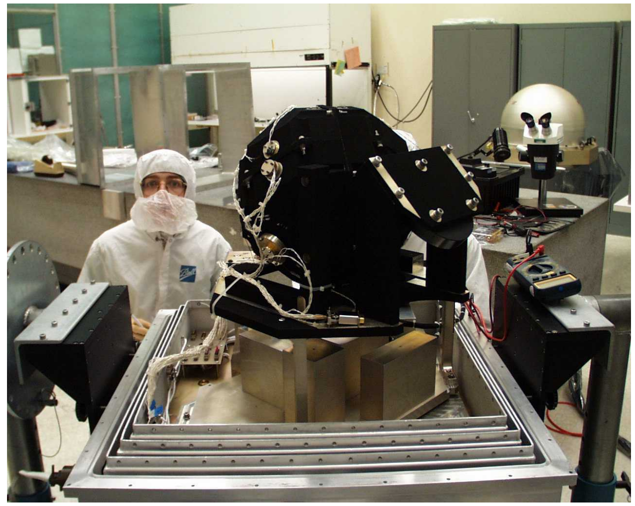
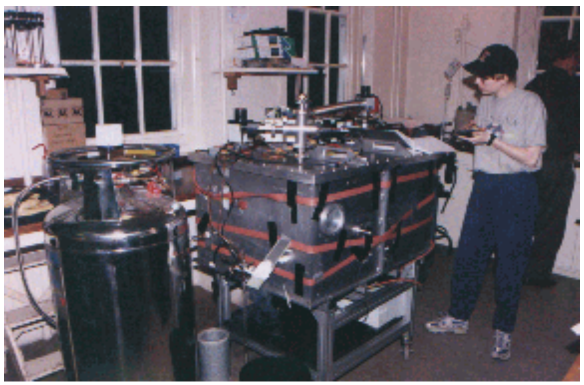
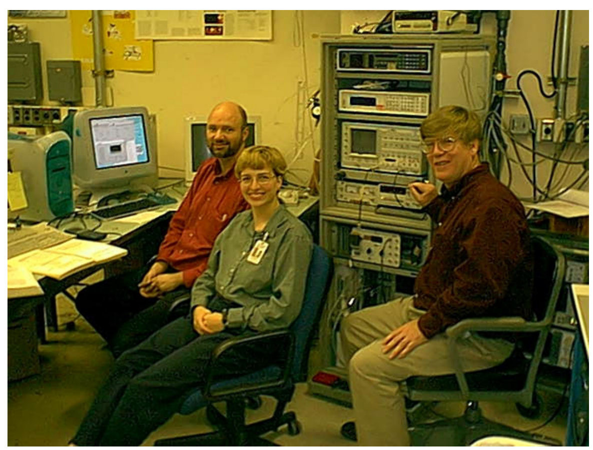
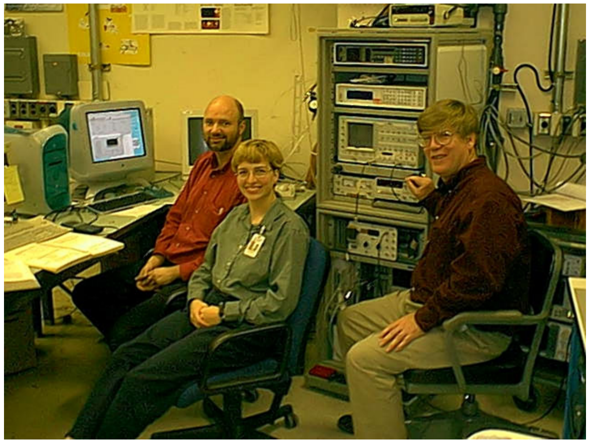




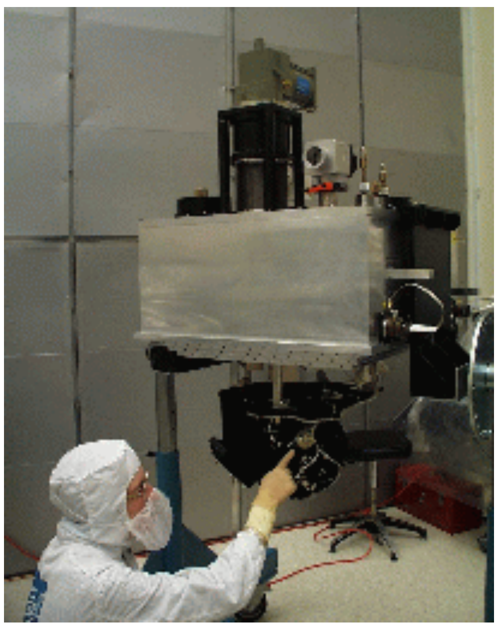
Playing with "Cool" Space Toys!

Kimberly Ennico
(kennico@mail.arc.nasa.gov)





NASA Ames December 2000



Ball Aerospace, Boulder, CO
December 1999

Who am I?

Kimberly (Kim) Ennico

Age 29

BA Physics (1994) – Johns Hopkins University, Baltimore, Maryland

PhD Astronomy (1999) – Cambridge University, Cambridge, England

Physicist, astronomer, instrument scientist, "kim" of all trades

Working at NASA Ames since September 25, 2000

Career Goals: Astronaut & PI of own satellite mission, & to be happy

Outline of Presentation

- Overview of what it takes to build a **space telescope**
- What is meant by an **infrared (IR) telescope** and **infrared astronomy from space**
- Examples of IR space telescopes
- NASA Ames & its role in testing **infrared detectors** for infrared space telescopes
- **Cryogenic** aspect of infrared telescopes & demo
- Field questions about building space telescopes

Things to learn:

