



IL LATO OSCURO DELL'UNIVERSO

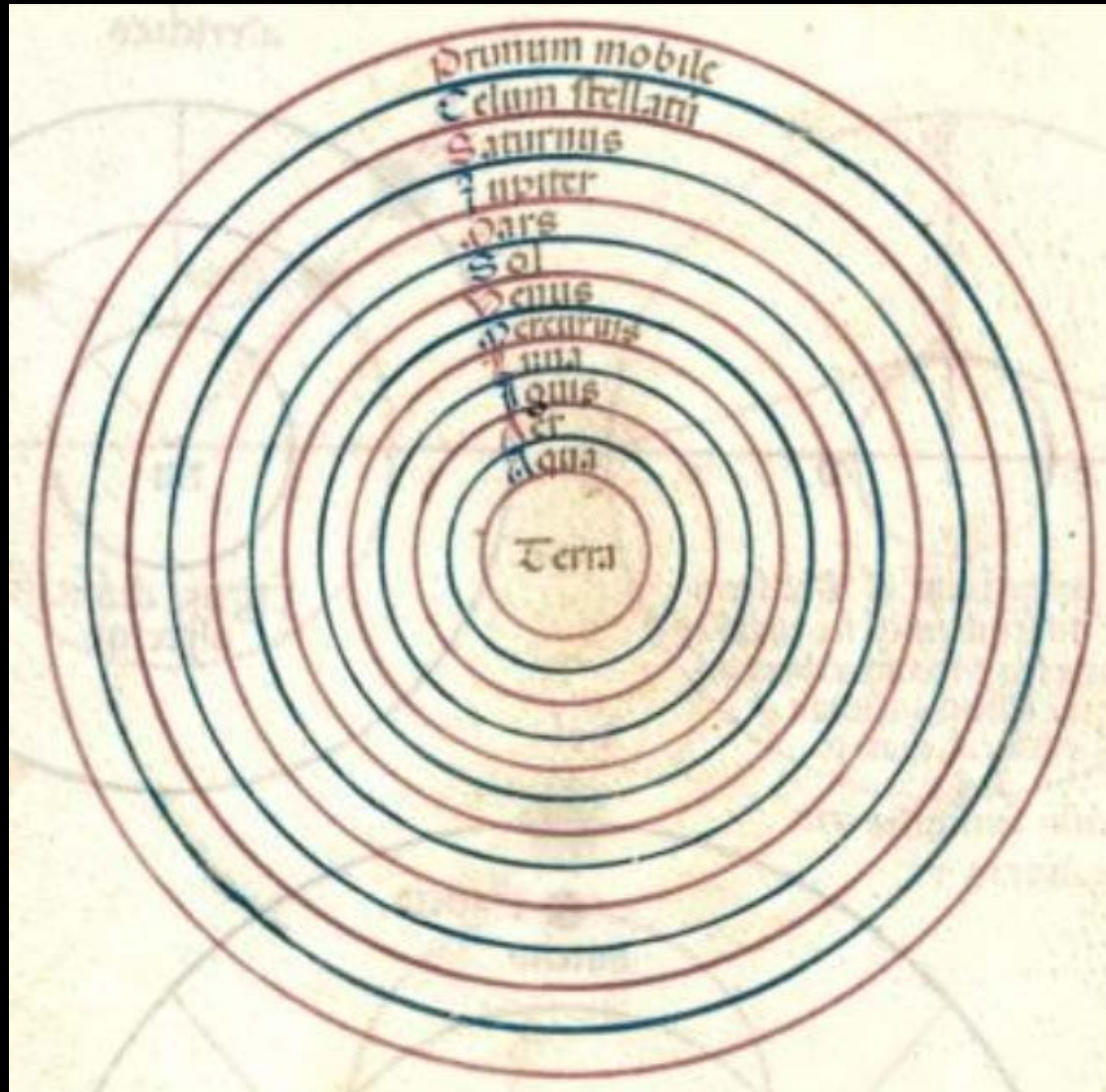
Mariachiara Rossetti

(IASF-Milano, Istituto Nazionale di Astrofisica)



DI COSA E' FATTO L'UNIVERSO?

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Etere o quintessenza

DI COSA E' FATTO L'UNIVERSO?



Anassagora
(496–428 a.C.)

Luna: roccia,
riflessione

Stelle: frammenti
infuocati

Sole: metallo
incandescente

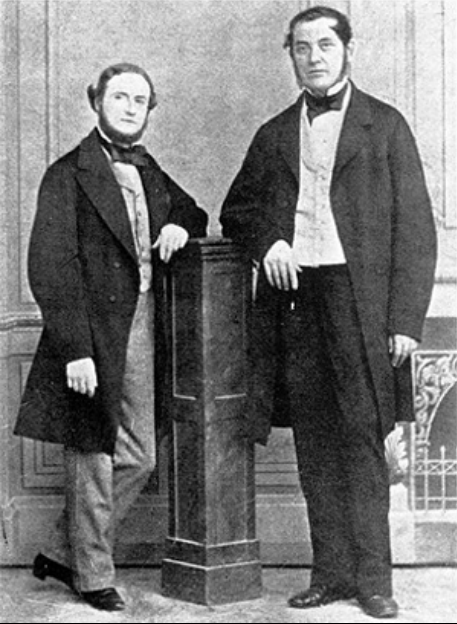
DI COSA E' FATTO L'UNIVERSO?



Auguste Comte
(1798–1857)

*"Non potremo mai e in
nessun modo
investigare la
composizione chimica
del sole e delle stelle"*

Gustav R. Kirchhoff & Robert W. Bunsen (1859)



Spectrum



Light source

Spectrum with
absorption line



Light source

Emission line

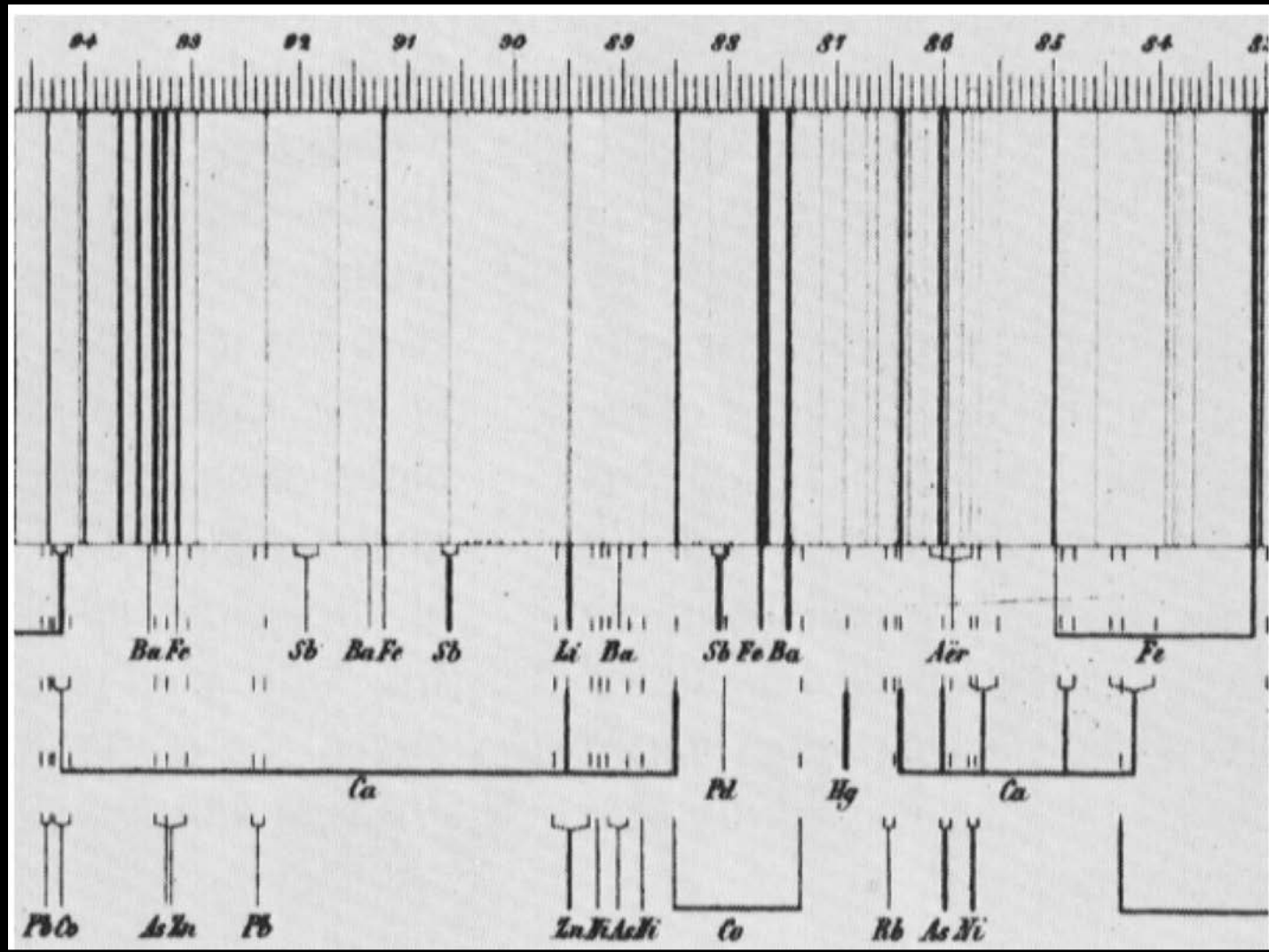


Gas cloud

Gas cloud



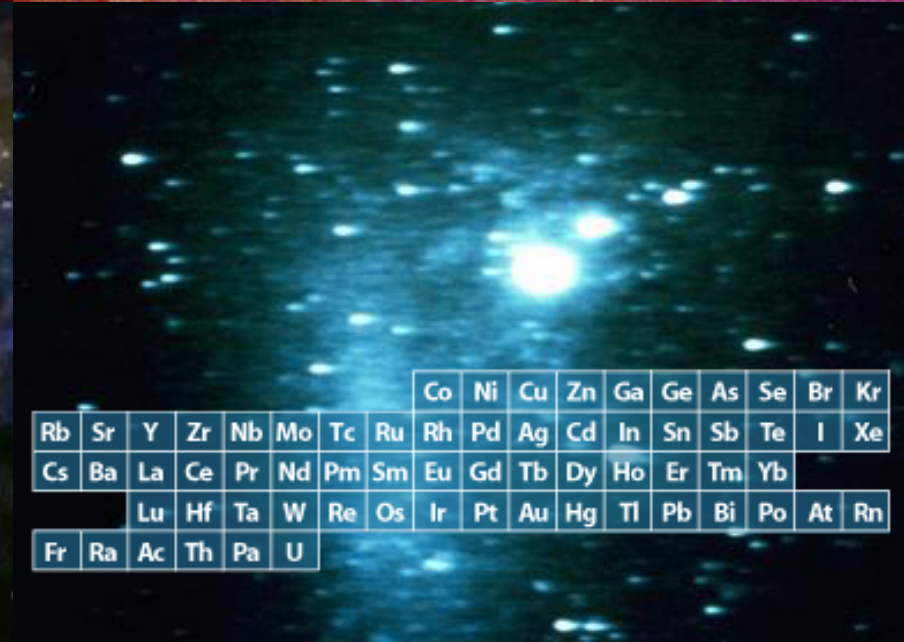
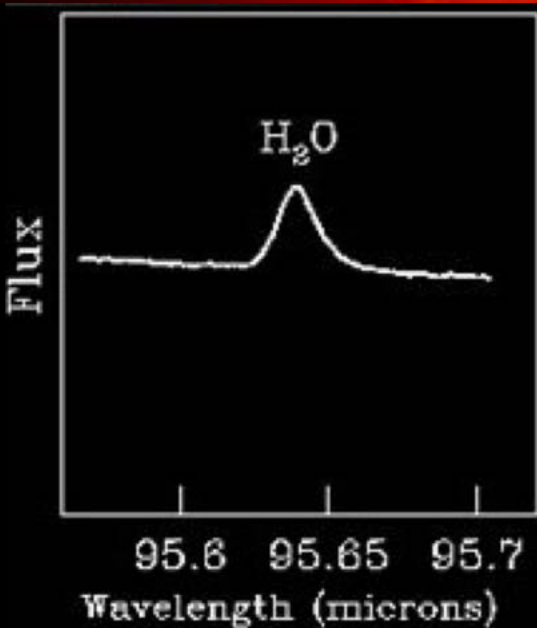
Gustav R. Kirchhoff & Robert W. Bunsen (1859)



