

Humans and Cosmology: Tenacious Myths and Epicycles

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COSMOLOGICAL MODELS AND EPICYCLES

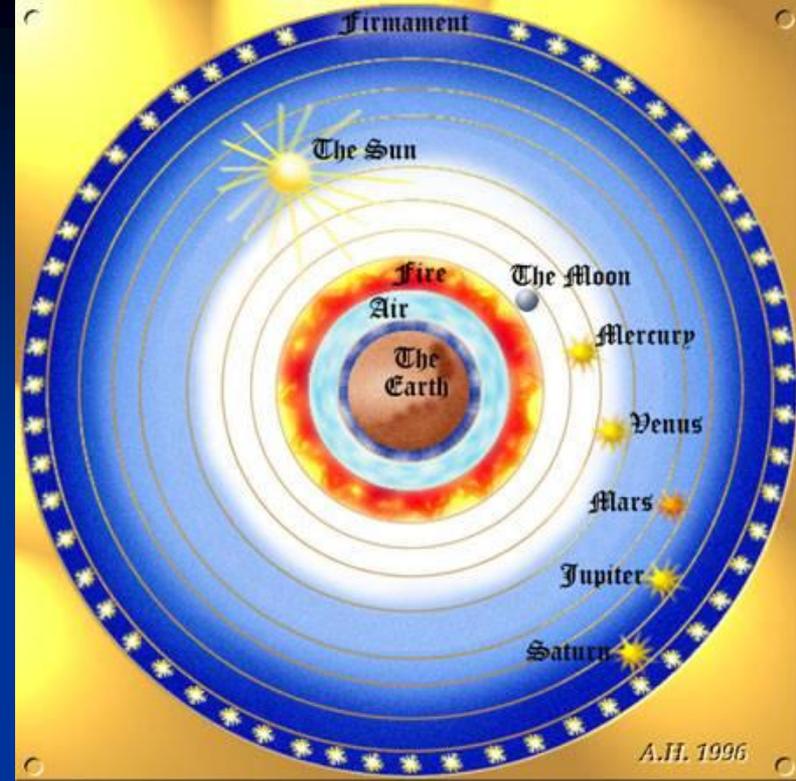
- An epicycle: Any invoked device whose physical nature is completely mysterious and questionable but whose existence is absolutely required to preserve the model. This then provides a useful operational framework, but not necessarily a correct physical framework
- Deus ex machina.



Once Upon a Time

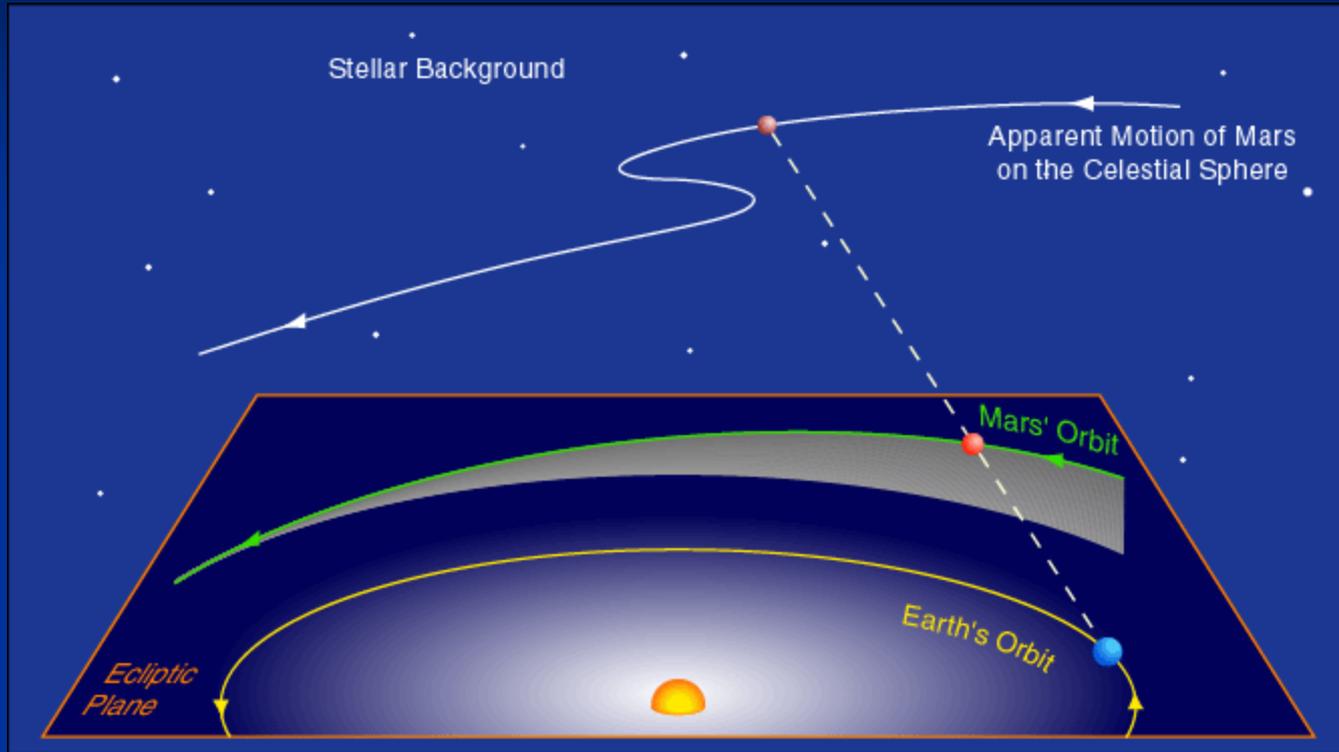
We were **certain** that:

