Team project #1

Telescope design
Astronomical measurement

Team projects

2 teams, ~5 students per team.
Each team is given a project in the form : how would you design, build, test and operate a telescope/instrument to solve an astrophysical problem

Schedule:

TODAY (Jan 28): Project assignments given and discussed

NEXT 14 DAYS (Jan 28 → Feb 16): work on project, ask questions to Guyon, Hinz & Hart
*guyon@naoj.org**, phinz@as.arizona.edu, mhart@optics.arizona.edu*

IN NEXT FEW DAYS : email us team & project choice + where you are at (brief email OK)
     This will help us make sure you're on the right track. As questions if you have some. If
        possible, tell us what is hard about the project, what you don't understand.

IN 14 DAYS (Feb 16): present your project to the class, discuss it with the class
     45mn per team including questions. Aim for ~30 slides (+ backup slides OK). This will be
        very interactive. Other team will ask questions / comment.

On Feb 16: email slides to Guyon, Hinz & Hart
     After Feb 16 presentation, update your slides, answer questions & comments. This is
        your final report.

Team projects - expectations

Think, learn something, have fun, work together

Some advice:

- **work together**: work should be interactive between team members, distributed among team members. Schedule time to meet and talk about the project.

- **keep it simple – do not focus on details**: no need for detailed optical design. focus on big choices, strategy. Identify what you think is difficult, easy, how you think you would solve or analyze problems. Present what you think the system should look like (eg: wide field telescope, 8m, with a refractive corrector and a ~Gpix camera with 0.2" pixels), how you would use it to solve the problem.

- **look around at what might already exist**: if you find that a telescope/system already does this pretty well, try to complement it: do better or different. Build a project that makes sense even if the existing project goes along.

- **be honest**: explain what you understand and what you don't. The discussion session is a good time to ask questions like: "we didn't know if we need xxxx" or "We don't understand why xxx"
Note: An oral interactive discussion is very unforgiving – you can't hide what you don't know !

- **present as if you are trying to get us to give you money to do a detailed study**. Can we trust you to make the right design choices ? Do you understand the problem and challenges ?

Team projects - expectations

Think, learn something, have fun, work together

<u>Some advice:</u>

- **think through all steps**: design, fabrication, test, operation
    – Do you expect testing to be challenging ? how do you operate the system ?
    – any information on level of effort (years required to build and test, cost, number of people required) is valuable (but not required !)

- **don't be too nice to other team, ask hard questions (the ones you would not want other teams to ask you)**
    If you suspect something to be wrong, say it. If you're right, the other team will learn something, if not, you will learn something.

- **think broad**
    Is a conventional telescope optimal for this problem ?
    Should several small telescopes work better ?
    Space or ground ?
    What wavelength ? is optical better, or IR ?
    by the way... once we build this, it could also measure xxxxx ….

Team projects – Roles within team (example)

Program manager (PM)
- Call the meetings. Make sure everybody has well-defined tasks and that they work towards the common goal. He makes sure that things get done.

Chief Scientist (CS)
- Relate science requirements to technical requirements. He is the real driver behind the project

Chief System Engineer (CSE)
- Work towards technical requirements, define system level tradeoffs, report jointly to PM, CS

Chief Optical Engineer (COE)
- Provide preliminary optical designs and optical performance analysis, report to CSE

Team projects – Steps

1. Quantify the physical effects that of interest. Relate them to specific signals that can be observed

2. Choose several ways of getting information from the signals. Identify fundamental limits.

3. Choose a single architecture that seems practical.

4. Define all of the performance requirements that must be met. Relate these to the science.

5. Define specific trade studies that are needed to make decisions. Define these decisions and the information that needs to be obtained to make them.

6. Perform preliminary design and analysis as necessary to make the big decisions.

7. Follow the complete chain: physics in space - atmosphere - telescope optics - instrument optics - detector - data bits - processing.
Understand and quantify how signal flows from space to data. Understand and quantify how and where uncertainties come in: random noise and systematics.

