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... for a Darker future

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The Fate of the Universe and the Mystery of Dark Energy

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QuarkNet Masterclass

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Argonne National Lab

Outline

- Messengers from the cosmos

The study of the Universe in its totality

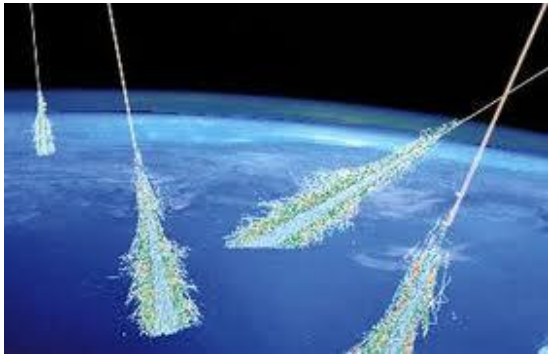
- Introduction to cosmology
- Introduction to dark energy & dark matter
- The Dark Energy Survey
- Summary & conclusions

How we learn about the Universe: cosmic messengers

- Photons (“light”)

Courtesy: http://www.cfa.harvard.edu

- Particles (e.g., cosmic rays)

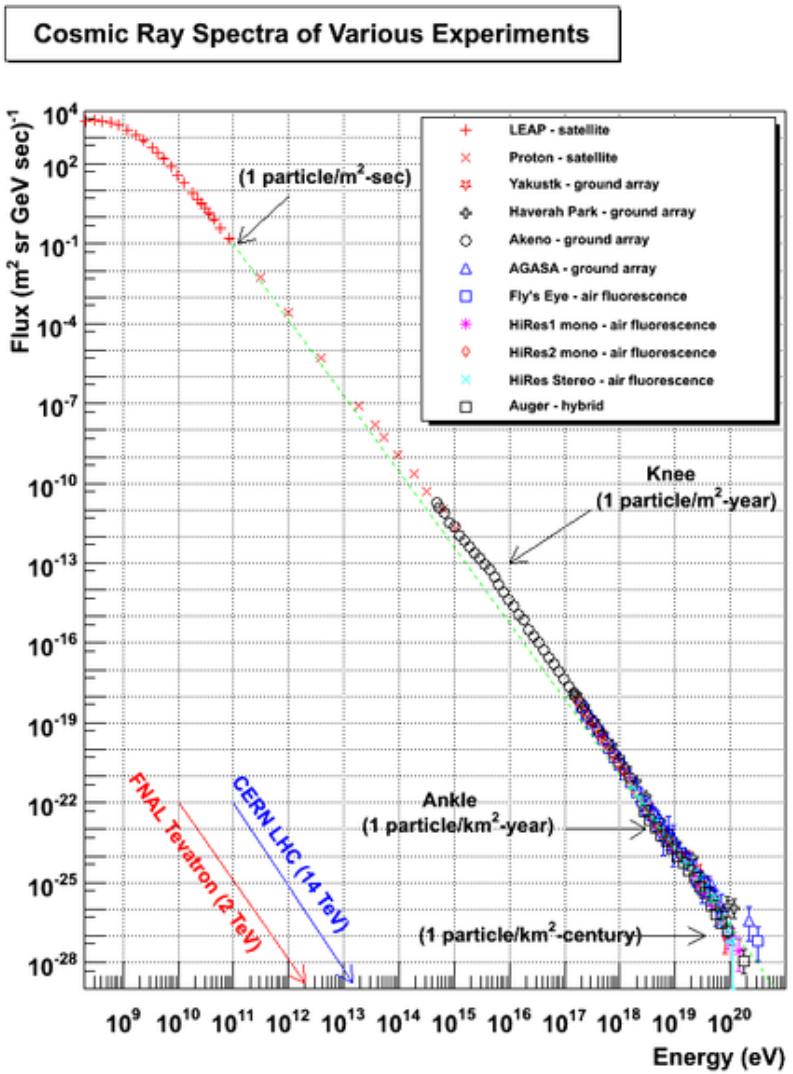


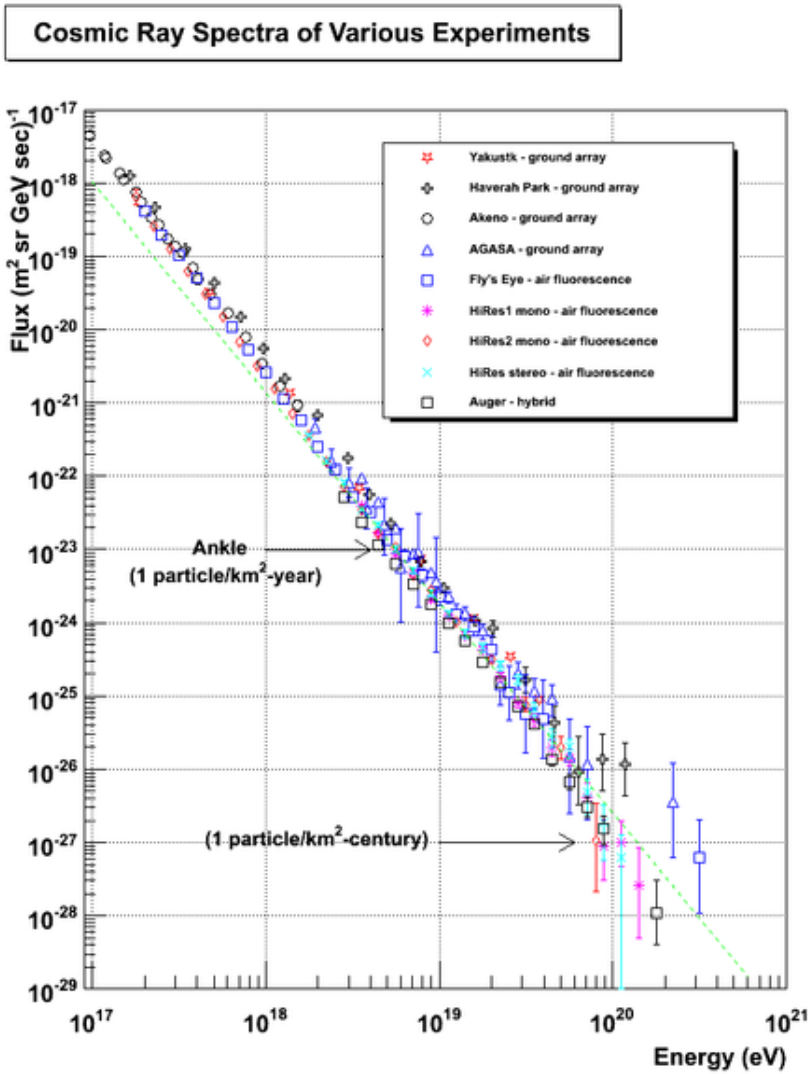
Courtesy: http://www.newscientist.com

- Gravitational waves (someday soon)