- 1) The Earth was the Center of the Universe (consistent with observations)
- 2) The Earth was motionless **
- 3) All things fell toward the Earth unless they were located in the celestial realm



*** it is manifest to any observer that the [spherical] earth occupies the middle place in the cosmos, and that all weights move toward it"*

A Motion Anomaly*

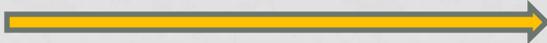


*Not Obeying the Prime Mover → Opps
What to do with an anomaly → Ignore it since its probably bad data

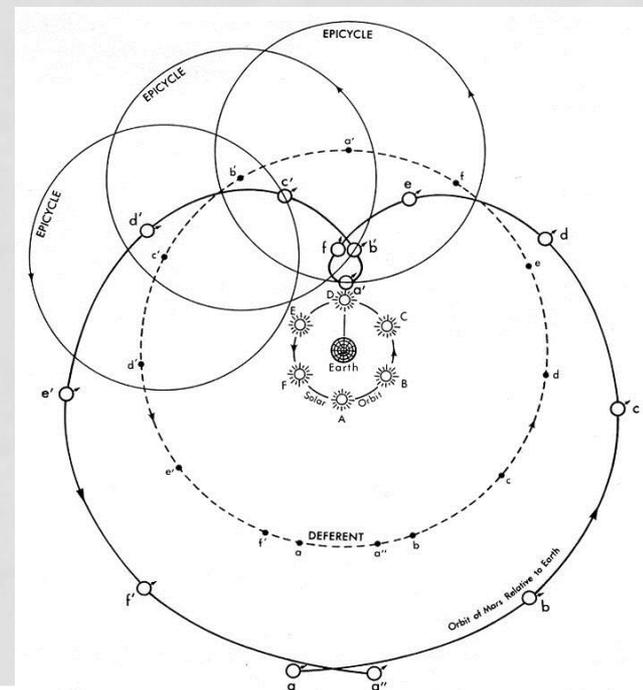
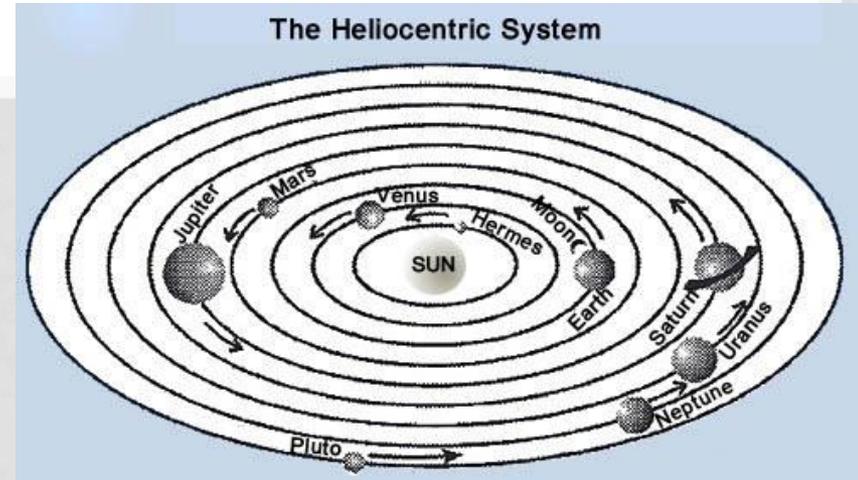
TWO OTHER CHOICES:

- Make a New Model
Aristarchus of Samos (~270 BC)

Nah – Earth Can't Move ...

