Due Date: Wednesday April 6

The purpose of this project is to give you hands-on experience with astronomical imaging, basic data reduction, and basic image analysis. This project is worth 100 points and comprises 20% of your grade in the class.

Part 1 includes instructions and requirements for the observing part of the project. Part 2 (which will be distributed later in the semester) will describe the analysis goals after your data have been collected at the observatory.

Each student is assigned to a group of 2-3, and each group is scheduled to spend three evenings observing at Hard Labor Creek Observatory (Rutledge, GA). While at HLCO, students are expected to take turns operating the telescope and imaging camera so that all students can develop a familiarity with the equipment.

Objectives:
-- practice operating a telescope and imaging camera
-- practice at carrying out proper observing techniques
-- familiarity with IRAF, the astronomical community’s standard software for data reduction and simple analysis
-- practice with basic data reduction for astronomical imaging
-- practice making simple measurements and plots

While datasets acquired at HLCO will be shared between the students who observed on that night, each student is required to submit his/her own project showing the results of his/her own data reduction and analysis.

The project summary:

You will be observing Delta Scuti pulsating variable stars. One full night, from evening twilight to morning twilight, will be dedicated to multi-color monitoring of a single pulsating star, during which the system will undergo more than one full pulsation period. The remaining nights will be divided into a few hours spent monitoring other systems (if possible given weather conditions).

The observatory:

Hard Labor Creek Observatory is located in Rutledge, GA. Directions and GPS coordinates can be found here: http://www.astro.gsu.edu/HLCO/directions.html
Each student has been assigned to a group of three, and each group has been scheduled for 3 nights at the observatory during the semester. The observing schedule is reproduced below for reference.

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<td>1</td>
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<td>3</td>
<td>4</td>
<td>5 Group 2</td>
<td>6 Group 4</td>
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<td>1</td>
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<td>2</td>
<td>Freddie</td>
<td>Kristina</td>
<td>Ian</td>
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<td>4</td>
<td>Steven</td>
<td>Leonardo</td>
<td>Ann</td>
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Students in each group should make the final decision together about whether to travel to the observatory on a scheduled night or not. Please get contact information (i.e., phone, email, text...) for all group members sooner rather than later.

**Reasons not to go to HLCO:**
- it is snowing or icy and the roads are dangerous
- it is foggy and the roads are dangerous
- there is a tornado warning for the area or severe thunderstorms
- there are very high winds, causing potential danger from falling trees
- it is pouring rain in Atlanta and in Rutledge with no signs of stopping all night long

**Important Note:**

All groups are required to go to HLCO for their first night, as long as it is safe, even if it is impossible to open the dome. This is for training and familiarity with the equipment. Someone (either Dr. Bentz, Katie Gordon, or Clay Turner) will meet you there the first night. You should arrive 45-60 minutes before sunset.
If it is partly cloudy, your group should still go to HLCO and plan to observe what you can. Useful resources for monitoring the weather and making a “go/no-go” decision:
- HLCO weather page http://www.astro.gsu.edu/HLCO/weather.php
- Rutledge weather from NOAA (with satellite images) http://goo.gl/EcPEmq

**Reasons to keep the dome closed or shut it immediately if it’s open:**
- there is snow or ice on top of the dome
- it is raining or snowing or sleeting (moisture is falling from the sky)
- it is foggy or you can see moisture in the air in a flashlight beam or see it condensing on cars or metal outside
- high winds are coming from the direction you need to point the telescope
- the humidity has increased and the numbers have turned red on the HLCO weather page
- the radar shows rain coming towards HLCO (turn on the animation to see the loop)

*** Remember: your top priority is always your group’s safety, followed by the safety of the telescope and instrument. Do not ever put yourselves or the equipment in danger.

Dress warmly and bring extra layers with you. Middle of the night winter weather in Georgia can easily be below freezing, and you will be tired and sitting still, making it much worse. You will spend quite a bit of time in the dome during the night. Hats, gloves, scarves, thick coats, thick socks, extra layers under pants and shirts, whatever you have, bring it with you. Blankets too. It’s better to be overprepared rather than shivering and wishing you had brought something with you.

Food and hot beverages are encouraged, but you must clean up after yourself. No one is paid to clean up after you. The observatory is not visited often in the winter, so messes tend to stay for a long period of time, attracting pests that can sometimes be dangerous (e.g., scorpions). There is a coffee maker, microwave, refrigerator, and stove top available, so you can have a continuous supply of coffee or hot chocolate or ramen to keep you warm and awake. Bring your own drinking water (the tap water may be ok, but I don’t trust it myself).

**The observations:**

It is important that everyone has read the observing manual (on the class website) in advance to help prepare for the observations as much as possible. Check it before each trip for any changes or updates.