- Infrared
- Telescope
- Systems
- Detectors
- Cryogenics

How to Build a Space Telescope

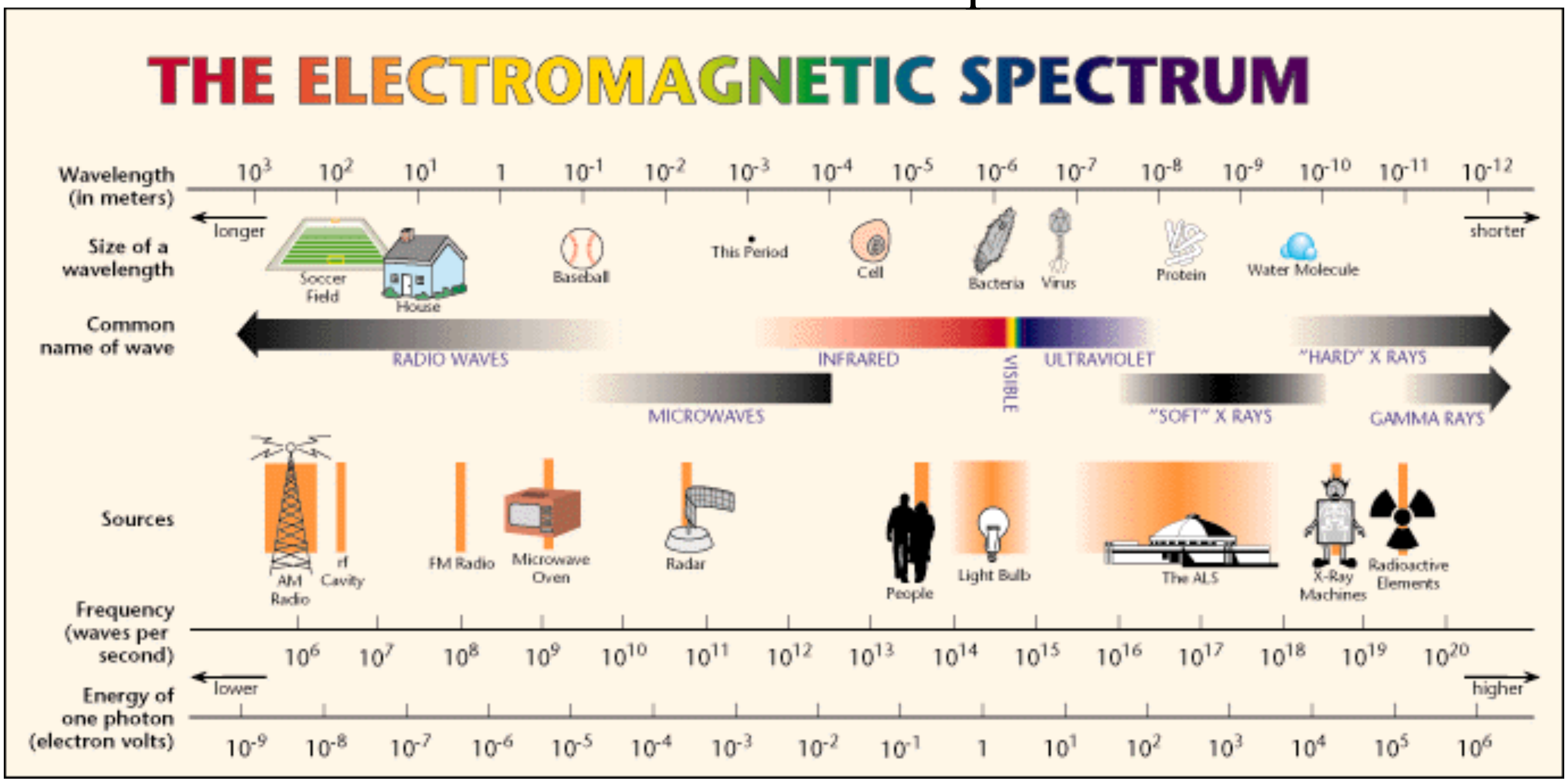
- Need an idea (**science objectives**).
- Ask yourself what sort of **instrument(s)** you need to do the science (camera? spectrograph? counter?). Will it be manned/unmanned?
- Choose a **team/partners** for expertise.
- Do a **preliminary design**.
- Estimate how much it might **cost** and **how long** it would take to design, build, test, launch & operate.
- Apply to NASA with a proposal.
- Be **very patient**, and be willing to gamble.

Hubble Space Telescope getting a facelift (STS-61) 12/1993

At NASA Ames, I'm working to support current and future infrared (IR) space telescopes.

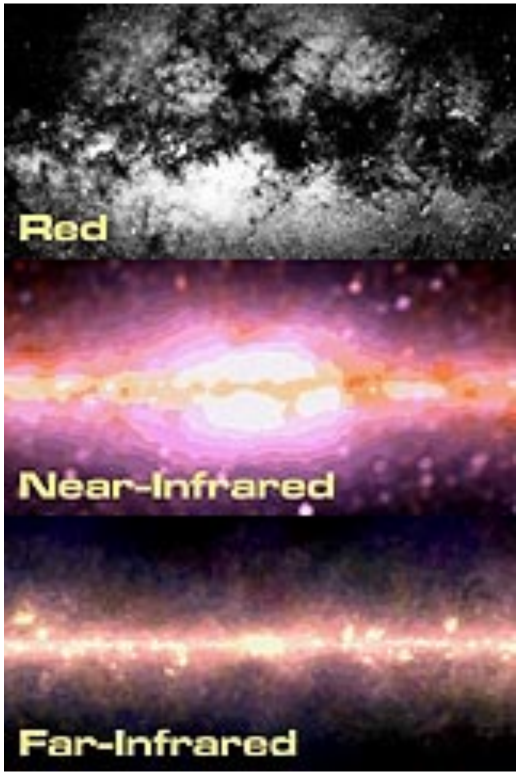
How would you build an IR telescope?

First of all, **what is the infrared**, and why would you want to build an infrared telescope?

