

Title: The Mystery of Dark Matter

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Abstract: Historically, astronomy has always been about light. Light from distant stars, galaxies and so forth. However, over the last few decades, researchers have come to think that the vast majority of the “stuff”™ making up the universe does not emit any light whatsoever and so is unseen. This presentation will focus something called dark matter, an exotic substance researchers now think dominates the mass of every single galaxy in the universe, including our own. It will discuss evidence supporting the existence of dark matter, and talk about how scientists around the world today are currently trying to directly detect dark matter through a range of highly sensitive experiments around the globe.

The Mystery of Dark Matter: A Revolution in our Understanding of the Universe

Damian Pope

Perimeter Institute for Theoretical Physics, Waterloo

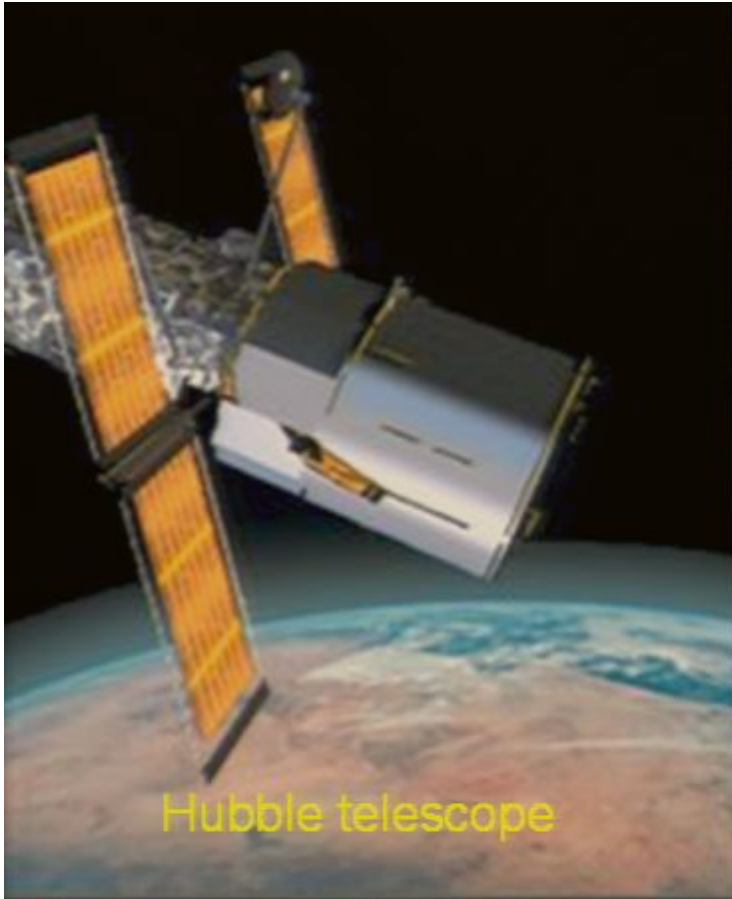
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Hubble telescope



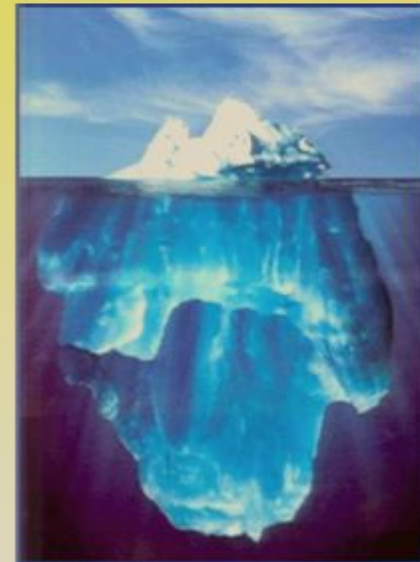
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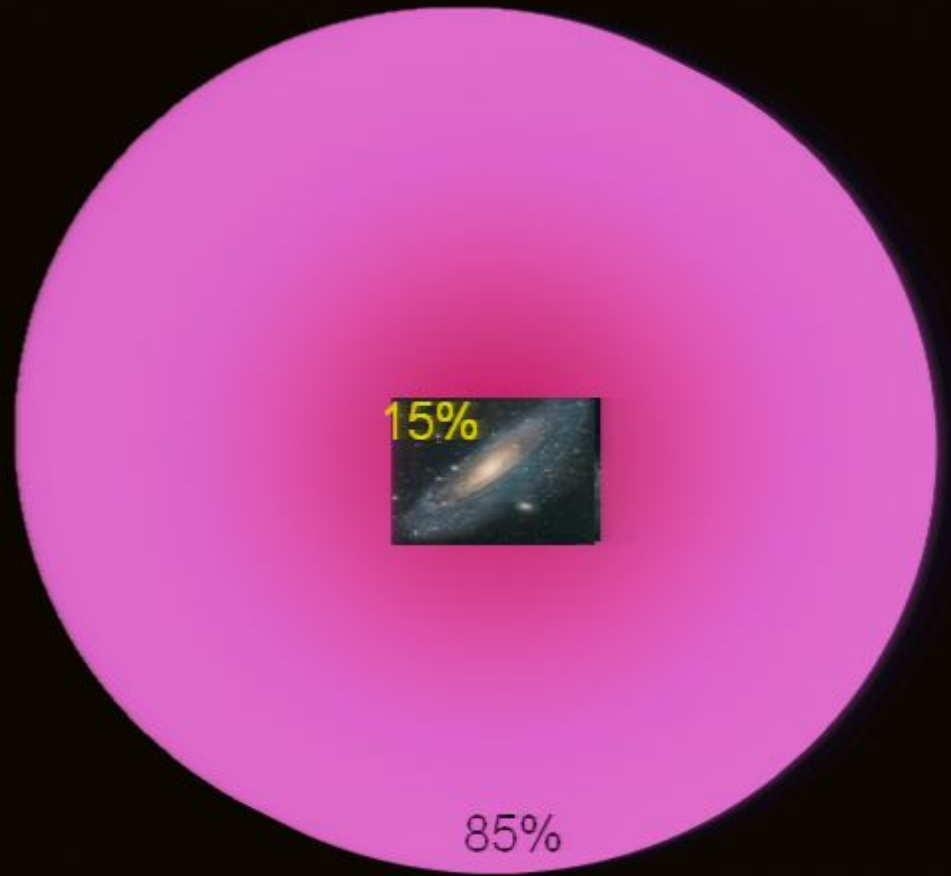
Super computer

