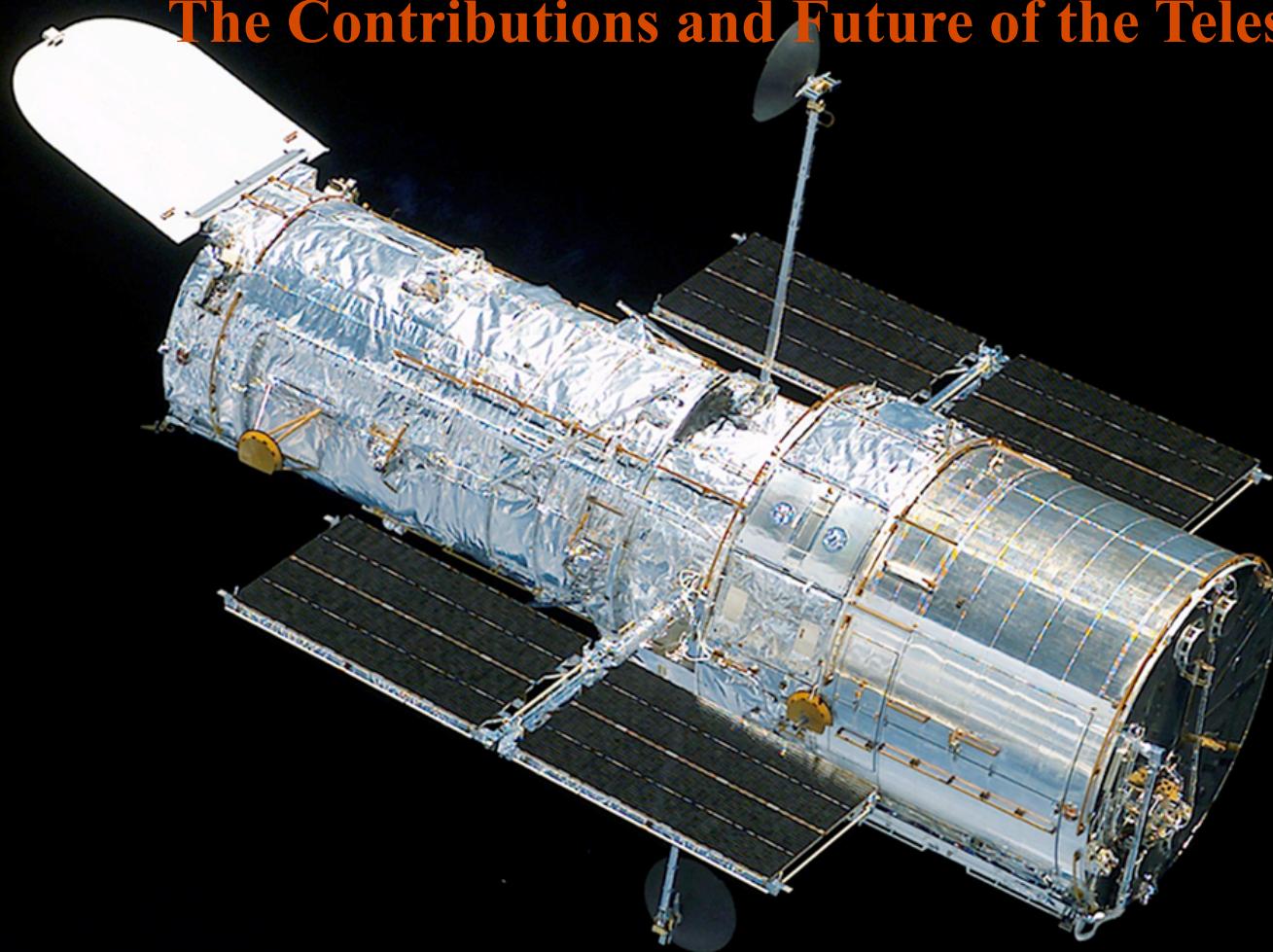


From Galileo to Hubble and Beyond: The Contributions and Future of the Telescope



Interpreted by
George Helou

The Extragalactic Perspective

Duccio Macchietto

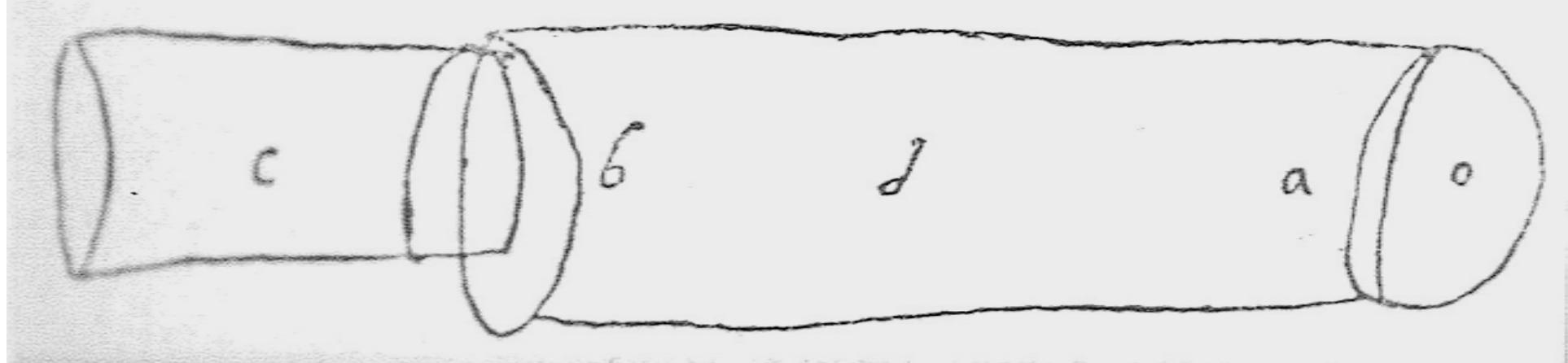
CALTECH, NOVEMBER 2009





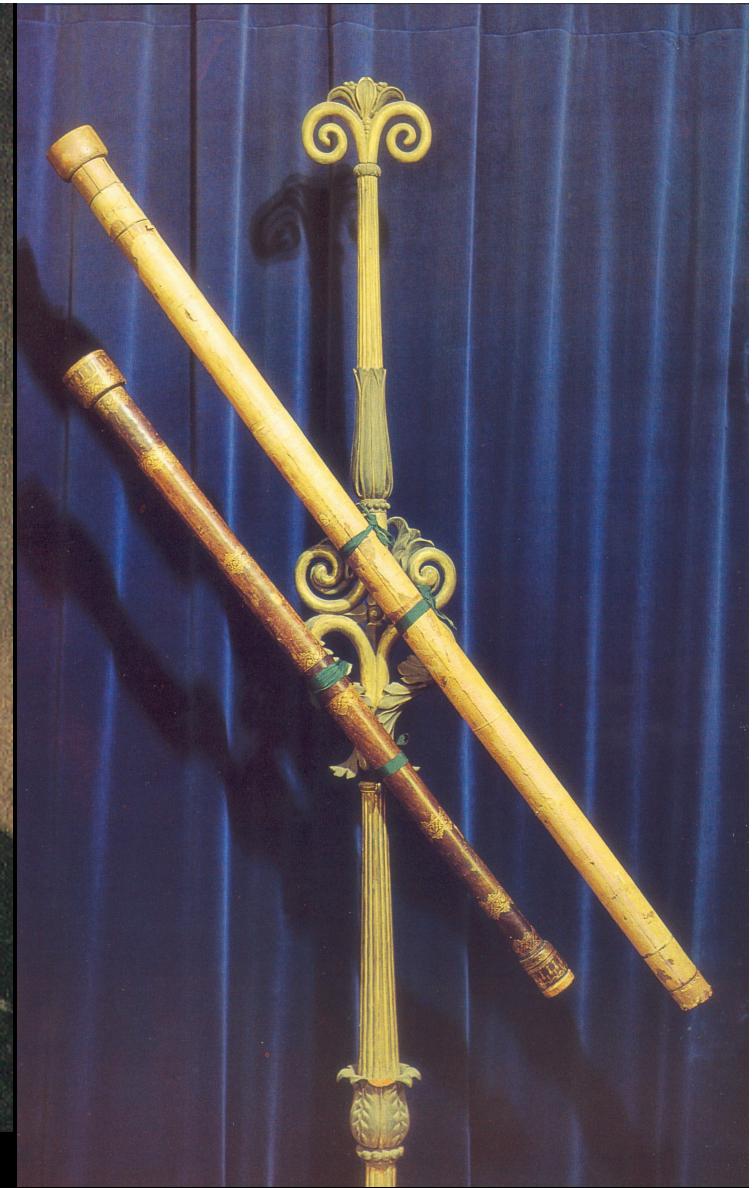
- The earliest record of the existence of the telescope is a letter of the government of Zeeland to its delegation to the States General of the Netherlands, dated 25 September 1608, which instructs them to be of help to the bearer, "who claims to have a certain device by means of which all things at a very great distance can be seen as if they were nearby, by looking through glasses which he claims to be a new invention."

Hans Lippersheim (Lippershey) 1570-1619, Wesel, Middelburg



“PHASE A” SPECS!

GAILILEVS
GAILILEVS
MATHVS:

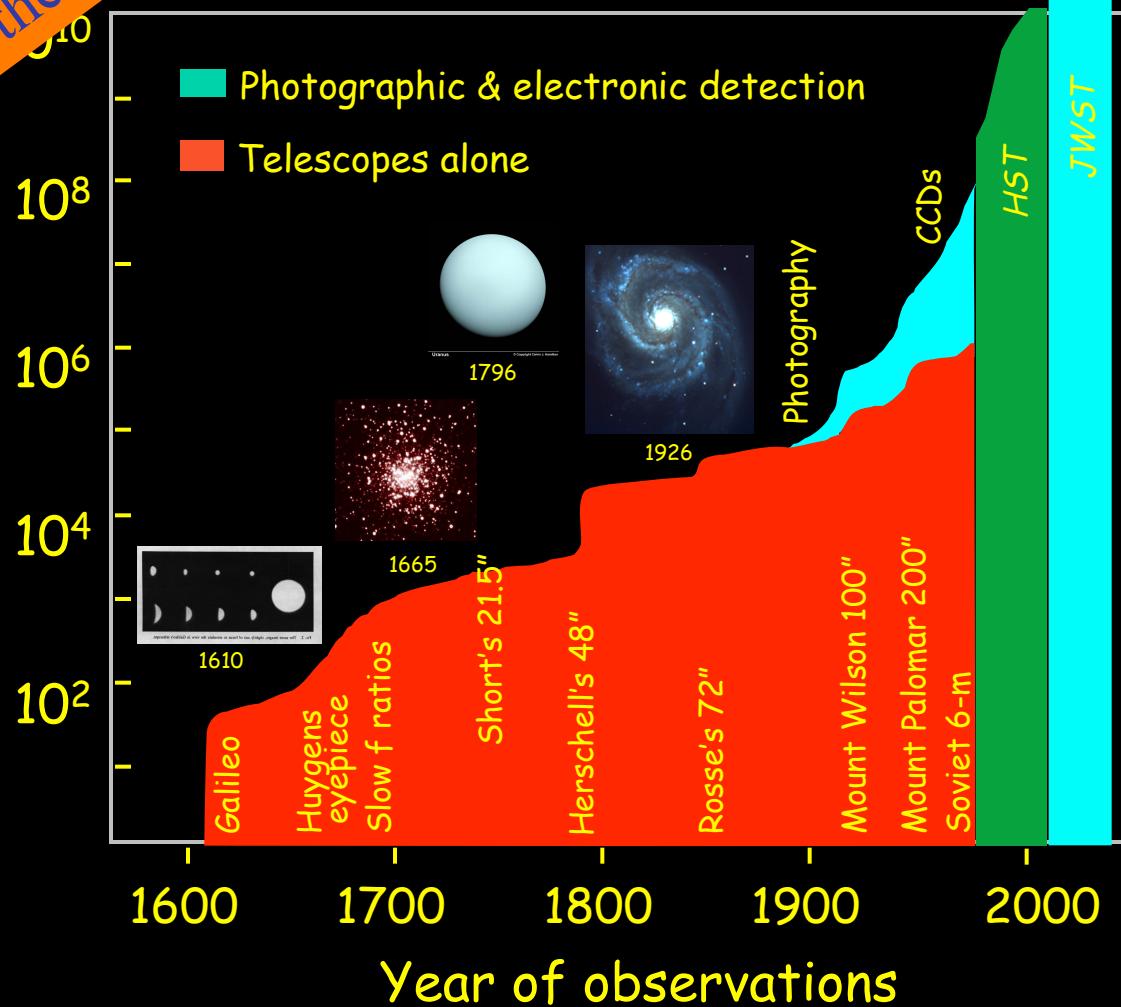


How to win in Astronomy

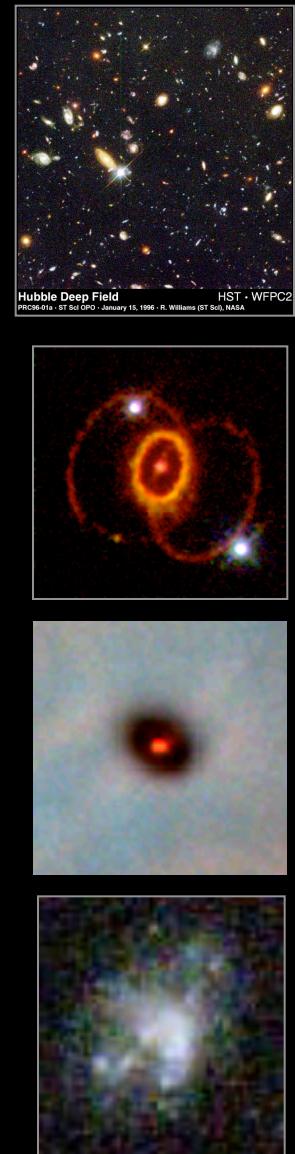
Big Telescopes with Sensitive Detectors in Space

Space opened up the full register of "light"

