and
effects on other matter**

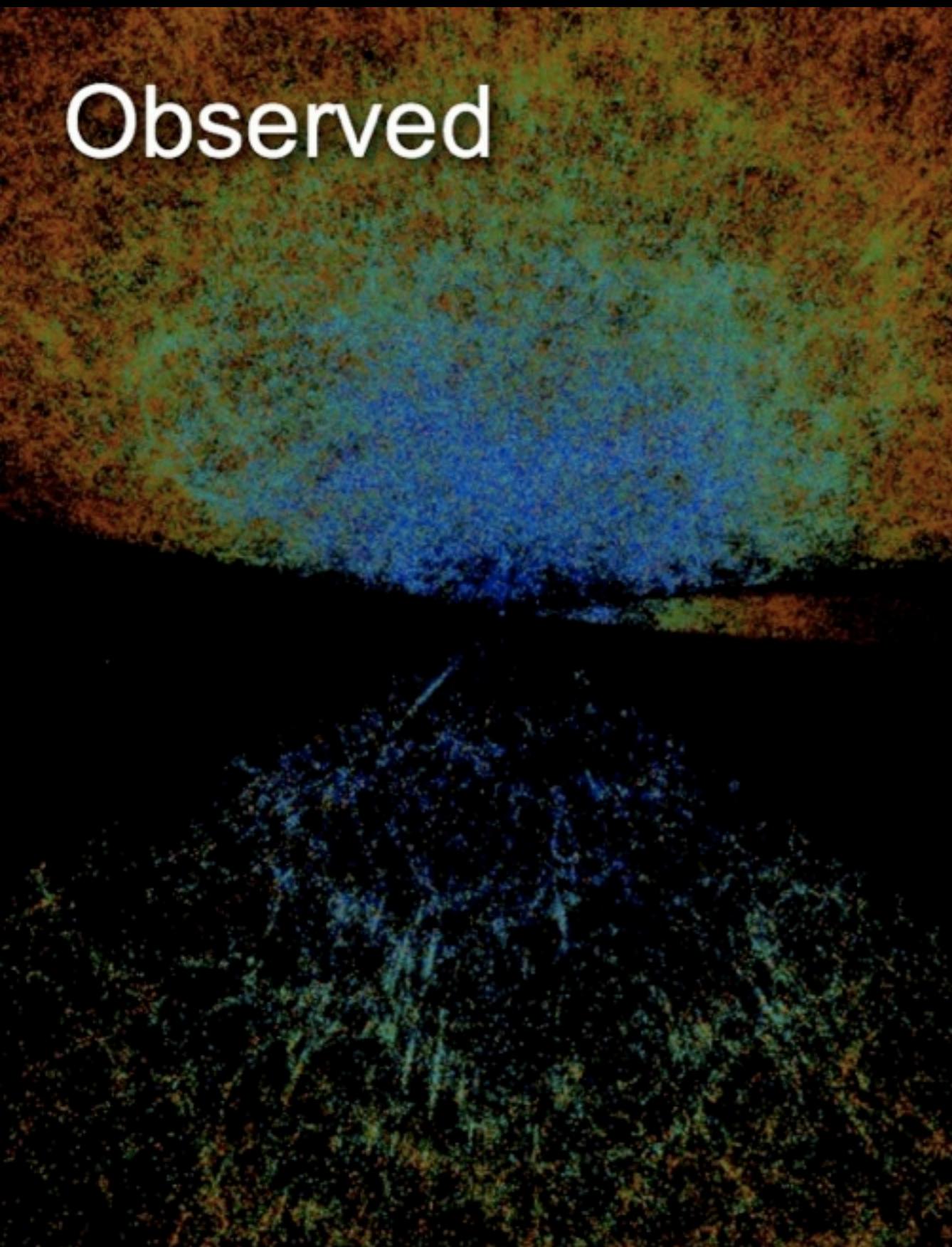
$z = 48.4$

$T = 0.05 \text{ Gyr}$

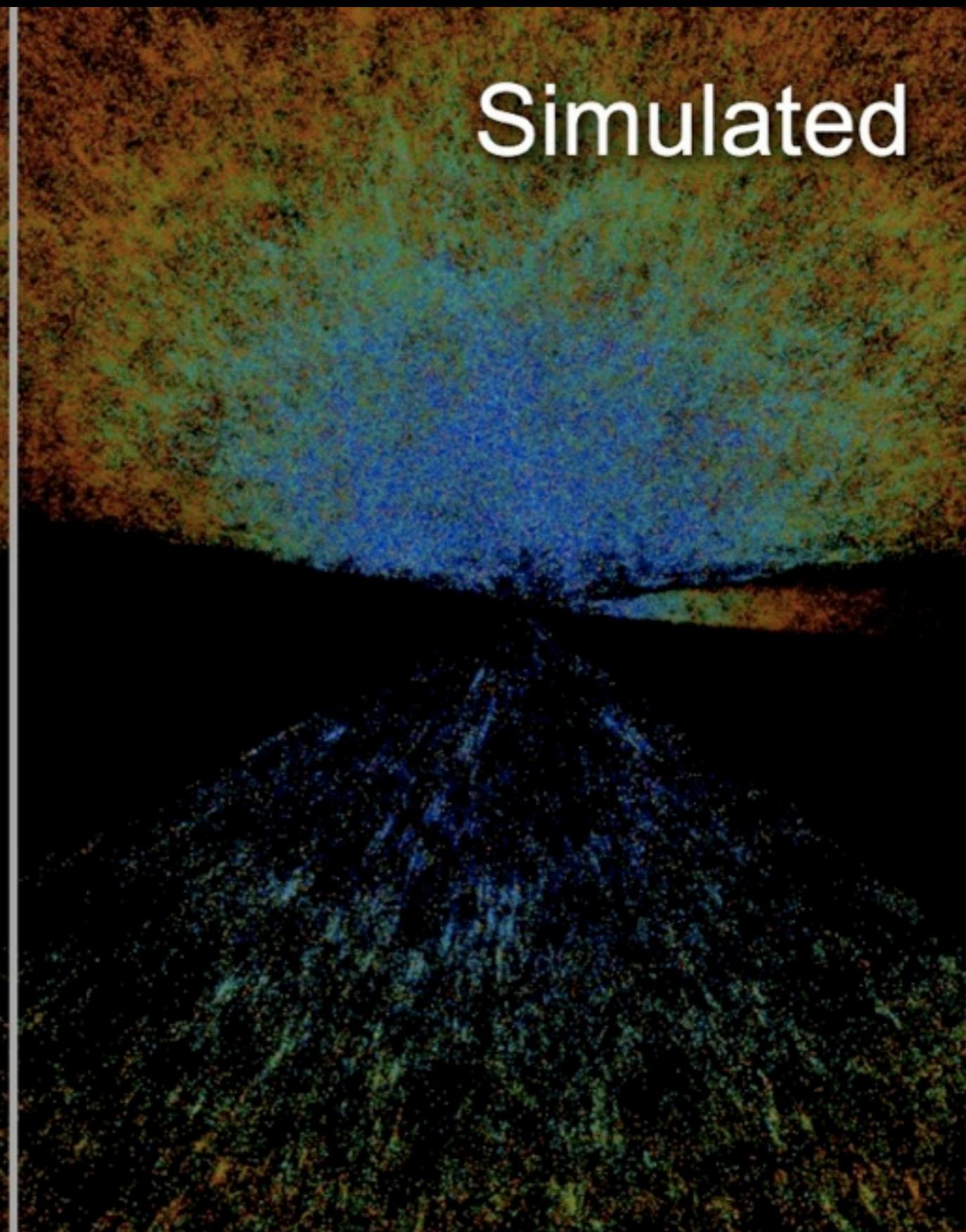


500 kpc

Observed



Simulated



Galaxies in Observed
and Simulated Universes

Simulated galaxies: Busha & Wechsler, Visualization: Kaehler & Marshall
Bolshoi simulation: Klypin, Trujillo-Gomez & Primack (2011)
SDSS DR7 NYU-VAGC Blanton et al (2005), Abazajian et al (2009)

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**How do you learn about something in the universe
that you cannot see?**

