Lecture 16: Announcements

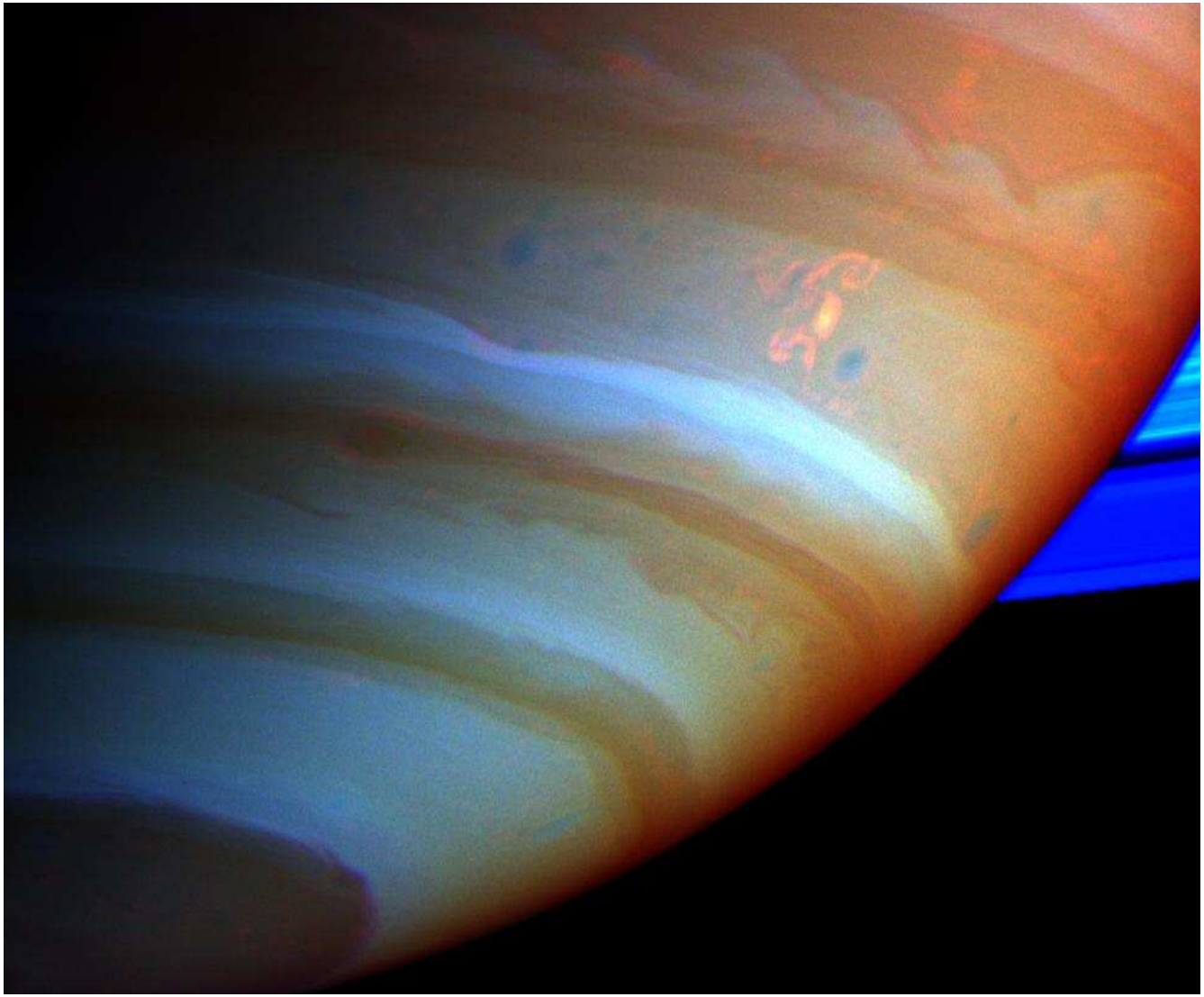
- Homework 2 due Mon Feb 28
- Exam on Wed Mar 9 : Makes up 20% of total grade . See webpage for a description of the exam format

  http://www.as.utexas.edu/~sj/a301-sp05.html

- On Mon Mar 7, we can spend part of the lecture on a short review where I can answer questions that you email me by Sat Mar 5 at noon. If there are no emails, we will have a regular lecture
- We will have a review session on Wed Mar 2 from 6.30 to 8.00 pm in RLM 5.118. Each of you should email me by Monday Feb 28 at noon what concepts you want me to review and re-explain. If there are no emails the review session will be cancelled.
- The following students should see me after class today:

  J. Galleher, A. Abdulrahim, S. Merani,

Lecture 16:Astronomy Picture of the Day

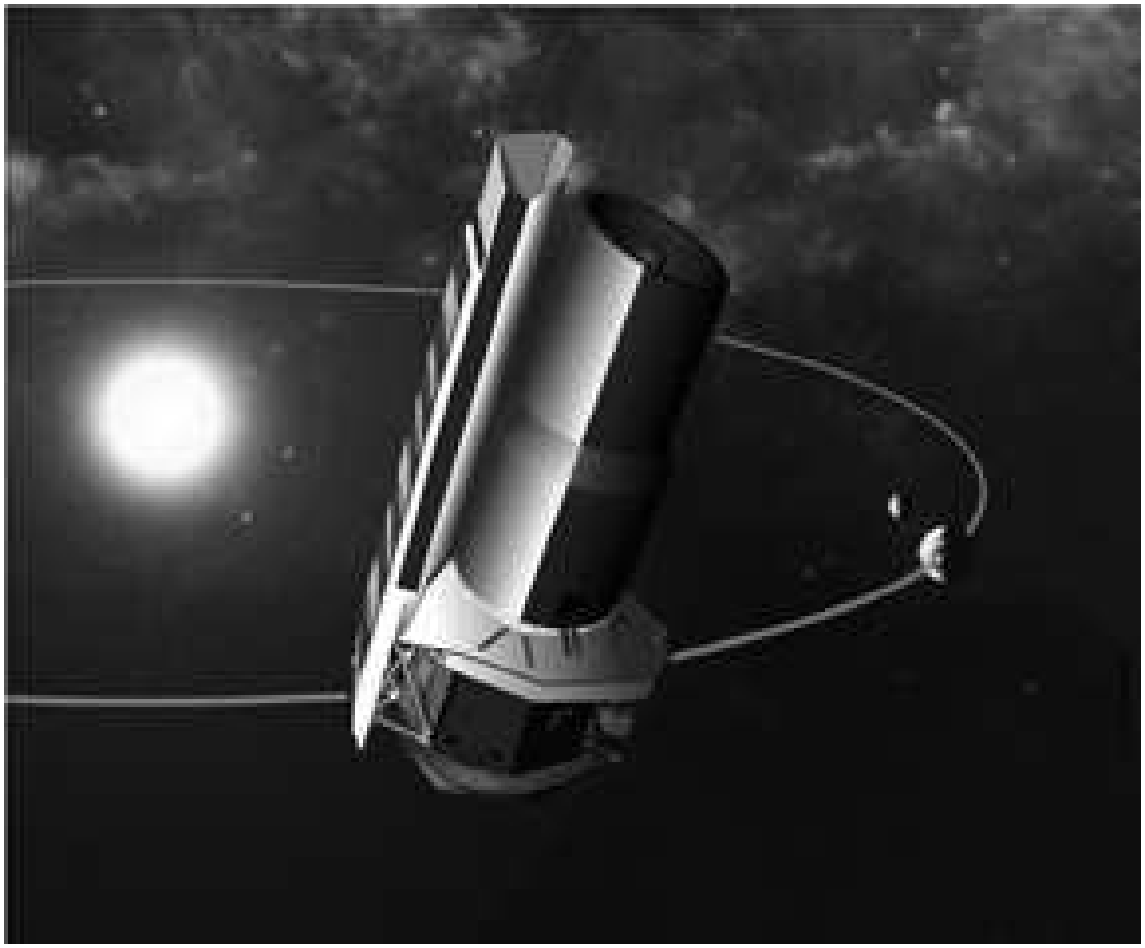


“Dragon Storm” = convoluted, swirling cloud (tinted orange) in near-IR image of Saturn's.

Giant Saturnian thunderstorm, with radio noise produced in high-voltage lightning discharges.

