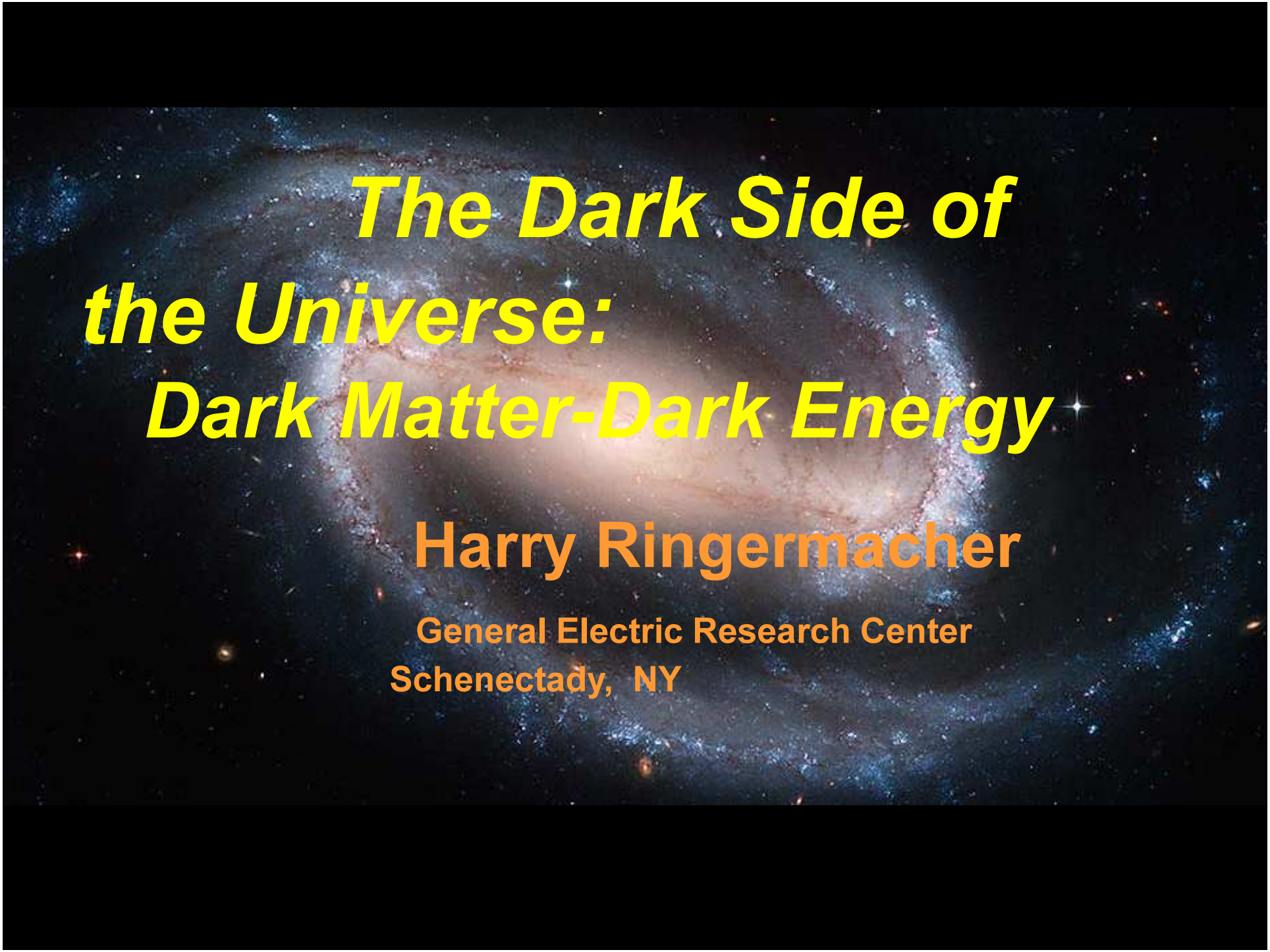


The Dark Side of the Universe: Dark Matter-Dark Energy

Harry Ringermacher

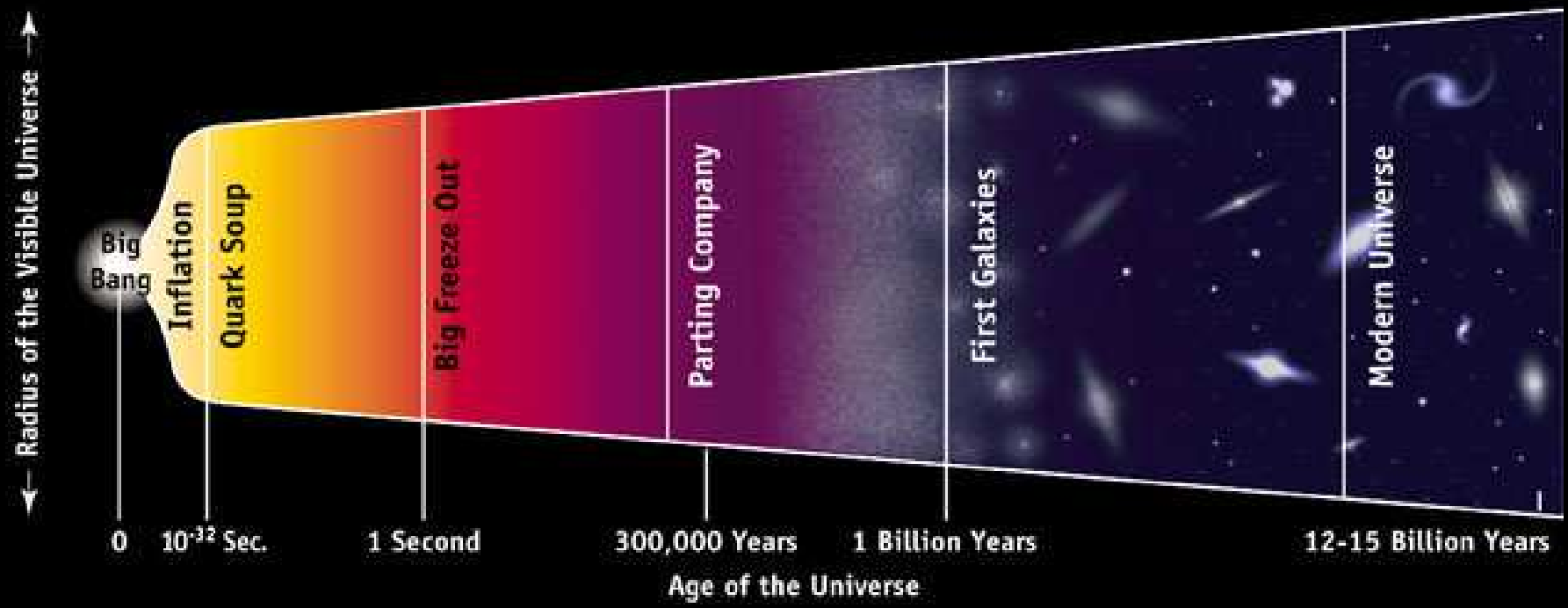
General Electric Research Center

Schenectady, NY

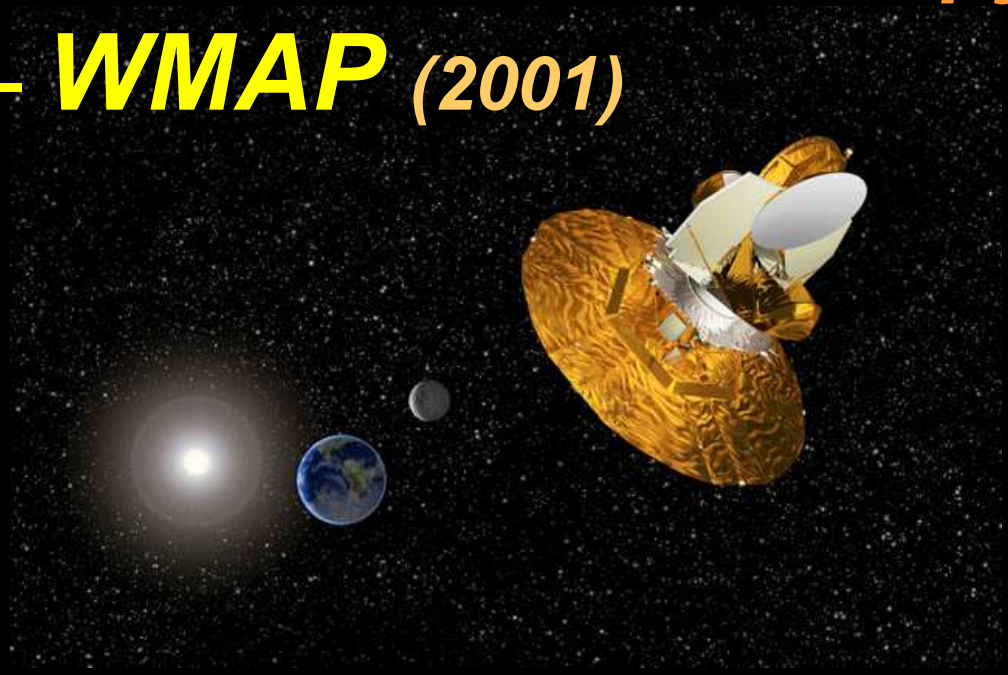
Overview

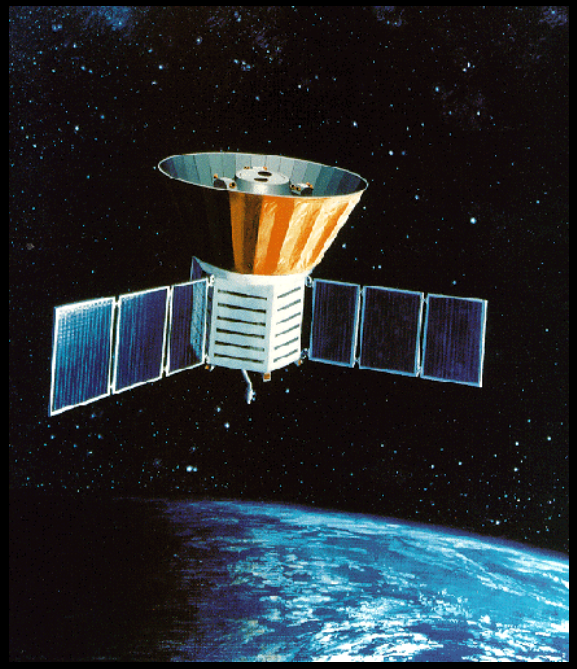
- The “Big-Bang Universe” – how we see
- What do we know about Dark Matter and Dark Energy ?