- 1. Simulate its distribution in the Universe and effects on other matter**
- 2. Make it in the lab**

Production at a collider



(Large Hadron Collider = LHC)

Production at a collider



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**How do you learn about something in the universe
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- 1. Simulate its distribution in the Universe and effects on other matter**
- 2. Make it in the lab**
- 3. Make it come to you (and your detectors)**

Direct detection



LUX experiment

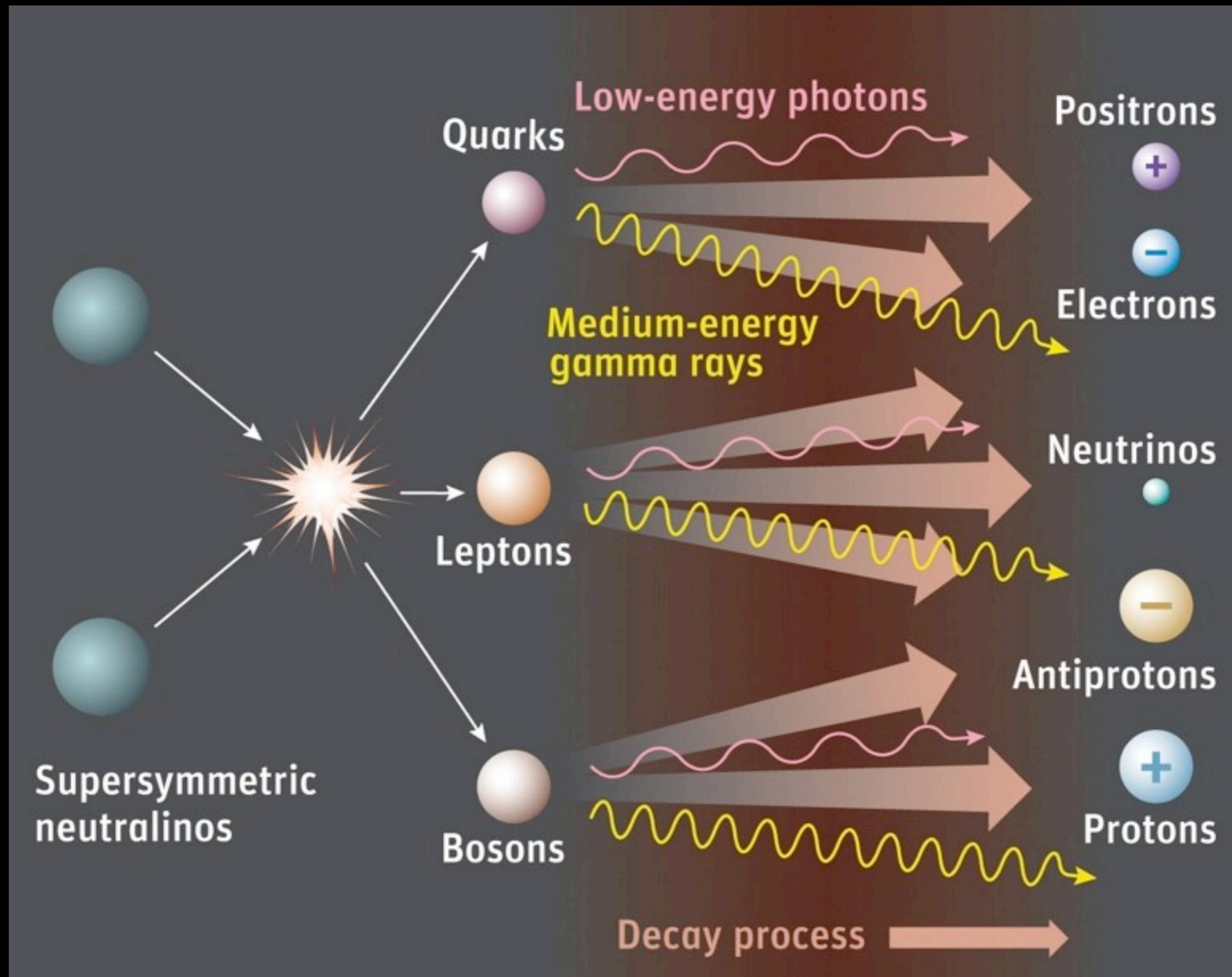
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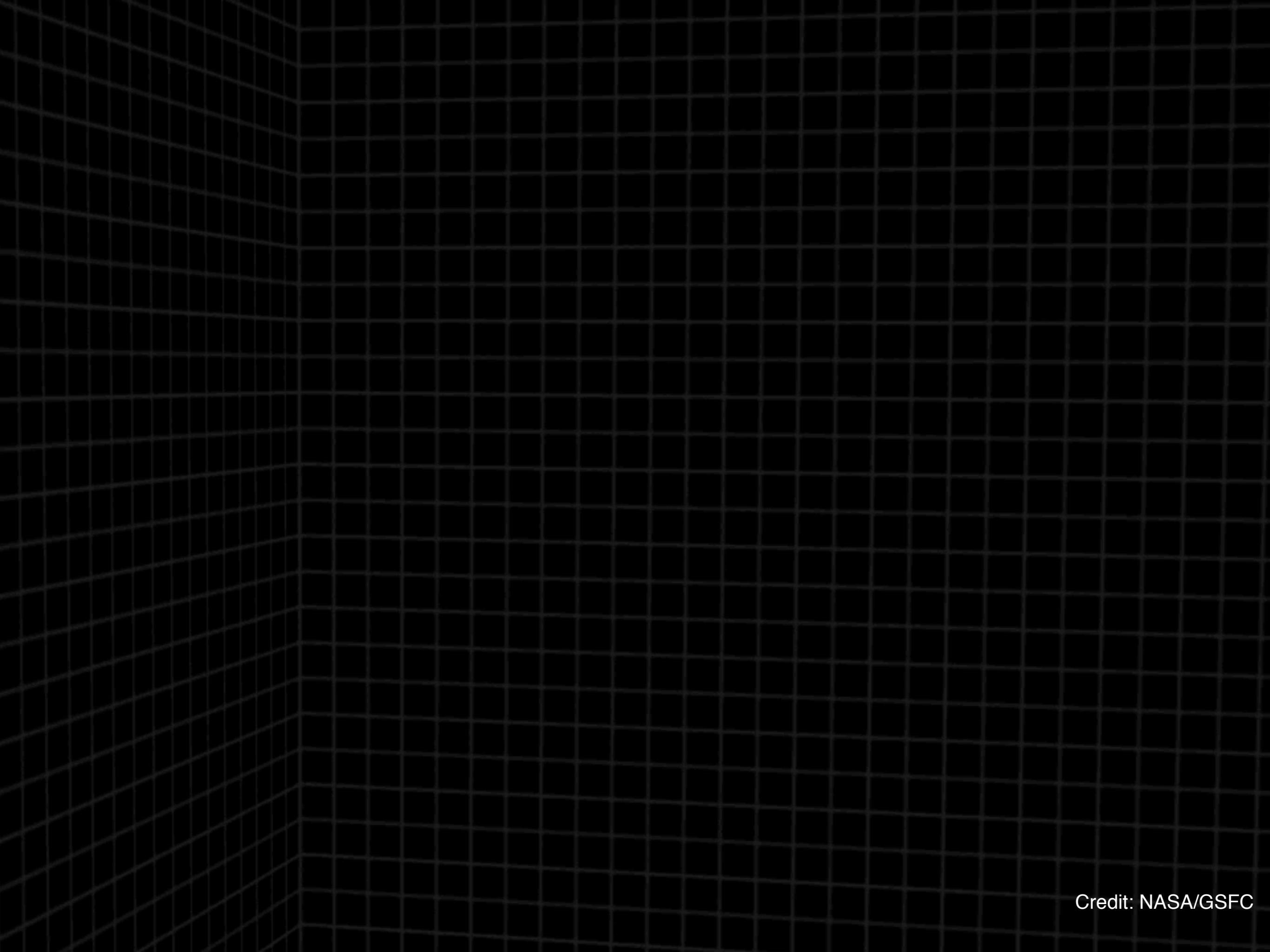
- 1. Simulate its distribution in the Universe and effects on other matter**
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**How do you learn about something in the universe
that you cannot see?**