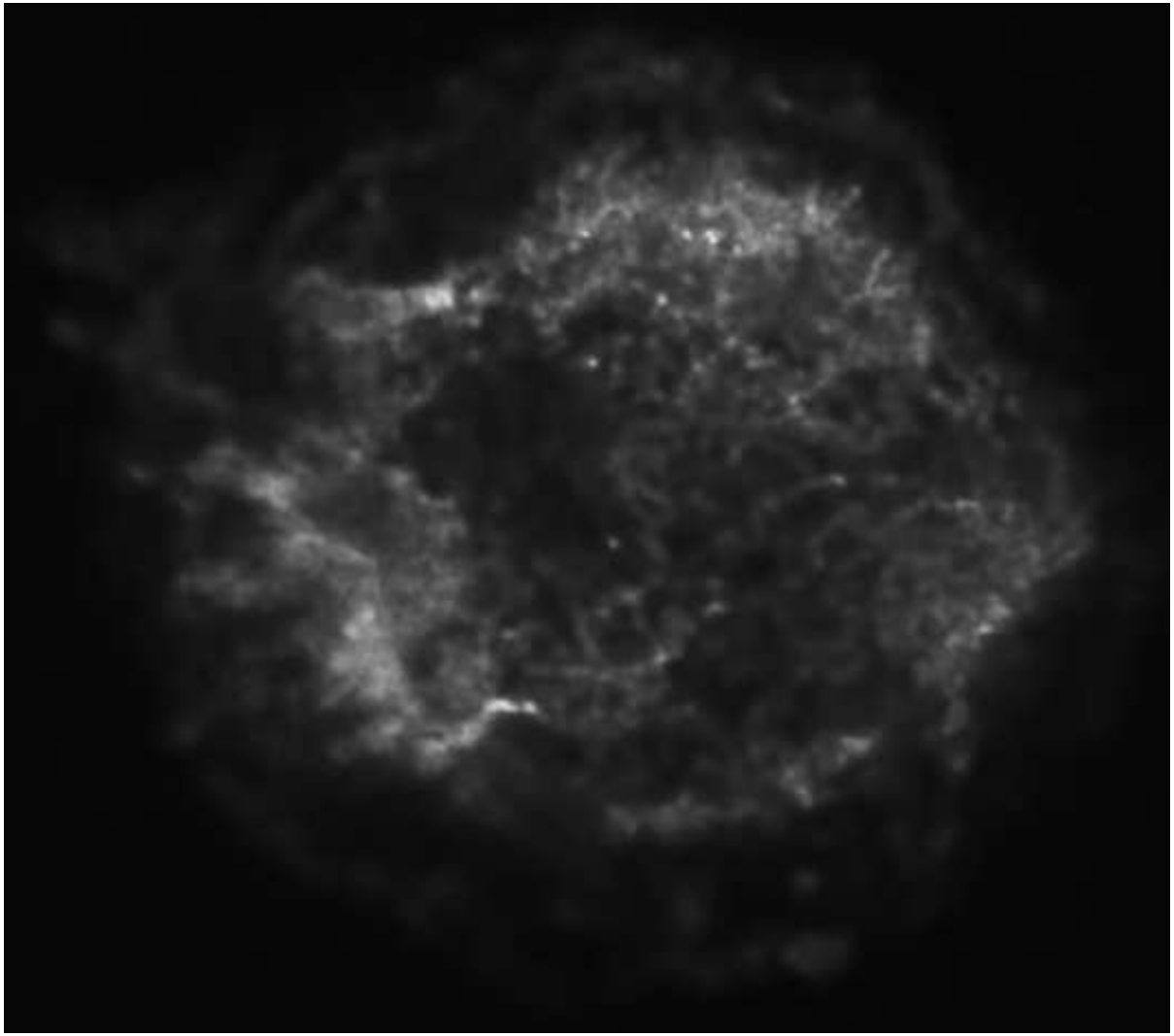
X-Ray Observatories

Early X-ray observatories: Einstein (1978-1980), ROSAT (1991-1999)



- Chandra X-Ray Observatory. Launched by NASA in1999
- Larger field of view, sensitivity,resolution than predecessors

X-Ray Wavelengths

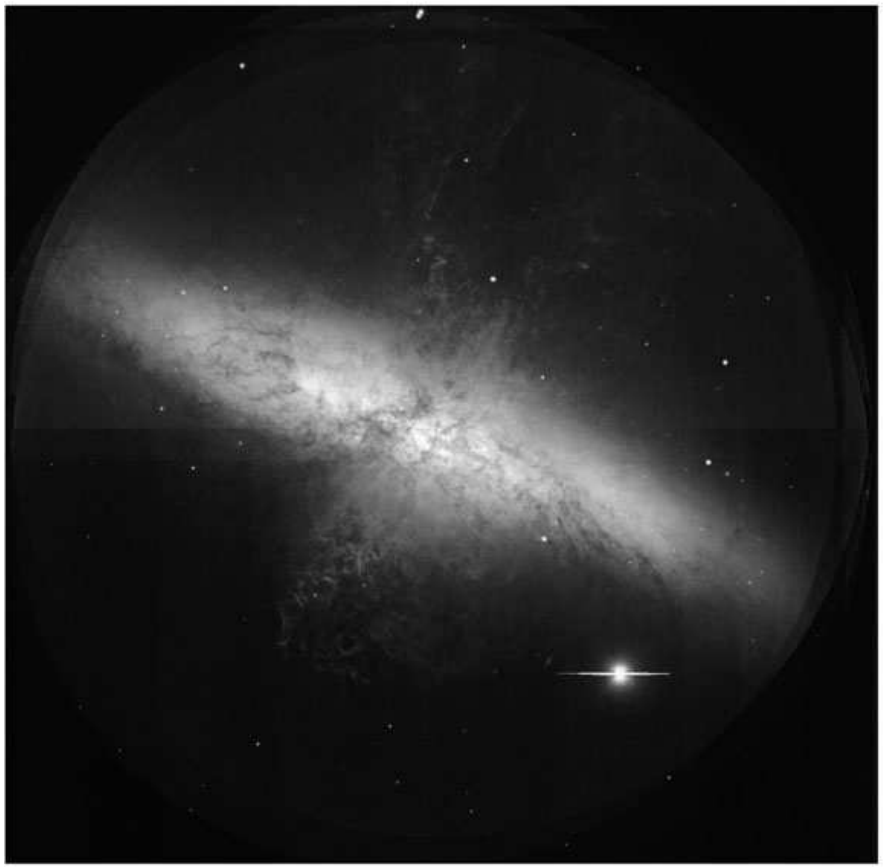


Supernova Remnant
Cassiopeia A

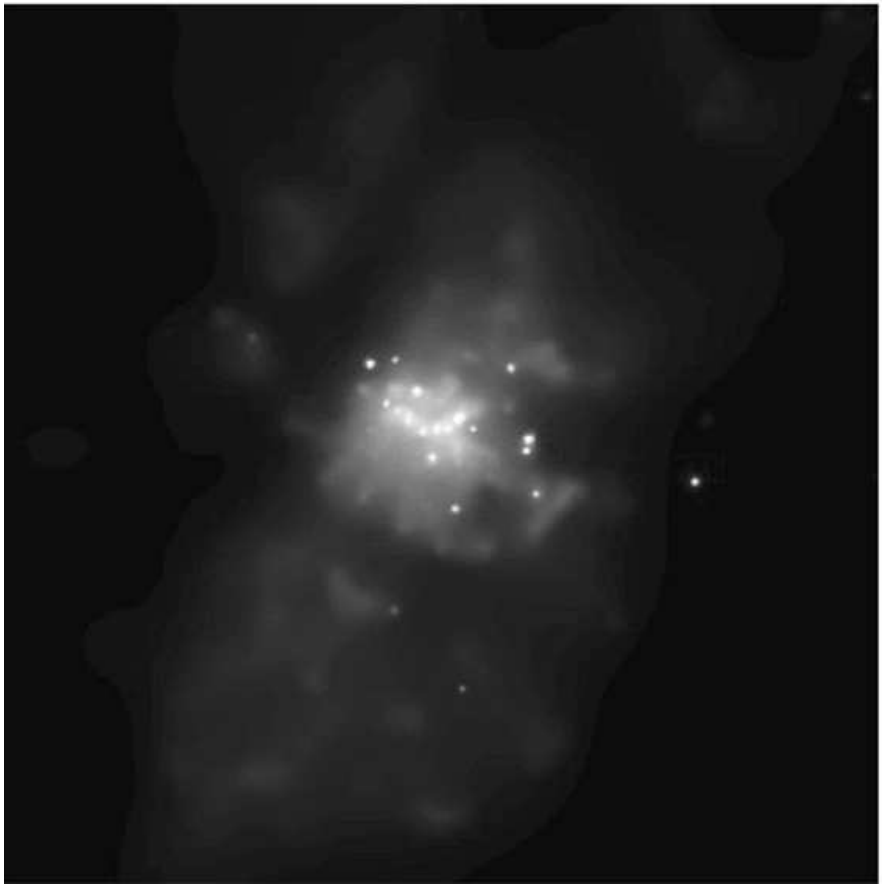
X-ray shows a hot bubble of 10^7 K gas that is heated by shocks from the supernova remnnant

