Technologies & Techniques to EXPLORE DISTANT Objects and Phenomena

How We Know What We Know about
Nature of Objects in Deep Space

Program by Rick Kang

Who's Rick Kang?

- Education/Public Outreach Presenter –
  Oregon Astrophysics Outreach
  visiting many classrooms in Oregon
  http://oregonsky.org/
- Collaborator/Tourguide -University of Oregon's
  Pine Mountain Observatory
  You can visit Fri/Sat evenings
  June-September (east of Bend)
  http://pmo.uoregon.edu/

Program Topics

- Today:

1. The Photons are the Data from far away.
2. The Photons are Sparse!
3. Technologies to Collect/Detect Photons.
4. What can we actually measure?
5. What can we deduce?

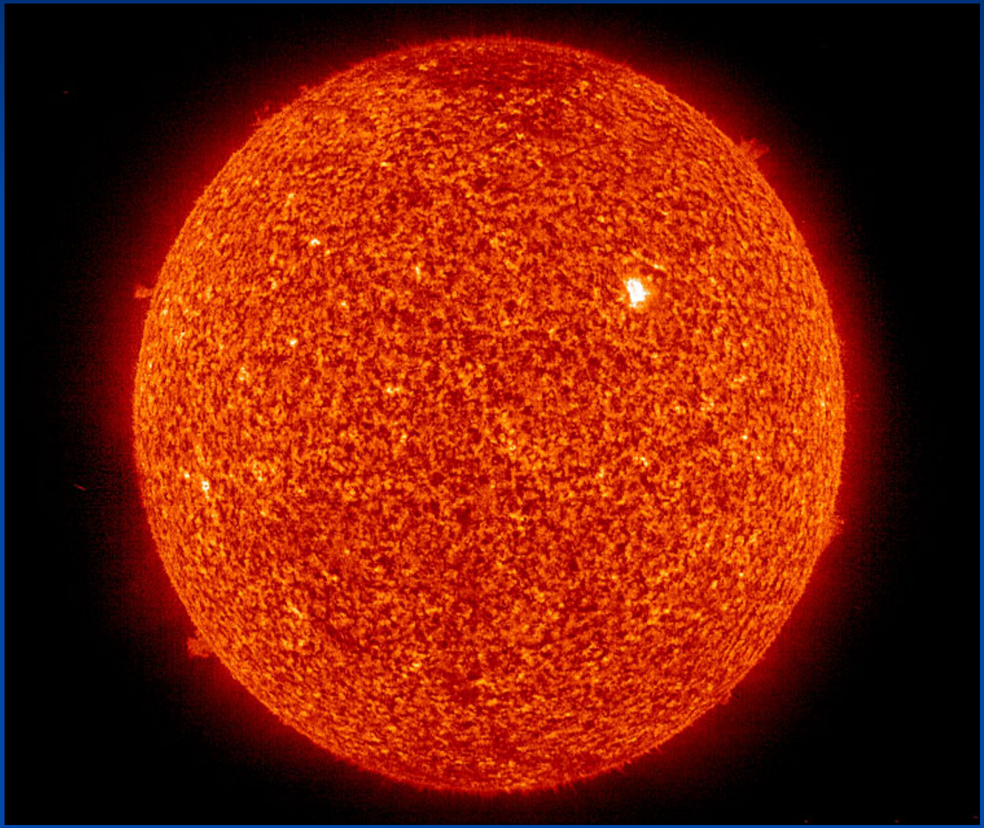
- Tomorrow:

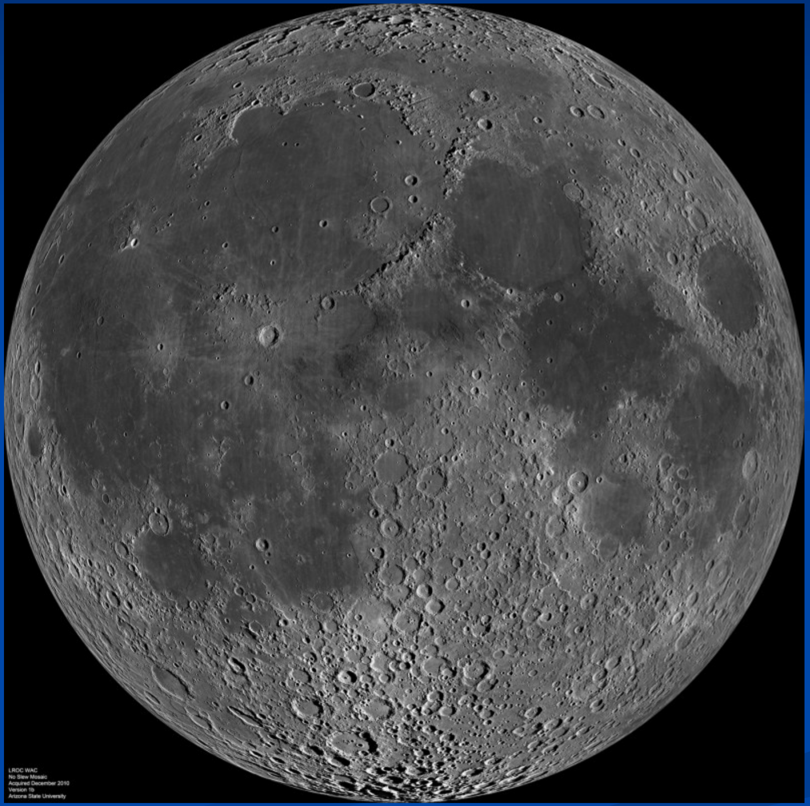
1. Your Questions about Space

INVENTORY of the SKY:

DESCRIBE types of objects you can see or know of in the daytime or nightime sky (that are far away from Earth).

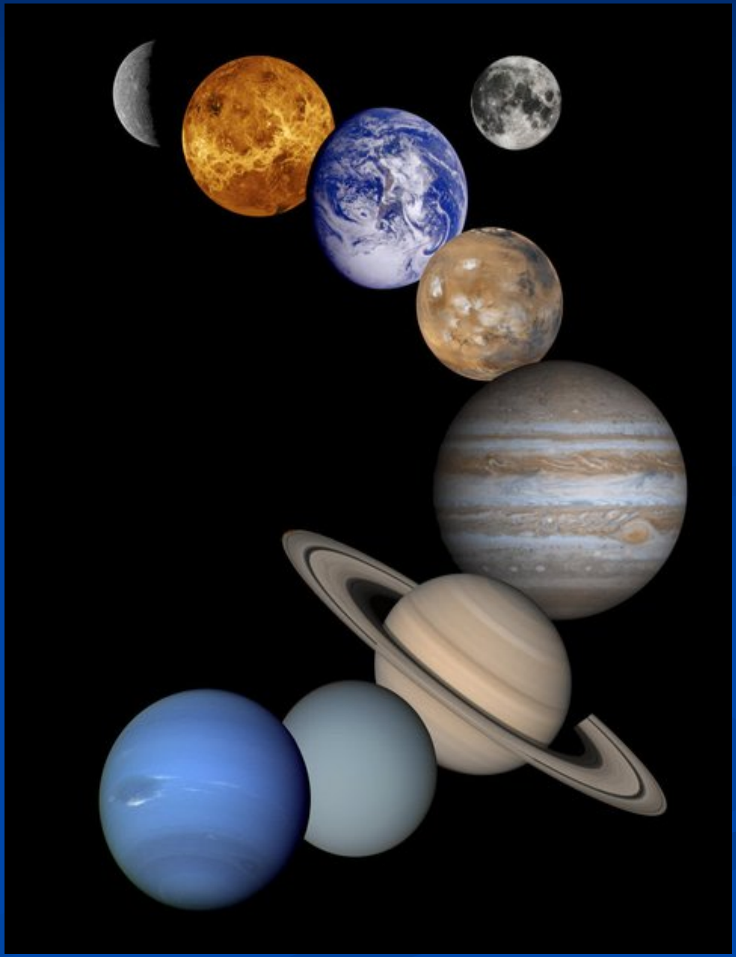
The 2 Brightest Objects, but Not alike at all!





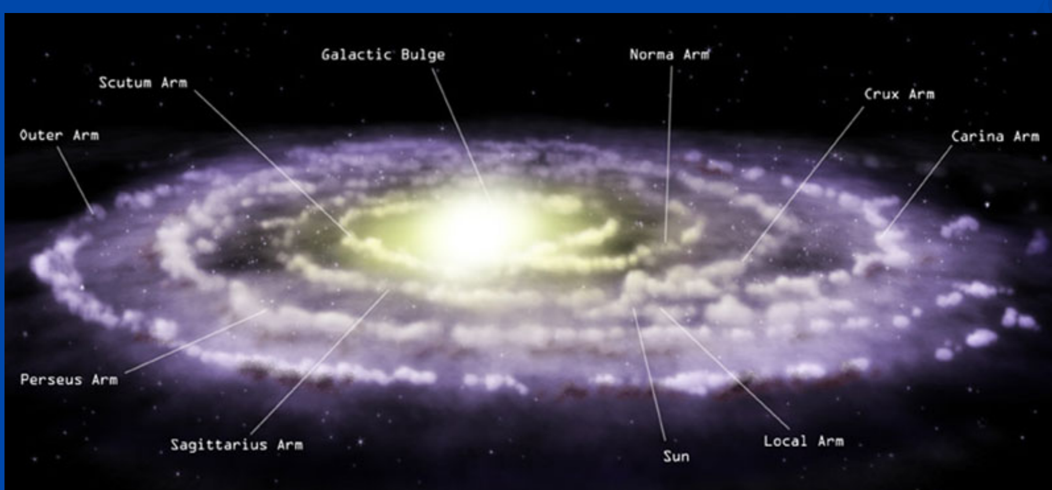
Bright, Wandering dots relatively CLOSE!

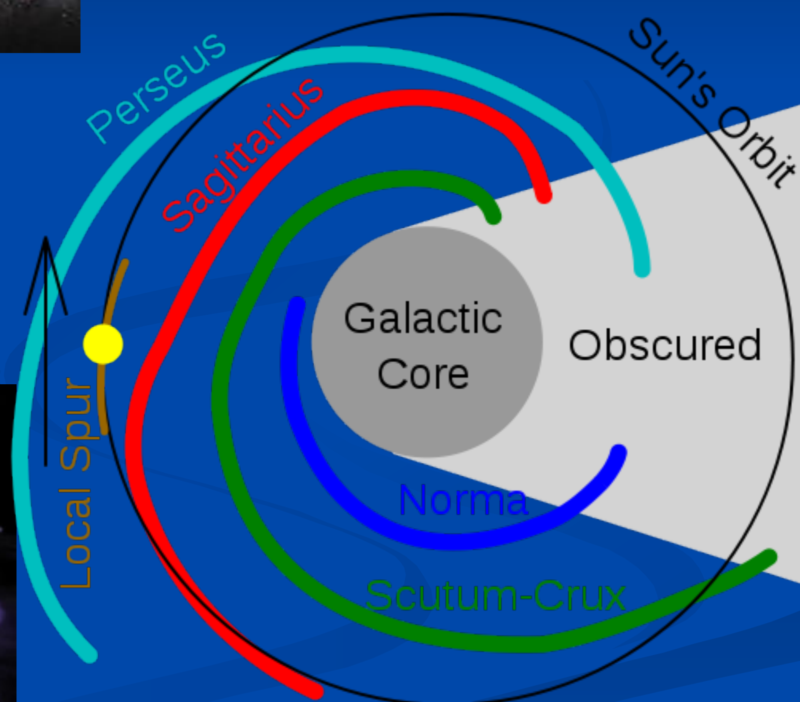
- Viewed through a Telescope these objects appear as disks: THE PLANETS of our SOLAR SYSTEM.



