NS 102 Lecture 11

The Well Tempered Cosmology Class

Johann Sebastian Bach
(1685-1750)

News of the week

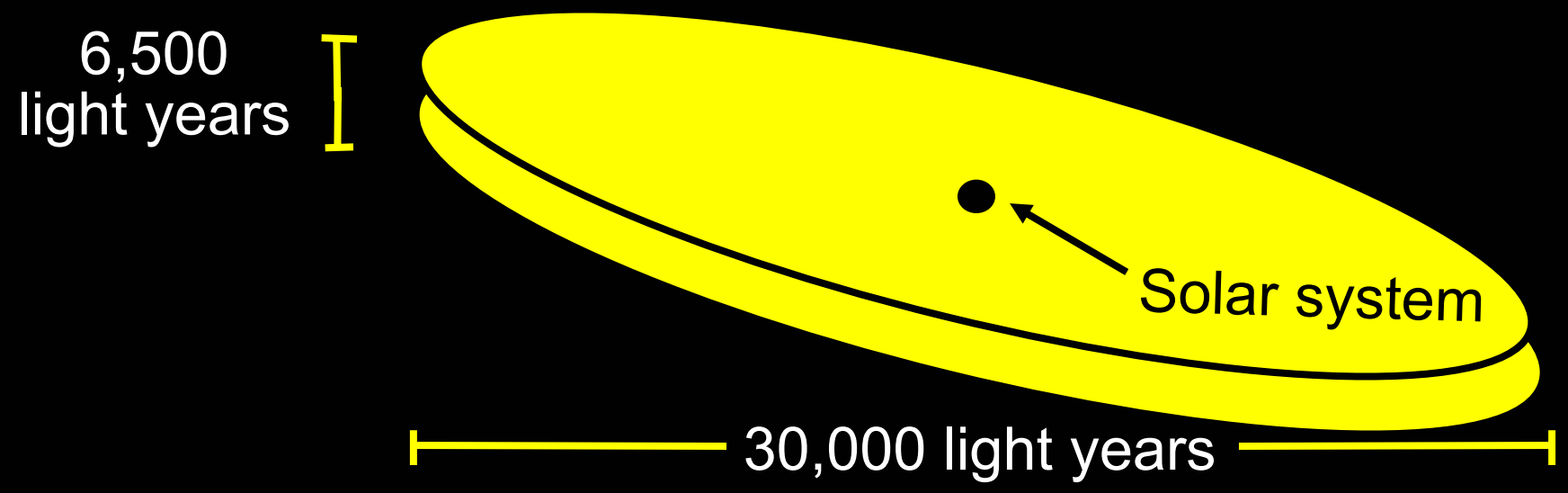
- No office hours today
- Lab this week: 1st week of geometry of the universe
- Lab next week: 2nd week of geometry of the universe

A view of the universe, circa 1903 A.D.

Kapteyn Universe

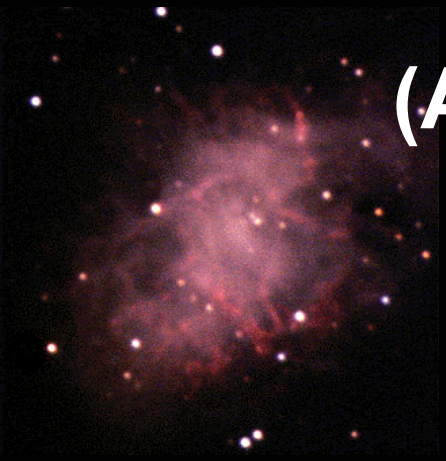
1) **Composition**: Starz' in the 'hood

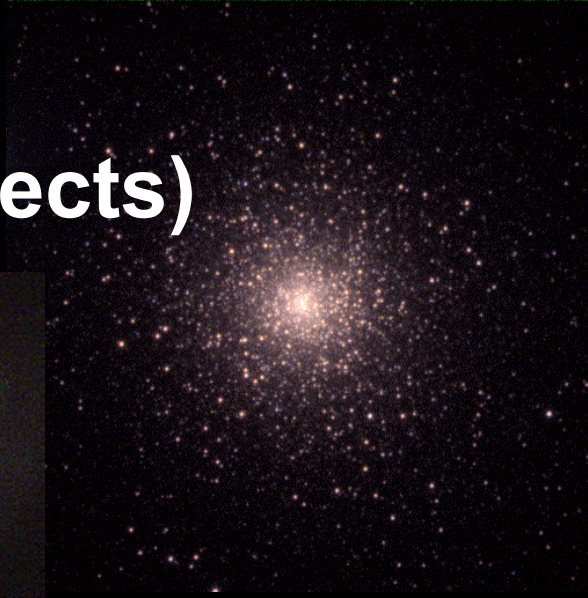
2) **Arrangement**:

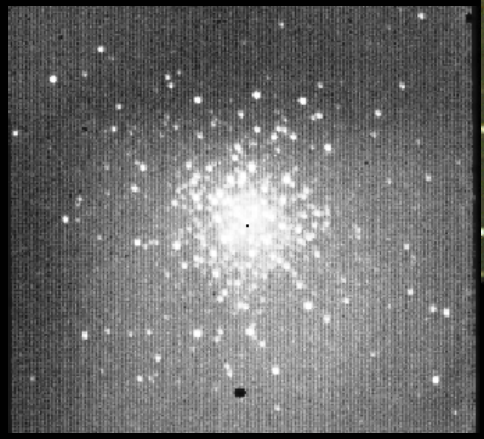


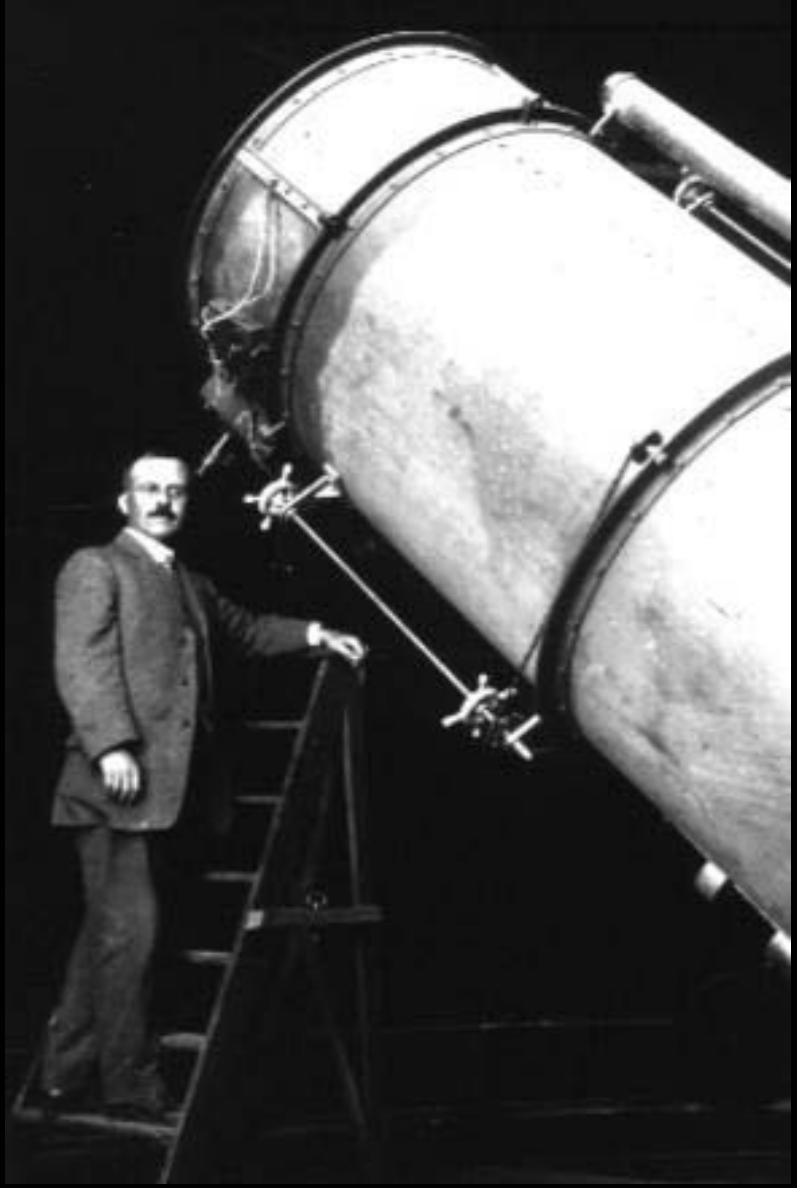
3) **Origin**: ?

Clouds in the Sky
(A Mess of Messier Objects)









