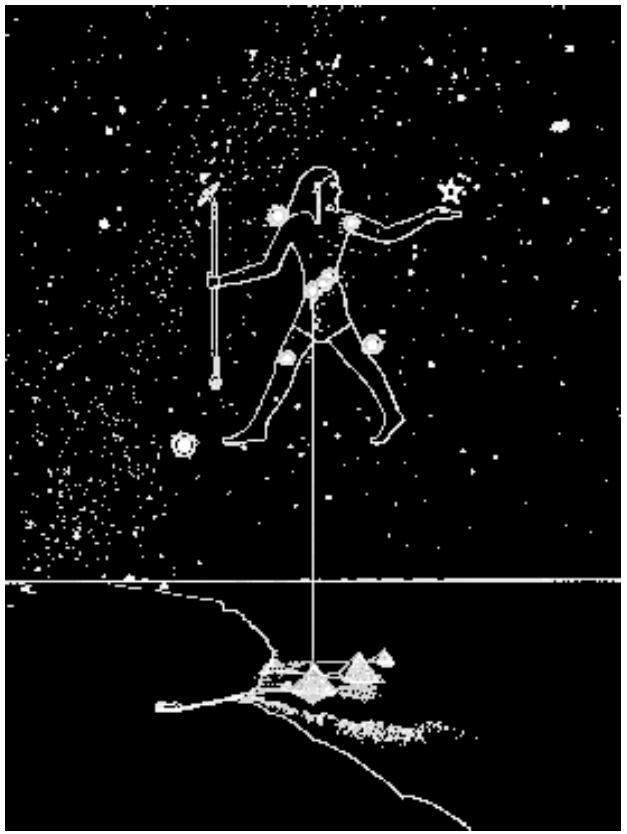
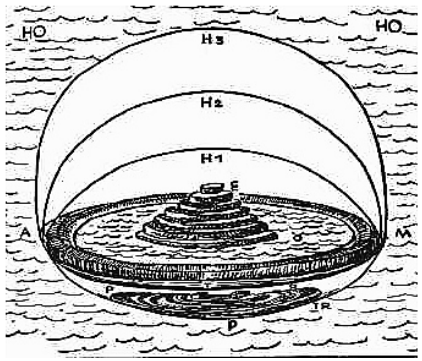
Historie kosmologie

Klíče k neolitické kosmologii (před 20 000 až 100 000lety) vnímání fází Měsíce, příchod jarního úplňku, rovnodennost - vědomí kosmologického řádu



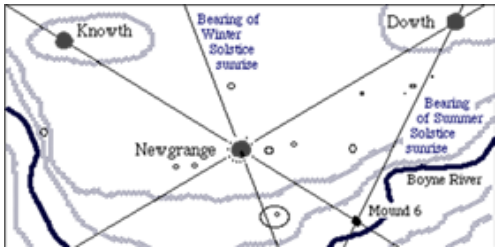
Počátek stvořitelských mýtů



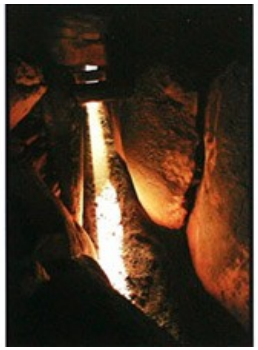
Pyramidy 2600 let před n.l..

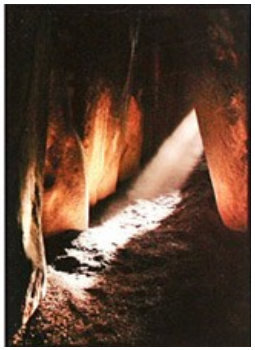
Astronomie - jedna z nejstarších „věd“, počátky před šesti tisíci roky

Newgrange, Knowth a Dowth
počátky spadají do 4. tisíciletí př. n. l.



200
zdobných
kamenů





observatoř Stonehenge
2. tisíc let př.n.l.

1. Starší dějiny kosmologie

Pohleď na nebe
a sečti hvězdy,
dokážeš-li je spočítat.
Tak tomu bude
i s tvým potomstvem.

(Genesis I.15)

Antické Řecko.

Antičtí myslitelé oddělovali „vědecké“ poznání od mýtů a magie.

Thales z Milétu (624 - 545) vše pochází z vody,
předsókratovský filosof, geometr, astronom

Pythagoras ze Samu (569 - 490) sférický tvar Země

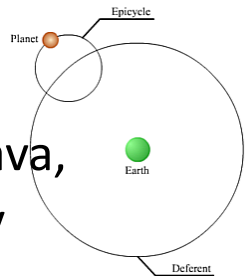
Aristoteles (384 - 322) Země - střed vesmíru, geocentrismus,
Slunce a jiná tělesa obíhají kolem po kružnicích

Aristarchos ze Samu (310 - 250) heliocentrická soustava,
vzdálenost Země-Měsíc-Slunce

Eratosthenes (276 - 194) stanovení poloměru Země

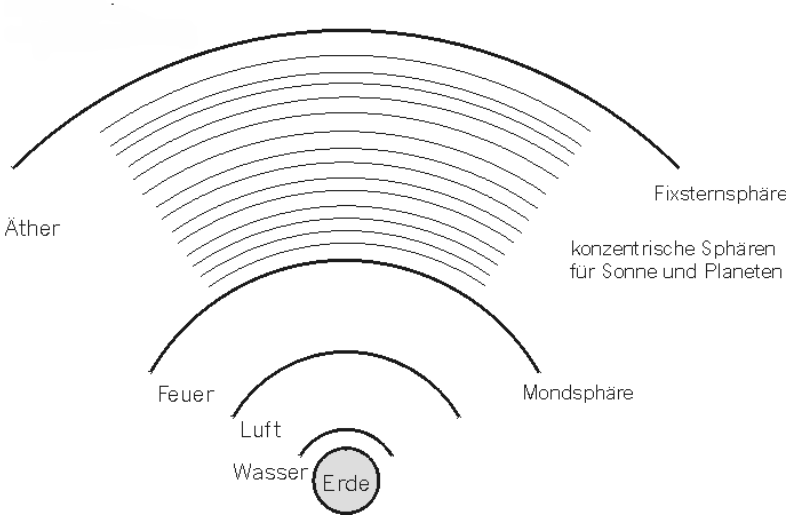
Hipparchos (190 - 120) precese, katalog hvězd

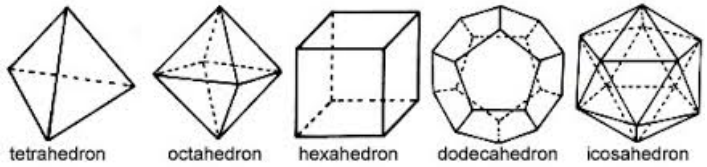
Klaudios Ptolemaios video (90 - 165) geocentrická soustava,
zachytil zdánlivé pohyby planet, epicykly



Platon (427 – 347)

Idea dokonalosti, dokonalý kulovitý tvar, dokonalost rovnoměrného kruhového pohybu. Pozorované nepravidelnosti jsou jen zdánlivé, skutečné pohyby jsou pravidelné. Hmota se skládá ze 4 prvků: zem, voda, vzduch, oheň Podstatou každého prvku je tvar daný určitou kombinací mnohoúhelníků. Čas je pohybem nebeské sféry. Existuje éter Hvězdy a planety jsou „nebeskými božstvy“.





Herakleides z Pontu (asi 390 – 310)

Praotec helicentrické soustavy, Země rotuje, Merkur a Venuše obíhají kolem Slunce, Slunce obíhá kolem Země. Teorie epicyklů. (?)

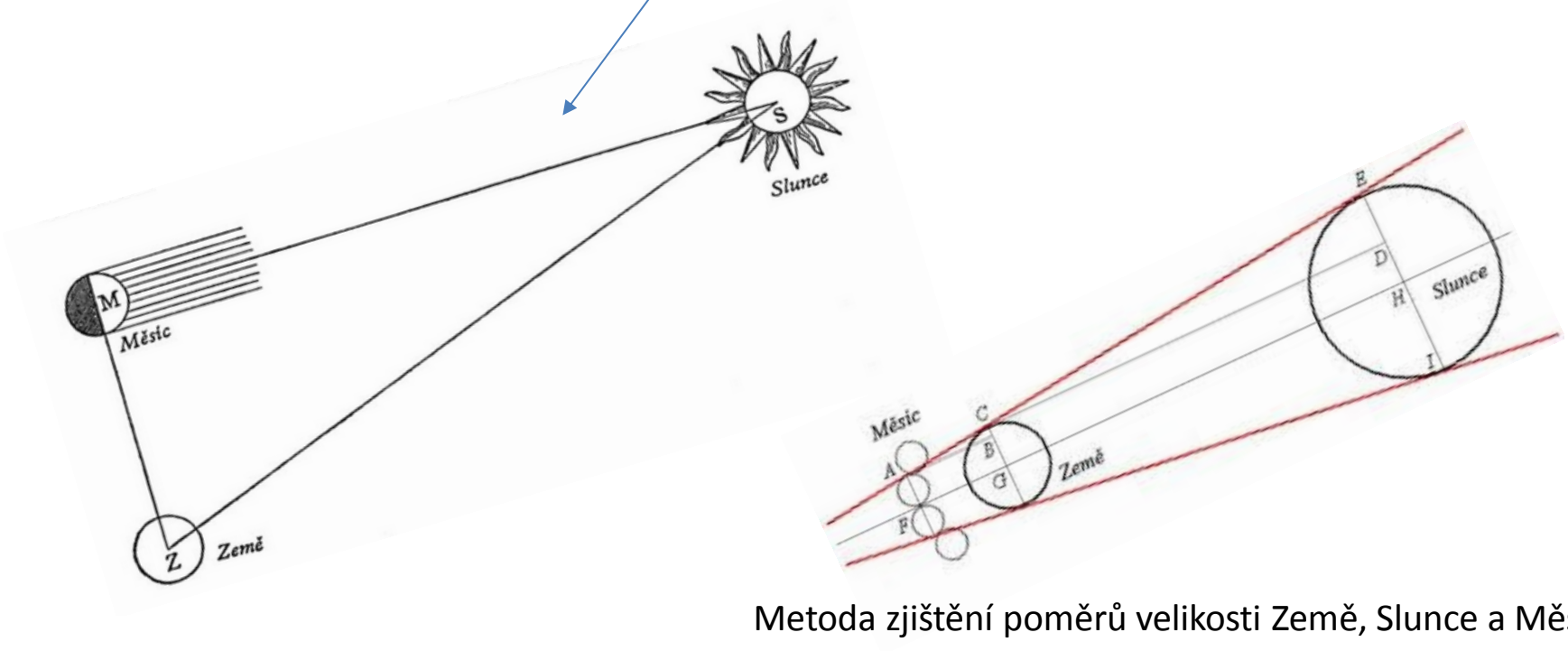
Eukleides (kolem roku 300 př. Kr.)

Vytváří matematické teorie (definice, postuláty, axiomy, věty a důkazy – význam předpokladů), základní postupy zejména od Aristotela.

Aristarchos ze Samu (asi 320 – 230)

Astronom, matematik, filozof, sluneční hodiny, výpočty a měření vzdáleností
- heliocentrický systém,
- hvězdy a Slunce jsou nehybné, Země rotuje a její sféra rotuje kolem Slunce.
- obviněn z bezbožnosti (ruší klid Země).

Aristarchova metoda zjištění poměrů vzdáleností Slunce od Země a Měsíce od Země
Je založena na změření velikosti úhlu, který svírají spojnice Země-Měsíc a Země-Slunce v okamžiku, kdy je Sluncem osvětlena přesně polovina měsíčního kotouče.



Metoda zjištění poměrů velikosti Země, Slunce a Měsíce

Eratosthenes z Kyreny (276 – 194)

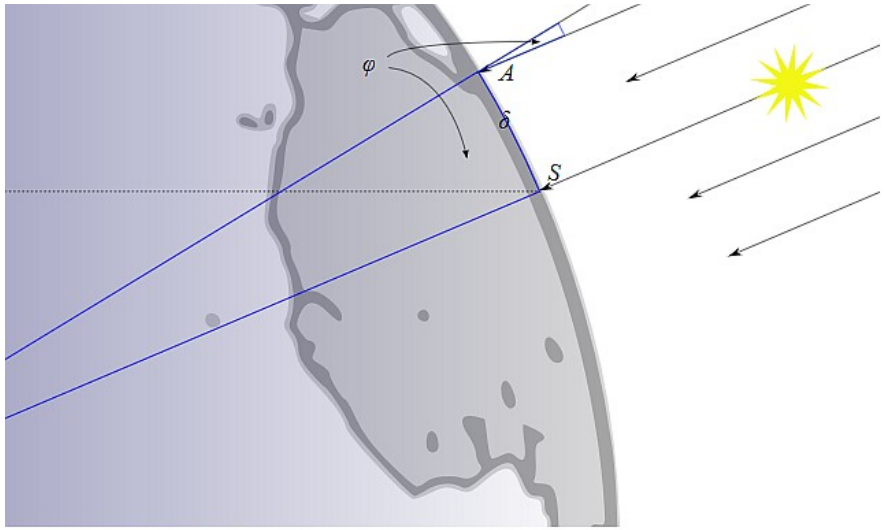
Matematik, astronom, geograf, kartograf, chronolog, historik, etik, básník
Správce alexandrijské knihovny.

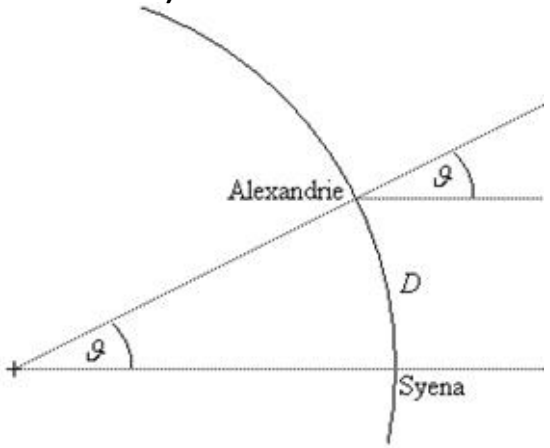
Eratosthenovo měření Země (kolem roku 220 př. Kr.)

Na základě rozdílu výšek Slunce nad obzorem ve dvou městech ležících přibližně na stejném poledníku určil rozdíl zeměpisných šířek těchto dvou míst. Ze známé vzdálenosti D obou měst, kterou odměřili vojáci putující z Alexandrie do Syeny, dopočítal délku *o* poledníkové kružnice ze vztahu

$$\frac{D}{o} = \frac{\vartheta}{360°}$$

Délka poledníkové kružnice vyšla 252000 stadií (40 000 km) určil tuto délku celkem přesně.





http://fyzika.jreichl.com/main.article/print/1440-eratosthenes-z-kyreny

Ptolemaios 100 – 170

představa světa - v díle Almagest podává přehled všech dosažených astronomických poznatků na základě geocentrické soustavy založené na předepsaném systému pohybů „nebeských sfér“, na nichž jsou podle něho nebeská tělesa upevněna.

Fig. 1.1 Ptolemy's model of the Universe placed the Earth at the centre, with the Sun, Moon, planets and stars all moving about it. This drawing is taken from Peter Aplan *"Cosmographia"* (1524)

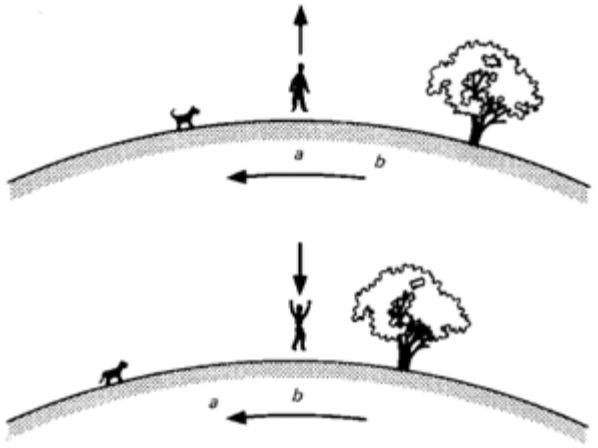


Figure 3.2. Ptolemy's "proof" that the Earth does not move or rotate. If a person on the Earth's surface at point *a* jumps up, and the Earth's surface moves, the person will fall back at point *b*. But observation shows that the person always falls back at the original point *a*. This proves, argued Ptolemy, that the Earth is stationary and hence the heavens must revolve around the Earth.

5.-11. století - několik astronomů včetně Aryabhata, Albumasar tvrdí, že Slunce je střed vesmíru
6. století - John Philoponus navrhuje vesmír, který je konečný v čase a argumentuje proti starořeckému pojetí nekonečného vesmíru

9. až 12. století - Alkindus (Alkindus), Saadia Gaon (Saadia ben Joseph) a Al-Ghazali (Algazel) podporují vesmíru, který má konečnou minulost a rozvíjejí logické argumenty proti konceptu nekonečné minulosti (jeden z nich později přijal Immanuel Kant)
964 - Abd al-Rahman al-Sufi (Azophi), perský astronom, první zaznamenané pozorování galaxie v Andromedě a Velkém Magellanově mračnu, jde o první galaxie jiné než Mléčná dráha, kniha stálic

12. století - Fakhr al-Din al-Razi pojednává o islámské kosmologii, odmítá Aristotelovu myšlenku Země-střed vesmíru, a v souvislosti s jeho komentáři k verši koránu, "Všechna chvála náleží Bohu, Pánu světů "navrhuje, že vesmír má více než" tisíc tisíců světů mimo tento svět takových, že každý z z nich může být větší a hmotnější než tento svět"[4] Tvrdil že existuje nekonečnost za hranicemi známého světa, [5] a že tam může být nekonečný počet vesmírů. [6]

13. století - Nasir al-Din al-Tusi poskytuje první empirický důkaz pro rotaci Země kolem své osy
13. století -. Nachmanides naznačuje, že vesmír se rozpíná

15. století - Ali Qushji poskytuje empirický důkaz pro rotaci Země kolem své osy a odmítá stacionární teorii Aristotela a Ptolemaila

15.-16. století - Nilakantha Somayaji a Tycho Brahe navrhují vesmír, v němž planety obíhají kolem Slunce a Slunce obíhá kolem Země, tzv. Tychonův systém

Mikuláš Koperník

obrat v chápání místa člověka v kosmu

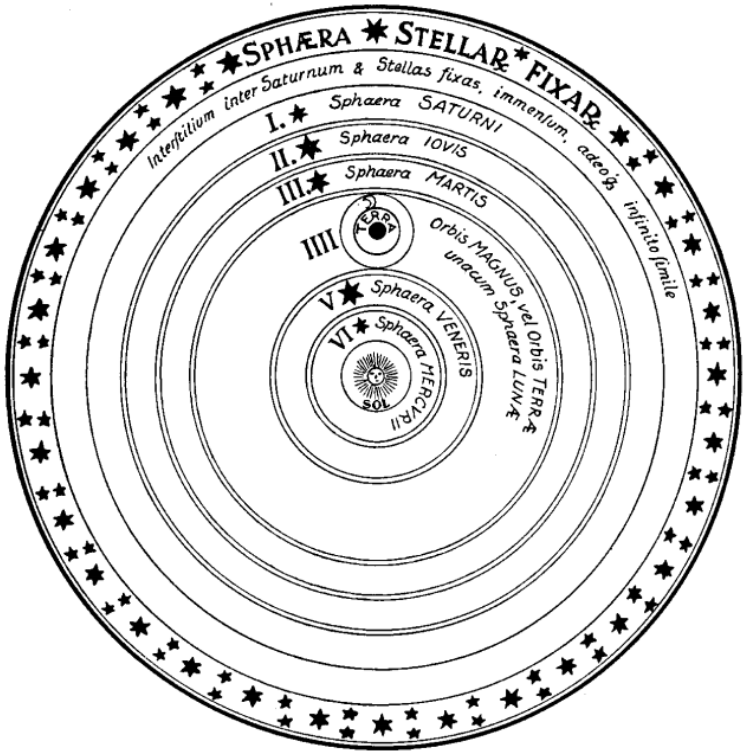
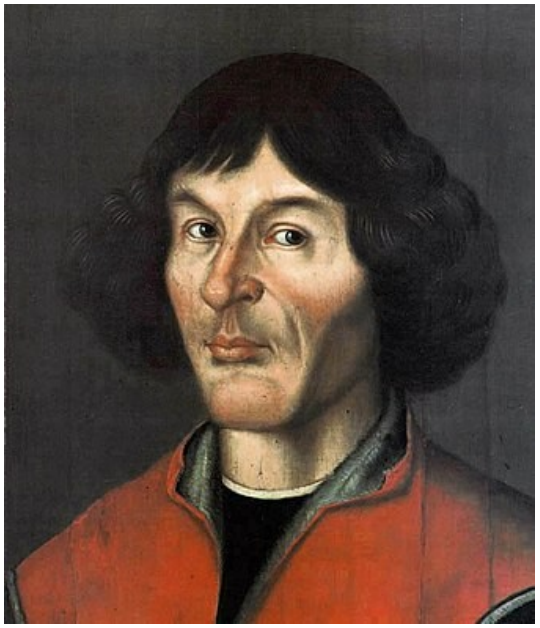


Figure 2.10. The universe according to Copernicus with the Sun occupying the center. The heliocentric universe originated in the third century BC and was proposed by Aristarchus of Samos who "brought out a book consisting of certain hypotheses in which the premises lead to the conclusion that the universe is many times greater than that now so called. His hypotheses are that the stars and the sun remain motionless, that the earth revolves about the sun in the circumference of a circle, the sun lying in the middle of the orbit" (Archimedes [about 287–212 BC], *The Sand Reckoner*. T. Heath, *Aristarchus of Samos*).



R.1533 bylo dílo De Revolutionibus předneseno papeži Klemensovi VII.

Norimberský teolog Osiander přemluvil Mikuláše Koperníka, aby v předmluvě ke svému dílu představil svůj model jako hypotézu, aby zjemnil odvážné myšlenky

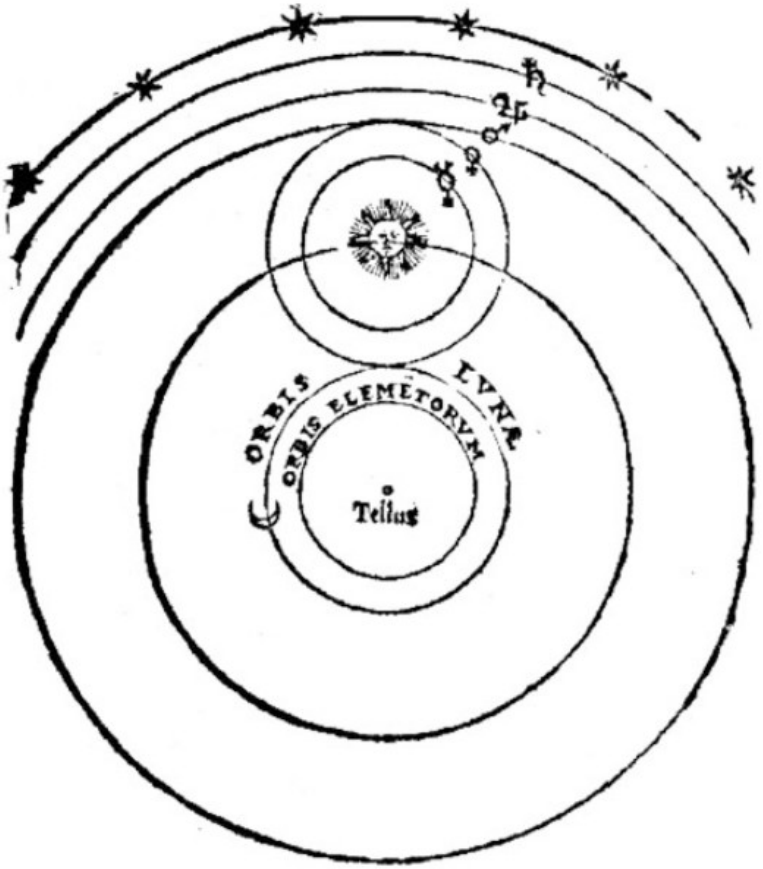


Fig. 1.4 Brahe's hybrid model kept the Earth at the centre of the Universe, with the Sun and other planets orbiting it, but with Mercury and Venus also orbiting the Sun (image from a drawing by Valentin Naboth in *Primae de coelo et terra institutiones* (1573))

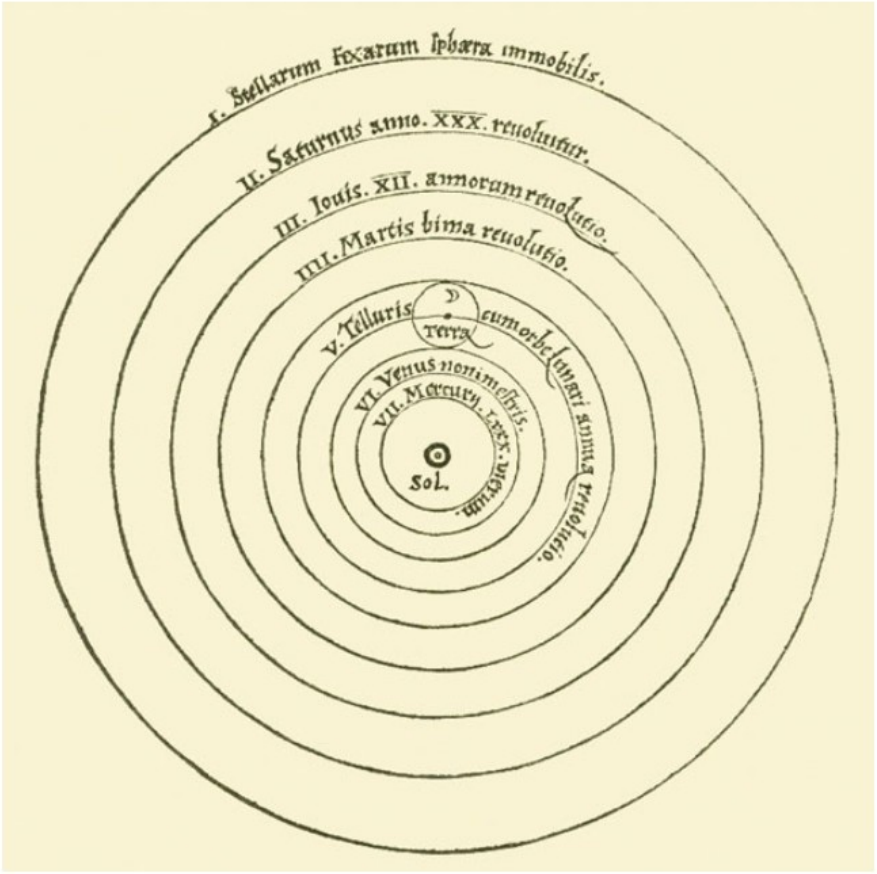
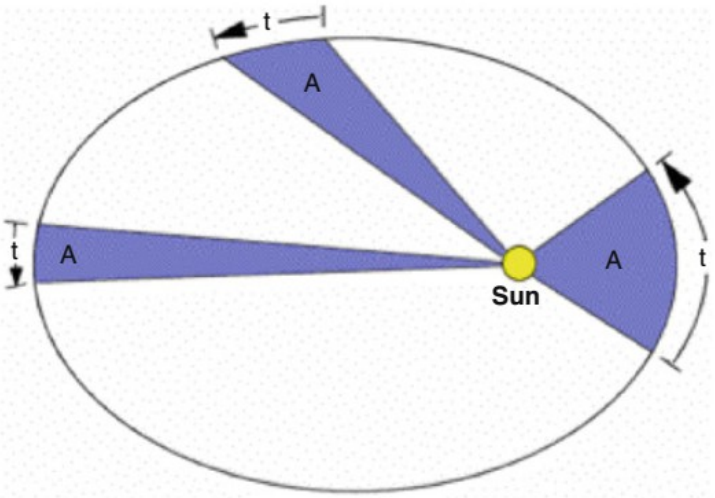


