Astro 301/ Fall 2006

(50405)

Introduction to Astronomy

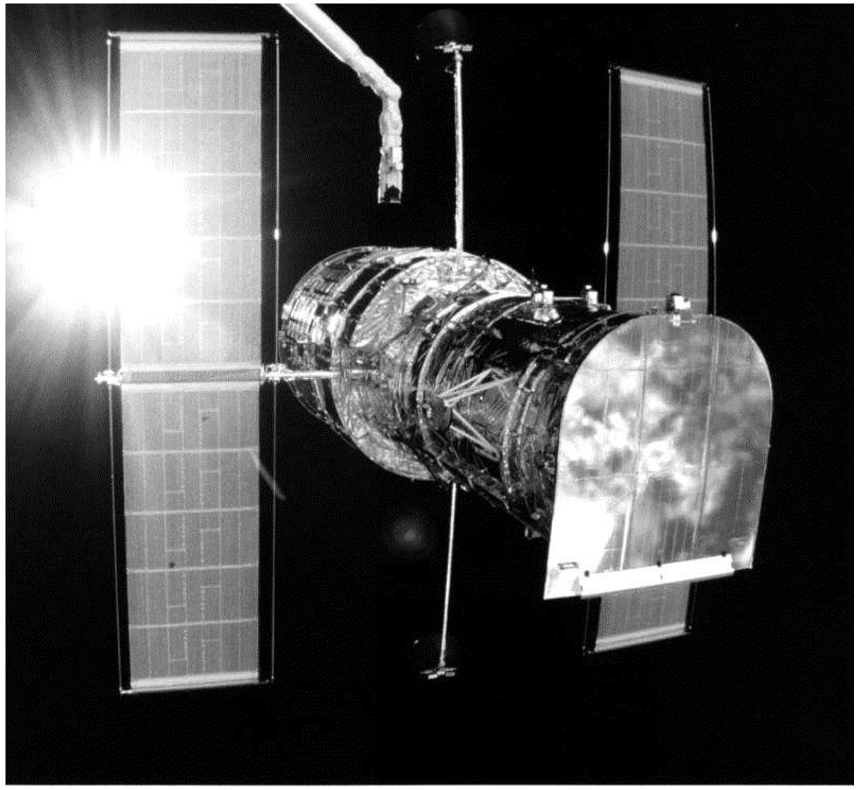
http://www.as.utexas.edu/~sj/a301-fa06

Instructor: Professor Shardha Jogee

TAs: Biqing For, Candace Gray, Irina Marinova

Lecture 18: Th Nov 2

Astronomy News of the Day



- à Two days ago, (on Tue Oct 31 2006) NASA apporoved the 5th servicing misssion (SM4) to Hubble and named the astronaut-crew for the mission, scheduled in Fa;ll 2008
- à 2 new instruments to be installed : WFC3 and COS
- à Last mission to Hubble was in 2002 …SM4 scheduled in 2004 was cancelled after Columbia disaster in Fe 2003

Recent and Upcoming topics in class

---Telescopes : Our Eyes on the Universe

-- Important properties of a telescope

1) Collecting Area: Current and Next Generation Largest telescopes. GMT

2) Resolving power

3) Space-based vs ground-based NASA's four Great Observatories

4) Operating Wavelength: Using observations at different wavelengths to unveil the mysteries of the Universe

Lecture 18: Announcements

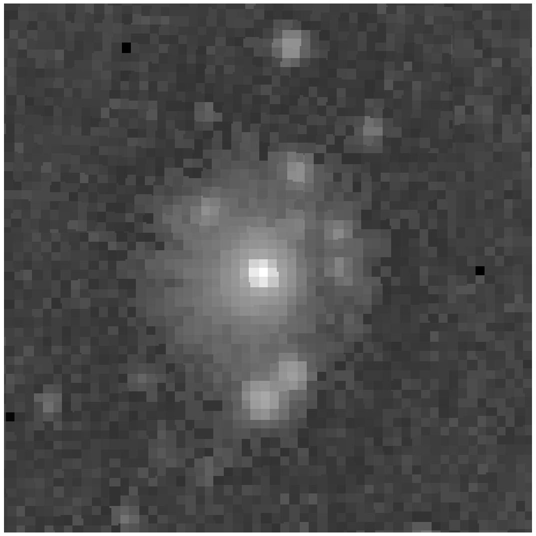
1) Exam 2 : Th Nov 9. See class website for details on Exam 2.
2) In class Q&A on Tu Nov 7

3) The course calendar and its reading list has been updated.

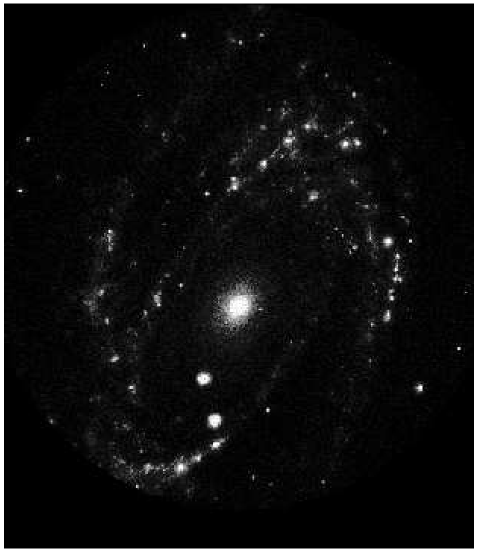
3) I will hold one extra office hour on Monday Nov 6 from 5 to 6 pm in order to answer questions you might have.

Using Wien's law to Infer the Sources traced by Observations at Different Wavelengths
from Xray to Far-infrared

Multi-Wavelength view of M81



X-ray/ROSAT

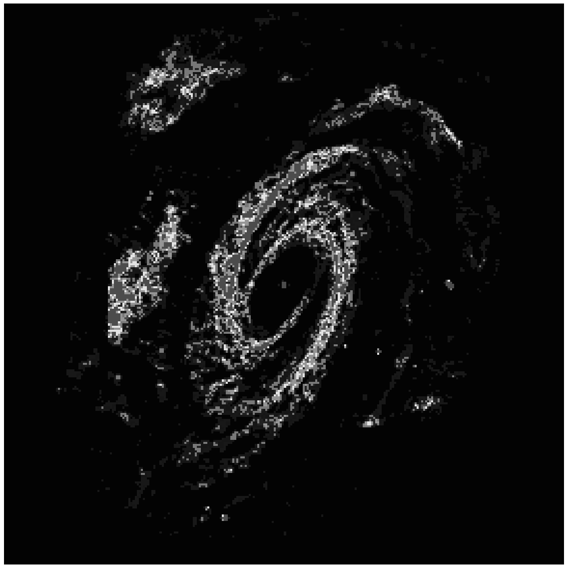


Ultraviolet/ASTR0-1

Visible light

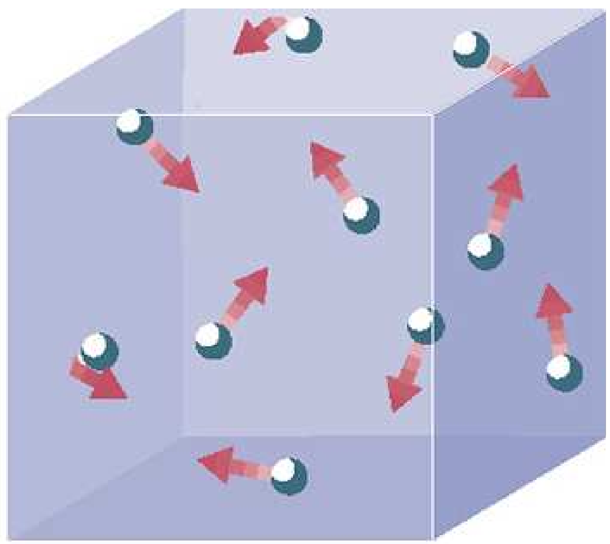
Near infrared/Spitzer

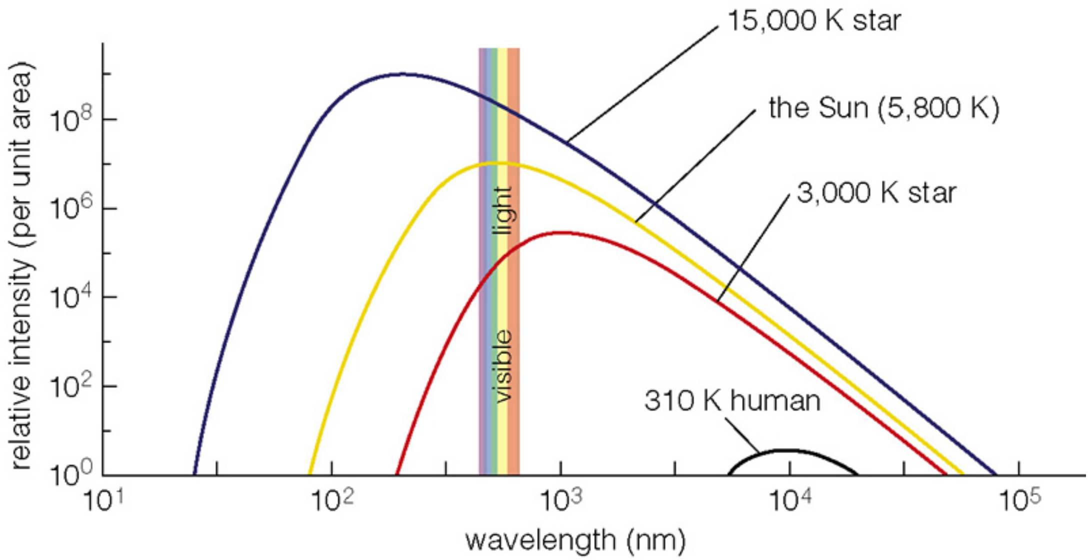
Mid-infrared/Spitzer



Radio 21cm/VLA

The continuum spectrum of a source depends on surface temperature





Recall 2 important concepts from earlier lectures

Kirchoff's first law:

