

GALILEO GALILEI



1564-1642

Part I: His Life to Padua and What He Would Have Known

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Michigan State University

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WHO AM I?

<https://web.pa.msu.edu/people/brock/>

WHAT'S GOING TO HAPPEN

The goal: understand the origins of Galileo's kinematics and his astronomy

My approach is that we need



worth of Plato and Aristotle

TO RALLY BEHIND

TO FIGHT AGAINST

WHAT'S NOT IN VOGUE IN HISTORICAL PRACTICE

many hate the "great man"
But: in the history of science

I understand it perfectly



Ernie Banks

Joe Torre

Hank Aaron

most of us

Roberto Clemente

Willy Mays

July 13, 1965 MLB All Star Game: 19/500 future Hall of Fame

BIOGRAPHY AND HIS EDUCATION

2 February

KINEMATICS, ASTRONOMY, AND THAT TRIAL

9 February?

HIS CV:

early education: Pisa

professor of mathematics: Pisa...until 30 years old

professor of mathematics: Padua...until 48 years old

*Chief Mathematician of the University of Pisa and Philosopher
and Mathematician to the Grand Duke of Tuscany*

prisoner in his own home...9 years, beginning 1633

died in 1642 at 78 years old

MY PLAN:

50,000 feet view of his early life

what he knew

Pisa

Padua

Florence

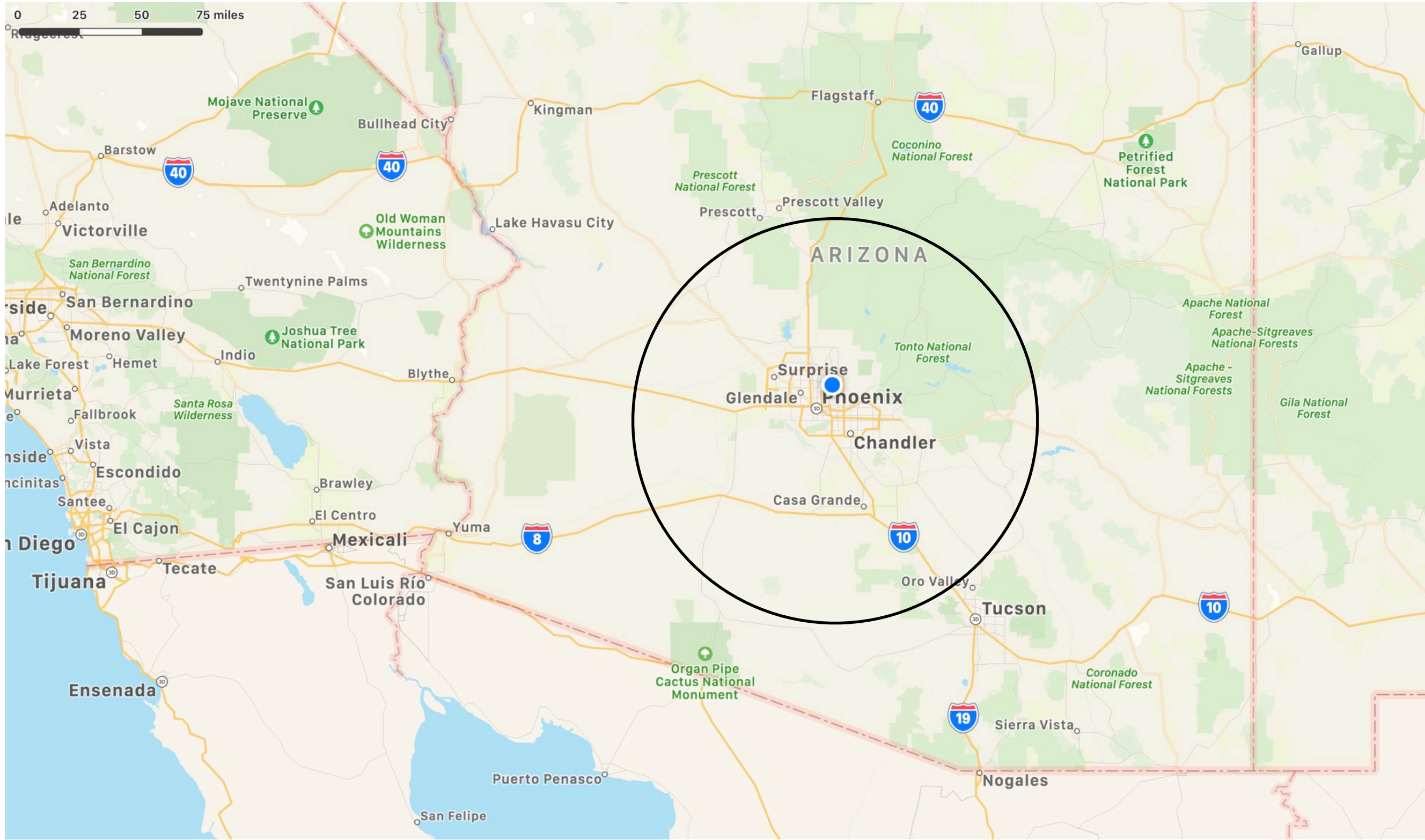
trouble

Galileo was born at a very early age.



← ~150 miles →

0 25 50 75 miles



ARIZONA

Surprise
Glendale
Phoenix
Chandler

Victorville

San Bernardino

Moreno Valley

Escondido

San Diego

Tijuana

Ensenada

Mexicali

San Luis Río Colorado

Puerto Penasco

San Felipe

Kingman

Bullhead City

Lake Havasu City

Old Woman Mountains Wilderness

Joshua Tree National Park

Brawley

El Centro

Yuma

Organ Pipe Cactus National Monument

Flagstaff

Prescott

Prescott Valley

Oro Valley
Tucson

Sierra Vista

Nogales

40

40

40

8

10

10

19

Petrified Forest National Park

Apache National Forest

Apache-Sitgreaves National Forests

Apache-Sitgreaves National Forests

Gila National Forest

Coconino National Forest

Prescott National Forest

Tonto National Forest

Coronado National Forest

Mojave National Preserve

San Bernardino National Forest

Santa Rosa Wilderness

Coronado National Forest

everything about Galileo is
interesting...even names

ONLY FIRST NAMES-AN ITALIAN THING

Galileo

Leonardo, Michelangelo, Dante, Raphael, GaGa

AH...BUT TWO FIRST NAMES?

Galileo Galilei?

FAMILY MATTERS

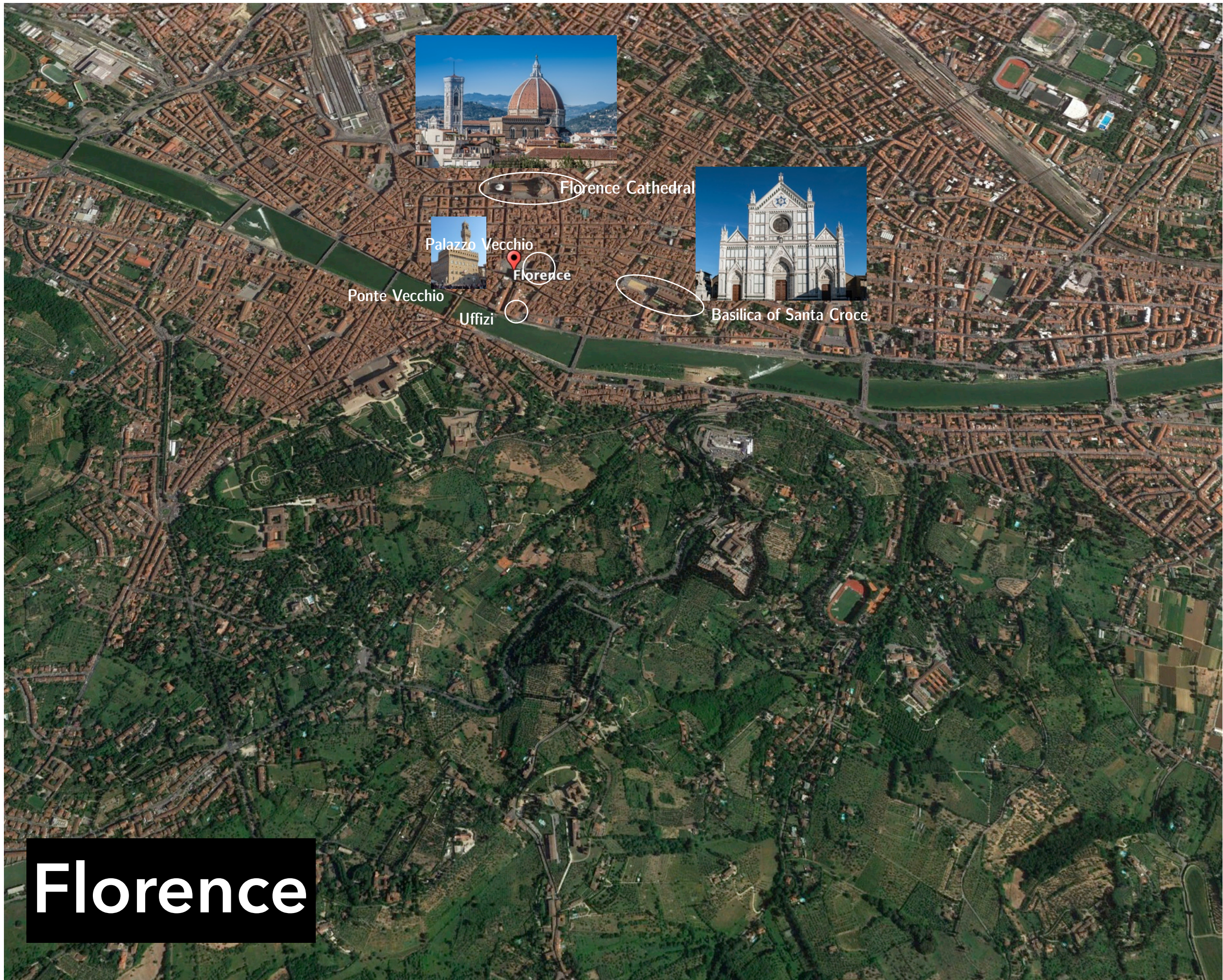
Family name: Bonaiuti

Our Galileo's great-grandfather's brother, Galileo Bonaiuti:

famous physician and University of Florence professor...

one of the two elected councils of the Republic of Florence





Florence Cathedral



Palazzo Vecchio

Florence



Basilica of Santa Croce

Ponte Vecchio

Uffizi

Florence



TEMPORIBVS · HIC · SVIS · PHYLOSOPYE ·
ATQ3 · MEDICINE · CVLMEN · FVIT · ET · MAGIST ·
GALILEVS · DEGALILEIS · OLIM · BONAVTIS · C



Santa Maria Novella



Florence Cathedral



Palazzo Vecchio

Florence



Basilica of Santa Croce

Ponte Vecchio

Uffizi



1629 - 1634

childhood and young-adult

Florence

1633 - 1641



OUR CONCERNS:

- 1590?: *De motu*
- 1610: *Sidereus Nuncius "Starry Messenger"*
...telescopic observations
- 1613: *Letters on Sunspots*
more telescopic adventures
- 1615: *Letter to the Grand Duchess*
open letter on truth designed to irritate
- 1623: *The Assayer*
almost no physics, but his philosophy of science and full war with the Jesuits
- 1625-1632: *Dialogue Concerning the Two Chief Systems*
the big conflict...resulting in house arrest in 1633
- 1638: *Discourses on Two New Sciences*
strengths of materials and kinematics
- 
- > 40 years

Early Life



Padua

Venice

Florence

Pisa

Rome

1,000 feet

Pisa



Cathedral of Pisa



University of Pisa



Galileo Birth home
Via Giuseppe Giusti 24
(Ammannati House)



Palazzo dei Medici
Lungarno Mediceo 8

PISAN

But not self-identified as such: "nobile Fiorentino"

b: 15 February 1564 (d: 1642)

Father: Vincenzo Galilei (1520-1591)

lutenist, composer, and musical theorist of some repute

clung to Florentine noble roots

Mother: Giulia Ammannati (Pisan)

dowry of linen and woollen cloth...her family's business

impoverished

1 brother (Vincenzo - professional lutenist)

at least 2 sisters: dowries

"\$"

Dad:

Della musica antica et della moderna,



Vincenzo Galilei

exponent of monody - some claim to inventing opera

public fight with his own teacher



"It appears to me that they who in proof of anything
rely simply on the weight of authority, without adducing
any argument in support of it, act very absurdly."

Vincenzo Galilei

EDUCATION

oscillated

standard humanist education: Latin, Greek, Aristotelian logic

close call as novice @ monastery Vallombrosa

later as teacher there: "sfrattato"

Vincenzio focused on a medical education for G



UNIVERSITY OF PISA

matriculated 1581 @ 17

as a medical student

EDUCATION: NOT A STRAIGHT PATH

Dad: medicine (remember who he's named after)

G: 1581, sure. University of Pisa

mathematics essential for medicine

1583, fell into a group learning Euclid from Ostilio Ricci, Court Mathematician to the Grand Duke Francesco in Florence

stopped attending classes

Dad: say what??

Talked to his friend, Ricci...

Dad: okay.

G: thanks. Home in 1581 to study mathematics openly
and brilliantly



what he would have known

Greek ideas...filtered

CAN'T LIVE WITH 'EM, CAN'T LIVE WITHOUT THEM

Bert and Ernie

Mantle and Maris

Venus and Serena

Kirk and Spock

Abbott and Costello

Bogart and Bacall

Tinker and Chance

Hope and Crosby

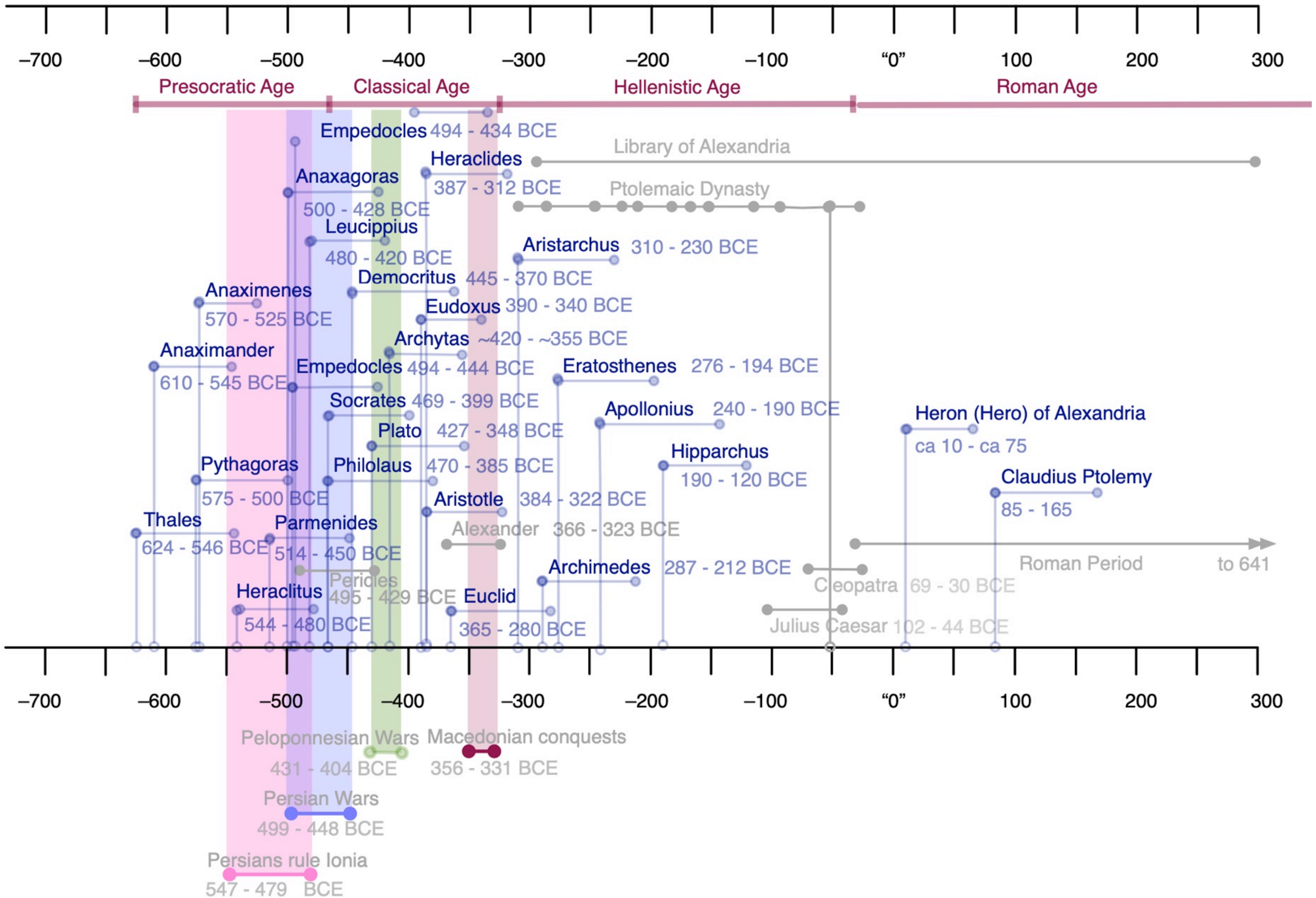
Plato and Aristotle

PLATO AND ARISTOTLE

factually
said nothing about physics that **was** correct
responsible for 1.5 millennia of problems
gotta consider Plato and his student, Aristotle.

