



Dark Matter: A Glimpse into the Invisible

Francisco Xavier Linares Cedeño



General Colloquium/Student-Oriented
Universidad de Deusto
Bilbao, 5 February 2026



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Dark Matter: A Glimpse into the Invisible

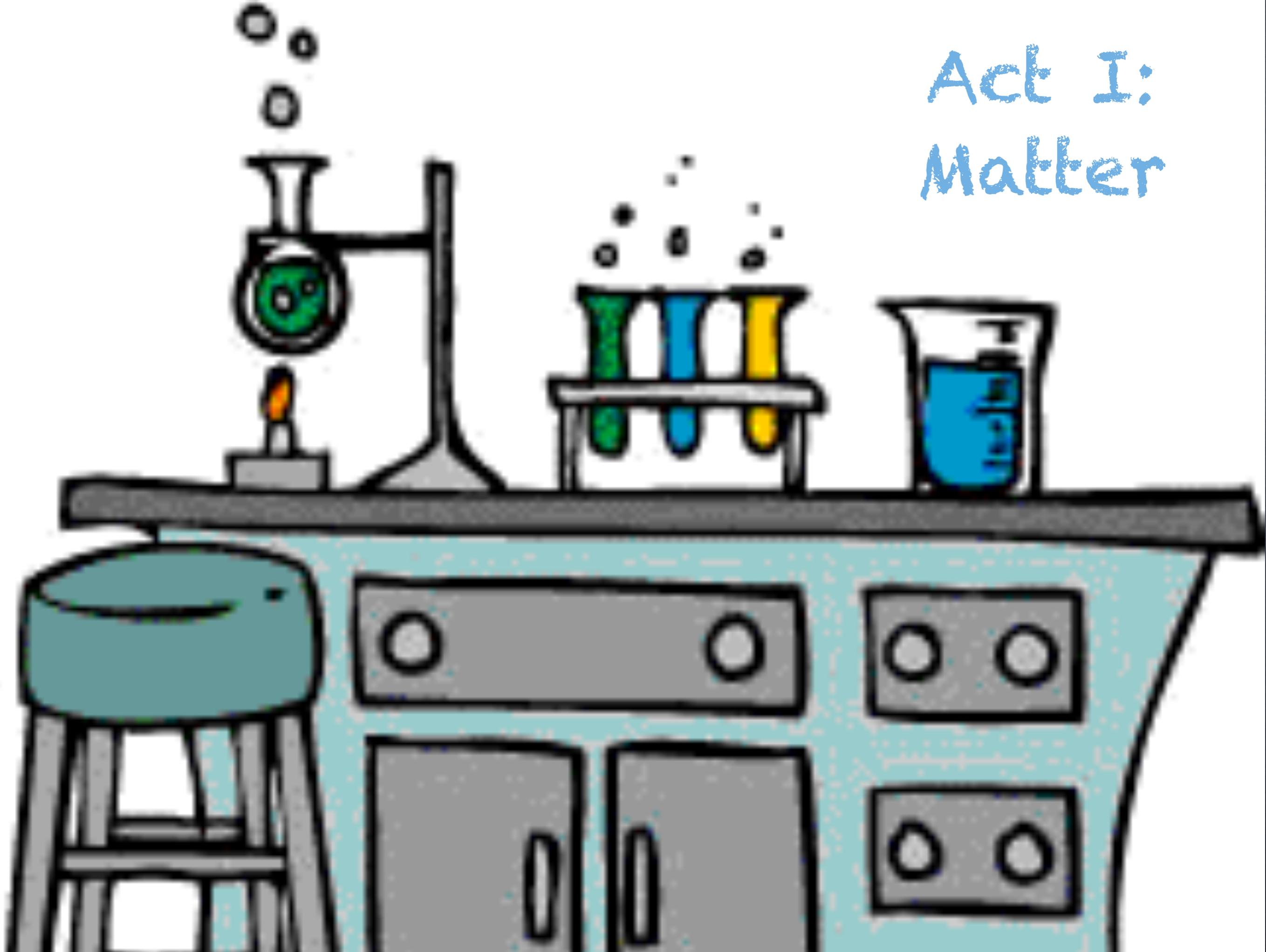
Francisco Xavier Linares Cedeño



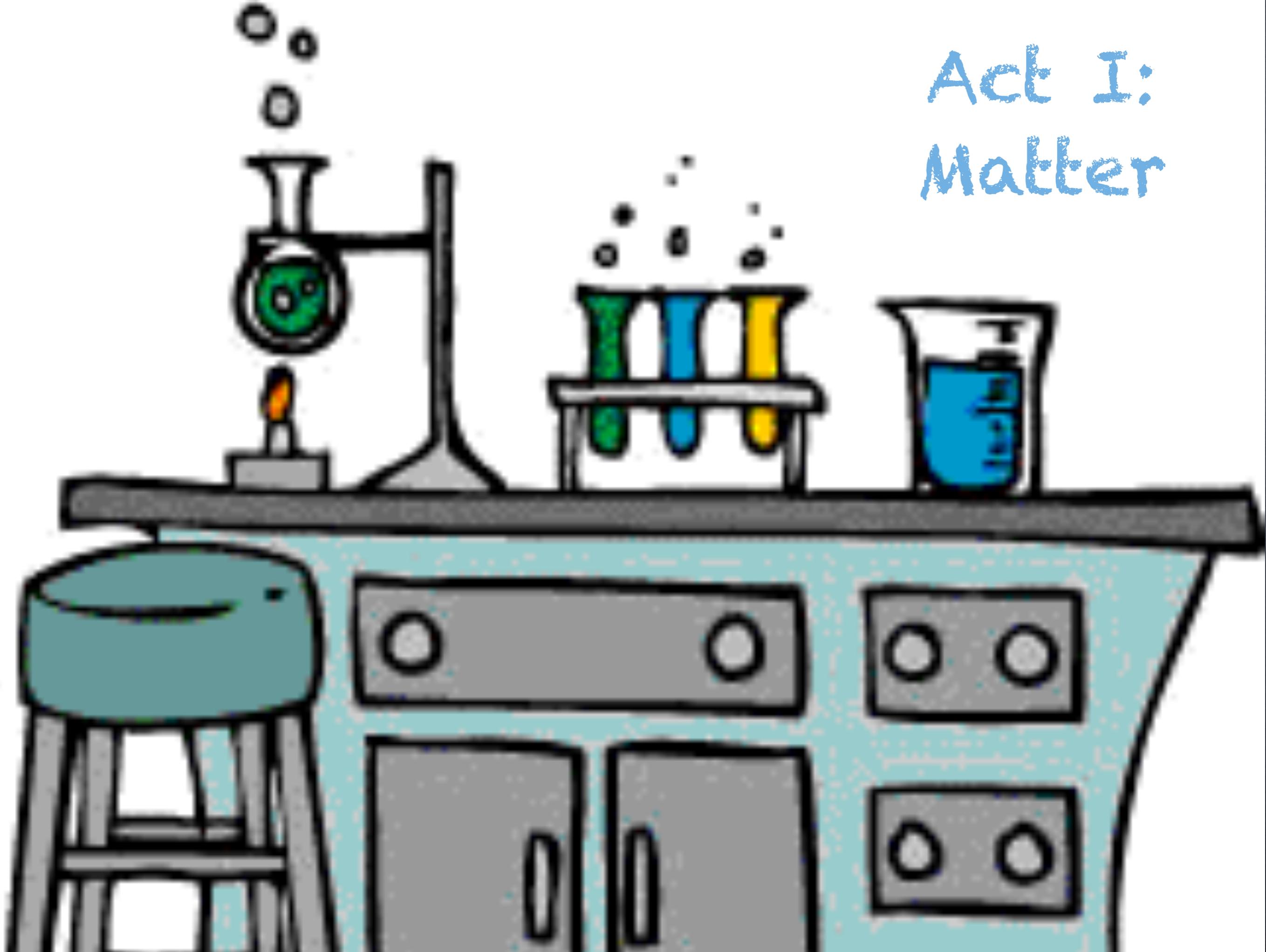
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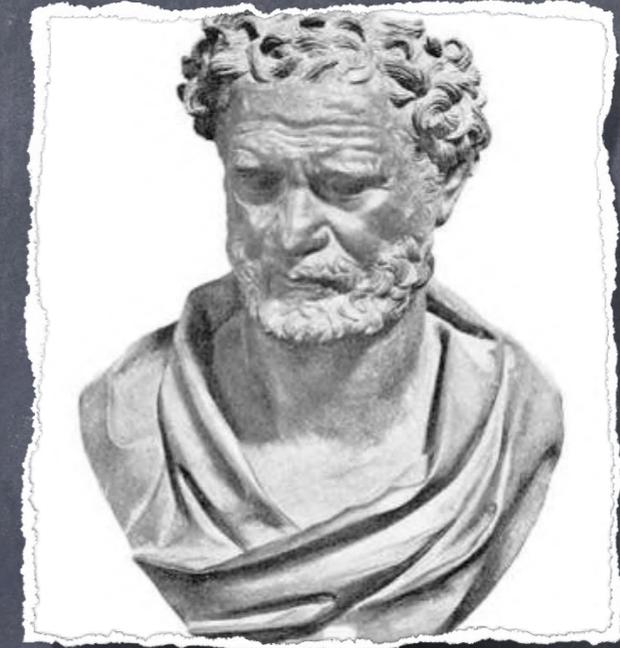
Act I: Matter



Act I: Matter

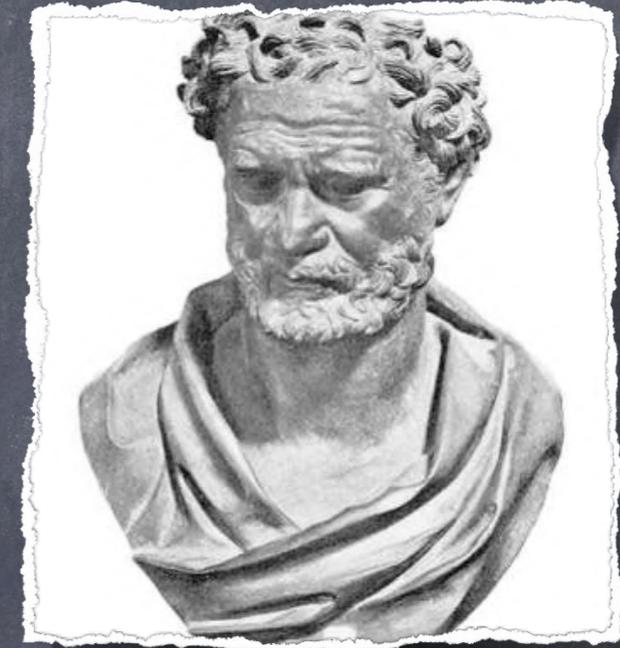


What is matter made of?

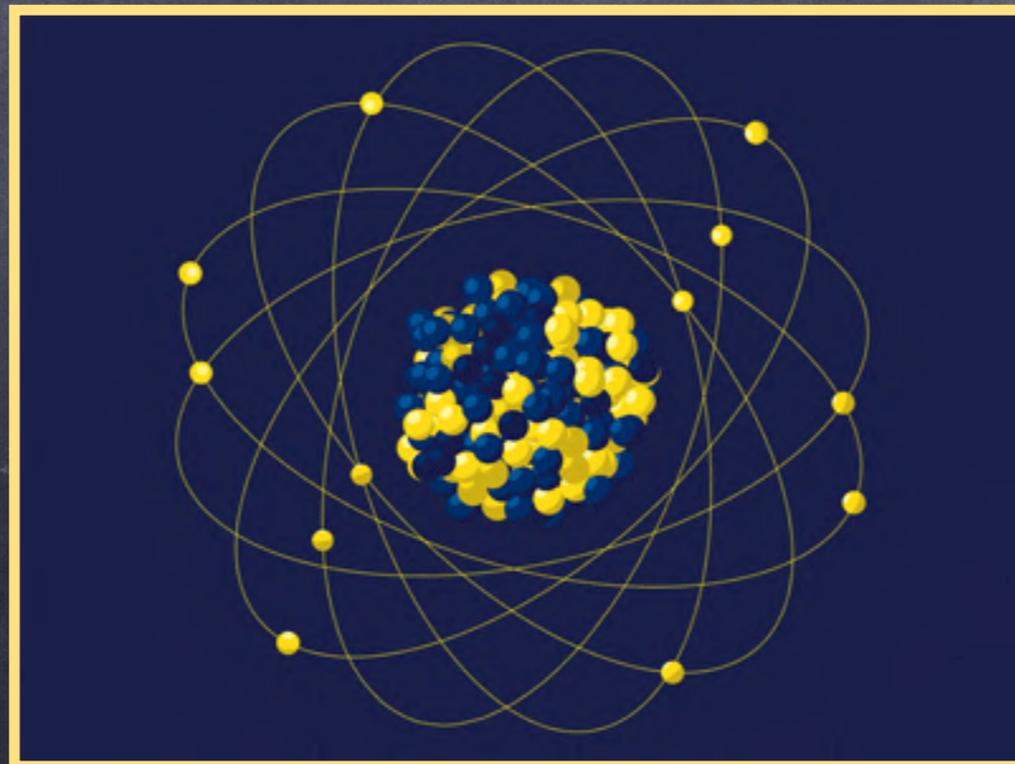


Democritus
(400 a.C.)

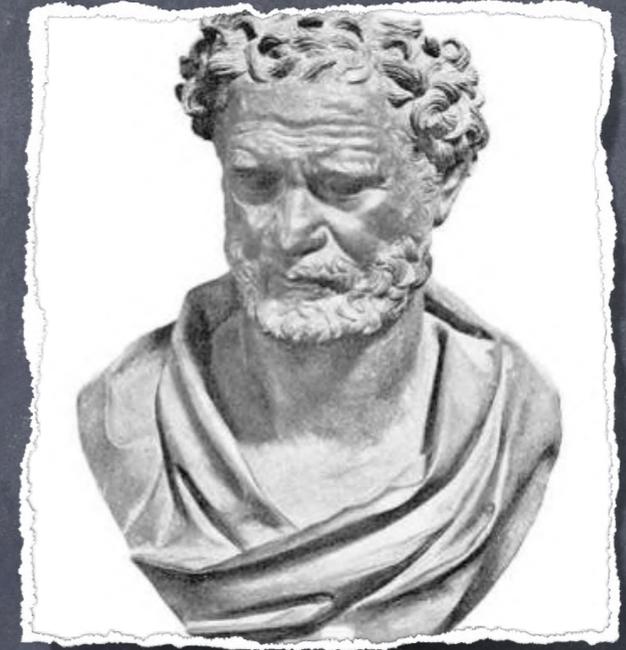
What is matter made of?



Democritus
(400 a.C.)

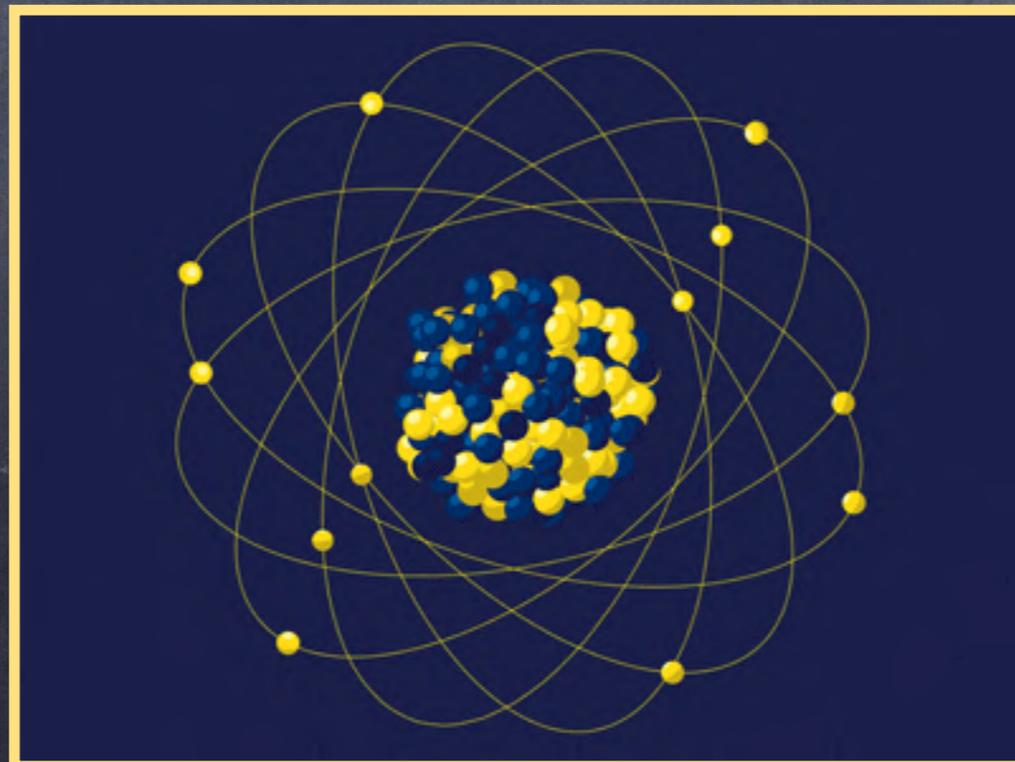


What is matter made of?



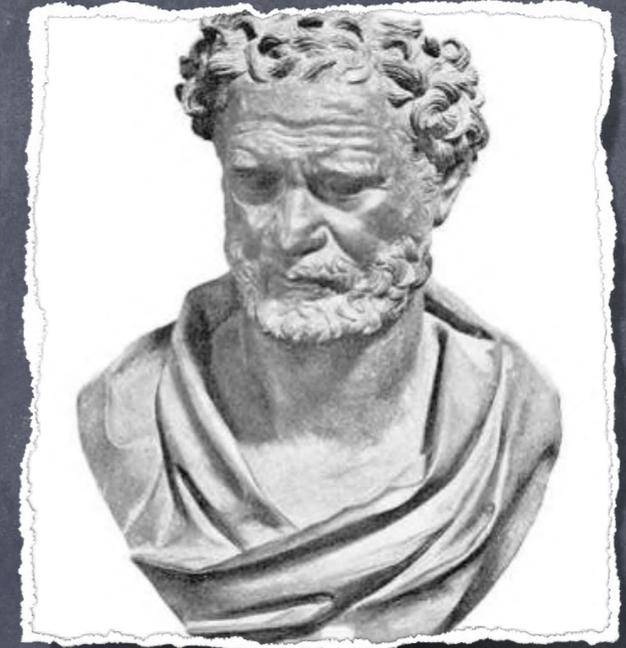
Democritus
(400 a.C.)

ατομο



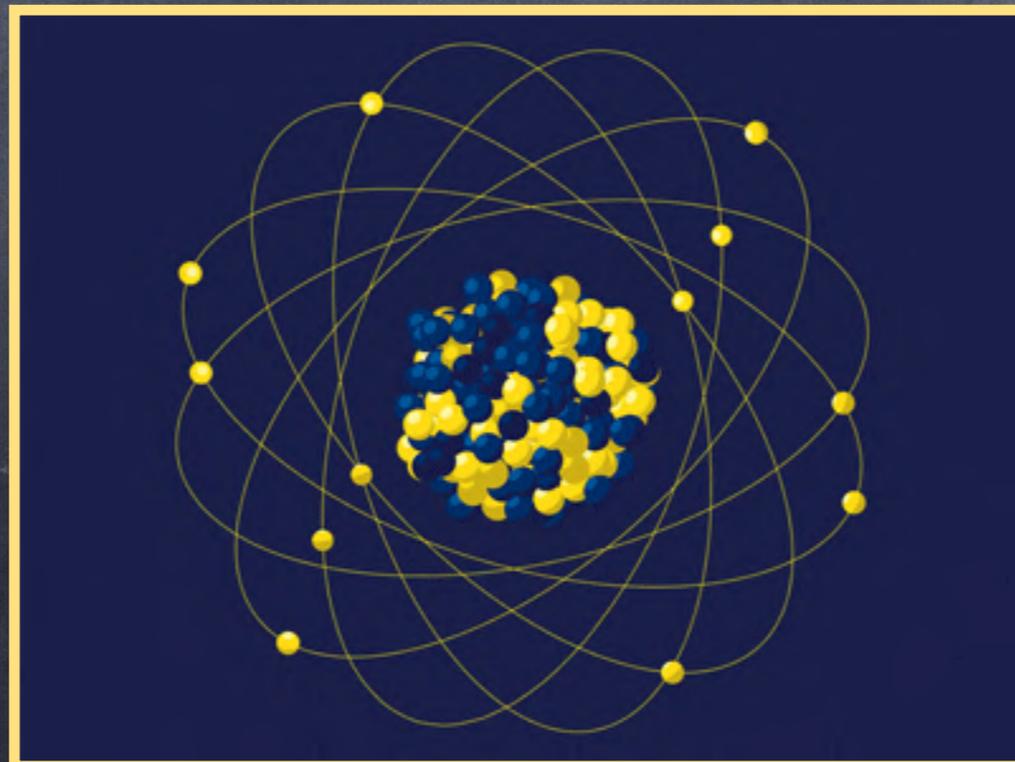
ATOM

What is matter made of?



Democritus
(400 a.C.)

ατομο



ATOM

α = without

τομο = cut

What is matter made of?