Any hot solid, liquid or opaque gas emits light (as a continuum spectrum). In a hot object, the atoms are moving randomly (vibrating) with an energy set by the temperature of the body. The vibrating electrons in the atoms cause vibrating electric fields à this is light

Wien's law: The continuum emission of a star or blackbody peaks at a wavelength λ_{peak} that depends inversely on its surface temperature T

λ_{peak} = W/ T , where W = Wien's constant = 2.9×10^{-3} m K

Tenperature of Normal Stars

Star	Temperature
Hottest normal star	100,000 K
Spica	23,000 K
Sirius	10,000 K
Sun	5,800 K
Betelgeuse	3,200 K
Coolest normal star	2,000 K

Wien's law: The continuum emisision of a star or blackbody peaks at a wavelength λ_{peak} given by λ_{peak}= W/ T , where W = Wien's constant = 2.9 x 10^{-3} m K

<u>In-class exercise</u>: Use Wien's law to calculate the temperature of the source which emits most of its continuum emission at wavelengths below

	Wavelength of peak emission	Surface Temperature of emitting source
X rays	3 x 10^{-10} m	
Ultraviolet	1 x 10^{-7} m	
Optical	blue= 3 x 10^{-7} m	
Optical	yellow=5 x 10^{-7} m	
Optical	red= 7x 10^{-7} m	
Near infrared	1x10^{-6} m	
Mid-infrared	3x10^{-5} m	
Far-infrared	1x10^{-4} m	

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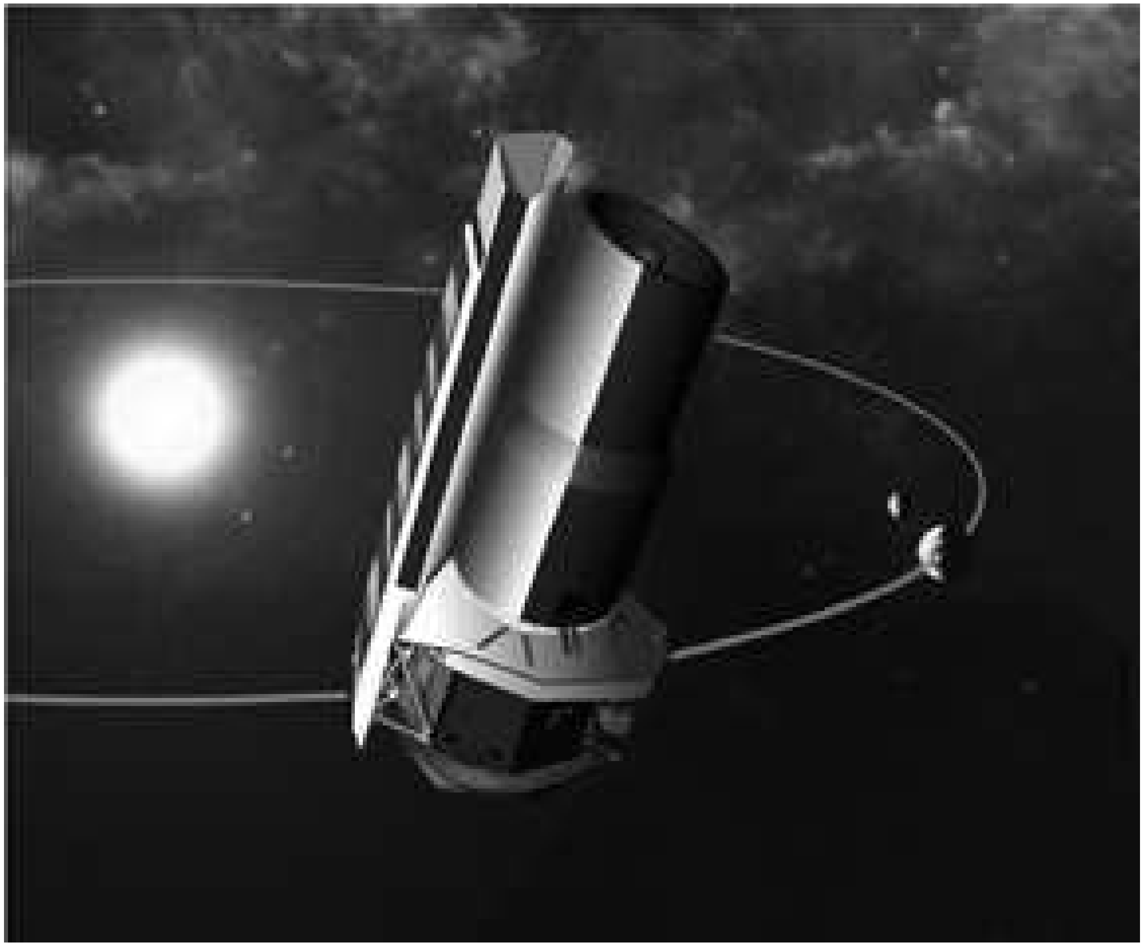
Near infrared	1x10^{-6} m	3,000 K
Mid-infrared	3x10^{-5} m	100 K
Far-infrared	1x10^{-4} m	30 K

Imaging the Universe at X-Ray Wavelengths

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

Wavelength of peak emission		Surface Temperature of emitting source	Nature of source
X rays	3×10^{-10} m	10^{7} K	?
Ultraviolet	1×10^{-7} m	30,000 K	
Optical	blue= 3×10^{-7} m	10,000 K	
Optical	yellow=5×10^{-7} m	6, 000 K	
Optical	red= 3×10^{-7} m	4.,300 K	
Near infrared	$1 \text{x} 10^{-6}$ m	3,000 K	
Mid-infrared	$3 \text{x} 10^{-5}$ m	100 K	
Far-infrared	$1 \text{x} 10^{-4}$ m	30 K	

Star	**Temperature**
Hottest normal star	100,000 K
Spica	23,000 K
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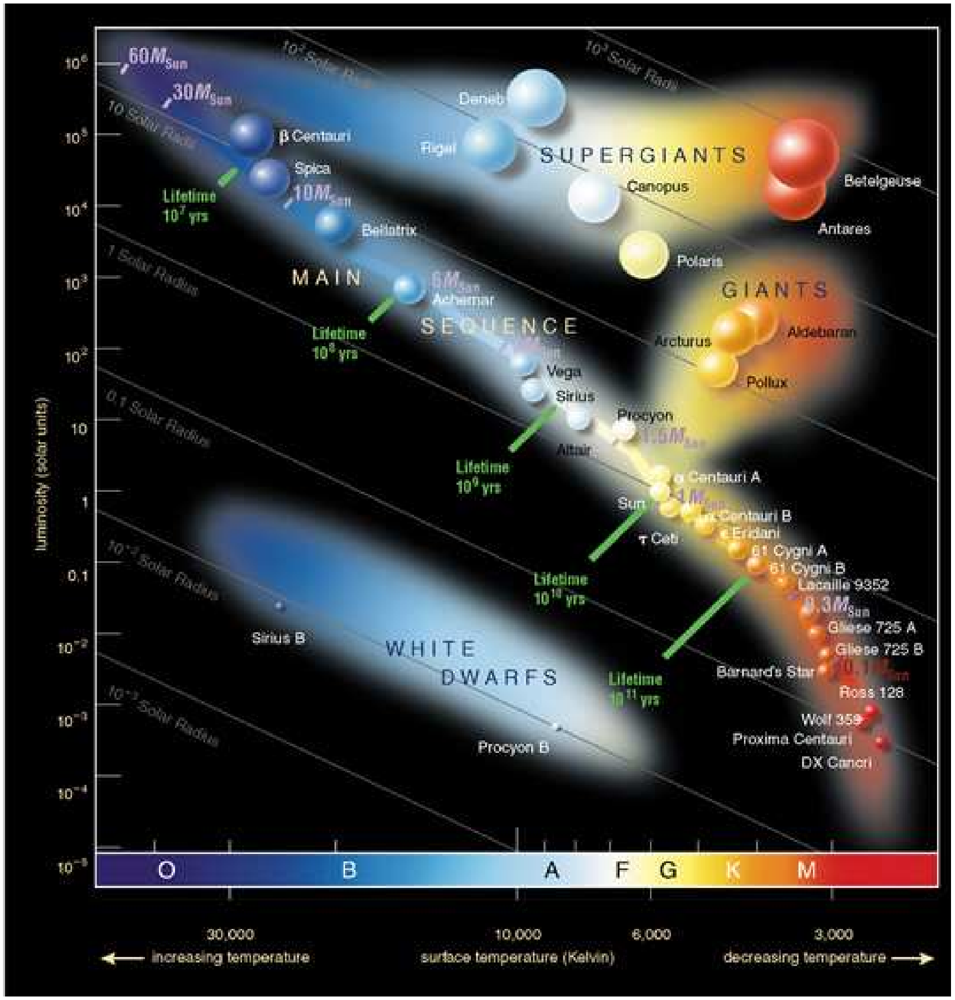
Coolest normal star	2,000 K