Courtesy: http://www.space.com

Energy Spectrum of Cosmic rays





Courtesy: http://www.physics.utah.edu

Edwin Hubble's 1929 Discovery of the Expanding Universe

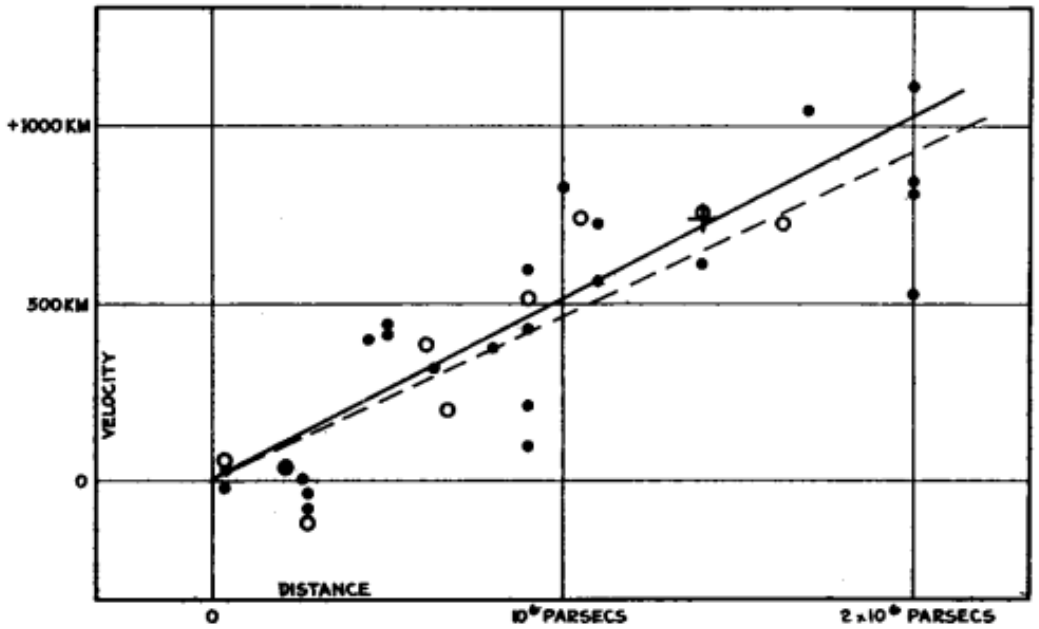
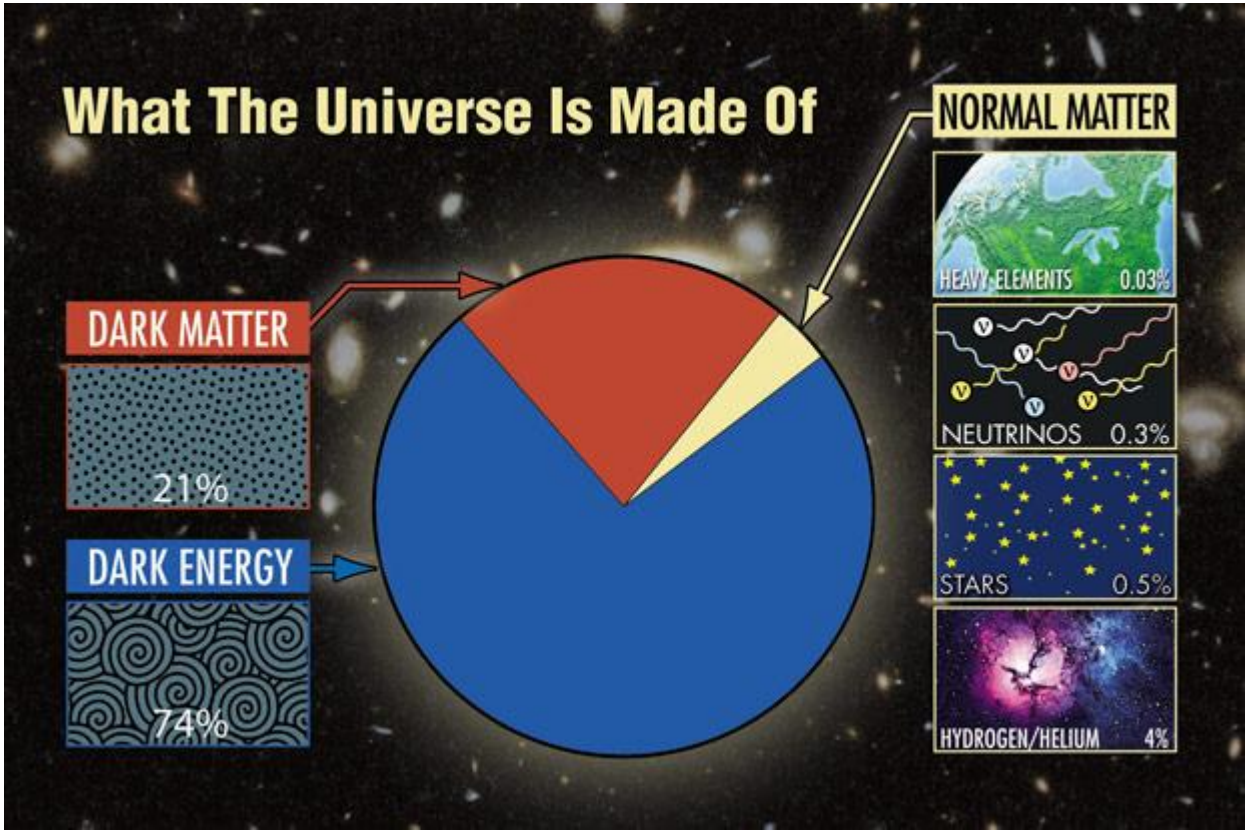


FIGURE 1

Velocity-Distance Relation among Extra-Galactic Nebulae.