Galileo RESOLVED the "river of milk" into many dots, each a distant Sun (STAR).

Our MILKY WAY GALAXY (star city)





Nebulas (clouds of gas/dust), Star Clusters fill our Galaxy (100,000 LY wide)

Several Neighboring Galaxies

Billions of Galaxies fill our Universe

All these objects are VERY FAR AWAY!

- Solar System Planets take years/decades to fly to.
- Other Stars/Suns are several to several thousand LIGHT YEARS distant (thousands of years to fly to).
- Other Galaxies are millions to billions of LIGHT YEARS distant.

- So, HOW DID WE DISCOVER THESE OBJECTS, and HOW DO WE KNOW

  ANYTHING ABOUT THEIR NATURE?

  What do we receive from them?

WE RECEIVE PHOTONS (light) from them.
The PHOTONS are the DATA.
(sometimes very old data, having traveled many years)

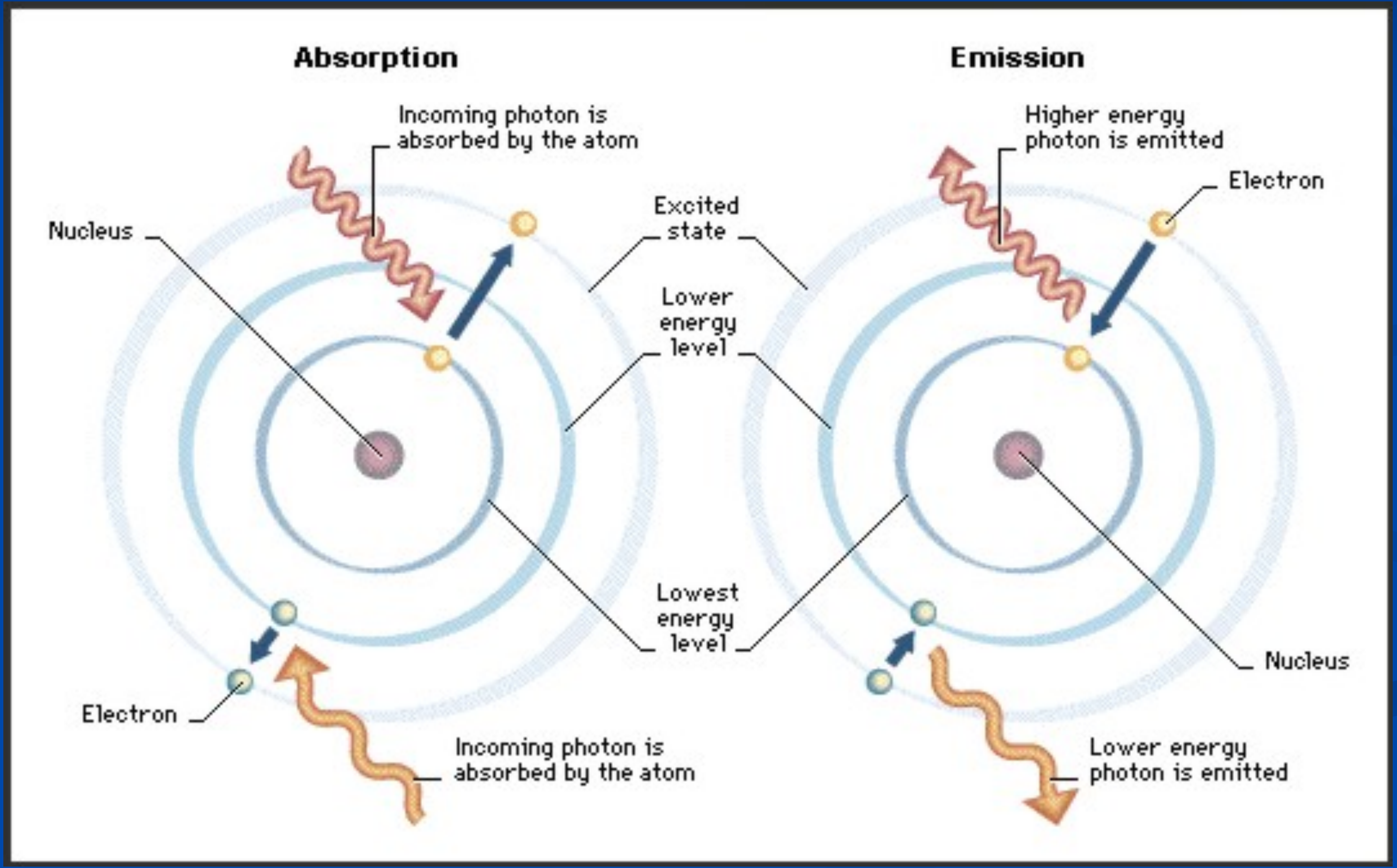
- What causes objects to launch photons?

What causes objects to launch photons?

- Our Moon and our Solar System Planets REFLECT SUNLIGHT toward us. (As do the Nebulas (clouds of dust and gas) within Galaxies.)

- Our Sun, and all other Suns/Stars in the Milky Way Galaxy and in other Galaxies, pump out zillions of photons because STARS ARE HOT!

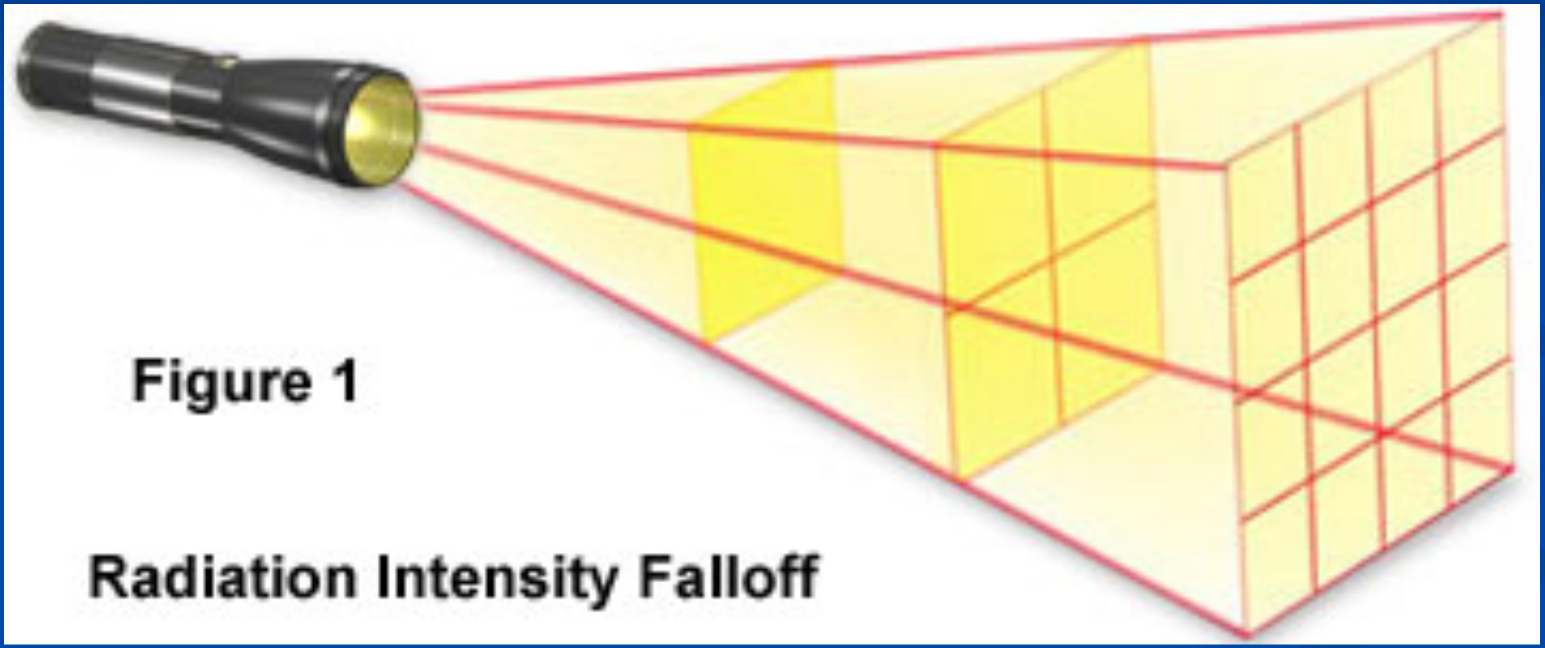
In ATOMS, Quantized JUMPS of ELECTRONS result in photon emission.



Good News/Bad News:

- Good News: Many Billions of Stars producing zillions of photons per second!
- Bad News: Over the huge distances, the photons SPREAD OUT, not many reach us at Earth ☹.
- Astrophysicicists have VERY LITTLE DATA to work with! HELP!

Photons disperse making distant object appear VERY FAINT!



Engineering Design project:

Design a TECHNOLOGY to COLLECT as many PHOTONS as possible from objects in sky…

Concept: consider how to COLLECT RAINDROPS

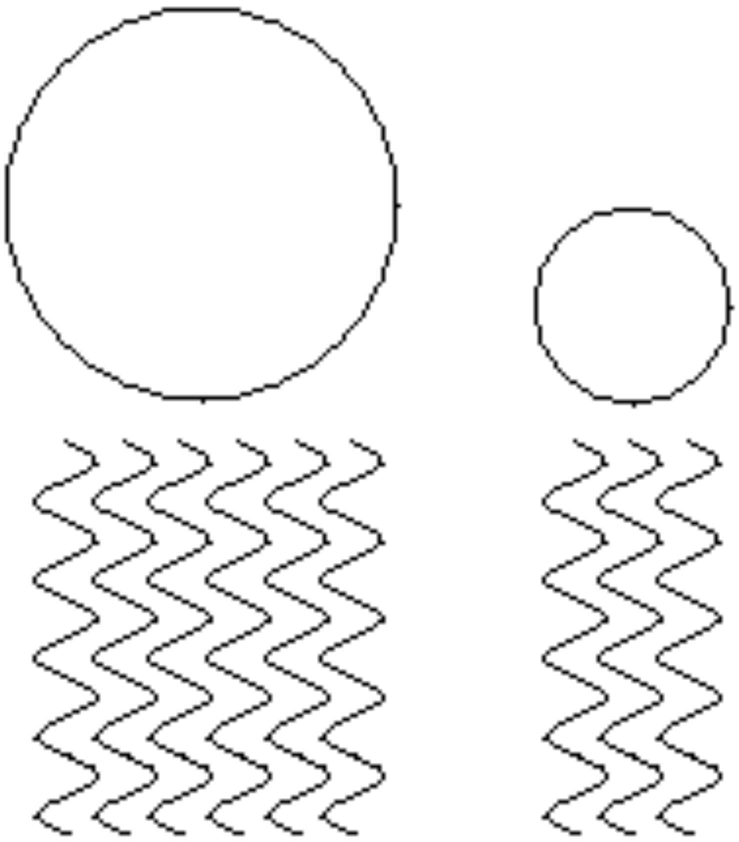
- General Solution: A Device that has LARGE SURFACE AREA!