ARISTOCKES (427-347BC)
Aka Plato





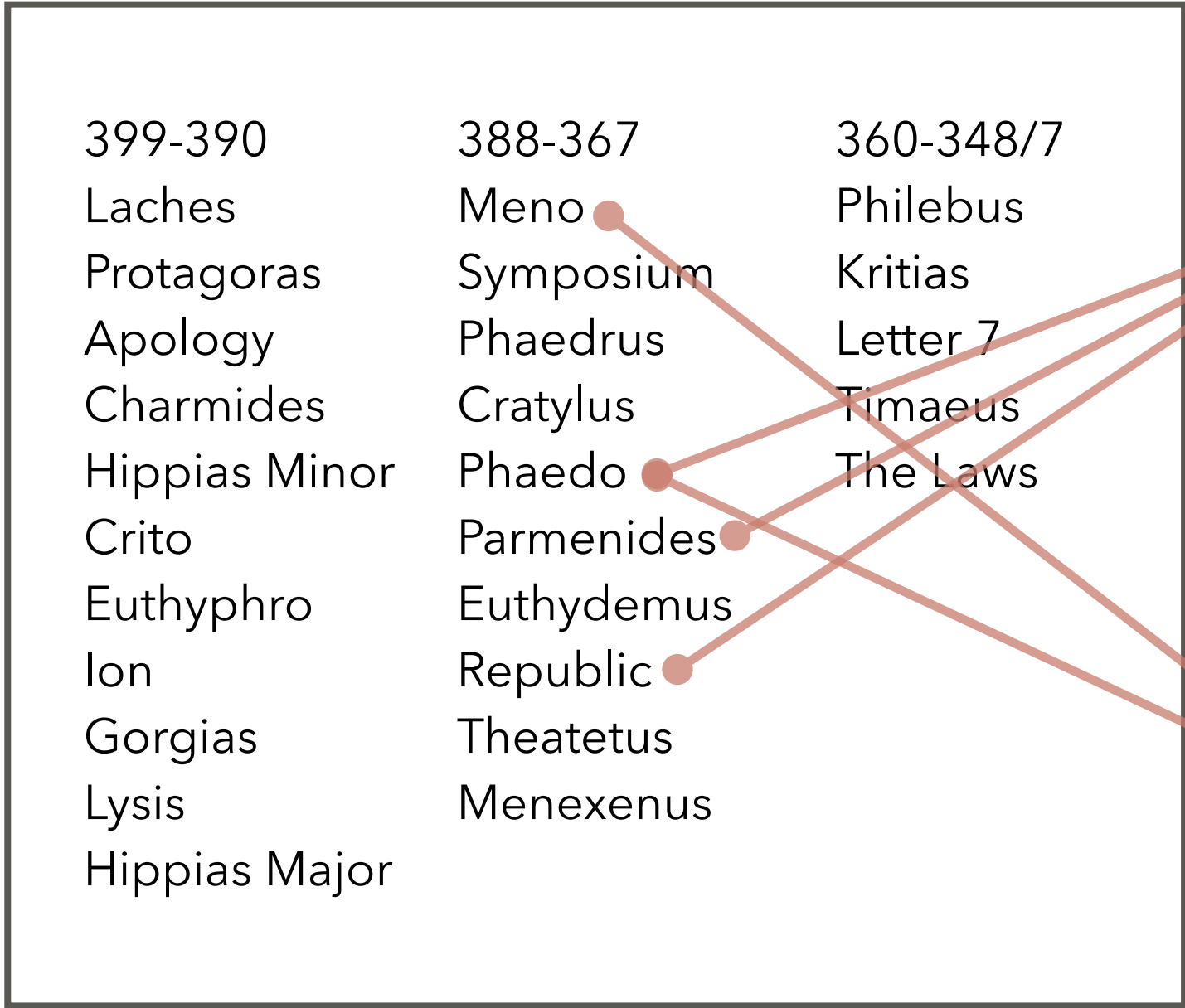
RESEARCH PROJECT:

what does it mean to know something:

“Epistemology”

what is the nature of reality:

“Metaphysics”



the forms

epistemology

MANY WORKS

for Physics, 2 primary dialogs:

The Republic

Parts of Books V-VII, what's real, intro to forms

The Timaeus

sequel to Republic

(one of the few to make it survive directly into the middle ages)

WHAT'S TRUE KNOWLEDGE?

discussed many places in Plato

The Theaetetus...

Theaetetus: Suggests that to have knowledge is to have a true opinion...which can be justified

Socrates: *"Excellent!"*

...then destroys him in his (Plato's) standard way...

SOMETIMES FORMALIZED:
"JUSTIFIED TRUE BELIEF"

1. x is true.
2. We believe that x is true.
3. We are justified in believing that x is true.

where's the rub?

JUSTIFICATION

that's a toughy.

JUSTIFIED TRUE BELIEF

It is 3 o'clock, I believe it's 3 o'clock, because I looked at my watch and see that time displayed. B, T, and J are all in play and this seems a reasonable example of knowledge.

There are holes.

What about instead of that J, how about J2: It is 3 o'clock, I believe it's 3 o'clock, because 3 is my favorite number. I'm right, since it really is 3 o'clock but that justification is silly.

How about J3: It is 3 o'clock, I believe it's 3 o'clock, because I looked at my watch and see that time displayed. But...I didn't know that my watch was broken and had stopped at precisely 3 o'clock.

In fact, it was only in 1963 that Edmund Gettier apparently found counterexamples to JTB which are now called "Gettier Cases."

PLATO CONCLUDES, TRUE KNOWLEDGE

must be of:

eternal things.

permanent, unchanging things.

which are infallible things.

the only Real things.

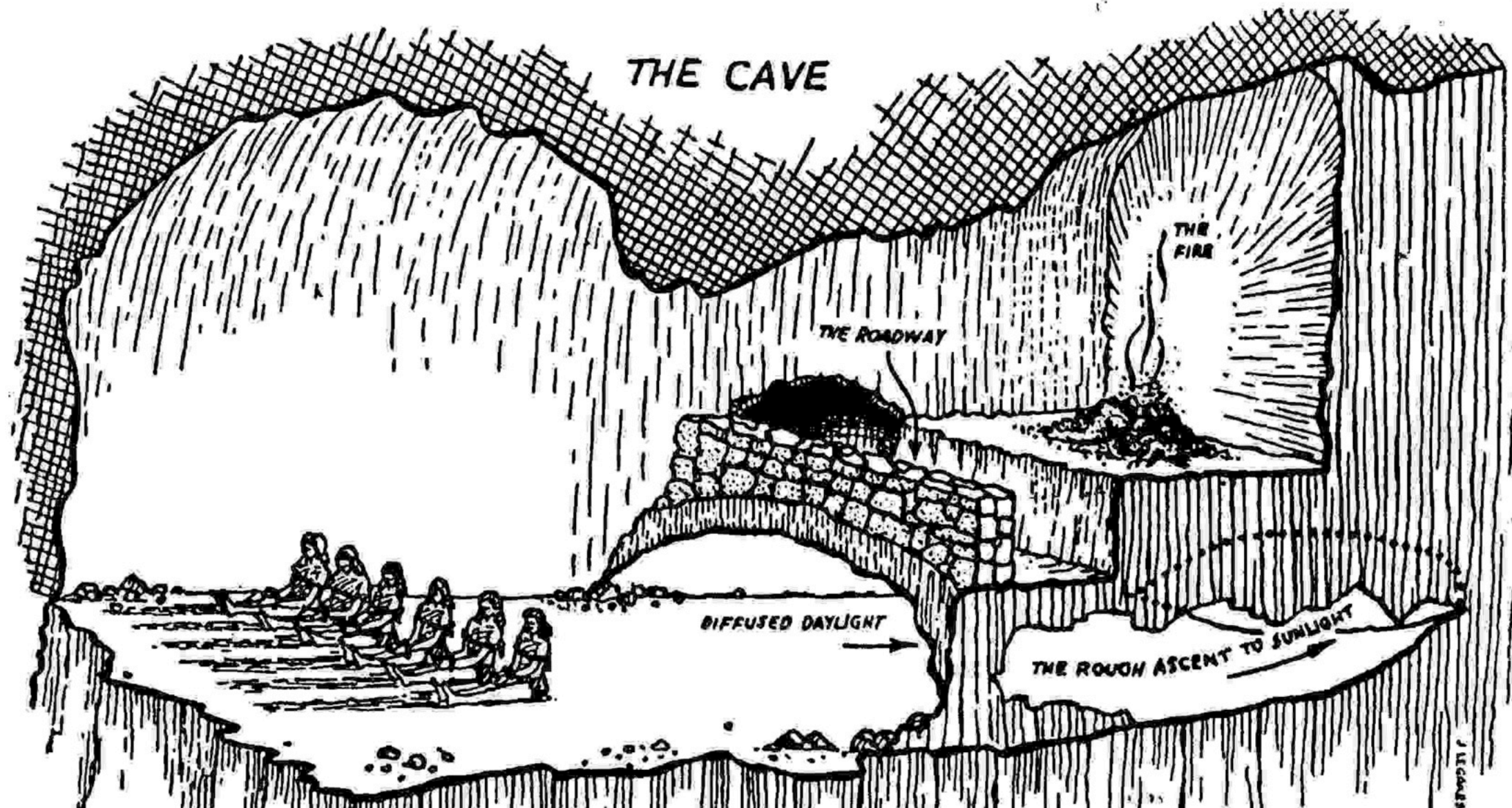
BEING

as opposed to

Becoming

FOLLOWS FROM

discussions in Books V-VII of the Republic
incl. the Allegory of the Cave.



THE PHYSICAL WORLD

the realm of change

assertions based on our (flawed) senses

only opinion possible

& THE REAL WORLD

things never change

a realm outside of Time



WHAT'S IN THAT REAL WORLD?

The "Forms"

a difficult notion

keep this in mind when we discuss Galileo's physics

Forms



Cabriole Sofa
\$899.00
reg. \$1,499.00

Furniture Collection



Plus Armless Sofa
\$999.00

Furniture Collection



Plus Armless Loveseat
\$799.00

Furniture Collection



Huntley Armless Loveseat
\$999.00

Furniture Collection



Axis Armless Loveseat
\$1,099.00

Furniture Collection



Vienna Daybed
\$1,499.00

Furniture Collection



Briarwood Leather Loveseat
\$2,899.00

Furniture Collection



Hennessy Leather Sofa
\$1,999.00

Furniture Collection



Nuevo Leather Sofa
\$2,999.00

Furniture Collection



Club Leather Apartment Sofa
\$2,499.00

Furniture Collection



Troy Sofa
\$1,099.00

Furniture Collection



Stockton Sofa
\$1,199.00
reg. \$1,999.00

Furniture Collection



Oxford Sofa
\$1,299.00

Furniture Collection



Cameron Sofa
\$1,499.00

Furniture Collection



Axis Sofa
\$1,599.00

Furniture Collection



Rochelle Sofa
\$1,699.00

Furniture Collection



Laguna Sofa
\$1,499.00

Furniture Collection



Huntley Sofa
\$1,399.00

Furniture Collection



Petrie Sofa
\$1,499.00

Furniture Collection



Brooke Sofa
\$1,199.00

Furniture Collection

WHAT'S THE FORM?

of a sofa?

an abstract, single entity...the un-particular sofa-ness

the occupants of your living room

"participate" in the Form of the Sofa



MATHEMATICAL OBJECTS

you are aware of "triangleness"

the perfect triangle of which all perceived triangles are copies...they participate in the form of the triangle

GEOMETRY

“Let no one ignorant of Geometry enter”

ABSTRACTION/IDEALIZATION

these guys invented it

Geometry?

only abstract, not practical

as befits the Athenian high-class self-image

So, only abstract/idealized:

Art. Philosophy. Mathematics.

BUT, ALSO: NOTIONS HAVE FORMS

the Forms of:

Justice

Love

the Good

PLATO AND ART?

notsomuch

worse



OBTW

we already know the Forms...

we don't discover them, we remember them

in the *Meno*, Socrates teaches a slave boy

that he already knows a geometrical proof

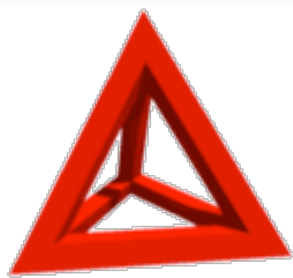
his Doctrine of Reminiscence

Galileo explicitly refers to remembering things

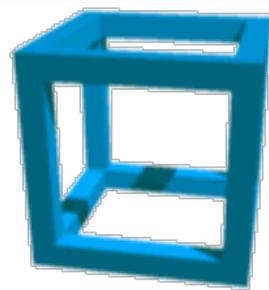
PLATO: MATTER IS GEOMETRICAL

the 5 "Platonic Solids"

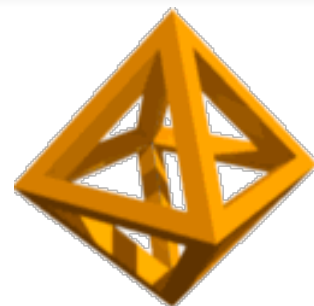
already shown to be all of 3d solid forms



tetrahedron
(4 faces, fire)



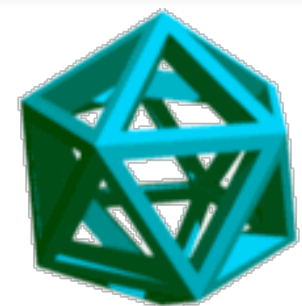
cube
(6, earth)



octahedron
(8, air)



dodecahedron
(12, zodiac)



isocahedron
(20, water)

“PLATONIC”

generally means

belief in the primacy or reality of pure form...mathematics

My discipline of particle physics?

totally Platonic

“

I believe that the numbers and functions of analysis are not the arbitrary product of our spirits: **I believe that they exist outside of us** with the same character of necessity as the objects of objective reality; and **we find or discover them** and study them as do the physicists, chemists, and zoologists.

