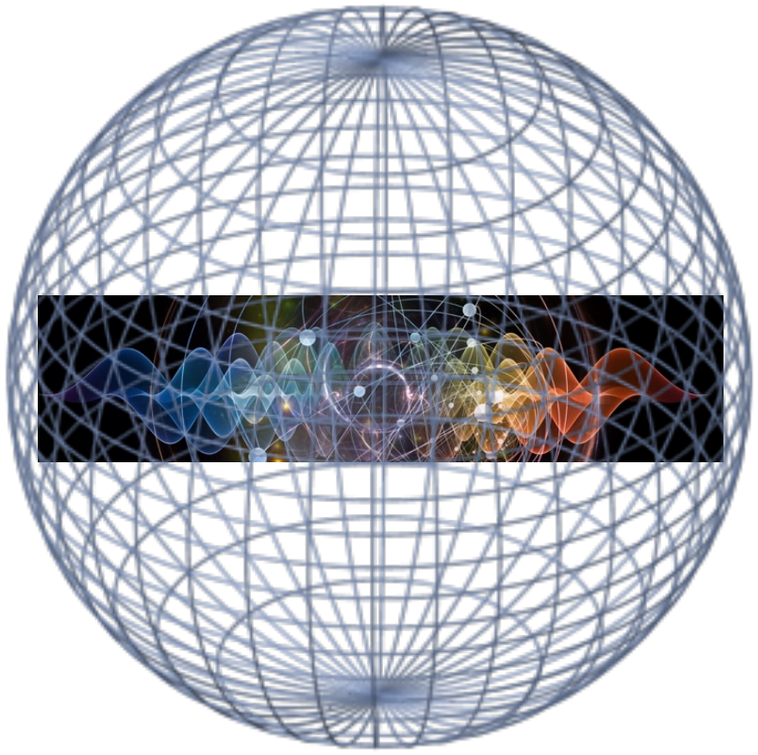
Mathematics & Physics Event

$a^2 + b^2 = c^2$



$E = mc^2$

Hosted by International Bilingual School
Mathematics and Physics department
Marie-Hélène LACOMBE & Russel HENSHELWOOD
& Pierros NTELIS

Outline

Presentation of speakers

Why we study mathematics and physics ?

Mathematics

Physics

Astrophysics and Cosmology

Telescopes

Conclusion

Dr. Pierros Ntelis

2008-2013, Bachelor of Mathematics and Physics
at National Technical University of Athens, Greece

2013-2014, Master in Astrophysics & Cosmology
at University of Paris, France

2014-2017, PhD in Fundamental Physics & Cosmology
at University of Paris, France

2018-2020, PostDoc in Observational Cosmology
at Aix-University, CPPM, France

Since 2022, Teacher of Mathematics in IBS

Specialised in

- Astrophysics
- Cosmology

Dr. Anaëlle Legros

2010-2015, Licence et Magistère in Fundamental Physics,
at Université Paris-Saclay

2015-2018, PhD in Experimental Physics, Condensed Matter Physics
at CEA Saclay, France and Sherbrooke University, Canada

2019-2021, Post-doctorate scholar in Materials and lasers
at Johns Hopkins University in the Baltimore, Maryland, US

Since 2022, Teacher of Mathematics in IBS

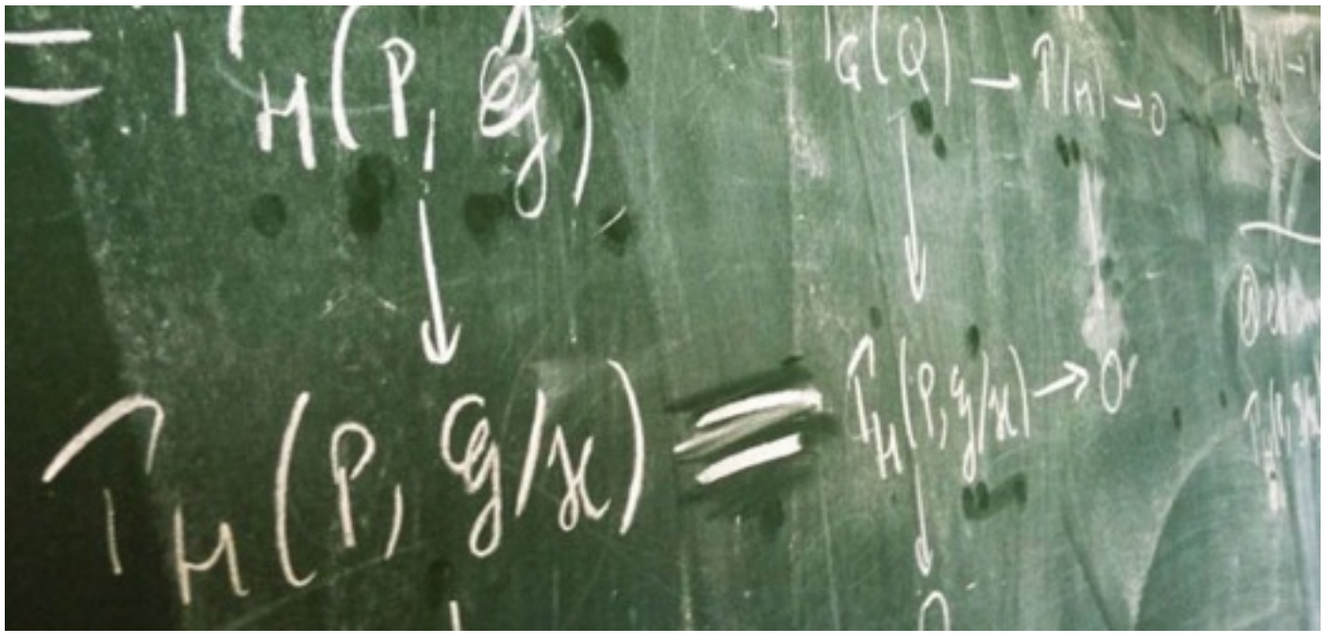
Specialized in:

- Experimental condense matter physics
- Studying materials with lasers.

Centre of Theoretical Physics (CPT)
in Marseille

Presenters:

Prof. Xavier Leoncini
&
Ass. Prof. Thomas Krajewski



Prof. Xavier Leoncini

Licence and Master at Ecole Normale Supérieur and Berkeley

PhD in South of France
Post Doc in Theoretical statistical Physics, at US - Princeton

Center of Theoretical Physics in Marseille, France,
2003-2018 , Lecturer in Physics
Since 2018, Professor in Physics

Specialised in:

- Classical statistical physics
- Chaos hamiltonians
- Classical dynamical systems
- Mechanics of fluids
- Fusion plasma
- biophysics

Ass. Prof. Thomas Krajeswski

1993-1995, Ecole Normale Supérieure de Lyon
at Lyon University, France
1995-1998,PhD in Geometry and particle physics
at Aix-Marseille University, France
1998-2002, Post doc in theoretical physics
at Scuola Internationale Superiore di Studi Avanzati (SISSA)
Italy

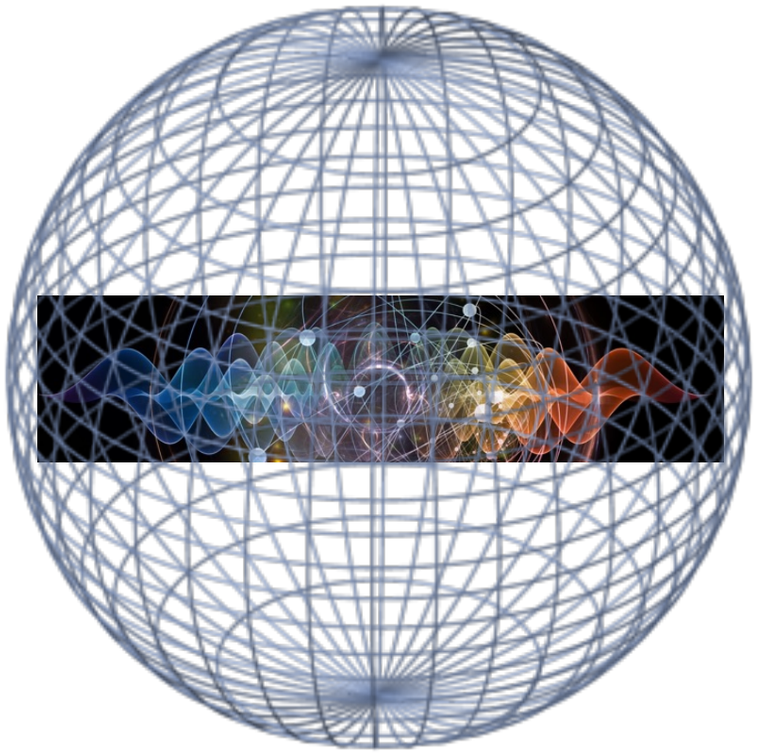
Center of Theoretical Physics in Marseille
Since 2002, Lecturer in Physics
Since 2018, Ass. Professor in Physics

Specialised in

- Aspects of physics
  - geometrical
  - combinatorial
- Renormalization theory
- Matrix and tensor models

Why we study Mathematics & Physics ?

