How We DISCOVER and CHARACTERIZE Very Distant Objects and Phenomena that are in Deep Space

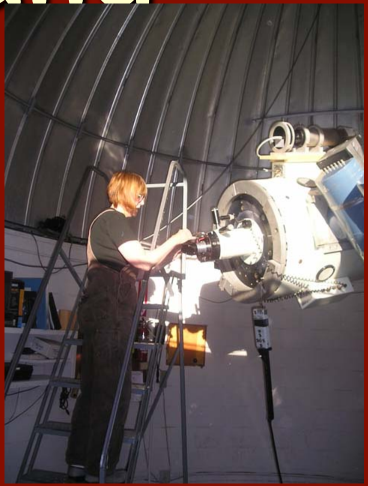
A program by Rick Kang

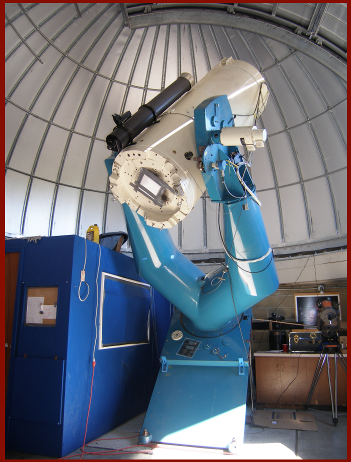
Who’s Rick Kang?

1. Education/Public Outreach Presenter – Oregon Astrophysics Outreach – I visit dozens of classes/year, all around Oregon, Kindergarten through University levels. info at http://oregonsky.org/

2. I collaborate with UO’s Pine Mountain Observatory east of Bend, I’ve been a Tour-Guide there. You can visit Fri/Sat evenings, June-Sept. http://pmo.uoregon.edu

Visit Pine Mountain near Bend Fri/Sat evenings, June-Sept. Great Camping and Sky Viewing!





Word of the day: CHARACTERIZE

- **Definition:**

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- Definition: Measure and determine (figure out) PHYSICAL PROPERTIES (Characteristics)
- Examples of PHYSICAL PROPERTIES:

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- Examples of PHYSICAL PROPERTIES:

1. Dimensions
2. Velocity
3. Composition
4. Temperature
5. Luminosity
6. Mass

How did ancient EXPLORERS characterize foreign lands?

Columbus lands in New World

How did ancient EXPLORERS characterize foreign lands?

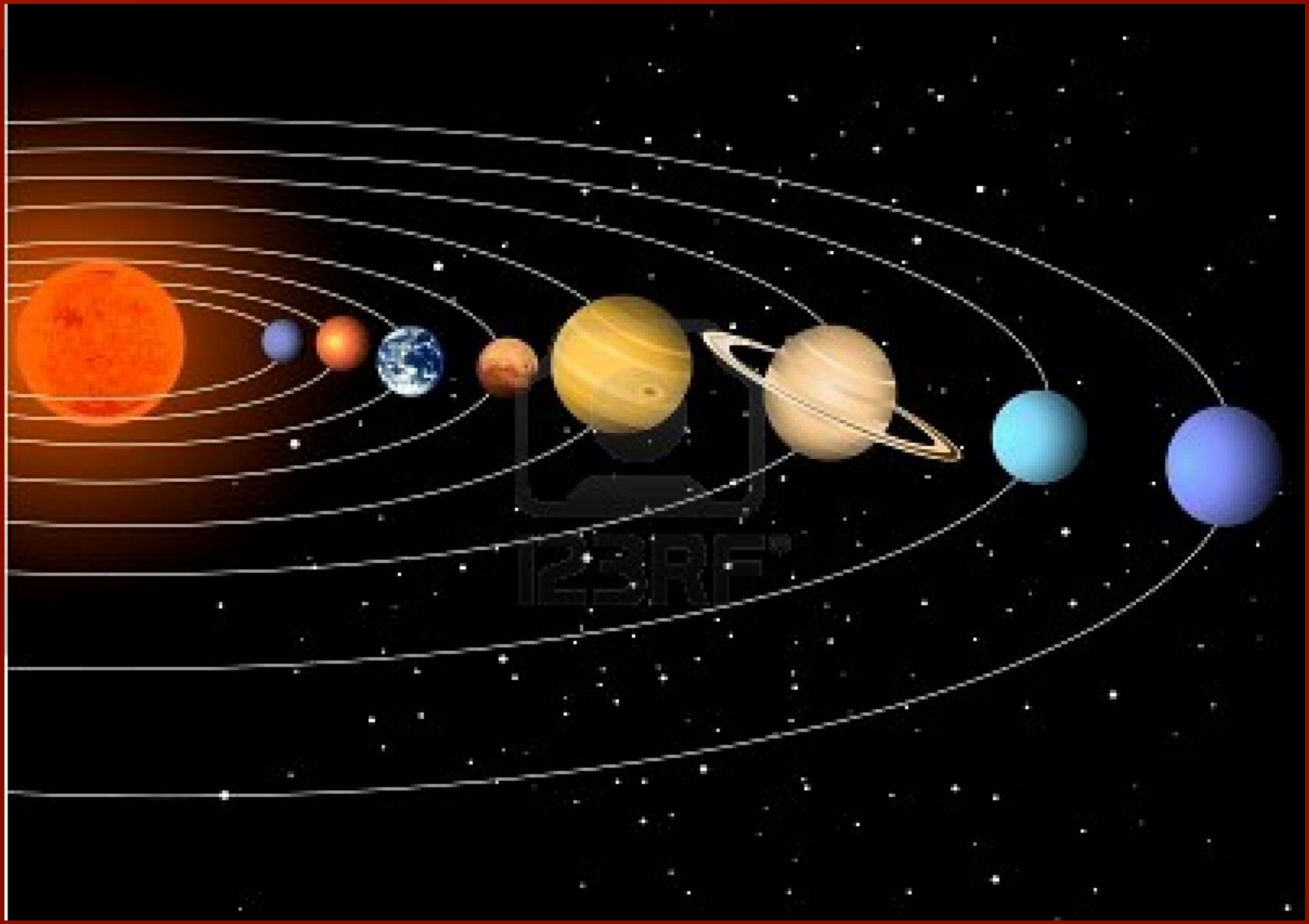
- Often the explorers VISITED those places, traveling great distances in elaborate expeditions.
- Sometimes a representative from a foreign place would arrive at a palace, bringing gifts from and information about their homeland.
- Why don't these methods work very well for objects in Deep Space?

HUGE DISTANCES!

- Even within our Solar System, travel times (at 20,000 MPH)

  to Moon, Mars, Saturn, Pluto are:

Our Solar System (not to scale!)



Current Travel Times

- Earth to Moon: 3 days one way
- Earth to Mars: 6 months one way
- Earth to Saturn: 7 years one way
- Earth to Kuiper Belt/Pluto: 15 years one way – how old would you be when you return from Pluto, if you launch from Earth today?
- VEHICLES TO USE FOR THE TRIP?

UN-MANNED for now! Consider supplies needed if manned.

- Spacecraft: a vehicle that carries the INSTRUMENTS and SENSORS that will gather the data
- Launch vehicle, a ROCKET, to transport the PAYLOAD (Spacecraft) to its destination – why not an airplane?
- Space is empty, a vacuum, no air, need a way to move rapidly to destination

How does a ROCKET work?