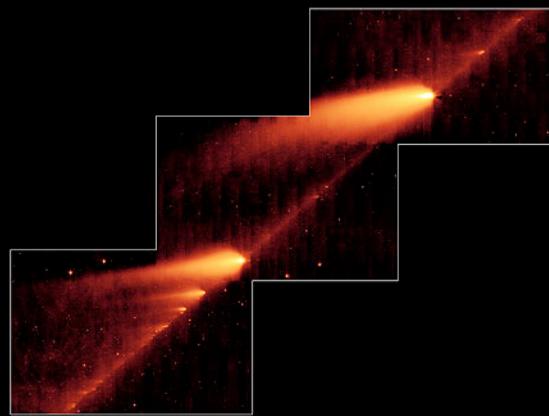
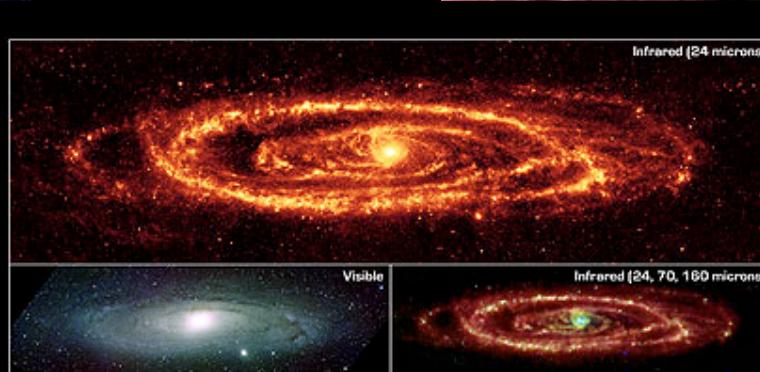
Sensitivity Improvement over the Eye



Adapted from *Cosmic Discovery*, M. Harwit

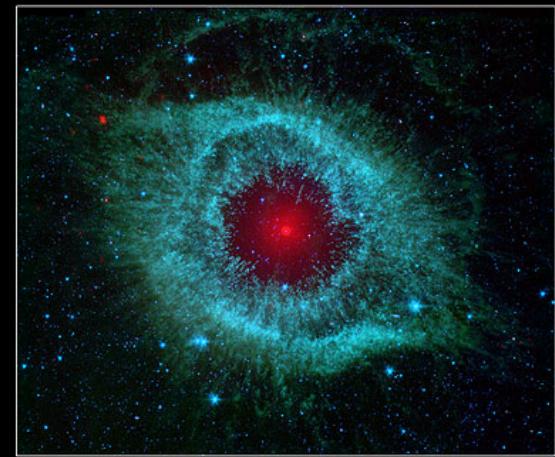


Spitzer Space Telescope



Comet 73P/Schwassmann-Wachmann 3

Spitzer Space Telescope • MIPS



Dusty Eye of the Helix Nebula (NGC 7293)

Spitzer Space Telescope • IRAC • MIPS



Herschel:
Submillimeter
May 15, 2009



©ESA and the SPIRE & PACS consortia



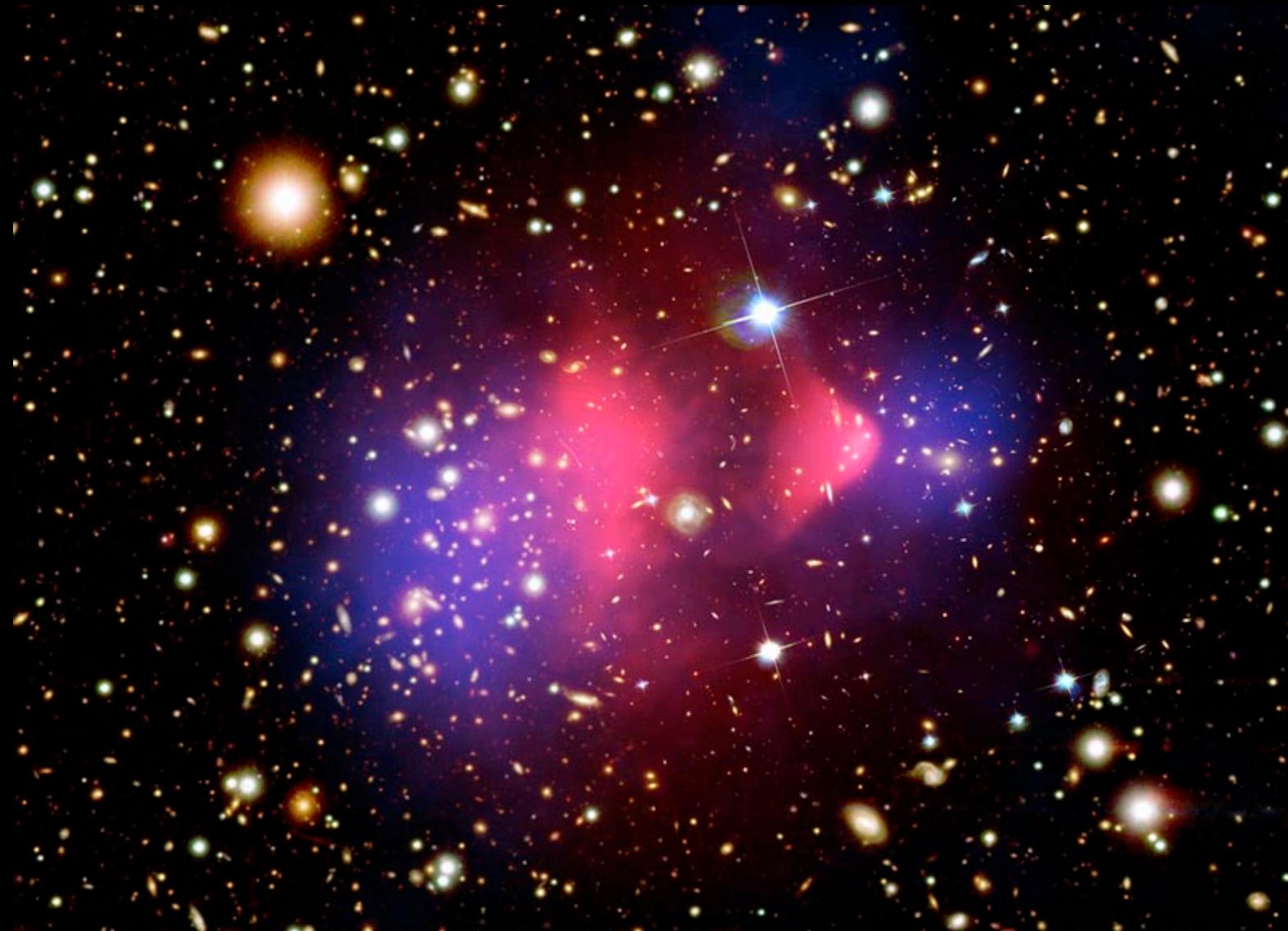
WISE:
Wide-Field Infrared Survey Explorer
Launch date: Dec 9, 2009



X-Ray Observatories reveal the violent Universe, probe Black Holes



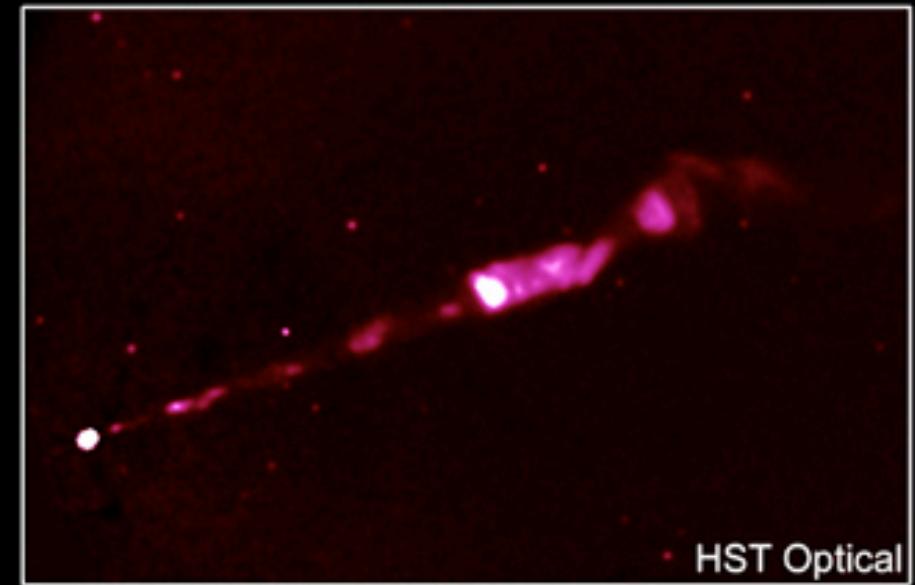
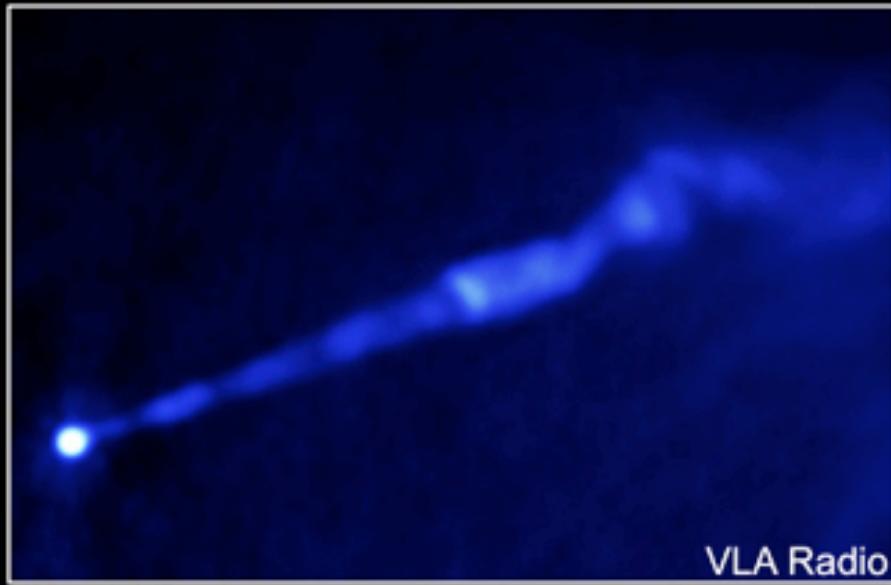
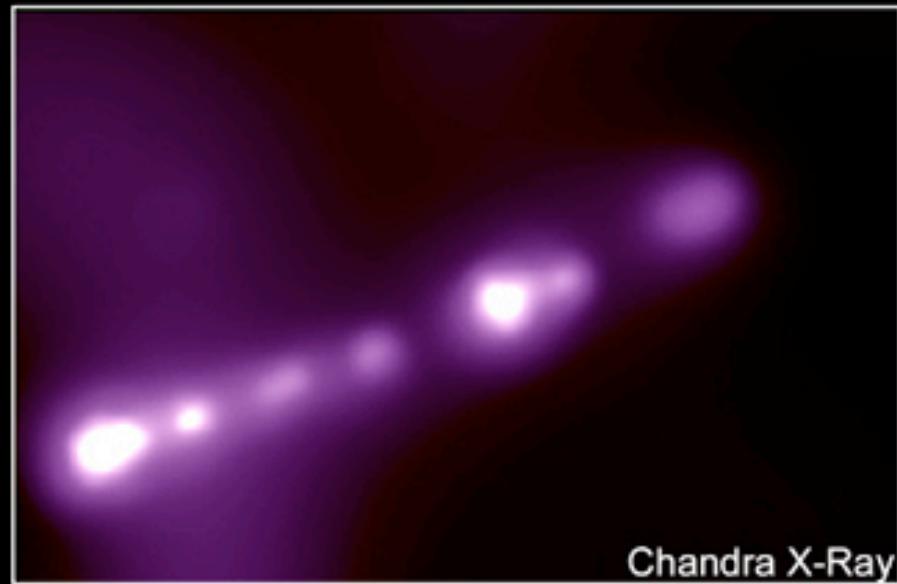
Normal and Dark Matter in two colliding clusters