$a^2 + b^2 = c^2$



$E = mc^2$

One simple question *multiple simple answers !*

Philosophy

Philosophy originates from the greek word, ***φιλοσοφία***,
which is a compound word, composed by
the word, **φιλο-, friendly**, and word **-σοφία, wisdom**.
Ergo, philosophy means being **friends with wisdom.**

Officially, modern Philosophy is the study of
general and fundamental questions:

abstraction, existence, reason, knowledge, values, mind, and language.

Such questions are often posed as problems to be studied or resolved.

wikipedia

Mathematics

Mathematics originates from the greek word, *μάθημα*, which means learning. In modern greek the term mathematics is translated as *μαθηματικά*

- Axioms

$1 \in \mathbb{N}, \pi \simeq 3.14 \in \mathbb{Q}', e^{0\pi} \in \mathbb{R}, e^{2\pi i} \in \mathbb{C},$

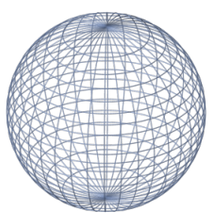
Numbers

$(a \pm b)^2 = a^2 \pm 2ab + b^2$

Algebra

Derivatives (changes)

$$f'(x) = \frac{\partial f}{\partial x}$$
$$f''(x) = \frac{\partial^2 f}{\partial x^2}$$
$$\ldots = \ldots$$
$$f^{(n)}(x) = \frac{\partial^n f}{\partial x^n}$$



Geometry

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$$

Limits

Integrals

$$F(x) = \int_0^x f(s)ds$$

$a^2 + b^2 = c^2$

Theorems

with Proofs

wikipedia

Physics

Physics originates from the greek word, *φυσική*, which means the study of nature and reality.

Newton 2nd law of motions

$$F = ma$$

$$\frac{\partial p}{\partial t} = m\frac{\partial^2 x}{\partial x^2}$$

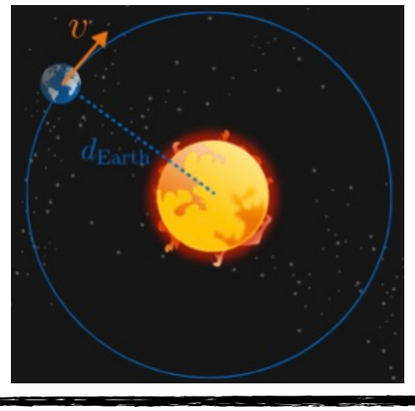
Special relativity (Quantum mechanics)

$$E = mc^2$$

Small world

Gravitational Forces

$$F_{12} = G_N \frac{m_1 M_2}{r_{12}^2}$$



General relativity (Gravity)

$$G_{\mu\nu} \propto T_{\mu\nu}$$

Large world

Geometrical curvature
tells the mass how to move

Astrophysics and Cosmology

Astrophysics originates from the greek words:

- *φυσική*, which means the study of nature,
- αστρο, which means star.

Cosmology originates from the greek words

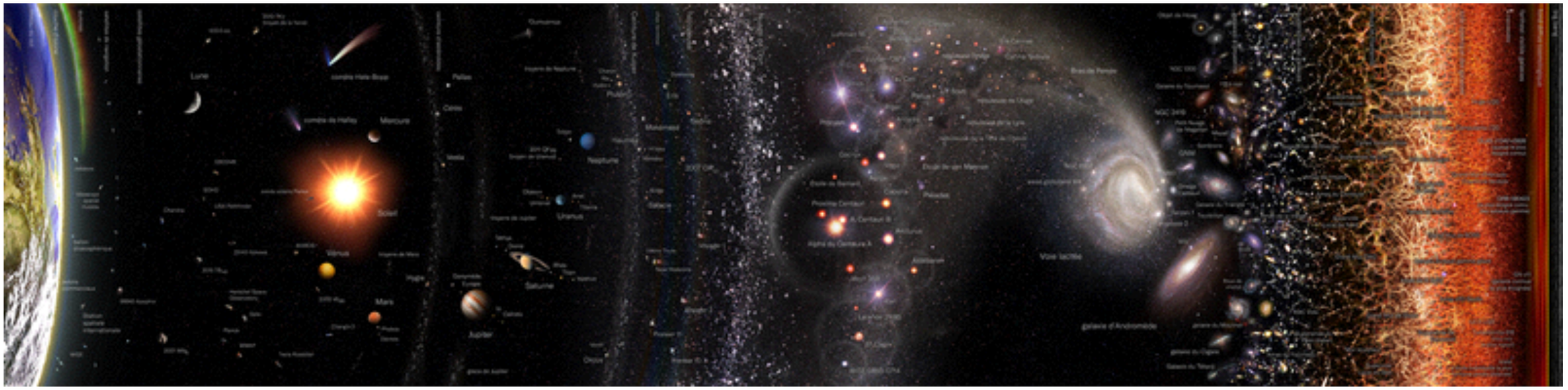
- κοσμος, which means universe
- λογος, which means speech.

Astrophysics and Cosmology

Combining previous concepts we can study the nature and the universe

Cosmology is the study of the origin, dynamics and content of the universe

Earth -> Solar system -> asteroids -> galaxies -> large scale structure -> origins

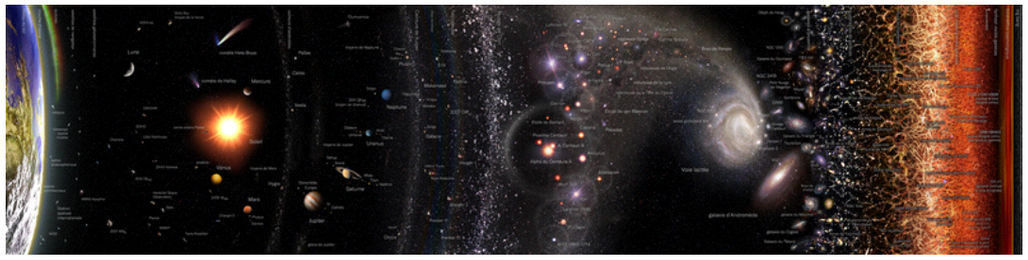


$$\mathcal{D}_\tau \left[f_X \left(\vec{x}, \vec{p}, \tau \right) \right] \simeq \mathcal{C} \left[f_X \left(\vec{x}, \vec{p}, \tau \right) \right]$$

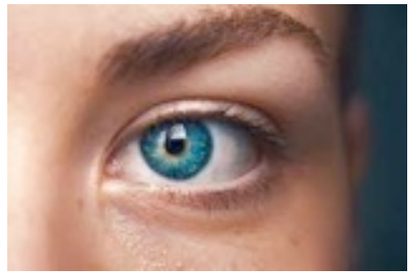
Large structure motions tells the origin of matter & interactions

How did we understand all these ?

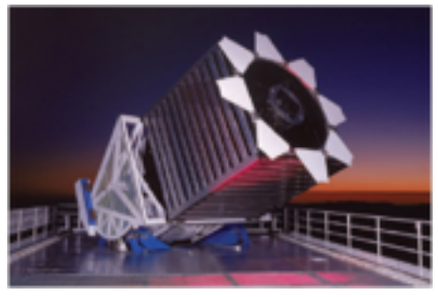
We just looked in the sky



with our naked eyes



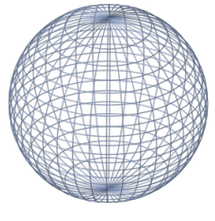
with telescopes



hyper
sensation

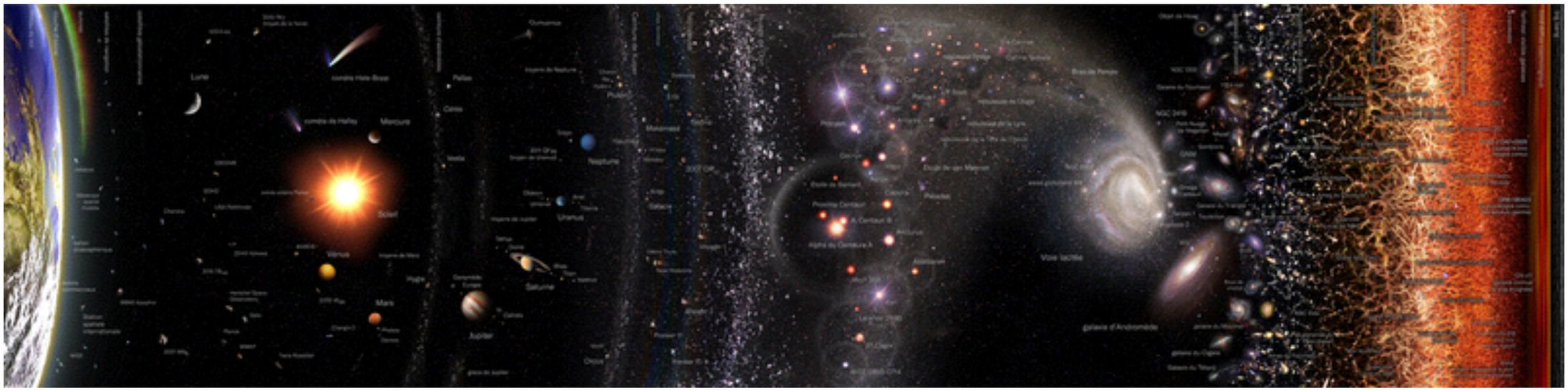
by using our
knowledge and imagination !