L'Univers atomique

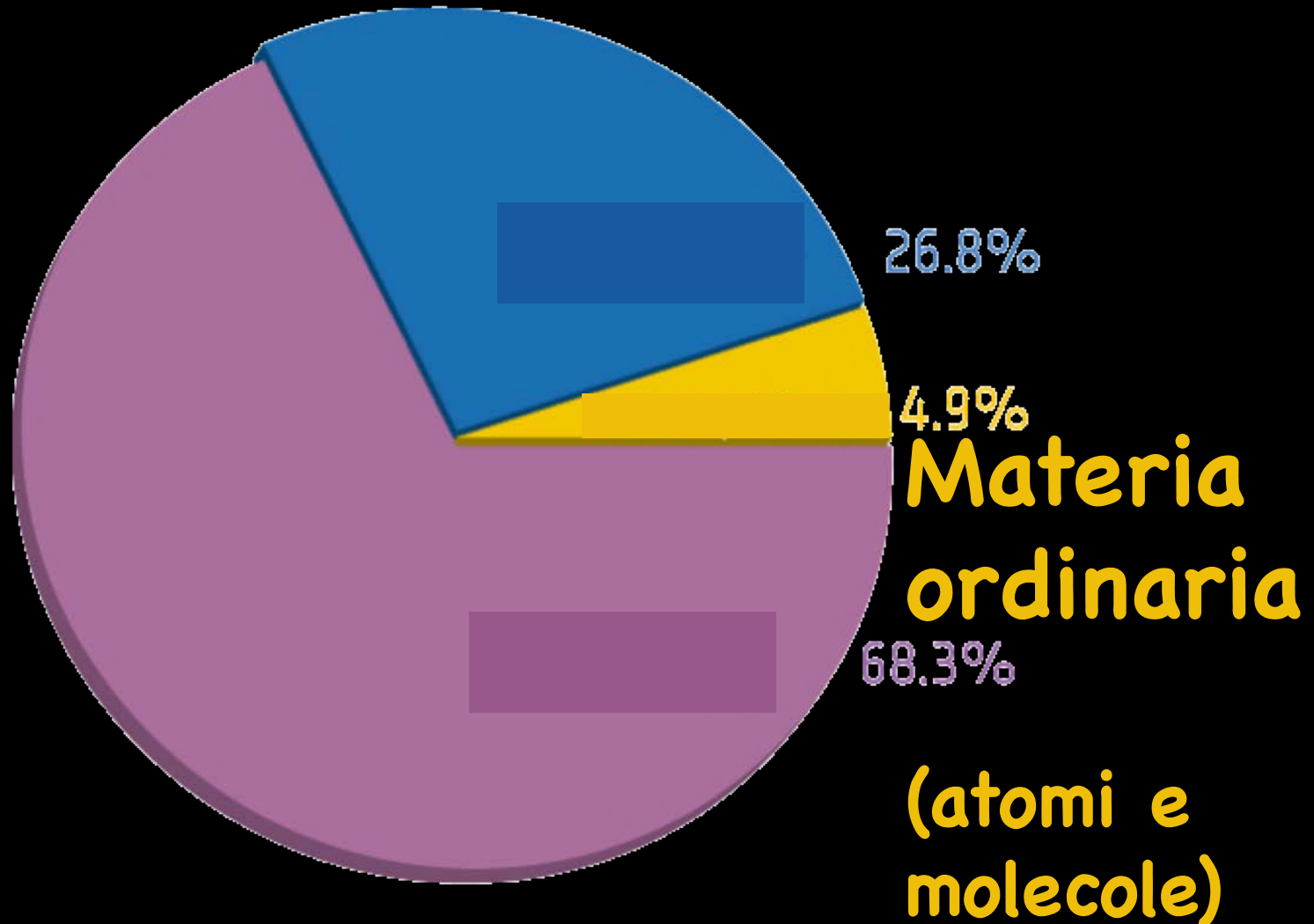
Li	Be						
Na	Mg						
K	Ca	Sc	Ti	V	Cr	Mn	Fe

B	C	N	O	F	He
Al	Si	P	S	Cl	Ar

Ar

Fr	Ra	Ac	Th	Pa	U
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DI COSA E' FATTO L'UNIVERSO?



WE'VE BEEN
STUDYING MATTER
FOR A COUPLE
HUNDRED YEARS...

...AND WE HAVE A
FINE UNDERSTANDING
OF CHEMICALS, ETC...



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OF CHEMICALS, ETC...

AND ALL OF A SUDDEN WE
DISCOVER THAT ALL THAT
WORK WE'VE BEEN DOING,

IS ONLY ON A
TINY FRACTION
OF WHAT THE
UNIVERSE IS
MADE OUT OF!



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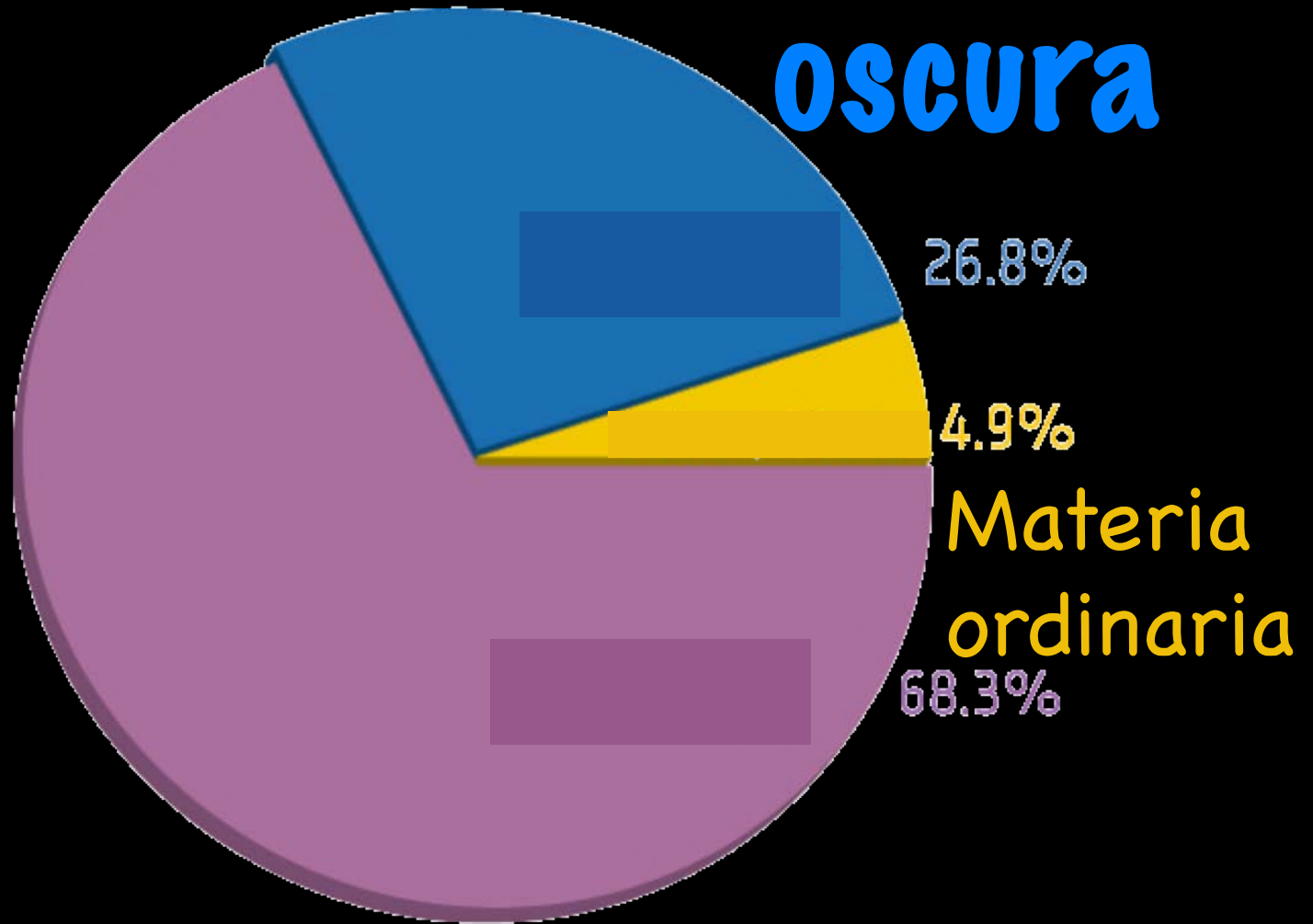
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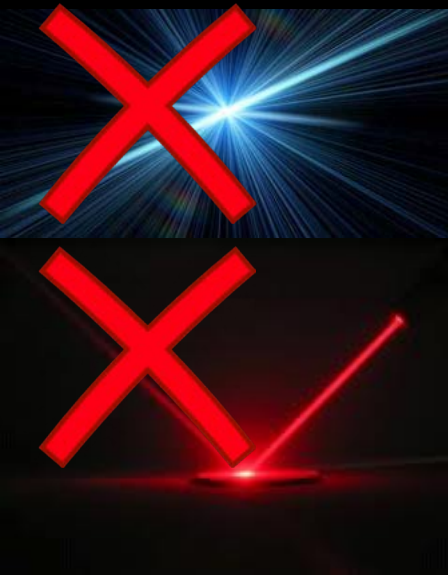
IS ONLY ON A
TINY FRACTION
OF WHAT THE
UNIVERSE IS
MADE OUT OF!

IT'S LIKE YOU'VE BEEN
STUDYING AN ELEPHANT'S
TAIL FOR TWO HUNDRED
YEARS AND YOU DISCOVER...

IT'S ONLY THE TAIL!

Materia oscura



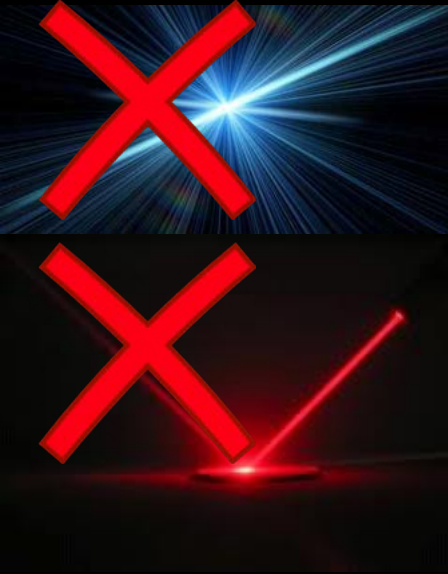


Non emette
né riflette radiazione
elettromagnetica
Non possiamo vederla
né rilevarla

Materia oscura

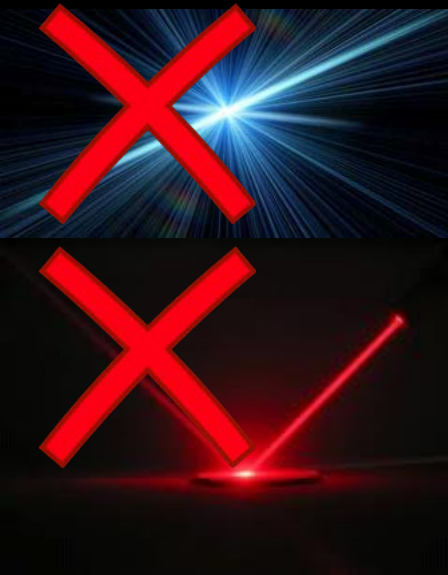
Materia oscura

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MA È MATERIA

Possiamo studiarne gli effetti tramite la forza di gravità sulla materia ordinaria e sulla radiazione



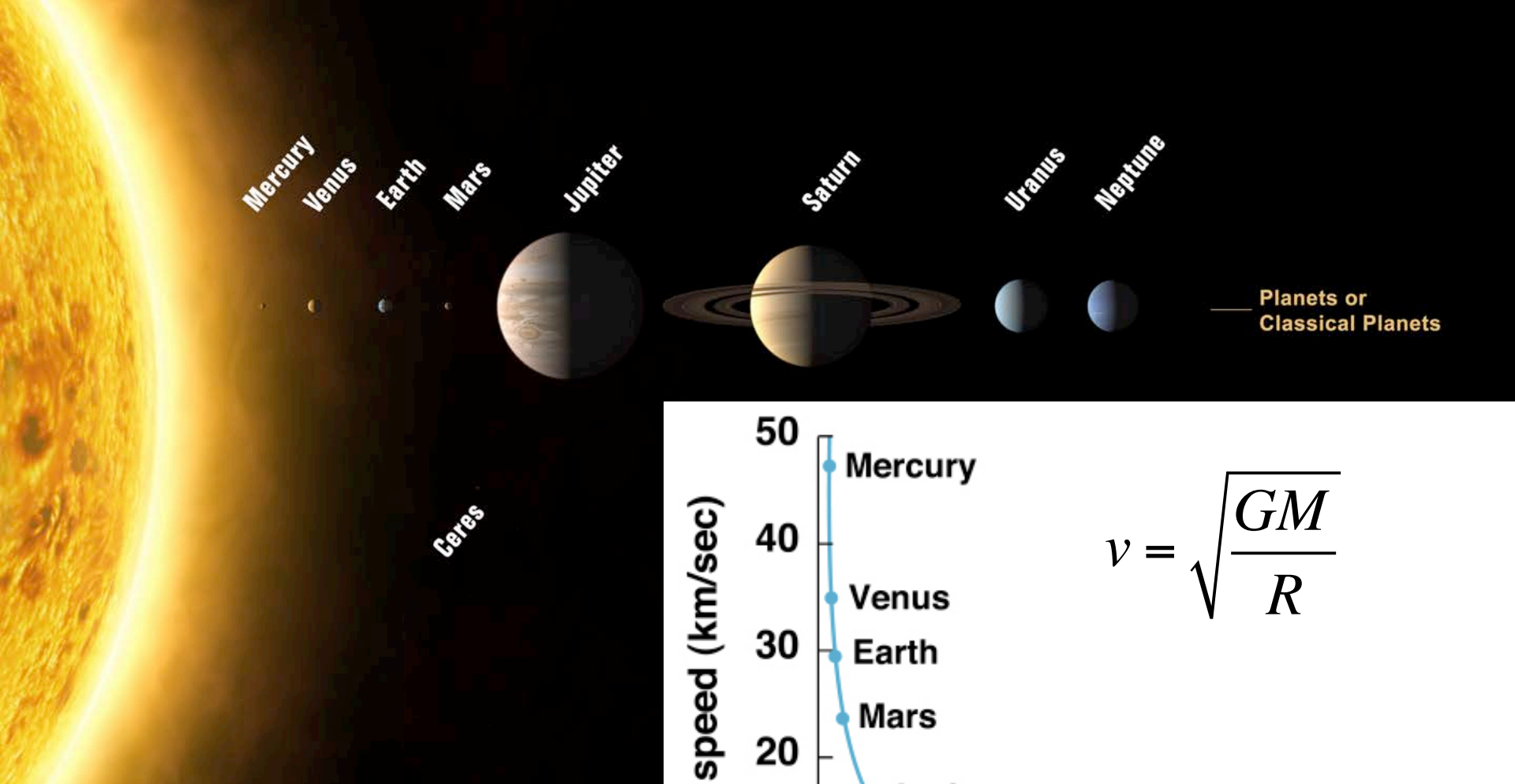
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**Materia
oscura**

