(Astro)Physics 344
Observational Optical Astronomy

physics course number = 01:750:344
web page = http://www.physics.rutgers.edu/ugrad/344/
Sakai page = 01:750:344:01 F17
# Personnel

<table>
<thead>
<tr>
<th>Professor</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>Tad Pryor</td>
<td>Jack Hay</td>
</tr>
<tr>
<td>Serin W302</td>
<td>ARC 228</td>
</tr>
<tr>
<td>848-445-8873 (office)</td>
<td>jhay[at]physics.rutgers.edu</td>
</tr>
<tr>
<td></td>
<td>pryor[at]physics.rutgers.edu</td>
</tr>
</tbody>
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(godfather = Prof. Ted Williams)

Please check your email regularly! This is how we will distribute information on schedules, labs, etc. It is also the best way for you to reach us when we are busy and/or travelling.
Professor Tad Pryor

B.S. and Ph.D. in Astronomy
Arrived at Rutgers in January 1988
Optical Observational Astronomy

In the background, the dome of the 4-meter diameter Mayall telescope at the Kitt Peak National Observatory, outside Tucson, Arizona.
Professor Pryor at the 6.5 m diameter MMT (Monolithic Mirror Telescope).

Research interests:
* globular clusters
* dwarf satellite galaxies of our own Milky Way galaxy
Much of my current research is carried out with the Hubble Space Telescope, a 2.4 m diameter telescope in low Earth orbit (about 570 km above the surface).


Requirements

Optional Textbook: Observational Astronomy, 3rd edition by Birney, Gonzalez, & Oesper

Prerequisite: (Astro)Physics 341/342 ("Principles of Astrophysics" with Professors Buckley and Brooks) should be taken previously or, in special cases, concurrently.

Other: a scientific calculator; access to a computer that can connect to the internet. For analysis of images taken with the computer, i.e., "image processing" you will connect to a the astrolab server running Linux using VNC. Can do this with your own computer or the two in the classroom.
Course meetings

Lectures: Serin 401, once a week, Th 6:40-8:00 PM

Labs: Serin 401, times TBD (you will have assigned slots)

In general: one week will be an “observation” week and the following will be an “analysis” week. During analysis weeks, one of us will be “on call” during office hours.
Lectures

We'll talk about material relevant to the labs, but also about optical astronomy in general:

+ techniques: optical telescopes, imaging, spectroscopy
+ science: stars, star clusters, nebulae, galaxies, etc.
Labs

Seven labs planned, most of which will use the 0.5 m diameter telescope of the Schommer Observatory. The tentative list is:

#1: Getting to Know The Sky & IDL
#2: Visual Observing with the 0.5 m Telescope
#3: Introduction to CCD imaging: Measuring Brightness and Position
#4: Observing with a CCD: Photometry of M31 and M32
#5: Measuring the Transit of an Exoplanet
#6: Color-magnitude diagram of a star cluster
#7: Nebular Spectroscopy
Grades

Course grades will be based on a combination of:

+ participation during lecture (5%)
+ preparation for and active participation during labs (5%)
+ lab reports (90%)

Lab reports should be written up individually even if observations were done in teams.
Regarding lab reports...

Do include:

(1) a brief description of the purpose of the observations
(2) a brief description of the observations (e.g., how many images/spectra taken? What day and time? Were any problems encountered?)
(3) a description of your analysis (number-crunching)
(4) a discussion of your results (plots and images help; consider your sources of uncertainty)

Do not include:

(1) unimportant or repetitive steps in observing
(2) detailed description of “routine” analysis steps

Write in active voice ("We did..."), and be faithful to the data!
Absences and late work

Absences:
(a) mine: none currently scheduled
(b) yours: unless you have a medical emergency, tell me in advance or get zero participation points

Late penalty, quoting from website/syllabus:
Maximum of 80% of credit for late labs. No labs accepted after solutions are handed out.
Good advice for this class (and beyond)

Ask questions (even if they seem “stupid”), and speak in lab!

Record everything you do in lab in a single, chronologically organized lab notebook. (This will help you remember what you did even days or weeks later, and will make it easier for us to help troubleshoot if there are problems.)