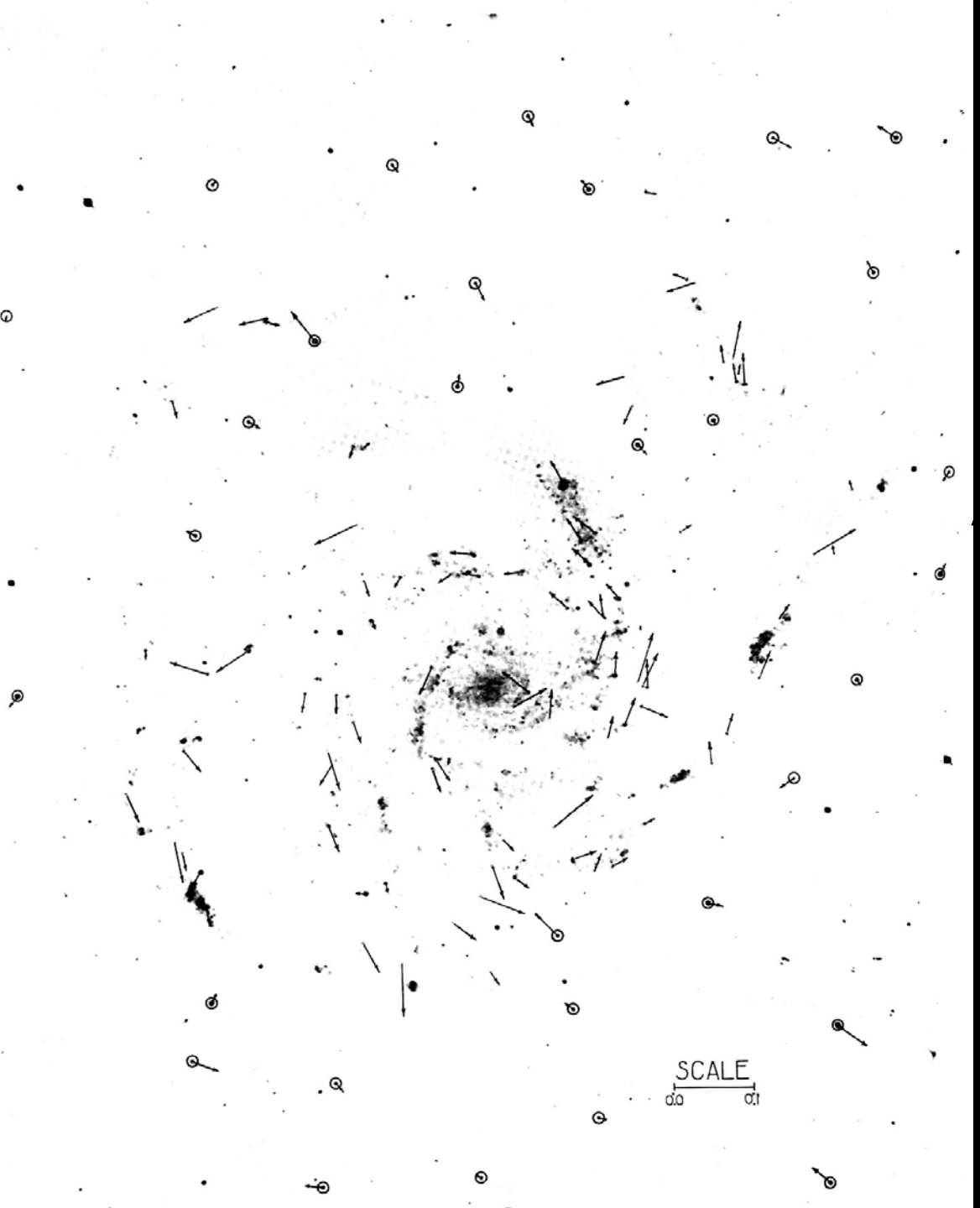
Heber Curtis
1872 - 1942

Harlow Shapley
1885 - 1972

Talking points in the Great Debate

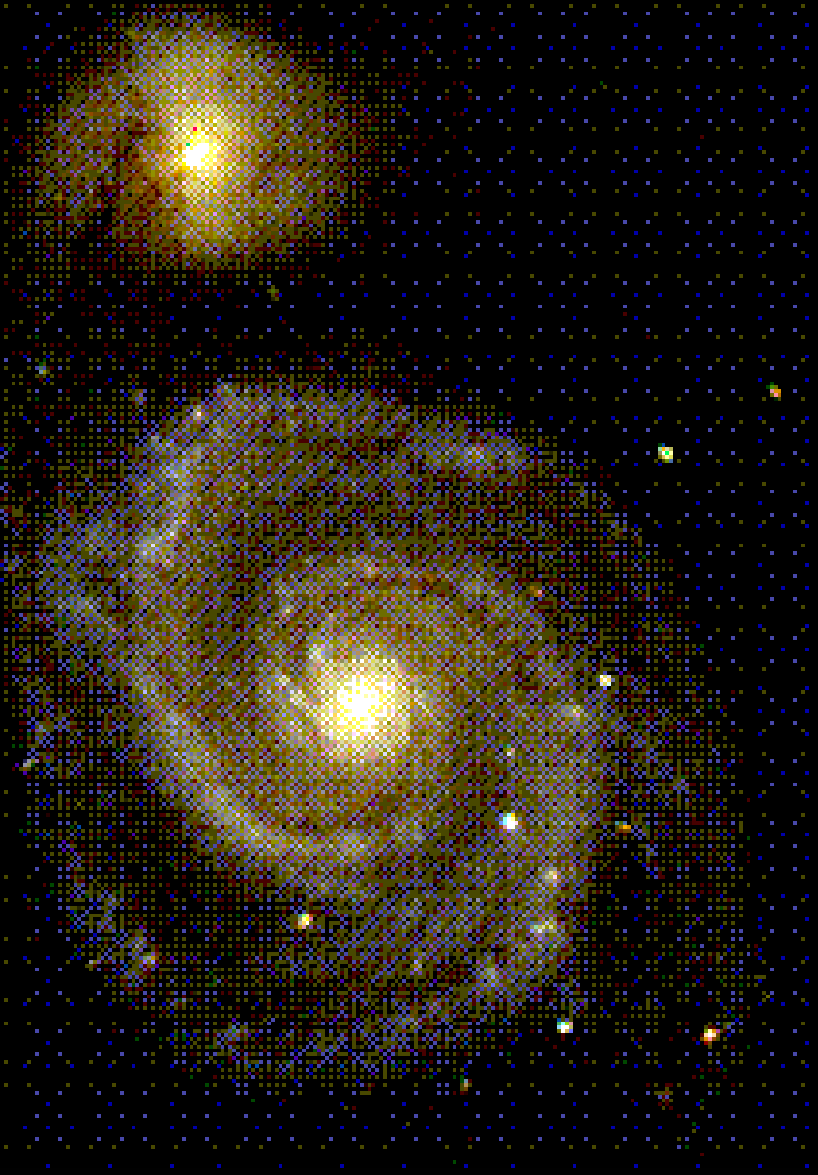
1. Rotation of M101
2. Variable stars
3. Stars or gas
4. Spatial distribution & velocity

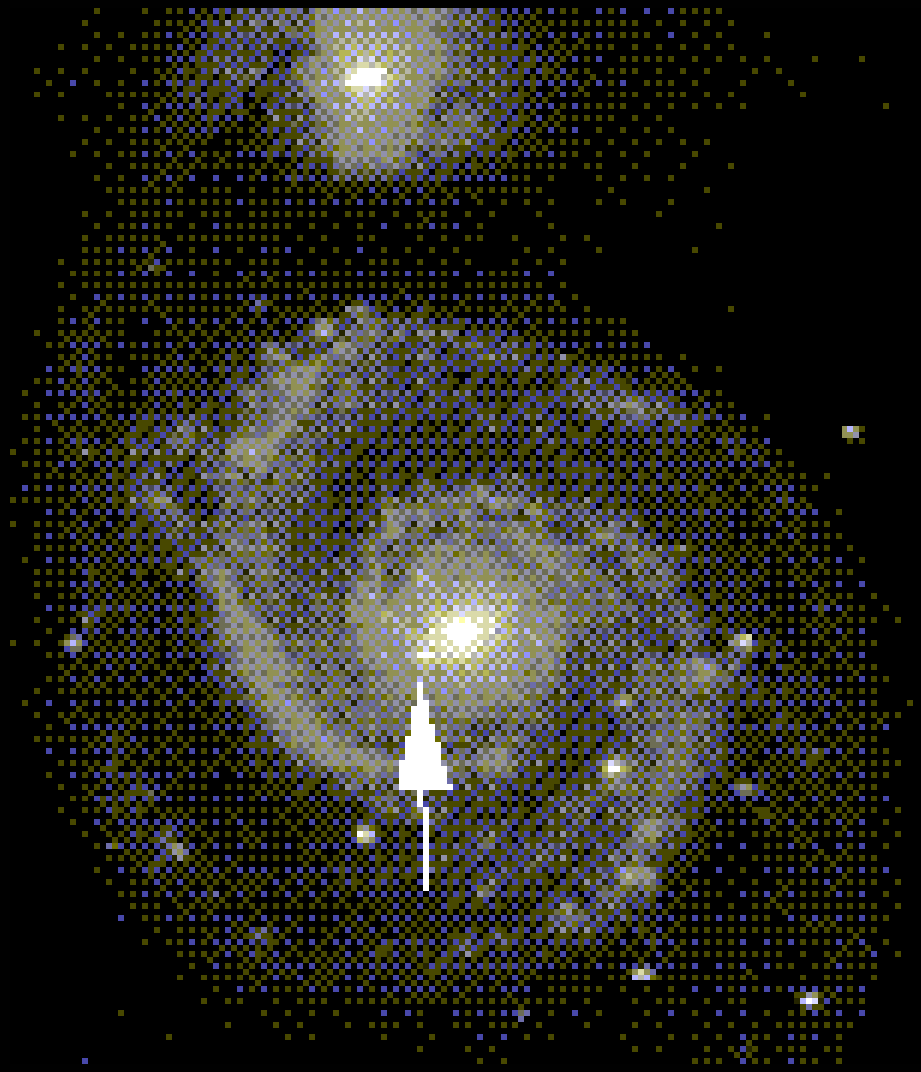
M101


SCALE