**Now This is Clever and the Earth
doesn't move:** 

Must be the right Cosmology



Epicycles Operationally Work for Calendars

- But there is speculation on moving Earth ...
- **Oreseme ~ 1350 on Relative Motion:** *One cannot demonstrate by any experience whatever that the heavens move with diurnal motion; whatever the fact may be, assuming that the heavens move and the earth does not or that the earth moves and the heavens do not, to an eye in the heavens which could see the earth clearly it would appear to move; if the eye were on the earth, the heavens would appear to move'.*

Cusa: Learned Ignorance (1440)

- **Discusses concept of relative motion in detail**
- **The earth, which cannot be the centre, must in some way be in motion; in fact; Just as the earth is not the centre of the world, so the circumference of the world is not the sphere of the fixed stars.**
- **Heliocentrism may (still historically controversial) have been introduced in Islamic science circa 800-1000 AD.**

COPERNICUS -THE EARTH MOVES PRINTING PRESS :FIRST REFEREE REPORTS:

- Anyone who wants to be clever must not let him-self like what others do. He must produce his own product, as this man does, who wishes to turn the whole of astronomy upside down
- To make a show of their cleverness, some people have argued that the earth moves. Even though subtle experts institute many investigations for the sake of exercising their ingenuity, nevertheless public proclamation of absurd opinions is indecent and sets a harmful example. Let us cherish the truth and let us not permit ourselves to be alienated from it by the tricks of those who deem it an intellectual honor to introduce confusion into the arts.
- No one who is in his right mind or who has had the slightest training in the physical sciences will ever believe that the dense and solid earth, with its heaviness simultaneously moves up and down, about its own center and around the sun, while performing a libration (oscillation around an axis)

Then Galileo Messed it all Up by making an instrument



GALILEO DESCRIBES HIS DISCOVERIES TO THE CHURCH

Observations Periscope
1610

20. Jouis. marc H. 12	○ **
30. marc	** ○ *
2. Jouis.	○ ** *
3. marc	○ * *
3. Ho. 5.	* ○ *
7. marc	* ○ **
6. marc	** ○ *
8. marc H. 13.	* * * ○
10. marc.	* * * ○ *
11.	* * ○ *
12. H. 4 week.	* ○ *
13. marc	* ** ○ *
14. Jouis.	* * * ○ *

