Development of an Innovative Observational Astronomy Class for High School Students in Collaboration with the University of Texas/Rio Grande Valley

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DEVELOPMENT OF AN INNOVATIVE OBSERVATIONAL ASTRONOMY CLASS FOR HIGH SCHOOL STUDENTS IN COLLABORATION WITH THE UNIVERSITY OF TEXAS/RIO GRANDE VALLEY

A Thesis

by

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Submitted to the Graduate College of
The University of Texas Rio Grande Valley
In partial fulfillment of the requirements for the degree of

MASTERS OF SCIENCE IN INTERDISCIPLINARY STUDIES

December 2017

Major Subject: Physics

DEVELOPMENT OF AN INNOVATIVE OBSERVATIONAL ASTRONOMY CLASS

FOR HIGH SCHOOL STUDENTS IN COLLABORATION WITH

THE UNIVERSITY OF TEXAS/RIO GRANDE VALLEY

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December 2017

ABSTRACT

Hendrick, Alan W., Development of an Observational Astronomy Class for High School Students in Collaboration with the University of Texas/Rio Grande Valley, Masters of Science in Interdisciplinary Studies (MSIS), December, 2017, 63 pages, 6 figures, references, 16 titles.

The vision presented by the National Academy of Science Standards is for all students to spend more time 'doing' science in order to develop science literacy and be better prepared not only for college but also in understanding and participation in global current events. A course in observational Astronomy is just that, an opportunity for student to "do 'science by collaborating with actual scientists in real research. The course follows a path in which students learn foundational knowledge and apply this knowledge to complete a successful celestial observation, interpreting the results by making inferences and predictions. This paper begins with a statement of need followed by specific learning objectives in a Texas Essential Knowledge and Skills format. Resources and activities follow along with specific directions on how to plan and operate the Observatory at Las Palms State Park in Olmito, Texas. Participation in this course will give students confidence to pursue science related subjects in higher education.

DEDICATION

I first want to recognize Dr. Phillip Dukes who talked me into continuing my education after having just completed a master program at 62years of age. This project was inspired by all the students in the inaugural Observational Astronomy class of 2016 at the University of Texas Rio Grande Valley led by Dr. Mario Diaz and invited guests Carlos Colazo and Raul Melia who baby stepped us into the world of observing the stars.

ACKNOWLEDGEMENTS

I am grateful to Dr. Mario Diaz who was the chair of my committee. I would also like to thank all the team members associated with the observatory: Richard Camuccio, Moises Castillo, Juan Garcia, Americo Hinojosa Lee, Ervin Vilchis, Erick Vallarino, Raúl R.Melia, and Carlos Alberto Colazo. I would also like to thank the other committee members who are Dr. Edgar Corpus, Dr. Phillip Dukes and Dr. Soma Mukherjee.

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CHAPTER I

INTRODUCTION

Course Description

Astronomy is probably the oldest natural science and even probably practiced in prehistoric times. Advances in technology allowing a look further into space have made for an exciting era in astronomy. The purpose of this course is to extend the present adopted course in high school astronomy by introducing students to techniques to complete an actual astronomical observation with a telescope and then to apply the images taken from these observations to current software for analysis.

The students will be introduced to ancient history of observational astronomy, electromagnetic radiation, optics and telescopes, and the basics of how to perform an observation and what images can reveal about stars, planets, and minor planets using current software.

The primary audience for this course are 11th and 12th grade high school students but could also include introductory astronomy classes at the university level or post high school students attending an institute of technology.

Course Justification

The leading statement of purpose of the Texas Education Agency is to prepare student to be career and college ready, therefore, whenever and wherever an educational institution can offer student's opportunities for authentic learning, it should do so. Observational astronomy is a course which gives students practical and hands on experience at authentic science and could be foundational to any career in science but specifically can prepare students to work with research in universities, planetariums, NASA, national observatories, aerospace, and many public service positions. The course is unique because it's primarily student focused, collaborative in structure, and it is about doing science that has not only statewide but also global implications.

Measurement and interpretation of data from the sky has a long history. Recent detection of gravitational waves by a collaborative effort involving the University of Texas, have made headlines and validated of a theory postulated by Einstein many years ago. Events in the sky are sending information to earth and this course in an introduction to the basics of the universe's language.

Students Needs

In a Call to Action, from the National Academy of Science Standards, science literacy for all students is the vision and the repeated theme throughout this document, in order to achieve the vision, is' doing' science. Students need to experience the beauty of real science with as many senses as possible. Having learned the basics of observational astronomy, students will have gained confidence in the doing of science, collaboration, research, problem solving, data analysis, and learn the skill of asking lots of questions.

