HISTORY OF ASTRONOMY

A Short History of Astronomy

Ancient (before 500 BC)

 Egyptians, Babylonians, Mayans, Incas, Chinese

Classical Antiquity (500 BC-500 AD)

- Greeks, Romans: Plato, Aristotle,
 Ptolemy
- Middle Ages (500-1450 AD)
 - Arabic astronomers
- Renaissance (1450-1550 AD)
 - Copernicus
- Baroque (1550-1700 AD)
 Brahe, Kepler, Galilei, Newton



Ancient Astronomy



Stonehenge, England

Pyramids, Gizeh near Cairo, Egypt

Early Cosmologies, Creation Myths

Early Uses of Astronomy: Calendars

• 7 day weeks (7 "planets")



GREGORIVS EPISCOPVS SERVVS SERVORVM DEI AD PERPETVAM REI MEMORIAM.

NTER granifimas Paftoralis officy noftri curas, ecooftremanonest, ut que à fa ero Tridentino Concilio Seda Apostolica refernata junt, illa ad finem optatum, Des adantors perducantur. Same etujdem Concily Pattes , cum ad reliquam coestatio ien Breatary quoque curain adungerent , tempore tamen exclusi rem tarames offini Concilij decreto ad suctoritatem & indicium Romani Pontificio resulerunt Ono autom Bremario precipae continentur, quoram Unum preces, laudesque due nas fejtis, profi fisque diebne per foluendas complectitur, alterum per timet ad annuo afelia, fojlarmanjaevi, vo pendenimim recurfui, šolia, or Lume mora metiendas : Arque illud quidem cheix vecordationin travé "prodecejior nofter abfolaendum curanit, atque edidie. Hoe vero, quod m segit legitimem Calendary vehittitionem, iamdina Romanis Pontificibus pradeceiforibue no n no se la primi tentarian est, verana abfatai, ez ad exitum perduci ad hae viguetempui nan poturi, qua Prises fapini tentarian est, verana abfatai, ez ad exitum perduci ad hae viguetempui nan poturi quae Ariones omend radi (Alendary , que a cal Alium matuum peritis proponebaniur, propter magnas, e ut ones emena tues e autoritates, quas lininfronds concadazio femper habuit peque pere neignos Ecclefisferos viens incolumes (quod in primis has inve curandum erat) fernabani. Dum narie nos generale credit anohie, luci tadi oni , a Deo dilpenfatione freti , m hac cogitatione ; tranque verfavemo ,all insist nobis liber à dileita filo dintonio la la artinen & medicina doctore, queco quea verfavemo ,all insist nobis liber à dileita filo dintonio la la artinen & medicina doctore, queco quea im Alayjius eius germanus frater conjertyjerat, in quo per nouum quendam Epactarum Cyclum ab o scengti suum, & ad terram lipfini aurei numeri normani directium, arque ad quamcunque enni felara n opitudinem accommodatum, omnia, qua in Calendario collopfa funt, conflantiratione, & feenije o bus duratura . fierefrui poffeoftendit , ut Calendarium iofum nulli unquam mutations in poffe umenysfunnessie volesner. Nonam hane reftomende Calendary rationem exigue volumme com ino, Francipes, celebrioresque universitates paucos ante annos milimos, utres es amniane communis est, commune ets em amnium confilio per ficeres urs, ille cum, que maxeme oper r des vefpondiffent, coram nos omnium confenfione adducts, vivos ad Calendaris emenda remen adhinan in alma Frhe harum rerum perrifinas, quas langeane ac permary (Confirm arbitratambin depermit i 1 cono milam tempero, 5 bilgenta ad can dicaberatorem adhi. baifan, & Cyclas tan everenna quim eccentariam vindaye conquilicase dilagentifian pepenfa inter fi contultiffent, fuo, és doctorum homanum, qui de exte firipferunt, inducio hune praestern elege van Epailarum Cyclum, cu nonunli estam adiecerunt, qua ex accurata etreumfactione unfa (unt a

- 30 day months (moon's synodic period)
- Julius Caesar (45 BC): 365 days + leap day
- Gregory XIII (1582): year divisible by 100 has no leap day, divisible by 400 does (1900 no, 2000 yes)

- This approximates the length of the year very well (38 sec difference)