8. Provide preliminary plan for processing the data and making decisions in the presence of noise and bias.

9. Perform preliminary definition of requirements for all of the important subsystems. How do these compare to existing systems?

10. Define the next step towards developing a real functioning system. Do you need special things made? Do you need to test anything first? Can you specify all of the parts well enough? What else do you need to know?

Team projects – proposed assignments

You can choose your project within or outside this list
If within the list: first come, first serve
If outside the list: email us your proposed project
OK to take a project and modify it along the way (email us if you do that)
(Note: the sooner you choose, the more time you will have to work on it)

Finding Planet 9
  – Telescope(s) system(s) (telescope(s) + camera(s)) to find Planet 9
  – Use existing telescope / instrument or build new one ?

Exoplanet transits: how many Earth-like planets around stars ?
  – transit: planet passes in front of star → drop in brightness
  – measure transit frequency → compute planet frequency

Near-Earth Objects: are we in danger ?
  – detect NEOs
  – measure their orbits
  – what size are they ?

How do stars die ? watching and counting supernovae in galaxies
  – measure supernovae rate & compare with number of existing stars

Mapping the Halos of nearby galaxies
  - detect and count individual stars in the halo of galaxies

Finding Planet 9

Planet 9 is a hypothetical large planet in the outer solar system
Its existence is predicted from statistical analysis of outer solar system bodies orbits

Planet 9 is very faint, and its position is poorly constrained

Can you find it ?
If you find it, can it be characterized (radius, mass, orbit) ?

# Exoplanet transits: how many Earth-like planets around stars ?

- transit: planet passes in front of star → drop in brightness
- measure transit frequency → compute planet frequency

Your goal: Extend KEPLER sensitivity to all sky

With proper alignment, a planet can pass in front of its host star as viewed from Earth. By looking at a large number of stars for a long period of time, it is possible to measure the statistical distribution of exoplanets in orbital radius / planet radius.