Fig. 1.2 Copernicus' model of the Universe placed the Sun and not the Earth at the centre (image from Copernicus' *De revolutionibus orbium coelestium* (1543))

Fig. 1.5 Johannes Kepler discovered that the planets orbit the Sun in ellipses and not circles (image from a 1610 oil painting of Kepler)



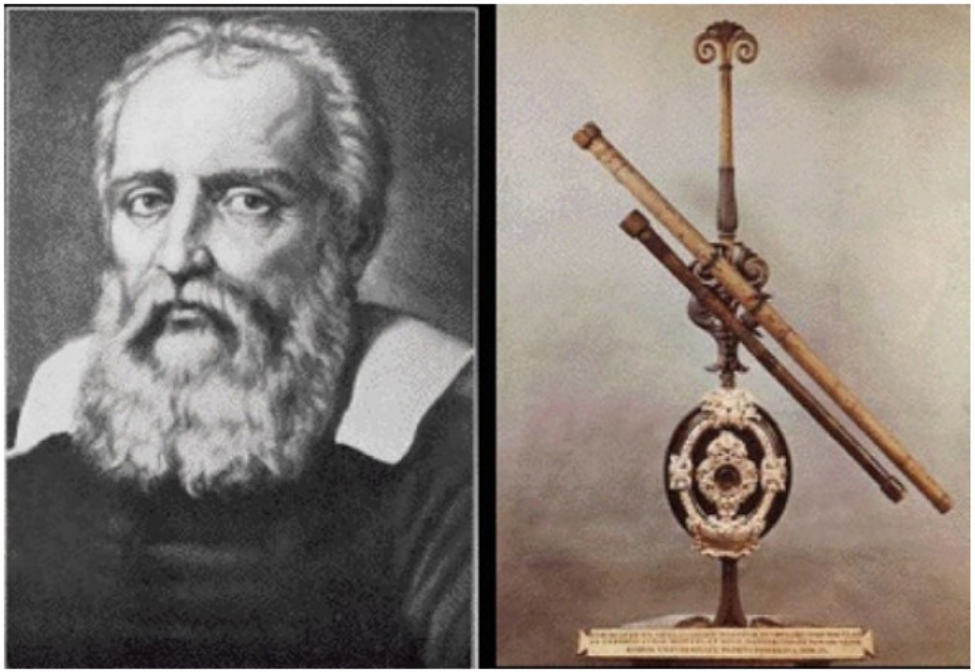
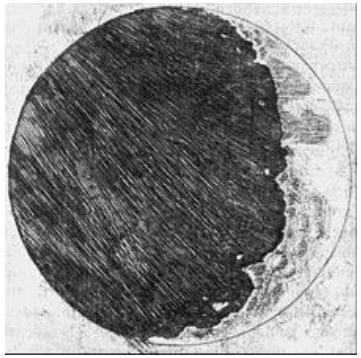
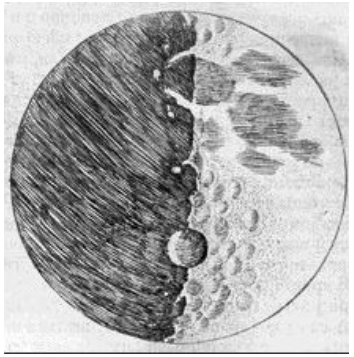
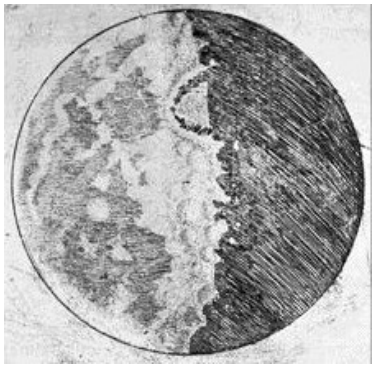


Fig. 1.9 Galileo with the telescope that he built to observe the moons of Jupiter and the phases of Venus (image of Galileo from *Popular Science Monthly Volume 78* (1911). Image of Galileo's telescope by the author)

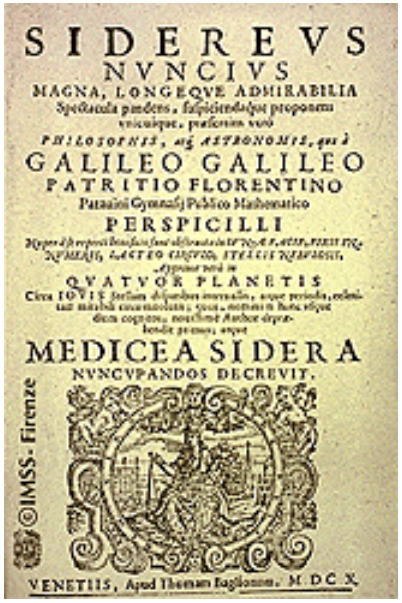
Galileo Galilei:
1564 – 1642 AD







Galileo Galilei:
1564 – 1642 AD



"I have observed the nature and the material of the Milky Way. With the aid of the telescope this has been scrutinized so directly and with such ocular certainty that all the disputes which have vexed philosophers through so many ages have been resolved, and we are at last freed from wordy debates about it.

The galaxy is, in fact, nothing but a collection of innumerable stars grouped together in clusters. Upon whatever part of it the telescope is directed, a vast crowd of stars is immediately presented to view. Many of them are rather large and quite bright, while the number of smaller ones is quite beyond calculation."

from The Starry Messenger (1610)

Isaac Newton (1643 - 1727)

Zákon všeobecné gravitace a jeho důsledky

Edmond Halley

Podle Newtonovy metody propočítal dráhy
24 komet v práci 1705

Charles Messier (1730 - 1817) lovec komet.

Jeho zásluhou byly komety systematicky popisovány do hvězdných map, pro usnadnění hledání vydal první **katalog mlhovin** a **hvězdokup**, který obsahoval 103 objektů (60 objeveno samotným Messierem).

Z těchto 103 objektů bylo 33 galaxií, především spirálních, 27 kulových a 30 otevřených hvězdokup a 11 plynných mlhovin.

Pouze u dvou z těchto objektů Messier chybně považoval za mlhovinu.

Později byl katalog doplněn o 7 dalších objektů. V Messierově katalogu M 1 označuje Krabí mlhovinu, M 31 mlhovinu v Andromedě a M 42 mlhovinu v Orionu.

Sir Frederick William Herschel

Catalogue of One Thousand new Nebulae and Clusters of Stars (1786)

zrcadlový dalekohled
objevil infračervené záření

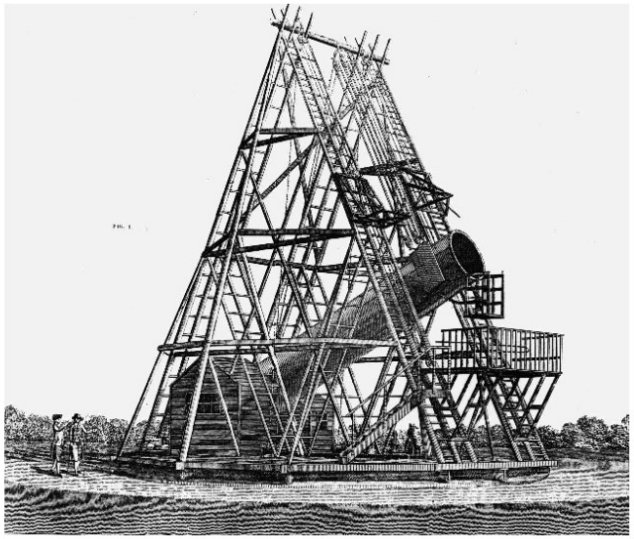


Figure 4.7. William Herschel's 40-foot telescope in 1795.

Fig. 1.19 Herschel's map of the Milky Way which came from counting the stars in over 600 different locations and assuming they all had the same intrinsic brightness (image from a paper entitled *On the Construction of the Heavens* by Herschel published in *Philosophical Transactions of the Royal Society of London, Vol. 75* (1785))

Dalekohled s f= 12 m
28. srpna 1789 objevil Saturnův měsíc Enceladus.

Velká debata 1920

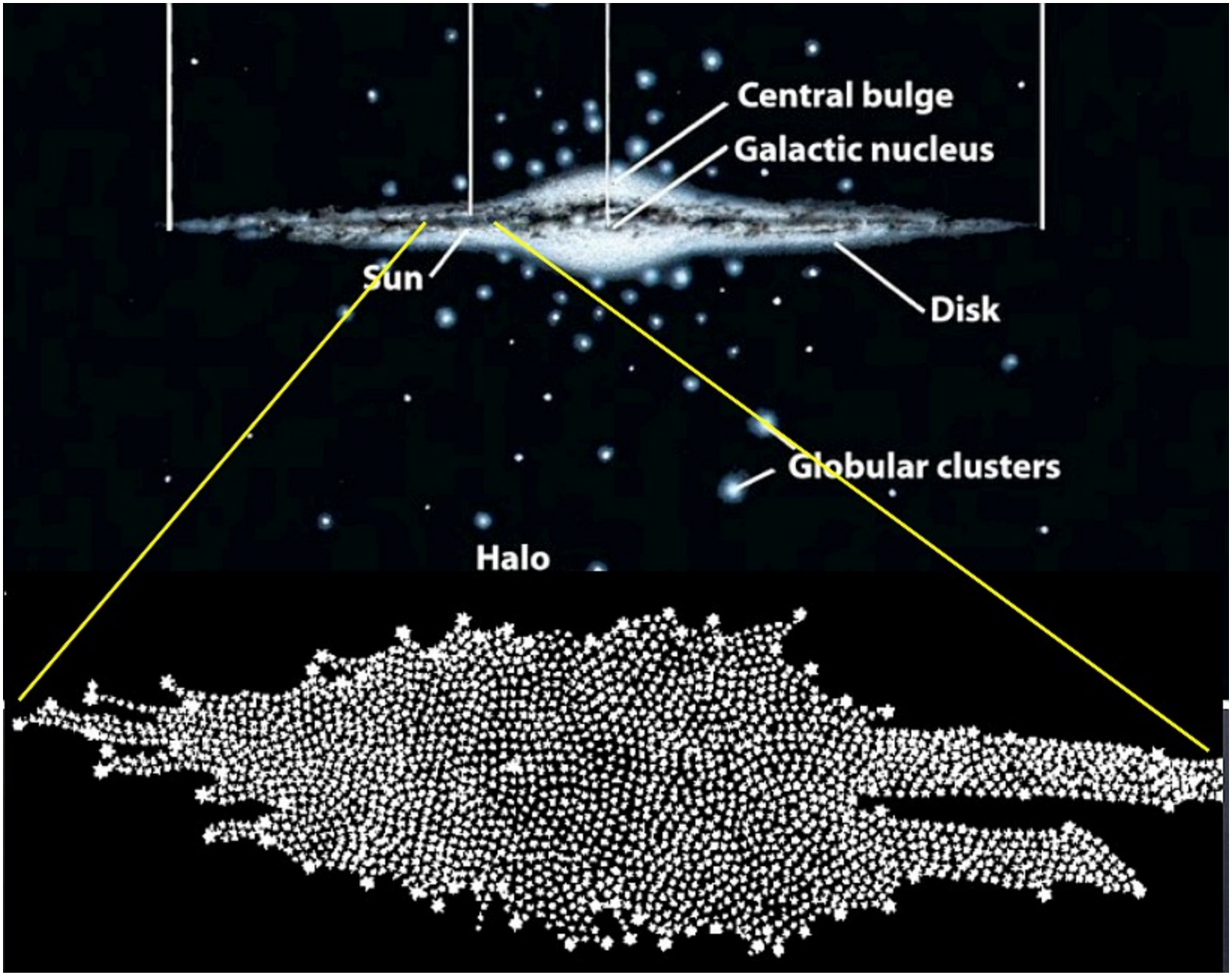
National Academy of Sciences, Washington

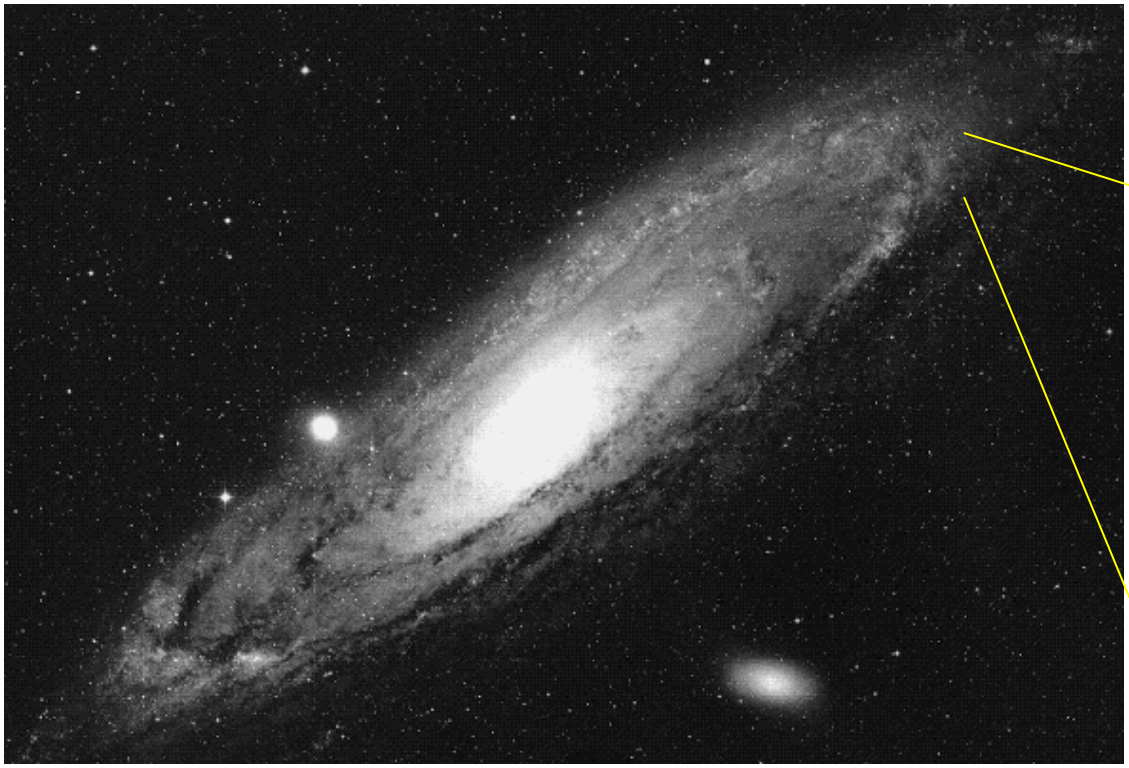
Harlow Shapley vs Heber D. Curtis

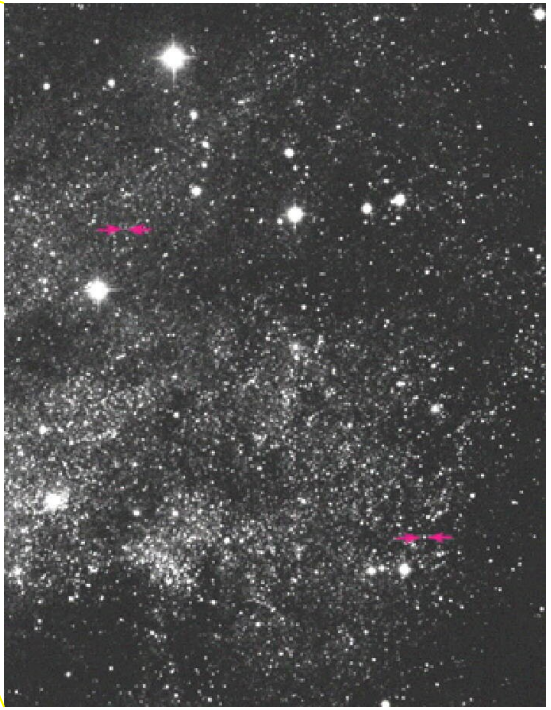
https://apod.nasa.gov/debate/1920/cs_lplan.html

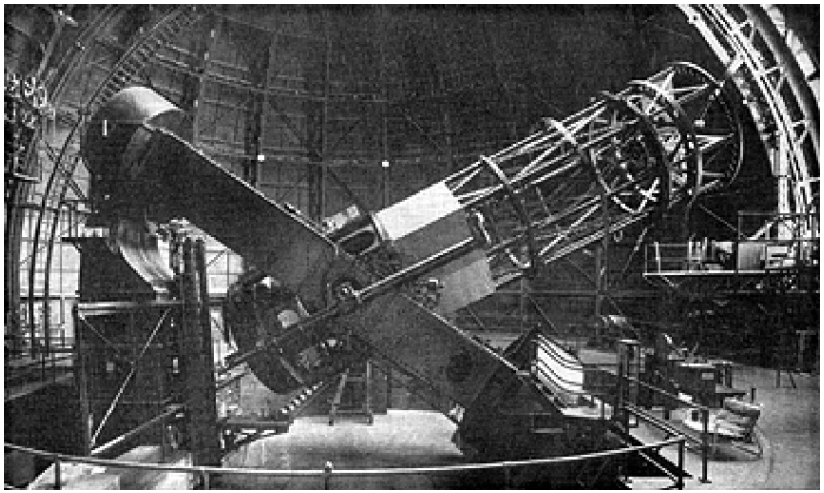
Předtím se věřilo, že Mléčná dráha má průměr 15 - 20 000 světelných let, a že Slunce leží v centru Galaxie

Shapley nakonec dospěl k závěru, že průměr je téměř 300 000 světelných let, ačkoli zjistil, že Mléčná dráha je mnohem větší, než si kdo představoval ,jeho odhad průměru byl příliš velký .

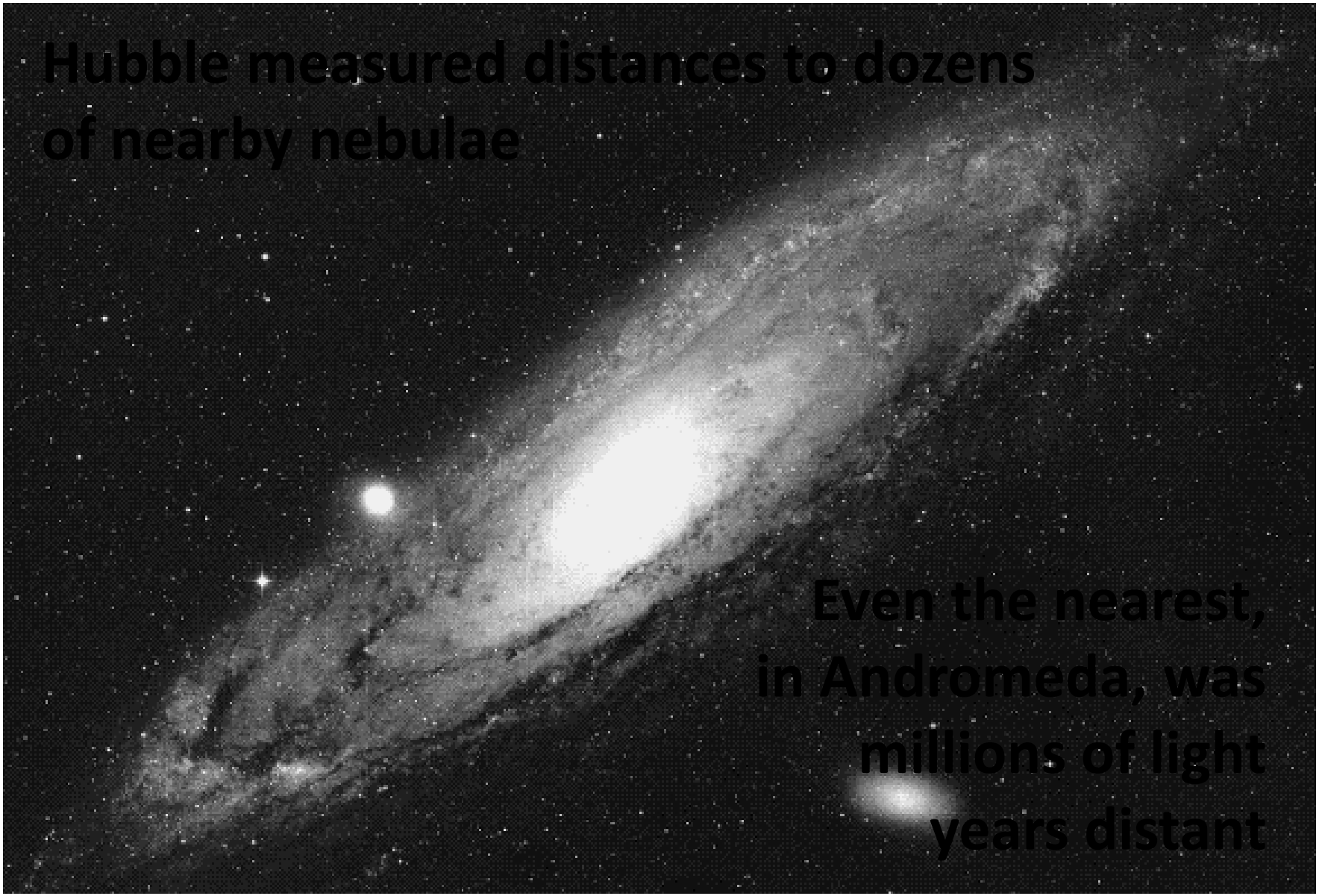

Central bulge
Galactic nucleus
Sun
Disk
Globular clusters
Halo



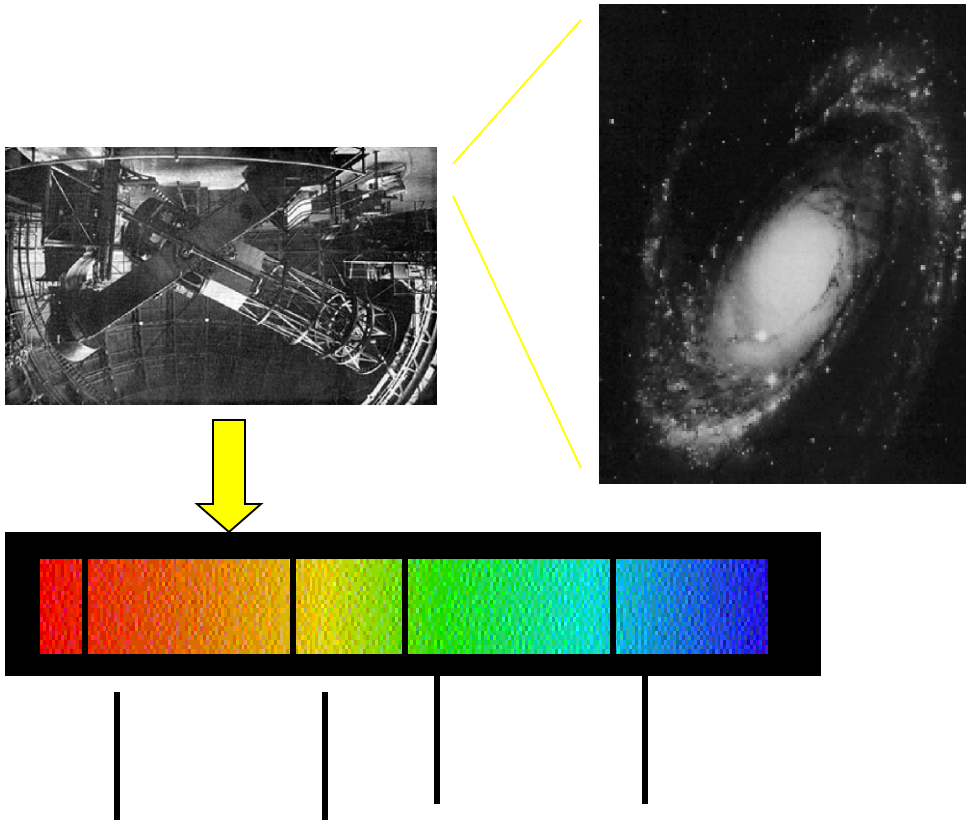




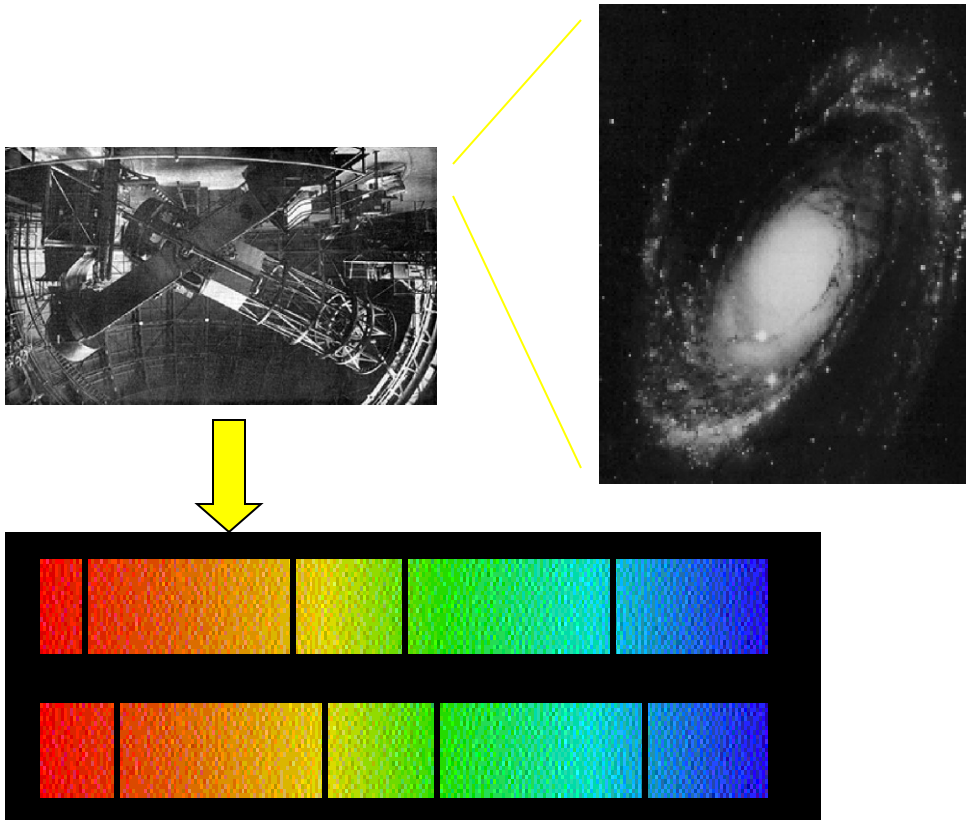
1922: Hubble finds Cepheids in the Great Nebula in Andromeda


Hubble measured distances to dozens of nearby nebulae
Even the nearest, in Andromeda, was millions of light years distant

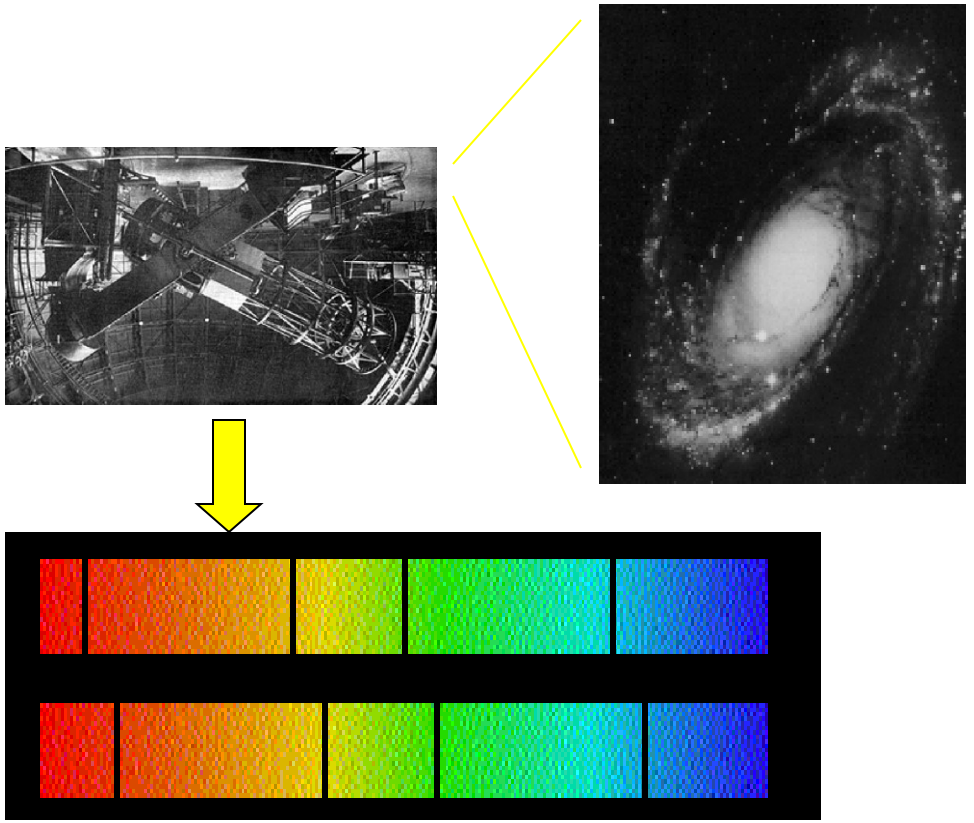
Hubble also measured the shift in colour, or *wavelength*, of the light from distant galaxies.