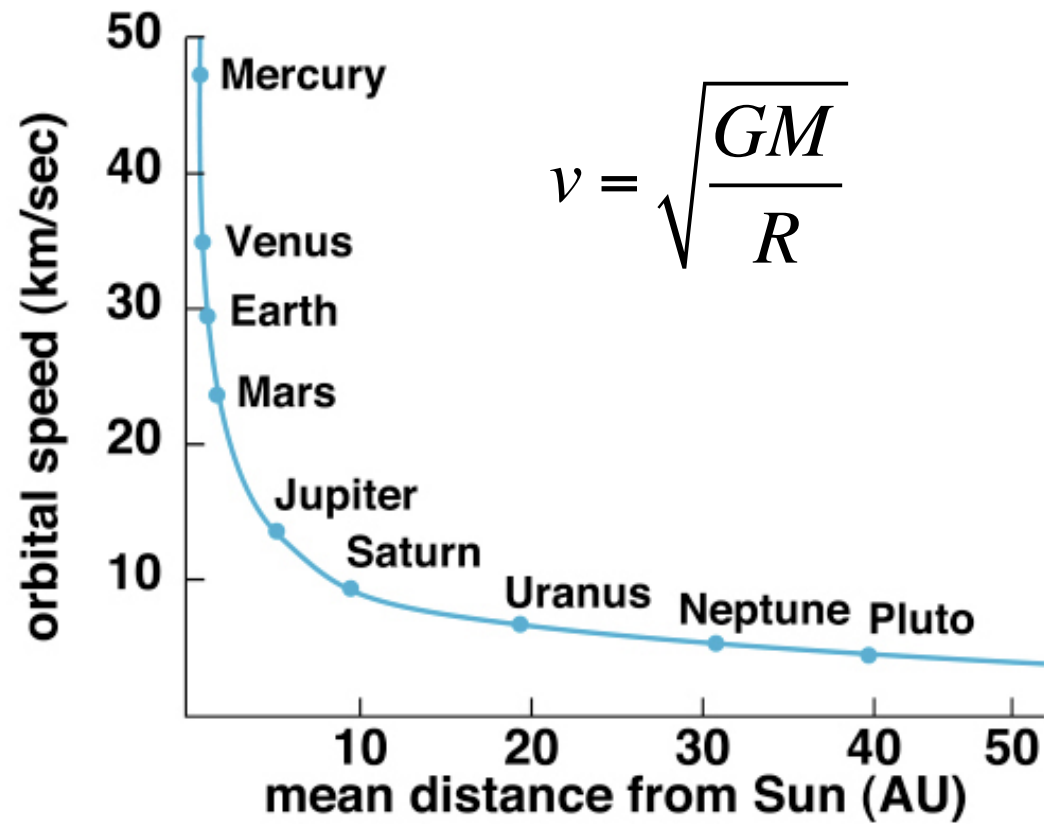
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Possiamo studiarne gli effetti tramite la forza di gravità sulla materia ordinaria e sulla radiazione

DARK MATTER



$$\frac{GMm}{r^2} = m \frac{v^2}{r}$$



(b)

Stelle e gas
ruotano intorno
al centro

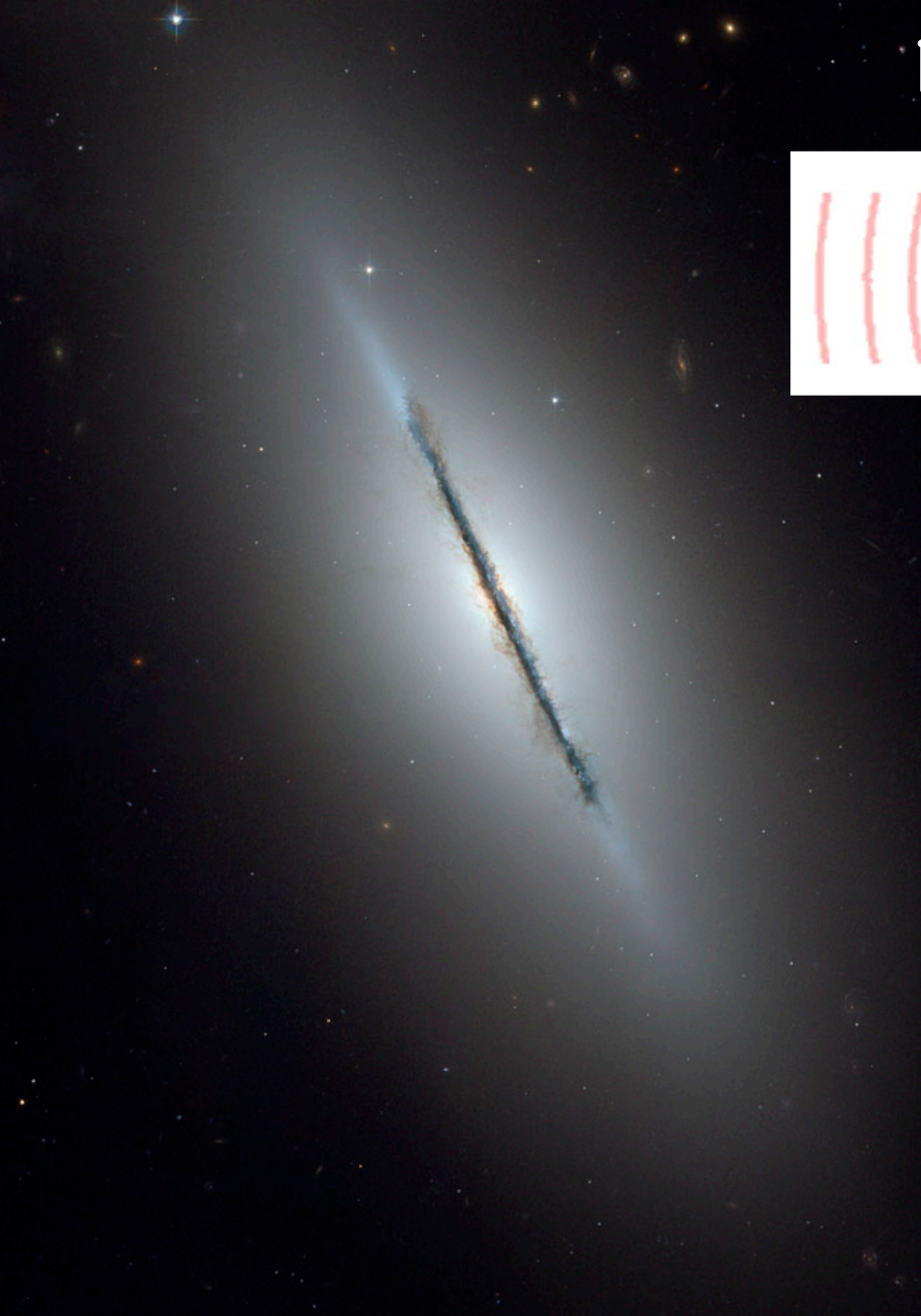
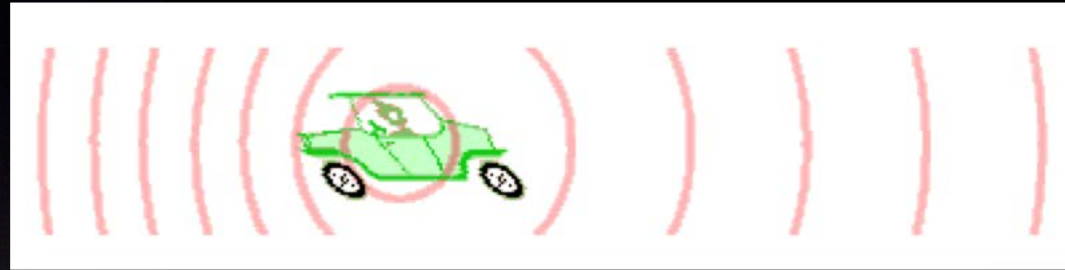
La maggior parte delle
stelle è concentrata nel
“bulge”