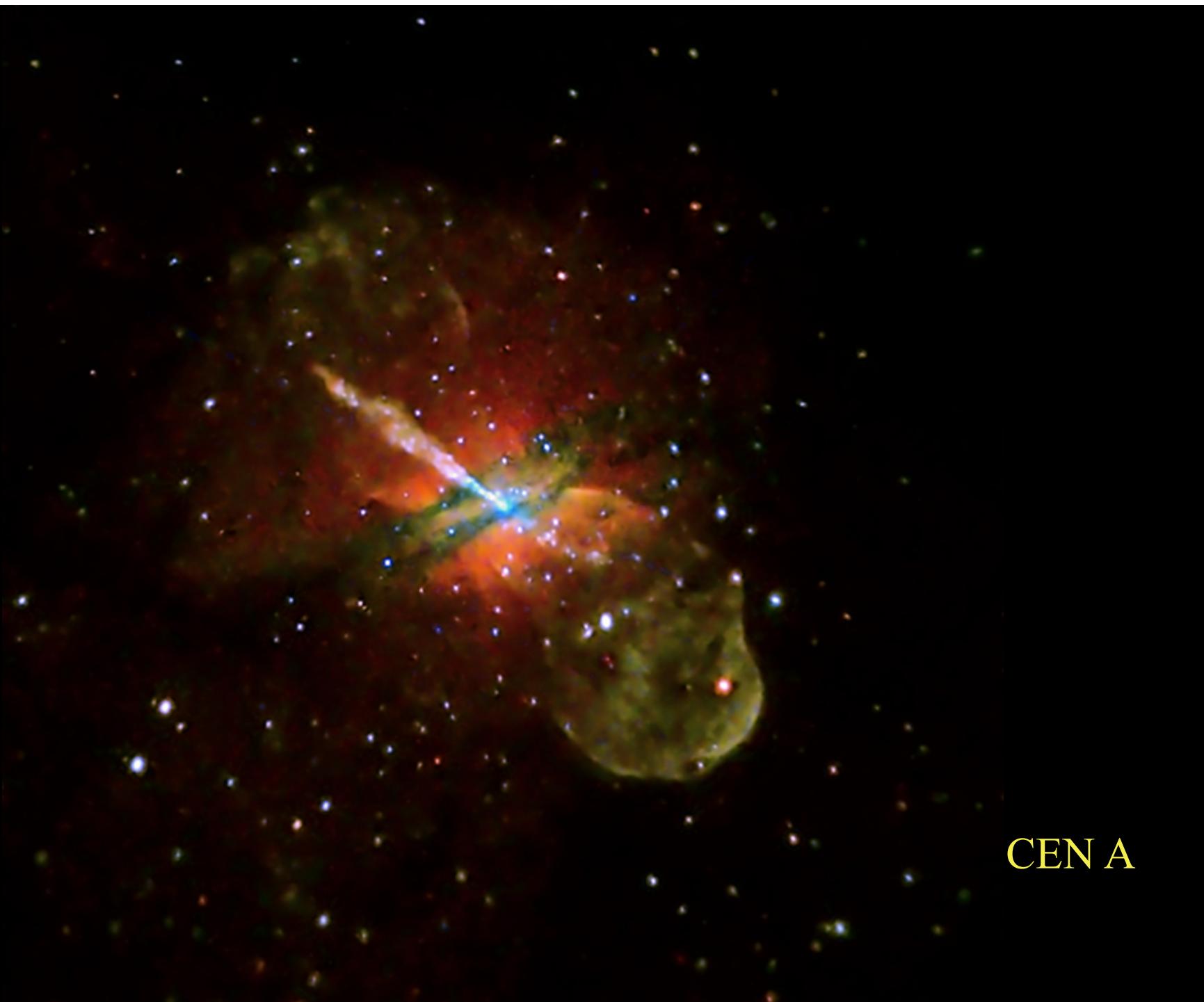


Hubble Space Telescope and the Chandra X-Ray Observatory

X-ray/Radio Jets

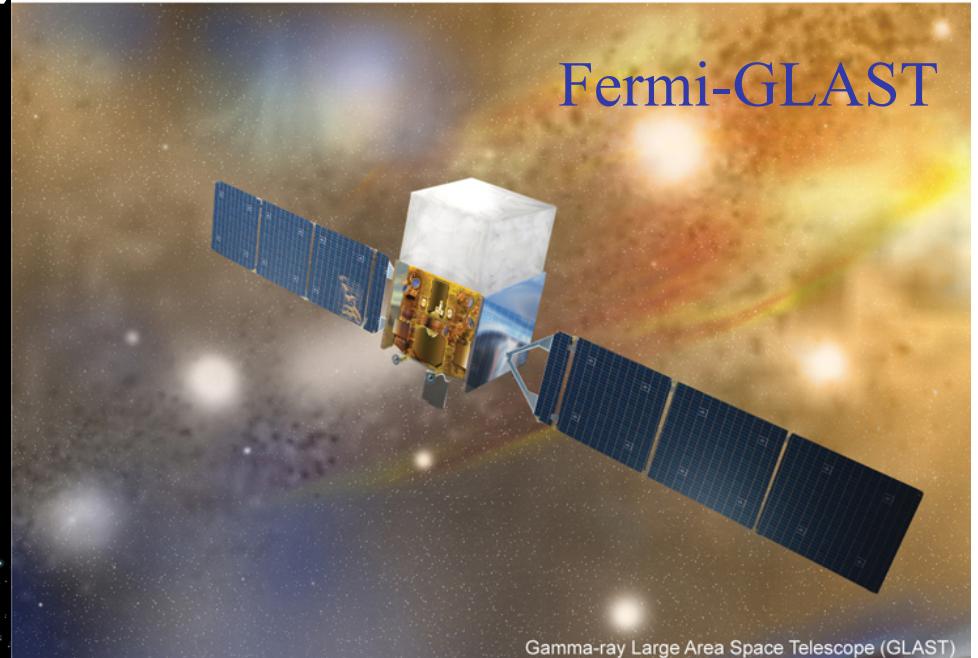
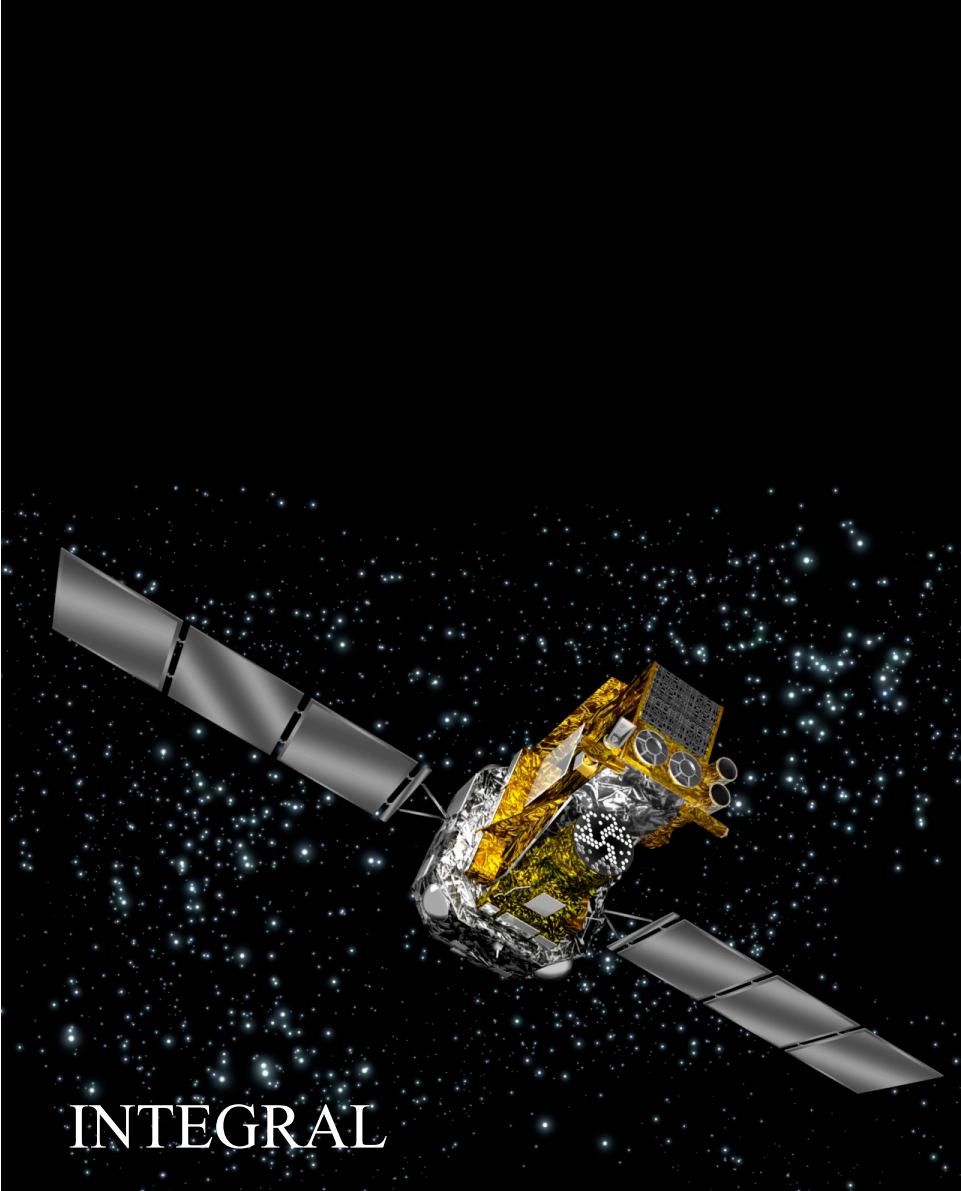
M87





CEN A

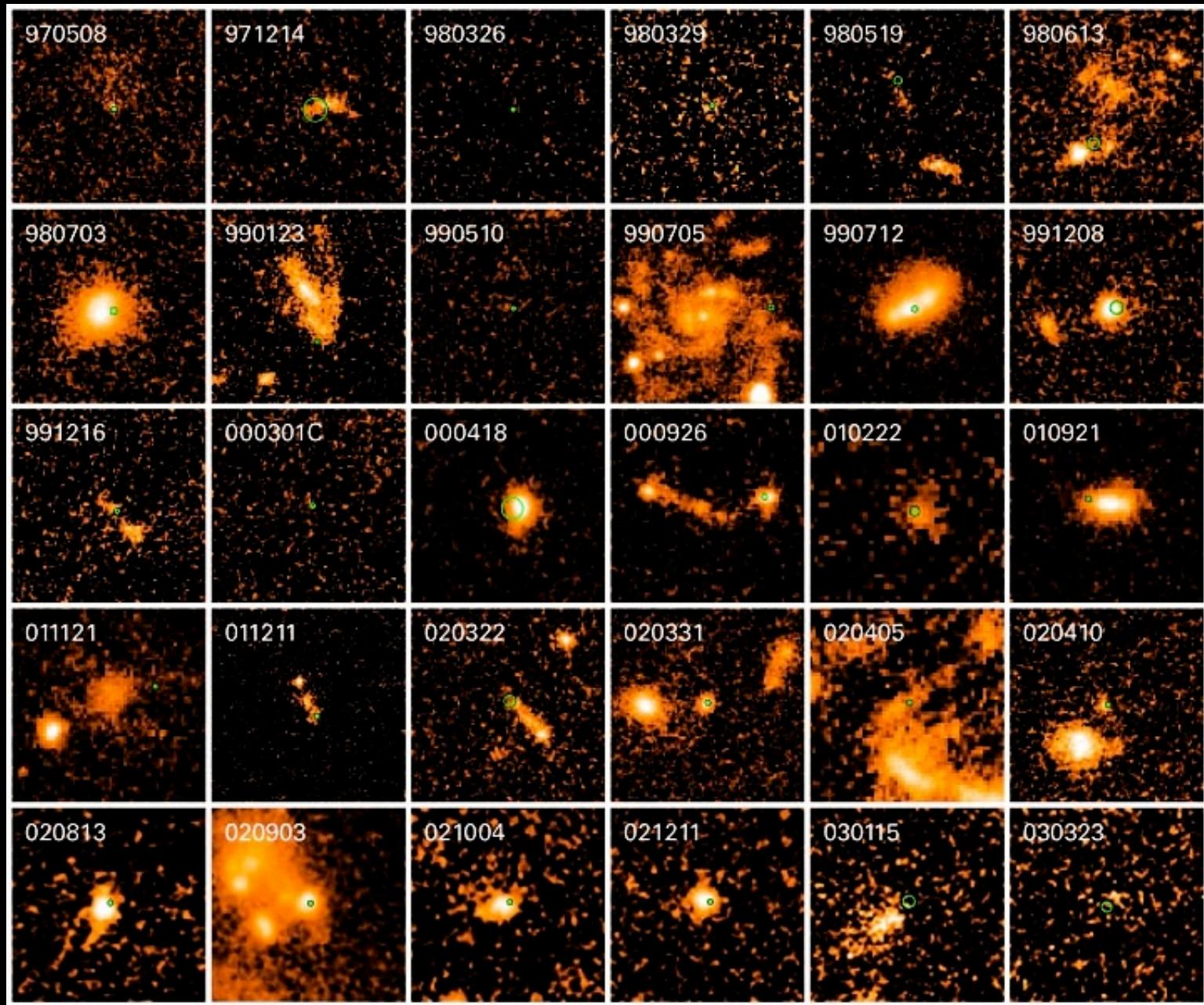
Gamma-Ray Observatories reveal the most intense explosions: GRB



Gamma-ray Large Area Space Telescope (GLAST)



A Galaxy on (nearly) Every Burst

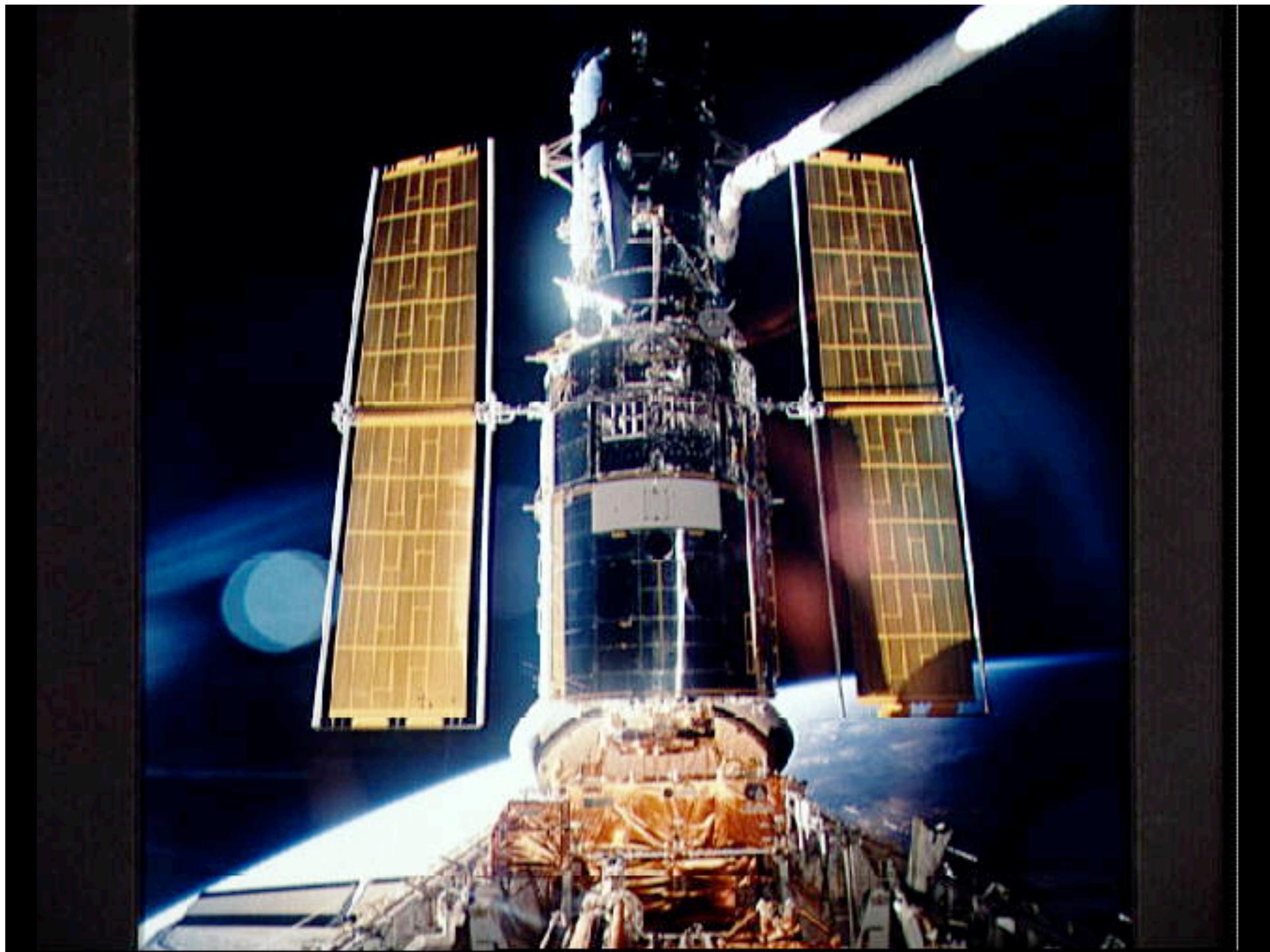




Hubble Space Telescope

- Length: 21 m
- Weight: 11,000 kg
- Mirror diameter: 2.4 m
- Launch: April 24, 1990