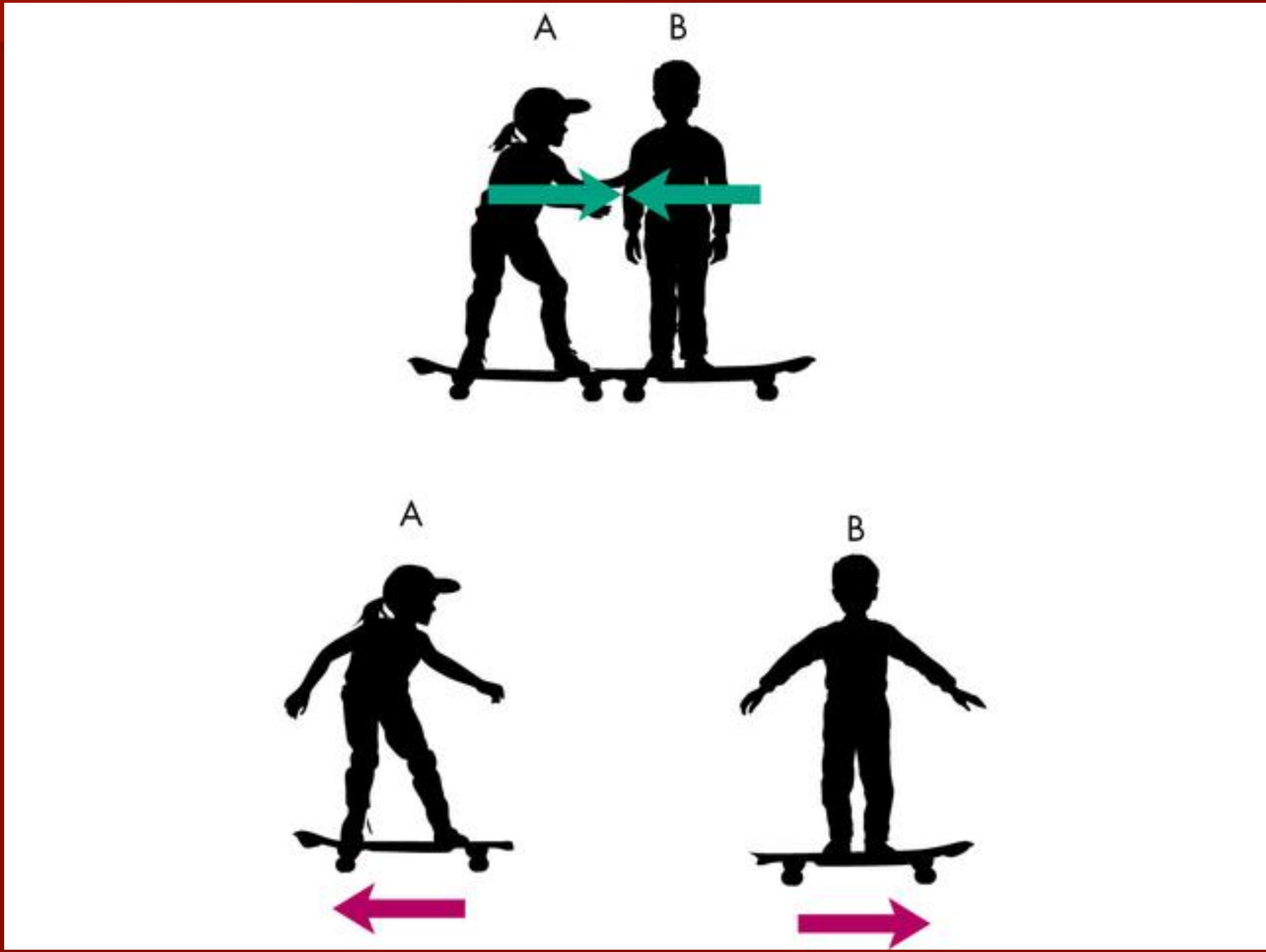
- Fuel burns (combines with oxygen) to create THRUST
- At the launch pad, the THRUST blasts downward, pushing against the pad, forcing the rocket upward – try this with your hand and arm.
- But, once launched, there's nothing solid to push against, now what do we do?

How does a ROCKET work after launch (when in space)?

- Let’s do some experiments with a skateboard ROCKET and a firelog for fuel.
- What could you do with the firelog to make your skateboard move (you’re not allowed to actually push against anything, but you can move or get rid of the firelog).

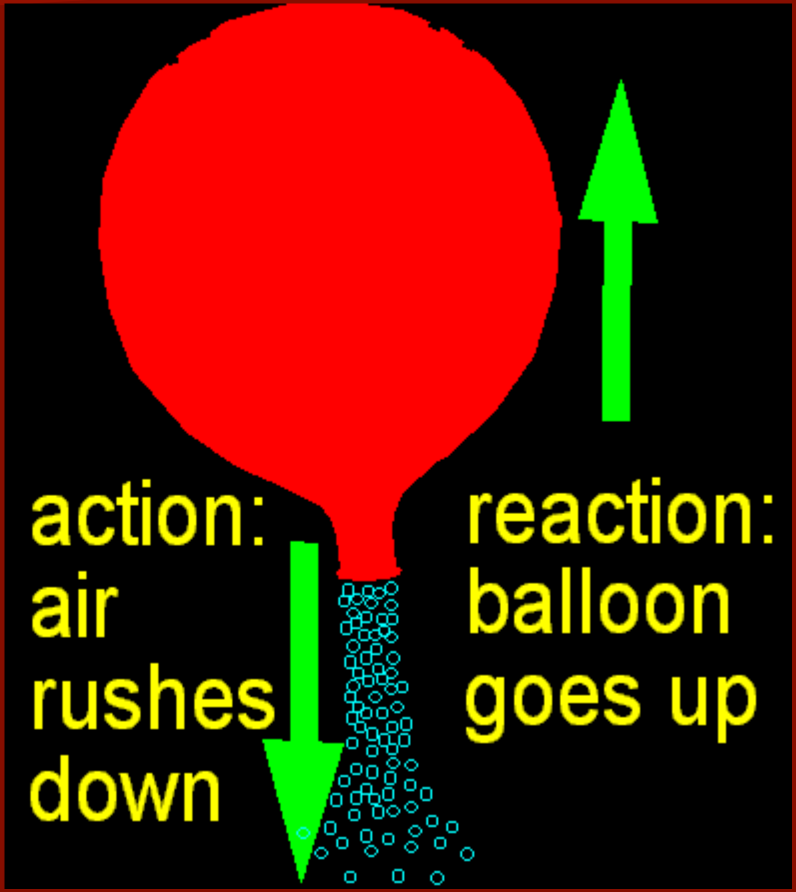
Isaac Newton's Third Law:

For every action there is…a reaction.



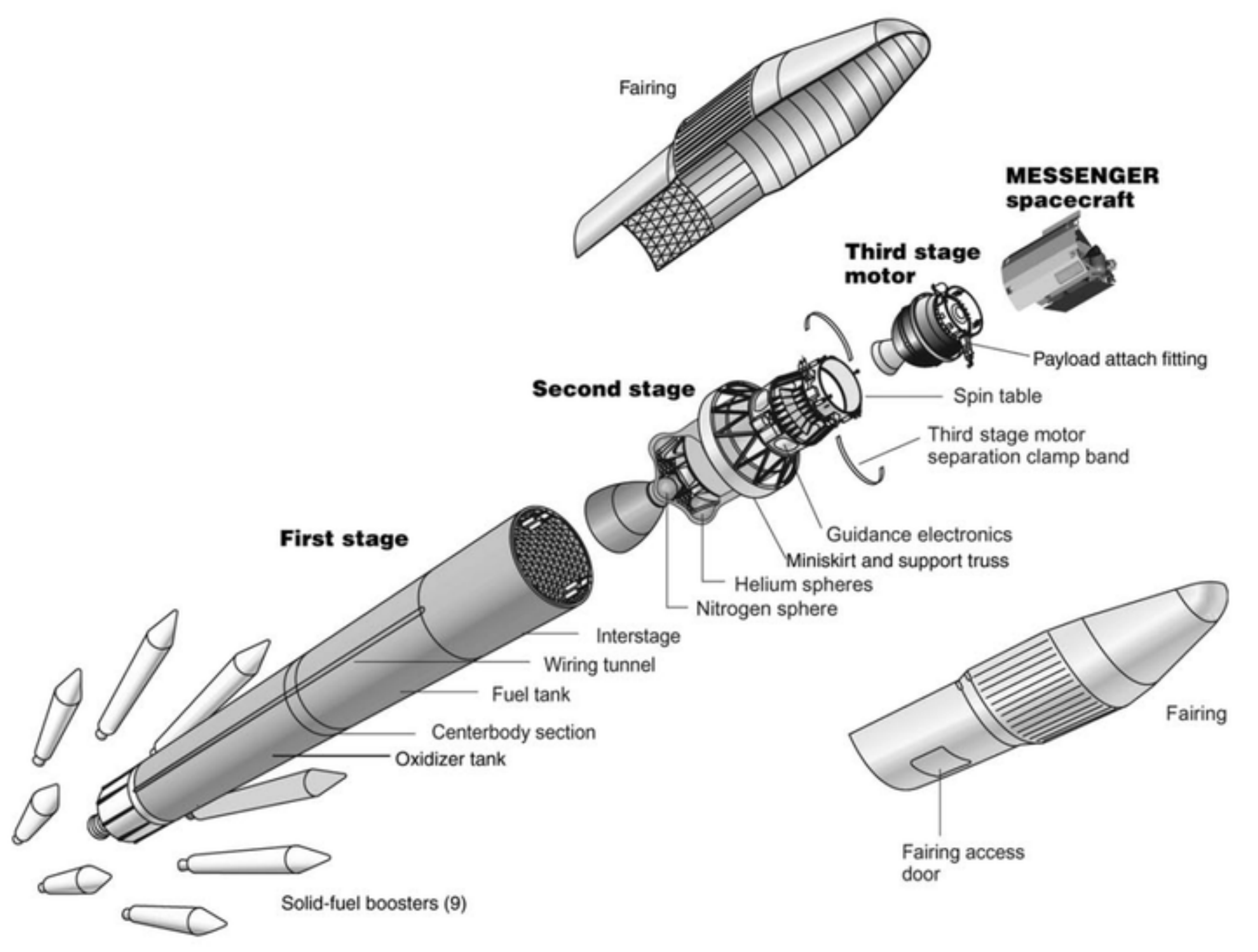
The Exhaust (Thrust) of the Rocket Engine blasts mass in one direction causing the Rocket to travel in the OPPOSITE direction, as Newton predicted.