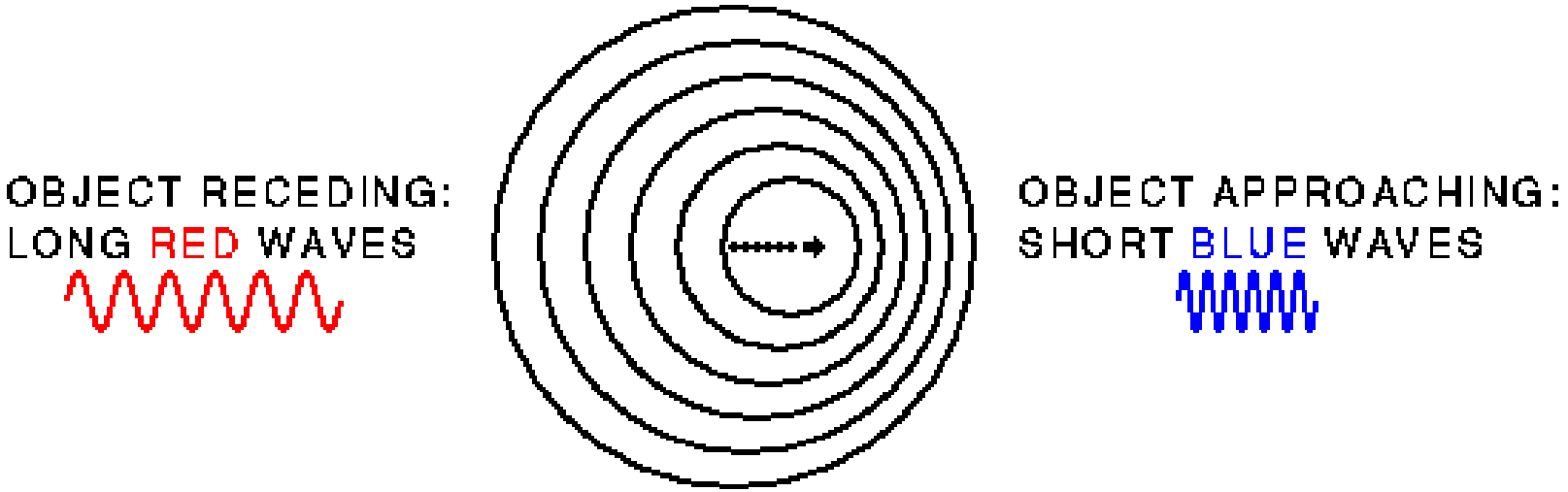


Hubble also measured the shift in colour, or *wavelength*, of the light from distant galaxies.



Hubble also measured the shift in colour, or *wavelength*, of the light from distant galaxies.





Hubble's Law: 1922

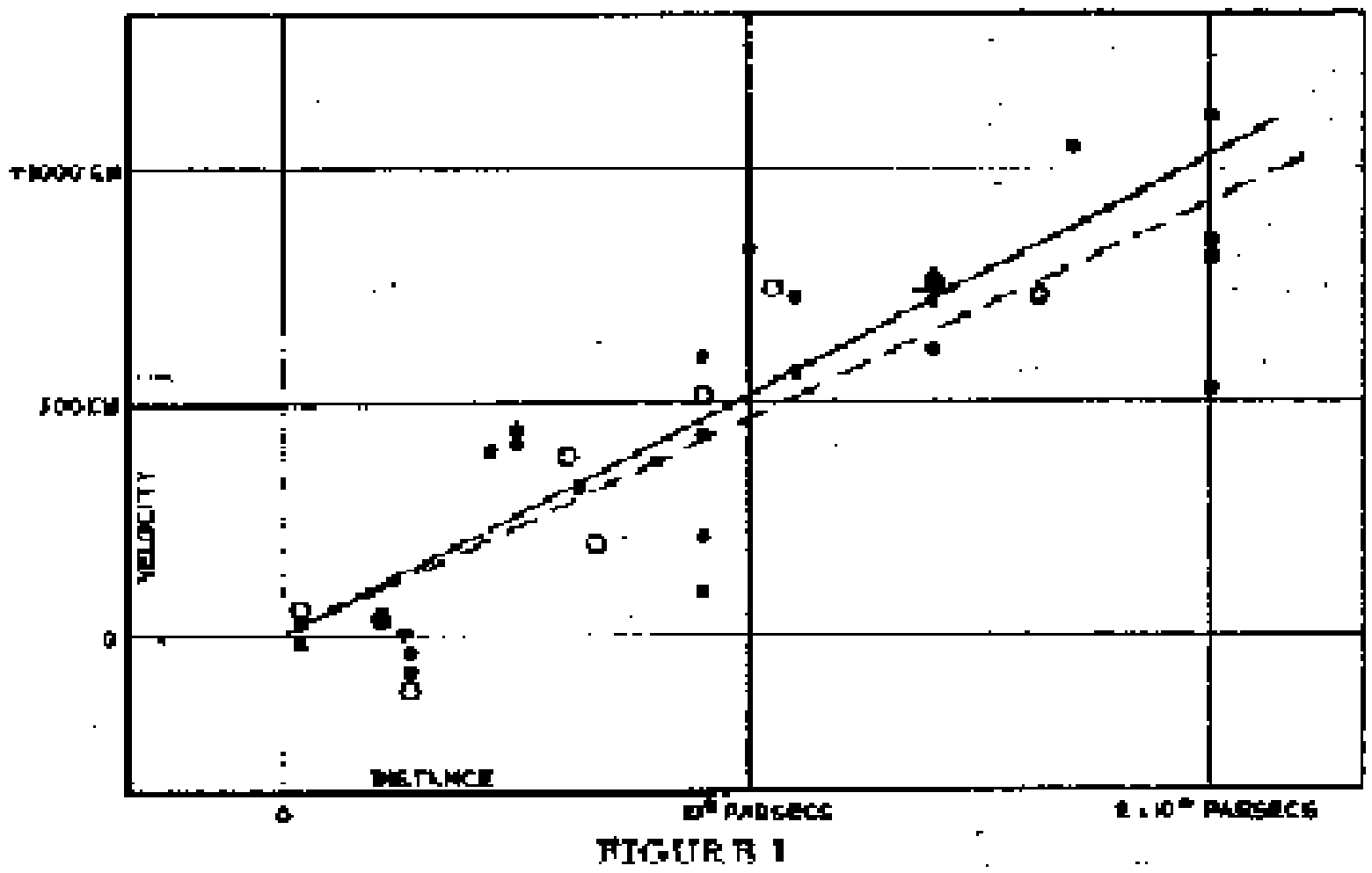
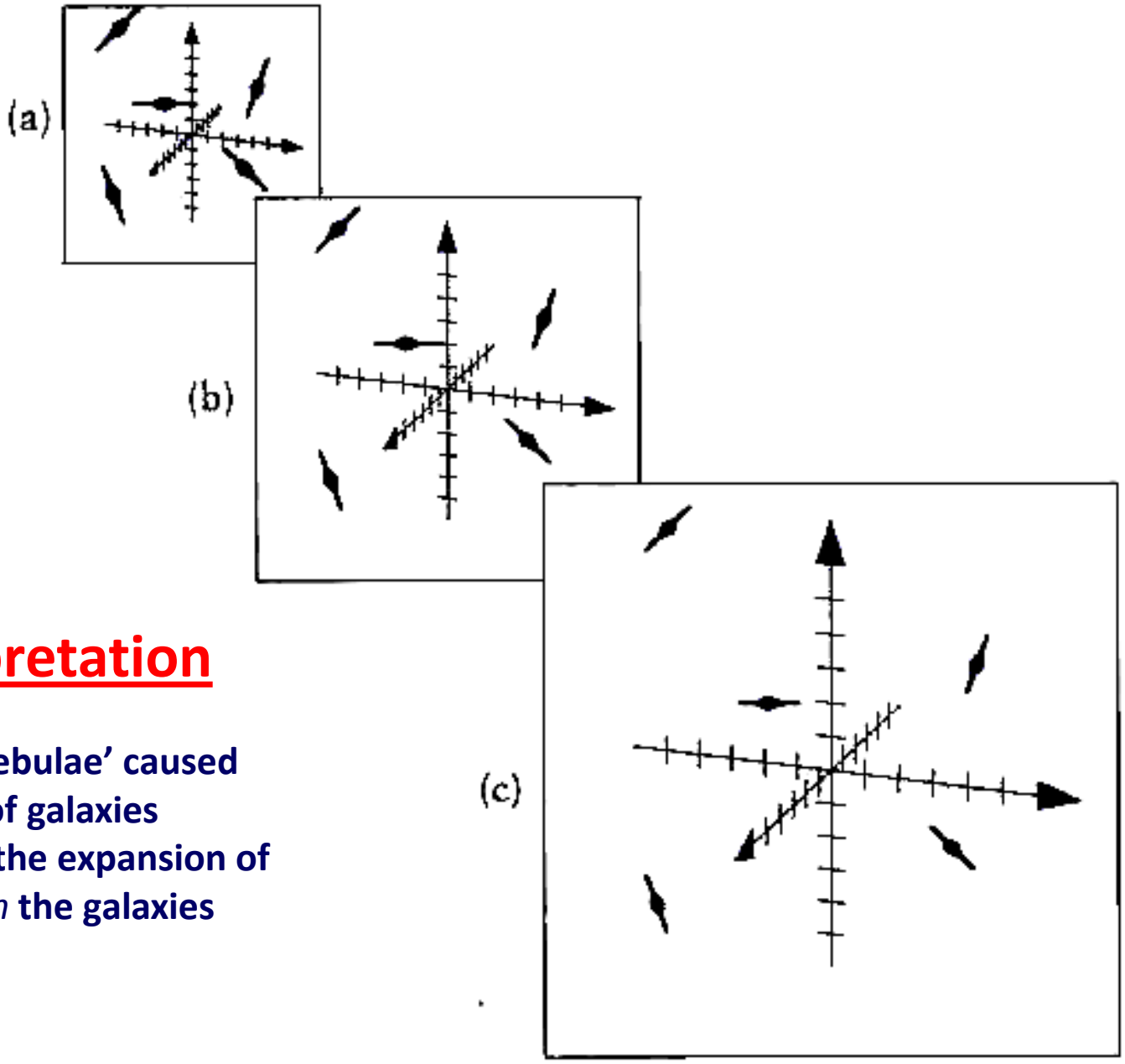


FIGURE 1

Distant galaxies are receding from us with a velocity proportional to their distance



Hubble's Interpretation

'Recession of the Nebulae' caused not by the motion of galaxies *through* space, but the expansion of space itself *between* the galaxies

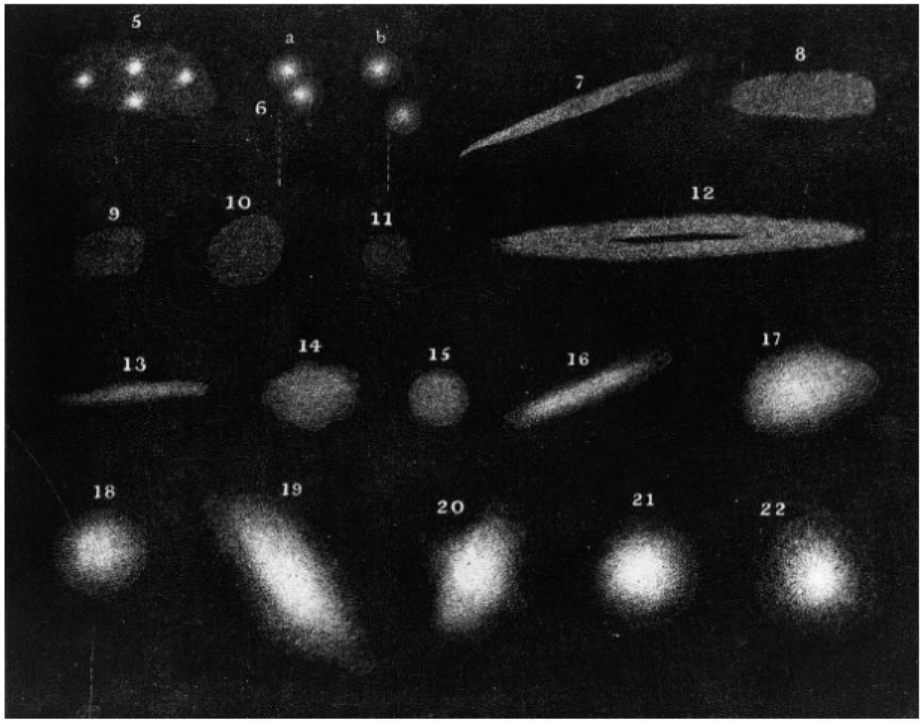
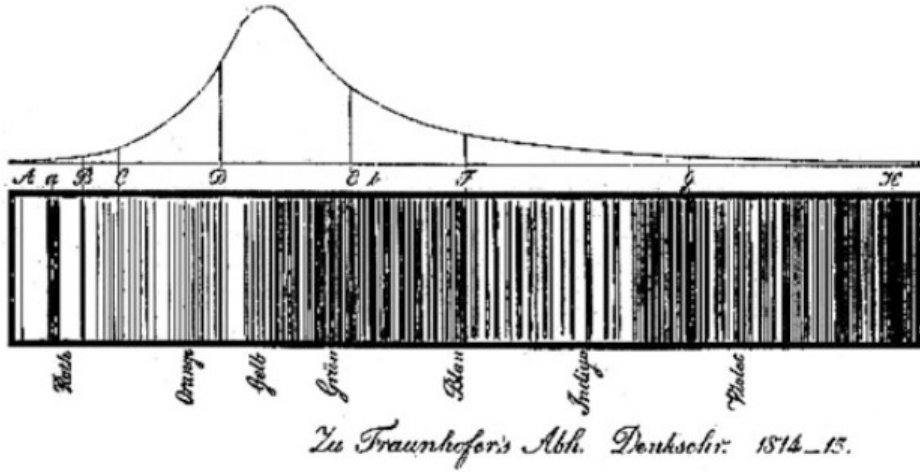


Figure 4.8. William Herschel's sketch of various nebulae in his paper "Astronomical observations relating to the construction of the heavens" (1811). According to the Wright–Kantian hypothesis the nebulae are distant milky ways like our Milky Way, and according to the Kant–Laplacian hypothesis they are swirling clouds of gas located in the Milky Way that are in the process of condensing to form new solar systems.



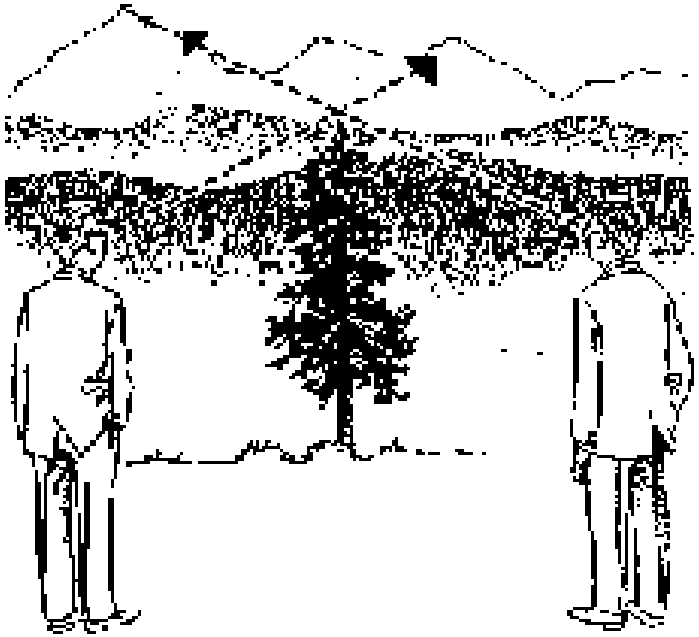
g. 1.20 Joseph von Fraunhofer's sketch of dark lines on the spectrum of the Su scovered in 1814–1815

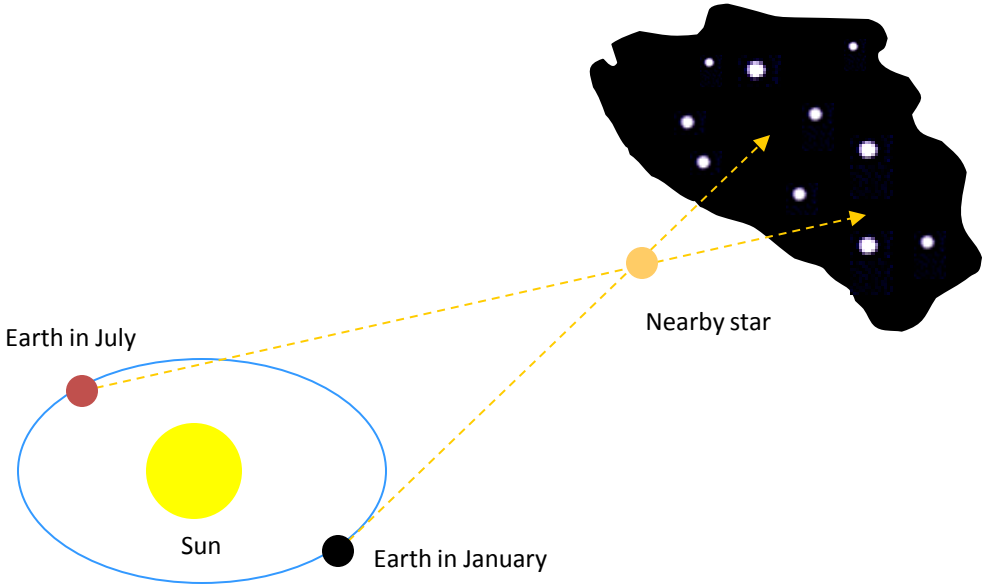
$$z = \frac{\lambda_0 - \lambda}{\lambda}.$$

- Může znalost kosmologie ovlivnit náš systém hodnot a etické postoje? V jakém smyslu?

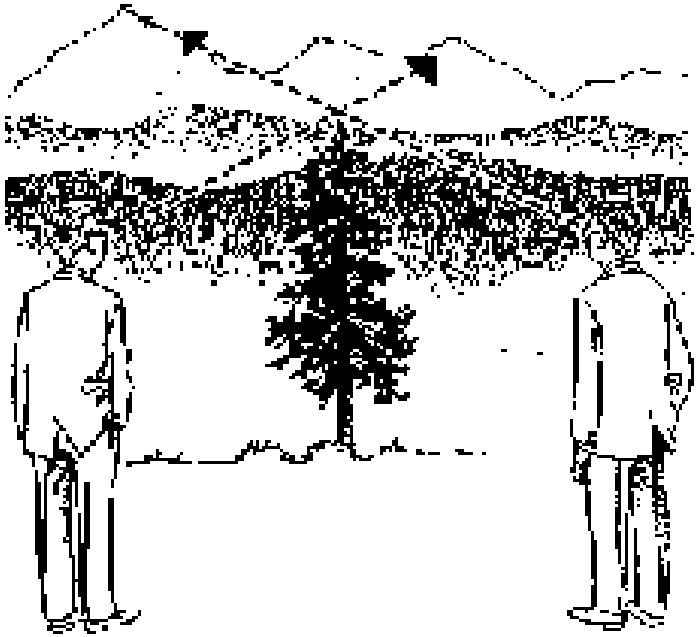
- Odkud jste čerpali dosavadní znalosti o vesmíru?

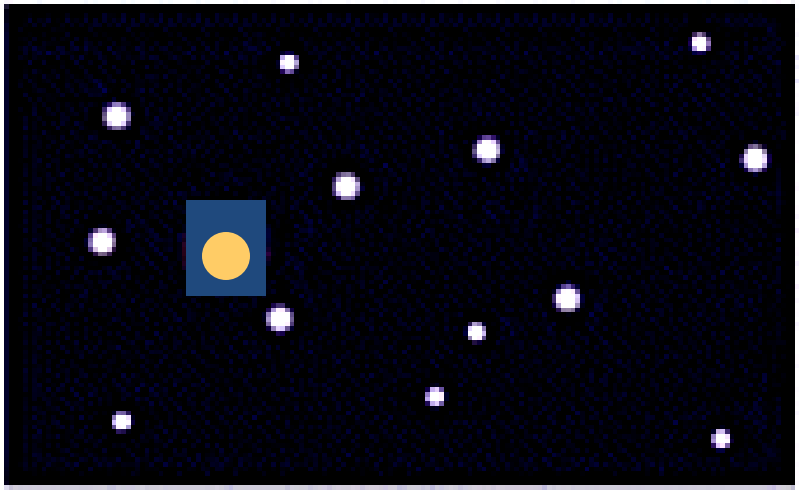
Measuring Astronomical Distances: Parallax



