"Astronomy is more than a spectator sport"

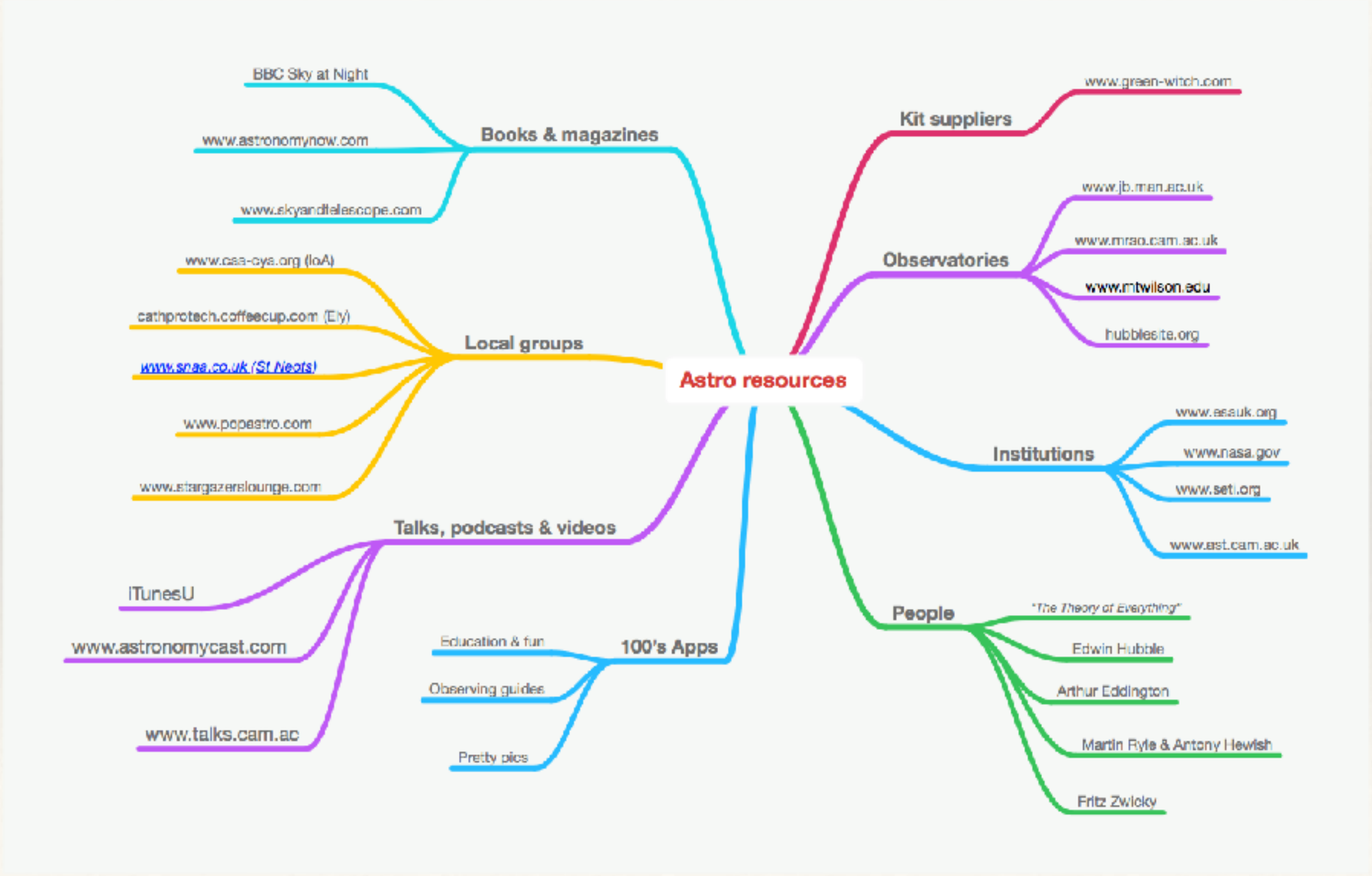
"where we came from & how we got here"

Tim Ewbank

25th April 2017

"To know where we're going,
we have to know where we are.
To know that, we have to know where we came from
& how we got here"

Some Astronomy Resources To Explore…



Recap from last week "Where we are"

- Where we are in universal space & time.
- Scale & units (km - Mpc)
- Four tier hierarchical structure of universe:
  - Solar system
  - Stellar neighbourhood
  - Galaxy, galaxy clusters, super-clusters
  - Universe
- Uniformity of galactic structure
- Continual motion

Questions from last week

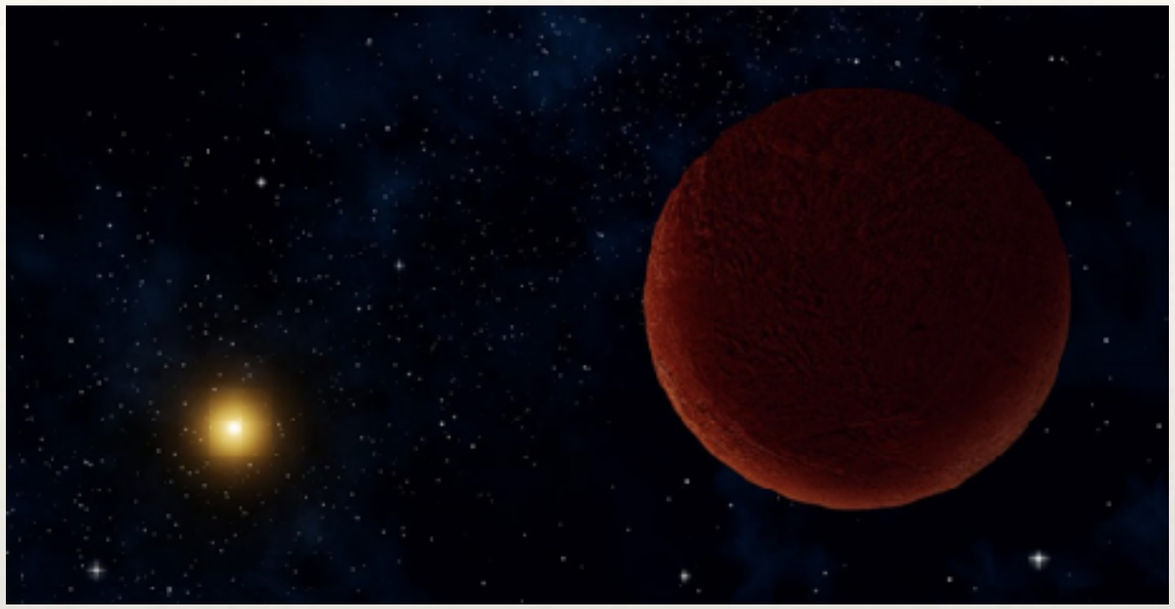
- How is a Parsec defined?
- Why do all planets in solar system circulate in the same plane?
- Why was Pluto “demoted” to being a dwarf planet?
- What is the The Local Group (of galaxies) circulating round?

Galactic scale orbits

Object	Size (ly)	# galaxies
Solar system	< 1	0
Milky Way	2×10^3	1
The Local Group	5×10^6	40
Virgo Supercluster	1.1×10^8	$1.3 - 2 \times 10^3$
Great Attractor	1.5×10^8	$3 - 5 \times 10^3$
Shapely Supercluster	?	8×10^3

Astronomy in the News

- "faint, distant object found at the outskirts of the Kuiper Belt"
  2014 UZ224, aka DeeDee.
  92AUs (approx M11 & M25 junction)
  635 Km diameter

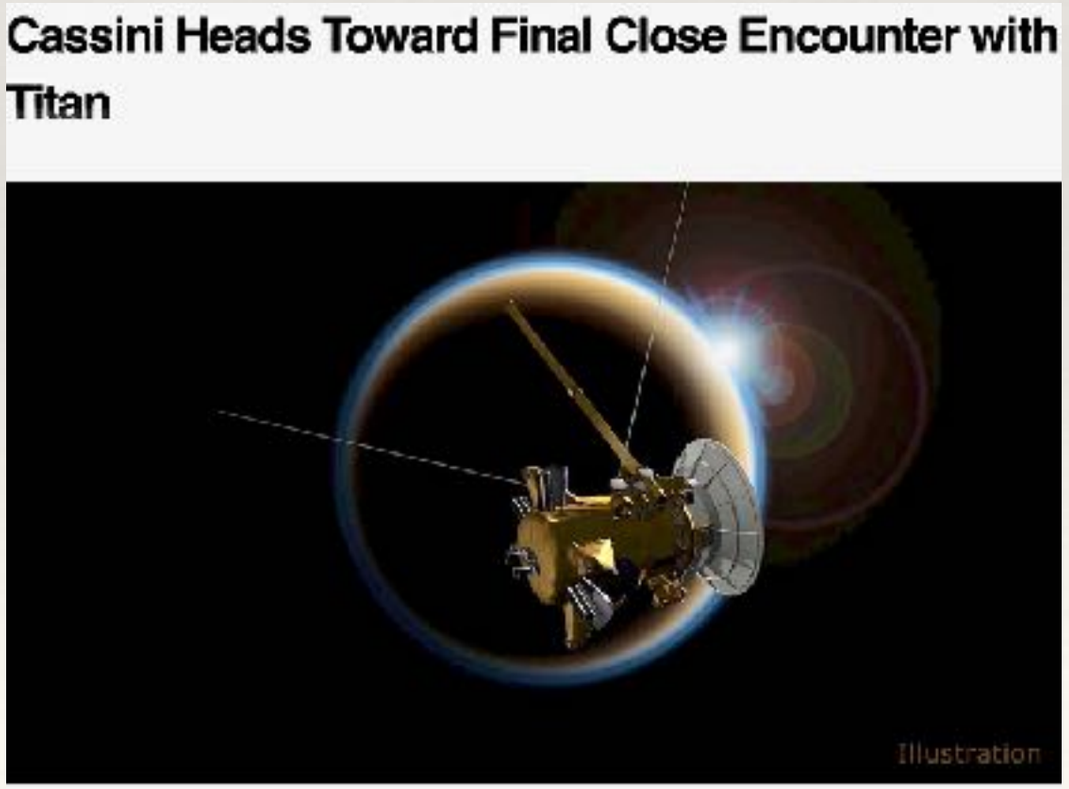


Astro news apps:

- NASA & JPL
- PTTUNIVERSE
  (Portal to the Universe)