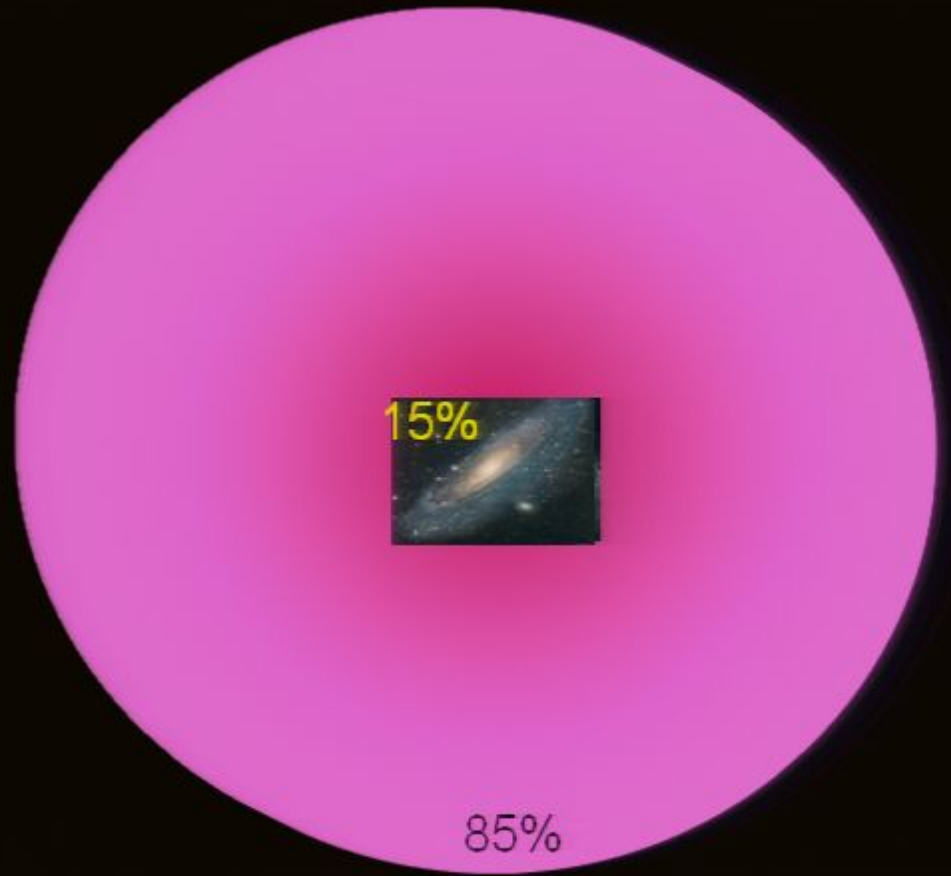
Summary

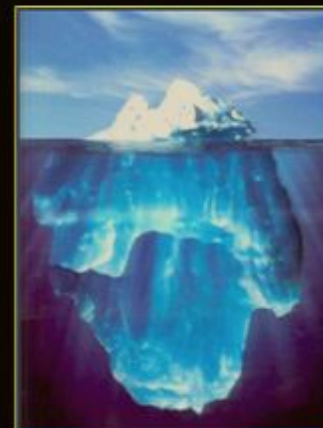
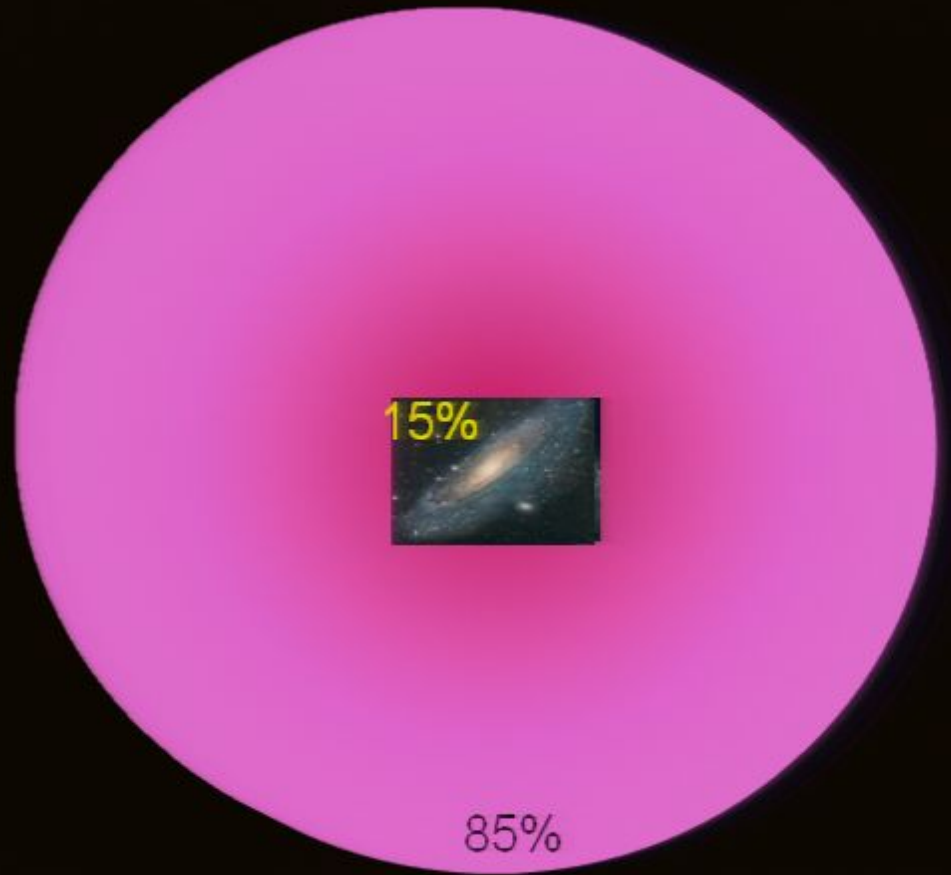
- Physicists have discovered that at least 90% of the matter in galaxies is unseen (like the fraction of an iceberg below the water).
- A gigantic revolution in our understanding of what makes up the universe.