Charles Hermite, 1822-1901 mathematician



I think that modern physics has definitely decided in favor of Plato. In fact the smallest units of matter are not physical objects in the ordinary sense; they are forms, ideas which can be expressed unambiguously only in mathematical language.

Werner Heisenberg 1901-1976, theoretical physicist

“

The creative principle resides in mathematics. In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed.

Albert Einstein 1879-1955, theoretical physicist

I imagine that whenever the mind perceives a mathematical idea, **it makes contact with Plato's world of mathematical concepts...**
When mathematicians communicate, this is made possible by **each one having a direct route to truth...**

Because...mathematical truths are necessary truths, no actual 'information', in the technical sense, passes to the discoverer. **All the information was there all the time.** It was just a matter of putting things together and 'seeing' the answer! -

“

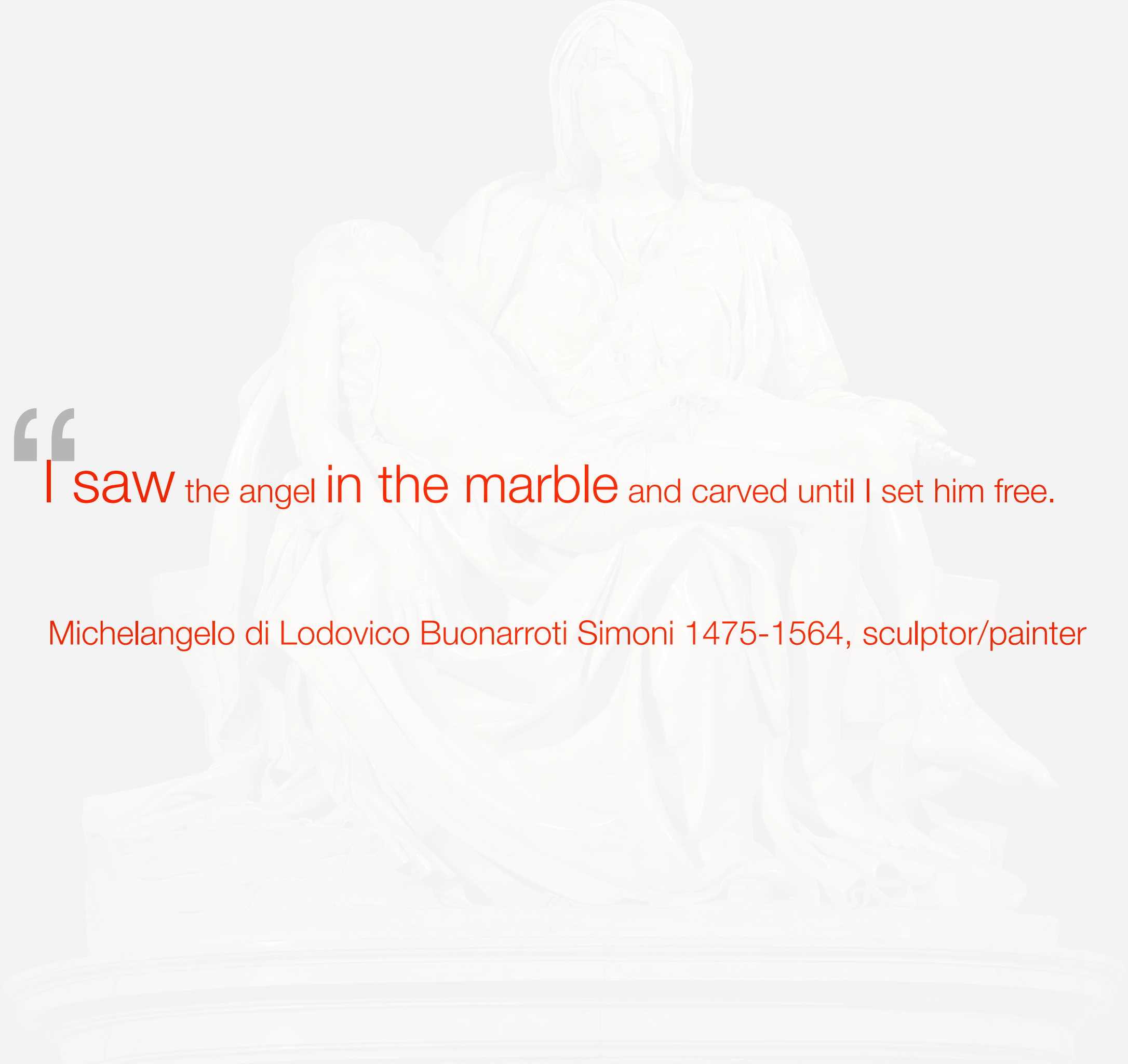
Every good mathematician is at least half a philosopher,
and every good philosopher is at least half a
mathematician.

Gottlieb Frege 1848-1925 mathematician

“

I saw the angel in the marble and carved until I set him free.

Michelangelo di Lodovico Buonarroti Simoni 1475-1564, sculptor/painter



PLATO'S ACADEMY

750 years

PLATO'S IDEAS?

about the physical world:

all wrong

about forms?

the basis of St Augustine's original Catholic dogma
and maybe 21st century physics

about mathematics...

well, you saw

BUT ABOUT THOSE FORMS.

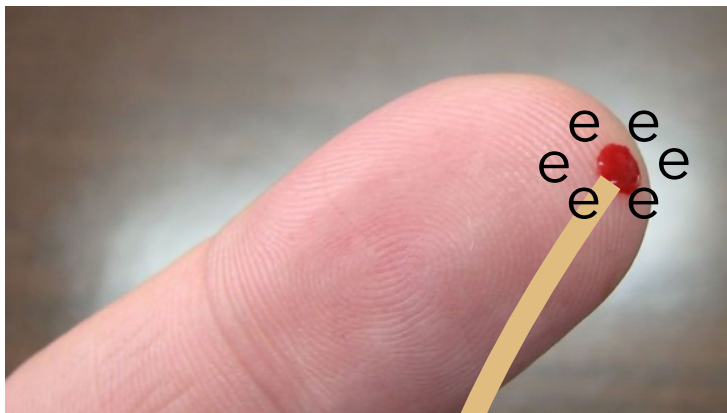
1 molecule of hemoglobin in your blood:

10,000 atoms of H, O, N, Fe

containing electrons, protons, neutrons (quarks)

every e in that drop of blood is identical

every e in that blood is identical to every electron in
gaseous H in the edge of Andromeda



WHAT'S THE FORM OF AN ELECTRON?

actual electrons, themselves

they are their own Platonic forms

we're forced to this by our need to describe reality with Relativistic
Quantum Field Theory

everything is a field.

WANT TO START A FIGHT AT A PARTY WITH
MATHEMATICIANS?

Is mathematics

invented

discovered?

DOES REALITY

include abstract mathematical objects?

“[talk of] mathematical entities is indispensable for science. . . therefore we should accept such talk. . . [which] commits us to accepting the existence of the mathematical entities in question.”

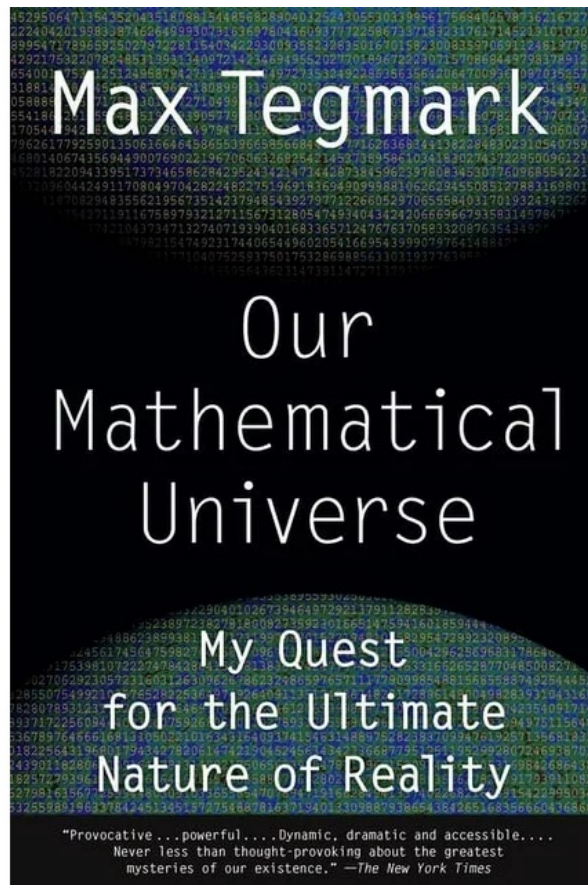
Hilary Putnam

“Quine-Putnam Indispensability Argument”

ψ

TAKE QUANTUM MECHANICS

is the wavefunction real?



Max Tegmark believes that the universe is mathematics.

PLATO'S COSMOLOGY?

naive and metaphysically biased

don't *do* astronomy...*think* about astronomy

armchair astronomy

PLATO'S SINGLE SCIENCE HOMEWORK:

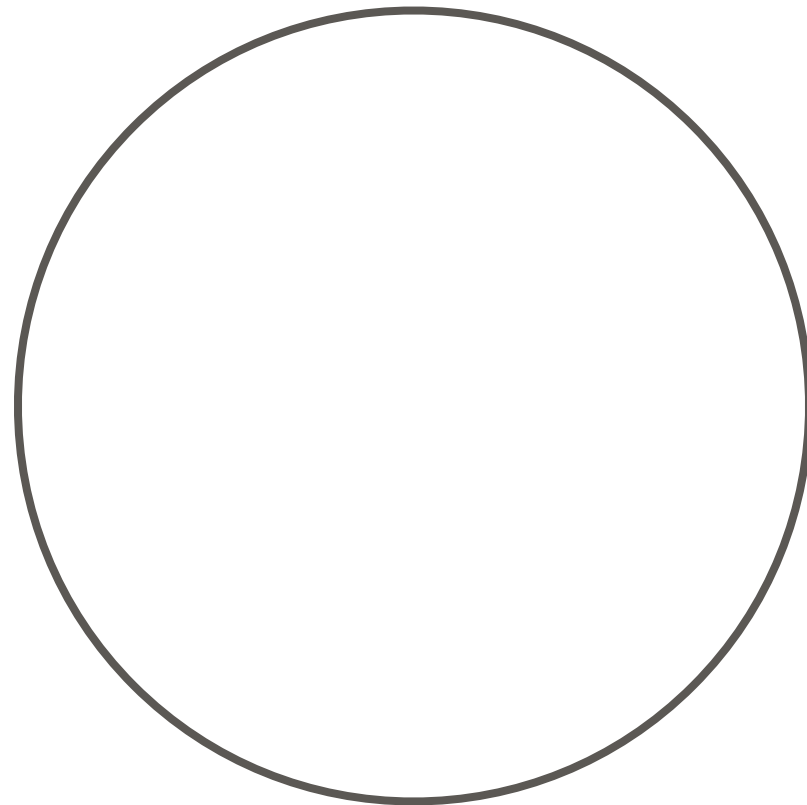
find a model of the planetary motions

which makes predictions and

which Saves the Appearances & fits his Ideal

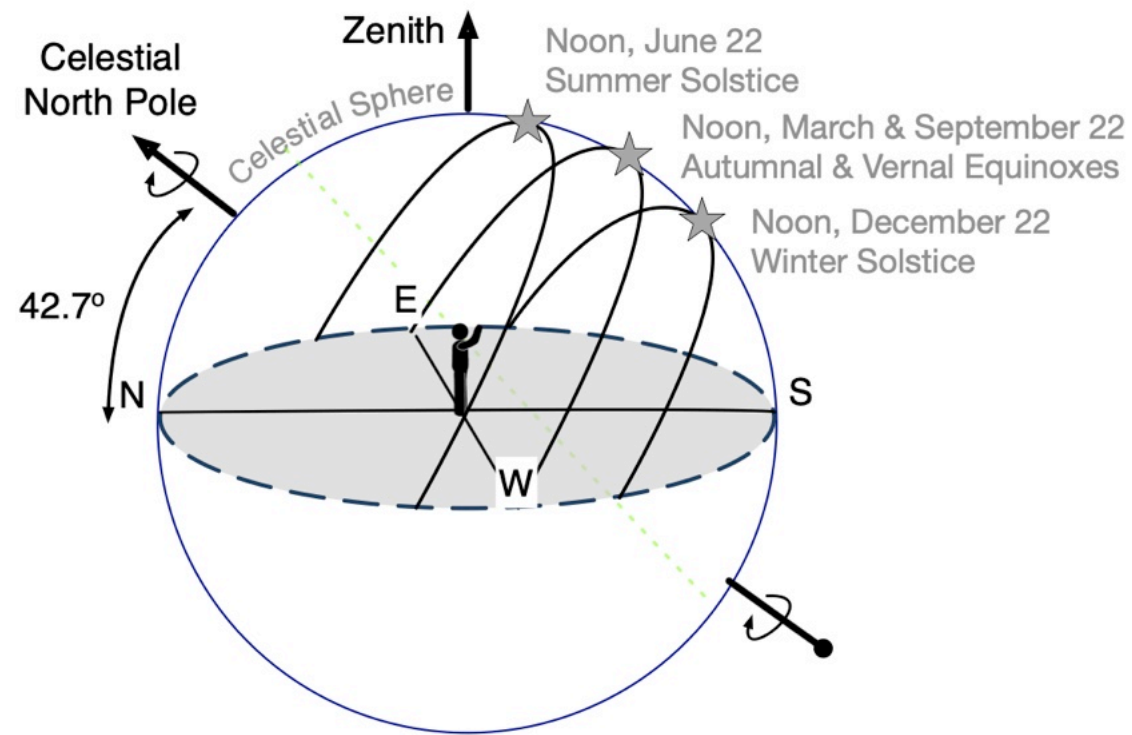
no need for realistic description...just a model that predicts the motions

OF COURSE:



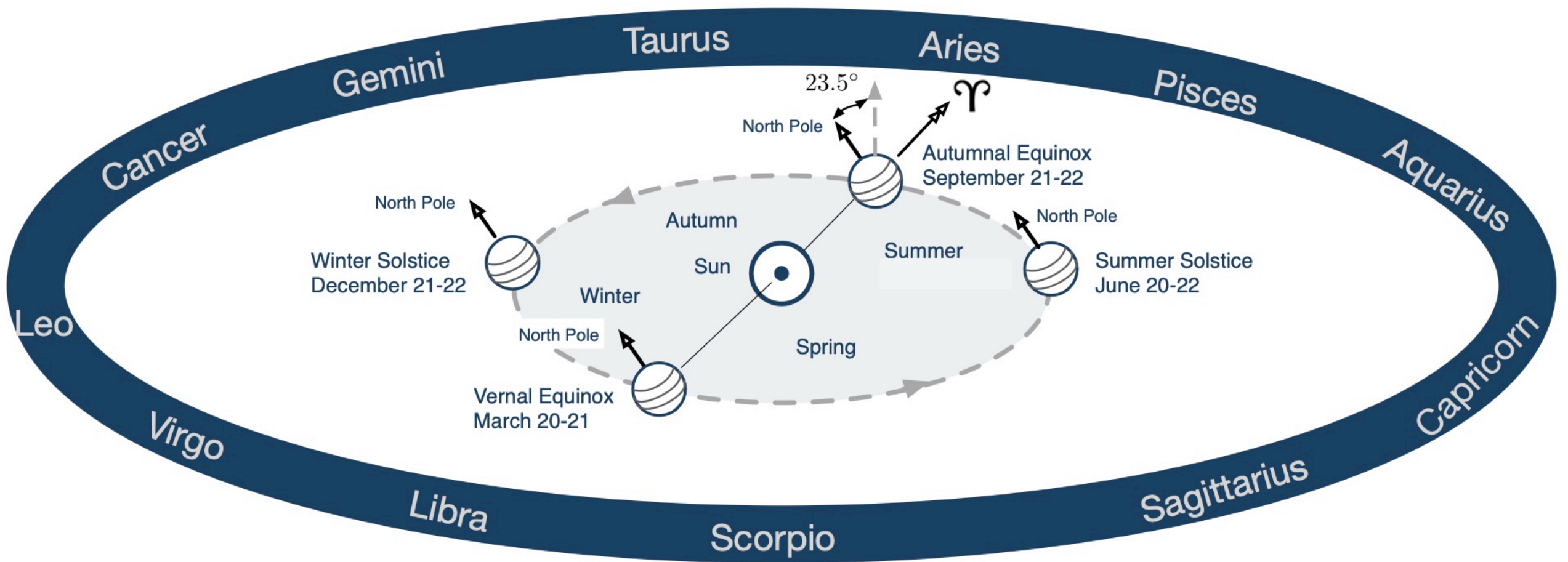
'S

REGULARITIES IN OUR SKY



(a)

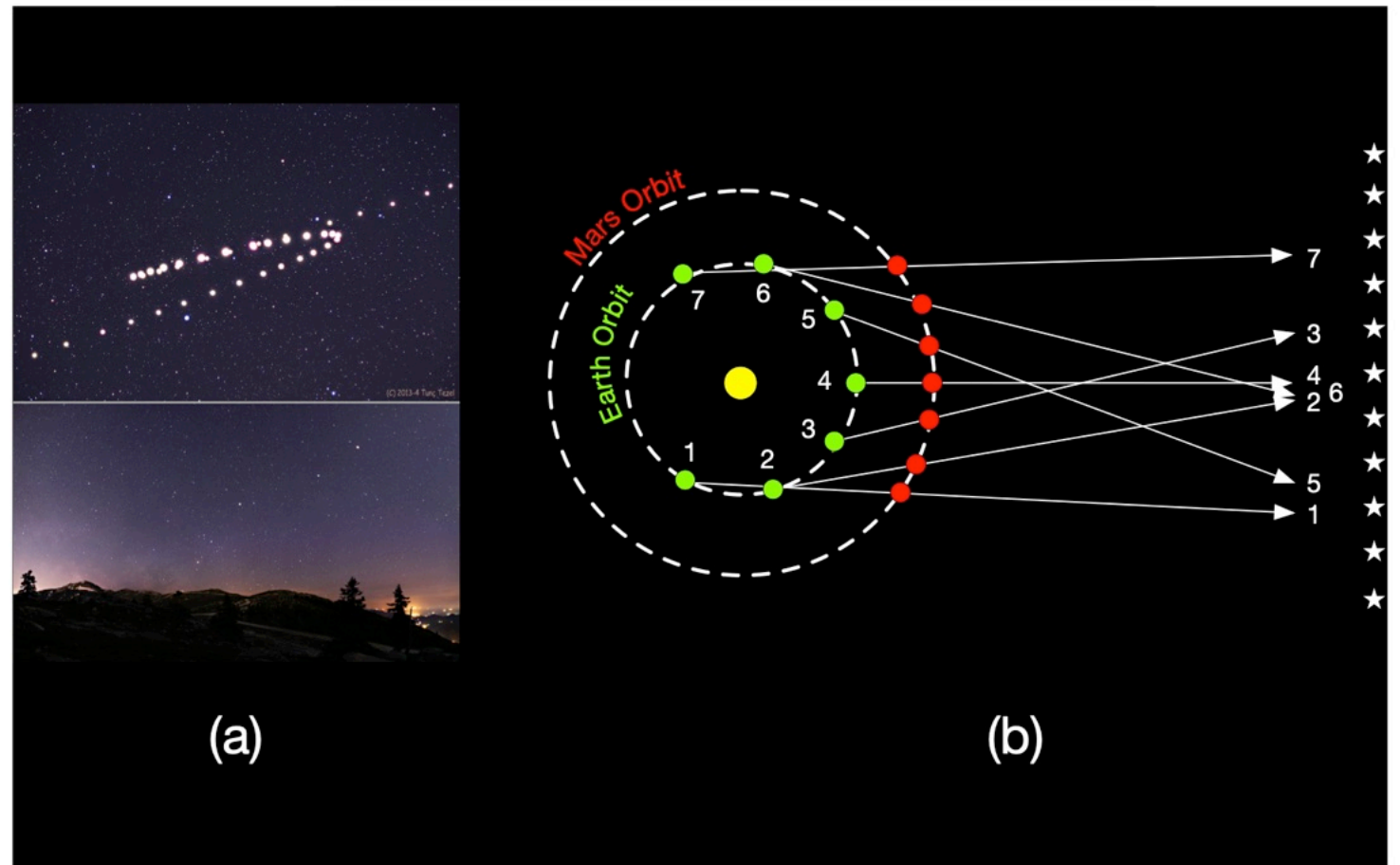
THE REAL STORY



RETROGRADE MOTION...YOU KNOW WHAT'S GOING ON HERE...

Mars, M, and a background star, A

Night #1 EastA.....M.....B West
 Night #2 EastA.....M.....B West
 Night #3 EastA.....M.....B West
 Night #4 EastA...M.....B West
 Night #5 EastA.....M.....B West
 Night #6 EastA.....M.....B West
 Night #7 EastA.....M...B West
 Night #8 EastA.....M.....B West
 Night #9 EastA.....M.....B West
 Night #10 EastA.....M.....B West
 Night #11 EastA.....M.....B West
 Night #12 EastA.....M.....B West
 Night #13 EastA...M.....B West



(a)

(b)

PLATO KNEW THESE THINGS

that the planets and sun moved within the ecliptic

that the planets (not not the Moon nor the Sun) exhibited
retrograde motion

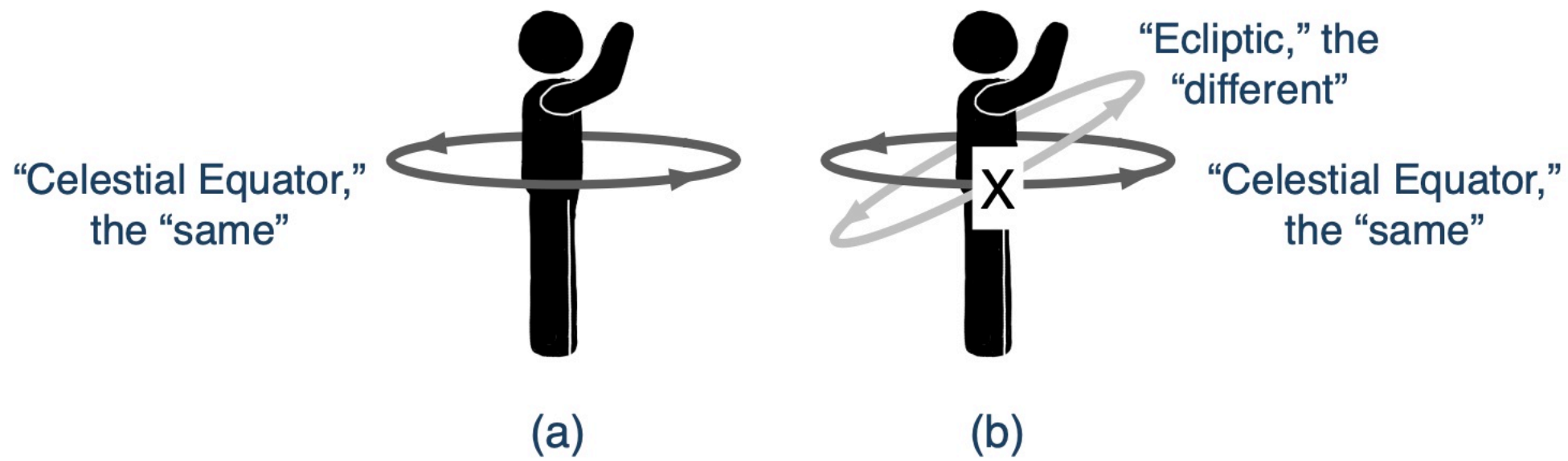
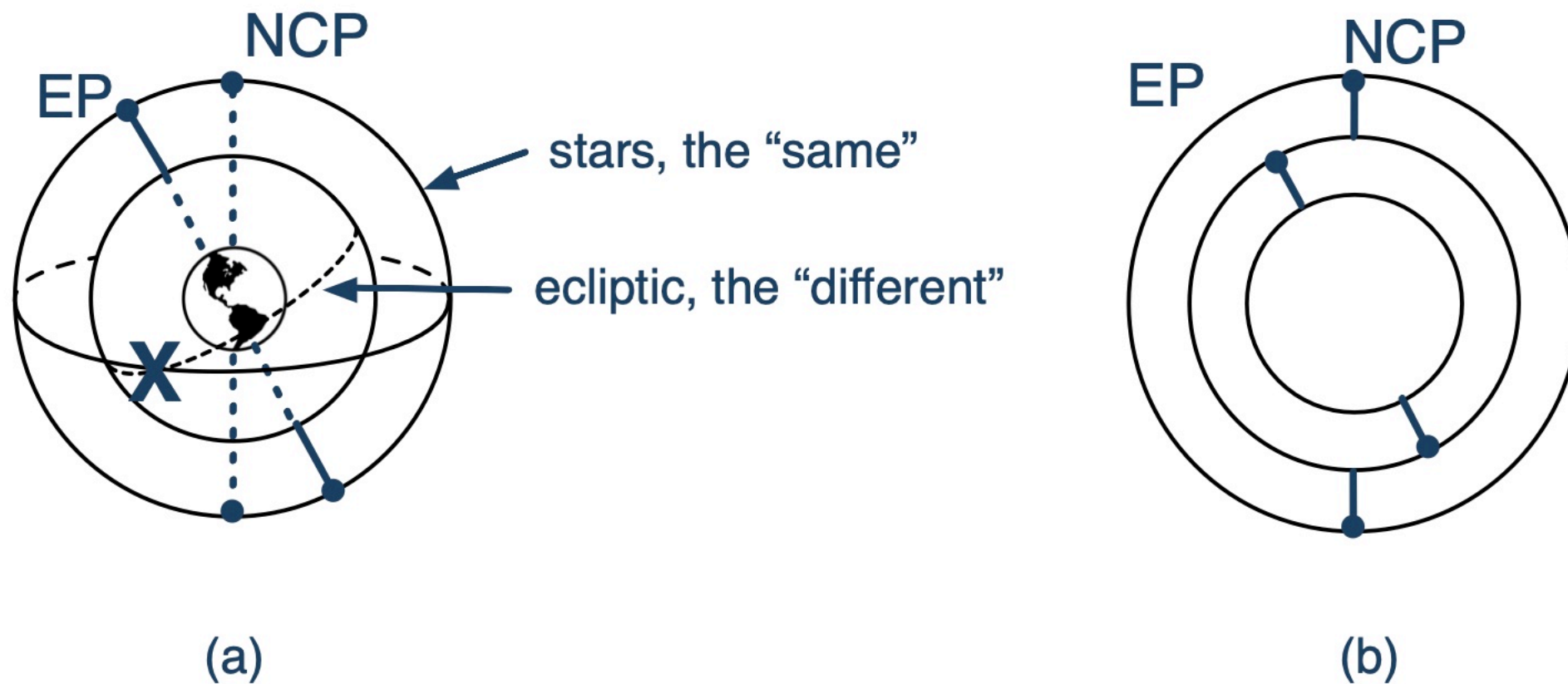
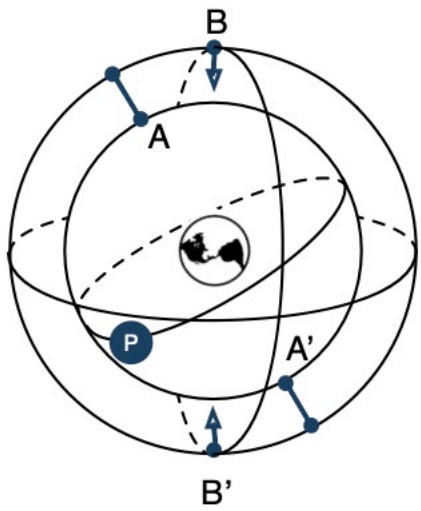


Figure 3.7: Pretty good hula hoops chops.



EUDOXUS' SOLUTION

Serious mathematics (geometry)



(a)

One for each planet

NUMBER OF SPHERES

Planet	Eudoxus	Callipus
Saturn	4	4
Jupiter	4	4
Mars	4	5
Sun	3	5
Venus	4	5
Mercury	4	5
Moon	3	5
Total:	26	33

RECAP:

Forms

eternal and universal

beyond perception and time

in a separate realm

comprehended only by reason

consistent with the Greek emphasis

beauty

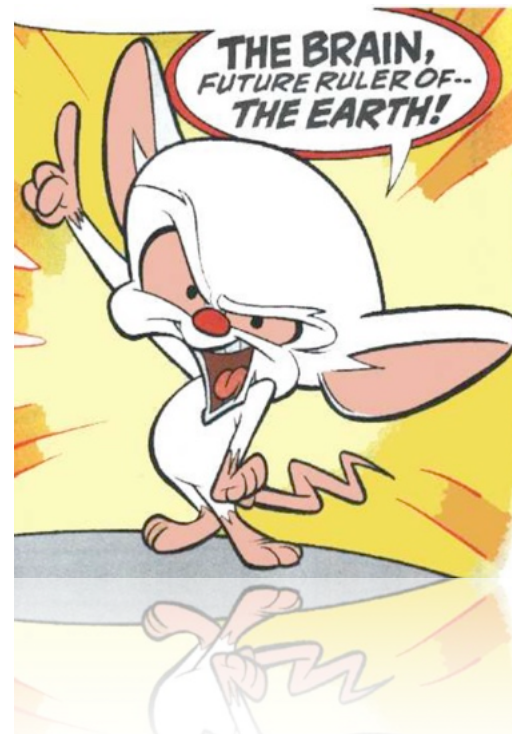
rationality

balance

ONE OF HIS LEGACIES?