Periodic table of the elements

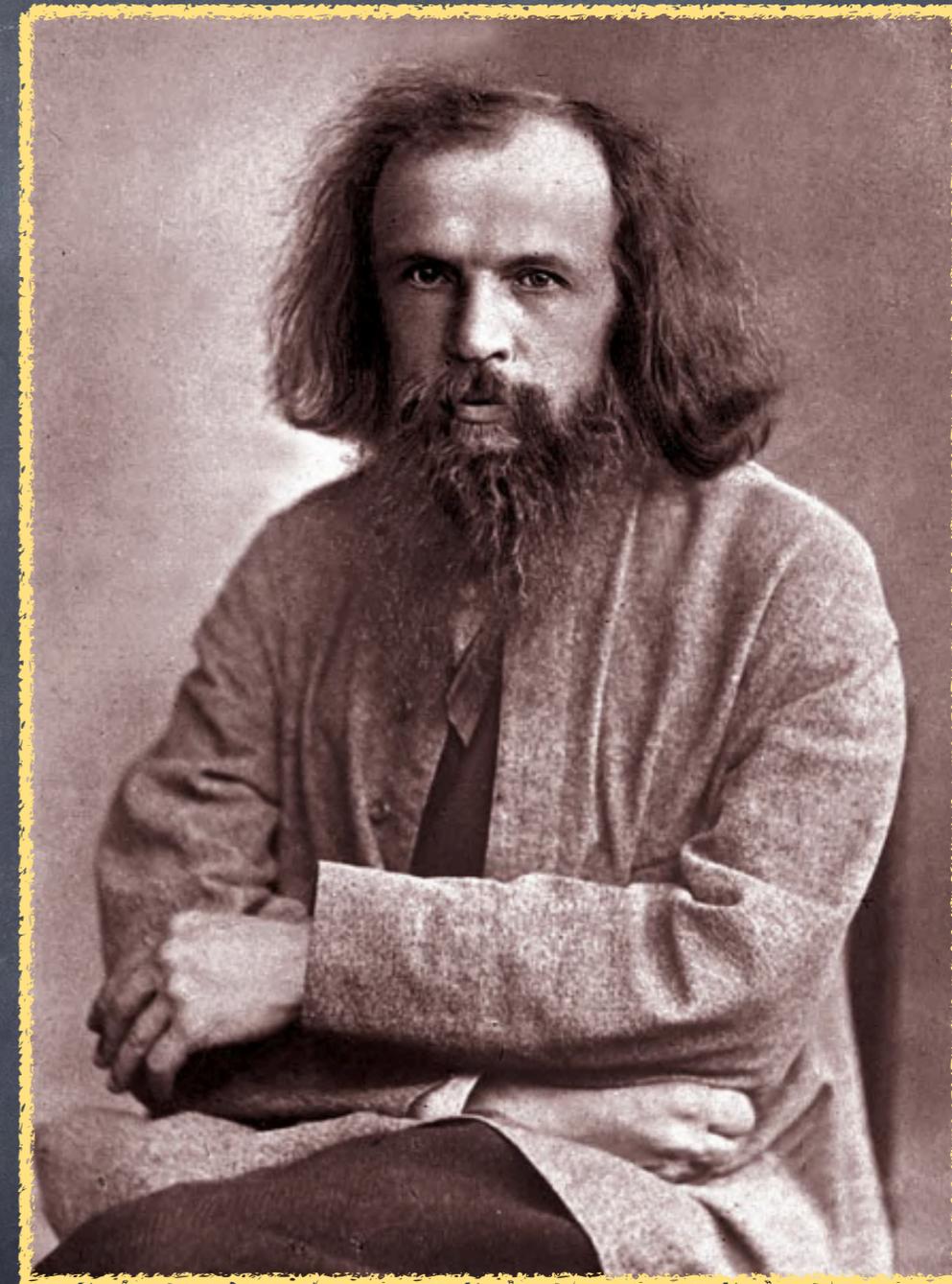
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Atomic masses in parentheses are those of the most stable or common isotope.

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57 La Lantano 138.9055	58 Ce Cerio 140.116	59 Pr Praseodimio 140.90765	60 Nd Neodimio 144.24	61 Pm Prometio (145)	62 Sm Samario 150.36	63 Eu Europio 151.964	64 Gd Gadolinio 157.25	65 Tb Terbio 158.92534	66 Dy Disprosio 162.500	67 Ho Holmio 164.93032	68 Er Erbio 167.259	69 Tm Tulio 168.93421	70 Yb Iterbio 173.04	71 Lu Lutecio 174.967
89 Ac Actinio (227)	90 Th Torio 232.0381	91 Pa Protactinio 231.03688	92 U Uranio 238.02891	93 Np Neptunio (237)	94 Pu Plutonio (244)	95 Am Americio (243)	96 Cm Curio (247)	97 Bk Berkelio (247)	98 Cf Californio (251)	99 Es Einsteinio (252)	100 Fm Fermio (257)	101 Md Mendelevio (258)	102 No Nobelio (259)	103 Lr Lawrencio (262)

Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.



Dmitri Medeláyev
(1869)

What is matter made of?

Periodic table of the elements

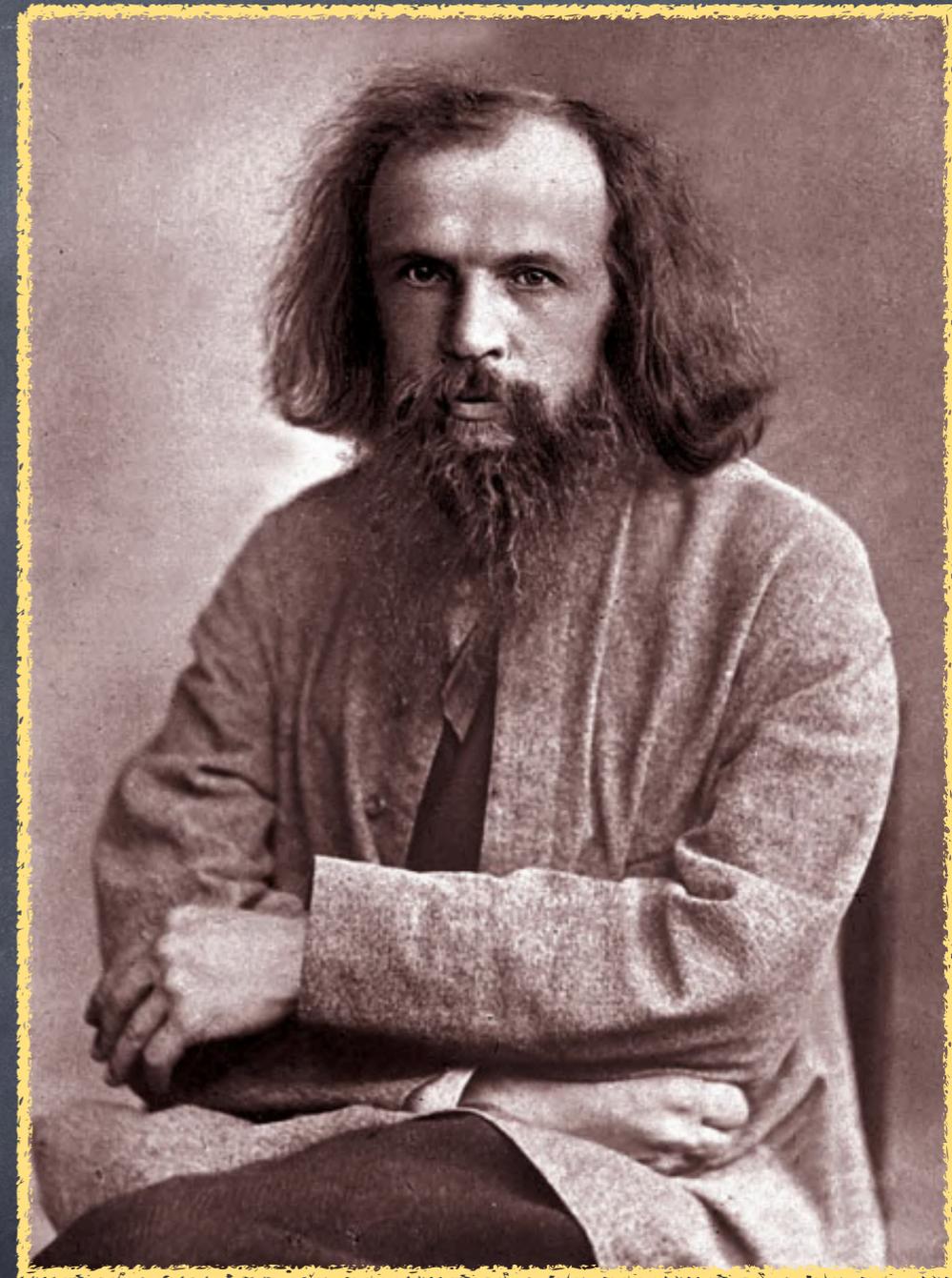
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Dmitri Medeléeiev
(1869)

- Periodicity of properties
- Discovery of new elements

What is matter made of?

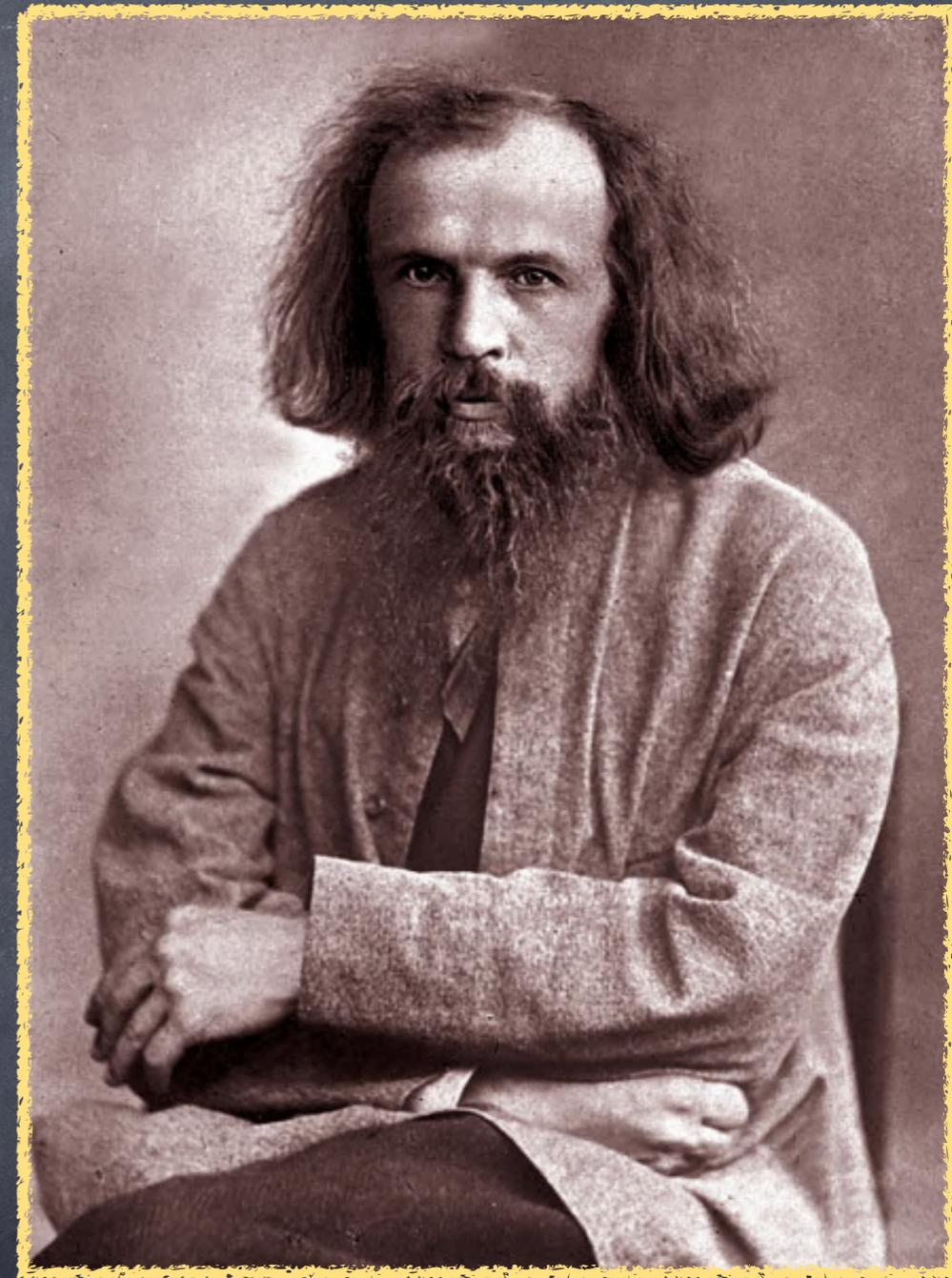
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Dmitri Medeléyev
(1869)

- Periodicity of properties
- Discovery of new elements

Atom = Protons + Neutrons + Electrons

What is matter made of?

	mass →	$\approx 2.3 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 173.07 \text{ GeV}/c^2$	0	$\approx 126 \text{ GeV}/c^2$
charge →	$2/3$	$2/3$	$2/3$	0	0	0
spin →	$1/2$	$1/2$	$1/2$	1	0	0
	u	c	t	g	H	
	up	charm	top	gluon	Higgs boson	
QUARKS	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0		
	$-1/3$	$-1/3$	$-1/3$	0		
	$1/2$	$1/2$	$1/2$	1		
	d	s	b	γ		
	down	strange	bottom	photon		
	$0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$		
	-1	-1	-1	0		
	$1/2$	$1/2$	$1/2$	1		
	e	μ	τ	Z		
	electron	muon	tau	Z boson		
LEPTONS	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$		
	0	0	0	± 1		
	$1/2$	$1/2$	$1/2$	1		
	ν_e	ν_μ	ν_τ	W		
	electron neutrino	muon neutrino	tau neutrino	W boson		
					GAUGE BOSONS	

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	u up	c charm	t top	g gluon	H Higgs boson
QUARKS	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
	$-1/3$	$-1/3$	$-1/3$	0	
	$1/2$	$1/2$	$1/2$	1	
	d down	s strange	b bottom	γ photon	

EXPERIMENT!!!

What is matter made of?

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		e electron	μ muon	τ tau	Z Z boson	
LEPTONS		$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$	
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		$1/2$	$1/2$	$1/2$	1	
		ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
						GAUGE BOSONS

proton
 $\sim 10^{-15} \text{ m}$

What is matter made of?

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	0	0	0	±1	
	1/2	1/2	1/2	1	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

Large Hadron Collider (LHC)



proton
 $\sim 10^{-15}$ m

What is matter made of?

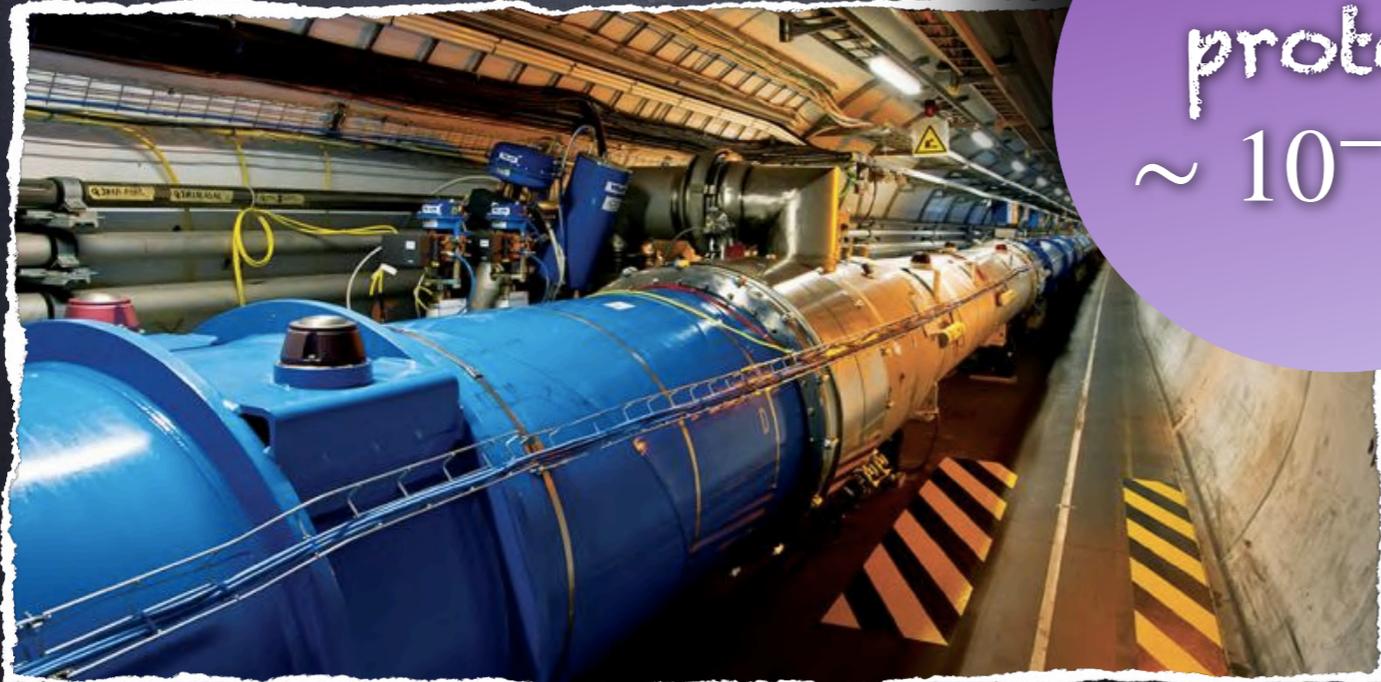
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u up	c charm	t top	g gluon	H Higgs boson
d down	s strange	b bottom	γ photon	
e electron	μ muon	τ tau	Z Z boson	
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

QUARKS (left side of the table)

LEPTONS (left side of the table)

GAUGE BOSONS (right side of the table)

Large Hadron Collider (LHC)



proton
 $\sim 10^{-15} \text{ m}$

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	$1/2$	$1/2$	$1/2$	1	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
					GAUGE BOSONS

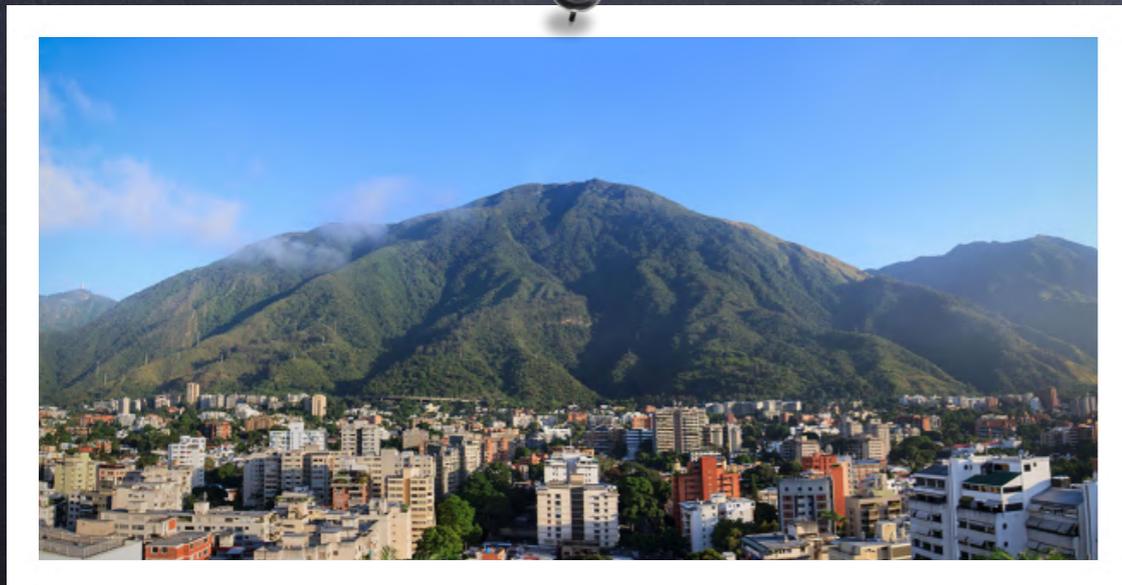
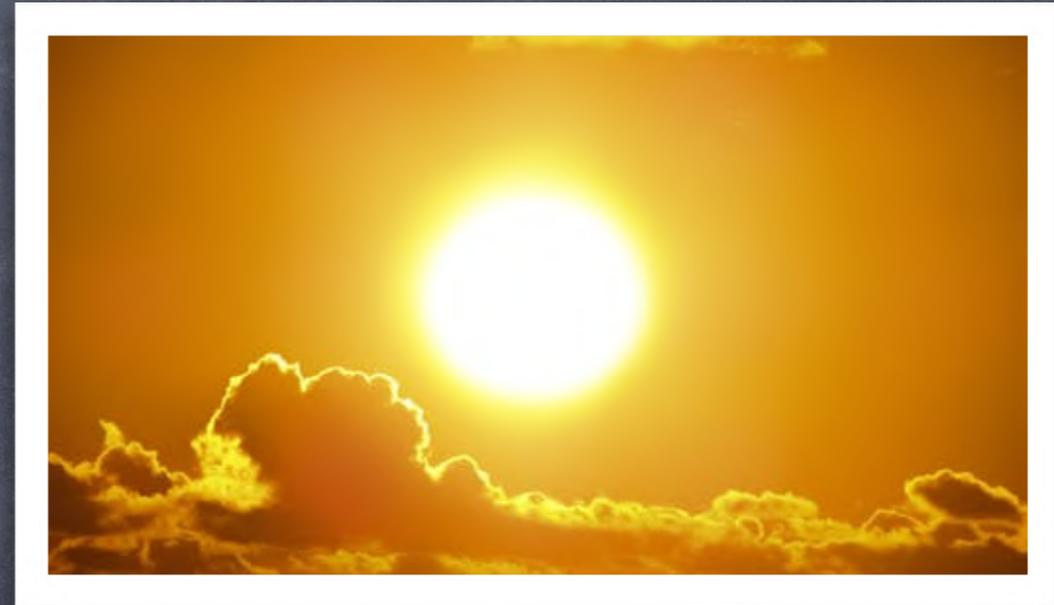
Large Hadron Collider (LHC)