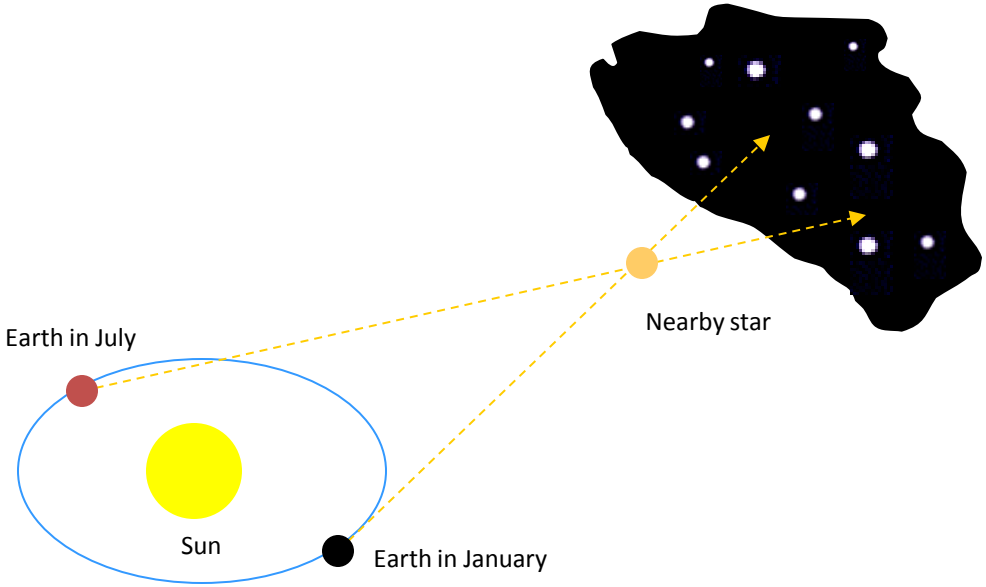


Measuring Astronomical Distances: Parallax

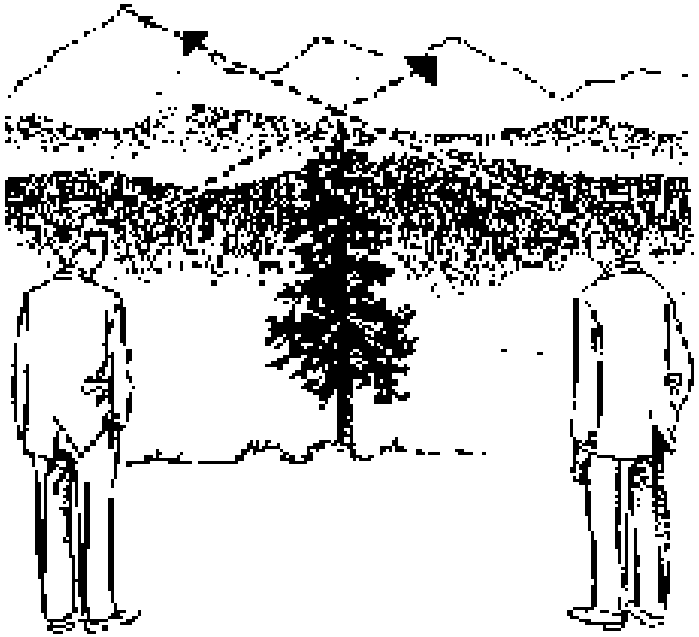


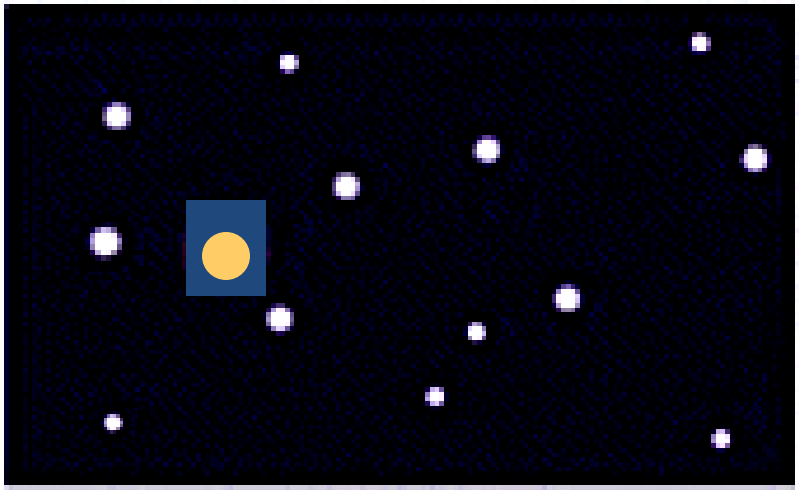


View from the Earth in January

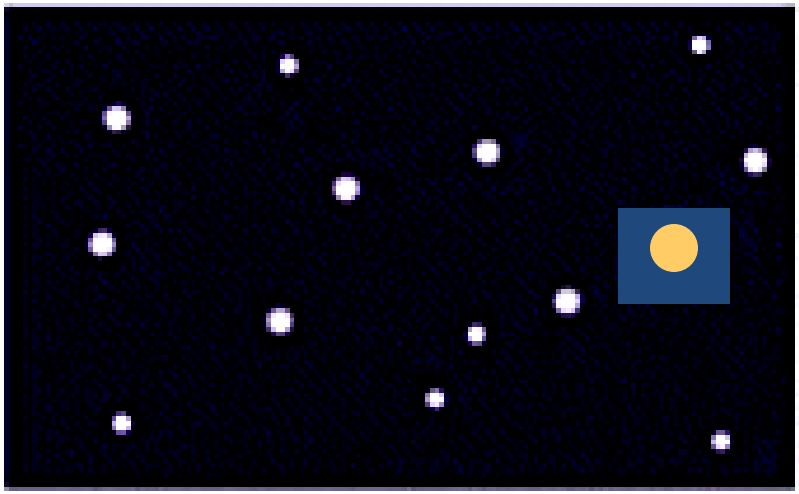


Measuring Astronomical Distances: Parallax

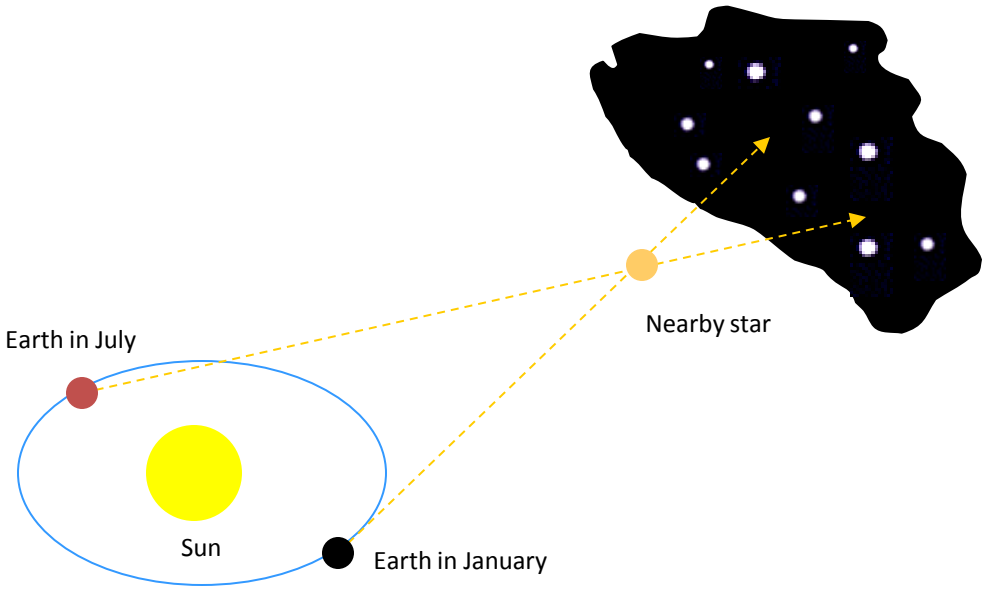




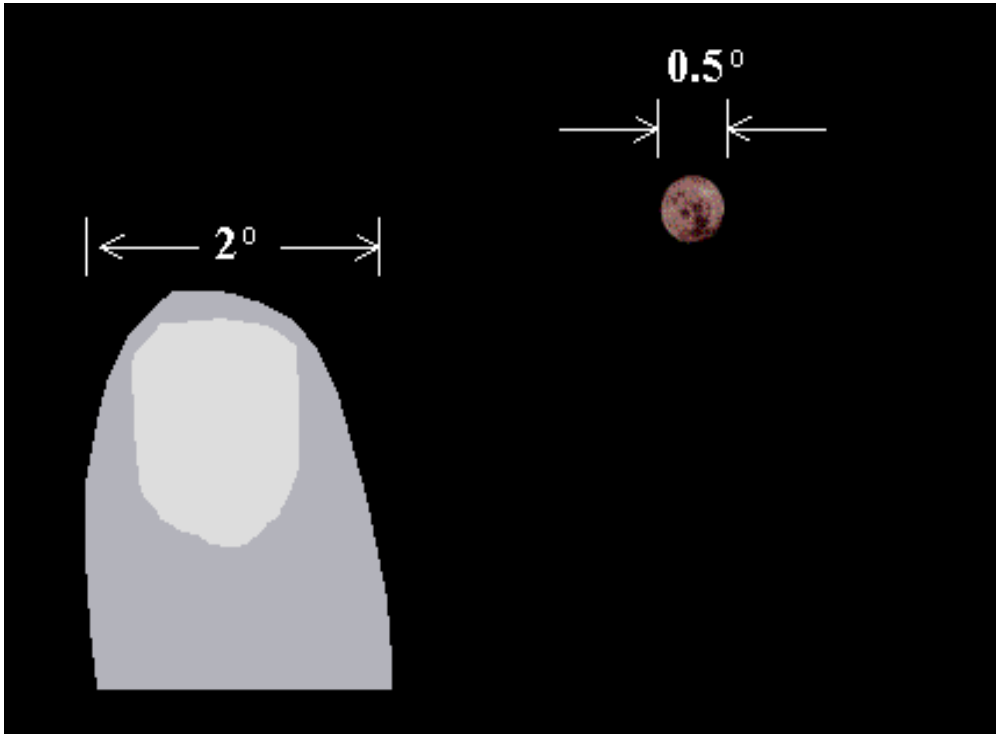
View from the Earth in January



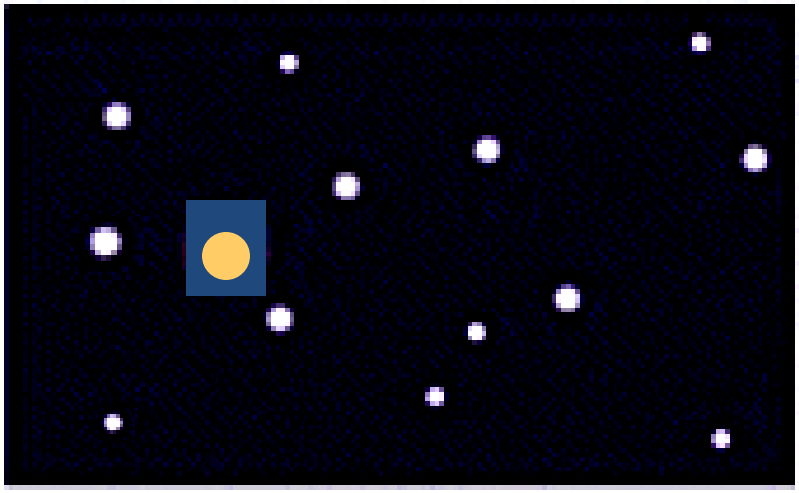
View from the Earth in July



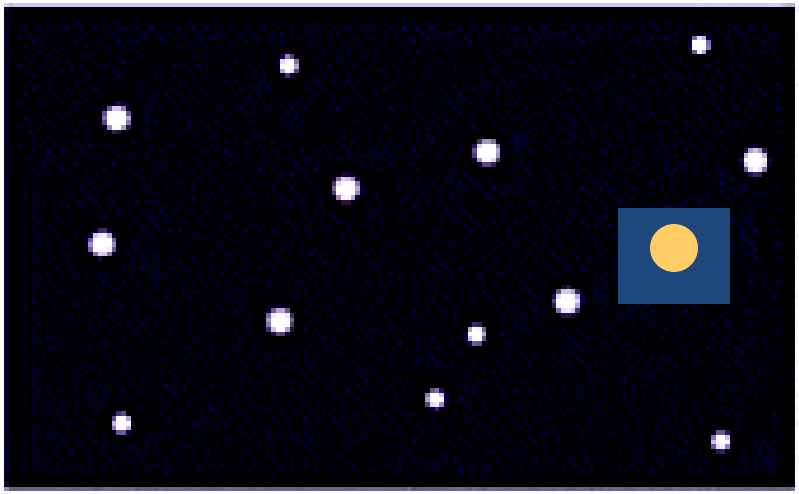
Measuring Astronomical Distances: Parallax



Even the nearest star shows a parallax shift of only 1/2000th the width of the full Moon

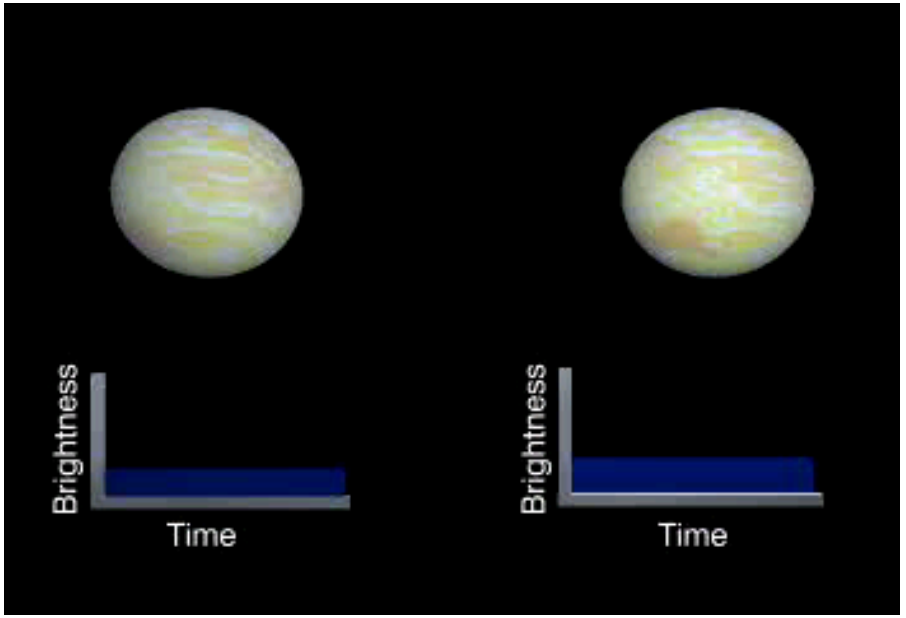


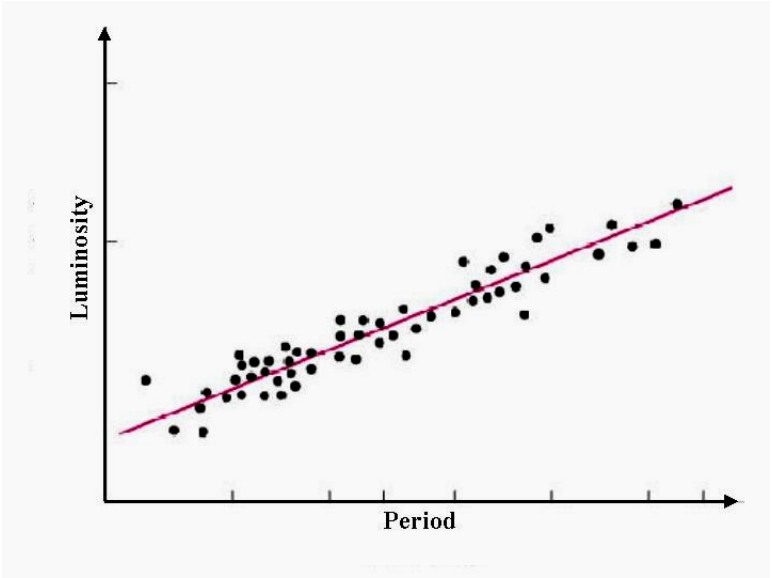
View from the Earth in January



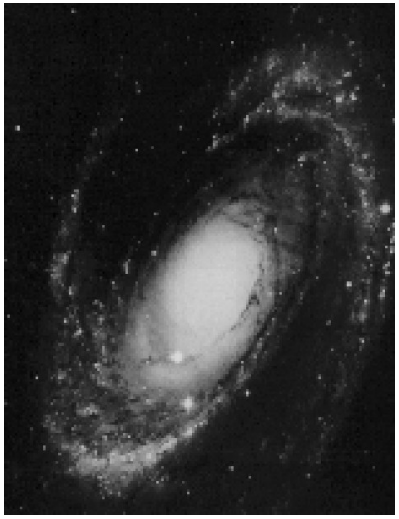
View from the Earth in July

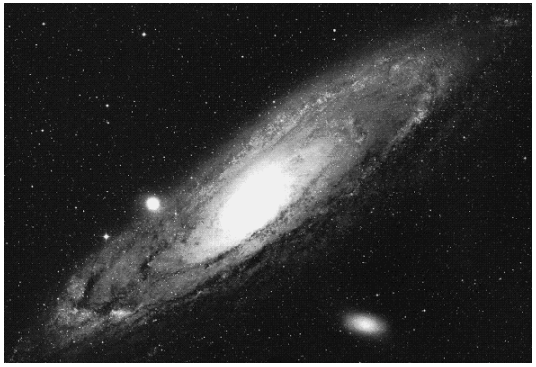
Cepheid Variables: Cosmic Yardsticks

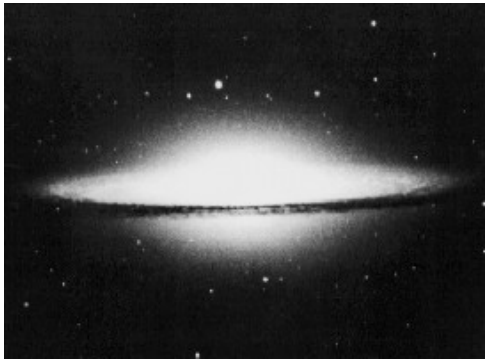


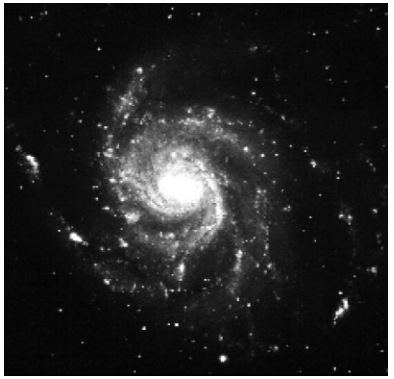


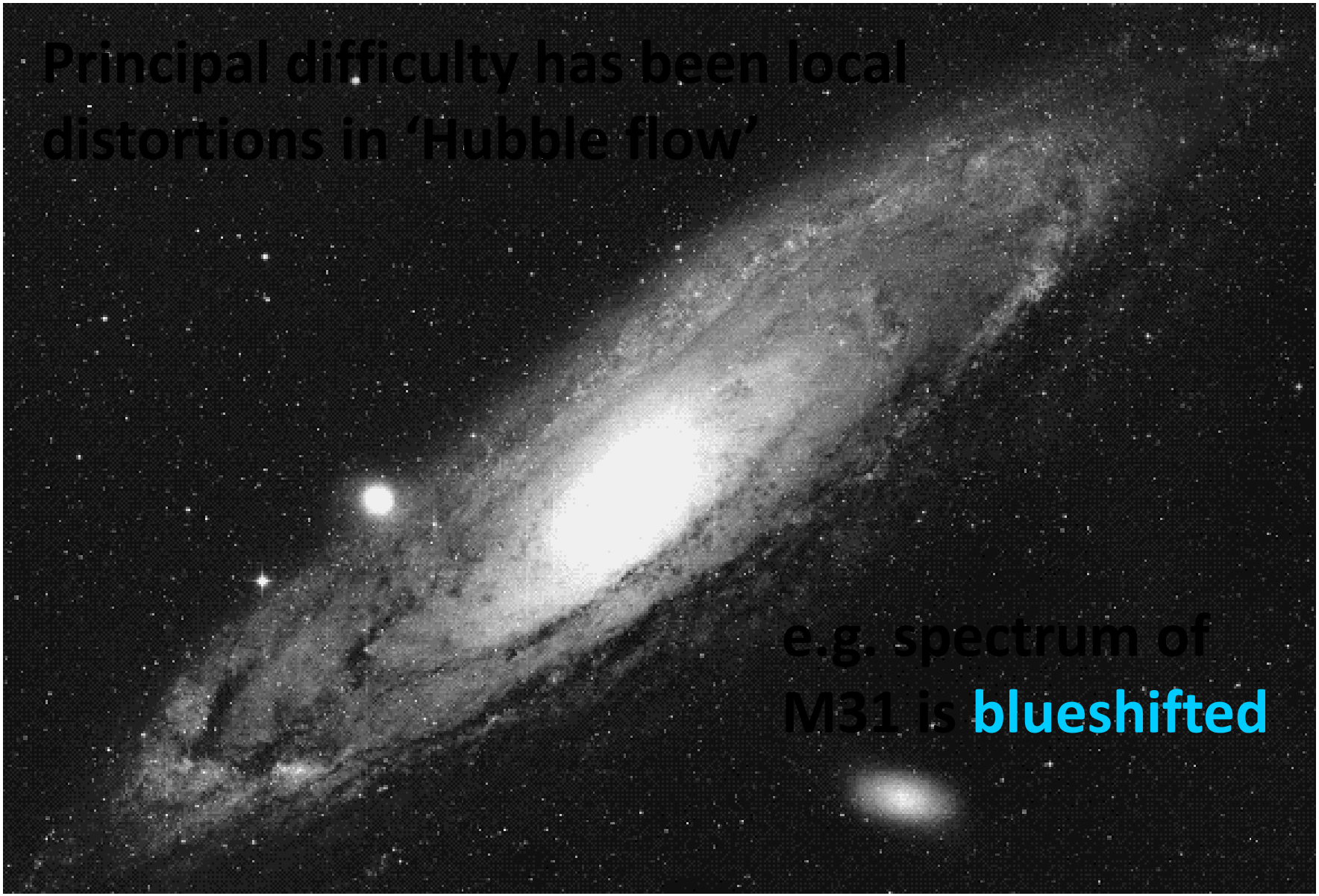
The nature of the nebulae?…





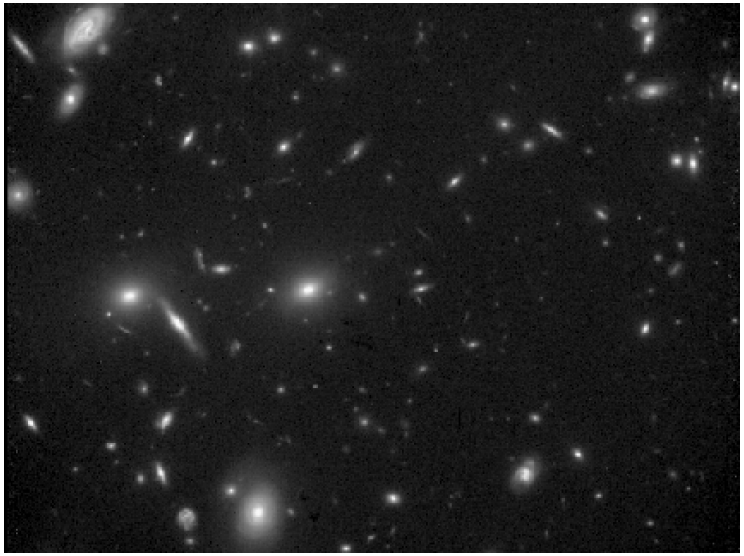


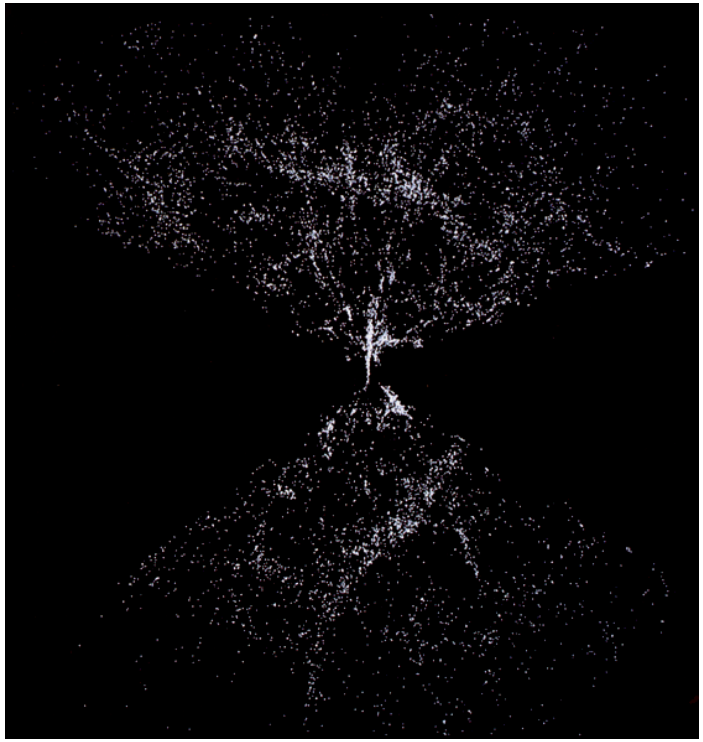



Principal difficulty has been local distortions in 'Hubble flow'
e.g. spectrum of M31 is blueshifted