- Candidates for Dark Matter
- The search for dark matter

Time-line of the Universe



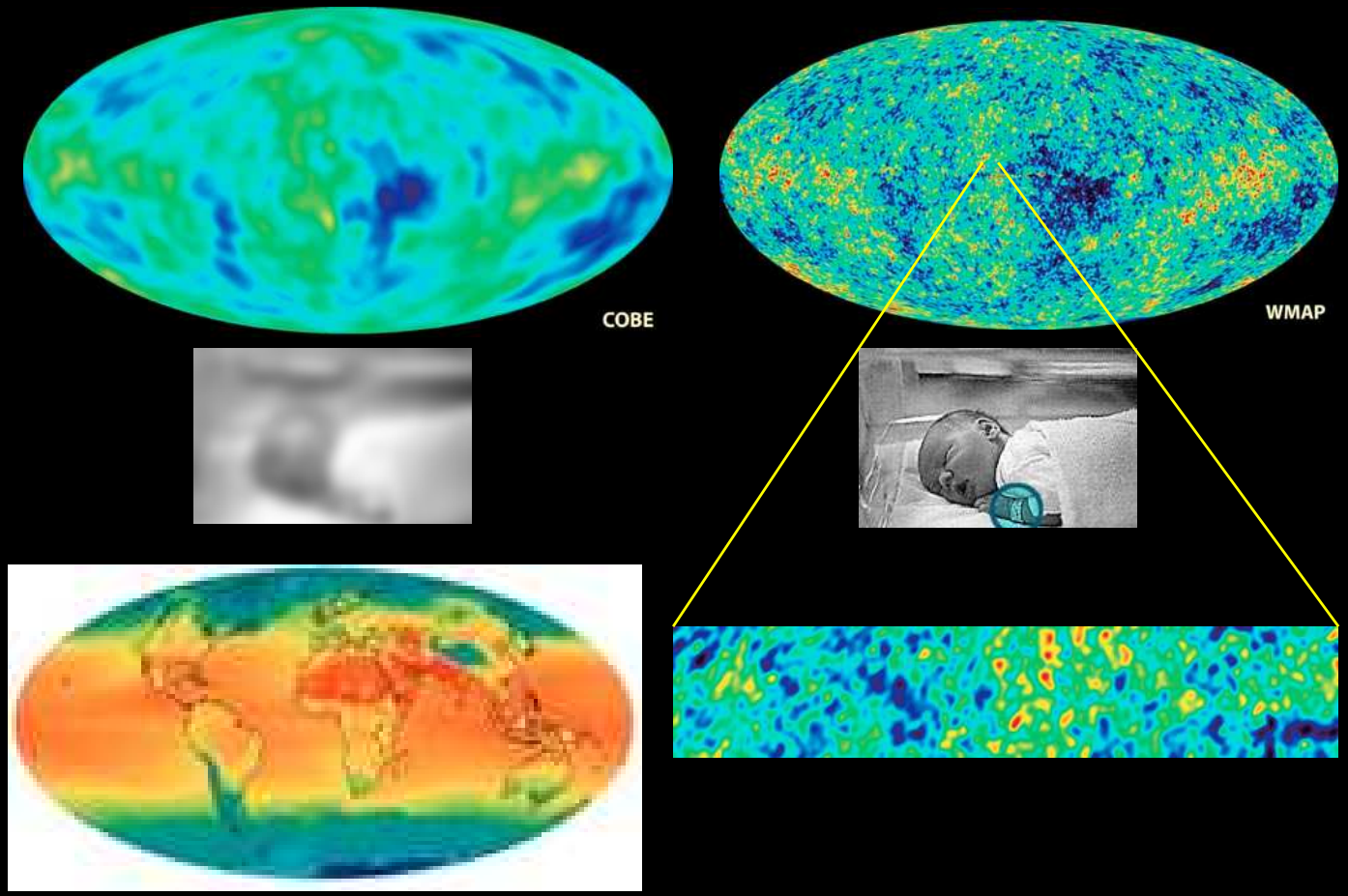
Wilkinson Microwave Anisotropy Probe – WMAP (2001)





Cosmic Background Explorer COBE – forerunner (1989)

WMAP produced unprecedented images of the earliest light in the universe – the Cosmic Microwave Background (CMB)



What did WMAP discover?