0.0
0.1

Talking points in the Great Debate

1. Rotation of M101
2. Variable stars
3. Stars or gas
4. Spatial distribution & velocity





Talking points in the Great Debate

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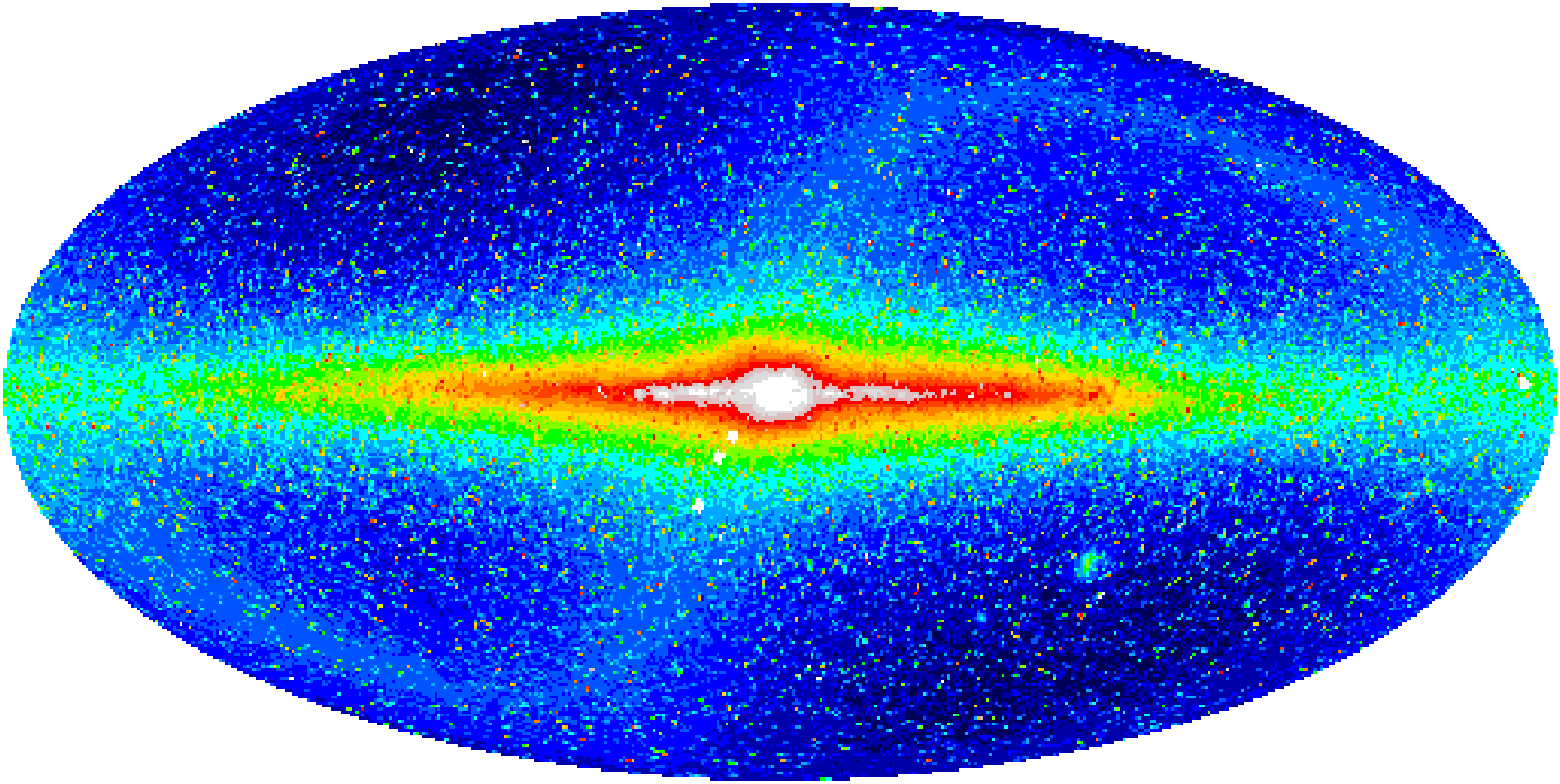
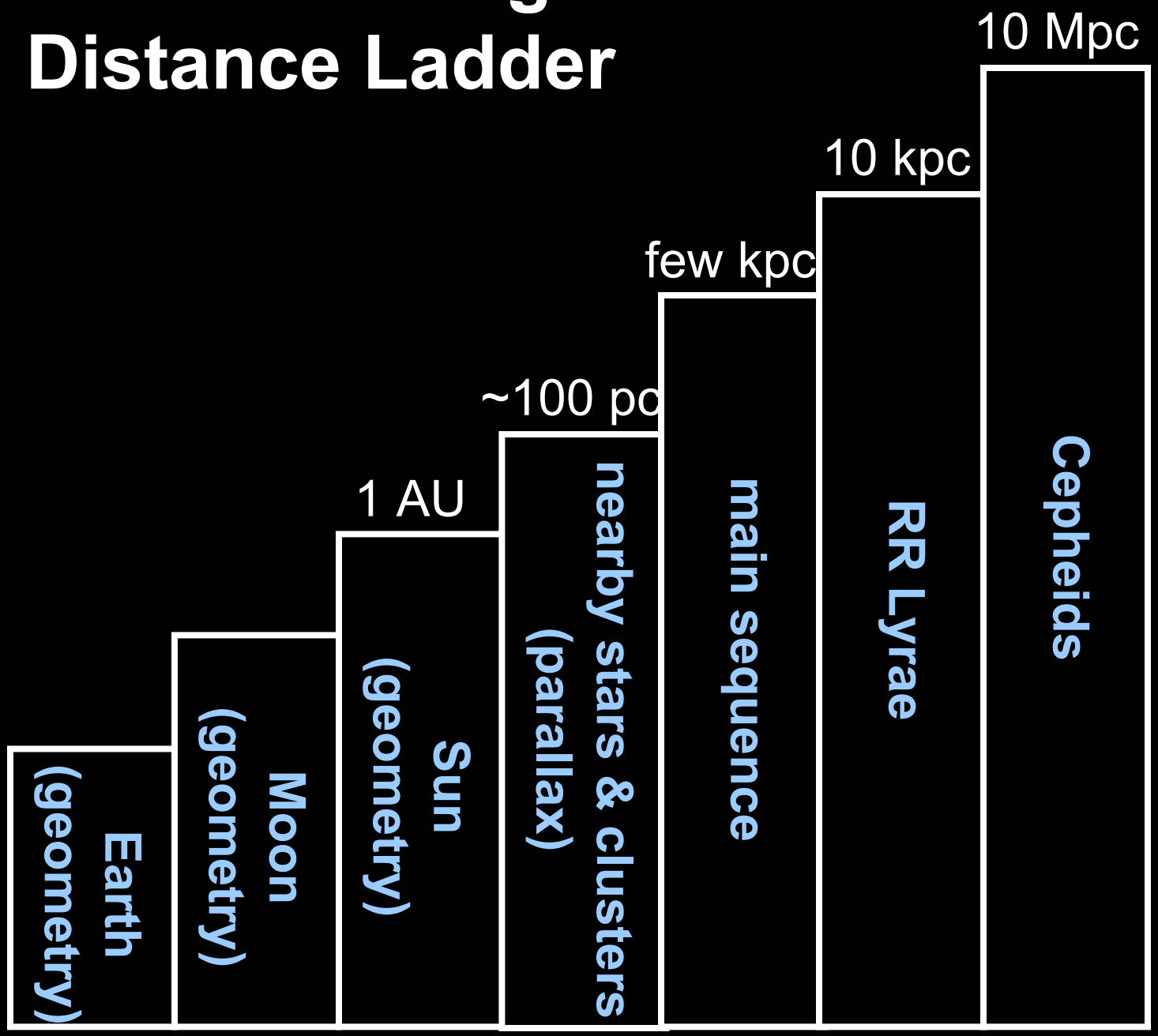