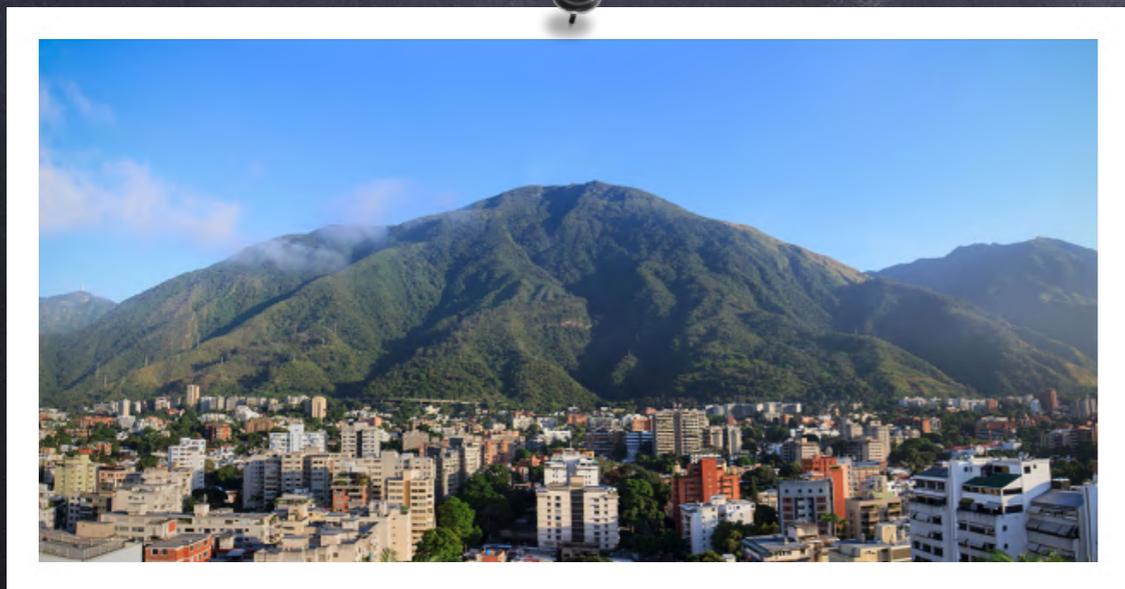
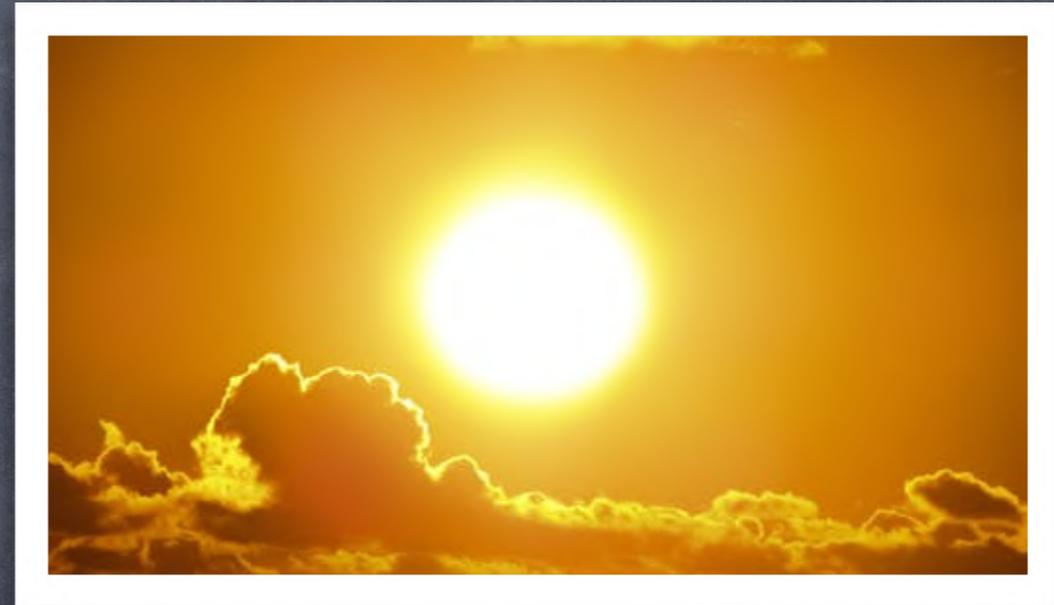
proton
 $\sim 10^{-15} \text{ m}$

Evidence 1: the matter we know is made of atoms and subatomic particles

Where is the Dark Matter?



Where is the Dark Matter?



Where is the Dark Matter?



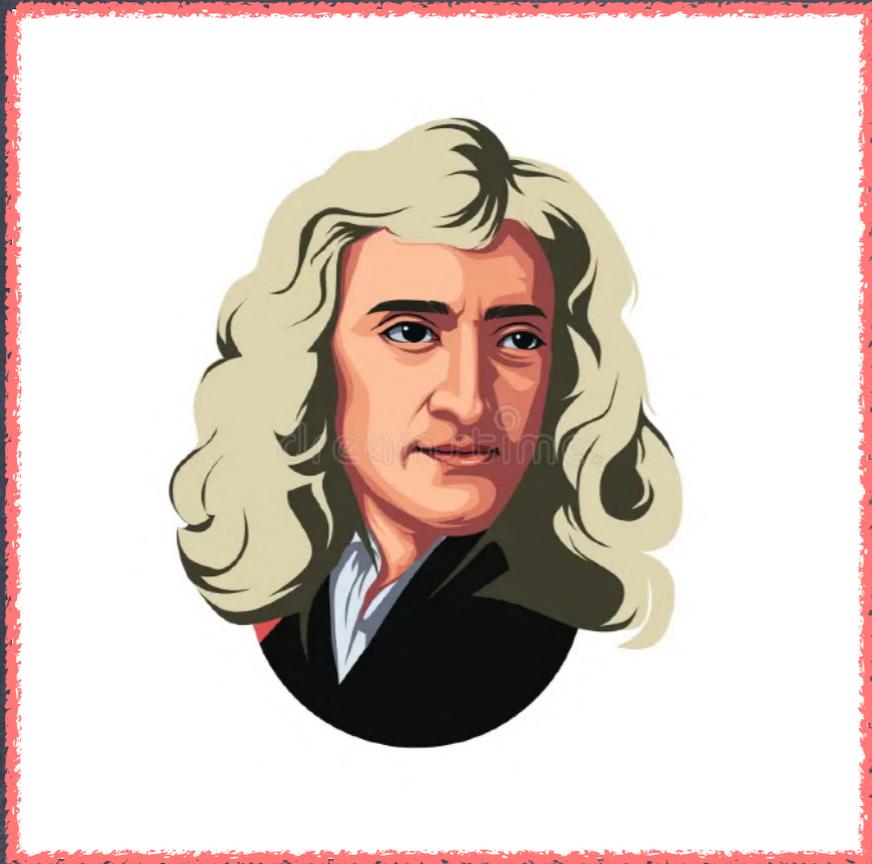
Act II:
Gravity



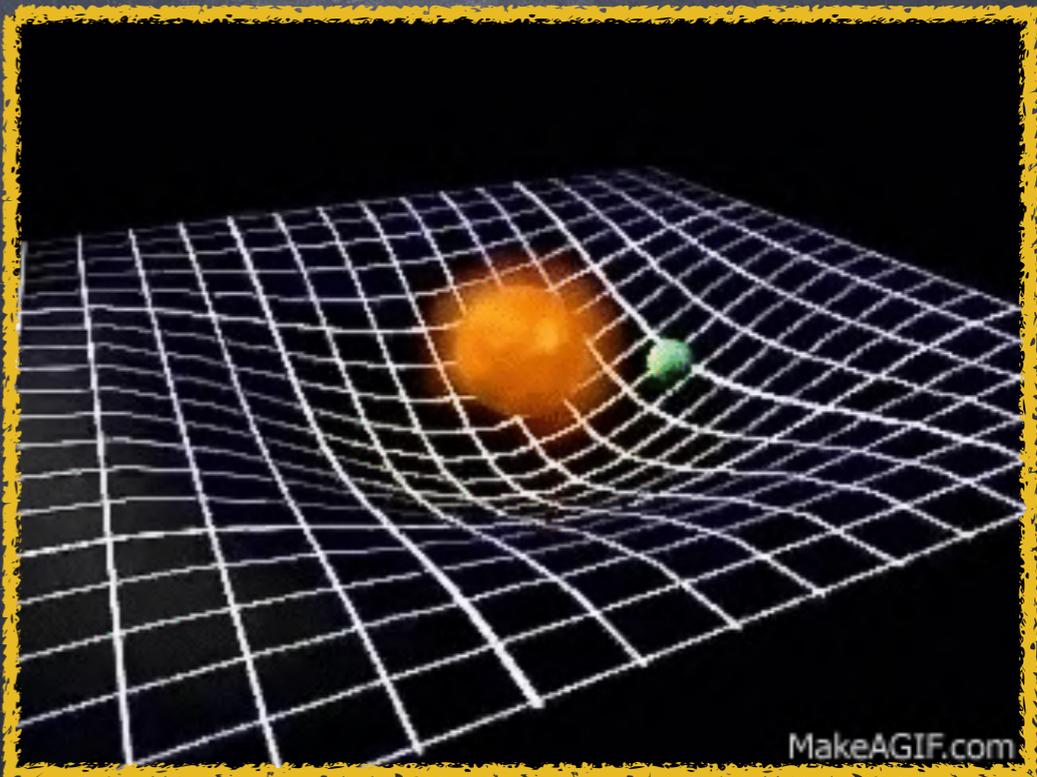
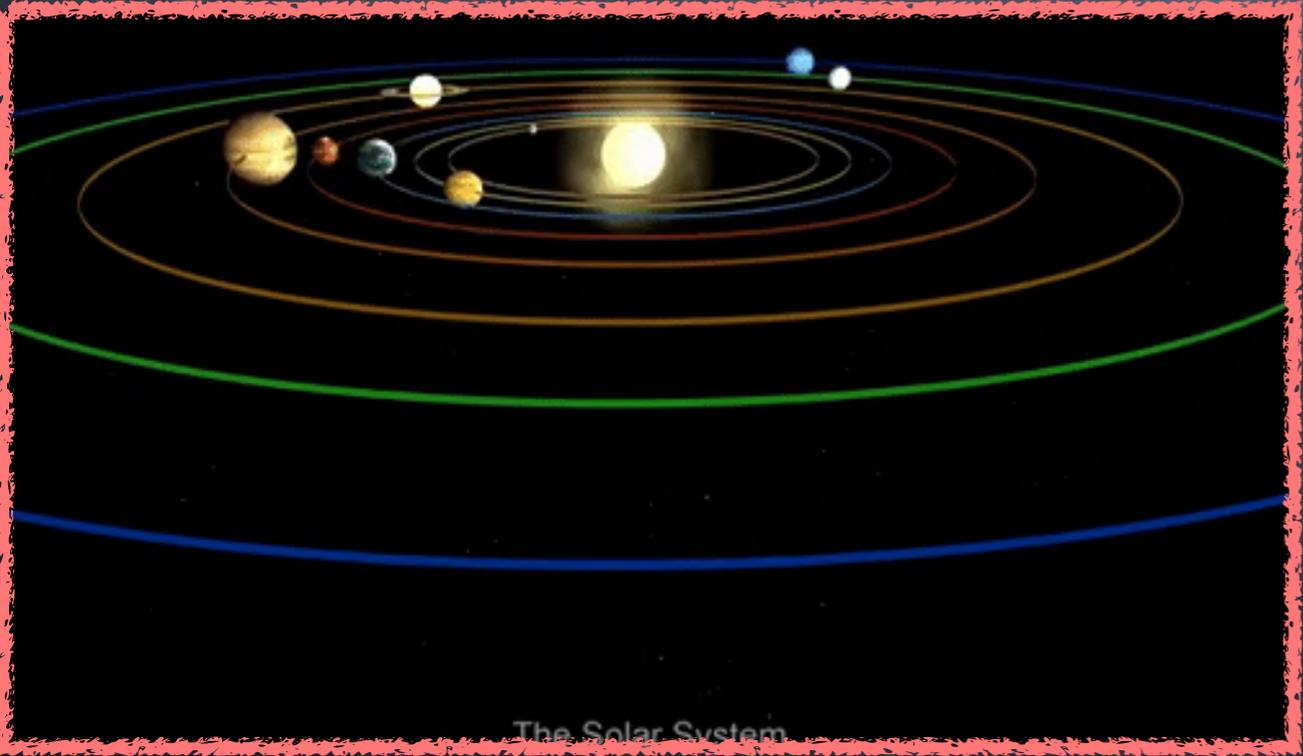
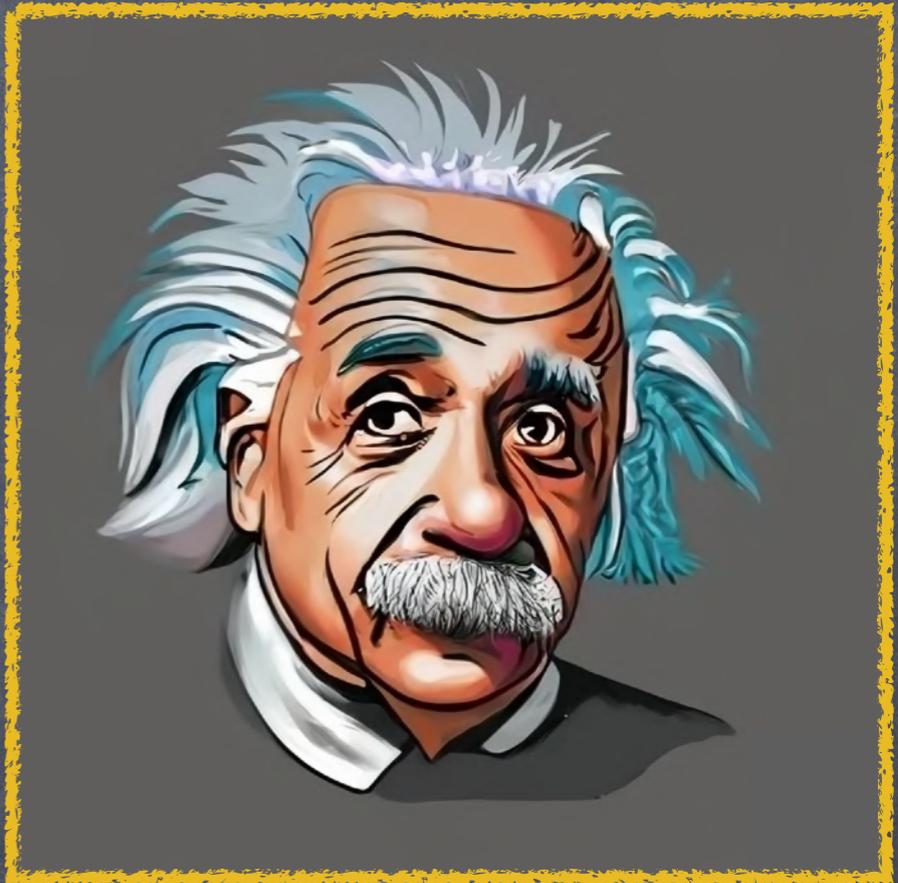
Act II:
Gravity



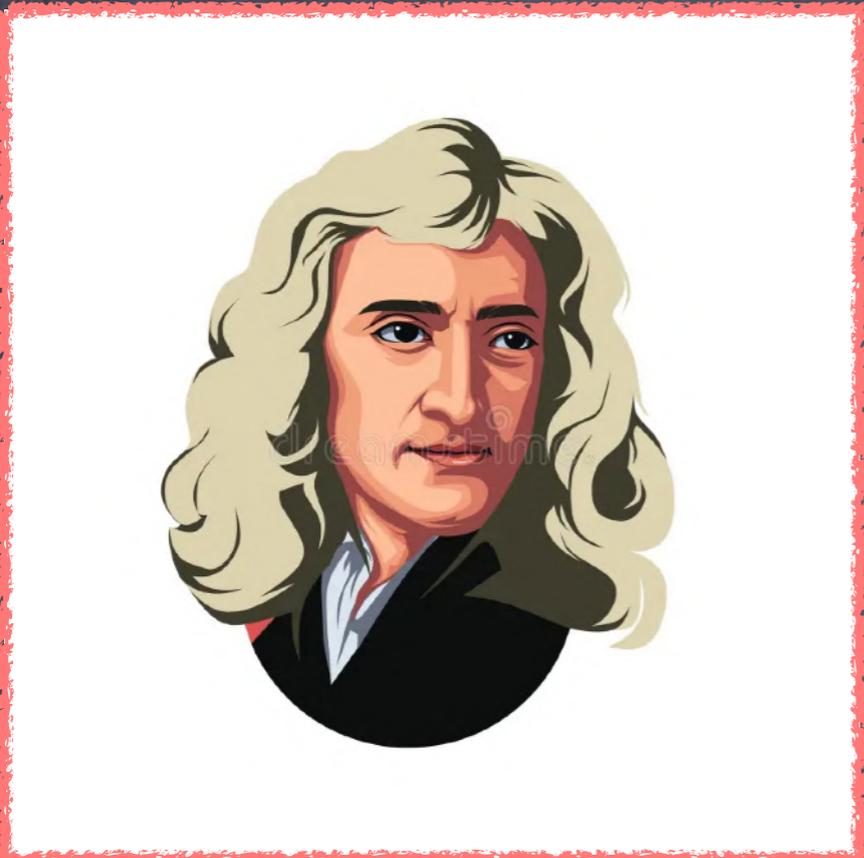
Isaac Newton (1667)



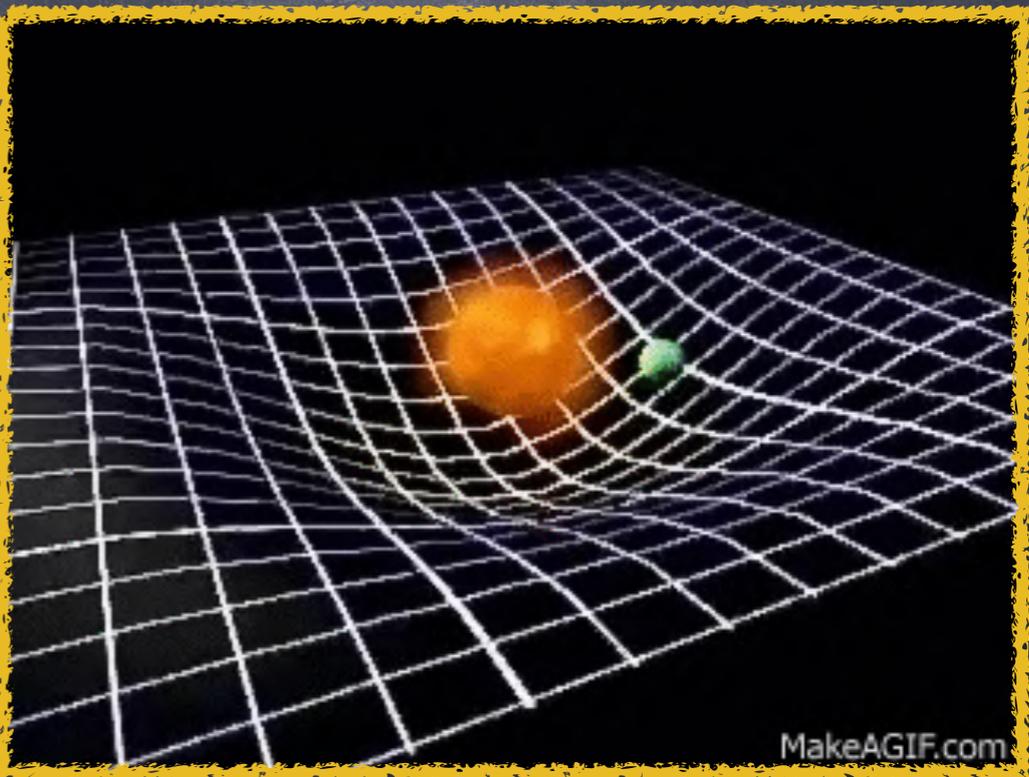
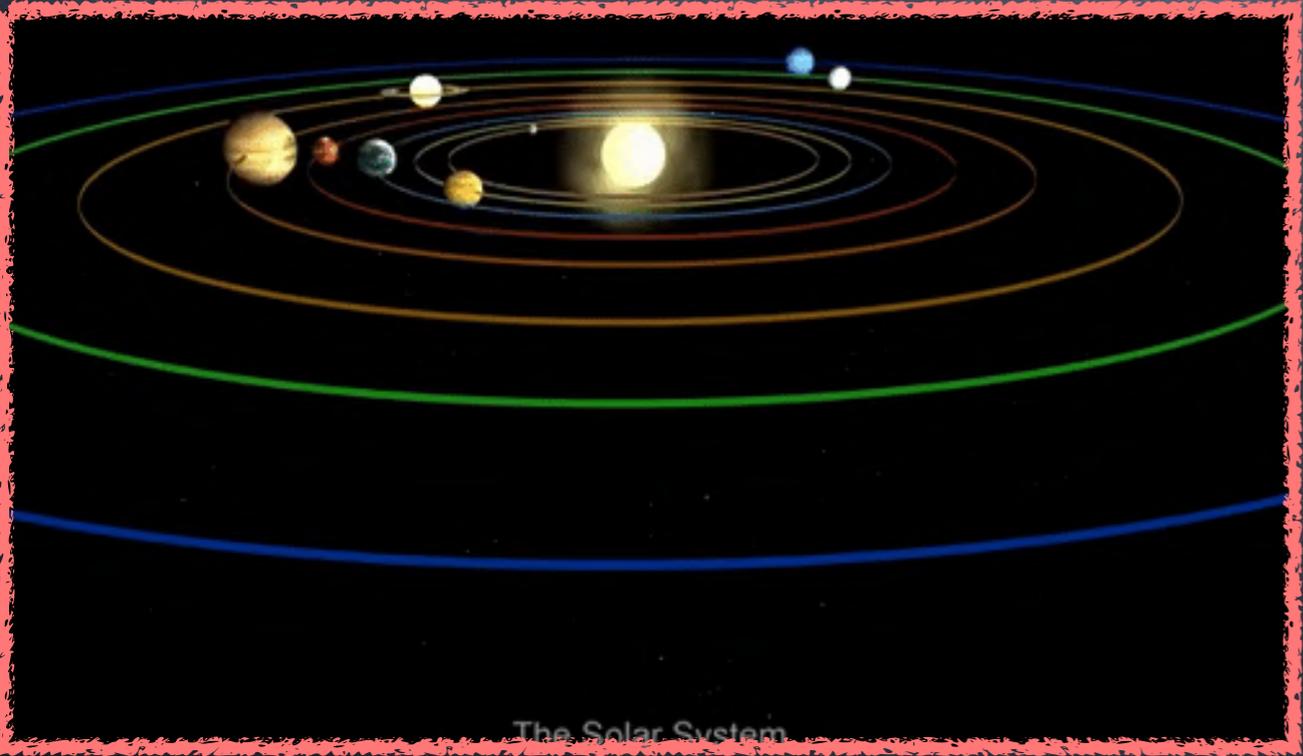
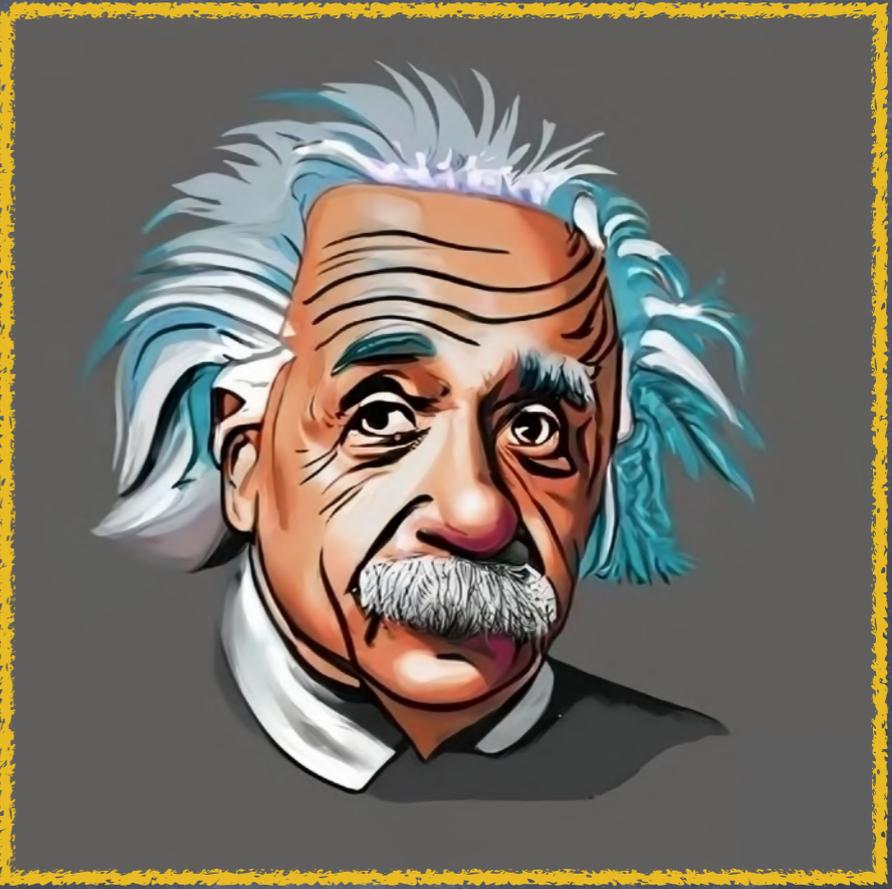
ALBERT EINSTEIN (1915)