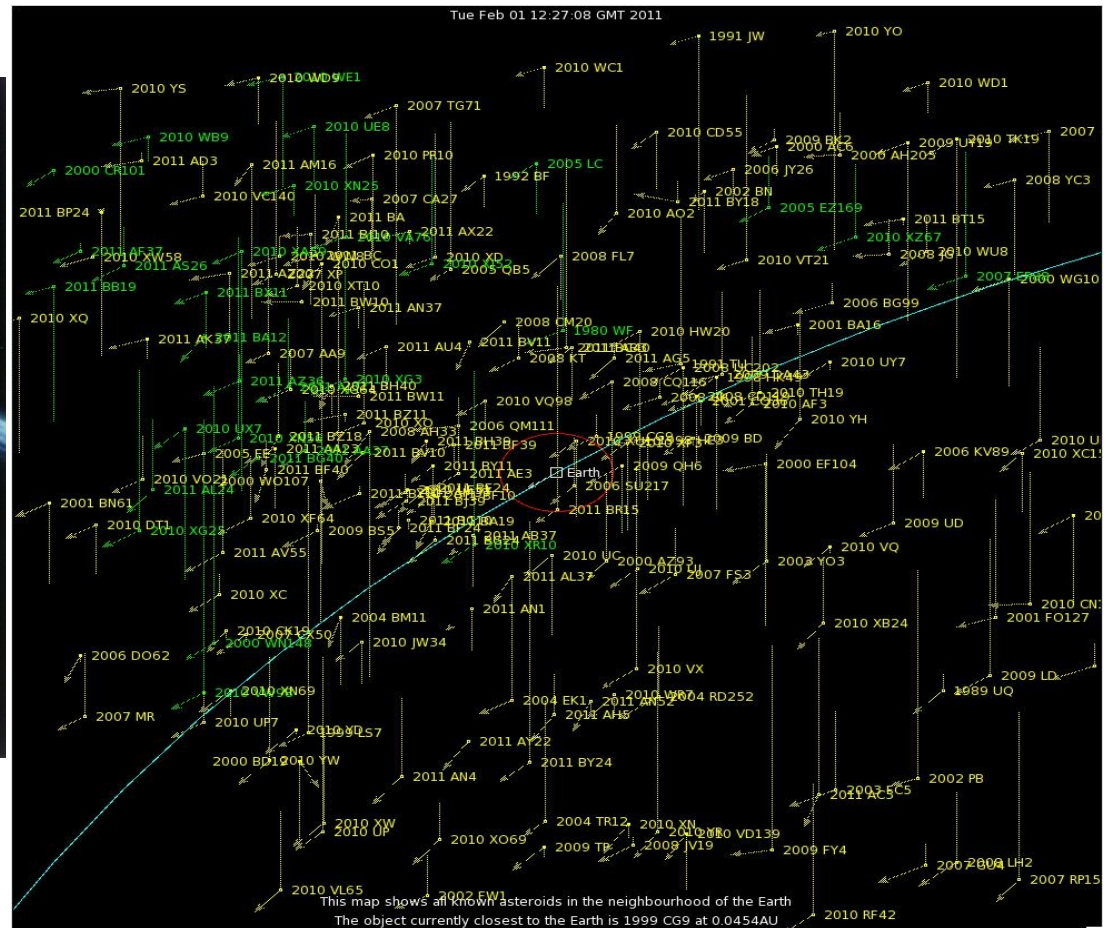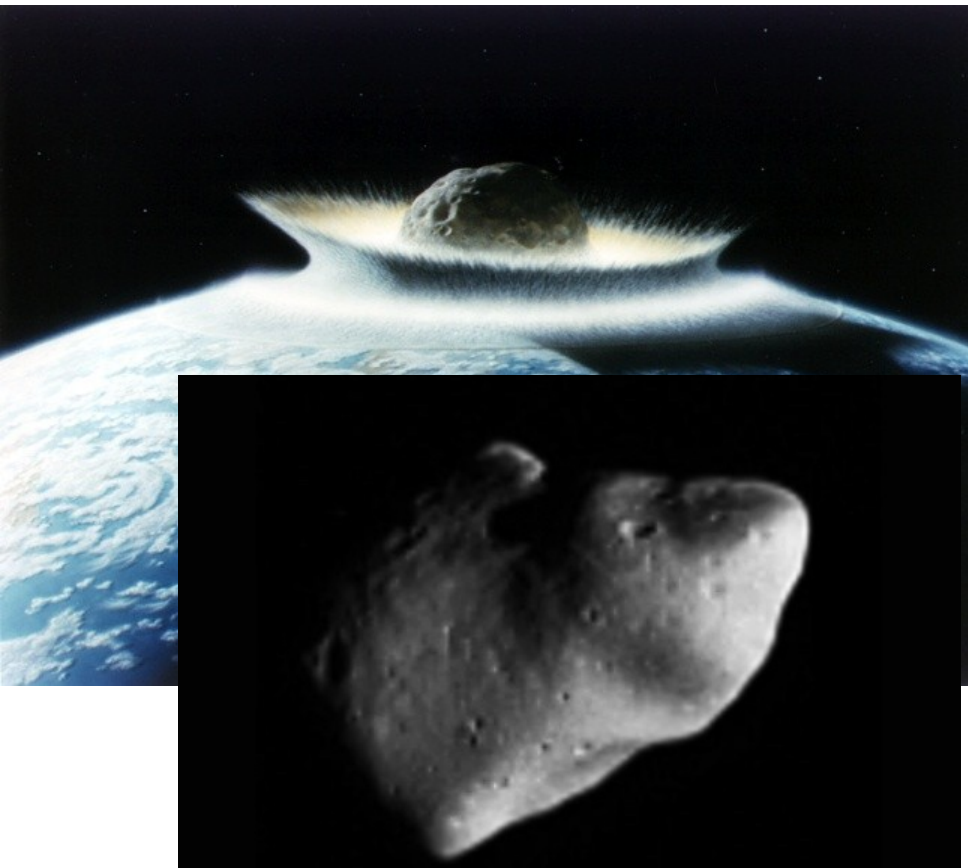Ground-based or space-based ? Or combination ?