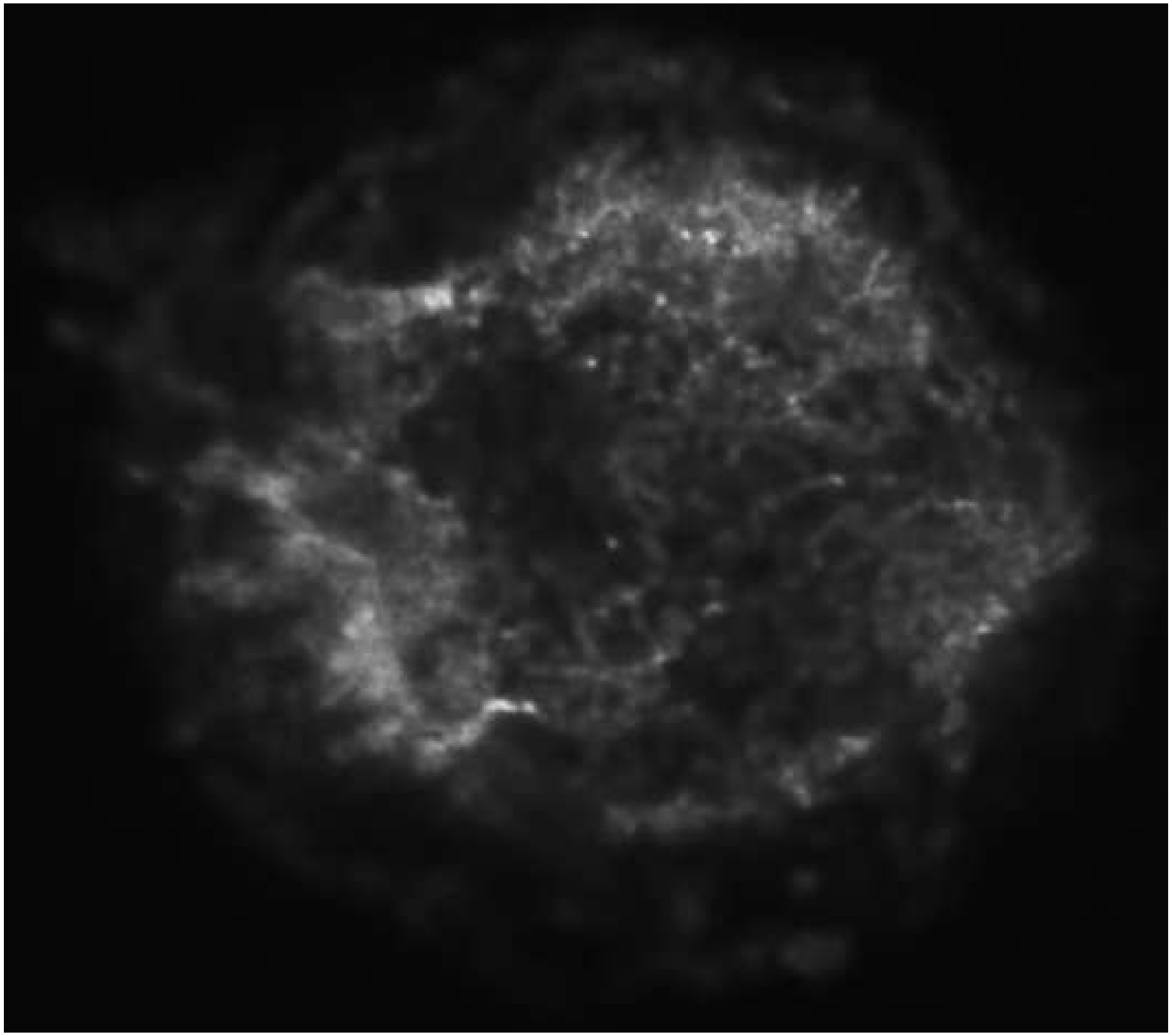


X-ray trace sources at 10^7 K .Check HR diagram for stars

à these sources are too hot to be stars!

à what is the nature of these X-ray emitting sources?

X-Ray Wavelengths



X-ray image

Wavelength of peak emission		Surface Temperature of emitting source	Nature of source
X rays	3×10^{-10} m	10^7 K	Hot gas shock-heated by supernovae remnants
Ultraviolet	1×10^{-7} m	30,000 K	
Optical	blue= 3×10^{-7} m	10,000 K	
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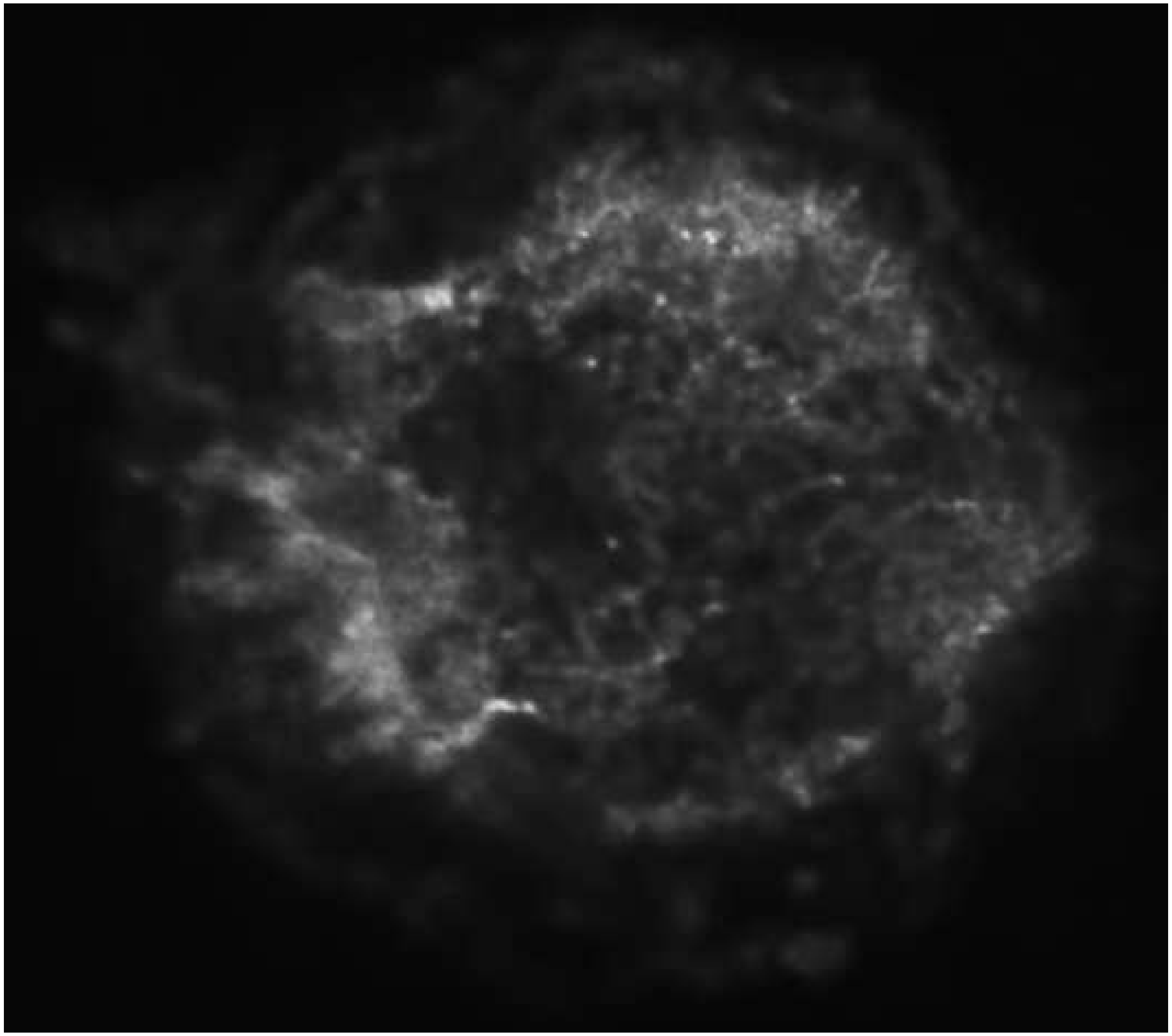
X-Ray Wavelengths