Balloon Rocket



Rocket Launch at pad and in flight

Faring protects Payload, with Stages of Rocket form “Stack”



Delta II rocket with MESSENGER

Nature of Mission – simplest, least expensive, to most complex and costly:

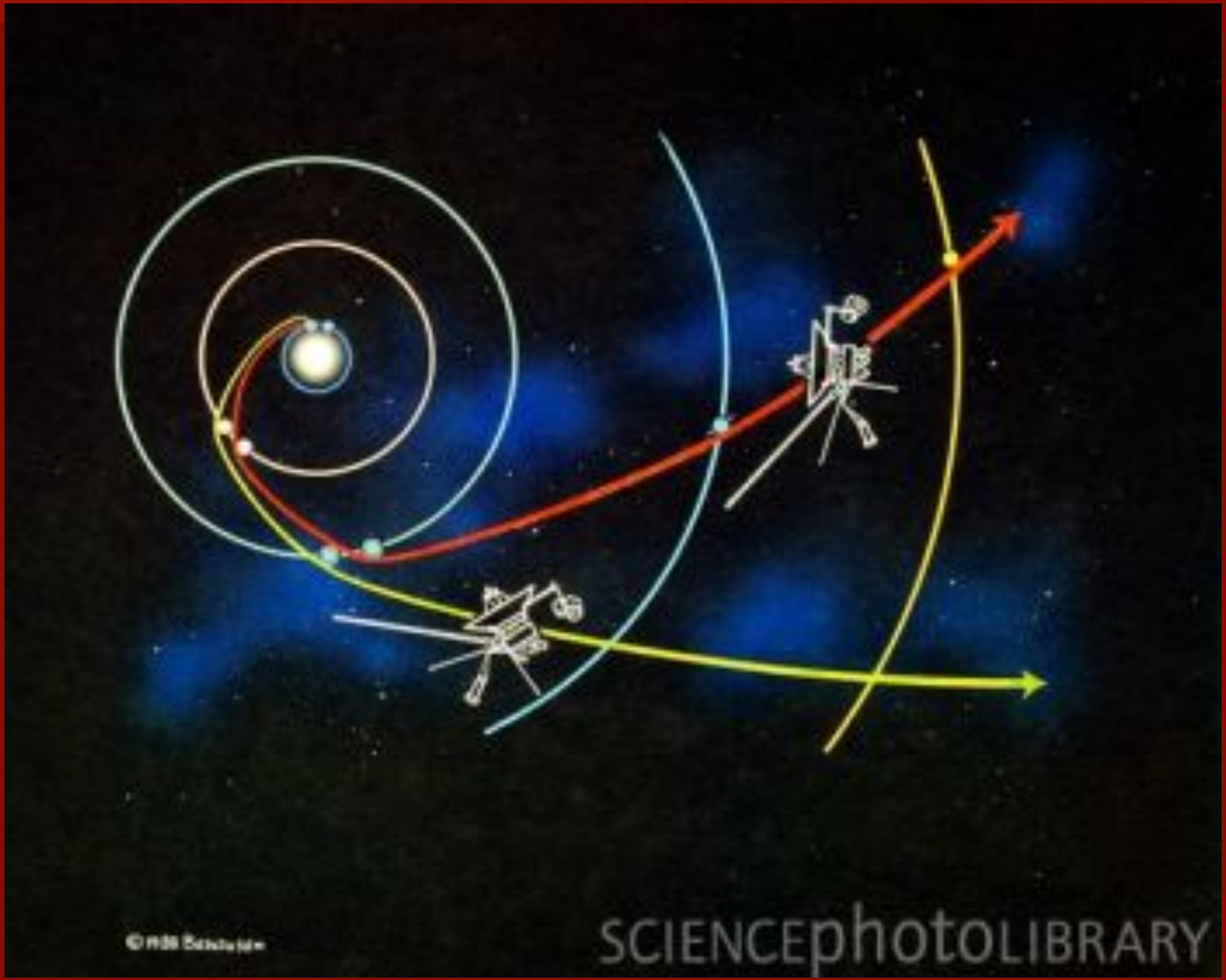
1. Fly-By – few minutes to gather data.

   Ex:

   Voyager flew by Uranus and Neptune

   New Horizons to fly by Pluto in 2015

Trajectories (flight paths) of Voyager 1 and Voyager 2



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2. Orbiter – survey, repeat many times.

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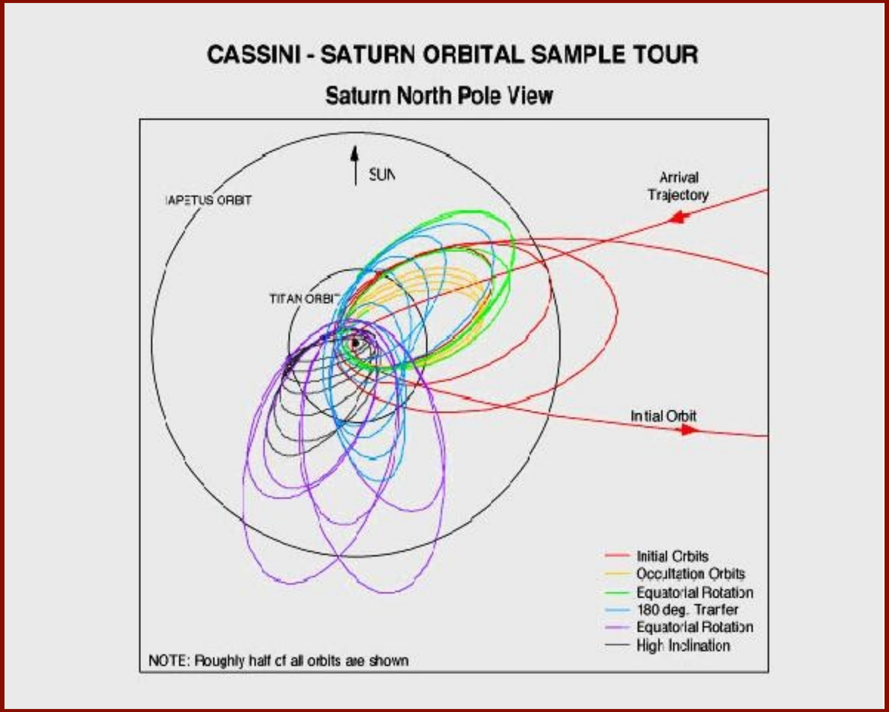
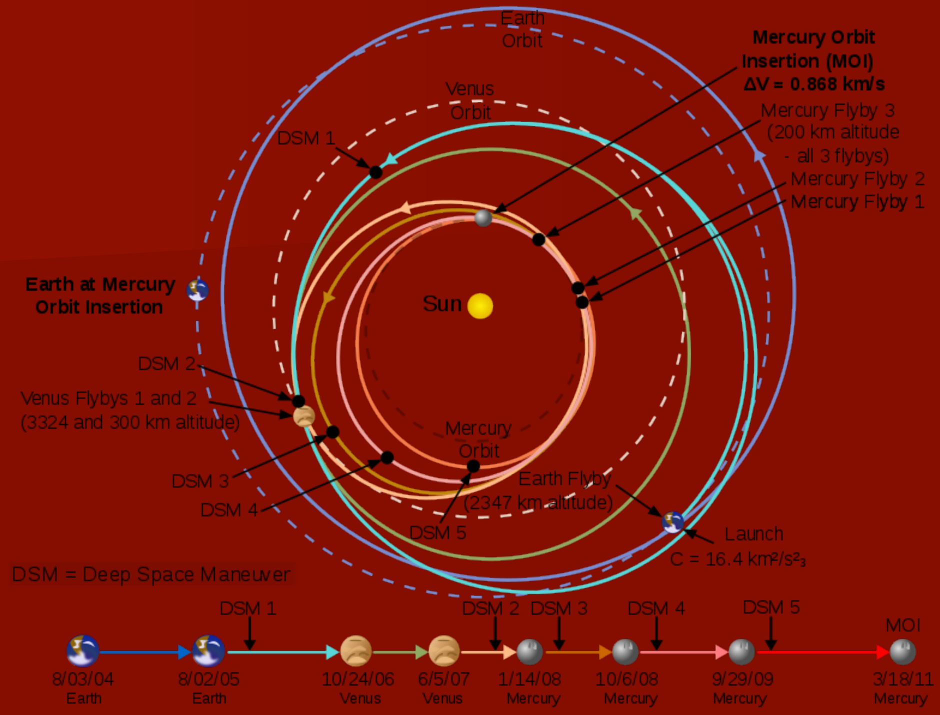
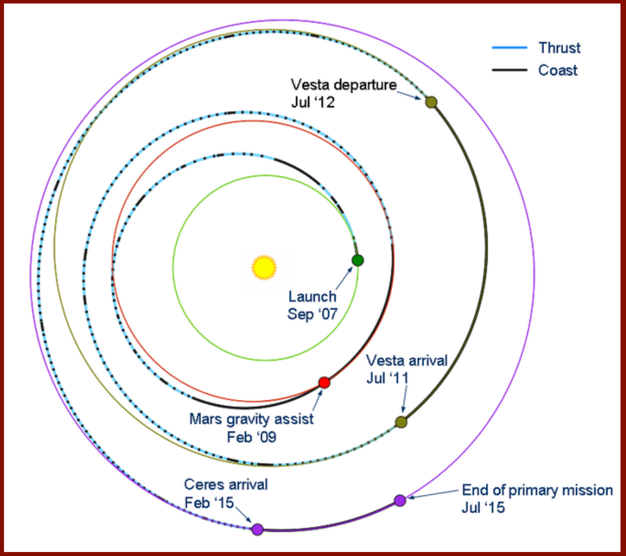
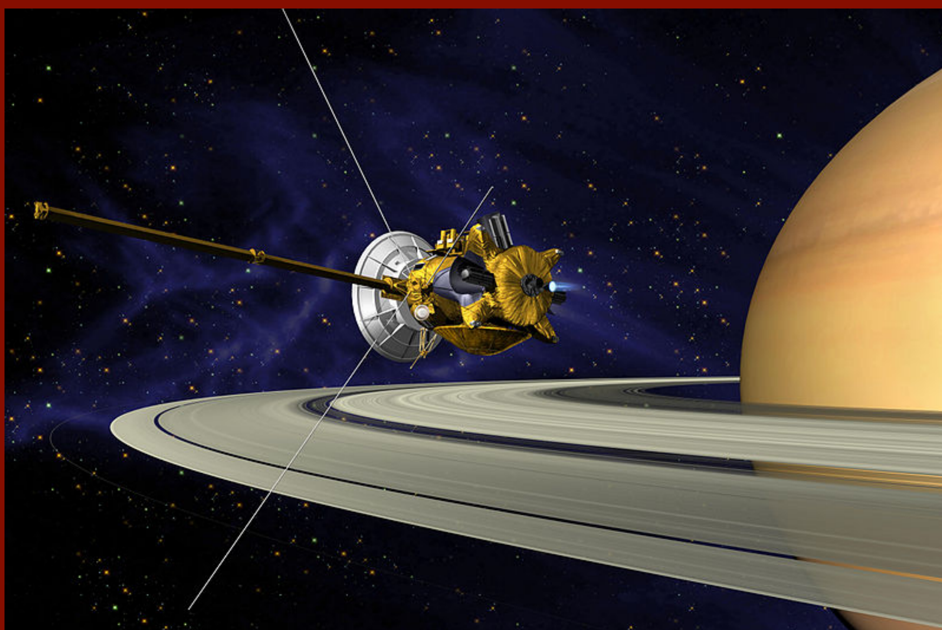
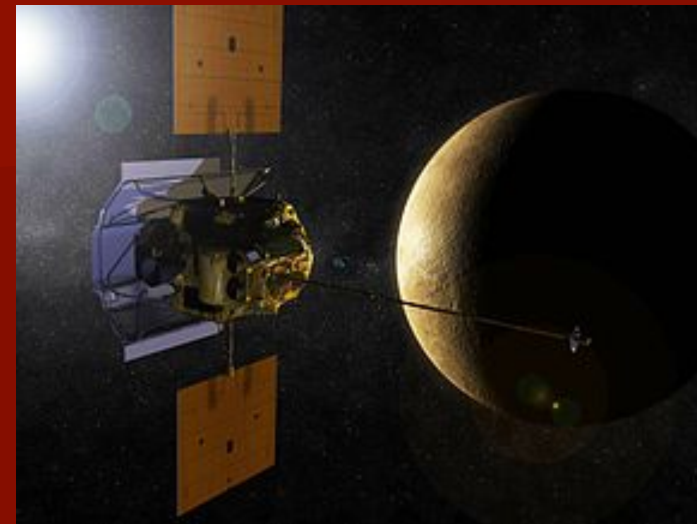