NGC 2841

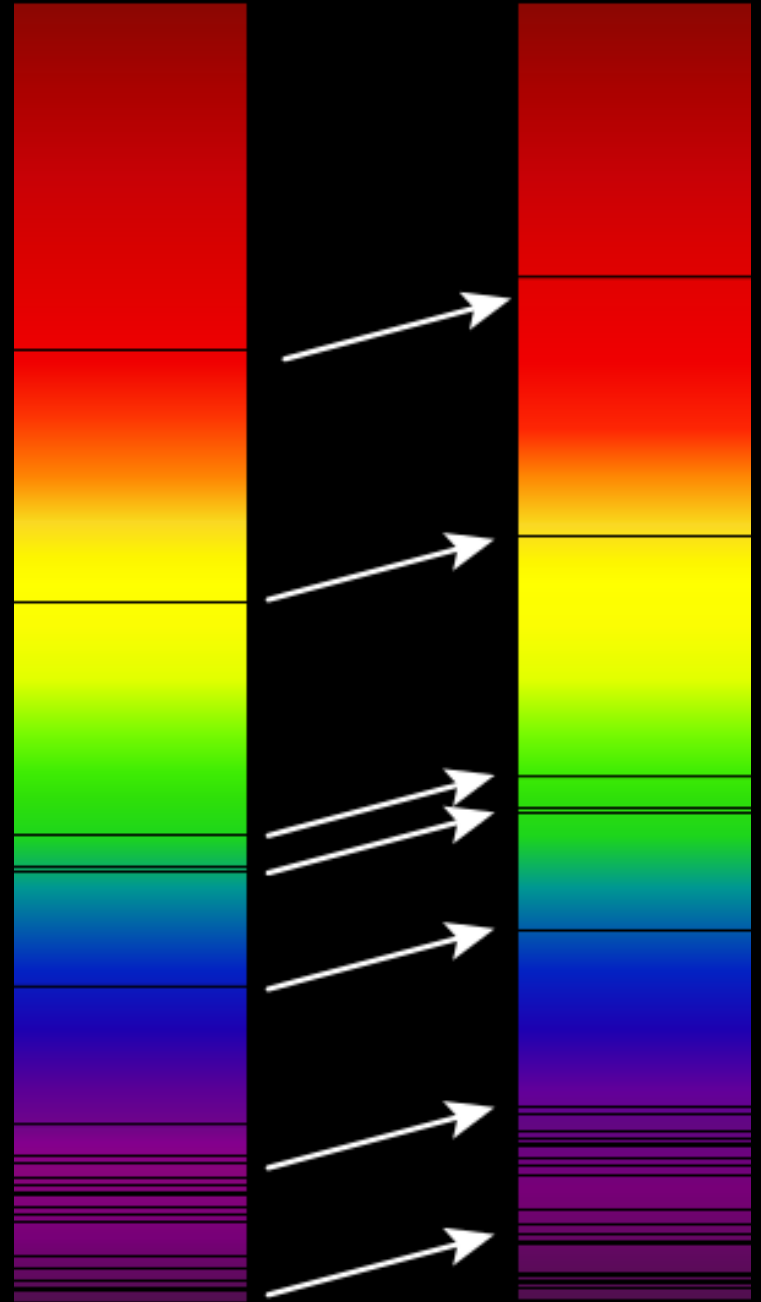
Credits: Hubble Space Telescope



EFFETTO DOPPLER

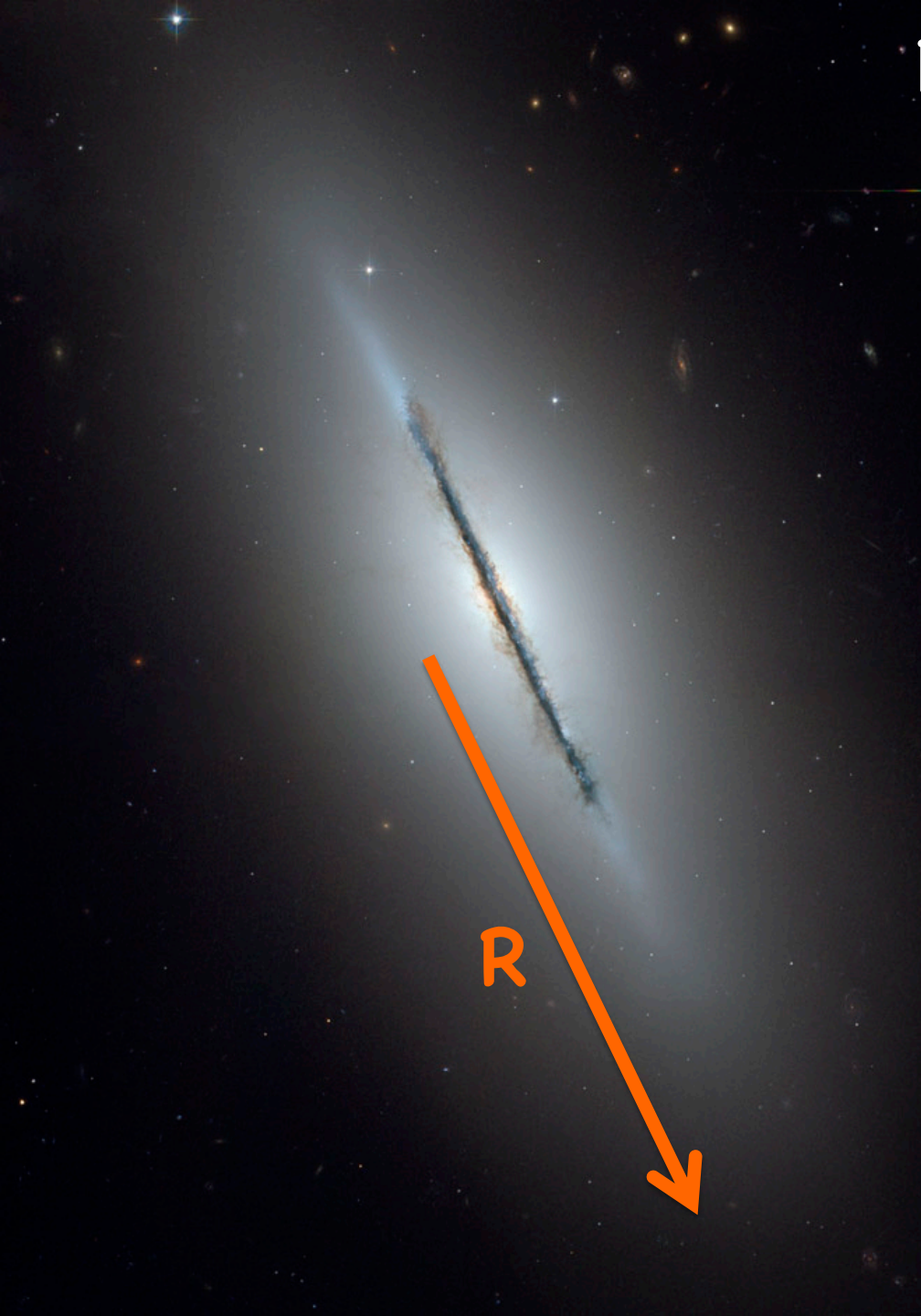


EFFETTO DOPPLER



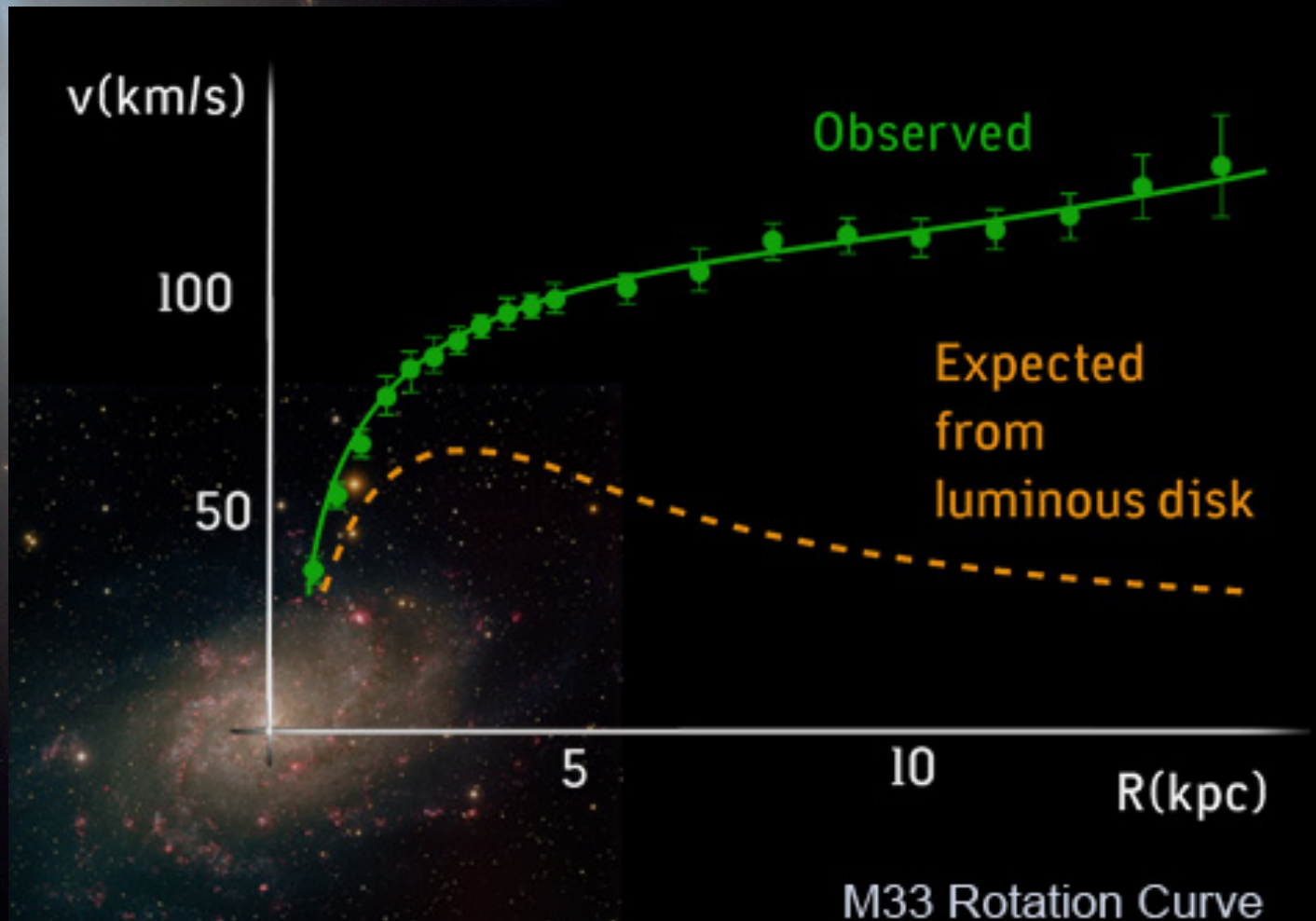
EFFETTO DOPPLER

misuro $v(R)$

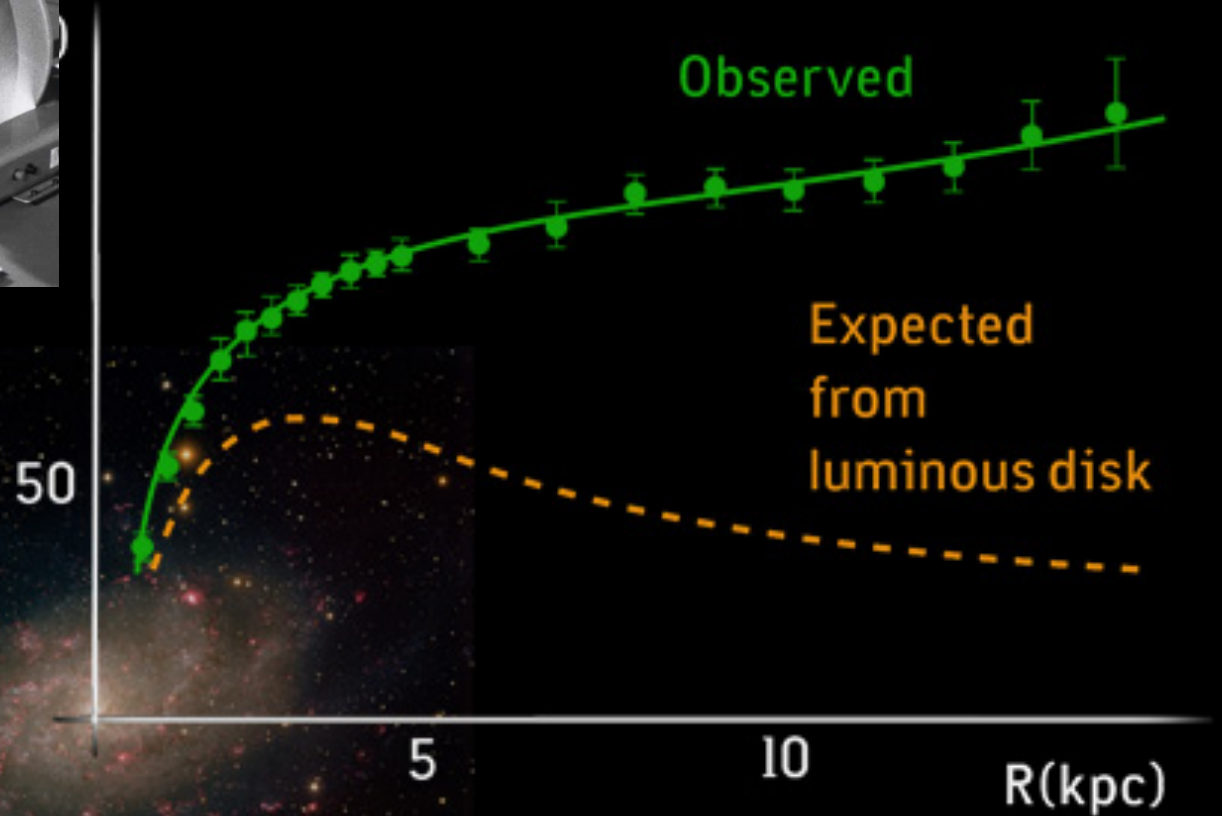
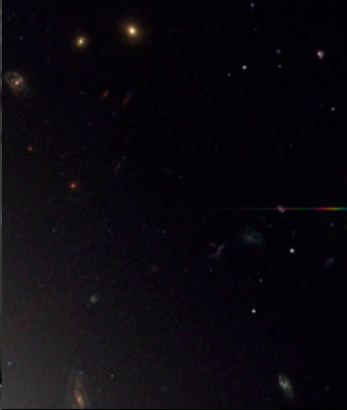


EFFETTO DOPPLER

misuro $v(R)$



Vera Rubin (1975)



M33 Rotation Curve

$$\frac{GMm}{r^2} = m \frac{v^2}{r}$$



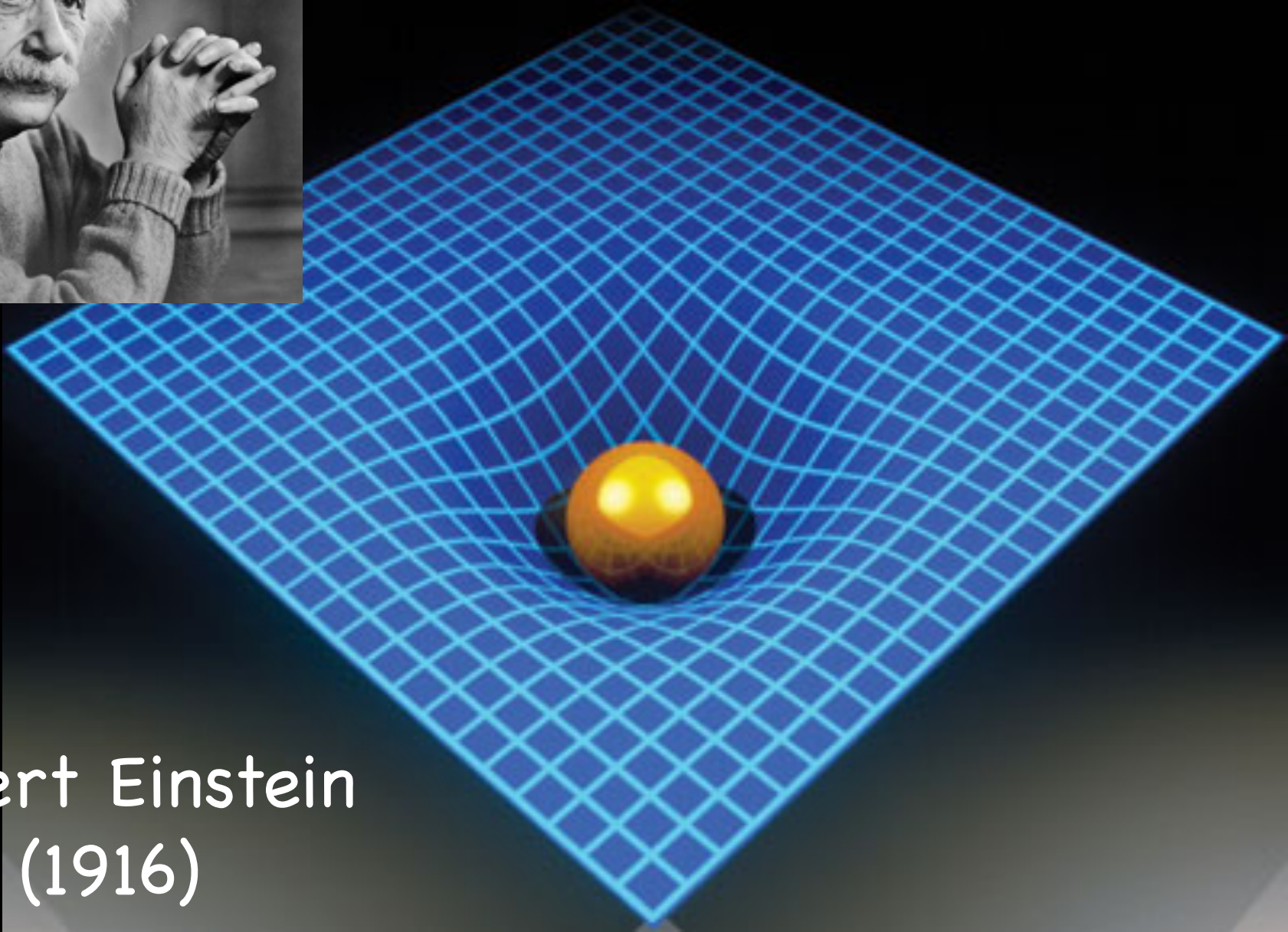
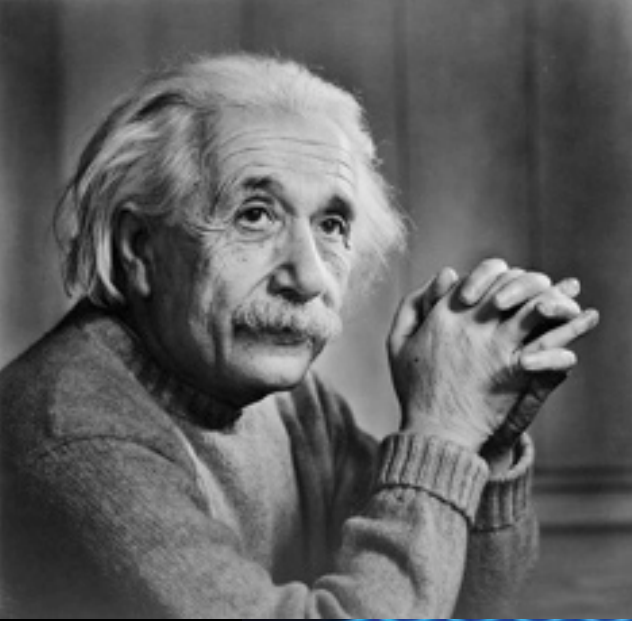
Alone di materia
invisibile
o
legge di
gravitazione
“sbagliata”?