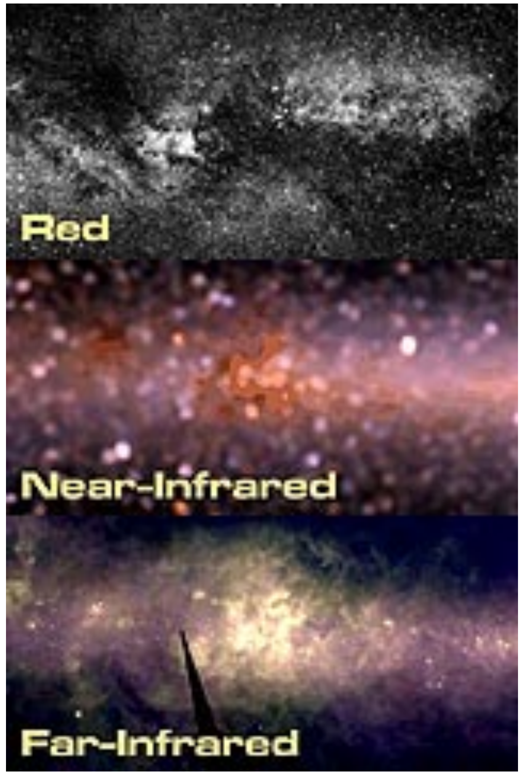


Ref: http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

Examples of what IR eyes would see in space



Milky Way
Galactic Center

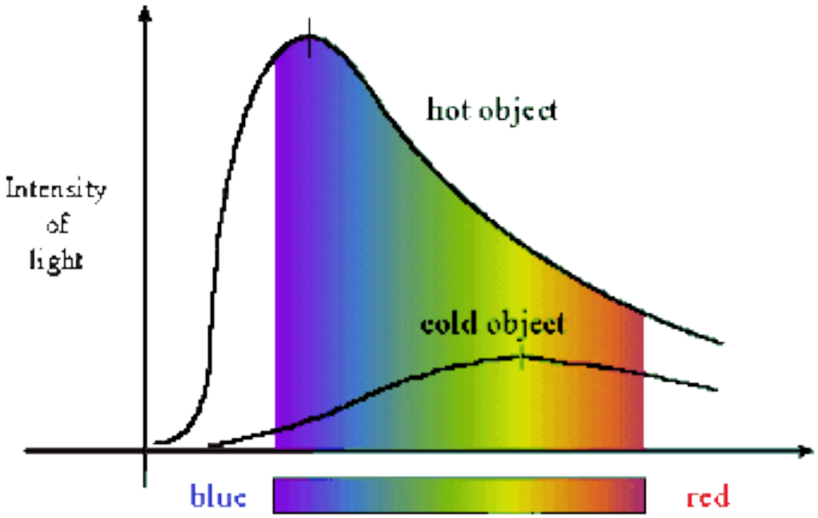


Cygnus star forming
region

- Seeing **cooler objects** (e.g., disks, planets around other stars, molecular vibrations)
- **Seeing through dust** (e.g., new stars, centers of galaxies)
- Edge of universe work ("redshift effect")

Ref: http:/www.ipac.caltech.edu/Outreach/Edu/importance.html

Black Body Radiation (Planck Law)