- Universe is 13.7 billion years old, (± 1%)
- First stars ignited 200 million years after the Big Bang.
- Light in the WMAP picture is from 379,000 years after the Big Bang.
- Content of the Universe:

  4% Atoms, 23% Cold Dark Matter, 73% Dark Energy.

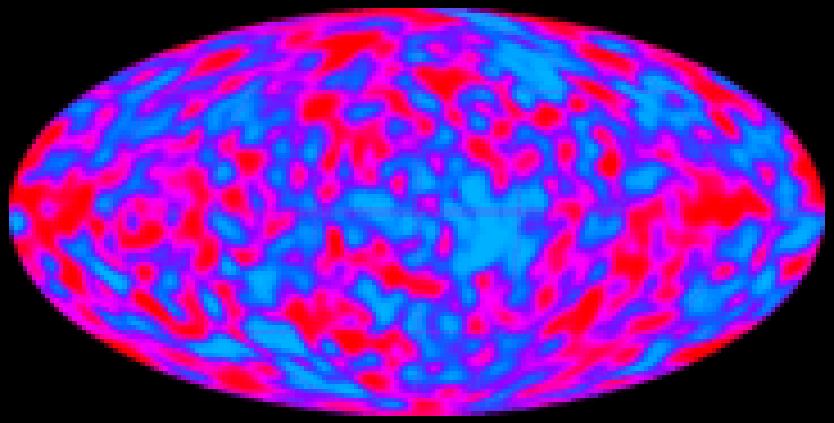
- The Universe will expand forever (it is "flat") .
- The nature of the Dark Energy and Dark Matter is still a mystery.

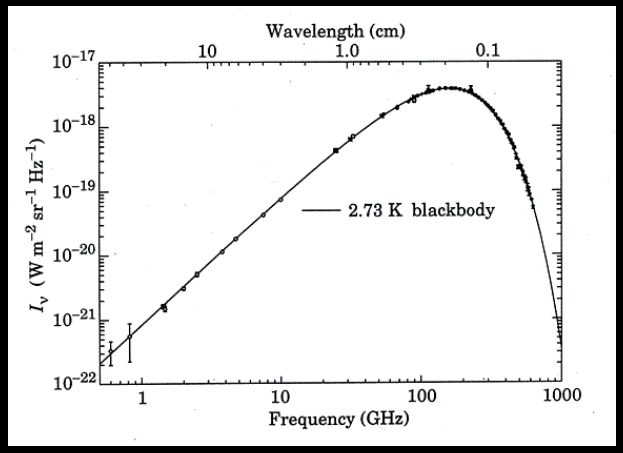
2006 Nobel Prize in Physics

Blackbody from and anisotropy of the Cosmic Microwave Background Radiation

John Mather
NASA Goddard

George Smoot
UC Berkeley

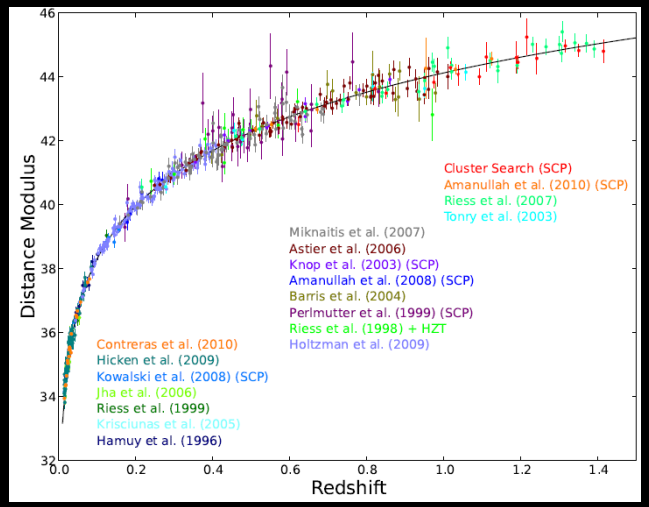


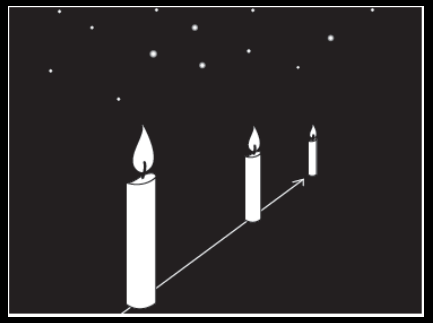


2011 Nobel Prize in Physics

Discovery of the accelerating expansion of the universe through observations of distant supernovae

Brian Schmidt, Australian Nat'l U.
Saul Perlmutter, U.C. Berkeley
Adam Riess, JHU





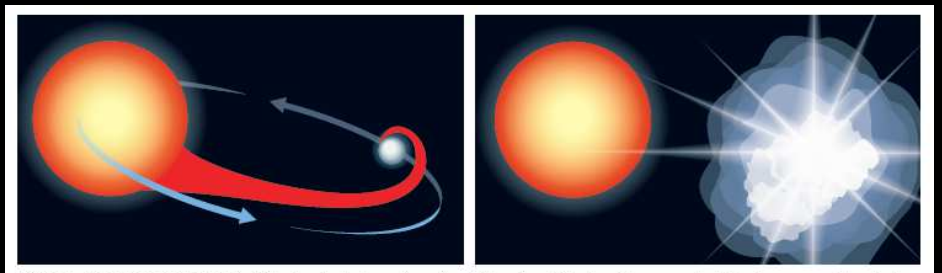


Figure 3. Supernova explosion. A white dwarf steals gas from its neighbour using its gravity. When the white dwarf has grown to 1.4 solar masses, it explodes as a type Ia supernova.

Type 1a supernova in M101

(photos by H. Ringermacher)