$$\frac{GMm}{r^2} = m \frac{v^2}{r}$$

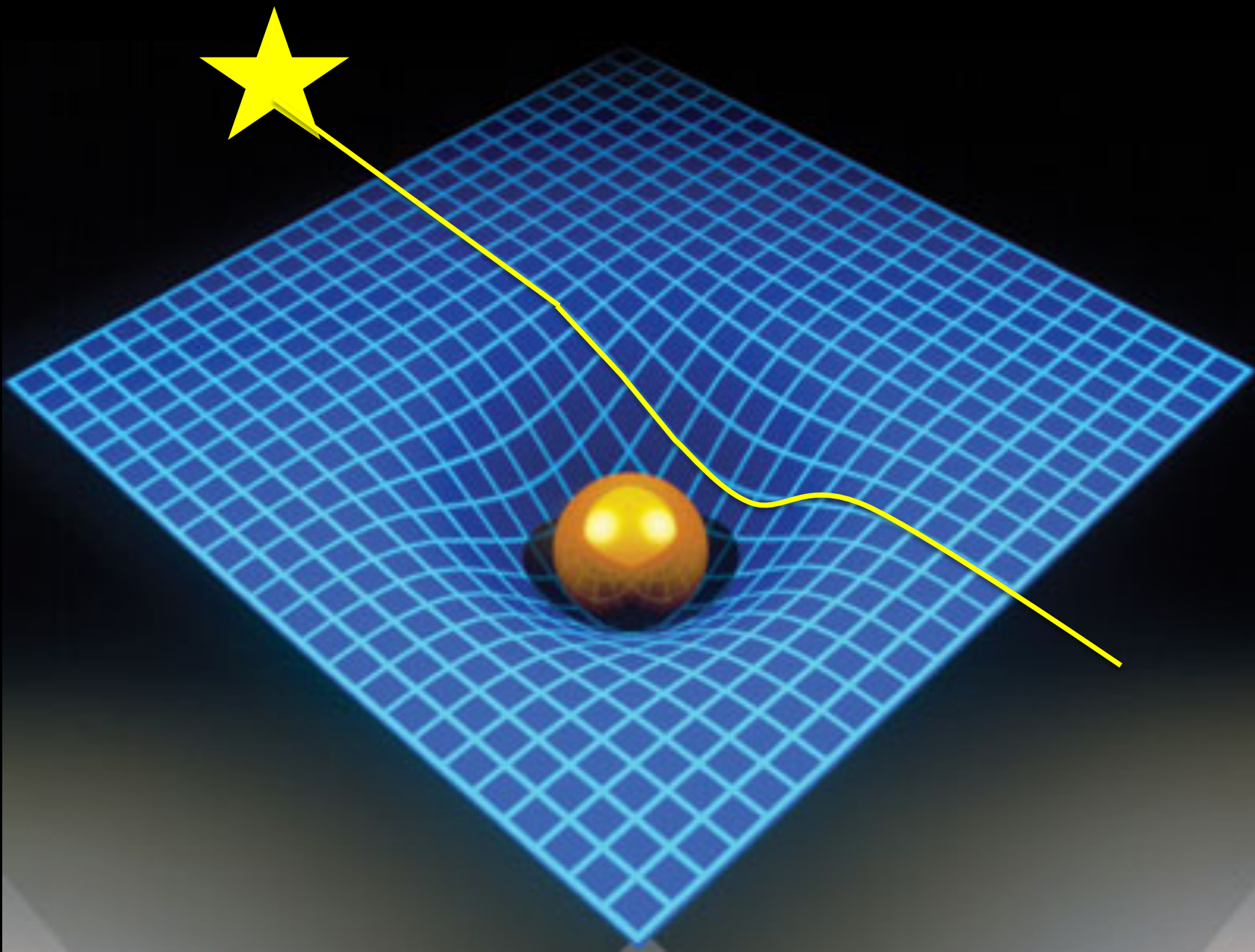
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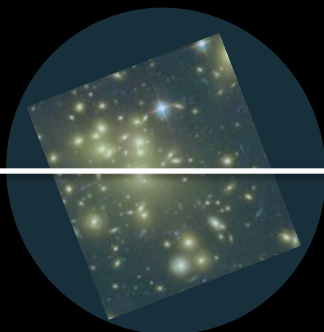


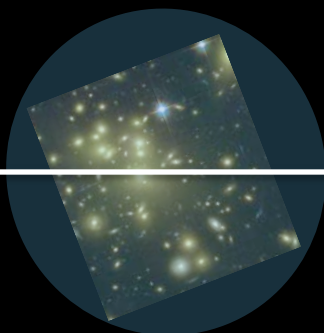
Indicazioni simili anche in altri oggetti astrofisici
(galassie ellittiche, ammassi di galassie, Universo...)

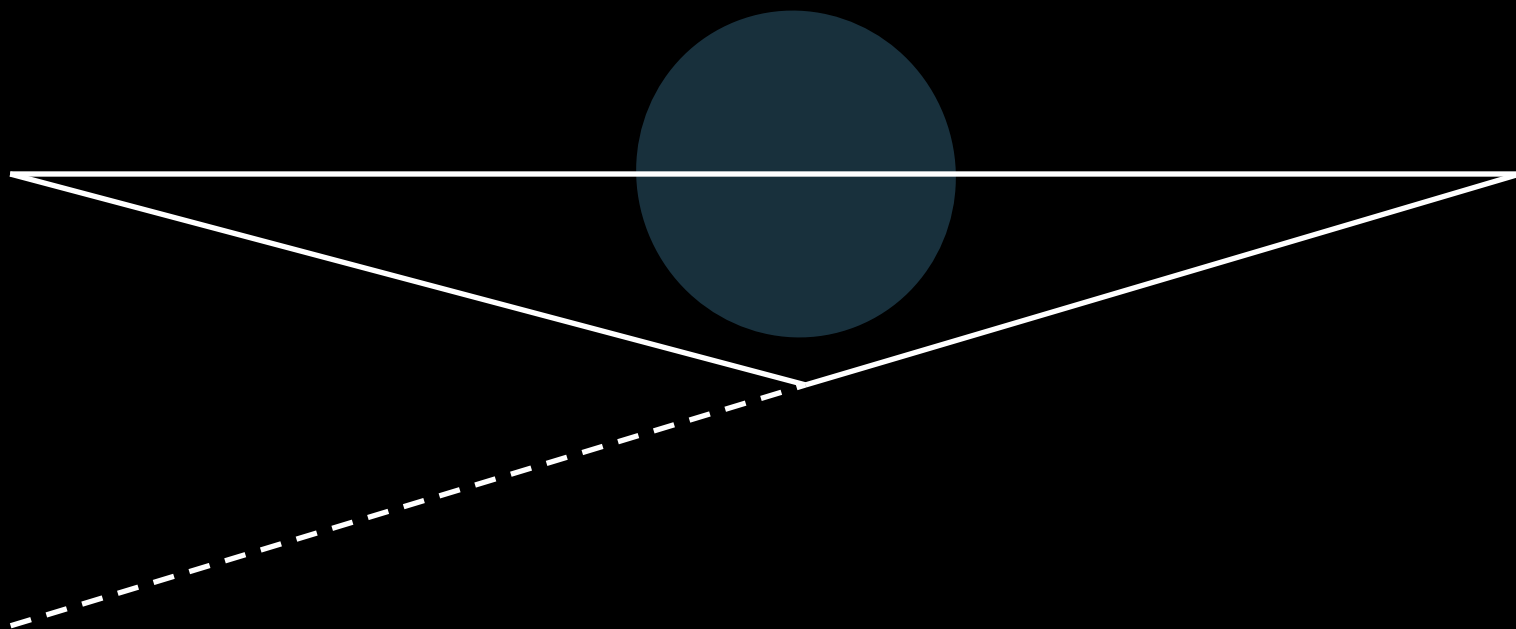


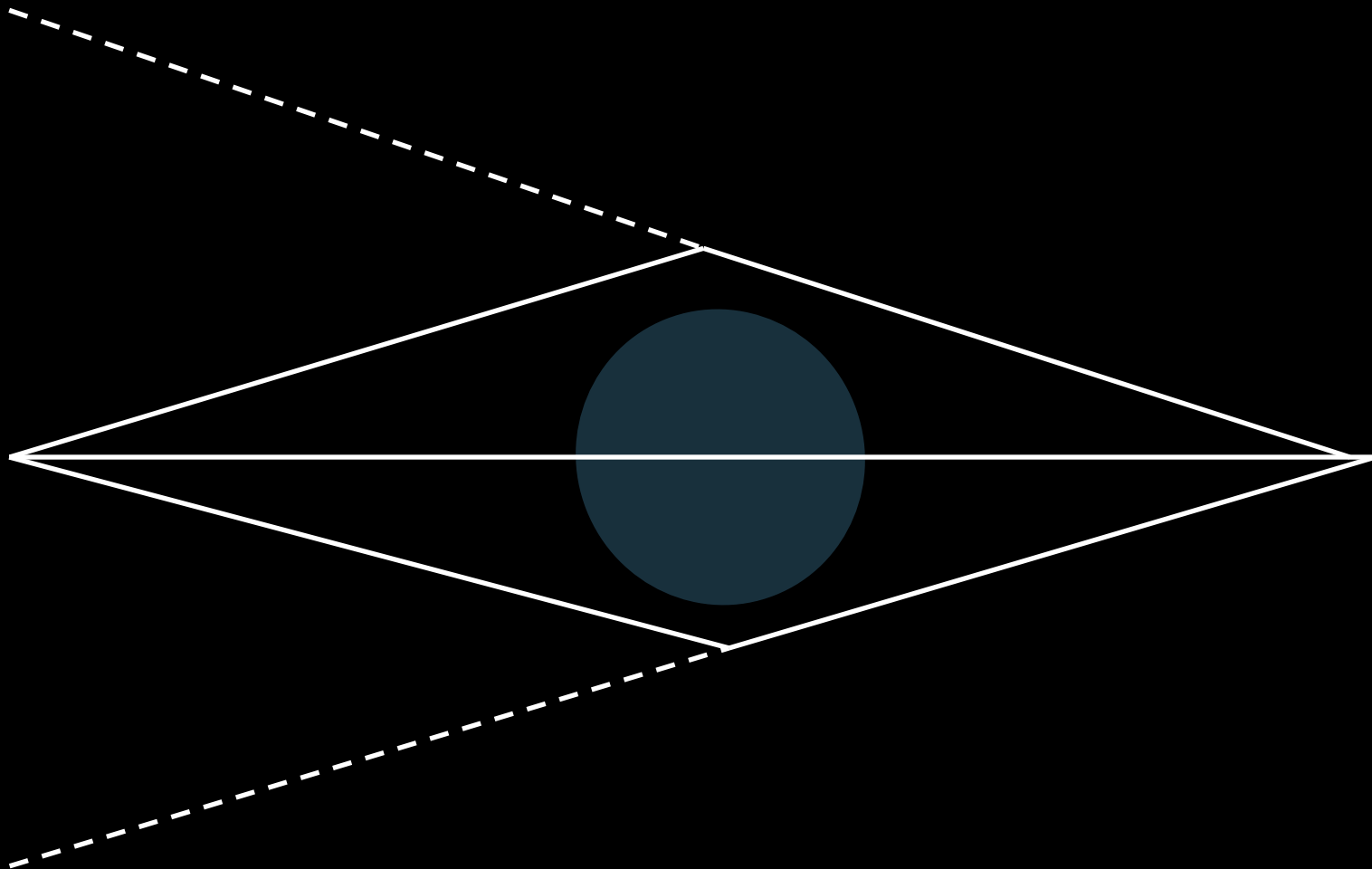
Albert Einstein
(1916)