Hubble Servicing Missions

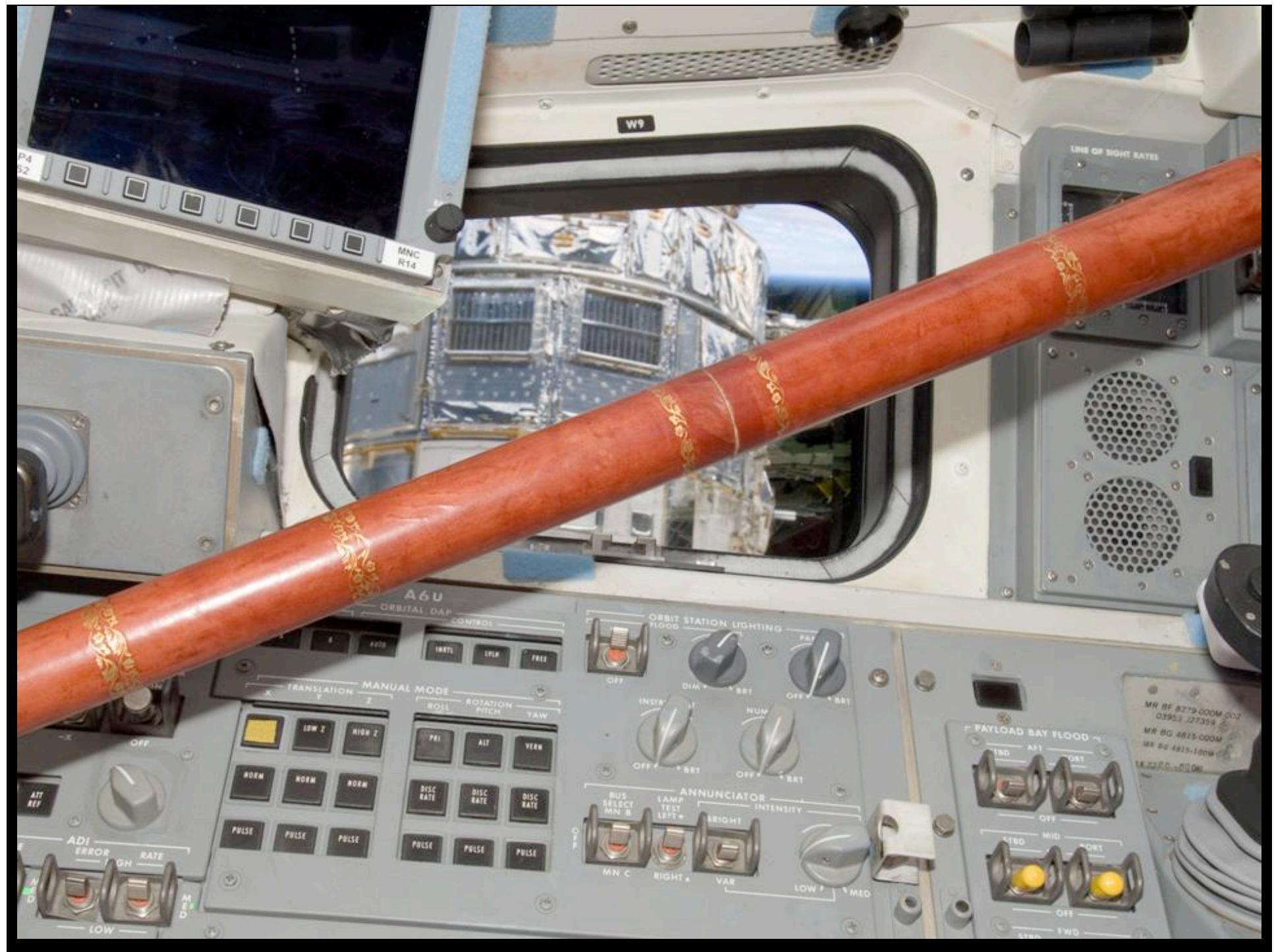
December 1993

February 1997

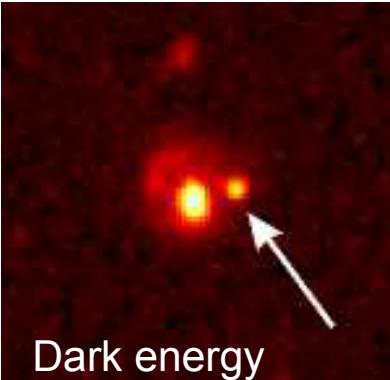
December 1999

March 2002

MAY 2009!!!

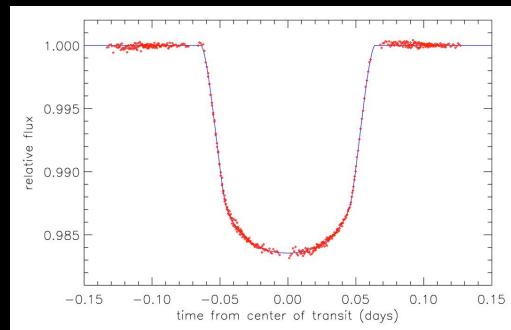


“Top 10”

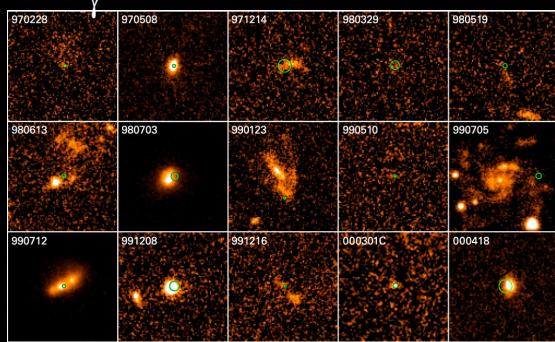


Dark energy

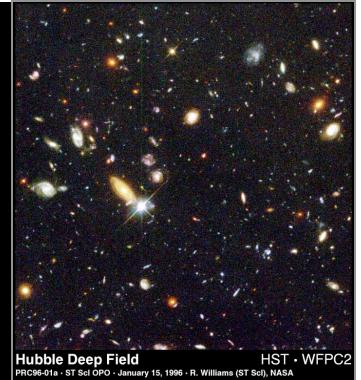
- Distance scale of the universe: H_0
- Giant black holes in galaxies
- Emission lines in active galaxies
- Intergalactic medium (QAL)
- Interstellar medium chemistry



E_γ

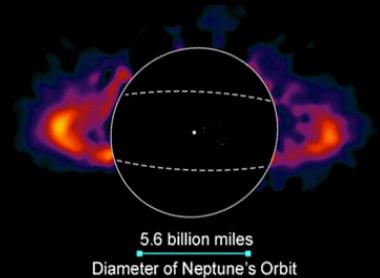


Aurorae on Jupiter



Hubble Deep Field
PRC96-01a • ST Scl OPO • January 15, 1996 • R. Williams (ST Scl), NASA