- Specific Solution for Photons: A LARGE CURVED MIRROR, curvature to FOCUS (concentrate) the photons.

TELESCOPE

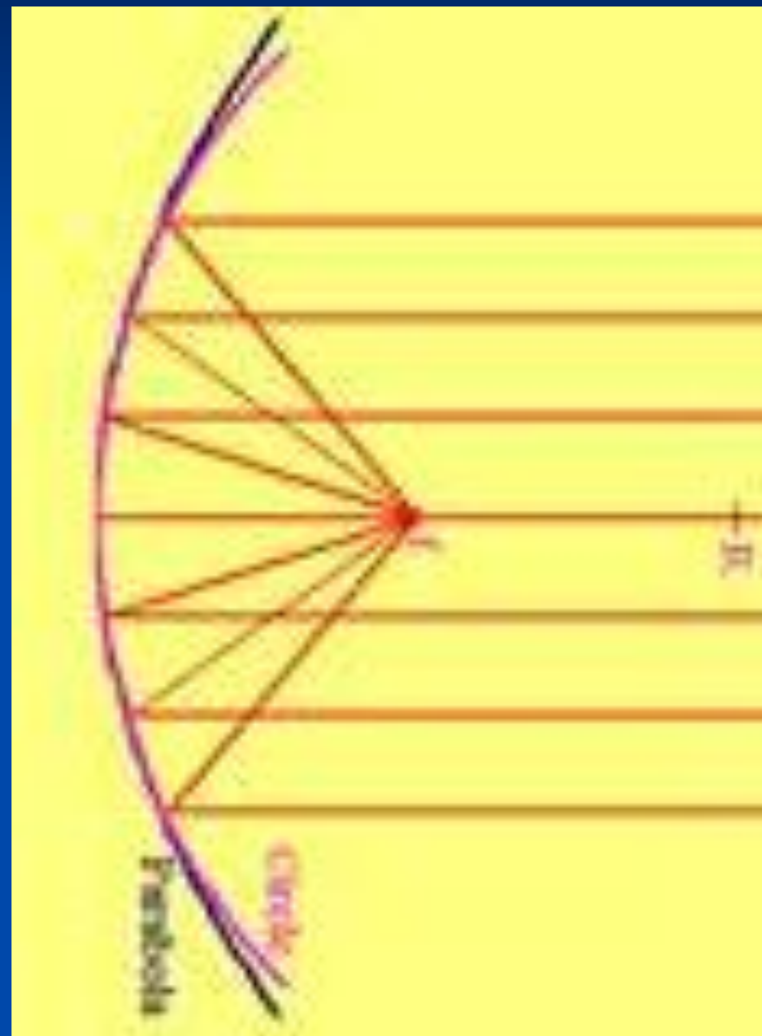
1. Collects lots of photons.
2. Focuses the photons to create an IMAGE.
3. Image can then be MAGNIFIED, ANALYZED, RECORDED, …
4. Main function is to BRIGHTEN the view of the distant object.

Larger Aperture collects more photons and improves resolution

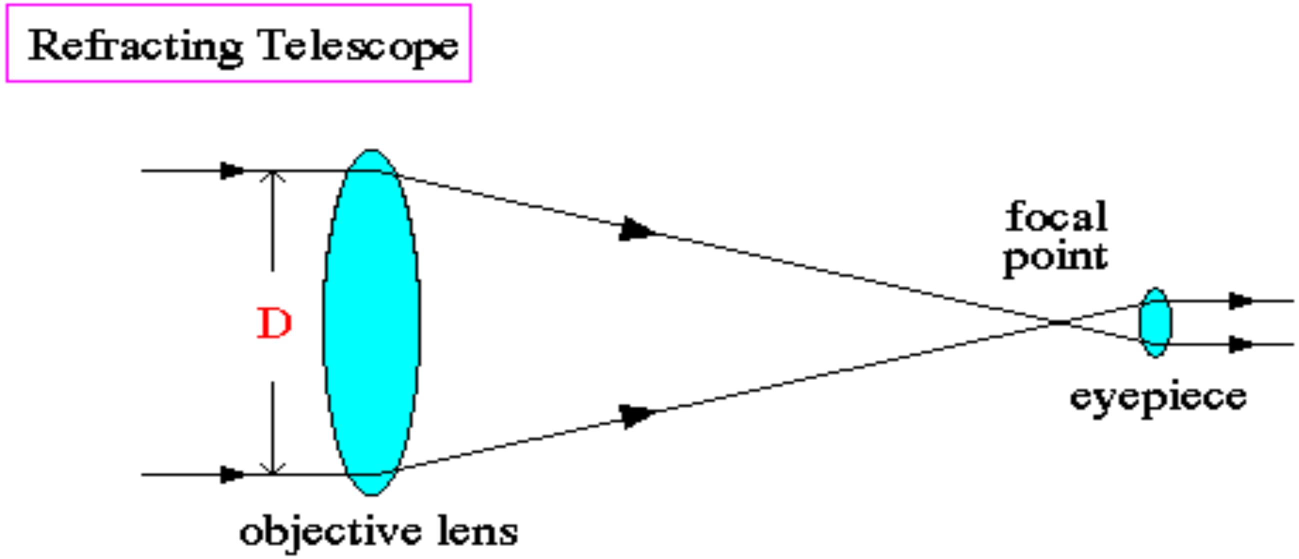


Bigger objective gathers more light: brighter images! Depends on **area** of objective = $(\pi D^2)/4$.

Concave Mirror Focuses Light



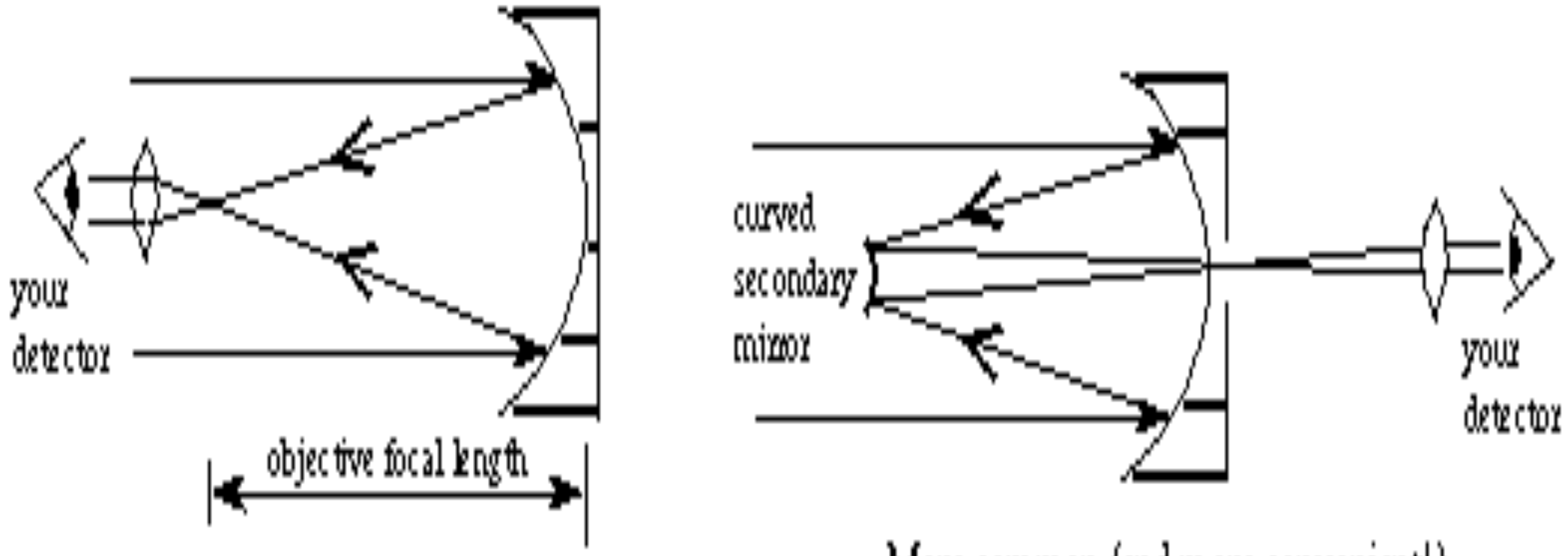
Basic “spyglass” Refractor first type of telescope



The light gathering power of a refracting telescope is given by the diameter of the objective lens, D. The power goes as D^2.

Refracting telescope (lens)

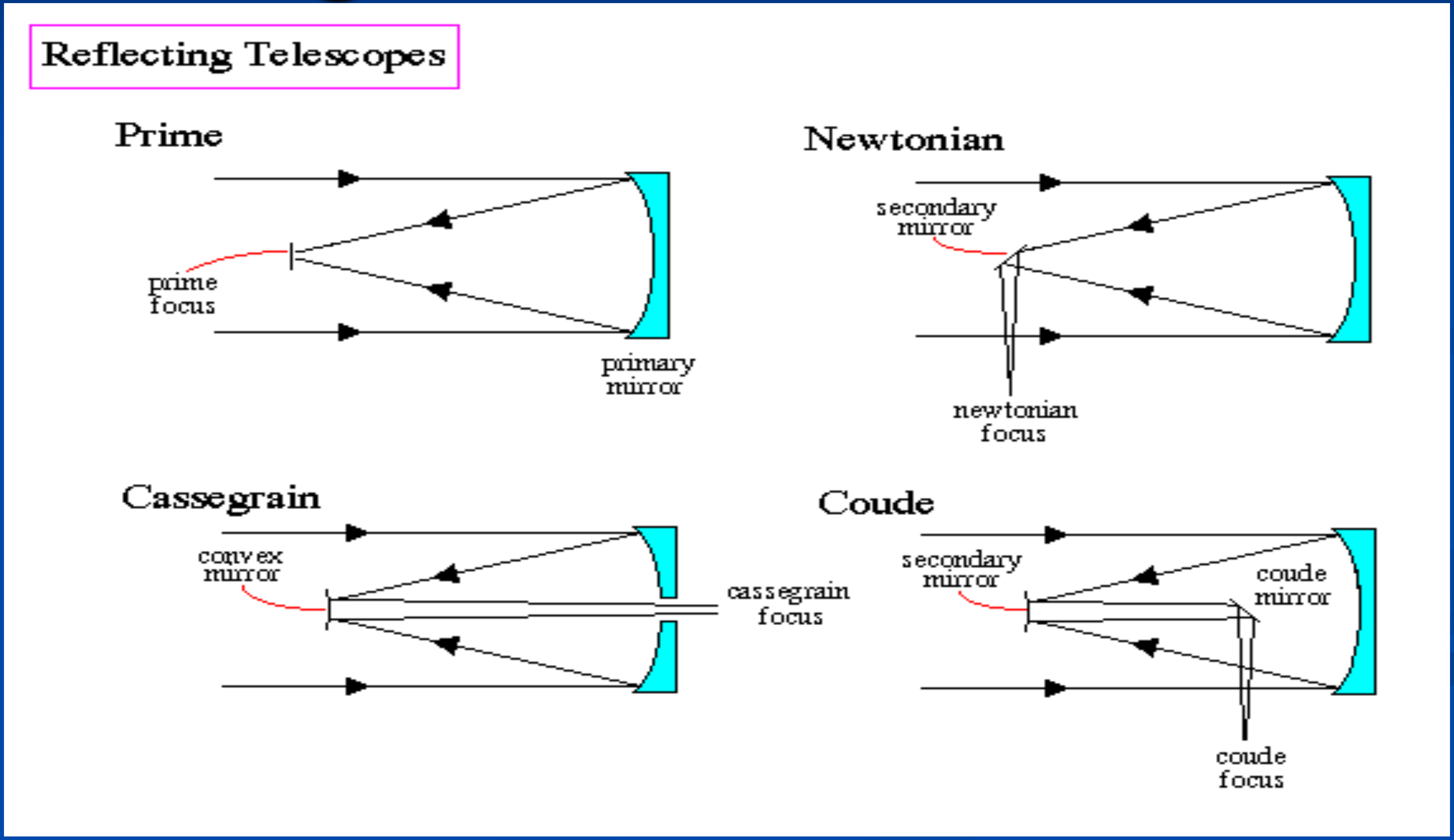
Newton invents Reflector: PRIMARY MIRROR collects, focuses light



Simplest design—Prime focus
(Why isn't there a shadow cast
by the observer on the image?)