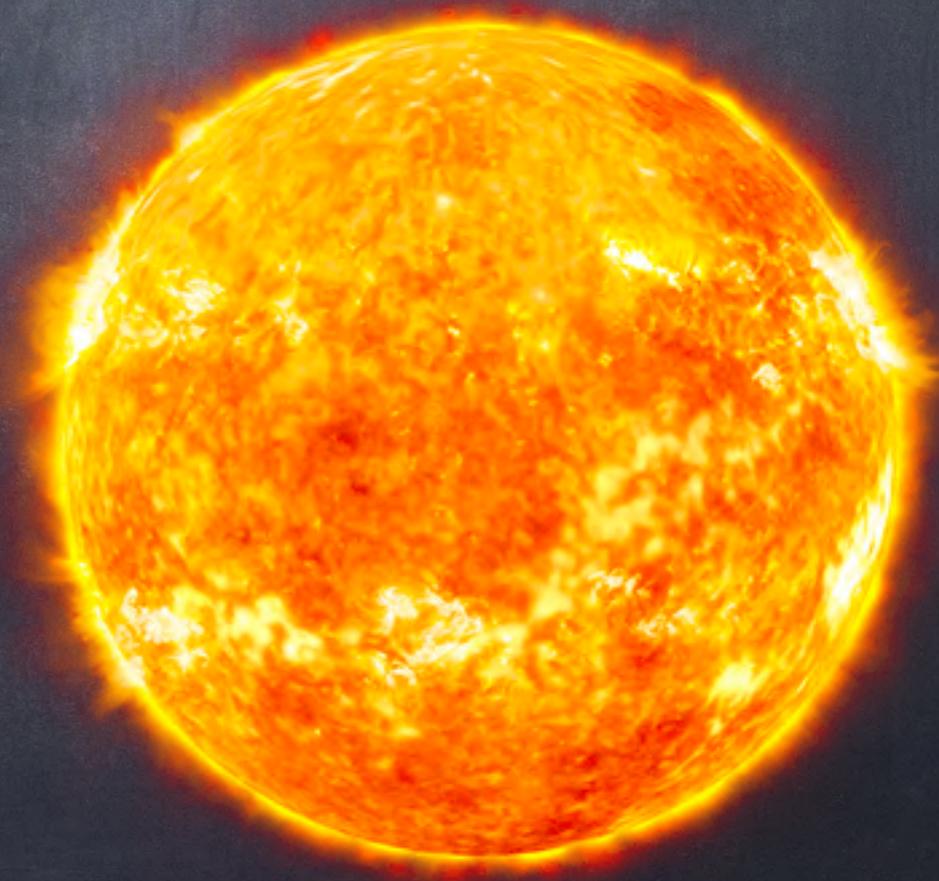
Isaac Newton (1667)



ALBERT Einstein (1915)



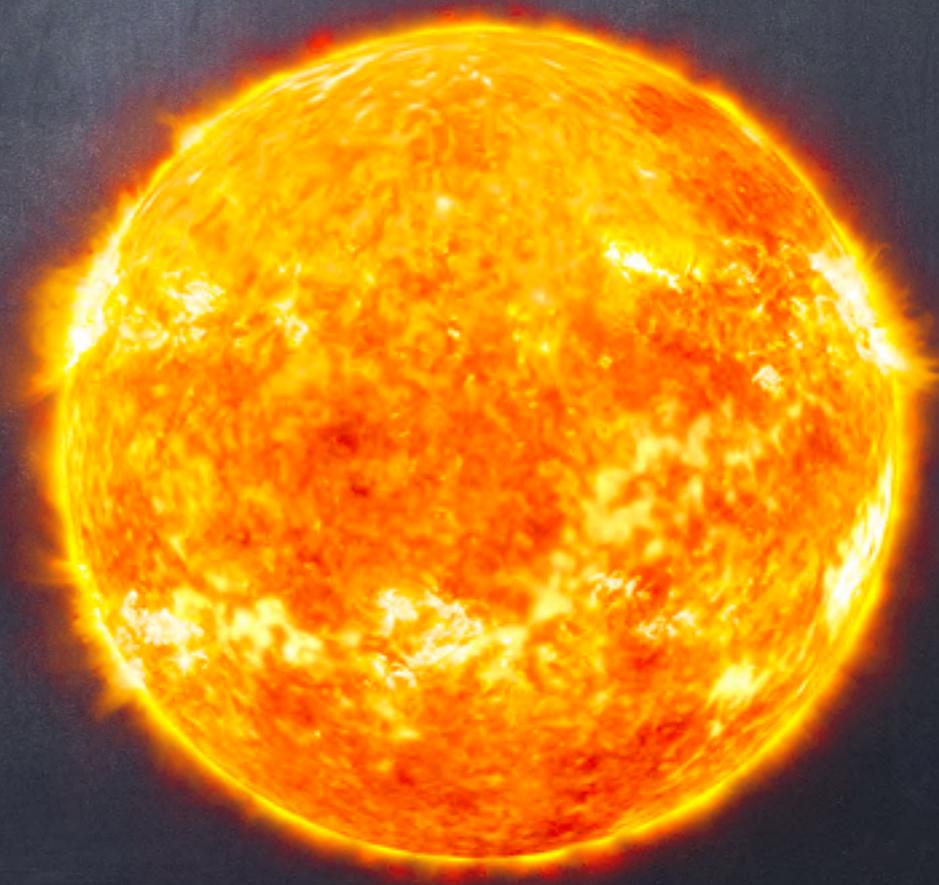
Gravity



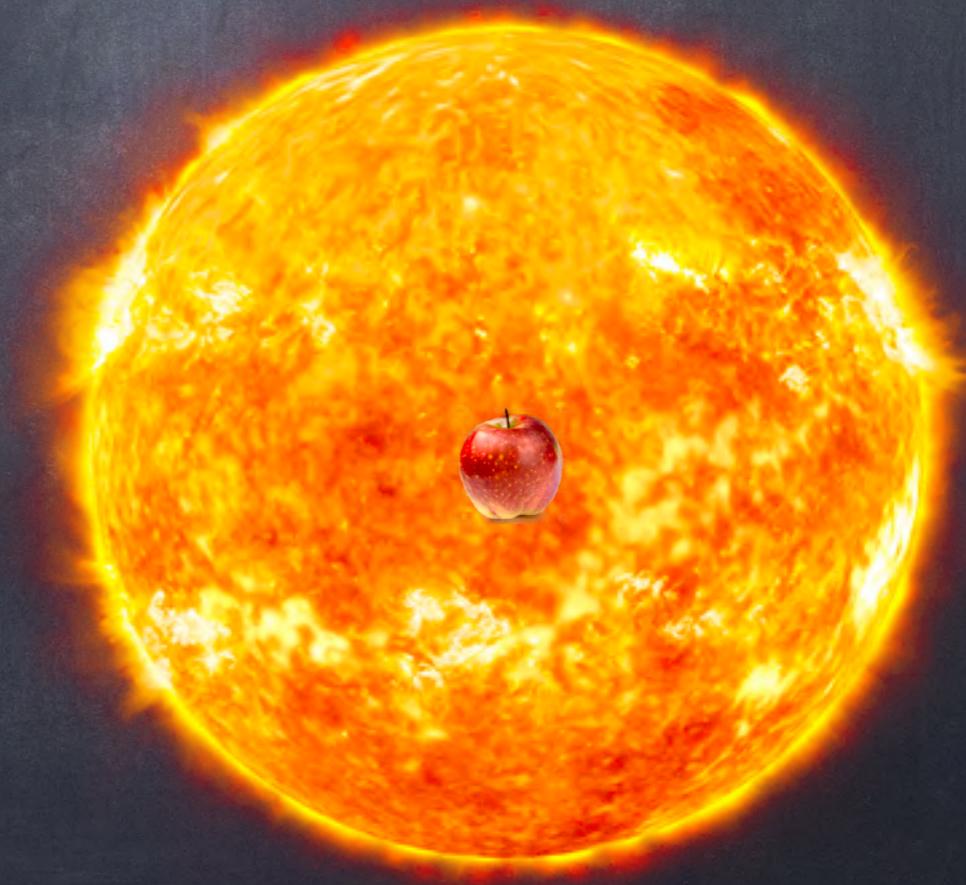
Gravity



Gravity



Gravity



Gravity

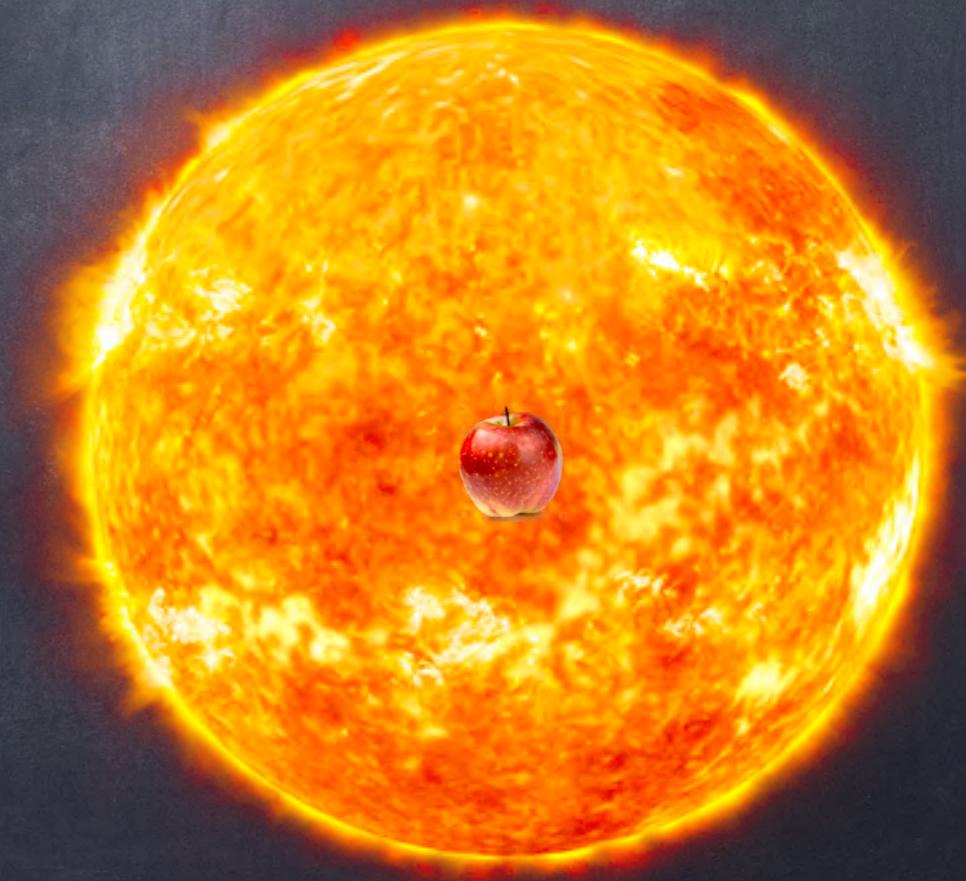
1.6 m/s²



9.8 m/s²



274 m/s²



Gravity

Evidence 2: the strength of gravity depends on the amount of matter generating it.