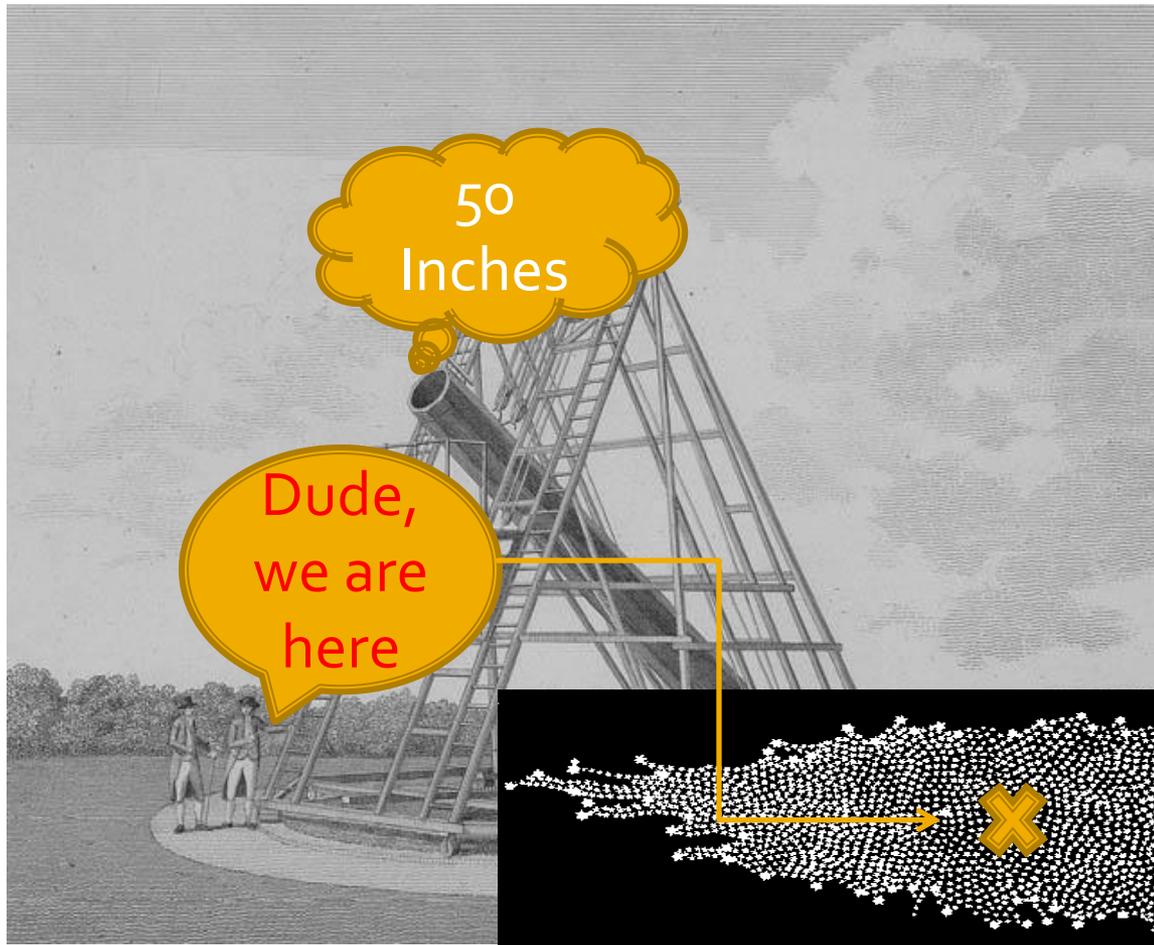
Newton's Dynamical Framework

Explains elliptical orbits therefore getting rid of the Copernican epicycles (compounds of circular orbits)

But, introduces a new (unphysical) requirement (e.g. an epicycle)

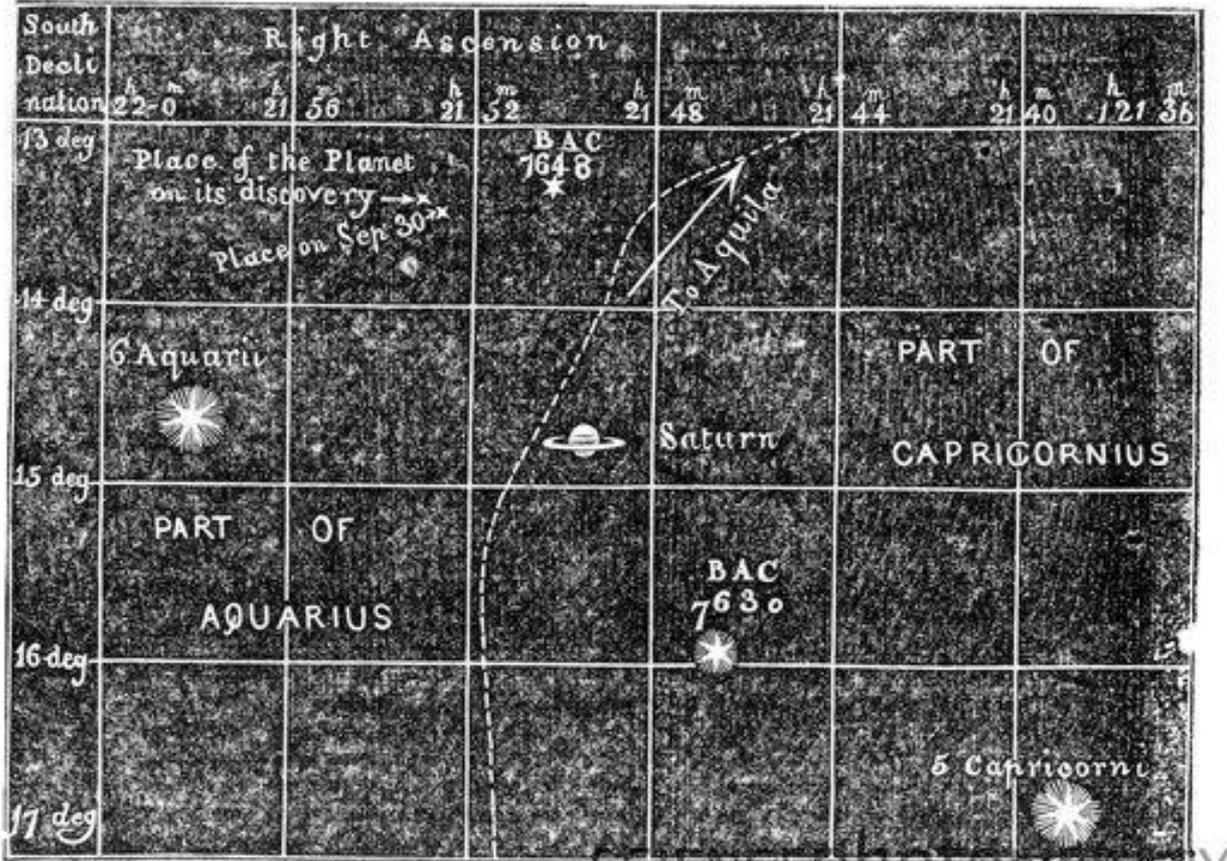
Newton says: It seems to me that if the matter of our sun and planets and all the matter of the Universe were evenly scattered throughout all of the heavens, and every particle had an innate gravity towards all the rest ...some of it would convene into one mass and some into another so as to make an infinite number of great masses, scattered at great distances from one another throughout all that infinite space.