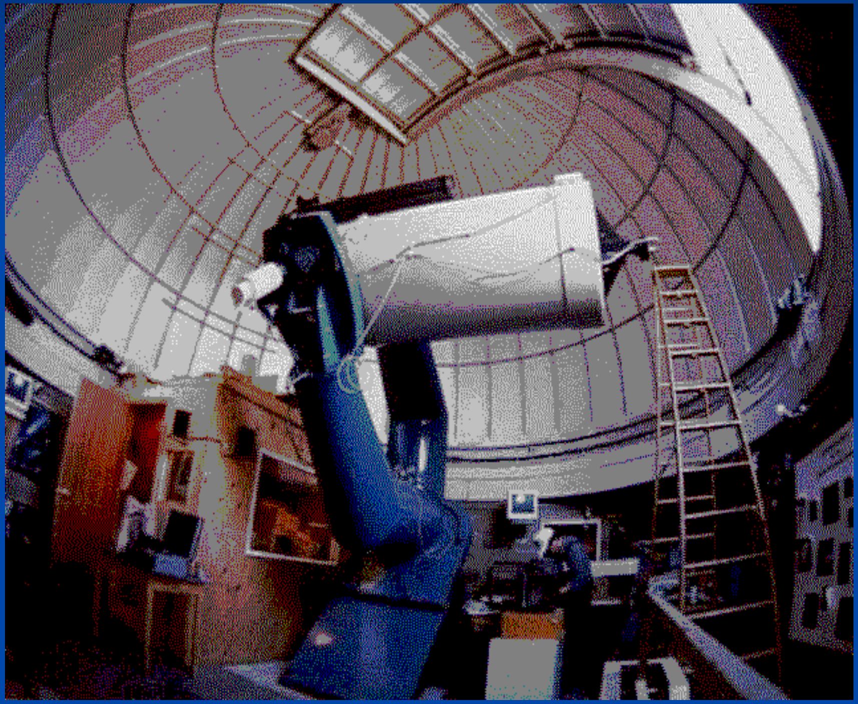
More common (and more convenient!)
Cassegrain design. Hole in
mirror—why doesn't that affect image?

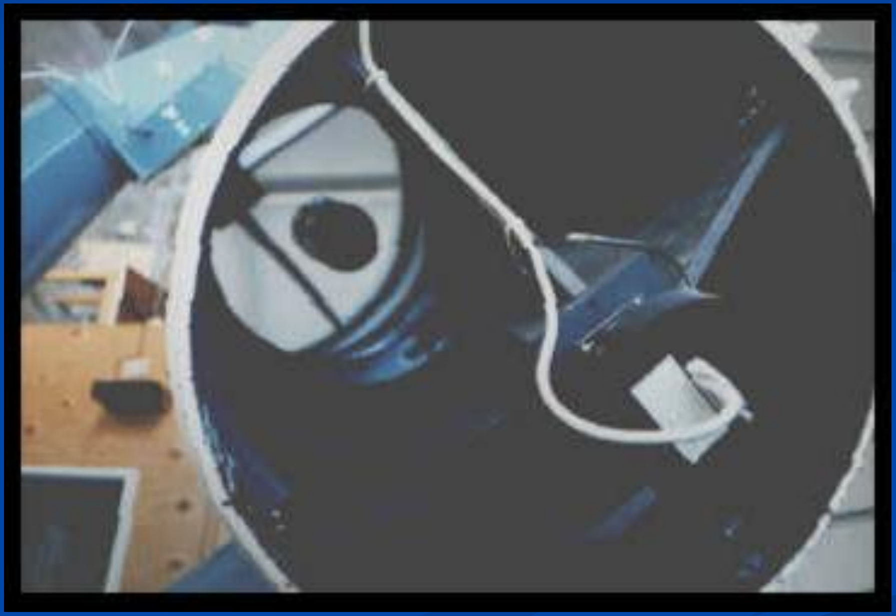
Getting the Image out of the incoming light path – adding SECONDARY MIRROR



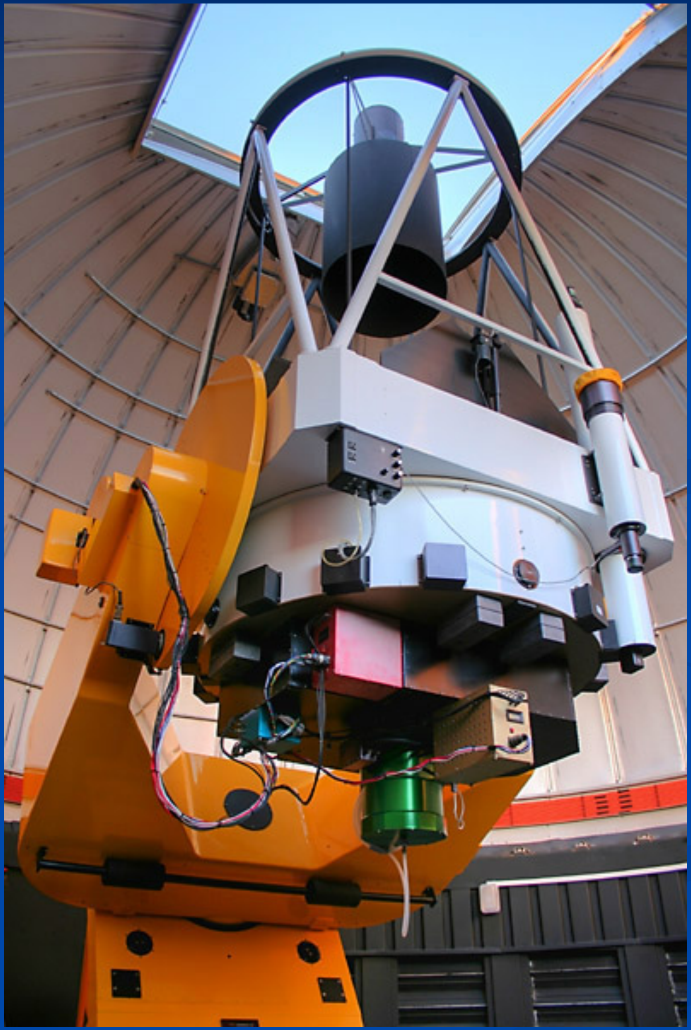
Newtonian Reflecting telescope (mirror) on Dobsonian mount