Remember that every measurement comes with a unit and an uncertainty.
Planning an Observation

- What information is needed about the target?
  - Consider the star KIC 8462852 (aka Tyc 3162-665-1)
Planning an Observation

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  - Might recognize it as Boyajian’s star or Tabby’s star
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Coordinate systems: Earth's point of view

Celestial coordinates:

+ **declination** ranges from 90º (north celestial pole) to -90º (south celestial pole) – like latitude

+ **right ascension** ranges from 0º (for stars, galaxies, etc. that transit at midnight on 9/21) to 90º (farther east)... to 360º – like longitude

Celestial coordinates of solar system objects change (relatively) rapidly.
Coordinate systems: telescope's point of view

**Horizontal coordinates:**

- **elevation** ranges from 90° (zenith) to 0° (horizon)
- **azimuth** ranges from 0° (north) to 90° (east) to 180° (south) to 270° (west) to 360° (north) around the horizon
Coordinate Systems: Rutgers View

Squash the bowl of the visible sky flat to a disk for display – note that this causes distortion.

The edge of the disk is the horizon. The center of the disk is the zenith.
North Celestial Pole (NCP) – where the Earth’s rotation axis intersects the celestial sphere.

NCP altitude is $90^\circ - \text{latitude} = 90^\circ - 40.52^\circ = 49.48^\circ$

Zenith at Dec. of 40.52°
0 hours R.A. is where the Sun crosses the celestial equator going north (on March 21\textsuperscript{st}).

R.A. increases towards the East. Thus, objects with larger R.A.'s cross the meridian later.
Celestial coordinates: units

Right ascension ("R.A.", $\alpha$) & declination ("Dec.", $\delta$) = celestial latitude and longitude that describe a source's position.

R.A. units: hours, minutes, & seconds of time
   24 hours = 360 degrees $\Rightarrow$ 1 hour = 15 degrees

Dec. units: degrees, minutes, & seconds of arc (60 minutes = 1 degree)

Example # 1:
   A source has R.A. 14:11:45.2.
   What is this in units of degrees?

Answer:
   $15 \times (14 + 11/60 + 45.2/3600) = 212.938333^\circ$.

(Note that R.A. 23:59:59 corresponds to 359.995833\(^\circ\).)
Celestial coordinates: source separations

Example # 2:
Source B lies at 02:33:32.9 +15:24:06.
How far apart are they on the sky?

For spherical coordinates, must use spherical geometry.

Answer:
\[ \Delta \delta \text{ is easy: } (24 \times 60 + 6) - (32 \times 60 + 29) = -503'' = -8.383' \]
\[ \Delta \alpha \text{ is harder: } 15 \times (32.9 - 24.5) \times \cos(15.4715) = 121'' = 2.024' \]

For small angles, separation \( \approx \sqrt{(\Delta \delta)^2 + (\Delta \alpha)^2} = 8.6' \)
Celestial coordinates: directions


How do they *look* on the sky?

\[ \Delta \delta = -8.383' \]
\[ \Delta \alpha = 2.024' \]

Note that east/west are reversed compared to terrestrial maps because you are looking up rather than down.
Celestial coordinates: precession

When can a source's right ascension and declination change?

(1) It's a solar system object (Sun, moon, planet, asteroid, etc.). The Sun moves \(\sim 1^\circ/\text{day}\).

(2) It’s a nearby star with a high “proper motion” (e.g., \(\alpha\text{ Cen}\)). 4470 stars known with p.m. > 0.5 arcsec/yr.

(3) We wait long enough that the earth's rotation axis wobbles a little (i.e., it precesses). Coordinates can change by tens of arcseconds/yr.

To deal with (3), every R.A. and Dec. must be specified with an epoch ("B1950" and "J2000" are common).
Changing “pole star” over the period of the precession of the equinoxes from *The Stars: A New Way to See Them* by H. A. Rey.
Astronomers use two principal time conventions:

1. **UT = Universal Time**
   - This is a (mean) solar time that corresponds (apart from daylight savings) to the local time in Greenwich, England. At a given moment, UT is the same everywhere.

2. **LST = Local Sidereal Time**
   - This is the R.A. of objects on the meridian right now. At a given moment, LST is different at different terrestrial longitudes.