And Herschel Built a Big Alt-Az Instrument; Detected Uranus (1789)



Which revealed
That there was a
lot of stuff in the
actual Universe –
Tho perhaps not
infinite stuff

Oops; 50 Years of orbital data: Uranus Motion Anomaly



Is it Dark Matter?



1859: Now Mercury is not Moving a la Newton

No Available Unseen Object → Newton is wrong?



Einstein's Epicycle

- $P = -\rho c^2$
- Huh? ρ Can't be negative!
- $-P = \rho c^2$
- Yeah, that's better, negative pressure – no problem
- Universe is precisely balanced
- Now we have three cosmological characters

Explicitly the stress energy tensor for a fluid in its rest frame is

$$T_{\mu\nu} = \begin{pmatrix} \rho c^2 & 0 & 0 & 0 \\ 0 & P & 0 & 0 \\ 0 & 0 & P & 0 \\ 0 & 0 & 0 & P \end{pmatrix} \quad (1)$$

After a Lorentz boost in the x -direction at velocity $v = \beta c$ we get

$$\begin{aligned} T'_{\mu\nu} &= \begin{pmatrix} \gamma & \gamma\beta & 0 & 0 \\ \gamma\beta & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \rho c^2 & 0 & 0 & 0 \\ 0 & P & 0 & 0 \\ 0 & 0 & P & 0 \\ 0 & 0 & 0 & P \end{pmatrix} \begin{pmatrix} \gamma & \gamma\beta & 0 & 0 \\ \gamma\beta & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \\ &= \begin{pmatrix} \gamma^2 \rho c^2 + \gamma^2 \beta^2 P & \gamma^2 \beta (\rho c^2 + P) & 0 & 0 \\ \gamma^2 \beta (\rho c^2 + P) & \gamma^2 \beta^2 \rho c^2 + \gamma^2 P & 0 & 0 \\ 0 & 0 & P & 0 \\ 0 & 0 & 0 & P \end{pmatrix} \quad (2) \end{aligned}$$

While it is definitely funny to have $\rho_{vac} \neq 0$, it would be even funnier if the stress-energy tensor of the vacuum was different in different inertial frames. So we require that $T'_{\mu\nu} = T_{\mu\nu}$. The tx component gives an equation

$$\gamma^2 \beta (\rho c^2 + P) = 0 \quad (3)$$

which requires that $P = -\rho c^2$. The tt and xx components are also invariant because $\gamma^2(1 - \beta^2) = 1$.

Cosmology's Most Wanted



Supernova Say I
am Real ???



But What Am I?



Ω_{Λ}

cosmological constant
energy of the vacuum
He never clumps
His evil plan is to
blow up the Universe