Websites

- www.astronomy.com
- www.sciencedaily.com/news/spacetime



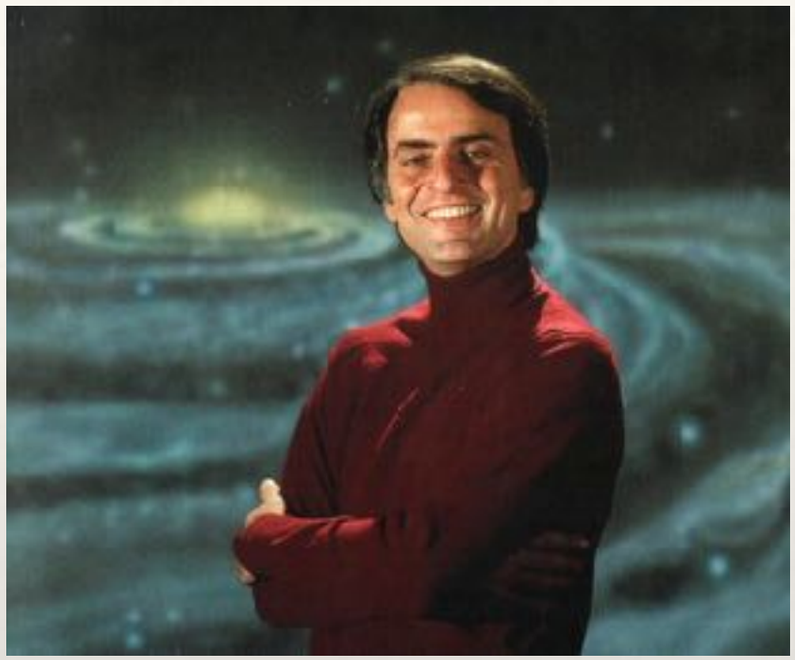
Today's Agenda

- Describe relationship between technological developments & progress of astro knowledge
- Explain developing understanding:
  - solar exploration
  - stellar evolution
  - development of galaxies
  - origins of the the universe
- Recap & trailer for next week

Progress of Astronomical Knowledge

"We can judge our progress by the courage of our questions and the depth of our answers, our willingness to embrace what is true rather than what feels good"

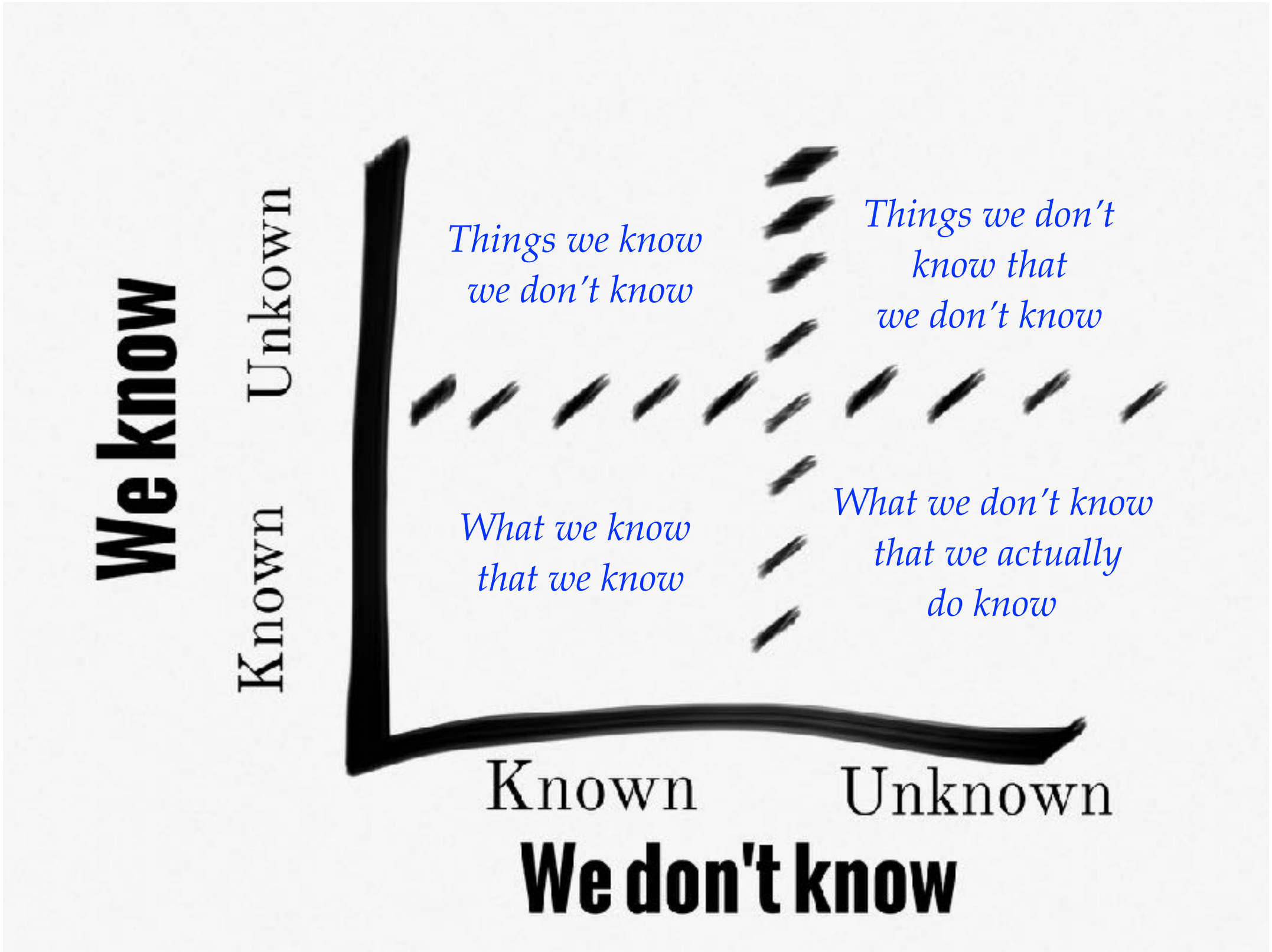
Carl Sagan "Cosmos"



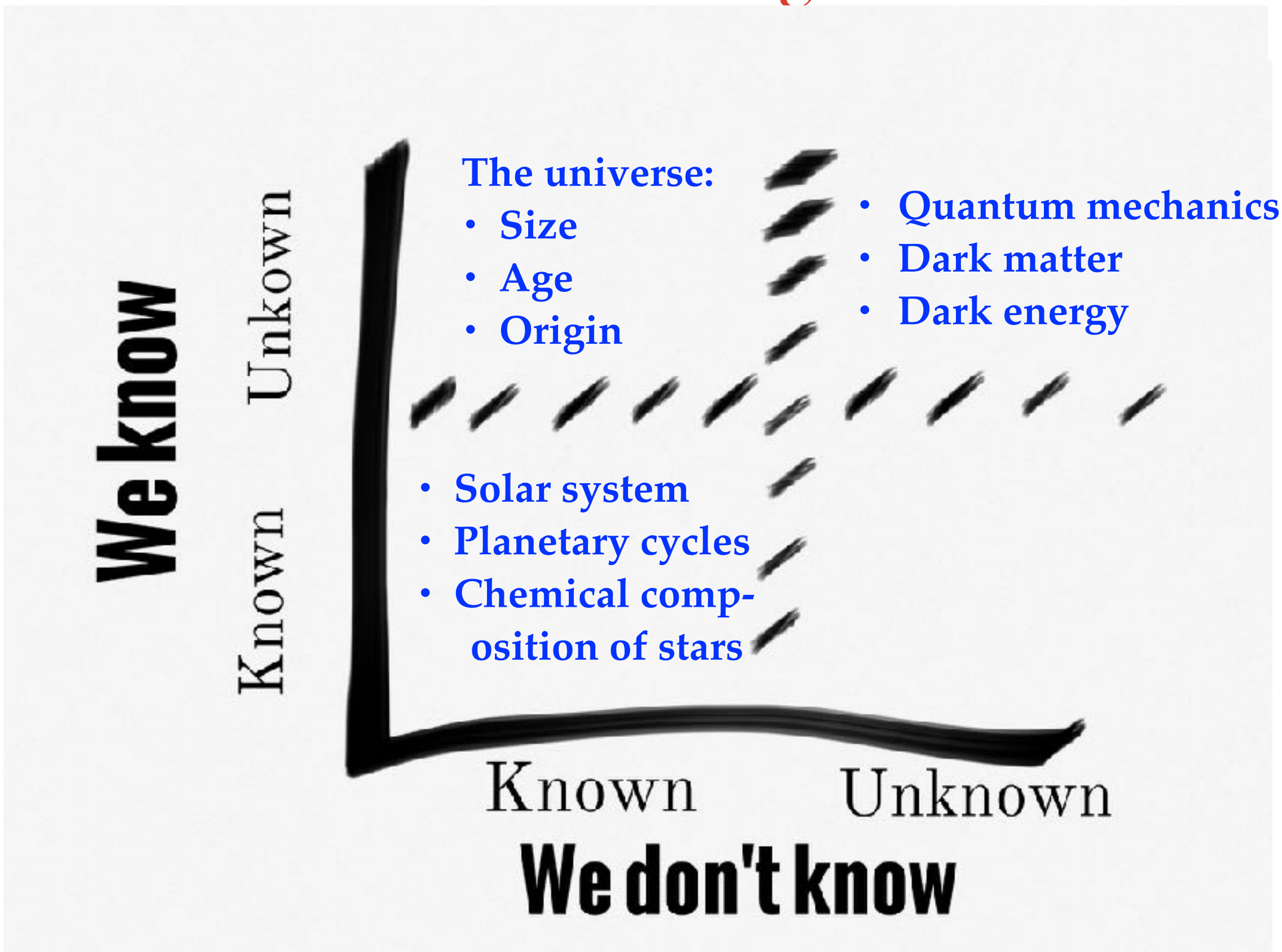
"Our greatest intellectual achievement is understanding our place in the universe"

Prof. Brian Cox "Human Universe"