Early galaxies



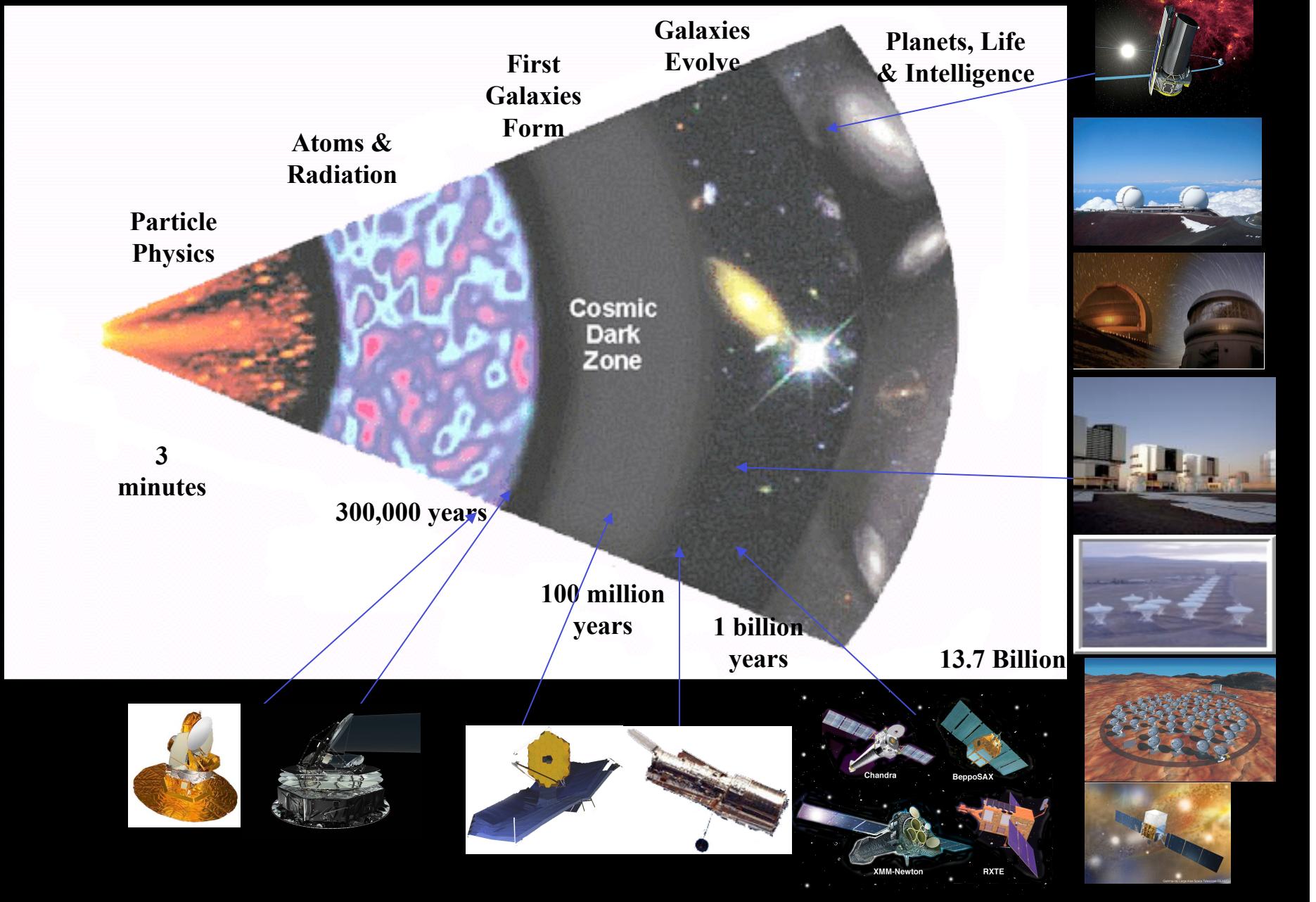
Diameter of Neptune's Orbit



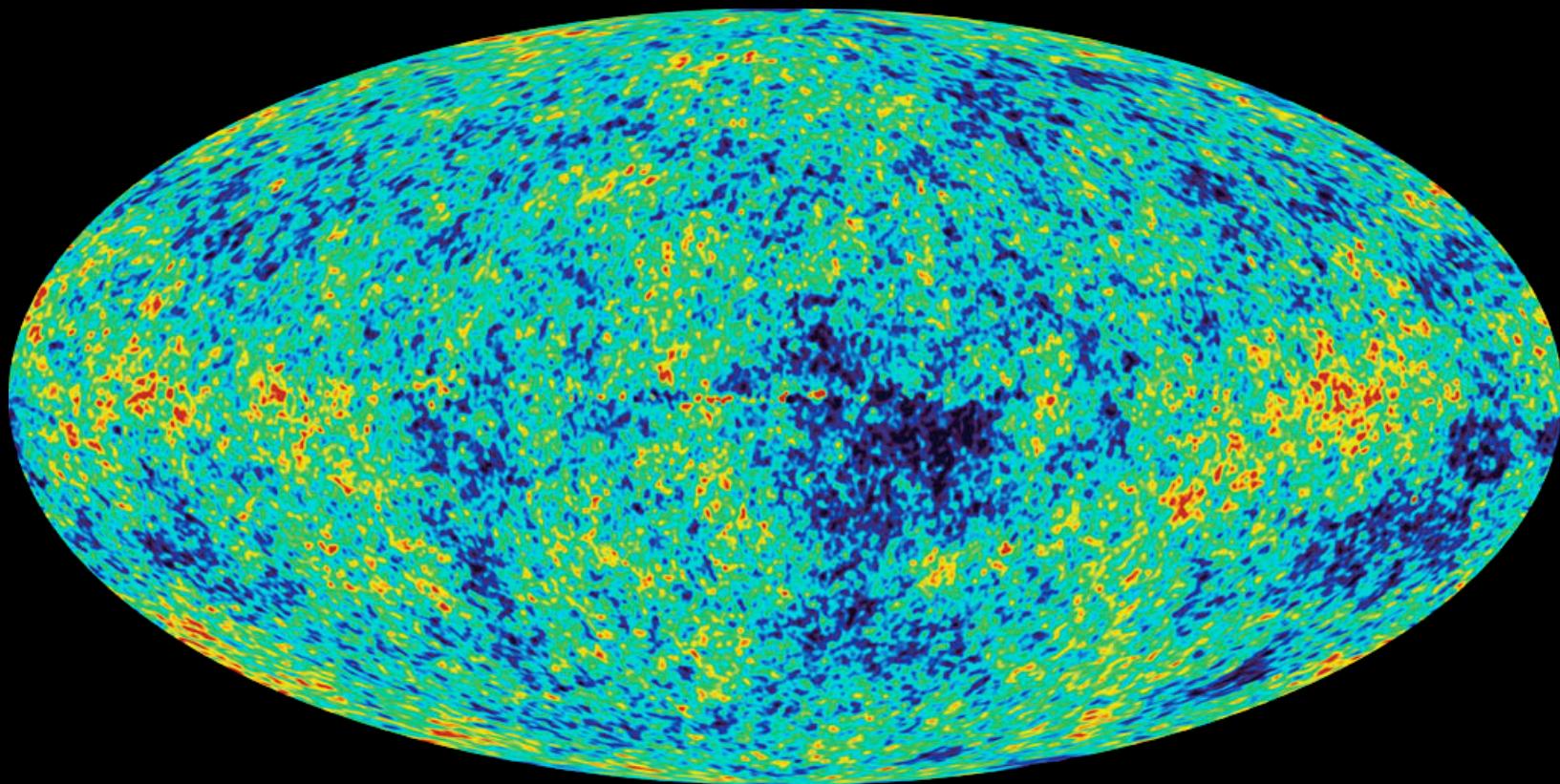
Young planetary systems

M_{planet}

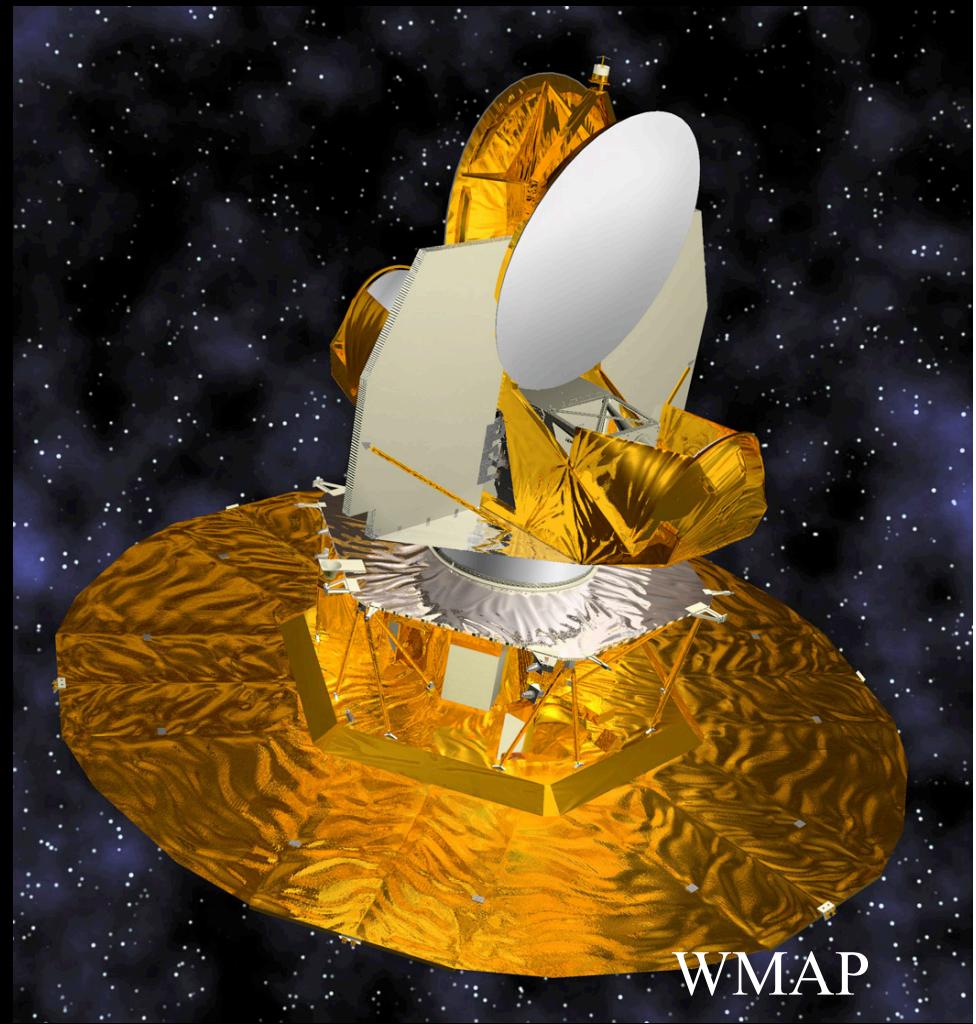
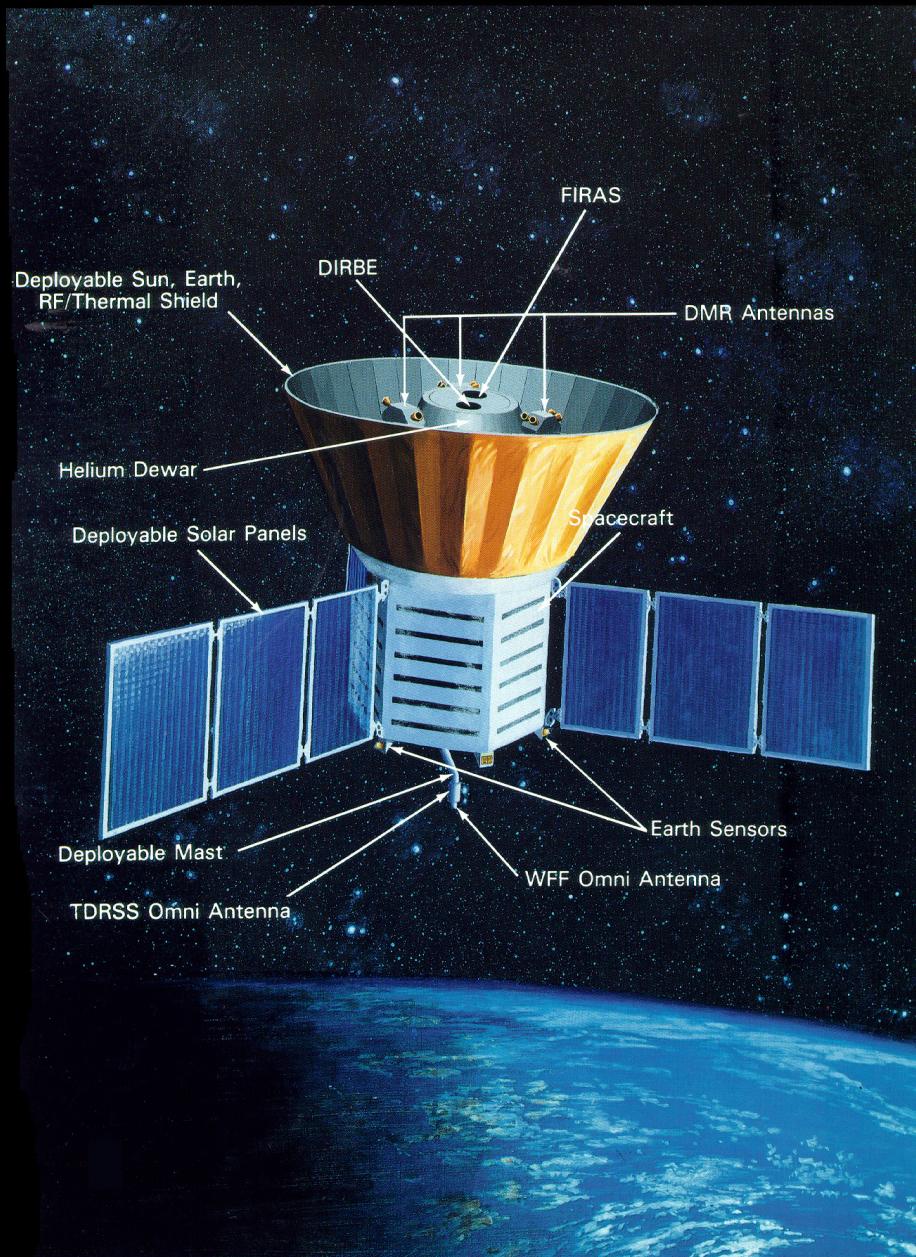
Mapping our History takes a range of facilities

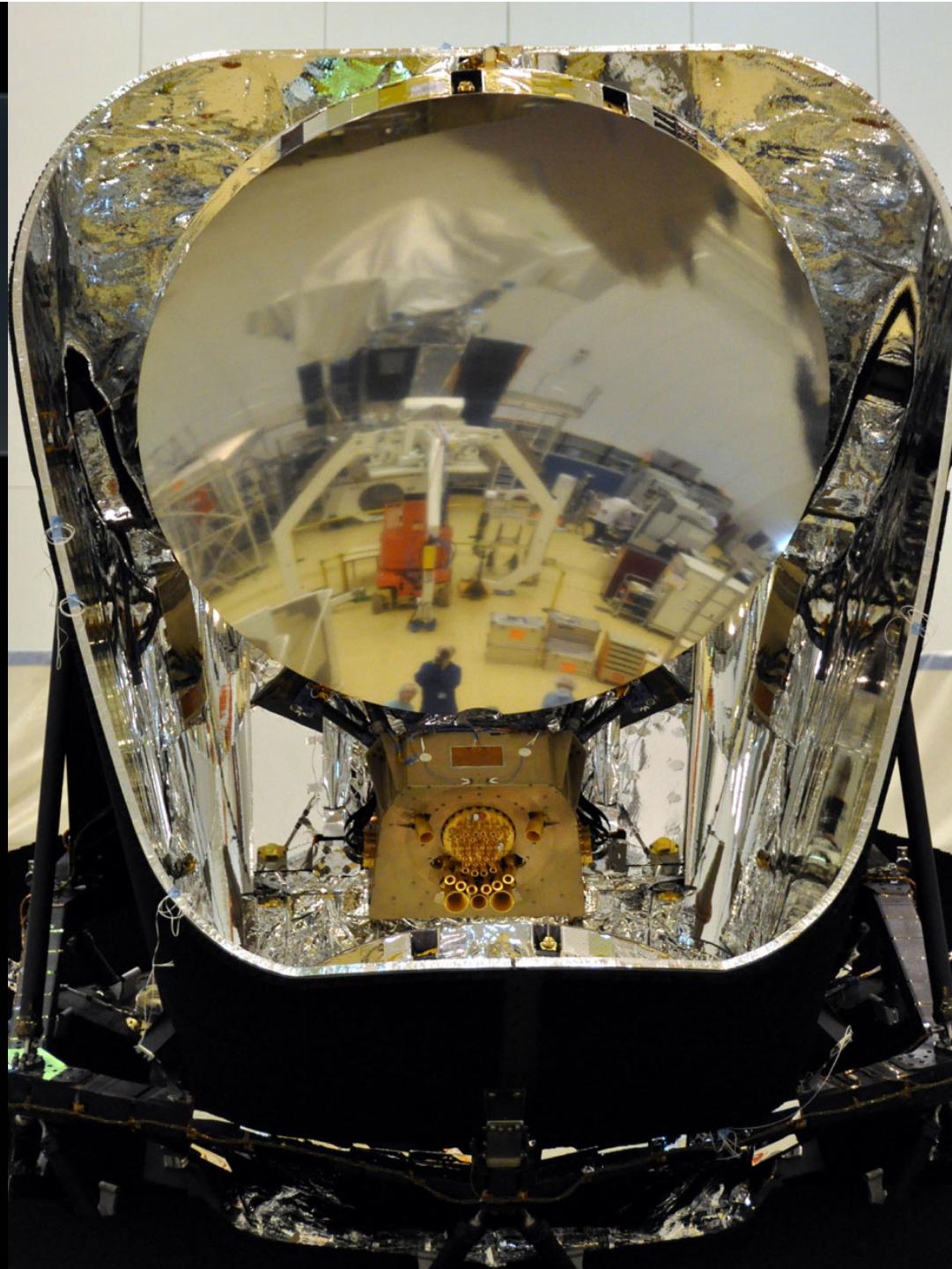


The Universe 380,000 Years After the Big Bang



The COBE Satellite

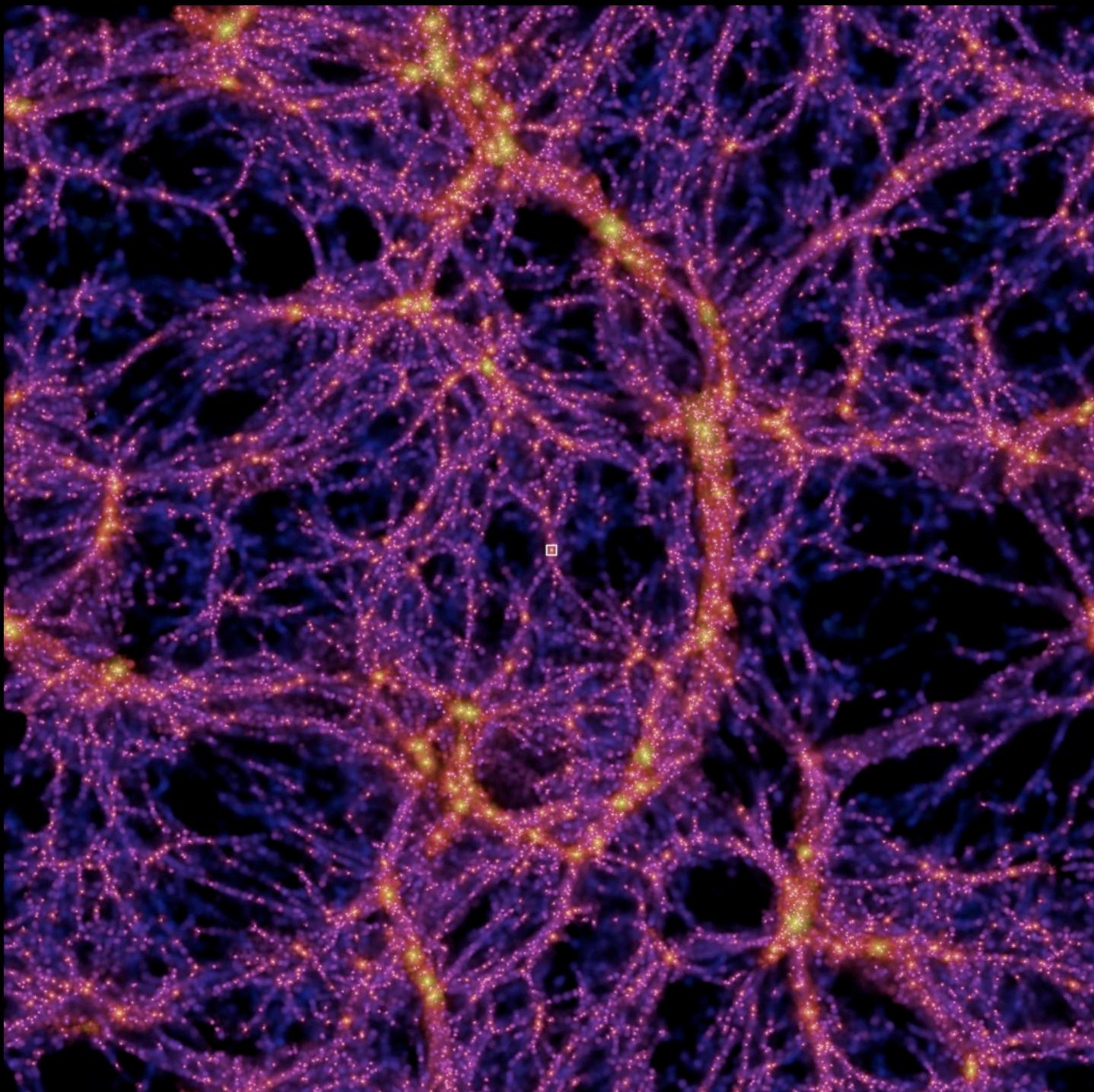




PLANCK
Launched
15 May 2009



How did the primordial fireball
evolve to what we see today?