- 1. Simulate its distribution in the Universe and effects on other matter**
- 2. Make it in the lab**
- 3. Make it come to you (and your detectors)**
- 4. Find indirect evidence of its existence**

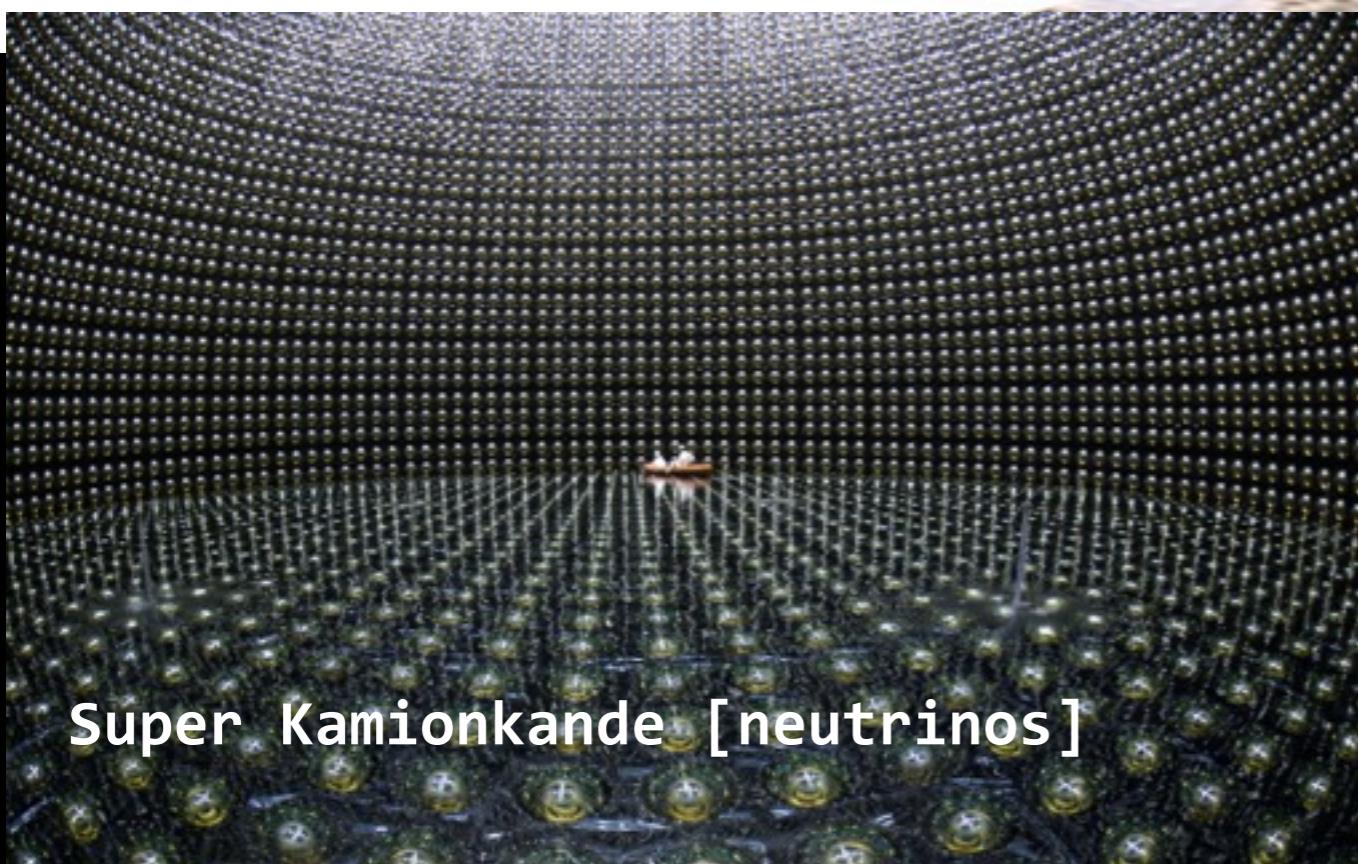
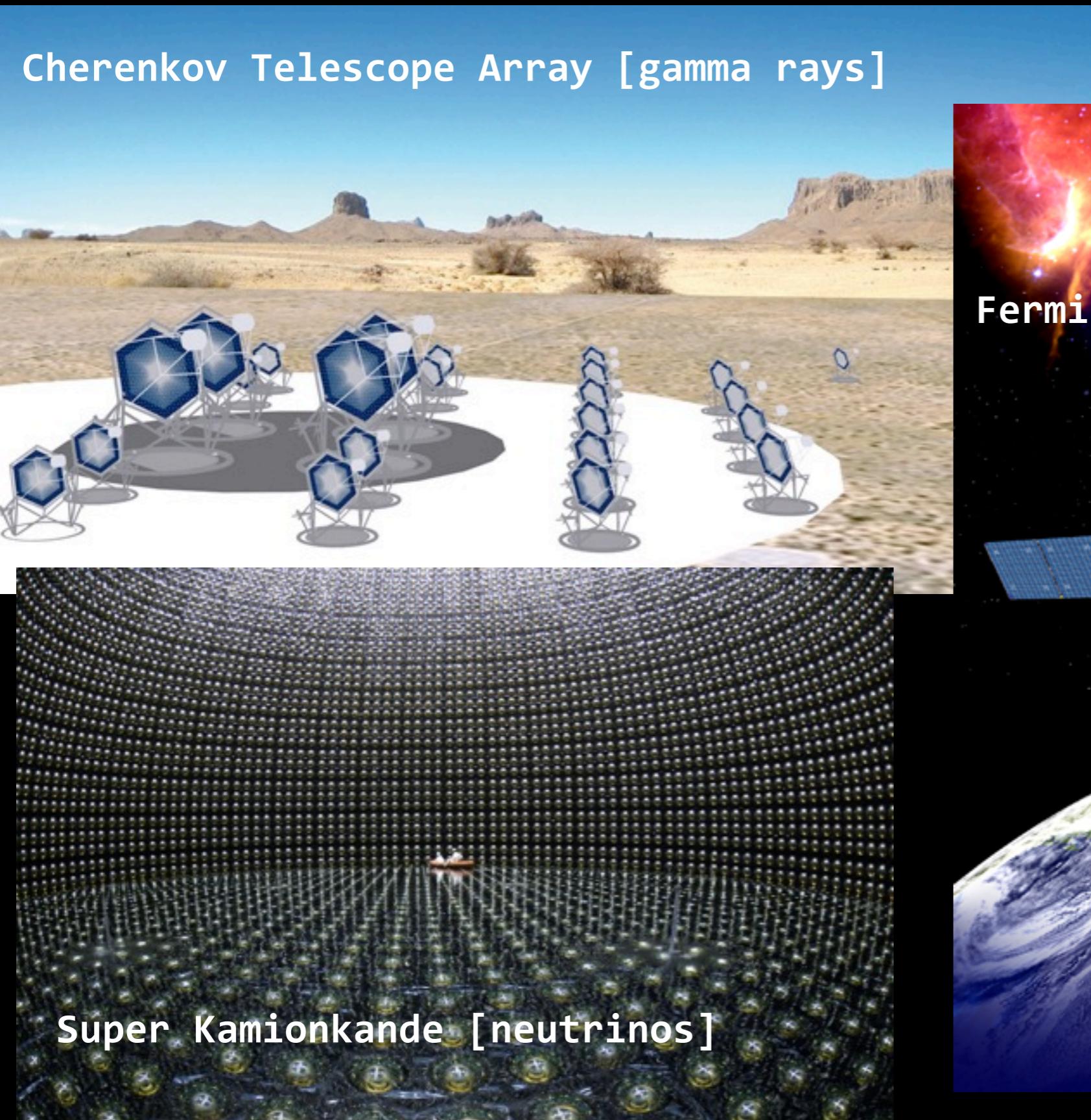
Indirect detection





Credit: NASA/GSFC

Indirect detection



Credit: NASA/General Dynamics

Dark matter: still a mystery after almost 80 years.