What We Know & Don't Know

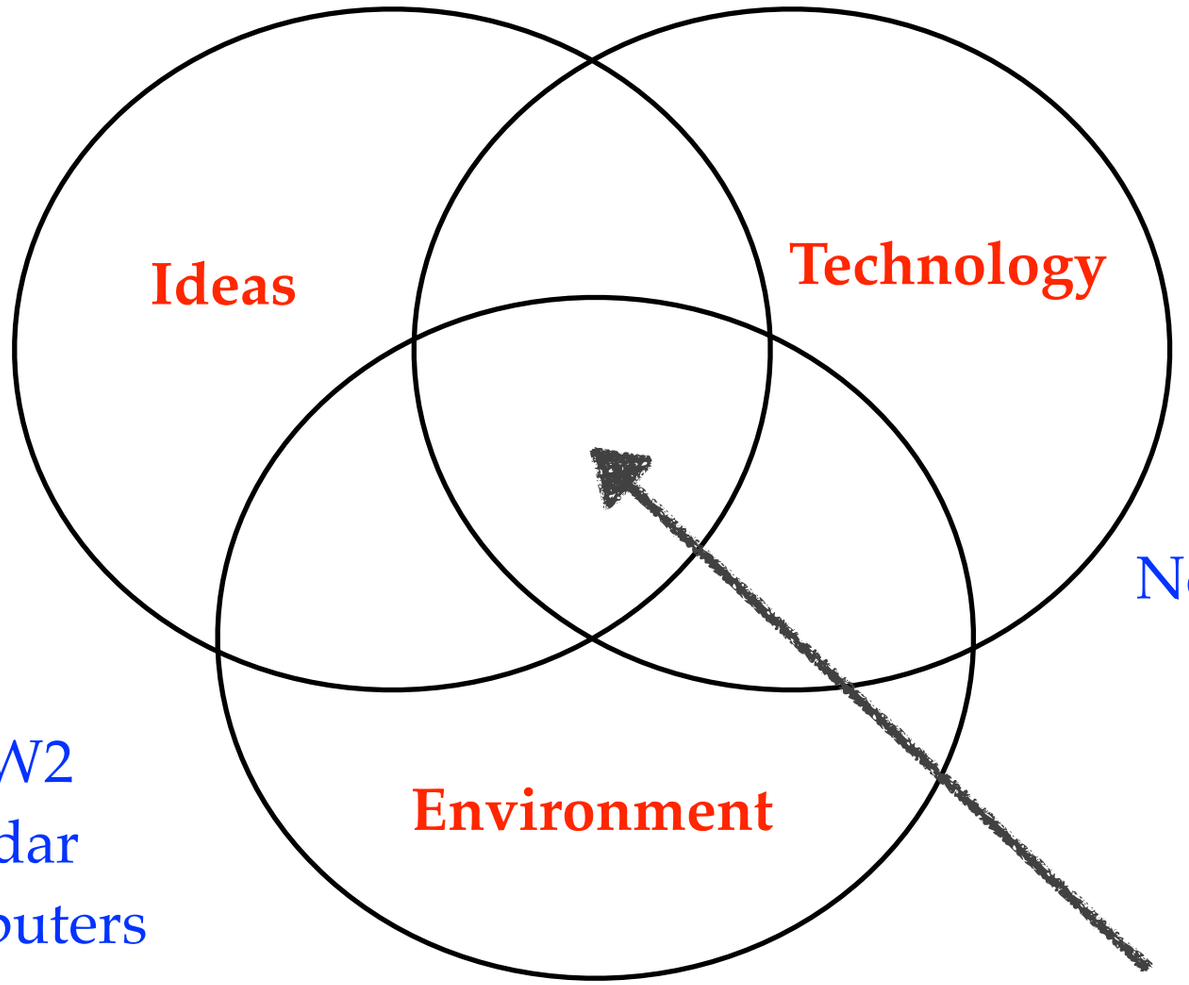


Astronomical Knowledge at 1900



The Fusion of Ideas, Technology & Context

Kepler's Laws
Theory of Relativity
The Scientific Method



Photography
Spectroscopy
Non-optical telescopes

WW2
Radar
Computers
Rocketry

Application to astronomy

http://www.nasa.gov/offices/oct/40-years-of-nasa-spinoff

Astrophotography

- previously only drawings

- 1st image of Orion in 1880
- technical challenges:
  - long exposures (2mins - hours)
  - accurate telescope mount drives
  - film sensitivity
  - Composition software

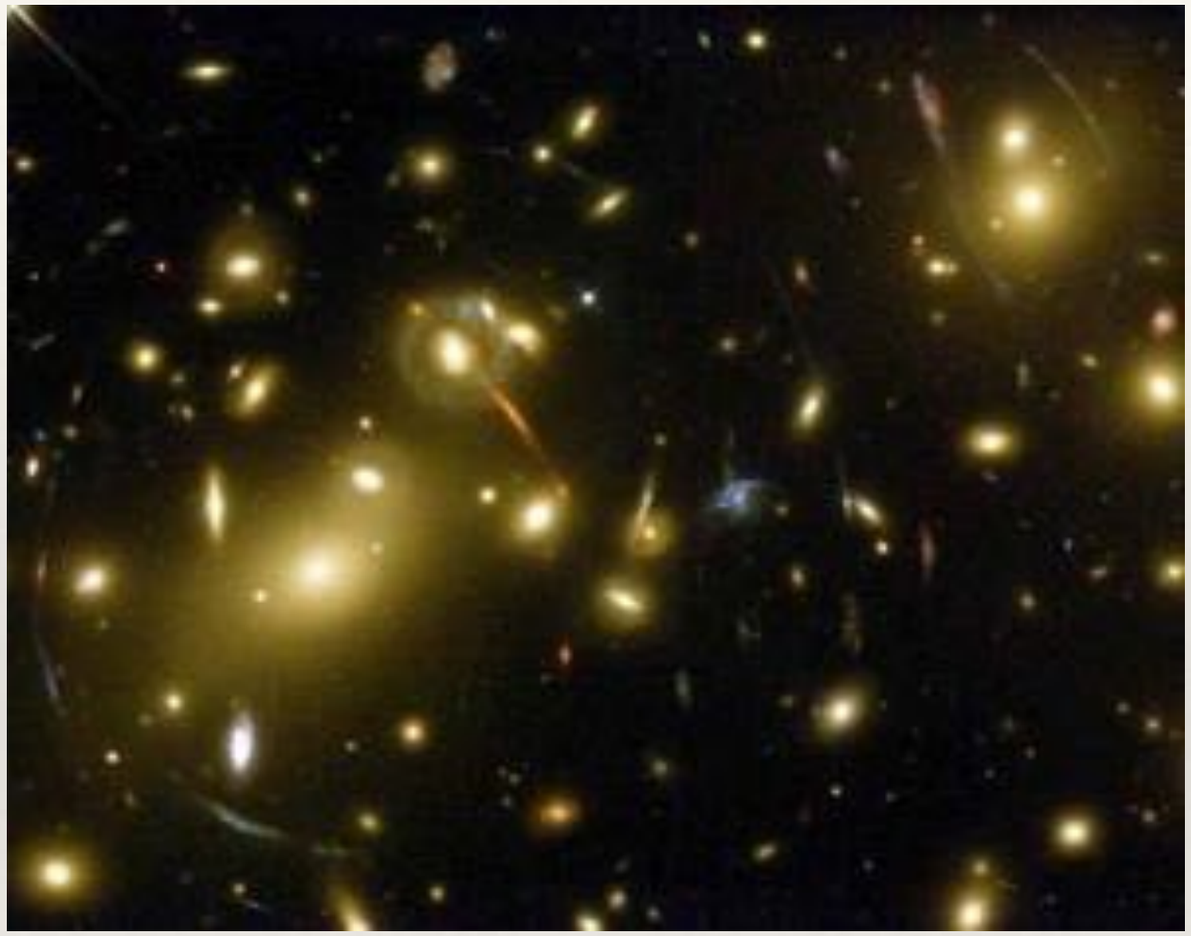
- Necessary technological pre-requisite to spectroscopy

Application of Astrophotography

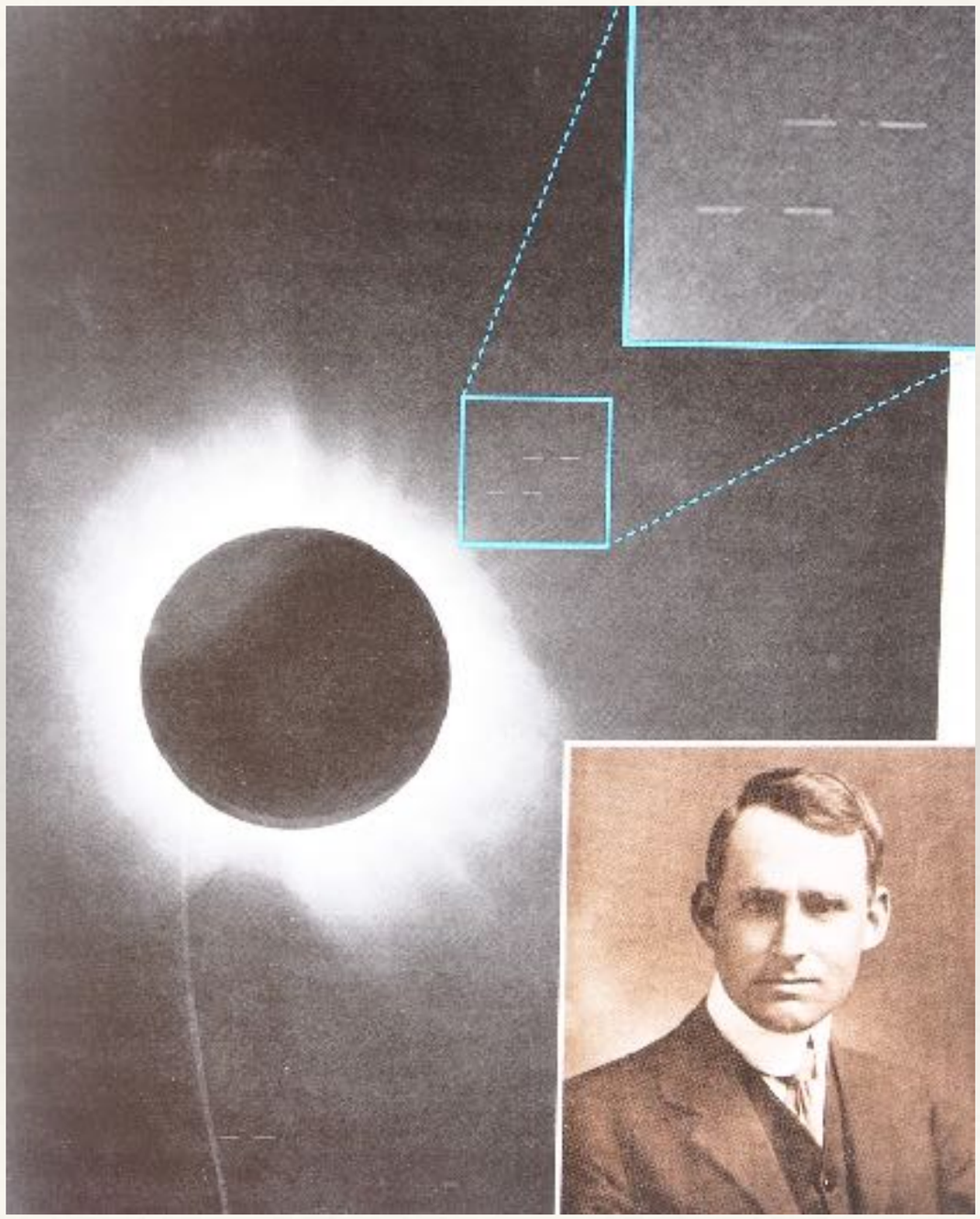
- more detailed & accurate image capture, beyond human eyesight
- creation permanent records
- comparison of sky between time points:
  - 1919 eclipse
  - discovery of supernovae
- Calculate the absolute distance to objects in the galaxy

