Order of Magnitude Icebreaker

FIRST
KATHMANDU ASTROPHYSICS SCHOOL
KAS16

How many galaxies in the Universe?

Order of magnitude modeling: The basics

★Goal:

★Understand the basic **but key** ingredients

★Obtain quick but reasonable answer

★Approach:

★Simplify as much as possible
"Spherical Horse"

★Identify scaling relations and use known anchors

★Take (informed) guesses if needed

A very simple example:
How many galaxies in the Universe?

★Think for 3 minutes about how to proceed

★ Don’t discuss with other students (yet)

★ Use your physical intuition, not google!

★ Remember: Multiple approaches possible!

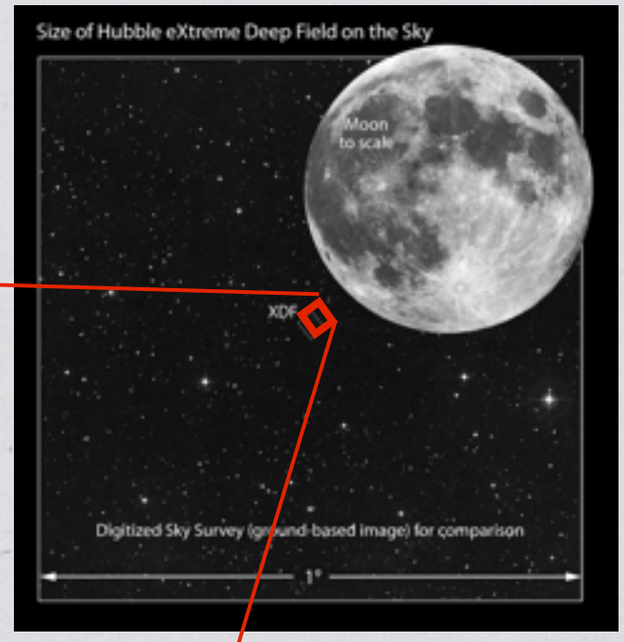
★Now discuss for 2 minutes with your neighbour

How many galaxies in the Universe?

★ Let's collect ideas and discuss them!

- ★ Estimate from small area ultradeep observations
- ★ Estimate from Local Group galaxy density
- ★ Estimate from baryonic content in the Universe
- ★ .....

Estimate from ultradeep observations



- We can count galaxies from Hubble *eXtreme Deep Field*
  [~23 days of exposure time]

Estimate from ultradeep observations

★ This image contains ~5000 galaxies

★ Area (4 arcmin^2) is one part in 13 million of the full sky

★ N_{gal}~ 5000 x 1.3x10^7

NASA/ESA, XDF team

N_{gal} ~ 65 * 10^9

Estimate from Local Group density

★ Idea:

★ $N_{gal} = N_{gal}^{(LocalGroup)} * Volume / Volume^{(LocalGroup)} / \eta$

★ $N_{gal}^{(LocalGroup)} \sim 100$

★ Volume: r~4 Gpc sphere ($r_{eff} \sim r/2$) $\sim 3 * 10^{10}$ Mpc^3

★ $Volume^{(LocalGroup)} \sim 4$ Mpc^3

★ $\eta \sim 10$ [Local group overdensity]

$$N_{gal} \sim 80 * 10^9$$

Estimate from baryonic content of the Universe

★ Idea:

★ N_{gal} = Volume * $<\rho>_{gas}$ * $Efficiency_{star\ formation}$ /M_{gal}

★ Volume: r~4 Gpc sphere (r_{eff}~r/2) ~$3*10^{10}$ Mpc^3

★ $<\rho>_{gas}$ ~10^{11} M_{sun} /Mpc^3 * Ω_b/Ω_{DM}

★ $Efficiency_{star\ formation}$ ~ 0.1

★ M_{gal} ~ 10^9 Sun

N_{gal} ~ 70 * 10^9

Order of magnitude estimates
Ideas to bring home

★ Multiple pathways, depending on available information

★ Good illustration of what research is about

★ Do not hesitate to simplify as much as possible

★ Rescale to situations you are familiar with

★ Basic physics can give good insight on many problems!