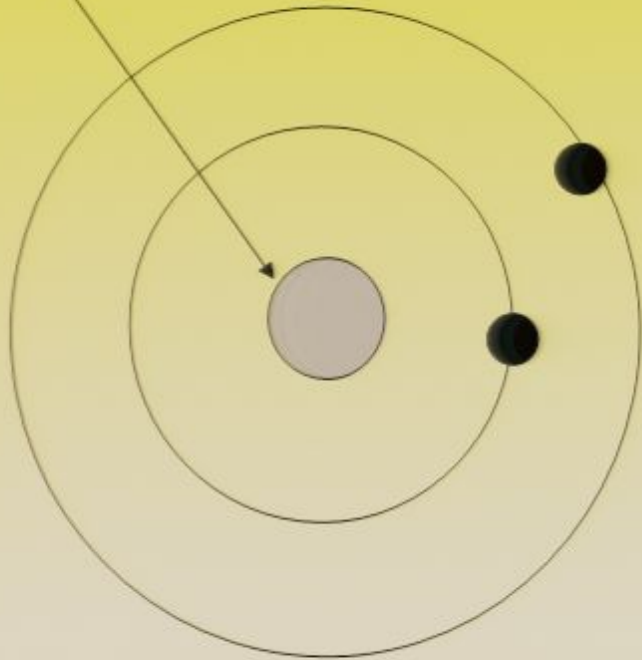


Summary

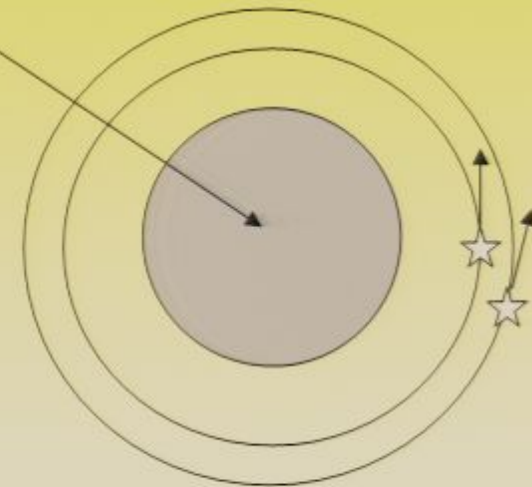
- What is the mass of a galaxy?
- The hidden parts of galaxies