clustered

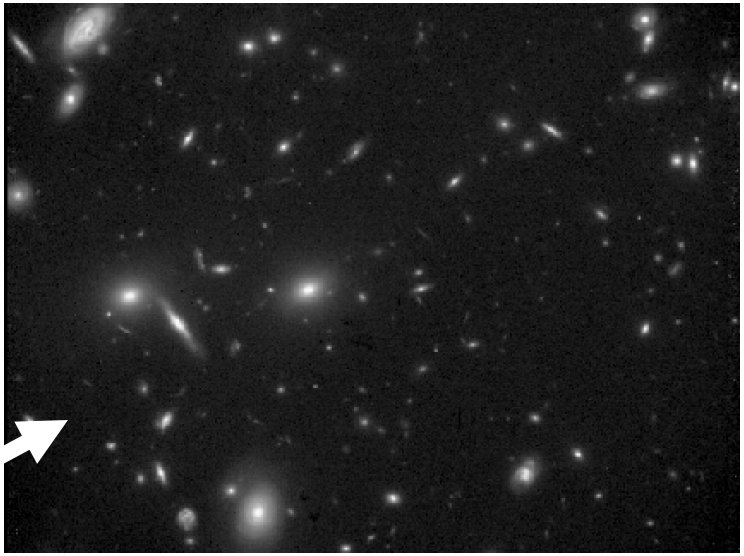
gravity

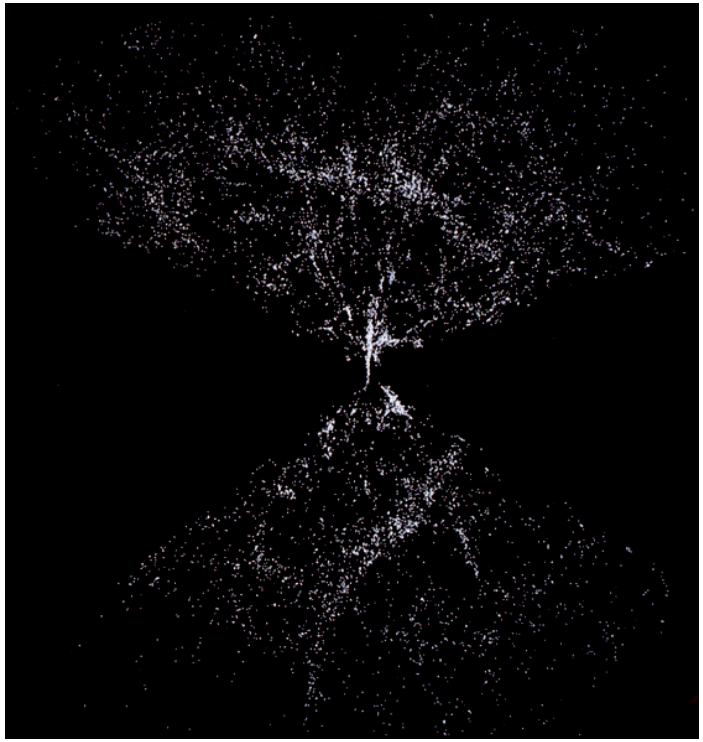




clustered

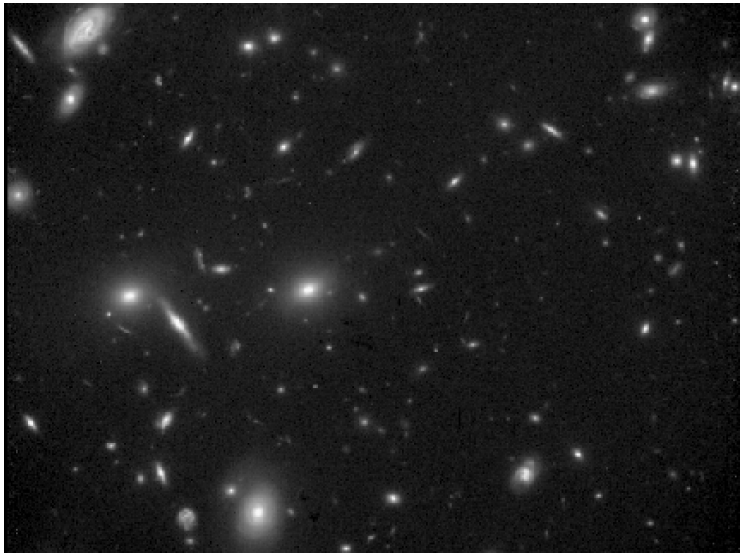
gravity





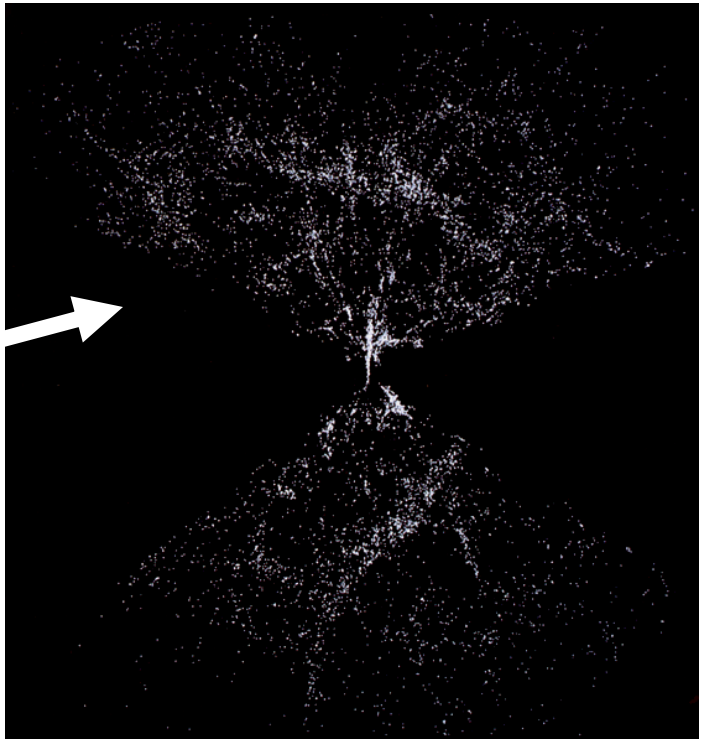
clustered

gravity

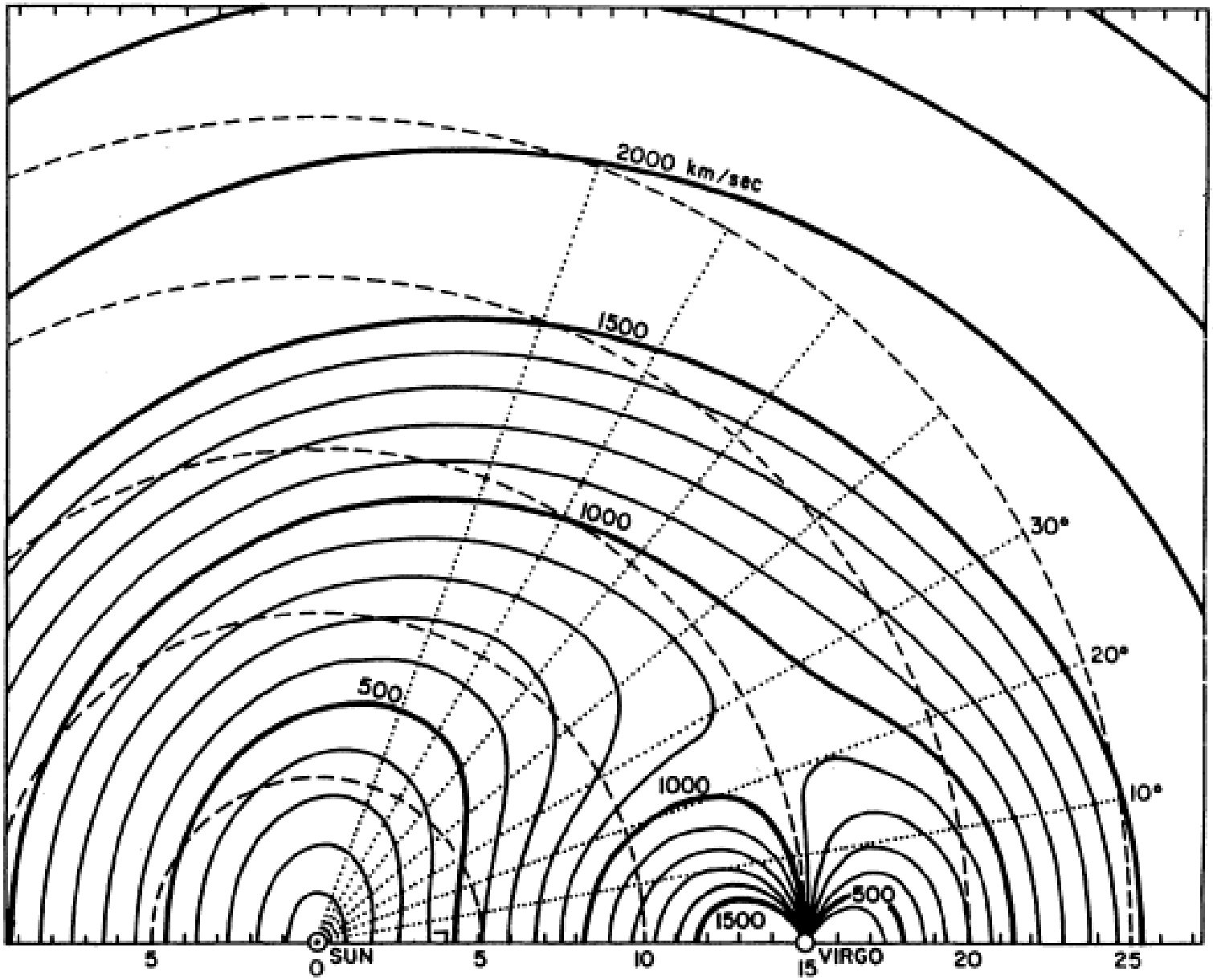


peculiar

velocity



Main local distortion due to Virgo cluster



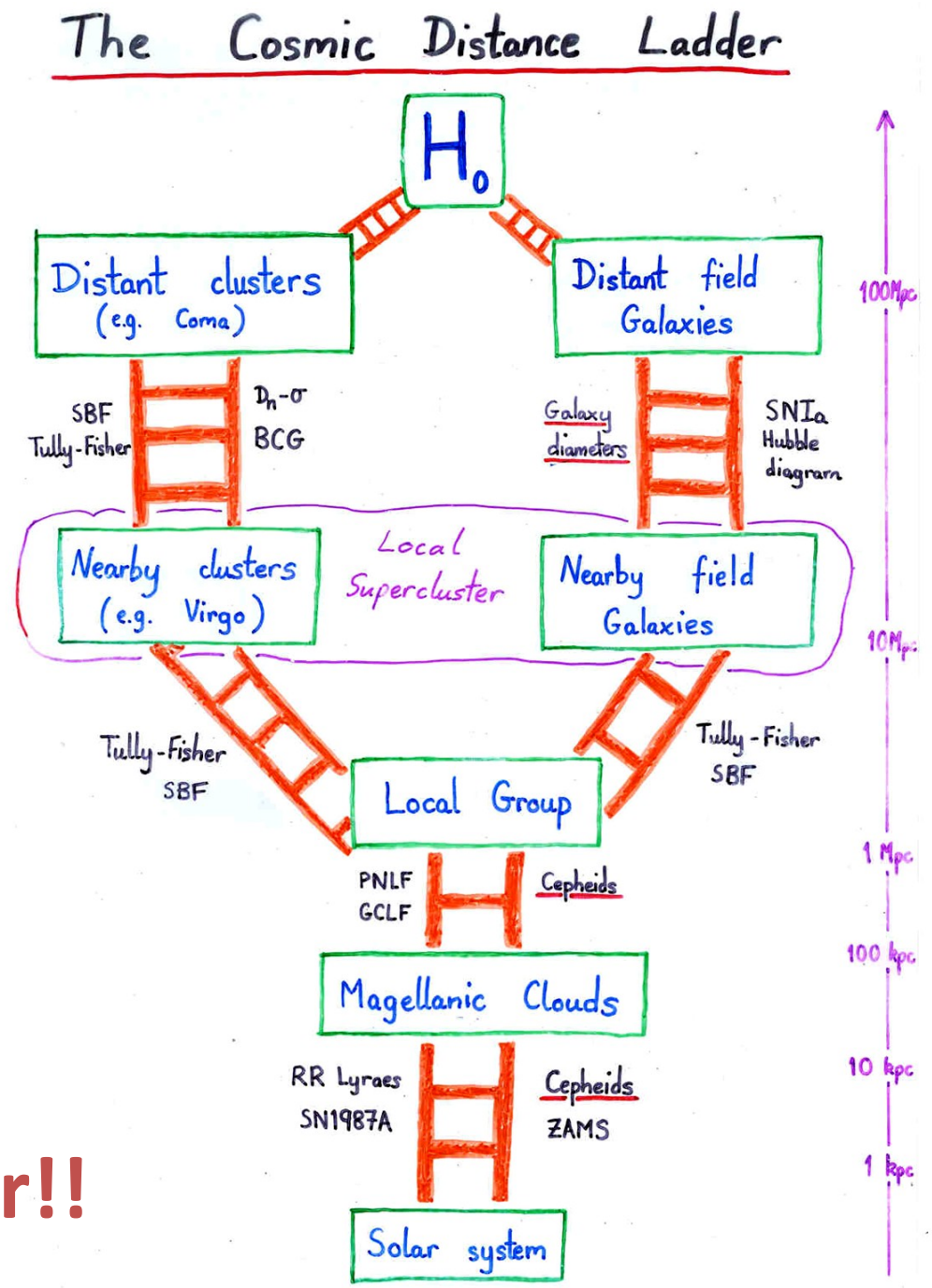
Problem:

Need to determine H_0 from remote galaxies, where peculiar motions are less important....

....**but....**

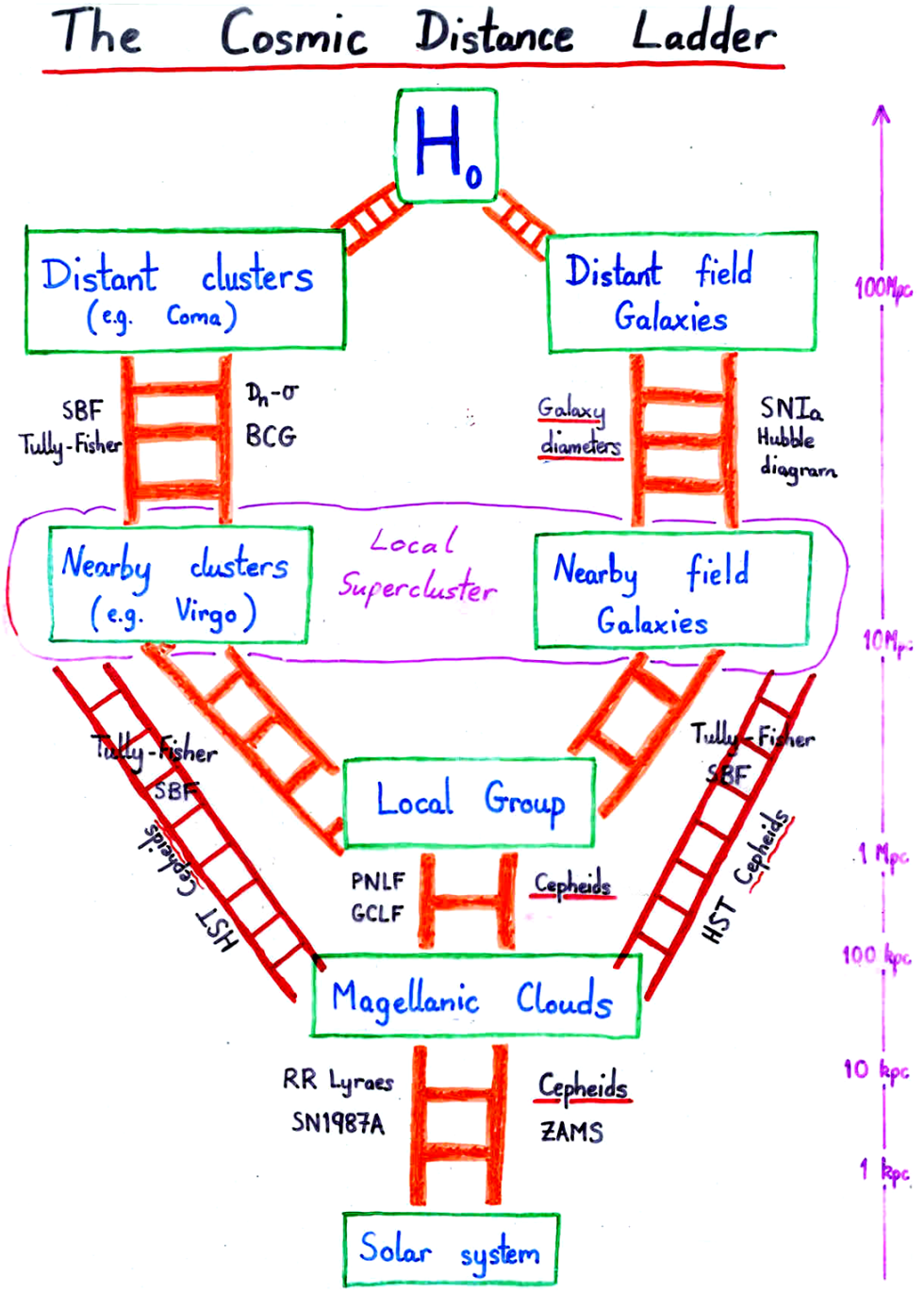
We cannot use primary distance indicators to measure their distance

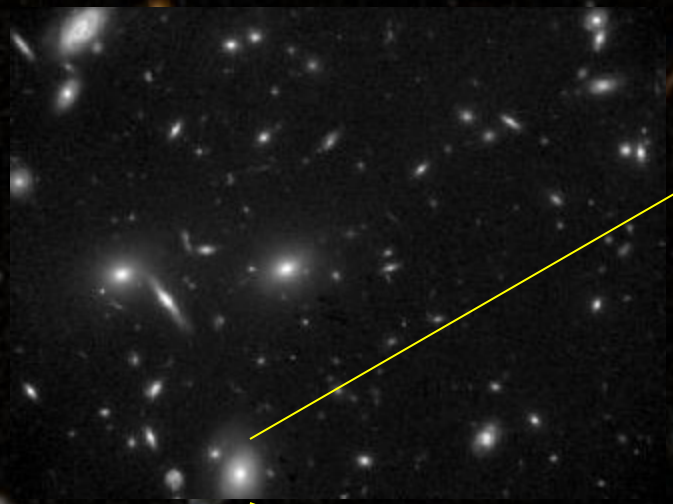
Need Distance Ladder!!



HST has ‘bypassed’ one stage of the Distance Ladder, by observing Cepheids beyond the Local Group of galaxies

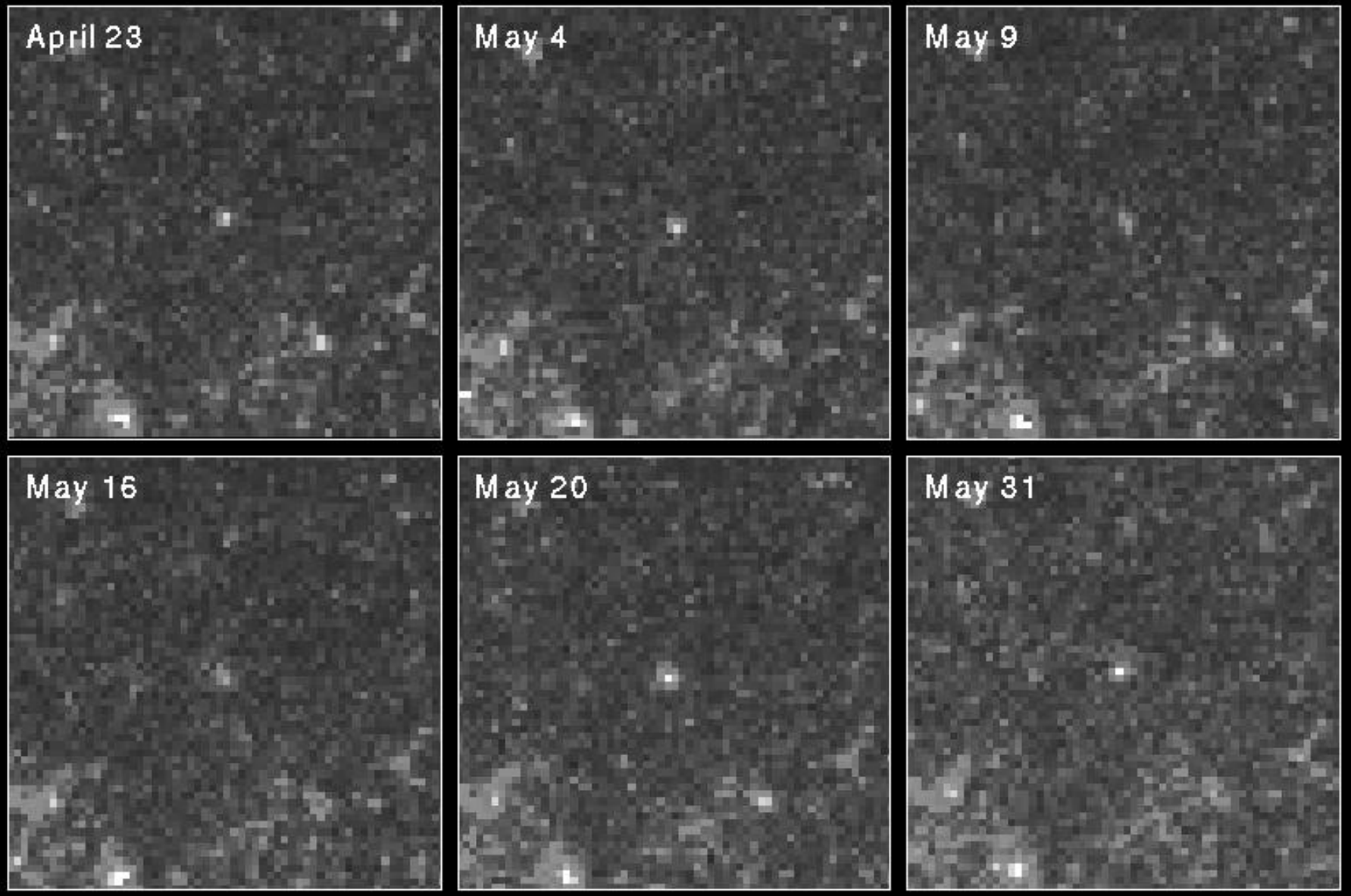
This has dramatically improved measurements of H_0

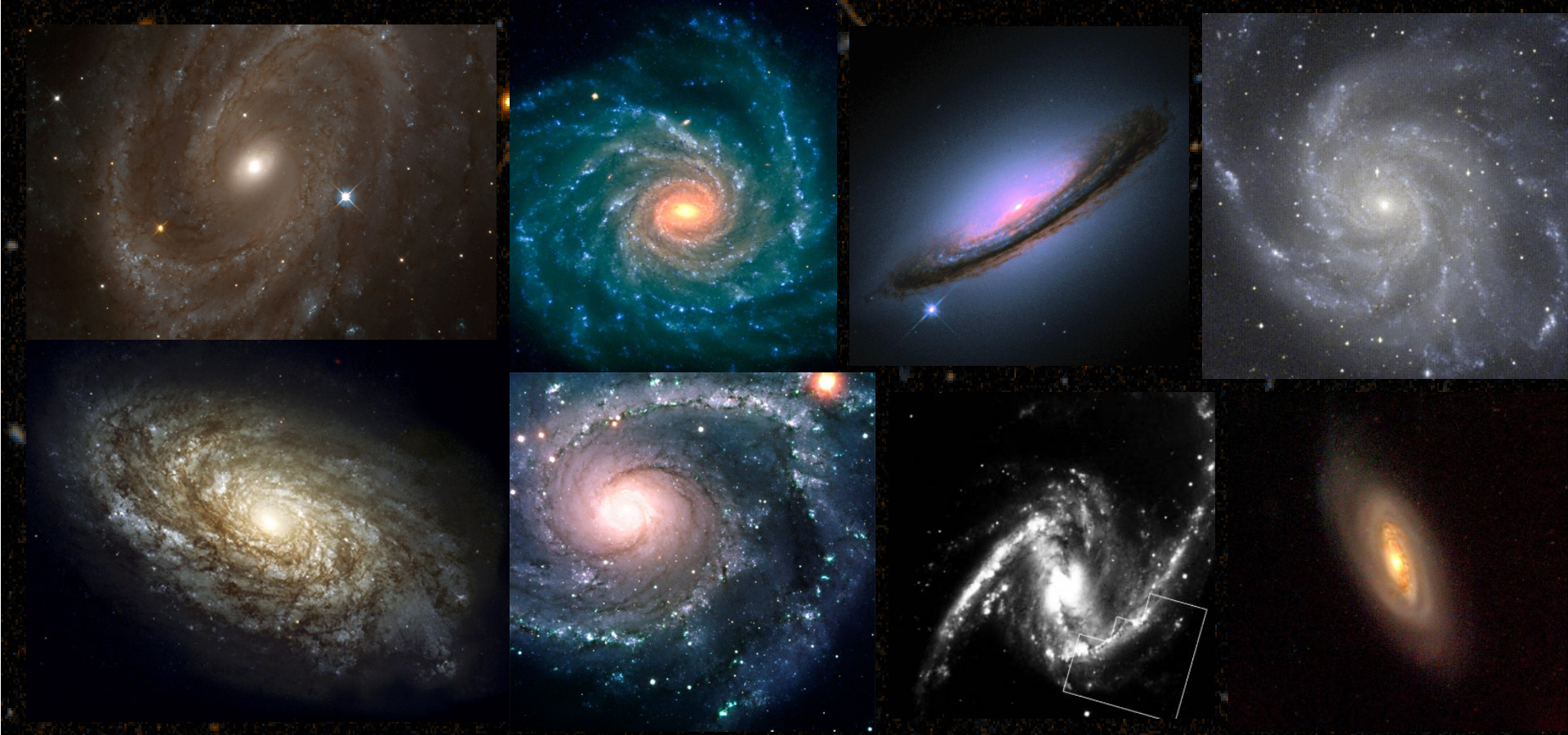




Virgo Cluster galaxy
M100, 60 million light years distant…..

Cepheid Variable Star in Galaxy M100 HST•WFPC2



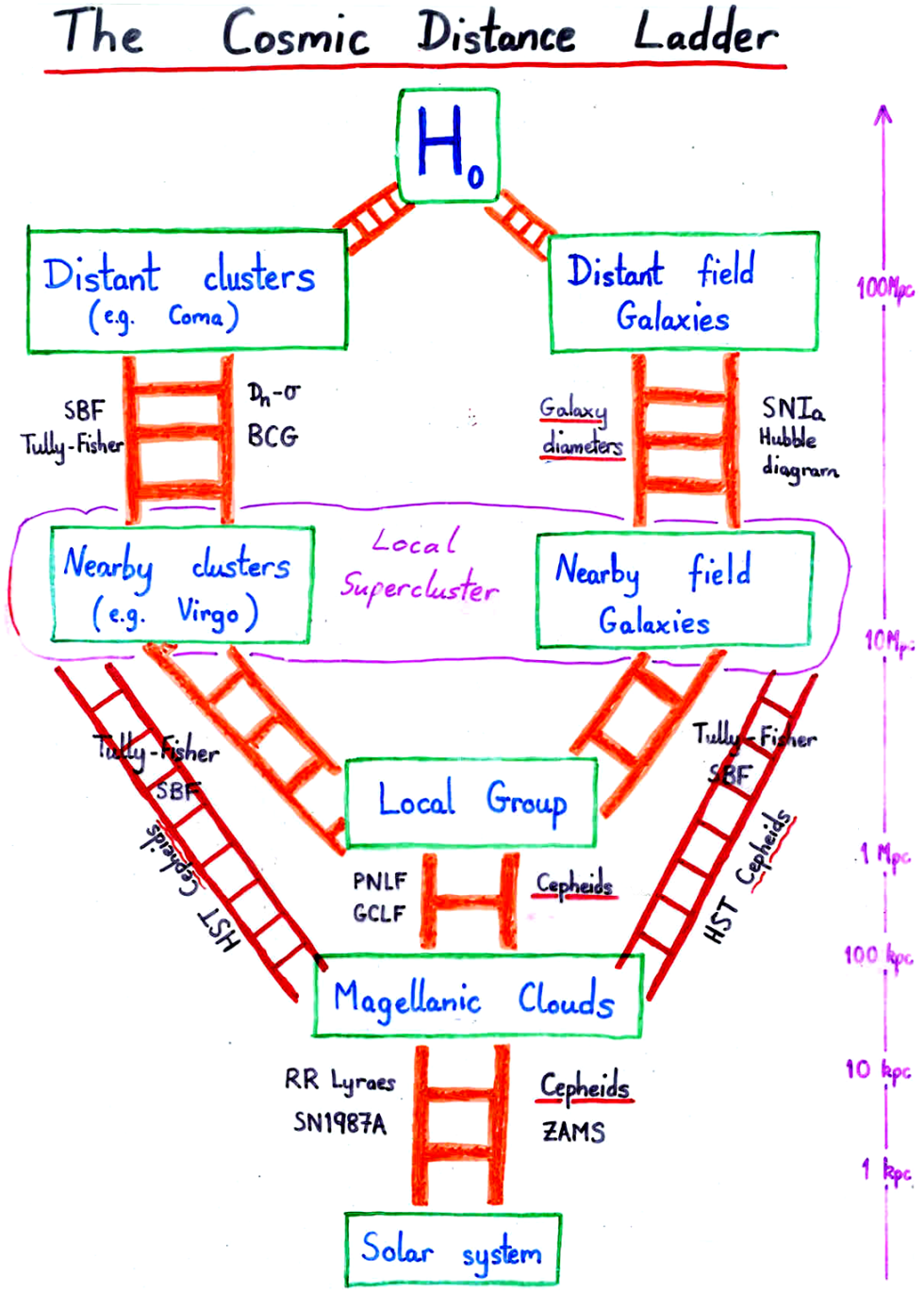


Measure Cepheid distances to ~30 nearby galaxies,

Link Cepheids to Secondary distance indicators

Must ensure that remote galaxy data are free from **Selection Effects**

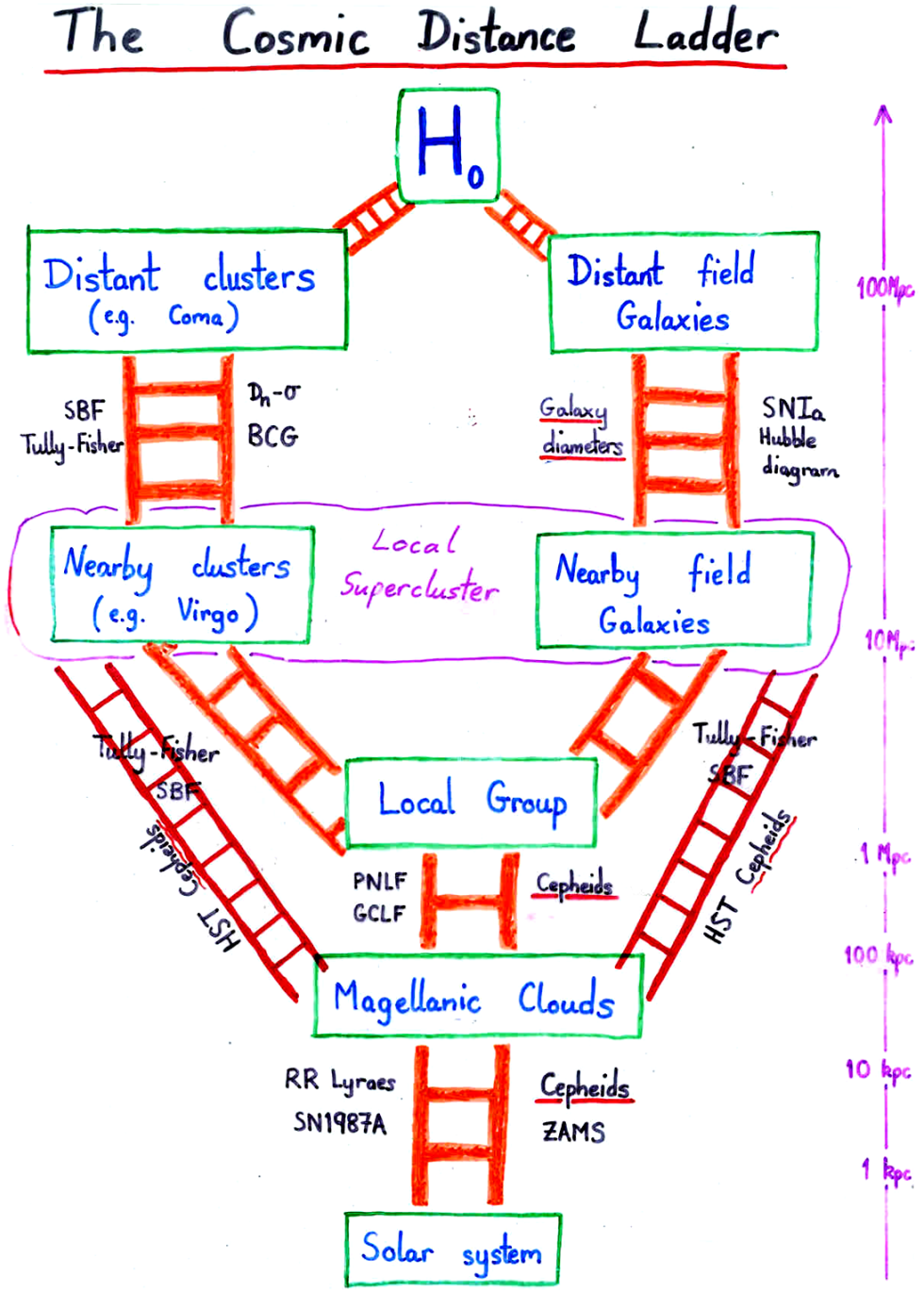
e.g. intrinsically brighter or bigger?…



Must ensure that remote galaxy data are free from **Selection Effects**

e.g. intrinsically brighter or bigger?...