CASSINI - SATURN ORBITAL SAMPLE TOUR
Saturn North Pole View
SUN
IAPETUS ORBIT
Arrival Trajectory
TITAN ORBIT
Initial Orbit
Initial Orbits
Occultation Orbits
Equatorial Rotation
180 deg. Transfer
Equatorial Rotation
High Inclination
NOTE: Roughly half of all orbits are shown


Earth Orbit
Venus Orbit
Mercury Orbit Insertion (MOI) ΔV = 0.868 km/s
Mercury Flyby 3 (200 km altitude - all 3 flybys)
Mercury Flyby 2
Mercury Flyby 1
DSM 1
Earth at Mercury Orbit Insertion
Sun
DSM 2
Venus Flybys 1 and 2 (3324 and 300 km altitude)
DSM 3
DSM 4
DSM 5
Mercury Orbit
Earth Flyby (2347 km altitude)
Launch
C = 16.4 km²/s²₃
DSM = Deep Space Maneuver
DSM 1
DSM 2
DSM 3
DSM 4
DSM 5
MOI
8/03/04 Earth
8/02/05 Earth
10/24/06 Venus
6/5/07 Venus
1/14/08 Mercury
10/6/08 Mercury
9/29/09 Mercury
3/18/11 Mercury


Thrust
Coast
Vesta departure Jul '12
Launch Sep '07
Vesta arrival Jul '11
Mars gravity assist Feb '09
Ceres arrival Feb '15
End of primary mission Jul '15





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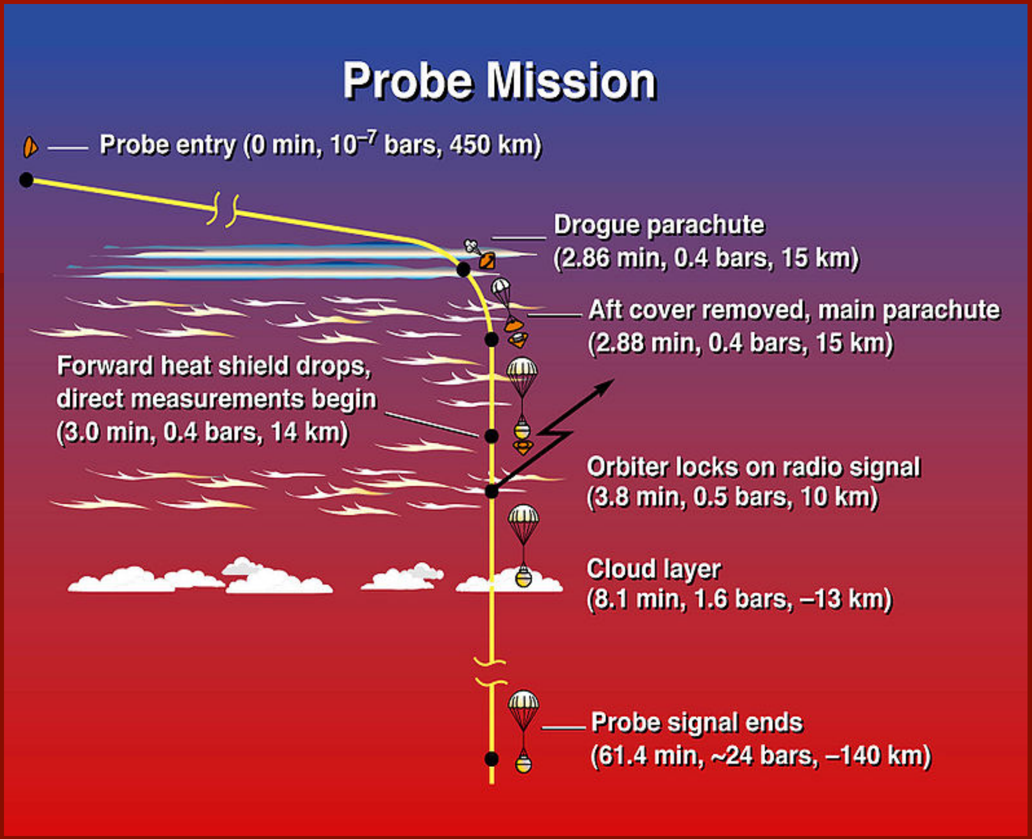
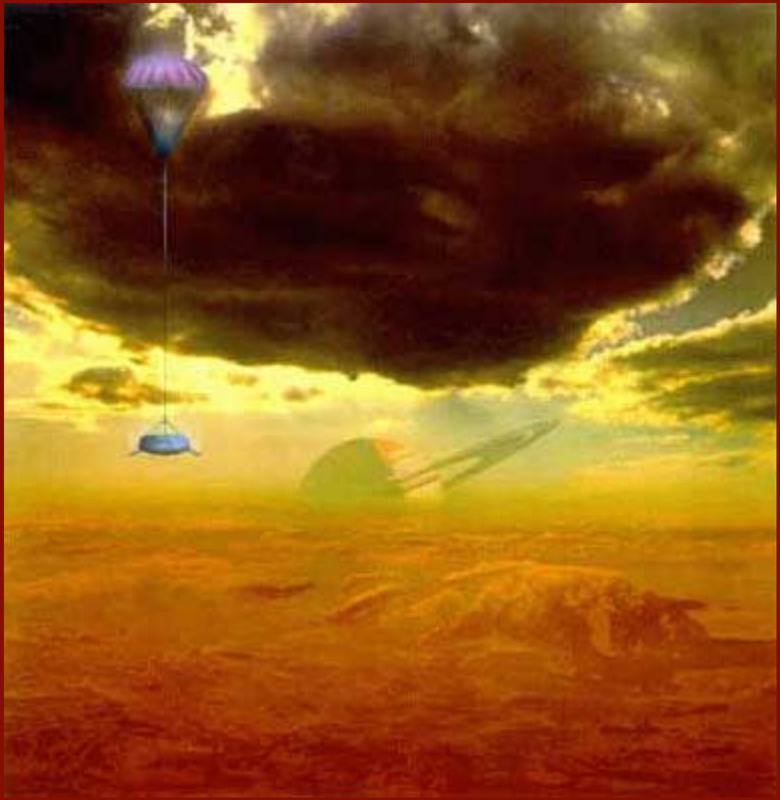
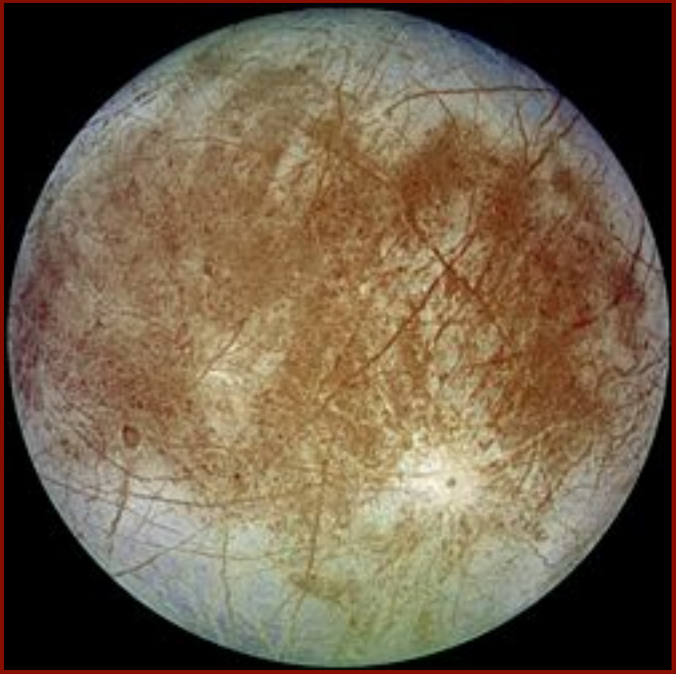
3. Probe – drops through atmosphere