The skills learned from this course will prepare students for any field in science and more specifically fields in astronomy and space exploration. Students will become good observers while using tools from many other fields: optics, chemistry, atomic physics, computer science, mechanical and electrical engineering, biology, and fluid dynamics, to name a few. Astronomy is very interdisciplinary and can connect with many fields in science.

CHAPTER II

ESSENTIAL KNOWLEDGE AND SKILLS

General Requirements

Observational Astronomy

Students shall be awarded one credit for successful completion of this course. Suggested prerequisite: one unit of high school science and algebra with basic trigonometry. This course is recommended for students in Grades 11 or 12.

Introduction.

(1) In Observational Astronomy, students conduct laboratory and field investigations, use scientific methods, and make informed decisions using critical thinking and scientific problem solving. Students study the following topics: observational astronomy in civilization, patterns. location and objects in the sky, our place in the celestial sphere, planets, the sun, stars, galaxies, cosmology, and methods of observing celestial bodies. Students who successfully complete Observational astronomy will acquire knowledge within a conceptual framework, conduct observations of the sky, work collaboratively, and develop critical-thinking skills. The following is a list of student learning objective during a typical school year.

(2) Nature of science. Science, as defined by the National Academy of Sciences, is the "use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process. Physical, mathematical, and conceptual models describe this vast body of changing and increasing knowledge. Students should know that some questions are outside the realm of science because they deal with phenomena that are not scientifically testable.

(3) Scientific inquiry. Scientific inquiry is the planned and deliberate investigation of the natural world. Scientific methods of investigation can be experimental, descriptive, or comparative. The method chosen should be appropriate to the question being asked.

(4) Science and social ethics. Scientific decision making is a way of answering questions about the natural world. Students should be able to distinguish between scientific decision-making methods and ethical and social decisions that involve the application of scientific information.

(5) Scientific systems. A system is a collection of cycles, structures, and processes that interact. All systems have basic properties that can be described in terms of space, time, energy, and matter. Change and constancy occur in systems as patterns and can be observed, measured, and modeled. These patterns help to make predictions that can be scientifically tested. Students should analyze a system in terms of their components and how these components relate to each other, to the whole, and to the external environment.

Knowledge and skills

(1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

(a.) Demonstrate safe practices during laboratory and field investigations; and

(b.) Demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) Scientific processes. The student uses scientific methods during laboratory and field investigations. The student is expected to:

(a.) Know the definition of science and understand that it has limitations, as specified in subsection (b) (2) of this section;

(b.) Know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(c.) know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but may be subject to change as new areas of science and new technologies are developed;

(d.) Distinguish between scientific hypotheses and scientific theories;

(e.) Plan and implement investigative procedures, including making observations, asking questions, formulating testable hypotheses, and selecting equipment and technology

(f.) Collect data and make measurements with accuracy and precision;

(g.) Organize, analyze, evaluate, make inferences, and predict trends from data, including making new revised hypotheses when appropriate;

(h.) Communicate valid conclusions in writing, oral presentations, and through collaborative projects; and

(i) Use astronomical technology such as telescopes, binoculars, sextants, lasers, computers, and software

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(a) In all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(b) Communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

(c) Draw inferences based on data related to promotional materials for products and services;

(d) Evaluate the impact of research on scientific thought, society, and the environment; and

(e) Describe the connection between astronomy and future careers." (TEA)

(4) Science concepts. The student recognizes the importance and uses of astronomy in a historical context. The student is expected to:

(a) Research and illustrate the use of observational astronomy in ancient civilizations such as the Egyptians, Mayans, Aztecs, Europeans, and the native

Americans and historical origins of the perceived patterns of constellations and the role of constellations in ancient and modern navigation;

(b) Research and arrange in order contributions of scientists to our changing understanding of astronomy, including Pythagoras, Aristarchus, Ptolemy, Aristotle Copernicus, Tycho Brahe, Giordano Bruno, Kepler, Galileo, Jean-Bernard-Léon Foucault, Newton, Einstein, and Hubble, and;

(c) Research and discuss the contributions of women astronomers, including Maria Mitchell, Vera Cooper Rubin, Carolyn Proco, Nancy Roman, Jocelyn Burnell, Debra Fischer, Carolyn Shoemaker, Henrietta Swan Leavitt, Heidi Hammel, Sandra Faber, Jill Tarter, Vera Rubin, and Annie Jump Cannon.