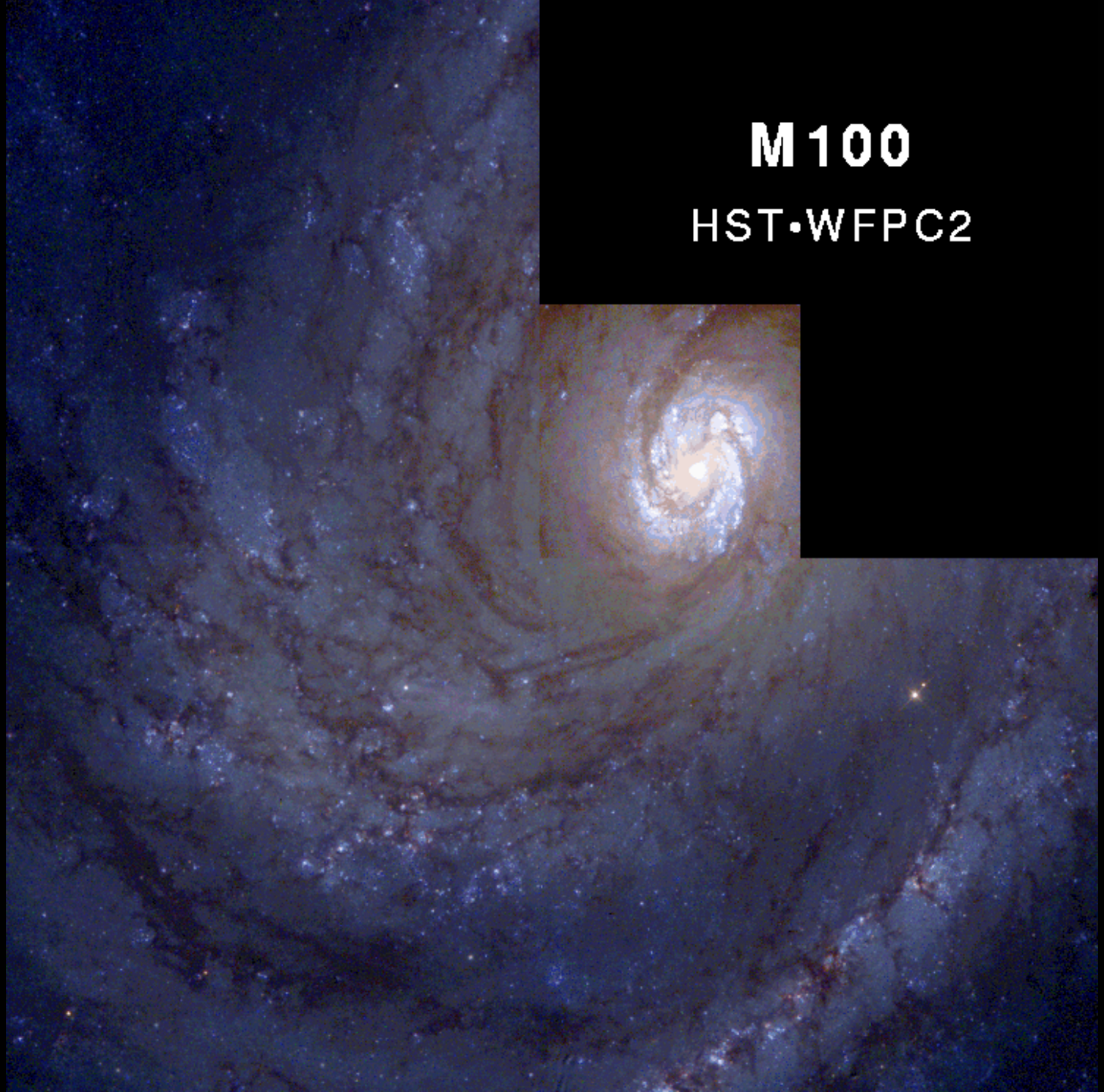
Dust in the galactic plane

Edwin Hubble
1884 - 1953

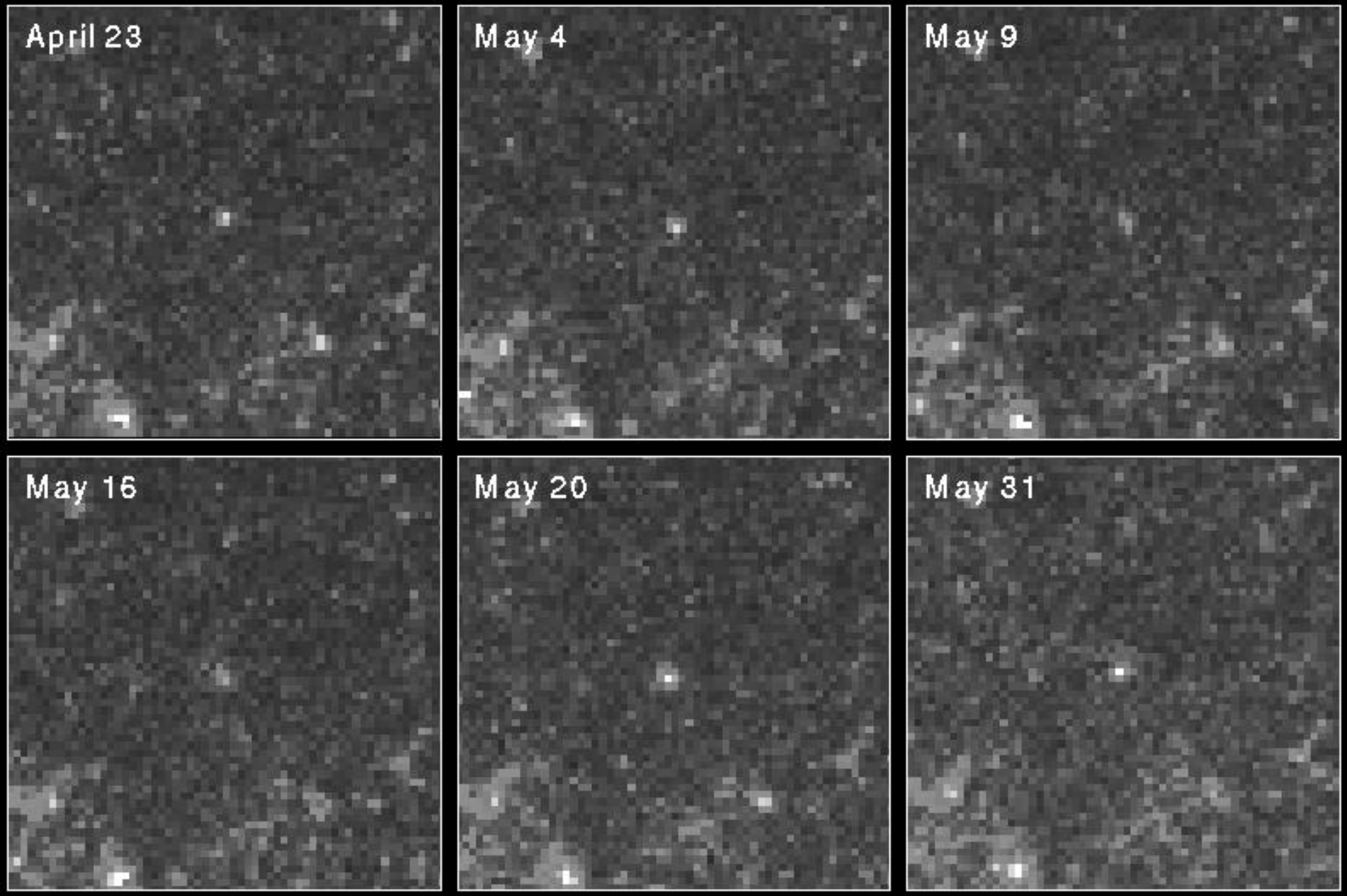
N
VAR!
N
6-Oct
1923
N

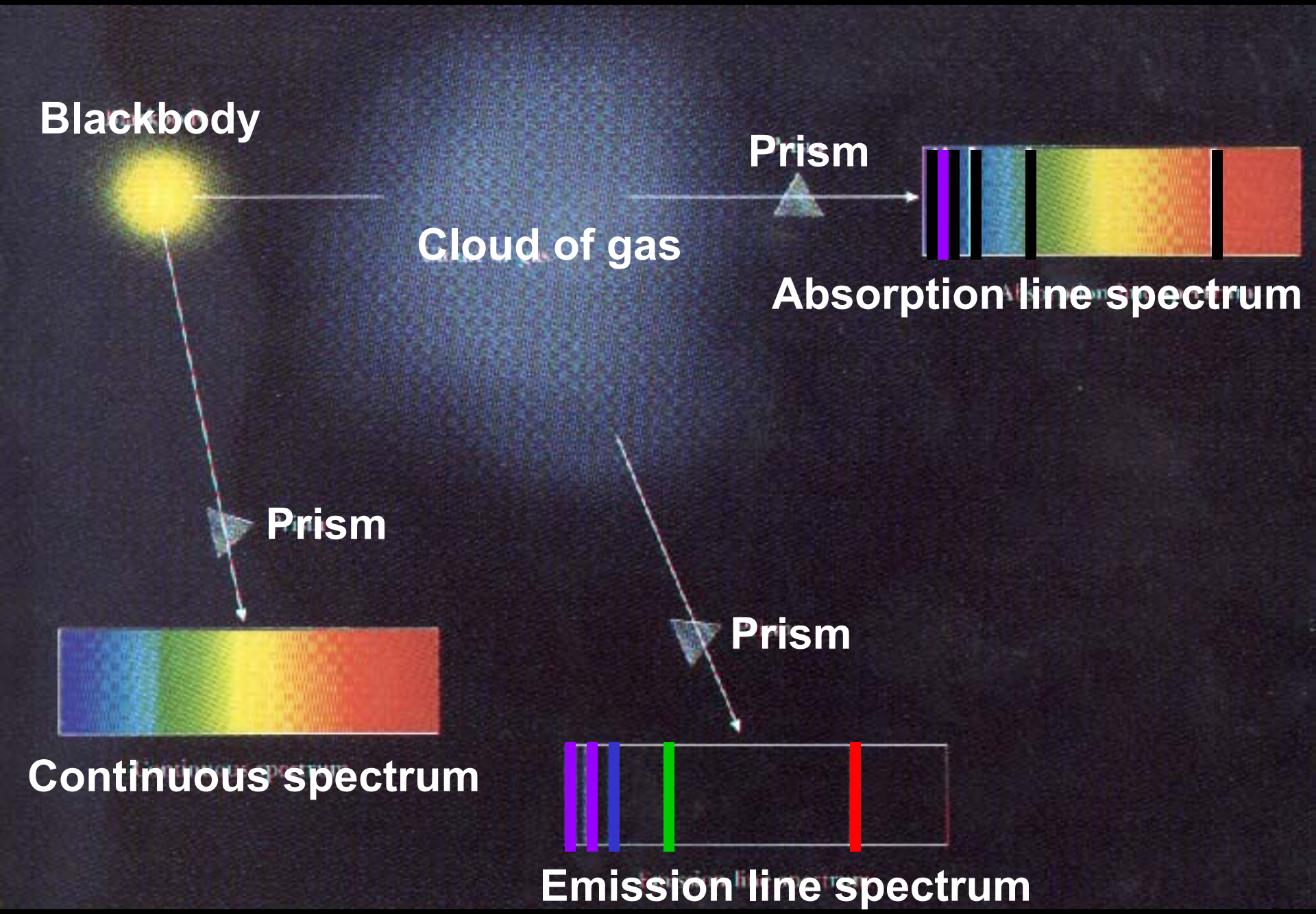
The Cosmological Distance Ladder




M100
HST•WFPC2

Cepheid Variable Star in Galaxy M100 HST•WFPC2




Blackbody
Prism
Cloud of gas
Absorption line spectrum
Prism
Prism
Continuous spectrum
Emission line spectrum

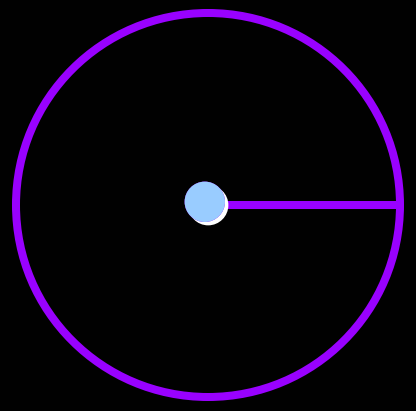
Nothing exists but atoms and empty space; everything else is opinion.