Malmquist Bias



Must ensure that remote galaxy data are free from **Selection Effects**

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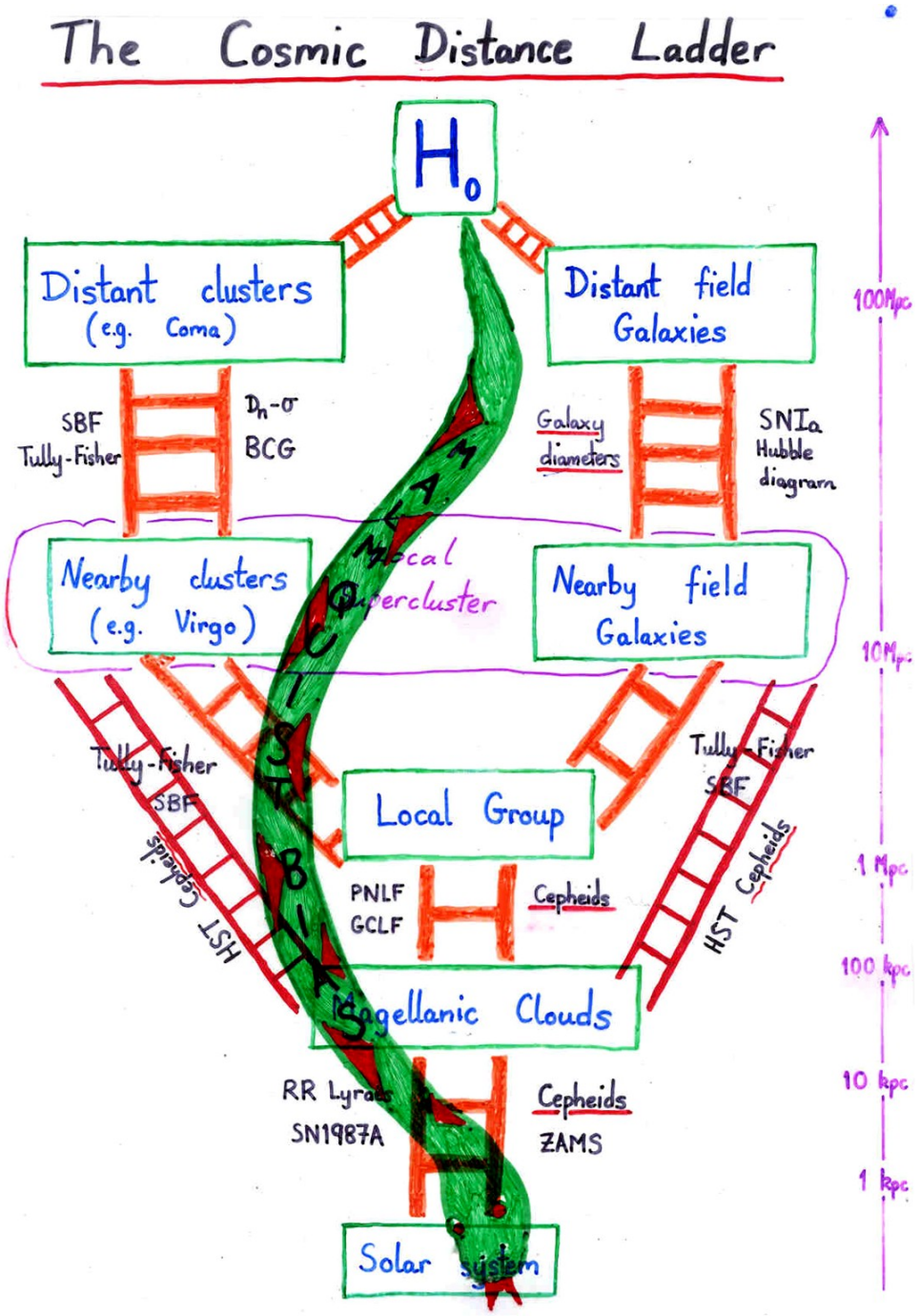
Malmquist Bias

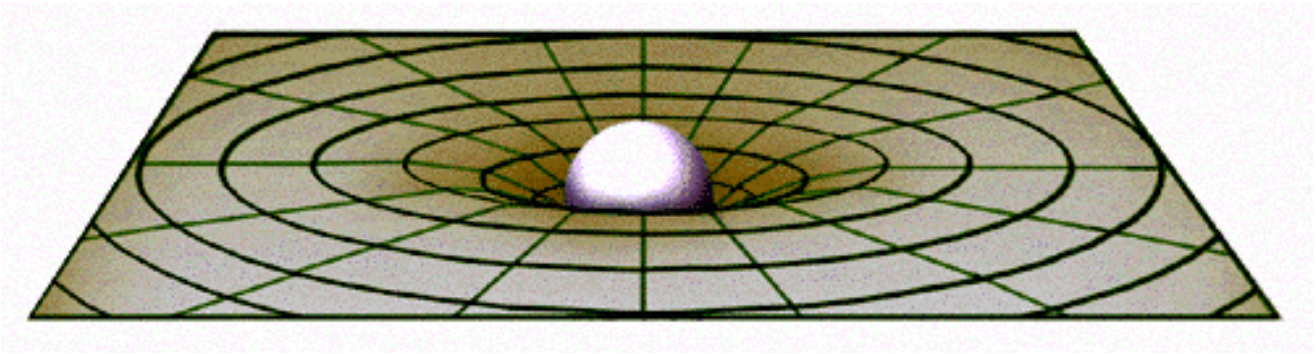


Will the Universe continue to expand forever?

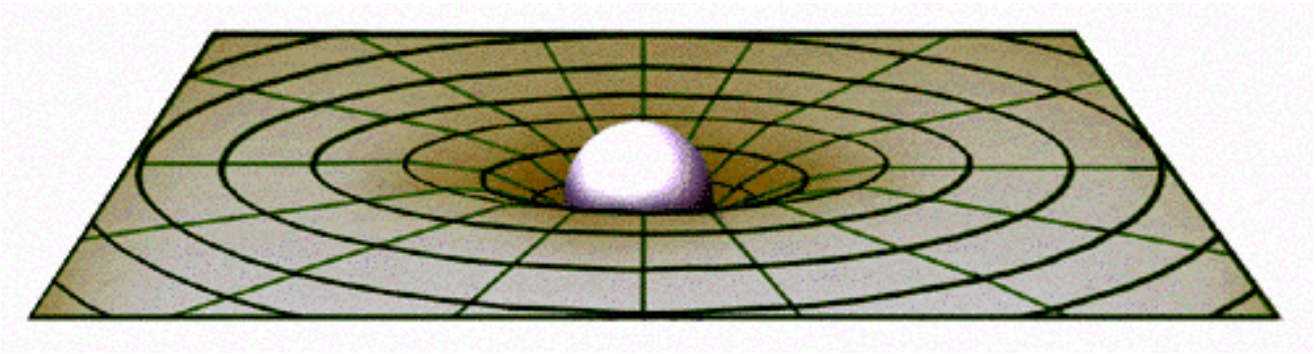
To find out we need to compare the expansion rate now with the expansion rate in the distant past…

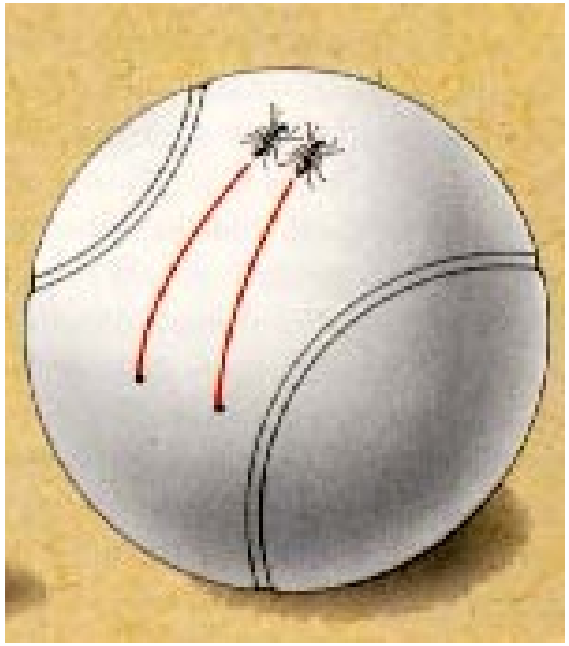
Is the Universe speeding up or slowing down?

Answer depends on the **geometry** of the Universe



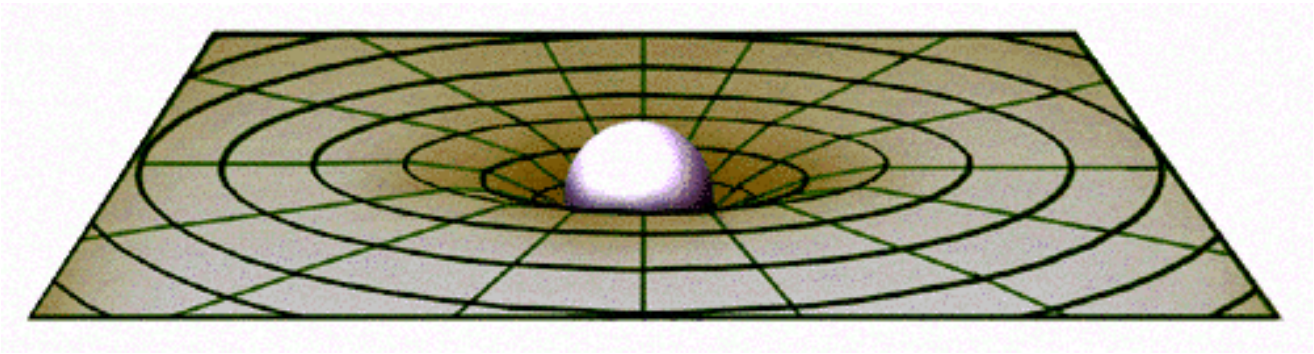
Answer depends on the **geometry** of the Universe

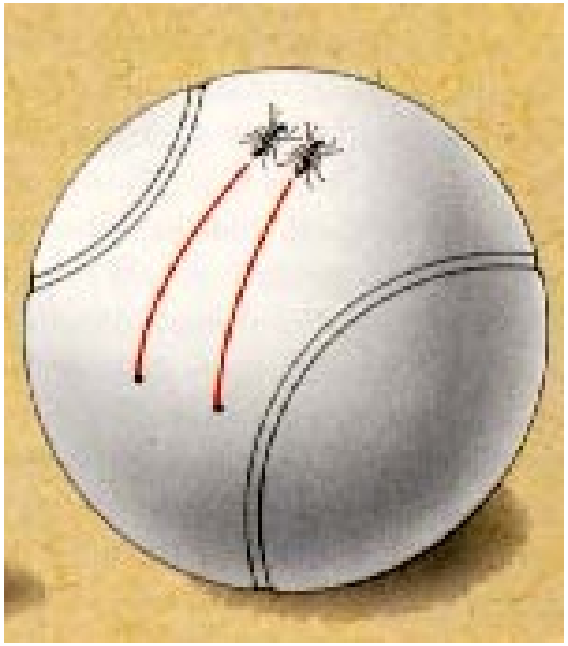


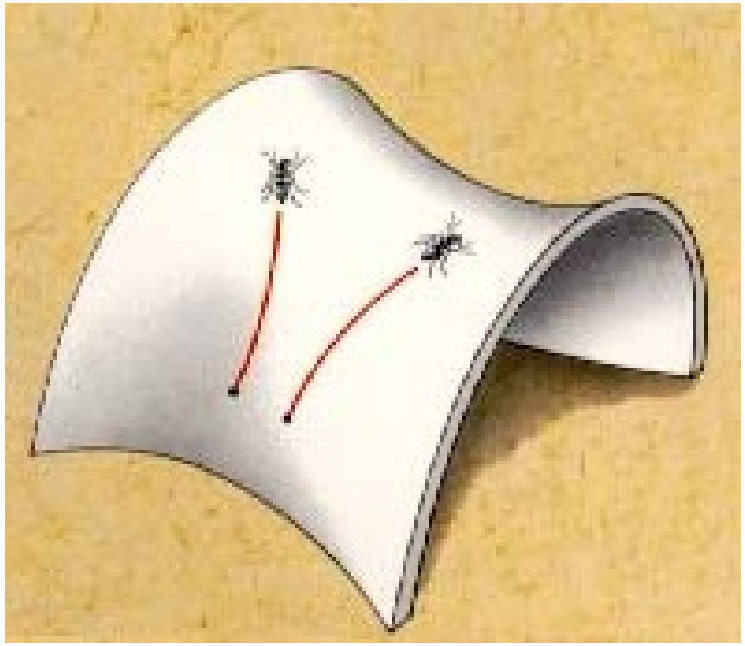


Closed

Answer depends on the **geometry** of the Universe

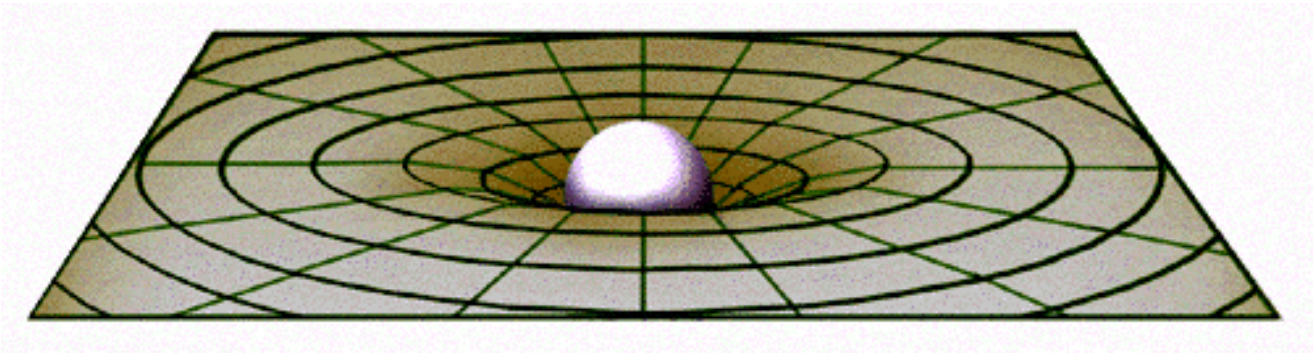


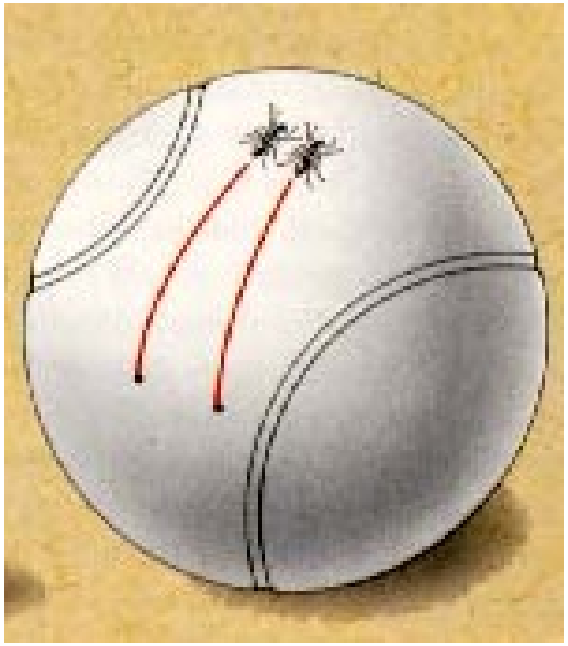




Closed **Open**

Answer depends on the **geometry** of the Universe





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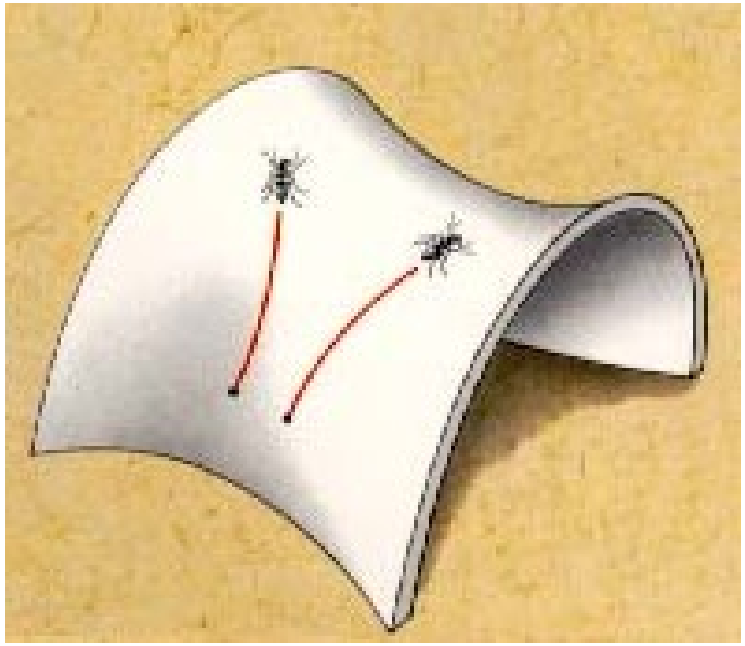

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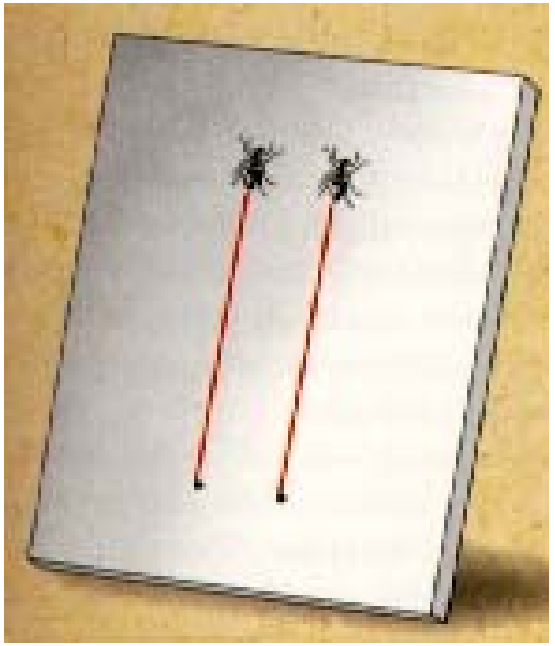
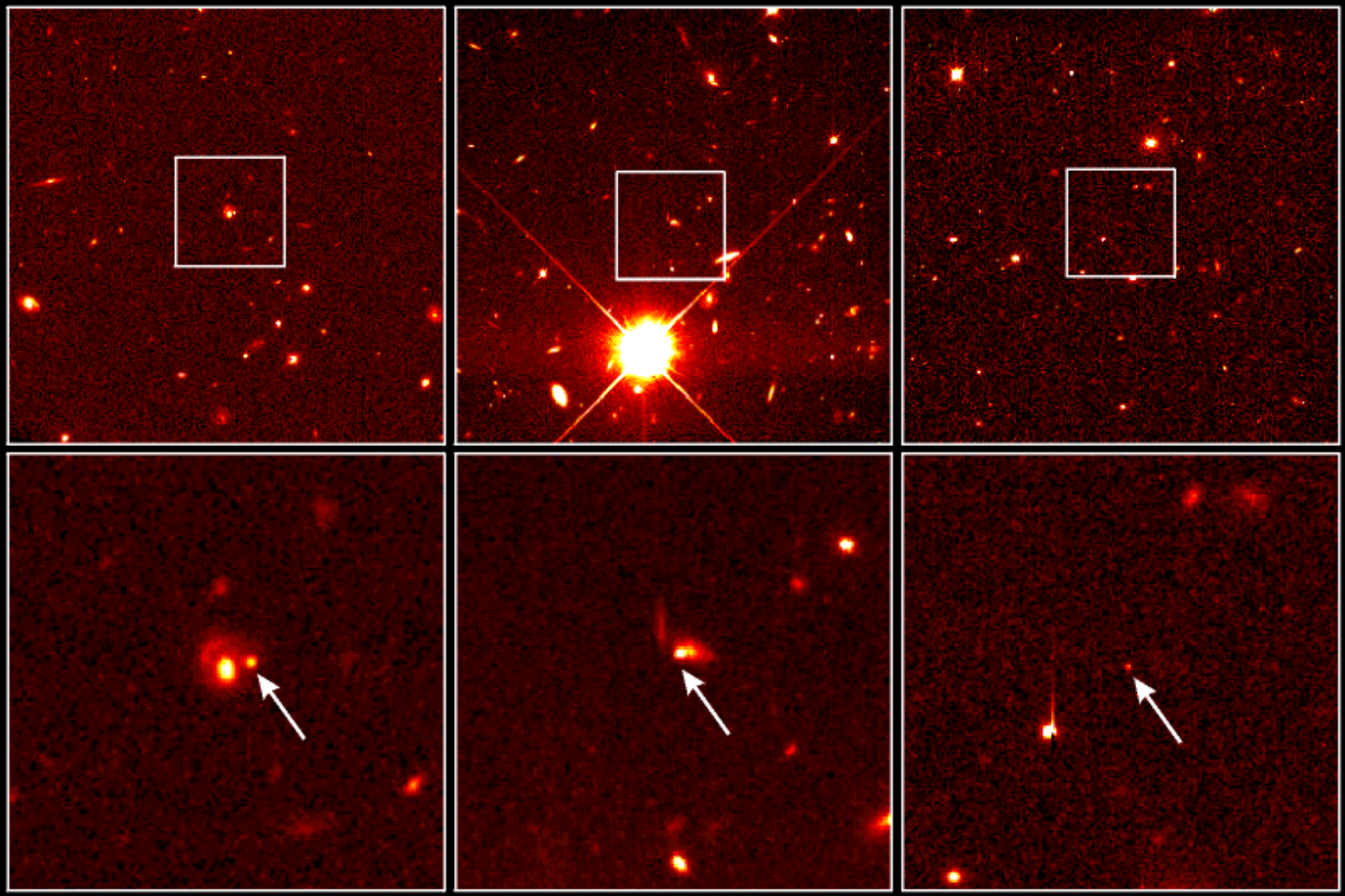
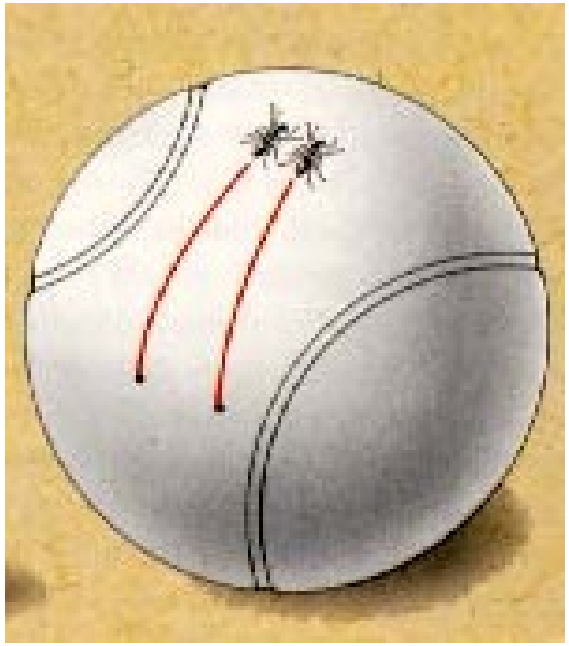


Flat

Supernovae



Geometry of the Universe affects the relationship between distance and redshift of the supernovae



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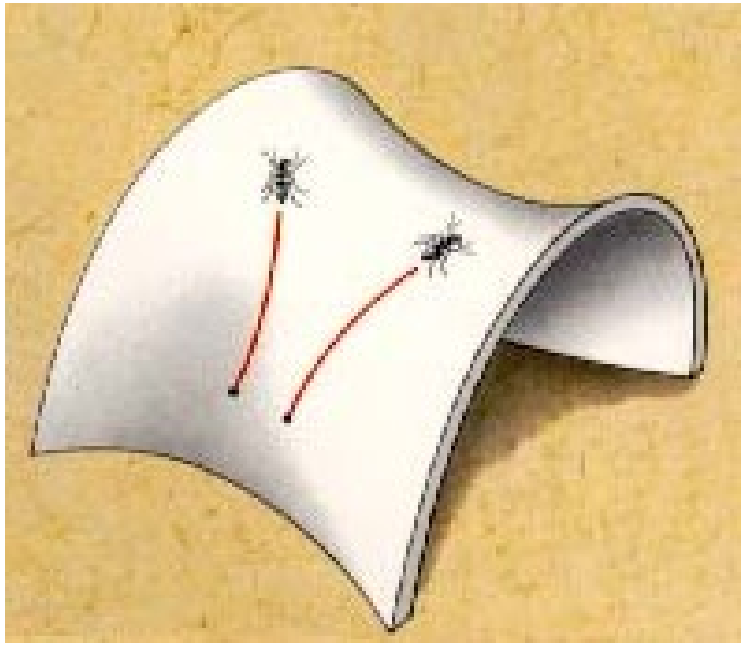