Ancient Greeks Discover that the Universe can be Discovered

- Reasons: seafaring nation, open, geography, trading
- What "is" the universe?
 - Thales: Water! (liquid, solid, gas)
 - Empedocles: Fire, Earth, Water, Air \rightarrow Substance!
 - Democritos: Atoms! (smallest, elementary particles)
 - Pythagoras: Math!
 - Find "harmonic" mathematical relations to explain patterns, e.g. vibrations of a violin string, perfect circles

Plato: Senses are Suspicious, Circles are Perfect



• We cannot always trust our senses

- Cave analogy \rightarrow we only know how things APPEAR, not how/what they really "are"
- Plato introduces the prejudice that all heavenly motion has to be uniform circular motion
 - Circles have no beginning nor end
 - Specified by just one number (radius)
- HW for astronomers: <u>save the appearances</u> while only using uniform circular motion

Eudoxus: Homocentic Spheres

- Planetary motions are explained by having the planet move on a set of 4 spheres, each inclined wrt to the others
 - Daily motion
 - Seasonal motion
 - Retrograde motion



Aristotle (384 – 322 BC)

- Arguably the first genuine scientist in history
- Aristotle's views on physical science shaped medieval scholarship → Scholasticism
- His views on motion of the objects was deeply flawed but compelling
- Thomas Aquinas made Aristotle compatible with Christian beliefs



Physics and Metaphysics • Aristotle's "Physics" (Greek: Φυσική άκρόασις or physikes akroasis; Latin: Physica) is one of the foundational books of science and philosophy

 His book on philosophy is called *Metaphysics* (Greek: τὰ μετὰ τὰ φυσικά) – beyond physics

ΦΥΣΙΚΗΣ *ΑΚΡΟΑΣΕΩΣ Α.

ΈΠΕΙΔΗ τὸ εἰδέναι καὶ τὸ ἐπίστασθαι συμβαίνει περὶ πάσας τὰς μεθόδους, ŵν εἰσὶν ἀρχαὶ ἡ αίτια ἡ στοιχεία, ἐκ τού ταύτα γνωρίζειν (τότε γαρ ολόμεθα γινώσκειν έκαστον, όταν τὰ αίτια γνωρίσωμεν τὰ πρῶτα καὶ τὰς ἀρχὰς τὰς πρώτας και μέχρι των στοιχείων), δήλον ότι και τής περί φύσεως έπιστήμης πειρατίον ^bδιορίσασθαι πρώτον τα περί τάς άρχάς. Πέφωκε δε έκ των γνωριμωτέρων ήμιν «ή όδος και σαφεστέρων έπι τα σαφέστερα τη φύσει και γνωριμώτερα ού γαρ 4 ταυτά ήμιν τε γνώριμα και άπλως. Διόπερ : ανάγκη "τον τρόπον τοῦτον προάγειν ἐκ τῶν ἀσαφεστέρων 'μέν ε τη φύσει ήμεν δε σαφέστερων επί τα σαφέστερα " τη φύσει καὶ γνωριμώτερα. "Εστι δ' ήμιν πρωτον δήλα καὶ σαφή τὰ ^k συγκεχυμένα μάλλον ύστερον δ èκ τούτων γίνεται γνώριμα τὰ στοιχεία καὶ αἰ ἀρχαὶ διαιροῦσι ταῦτα. Διό έκ των καθόλου = έπὶ τὰ καθ' ἔκαστα δεί προϊέναι. Τὸ γαρ όλον κατά την αίσθησιν γνωριμώτερον, το δε καθόλου όλον τι έστιν πολλά γάρ περιλαμβάνει " ώς μέρη το καθόλου. Πέπονθε έξ ταὐτὸ τοῦτο τρόπον τινὰ καὶ τὰ ὀνόματα 3 πρός τον λόγον όλον γάρ τι και ° άδιορίστως σημαίνει. οίον ό κύκλος ό δε όρισμός αύτοῦ διαιρεί εἰς τὰ καθ ξκαστα. Kal τὰ παιδία P τὸ 9 μέν πρώτον ' προσαγορεύει πάντας τούς άνέρας πατέρας και μητέρας τας γυναϊκας, ύστερου " δέ διορίζει τούτων εκάτερον.

Codices E.F.I. ^a Tit. depoidreur] depoidreur fi repi depoir F. om. titu-Inm I. ^b mpieror deopiranden F. c from. I. ^d rà airà F. c roirouriu referen F. f pir om. F.I. K royapiune F. ^b rĝ defore om. pr. E. i spieron Jr de spiero F.I. ^k royapiune F. ^b vieren post yrôdepun I, om. F. ^m éril eic E. ⁿ del dorme E. ^o delepurror I. et corr. E. p rål di rå I. ^q pir om. F. ^r imolaµßine I, imolaµßine mporagoprise maripes E. ^o di om. F.