Radial velocities, corrected for solar motion, are plotted against distances estimated from involved stars and mean luminosities of nebulae in a cluster. The black discs and full line represent the solution for solar motion using the nebulae individually; the circles and broken line represent the solution combining the nebulae into groups; the cross represents the mean velocity corresponding to the mean distance of 22 nebulae whose distances could not be estimated individually. **E. Hubble, 1929, PNAS,15,168**

Have A Slice Of Universe Pie



Courtesy: http://hetdex.org

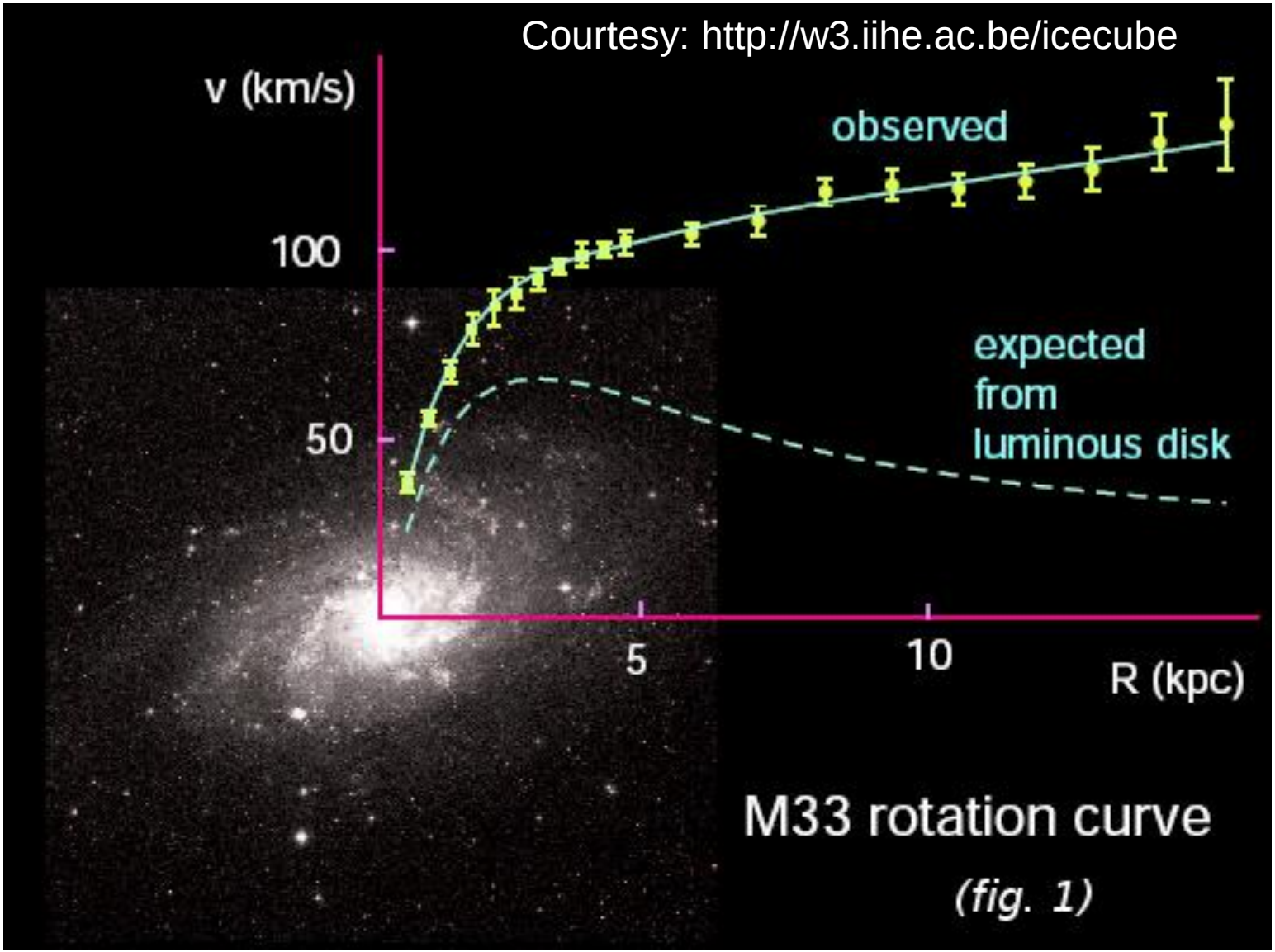
Fundamental Motivation

DARK ENERGY SURVEY

Discovering the evolution & ultimate fate of the Universe and determining what constitutes 95% of the Universe!

Evidence for Dark Matter

Or does the theory of gravity just need to be modified?



Big Problem For Modified Gravity: The Bullet Cluster

Best evidence to date for existence of dark matter: gas (pink) and gravitational mass distribution (blue) don't match – very hard to explain with MG

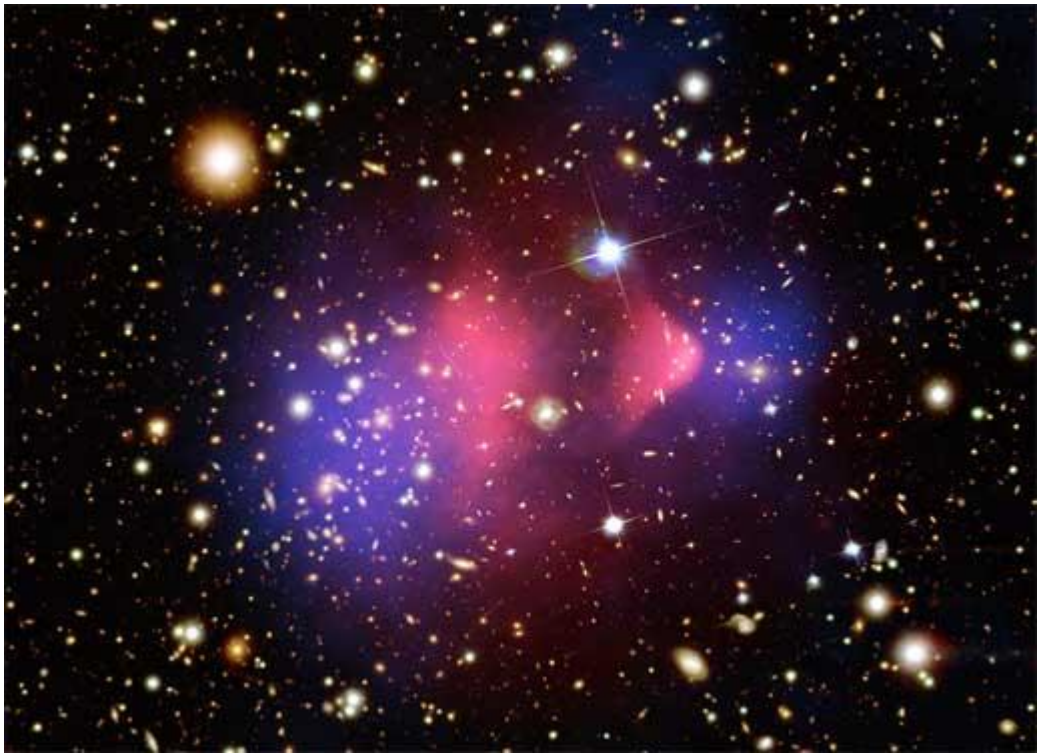


Image credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.