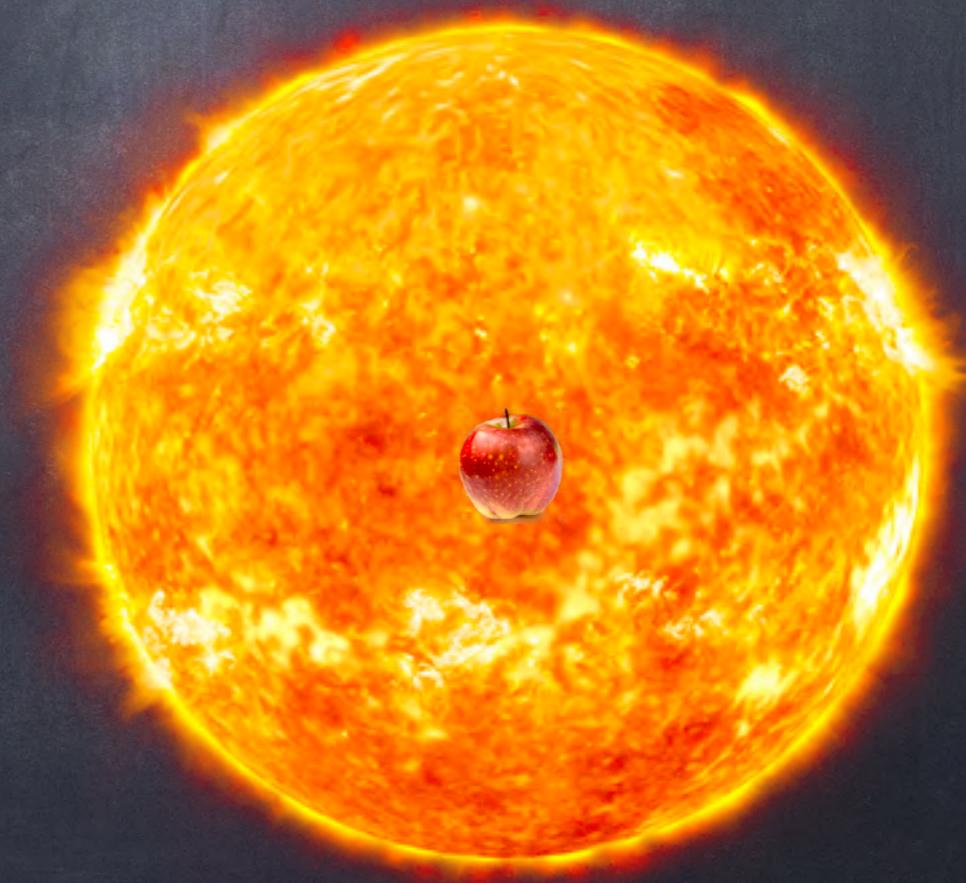
1.6 m/s²



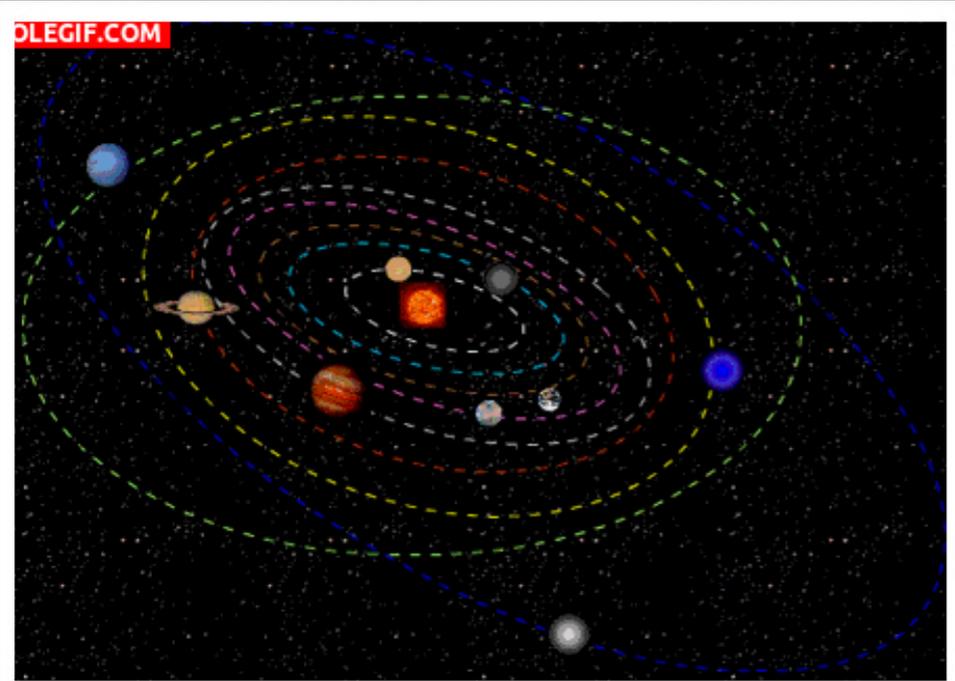
9.8 m/s²



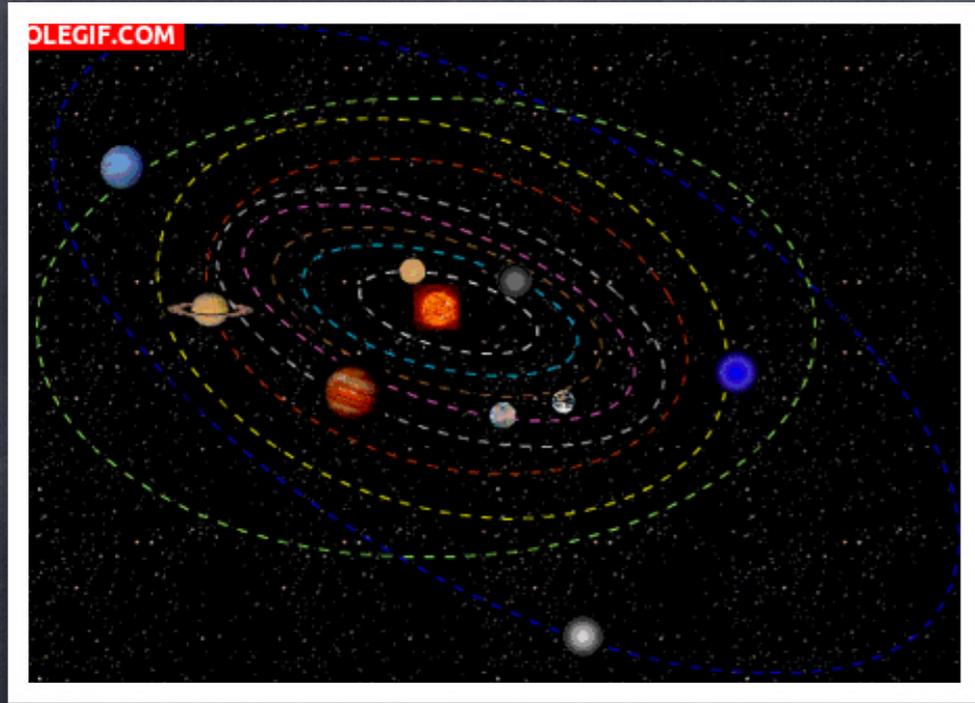
274 m/s²



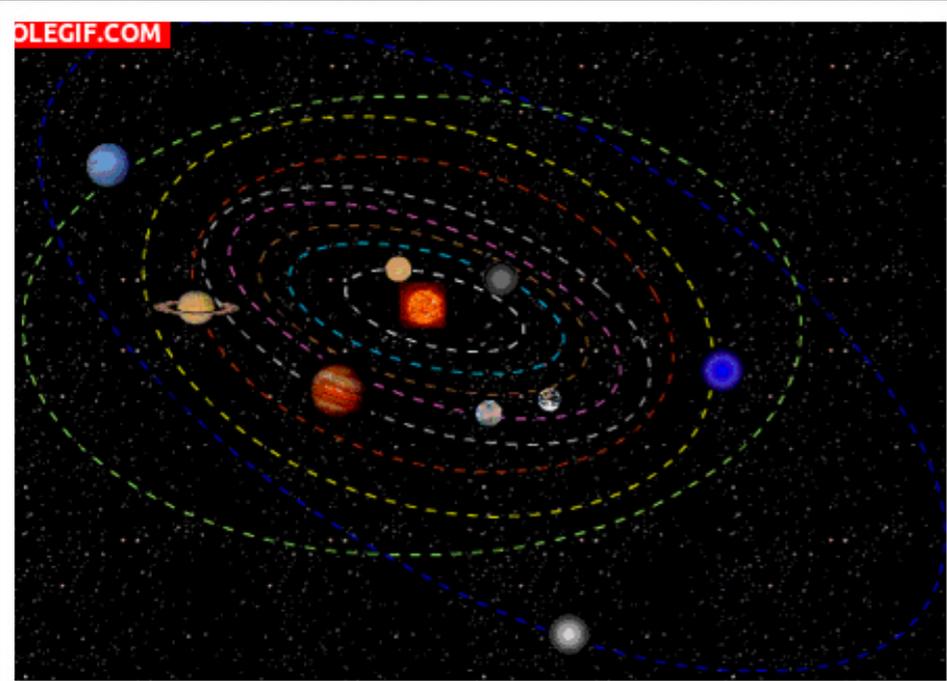
Gravity



Gravity



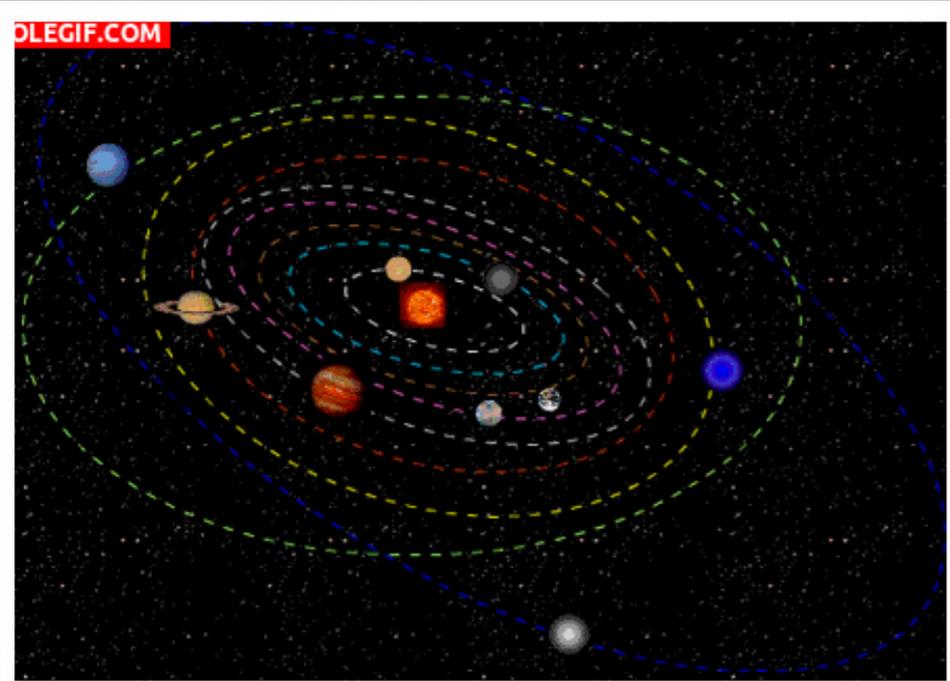
Gravity



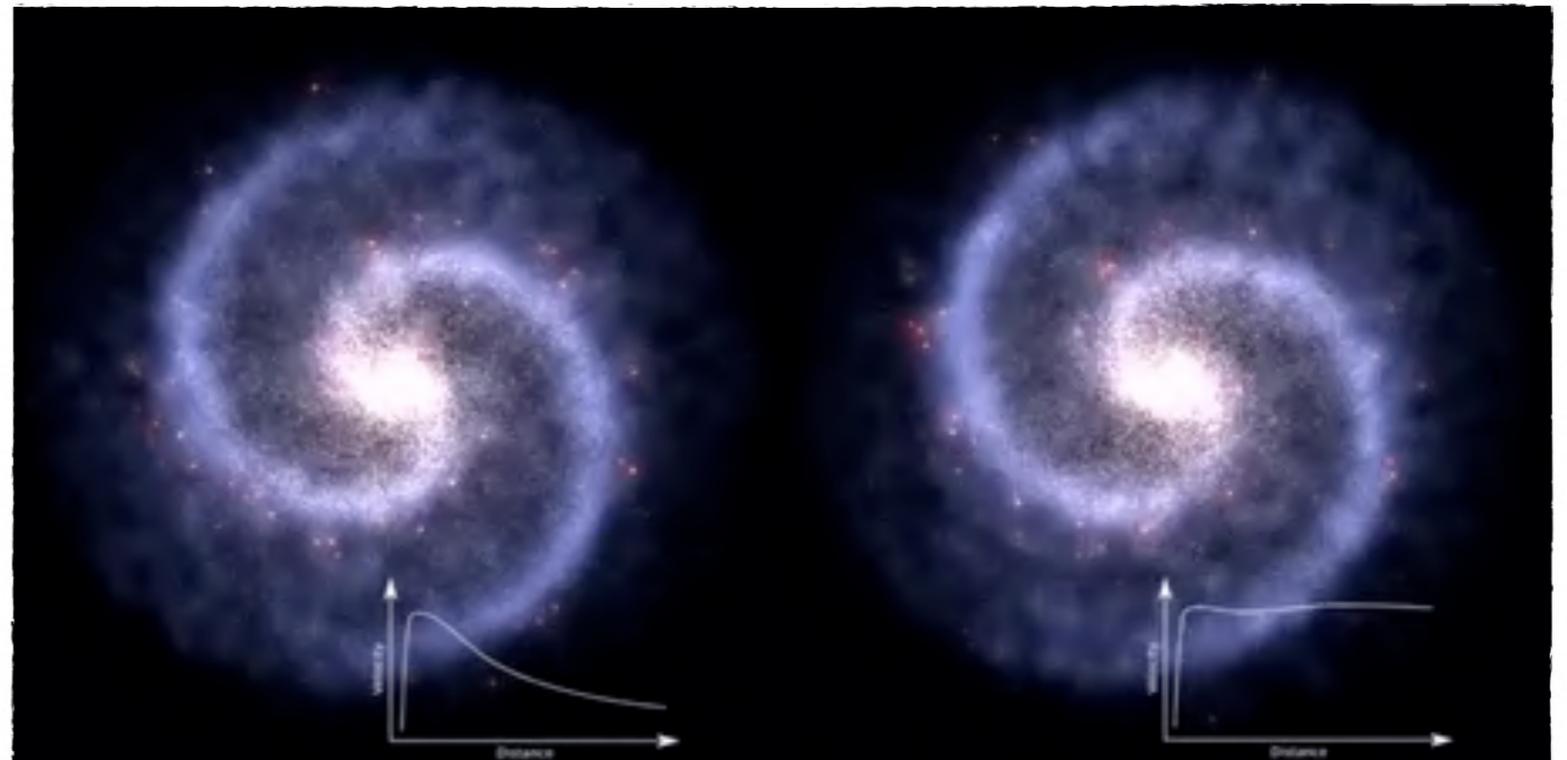
Evidence 3: Objects fall faster the closer they are to the matter generating gravity



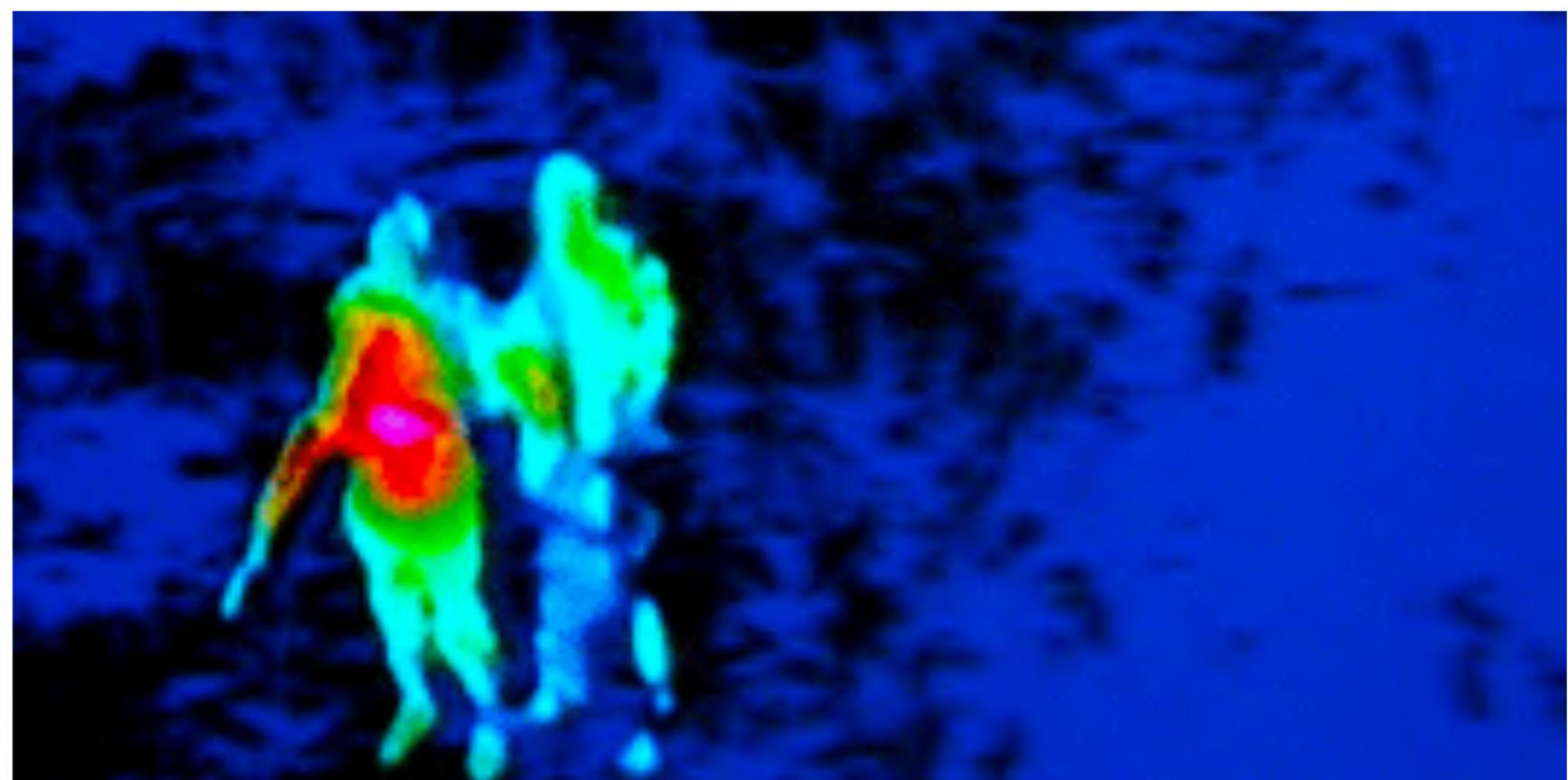
Gravity



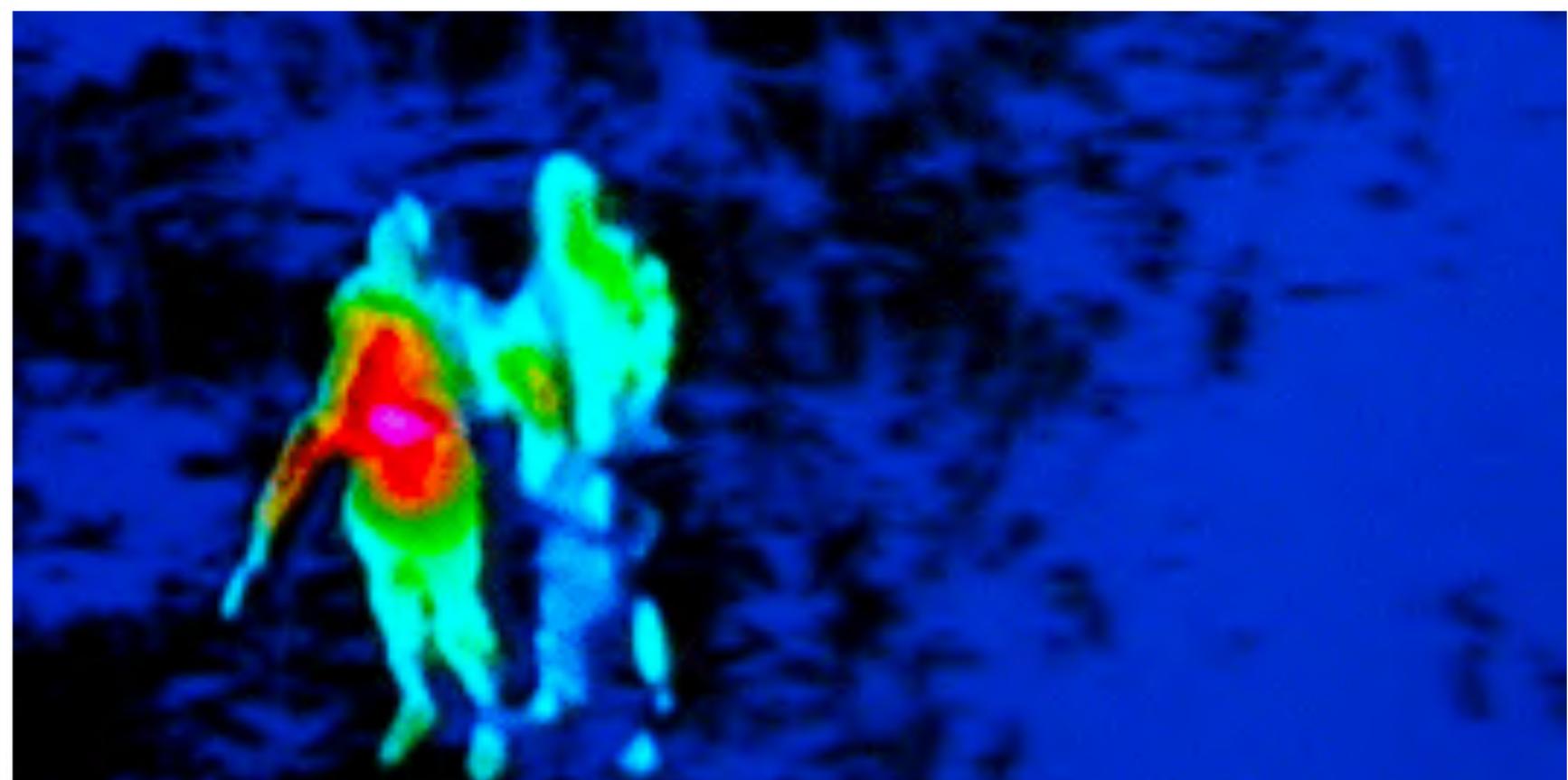
Evidence 3: Objects fall faster the closer they are to the matter generating gravity