http://apod.nasa.gov/apod/archivepix.html

Lensing as Proof of Relativity Theory

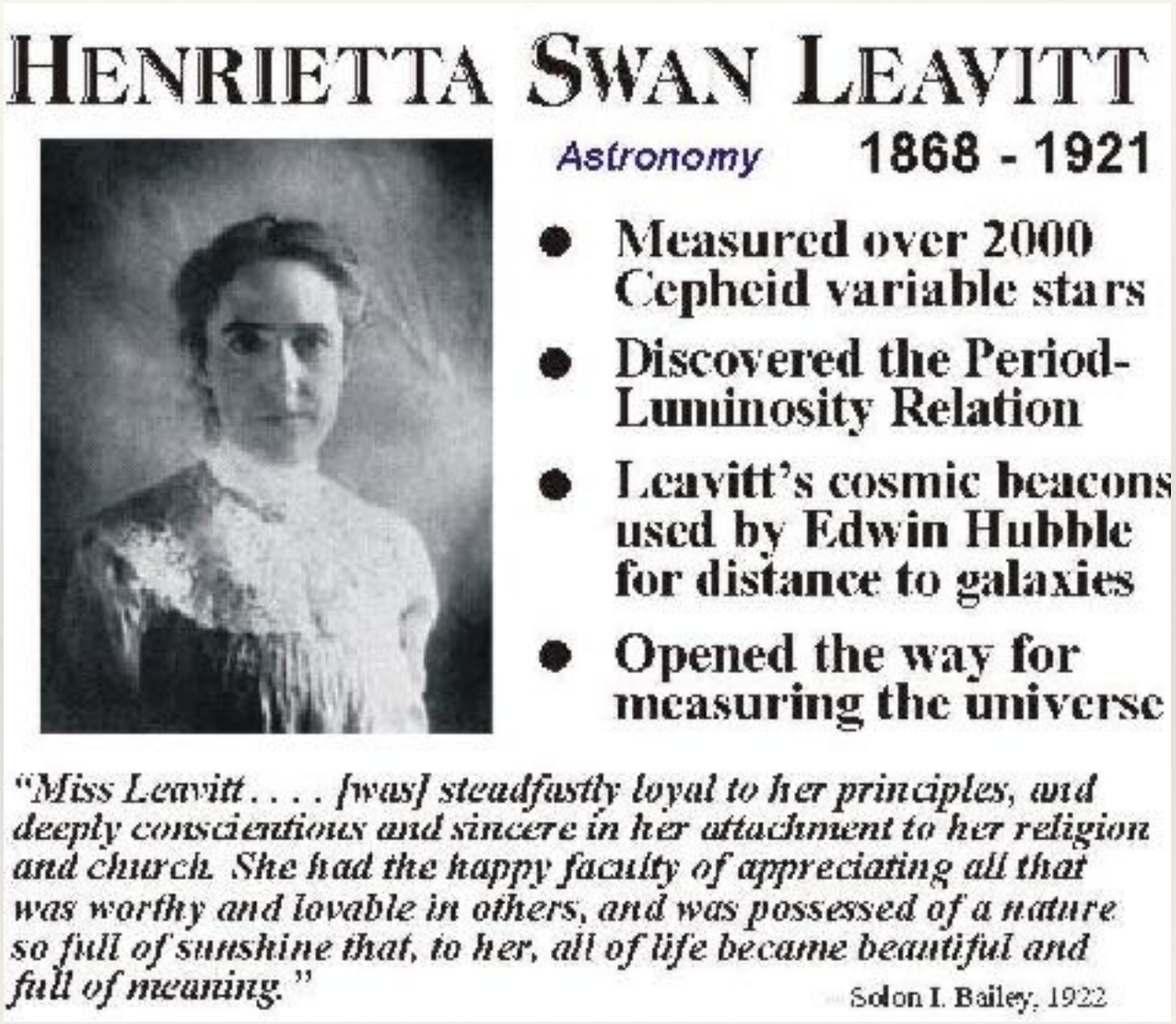


Predicted by *Theory of General Relativity*

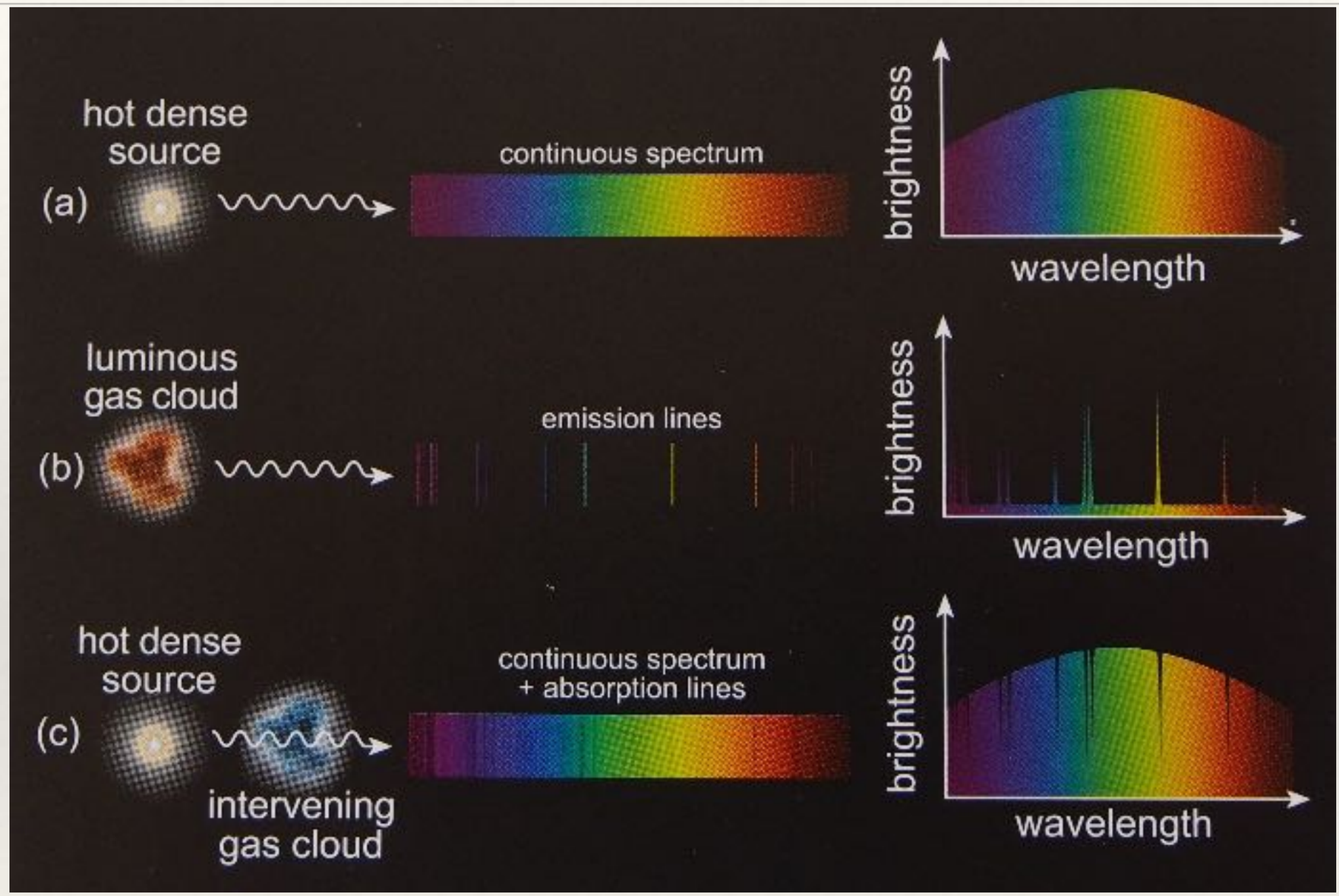


Finding a celestial yardstick

- Established the relationship between frequency & brightness of cepheid variables in SMC
- Enabled distinction between apparent & absolute brightness
- Used in combination with parallax to determine absolute distances to nearby objects in the galaxy
- Proved decisive to the outcome of *The Great Debate* of 1920



Spectroscopy



Nicholson "the Dark Side of the Universe"

- obtaining & analysing the spectrum of objects from fragmentation of light spectrum

Uses of Spectroscopy

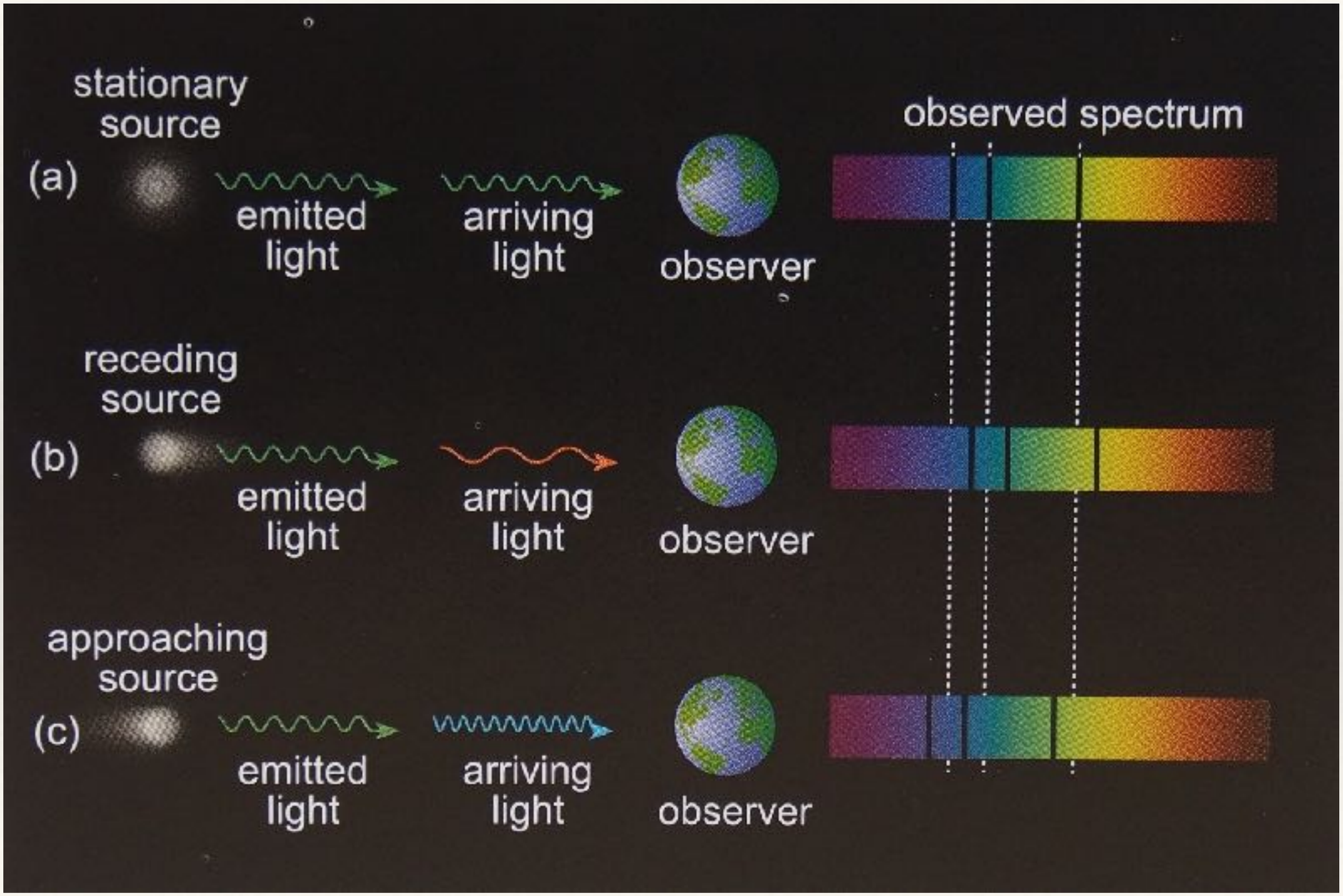
- Can be used to determine properties of celestial objects:
  - temperature
  - density
  - chemical composition