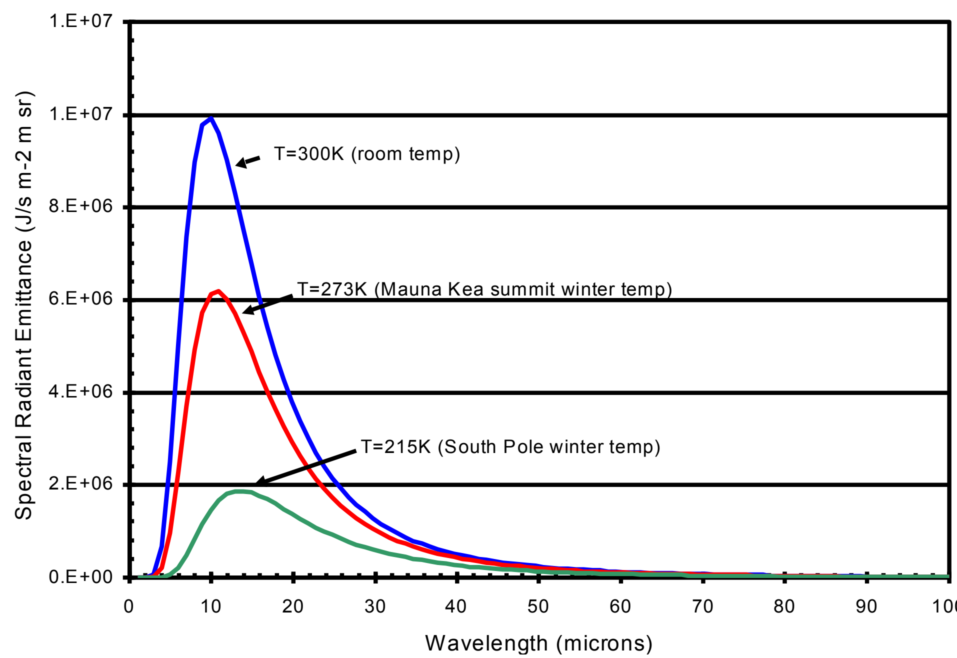


• Cooler objects have their peak in intensity at longer (redder) wavelengths

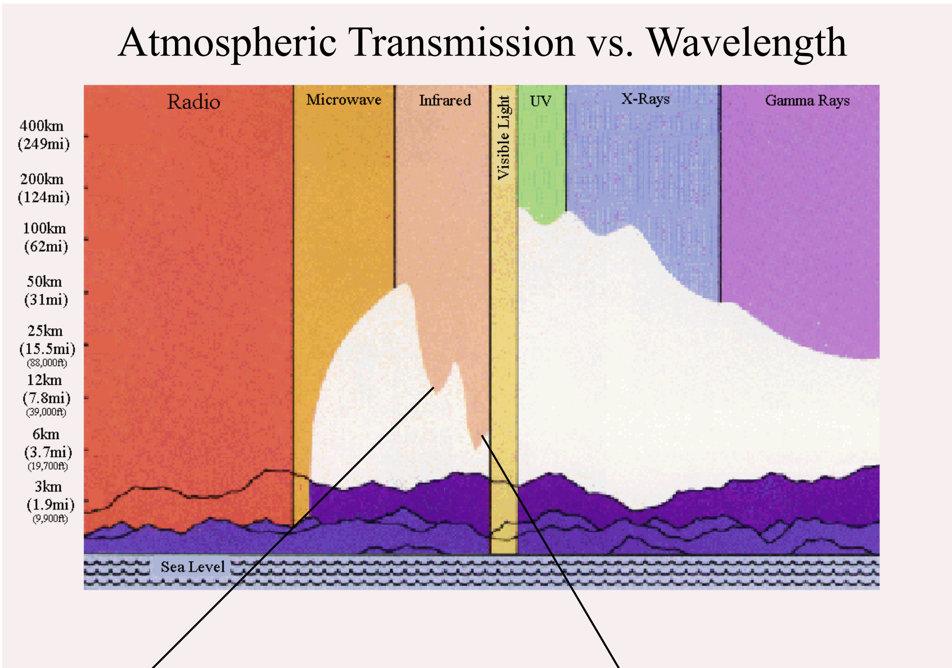
• But, a cooler object will also emit a lower intensity (summation under the curve), lower energy than a hotter object

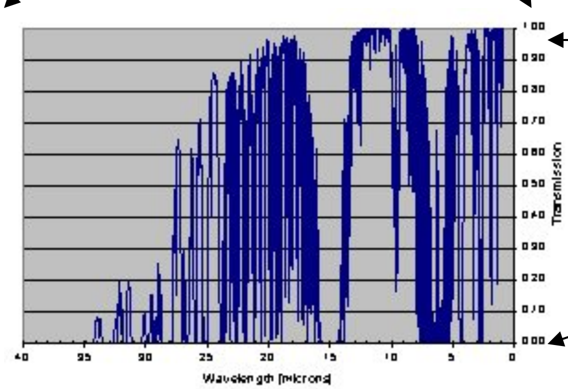
• Room temperature (300K) objects will emit radiation to swamp IR detectors (peak at 10μm)

• Requires you to cool your detectors & surrounding optics (including telescope!) to maximize performance

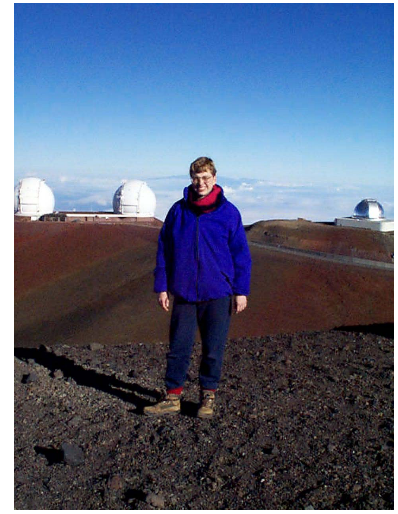


Some IR astronomy can be done from the ground… sort of…

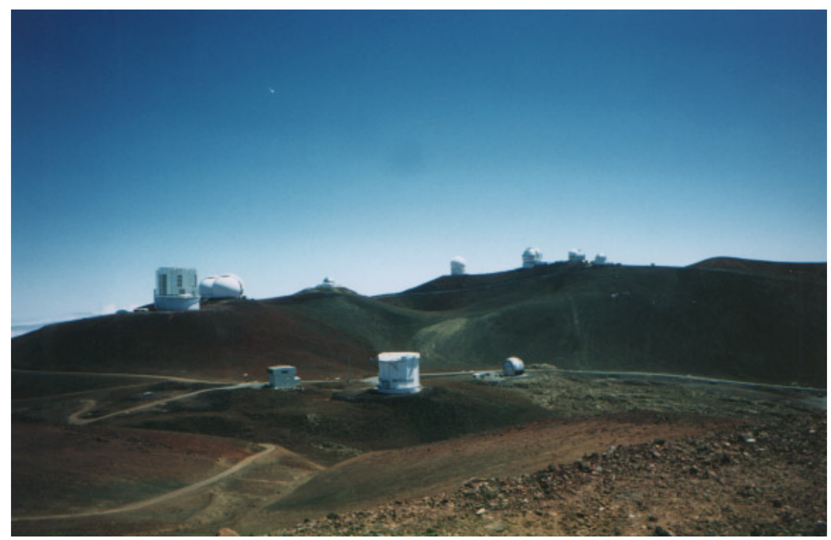




Ref: http://imagine.gsfc.nasa.gov/docs/science /know_l1/emspectrum.html



Go to Hawaii!
(or Chile, or the South Pole)
Kim atop Mauna Kea, Hawaii (1998)



SIRTF – Space InfraRed Telescope Facility

<u>Brief History</u>

1979: On Space Shuttle concept

1983: Proposals for Instruments

1985: IRT in SpaceLab (15.2cm) poor performance

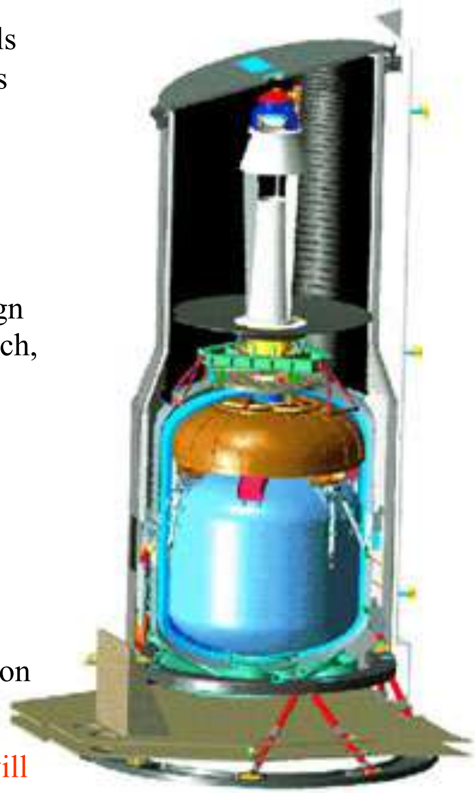
1990s: Redesign for rocket launch, D/A orbit