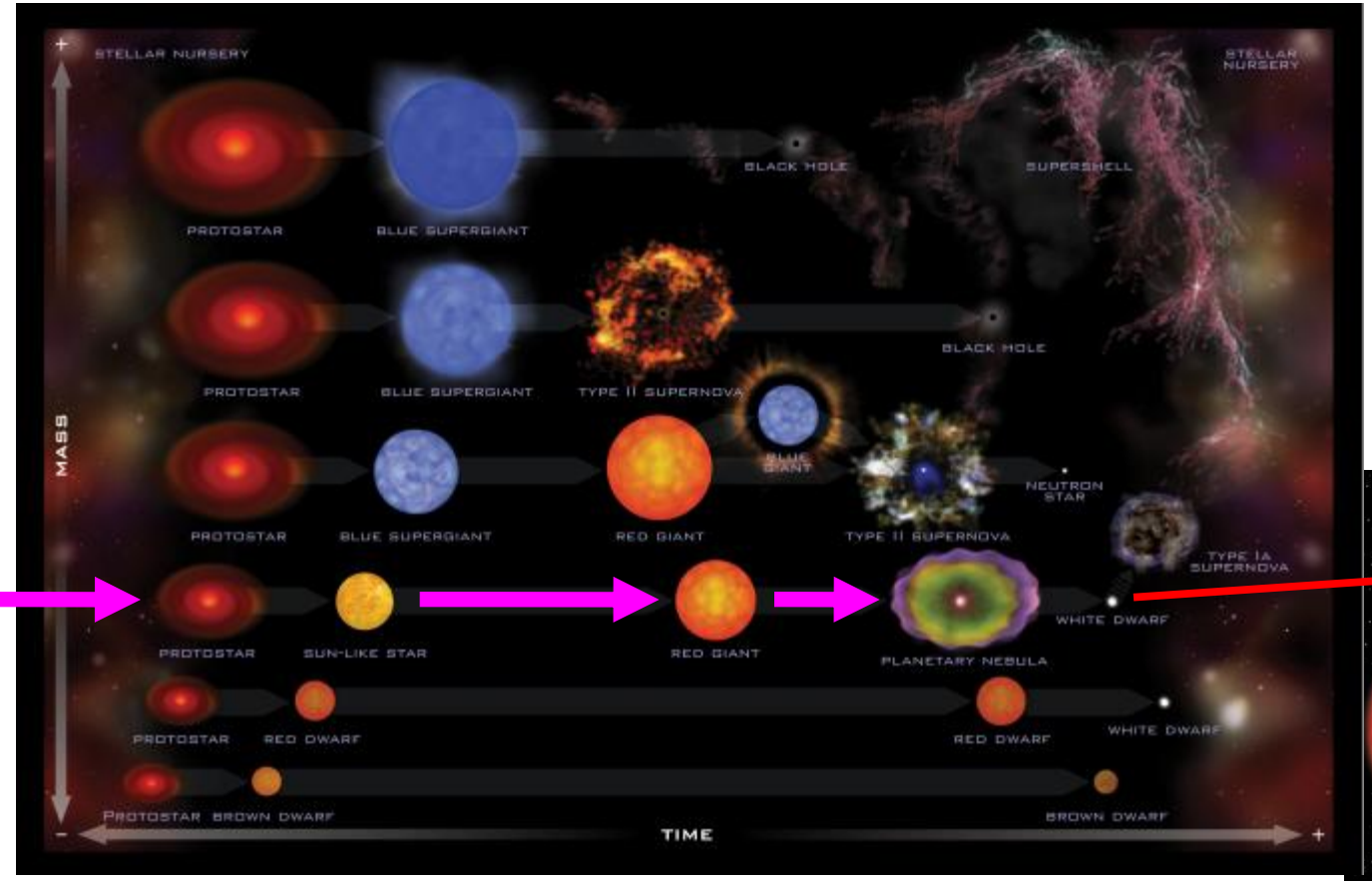
Quantifying Cosmology

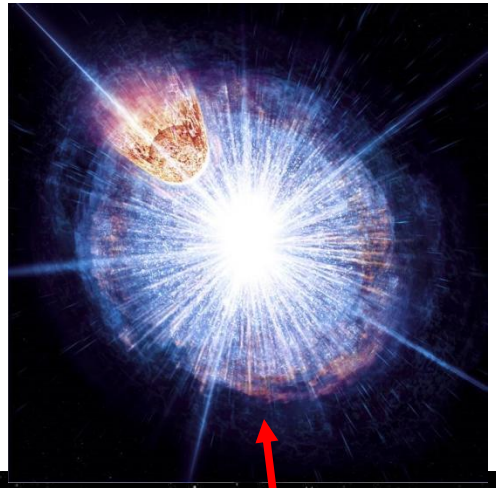
Observations show matter comprises only 25% of the Universe

What makes up the other 75%?