- Combined with Doppler Effect:
  - movement relative to the observer (blue or redshift)
  - radial velocity of galaxies

- Classification of stars into Hertzsprung - Russell sequence

- Calculating age of stars

Spectroscopy & Redshift



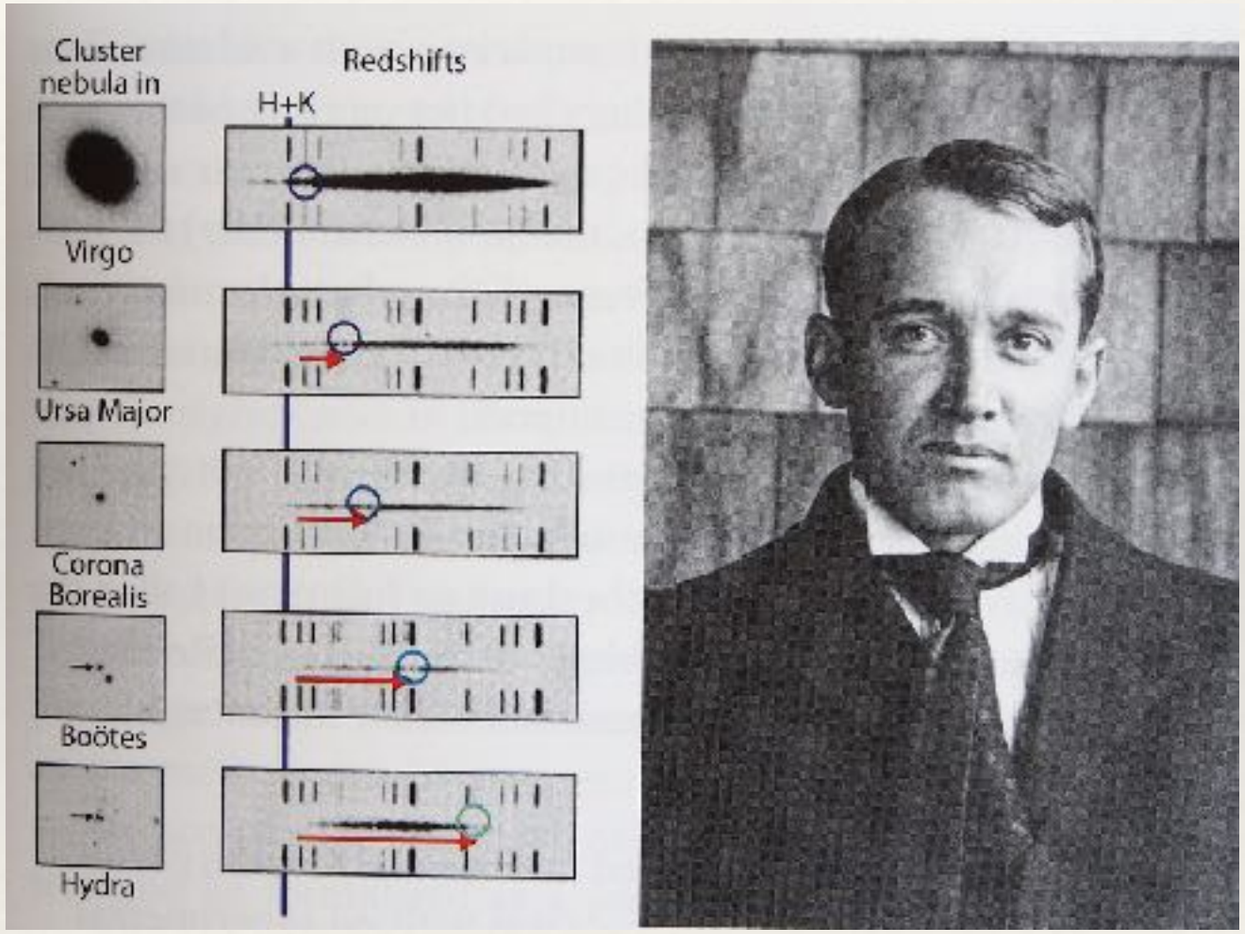
Redshift

Blueshift

Nicholson “the Dark Side of the Universe”

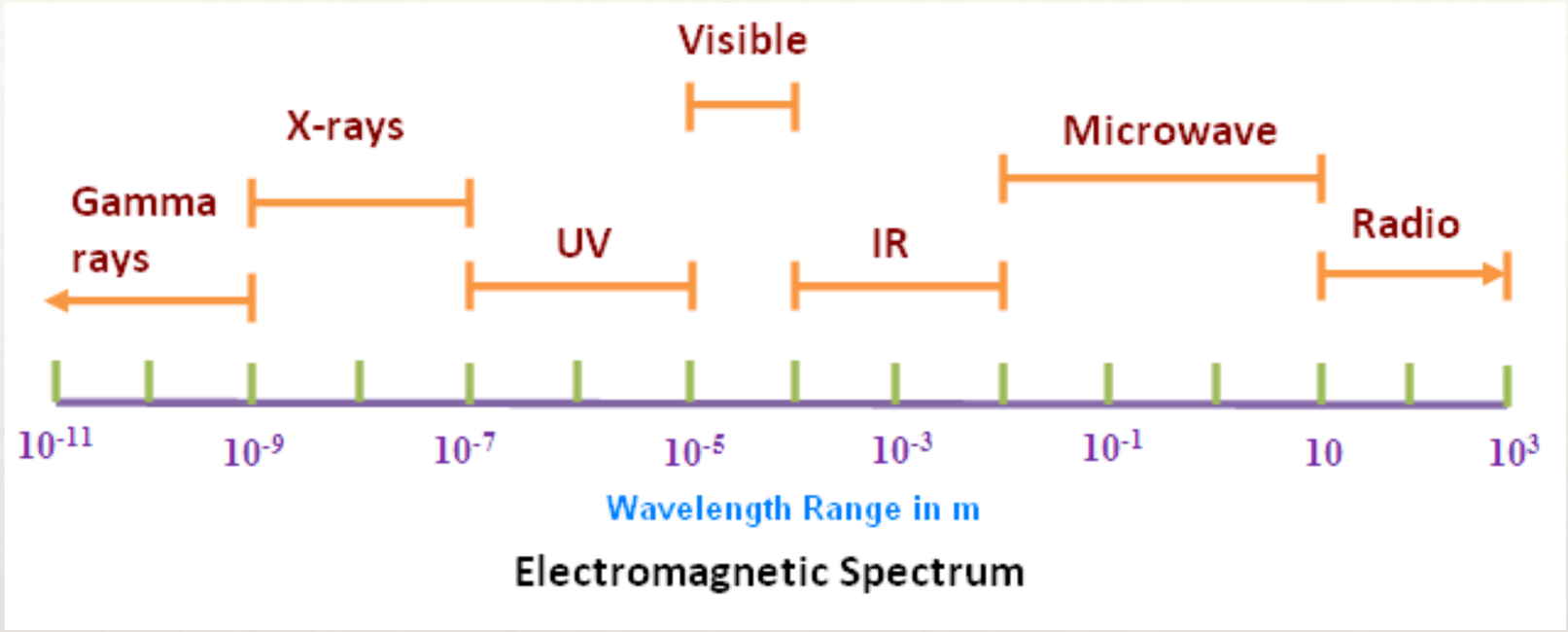
1st Application of Spectroscopy to Stellar Movement

- 1912-1917 Vesto Slipher at Lowell Observatory, AZ, USA
- Measured motion of nebulae
- Majority were redshifted
- Caused some confusion in an era where majority opinion favoured the Milky Way as a single static galaxy



Ostriker & Mitton *Heart of Darkness*

Telescopes at Non-Optical Wavelengths



Electromagnetic Spectrum

Compton

James Webb ST

Jodrell Bank

Mullard

Chandra

TVLA

Spitzer ST

Different wavelengths are better suited to certain types of observation:
e.g. IR is good for looking through dust & gas in the Milky Way; gamma rays study hi-energy sources

NASA example of all sky survey at different wavelengths:
http://apod.nasa.gov/htmltest/jbonnell/www/multiw_sky.html