X-Ray Wavelengths

Starburst Galaxy M82: central starburst driving an outflow



Visible light



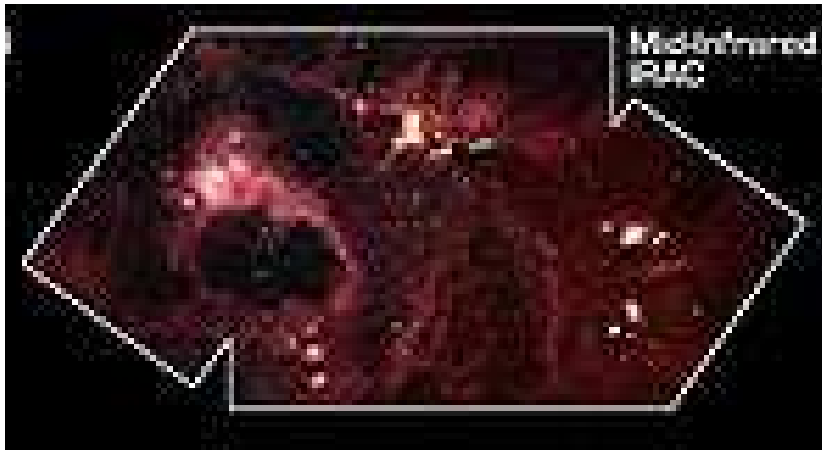
X-ray

Infrared Wavelengths: Penetrating the dust

Infrared Wavelengths: Penetrating the dust

Stellar nursery DR21

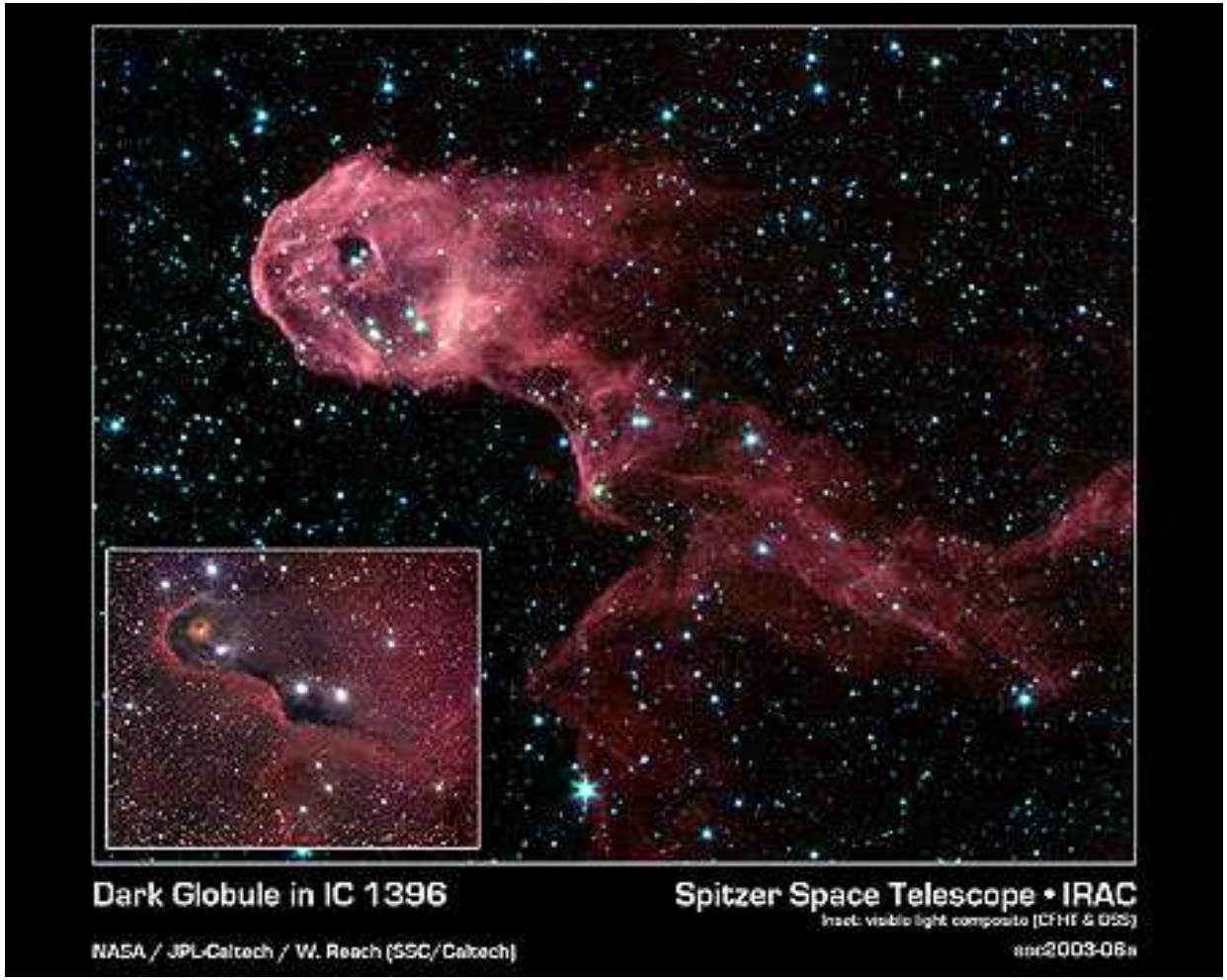
Visible light image: no sign of action!



IR image : Shows cloud forming some of most massive stars in our Galaxy; Powerful outflow; Filaments from gravity,pressure magnetic fields

Composite made from visual and Spitzer infrared images (Courtesy: NASA/Spitzer)

Infrared Wavelengths: Penetrating the dust



- Infrared images of dark globule in IC 1386 (Courtesy:NASA/Spitzer)
- Reveal : Birth of previously unseen young stars ; Cavity and filaments made when gas is cleared or compresed by winds from massive stars; Thick and dusty discs around young stars as precursor of planetary systems

Infrared Wavelengths: Penetrating the dust

- Movie : From visual to infrared look at dark globule in IC 1386 (Courtesy:NASA/Spitzer)
- Reveal: 2nd star and spherical cavity in globule head; Filaments of compressed gas

Infrared Wavelengths: Penetrating the dust

M81 galaxy

Underlying old stars

Regions with hot dust and gas forming young stars

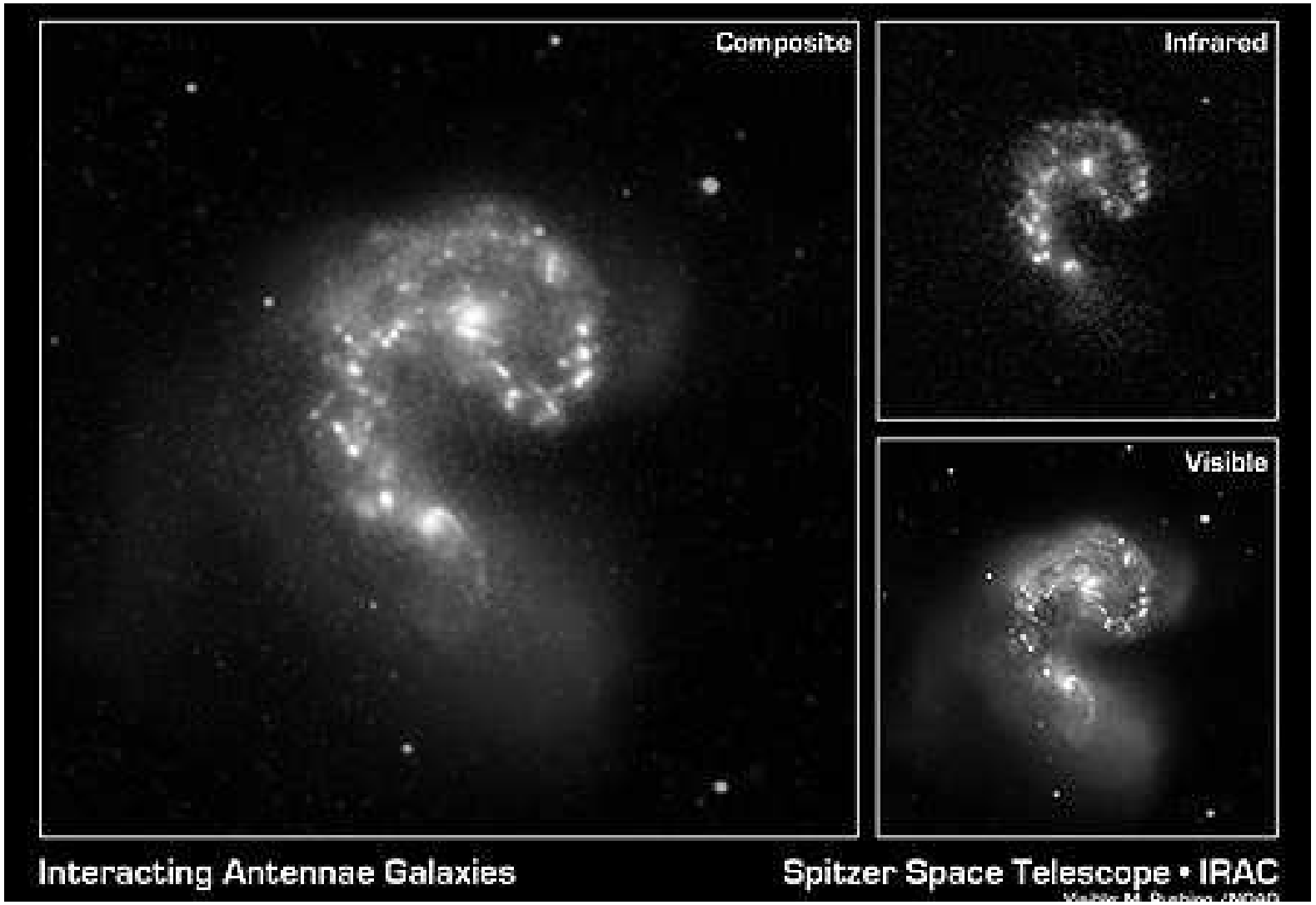
(Courtesy: NASA/Spitzer)

Infrared composite made from 3.6, 8.0, 24 micron images

Infrared Wavelengths: Penetrating the dust

Movie: From optical to IR view of M81 (Courtesy: NASA/Spitzer)
Reveals regions with hot dust and gas forming young stars + old underlying stars

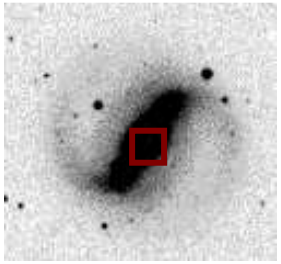
Infrared Wavelengths: Penetrating the dust



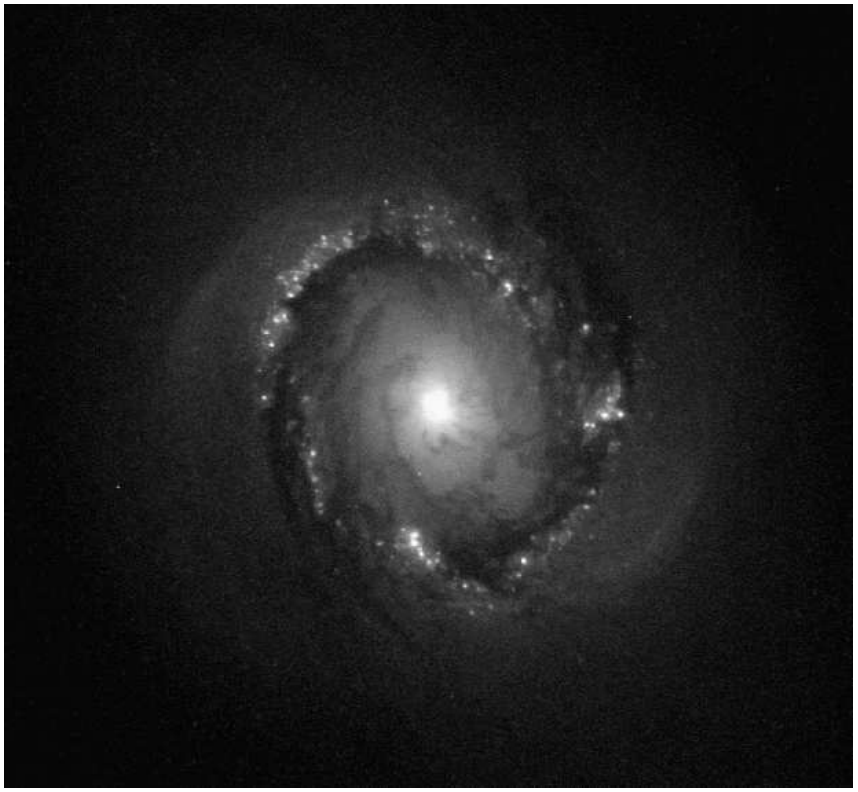
- hidden populations of newborn stars at the heart of the colliding "Antennae" galaxies.
- tremendous burst of star formation triggered in overlap region of the 2 galaxies