Ex: Galileo at Jupiter, Huygens at Titan


Probe Mission
Probe entry (0 min, 10⁻⁷ bars, 450 km)
Drogue parachute
(2.86 min, 0.4 bars, 15 km)
Aft cover removed, main parachute
(2.88 min, 0.4 bars, 15 km)
Forward heat shield drops,
direct measurements begin
(3.0 min, 0.4 bars, 14 km)
Orbiter locks on radio signal
(3.8 min, 0.5 bars, 10 km)
Cloud layer
(8.1 min, 1.6 bars, –13 km)
Probe signal ends
(61.4 min, ~24 bars, –140 km)



Jupiter's moon, Europa, appears to have ice covered salty ocean…land, drill, sail??? HYDROBOT plan



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Ex: Galileo at Jupiter, Huygens at Titan, Europa

4. Lander/Rover – soft lands, can travel

Ex: Mars Exploration Rovers, Phoenix Lander, Curiosity Mars Science Lab

Phoenix lander imaged by MRO and lands on real ice

“sky crane” to lower MSL

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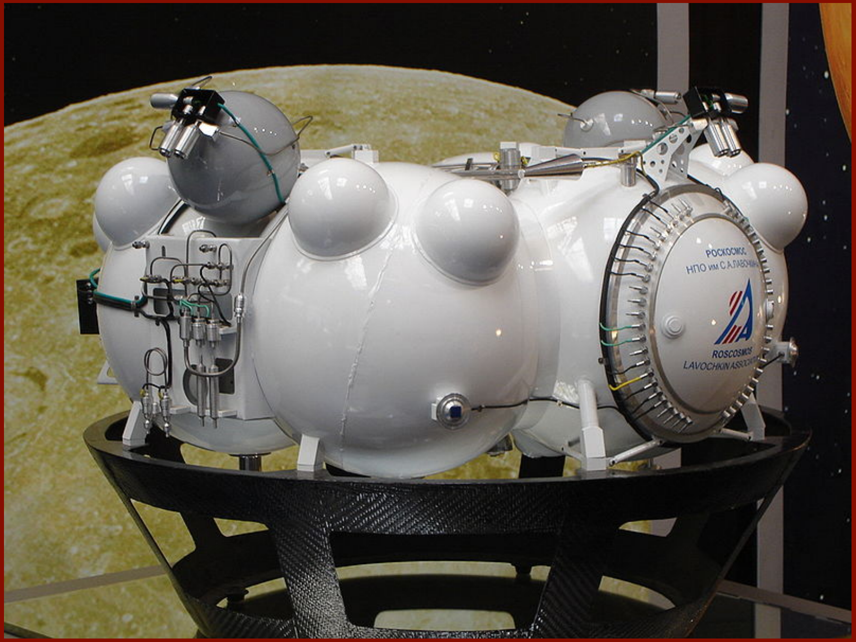
5. Sample Return – Ex: ill fated Phobos-Grunt mission

Martian moon, PHOBOS, and Russian Grunt (Ground) spacecraft



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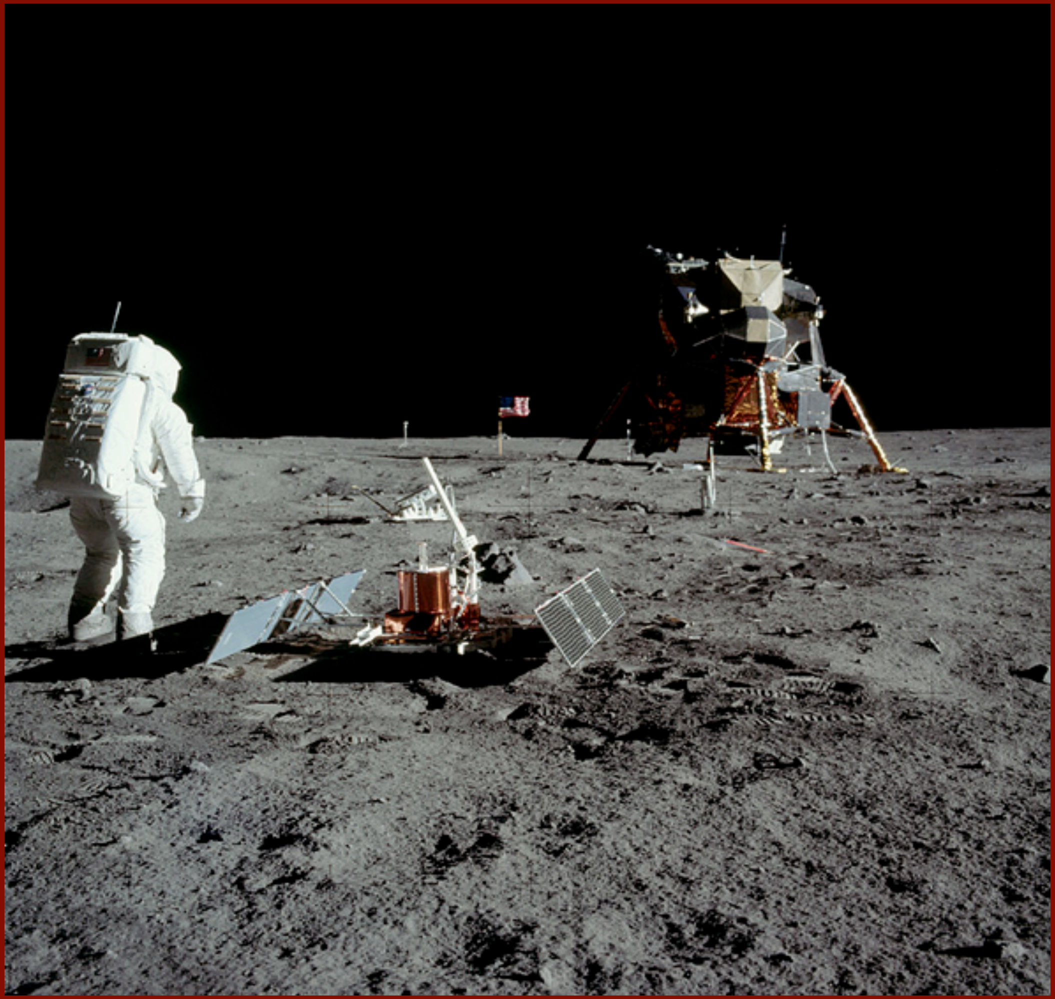
Ex: Mars Exploration Rovers, Phoenix Lander,

Curiosity Mars Science Lab, Europa Ice Drill & Hydrobot

5. Sample Return – Ex: ill fated Phobos-Grunt mission
6. If location is safe, perhaps we can send Astronauts

U.S. Apollo Missions to Moon the only manned flights that left Earth’s realm, so far



Lots of opportunities for current students to:

- Pursue a career as an Astronaut
- Pursue a career as a Planetary Geologist, (or Stellar Physicist, or Cosmologist.)
- Pursue a career as an Engineer working on Manned or Unmanned Spacecraft Systems, including Launch Vehicles,

  instrumentation, navigation, control, communications.