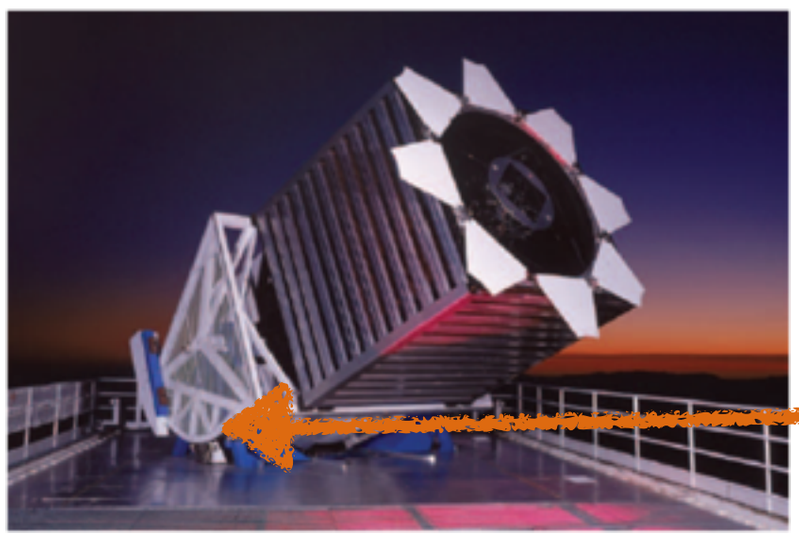
$$(a \pm b)^2 = a^2 \pm 2ab + b^2$$

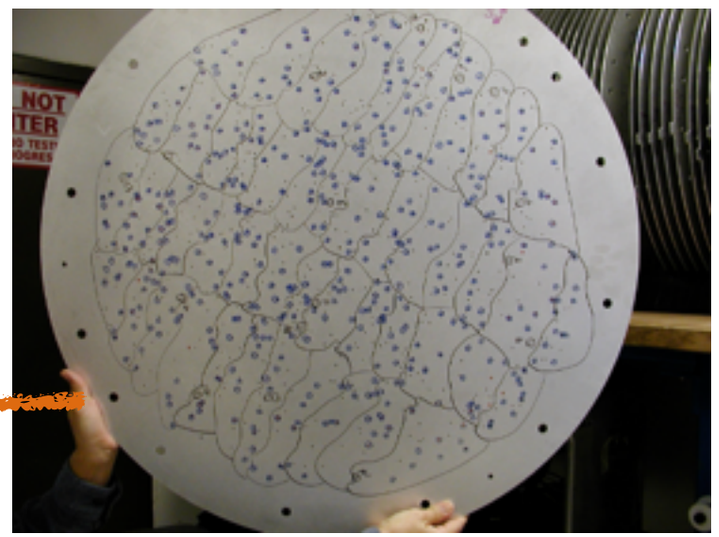


Basics of a Telescope

Earth -> Solar system -> asteroids -> galaxies -> large scale structure -> origins

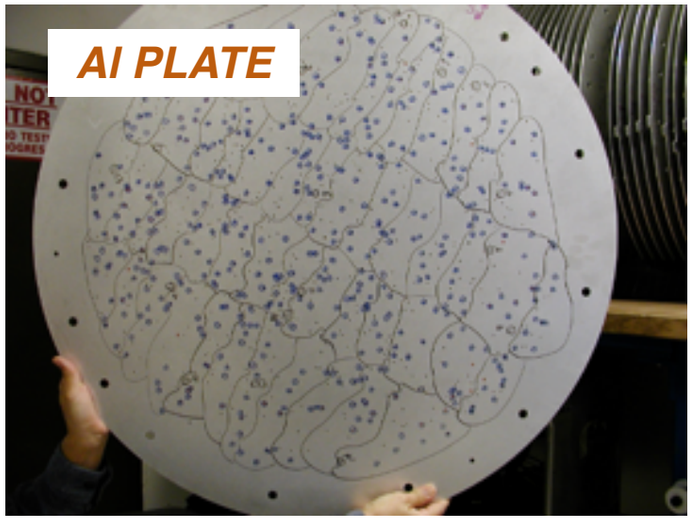


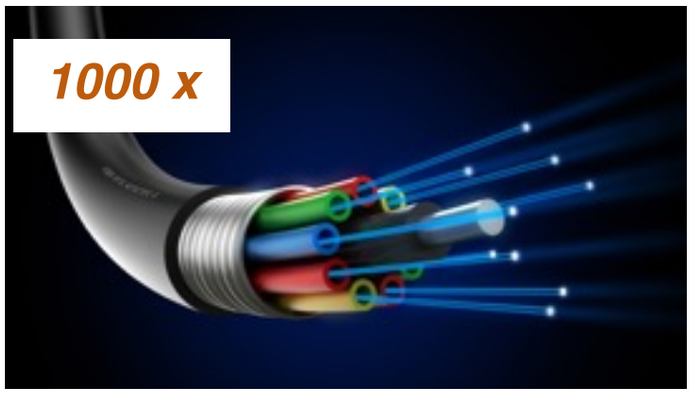




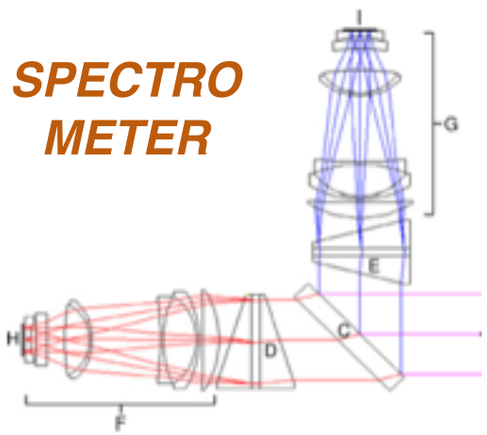
aluminum plate with wholes
in the base of the telescope

Take images of the night sky, to obtain galaxy targets !