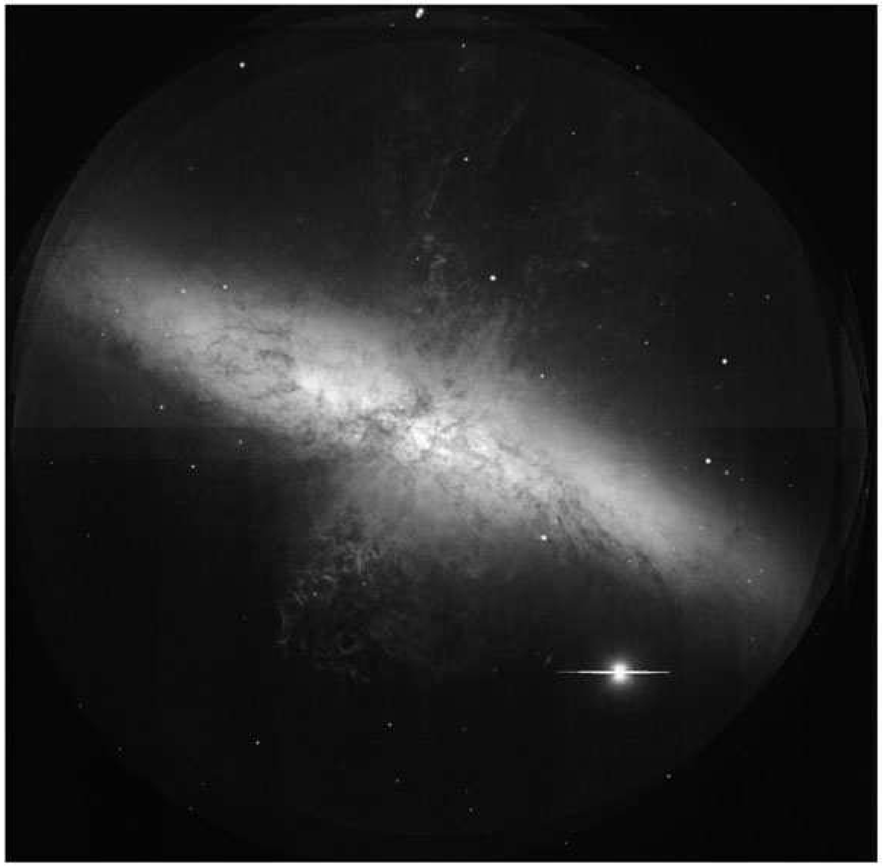


Supernova Remnant
Cassiopeia A

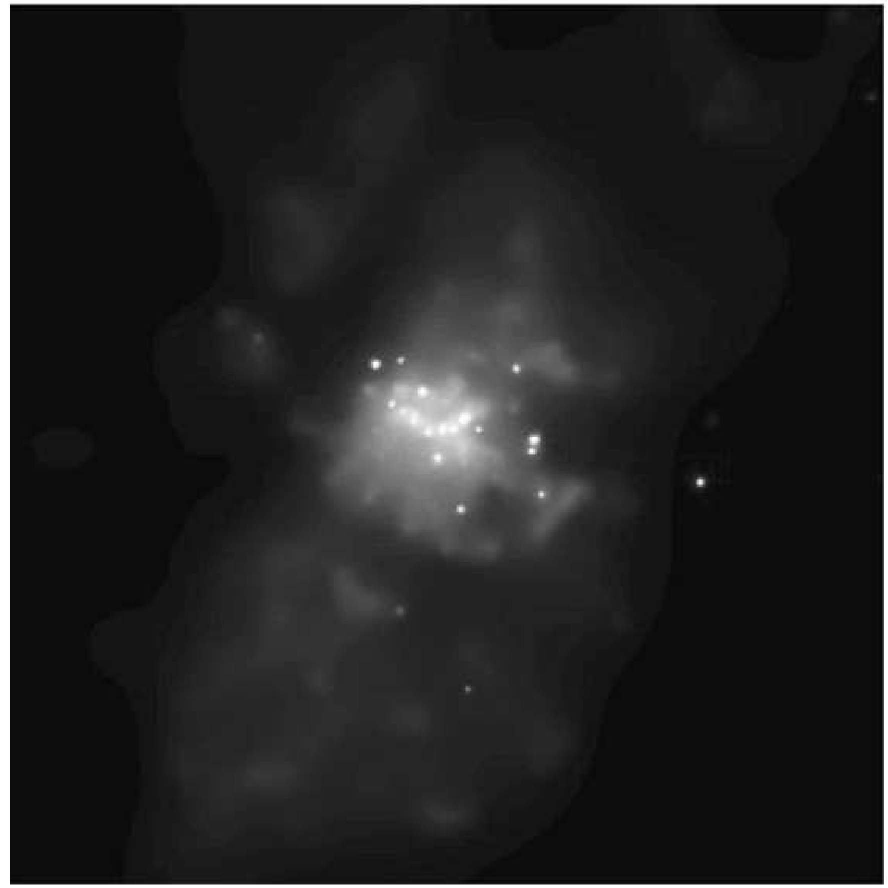
X-ray shows a hot bubble of 10^7 K gas that is
heated by shocks from the supernova remnnant