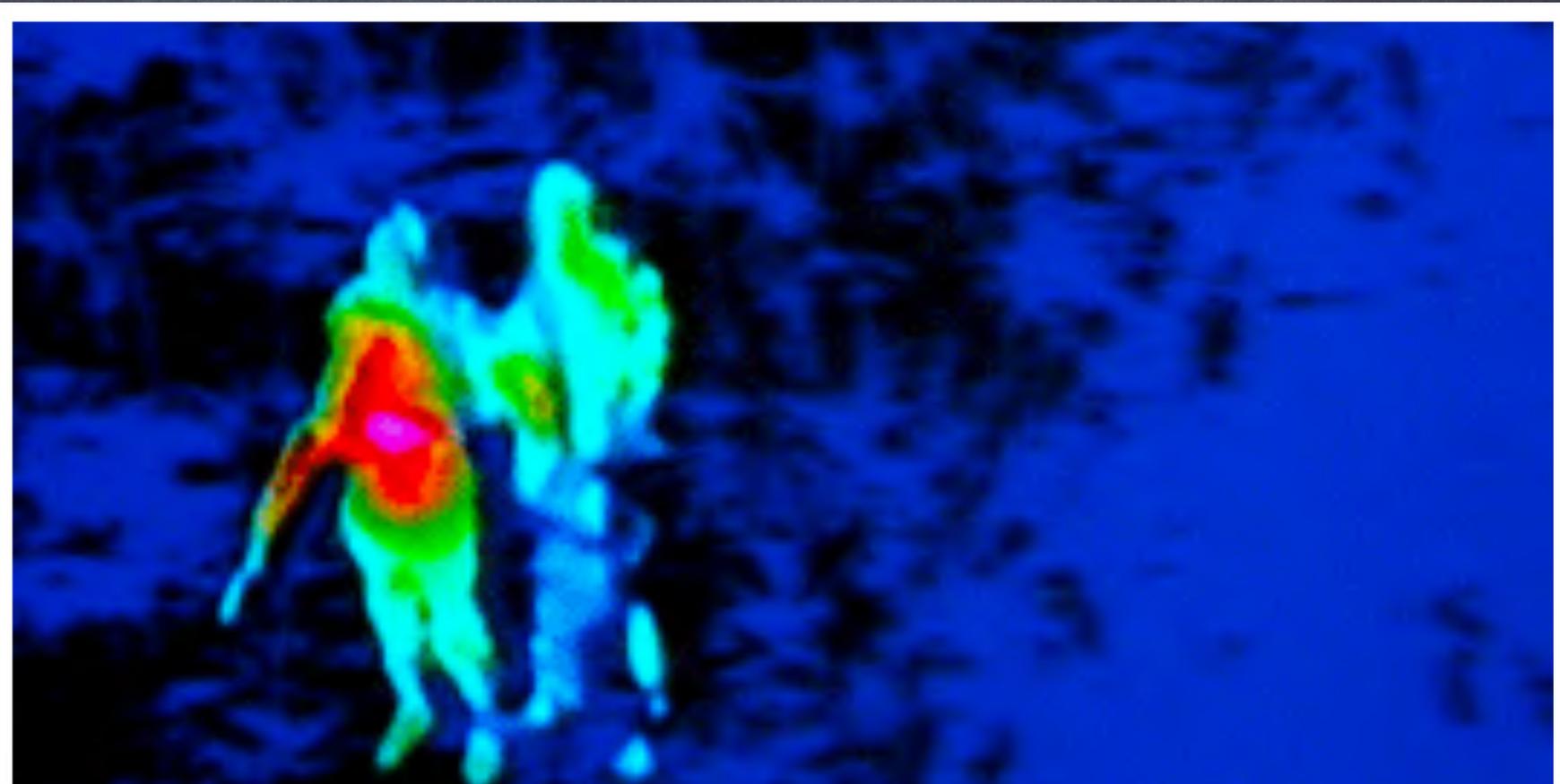
Galactic matter composition



Galactic matter composition

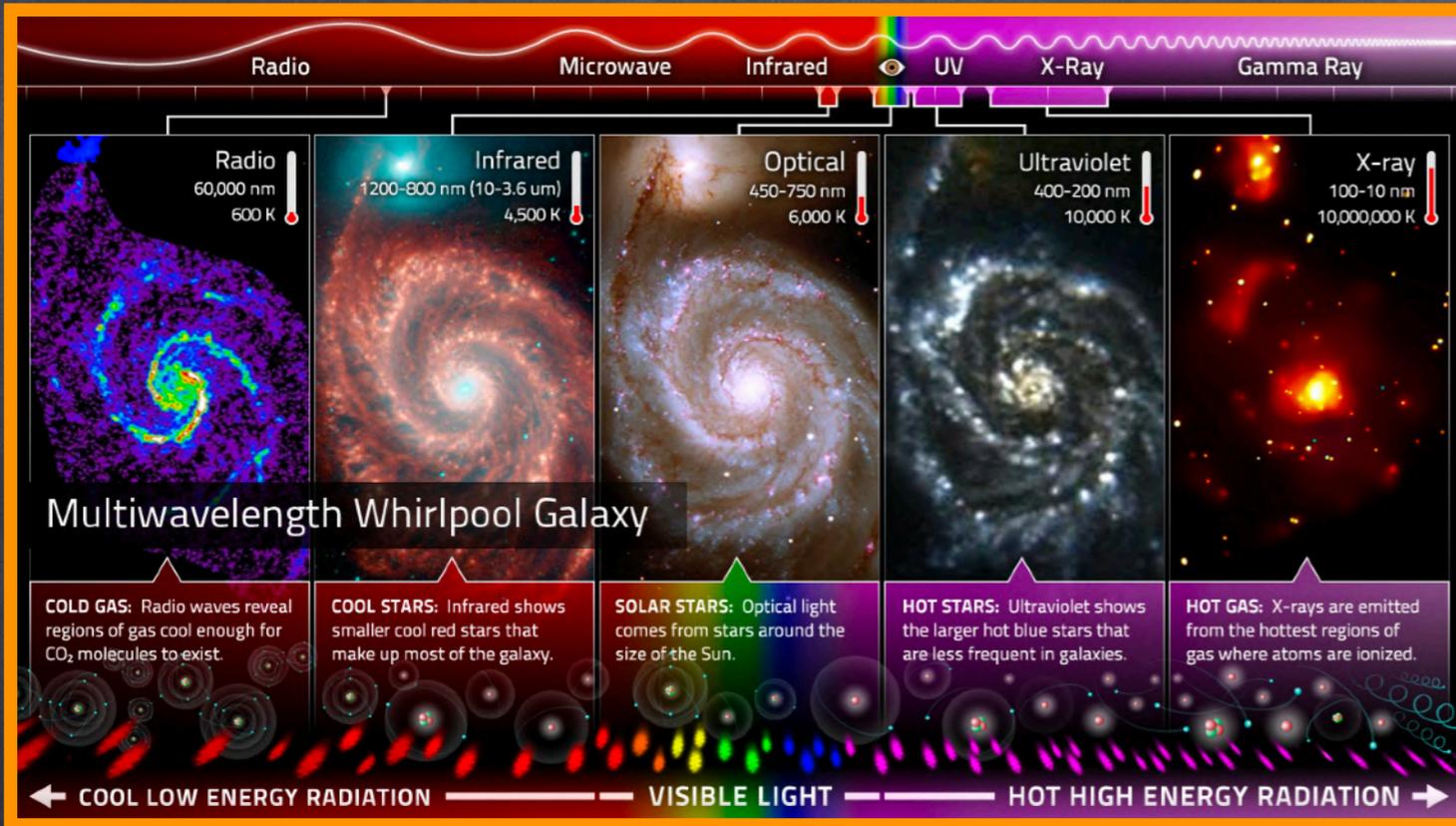


Galactic matter composition



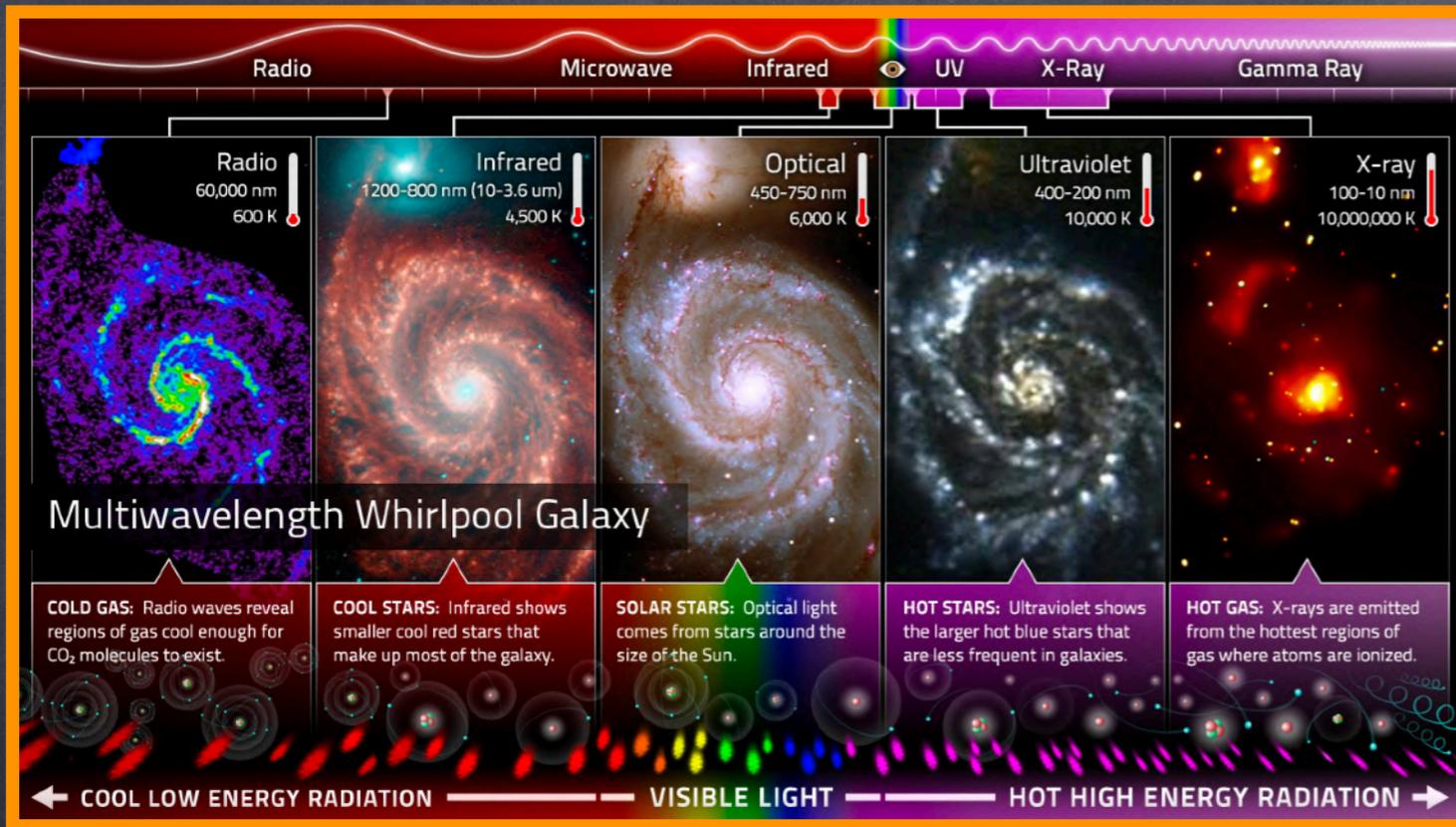
Galactic matter composition

Galactic matter composition



<https://ecuip.lib.uchicago.edu/multiwavelength-astronomy/astrophysics/05.html>

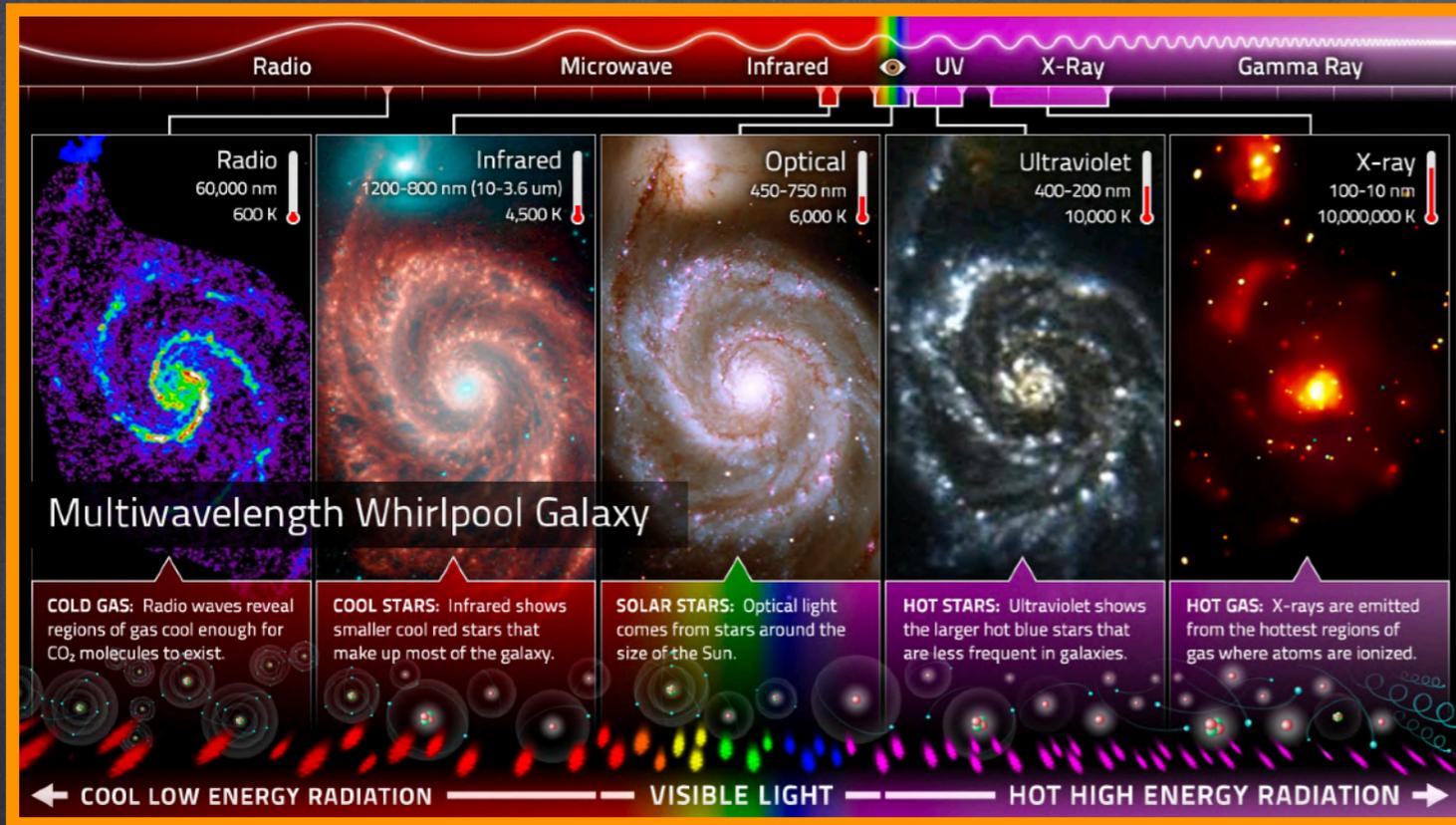
Galactic matter composition



<https://ecuip.lib.uchicago.edu/multiwavelength-astronomy/astrophysics/05.html>

Is there more matter we cannot see?

Galactic matter composition

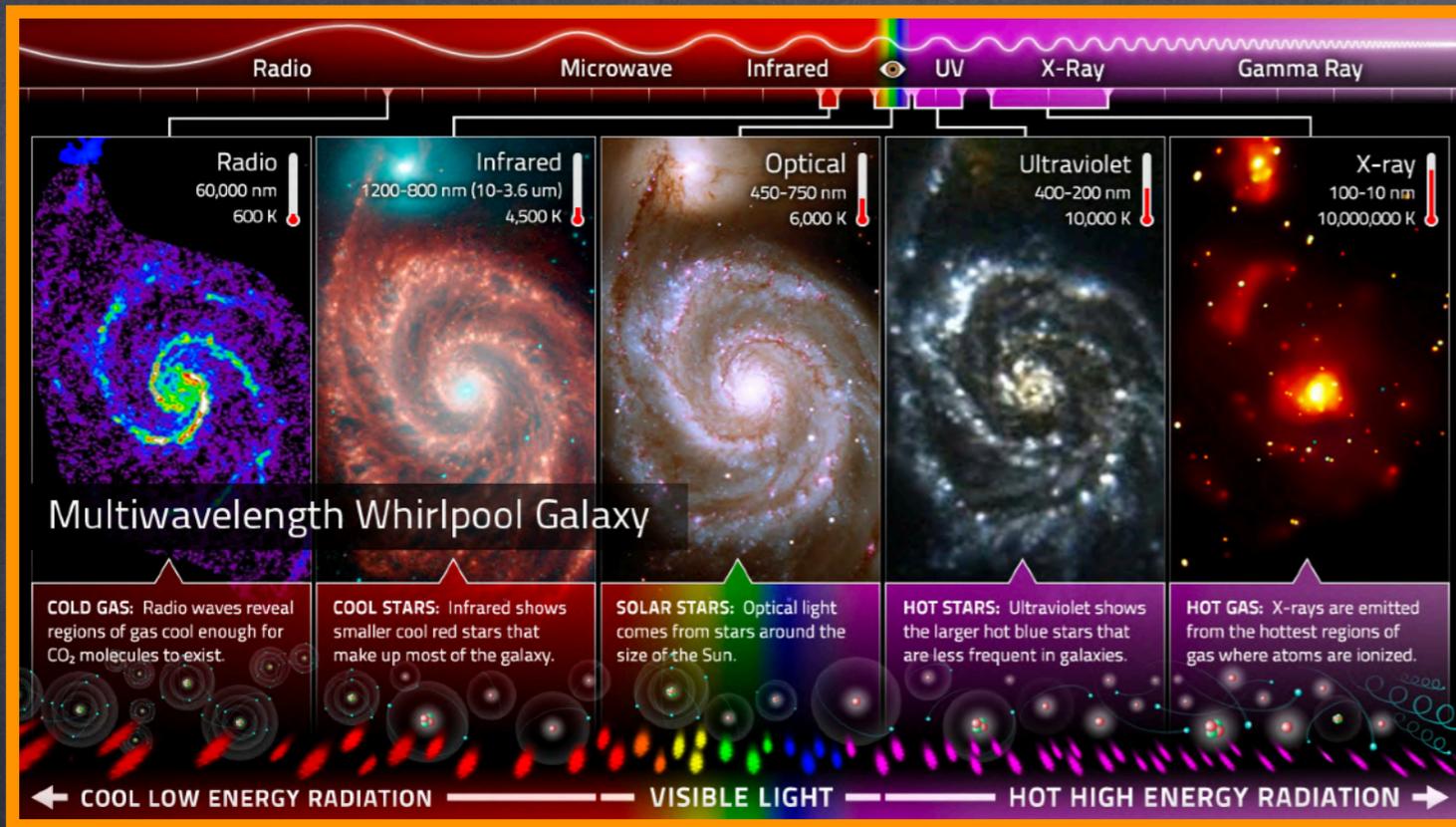


<https://ecuip.lib.uchicago.edu/multiwavelength-astronomy/astrophysics/05.html>



Is there more matter we cannot see?

Galactic matter composition



<https://ecuip.lib.uchicago.edu/multiwavelength-astronomy/astrophysics/05.html>

Is there more matter we cannot see?

Dark Matter!!!

Galactic matter composition



<https://ecuip.lib.uchicago.edu/multiwavelength-astronomy/astrophysics/05.html>

Dark Matter!!!

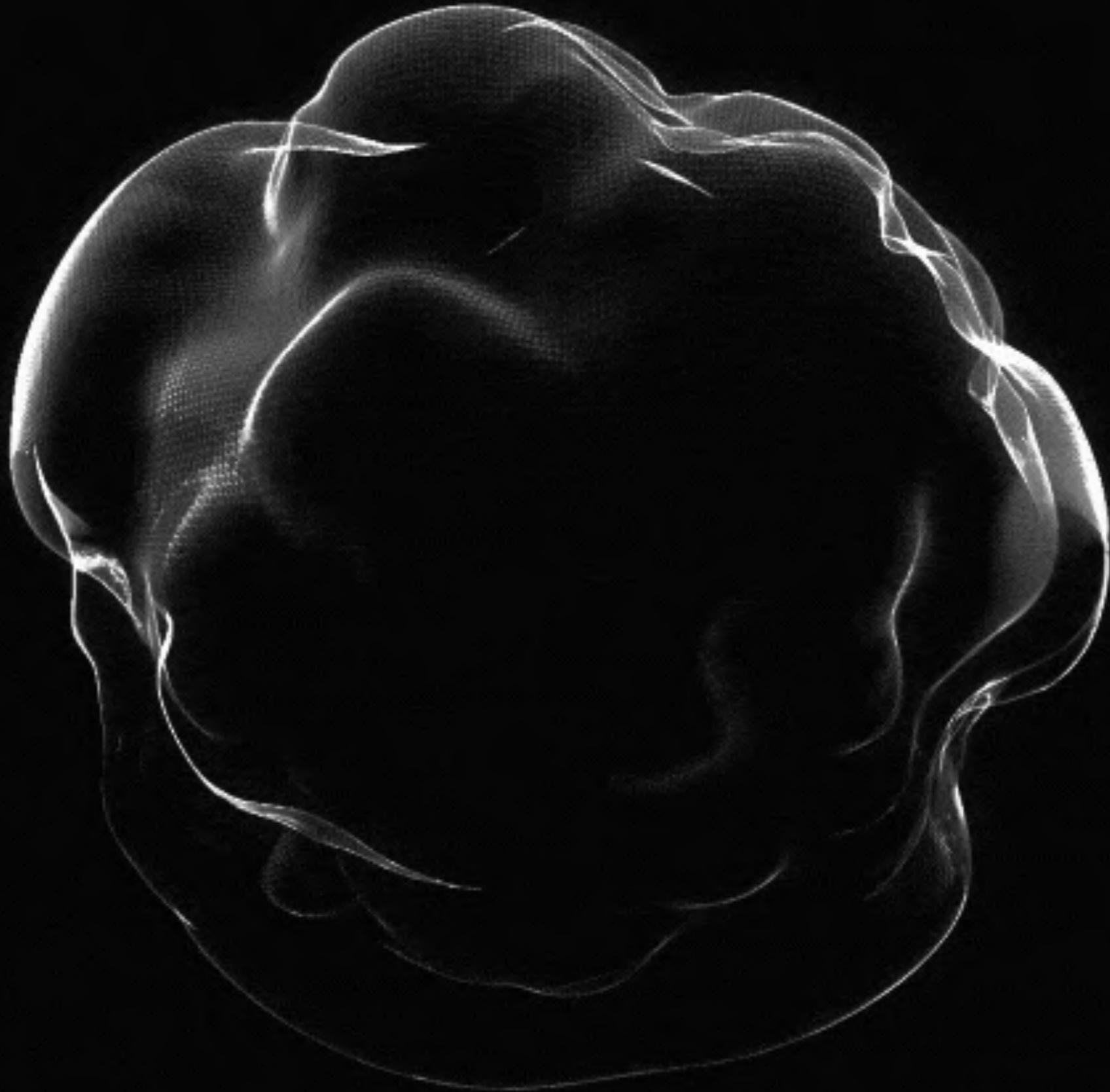
Is there more matter we cannot see?

“It seems that much of the matter in spiral galaxies does not emit light. Moreover, it is not concentrated near the centers of the galaxies.”

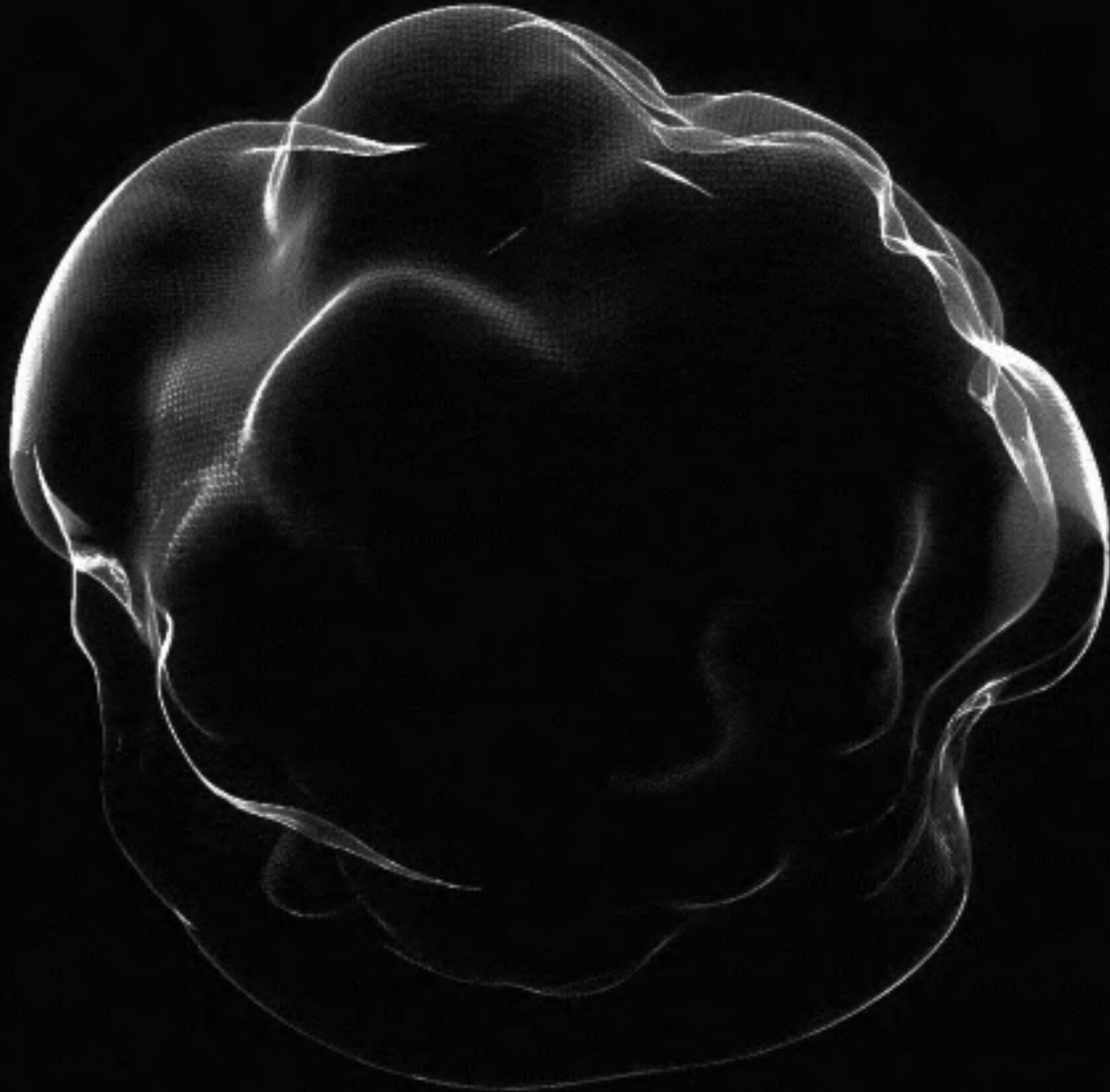
Vera Rubin, “Dark Matter in Spiral Galaxies”, 1983.