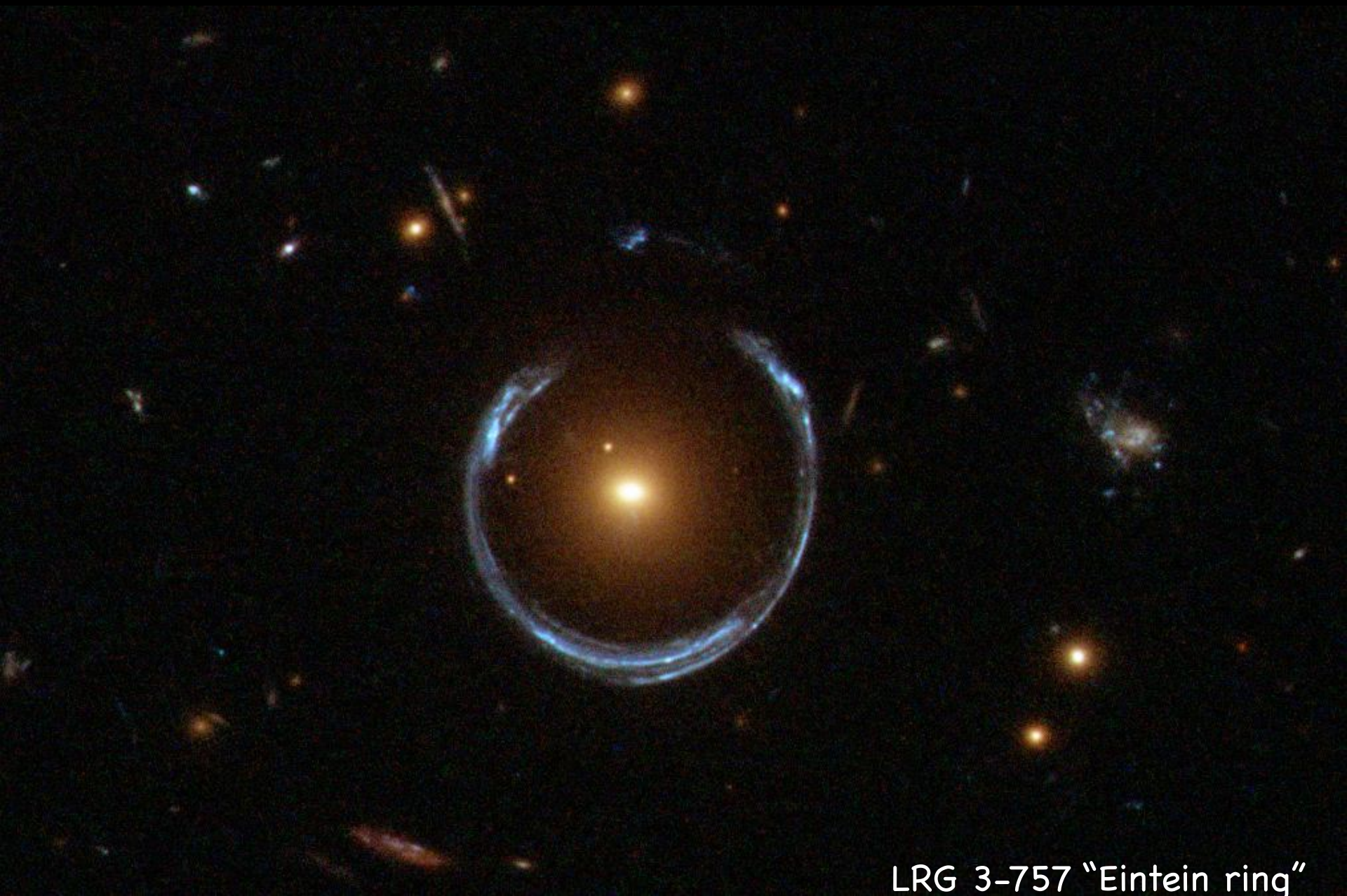




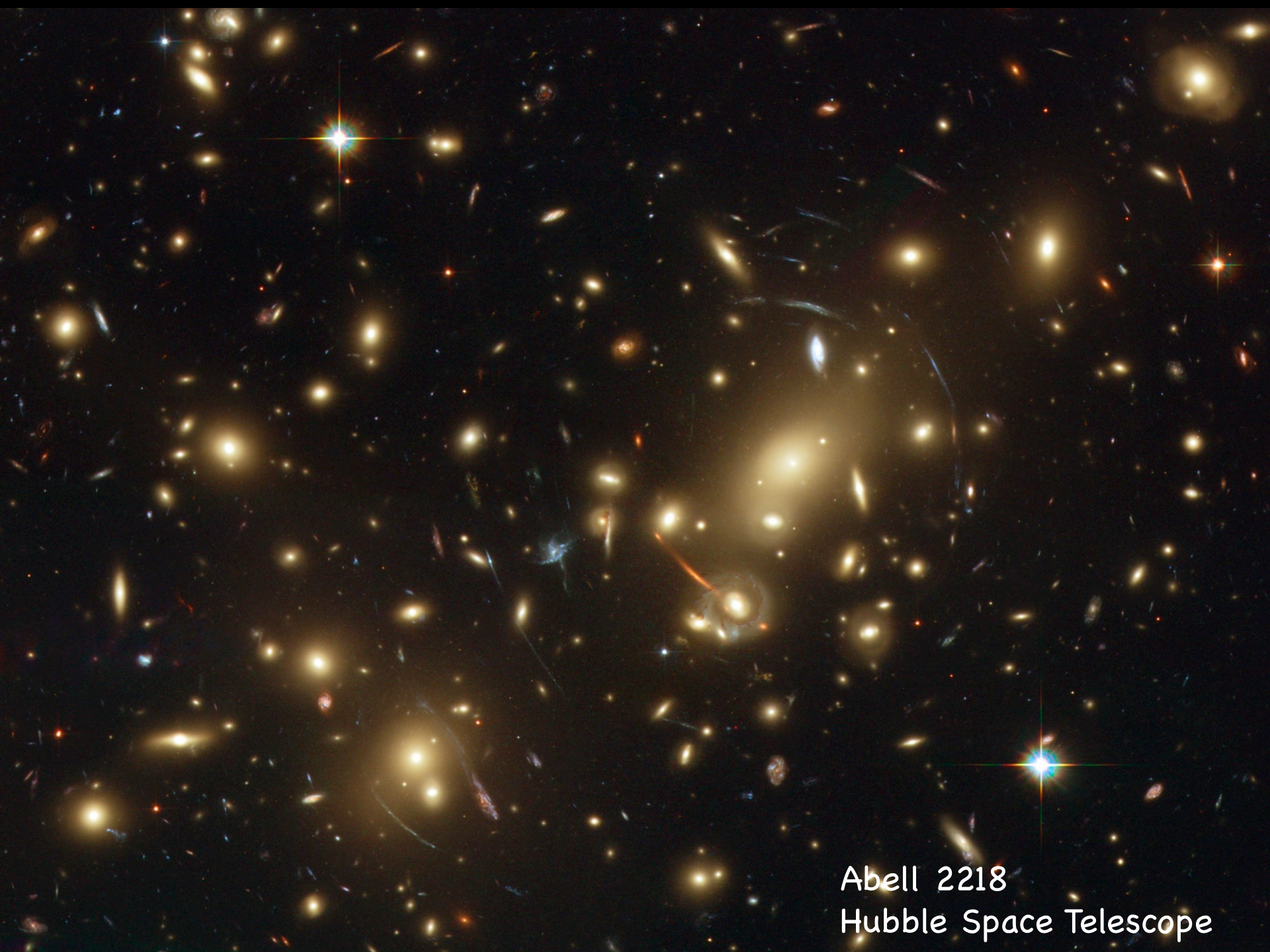




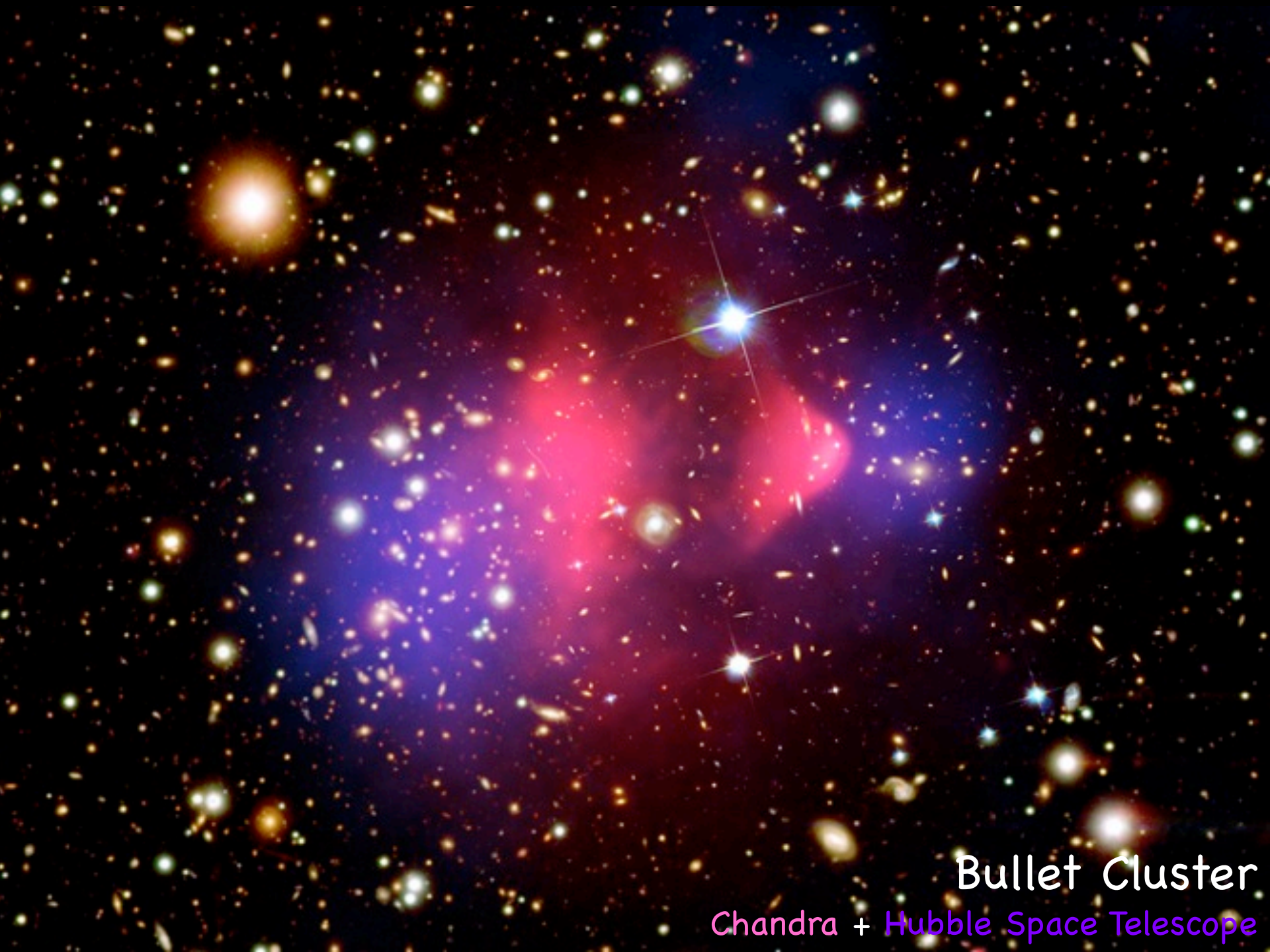




LRG 3-757 "Einstein ring"
Hubble Space Telescope



Abell 2218
Hubble Space Telescope



Bullet Cluster

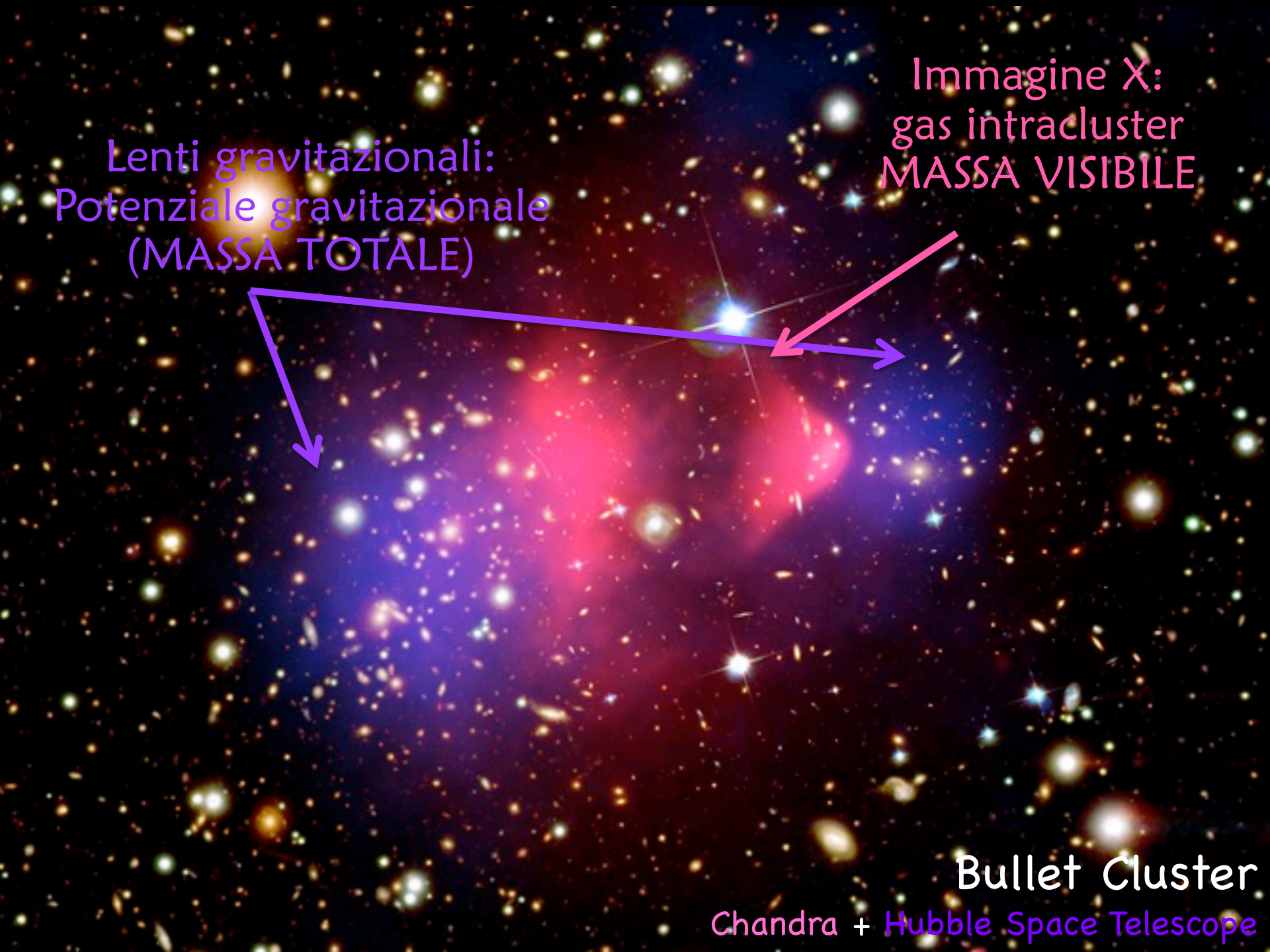
Chandra + Hubble Space Telescope

Lenti gravitazionali:
Potenziale gravitazionale
(MASSA TOTALE)

Immagine X:
gas intracluster
MASSA VISIBILE

Bullet Cluster

Chandra + Hubble Space Telescope



Alone di materia
invisibile

o

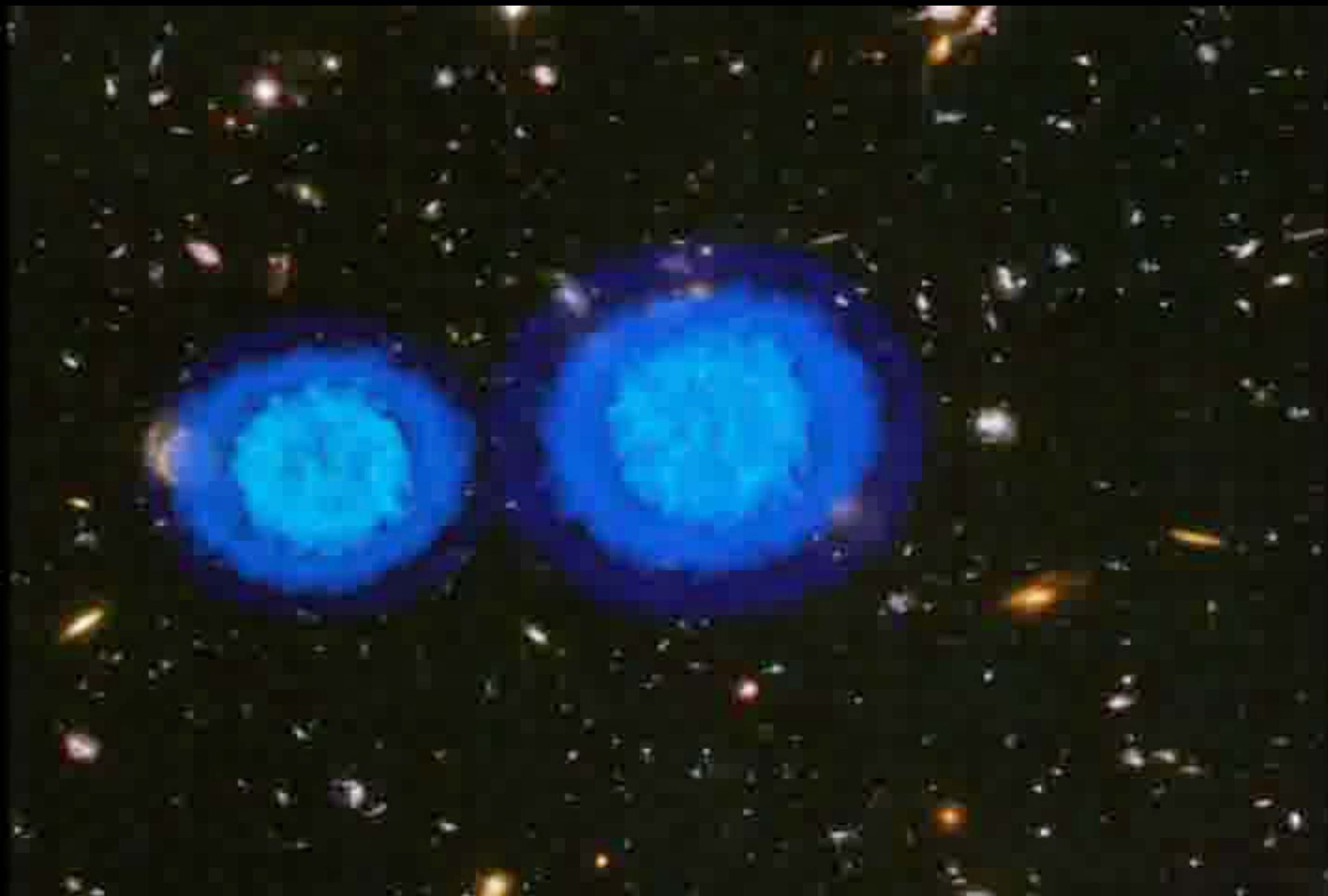
~~legge di
gravitazione
"sbagliata"?~~

A direct empirical proof of the
existence of Dark matter
(D. Clowe et al. 2006)