Sun



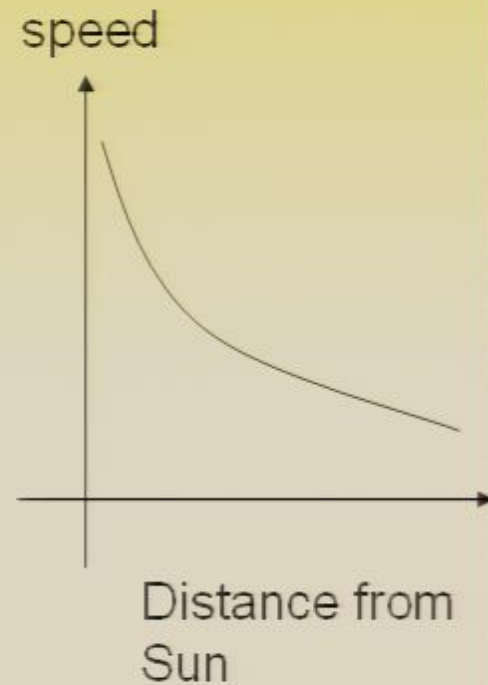
Rest of
the
galaxy



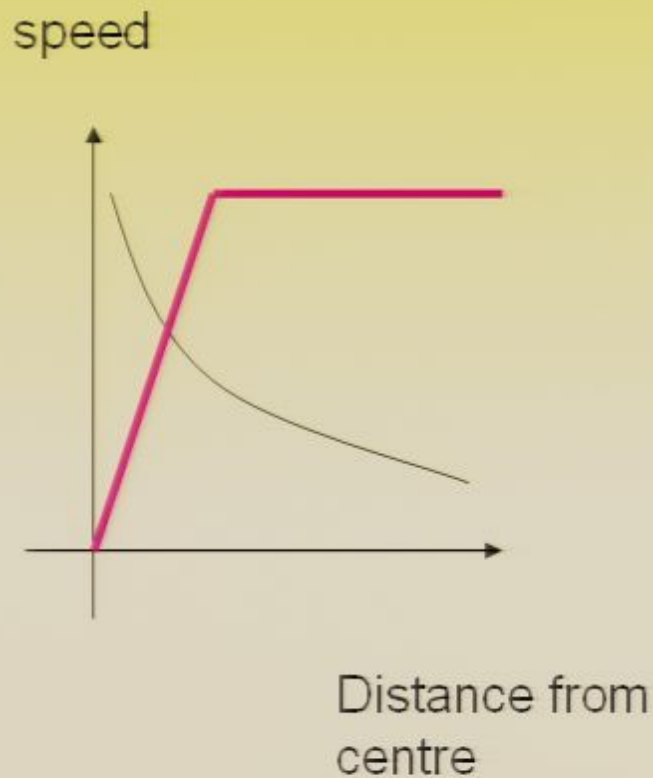
Outer
stars

Speeds of planets in the solar system

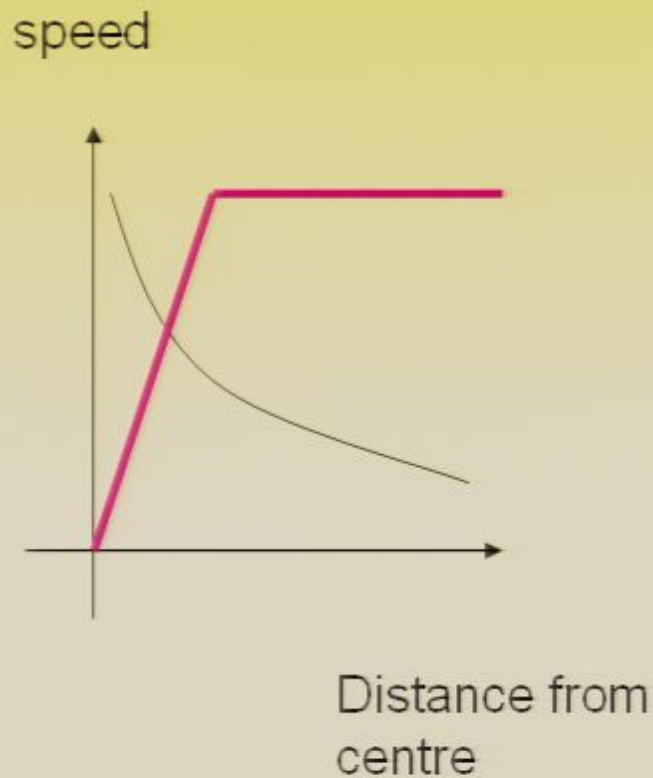
Planet	Orbital speed (km/s)	
Mercury	47.9	
Venus	35.0	
Earth	29.8	
Mars	24.1	
Jupiter	13.1	
Saturn	9.6	
Uranus	6.8	
Neptune	5.4	



Speeds of stars in Andromeda



Speeds of stars in Andromeda



- Similar discrepancies have been observed in over 1,000 galaxies.



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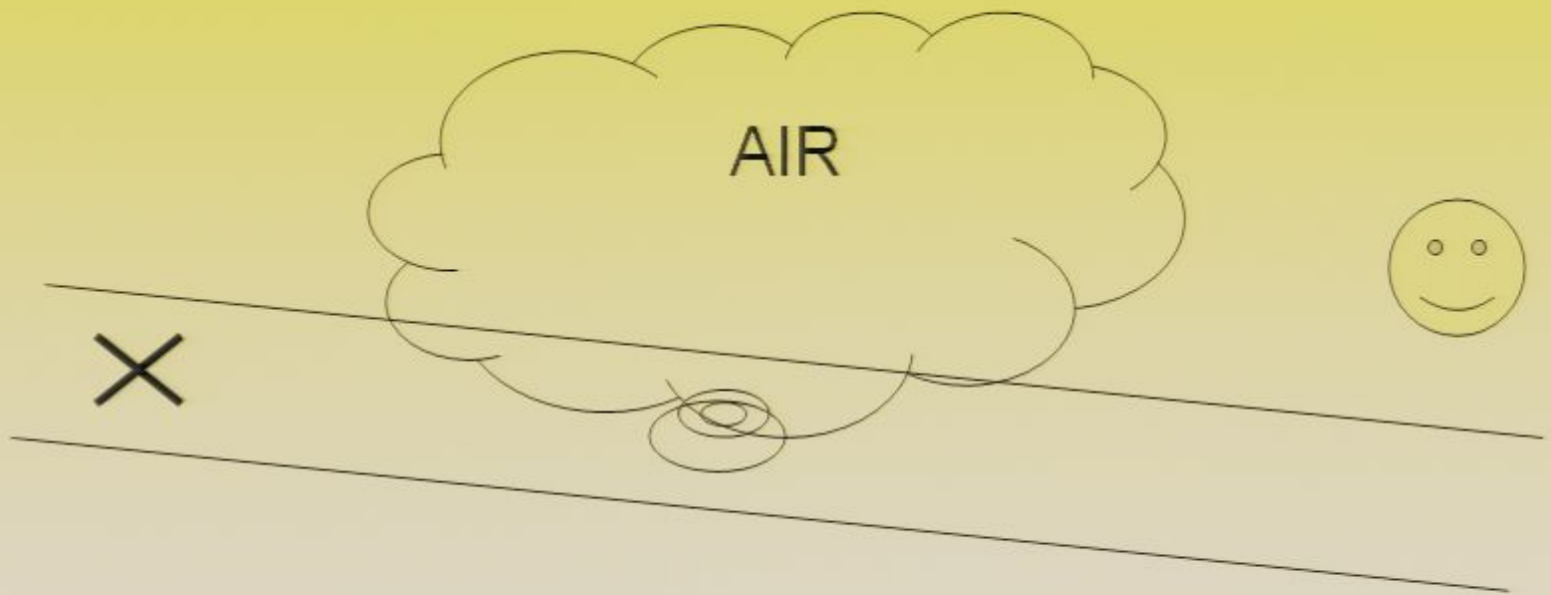


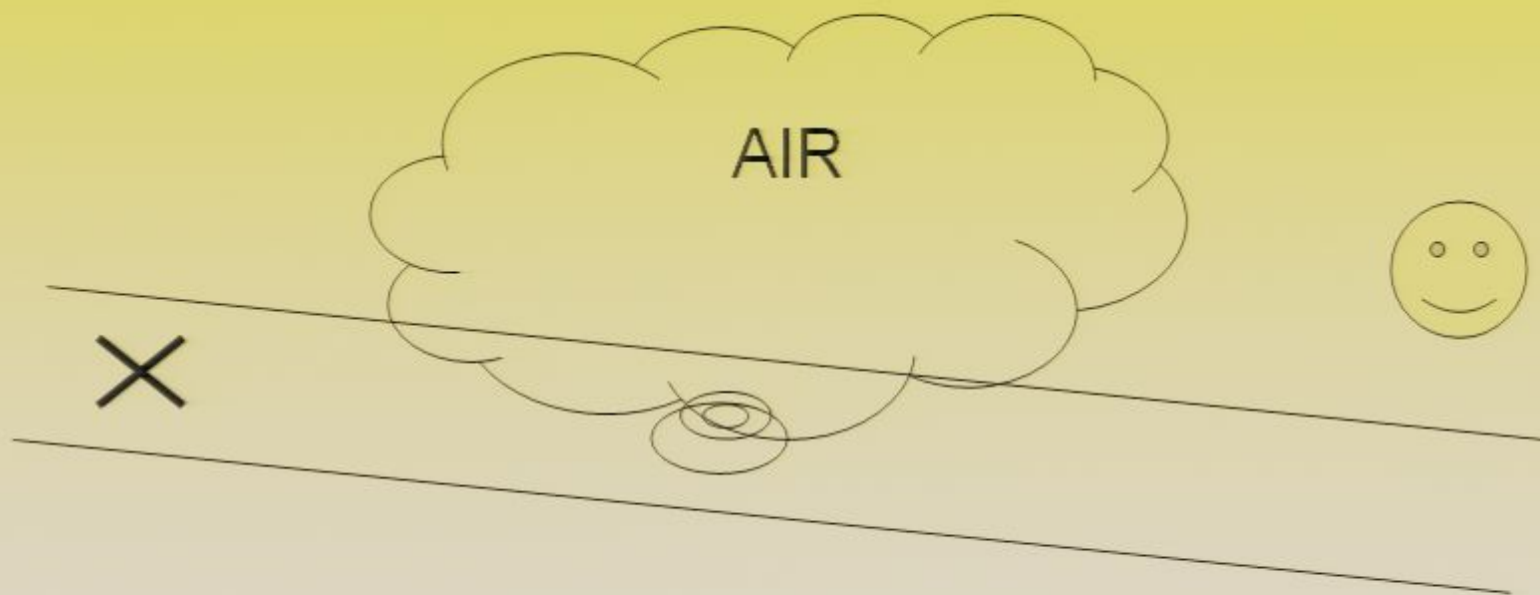
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Road on a hot day