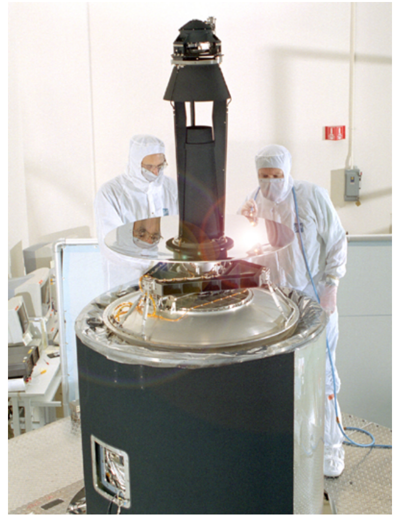
1995: Delta configuration

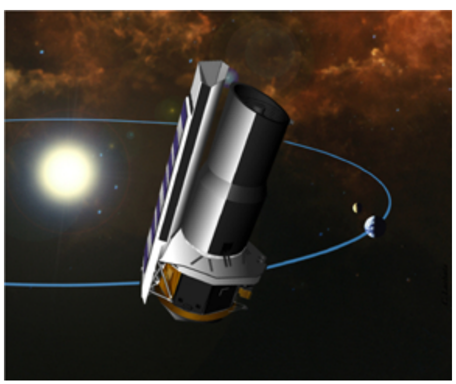
Late 1990s: Building & Testing

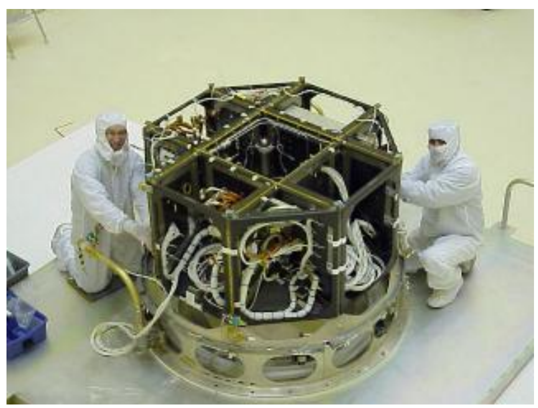
Now: Integration at S/C level

At launch, it will be a 23 year old concept!









Launch Date: July 2002

Launch Vehicle: Delta 7920, from KSC

Orbit: Earth trailing, heliocentric

Wavelength: 3-180 microns

Telescope: 85cm (33.5in) diameter

Science Instruments (3): Imaging

3-180µm, Spectroscopy 5-40µm

Cryogen: Liquid He (360 liters, 95 Gallons)

Launch Mass: 950 kg (2094 lb)

Mission Lifetime: 2.5-5 years

Cost: ~$500M

More info, see: http://sirtf.jpl.nasa.gov

AstroBiology Explorer (ABE) MIDEX Mission Concept
NASA Ames & Ball Aerospace

<u>Timeline</u>

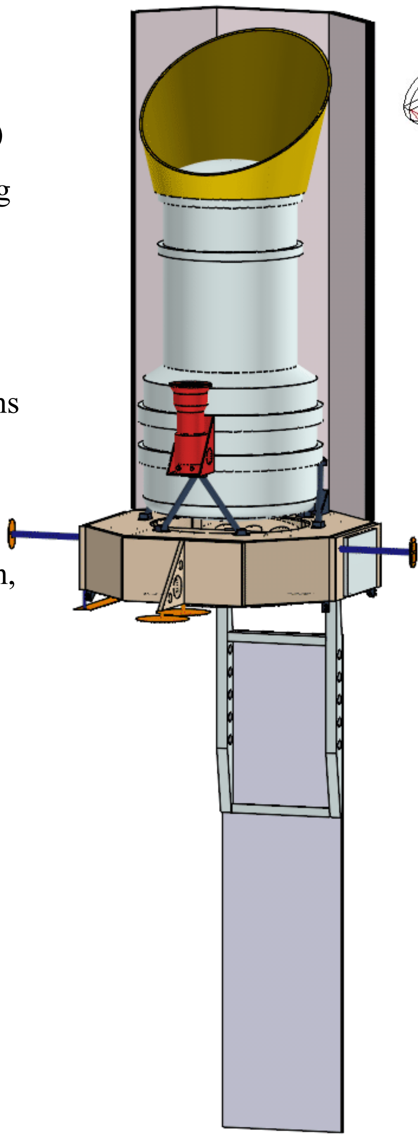
Working the concept for about 1.5 years (1/2000)

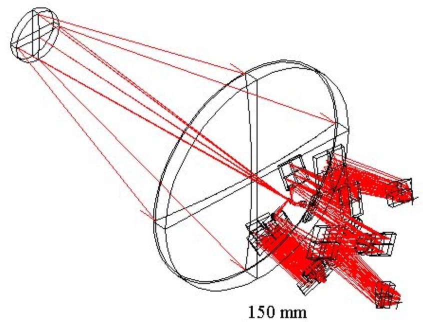
Present: Proposing to a NASA MIDEX AO (10/2001)

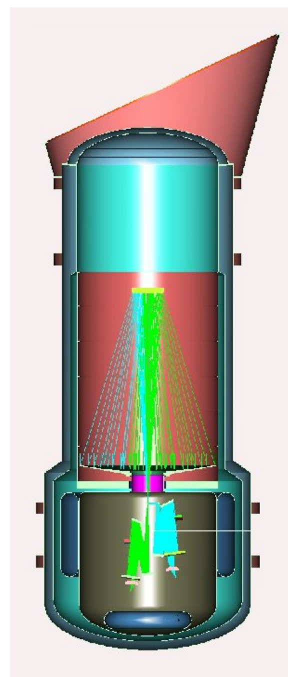
If successful, we would be 1/3 teams selected to do a 4-6month deeper study (1/2002)

If successful again, we would design, build, test, and prepare for a 2007/2008 launch date.