Bullet Cluster

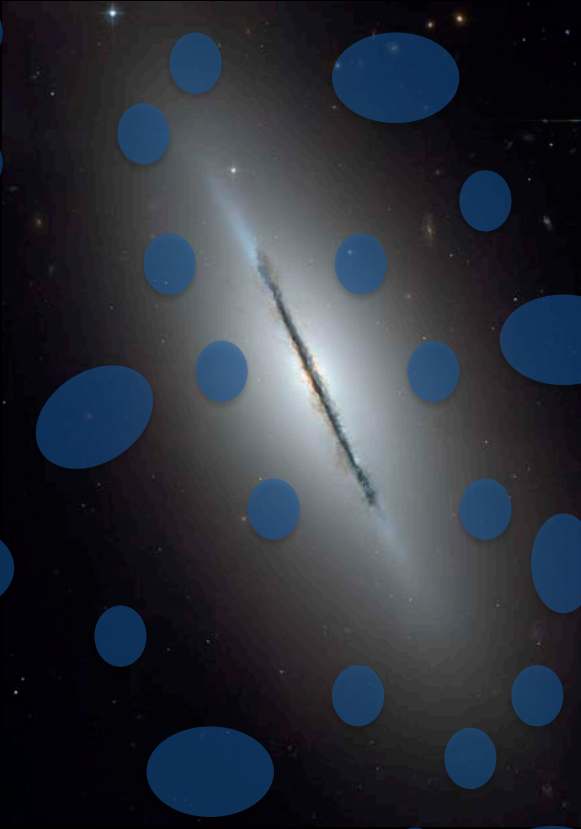
Chandra + Hubble Space Telescope



MACHOs

(MAssive Compact Halo Objects)

Pianeti, Nane brune,
Nane bianche, stelle di
neutroni, buchi neri...



~~MACHOs~~

(MASSive COmpact HUB Objects)

Pianeti, buche brune,
Nane bianche, stelle di
neutroni, buchi neri...
o alone di particelle

WIMPS

(Weakly Interacting
MASSive Particles)



THIS IS WHAT'S SO
COOL ABOUT IT...

IT'S A **CLASH**
OF **WORLD**
VIEWS:

FOR A LONG TIME,
PARTICLE
PHYSICISTS

HAVE BEEN
DRILLING DOWN
INTO SMALLER AND
SMALLER LENGTH
SCALES.



atom

nucleus

quarks



solar system

milky-way

the whole universe

ASTRONOMERS
LOOKING
FURTHER AND
FURTHER OUT...

THEN COMPLETELY
SEPARATE, YOU HAD

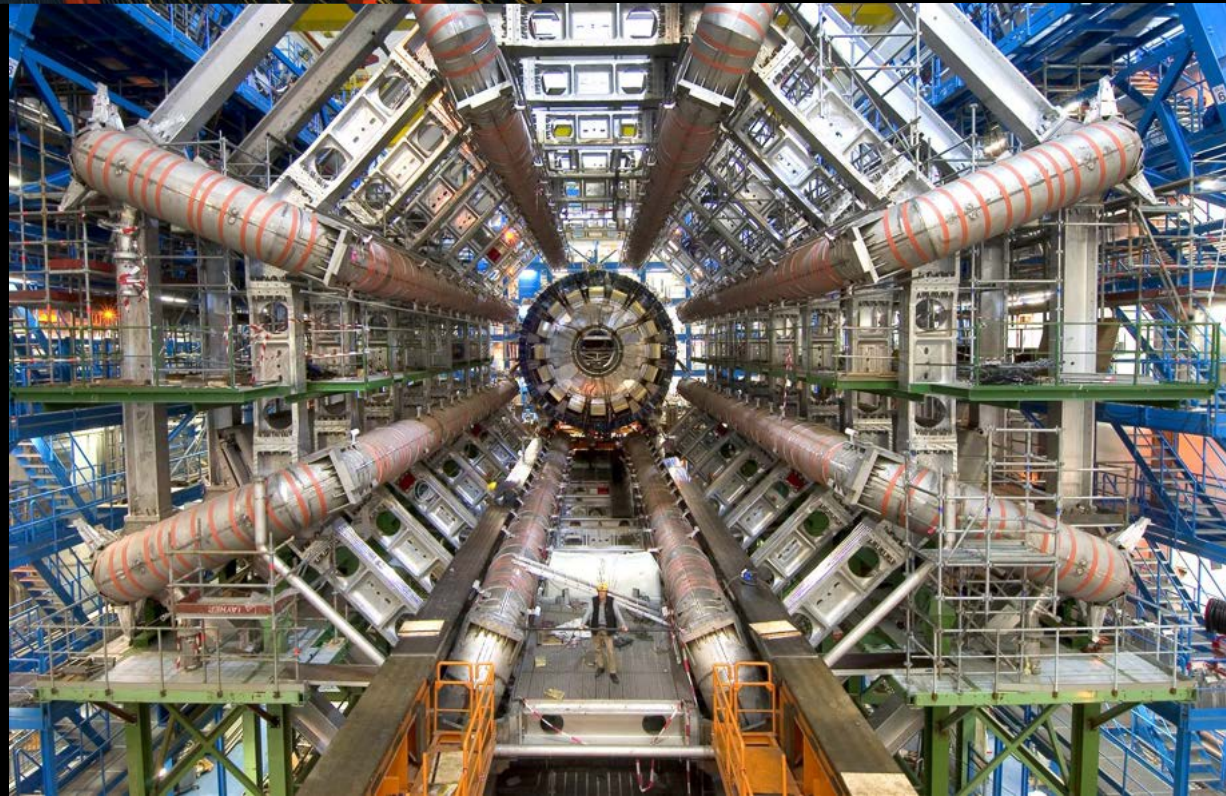
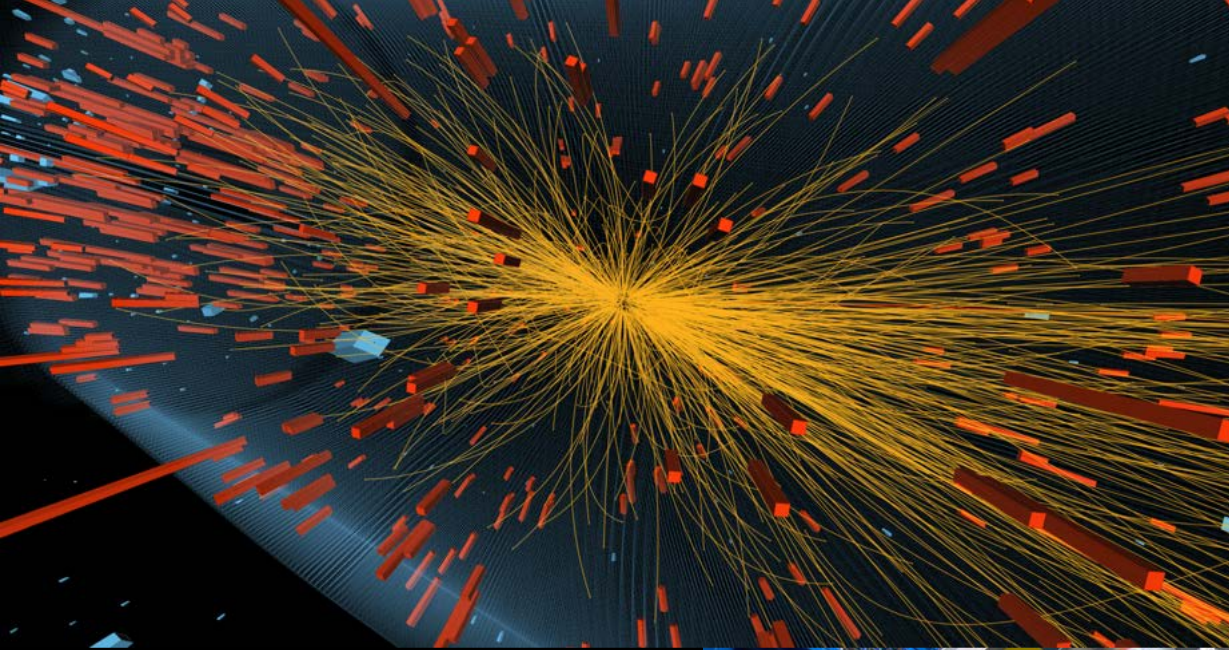
JUST RECENTLY, THESE TWO SUCCESSFUL WAYS OF
DOING SCIENCE SORT OF... CLASHED.

WHAT ARE
YOU
LOOKING AT?

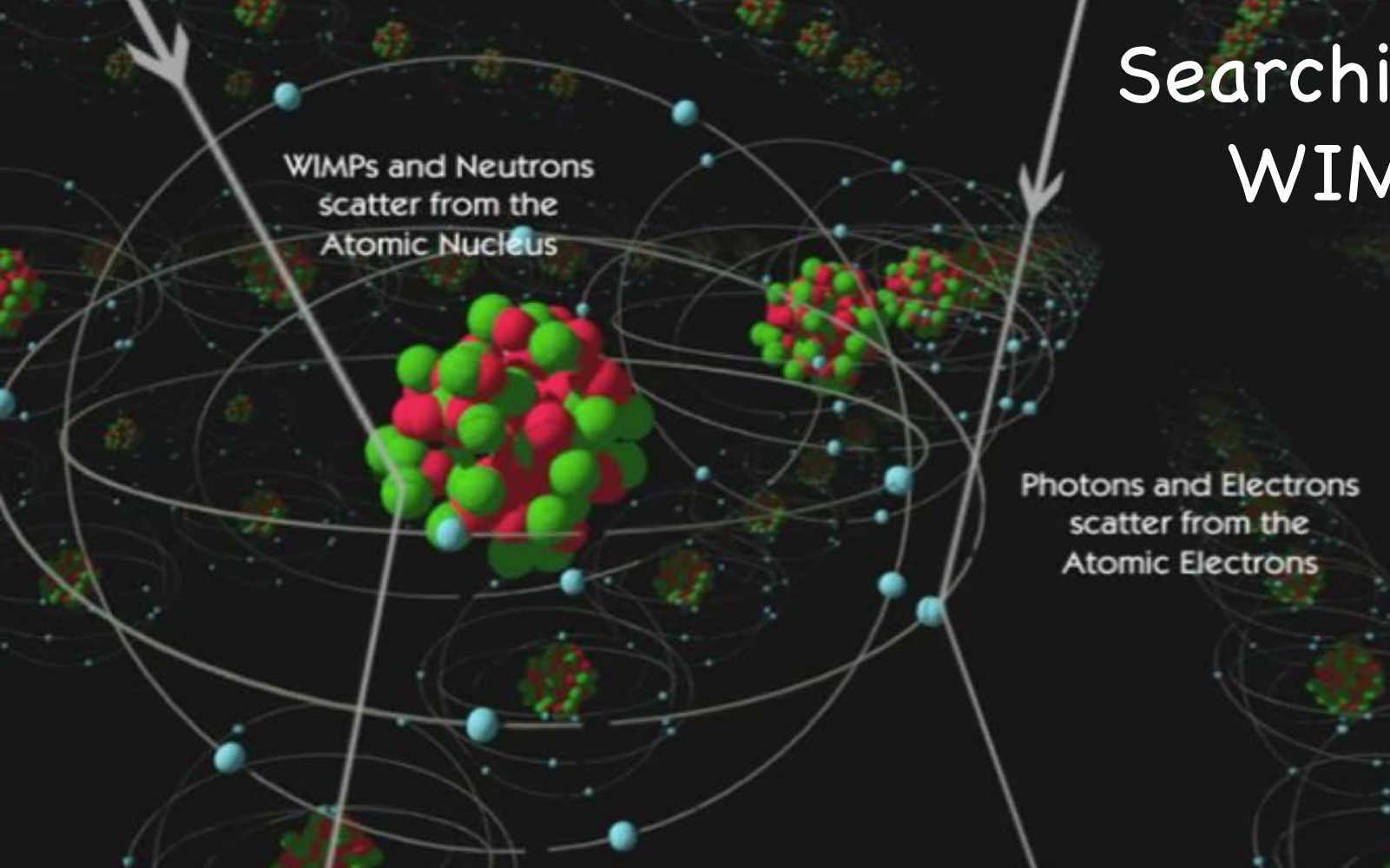
JORGE CHAM © 2011

Searching for WIMPS

Produzione
negli
acceleratori
(LHC Cern)