What about BEYOND the Solar System, how do we explore?

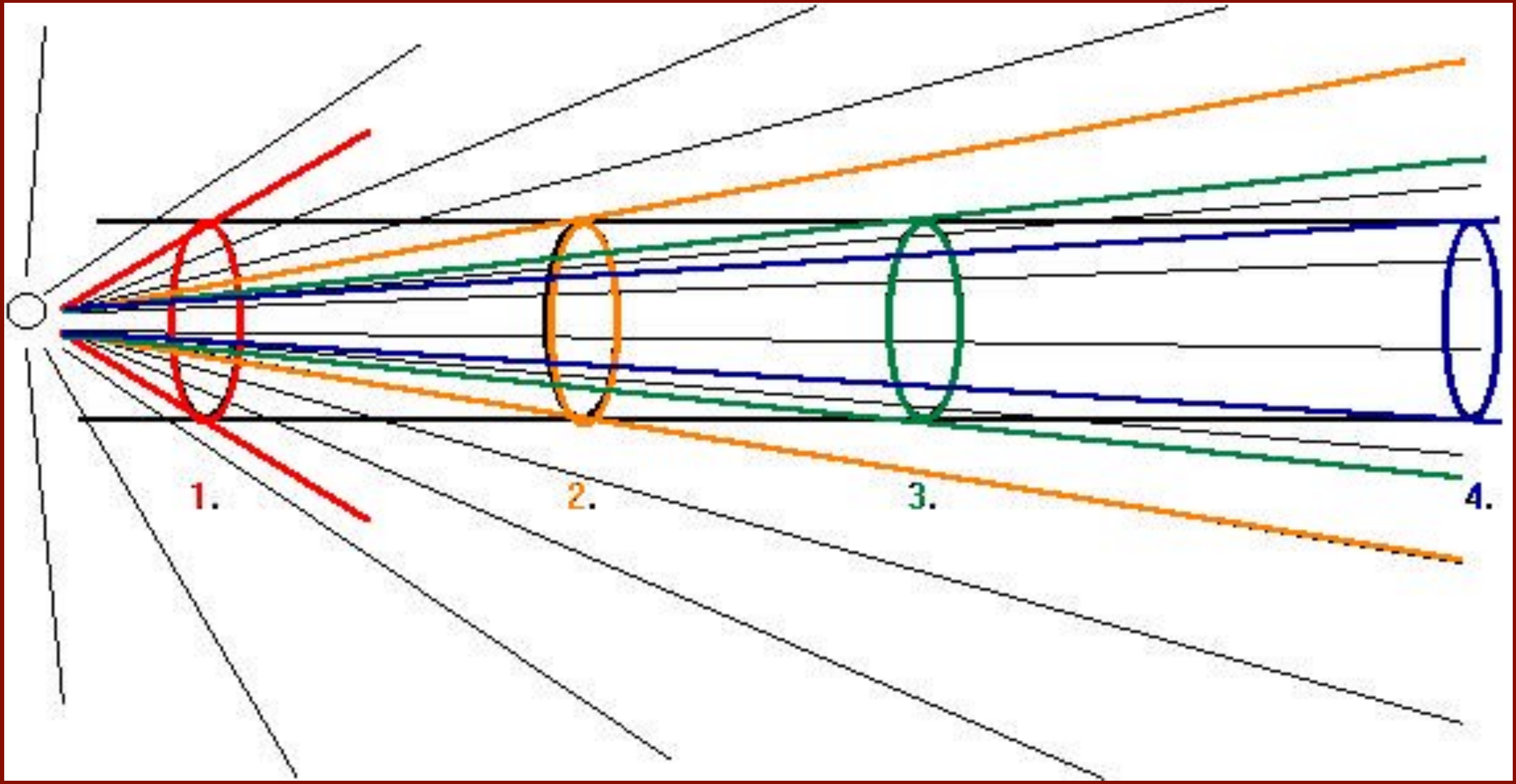
1. A real challenge: Distances are larger by a huge factor!
2. Current trip to NEAREST star beyond our Sun would take about 120,000 YEARS! (4 Light Years away)
3. What can we receive and collect from such distant objects/places (bear in mind that Stars are very hot)?

We receive PHOTONS (starlight)!

- Why is our data (photon count) very limited?

The PHOTONS SPREAD OUT over the vast distances!

Distant objects appear very FAINT ☹

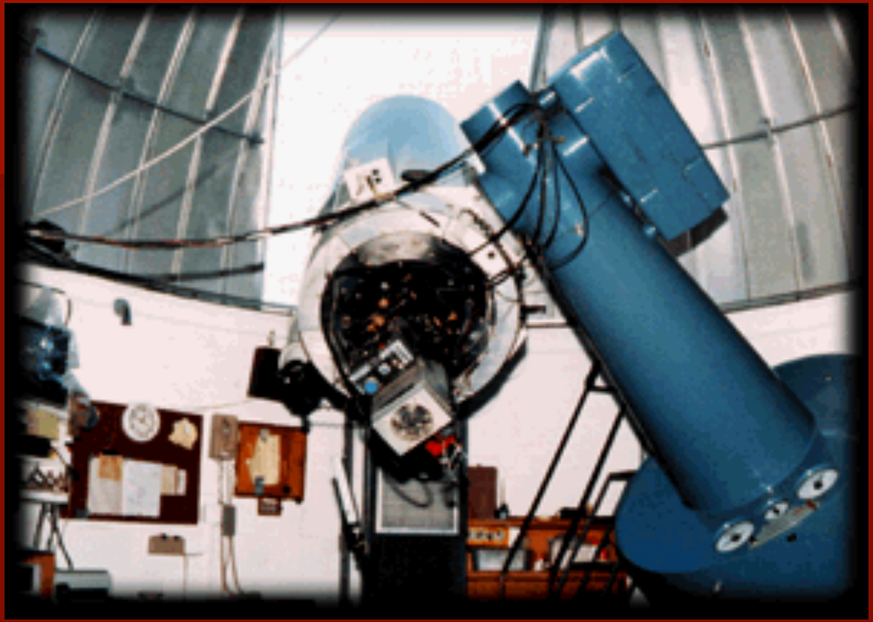


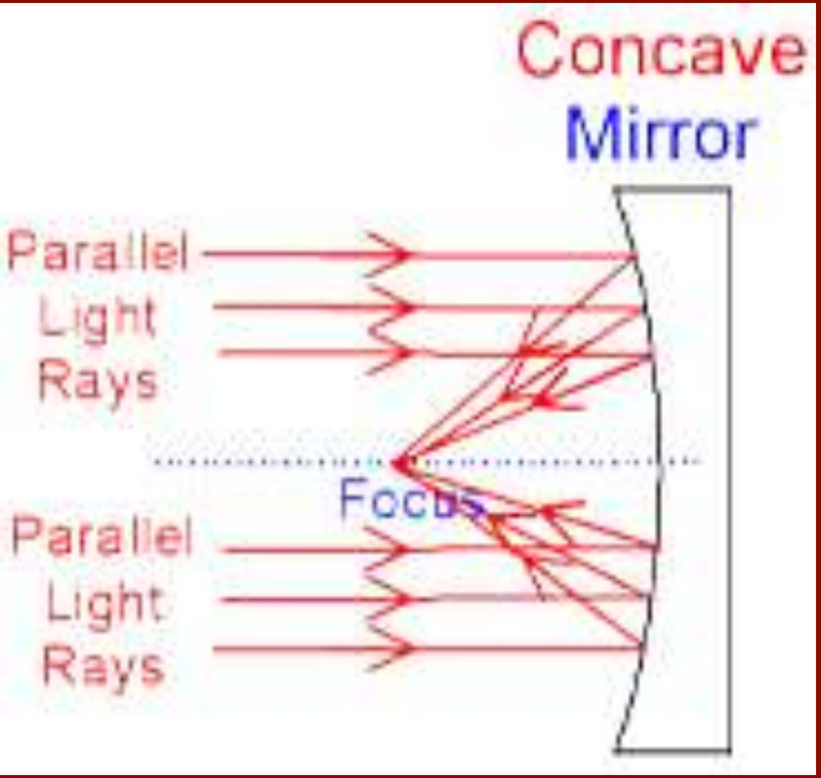
Engineer a solution to COLLECT Photons

- Engineering Design tip: Simplify problem to something you're familiar with…
- Let's design a device to COLLECT RAINDROPS.