Hint: check scintillation
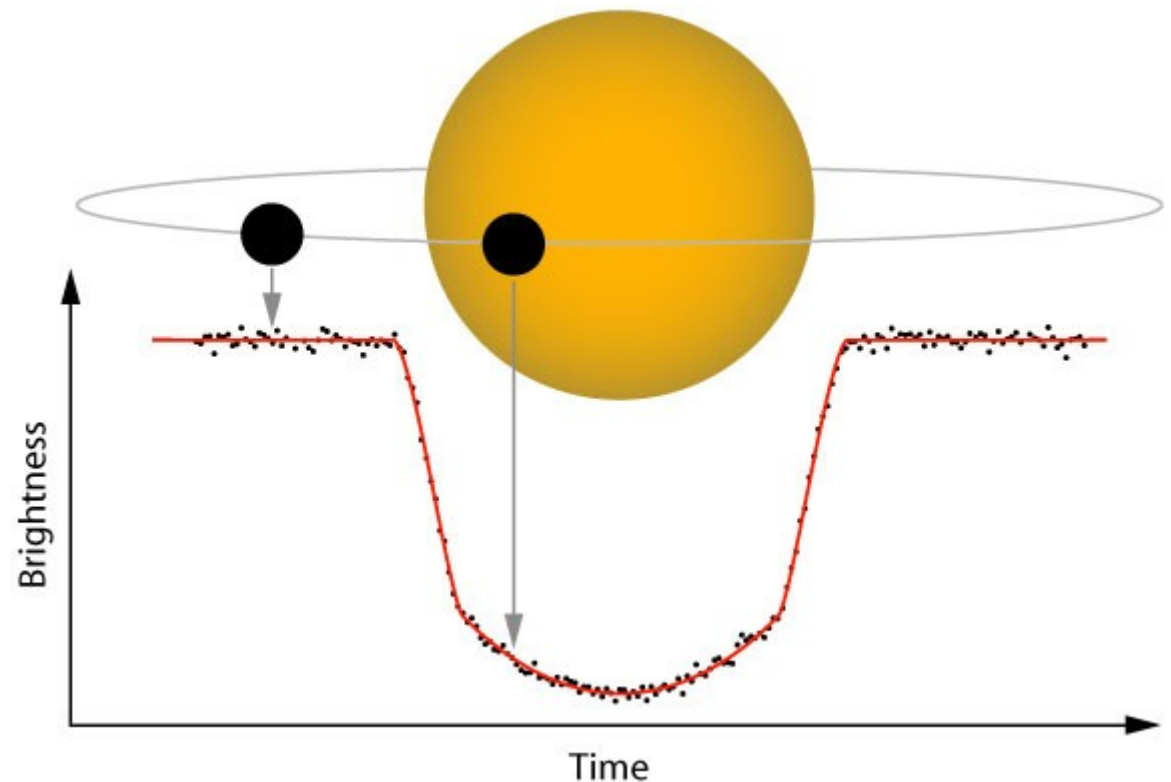
Near-Earth Object (NEOs): are we in danger ?

- detect NEOs down to mass/size sufficient to cause significant damage
- measure their orbits
- what size are they ?

Near-Earth Objects are asteroids with orbits close to Earth's orbit. NEOs could collide with Earth and cause massive destruction. Identification of all NEOs sufficiently large to cause damage is therefore of high importance. Accurate knowledge of their orbits is essential to predict their future position and impact probability with Earth.

This map shows all known asteroids in the neighbourhood of the Earth
The object currently closest to the Earth is 1999 CG9 at 0.0454AU

How do stars die ? watching and counting supernovae in galaxies

- measure supernovae rate & compare with number of existing stars

With ~10^{11} stars per galaxy, and most stars living several billion years, the death rate of stars in a large galaxy is on the order of 1/year. Some of these stars will produce supernovae (the most massive ones). The supernova rate in galaxies provides a measurable link between number of stars and their lifetimes.