The Mice • Interacting Galaxies NGC 4676
Hubble Space Telescope • Advanced Camera for Surveys

NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI) and the ACS Science Team • STScI-PRC02-11d



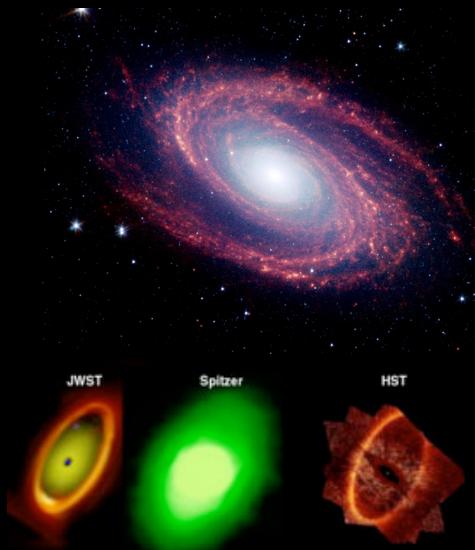
Earth & Moon imaged with Galileo

Main Science Themes

First Light (after the Big Bang)



Assembly of Galaxies



*Birth of Stars and
Protoplanetary Systems*



*Planetary Systems and
the Origins of Life*

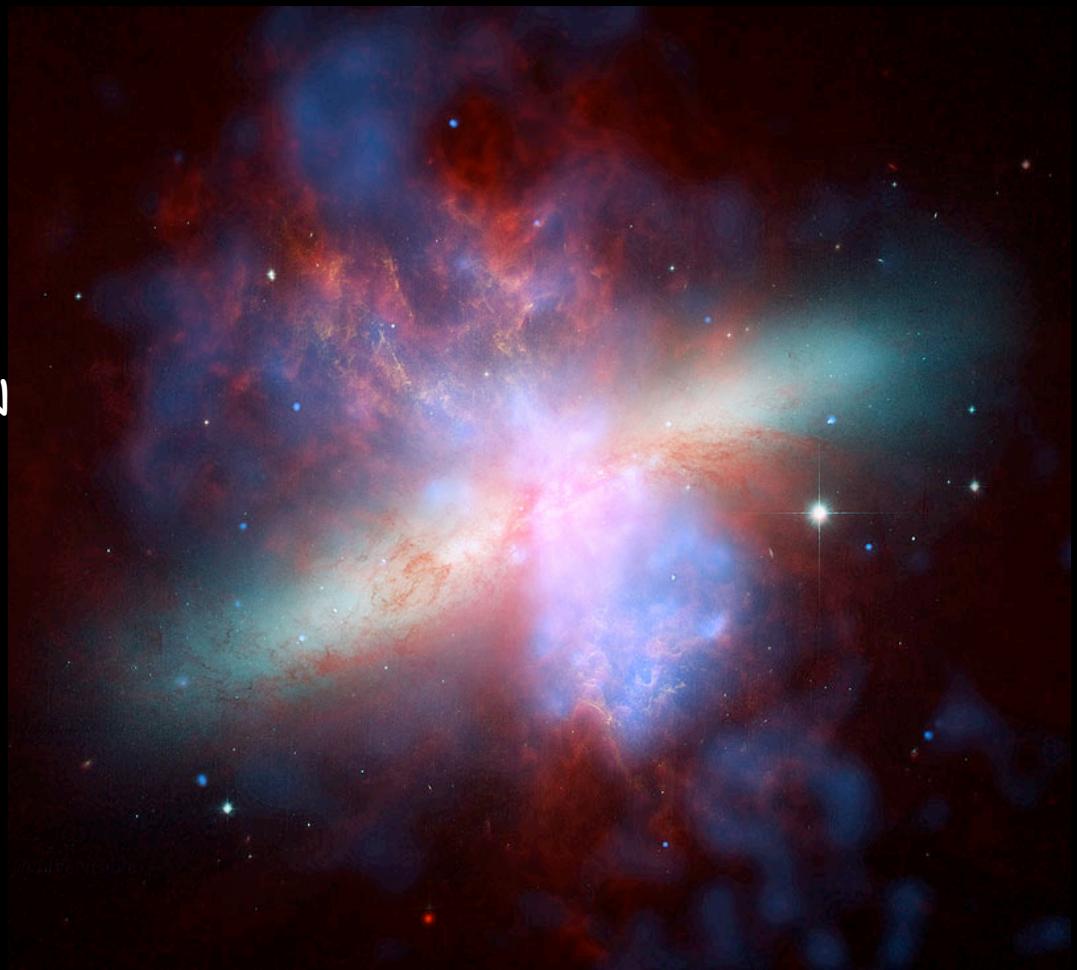


Along the way, we study key processes, mysterious Dark Matter and Dark Energy

CXO/XMM/HST/Spitzer Science

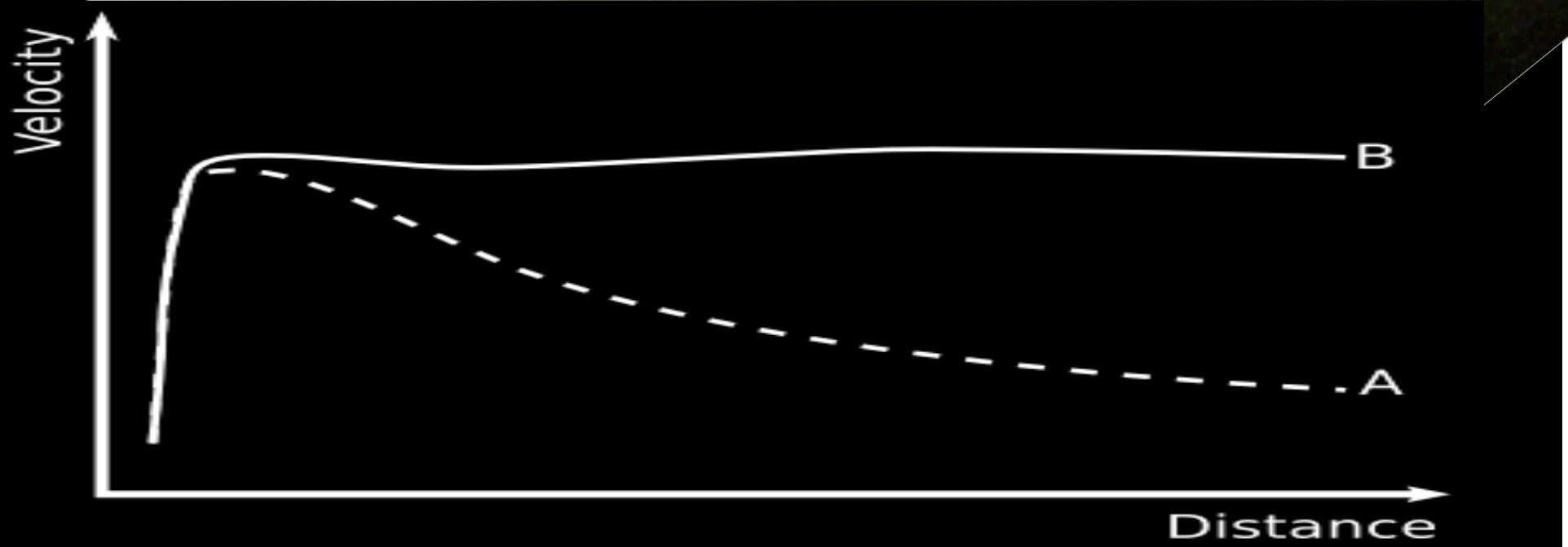
Mechanisms in Starbursts

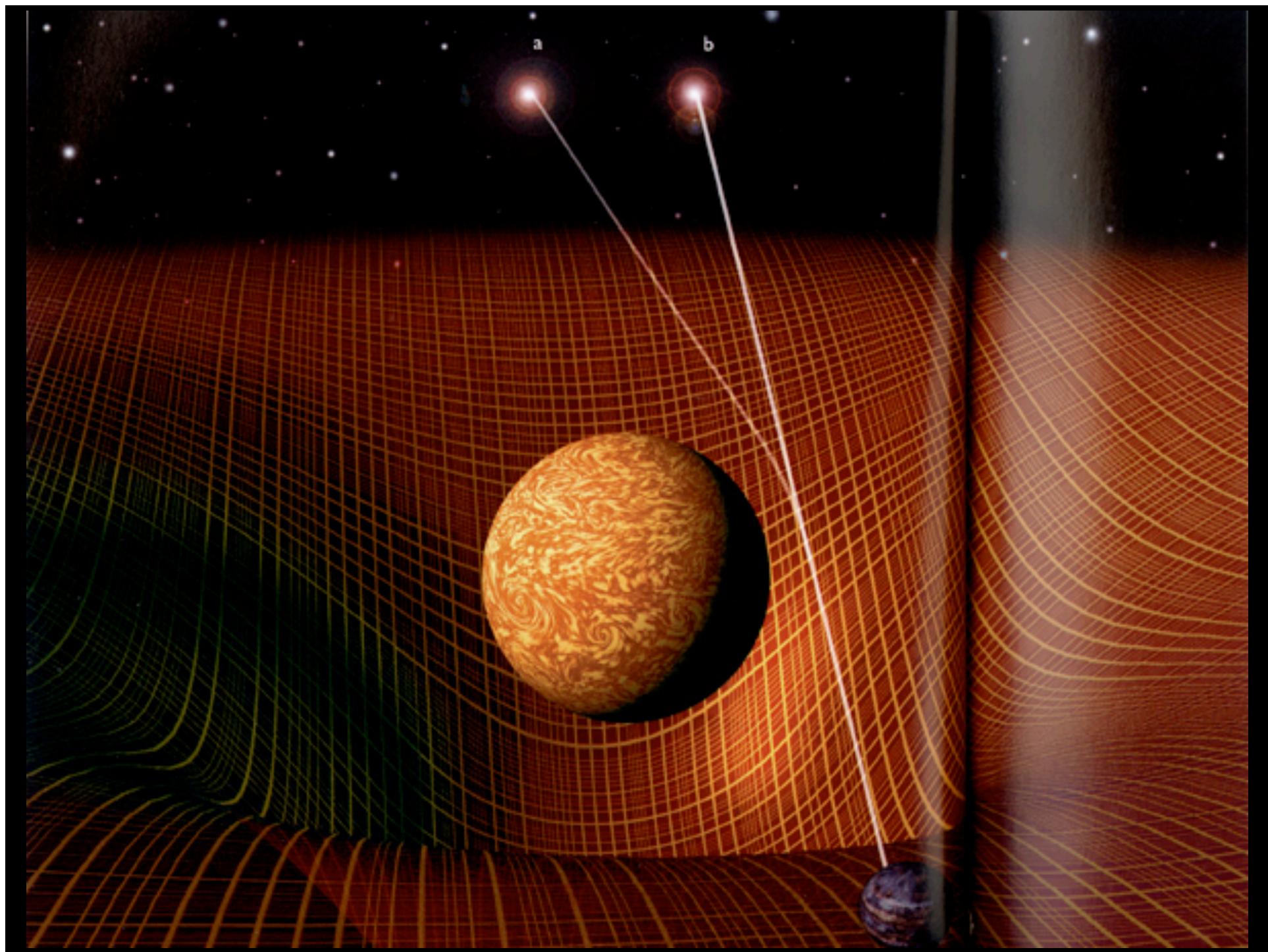
- triggering, regulation of SF, bursts
- feedback and galactic winds, superwinds, metal, dust ejection
- central starbursts: the AGN connection
- SF in extreme environments, IMF, abundances, etc