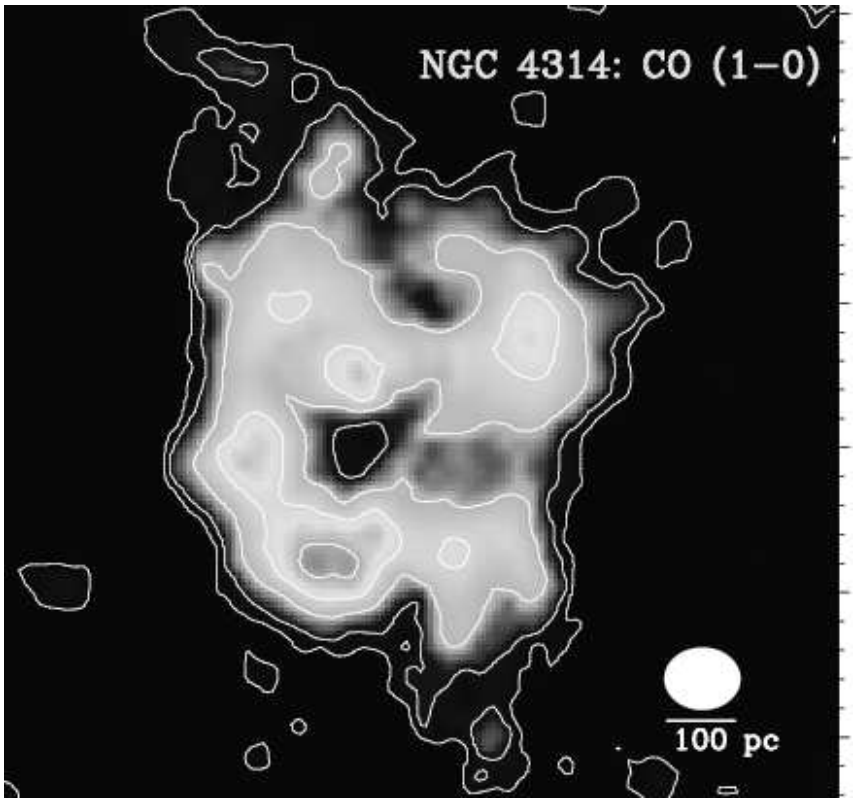
(Courtesy: NASA/Spitzer)

Radio Wavelengths



Radio (mm) Wavlengths





Speactacular ring of young star clusters, only a few millon yrs old. Revealed by UV and optical observations fromHubble. (Courtesy: Benedict/ NASA)

Molecular hydrogen in the ring where star clusters are forming. Revealed by observations at mm (radio) wavelengths from Caltech's Owens Valley Radio Observatory (Jogee et al . 2004)

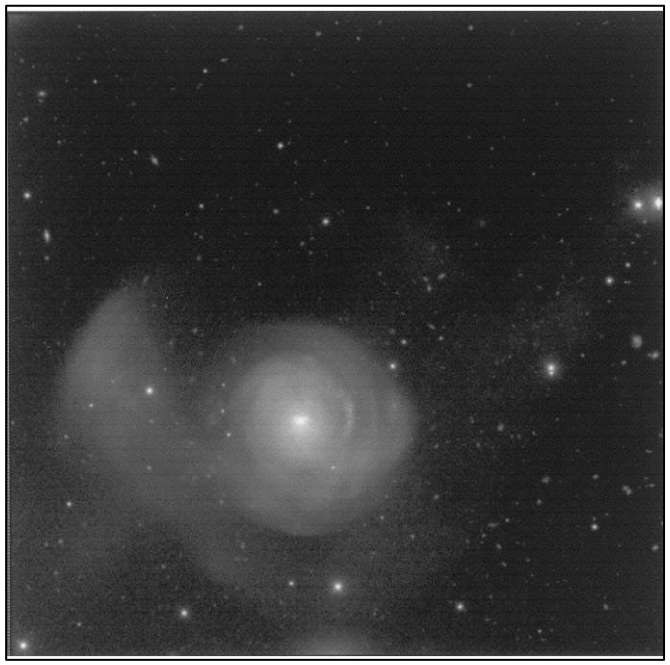
Radio (mm) Wavlengths

Caltech's Owens Valley Radio Observatory (OVRO) : 8 radio telescopes, each 10.2 meters in size, operate in tandem as a mm array.

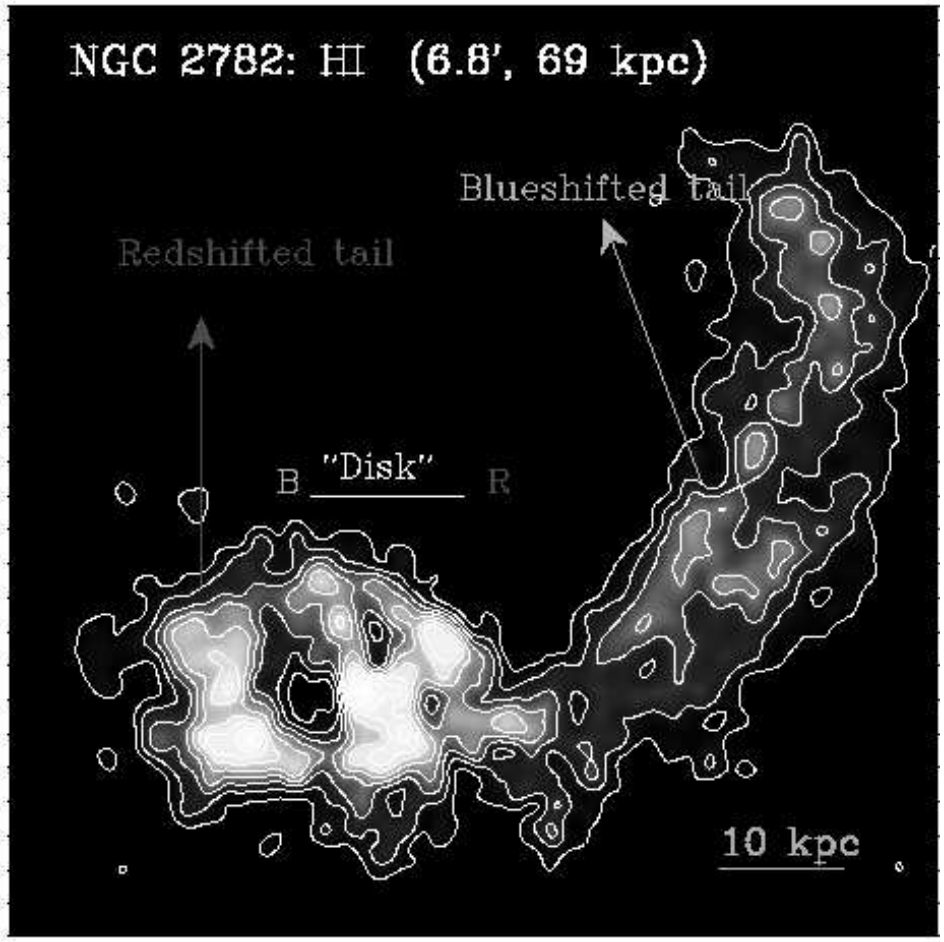
Located on east side of the Sierra Nevadas in California, ~250 miles north of Los Angeles.

At radio λ : observe 24 hrs a day. Only shut down in the summer when humidity is high….

Radio (21 cm) Wavlengths



Visible light image: a relatively undisturbed disk and a 20,000 pc tail to the left