M101, “Pinwheel”
(4/20/10)
22 Mly, 120min


M101
(9/18/11) Sn 2011 fe

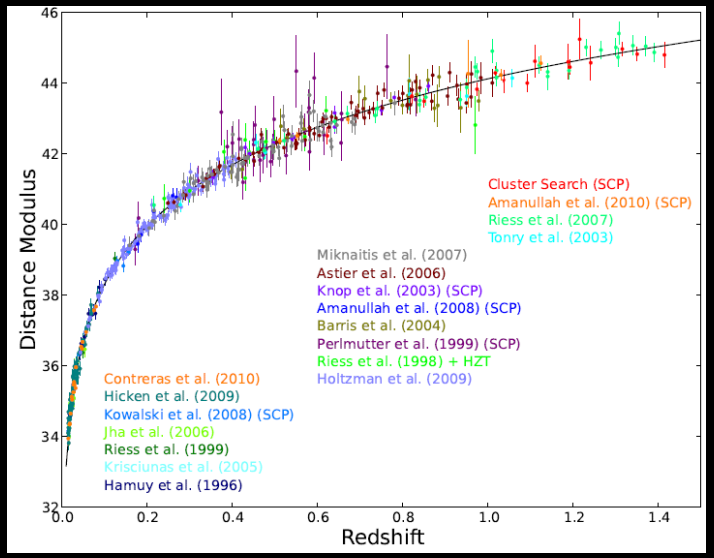
DARK ENERGY - properties

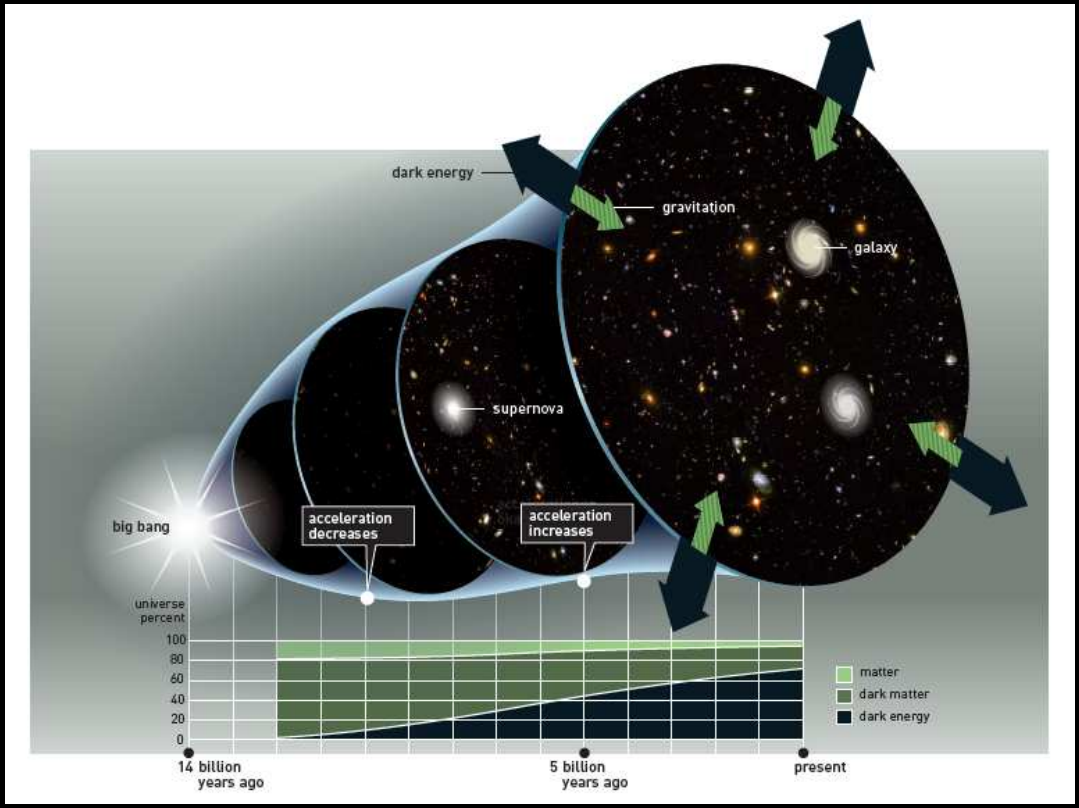
- **Uniform everywhere – positive energy density (6 H^1/m^3)**
- **Gravitationally repulsive - Controls cosmic accelerated expansion(about 6By ago)**
- **Origin/nature unknown**
- **Possible candidates: Cosmological constant(constant throughout space for all time)**

Evidence for DARK ENERGY

The accelerating universe

Data from type 1a supernovae





Dark Matter

Galaxies

90% Dark Matter

10% stars, dust, gas

Universe

Dark Matter is about 85% of mass of universe

DARK MATTER: what we know

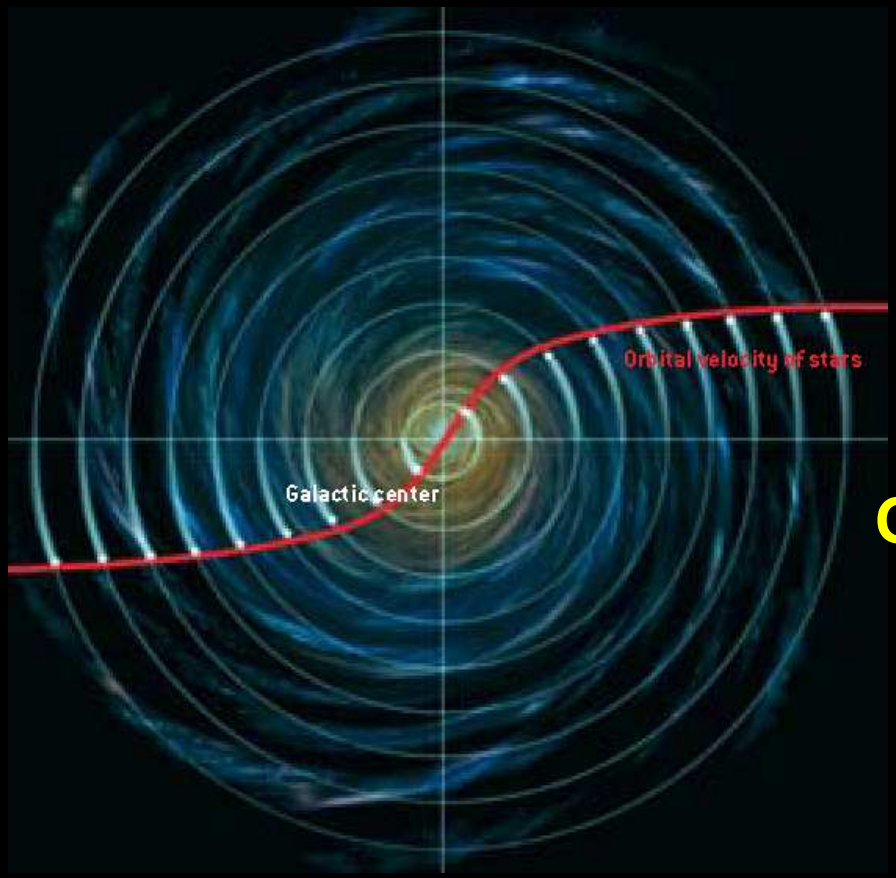
- DM is gravitationally attractive
- Seems to "control" and evolve cosmic structures.
- DM does not interact with light (dark!)
- Non-collisional

DM may be:

- Weakly Interacting Massive Particles(WIMPS)
- neutralino (lightest particle of SuperSym)
- nothing (but a new force from Einstein's Eqn)