~8-(10) year timescale from ideas to launch







Launch Date (proposed): March 2007

Launch Vehicle: Delta from KSC

Orbit: Earth trailing, heliocentric

Wavelength: 2.5-16 microns

Telescope: 60cm (23.7in) diameter

Science Instruments (1): Spectroscopy 2.5-16μm

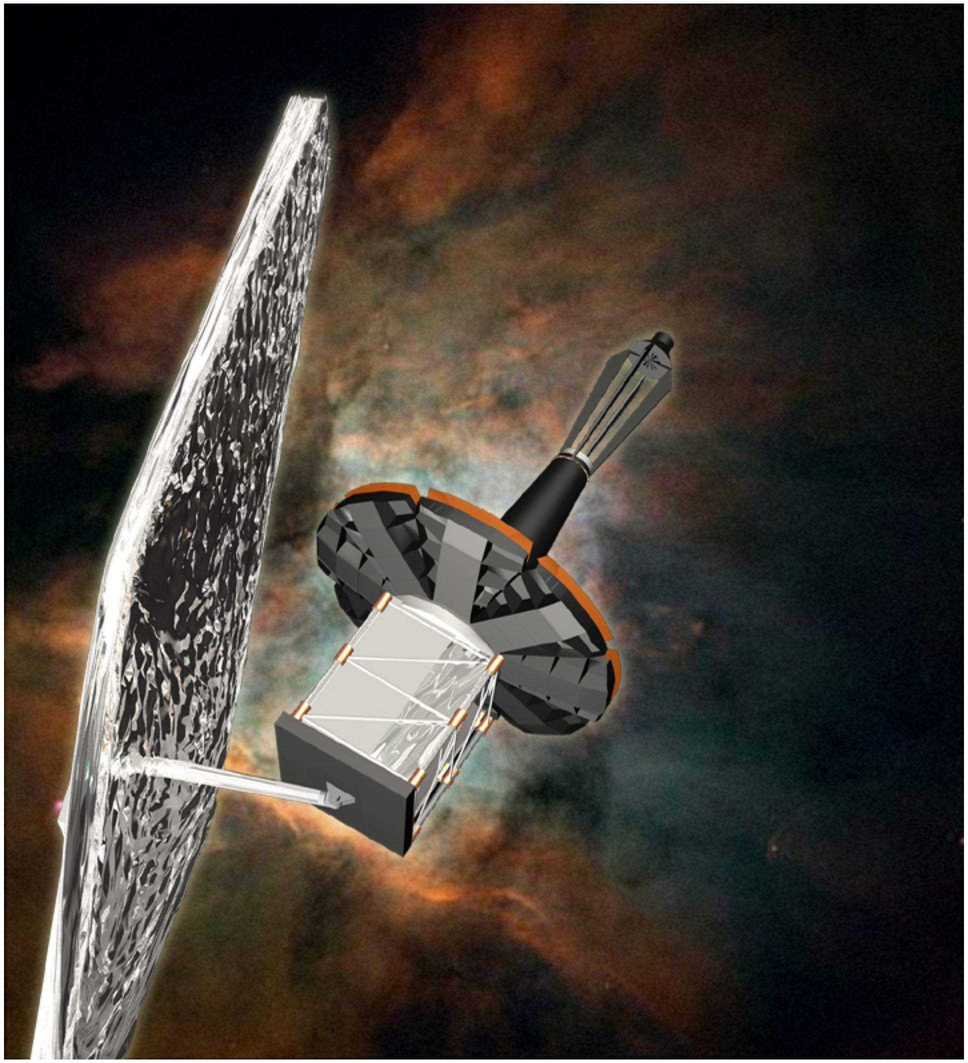
Cryogen: Solid Hydrogen (190 liters, 49 Gallons)

Launch Mass: ~560 kg (1235 lb)

Mission Life Time: 1.5 years

Cost (capped): $180M

NGST – The Next Generation Space Telescope



Launch Date (proposed): 2010

Launch Vehicle: TBD

Orbit: L2 libration point

Wavelength: 0.6-28(?) microns

Telescope: 6m (~20ft) diameter

Science Instruments (3-4): Cameras & Spectrographs

Cryogen: Passive cooling with possibly solid cryogens for MIR instruments

Launch Mass: ~3000 kg (6614 lb)

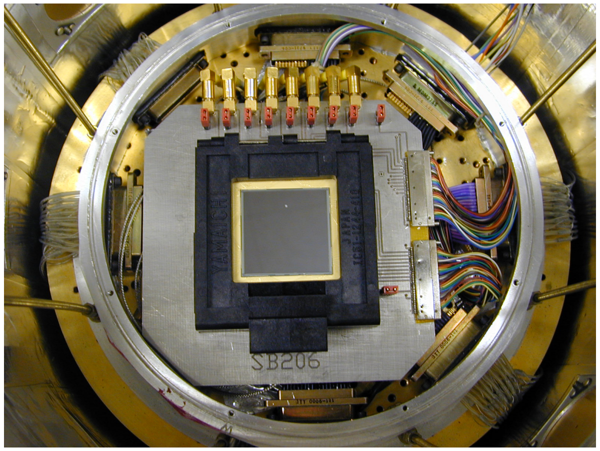
Mission Life Time: 5-10 years

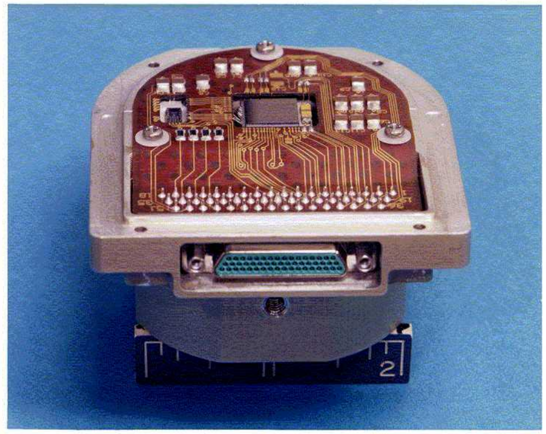
Cost: $900M (?)