Act III: Dark Matter



Act III: Dark Matter



What is Dark Matter?



What is Dark Matter?



NOBODY KNOWS YET!!!

What is Dark Matter?



NOBODY KNOWS YET!!!

Although dark matter exists in many large-scale structures in the universe—not just galaxies—we currently only know that it is invisible and that it interacts via gravity.

What is Dark Matter?



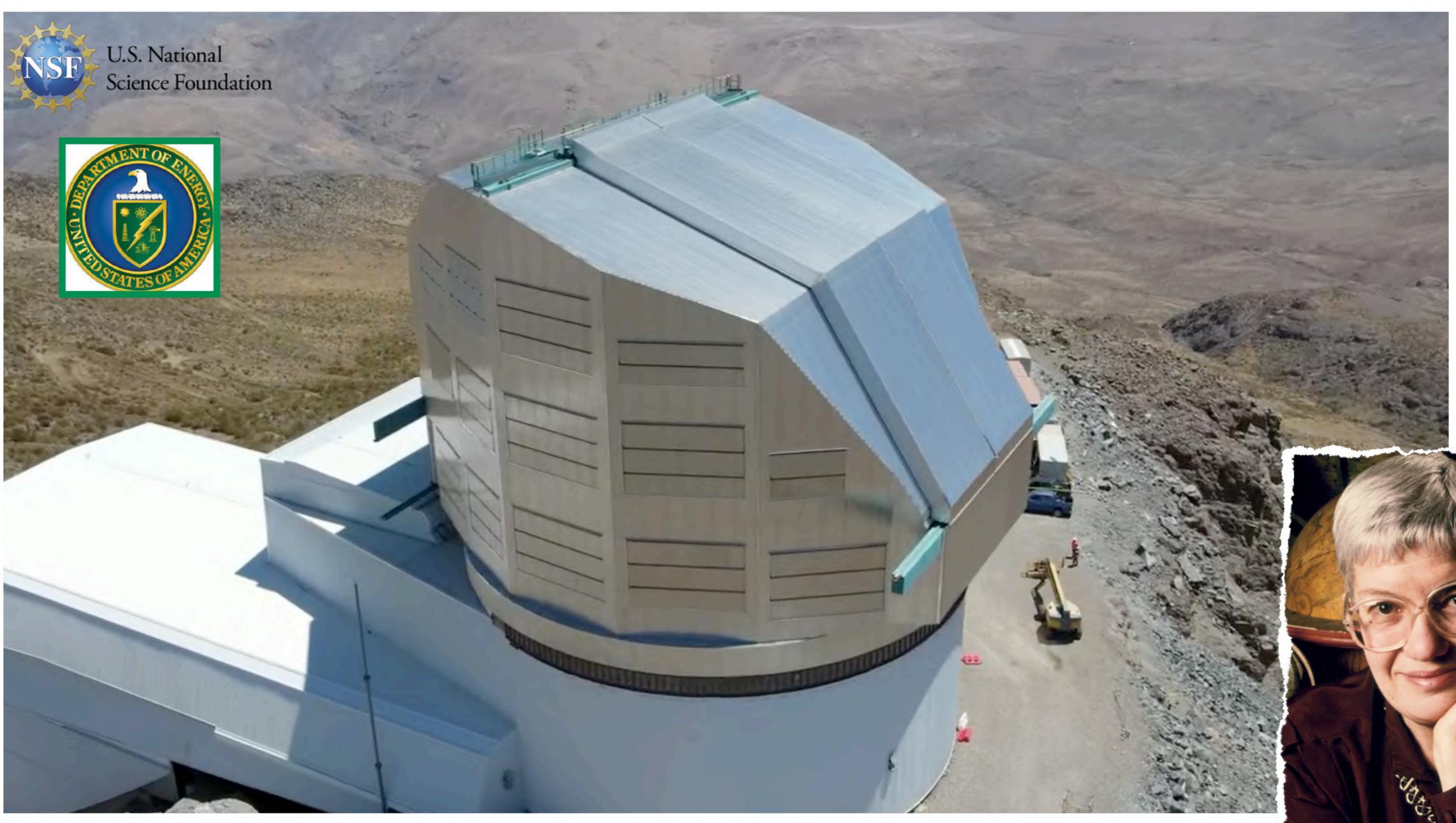
NOBODY KNOWS YET!!!

Although dark matter exists in many large-scale structures in the universe—not just galaxies—we currently only know that it is invisible and that it interacts via gravity.



Vera C. Rubin Observatory

Legacy Survey of Space and Time (LSST)



Located on Cerro Pachón, Chile, it will carry out a 10-year survey of the entire southern sky beginning in 2026.

Vera C. Rubin Observatory

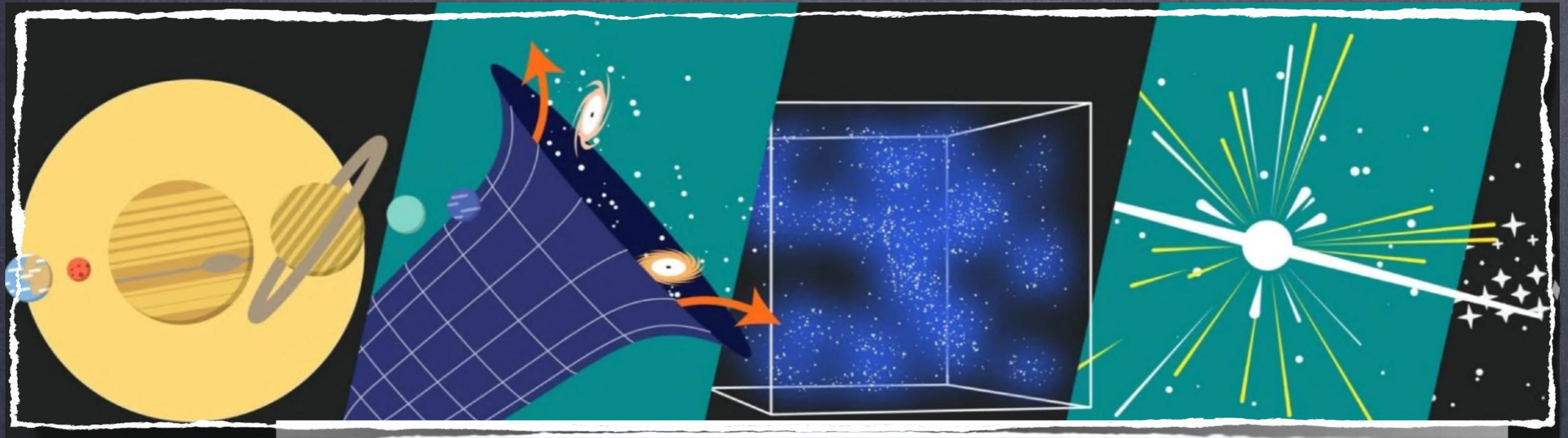
Legacy Survey of Space and Time (LSST)



Located on Cerro Pachón, Chile, it will carry out a 10-year survey of the entire southern sky beginning in 2026.

Vera C. Rubin Observatory

Legacy Survey of Space and Time (LSST)



Four major scientific goals:

- Understanding the nature of dark matter and dark energy.
- Creating an inventory of the Solar System.
- Mapping the Milky Way.
- Exploring objects that change position or brightness over time.

Vera C. Rubin Observatory

Weighing roughly 2,800 kg and the size of a compact car, the camera features a 3,200-megapixel sensor.

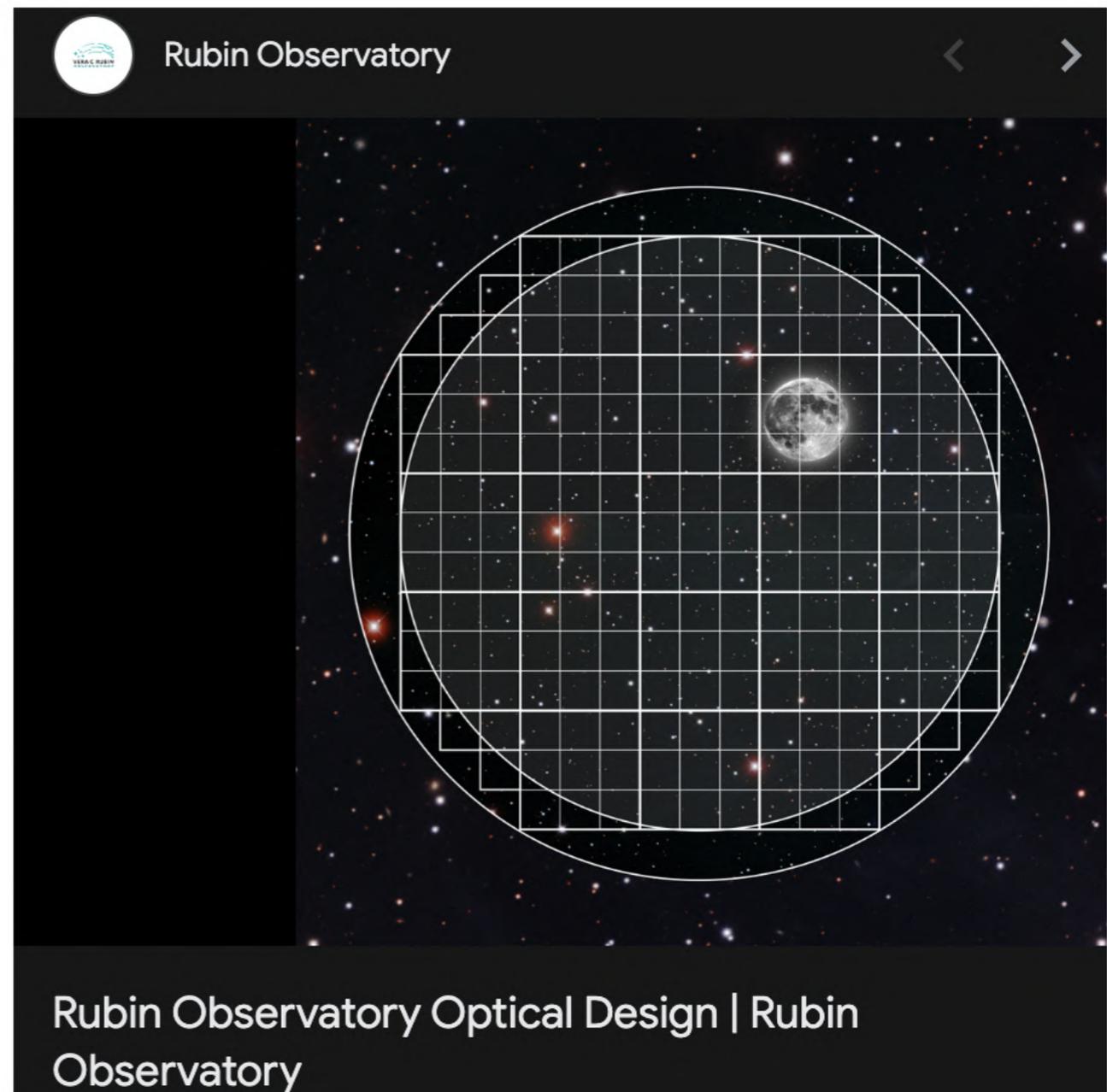


Vera C. Rubin Observatory

Weighing roughly **2,800 kg** and the size of a compact car, the camera features a **3,200-megapixel** sensor.



The camera's field of view spans an area just a bit larger than 40 full moons.

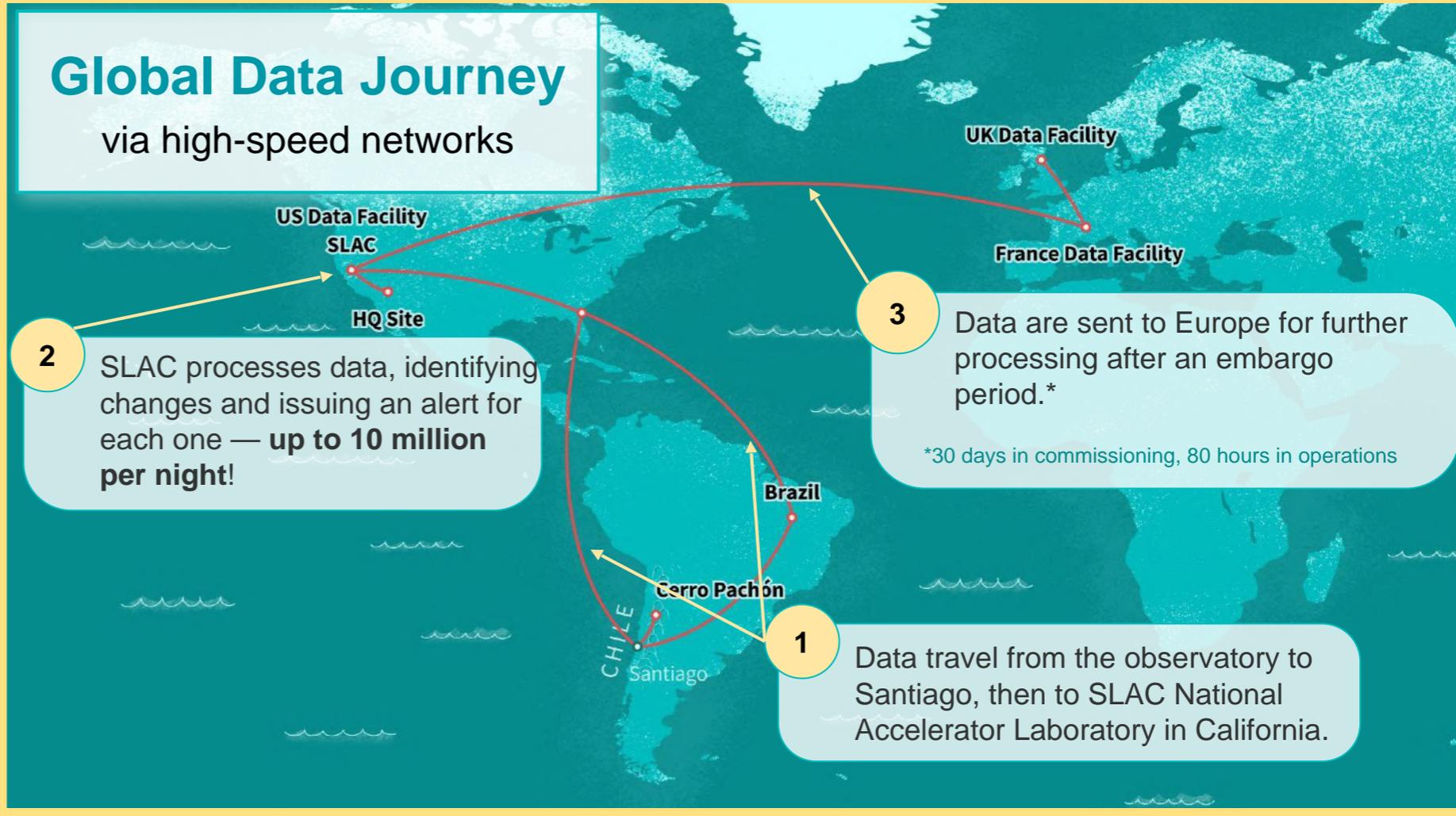


Vera C. Rubin Observatory



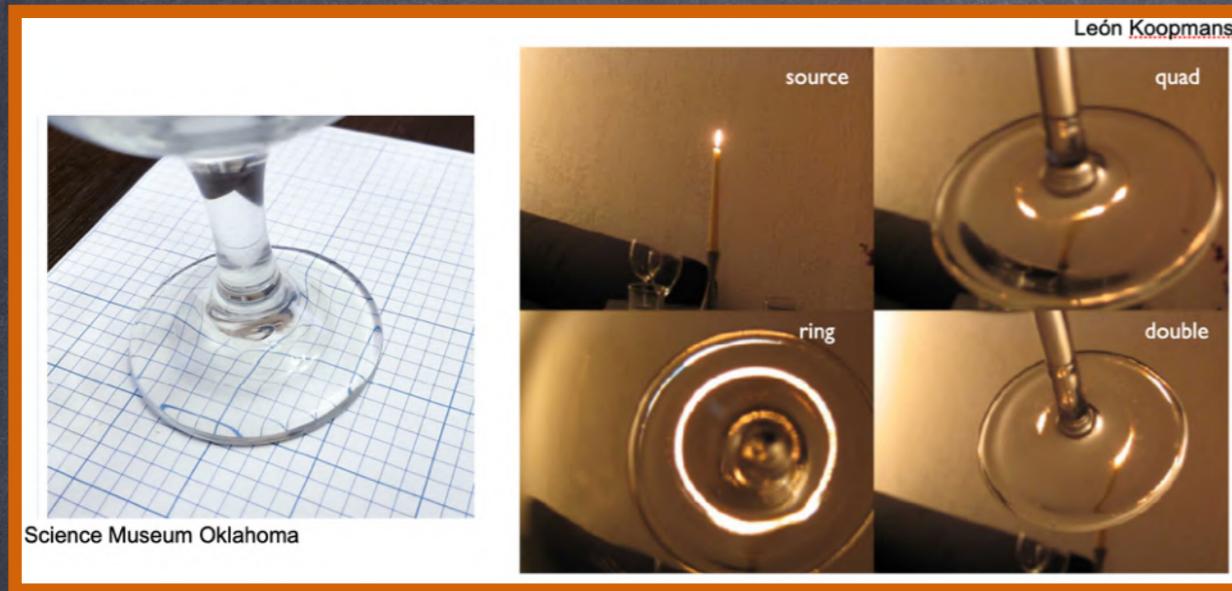
Global Data Journey

via high-speed networks

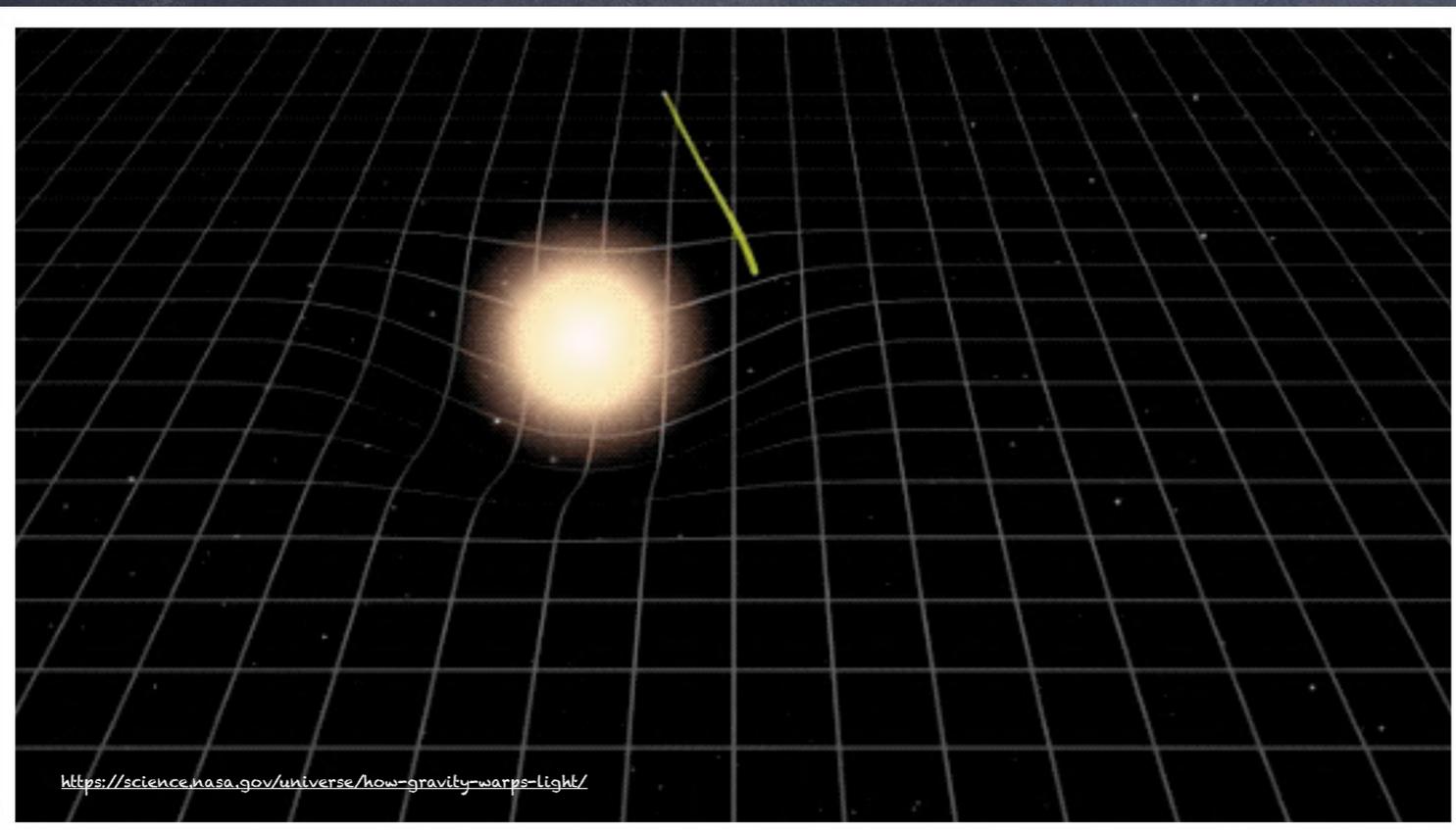


It will produce about **20 terabytes** of data every day, which is like watching Netflix continuously for over three years or listening to Spotify for roughly 50 years.