Dark Matter in Galaxies

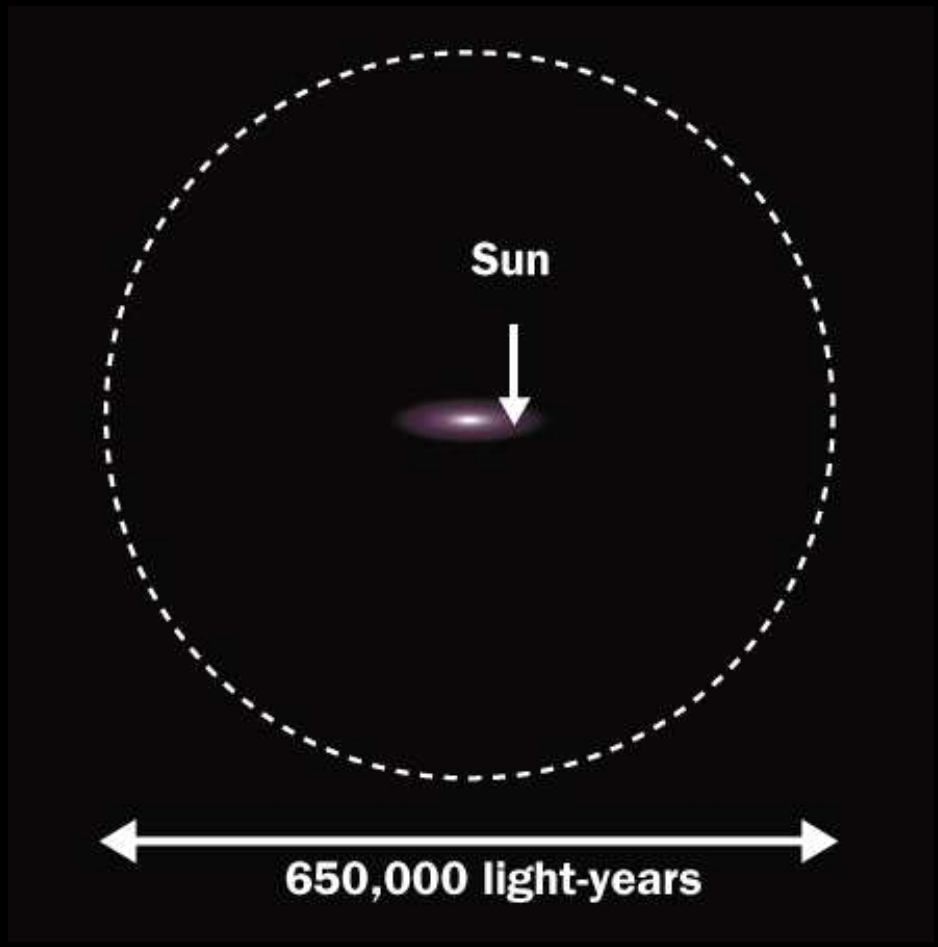
Rotation Curves for Spiral Galaxies are "FLAT" angular momentum is "not conserved"….



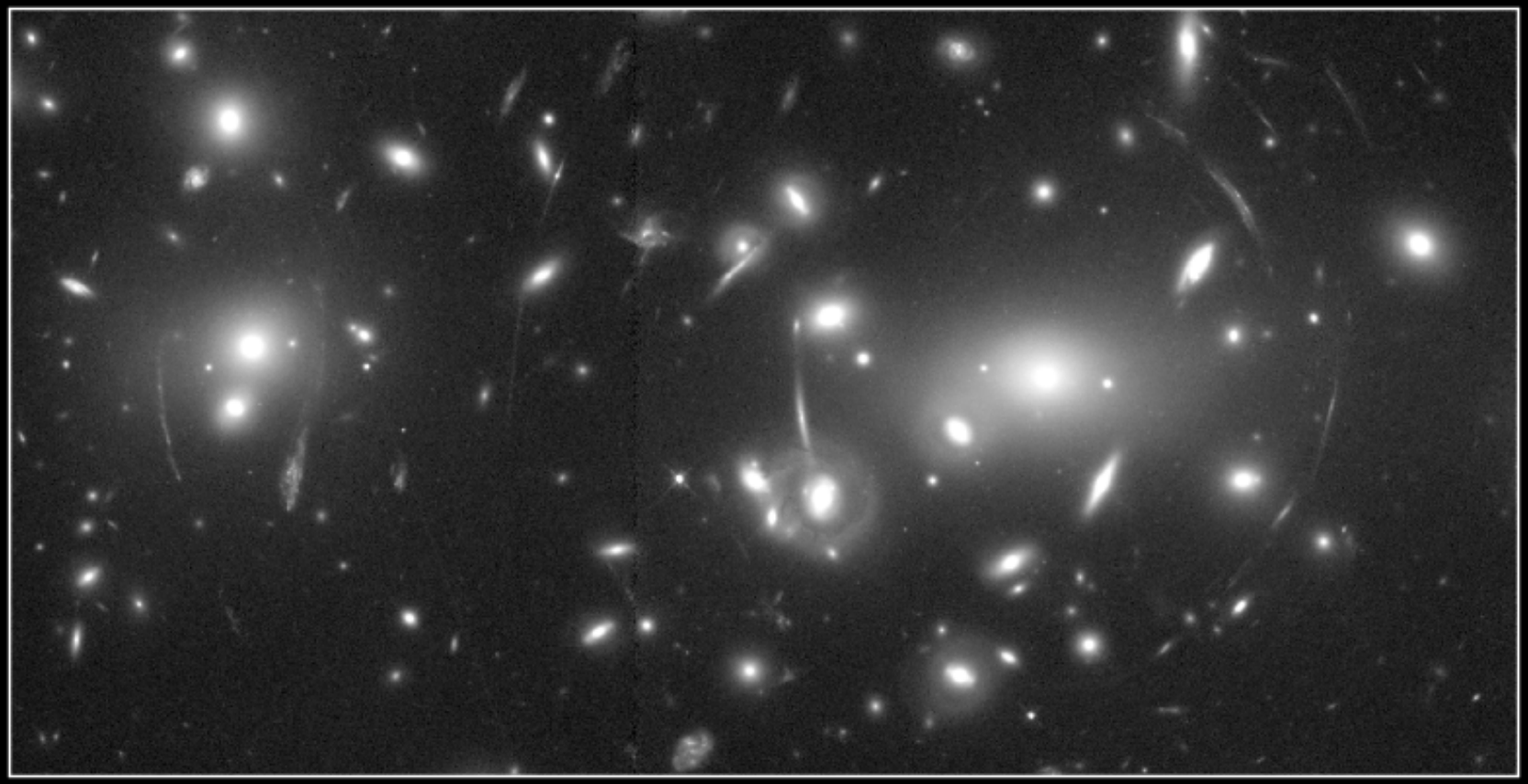
Invisible mass surrounding the galaxy must be postulated to fix this problem.

Observed by Vera Rubin in 1970's in galaxies

Current picture of DM surrounding galaxies – 10x sphere



Evidence for Dark Matter – Gravitational Lensing (bends light)