Searching for WIMPS



Rare interazioni con la materia ordinaria

Searching for WIMPS



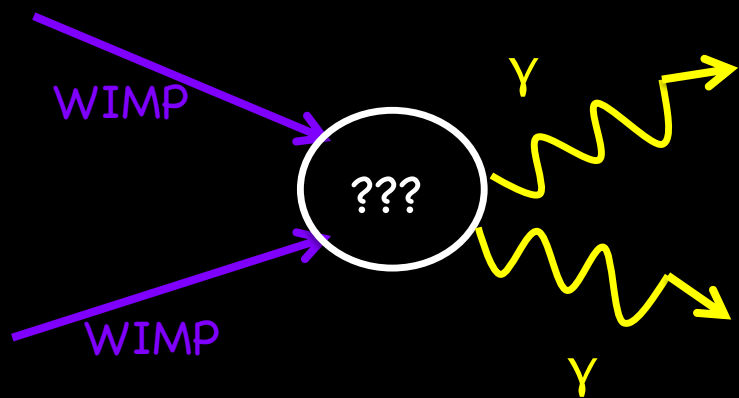
JFS • JOSEFRANCISCO.ORG

Esperimento LUX
Miniera di Homestake (USA)

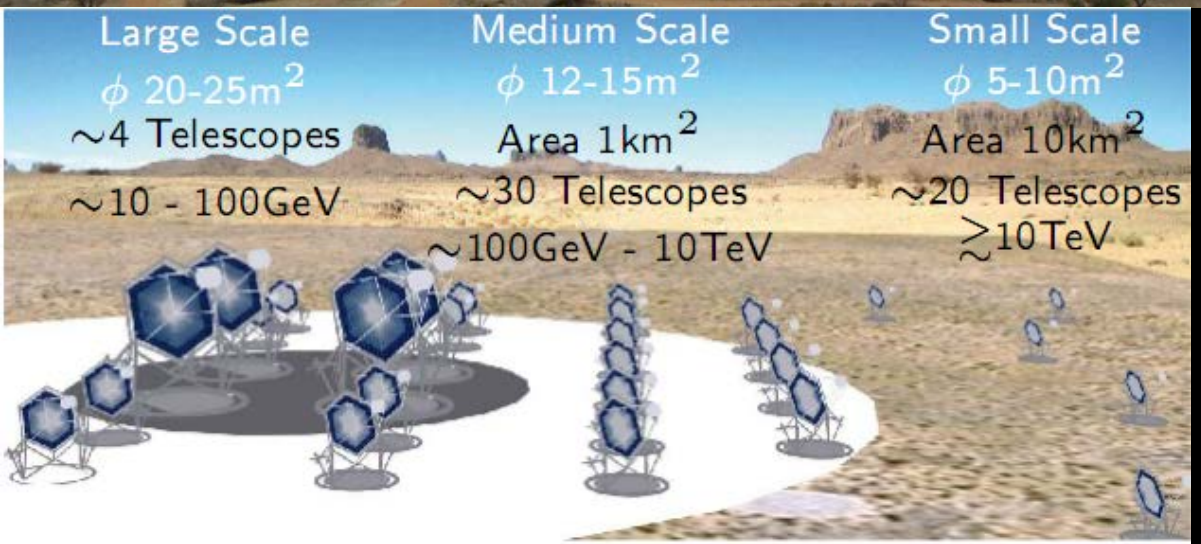


JFS • JOSEFRANCISCO.ORG

Rare interazioni con la materia ordinaria



Searching for WIMPS



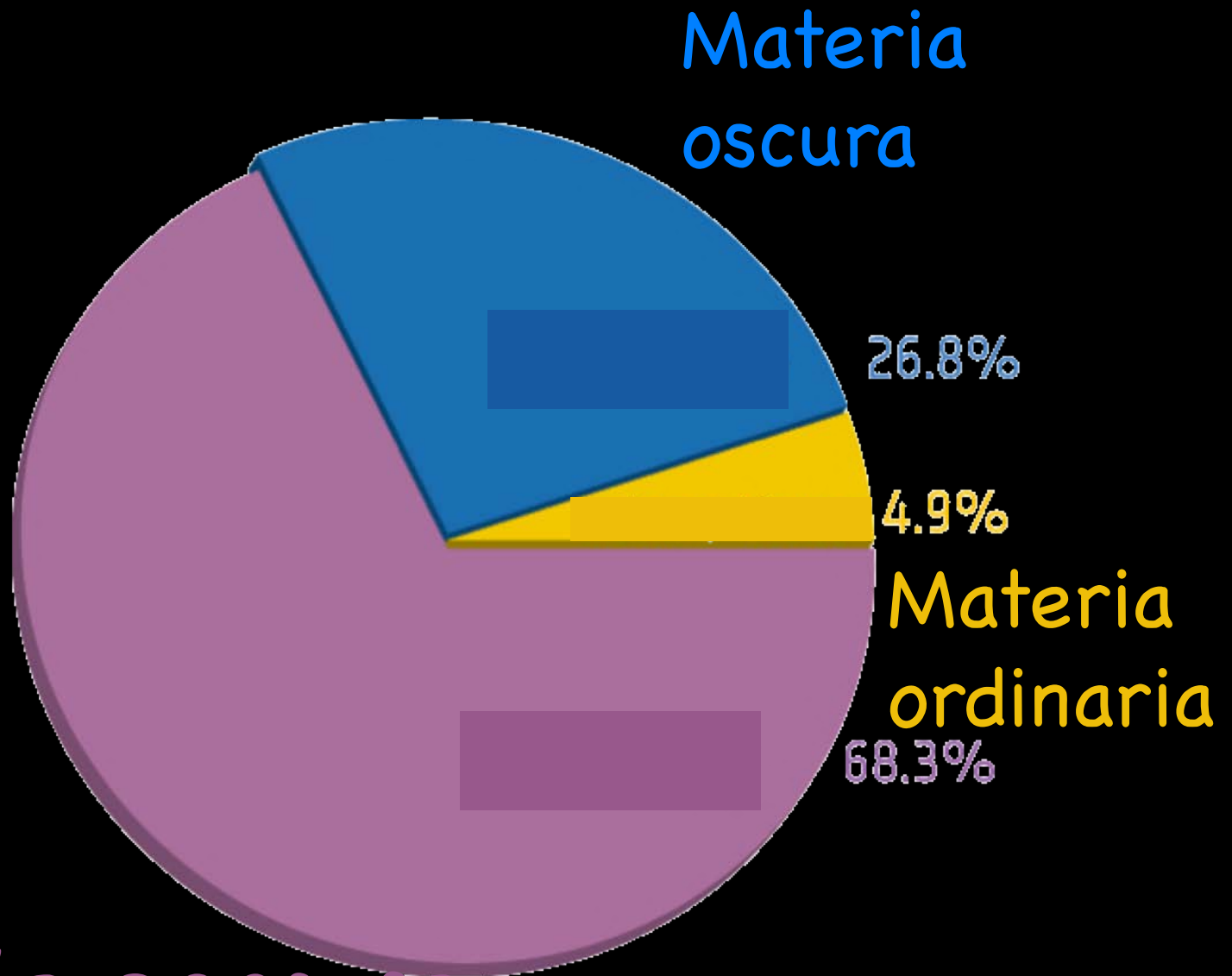
WHAT YOU SHOULD
TAKE AWAY FROM
ALL OF THIS IS...

WE DON'T KNOW WHAT
THE REST OF THE
ELEPHANT LOOKS LIKE...

AND YOU SHOULD BE
READY FOR SOME

SURPRISES.

Energia oscura



Il grande enigma



Energia oscura

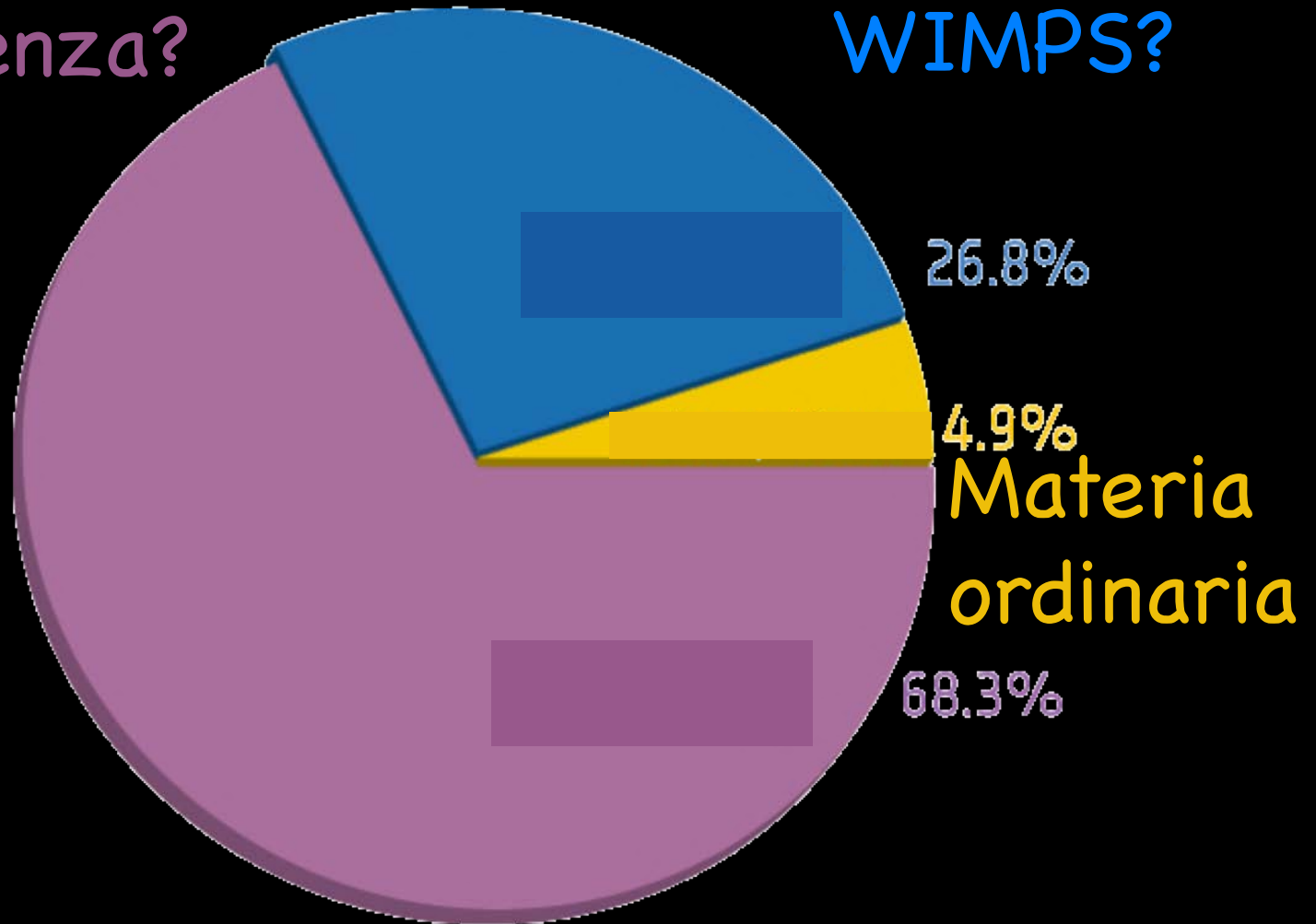
- Causa l'accelerazione nell'espansione dell'Universo (premio Nobel 2011)
 - Si oppone alla forza di gravità
- Visibile solo su scala dell'Universo intero
 - Determina il destino dell'Universo
 - Solo modelli teorici

Energia oscura?

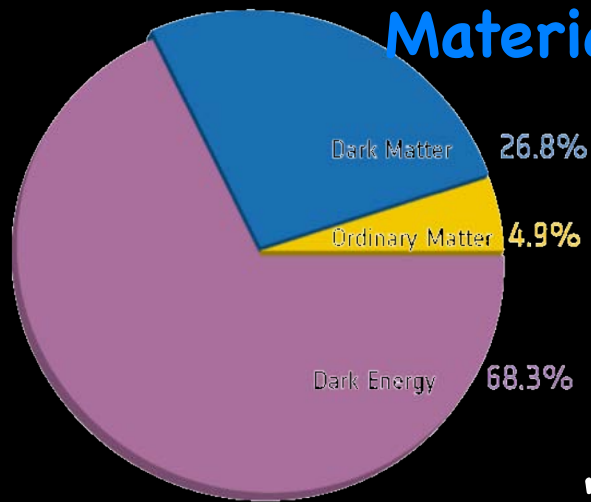
Costante cosmologica,
quintessenza?

Materia oscura?

WIMPS?



Materia oscura?



Energia oscura?

"A una maggiore conoscenza si accompagna un più insondabile e meraviglioso mistero, che spinge a penetrare ancora più in profondità.

Mai preoccupati che la risposta ci possa deludere, con piacere e fiducia solleviamo ogni nuova pietra per trovare stranezze inimmaginabili che ci conducono verso domande e misteri ancora più meravigliosi. Certamente una GRANDE AVVENTURA!"
(R. Feynman, The value of science, 1958)



DON'T LET THE BRIGHT
LIGHTS FOOL YOU

THE DARK SIDE

CONTROLS THE UNIVERSE

OUR UNIVERSE

STARS: 0.5%

DARK
MATTER: 33%

DARK
ENERGY: 66%

DARK MATTER HOLDS IT TOGETHER

DARK ENERGY DETERMINES ITS DESTINY

Credits:

- PhD Comics <http://www.phdcomics.com/comics/archive.php?comicid=143>
- Cham & Whiteson, "We have no idea" (libro)
- A. Balbi "Il buio oltre le stelle" (libro)
- R. Kolb "Blind Watchers of the sky" (libro)
- M. Bersanelli "Il grande spettacolo del cielo" (libro)
- Dark Matter TED Talk P. Burchat
https://www.ted.com/talks/patricia_burchat_leads_a_search_for_dark_energy
- Dark Energy TEDxSF Talk A. Filippenko
<https://www.youtube.com/watch?v=-gAtPyEu0G4>