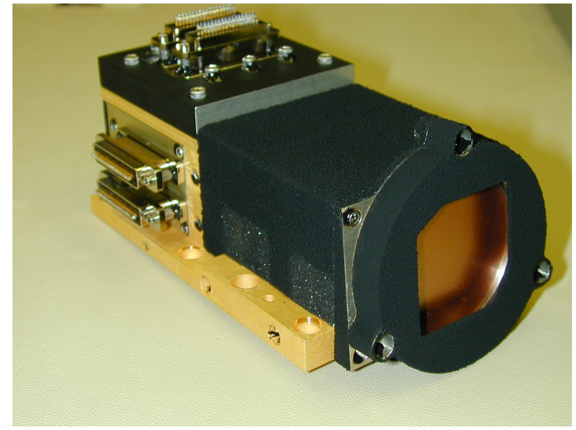
For more info, see:

http://www.ngst.nasa.gov

Infrared (IR) Detectors







- **CCD**s (charged coupled devices) are semiconductor devices which are sensitive at long-UV/visible wavelengths (0.2-0.8μm).

- You use them in **digital cameras**, **video cameras**, etc.

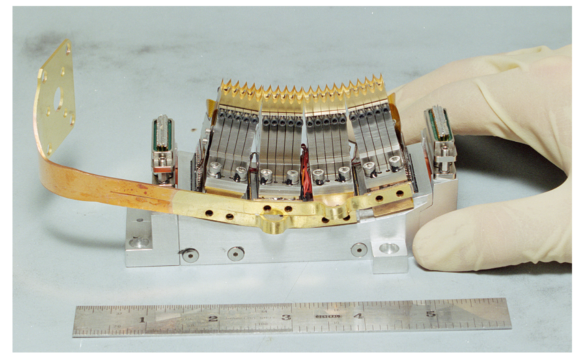
- But CCDs are not sensitive longward of ~1μm.

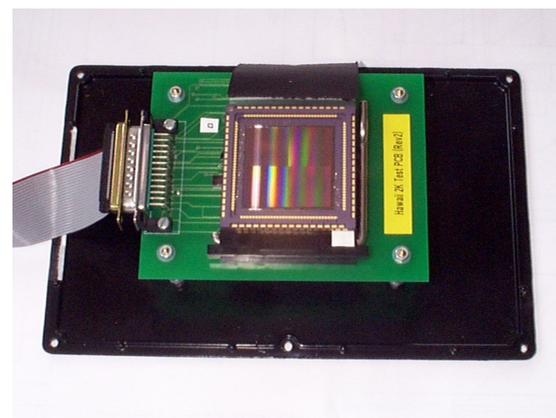
- To detect infrared radiation (>1μm) you need a different type of detector.

- Several IR detector types exist. Each have certain operating constraints.

- The most common **IR detector type** for astronomy is the **hybrid array**.

- Space qualified IR arrays need to be robust, have redundancy, and be radiation hard.



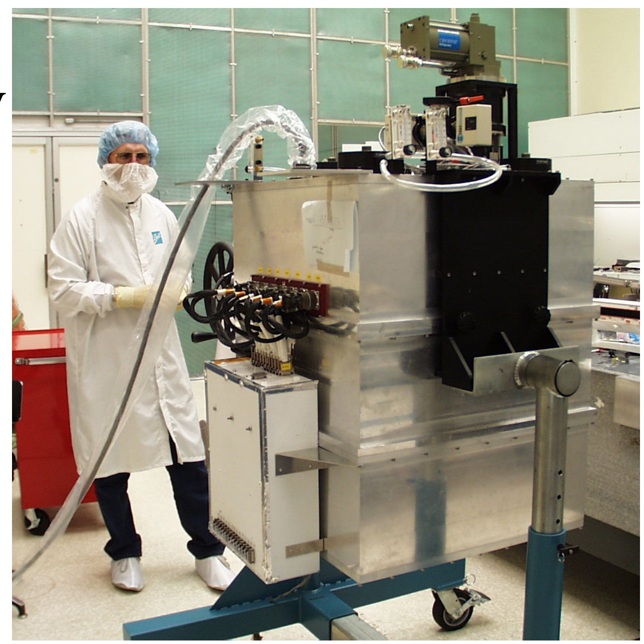


IR Detectors & Instruments Need to be Kept Cold

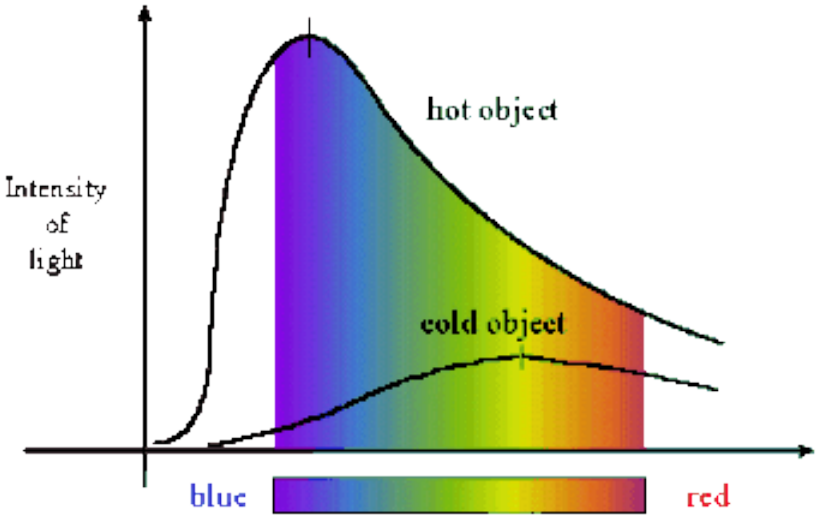
Generally IR detectors & their surrounding optics need to be "cooled" to

1) reduce the background hitting the array, and
2) reduce the detector's own internal, thermally generated background.