Towards An Answer: Type Ia Supernovae

Courtesy:
http://dahowell.googlepages.com





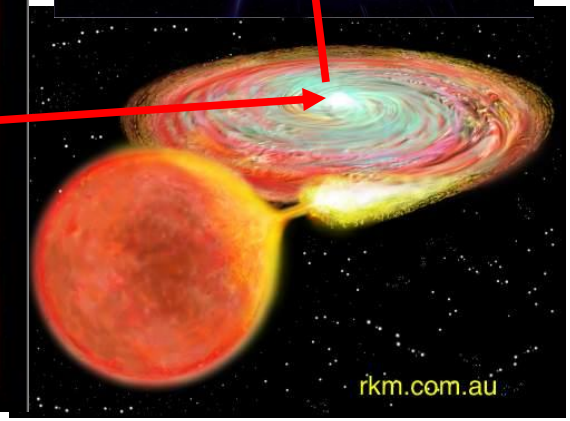
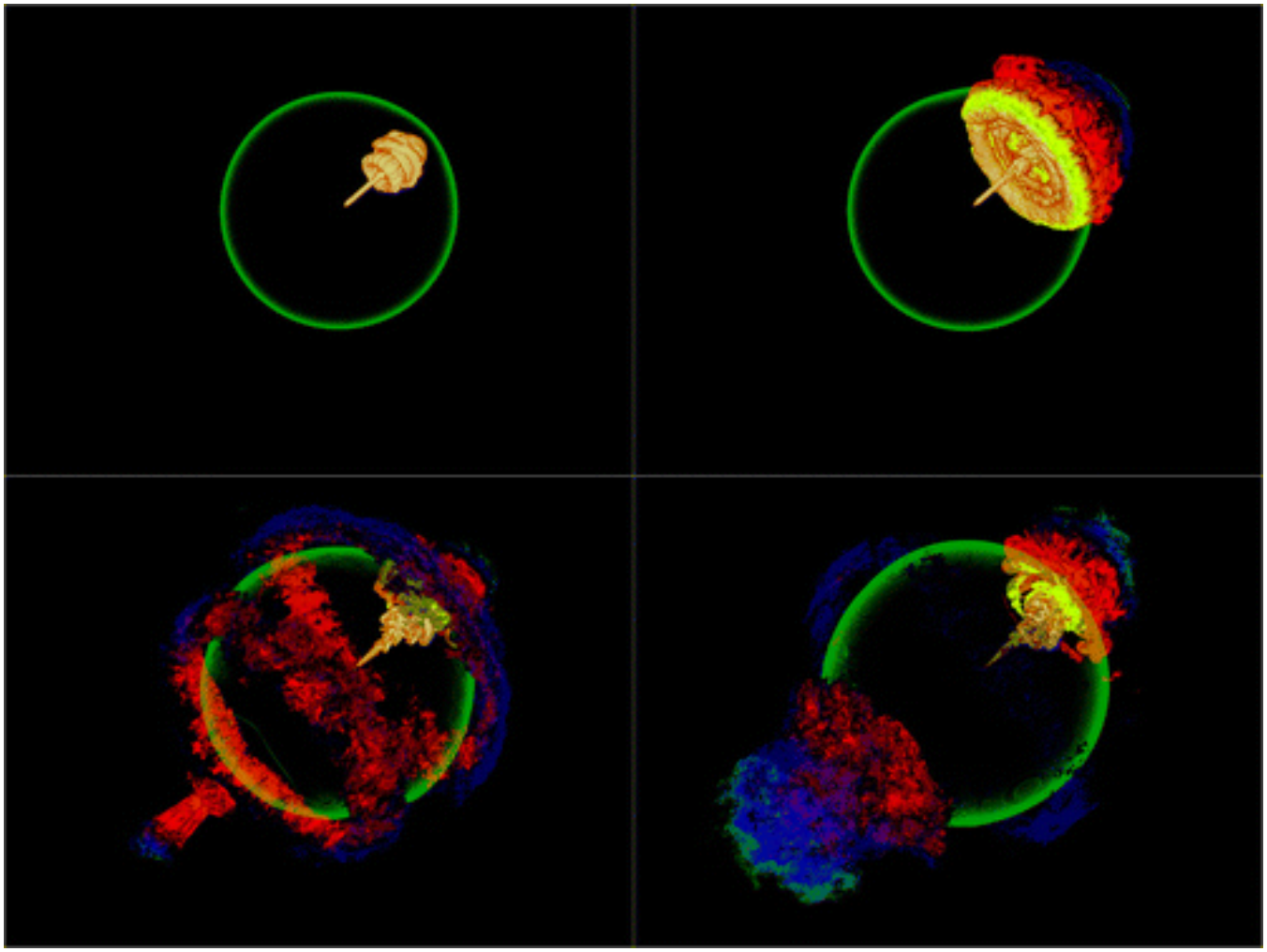