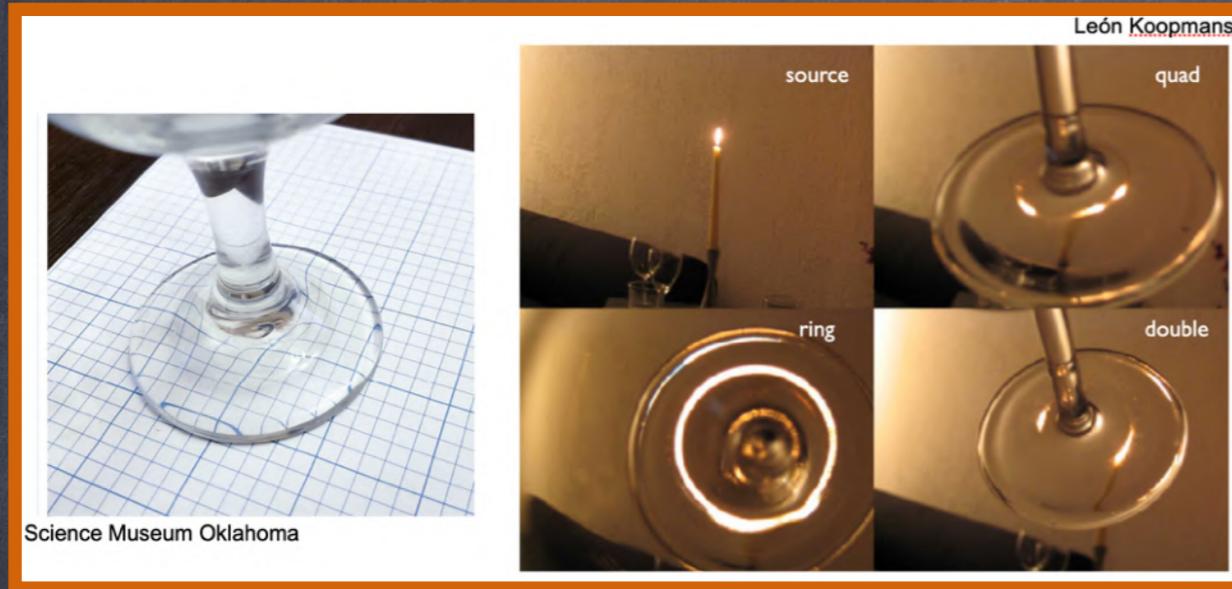
How will the Vera C. Rubin Observatory look for dark matter?



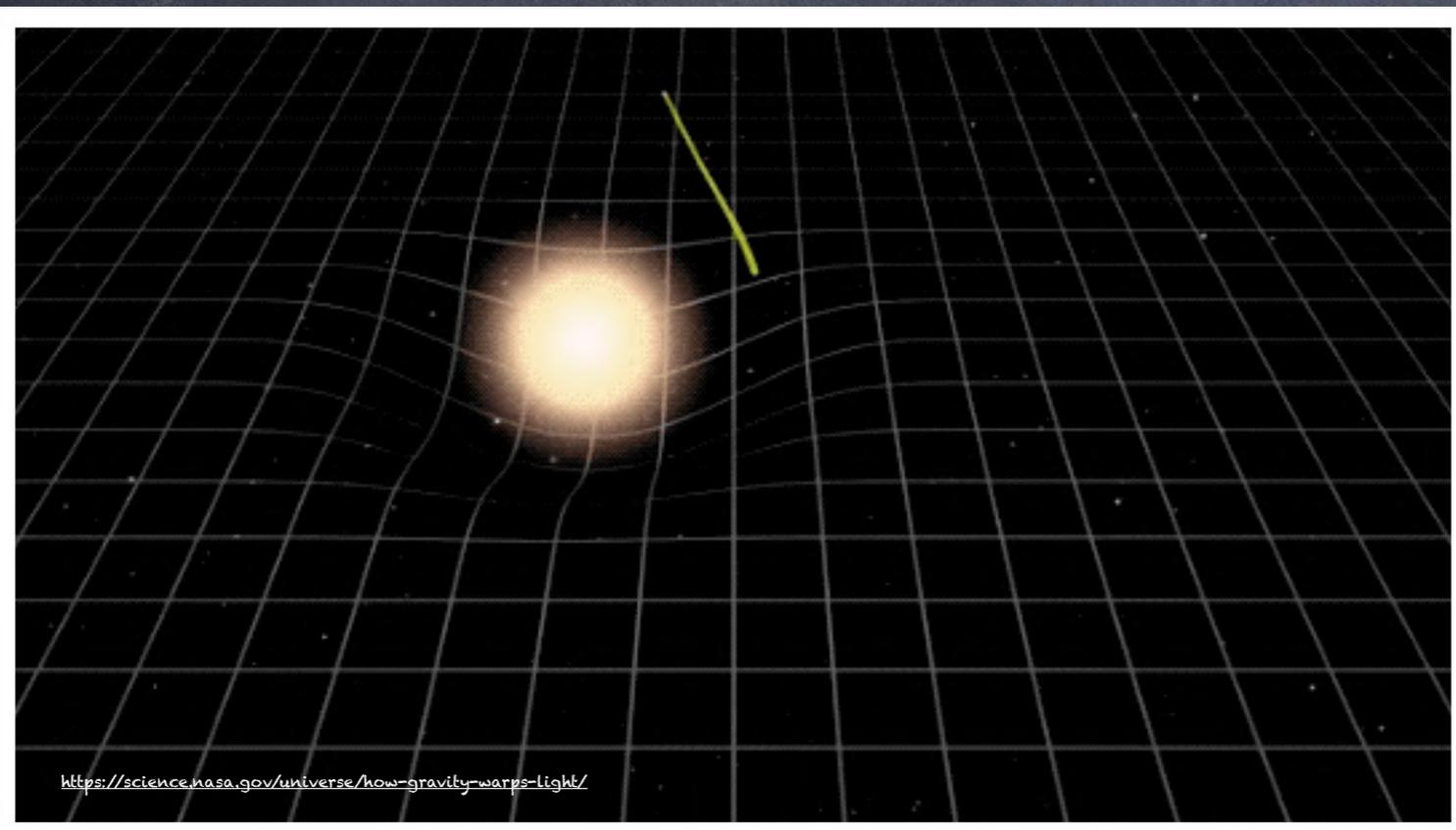
Gravitational Lenses



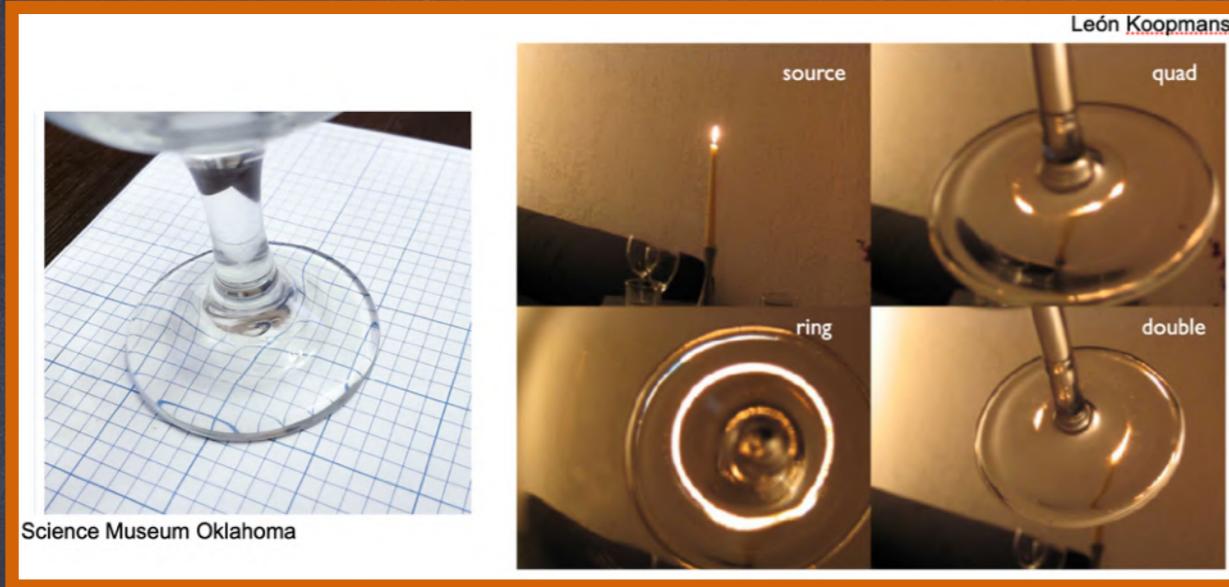
How will the Vera C. Rubin Observatory look for dark matter?



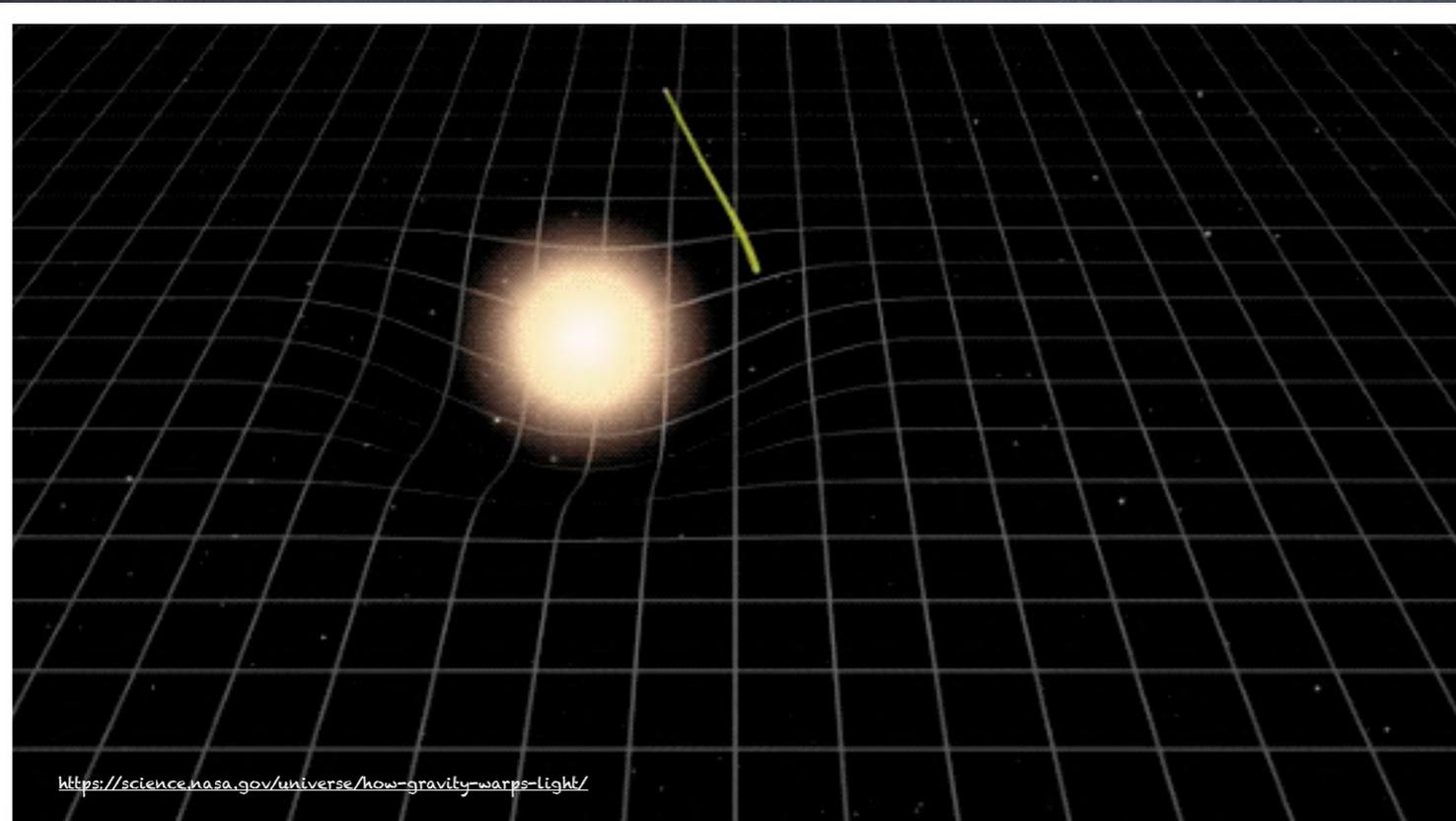
Gravitational Lenses



How will the Vera C. Rubin Observatory look for dark matter?



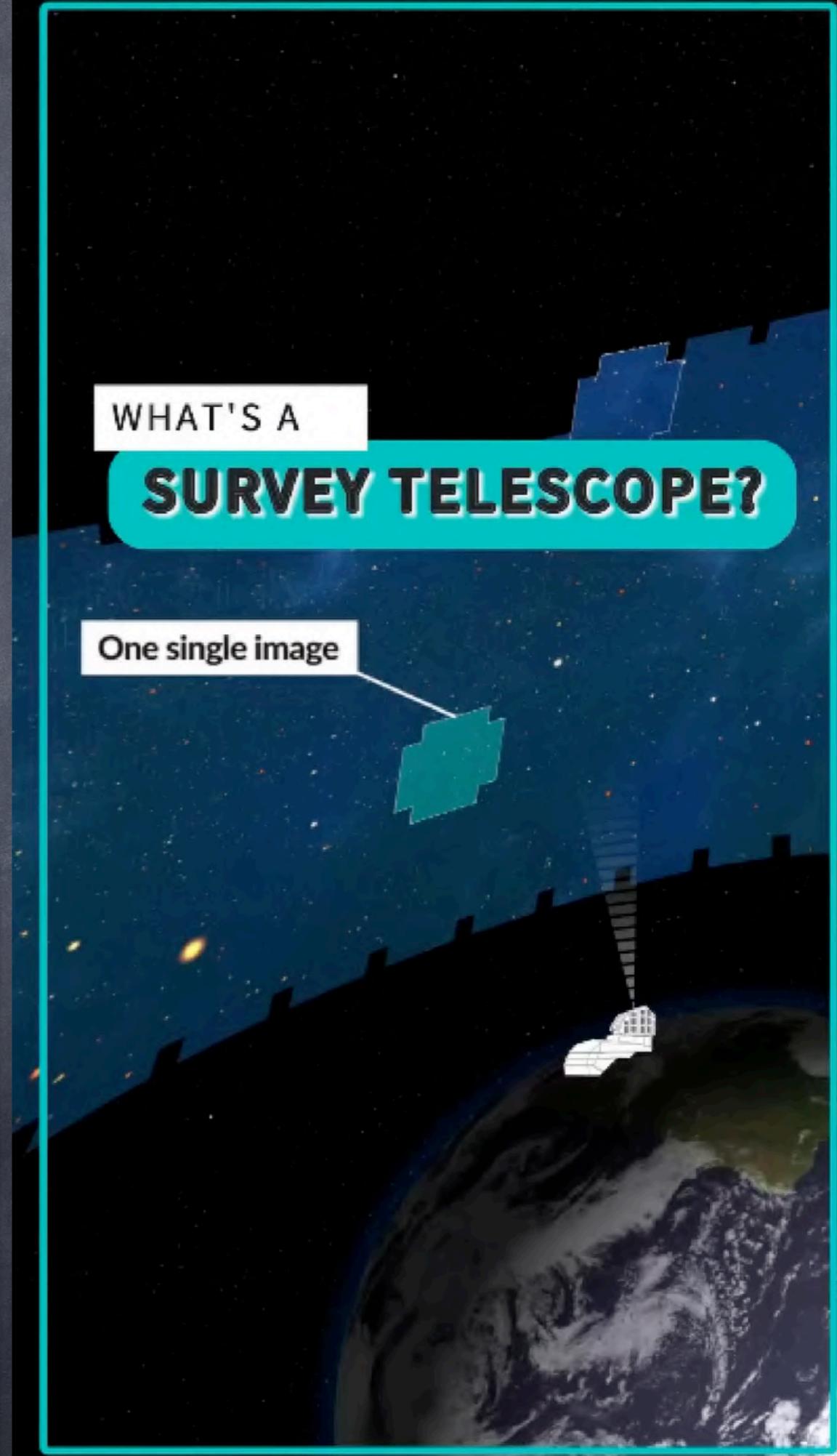
Gravitational Lenses



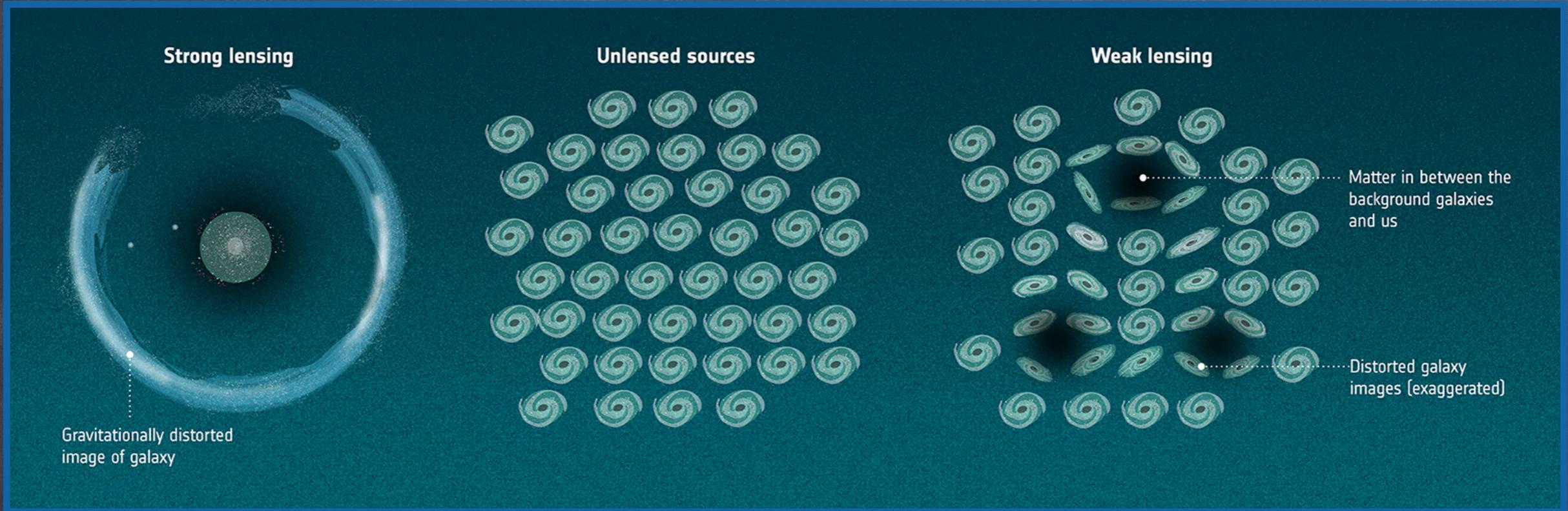
WHAT'S A

SURVEY TELESCOPE?

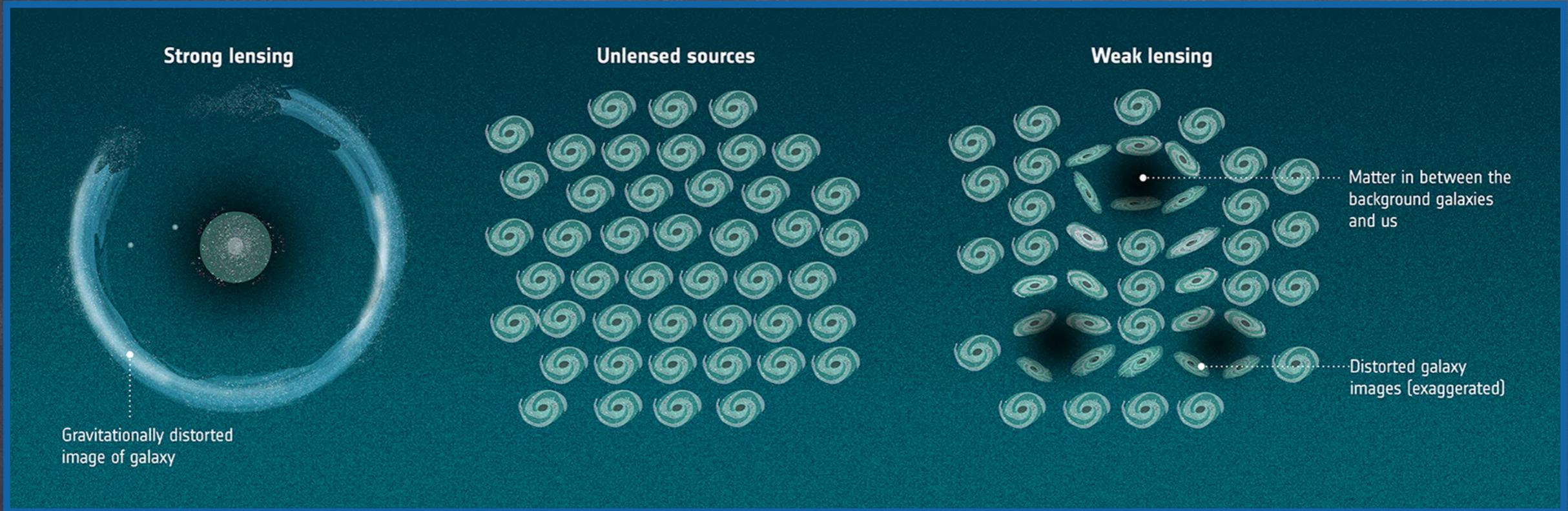
One single image



How will the Vera C. Rubin Observatory look for dark matter?



How will the Vera C. Rubin Observatory look for dark matter?





VERA RUBIN



astronomer

Matteo Farinella



@rubin_observatory



@VRubinObs

Take control of the Vera
Rubin Telescope



SCAN ME



VASO COSMICO

Science outreach
articles



"Don't shoot for the stars, we
already know what's there. Shoot
for the space in between because
that's where the real mystery lies."

-Vera C. Rubin

Thank you for your
kind attention!!!

Contact: linares.francisco@gmail.com

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