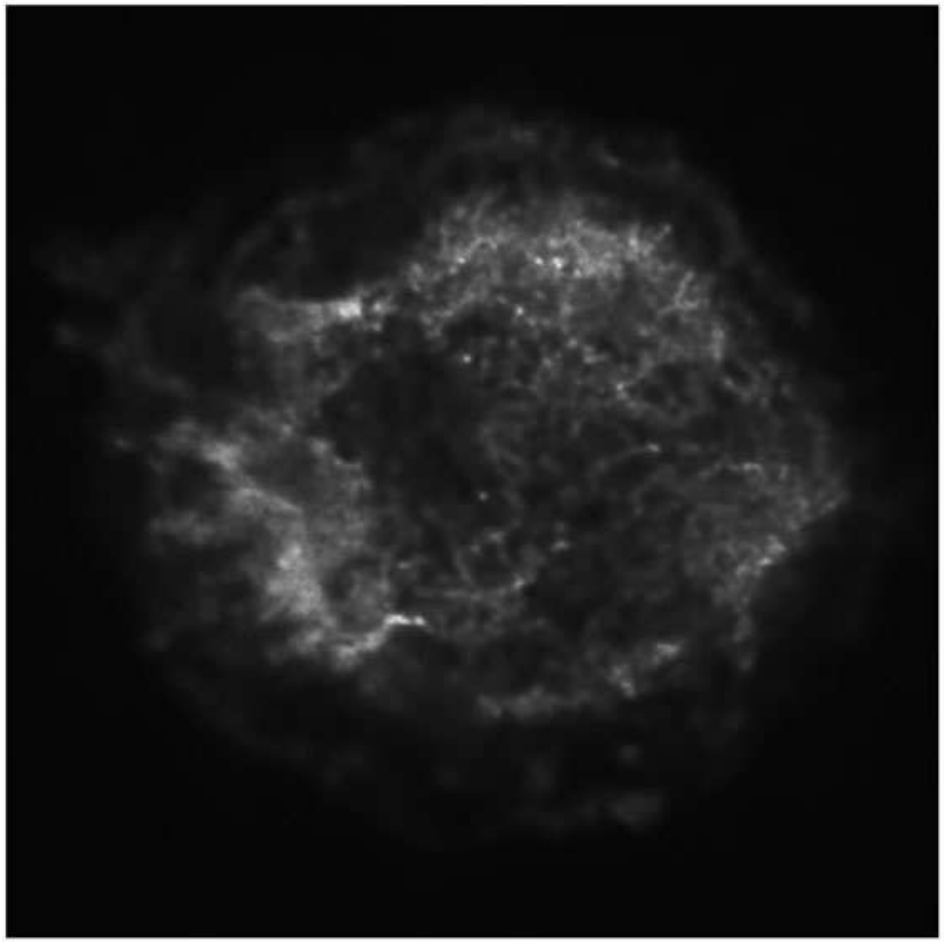


21 cm map: a 50,000 pc tail of atomic H to the right

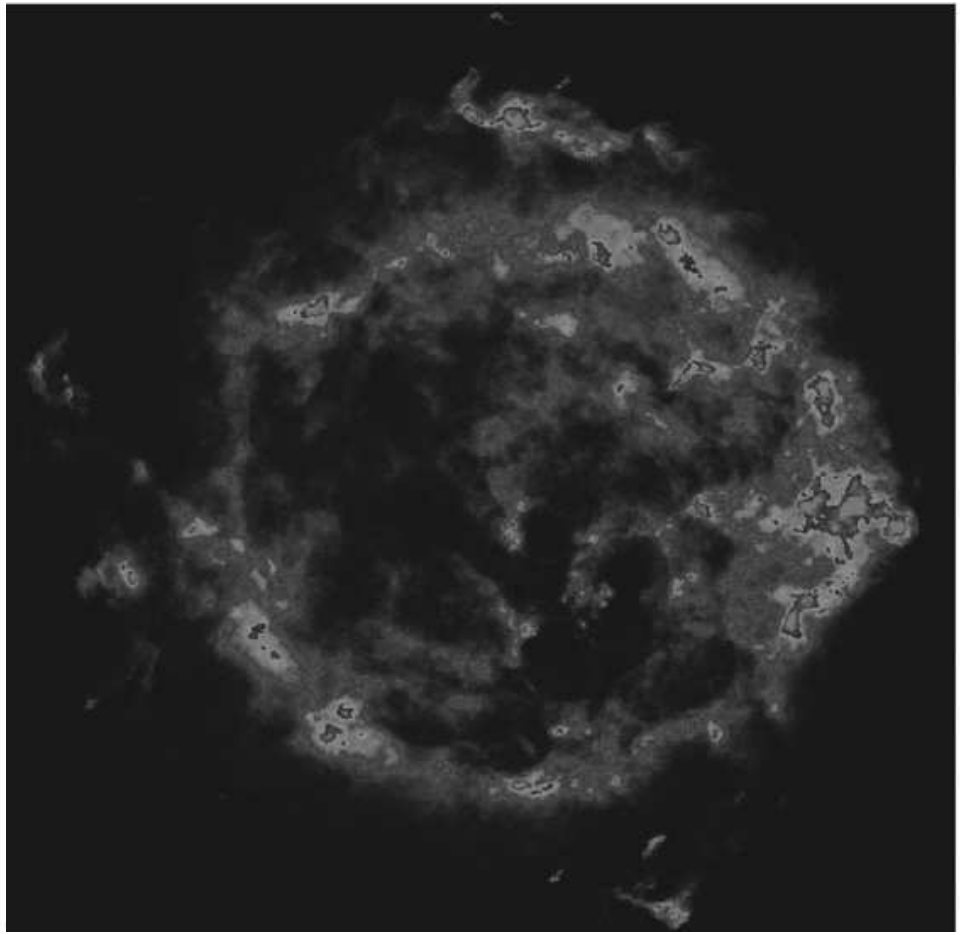
Observation of 21 cm atomic H lines trace atomic gas out to large radii, reveals tidal tails, and interaction history

Radio continuum

Supernova Remnant Cassiopeia A :



X-ray shows a hot bubble of 10^7 K gas that is heated by shocks from the supernova remnnant



Radio continuum (range of wavelengths centered ~ 20 cm) map shows radiation emitted in a thin dense compressed shell of material around the bubble

Radio (cm) Wavlengths

Very Large Array (VLA) : 27 radio antennas, each 25-m , arranged in a Y-shaped array

Data from the antennas is combined electronically to give the resolution of an antenna 36, 000 m across

Located in Plains of San Agustin fifty miles west of Socorro, New Mexico

NASA's Three Great Observatories

• Hubble Space Telescope (HST) launched in 1990

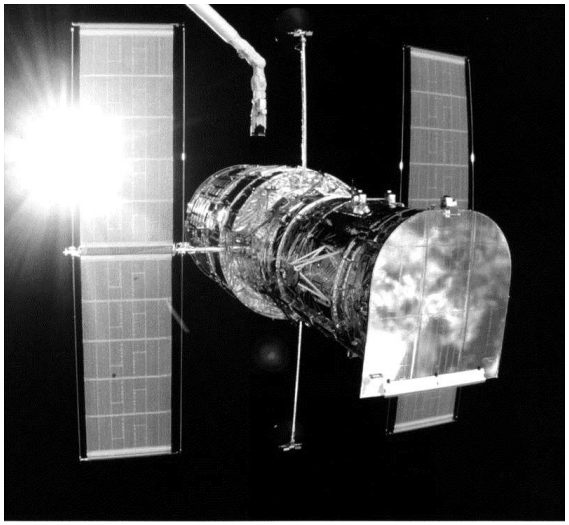
à Works at ultraviolet, optical and infrared wavelengths

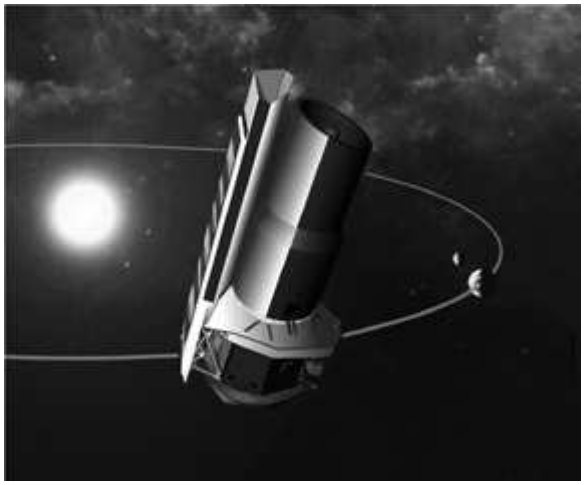
•Chandra X-ray Observatory (CXO) launched in 1999?

à Works at X-ray wavelengths

• Spitzer Space Telescope (SST) launched in 2004

à Works at mid to far infrared wavelengths : penetrates the dust to reveal hidden Universe

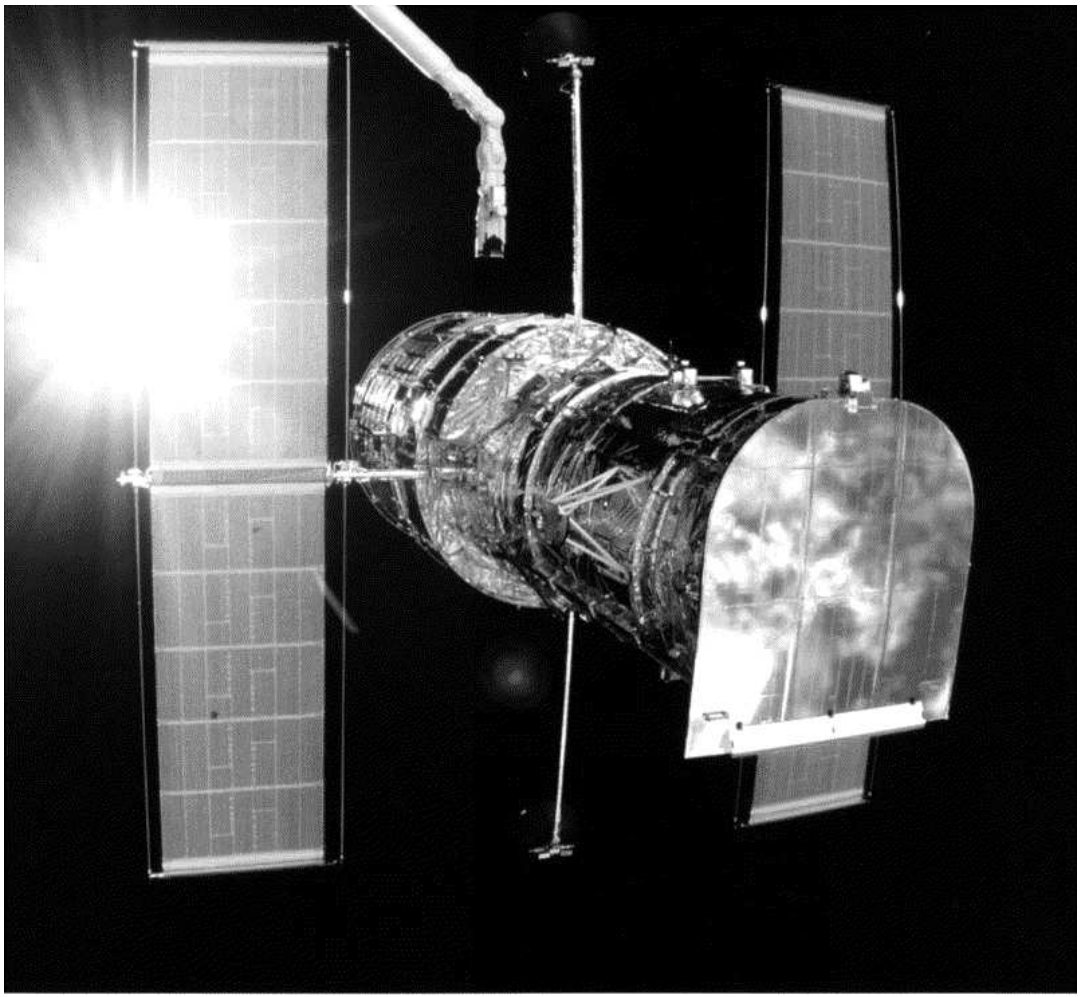




Our Eyes on the Universe

A Short History of the Hubble Space Telescope

Hubble Space Telescope (HST)



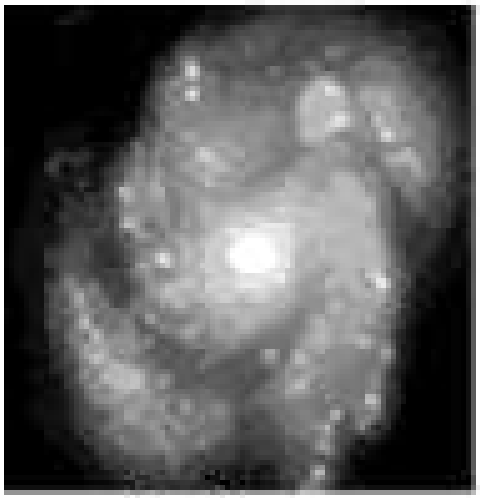
- Launched in 1990
- Mirror diameter= 2.5-m
- Orbits 600 km above Earth
- Powered by solar batteries
- Instruments on board :
  uv, optical, infrared

à No blurring by Earths's atmosphere à high spatial resolution.