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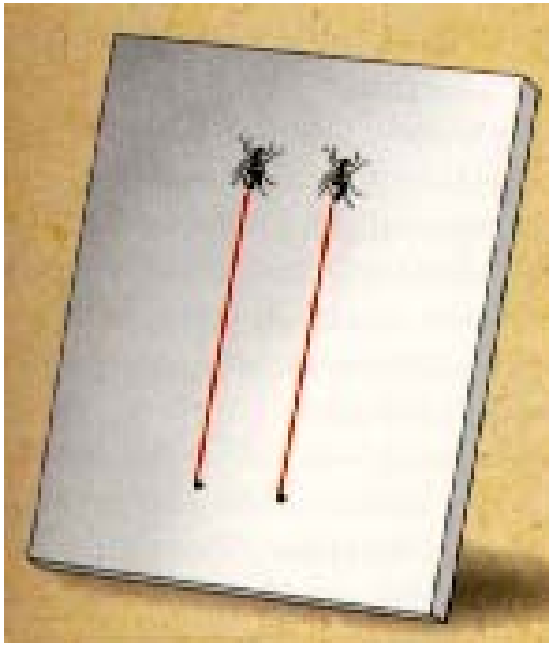
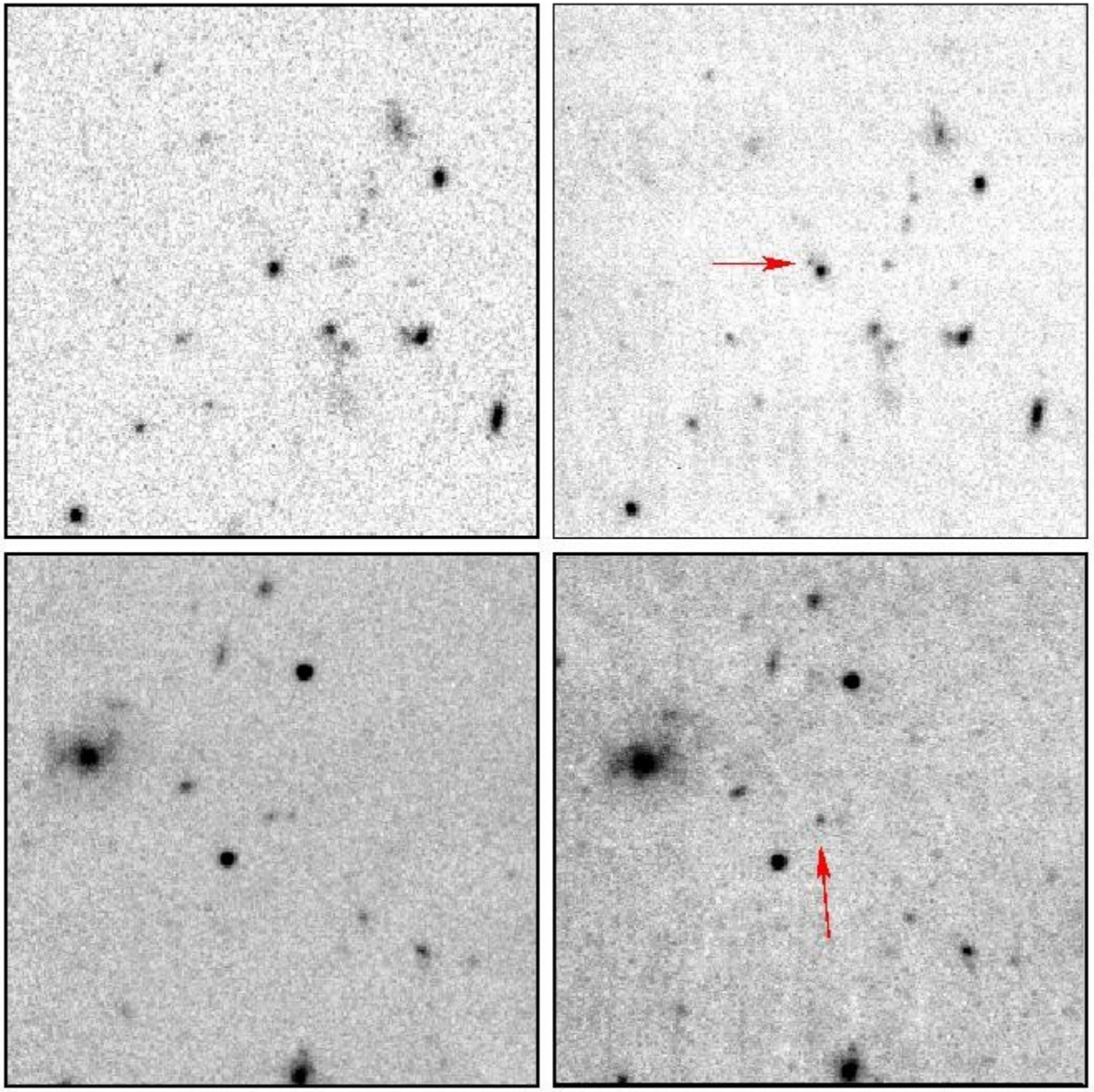


Flat



Supernova
"Velma"

z=1.05

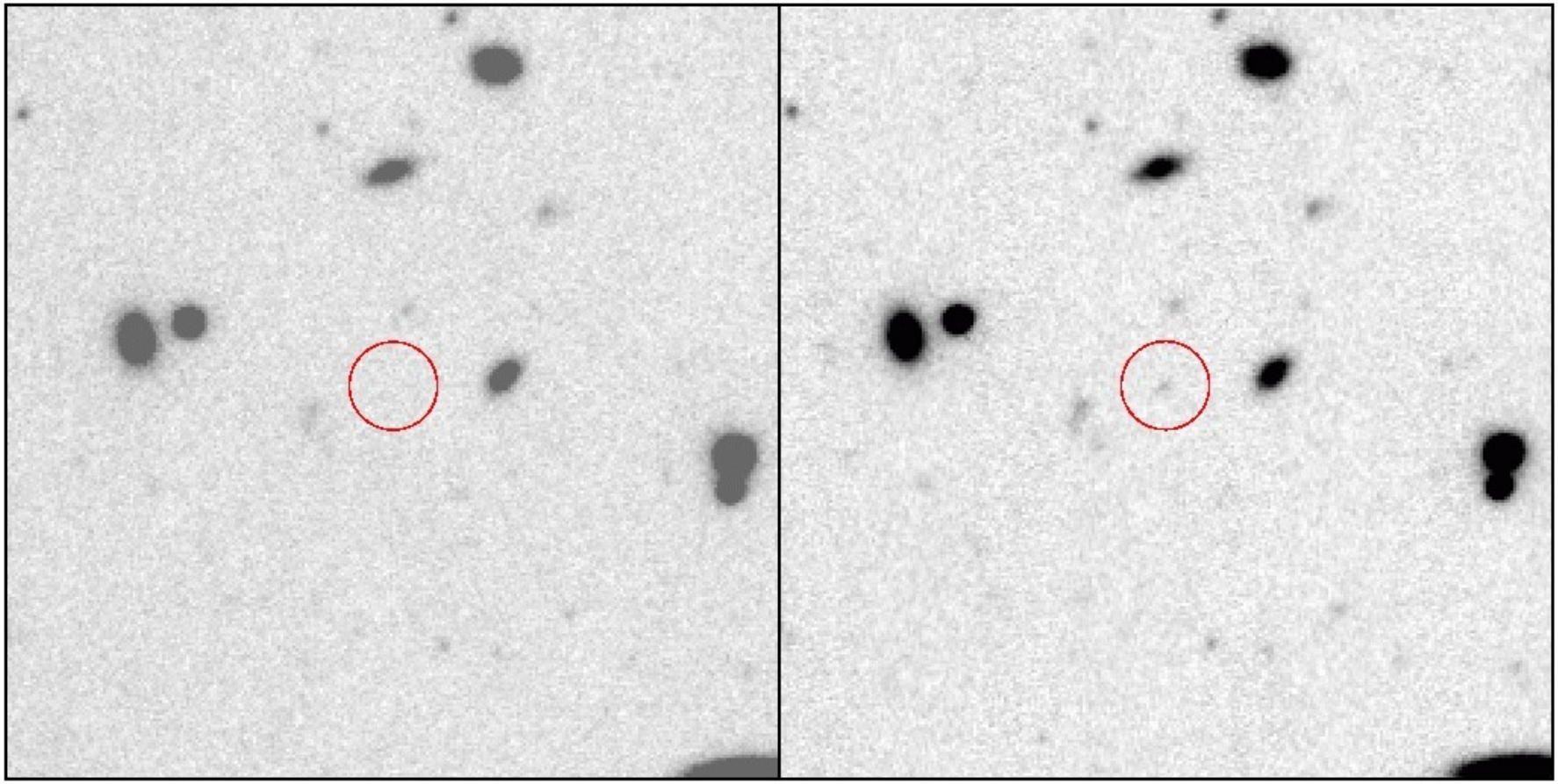
Supernova
"Alvin"

z=1.04

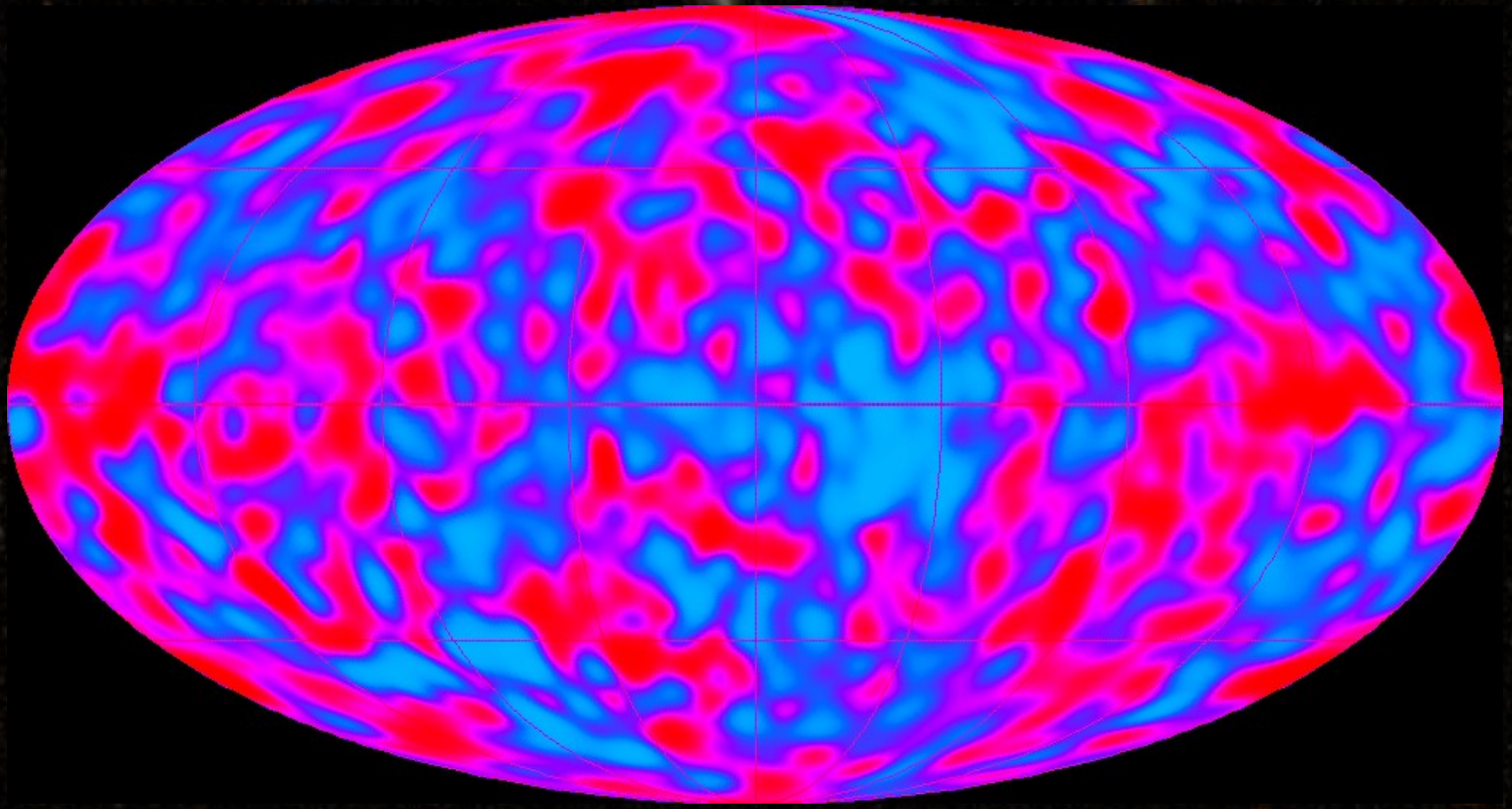
SN 1999fv "Dudley Doright" z=1.23

CFHT Oct. 3, 1999

CFHT Nov. 4, 1999

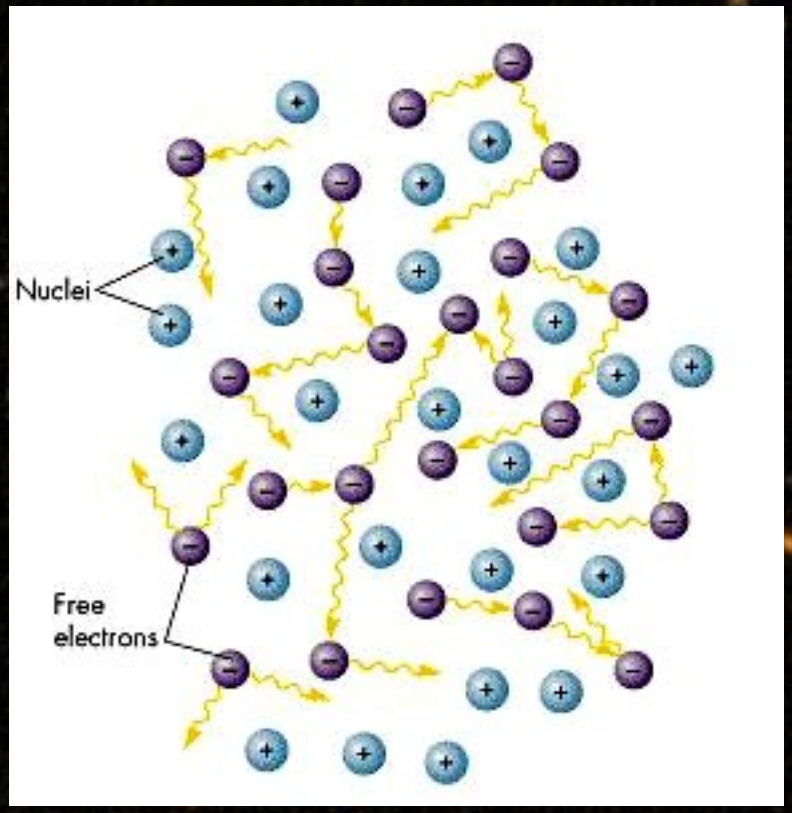


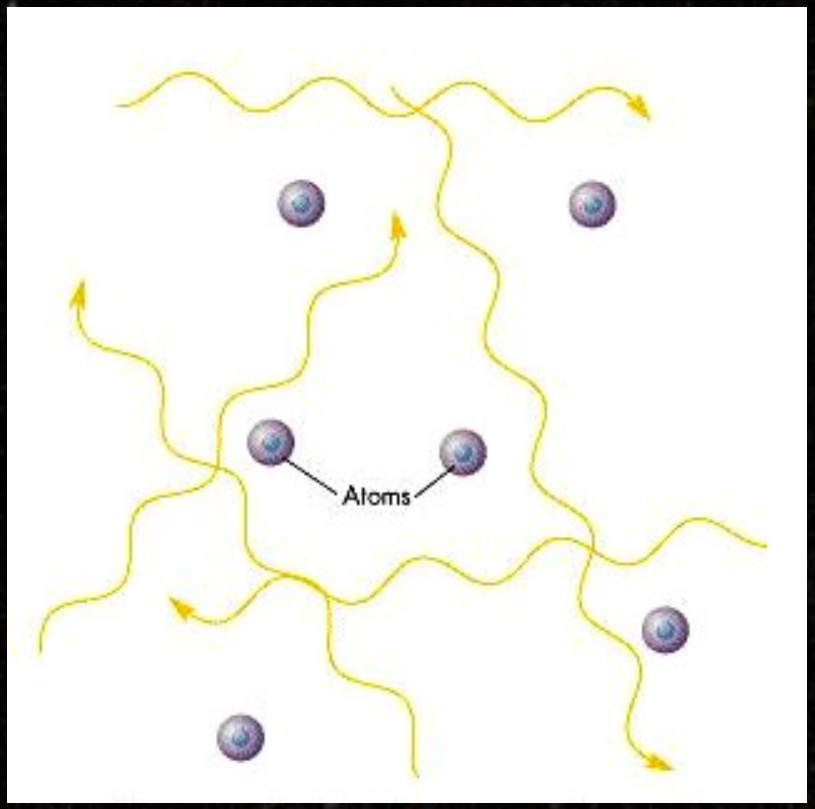
background radiation



Free electrons scattered light (as in a fog)

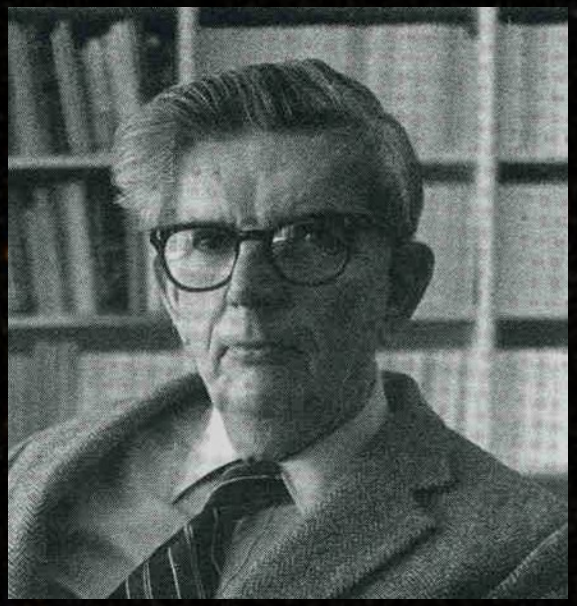
After 300,000 years, cool enough for atoms; fog clears!





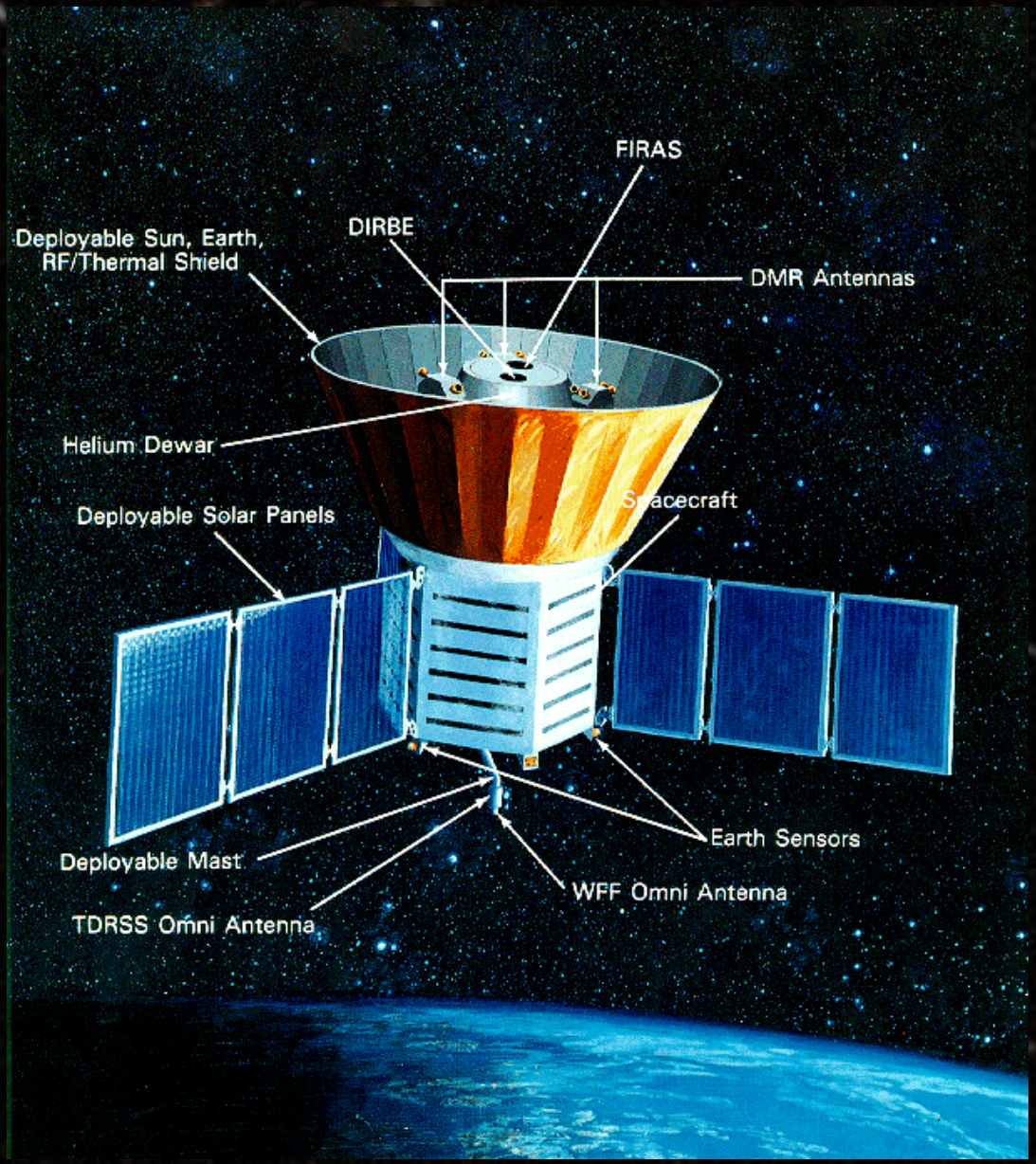
Discovered in 1965 by Penzias and Wilson

Arno Penzias and Robert Wilson



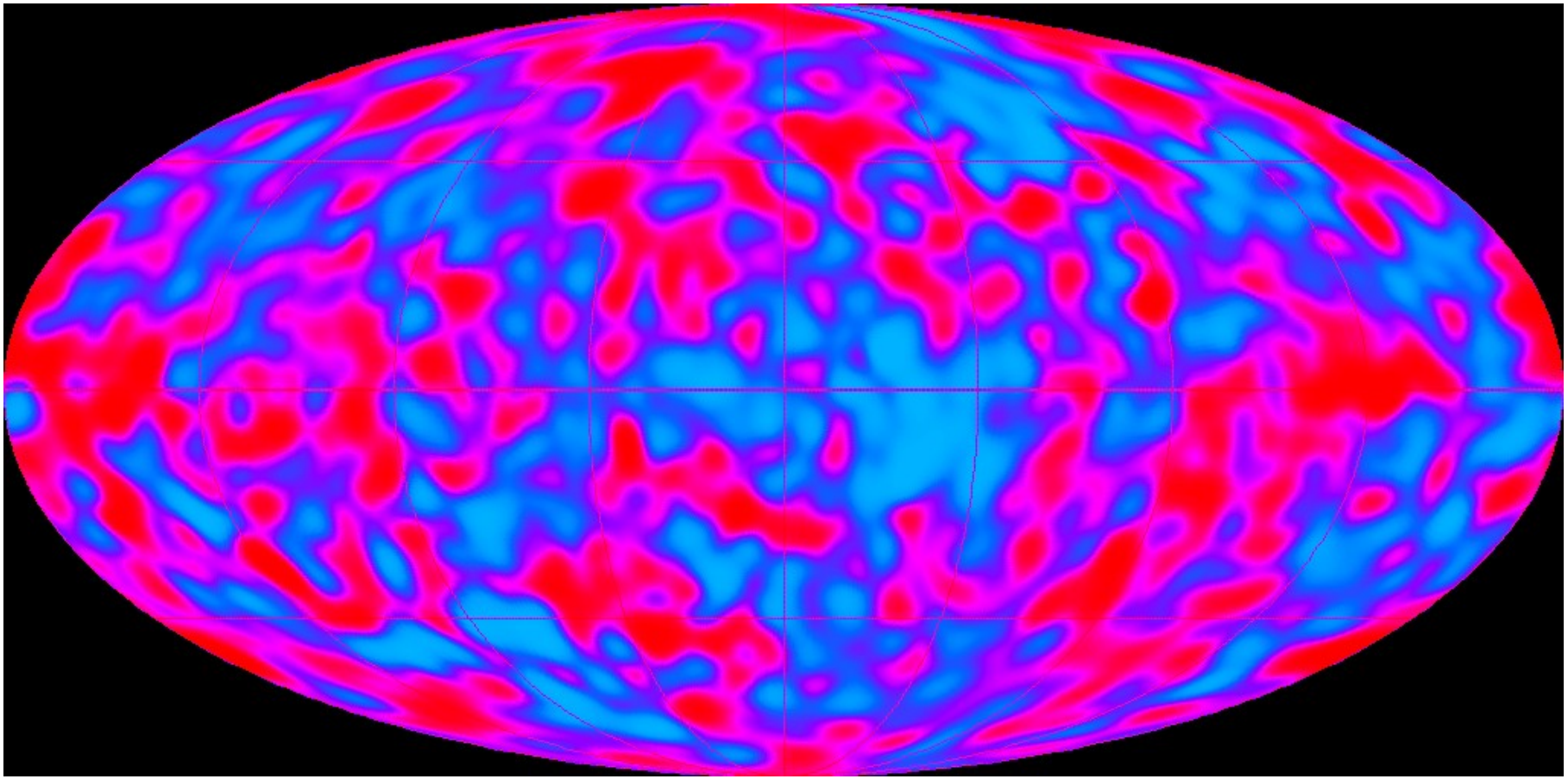
Robert Dicke

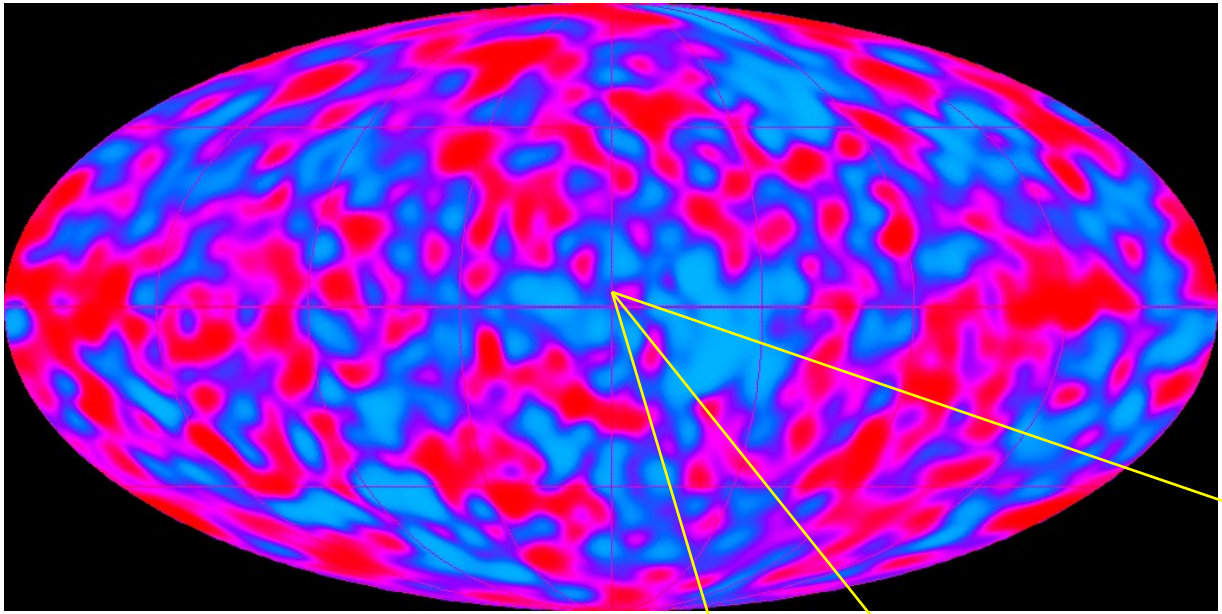
Jim Peebles

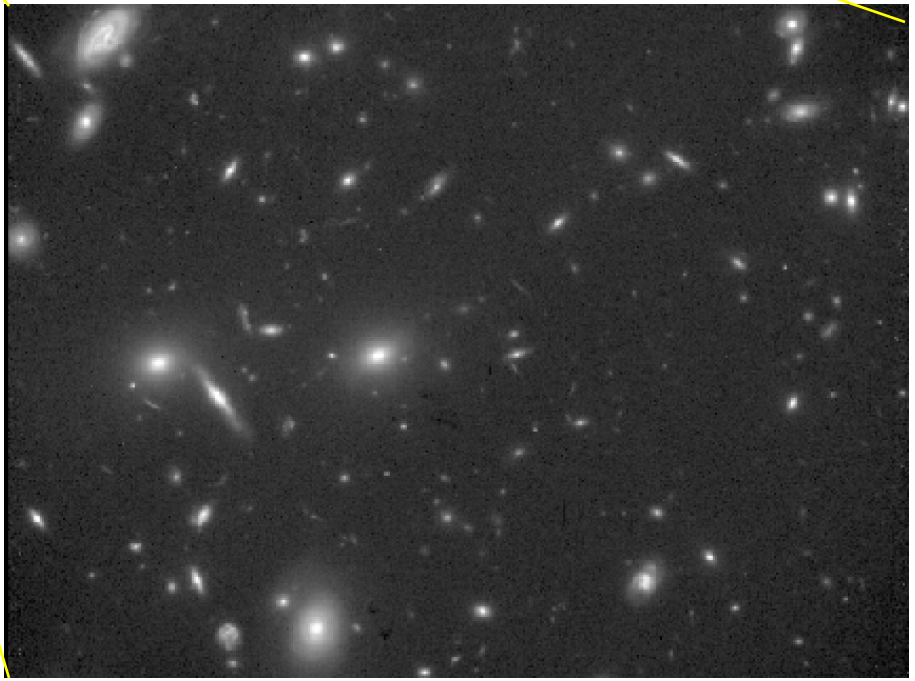

FIRAS
DIRBE
Deployable Sun, Earth,
RF/Thermal Shield
DMR Antennas
Helium Dewar
Deployable Solar Panels
Spacecraft
Earth Sensors
Deployable Mast
WFF Omni Antenna
TDRSS Omni Antenna