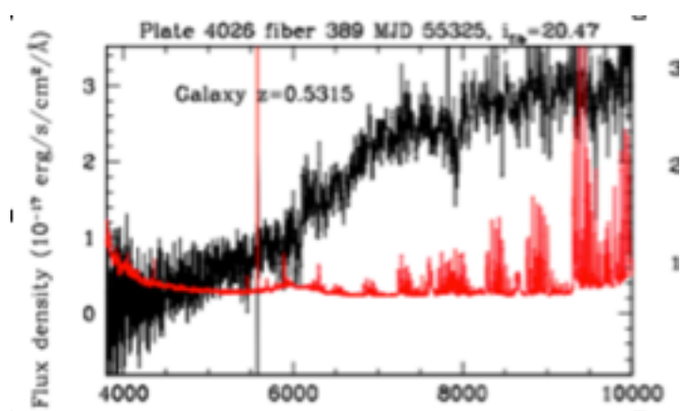




SPECTRO METER



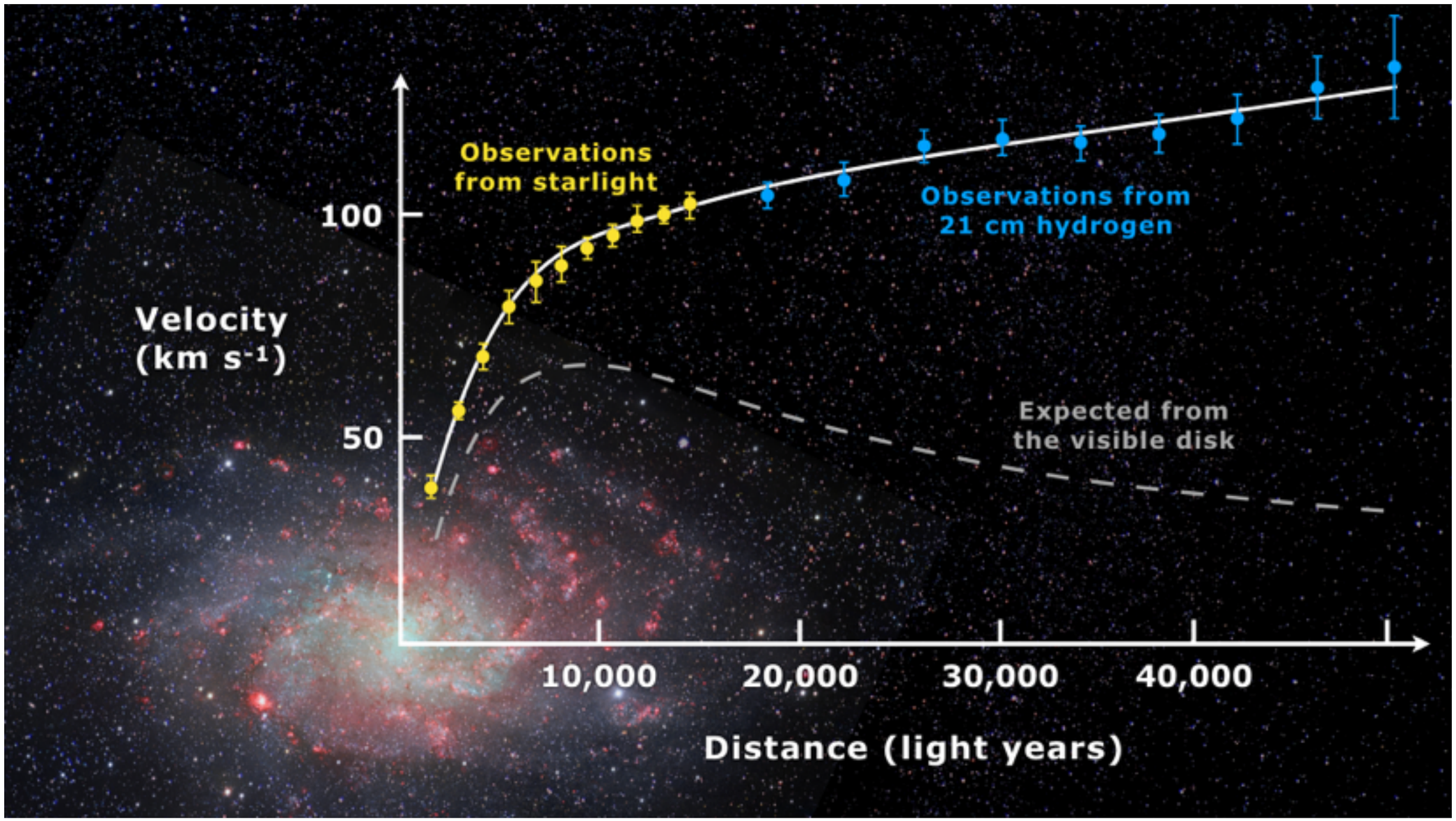
SPECTROSCOPY



Analyse galaxies with spectrometer
to get their velocity from light

What we have discovered ?

Dark Matter = Invisible Matter

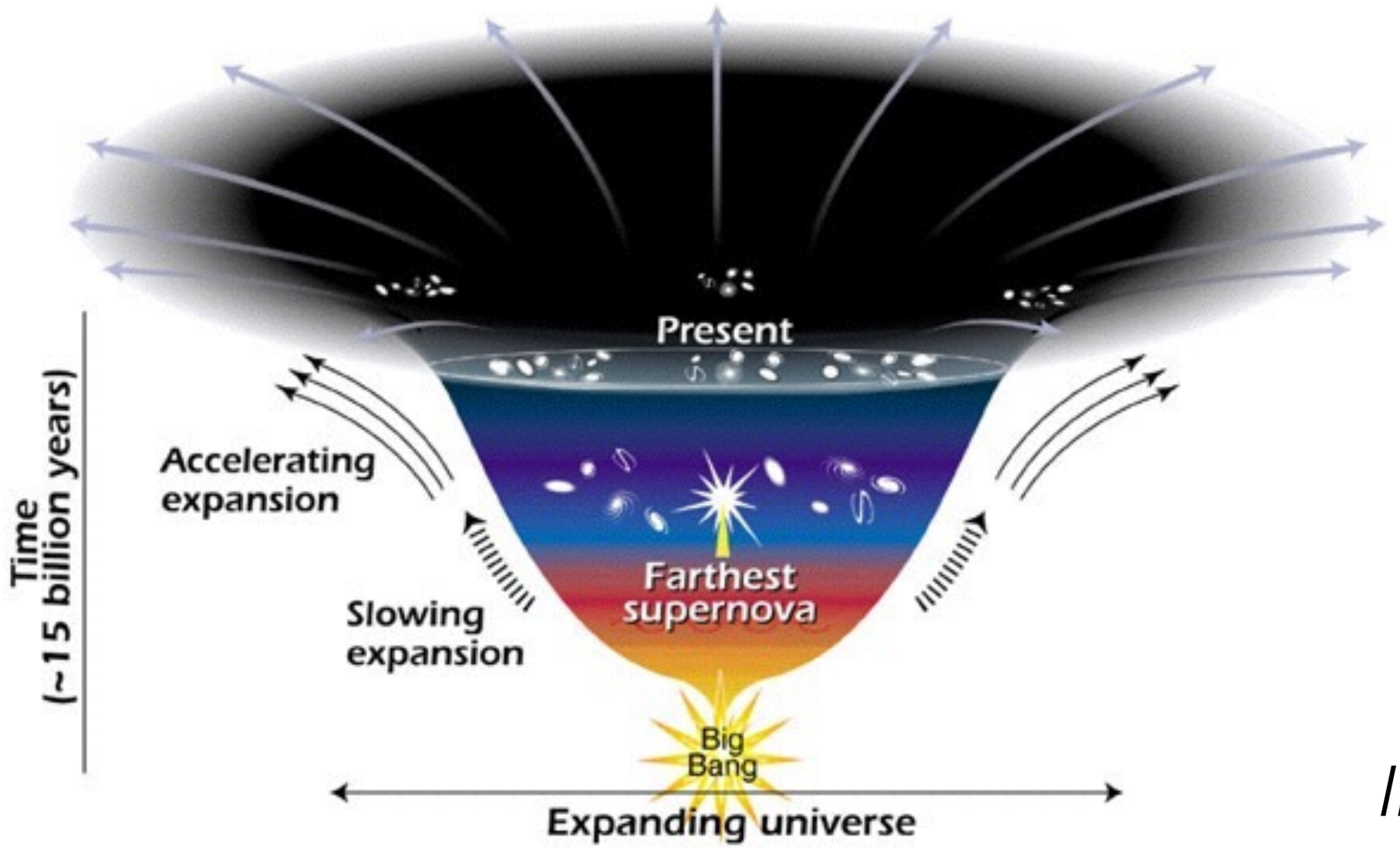


Galaxy velocity proportional to inverse square root of its radius and square root of its mass

$$v(r) = \sqrt{\frac{GM(r)}{r}}$$

Need more invisible mass !