- Demokritos

Everything has been thought of before. The problem is to think of it again.

- Goethe

$t = \Delta t$

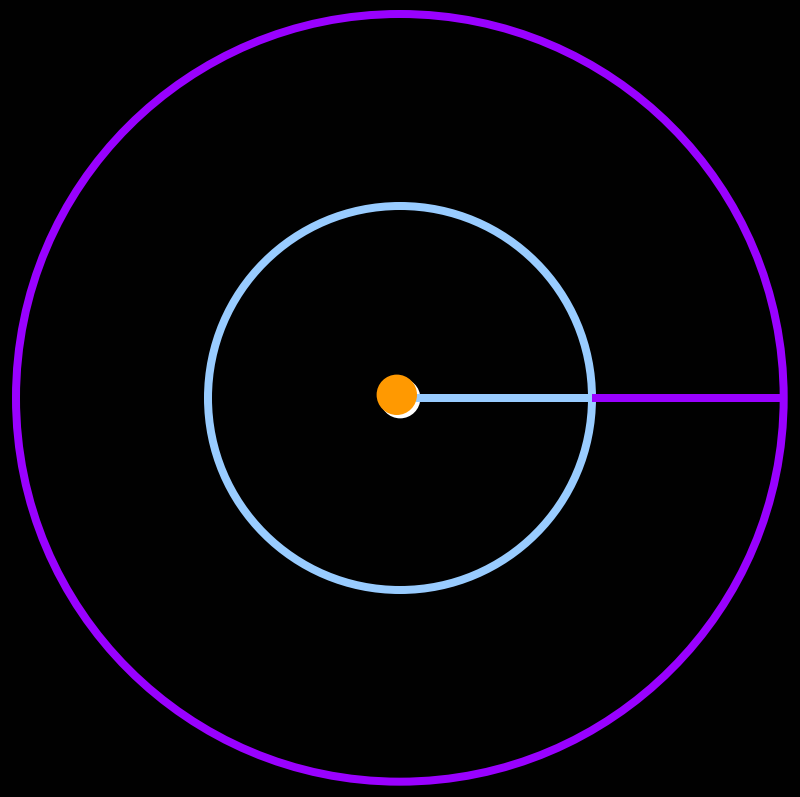


c = velocity of wave

Δt = time difference

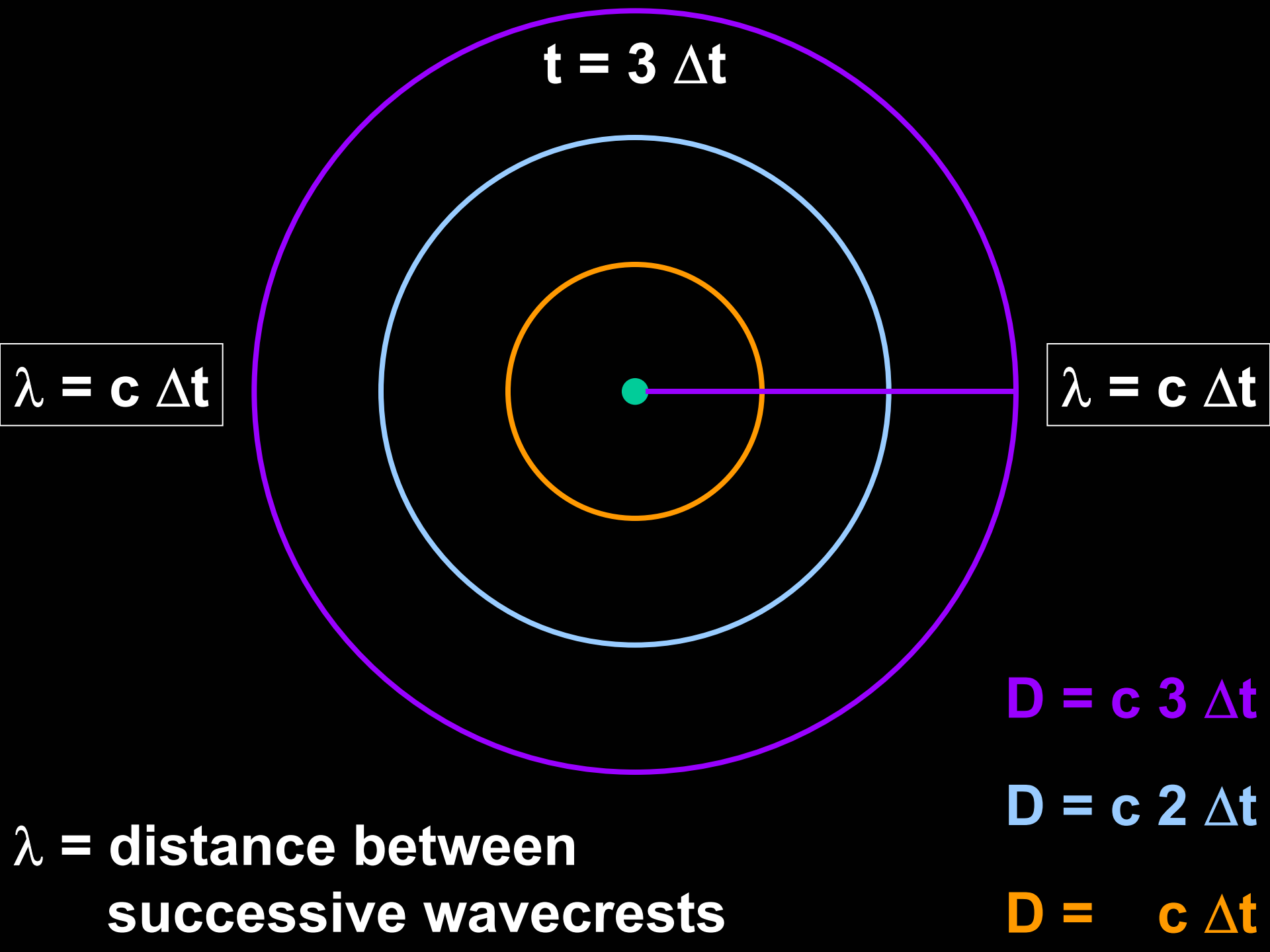
$$D = c\,\Delta t$$

$t = 2\,\Delta t$

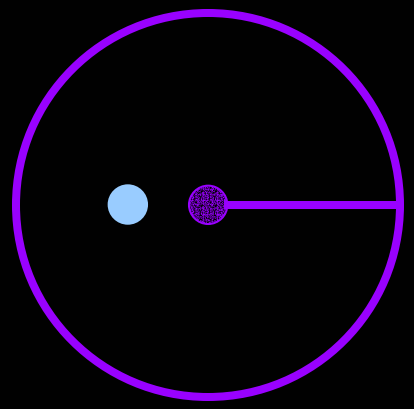


$D = c\,2\,\Delta t$

$D = c\,\Delta t$

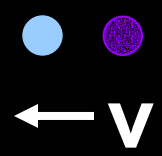

t = 3 Δt
λ = c Δt
λ = c Δt
D = c 3 Δt
D = c 2 Δt
D = c Δt
λ = distance between
successive wavecrests