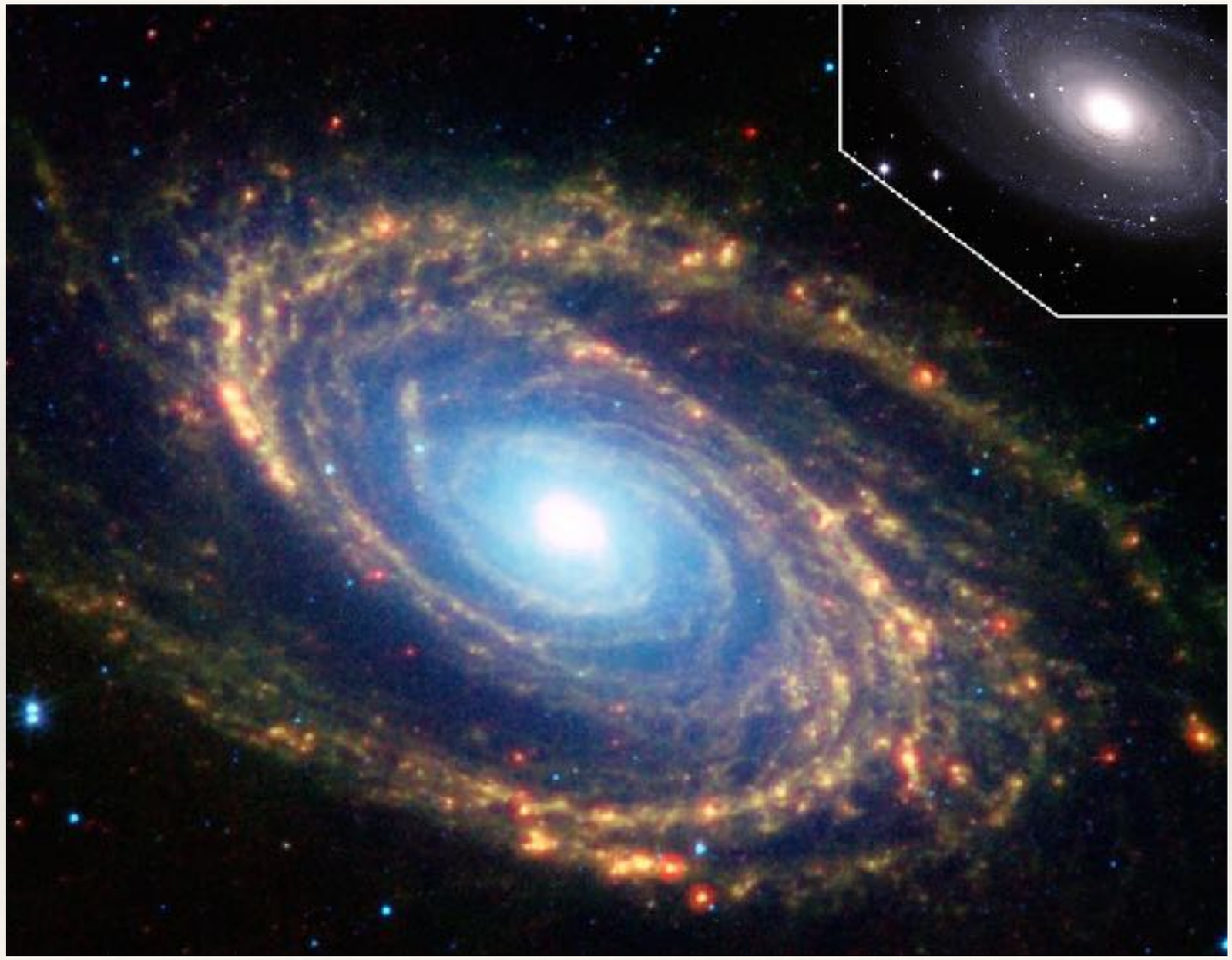
Multi-wavelength image of M81

Imaging at multiple wavelengths can enhances definition:

Top right is visible light spectrum

Main image includes infra-red & ultra-violet

Reveals start forming regions



Spitzer Space Telescope 2003

Radio Astronomy

- Jansky, (USA in 1930s) realised some radio signals originated from outer space.
- developed rapidly after WW2
- Initially used to conduct sky surveys
- Mullard Observatory played major role in development:
  - identified 1st pulsar
  - pioneered aperture synthesis
- Proved the existence of CMB (Cosmic microwave background)

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Solar System Exploration

- German V2 rockets & Cold War provided the technological thrust.
- Sputnik 1957 start of "Space Race" culminating in lunar landing in 1969

- Curtailed by Challenger disaster in 1986
- Main research areas are origins of the solar system/universe & search for life
- Current NASA work on CubeSats - small, single task, disposable
- SpaceX reusable rockets

Current Spacecraft to Our Planets

Planet	No. Missions	Orbit Period
Sun	20+	SOHO 1995; Hinode >2006; Solar Dynamics Observatory (SDO)
Mercury	1	Messenger >2011
Venus	1	Venus Express >2006
Earth's moon	3	Challenger 2 >2010 ;LADEE 2013 Lunar reconnaissance >2009;
Mars	5	Mars Odyssey 2001; Mars Express & Beagle 2 >2003; Opportunity Rover >2004; Reconnaissance >2006; Curiosity Rover >2012
Jupiter	1	Juno (ETA 2016)
Saturn	1	Cassini >2004
Uranus & Neptune	0	

Current Spacecraft to Dwarf Planets & Beyond

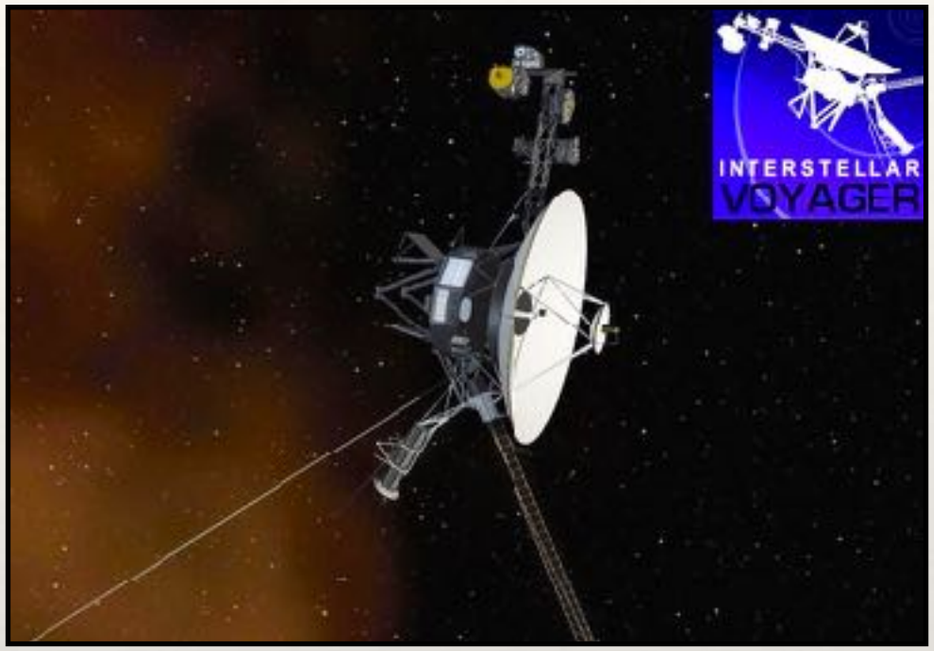
Dwarf Planet	No. Missions	Orbit Period
Ceres	1	Dawn 2015
Pluto	1	Venus Express >2006
Makemake	0	
Haumea	0	
Eris	0	
Comet 67P	1	Rosetta & Philae Lander (12 Nov 2014)
Comet temple 1	1	Stardust - NeXT
Beyond solar system	1	Voyager 1 (1977)

List of NASA missions:
http://www.nasa.gov/content/solar-missions-list/#.VNySz0J140w

Voyager 1

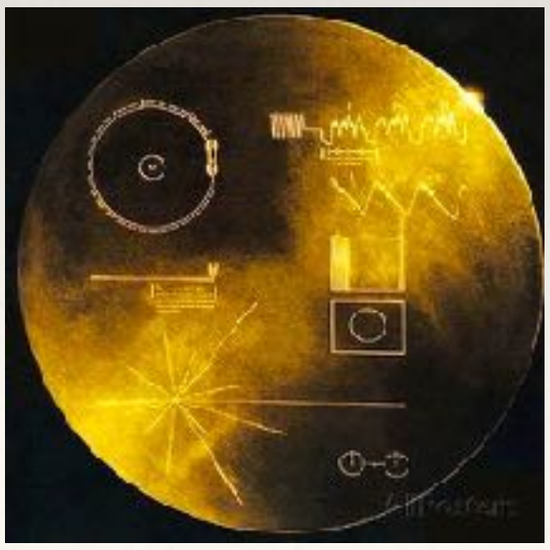
Launched in 1977

So far has travelled 20.6 x 10^9 km.
(on *Bridge St Scale* is crossing the M25 @ M23 junction)