Image courtesy http://www.siprep.org/faculty/aokeefe

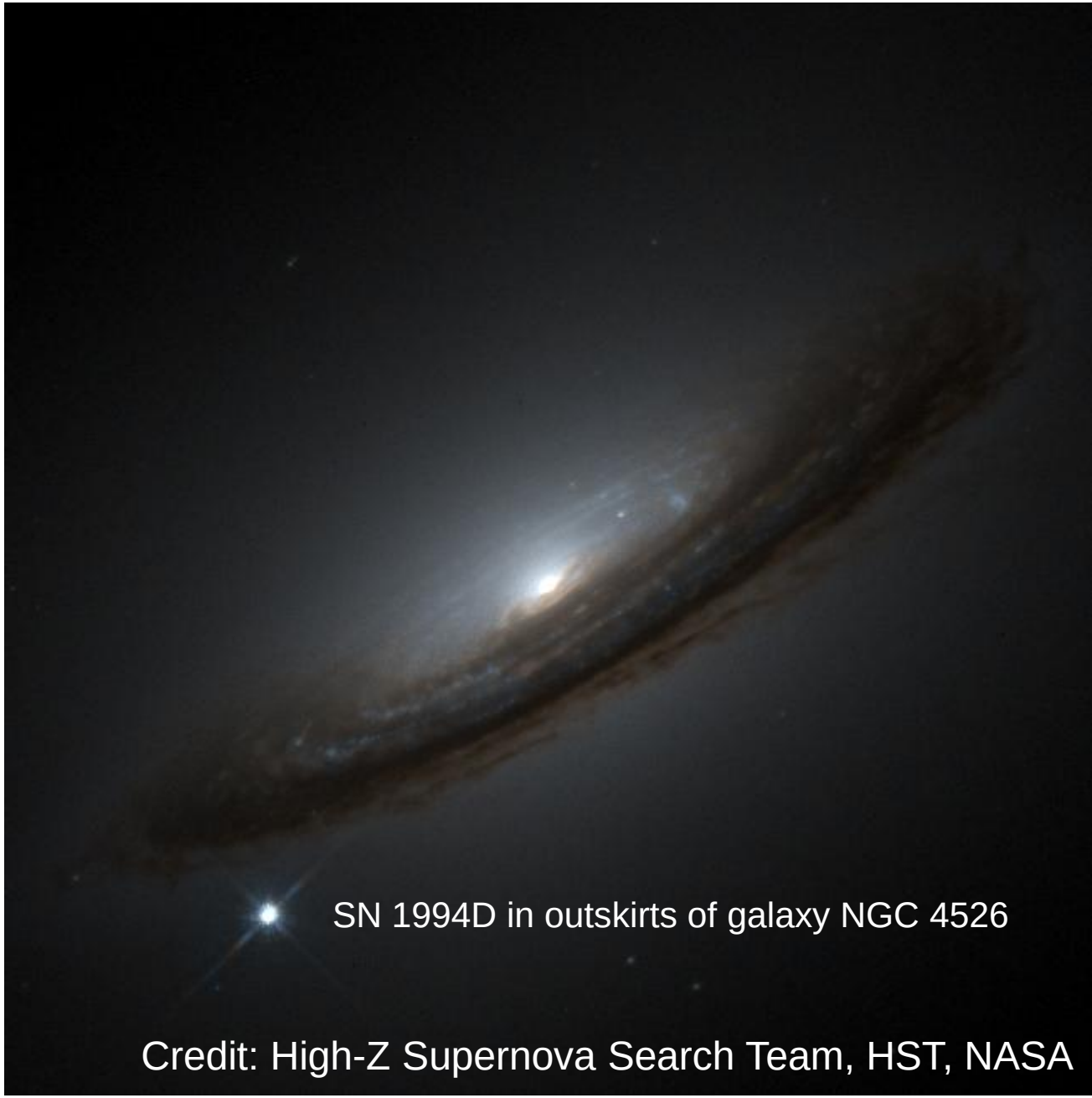
Studying SN Light Curve Origins

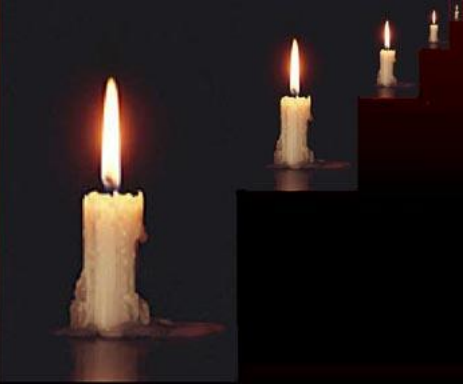


Credit: University of Chicago FLASH Center

BRIGHT!

NCG 4526 is ~55 million light years away from Earth ⇒ the light from SN 1994D started traveling towards Earth ~55 million years before 1994!





SNe Are Standard Candles

DARK ENERGY SURVEY

Big surprise:

Distant SNe dimmer than predicted for a matter-only Universe! (originally discovered in 1998)

Quantitative Framework For Dark Energy

Explanation: expansion of Universe is accelerating due to dark energy that has strongly ***negative*** pressure (p_{DE})

Just one problem: best current model explaining dark energy is off by a factor of 10^{120} =
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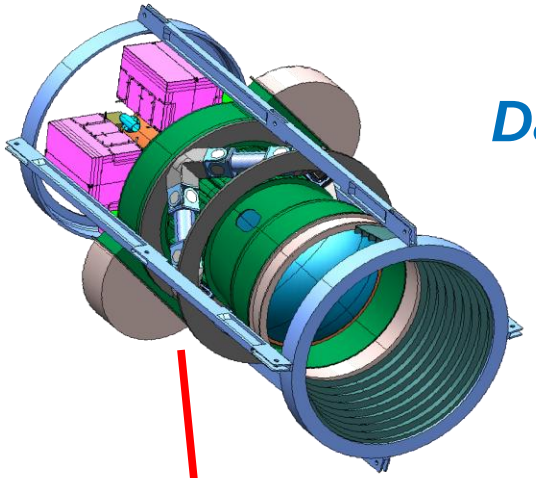


Dark Energy Survey (DES)

DES will survey a big chunk of the sky and will provide new 500Mpixel CCD camera (“DECAM”) for Blanco 4m telescope at the Cerro Tololo Inter-American Observatory (CTIO), Chile, in exchange for 525 survey nights over 5 years starting in 2011.

ANL DES group: Joe Bernstein, Jim Grudzinski, Vic Guarino, Steve Kuhlmann, Hal Spinka, Rich Talaga, Allen Zhao.

Handling of the Secondary mirror

Alignment must be better than 300 microns and handling robust enough for earthquakes