Try to monitor a large # of
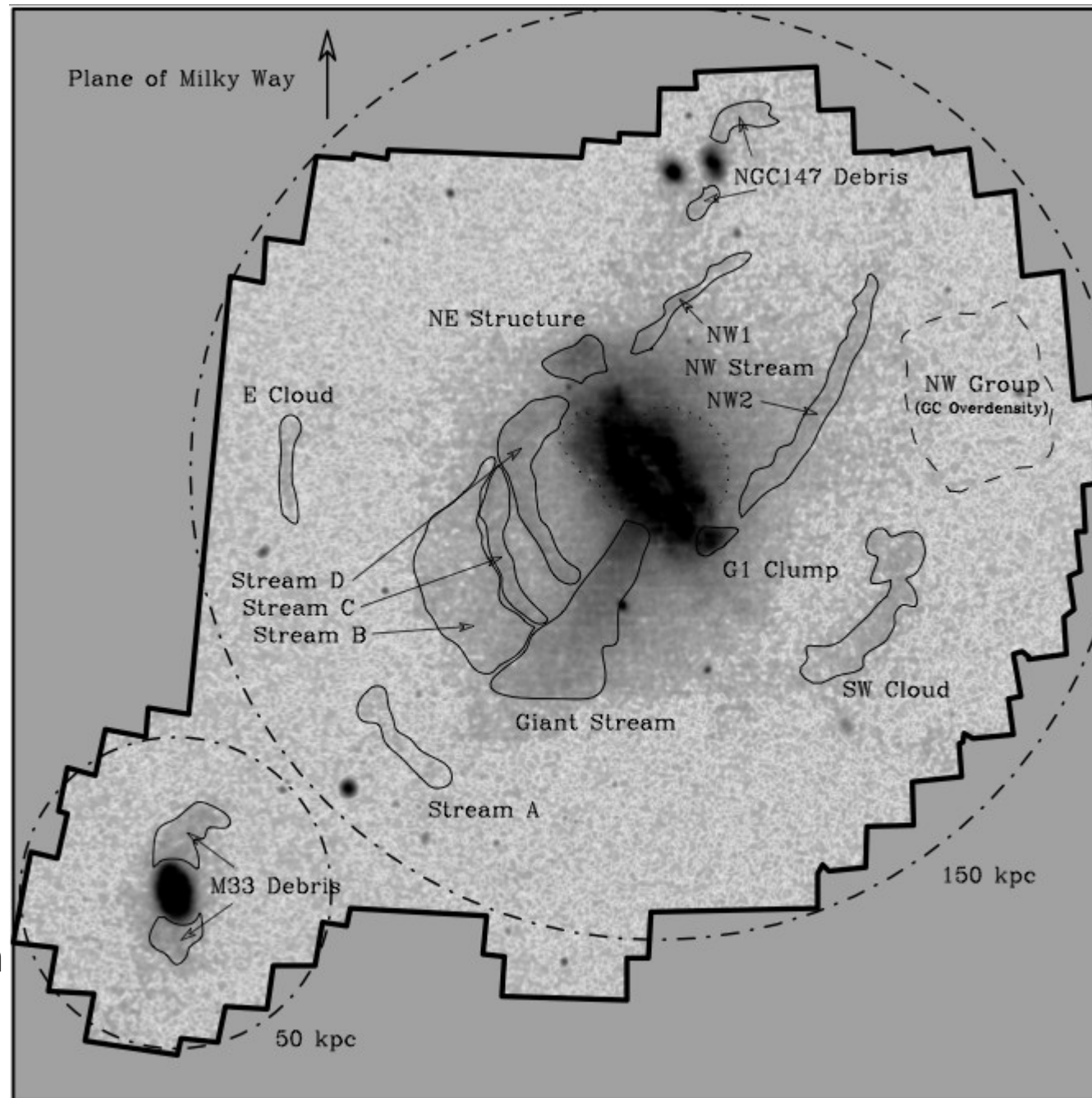Galaxies, with high sensitivity

*Supernova 1994 D in NGC4526
(HST)*

Mapping the outer halos of nearby galaxies
understand history and evolution of galaxies

Perform measurement
for galaxies
within 30 Mpc

PAndAS image of M31 system