Ω_{CDM}

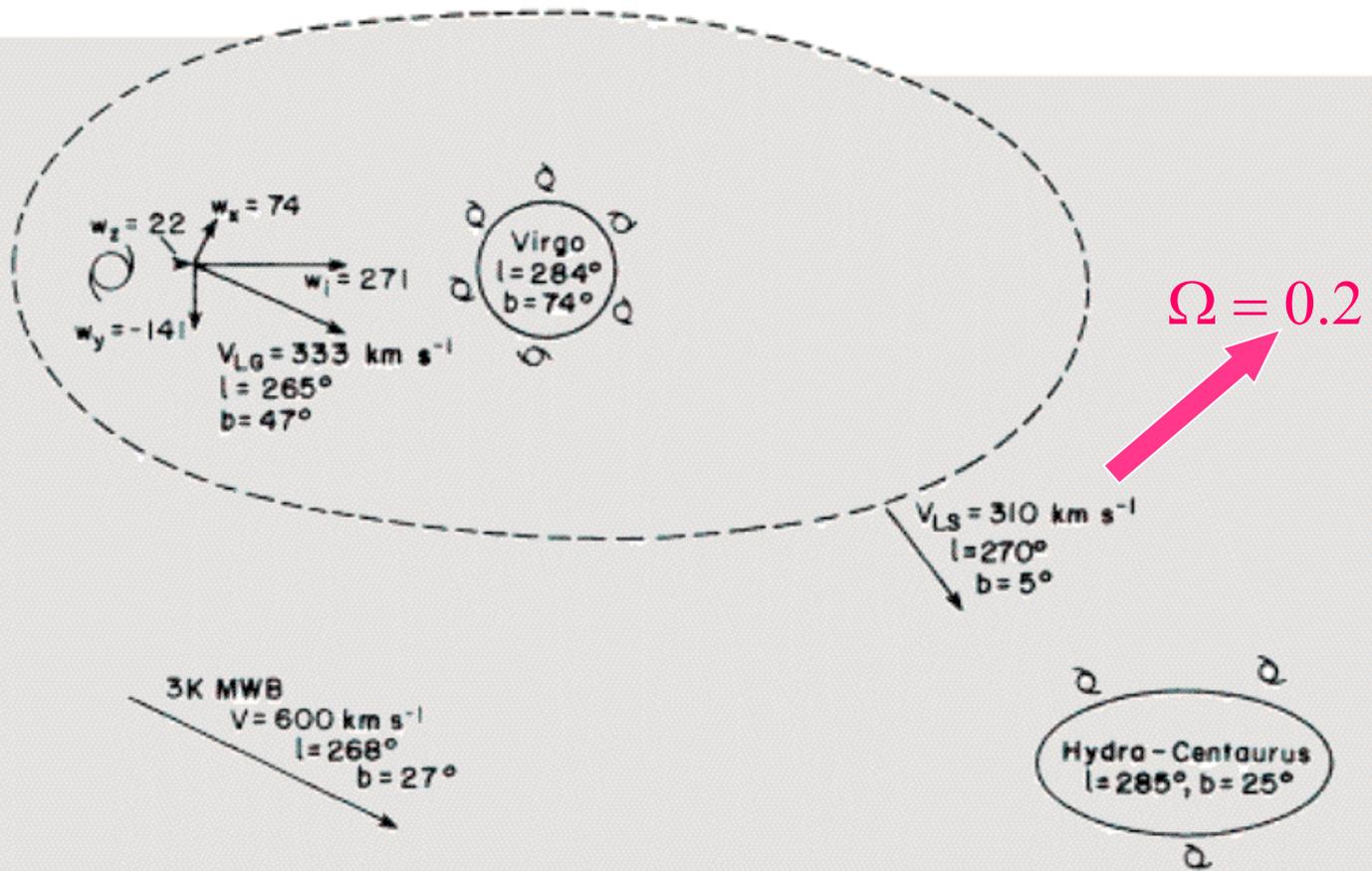
cold dark matter
He likes to clump but
has never been detected
directly
His evil plan is to make
the Universe collapse

Ω_{b}

normal baryonic matter
a pawn in the cosmic
game who just follows
CDM around. He thinks
he's a complex life form
but is really just a bunch
of hydrogen

1980: The New Aristotelian Cosmology: Inflation Epicycle → fixes horizon problem

- Requires the Universe to be “flat” and therefore sets the large scale energy density; $\Omega=1$
- By 1980 it is known that the “material” visible in the Universe provides only $\Omega = 0.005$
- Since we know the “answer” we now require a Dark Matter Dominated Universe
- And this is now the “Truth”; $\Omega_b = 0.005$;
 $\Omega_{dm} = .995 \rightarrow$ Lasts for 25 years



FAITH VS. SCIENCE

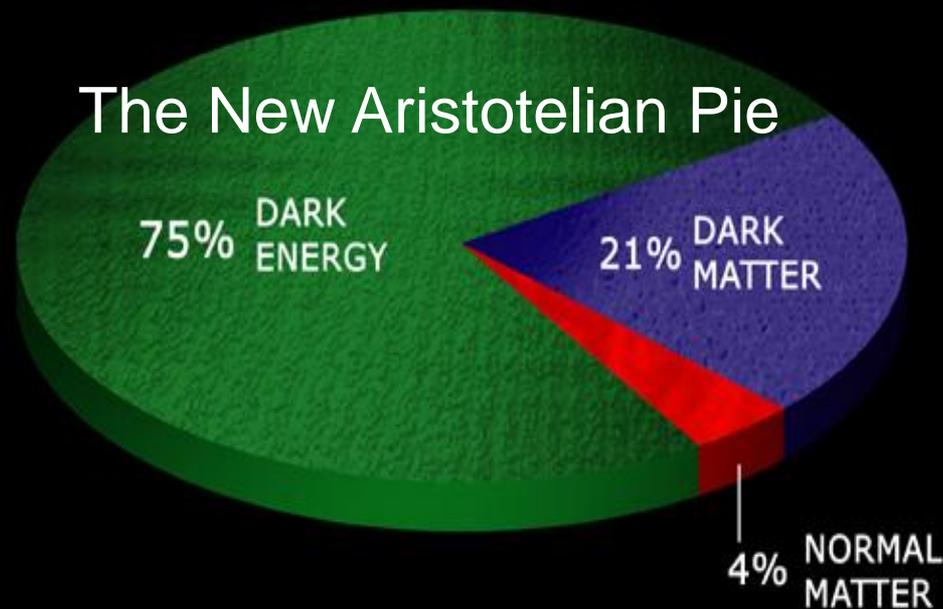
Observations Don't Matter

$$\Omega = 1$$

The Universe is Dark Matter
Dominated

END OF STORY

The New Improved Cosmology (How long will this one last?)