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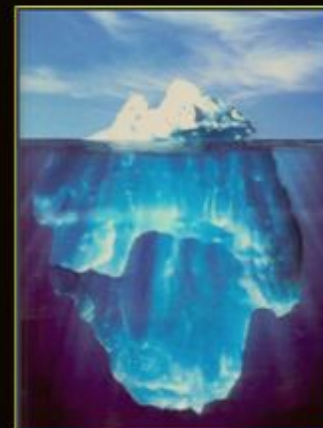
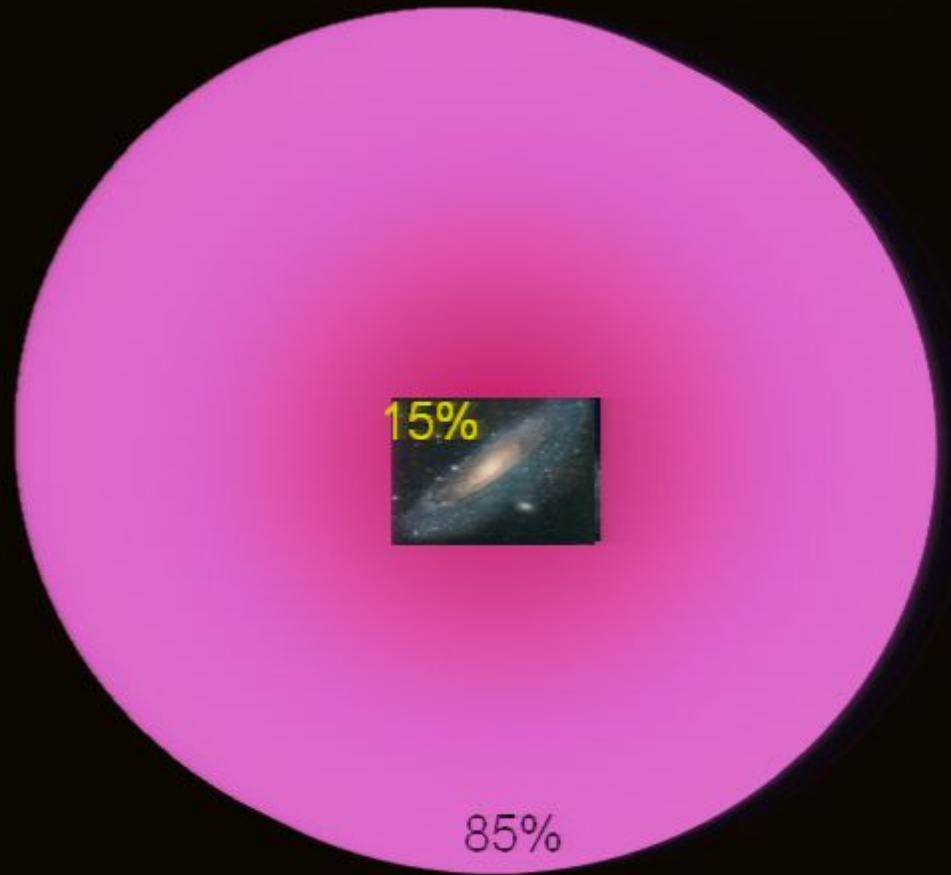