**Goal 1:** Each group will spend one full night monitoring a short-period pulsating star from the list below. You will observe the star in B, V, and R, with emphasis on the V observations to carefully cover the light curve (observing order should be something like B-V-R-V repeat). Choose your target so that its coordinates will allow you to maximize the time you can observe it on your scheduled night. Be sure to bring a finding chart that matches the field of view of the detector so that you can locate your target and position it appropriately on the detector (many finding chart generators exist online - it’s best to find one that uses CCD images of the sky for comparison with the observations that you will be taking).
The weather is likely to vary between your scheduled dates. To the best of your ability, dedicate the night with the best conditions to following your chose pulsating star. If you have a decent night (clear or only slightly cloudy) early in the campaign, use it for this goal. As your nights pass, your opportunities decrease but the weather might be better. All you can do as an observer is play it by ear and make the best decisions you can based on the information that you have.

Delta Scuti stars:

<table>
<thead>
<tr>
<th>Name</th>
<th>RA(1950)</th>
<th>Dec(1950)</th>
<th>P(days)</th>
<th>ΔV(mag)</th>
<th>V(mag)</th>
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<tbody>
<tr>
<td>TV Lyn</td>
<td>07 29 50</td>
<td>+47 54.7</td>
<td>0.2407</td>
<td>0.440</td>
<td>11.45</td>
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<tr>
<td>UY Cam</td>
<td>07 53 16</td>
<td>+72 55.4</td>
<td>0.2670</td>
<td>0.340</td>
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<td>+42 58.2</td>
<td>0.0983</td>
<td>0.180</td>
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<td>+46 21.8</td>
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<td>AE UMa</td>
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<td>+44 17.5</td>
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<tr>
<td>UW CVn</td>
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<td>+28 26.7</td>
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**Goal 2:** Each group will spend their remaining observing time monitoring as many pulsating stars as possible from the list above in V only to verify the reported pulsation period. Because you will not know where the star is in its cycle when you arrive at it, you should spend the equivalent of at least two pulsation periods monitoring the star so that you will be likely to catch two maxima or minima so you can verify the period. Preparation should again include finding charts as well as a schedule for the night with the time ranges during which you can observe each object. Be sure you have these plans ready for your first trip, because it may not be a night with mediocre weather that won’t allow you to attempt Goal 1.

**Calibrations and supporting observations for both goals:**
In addition to the science goals, you will need to take calibrations each night at HLCO to help you make accurate measurements from your images when you get home. These calibrations include the following:

1. **Beginning of the night calibrations**
   -- biases x 10
   -- dome flats (20,000-30,000 counts per image in >2sec exposure)
     5 x B  5xV  5xR
   -- sky flats (if clear, do not bother if partly cloudy)
     5 x B  5xV  5xR

The observing manual will help you with these. We will also talk about them in detail in class.
(2) Calibrations during the night
-- standard star field in B,V,R every 2-3 hours (may need one field for first half of night, other field for second half)

Information and charts for Landolt standard star fields are available on many web sites (just ask Google for “Landolt standards”). Choose appropriate fields for your observations. The best fields will have two or more standard stars in them, and some observatories list “recommended” fields based on all the options. Make sure that each time you go back to your standard star field, the field is centered properly so you can see all your standards.

(3) End of the night calibrations
-- dark frames x 5 to match every exposure time used for on-sky exposures

Be sure to read the entire observing manual before you show up at the telescope, so that you are familiar with the contents (even if they don’t all make sense yet), and you know where various topics are covered. NEVER EVER show up at the telescope unprepared. Telescope time is a rare, and often times expensive, commodity. Don’t waste it.

The observing logs:

Observing logs must be completed for each trip to HLCO. It will work best if one person is designated to handle the log for each trip (but not necessarily the same person for every trip). Logs should be shared with all the group members upon return after each trip, as should all data collected.

Example electronic logs can be found here:
http://www.astro.gsu.edu/~bentz/a4100.6100/photlog_template.xls

Be sure to fill in all of the fields. Use your log to help you remember every little thing that happened that night. You will be working with your data days or weeks after you take it. Don’t expect that you will remember what happened in the middle of the night. Log it. In particular, use the notes column extensively to help you identify problem images immediately. Was it a test image? Were the lights on? Did someone turn on a flashlight in the middle of the image? Anything of note, no matter how small, should go here.

Weather conditions should be thoroughly monitored throughout the night on the HLCO weather page and documented in your log including the following:
-- clouds
-- wind
-- humidity
-- moon phase and proximity
-- temperature
Be sure to copy all your data from the night to a thumb drive and bring it back with you. Put an extra copy on the laptop of the person who was in charge of the observing log for the night too, in case anything should happen to the thumb drive.

Collect all trash and food leftovers and bring them back with you. There are no janitorial services at HCLO during the winter because we have no winter open houses for the public. Leaving trash or food of any kind will invite pests into the building (mice, cockroaches, scorpions, and other yucky creepy crawlies).

Triple-check that everything is closed and shut down. You will be tired, but there will be three of you. Don’t assume someone did something, make sure you see it for yourself.

Watch carefully for deer on the drive home. Everyone should be helping the driver stay vigilant, no one gets to snooze on the drive back.

Part 2 will describe what to do with your data once you get it home.