1. Where did all the DM go?
(It went to the value the observers said it was!)
2. How come there are 8 times more Baryons than there were in 1980?
3. Most of the Universe is currently unobtainable knowledge – Aristotle is unhappy

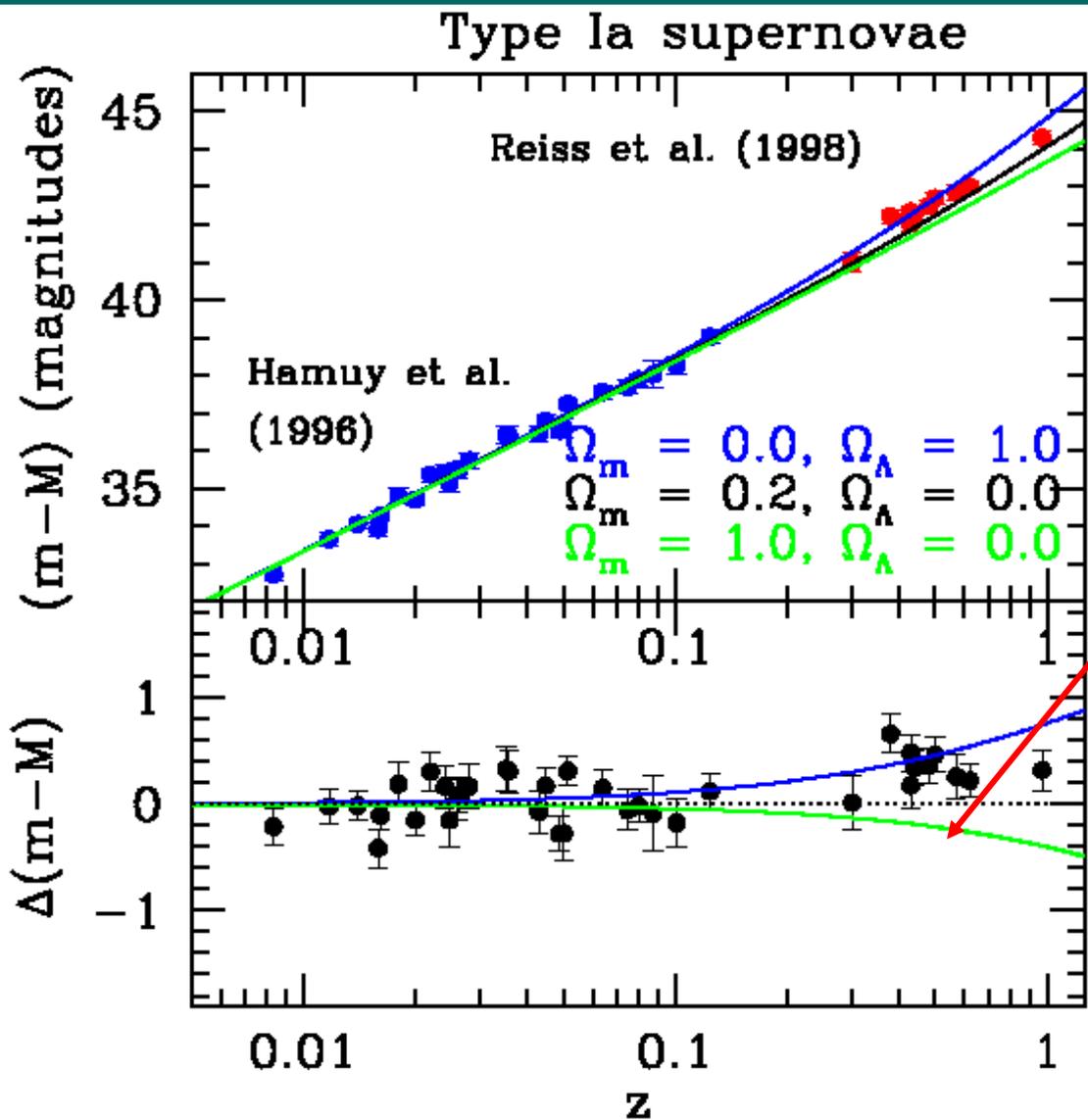
Age of Universe = 13.5 Gyr

SN Ia as observational support for the New Aristotelian Pie; no evolution in explosion physics; all host environments are the same.



At larger distances, the host galaxy is difficult to detect, but the SN is visible (so how do you subtract out the underlying galaxy light?)