Dark Energy = Repulsive Gravity

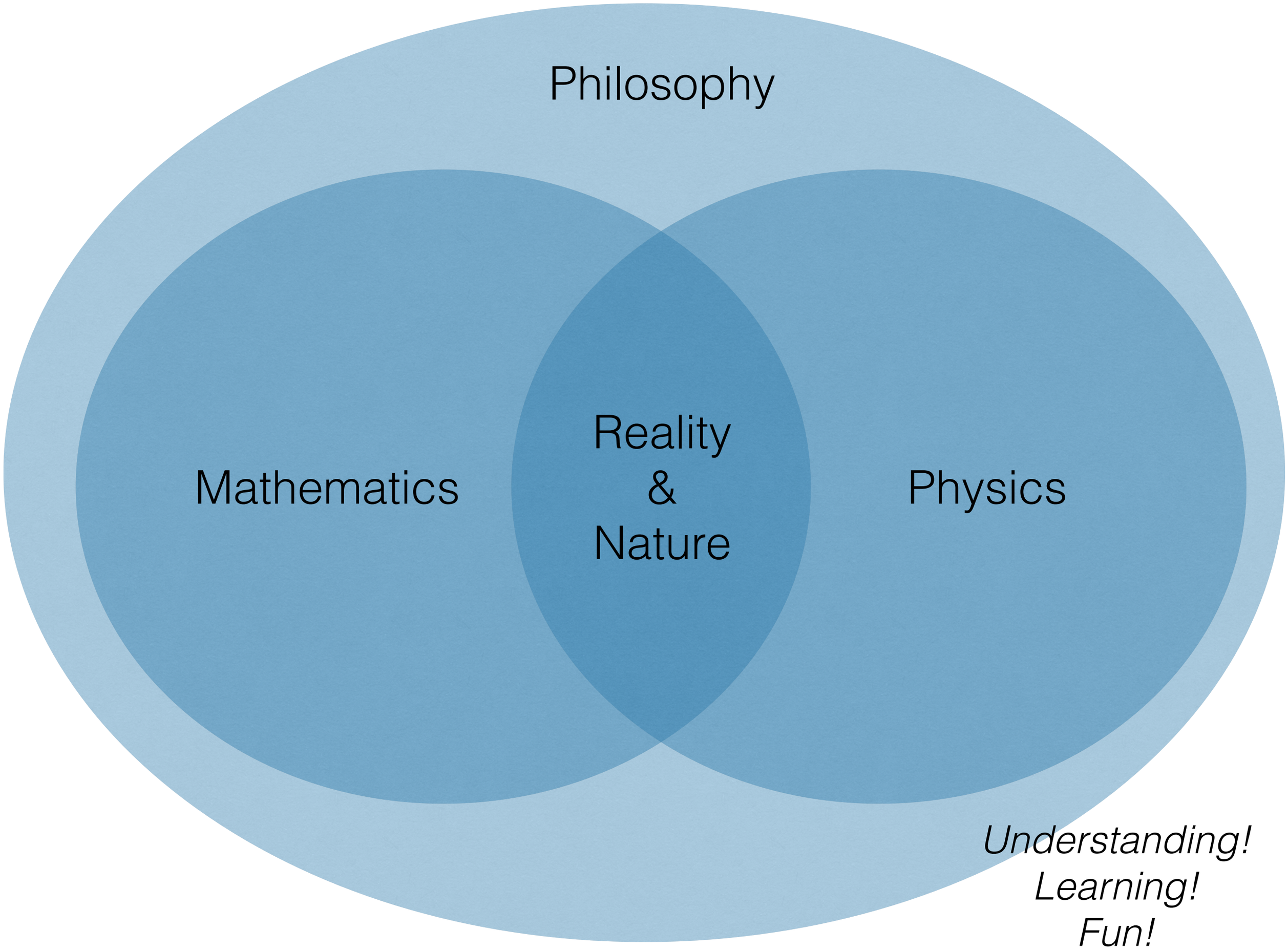


This diagram reveals changes in the rate of expansion since the universe's birth 15 billion years ago. The more shallow the curve, the faster the rate of expansion. The curve changes noticeably about 7.5 billion years ago, when objects in the universe began flying apart at a faster rate. Astronomers theorize that the faster expansion rate is due to a mysterious, dark force that is pushing galaxies apart.

Inflation is expansion in an exponential rate

So why we study Mathematics & Physics ?

Understanding!
Learning!
Fun!


Philosophy
Mathematics
Reality
&
Nature
Physics
Understanding!
Learning!
Fun!

Back up

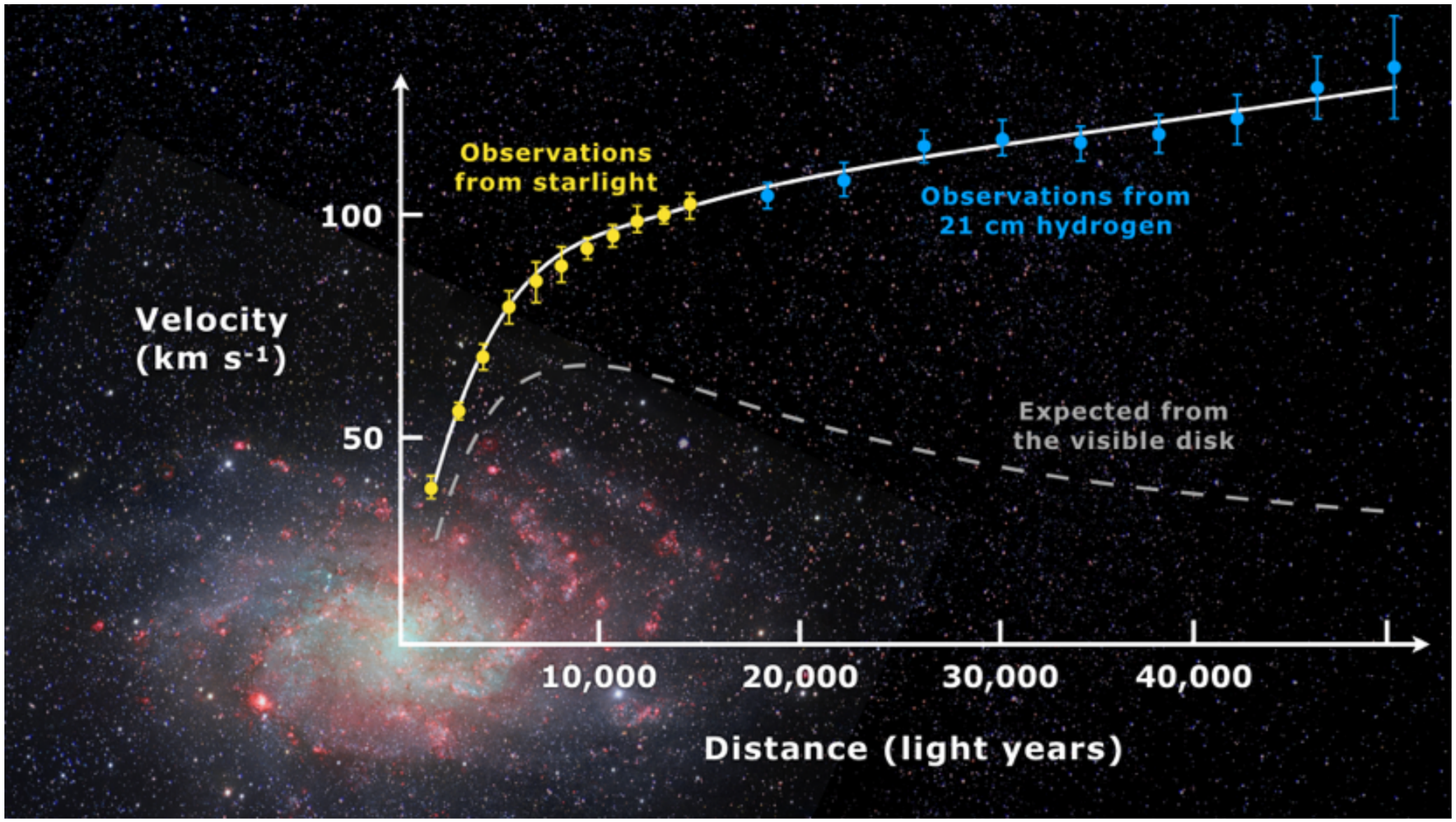

Thomas Krajeswski


Xavier Leoncini


Pierros Ntelis


Anaëlle Legros

Dark Matter !