32" mirror diameter research scope

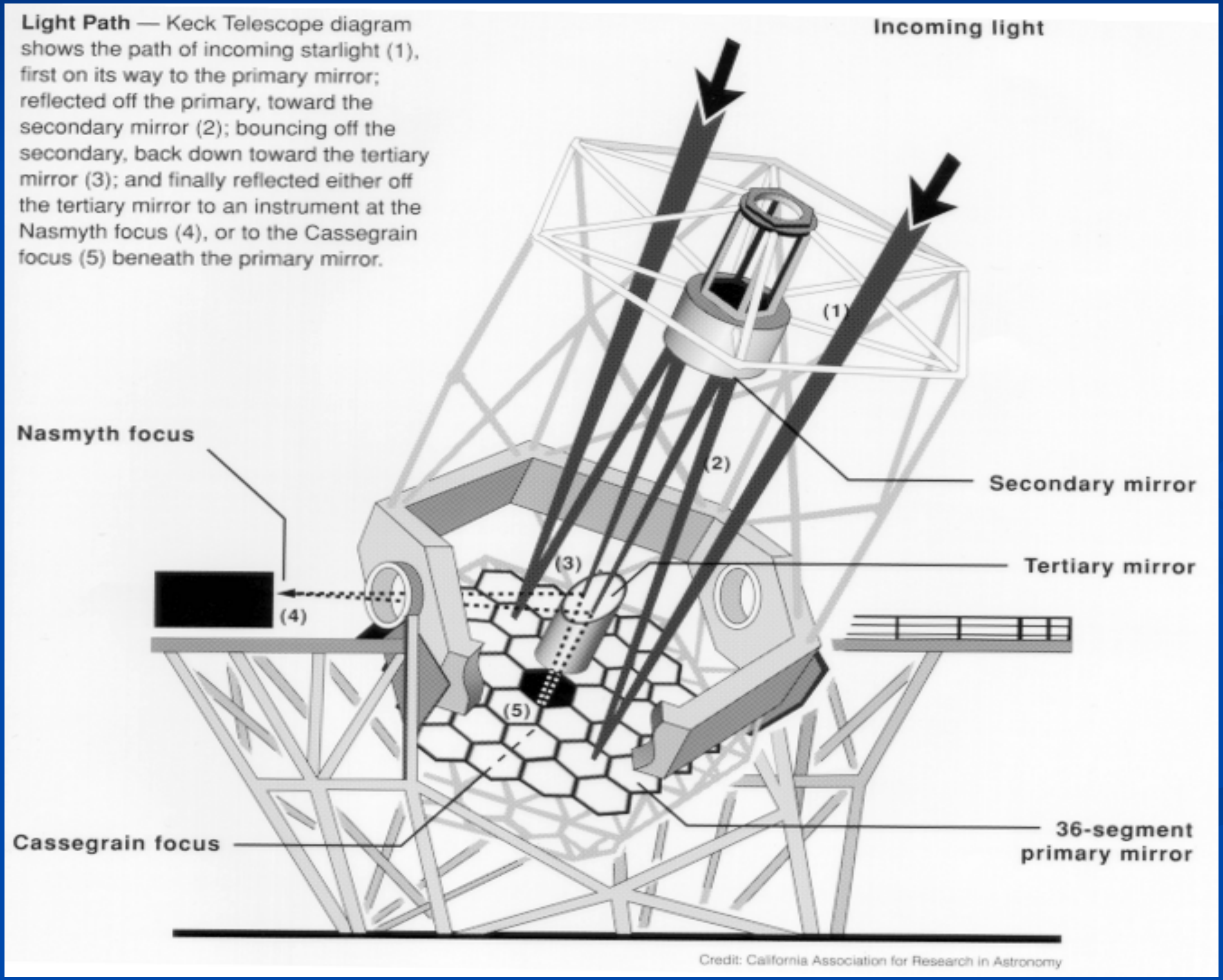




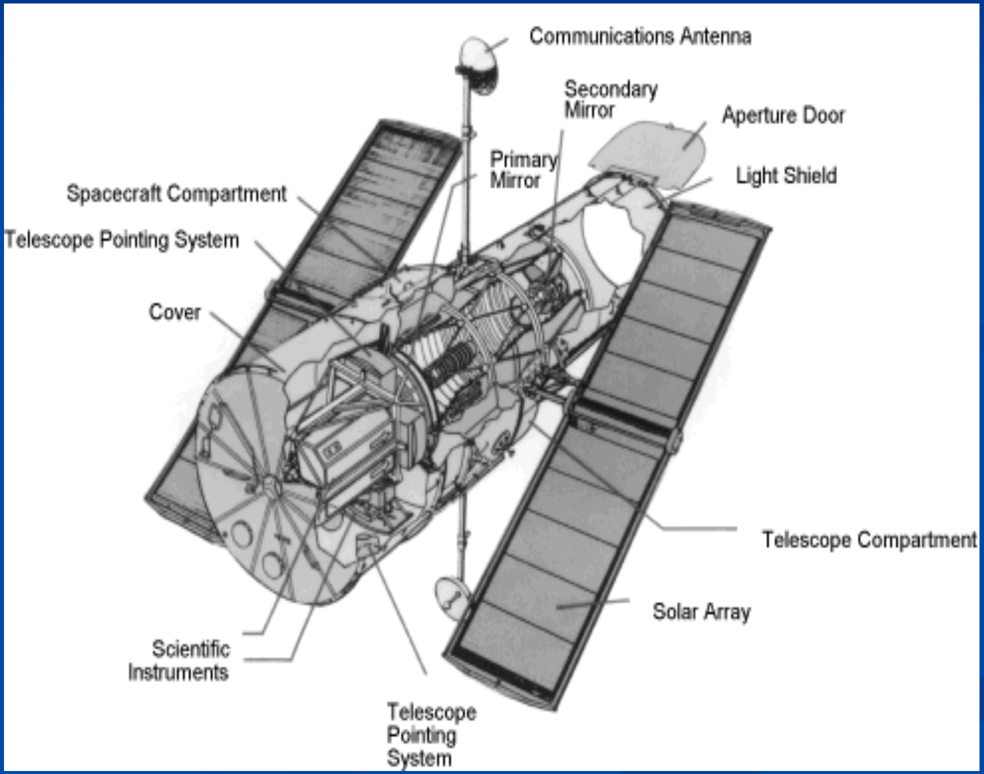
large Cassegrain reflecting telescope on Equatorial mount



World's currently largest working telescope: Keck twins atop Mauna Kea in Hawaii- MULTIPLE MIRRORS



World's "best" telescope: Hubble Space Telescope orbiting above atmosphere



What else could we do to gather more photons?

What else could we do to gather more photons?

- Think of a SPONGE placed out in the rain…
- How about a PHOTON SPONGE?

The Charge Coupled Device (CCD) CAMERA!

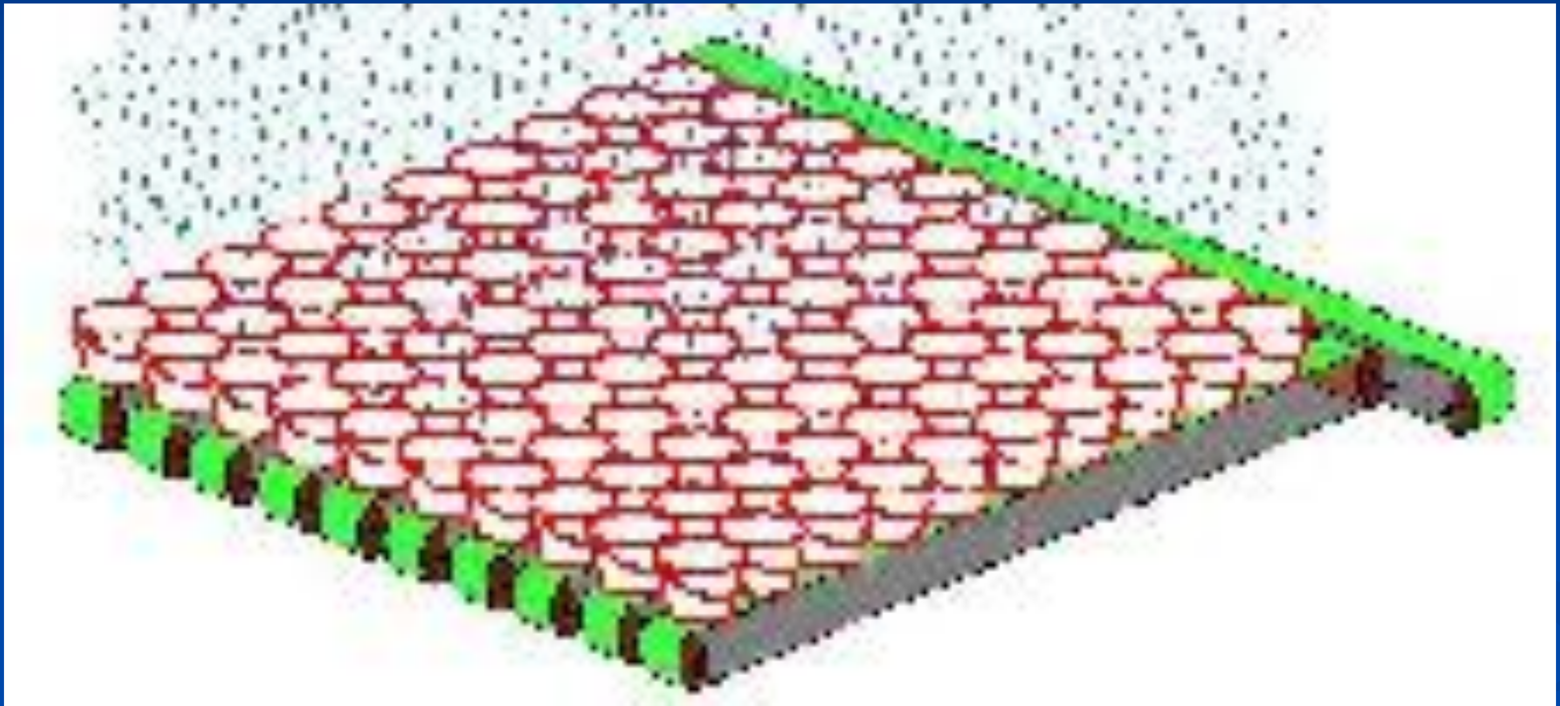
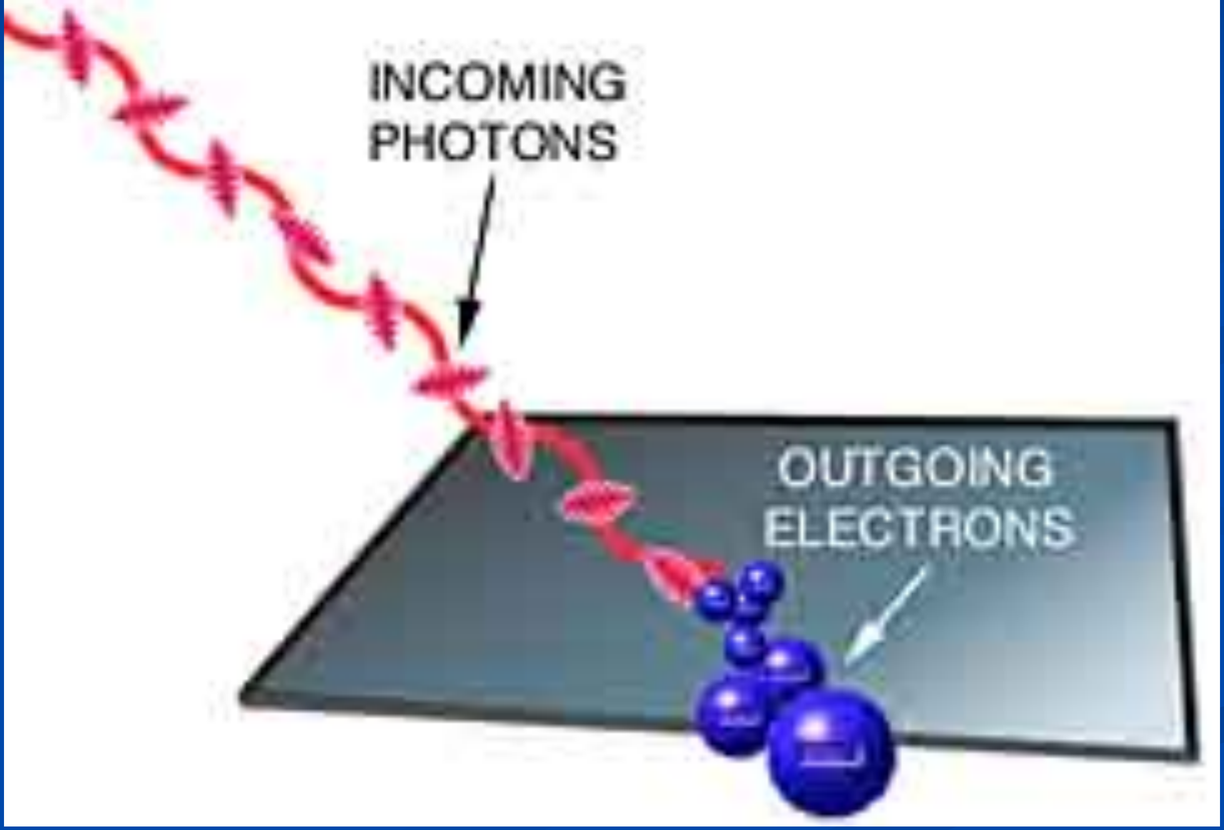
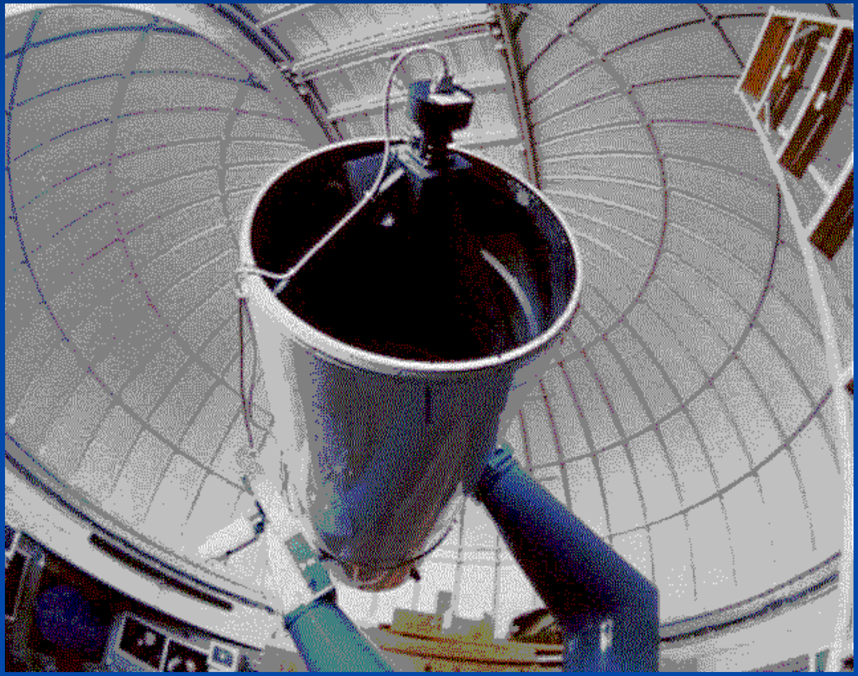