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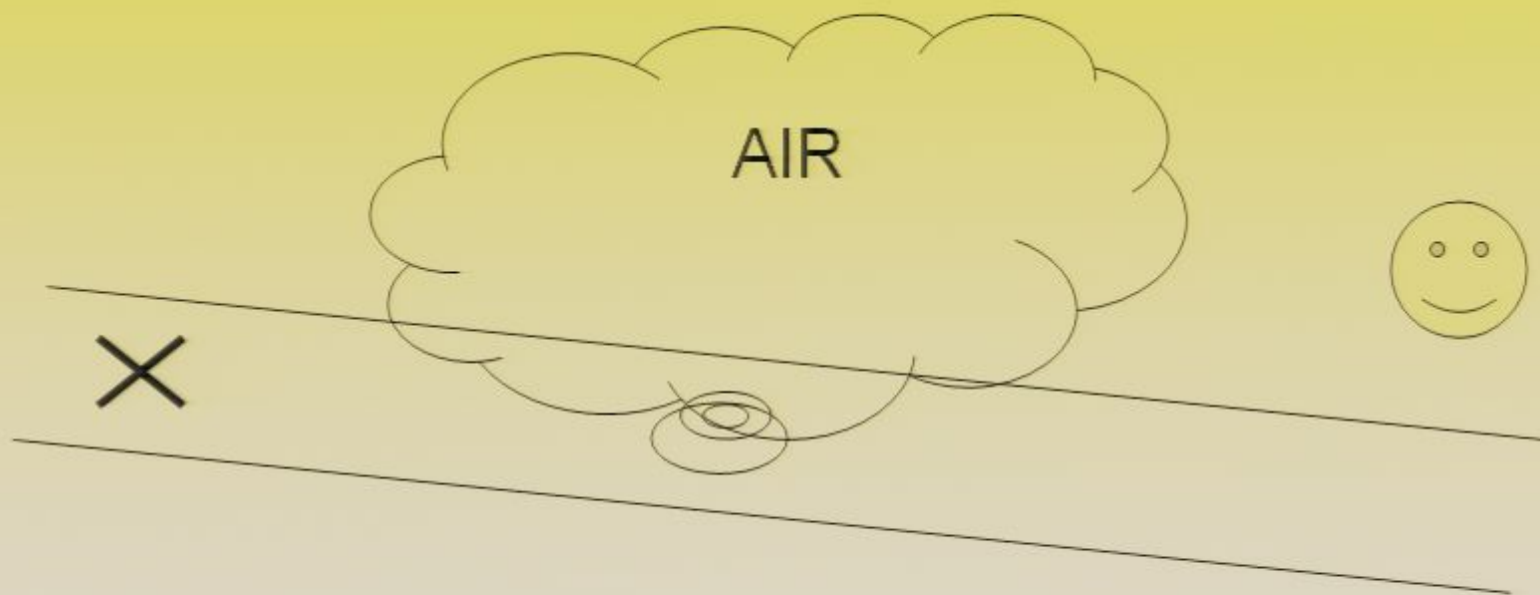