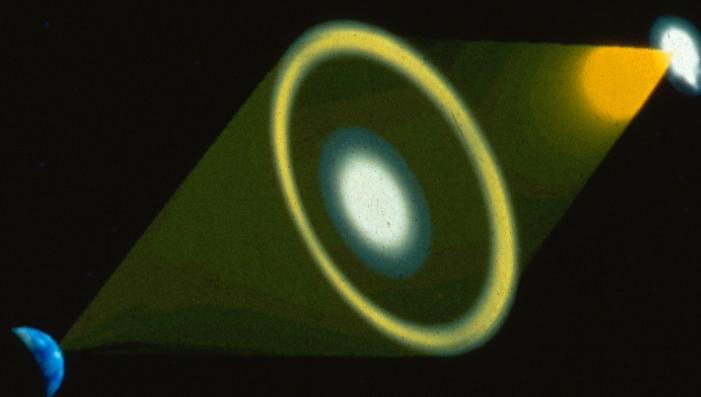


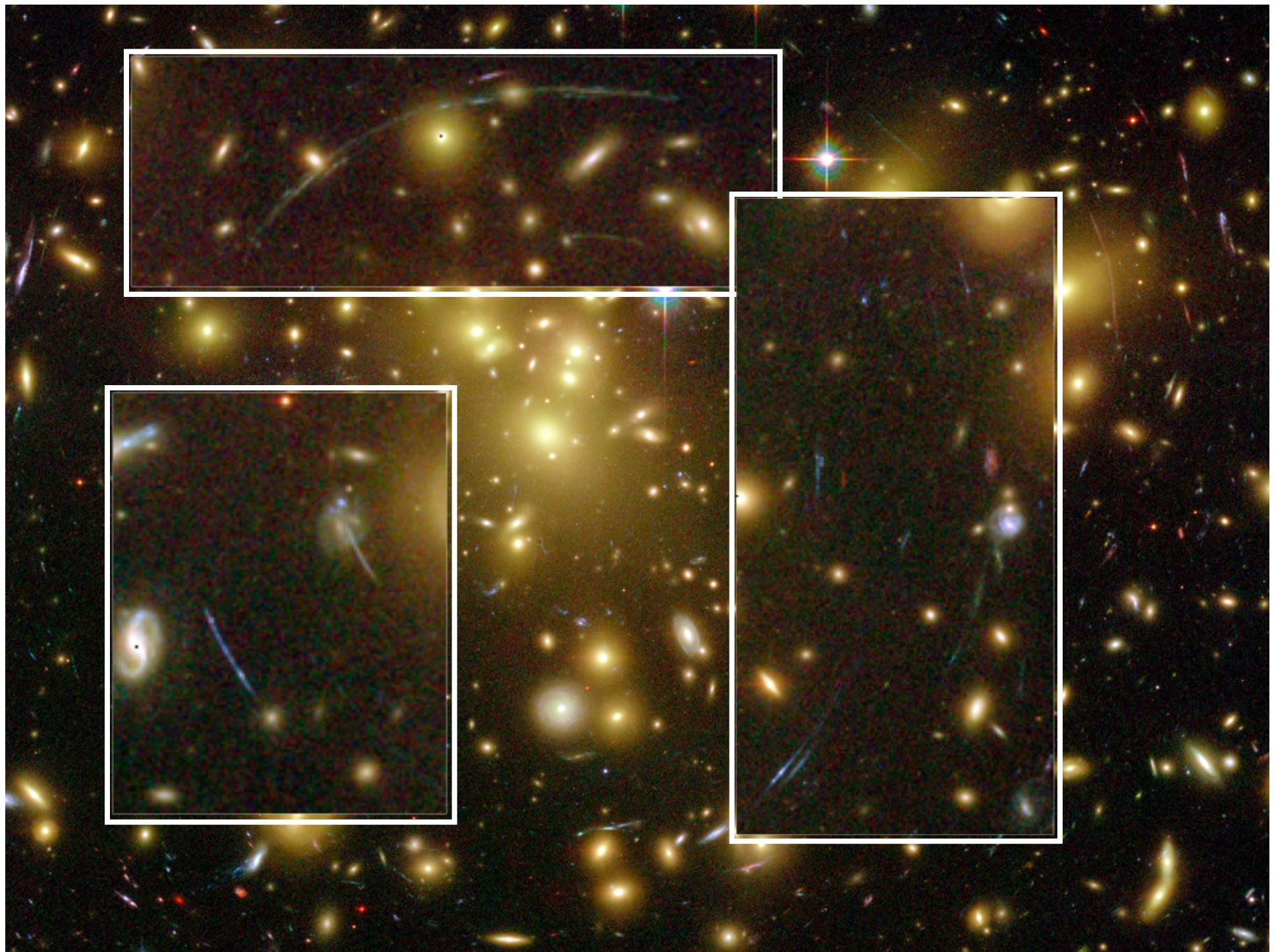
DARK MATTER

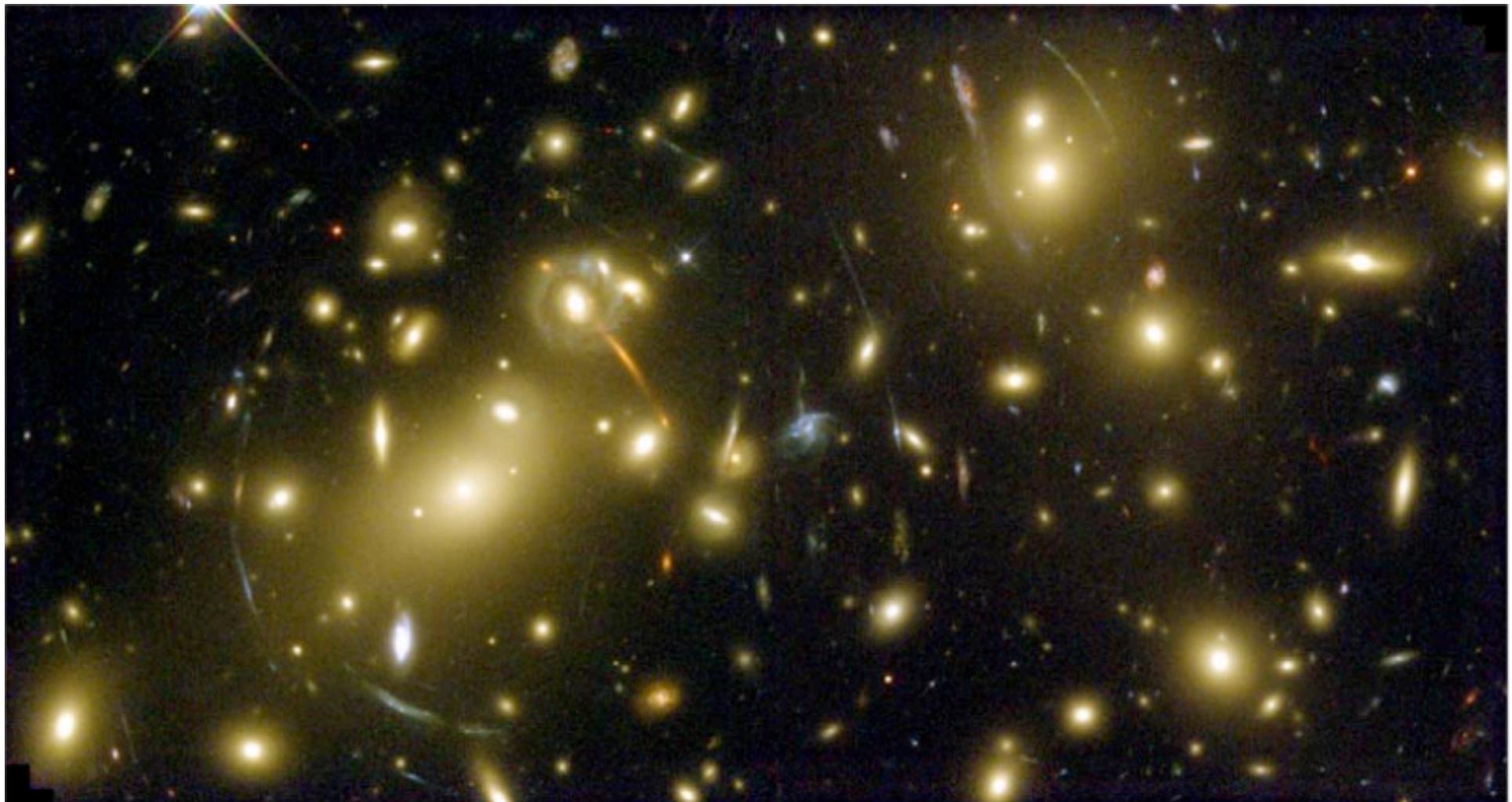
Rotation Curves of Spiral Galaxies





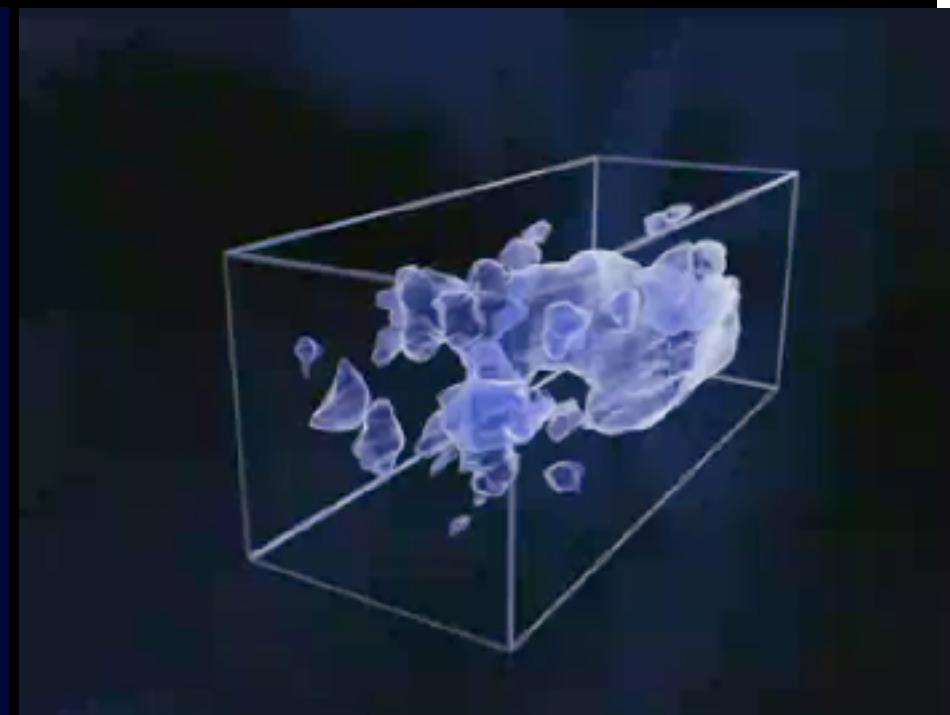
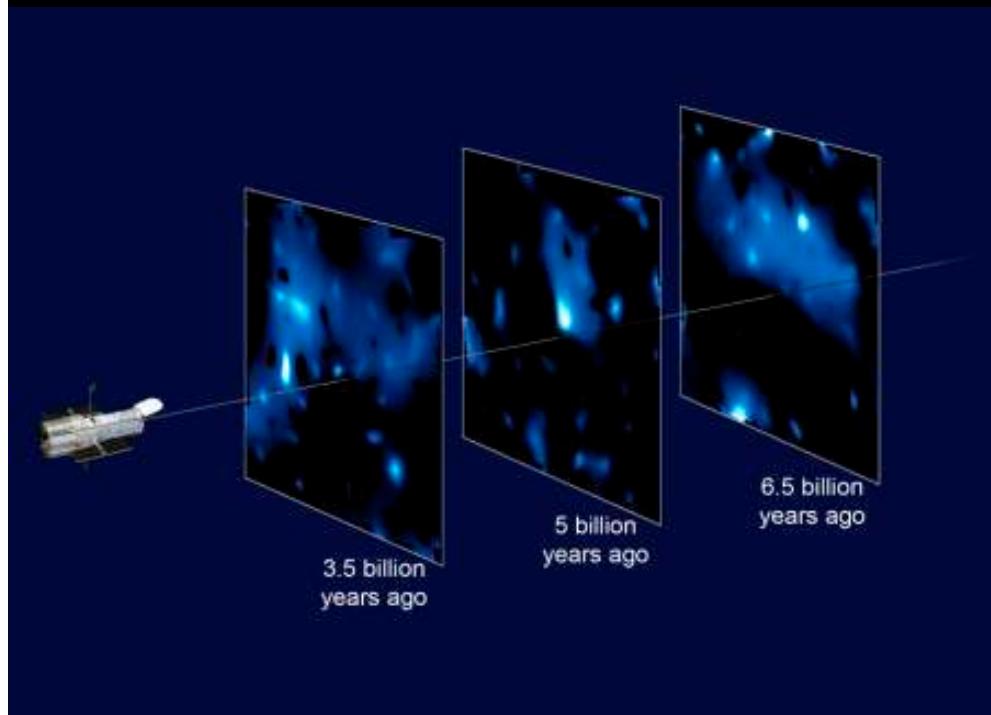




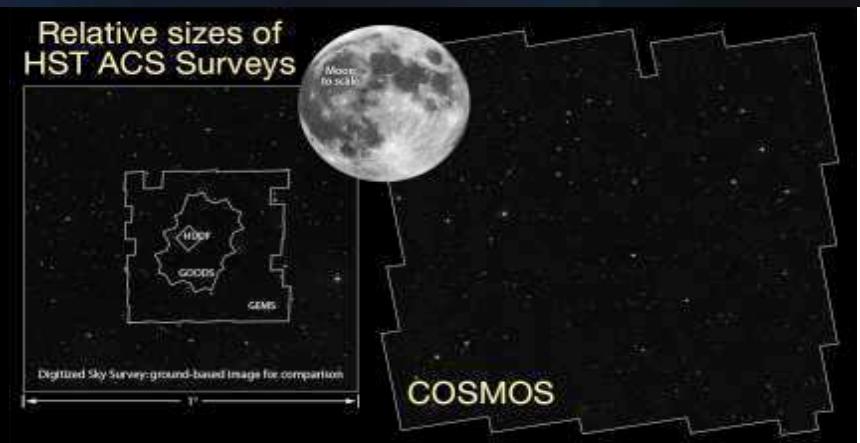


$$\Omega_d = 10 \Omega_m$$

Hubble Maps the Cosmic Web of "Clumpy" Dark Matter in 3-D



Three-Dimensional Distribution of Dark Matter in the Universe offers a first look at the web-like large-scale distribution of dark matter. This milestone takes astronomers from inference to direct observation the dark matter “Cosmic web”. The map stretches halfway back in time to the beginning of the universe.



EXPANSION VELOCITY AND DARK ENERGY

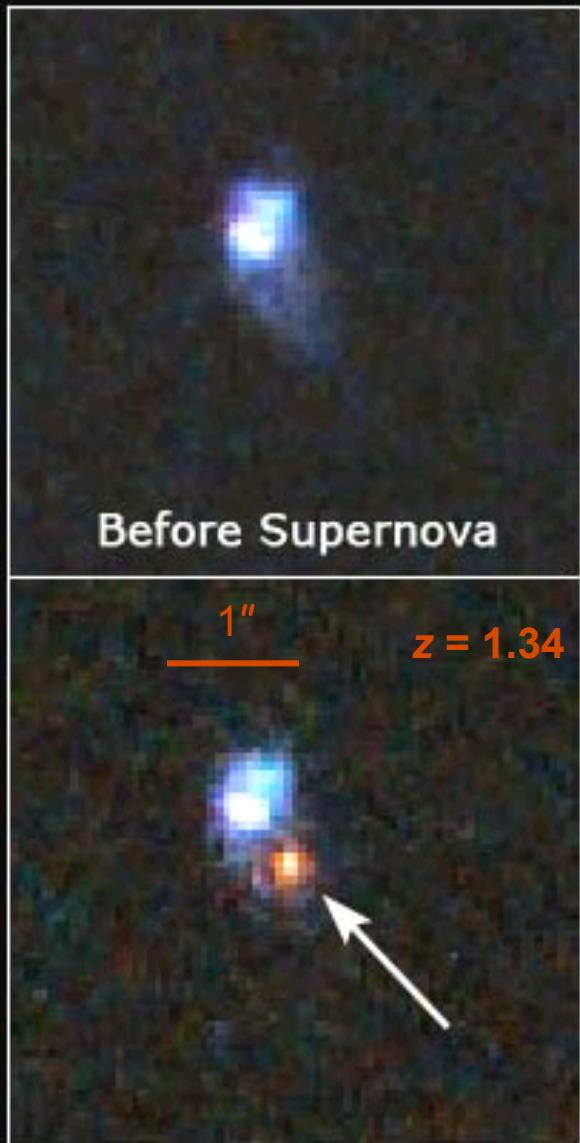


Edwin P.
Hubble
(1889-1953)

Mt. Wilson
Observatory
Pasadena, CA

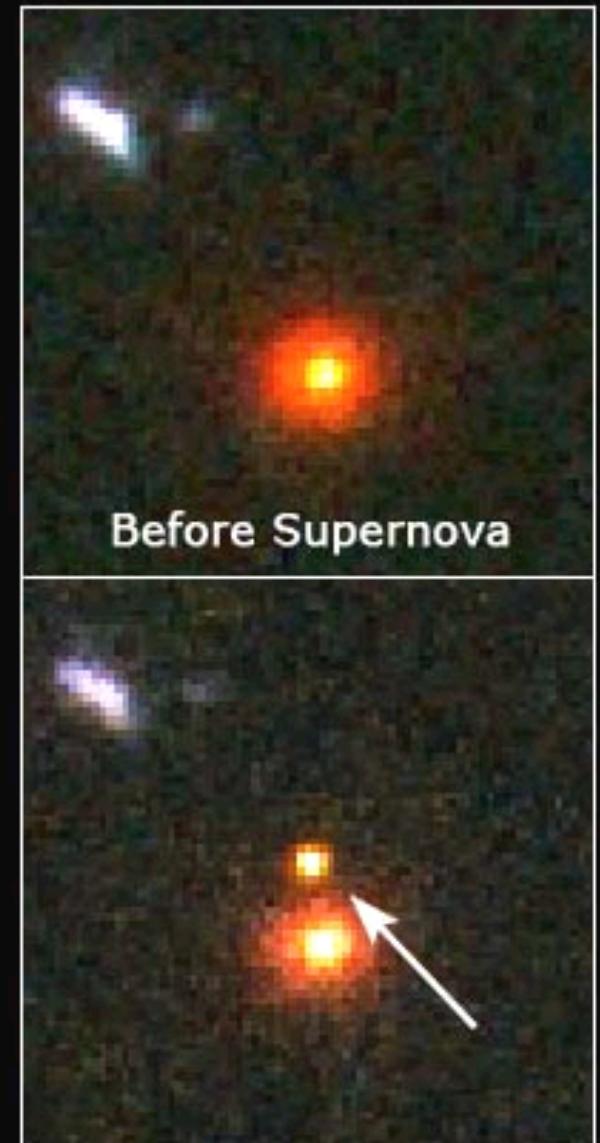
HST Images of SN Ia

Distant Supernovae



NASA and A. Riess (STScI)