$t = \Delta t$

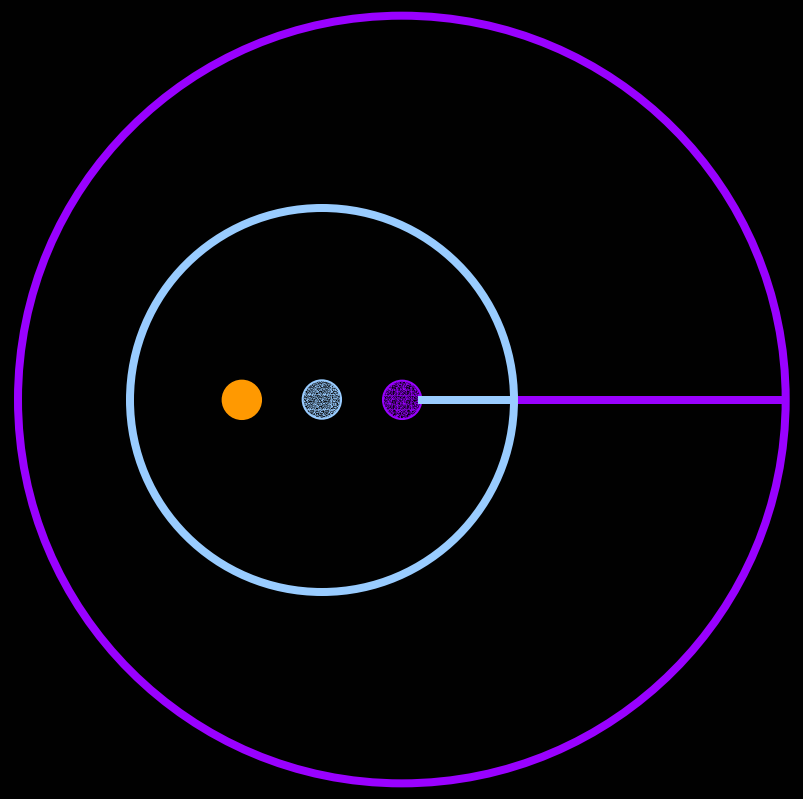


$D = c \quad \Delta t$

$d = v\,\Delta t$



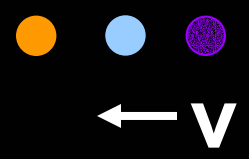
$t = 2\,\Delta t$

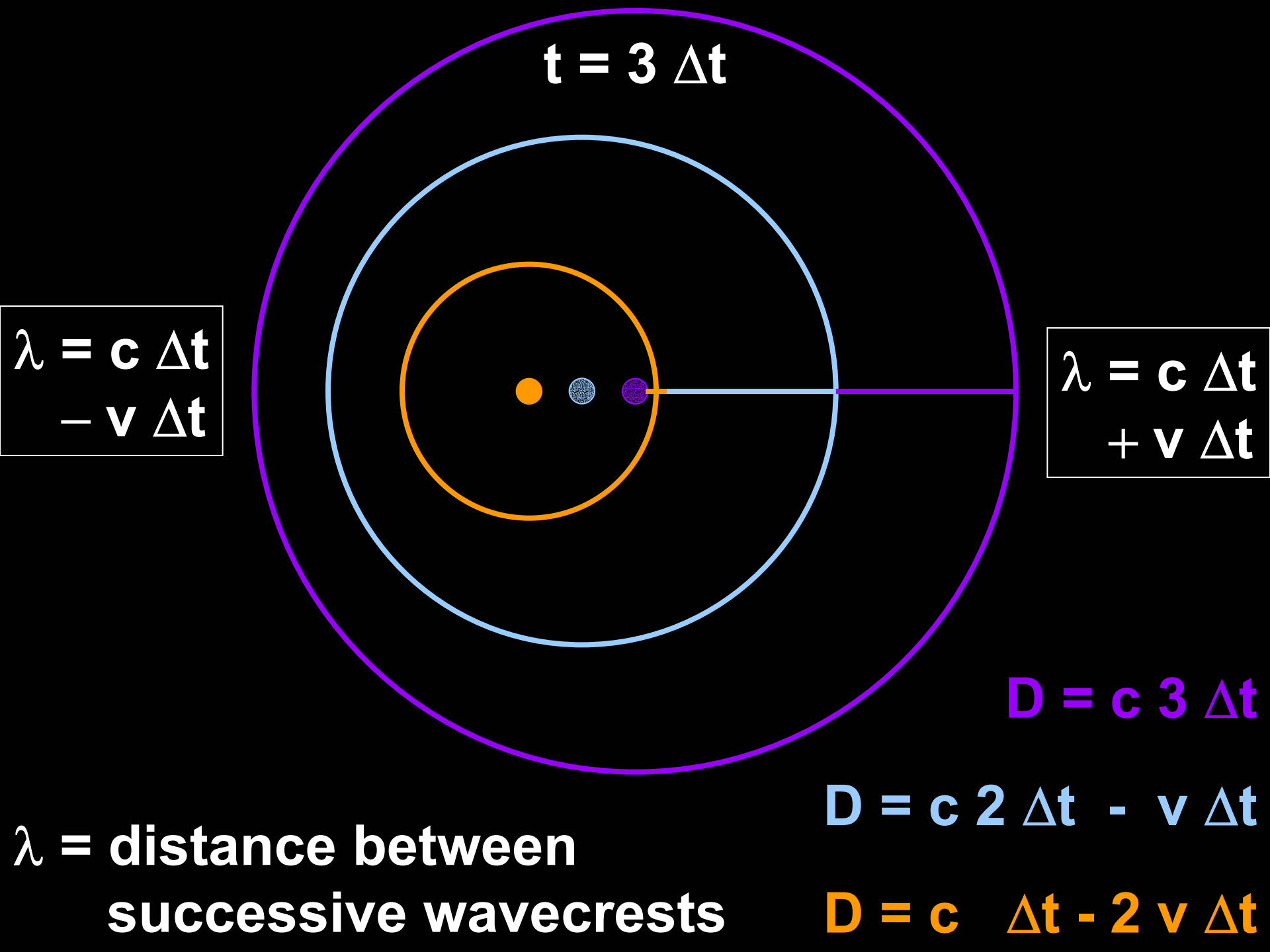


$D = c\,2\,\Delta t$

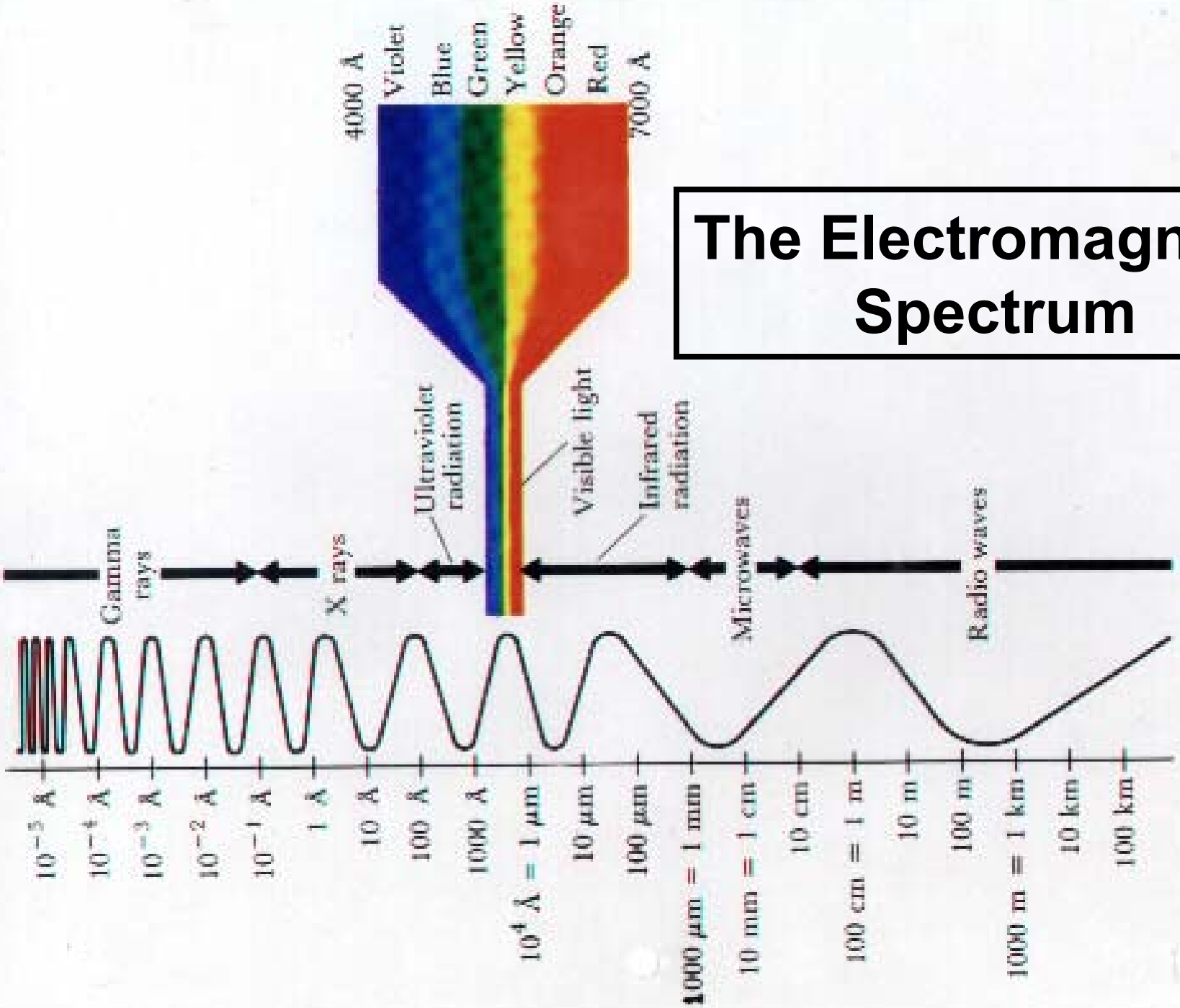
$d = v\,\Delta t$

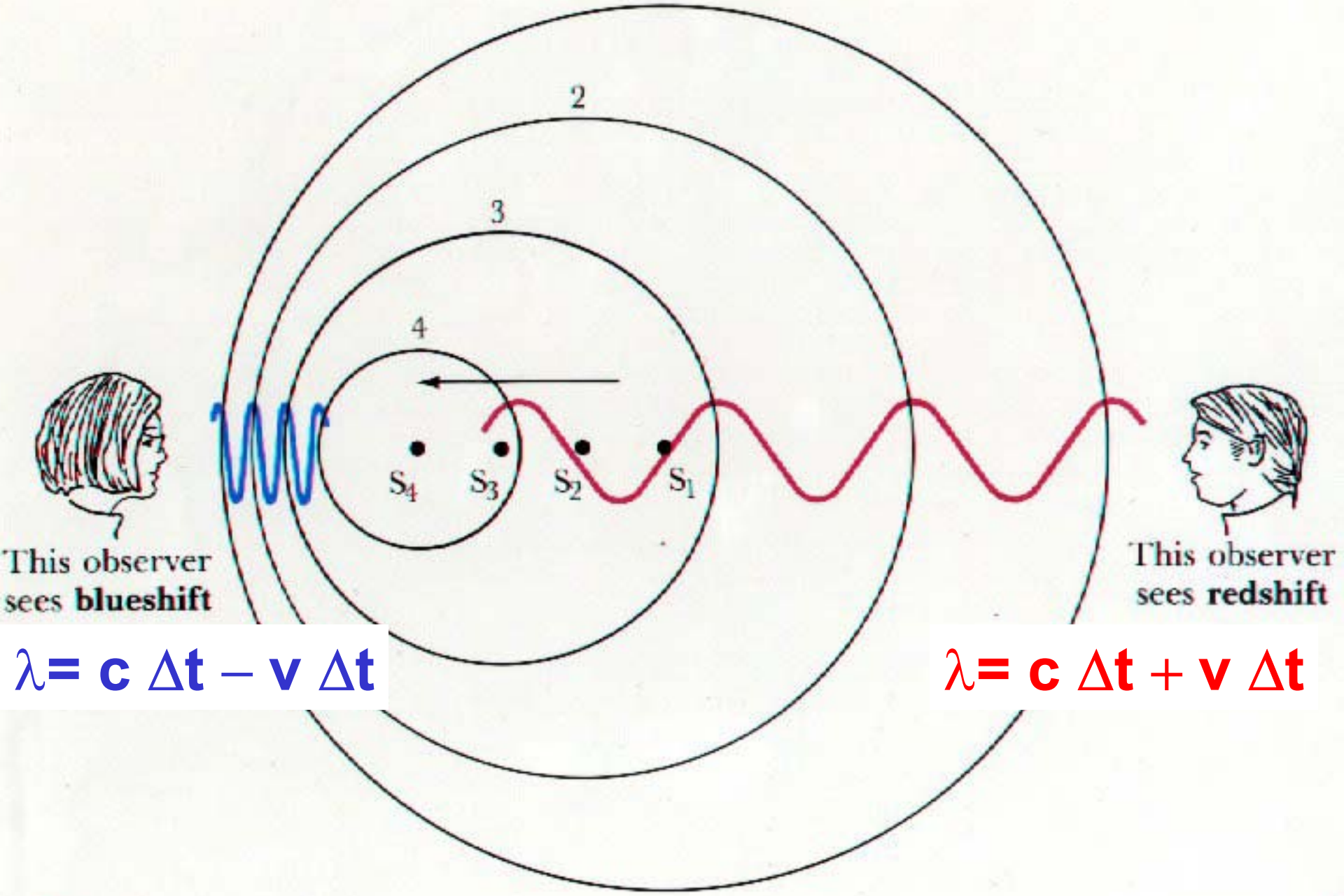
$D = c\,\Delta t - v\,\Delta t$




t = 3 Δt
λ = c Δt
– v Δt
λ = c Δt
+ v Δt
D = c 3 Δt
D = c 2 Δt - v Δt
D = c Δt - 2 v Δt
λ = distance between
successive wavecrests

The Electromagnetic Spectrum





$$\lambda = c\,\Delta t - v\,\Delta t$$

$$\lambda = c\,\Delta t + v\,\Delta t$$

$$\lambda = c\,\Delta t \pm \mathrm{v}\,\Delta t$$

$$c\,\Delta t = \lambda_0 \qquad \Rightarrow \qquad \lambda = \lambda_0 \pm \mathrm{v}\,\Delta t$$

$$\Delta t = \frac{\lambda_0}{c} \qquad \Rightarrow \qquad \lambda = \lambda_0 \pm \frac{\mathrm{v}}{c}\lambda_0$$

$$\boxed{\frac{\lambda}{\lambda_0} = 1 \pm \frac{\mathrm{v}}{c}}$$

Frequency

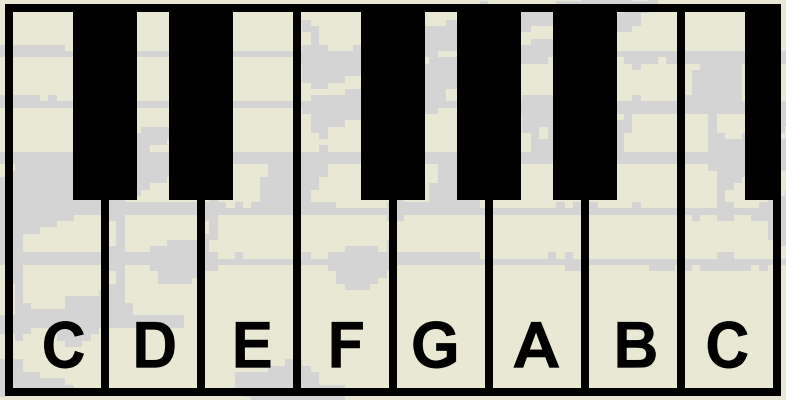
$$c\,\Delta t = \lambda_0$$

$$\frac{1}{\Delta t} = \text{ frequency } = \nu_0$$

$$\frac{c}{\nu_0} = \lambda_0 \qquad\qquad \frac{c}{\nu} = \lambda$$

$$\boxed{\frac{\lambda}{\lambda_0} = \frac{\nu_0}{\nu}}$$

The Well Tempered Cosmology Class



262	277	294	311	330	349	370	392	415	**440**	466	494	523
C	D^b	D	E^b	E	F	G^b	G	A^b	A	B^b	B	C
1	a	a^2	a^3	a^4	a^5	a^6	a^7	a^8	a^9	a^{10}	a^{11}	a^{12}

Frequency increase by a factor of 2

$$\mathbf{a^{12} = 2 \qquad a = 1.05946}$$

$$\frac{\lambda}{\lambda_0} = 1 \pm \frac{v}{c} \qquad v = 70\ \text{mph} \qquad c = 700\ \text{mph} \qquad \frac{v}{c} = 0.1 \qquad \frac{\lambda}{\lambda_0} = \begin{cases} 1.1 \\ 0.9 \end{cases}$$

$$\nu_0 = 415\,\text{Hz} \quad A^b$$

$$\frac{\nu}{\nu_0} = \frac{\lambda_0}{\lambda} = \begin{cases} 0.9 \\ 1.1 \end{cases} \qquad \nu = \begin{cases} 370\ \text{Hz}\ G^b \\ 466\ \text{Hz}\ B^b \end{cases}$$