How do things move? Aristotle (c. 350 B.C.)



Aristotle **observed** how things move, and constructed the following **theory**:

- Things have a tendency to stay stationary.
- If you push comething, it will move, then return to it's natural state: stationary.

• Actually, it will try to return to it's natural place: smoke and gas Wrong, will go that ock and clater will so performents!

• If you fire an arrow from a bow, you give it *impetus*: it will travel until this impetus runs out, at which time it will fall to to ground and return to it's natural state.

This was stated in a series of books called 'Physics', and gives us the name of the science. This theory makes intuitive sense, and allows us to make a prediction: rocks won't move unless they are pushed. People took this as truth for ~1900 years.

Aristotle easily falsified by experiment – but emphasis was not on observation



How people thought about projectiles up until the Renaissance: the cannonball moves in almost a straight line, until it runs out of impetus and falls on the house. WRONG!

Aristotle: On the Heavens

- Aristotle on astronomy
- Improvement on Eudoxus:
 55 homocentric spheres
- Plus: explain motion by "tendencies" of the elements: fire/air rise, earth sinks to center of the universe

Schema huius præmiffæ diuifionis Sphærarum.









- Sublunar: ever changing, complicated, chaotic, human (i.e. lowly)
- Supralunar: eternal, no changes other than "perfect" (i.e. complete) circular motion, divine

The Grand Mystification of the Cosmos

- Aristotle's thoughts ossified and prevented progress
- Disempowerment of the inquisitive mind
 - Trapped in a realm of chaos, what can we do?
 - There is no connection of what goes on on Earth and in the heavens, so how can we find out?
 - We are lowly, how can we ask divine questions or question the word of God?

Progress in the Hellenistic Period

- Not classical antiquity, i.e. Hellenic
- Geographic shift from Athens, Greece to Alexandria, Egypt (at this point part of the Greek-speaking part of the Roman Empire)
 - Aristarchus (310 230 BC)
 - Archimedes (c. 287 BC c. 212 BC)
 - Eratosthenes (276 194 BC)
 - Hipparchus (190 120 BC)
 - Ptolemy (90 168 AD)

Using the Parallax Effect to Measure Distances

- From different viewpoints, objects appear in front of a different background
- The closer they are, the larger this parallactic effect
- → We can use this to determine distance!



 Demo: look at you thumb with one eye closed

Using the Parallax Effect to Measure Distances

- Measure the baseline (distance A to B)
- Measure angle at B
- Measure angle at A
- Use geometry of triangles to determine distance to object:
 - If two angles plus one side of a triangle are known, everything else can be computed



Triangulation and Parallax in Astronomy



Earth's motion around Sun



Triangulating the Size of the Earth

- Eratosthenes (ca. 276 BC)
 - Measures the radius of the earth to about 20%



Calculation



- Angle is measured to be 7.2 = 360/50
- So distance Alexandria-Syene is 1/50 of Earth's circumference
- Baseline can be measured: 5000 stades
- → Circumference is
 23,330 miles (modern value: 25,000 miles only 7% off

Aristarchus: How far away is the Moon?

- The Greeks used a special configuration of Earth, Moon and Sun (<u>link</u>) in a lunar eclipse
- Can measure EF in units of Moon's diameter, then use geometry and same angular size of Earth and Moon to determine Earth-Moon
 - distance
- See <u>here</u> for method



Earth's Shadow on the Moon (UT)

Geometrical Argument

- Triangles AFE and EDC are congruent
- We know ratio FE/ED = f
- Therefore AE=f EC, and AC = (1+f)EC
- AC=108 R_{Earth}
- EC = distance to Moon



That means we can size it up!

- We can then take distance (384,000 km) and angular size (1/2 degree) to get the Moon's size
- $D = 0.5/360 \times 2\pi \times 384,000 \text{ km} = 3,350 \text{ km}$

How far away is the Sun?

- This is much harder to measure!
- The Greeks came up with a lower limit, showing that the Sun is much further away than the Moon
- Consequence: it is much bigger than the Moon
- We know from eclipses: if the Sun is X times bigger, it must be X times farther away

Simple idea – hard measurement



- The angle α is different from 90° by only 1/6 degree
- Very hard to measure such a small angle \otimes

Hipparchus's achievements

- Star Catalog
- Precession (Shift of the equinoxes)
- Eccentric Circle