the Brain

Aristotle

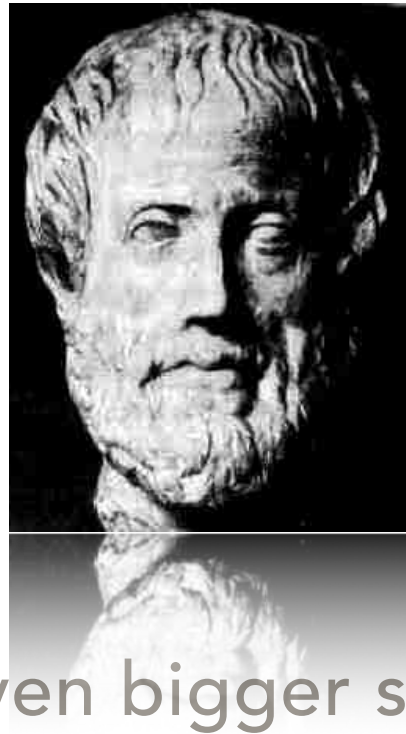


“

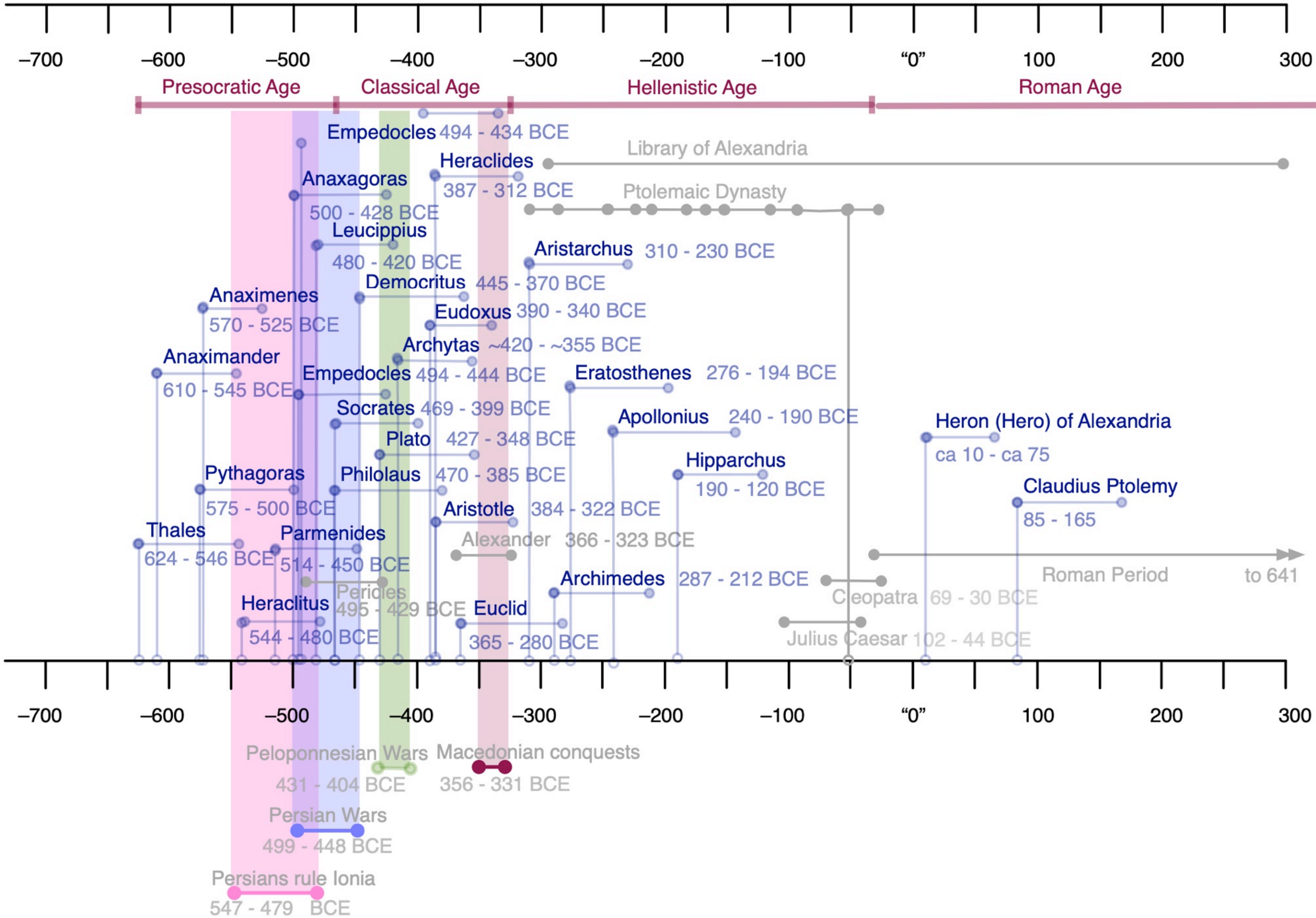
Aristotle is a Foal. When a foal has had enough milk, it is known that it kicks its mother.

paraphrase, attributed to Plato

ARISTOTLE OF STAGIRA (384-322 BC)



an even bigger subject



Organon

Categories (Cat.)

De Interpretatione (DI) [On Interpretation]

Prior Analytics (APr)

Posterior Analytics (APo)

Topics (Top.)

Sophistical Refutations (SE)

Theoretical Sciences

Physics (Phys.)

Generation and Corruption (Gen. et Corr.)

De Caelo (DC) [On the Heavens]

Metaphysics (Met.)

De Anima (DA) [On the Soul]

Parva Naturalia (PN) [Brief Natural Treatises]

History of Animals (HA)

Parts of Animals (PA)

Movement of Animals (MA)

Meteorology (Meteor.)

Progression of Animals (IA)

Generation of Animals (GA)

Practical Sciences

Nicomachean Ethics (EN)

Eudemian Ethics (EE)

Magna Moralia (MM) [Great Ethics]

Politics (Pol.)

Productive Science

Rhetoric (Rhet.)

Poetics (Poet.)

SUBSTANCE

THE CAUSES

MOTION

COSMOLOGY

A System-Builder

ASTONISHING RANGE

Logic

Physical Science

Psychology

Natural Science

Philosophy

ethics

arts

WORDS FROM HIM:

energy, dynamic, induction, demonstration, substance, attribute,
essence, property, accident, category, topic, proposition,
universal,...

METAPHYSICS

informed the development of his natural science

& confused the awakening West

from 1100-1600

ARISTOTLE IS NOT SIMPLE

“Aristotle’s metaphysics, roughly speaking, may be described as Plato diluted by common sense. . . He is difficult because Plato and common sense do not mix easily.” Bertrand Russell,

A VERY OLD CONCERN

permanence and change

LONG 18 YEARS

at Plato's Academy

“...speaking of phenomena, they [Plato and his school] say things that do not agree with the phenomena...**They are so fond of their first principles** that they seem to behave like those who defend theses in dialectical arguments; for **they accept any consequence**, thinking they have true principles—as though principles should not be judged by their consequences.

Aristotle

3 ISSUES

for us:

what's real

how does change happen

his science

WHAT'S REAL?

FORMS->UNIVERSALS? NO.

there is no supersensible realm for Aristotle

form and substance go together

WHAT WE KNOW IS SIMPLE.(!)

particular, individual things

which we learn of through personal experience

NOT an intellectual abstraction

“

If we did not **perceive** anything we would not learn or understand anything.

Aristotle

Substance and Form

WHAT'S A HOUSE?

CONDITION FOR EXISTENCE:

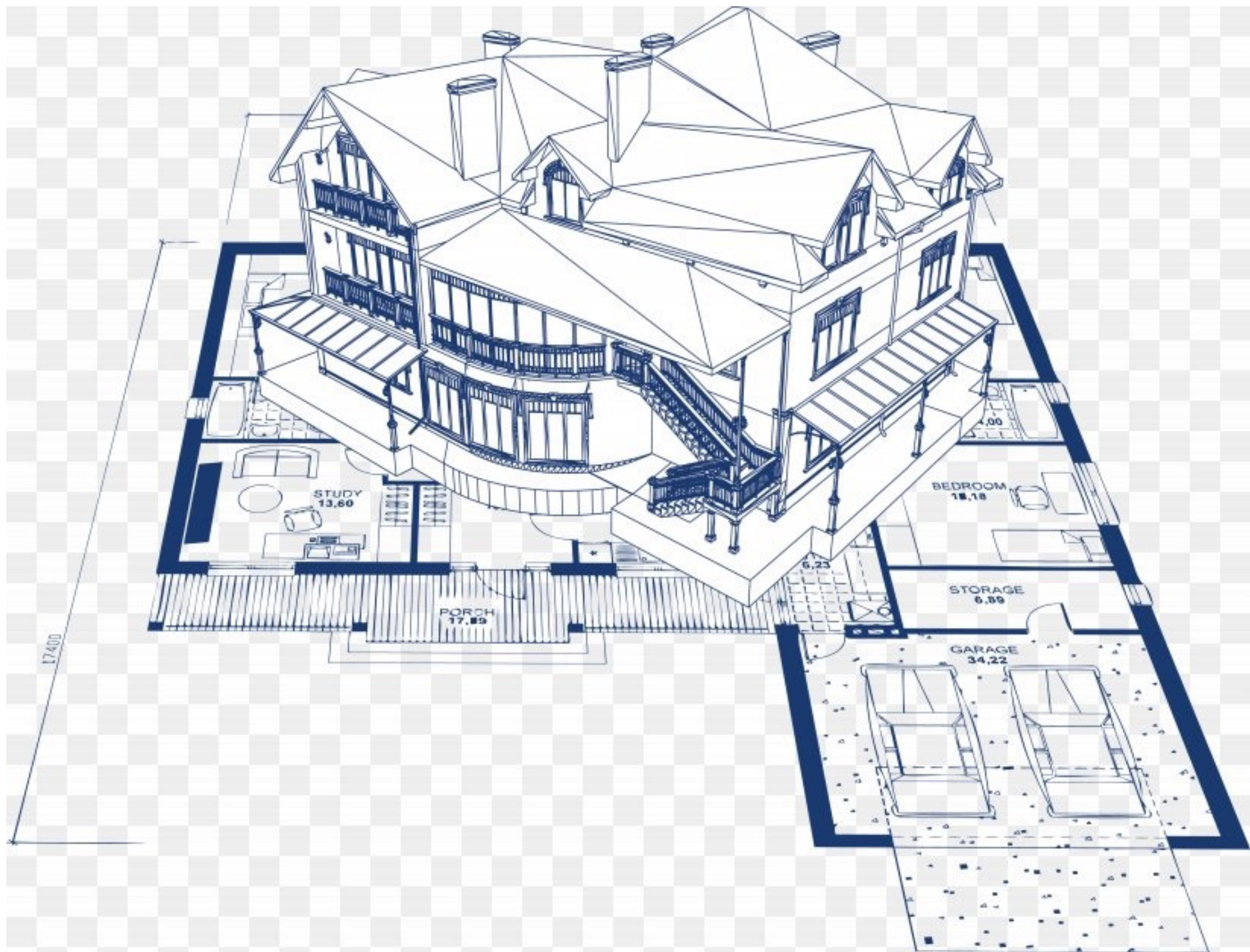
substance (stuff)

and

form (an organizing principle)

in the right combinations





AN INDIVIDUAL THING

matter which has been given a **form**

inseparable

PLATO'S FORMS? NOT

What's Knowledge?

FACTS

perceive individual facts

necessary for knowledge

collect them together in memory

an "experience"

close to...Knowledge

FACTS → SIMILARITIES

from observing

individual, particular facts ->

a relationship->

comparing with mental database

classical Empiricism

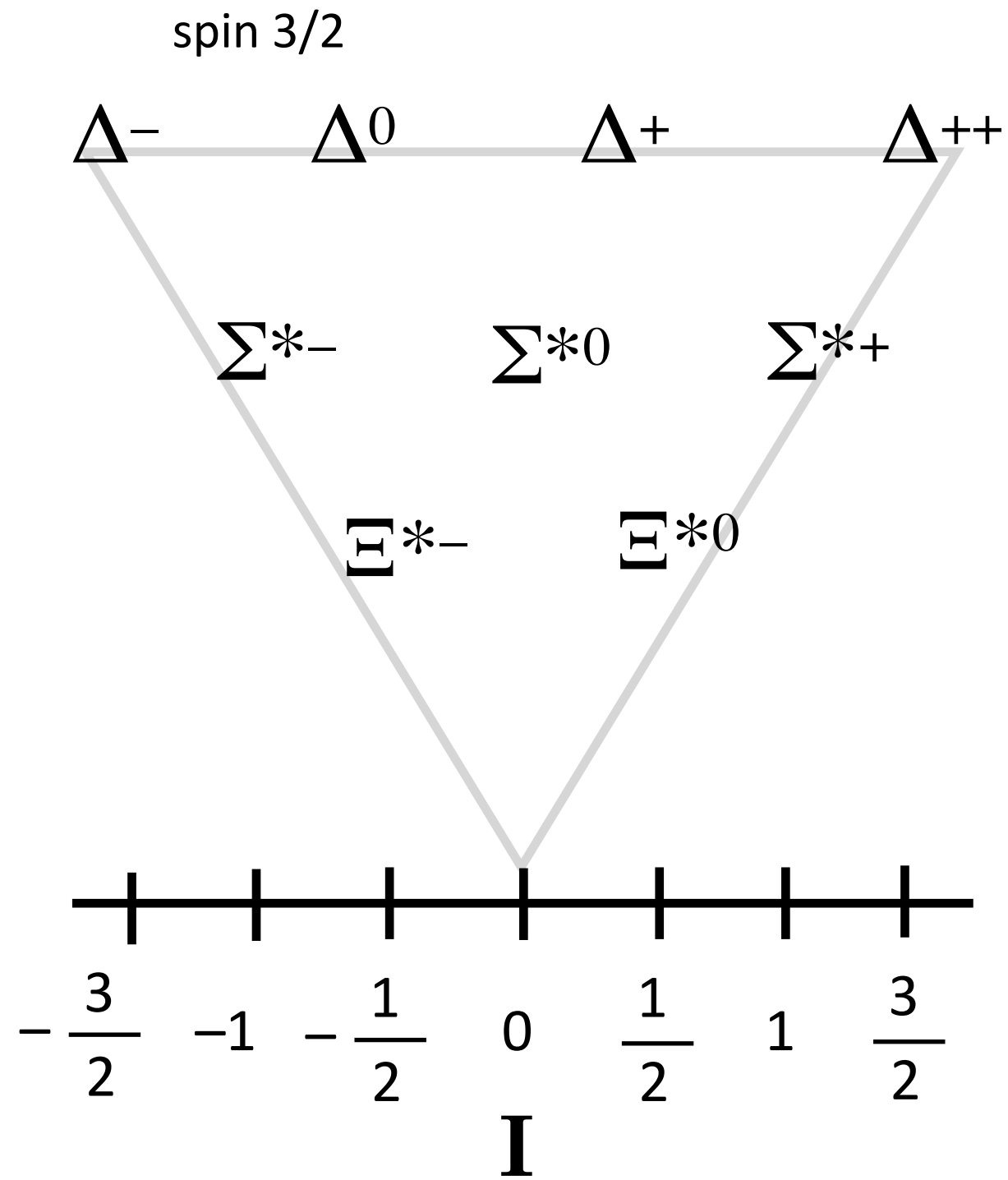
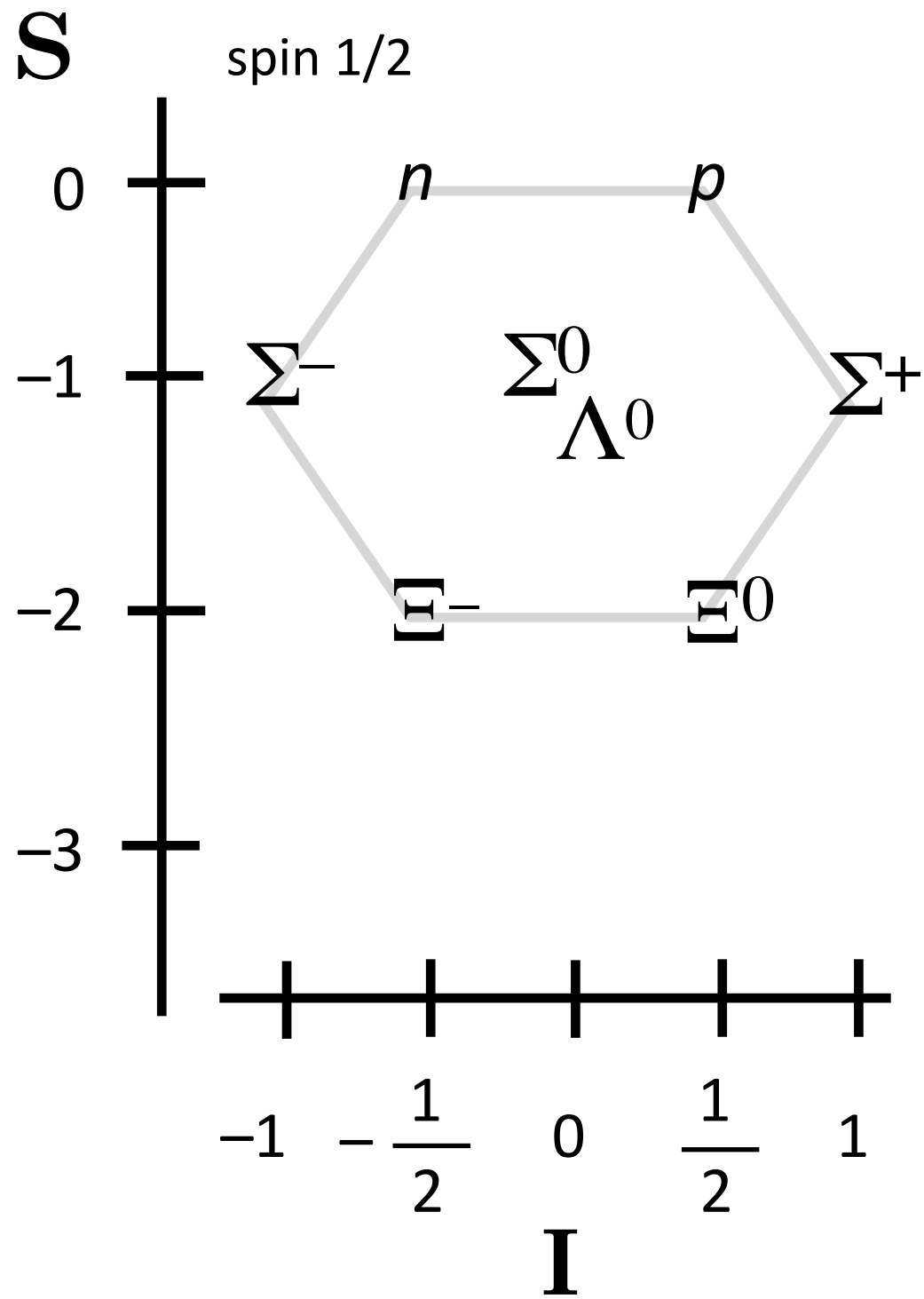
ORGANIZING