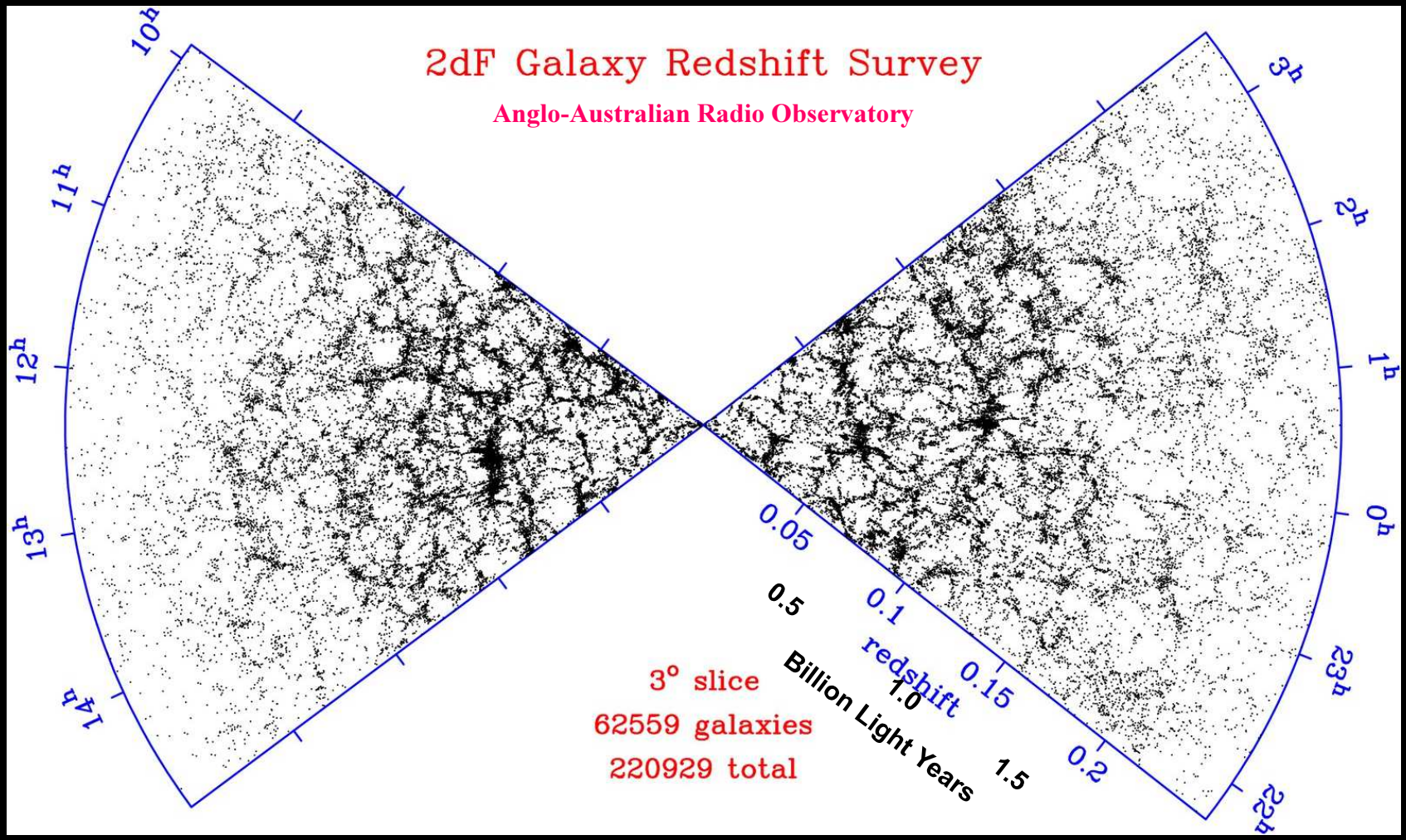


Gravitational Lens in Abell 2218 HST • WFPC2

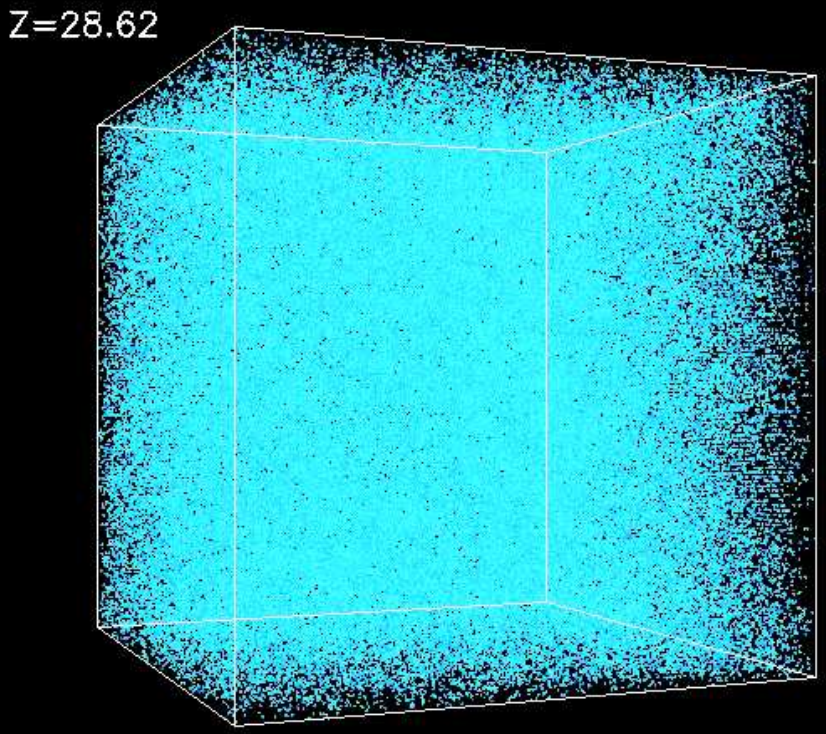
PF95-14 · ST ScI OPO · April 5, 1995 · W. Couch (UNSW), NASA

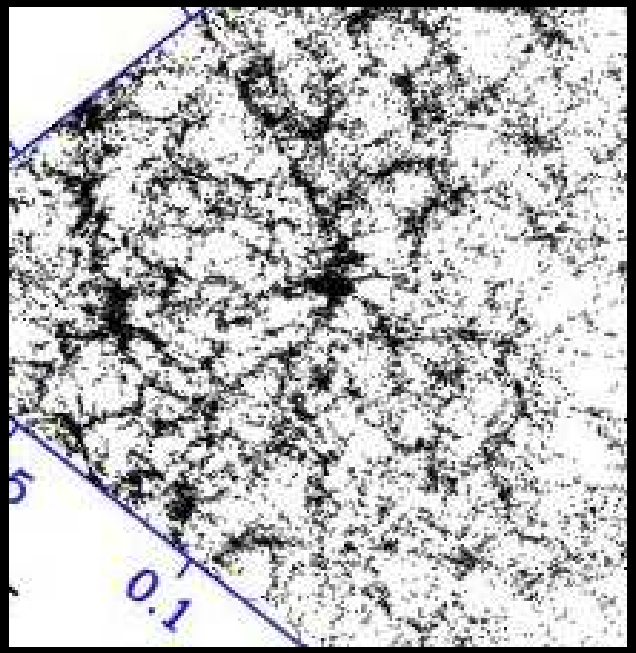
Dark Matter in the Universe -"structure"

Each dot is a galaxy



Computer Modeling Structure in the Universe
Dark Matter Simulation - filaments and voids





The Search for Dark Matter

This is really a search for the neutralino.

That is the “only show in town”.

Neutralino Properties

- Lightest, stable supersymmetric particle
- Weak interaction – therefore "non-collisional"
- About right density created at BB to account for missing matter now (WIMP Miracle)

Fundamental Forces

		Strength	Range (m)	Particle
Strong	Force which holds nucleus togeher	1	10^{-15} (diameter of a medium sized nucleus)	gluons, π(nucleons)
Electro-magnetic		$\frac{1}{137}$	Infinite	photon mass = 0 spin = 1
Weak	neutrino interaction induces beta decay	10^{-6}	10^{-18} (0.1% of the diameter of a proton)	Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin =1
Gravity	m m	6×10^{-39}	Infinite	graviton ? mass = 0 spin = 2

Experimental Methods
Rely on collisions with detectors

- *Collision ⟶ Sound*
- *Collision ⟶ Heat*
- *Collision ⟶ Ionization*
- *Collision ⟶ Light*

Experimental Methods

- *Experiments must block muons, neutrons, gammas, alphas.*

- *All must be underground to be shielded from cosmic rays and also background radiation from being underground .*

Ego Wars, > dozen experiments

Who has best acronym ?