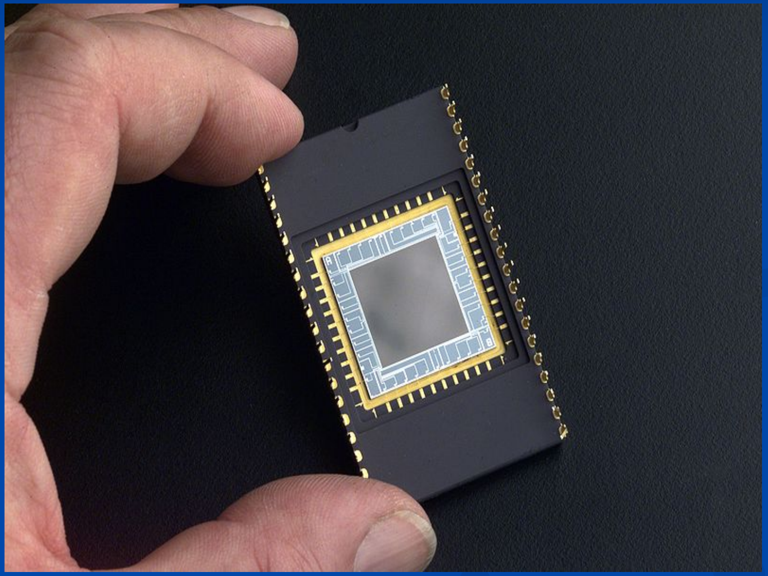
Photo-Electric Effect: incoming PHOTONS energize ELECTRONS.

The CHARGE COUPLED DEVICE accumulates the incoming photons as ELECTRIC CHARGES



CCD Camera mounted to 32" telescope at PMO, a 2048x2048 array CCD



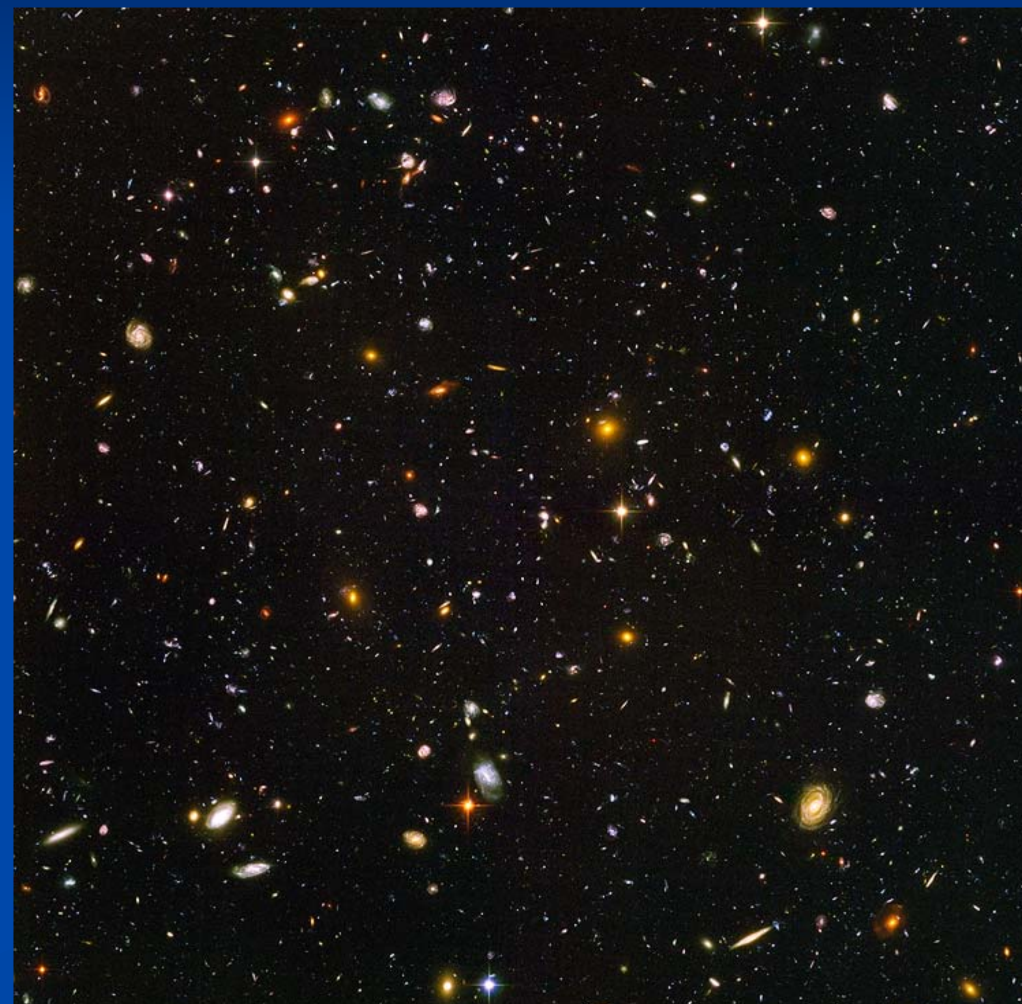


CCD Technology soaks up all the light and lets us measure it.

- Due to efficiency of Photo-Electric physics, we can DETECT faint distant objects!

- Due to the X-Y Grid, we can readily measure POSITION/DISPLACEMENT.
- Due to Pixelized data, we can accurately measure NUMBER OF PHOTONS THAT ARRIVED from each part of image.
- DIGITAL IMAGE can be readily stored, sent, further analyzed.

What DIFFERENCES do you OBSERVE at various locations in both of these?



DIFFERENCES/CHANGES in

1. Shape/Size/Distribution/Geometry/Position-Coordinates
2. Colors
3. Brightness

That's ALL we can actually OBSERVE!

The "raw data" DOESN'T directly tell us about the physical nature of object!

CORRELATIONS (matching) to PHYSICAL FEATURES

- a. POSITIONS correlate to
- b. COLORS correlate to
- c. BRIGHTNESS correlates to

CORRELATIONS (matching) to PHYSICAL FEATURES

- a. **POSITIONS** correlate to
  Location, Velocity, Mass, Diameter,
  Volume, Density, Comp, State, Age
- b. **COLORS** correlate to
  Composition, Temp, Velocity, Age
- c. **BRIGHTNESS** correlates to
  Distance, Temp, Diameter

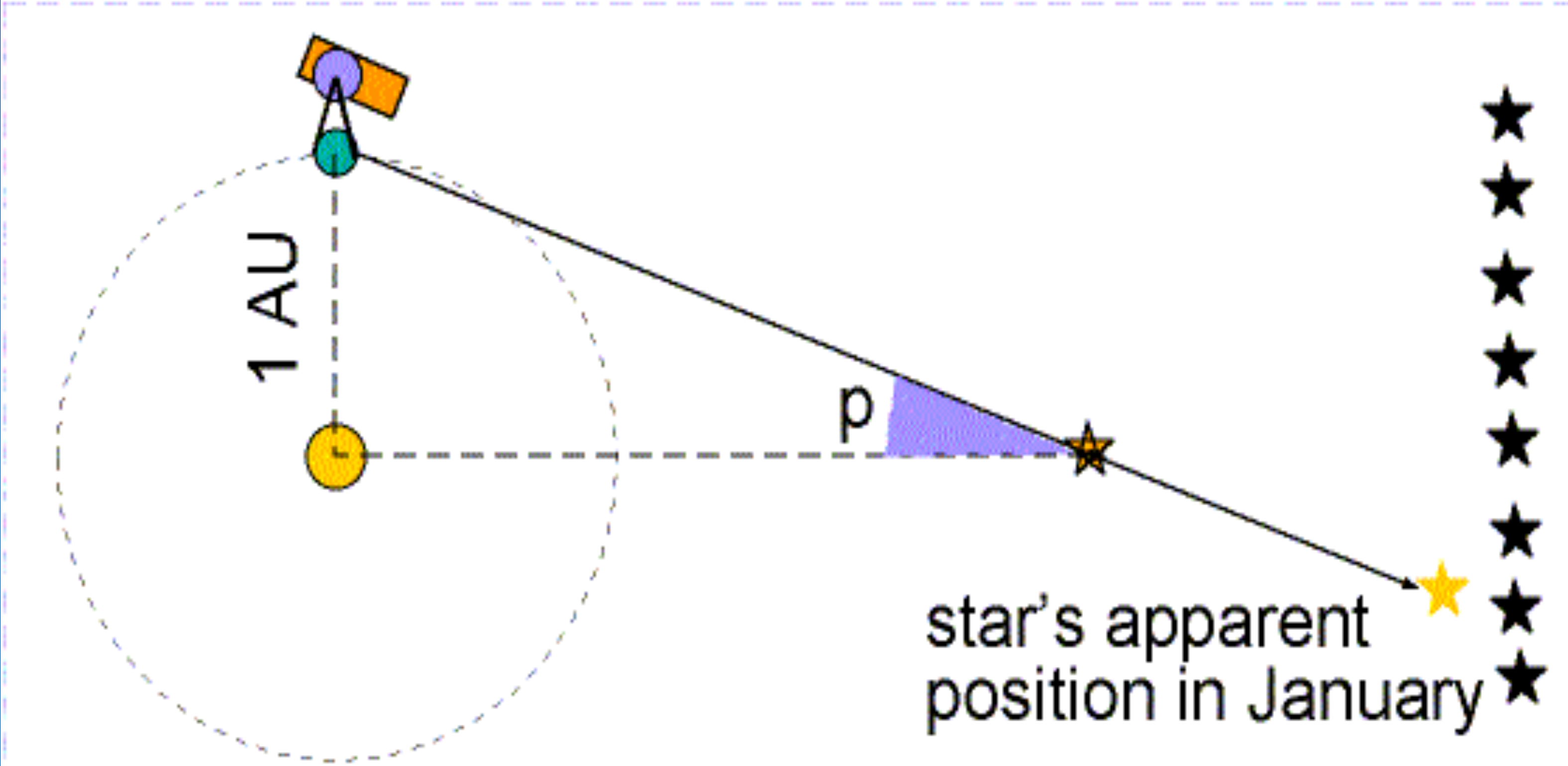
THAT's the HOW WE KNOW WHAT WE KNOW!