Strictly Empirical:

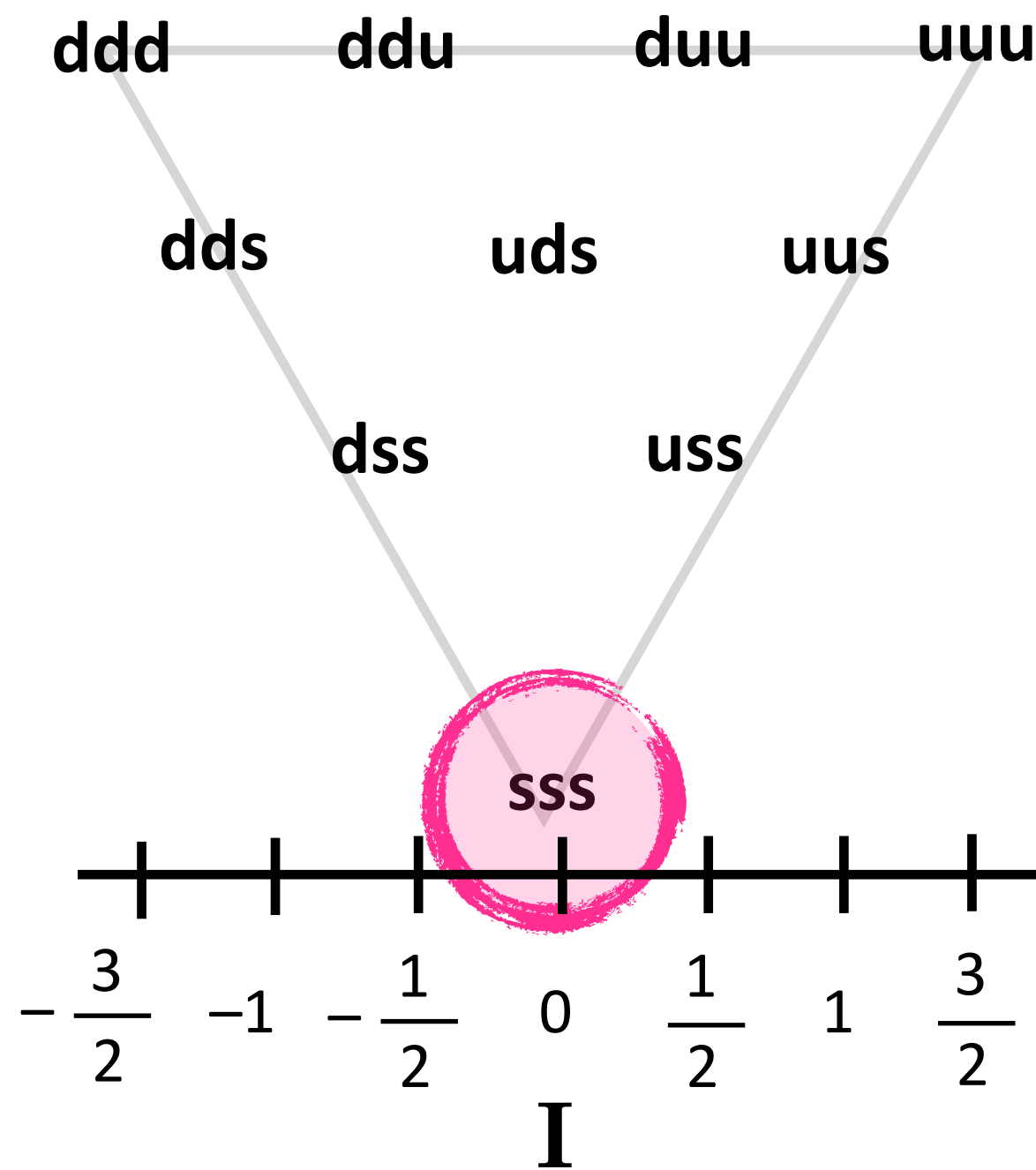
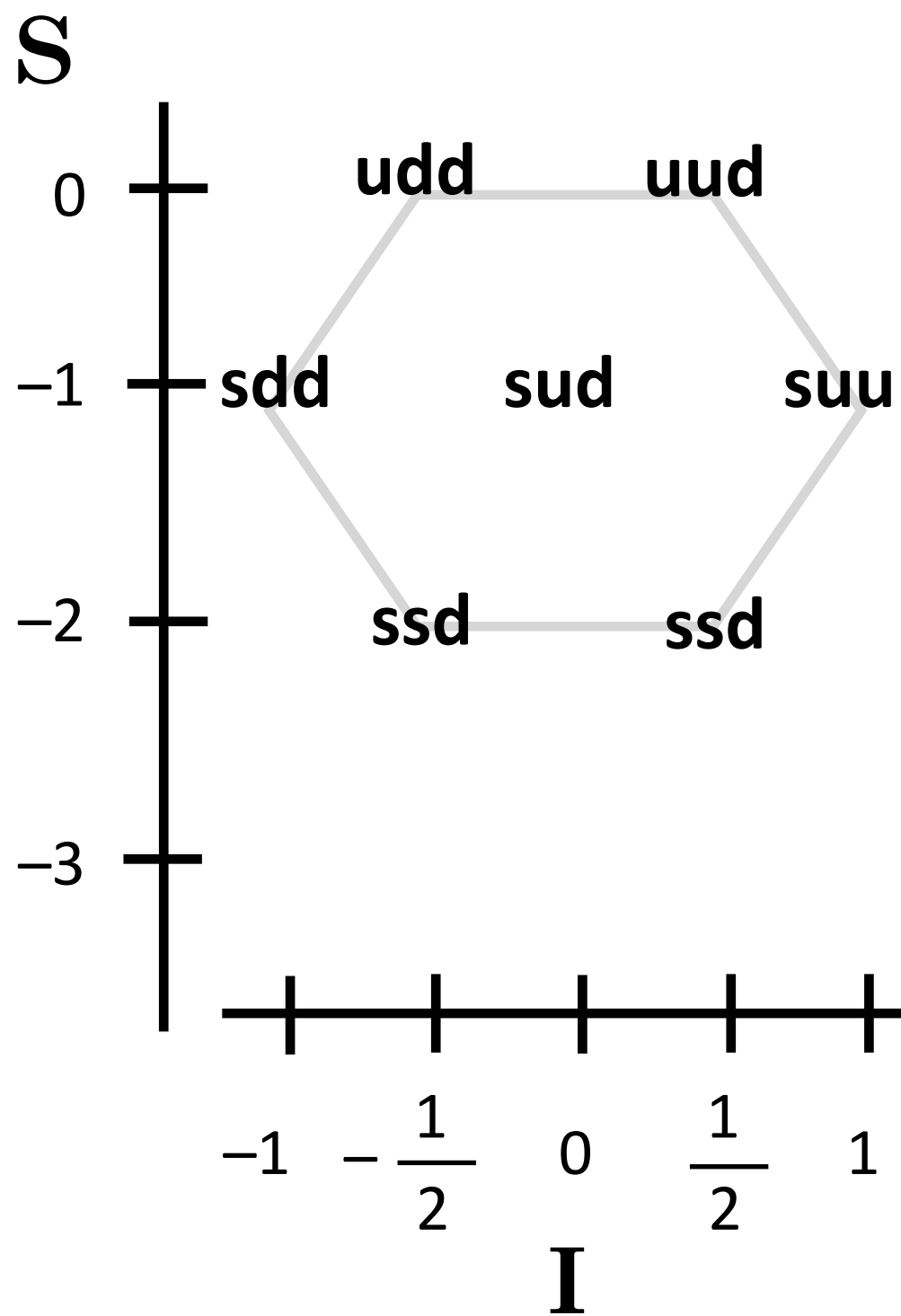
Can you imagine biology and zoology emerging from this sort of similarity-analyses?



they all fit



like a glove



Change

CHANGE RELIEVES A ...TENSION

actuality: what is

potentiality: what it will become

"deprivation"

a kind of inevitability

CHANGE IS CAUSED

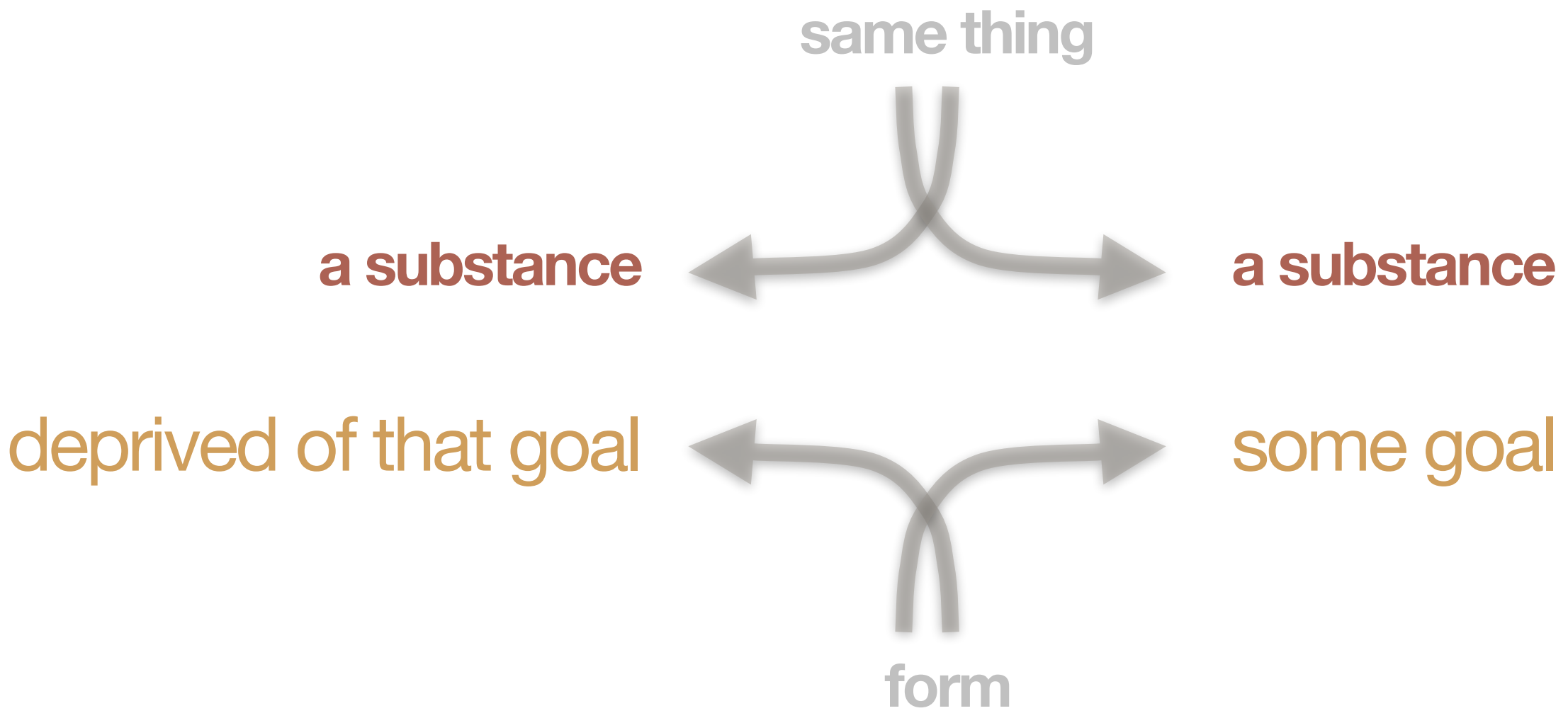
UNDERSTAND THE CAUSE

= to have knowledge

Motion

SUBSTANCES HAVE "MOTIONS"

IS TO SOMETHING



“MOTION”

is really confusing to the Medievals

usually:

change of quality

change of quantity

change of place

MOTION EXAMPLES:

kitten → cat:

motion of quality

kitten of 5lbs → cat of 10lbs:

motion of quantity

kitten here → kitten there:

motion of place... "locomotion"

→ locomotion...our "motion"

But: a phase transition? Water into ice? "motion of quality"?

But: a neutron decaying into a proton, electron, and neutrino"
"motion of quantity and quality"?