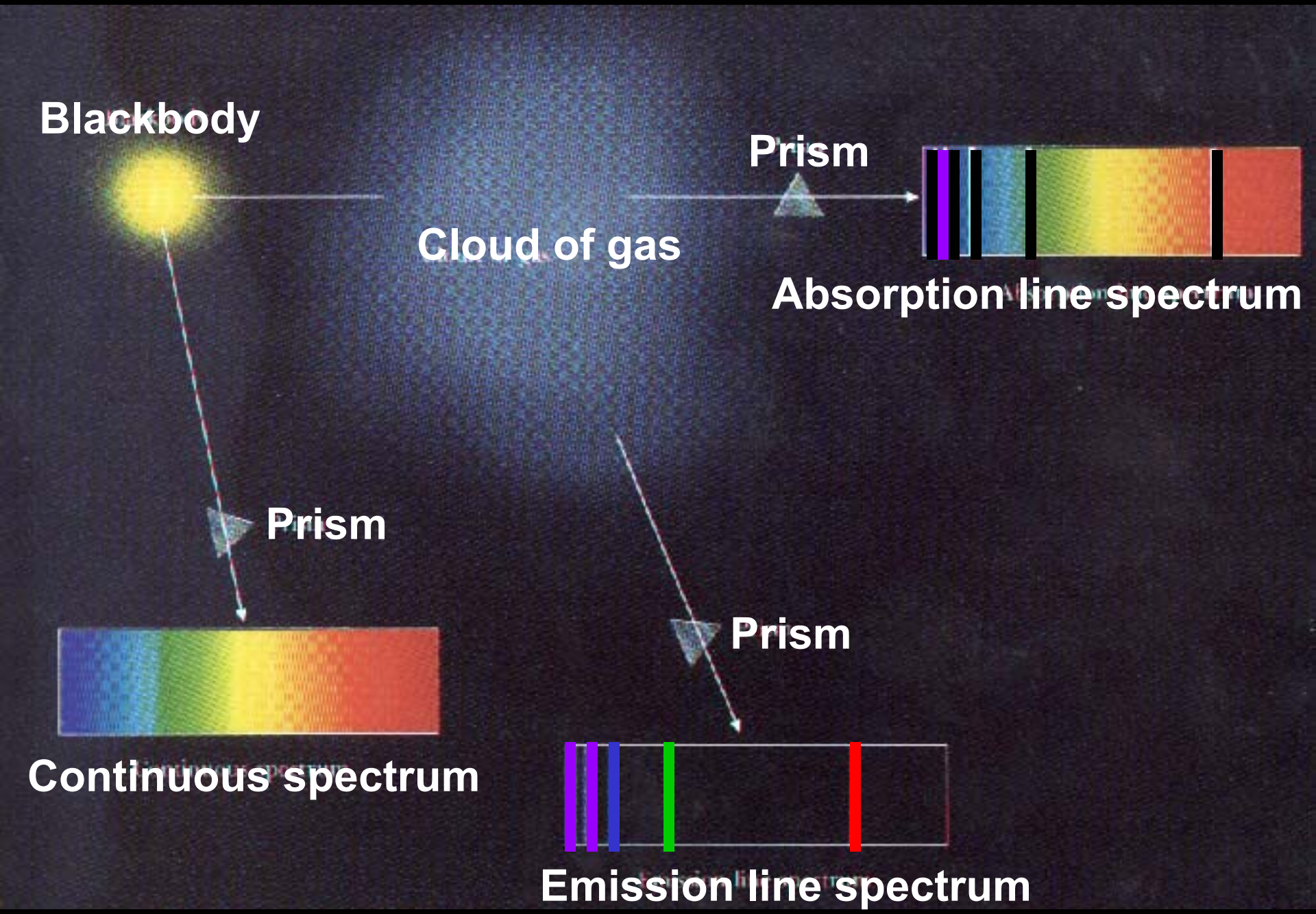
World Premiere

Car Horn in A^{b}

Sonata for Violin

New composition by
Maestro Rocky Kolb

Performed by
Thao Thai, violin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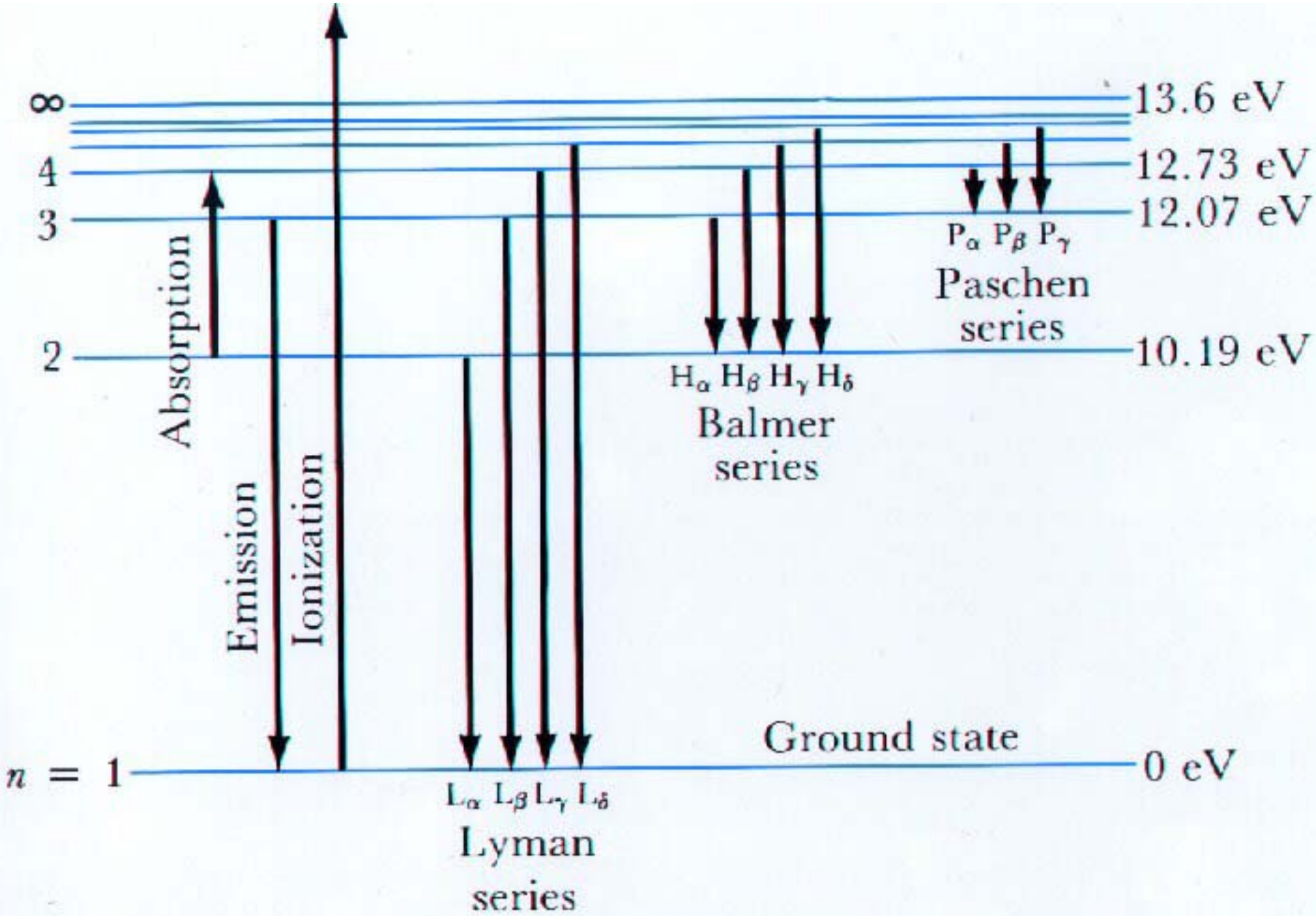
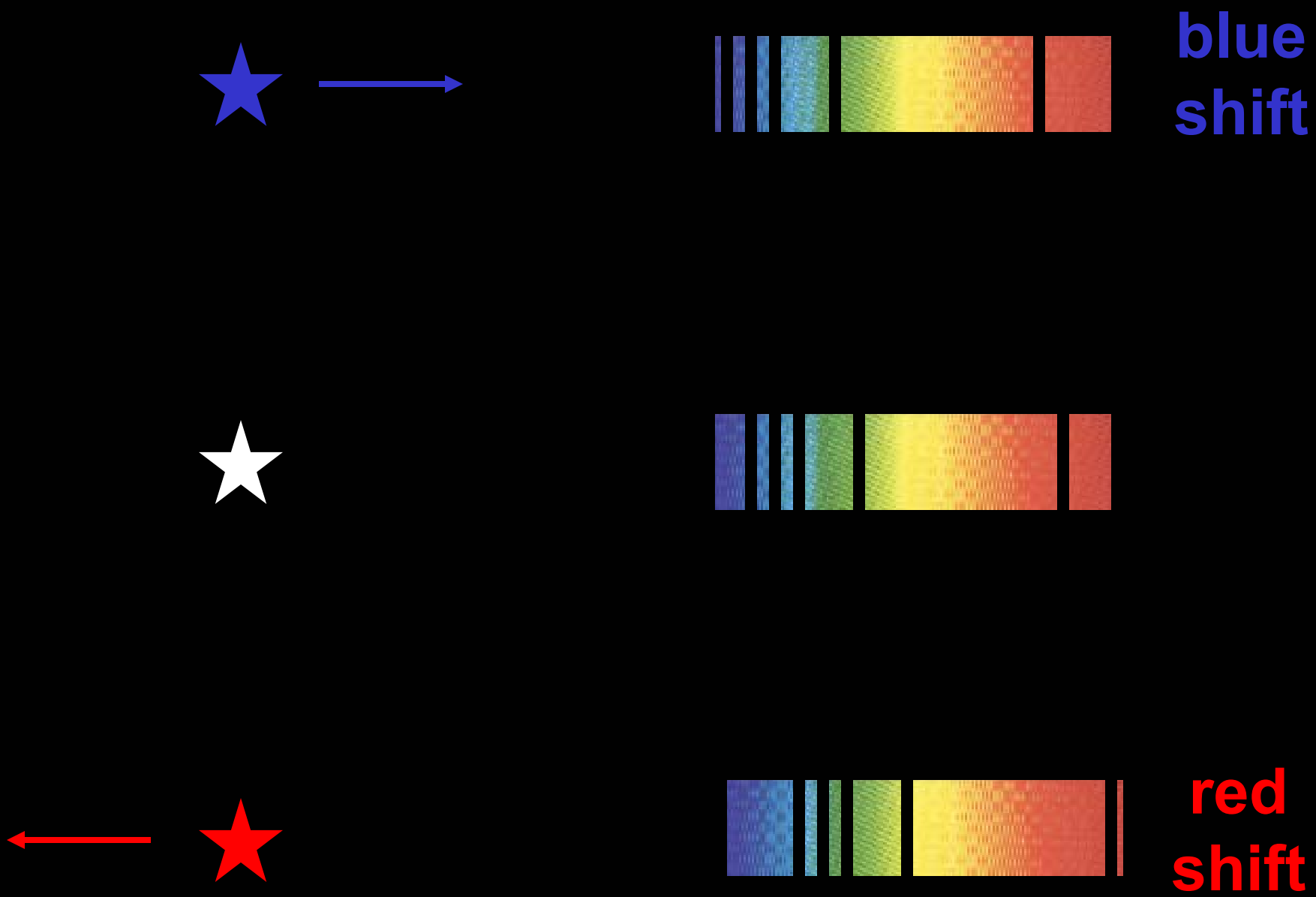

∞
4
3
2
n = 1
13.6 eV
12.73 eV
12.07 eV
10.19 eV
0 eV
Absorption
Emission
Ionization
Ground state
Lα Lβ Lγ Lδ
Lyman series
Hα Hβ Hγ Hδ
Balmer series
Pα Pβ Pγ
Paschen series