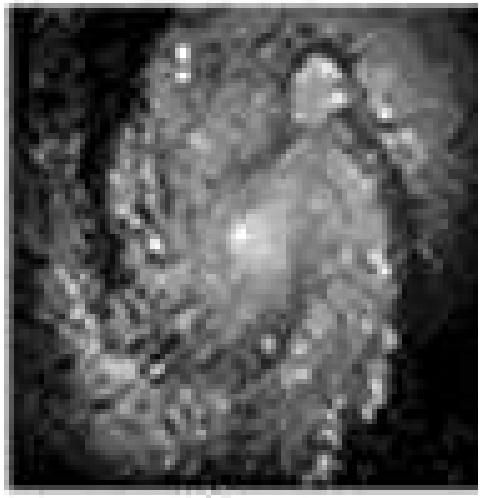
à Can observe UV photons without absorption by E's atmosphere

à Can observe infrared emission without high background (glare) from sky

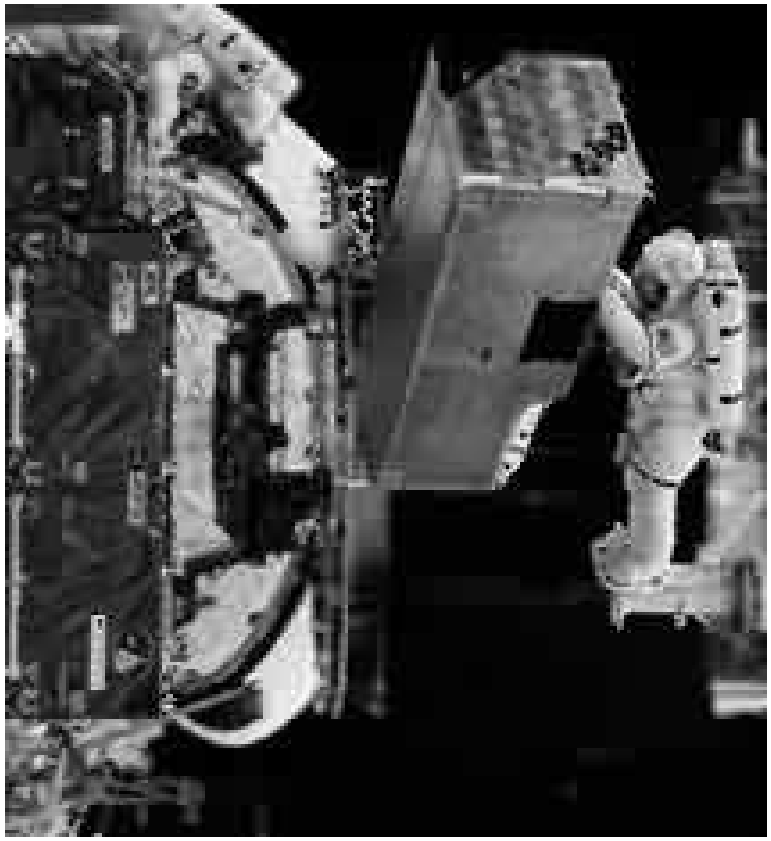
SM1 : Restoring HST's Vision



Before



After



Hubble's mirror was incorrectly shaped à could not focus light à fuzzy images!!

Servicing mission 1 (SM1) via shuttle Endeavor: COSTAR installed to correct HST's vision!

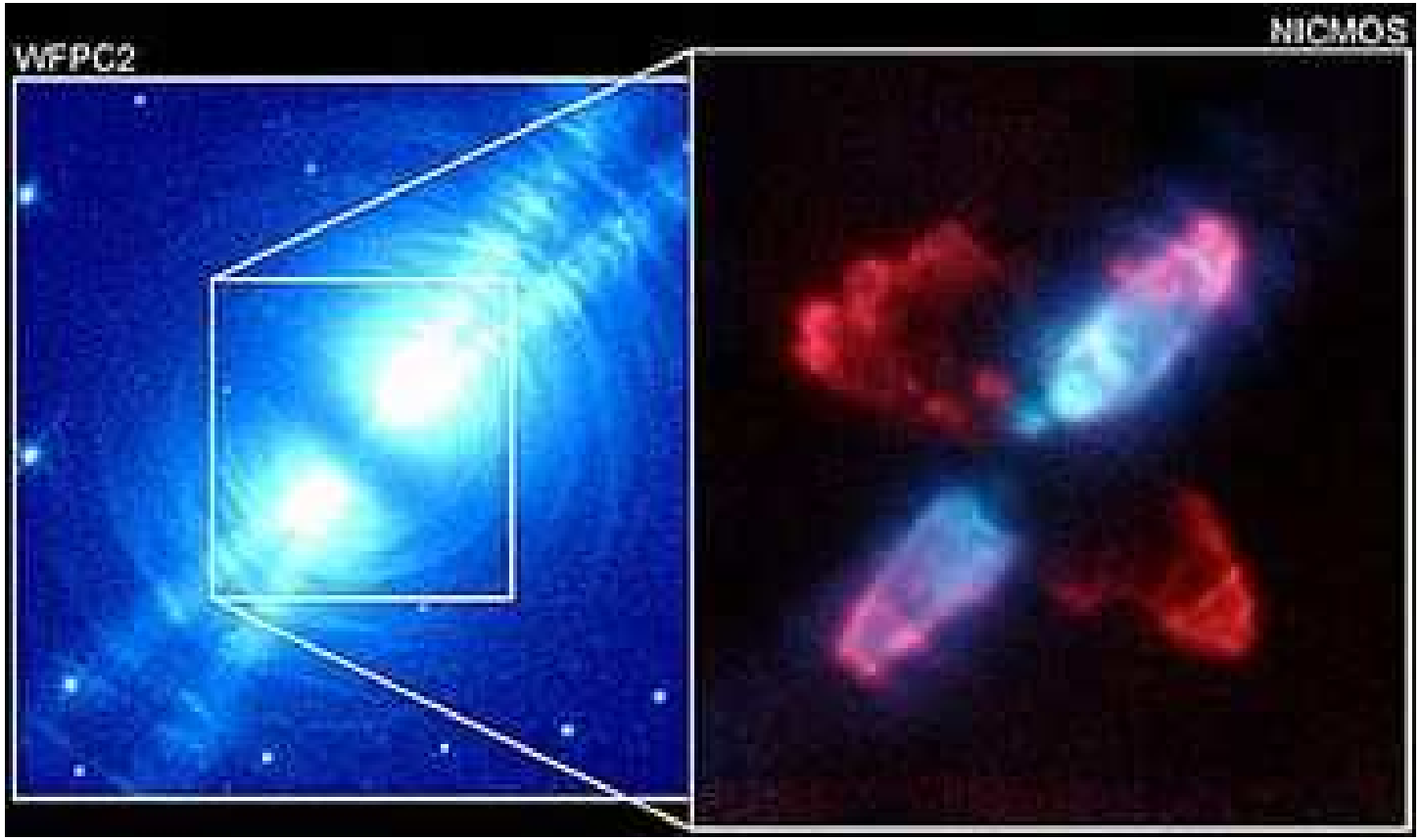
SM2: Adding NICMOS and STIS aboard HST

HST latched to dock of Discovery

Patching up insulation material of HST

SM2 in Feb 1997 via shuttle Discovery:
Astronauts install Infrared and ultraviolet instruments called NICMOS and STIS

The Egg Nebula



Visible light
WFPC2 image

NICMOS image: color coded
blue = starlight reflected by dust particles
red =heat radiation emitted by hot H2

Help astronomers understand how stars expel carbon and nitrogen —elements crucial for life — into space.

SM3: Installing new gyroscopes and ACS aboard HST

Advanced Camera for Surveys (ACS)

10 times more powerful than previous camera:

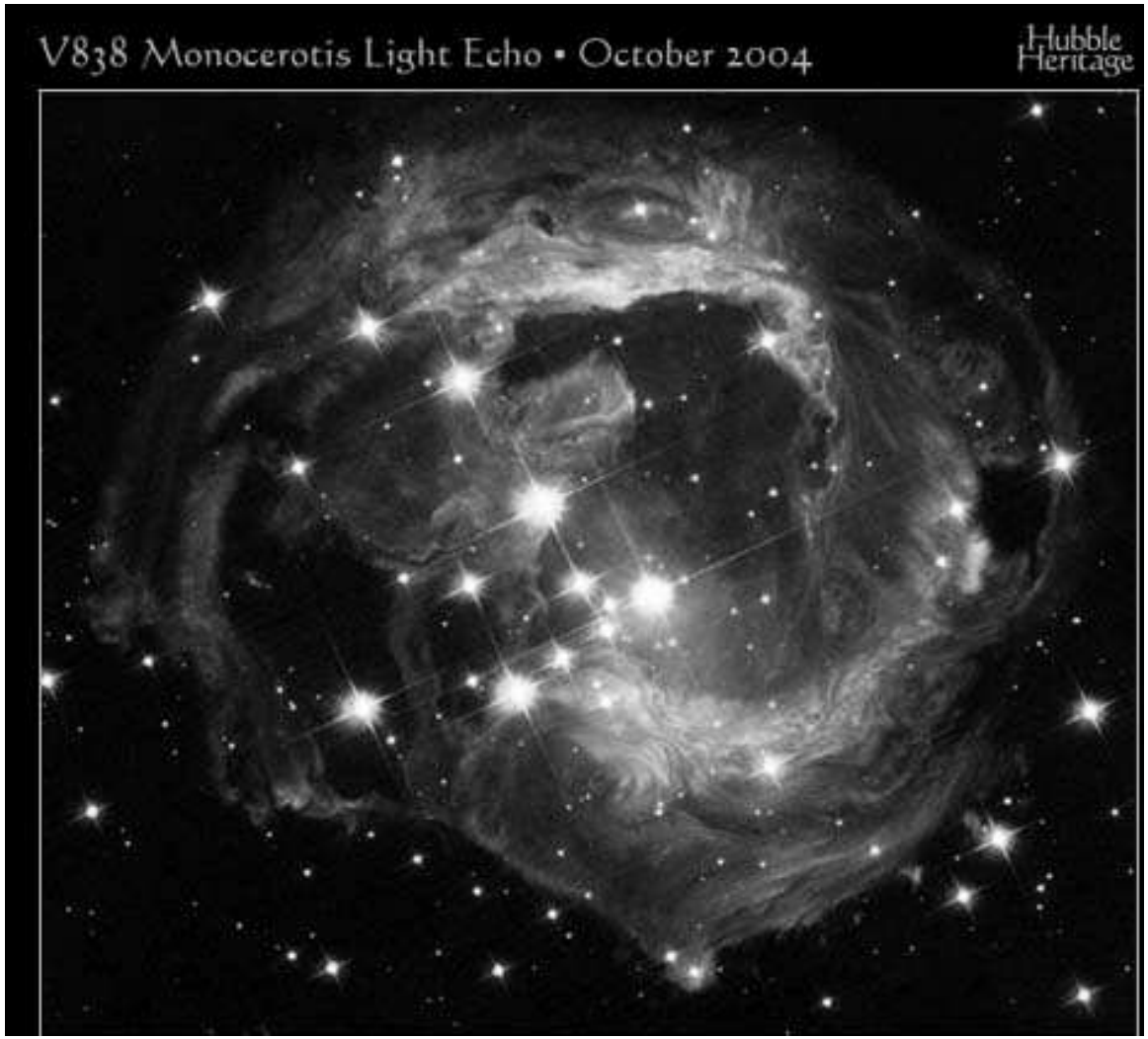
Much **larger field of view and sharper** images

Servicing Mission 3 (SM3) split into two parts.