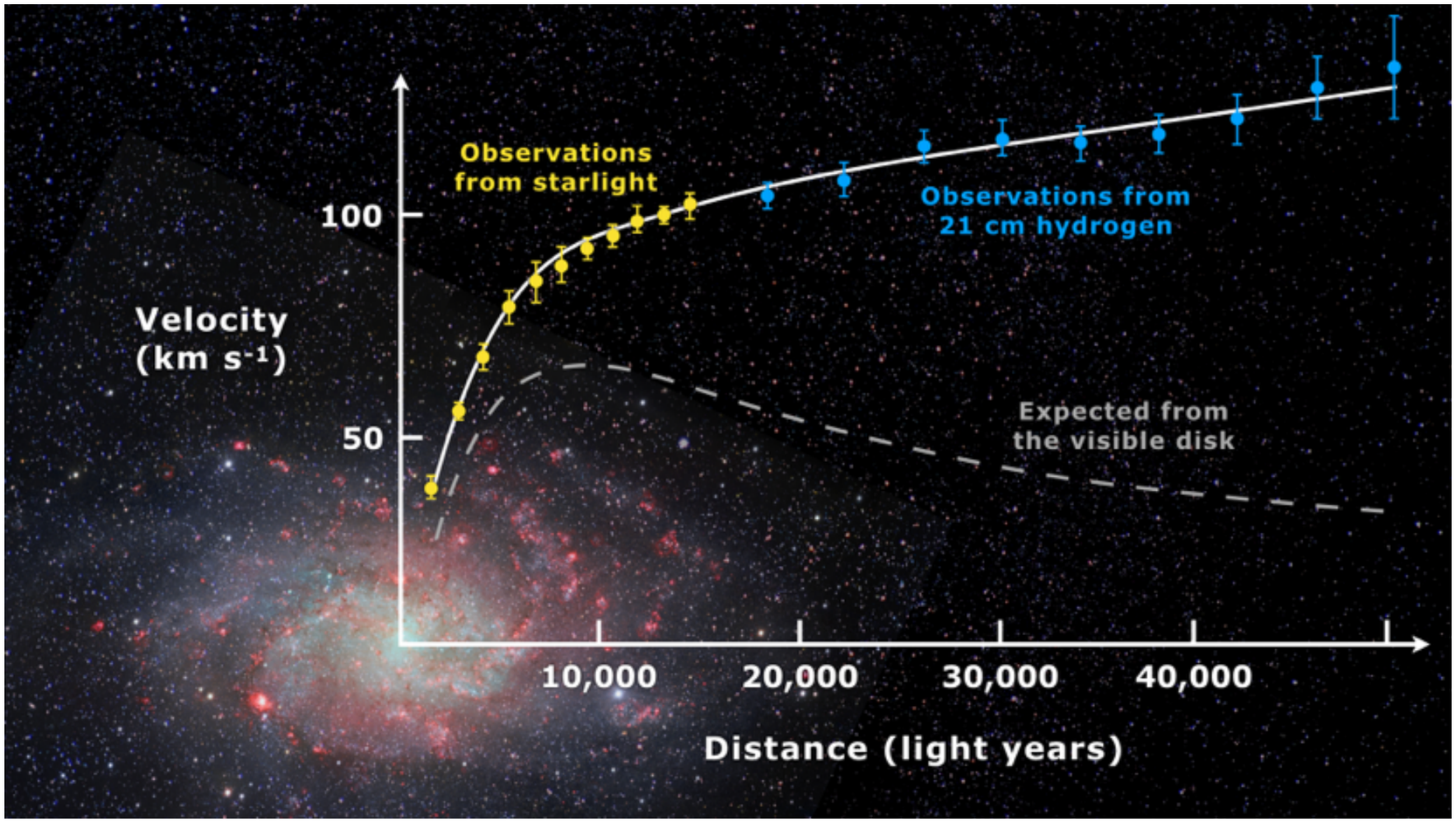
2 times Kinetic energy = Potential Energy

$$v(r) = \sqrt{\frac{GM(r)}{r}}$$

Mass profile:
Navarro–Frenk–White (NFW)

$$\rho_{\mathrm{NFW}}(r) = \frac{\rho_0}{\frac{r}{R_s}\left(1+\frac{r}{R_s}\right)^2}$$

Dark Matter !



2 times Kinetic energy = Potential Energy

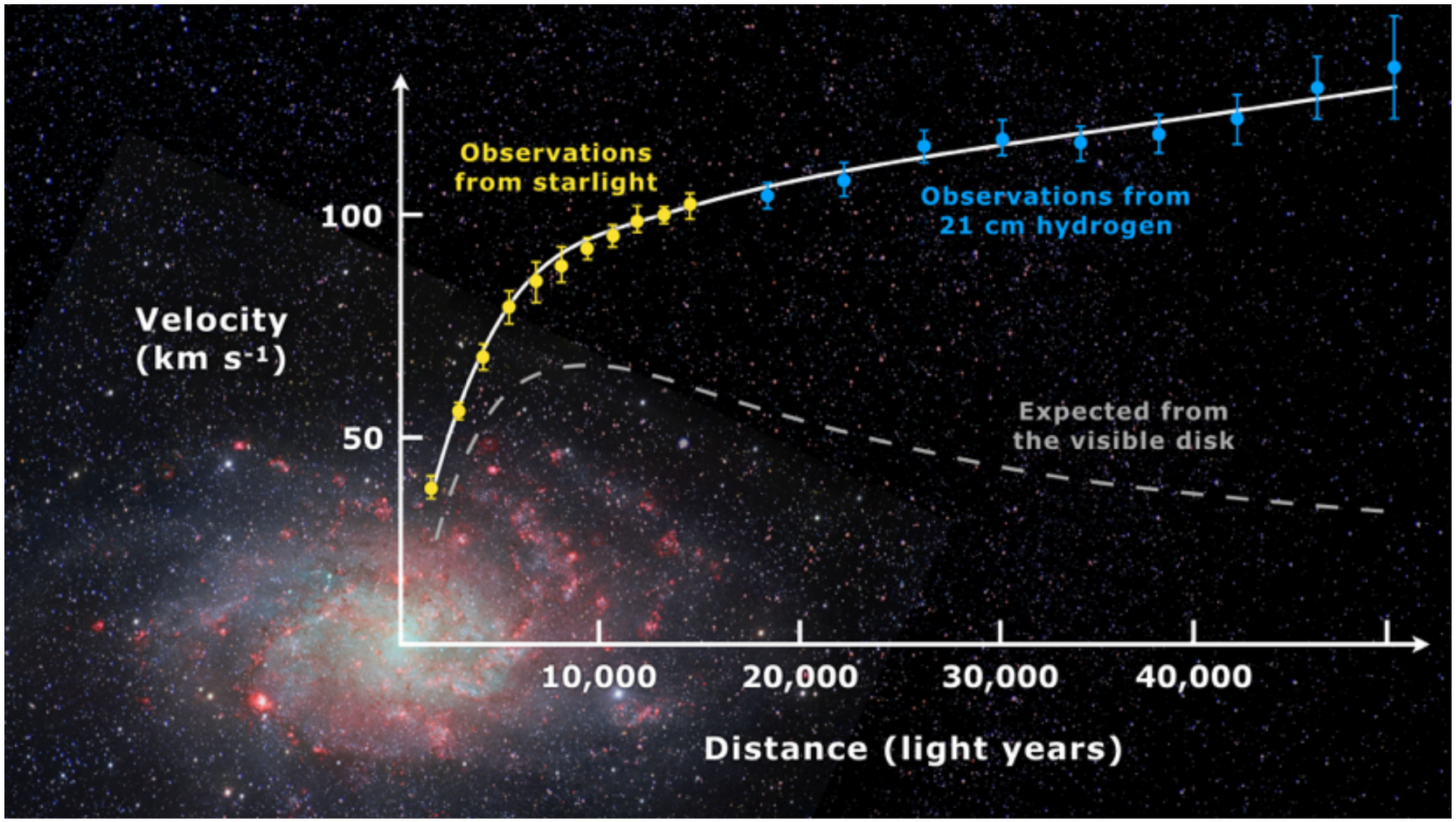
$$2\langle K\rangle = \langle V\rangle$$

$$2\ \ mv^2/2 = GMm/r$$

$$v^2 = GM/r$$

$$v(r) = \sqrt{\frac{GM(r)}{r}}$$

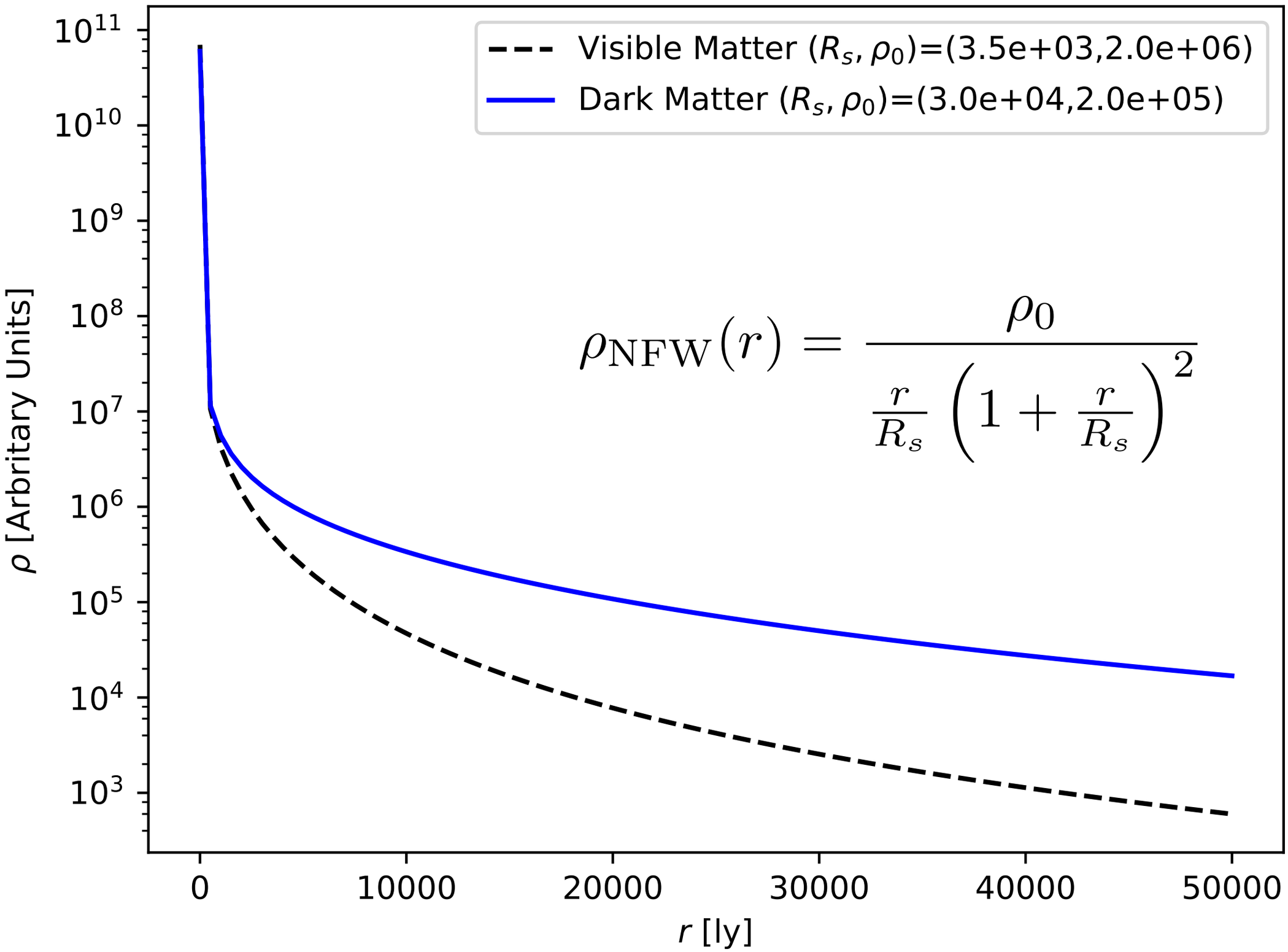
Dark Matter !