THE NATURE OF AN ACORN

its motion:

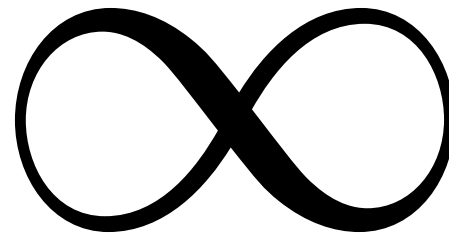
to realize its potential to be a tree



UNREALIZED POTENTIAL?

no.

no:



CHANGE

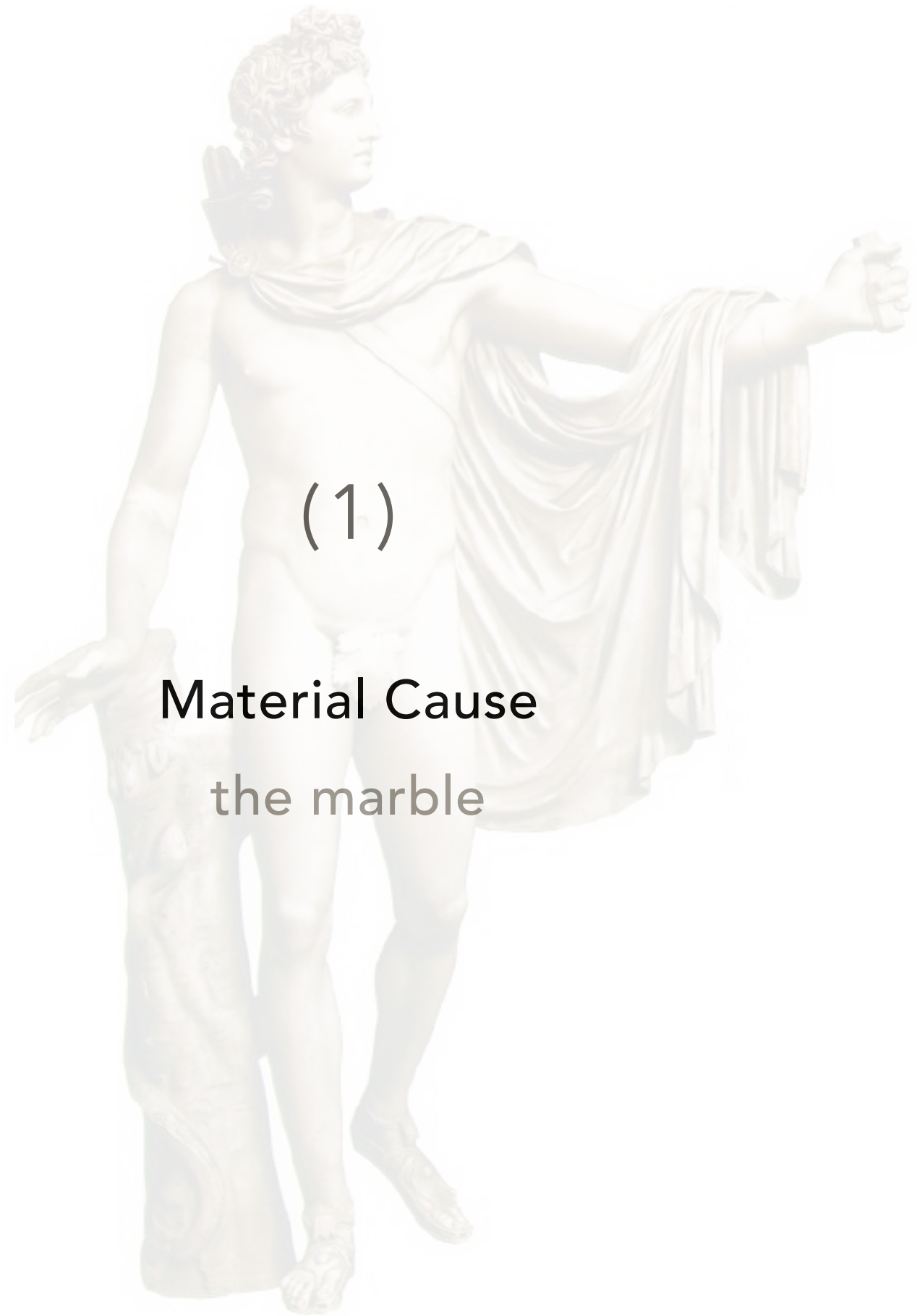
caused

Causes

TO UNDERSTAND:

identify each of 4 causes

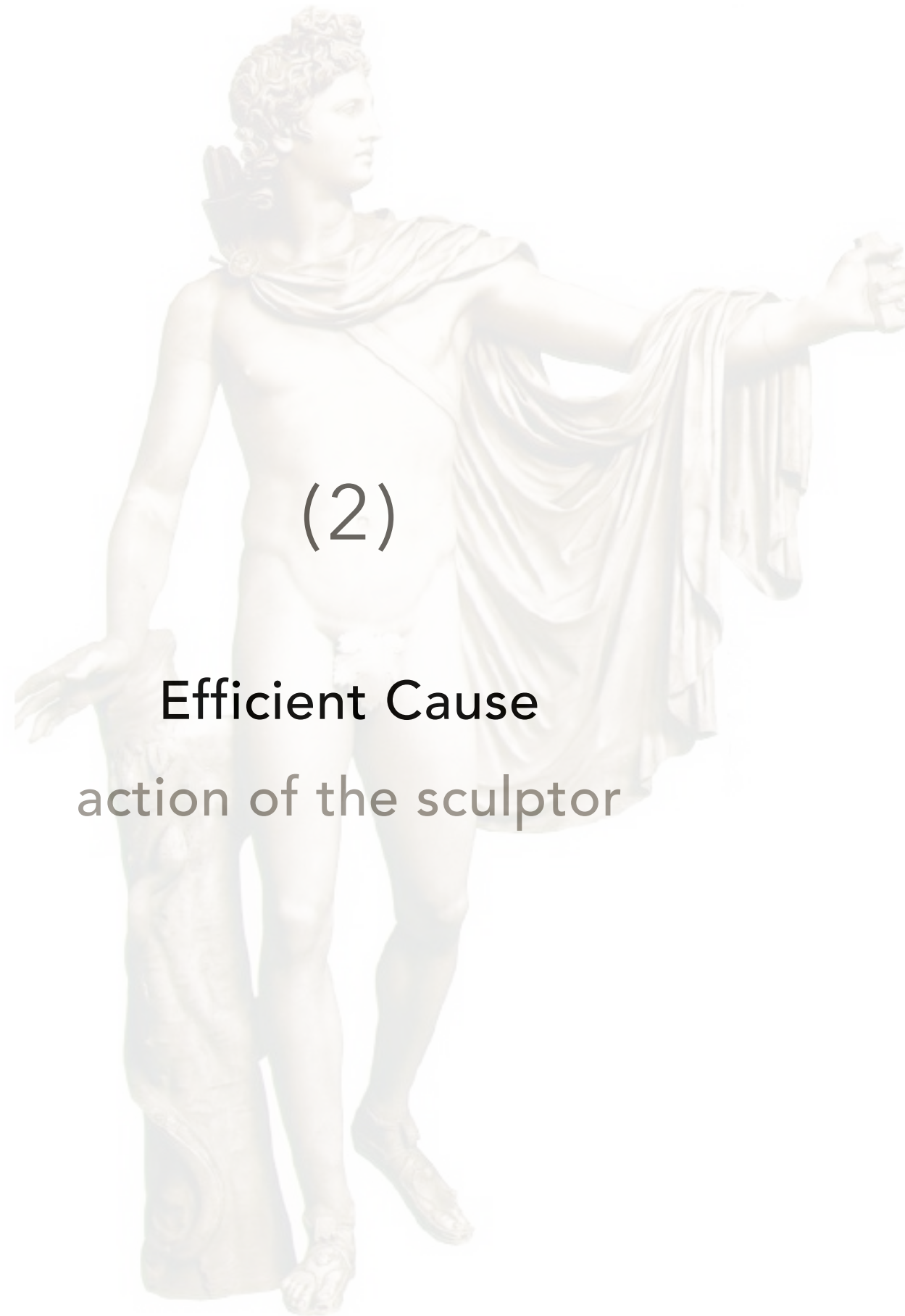




(1)

Material Cause

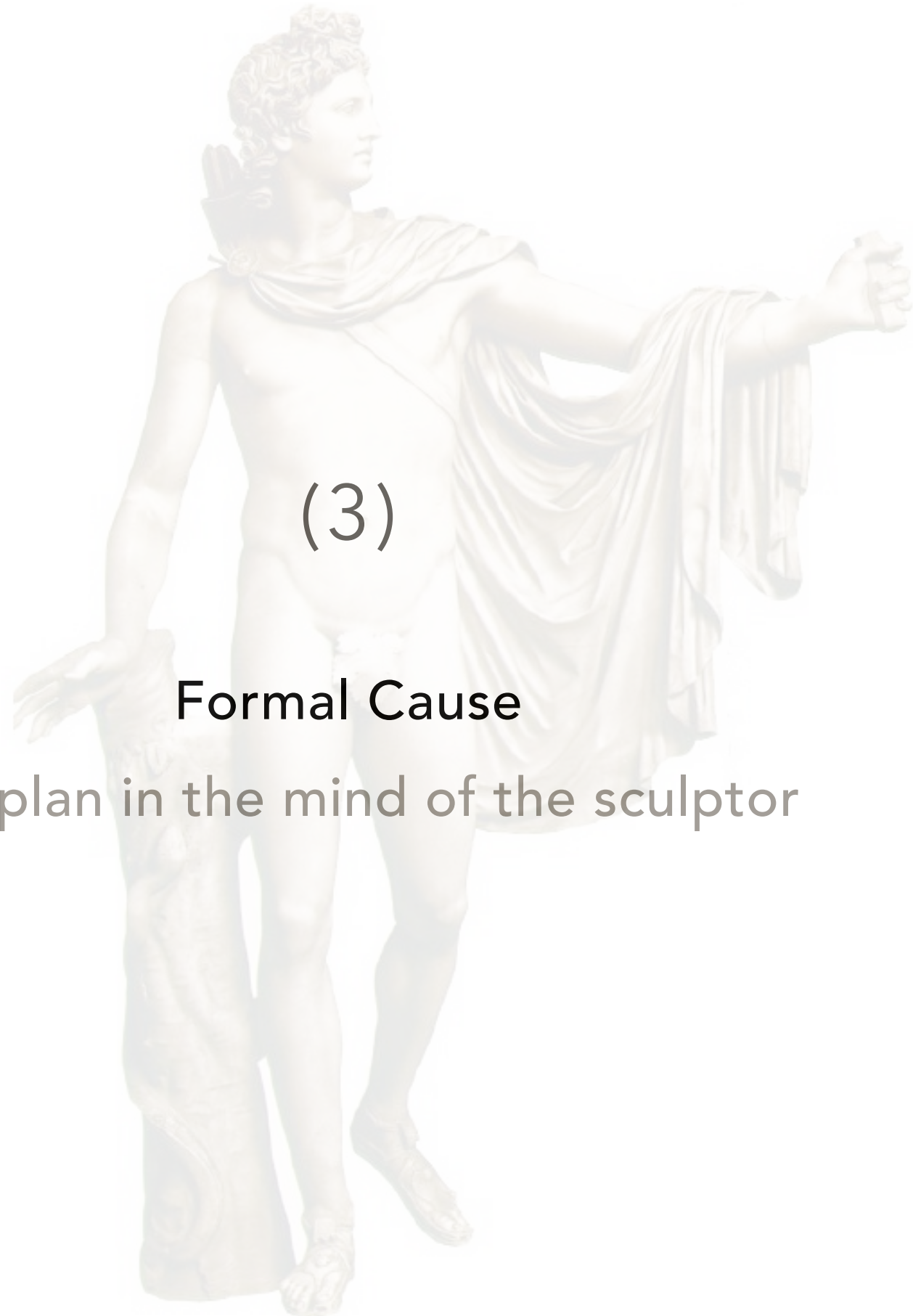
the marble



(2)

Efficient Cause

action of the sculptor



(3)

Formal Cause

the plan in the mind of the sculptor

(4)

Final Cause

the purpose for which the statue was made

teleological

the bummer

gotta understand all 4

to have knowledge of a phenomenon

His Science

HERE

it gets metaphysically

WEIRD.

NO EXPERIMENTS

ONTOLOGY

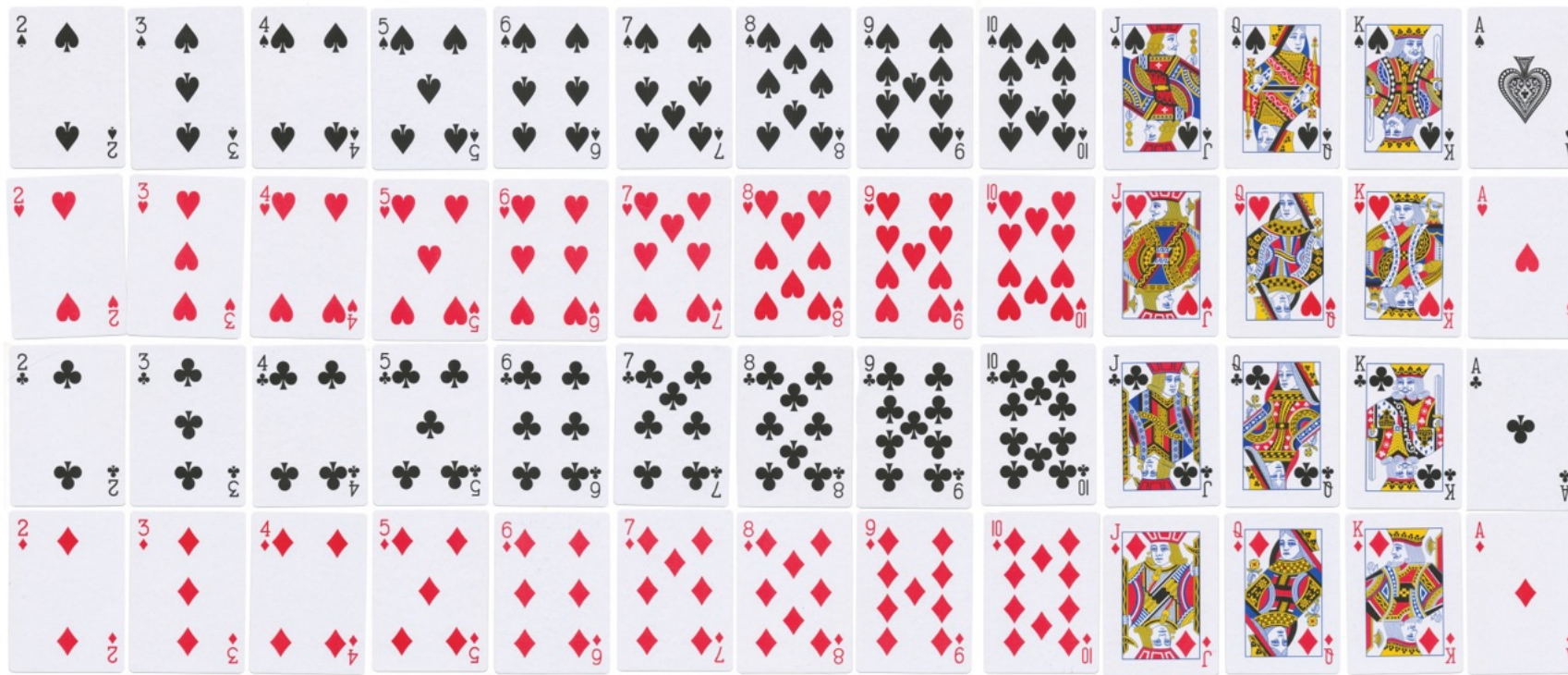
4 local elements:

earth, air, fire, water

"stuff" is a mixture

1 far-out element:

"aether" or "quintessence"



HIERARCHY

classification

incredibly complicated

categorization, description

You can see Botany, Biology, and Zoology here

Aristotle's Physics

2 KINDS OF LOCOMOTION

natural motion

violent motion



NATURAL MOTION

object's nature

two extreme kinds:

"earthy" objects: straight-line to the center of the earth

fire-y objects: straight-line away from the center of the earth

quintesscent objects: circular

SUB-LUNAR NATURAL MOTION

straight-lines

heavy: down

light: up

depending on mixture of earth with other 3

for Aristotle:



GOOD ADVICE!

