Astronomy 199 CIA

Lecture 5

Sept. 21, 2016

Today's Agenda

- ⋆ Upcoming Talks
- ⋆ Looking Ahead: Astronomy Awards
- ⋆ Looking Ahead: Summer Internshis
- ⋆ Astro-toolbox: estimation and dimensional analysis

No HW was due today! But there is some next week!

Events Tomorrow

Thursday, Sept. 22, this room, 11:00 to 11:50am

- Dr. Knicole Colon, NASA Ames Research Center
- "Exploring Planets Far and Near with NASA's Kepler and K2 Missions"

Thursday, Sept 22, 4:30–9:30pm, Krannert Center
Pygmalion Festival Demo Exhibits, including: Space Telescopes

Events Friday

Friday, Sept. 23, this room, 12 noon to 12:50pm

- Prof. Robert Scherrer, Vanderbilt
- "Science and Science Fiction"

Friday, Sept. 23, Memphis on Main, Downtown Champaign, 6:00 to 9:00 pm

Pygmalion Festival Astro Talks

- Prof. Peter Adshead, "The Forces"
- Prof. Joaquin Vieira, "How the Universe Began"
- Prof. Leslie Looney, "Life Out There"

Looking Ahead: Summer Research Internships

Summer Internships exist–for grad school and industry!

- you get paid (a little)
- spend time at a new University or Lab or company
- get research and work experience
- meet potential grad school mentors
- cultivate letter writers

Sounds greathow do I do it?

- Work hard, choose classes well, and develop a strong record
- Apply!
- info linked on today's lecture webpage

Looking Ahead: Astronomy Department Awards

Frosh: too soon to apply, but **not too soon to plan!**

Transfers: *take a close look now!*

Stanley Wyatt Memorial Award

for the *graduating Astronomy major or minor* with

- the most *outstanding GPA* and *track record of undergraduate research.*

Layla S. Ryan Memorial Scholarship

- Is a Junior or Senior major or minor in Astronomy
- has a minimum GPA of 2.75
- Exhibits community service participation

Preference is given to a female student of minority descent

iClicker Poll: Chicago Skyline

`www: Chicago skyline as seen from Indiana Dunes`

Q: Chicagolanders: what is peculiar about the skyline in the image?

Q: What are some possible scientific explanations for the peculiarity?

Vote: go with your gut–which suggestion sounds best to you?

Q: How can we test the possibilities?

Introduction to the Art of Estimation

Why estimation?

You are taking and will take courses and spent lotsa time learning complex and powerful tools for precise calculations

Isn't this course a step backwards?
Maybe: *Those who can't calculate, they approximate!*

After all your effort to learn how to do things the hard way and the precise way
Q: why learn to make rough, imprecise approximations?

Approximation is Real Science

the real world is subtle and rich ($\equiv$ complicated)
physics/astro phenomena elaborately detailed, but
not all details equally important

no real-world system *ever* simple enough
to calculate without *any* approximation
and even if you could, complicated result hides insight

faced with a new problem: simplify!
...but keep the essentials

approximations and estimates help you
- to see what is relevant
- to see what is irrelevant
- to test ideas/hunches quickly

$\star$ identify which detailed calculation(s) are worth doing

Dimensional Analysis: The Estimator's Workhorse

physical quantities have dimensions (units)

all units can ultimately be expressed in terms of
three *fundamental dimensions (units)*

- [length] $\equiv [L]$
- [time] $\equiv [T]$, and
- [mass] $\equiv [M]$

Q: examples of each? Q: what are units of [velocity], [acceleration], [force]?

of course, some measurable physical quantities are dimensionless
Q: example?

Profound but seemingly innocent observation I:

the behavior of a physical system is independent of the units used to describe it

Profound but seemingly innocent observation II:

in any expression (equation) describing a physical system each term must have the same units

i.e., physical equations must be dimensionally **homogeneous**

Dimensional Analysis Illustrated

Consider
- a Newtonian particle in a uniform gravity field g
- released from rest, then after time t
- falls some height $h \leftarrow$ *want to find this*

You know the exact result, but imagine you don't

If we have fully characterized the problem
then it should be possible to write

$$h = f(g, t) \tag{1}$$

that is, g and t combine somehow to give h

to solve the problem: specify how h depends on g and t
- could use Newtonian mechanics, honest calculation takes work (integration), gives exact result
- but we can get far just by looking at dimensions

Group Work

our variables have:

- $[g] = [LT^{-2}]$
- $[t] = [T]$

given these dimensions, *only one grouping*
of variables t and g
gives a quantity with dimensions of h

Q: find this grouping!
Q: use this to find the most general form of $h(g, t)$*!*

we have $[f(g,t)] = [L]$
but the only way to form a length from g and t
is the unique combination: $\boxed{gt^2}$

so the most general dimensionally legal expression is

$$f(g,t) = Cgt^2 \tag{2}$$

with C a dimensionless *constant*
Q: what's wrong with $Cgt^2 + \Lambda$, *or* $C(gt^2)^2/\Lambda$, *with* Λ *a constant?*

and thus our dimensionless ratio can only be

$$\frac{h}{f(g,t)} = \frac{1}{C}\frac{h}{gt^2} = const = 1 \tag{3}$$

and so we can now solve

$$\boxed{h = Cgt^2} \tag{4}$$

Without calculus, but only considering dimensions, we find

$$h = Cgt^2 \tag{5}$$

with C an undetermined dimensionless constant that is independent of units used for h, g, t

Q: what does this equation teach us?
Q: what does this not *give us?*
Q: how could you test this equation without knowing C?
Q: if you didn't know C, what's a reasonable order-of-magnitude guess?
Q: how could you find C if you didn't know calculus?
Q: what is the actual value of C?

Dimensional Analysis: Lessons

what has

$$h = Cgt^2 \tag{6}$$

done for us?

- *scaling* relations $h \propto g$ and $h \propto t^2$
- don't know C: constant, so "invisible" to dim. analysis
- can test $h \propto t^2$ without knowing C
  measure fall time for different h, see if quadratic
- if you had to guess, would try $C \sim 1$
- without calculus, could get this *experimentally*:
  measure h vs t, find $C = h/gt^2$
- of course, freshman physics says $C = 1/2$
  order-of-magnitude guess off by factor 2: not bad!

Dimensional Analysis: T-Shirt Version

What else could it be?

E.g.: the only length arising from g and t is gt^2
so we must have $h \sim gt^2$: what else could it be?

Lessons:

- gather *all relevant* variables
- find dimensionless grouping(s)
- use to solve for the result of interest
- shortcut: find combinations of variables with dimensions of the answer you want

This is an excellent method for testing answers that you get the hard way!