Mass profile:
Navarro–Frenk–White (NFW)

$$\rho_{\mathrm{NFW}}(r) = \frac{\rho_0}{\frac{r}{R_s}\left(1+\frac{r}{R_s}\right)^2}$$

r = radius
ρ_0 = central density
R_s = scale radius

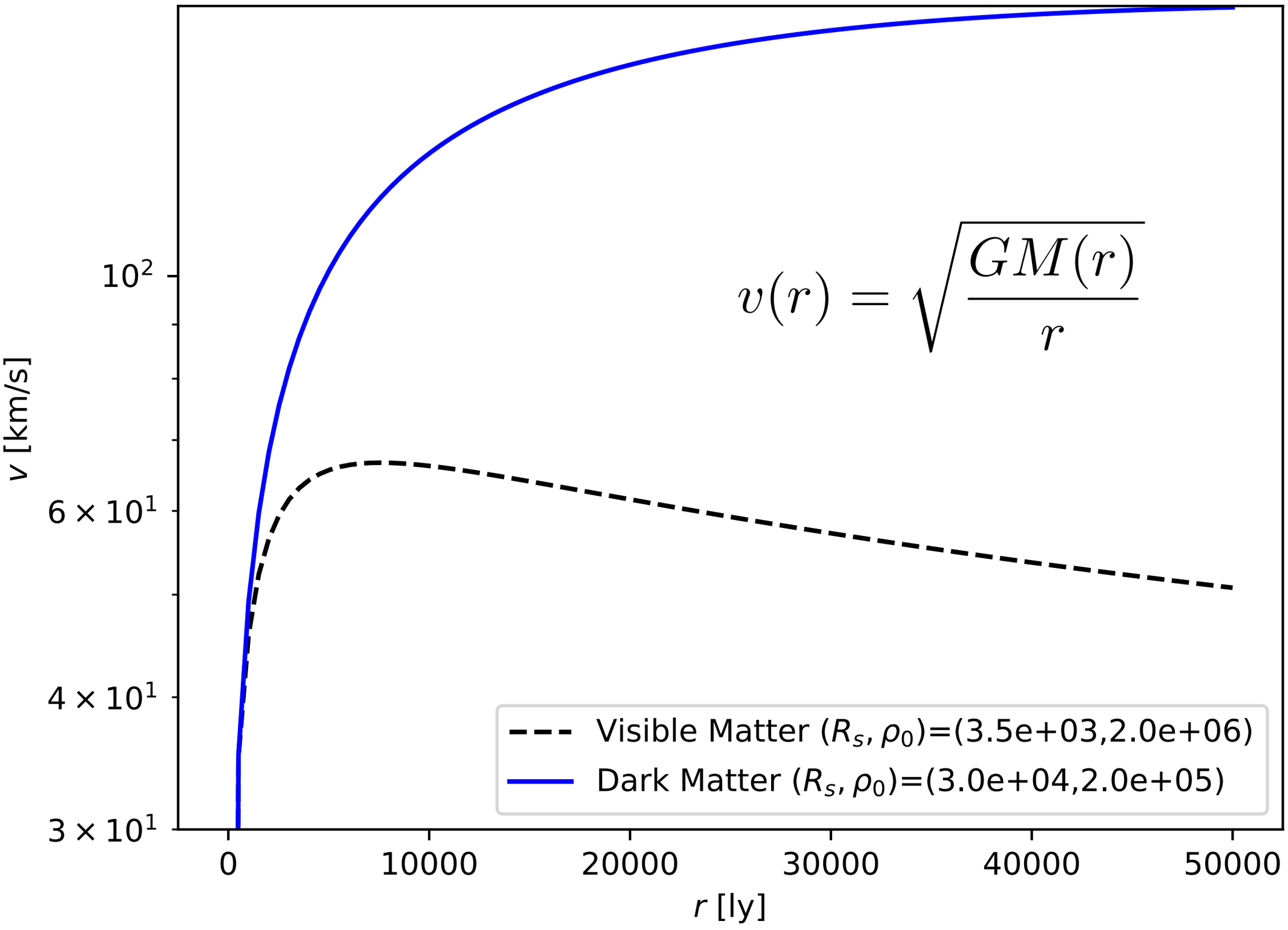

Visible Matter (R_s, ρ_0)=(3.5e+03,2.0e+06)
Dark Matter (R_s, ρ_0)=(3.0e+04,2.0e+05)
$\rho_{\mathrm{NFW}}(r) = \frac{\rho_0}{\frac{r}{R_s}\left(1+\frac{r}{R_s}\right)^2}$
ρ [Arbritary Units]
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
0
10000
20000
30000
40000
50000
r [ly]

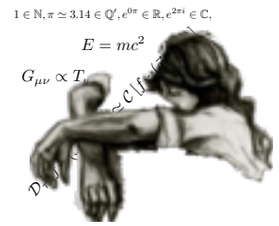
$$M(r) = \int_0^r ds\ 4\pi s^2\ \rho(s)$$

10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
M [Arbitary Units]

0
10000
20000
30000
40000
50000
r [ly]

Visible Matter (R_s, ρ_0)=(3.5e+03,2.0e+06)
Dark Matter (R_s, ρ_0)=(3.0e+04,2.0e+05)


$v(r) = \sqrt{\frac{GM(r)}{r}}$
10^2
6×10^1
4×10^1
3×10^1
v [km/s]
0
10000
20000
30000
40000
50000
r [ly]
Visible Matter (R_s, ρ_0)=(3.5e+03,2.0e+06)
Dark Matter (R_s, ρ_0)=(3.0e+04,2.0e+05)