Next: Problems for this week

Order of Magnitude Group Projects

★Basic goals:

★Experience a simple but interesting research project

★Learn to apply in practice what you learned at the University

★Learn to collaborate with peers

★Learn to present results effectively

Order of Magnitude Group Projects

★Nine projects proposed, with variety of

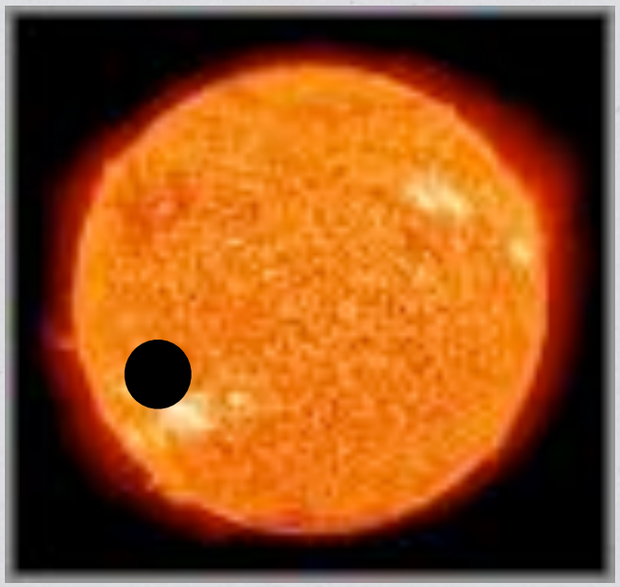
★Topics

★Level of difficulty

★Type of skills needed to work on them

Let's briefly look at them!

A black hole collides with the Sun!



★ Imagine that a black hole of mass $M_{BH}<M_{Sun}$ collides with the Sun

★ What is the minimum M_{BH} that we can detect?

Formation of life in the Universe

★Is life likely to emerge at the present time around a star like the Sun?

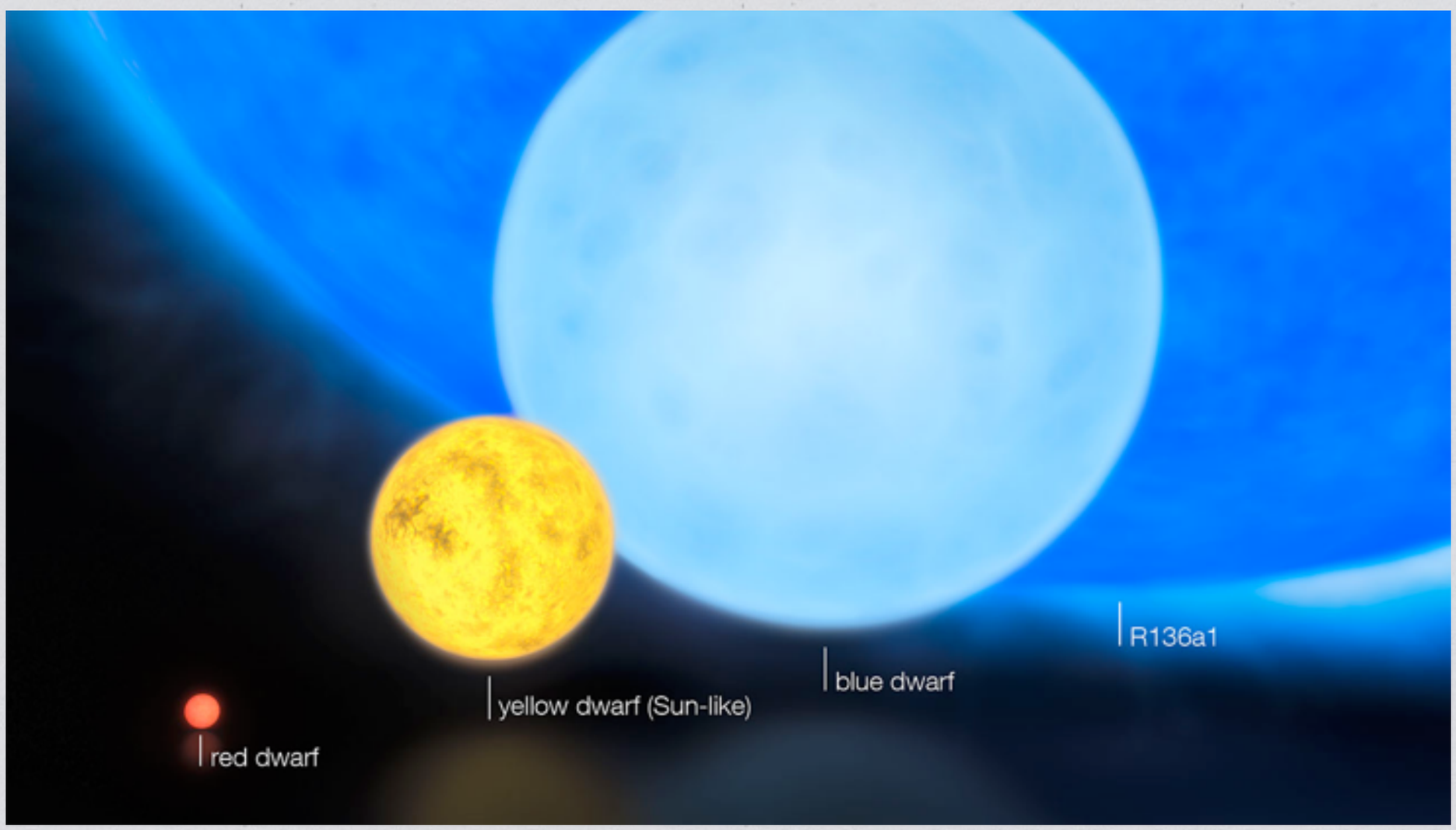
A starship drifting in a globular cluster

★What is the probability of colliding with a star in a globular cluster?