Examples of Data/ Measurements/Analysis

1. Parallax Shift to measure DISTANCE
2. Photometry to measure DISTANCE
3. Combining Photometry, Astrometry, and Spectroscopy to measure SIZE of a Star
4. More Spectroscopy

How FAR are objects in Deep Space?

- Let’s try a little PARALLAX SHIFT measuring…



Stellar parallaxes need largest possible baseline

“Fixed” (apparently stationary) Points and Smudges of Light

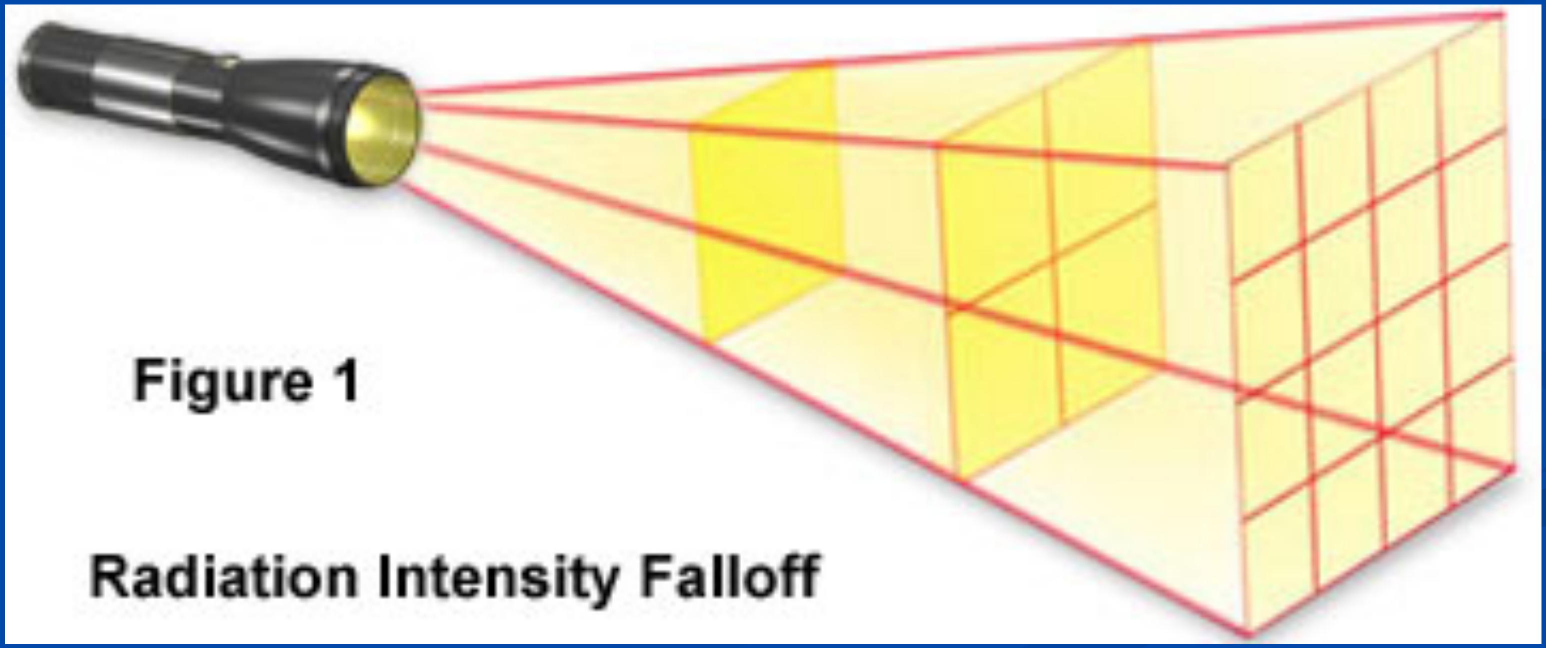
- Tens to Hundreds, to Millions to Billions of LIGHT YEARS AWAY…
- But appear relatively BRIGHT at great distance! Must be HOT and LARGE! Like our SUN…Distant Suns and also places where Suns form (Nebulas), and live (Galaxies)
- ~120,000 year trip to nearest star!

Bright, Wandering dots must be much

- CLOSER to EARTH…
- OBJECTS WITHIN our SOLAR SYSTEM (Light-Hours, not Light-Years away).

Can you think of another way to indirectly measure distance?

Alternative method to measure distances: Photometry: Dimmer=Farther, “INVERSE SQUARE LAW”



Consider ANTARES – What is it, how large is it?

Assume we can measure its DISTANCE by angles.

- Antares turns out to be SEVERAL HUNDRED LIGHT YEARS AWAY- (millions of years to travel there!)

- Antares sends us MANY photons – appears BRIGHT yet is far away.

More about Antares:

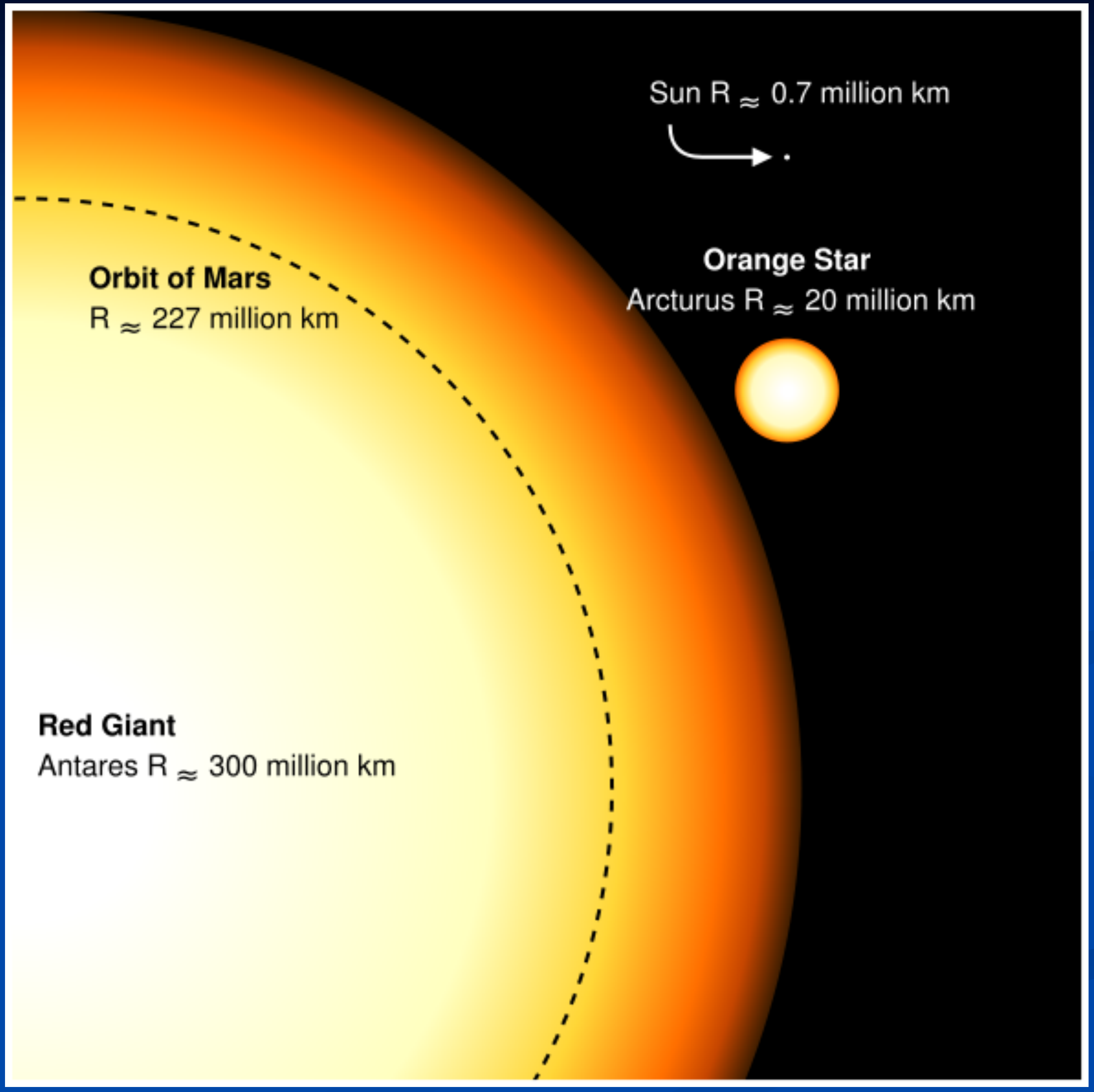
- Antares sends us MANY photons – appears BRIGHT. From far away?
- Must be HOT and LARGE, but what COLOR is ANTARES?

What else can we figure out about Antares?

- Antares sends us MANY photons – appears BRIGHT. From far away?
- Must be HOT and LARGE, but what COLOR is ANTARES?
- RED implies COOL! To appear BRIGHT, Antares must be VERY

Assume we can measure its DISTANCE by angles.

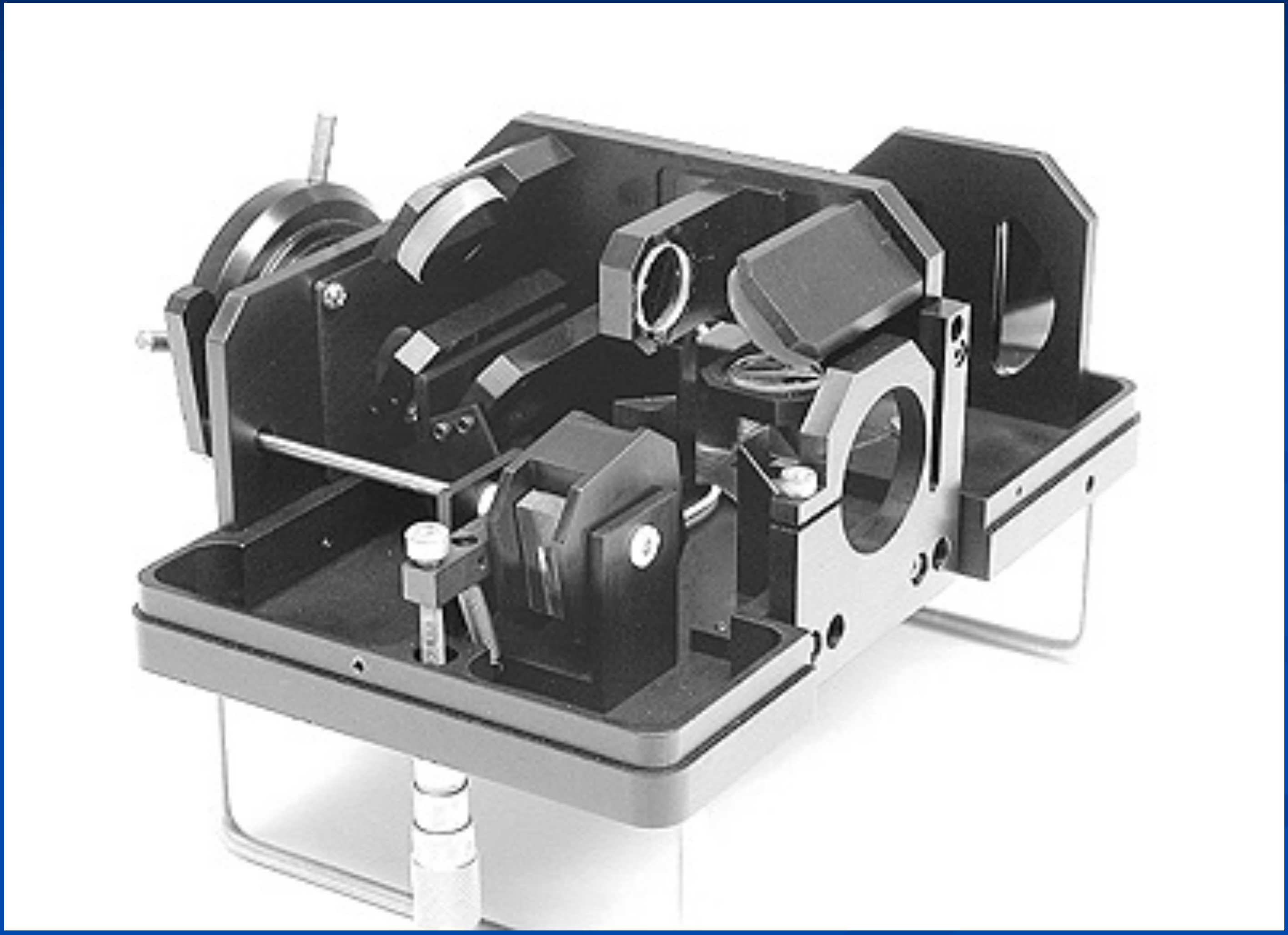
- Antares sends us MANY photons – appears BRIGHT. From far away?
- Must be HOT and LARGE, but what COLOR is ANTARES?
- RED implies COOL! To appear BRIGHT, must be VERY LARGE