Passed all the gaseous giants & Pluto

Beyond heliopause in Sept 2013 (100 AU) & into interstellar space

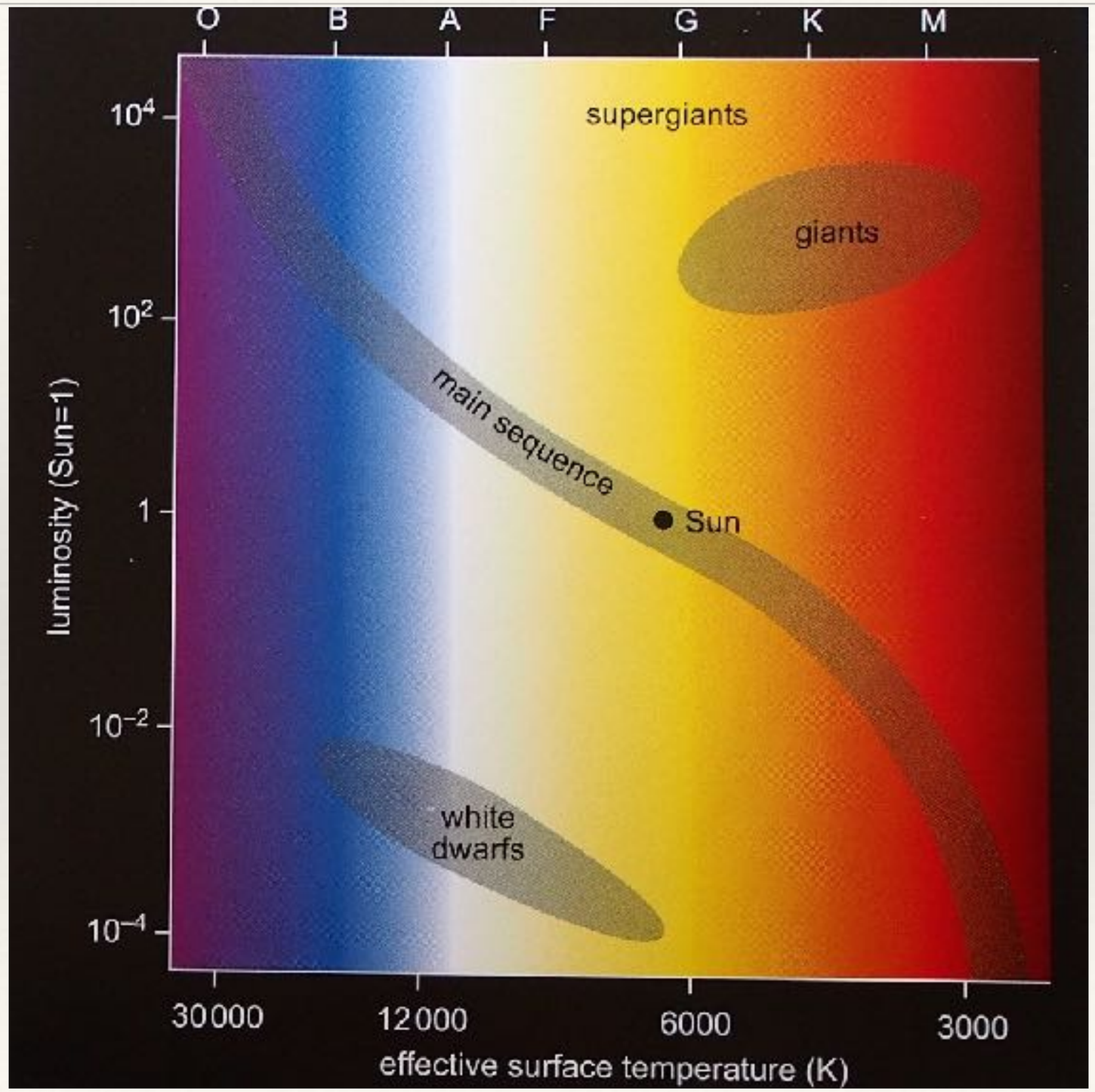


The Golden Record
Carries message for any intelligent beings it meets

http://voyager.jpl.nasa.gov

Attributes of Stars

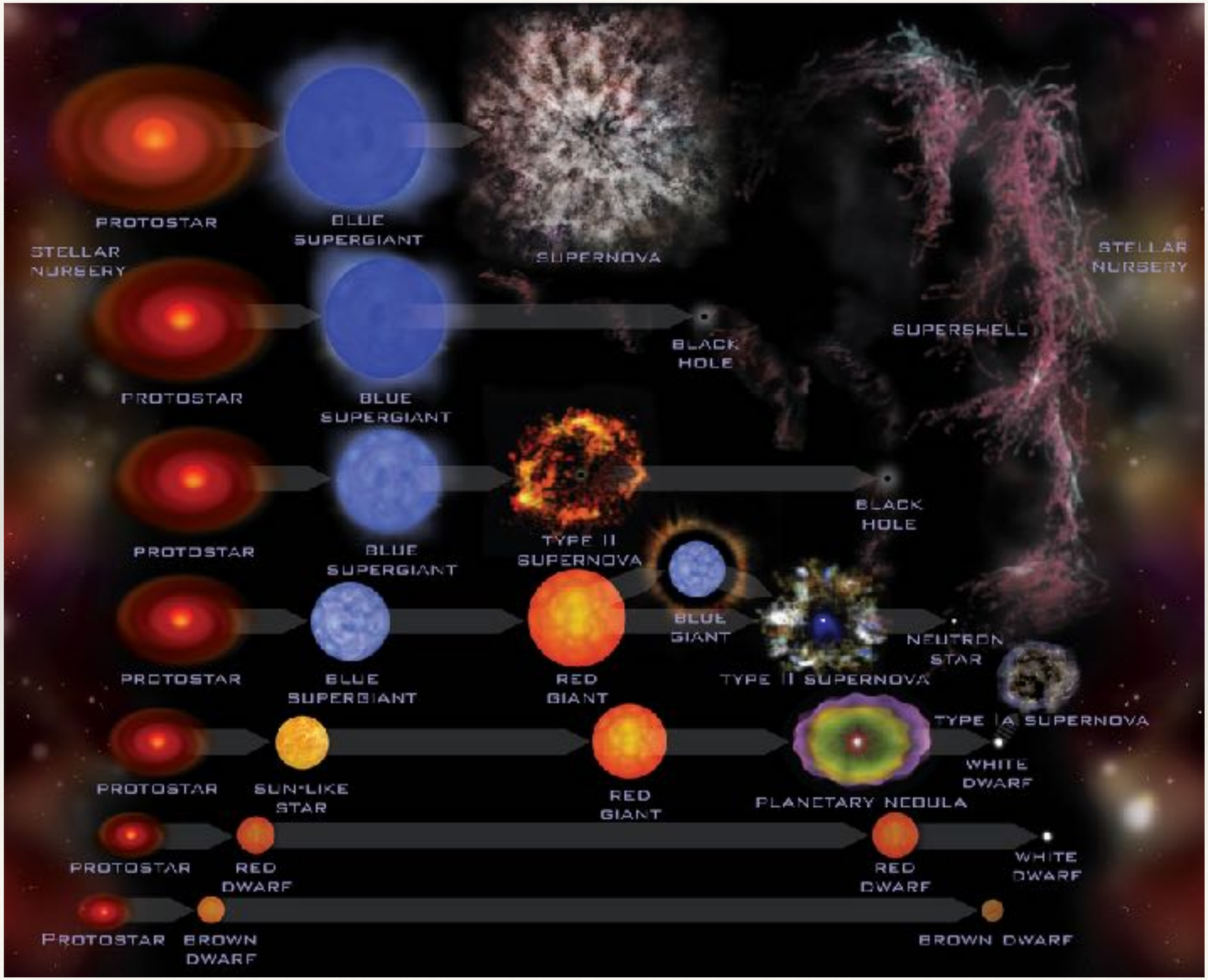
Hertzsprung - Russell sequence



- Emit energy
- Size (spectral classes)
- Brightness
- Chemical composition
- Density
- Temperature
- Motion through space
- Rotational Speed

- May be orbited by planets

The Lifecycle of Stars



JPL Infographics

Attributes of Galaxies

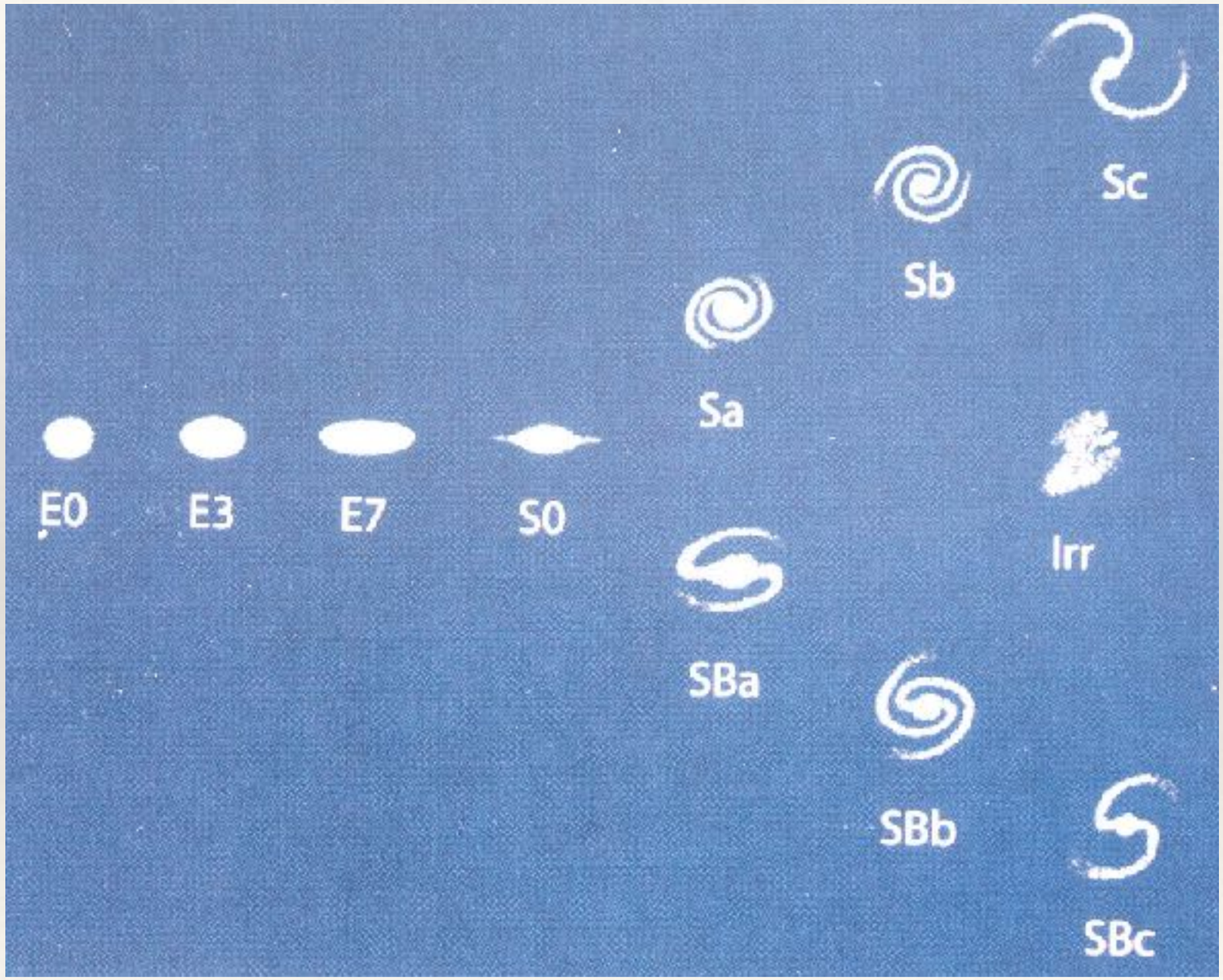
- fundamental building blocks of universe
- massive accumulations of matter (stars, planets, gas clouds & dust) held together by gravity
- flattened rotating discs often centred on a black hole
- dynamic entities - birthplace of stars, merge
- uniformly distributed across the universe
- variable size, luminosity & morphology

M51 Whirlpool Galaxy

Classification of galaxies

- Taxonomy not evolutionary pathways
- Prof John Ellis, Caltech (February 2015):