Charge Coupled Devices (CCDs) and DECAM

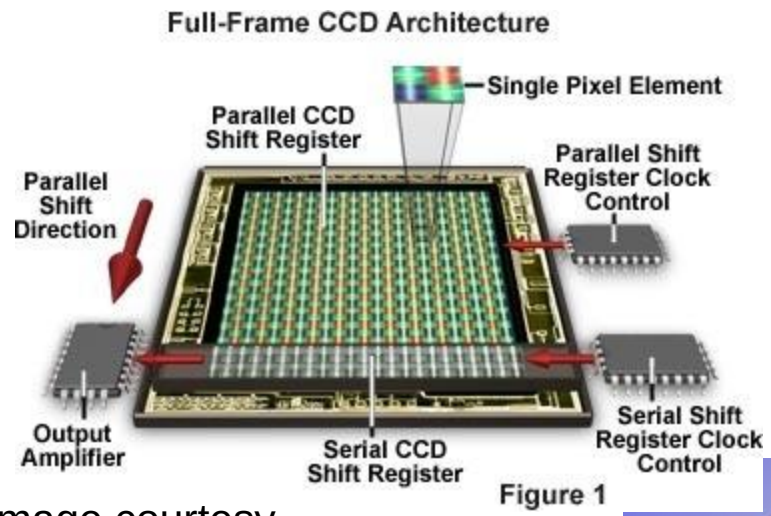


Image courtesy
http://www.astro.virginia.edu

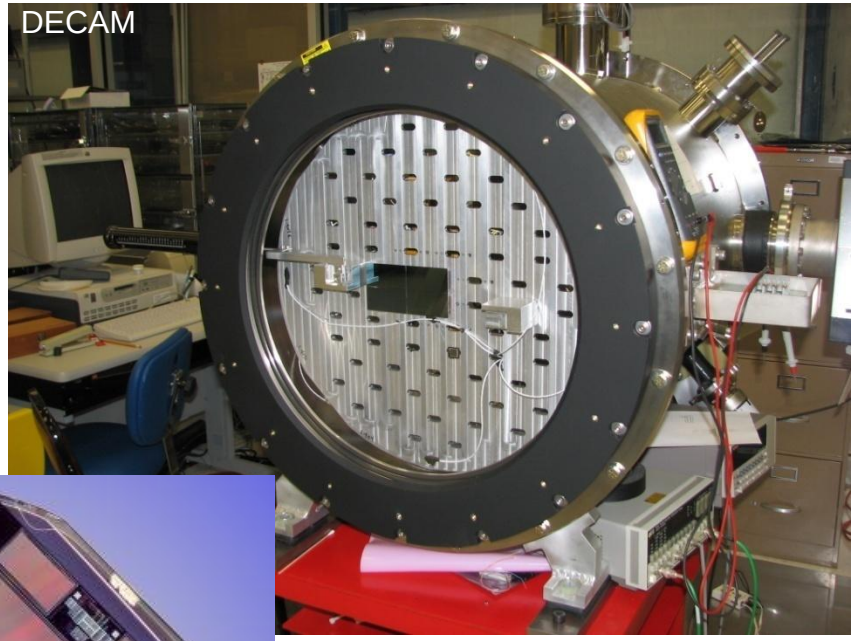
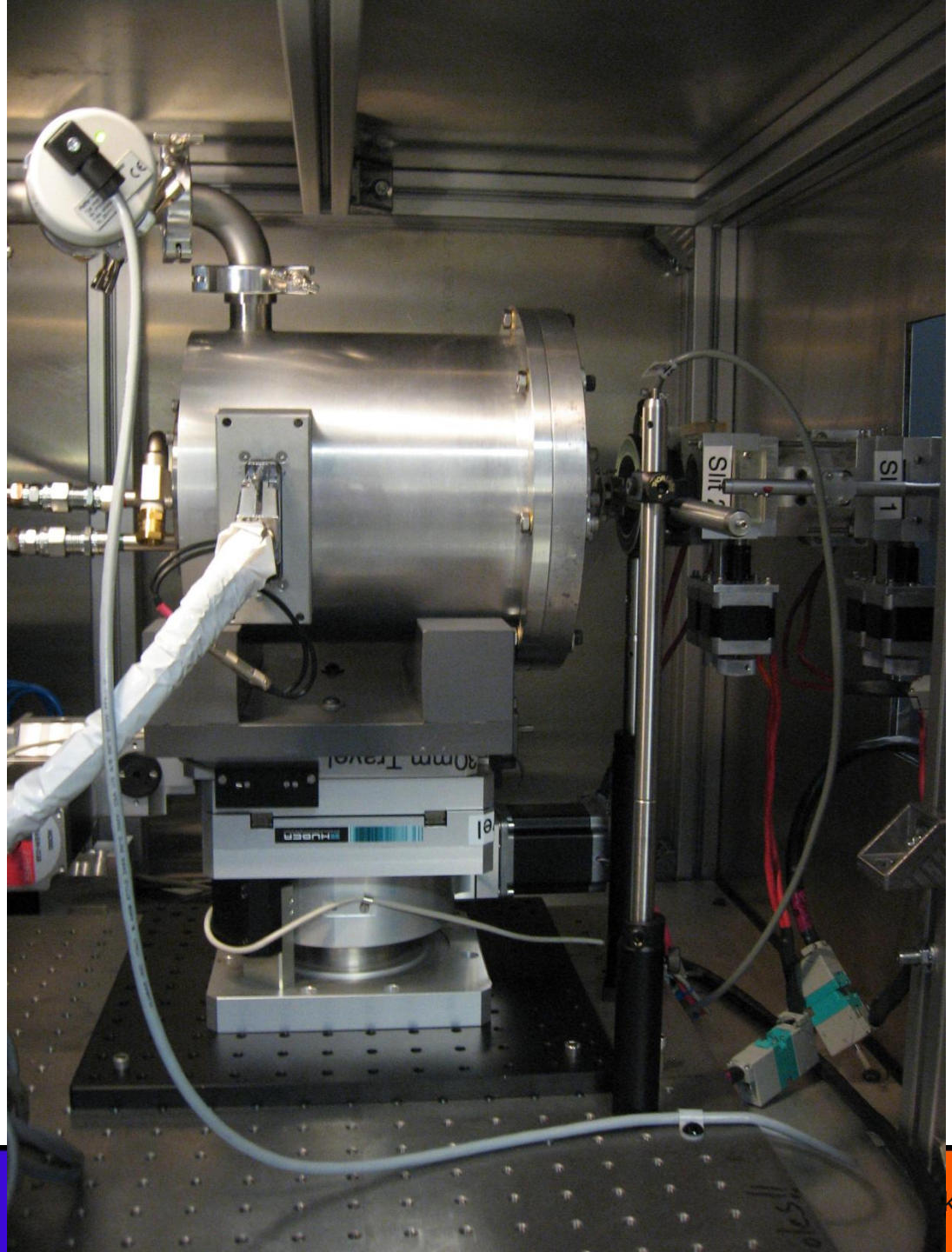


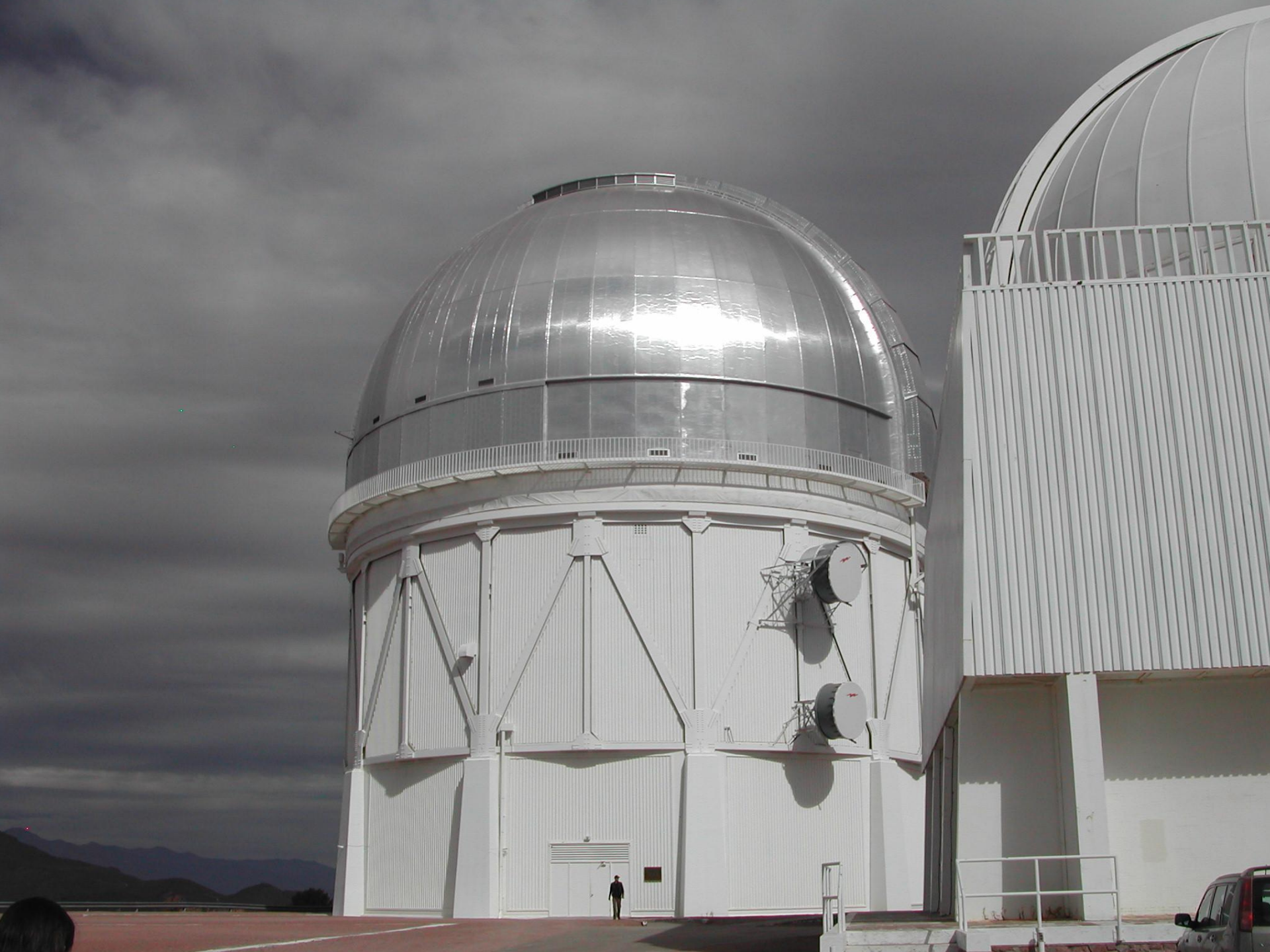
Image Using Prototype DECam Imager (used poor-grade CCDs)