To keep things cold, the entire detector/test set-up must be placed within a vacuum chamber.



Black Body Radiation (Planck Law)



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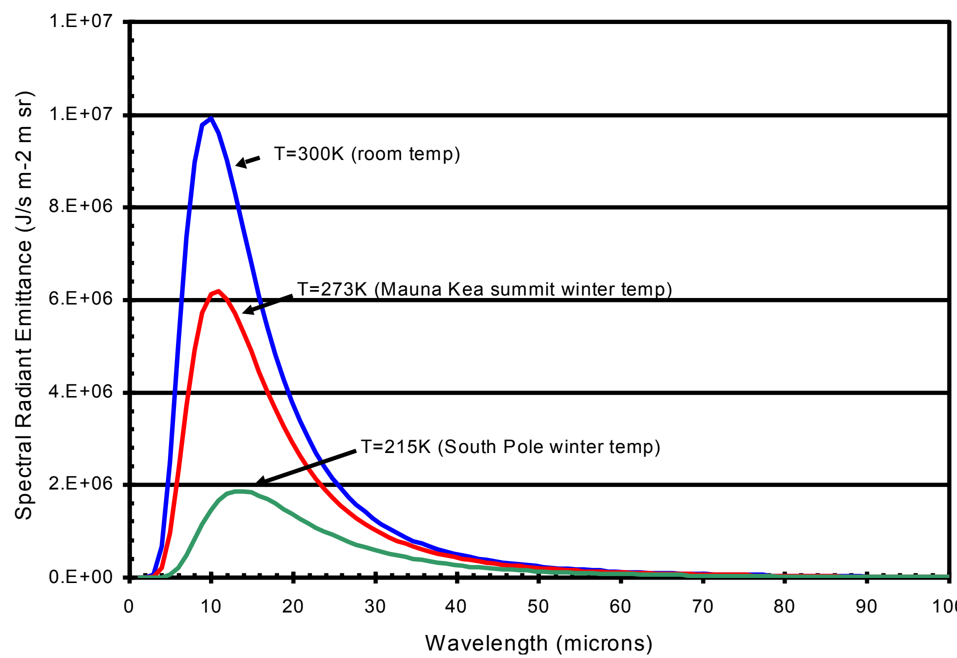

How would an IR space telescope get & stay cold?

Heat Transfer: Hot -> Cold

- **Radiation** – energy transfer vs. EM waves
- **Conduction** – energy transfer through solid matter
- **Convection** – energy transfer between flowing fluid (liquid/gas) and a solid

- Carry cryogens (nitrogen, helium) for conduction
- Different cryogenics for different components (detectors, computers, batteries, optics, mechanisms)
- Use sunshades & radiators to radiate heat away (your own electronics will generate heat!)
- Mechanical refrigerators/coolers
- Sometimes need heaters if the environment gets colder than what you need!
- Tricky to keep heat balance for all components at all stages in a mission (launch, orbit, landing/reentry, ground testing)

How Cold is "Cold"?

Colder

	Kelvin	Celsius	Fahrenheit
Sun	6000 K	5727 ºC	10,341 ºF
Space Shuttle reentry	1533 K	1260 ºC	2300 ºF
Low Earth Orbit High Temp	450 K	177 ºC	350 ºF
Water Boils	**373 K**	**100 ºC**	**212 ºF**
Human Body Temperature	310 K	37 ºC	98.6 ºF
Room Temperature	300 K	27 ºC	81ºF
Water Freezes	**273 K**	**0 ºC**	**32 ºF**
Antifreeze Freezes	243 K	-30 ºC	-22 ºF
Wind temp @ 33,000 feet	~230 K	-43 ºC	-45 ºF
South Pole Winter	~213 K	-60 ºC	-76 ºF
Low Earth Orbit Low Temp	116 K	-157 ºC	-250 ºF
Liquid Oxygen Boils	90 K	-183 ºC	-361 ºF
Liquid Nitrogen Boils	77 K	-196 ºC	-320 ºF
Solid Oxygen Melts	55 K	-218 ºC	-360 ºF
Liquid Hydrogen Boils	20 K	-253 ºC	-423 ºF
Solid Hydrogen Melts	14 K	-259 ºC	-434 ºF
Liquid Helium Boils	4 K	-269 ºC	-452 ºF
Deep Space	3 K	-270 ºC	-454 ºF
Absolute Zero	0 K	-273 ºC	-459 ºF

Hawaii Telescope

Aircraft IR Telescope

ABE/SIRTF Telescope

NGST IR detectors

ABE IR detectors

SIRTF IR detectors

Cryogenics Demonstration

- Liquid Nitrogen characteristics
- Self-Inflating Balloon – what is happening?
- Banana hammer vs. Rose– change of material consistency
- Rubber Ball

What (I hope ☺) you have learned this afternoon…

- Items involved for a successful **space telescope** mission.
- The meaning of "**infrared**."
- The main systems of an **infrared space telescope** & how you might go about to design/build/test them.
- The current state-of-art **infrared detectors**.
- The reason why infrared detectors, instruments, and space/ground telescopes **need to be cold**. And the challenges this has in design.