Sun R ≈ 0.7 million km
Orange Star
Arcturus R ≈ 20 million km
Orbit of Mars
R ≈ 227 million km
Red Giant
Antares R ≈ 300 million km

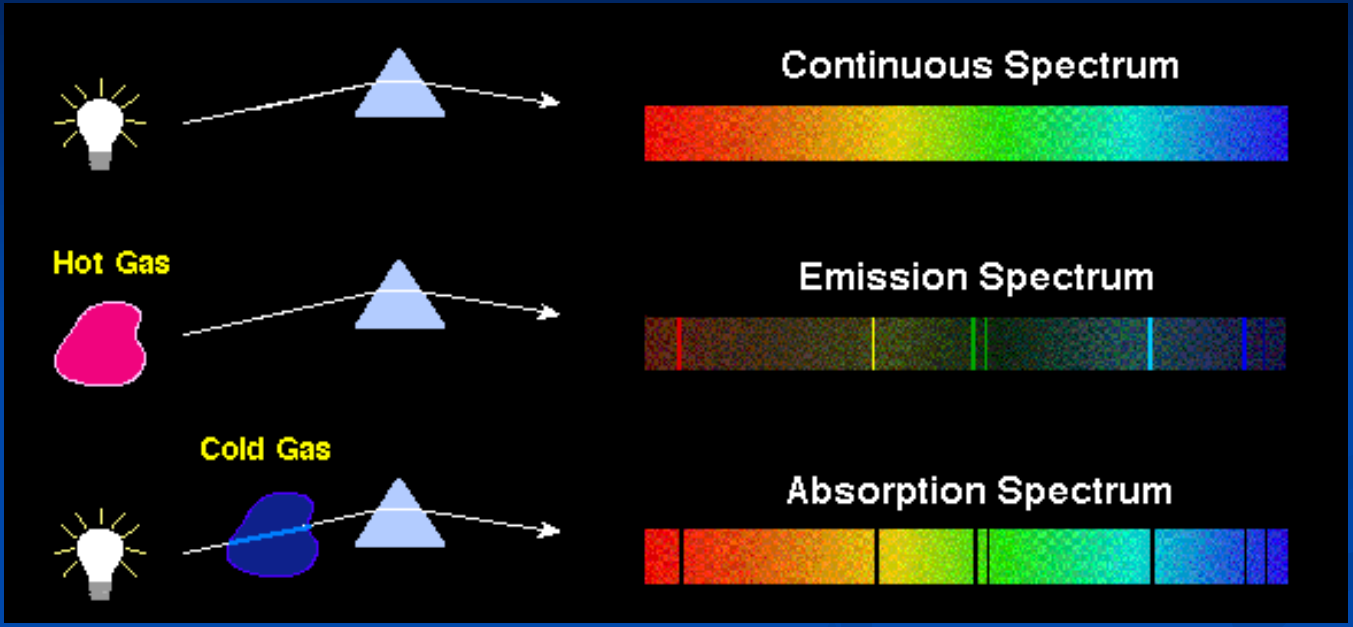
Spectroscopy

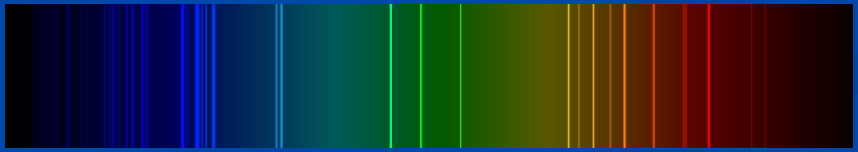
- Analyzing the ENERGY (COLOR) of the PHOTONS
- Light is split into colors by a GRATING or a PRISM (Spectrometer)

Spectrometer – between telescope and camera



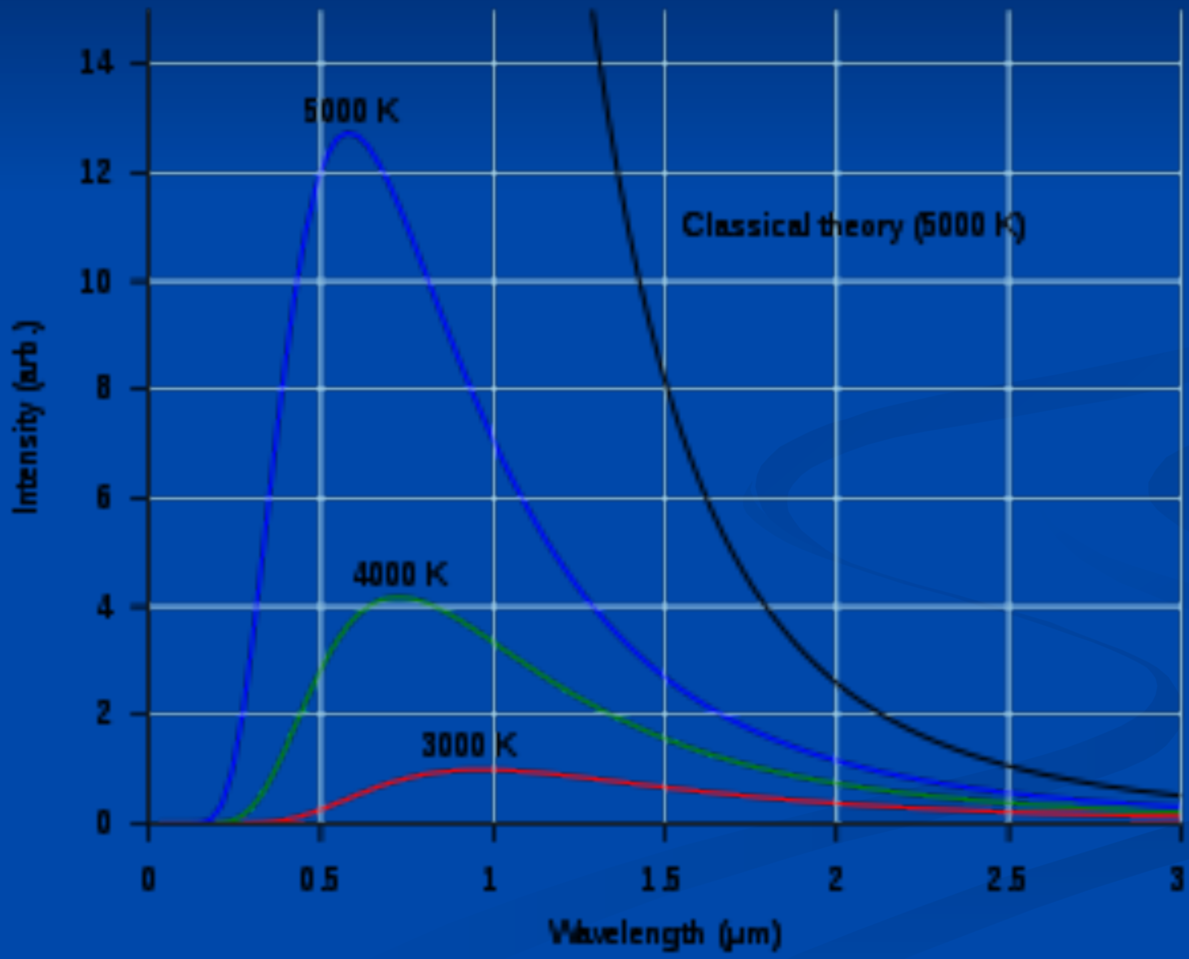
Spectra – H vs. O - lines reveal chemicals, temperature, velocity.





What does COLOR tell us? (Hot vs. Cold objects)

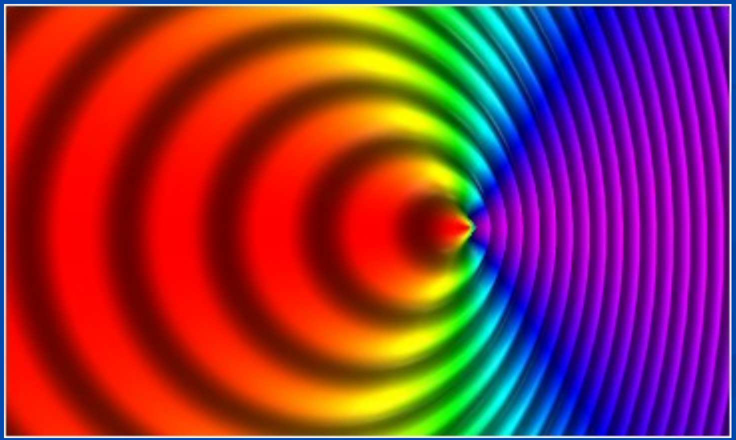
Color of HOT objects depends on Temperature.



Why do cold objects like PLANETS come in different colors?

Doppler Shift: object moving away shows “Red Shift”, moving toward observer shows “Blue Shift” –

Shift ~ Velocity and in case of Galaxies, ~ Distance!



Stuff we can’t see:

- Black Holes…they swallow all their light!
- Dark Nebulas…they don’t reflect nor emit light! They also block light from behind them!
- Very distant and/or very small objects…not enough photons get to us. (Andromeda Galaxy is about 2 million light years away, farthest object visible to your unaided eye.)

Please ask questions, there are lots of questions!

- We don’t know if there’s other life out there…very likely due to chemistry and number of planets.
- We don’t know size of our Universe nor where we are within.
- We don’t know how nor why our Universe began nor how it will end, it’s SOOOO BIG!