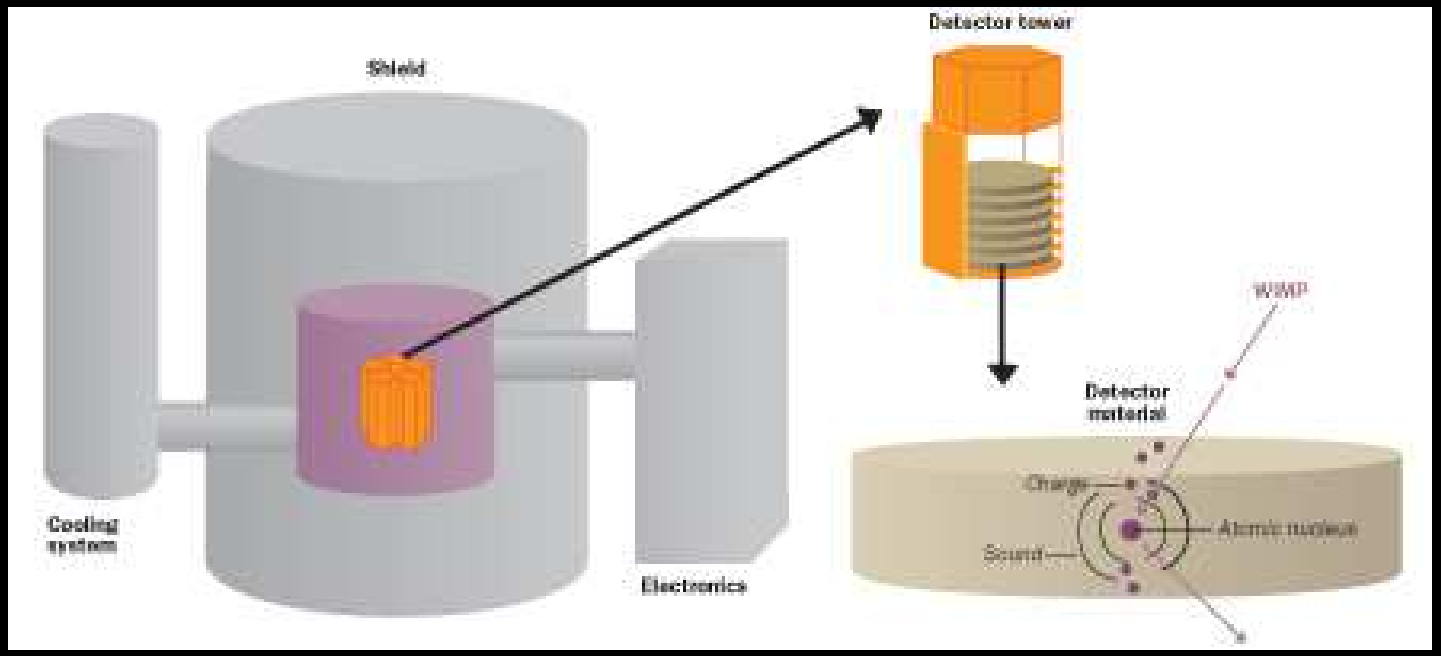
- **CDMS – Cold Dark Matter Search**
- **DAMA – DArk MAtter search**
- **WARP – Wimp ARgon Program**
- **PICASSO – Project In CAnada to Search for Super-symmetric Objects**

Soudan Underground Lab – N. MN

2300' deep

(CDMS collaboration)

Particle Sensors – acoustic transducers

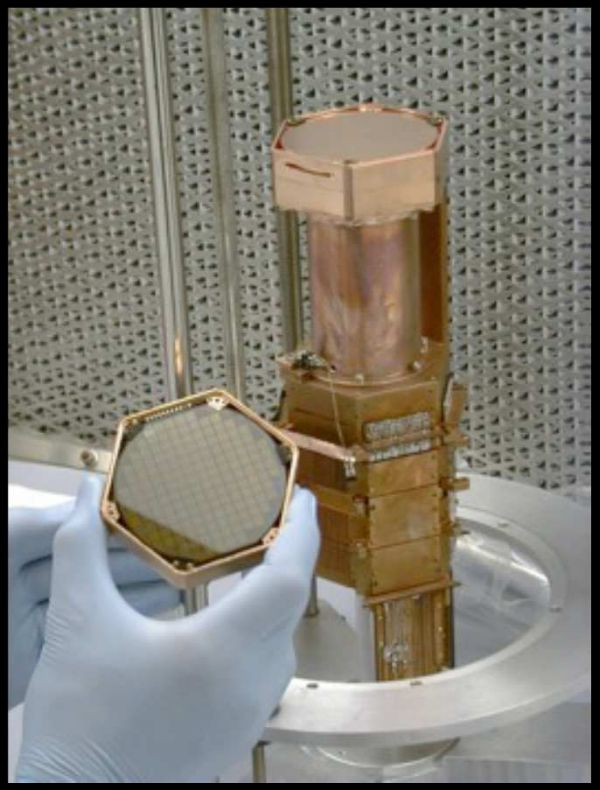


Detector "tower" is a stack of single xtal Ge or Si cooled to 40mK.

There are 5 towers - 4kg Ge, 1.5kg Si

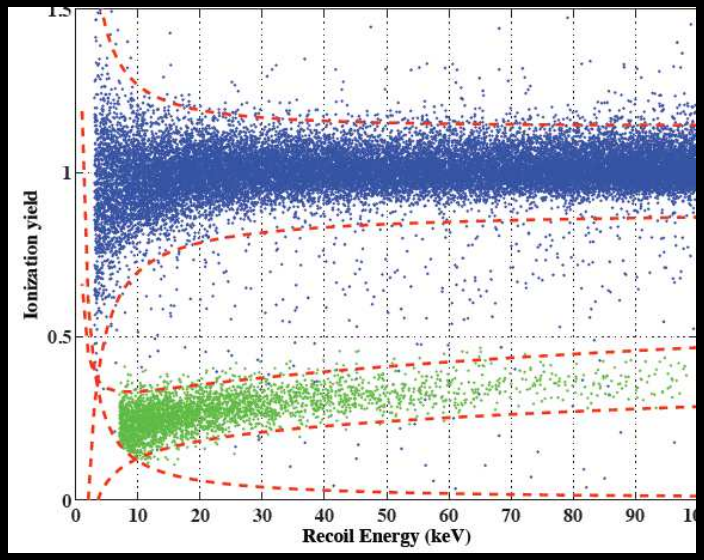
CDMS results
(ionization and phonon detection)

(1 cm thick, 7.5 cm diameter)

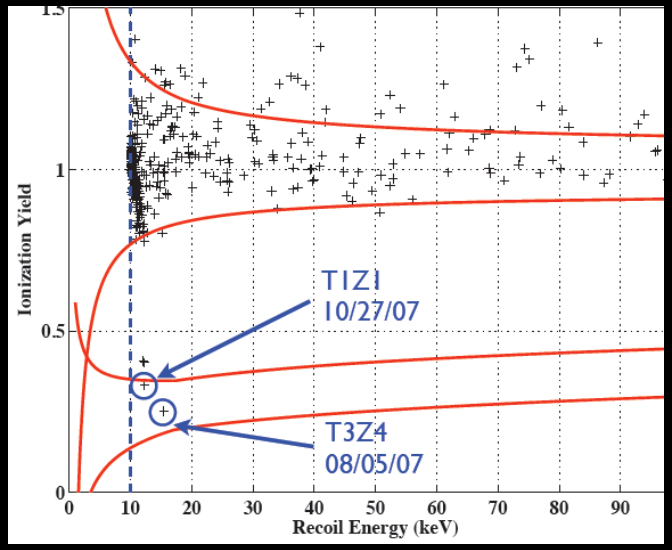


5 Towers – 30 detectors
cooled to 40mK

CDMS results
(ionization and phonon detection)