X-Ray Wavelengths

Starburst Galaxy M82: central starburst driving an outflow



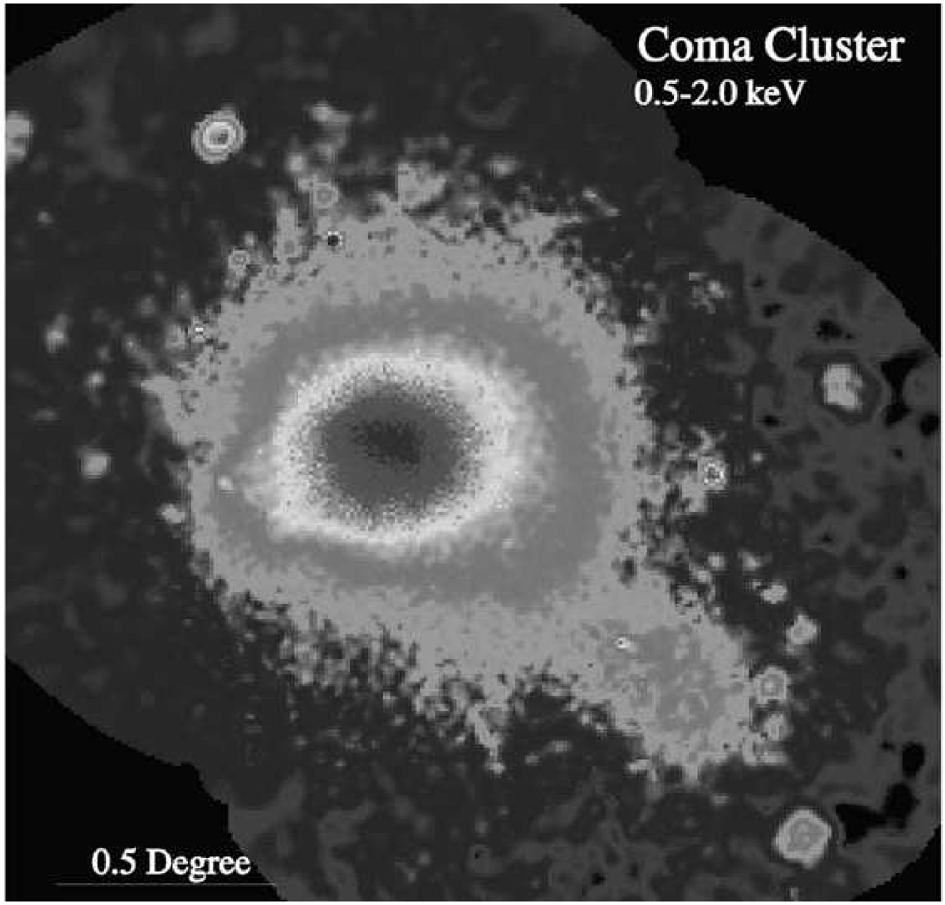
Visible light



X-ray
Hot gas and neutron stars

X-Ray Wavelengths

X-ray observations reveal hot (10^7 to 10^8 K) gas between galaxies in a cluster



Imaging the Universe at UV Wavelengths

Wavelength of peak emission		Surface Temperature of emitting source	Nature of source
X rays	3×10^{-10} m	10^{7} K	Hot gas shock-heated by supernovae remnants
Ultraviolet	1×10^{-7} m	30,000 K	?
Optical	blue= 3×10^{-7} m	10,000 K	
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Optical	red= 7×10^{-7} m	4.,300 K	
Near infrared	$1\text{x}10^{-6}$ m	3,000 K	
Mid-infrared	$3\text{x}10^{-5}$ m	100 K	
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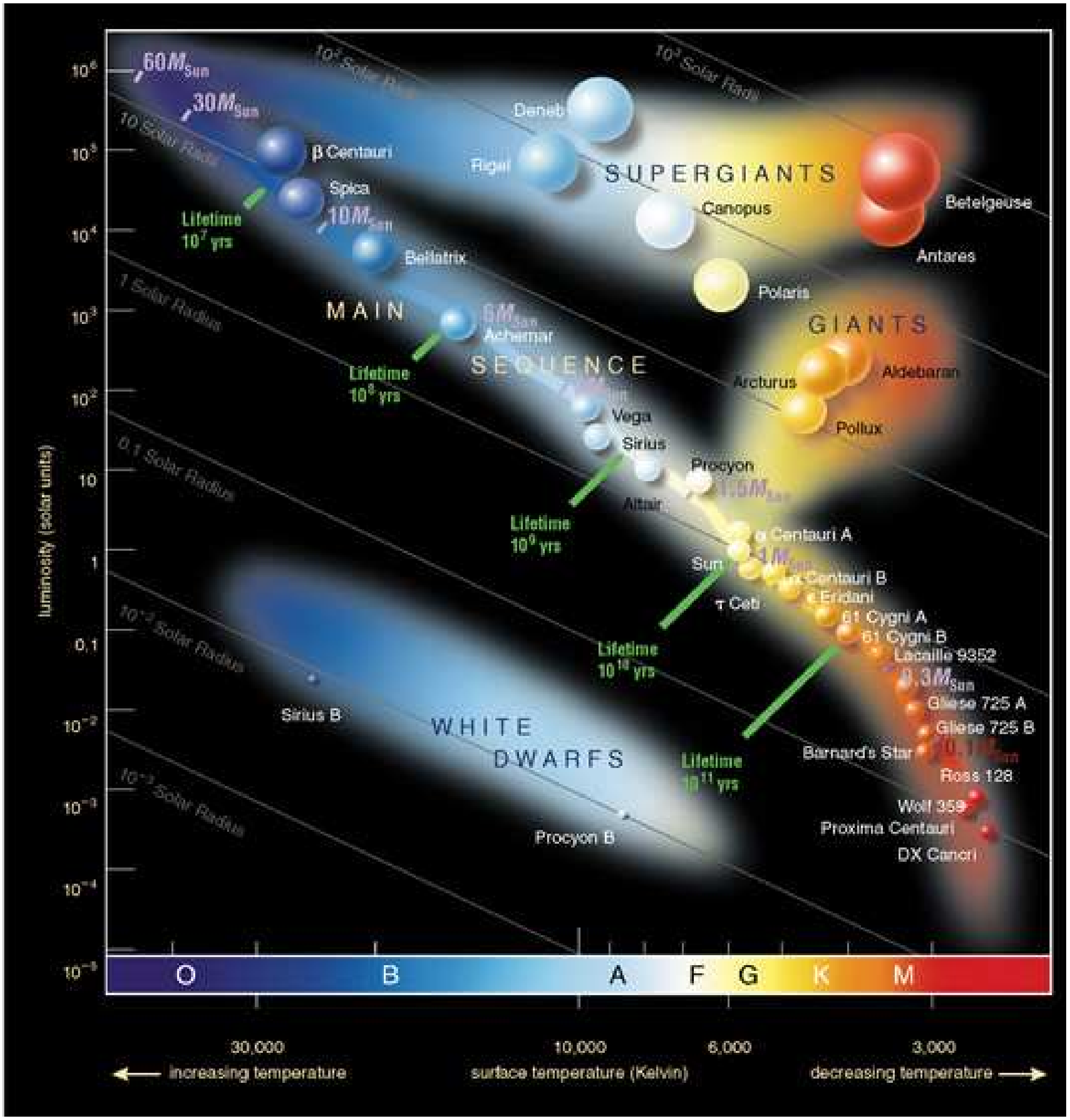

UV trace sources at 30,000K. Check HR diagram for stars

à these are high mass (>8 M o) stars

Wavelength of peak emission		Surface Temperature of emitting source	Nature of source
X rays	3×10^{-10} m	10^7 K	Hot gas shock-heated by supernovae remnants
Ultraviolet	1×10^{-7} m	30,000 K	Very massive (M> 8Mo) stars
Optical	blue= 3×10^{-7} m	10,000 K	
Optical	yellow=5×10^{-7} m	6, 000 K	
Optical	red= 7×10^{-7} m	4.,300 K	
Near infrared	$1\text{x}10^{-6}$ m	3,000 K	
Mid-infrared	$3\text{x}10^{-5}$ m	100 K	
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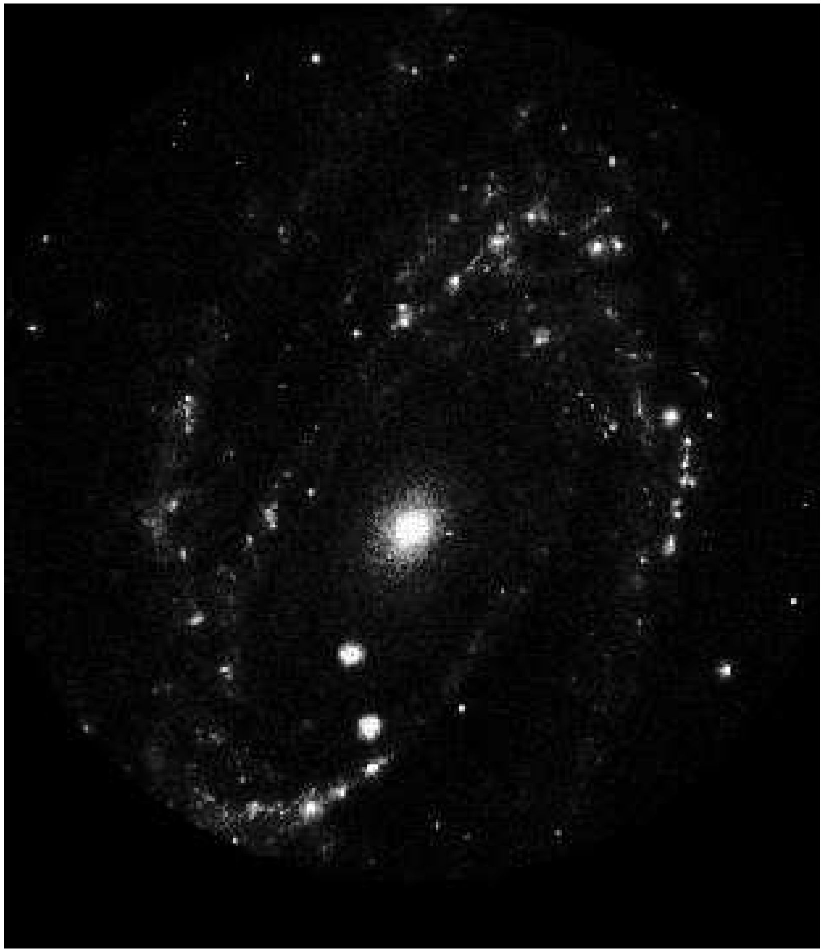

Ultraviolet/ASTR0-1

Optical light

- UV emission comes from hot stars. (Wien's law)
- Why do we say that UV light traces massive stars?
  à because hot stars are very massive stars
- Why do we say that UV light traces sites of RECENT star formation, namely sites where star formation happened only a few million years ago or a few x 10^7 years ago?
  à because massive stars are short-lived and exist only for a few million years