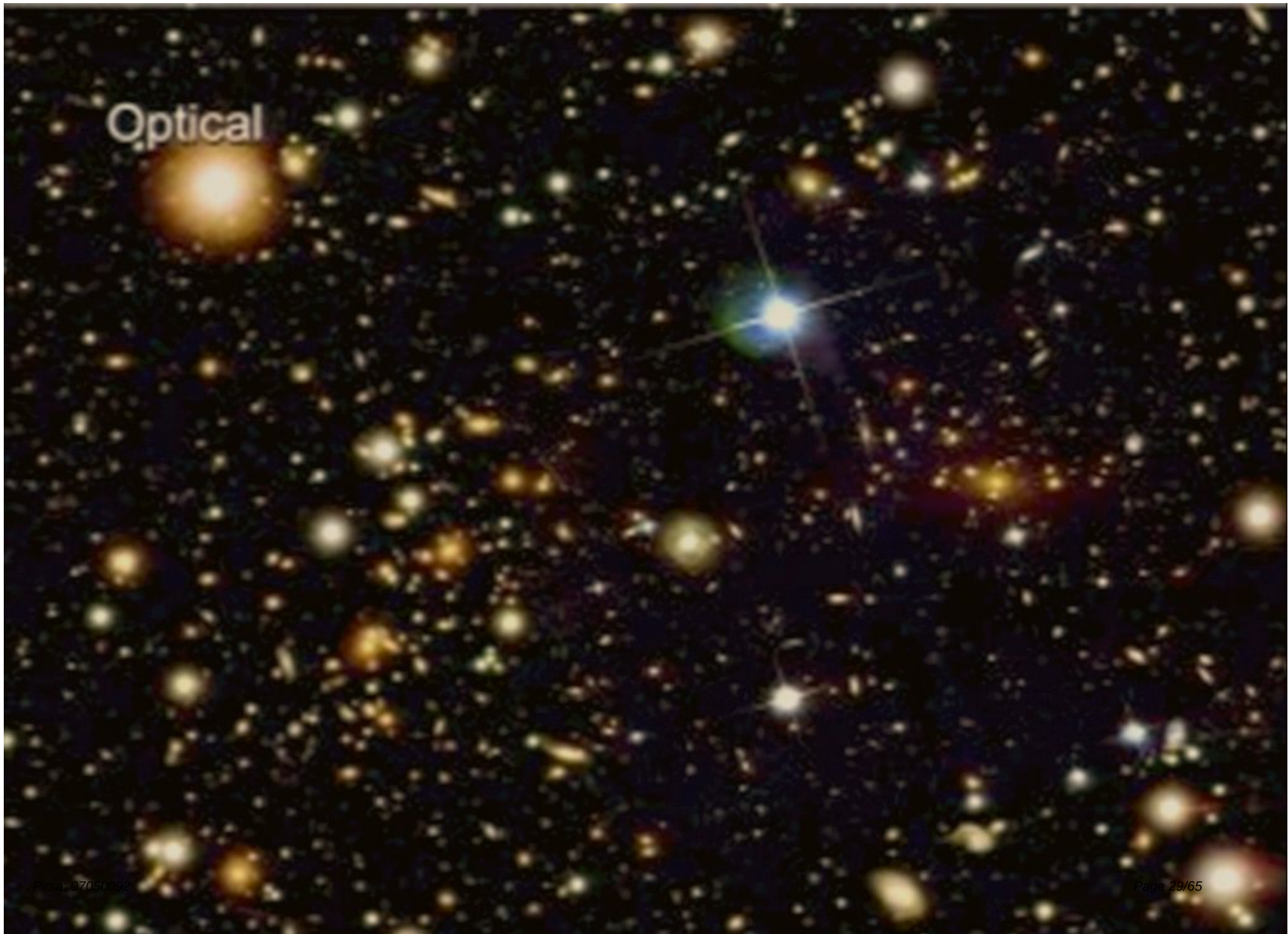
Road on a hot day



Road on a hot day







Optical Dark Matter

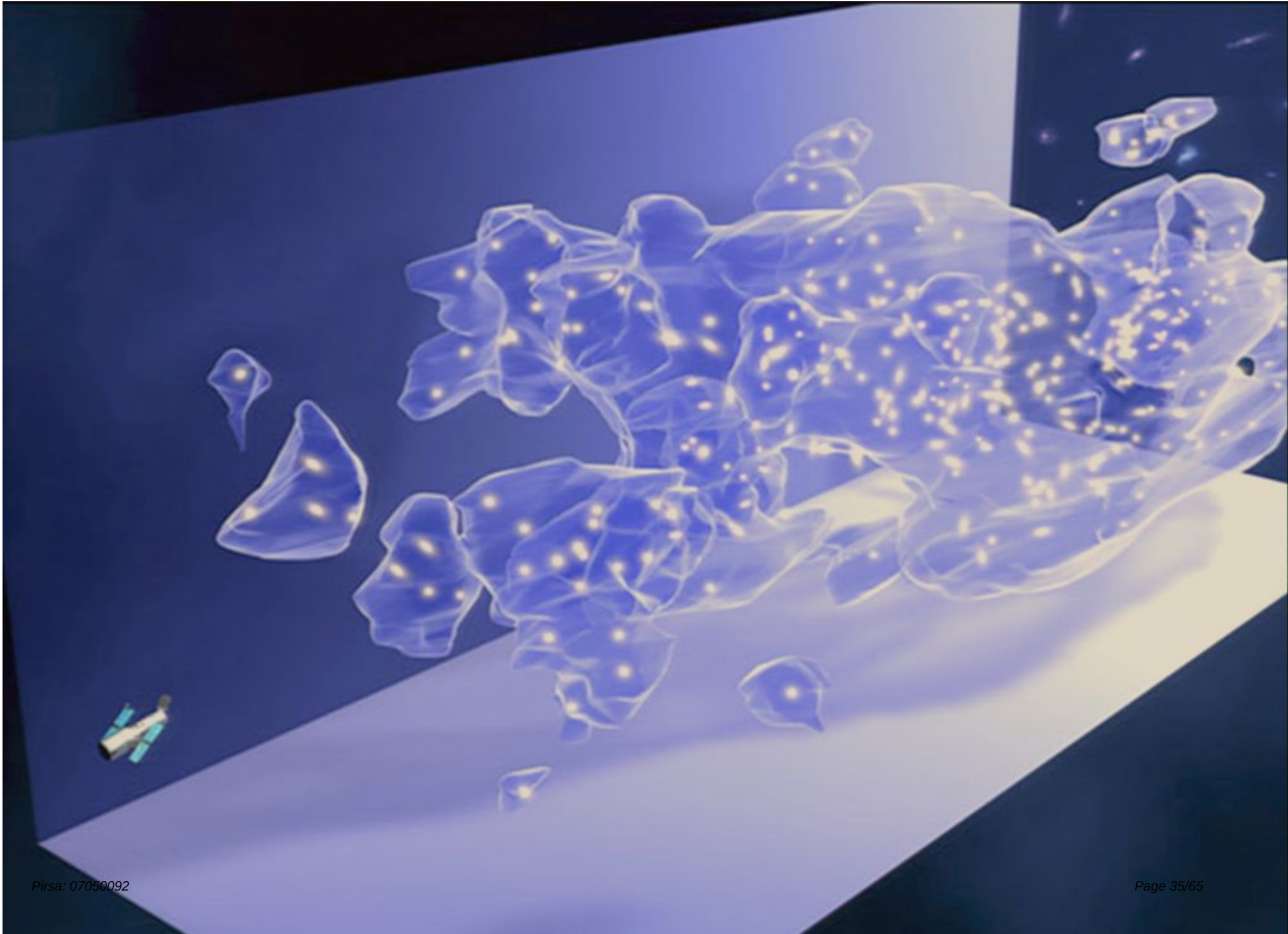
Optical Dark Matter

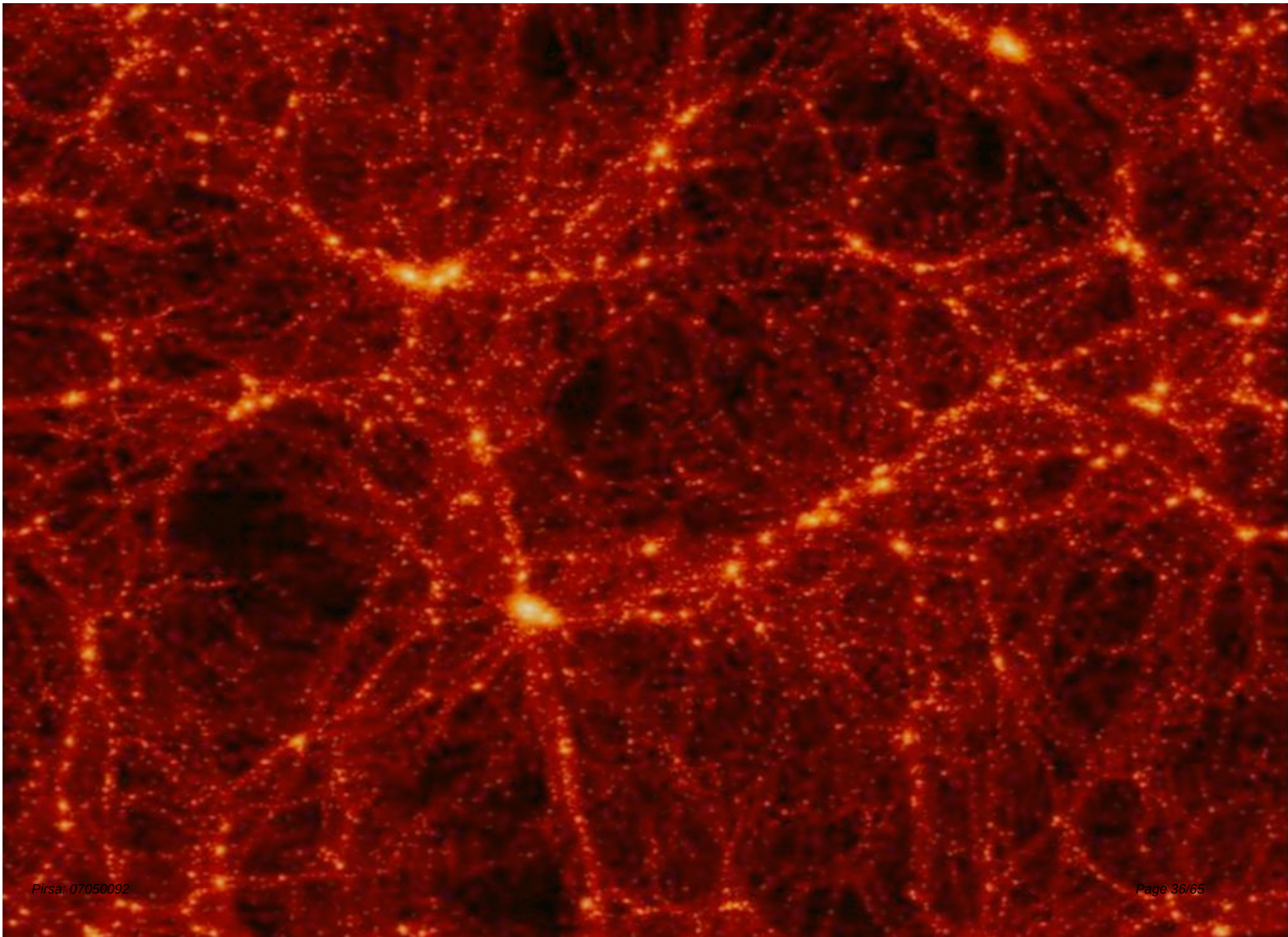
Optical Dark Matter



Optical Dark Matter

DARK MATTER





- Planets,
- Dead stars (brown dwarfs)
- Black holes

Macho theory

= Massive Astrophysical Compact Halo objects

- Planets: thousands for each star.
- Black holes: send as they slightly bend light passing near them. We've looked and haven't seen them.
- Same thing with brown dwarfs.

- Known subatomic particles that hardly interact with anything else (neutrinos).

What options are left?

- Mass that does not emit or reflect any light
- Such matter would be invisible or dark, i.e. it is **dark matter**
- It is present in *all* galaxies.

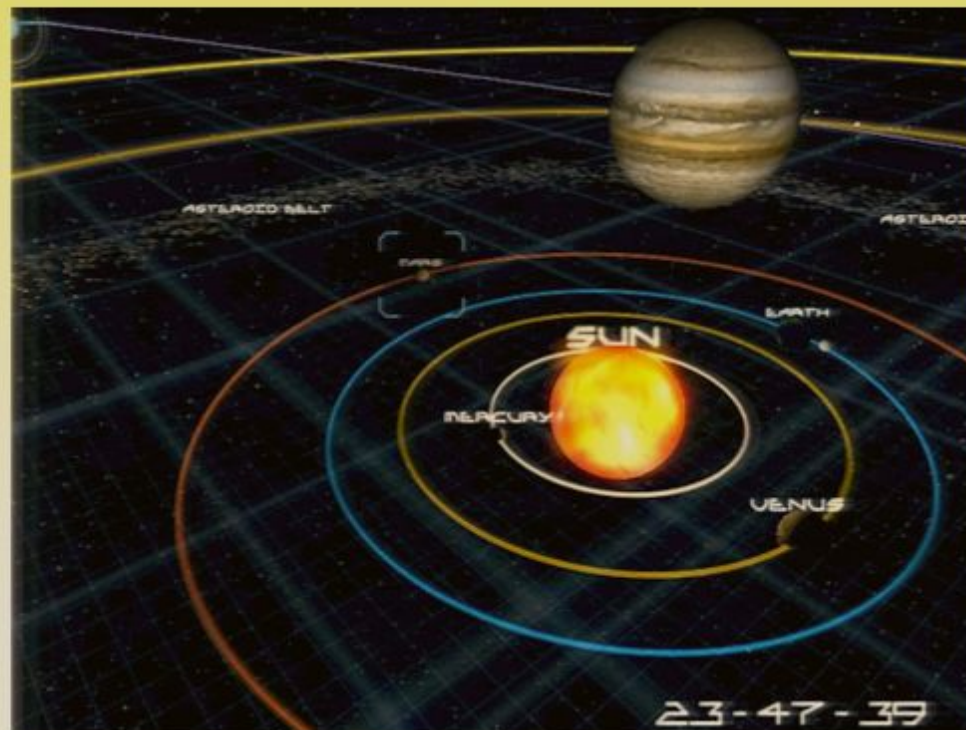
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- 2 million kilograms of dark matter in the solar system!







10 times larger than the
stars



10 times larger than the
stars



**90% of the mass
of the Milky Way
is dark matter**





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THEORY 1: WIMPs



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= weakly interacting massive particle