The luminosity density in the Universe

★Which type of galaxies dominate the luminosity density in the Universe?

Limits on the mass of stars

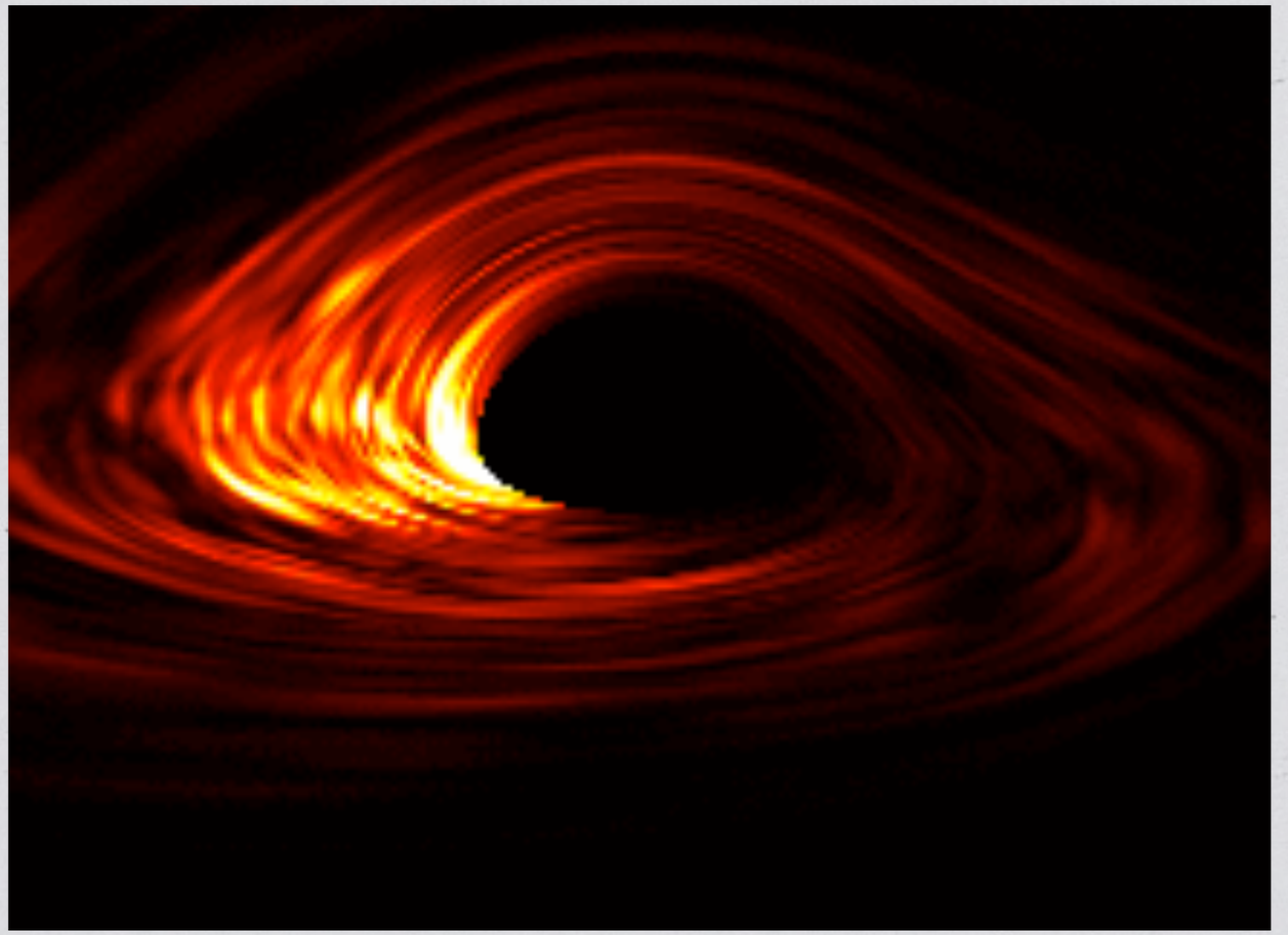


★What are the upper and lower mass limits for a star?