Imaging the Universe at Optical Wavelengths

Wavelength of peak emission		Surface Temperature of emitting source	Nature of source
X rays	3×10^{-10} m	10^{7} K	Hot gas shock-heated by supernovae remnants
Ultraviolet	1×10^{-7} m	30,000	Very massive (M>8Mo) stars
Optical	blue= 3×10^{-7} m	10,000 K	?
Optical	yellow=5×10^{-7} m	6, 000 K	?
Optical	red= 7×10^{-7} m	4.,300 K	?
Near infrared	$1 \text{x} 10^{-6}$ m	3,000 K	
Mid-infrared	$3 \text{x} 10^{-5}$ m	100 K	
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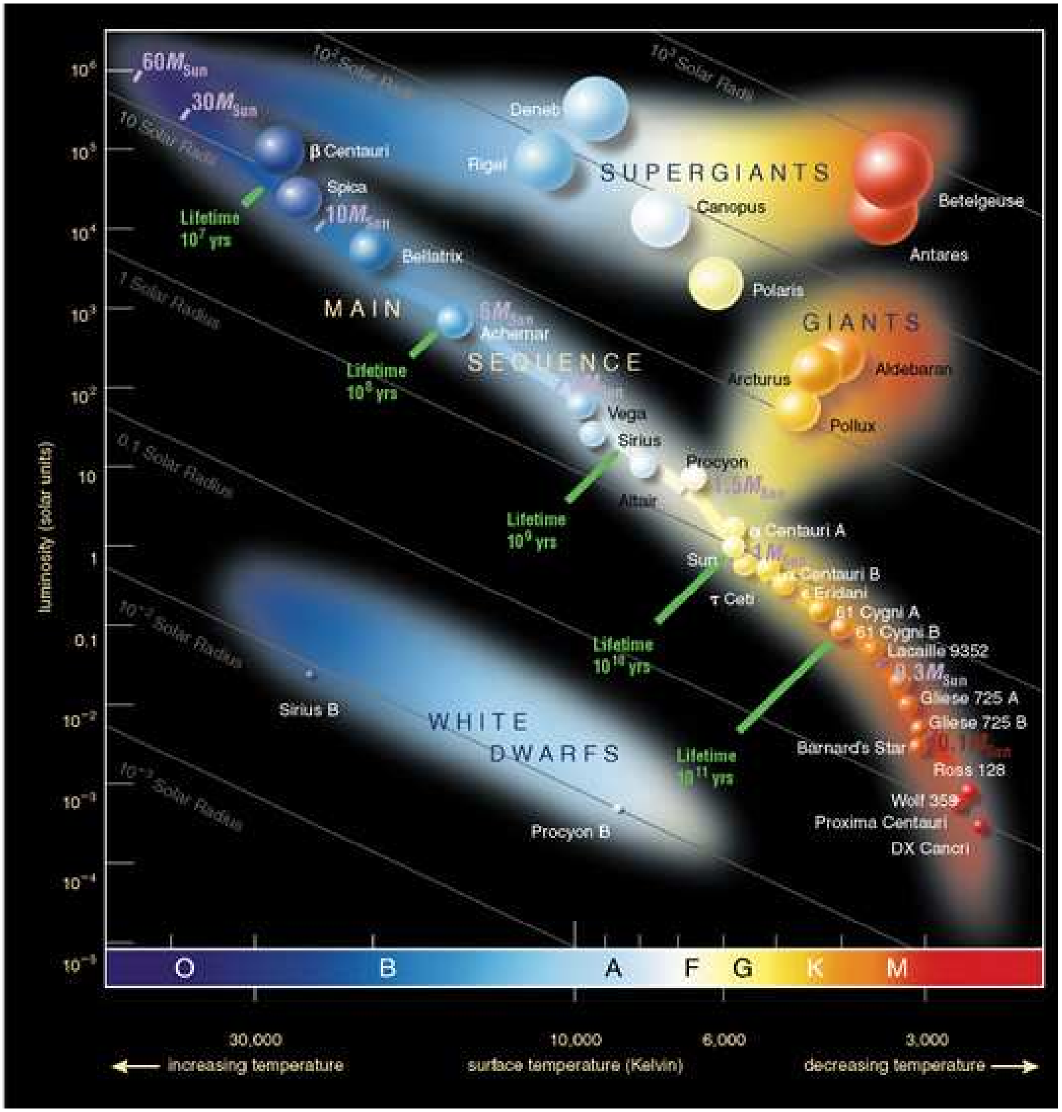

Blue, yellow, red light are emitted by sources at 10,000 K, 6,000 K, 4300 K
Check HR diagram for stars à these are stars with mass 3 Mo, 1 Mo , ~0.7Mo

Wavelength of peak emission		Surface Temperature of emitting source	Nature of source
X rays	3×10^{-10} m	10^7 K	Hot gas shock-heated by supernovae remnants
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Optical	yellow=5×10^{-7} m	6, 000 K	Low mass (1 Mo stars)
Optical	red= 7×10^{-7} m	4.,300 K	Very low mass (< 1Mo stars)
Near infrared	$1\mathrm{x}10^{-6}$ m	3,000 K	
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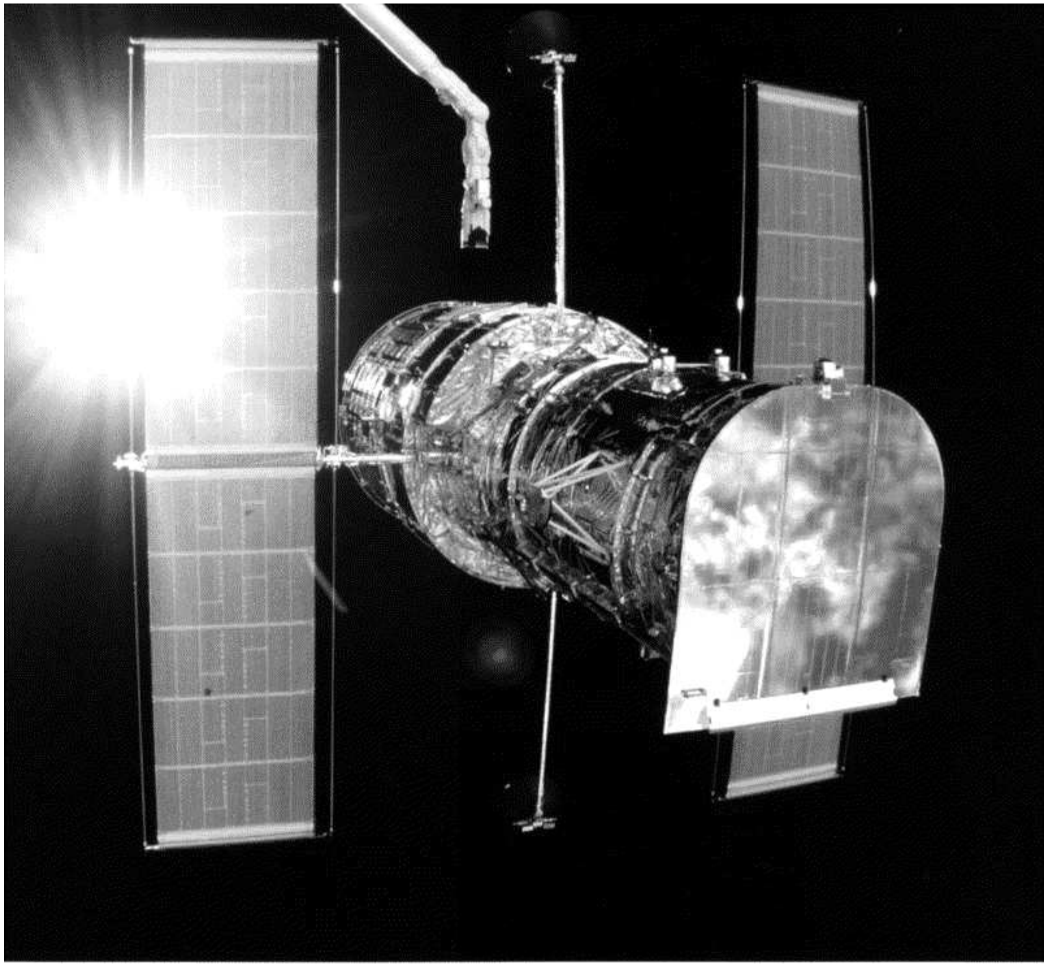
Optical Images from the Hubble Space Telescope (HST)