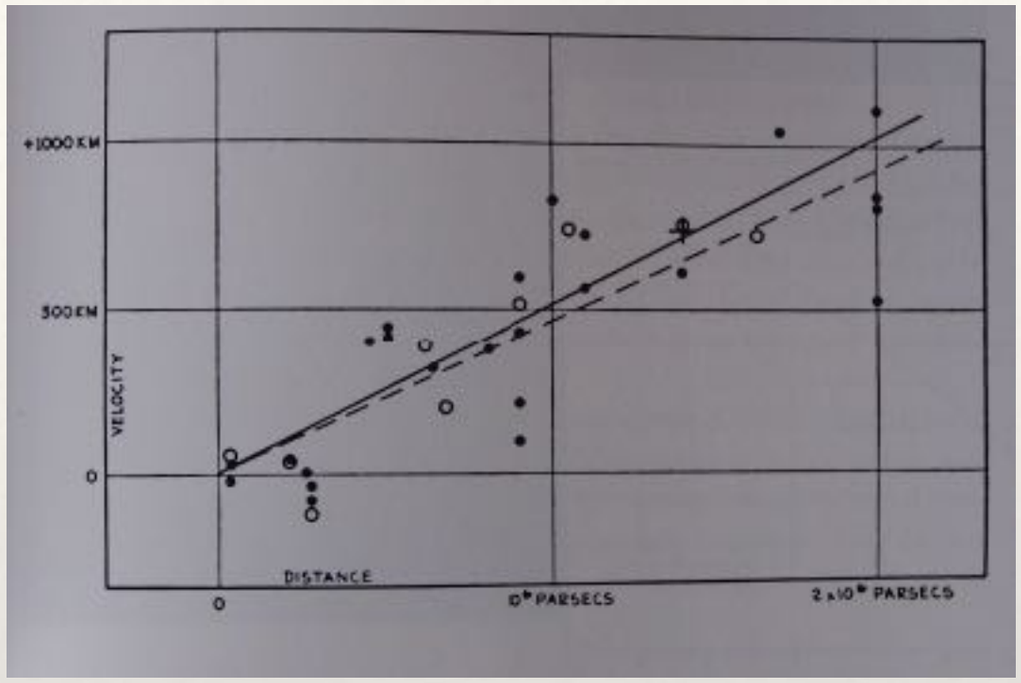
http://sms.cam.ac.uk/media/1898761

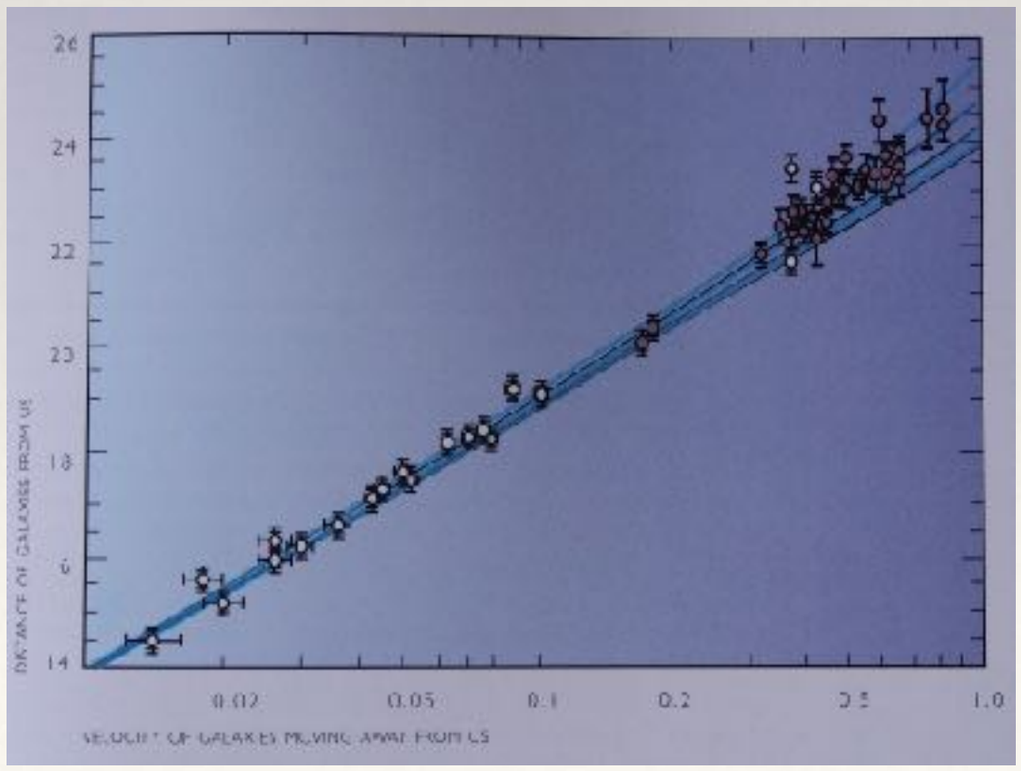


Stoyan *Atlas of Messier Objects*

The Expanding Universe

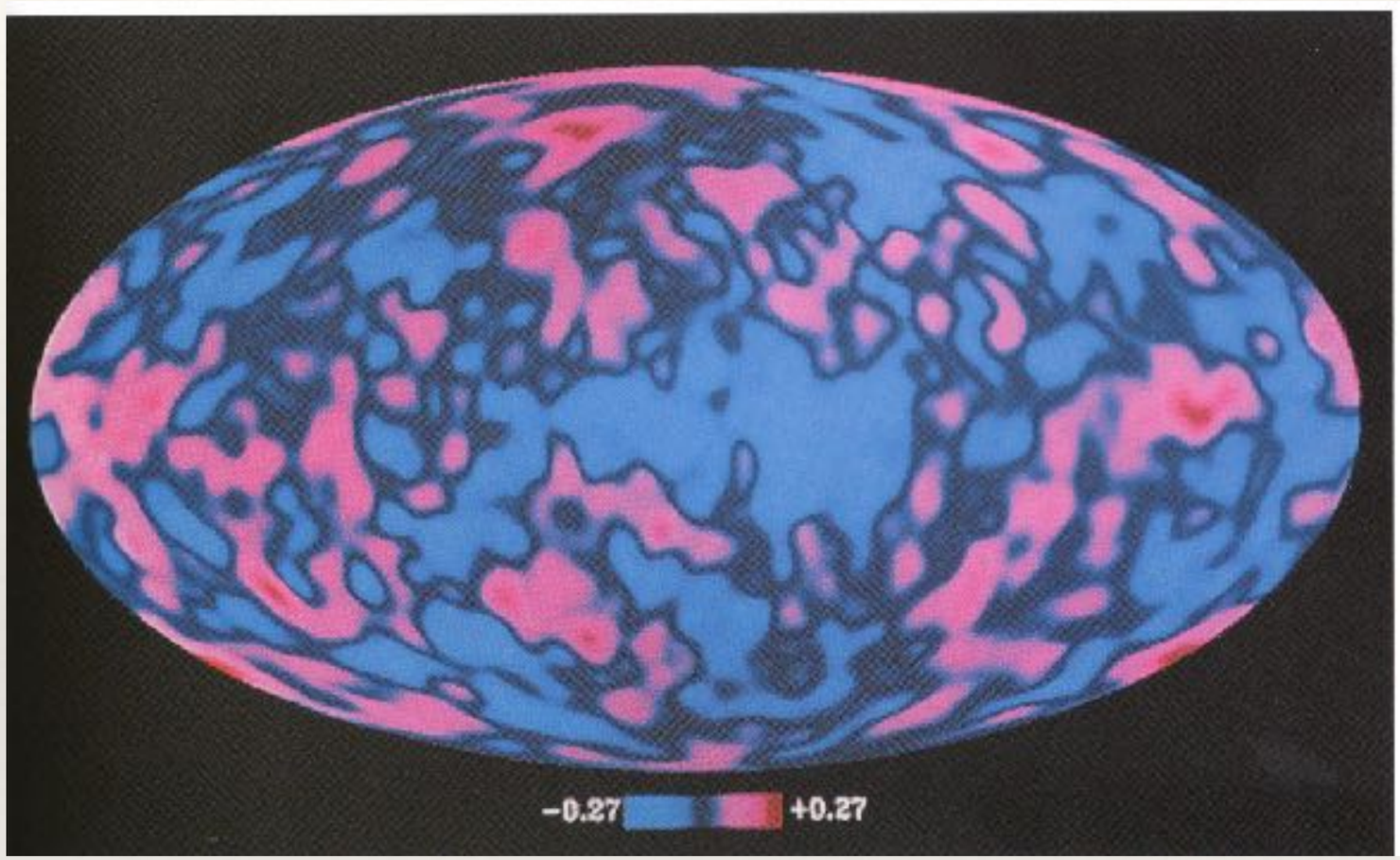
- 1929 Hubble established a linear relationship between distance & velocity of recession
- Hubble Law defines the relationship between distance & velocity of recession.
- Recession begs the question of when expansion began and from what
- Postulated by Lemaitre as "primeval atom" in 1927





The Big Bang

- Proof came from radio astronomy
- Term initially used to ridicule the idea
- CMB (cosmic microwave background) theoretically predicted in 1948
- Detected in 1964 by accident
- 1992 image of CMB showing tiny fluctations in the composition of the early universe
- subsequently confirmed by more precise measurements



Development of Structure in the Universe

- simulation of development of the universe:
- http://apod.nasa.gov/apod/ap140512.html

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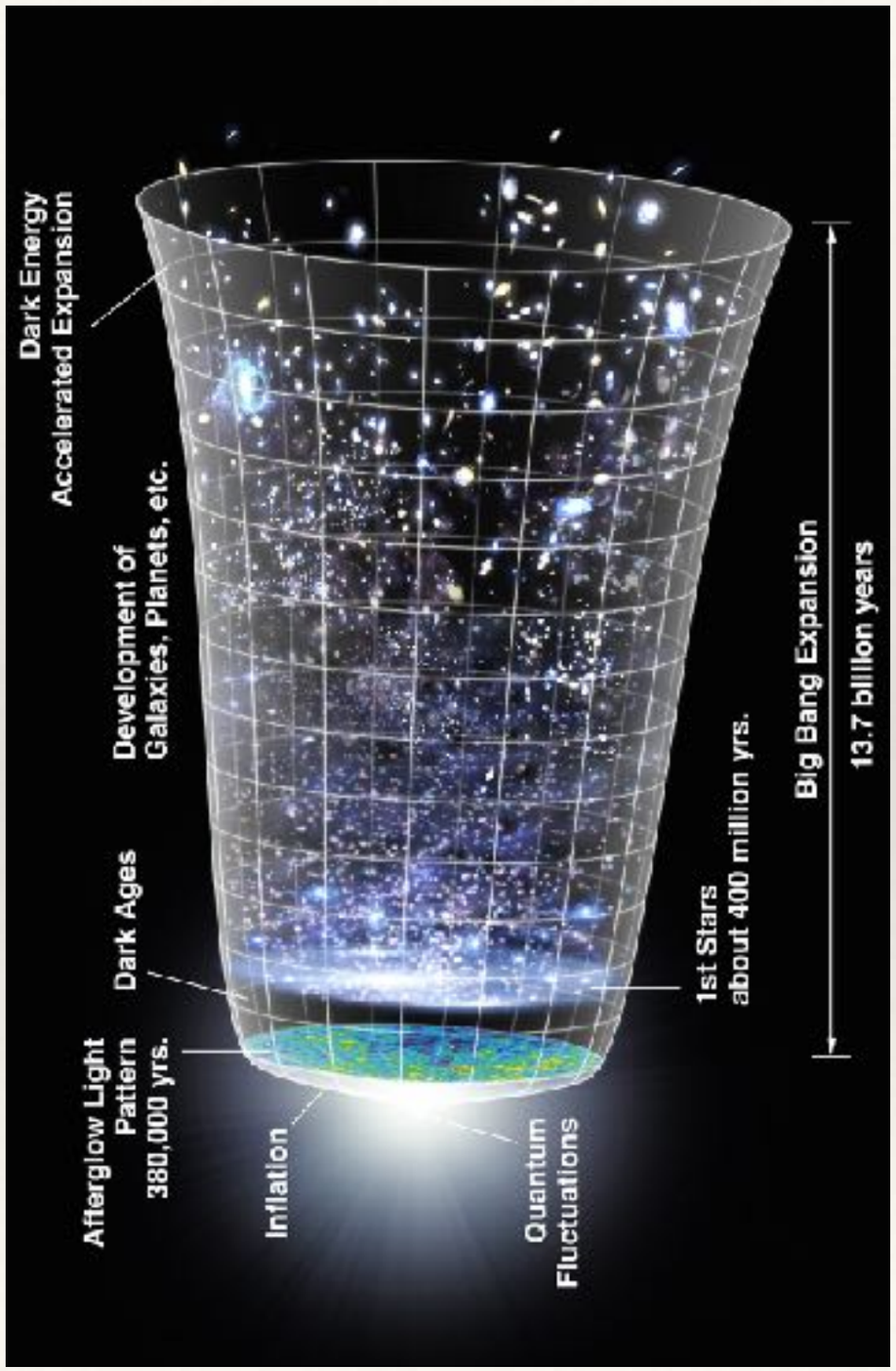

Astronomical Knowledge Today