à SM3A in Dec 1999 via shuttle Discovery replaced all 6 gyroscopes on HST

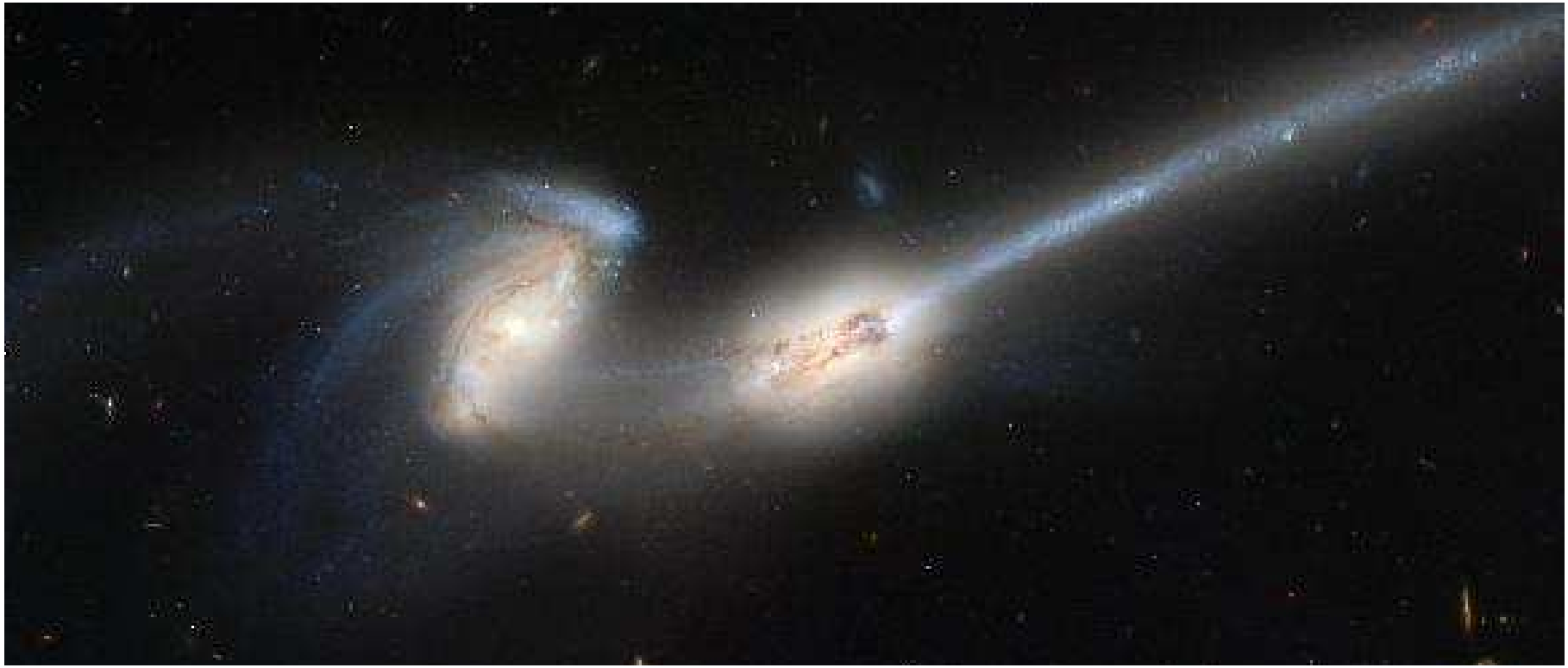
à SM3B in Mar 2002 via shuttle Columbia : replaced solar panels, installed ACS