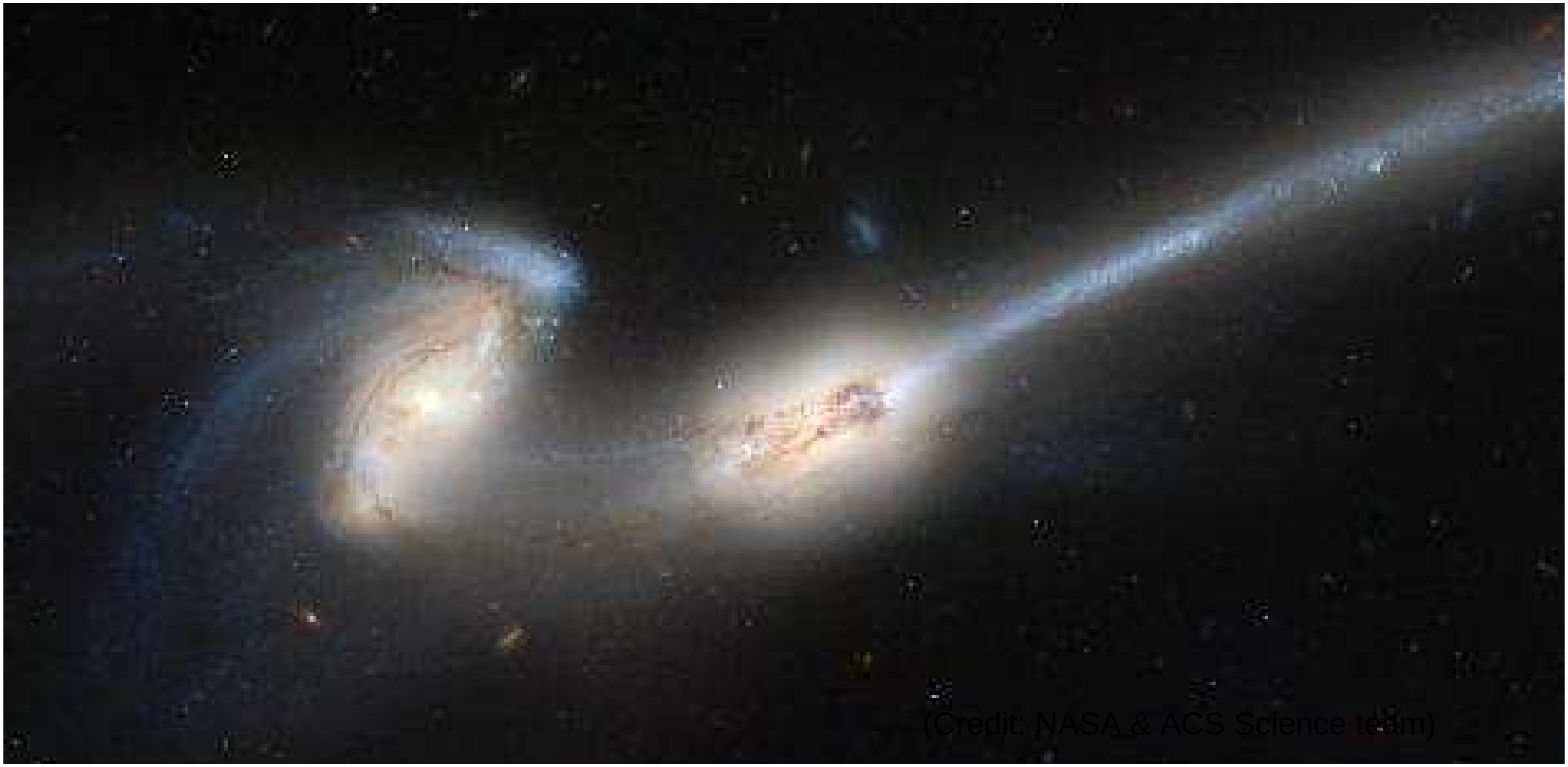


HST observes at UV, optical and near-IR wavelengths

Latest optical camera on borad is called the Advanced Camera for Surveys (ACS)

- Launched in 1990
- Mirror diameter= 2.5-m
- Orbits 600 km above Earth
- Powered by solar batteries

Optical Images from the ACS camera aboard Hubble



ACS image shows a collision between 2 spiral galaxies, 100,000 light years apart

Optical Images from the ACS camera aboard Hubble

Blue light trace hot stars according to Wien's law.
Why do we say blue light trace hot **massive young** stars ?
hot stars are usually massive, and massive stars are short-lived
Red light trace cool stars = cool **low mas**s stars
Dark patches on leading edge of the bar = dust lanes

Imaging the Universe at Infrared Wavelengths

Wavelength of peak emission		Surface Temperature of emitting source	Nature of source
X rays	3×10^{-10} m	10^7 K	Hot gas shock-heated by supernovae remnants
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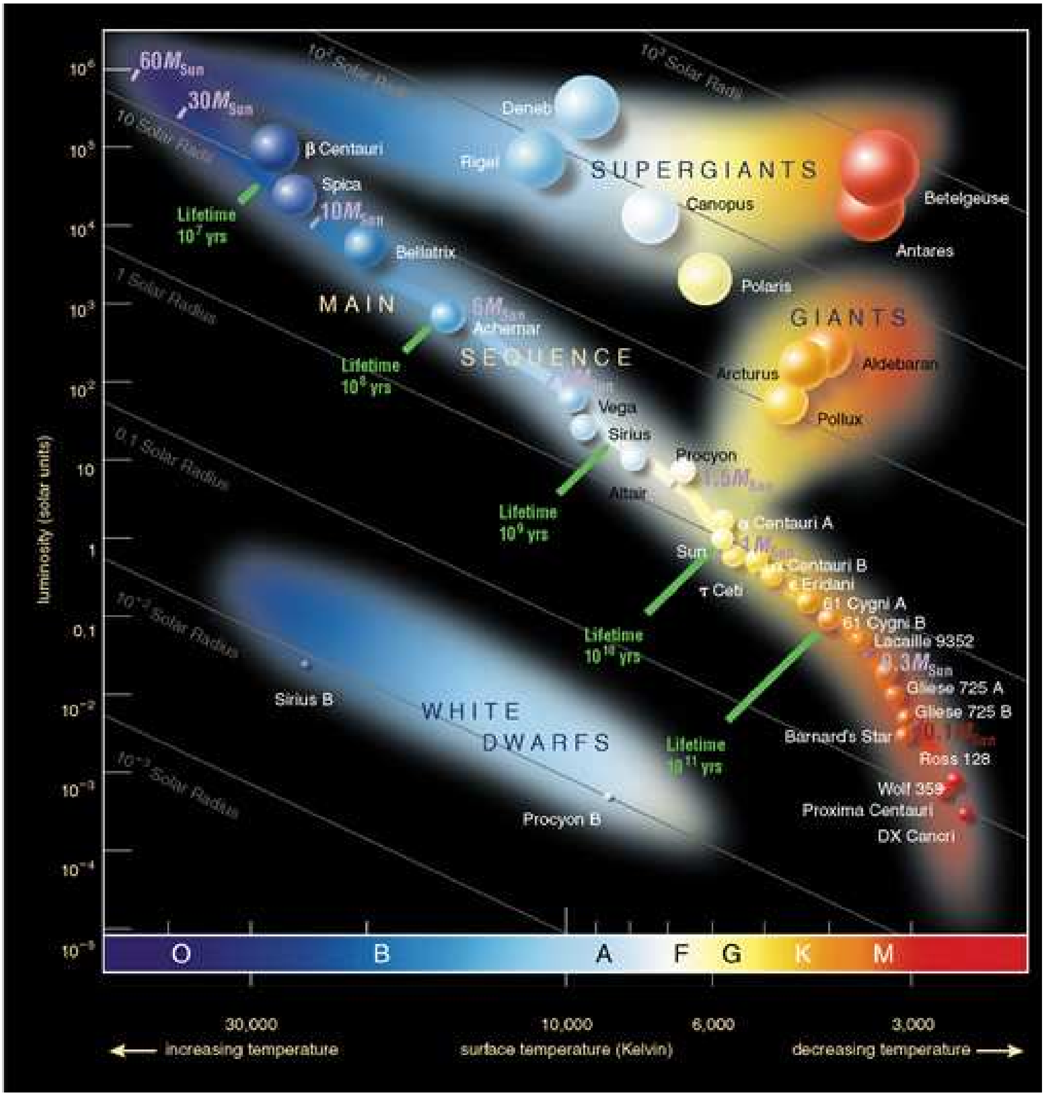
Near infrared	$1\text{x}10^{-6}$ m	3,000 K	?
Mid-infrared	$3\text{x}10^{-5}$ m	100 K	?
Far-infrared	$1\text{x}10^{-4}$ m	30 K	?



Near-IR trace sources at 3000K. Check HR diagram for stars

à the near_IR sources are lowest mass (0.3 M o) stars

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Ultraviolet	1×10^{-7} m	30,000	Very massive (M>10Mo) stars
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Optical	red= 7×10^{-7} m	4.,300 K	Very low mass (< 1Mo stars)
Near infrared	$1\text{x}10^{-6}$ m	3,000 K	Lowest mass (~0.3 Mo) star
Mid-infrared	$3\text{x}10^{-5}$ m	100 K	?
Far-infrared	$1\text{x}10^{-4}$ m	30 K	?

Near- Infrared vs Optical

M81 galaxy

(Courtesy: NASA/Spitzer)

Near-IR image

Optical light image

- Near infrared light comes from cool (few 1000 K) stars = cool low mass stars
- Near infrared light is NOT blocked by dust and can penetrate the dust to reach us
  à   This is why the near_IR image looks so smooth, while optical image looks patchy
  à   see in-class figure
- Why do we say near-IR light traces the total mass of a galaxy?