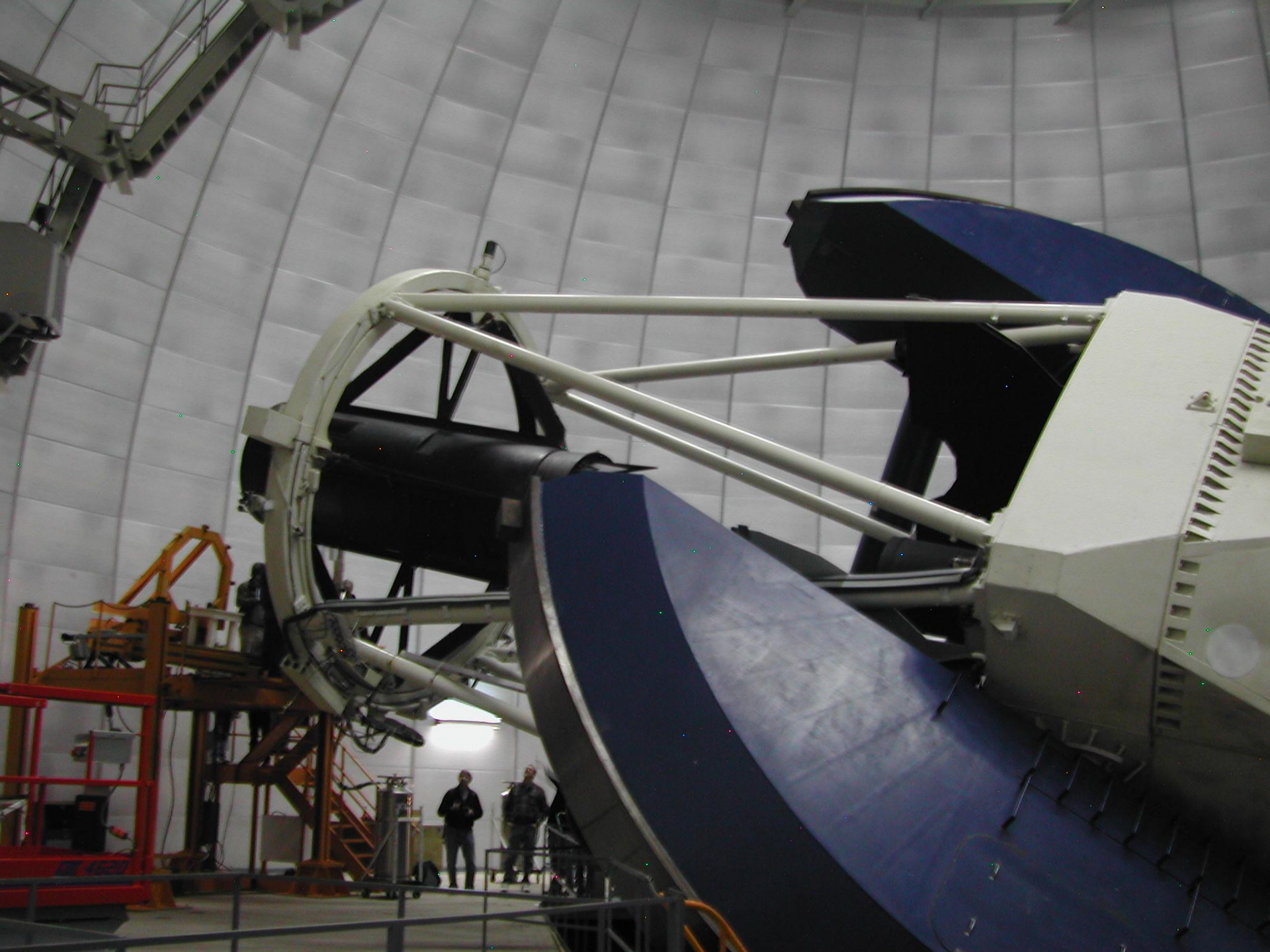
ANL CCD Test Stand



DARK ENERGY SURVEY

Cerro Tololo Inter-American Observatory (CTIO)





AEROPUERTO LA FLORIDA
NISSAN

EN ESTAS TIERRAS
NACE EL PISCO
DE TODOS LOS CHILENOS
FRENTE
A SOLERAS
AMARILLA
Banda Ancha
Movil Ilimitada
SENARQ

LAN

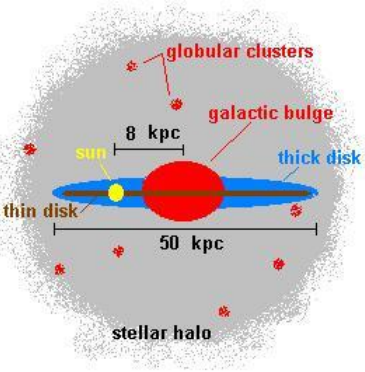
Summary & Conclusions

- Observations show Universe is composed of 95% weird stuff
  - ~21% dark matter
  - ~74% dark energy
- Dark energy: explanation of dimness of distant supernovae
  - fundamental physics mystery: what is it?
  - prediction of best model to date is WAY off!
- Supernovae are excellent cosmological tools
- Dark Energy Survey (DES): next step in addressing dark energy
- DES on schedule for first light in 2012

Thanks for listening!

The Blanco & The Milky Way

Image courtesy
Mike Fanelli



The Blanco telescope dome at Cerro Tololo, Chile. Single, non-composite image taken using a 2Kx2K scientific CCD temporarily mated to a custom camera. 20 sec exposure, 40mm f/4 lens, starlight only.
Credit: Roger Smith/NOAO/AURA/NSF

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