The power of ACS imaging



The power of ACS imaging

The power of ACS imaging

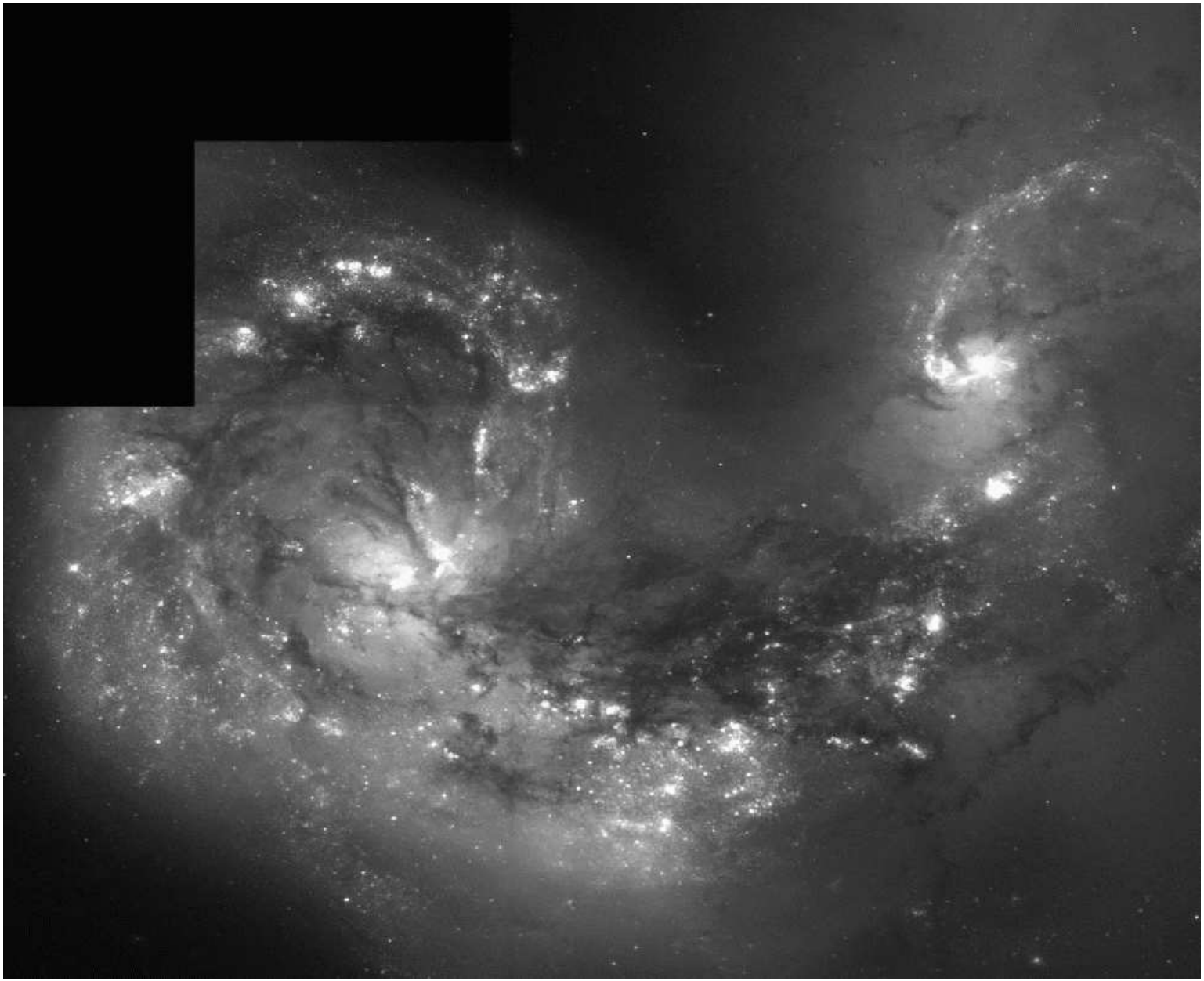


NGC 4736 / The Mice

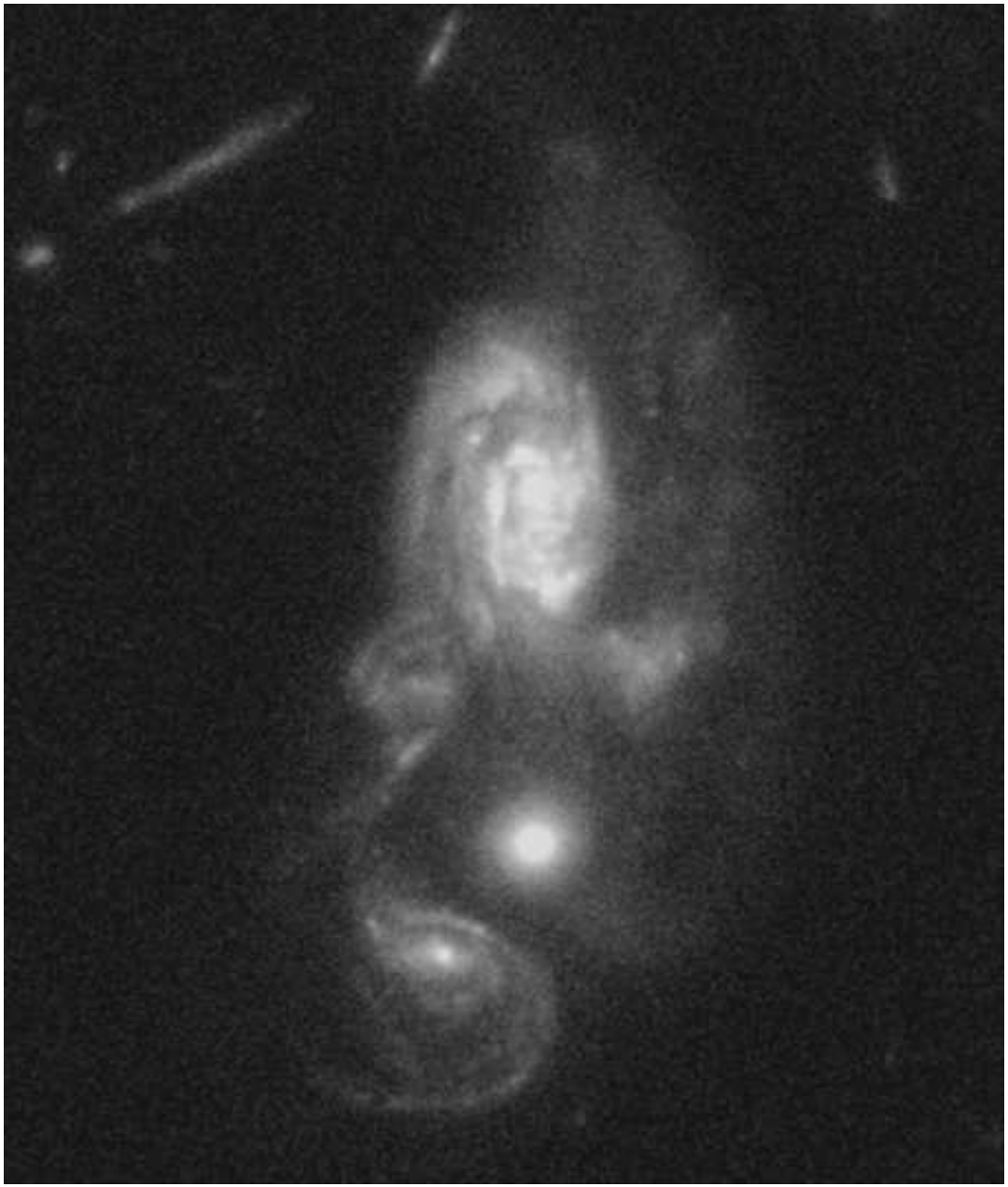
(Credit: NASA & ACS Science team)

Collision of 2 spiral galaxies, 100,000 light years apart

The power of ACS imaging



The power of ACS imaging



SM4 and the Future of HST

Last shuttle servicing Mission (SM4) to HST scheduled for 2004 with goals:

à Replace gyroscopes and solar batteries of HST …. w/o which HST drifts or dies

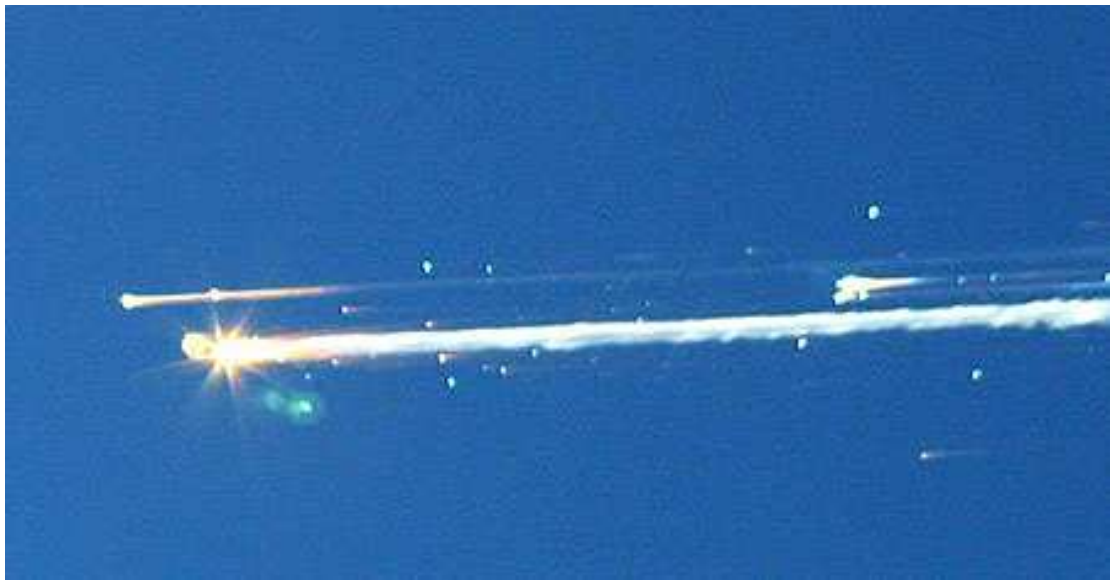
à Install 2 instruments already built to push frontiers of knowledge

Wide Field Camera 3 (WFC3) : Dark energy & the Fate of the Universe
Most masssive galaxies

Cosmic Origins Spectrographs (COS) : First light in the Universe

SM4 and the Future of HST

Following a mission to conduct lab experiments in space, Columbia shuttle explode, killing 7 astronauts, during re-entry of Earth on Feb, 1 2003



Shuttle flights suspended till Columbia Accident Investigation Board Report in Nov 2003:

- à a seal on the left wing was struck by foam during liftoff and fell off, creating a gap that let hot gas enter the ship during re-entry.
- à Space exploration intrinsically risky
- à Recommends on-orbit capability to inspect and repair shuttles in the future

SM4 and Future of HST

Last shuttle servicing mission (SM4) to HST cancelled by NASA in Sep 2004
Safety of astronauts and financial concerns invoked. HST left to die, likely by 2007, from early gyroscope and battery failure

à NASA will allow > 10 shuttle missions to International Space Station, so why not 1 to HST?
Uproar in scientific and **general community** worldwide

à Several studies show the risk to the shuttle in going to ISS is >= risk in going to HST

à 26 astronauts offer signed statement saying they would risk it any day for HST

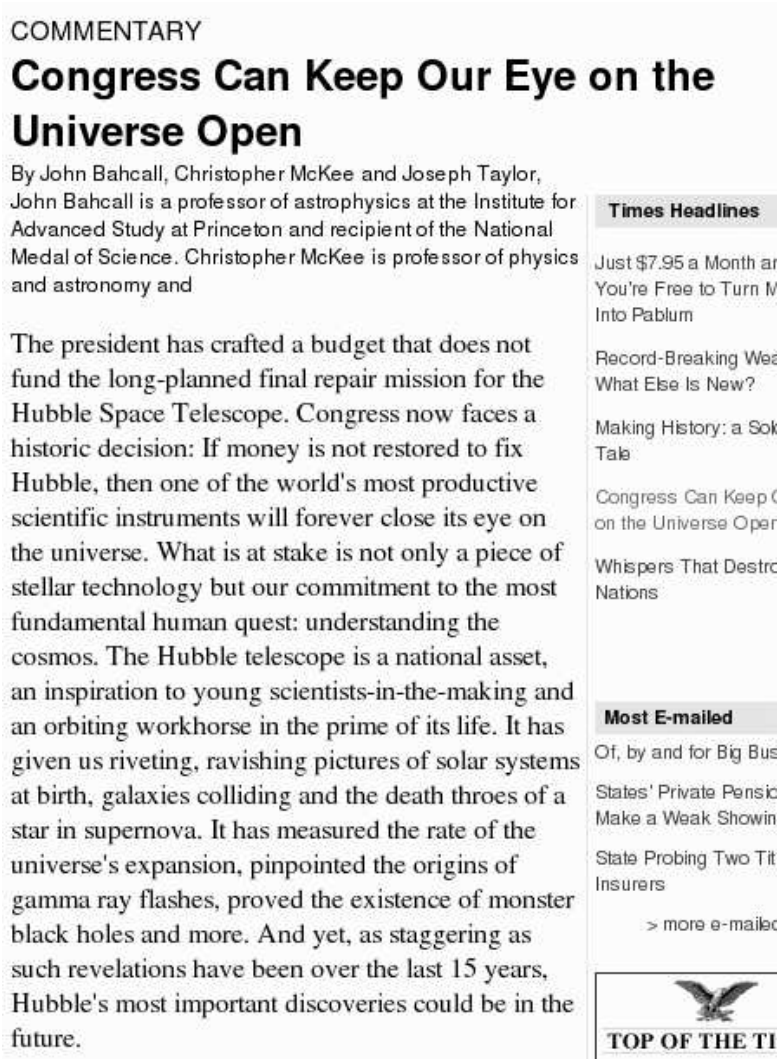
à Cost of saving HST (1-5 billions), but program to send man to Mars > 800 billions
Some of 1-5 B has to be incurred to de-orbit HST and bring it safely back to Earth.

à HST is most successful of all NASA missions in terms of science return versus cost
Our 'eye' on the Universe to epochs no one has seen before.
Our probe for the quest of our origins: planets, stars, black holes, galaxies,,dark energy.
No future space mission will cover optical visible light regime.

à National Academy of Science asked NASA in 2004 to reconsider shuttle missions + robotic missions to service Hubble. Several such options under considerations

SM4 and Future of HST

Second blow ! White House budget in 2005 cuts all funds for a servicing mission to HST leaving HST to die … unless Congress acts now



COMMENTARY

Congress Can Keep Our Eye on the Universe Open

By John Bahcall, Christopher McKee and Joseph Taylor,
John Bahcall is a professor of astrophysics at the Institute for Advanced Study at Princeton and recipient of the National Medal of Science. Christopher McKee is professor of physics and astronomy and

The president has crafted a budget that does not fund the long-planned final repair mission for the Hubble Space Telescope. Congress now faces a historic decision: If money is not restored to fix Hubble, then one of the world's most productive scientific instruments will forever close its eye on the universe. What is at stake is not only a piece of stellar technology but our commitment to the most fundamental human quest: understanding the cosmos. The Hubble telescope is a national asset, an inspiration to young scientists-in-the-making and an orbiting workhorse in the prime of its life. It has given us riveting, ravishing pictures of solar systems at birth, galaxies colliding and the death throes of a star in supernova. It has measured the rate of the universe's expansion, pinpointed the origins of gamma ray flashes, proved the existence of monster black holes and more. And yet, as staggering as such revelations have been over the last 15 years, Hubble's most important discoveries could be in the future.

LA times article
Wed Feb 23 2005

For more info + to voice your opinion either way

www.savethehubble.org