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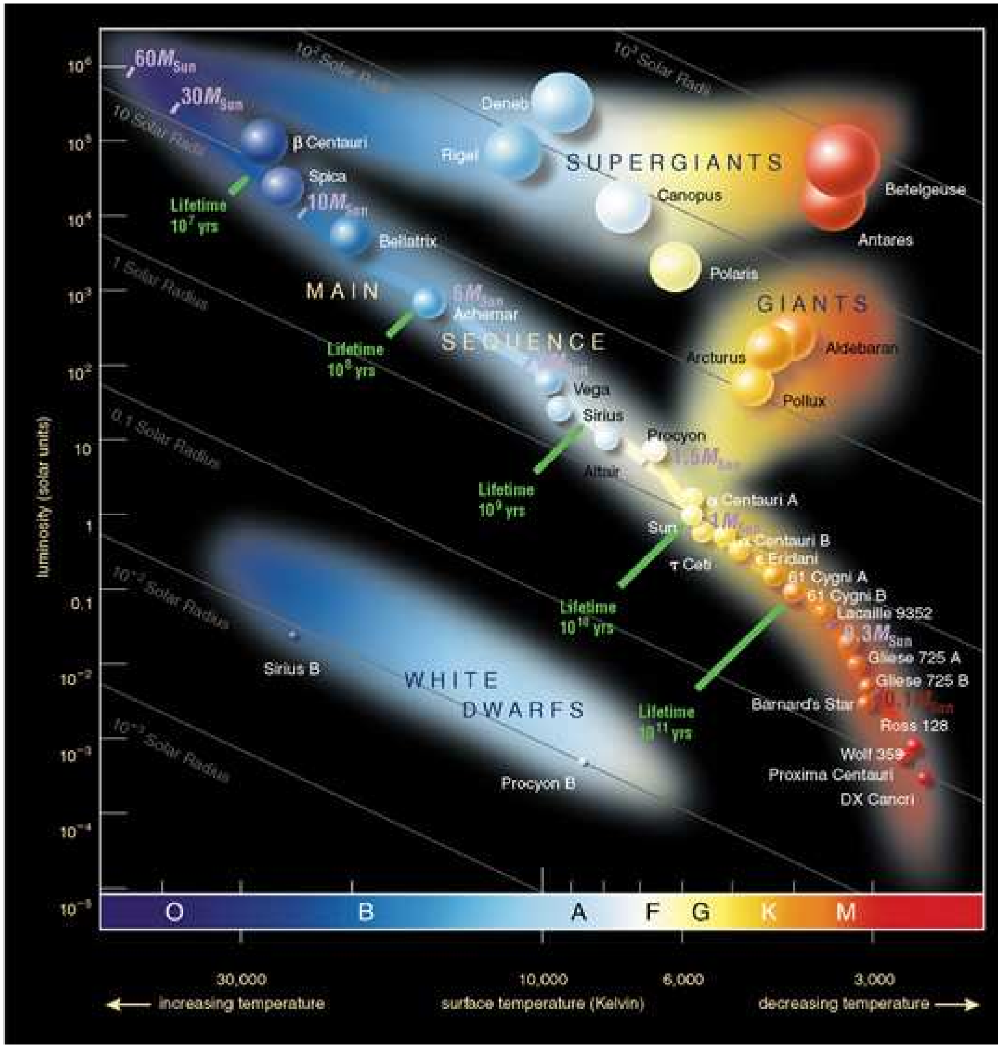
Near infrared	1×10^{-6} m	3,000 K	Lowest mass (~0.3 Mo) star
Mid-infrared	3×10^{-5} m	100 K	?
Far-infrared	1×10^{-4} m	30 K	?



Mid-IR and Far-IR trace sources at 100 K and 30K. Check HR diagram for stars

à these sources are too cool to be stars!

à what is the nature of the sources emitting mid-IR and far-IR light?

See in-class figure re. reprocessing of light by dust!!!

Near-IR and Mid-IR images

M81 galaxy

(Courtesy: NASA/Spitzer)

Near infrared light
- comes from cool low mass stars
- penetrates through intervening dust to reach us

à See in-class figure

Mid-IR light is emitted by

à warm (100 K) dust and gas that is heated by UV/blue light from hot massive young stars

à See in-class figure

Wavelength of peak emission		Surface Temperature of emitting source	Nature of source
X rays	3 x 10^{-10} m	10^7 K	Hot gas shock-heated by supernovae remnants
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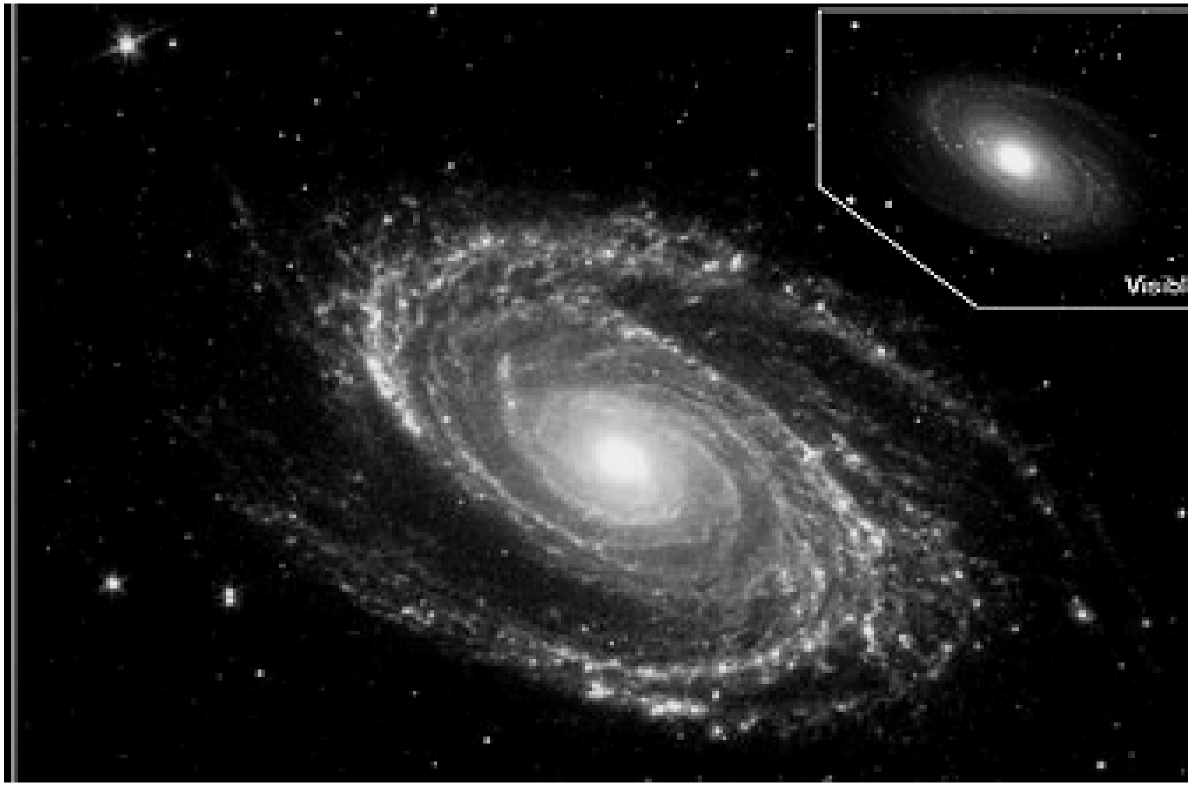
Optical	red= 7x 10^{-7} m	4.,300 K	Very low mass (< 1Mo stars)
Near infrared	1x10^{-6} m	3,000 K	Lowest mass (~0.3 Mo) star
Mid-infrared	3x10^{-5} m	100 K	Hot dust heated by UV/optical light coming from high mass stars behind the dust
Far-infrared	1x10^{-4} m	30 K	Warm dust heated by Uv/optical light coming from high mass stars behind the dust

Near-IR and Mid-IR images

M81 galaxy

(Courtesy: NASA/Spitzer)

Near IR light
- trace low mass stars
-penetrate dust



Infrared composite made from 3.6, 8.0, 24 micron images

Mid-IR image trace hot dust heated by UV/blue light of hot young massive stars

Infrared Wavelengths

Movie: From optical to IR view of M81 (Courtesy: NASA/Spitzer)

- à Near-IR at 1 to 3 micron: penetrate the dust and shows **old stars**
- à Mid and far-IR from 10 to 100 micron shows **hot dust and gas forming young stars**

Infrared Wavelengths

Movie : From visual to infrared look at dark globule in IC 1386
(Courtesy:NASA/Spitzr)

- Visual image shows one star + dark patch of dust in globule head
- Near-IR 3.6 mu image penetrates the dust to show 2nd star and cavity in globule head
- Mid IR 8 and 24 mu images trace hot dust+ gas filaments made when winds from massive stars compress gas à Thick dusty discs around young stars = precursor of planetary systems