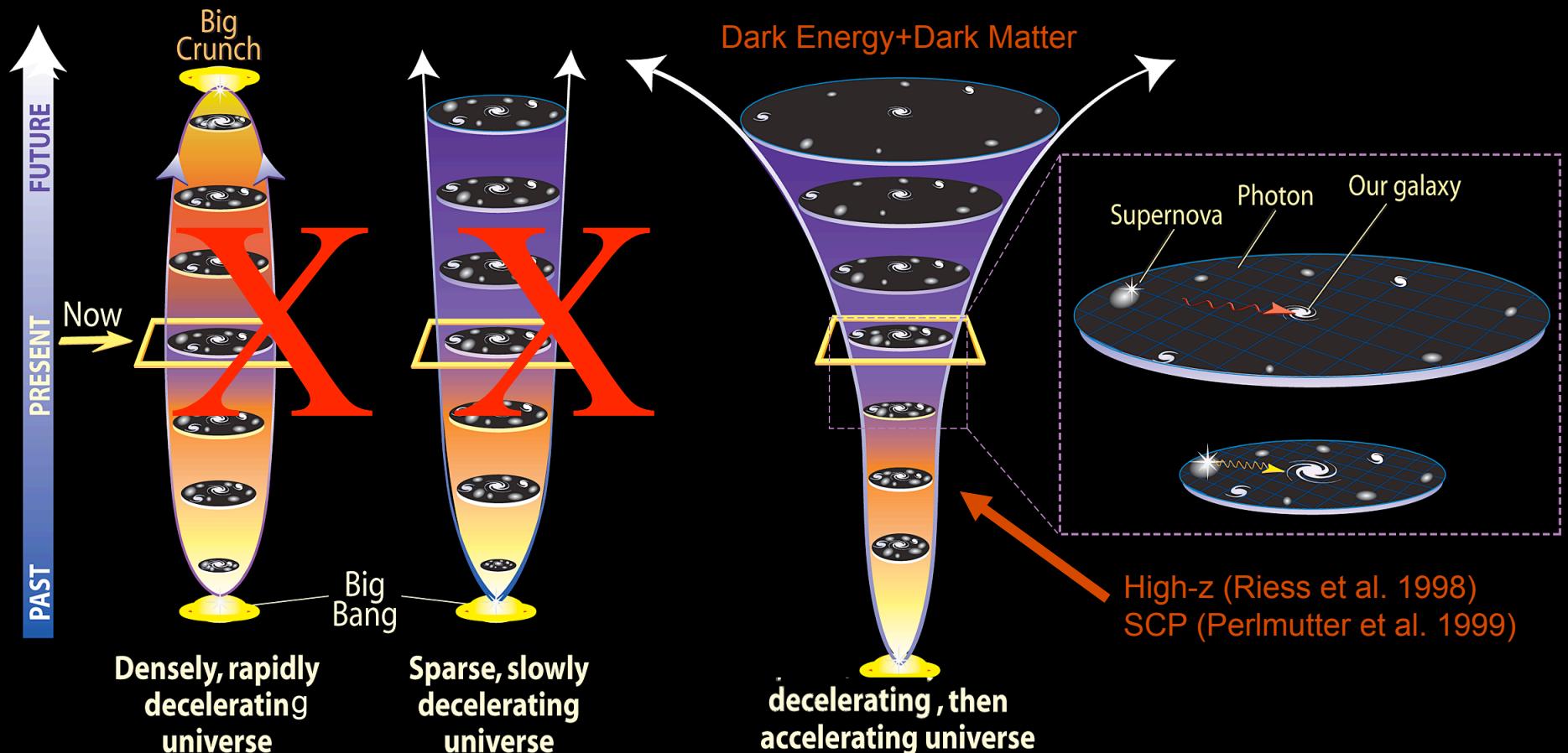
Hubble Space Telescope • ACS



STScI-PRC04-12

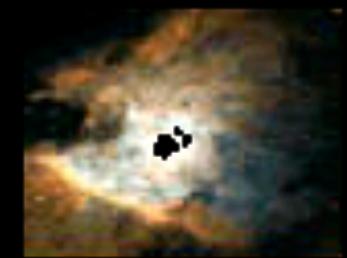
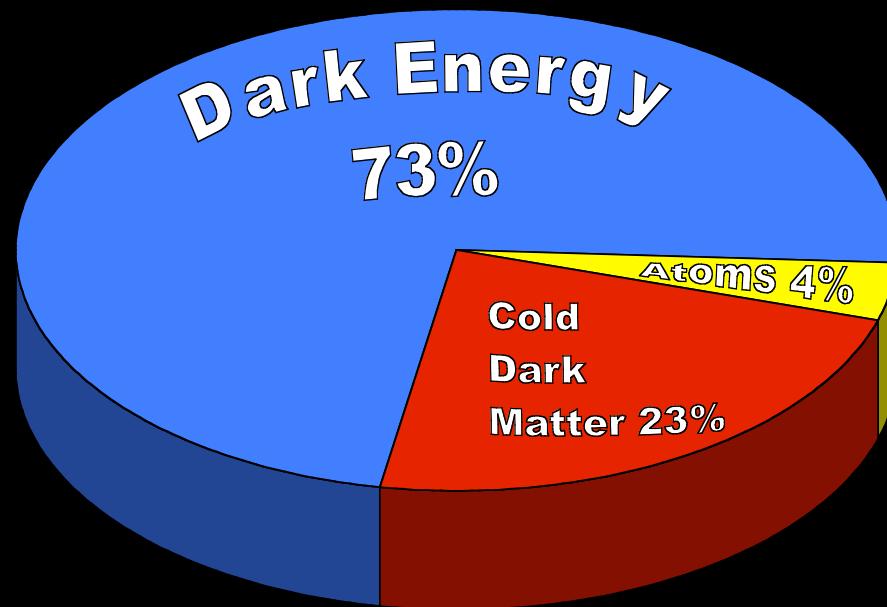
Expansion History reveals: THE ACCELERATING UNIVERSE

Models of the Expanding Universe



Now need greater precision, longer history to understand Dark Energy!

The new Galilean revolution



Not only we are NOT at the center of the Universe
We are not even made of that most of the Universe is made of !!!!

VLBA

Planet Earth as the “telescope’s” backbone



VERITAS (Very Energetic Gamma Rays)

Earth's atmosphere is part of the “telescope”



How big is IceCube? (Neutrinos)

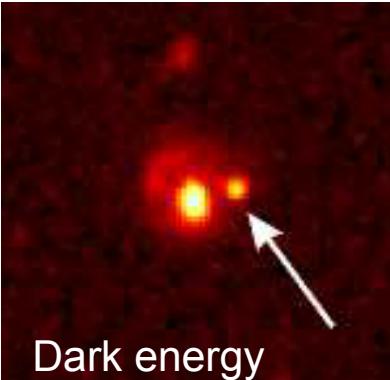
IceCube Detector Array – 1 Km across!

Skiway

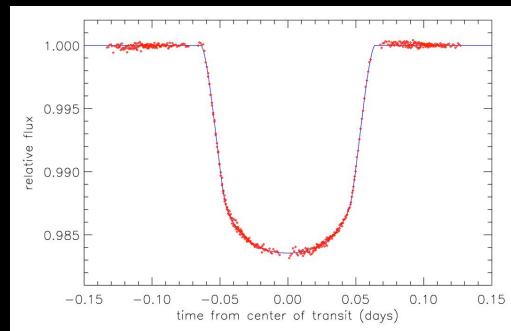
Station

Antarctic Ice is part of the “telescope”

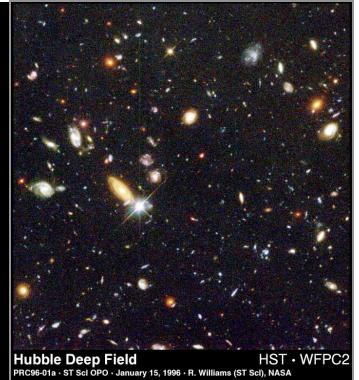
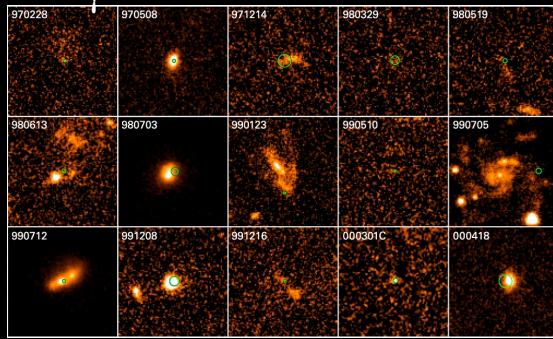
“Top Problems”



Dark energy

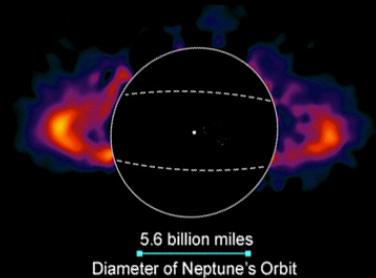


E_{γ}



Hubble Deep Field HST - WFPC2

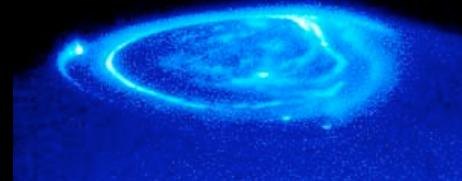
Early galaxies



Diameter of Neptune's Orbit

- Acceleration of the universe; dark energy
- Dark matter
- Formation of galaxies
- Formation and evolution of supermassive black holes; the BH galaxy connection
- Gamma Ray Burst sources
- Star formation and feed-back
- Protoplanetary disks
- Extra solar planets

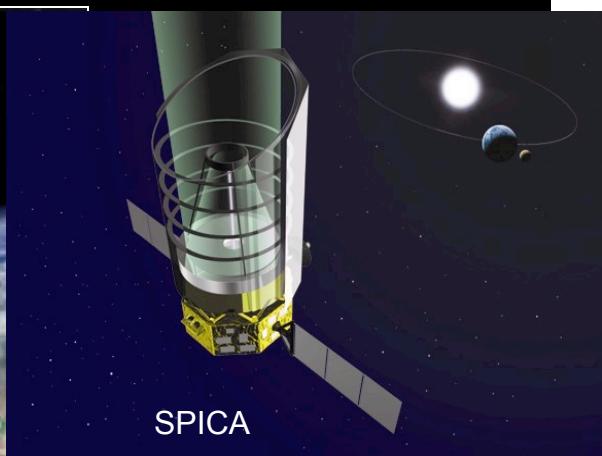
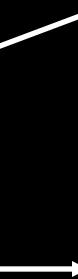
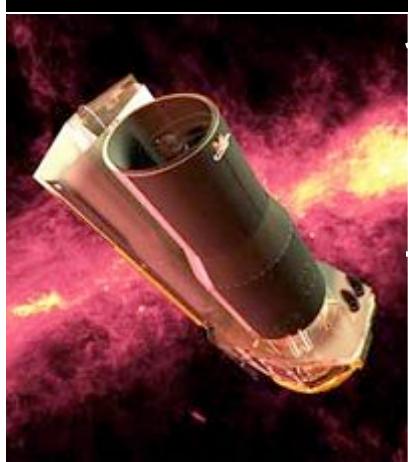
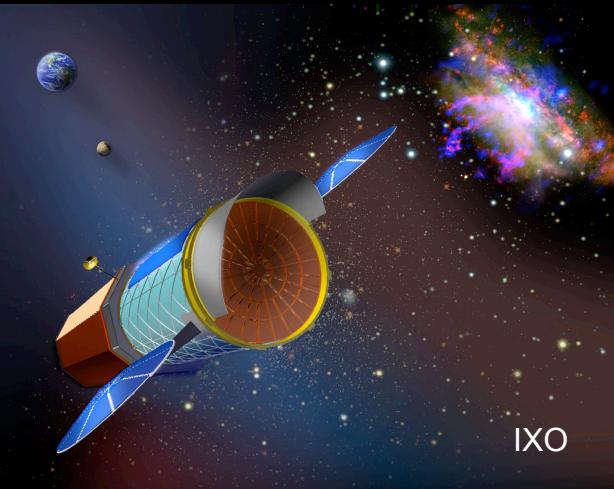
Aurorae on Jupiter



Young planetary systems

M_{planet}

New Capabilities



SPICA

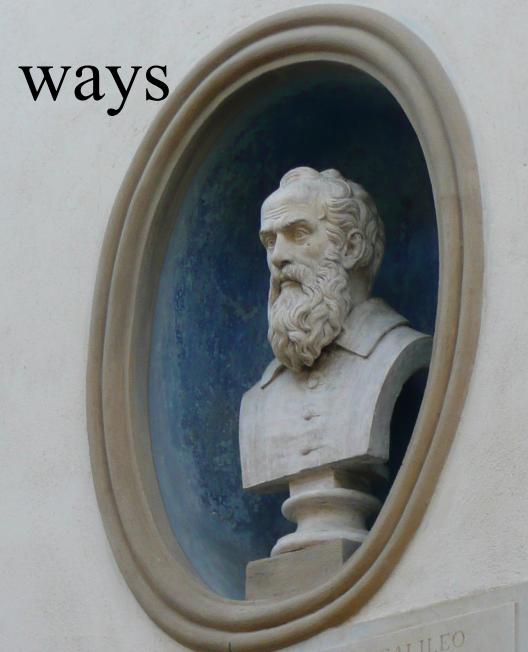
Galileo: Ahead of his time in many ways

Recognizing the potential of new technology

Adapting new technology for Astronomy

Doing the research, recognizing the breakthrough

Publishing quickly, while proposing for more!



QUESTA EFFIGIE DEL DIVINO GALILEO
FECE PORRE NEL MDCCXLIII
ANTON FILIPPO MARCHIONNI

ΣΥΝ ΘΕΩ
AEDES QVAS VIATOR INTVERIS LICET EXIGVAS
DIVINVS GALILAEVS
ET COELI MAXIMVS SPECTATOR
SEV POTIVS PARENTS
PSEUDOSOPHORVM MALIS ARTIBVS COACTVS
INCOLVIT AB ANNO MDCCXLII VI IDVS Ianvari
AD ANNVM MDCCXLII VI IDVS Ianvari
HIC NATVRAE CONCESSIT
LOCI GENIVM SANCTVM VENERARE ET TITVLUM
AB IO BAPTISTA CLEMENTE NELLIO
STEPHANIANI ORDINIS EQVITE
AETERNITATI DICATVM SVSPICE
ANTONIO BONAVITI IC: FVNDI DOMINO ANNVENTE

- “Grandissima mi par l’innezzia di coloro che vorrebbero che Iddio avesse fatto l’Universo più proporzionato alla piccola capacità del loro discorso...”
- “It’s very great the “stupidity” of those who wish that God had made the Universe more proportionate to the small size of their intellect...”



Galileo Galilei
Opere VII, 397