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= weakly interacting massive particle

- no electric charge
- 100 times the mass of a proton
- completely different to all of the particles we currently have seen
- Travel at speeds of around 360 km/s.
- Millions of WIMPs passing through your body each second

- **THEORY 2: Axioms**





- **THEORY 2: Axions**

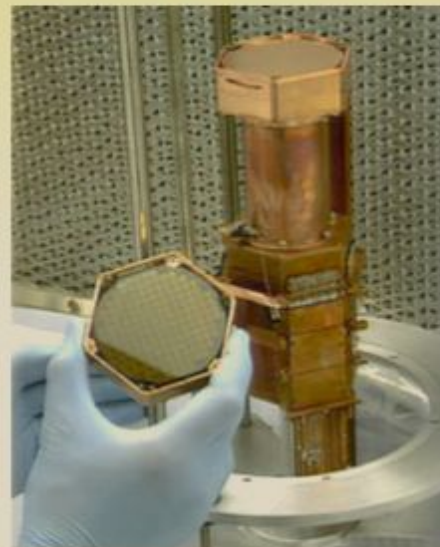
- no electric charge

- mass of around one one hundred billionth of the mass of an electron (10^{-40} kg).

- earliest physicists involved were Roberto Peccei, Helen Quinn, Frank Wilcek and Steven Weinberg in the 1970s.

Dark matter experiments

- Cryogenic dark matter search (CDMS)
- 100-gram crystals of Silicon/Germanium located kilometres underground in a mine in Minnesota, U.S.A.



crystal

Canadian dark matter experiment

- Sudbury



- PICASSO



Atom smasher

- Large Hadron Collider (LHC), CERN, Switzerland/France
- Atom smasher or particle accelerator
- 27 kms in circumference
- \$6 billion
- Probe distances of 10^{-19} metres



Recap

Vast majority of the matter in the universe is unseen

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Superposition.

genuine randomness

entanglement