Nature's action item:

Realize your potential

...heavy object is in a state of privation

Fulfill your "Essence"

THIS IS WRONG

Aristotle did NOT know algebra

time of descent: $t \propto \frac{1}{W}$



THIS IS WRONG

Aristotle did NOT know algebra

had a sense of a resisting medium: $v \propto \frac{W}{R}$

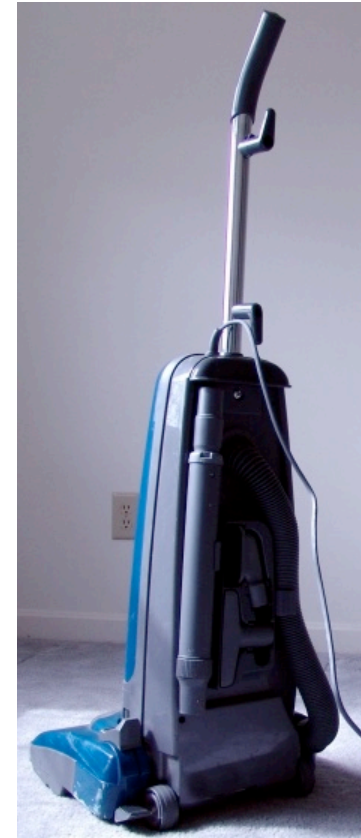


CAUSE OF NATURAL MOTION

weight

and lightness...lightness is a thing

WHY NO



?

If $R = 0$, $v \propto \frac{W}{R}$ means that $v = \infty$

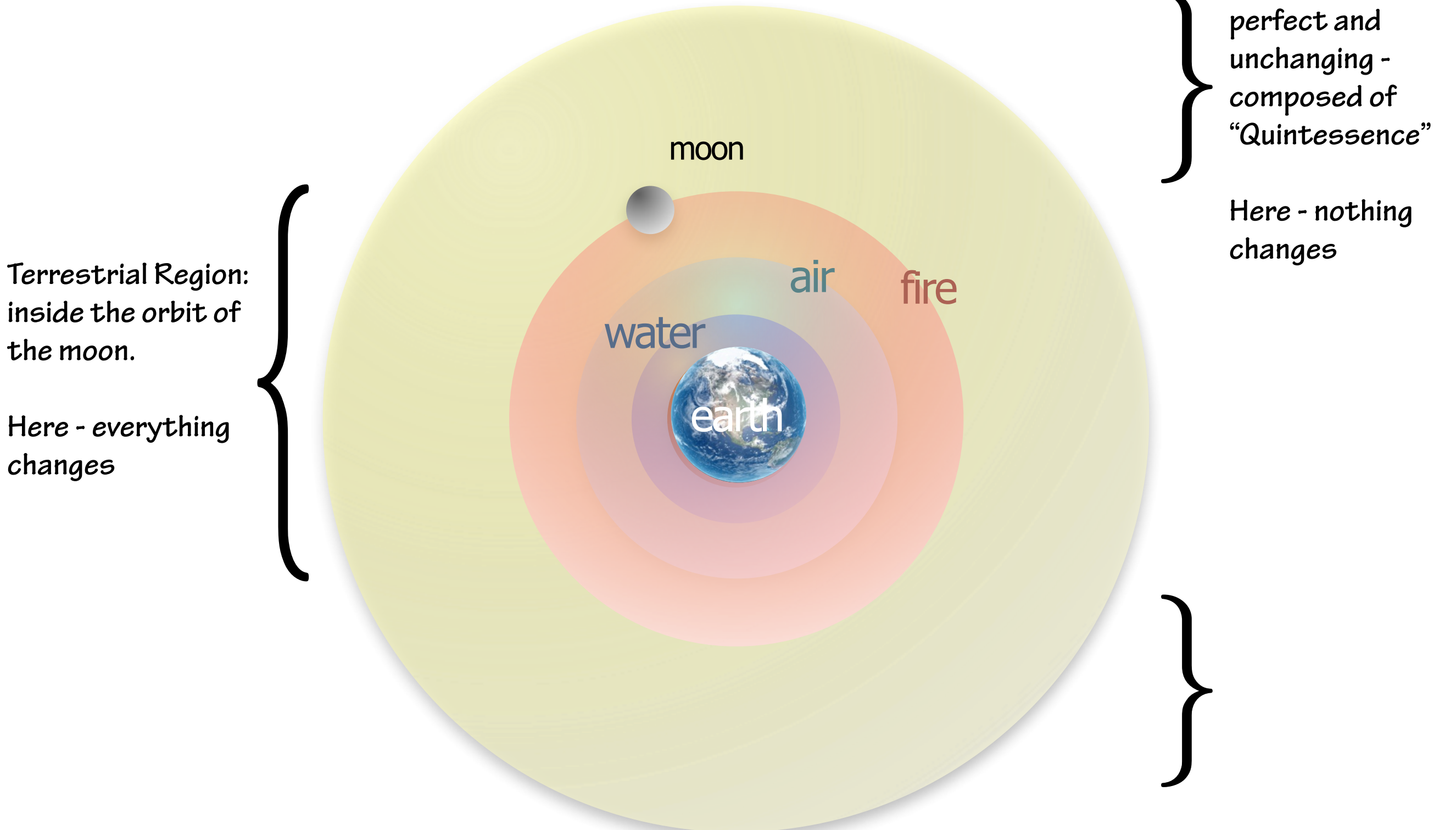
but: there is no ∞ **So, there is no vacuum.**

THIS IS WRONG
Aristotle did NOT know algebra

ARISTOTLE'S SYSTEM:



COSMOLOGY



Terrestrial Region:
inside the orbit of
the moon.

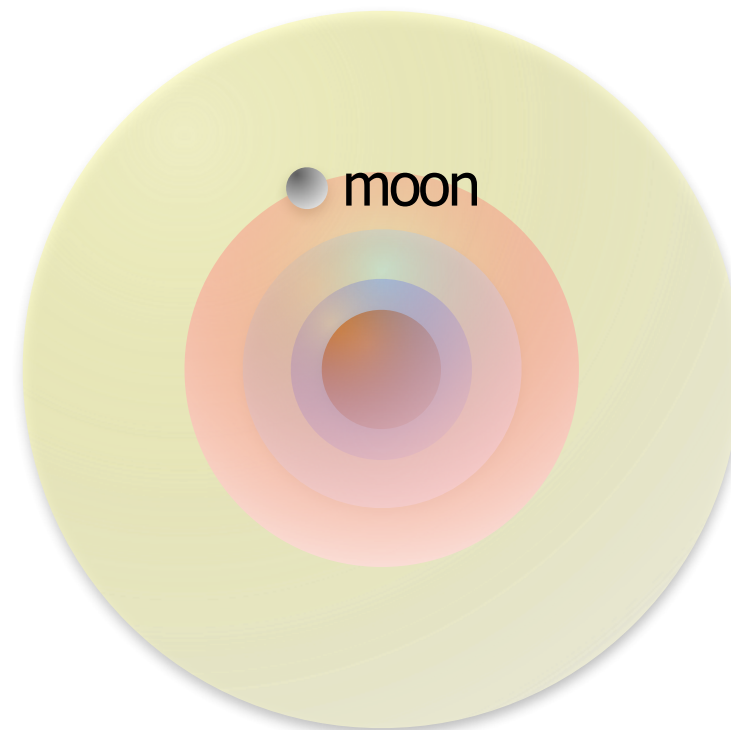
Here - everything
changes

Celestial Region:
Everything is
perfect and
unchanging -
composed of
"Quintessence"

Here - nothing
changes

EXTRA-LUNAR NATURAL MOTION

consistent with Eternal motion:



period.

VIOLENT MOTION?

any that is not-natural

THIS IS WRONG

Aristotle did NOT know algebra

push with a force, something moves: $v \propto \frac{F}{R}$

with a velocity inversely proportional to the resistive medium.

VIOLENT MOTION

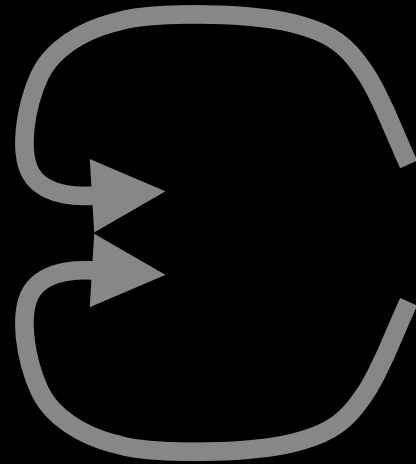
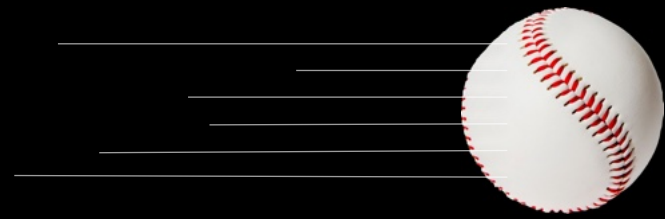
requires

a contact force

which is persistent

HOO BOY

is this a problem



clearly crazy

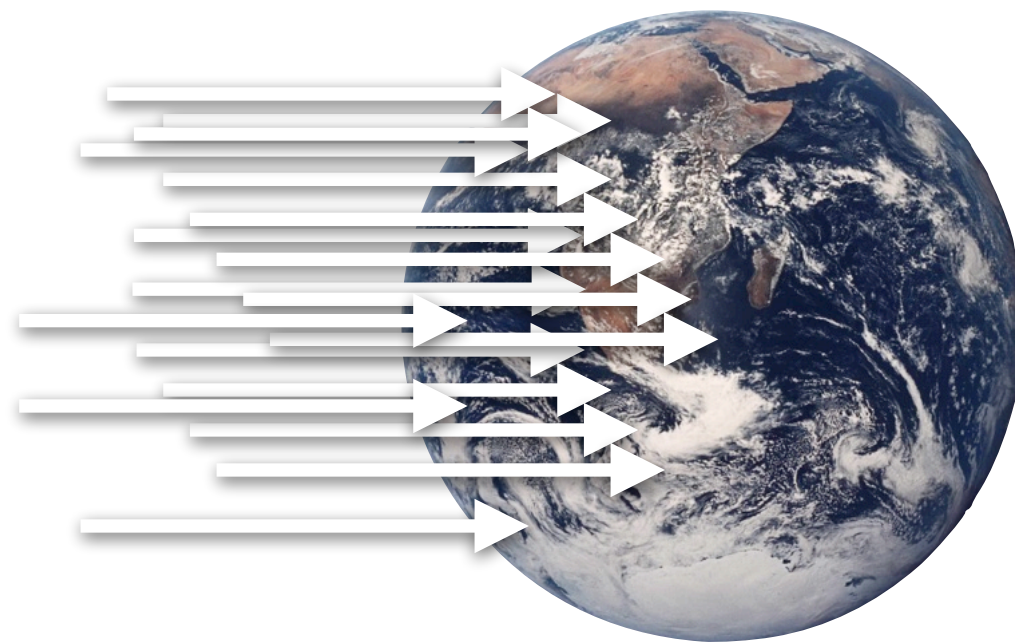
AS THE WORLD TURNS?

not.

NATURAL? VIOLENT?

circles are for heavenly bodies

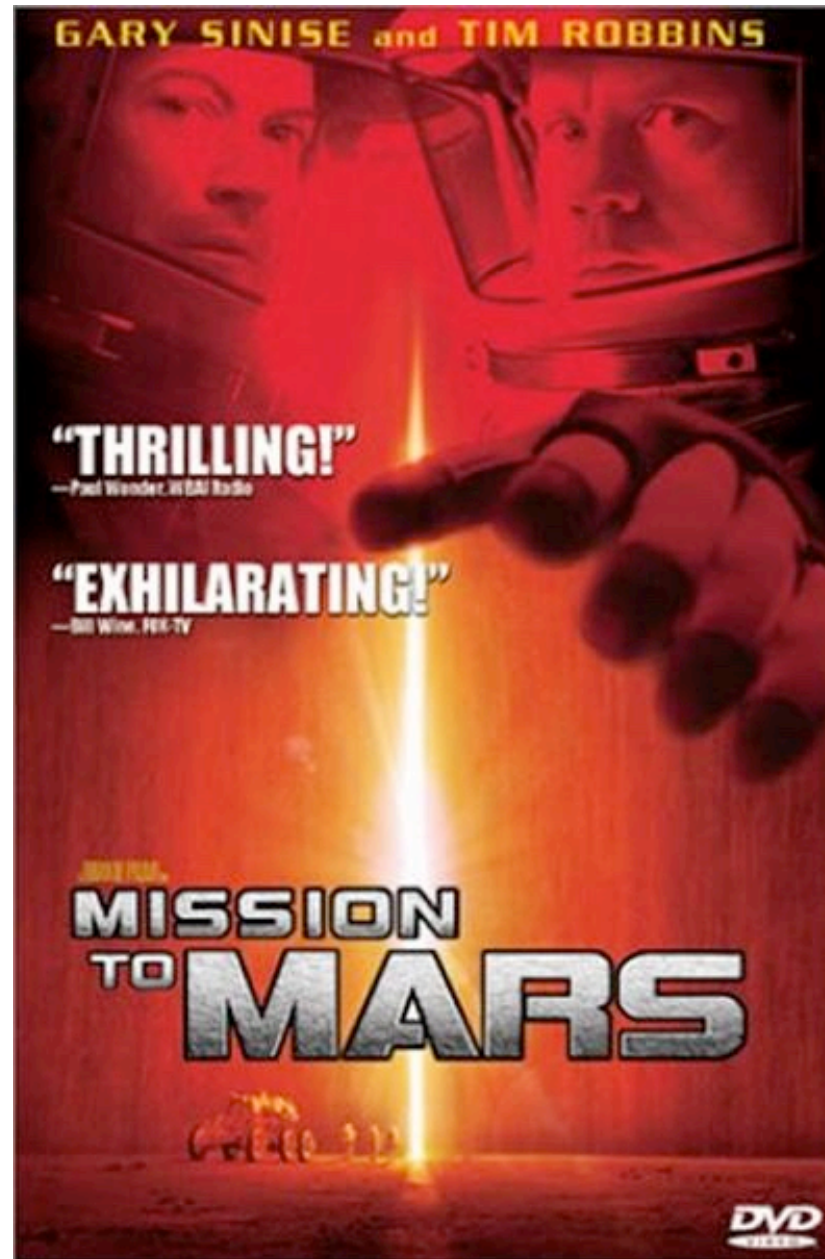
and...what
would do the
pushing?



GALILEO

would have learned all of this

and more...the Greeks had come to his town



bad physics, but got me thinking

AFTER 1085, 1091

Spain: Muslim scholars ruled for 1000 years

after 1085, 1091 conquered Toledo (& Normans in Sicily)

The found ALL of:

Aristotle, Galen, Euclid, Plato, Archimedes, Ptolemy

the Arab Commentators: Avicenna & Averroes

Jewish commentator: Maimonides

everything we know, they found all at once

Council of Florence - Cosimo de' Medici

Neoplatonic Florentine Academy, 1438

translation of all of Plato, Greek->Latin



TRANSLATION -> LATIN

The background of the image is a photograph of a bright blue sky filled with soft, white, wispy clouds. The clouds are scattered across the frame, with some appearing more dense and others more sparse. The overall lighting is bright and natural, suggesting a clear day.