The growth of supermassive black holes

★How quickly can a supermassive black hole reach 10^9 M_{sun}?

Accretion on black holes

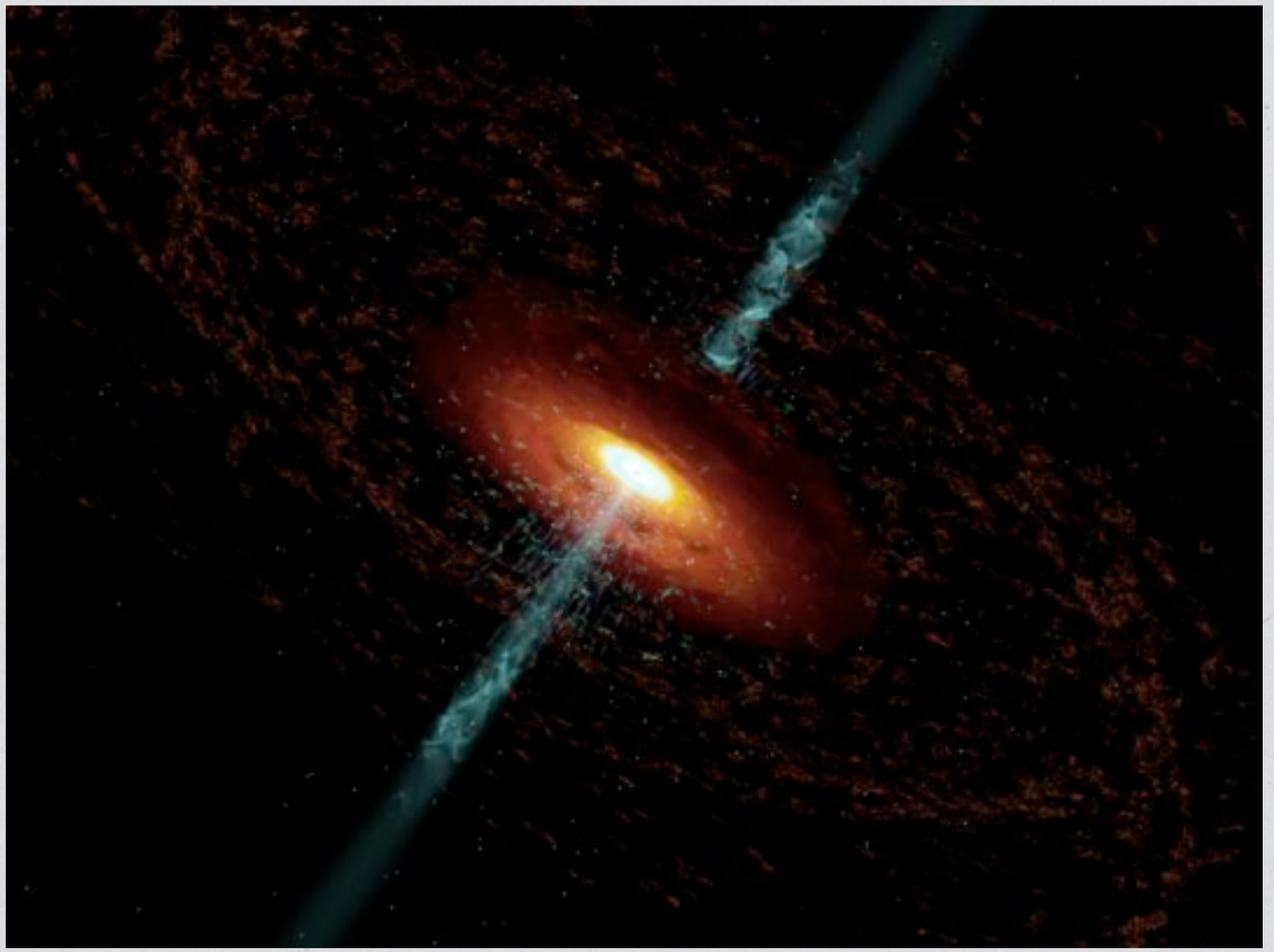


★Derive the maximum rate for black hole growth

Radiation from accreting black holes

★Characterize radiative processes in black hole jets

Black hole jets: Superluminal motion



★Is it possible to observe apparent velocities exceeding the speed of light in blazars?

Organization

★ Take some time to read the full description of the 2-3 problems that you find most interesting

★ Write down your name on the whiteboard for your preferred problem (and for your second choice)

★ Start the project (with your team):

  ★ Two afternoons of team work

  ★ One afternoon to prepare a presentation

  ★ Present on Friday