Solutions to corral Photons

- COLLECT THEM USING LARGE SURFACE AREA – actually a large curved mirror, heart of TELESCOPE



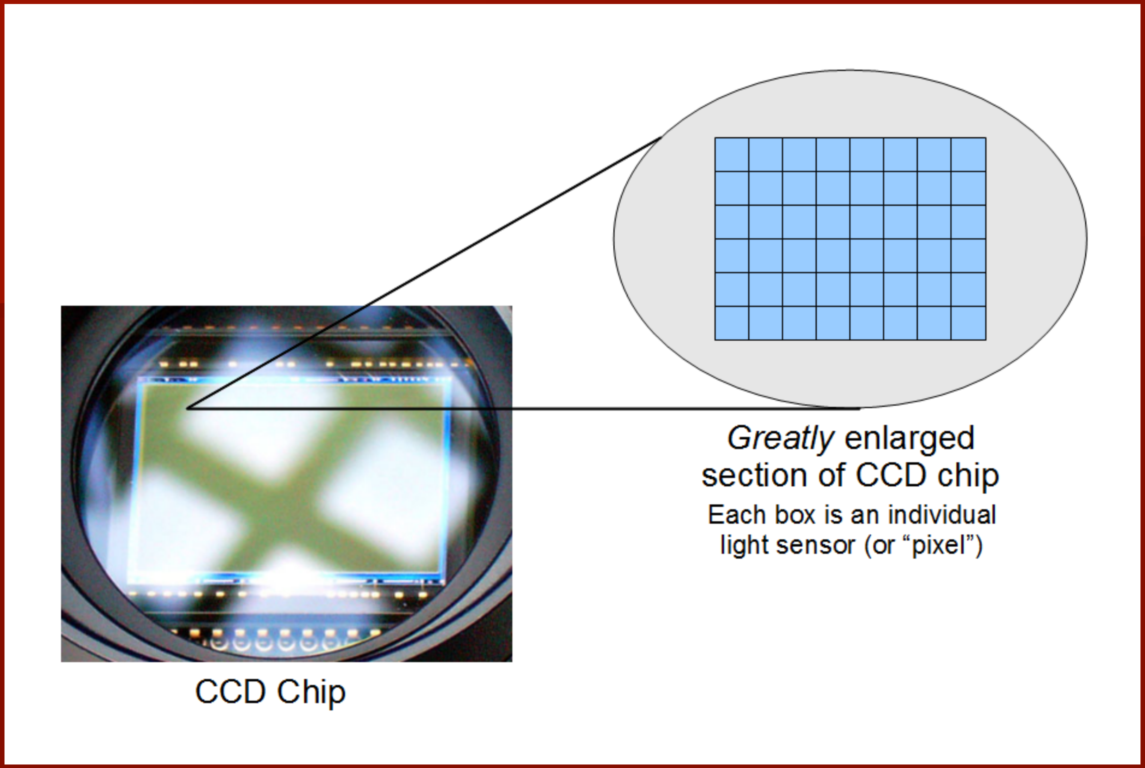

Concave
Mirror
Parallel
Light
Rays
Focus
Parallel
Light
Rays

Can you engineer another method to collect raindrops?

Can you engineer another method to collect raindrops?

- How about a SPONGE?
- Just let it sit for a period of time!

- Can we adapt the strategy to PHOTONS?
- **ACCUMULATE THEM OVER TIME: Use Silicon Grid as a photon sponge: the Charge Coupled Device (CCD) Camera**


Greatly enlarged
section of CCD chip
Each box is an individual
light sensor (or "pixel")
CCD Chip

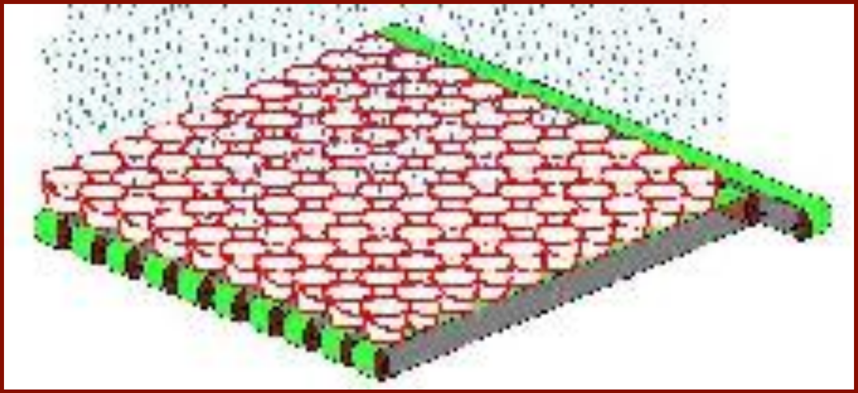
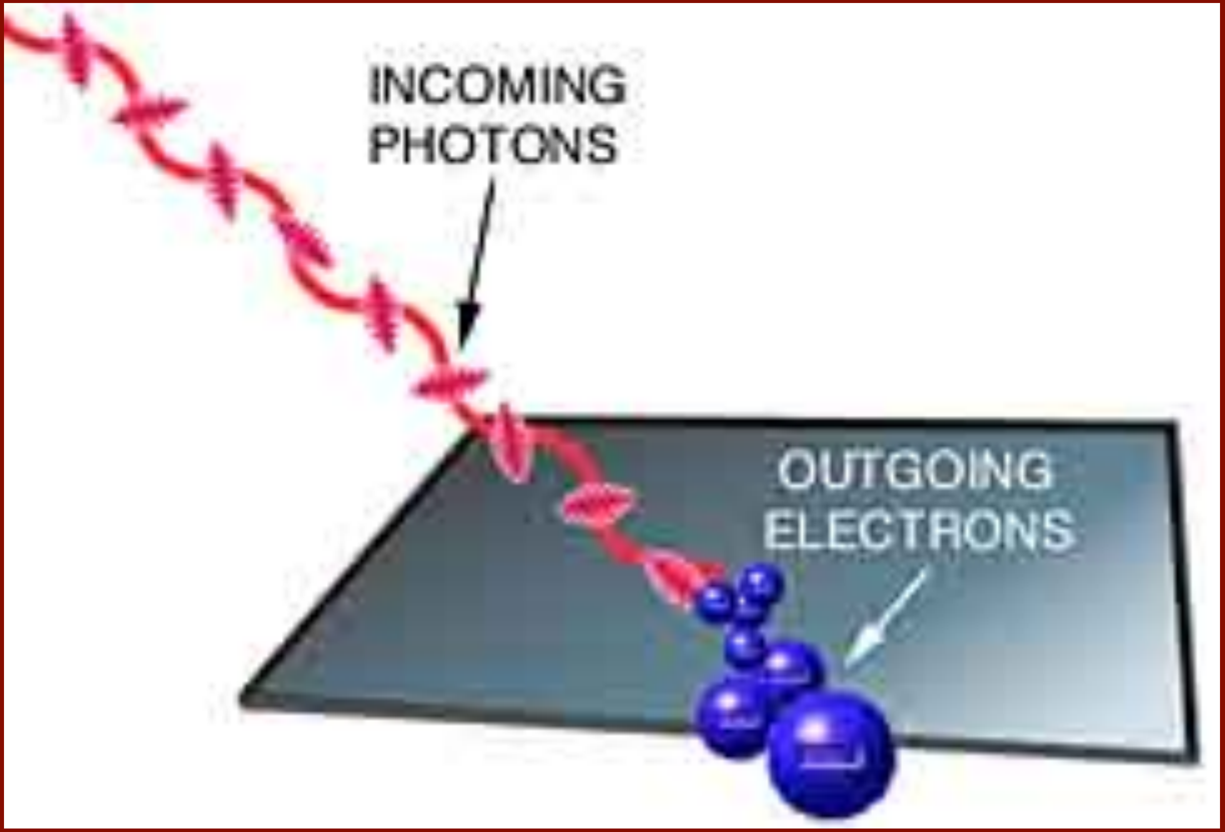


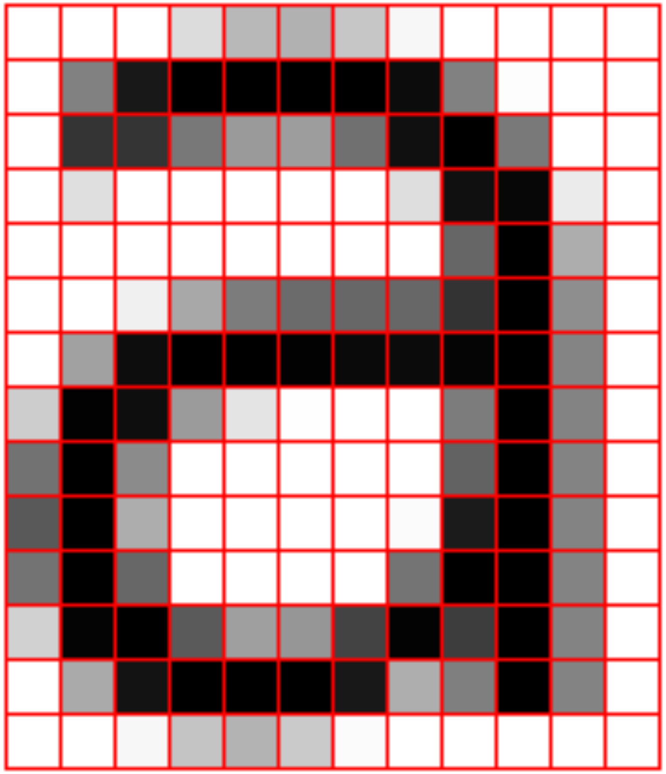
Photo-Electric Effect: incoming PHOTONS energize ELECTRONS.