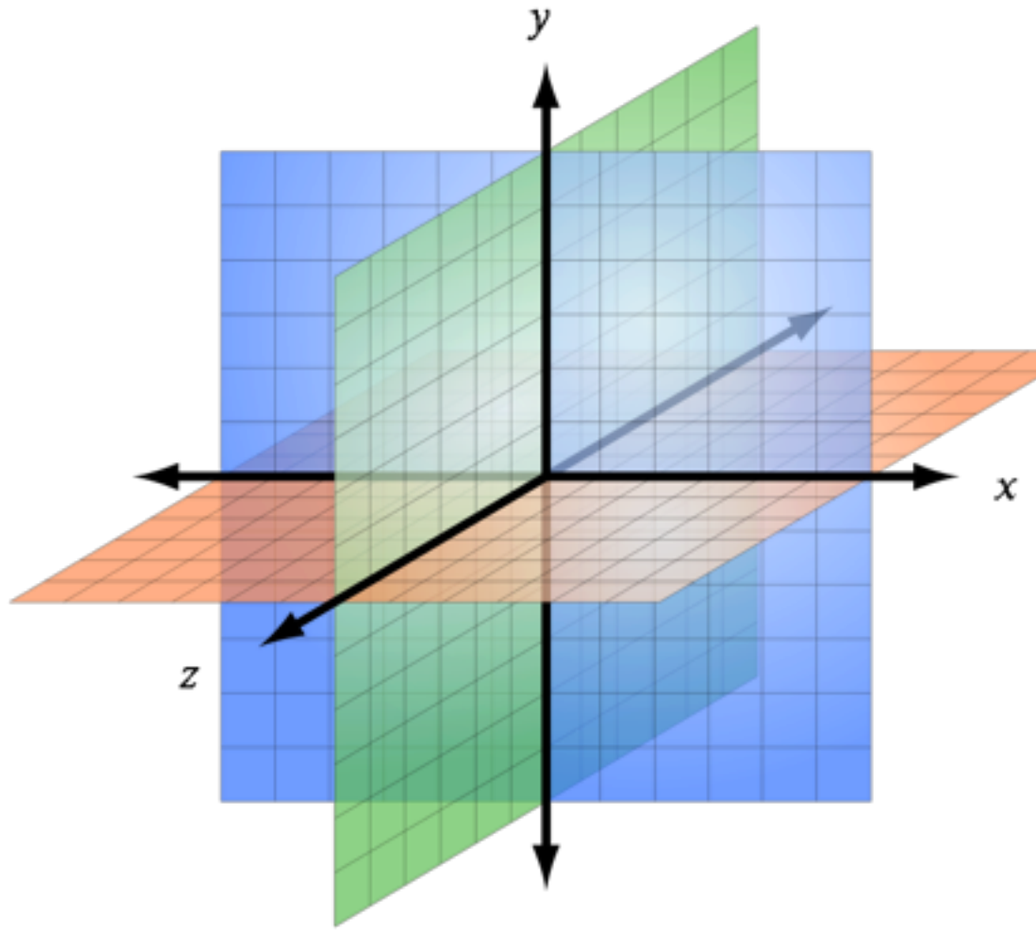


SPACE

Space is a boundless any number of dimensional extent
in which objects and events have relative position and direction.

The concept of space is considered to be of
fundamental importance to our
understanding of the physical universe,
as well as our generic abstract intuition.

However, disagreement continues
between philosophers over whether
it is itself an entity,
a relationship between entities,
or part of a conceptual framework.



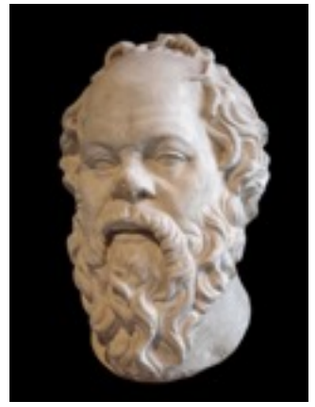
3 dimensional extent

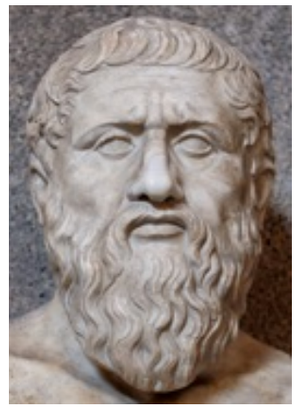
wikipedia

Debates concerning the nature,
essence and the mode of existence of space date back to antiquity;
namely, to treatises from

Greeks:

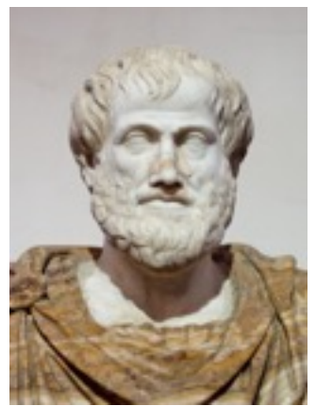
470–399 BC, *Socrates*' reflections of *khôra* (i.e. space)





428– 348 BC, Timaeus dialogues of *Plato*, *khôra*

384–322 BC, *Aristotle* definition of *topos* (i.e. place)



300 BC, Euclid, properties of space,
i.e. Euclidean geometry

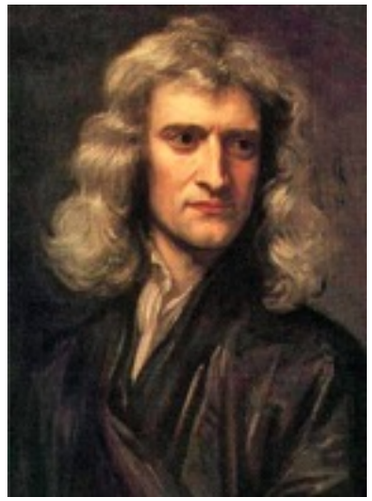
Arab polymath 11th-century:
Alhazen'
definition of
"geometrical conception of place"
as "space qua extension"

Notice the change of depiction technology of people
marble, coloured marble, (non-)coloured sketch

wikipedia

17th century (Renaissance Philosophers)

I. Newton said: Space was absolute,
in the sense that it existed
permanently and independently
of whether there was any matter in the flat space



G. Leibniz said: Space was a collection of
relations between objects, given by
their distance and direction from one another.

18th century,

G. Berkeley (philosopher and theologian)
attempted to refute the "visibility of spatial depth"
in Essay Towards a New Theory of Vision.

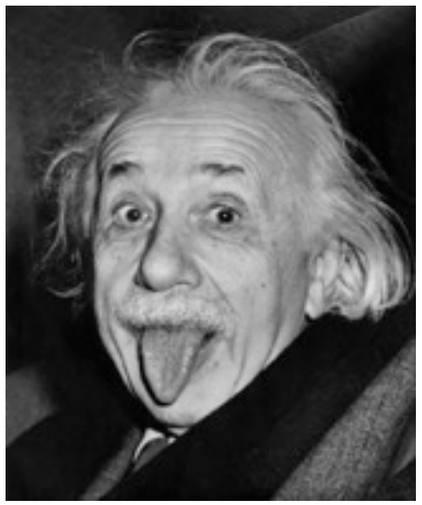
I. Kant (metaphysician) said that the concepts
of space and time are not derived
from experiences of the outside world,
but they are elements of an already given
systematic framework that humans possess
and use to structure all experiences.
The experience of "space" is
a subjective "pure a priori form of intuition".

wikipedia

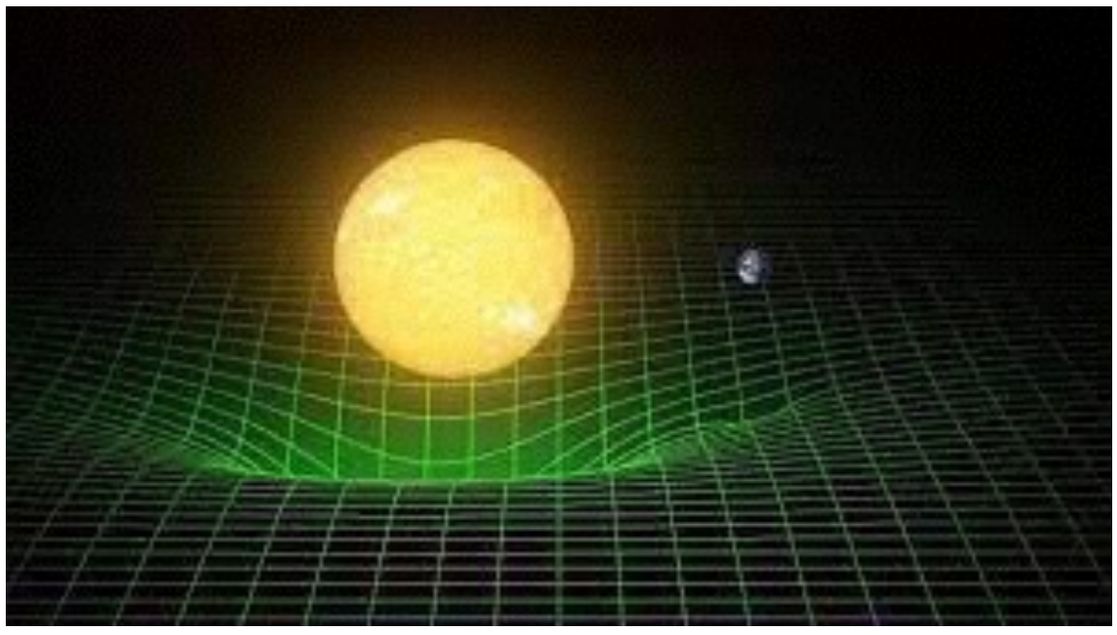
19th century

Mathematicians, such as *N.I.Lobachevsky*
and *C.F.Gauss*
examine geometries
that are non-Euclidean, i.e. non-flat,
in which space is curved, rather than flat.

20th century



A. Einstein's theory of general relativity,
space around gravitational fields of matter changes from flat space.
Experimental tests of general relativity
confirmed that non-Euclidean geometries
provide a better model for the shape of space.



wikipedia

We also commonly use the term *space*, to define

the *outer space* meaning

the space of whatever is outside the Earth

google