SN Cosmological Signal



Data clearly show that the Green 1985 Truth is ruled out – but you have to reach large distances to show this

→ THE TRUTH

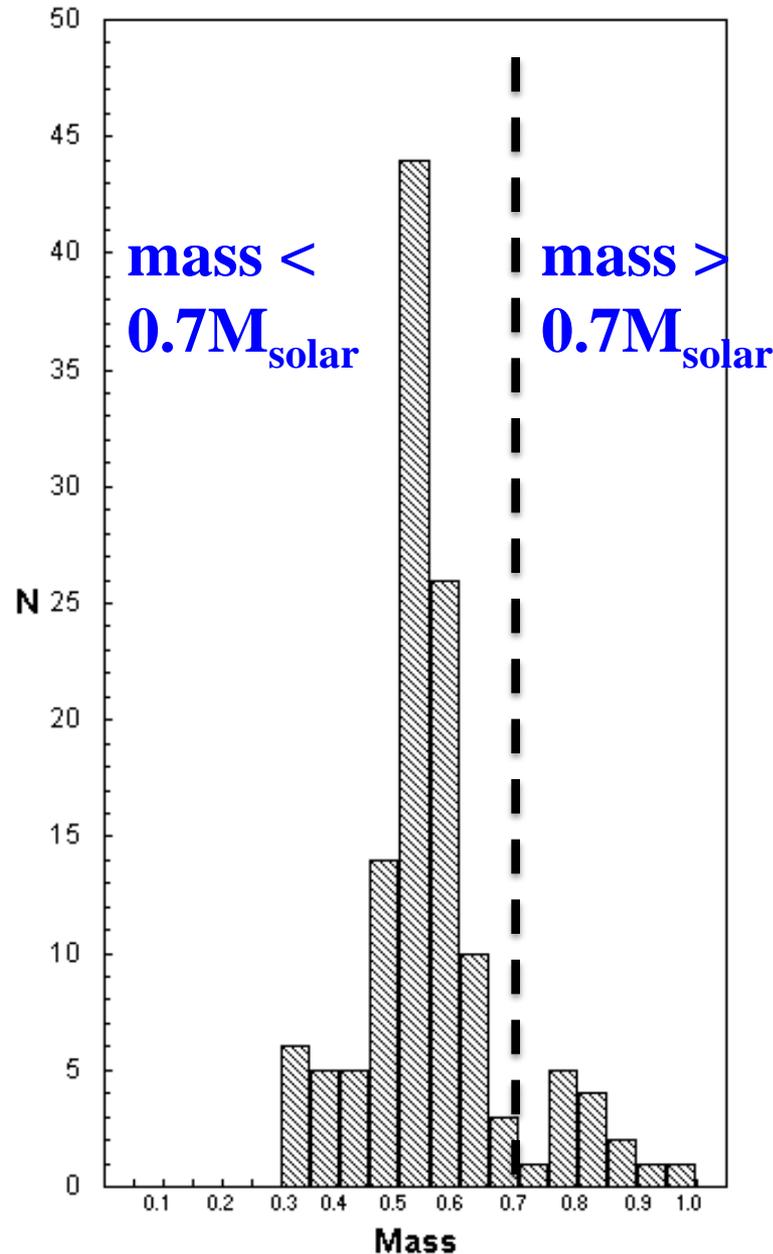
Data do not adequately discern between Blue and Black models; Inflation does → still 2011 Nobel Prize for this graph

SN Ia Systematics?

- Explosions not fully understood
 - many possible models
 - Chandrasekhar-mass models
 - deflagrations vs. detonations
 - Progenitor systems not known
 - white dwarfs yes, but ...
 - double degenerate vs. single degenerate binaries
- Evolution very difficult to control

White Dwarf Mass Function

1. If 0.7 ± 0.7 needed for SNIa then rate is strongly determined by the tail
1. If sub-mass SN occurs via WD-WD merger then Ia rate can be much higher
2. Is the WDMF a universal?



According to the WDMF distribution we should be seeing many more underluminous events in nearby Universe

Nature of the Dark Energy?

- Currently four viable proposals:
 - Einstein: cosmological constant $\omega = -1 = \frac{p}{\rho c^2}$
 - Plato: quintessence
 - decaying particle field (the ether)
 - signature: $\omega \neq -1$
 - Bologno: phantom energy $w < -1 \rightarrow$ leads to the Big Rip (good for media hype)
 - Large scale anti-gravity: leaking of gravity into a higher dimension; graviton flux not conserved

Summary

- In the historical context – no cosmology should be viewed as correct or free from epicycles
- Dark Matter Epicycle: no physically verified objects (despite 30 years of searching)
- Dark Energy: Pick your favorite explanation.
- **empty space exponentially creates more empty space (Lucretius is laughing)**
- New Paradigm: GR not complete; in some environments the inertial mass is not the same as the gravitational mass → space time is more complicated than we think and we need more than 10,000 years of thinking about it.