The CHARGE COUPLED DEVICE accumulates the incoming photons as ELECTRIC CHARGES



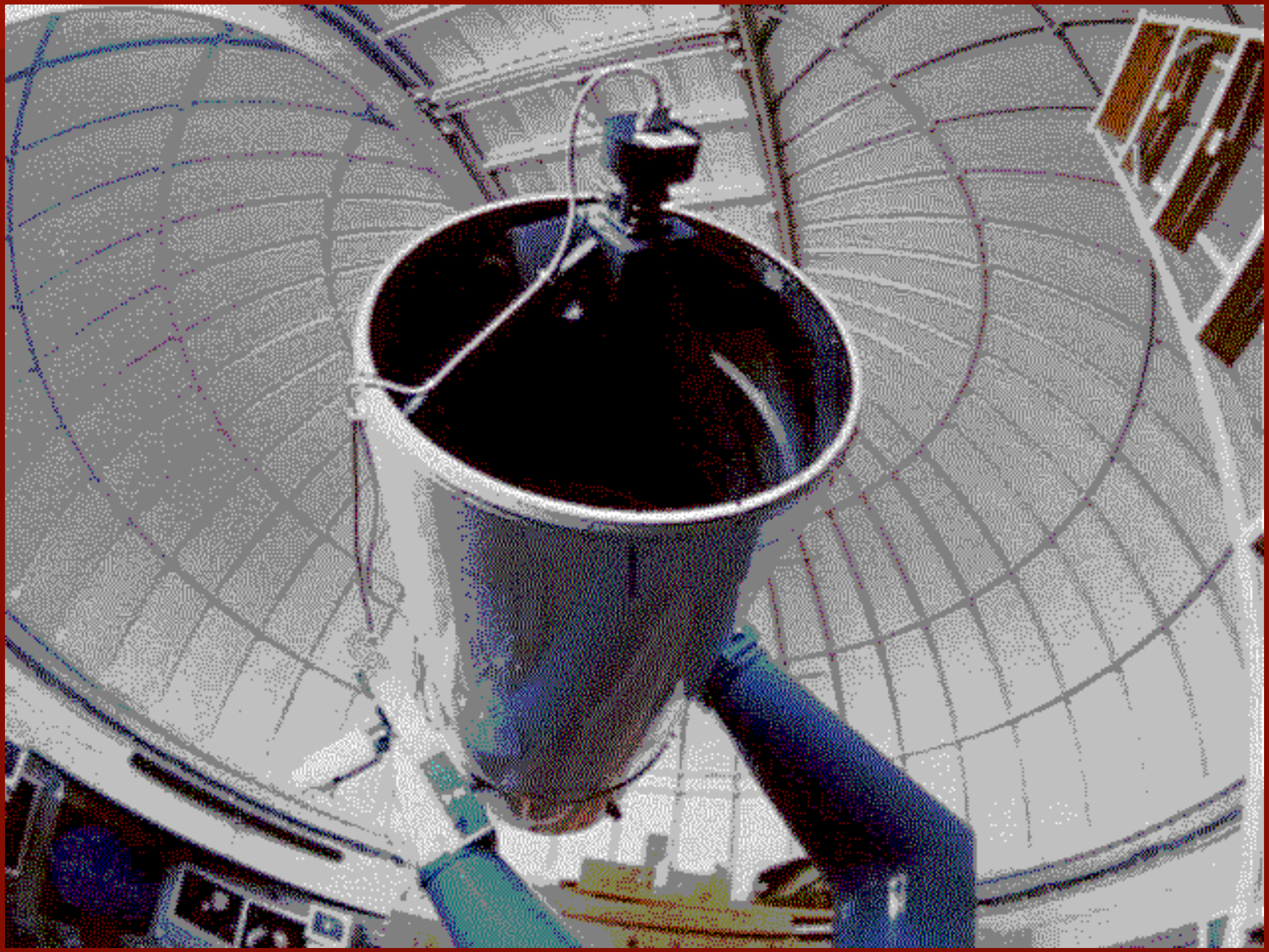
Result is "digital image": 3 numbers per "photosite": Coordinates and Value

a



1.0	1.0	1.0	0.9	0.6	0.6	0.6	1.0	1.0	1.0	1.0	1.0
1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.0	1.0
1.0	0.2	0.2	0.5	0.6	0.6	0.5	0.0	0.0	0.5	1.0	1.0
1.0	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.0	0.0	0.9	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
1.0	1.0	1.0	0.5	0.5	0.5	0.5	0.5	0.4	0.0	0.5	1.0
1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0
0.9	0.0	0.0	0.6	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
0.5	0.0	0.6	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
0.5	0.0	0.7	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.5	1.0
0.6	0.0	0.6	1.0	1.0	1.0	1.0	0.5	0.0	0.0	0.5	1.0
0.9	0.1	0.0	0.6	0.7	0.7	0.5	0.0	0.5	0.0	0.5	1.0
1.0	0.7	0.1	0.0	0.0	0.0	0.1	0.9	0.8	0.0	0.5	1.0
1.0	1.0	1.0	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0

Telescope "feeds" photons to CCD Camera



The Three Basic Features that we can actually OBSERVE

- Look at the abstract art painting and also at the Hubble Ultra Deep Field image.
- What features immediately strike you as DIFFERENCES between various places or objects in either of the pictures?

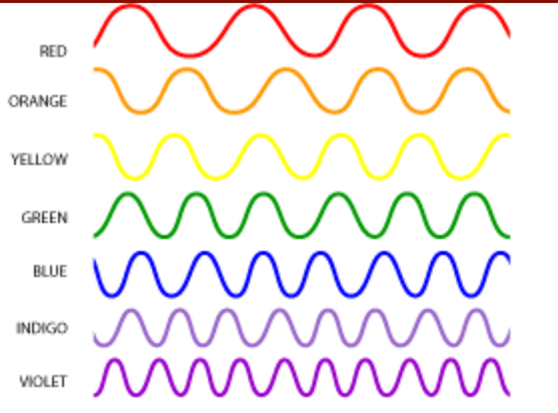
Look for DIFFERENCES

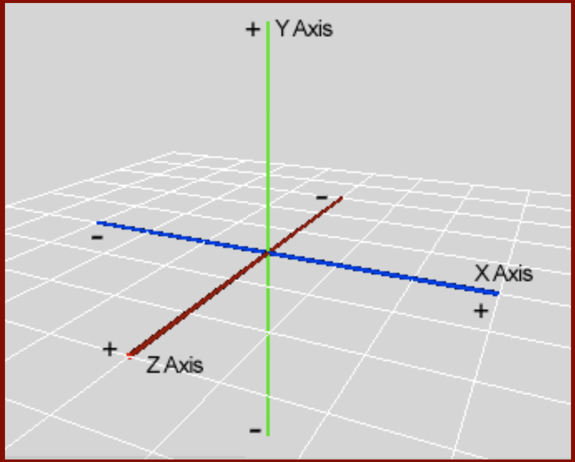
The ONLY features we can see:

1. **Difference in BRIGHTNESS**
2. **Difference in COLOR**
3. **Geometry: Shape, Size, Length all specified by COORDINATES (position)**

This is all that the instruments measure!

CCD grid measures Brightness (Flux Rate) and Position, Spectroscope measures Color (Energy)





In CONCLUSION, how do we know Characteristics of Distant Objects?

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- **We need to CORRELATE (match up) features of the light (brightness, color, and position, and CHANGES), with related PHYSICAL CAUSES**
- **Let's try this, one by one:**

One object appears BRIGHTER than another because of

One object appears BRIGHTER than another because it’s

1. CLOSER
2. HOTTER
3. BIGGER

Apparent Brightness depends on the above factors.

An object has a color because

An object has a color because

1. of its COMPOSITION, like ice cream.
2. of its TEMPERATURE, like Stars.
3. of its RADIAL MOTION (to, from) stretching or squashing the light waves (Doppler Shift)

Measuring the Color of the light will tell us about the above properties.

Coordinates or Change of Coordinates can tell us

1. Relative position
2. Velocity
3. Mass (velocity due to Gravity)
4. Sometimes the diameter -> volume
5. Density ->comp, state, age

All this information from just X and Y Coords!

(the Z (distance) can be very tricky!)

Amazing that we know so much about objects that are so far away!