Actual data

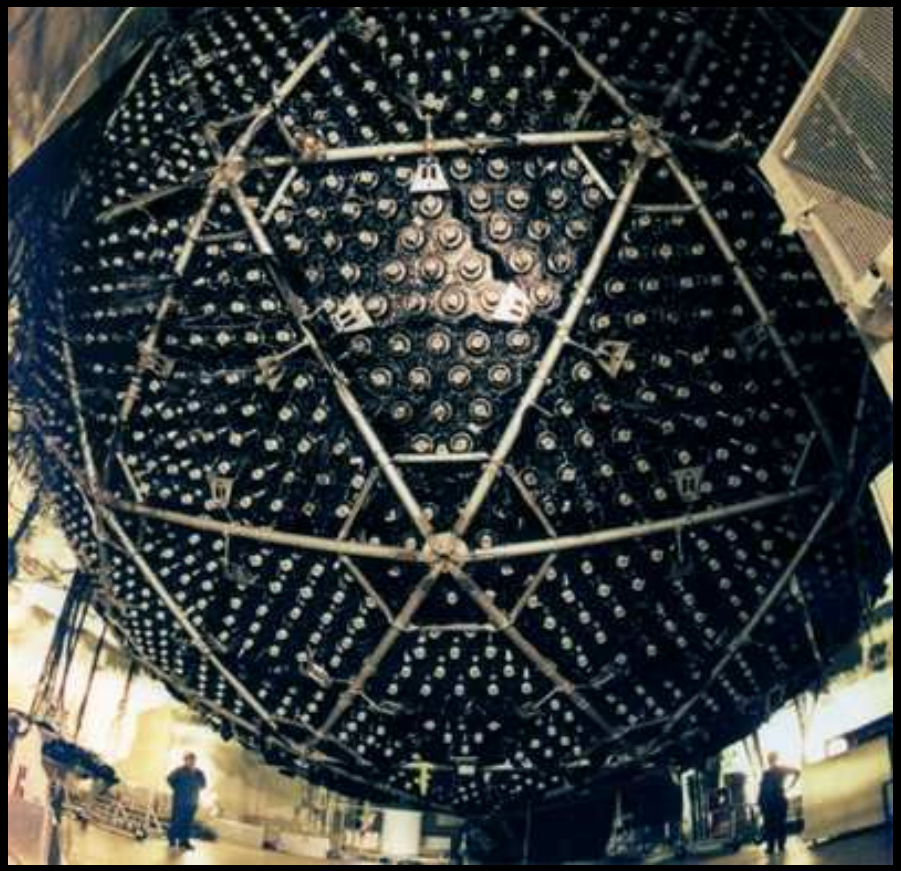


Results after test screening

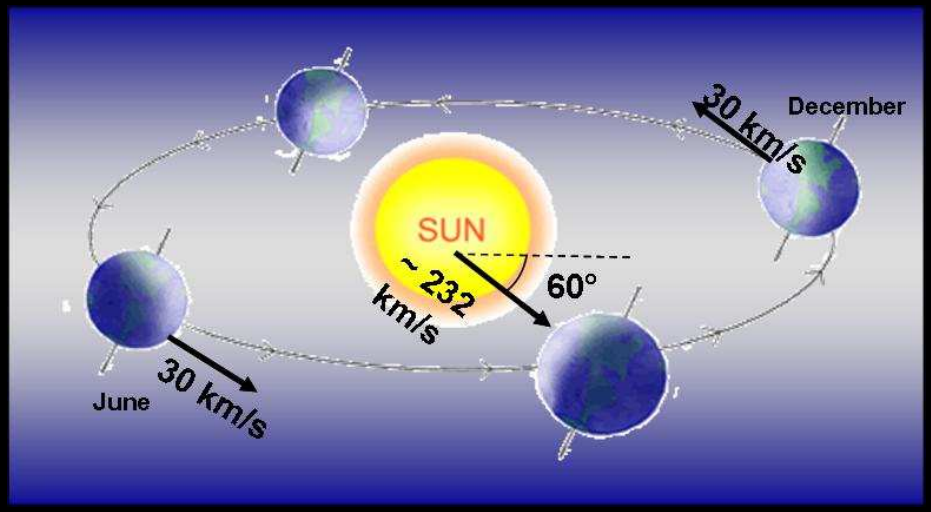
4 years - 2 possible events (@ 70GeV)
Not rejectable, but not good evidence

PICASSO – Freon bubble/acoustic detection (@ Sudbury, Canada)

No events

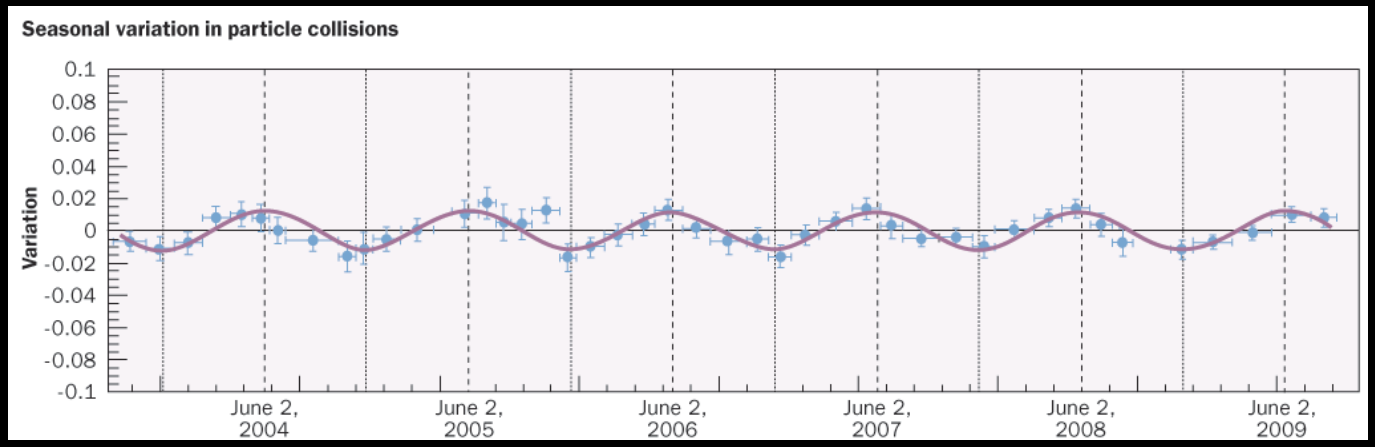


DAMA – Gran Sasso, Italy



NaI detectors

DM "wind" – too many particles? Consistent with <u>low mass</u>



Summary

- *Data for dark matter particles is minimal or non- existent after at least 8 yrs search. But the stuff must be there!*
- *Dark energy is being studied, and we know what its doing, but not what it is.*
- *Dark matter and dark energy are still a great mystery!*