Solar Spectrum 4300 – 4400 Angstroms

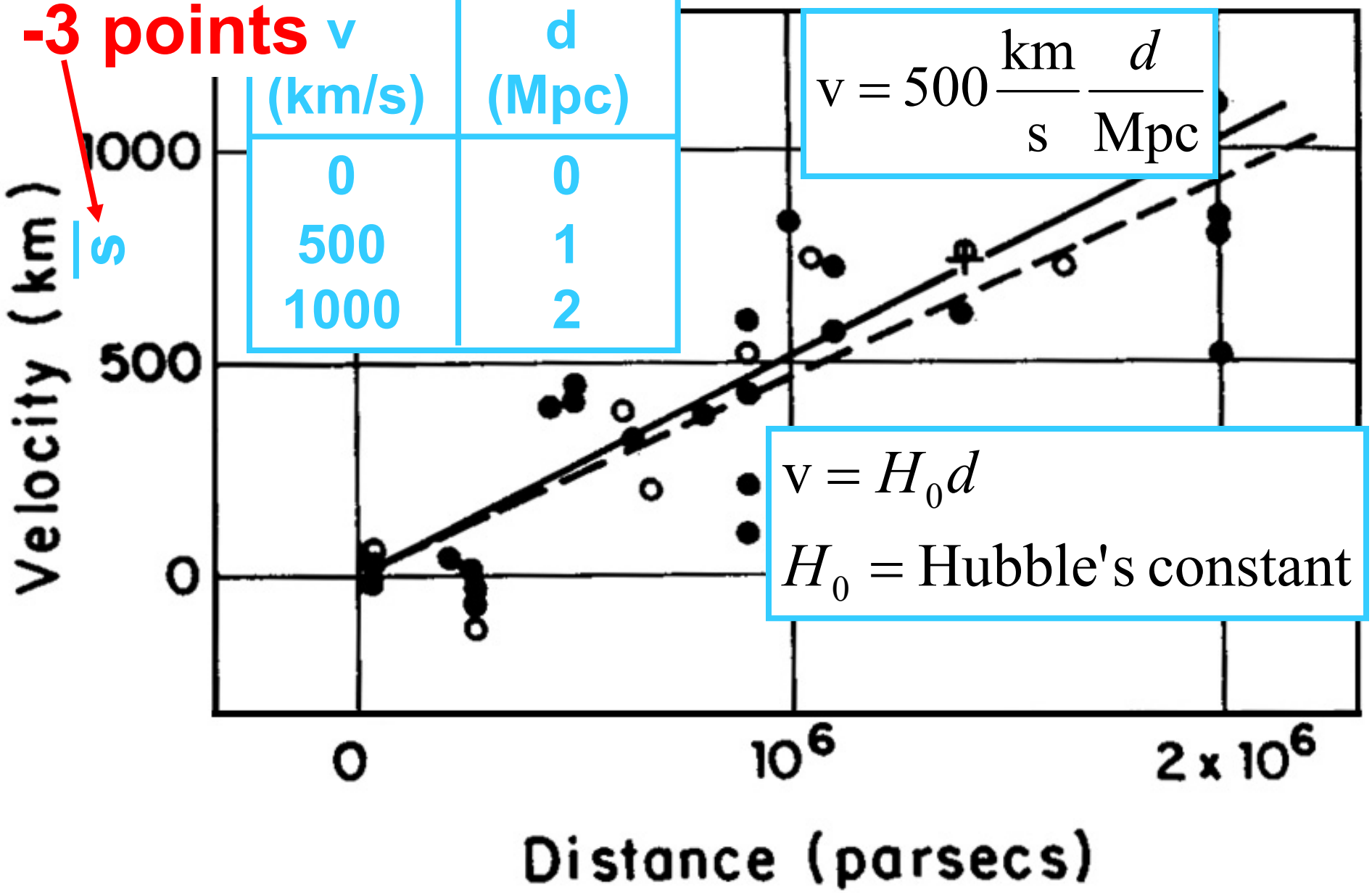

blue
shift
red
shift

Hubble's Discovery Paper - 1929

-3 points

v (km/s)	d (Mpc)
0	0
500	1
1000	2

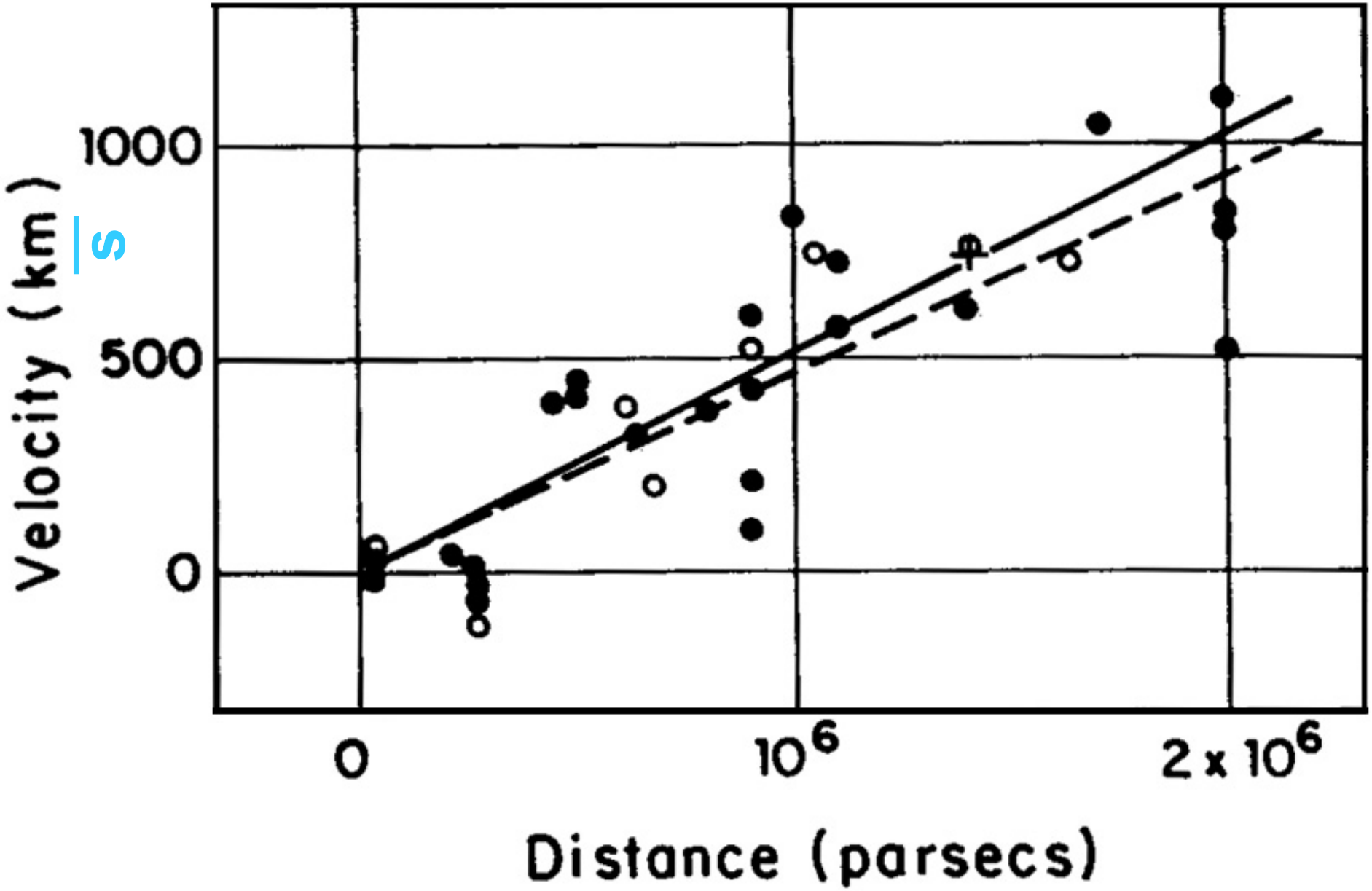
$$v = 500 \frac{\text{km}}{\text{s}} \frac{d}{\text{Mpc}}$$

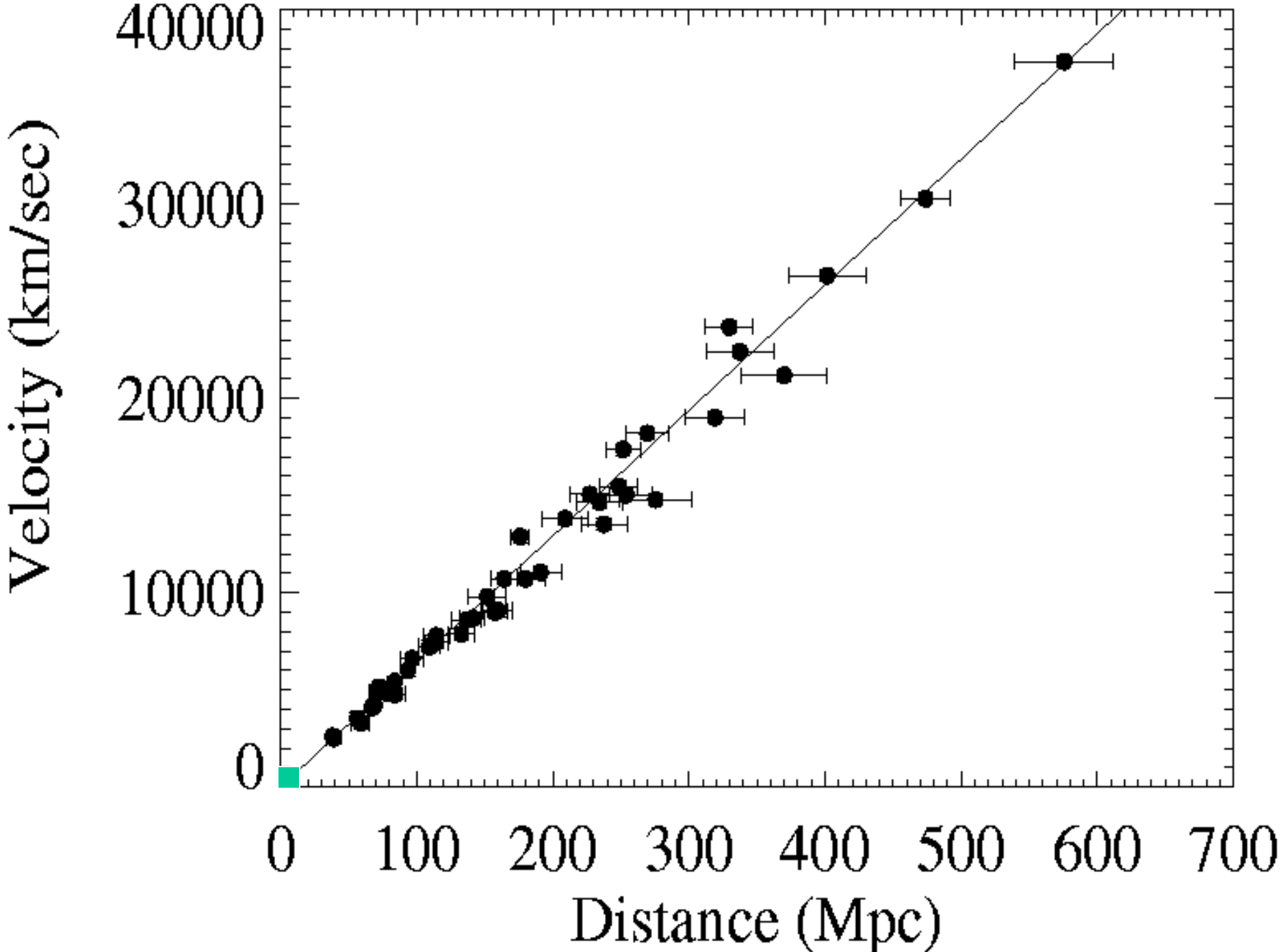


$$v = H_0 d$$

$$H_0 = \text{Hubble's constant}$$

Hubble's Discovery Paper - 1929




Velocity (km/sec)
40000
30000
20000
10000
0
0
100
200
300
400
500
600
700
Distance (Mpc)

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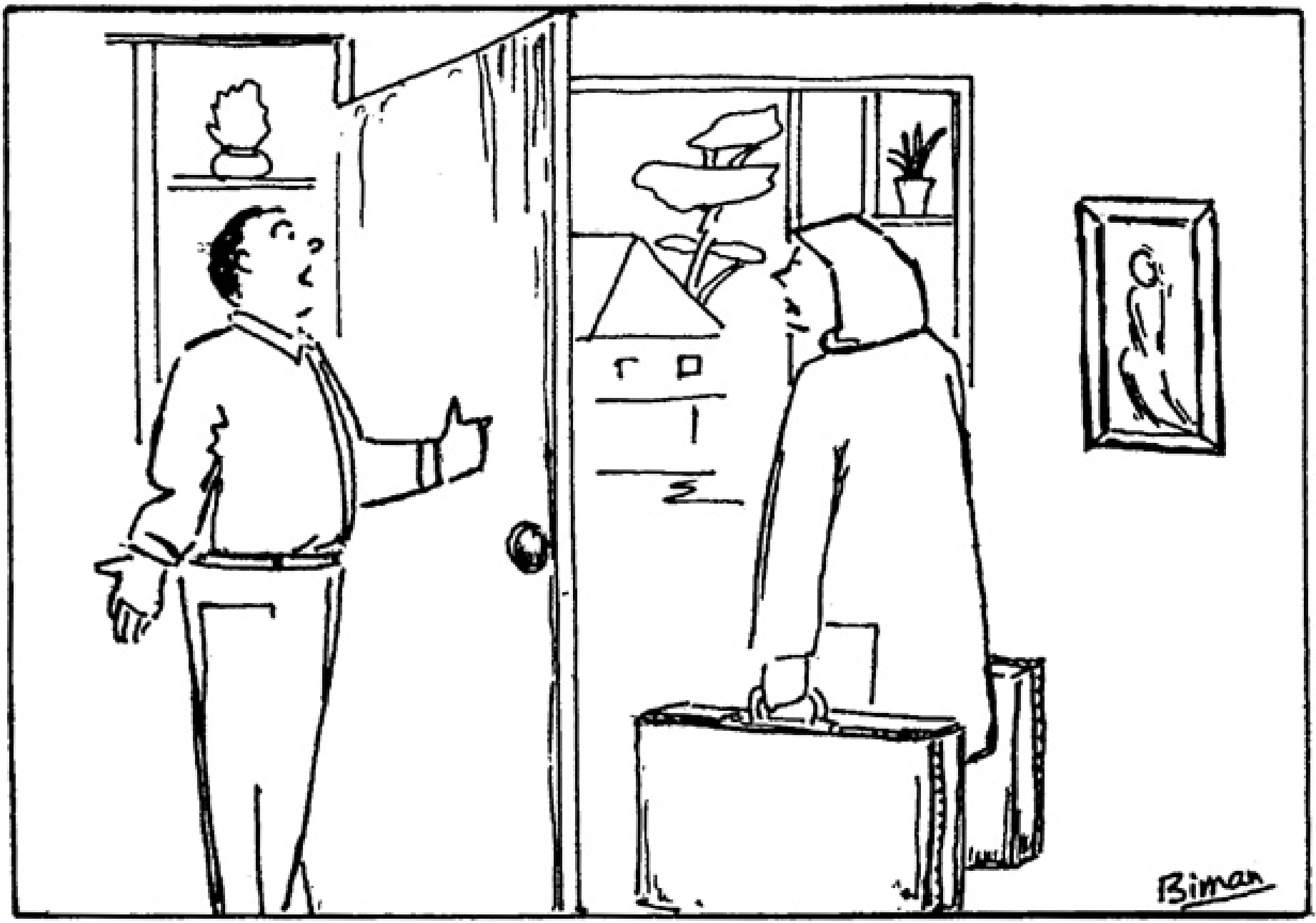

"THE HUBBLE CONSTANT? I WOULDN'T HAVE THOUGHT THAT WOULD EVER COME BETWEEN US!"