CoBE map of temperature across the sky

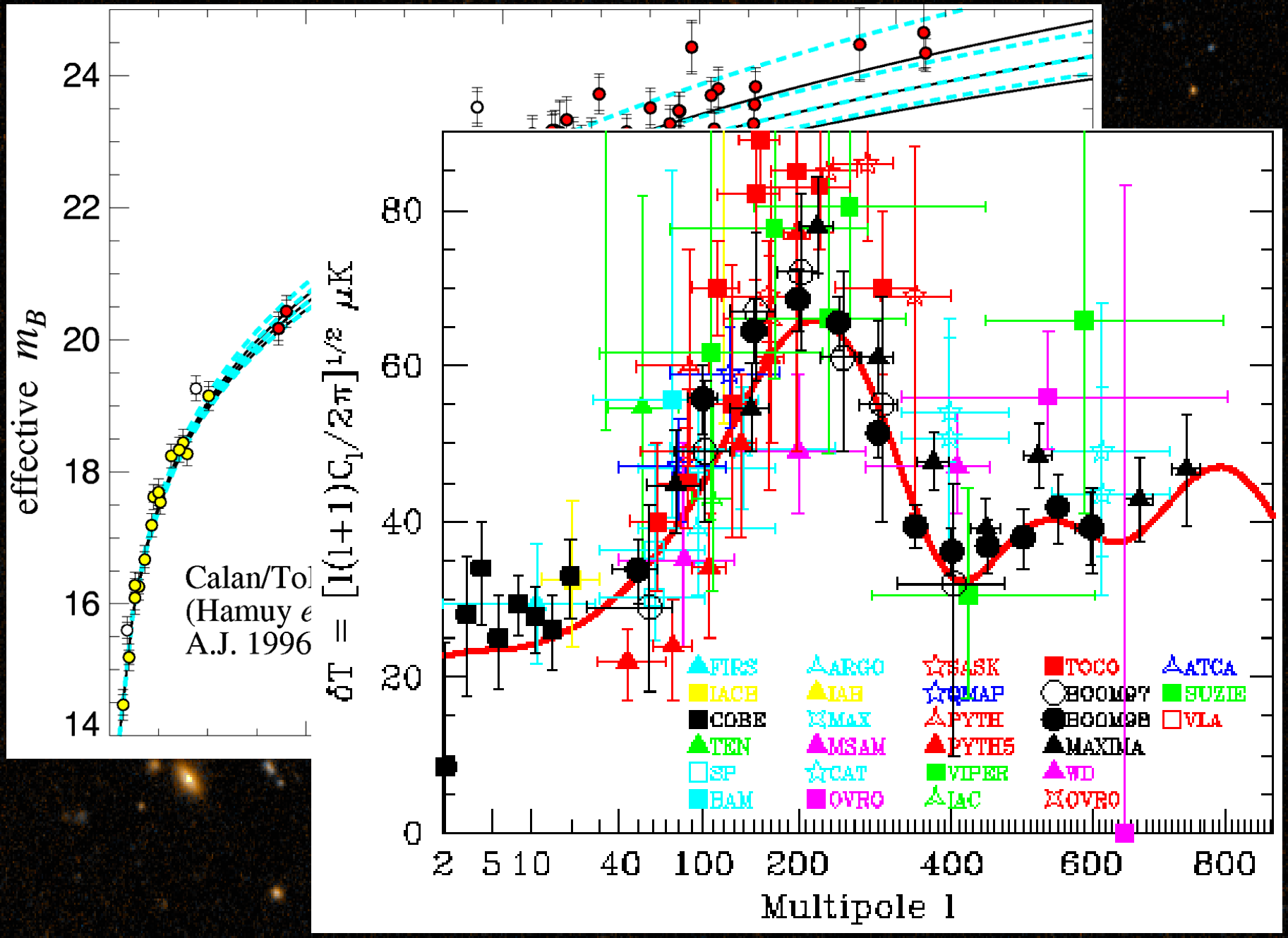
CoBE map of temperature across the sky

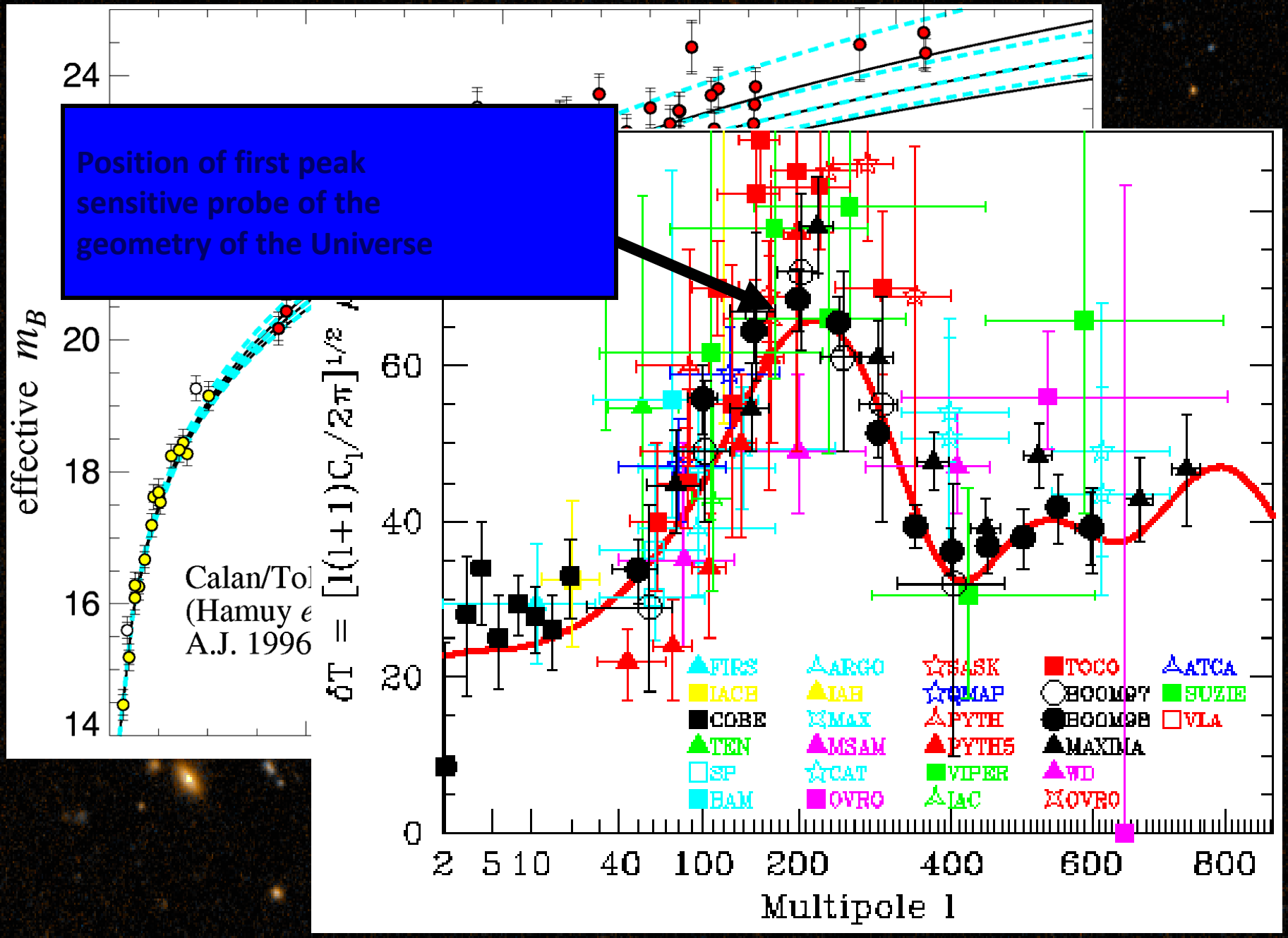






Galaxy formation is highly sensitive to the pattern, or power spectrum, of CMBR temperature ripples


effective m_B
24
22
20
18
16
14
Calan/Tol
(Hamuy e
A.J. 1996
$\delta T = [l(l+1)C_l/2\pi]^{1/2}$ μK
80
60
40
20
0
2
5
10
40
100
200
400
600
800
Multipole l
FIRS
ARGO
SASK
TOCO
ATCA
IACE
IAB
QMAP
BOOMP97
SUZIE
COBE
MAX
PYTH
BOOM98
VLA
TEN
MSAM
PYTH5
MAXIMA
SP
CAT
VIPER
WD
BAM
OVRO
IAC
OVRO


Position of first peak
sensitive probe of the
geometry of the Universe
effective m_B
24
20
18
16
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Calan/Tol
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A.J. 1996
$\delta T = [l(l+1)C_l/2\pi]^{1/2}$
60
40
20
0
2 5 10 40 100 200 400 600 800
Multipole l
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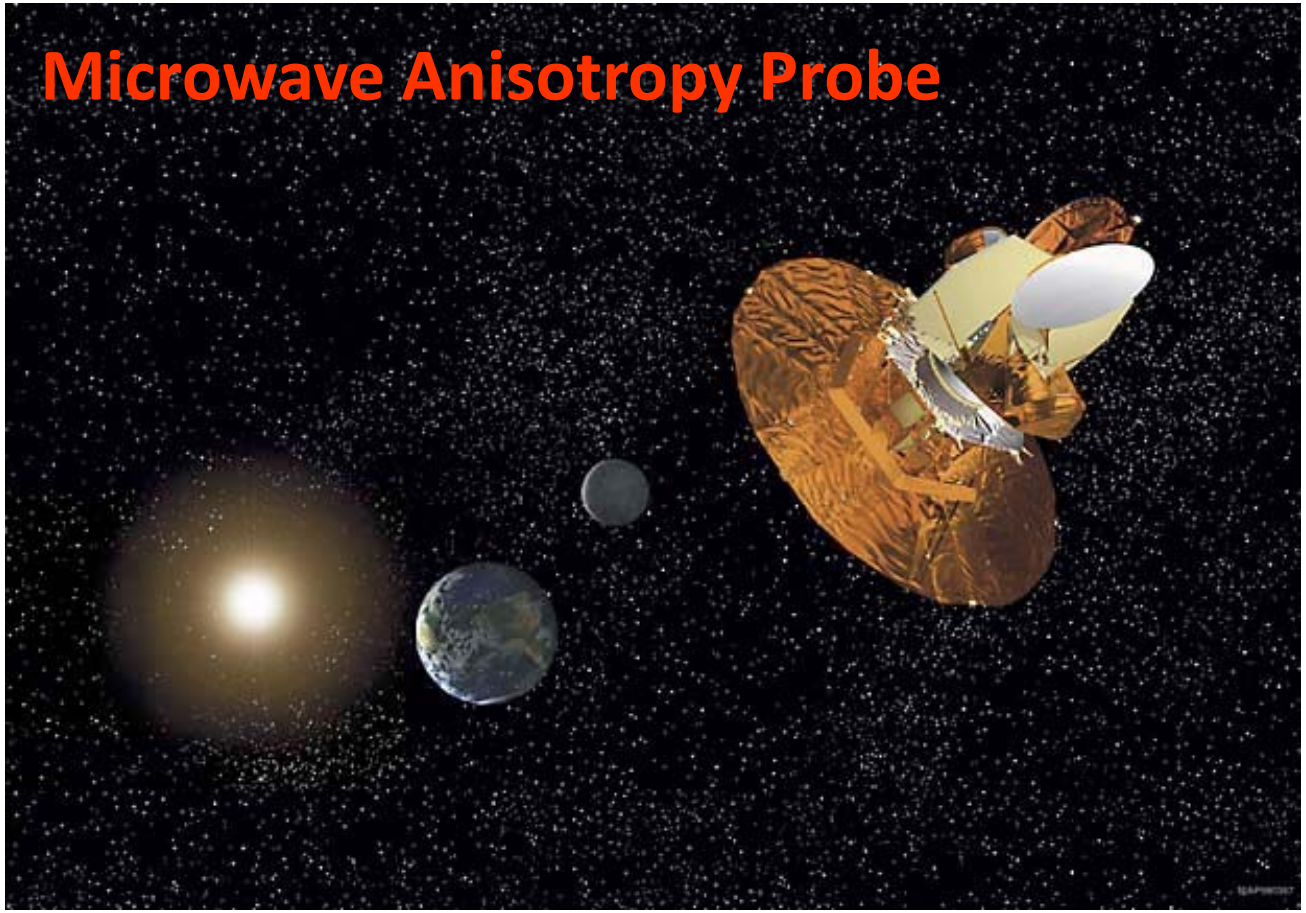
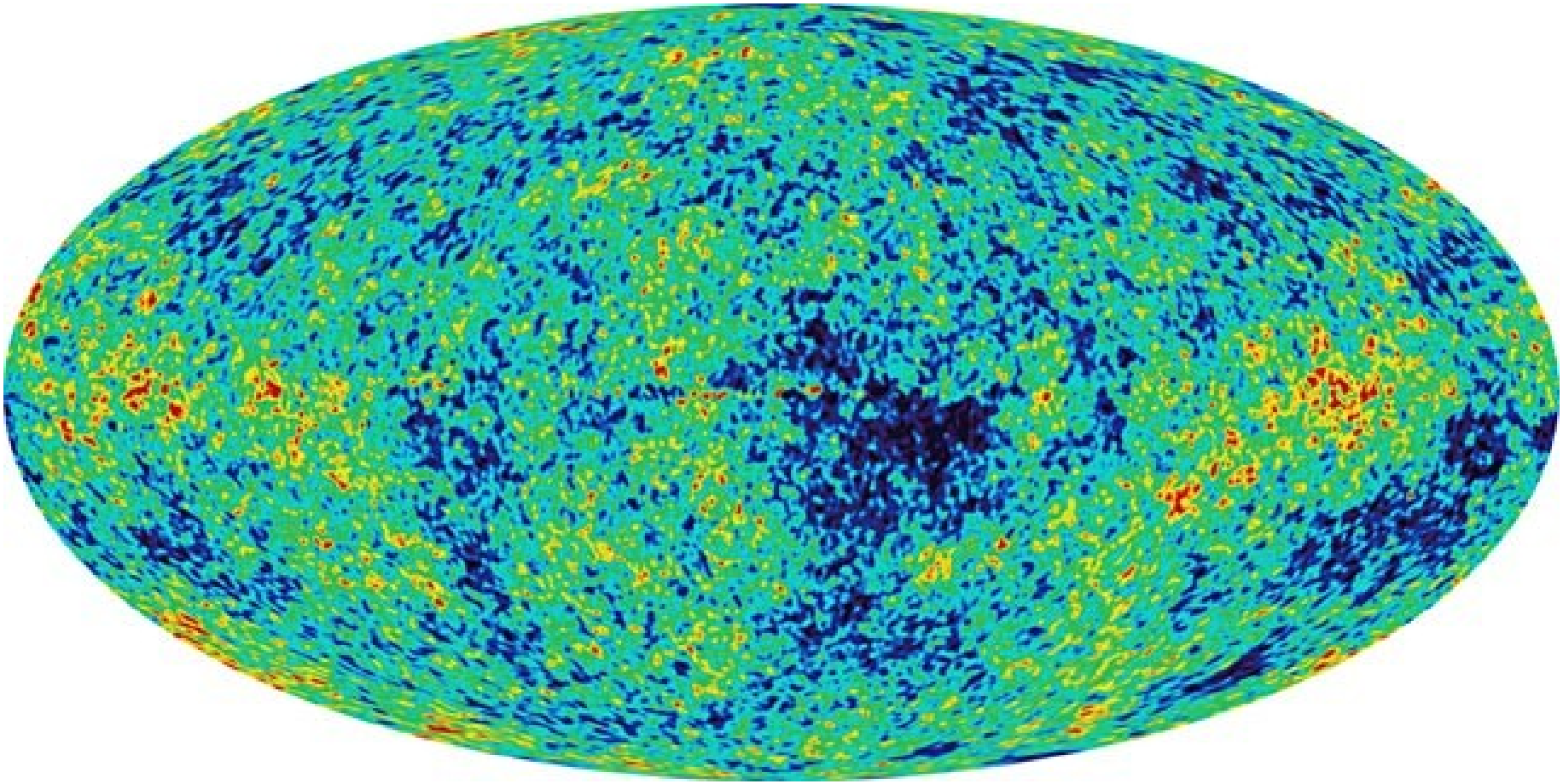
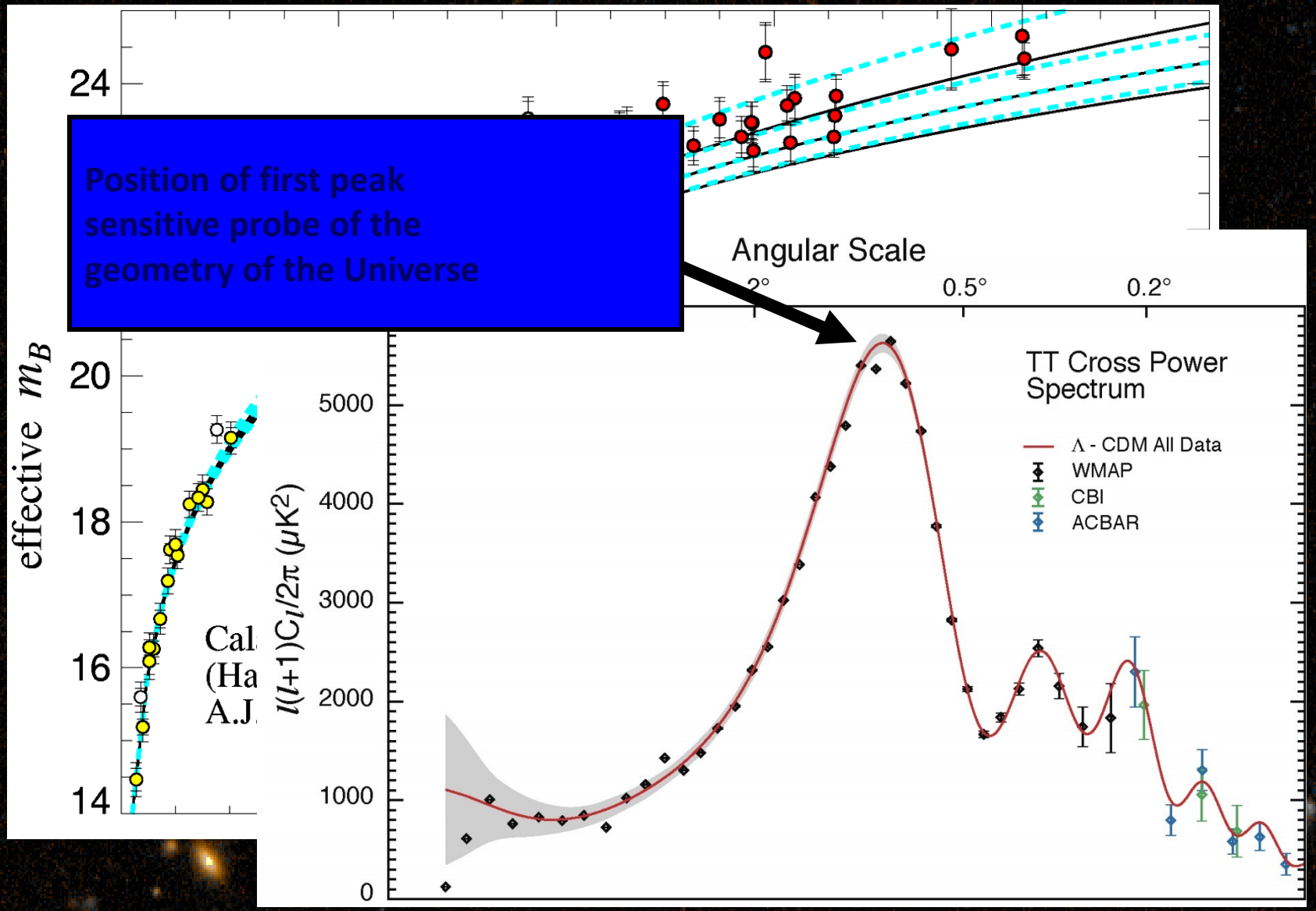

Microwave Anisotropy Probe

From Bennett et al (2003)



First year WMAP results published Tuesday 11th Feb


Position of first peak
sensitive probe of the
geometry of the Universe
24
20
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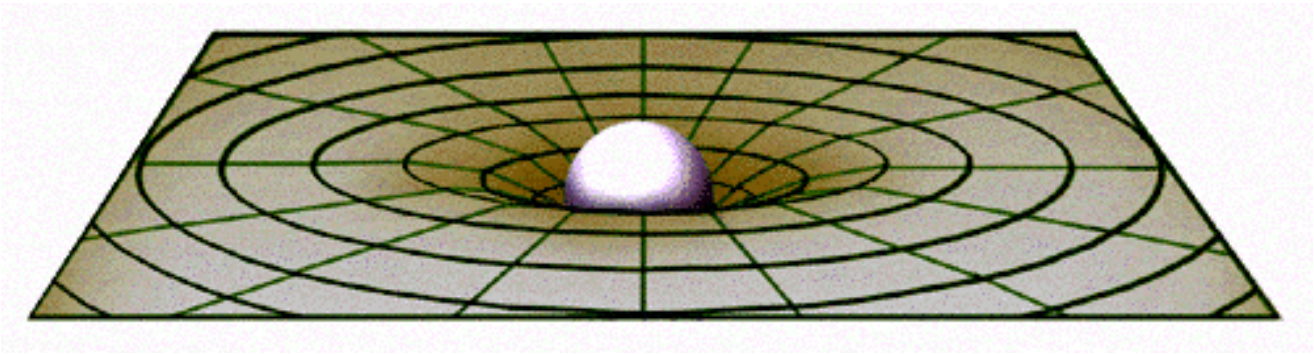
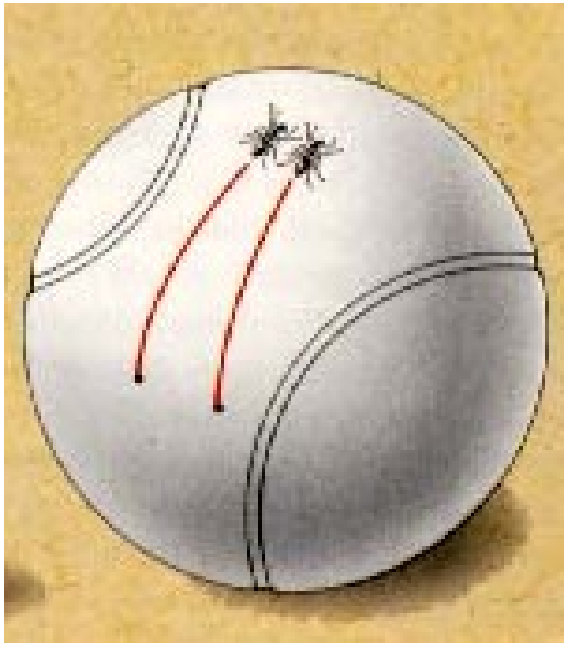
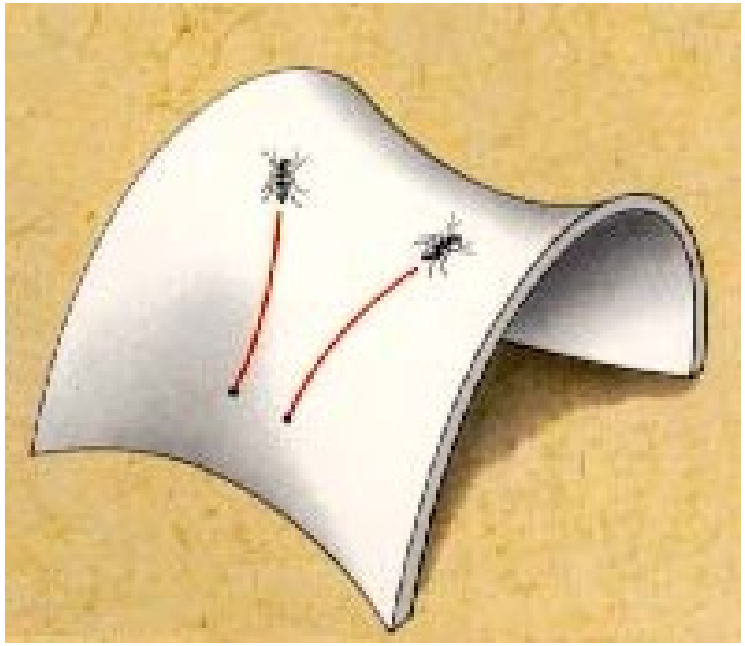
14
effective m_B
Cal
(Ha
A.J
Angular Scale
2°
0.5°
0.2°
5000
4000
3000
2000
1000
0
$l(l+1)C_l/2\pi$ (μK^2)
TT Cross Power
Spectrum
Λ - CDM All Data
WMAP
CBI
ACBAR

Answer depends on the **geometry** of the Universe

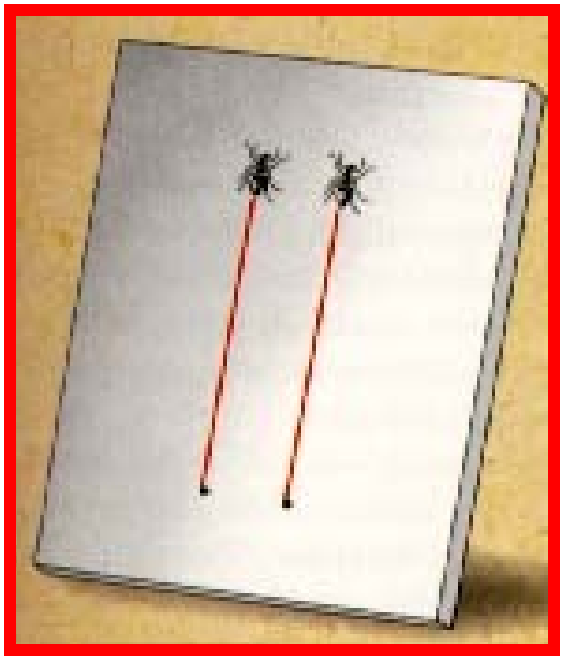




Closed



Open



Flat

Results:

th

ndefi

What is driving the cosmic acceleration?...

Dark Energy