(d) Correlate the contributions of modern astronomy to today's society, including the identification of potential asteroid/comet impact hazards, the importance of cataloging orbiting celestial bodies, and gathering information techniques from all types of electromagnetic radiation reaching the earth including gravitational wave

(5) Science concepts. The student knows the earth's place in distance, time and motion in the universe. The student is expected to:

(a) Describe and solve problems using units of distance in astronomy, including Astronomical Units, light years, parsecs, powers of ten, solar masses, solar radius, the astronomical triangle, stellar parallax and;

(b) Describe and solve simple problems with solar time, arc seconds, arcminutes, local apparent/mean time, sidereal time, universal time (Greenwich time) and coordinated universal time, Julian date and;

(c) Explain and sketch motion in terms of redshifts, Hubble constant, and the Doppler Effect.

(d) Compare and contrast the scale, size, and distance of the Sun, Earth, and the planet system including the oort cloud and proxima centauri through the use of data modeling and astronomical units.

(e) Illustrate by use of models such as sand, marbles and balls the scale of size and distance of celestial objects in fundamental metric astronomical units

(f) Create a cosmic calendar of Time compressed to one year and explain time in terms of light from distant stars and galaxies.

(g) Estimate and compare travel times of known speeds on earth to travel time to distant astronomical locations

(6) Science concepts. The student develops a familiarity with the night sky and is able to locate a celestial object. The student is expected to

(a) Describe, paraphrase, and model the terms associated with location such as: celestial sphere, latitude. Longitude, right ascension, declination, prime meridian, zenith, nadir, altitude, elevation, and;

(b) Sketch the celestial equator, ecliptic, celestial north and south pole, the hour circle, vernal equinox, and culmination

(c) Observe and record using software the apparent movement of the Moon, planets, minor planets and stars in the nighttime sky at different seasons, locations, and at different times

(d) Recognize and identify types of celestial objects such as stars, (white dwarf, red, neutron, binary, variable, black holes) and non-stellar, deep sky objects (nebulae, star clusters, galaxies) and;

(e) Minor plants such as (dwarf planets, asteroids, Trojans, centaurs, Kuiper belt objects, and other trans-Neptunian objects

(7) Science concepts. Students understand concepts of light and various ways light carries information. The student will be able to:

(a) Illustrate the electromagnetic spectrum and the visible part of this spectrum.

(b) Describe various ways information is conveyed (Neutrinos, meteorites, cosmic rays, gravitational waves, electromagnetic waves).

(c) Distinguish between particles with mass and particles without mass

(d) Explain and illustrate the following spectral fingerprints (continuous, emission, absorption, and black body)

(8) Science concepts. The student knows basic optical concepts related to how telescopes work. The student is expected to

(a) Describe the two basic types of telescopes, refractors and reflectors

(b) Illustrate function and discuss the advantages and the disadvantages of refracting telescopes (chromatic aberration

(c) Illustrate function and describe the advantages and disadvantages of reflecting telescopes

(d) Combine the F number, brightness, size, and clarity to describe the image produced by a telescope

(e) Explain and illustrate the light gathering power and the resolving power of a telescope in terms of photons

(f) Explain and calculate the magnifying power of a telescope (least important) knowing the focal length of the telescope and the focal length of the eyepiece.

(g) Explain and discuss what is meant by ‘seeing’ in astronomy and relate ‘seeing’ to the atmosphere effect. (Reddening and extinction)

(h) Describe ways to minimize the atmosphere effect on an image from a telescope.(Speckle interferometry and adaptive optics)

(9) Science concepts. The student knows the basic concepts of the properties of stars which influence the images recorded by telescopes. The student is expected to:

(a) Describe main sequence stars and what fraction of stars are classified as main sequence.

(b) Describe apparent brightness of a star and relate this concept to flux

(c) Calculate flux with the inverse square law of brightness

(d) Explain and give examples of the magnitude system of star

(e) Distinguish between apparent and absolute brightness and luminosity

(f) Explain and assess the relationship between color and temperature (Wien's Law) of stars and black body curves.

(10) Science concepts. The students know ways to discover the properties of stars from an observation. The student is expected to:

(a) explain the concept of spectroscopy and absorption lines

(b) recognize the pattern of spectral emission lines of the su

(c) Calculate simple problems involving radial velocity using the concepts of Doppler shift and wavelength and tangential velocity from angular speed and distance

(d) compare and contrast between redshift and blue shift

(e) Describe and illustrate the method to determine a star's relative mass using Kepler's third law[(mass 1 + mass 2) = $(\text{separation distance})^3/(\text{orbital period})^2$], the diameter size, and orbital period. (Solar Mass

(f) Explain and calculate the size of stars using light curves from binary stars and the sun's temperature and radius as a reference

(g) Construct a chart to illustrate types of stars relating color to class, temperature, solar mass, solar diameter, and prominent spectral line

(i) Describe the use of the Hertzsprung-Russell diagram to explain intrinsic properties of main sequence star

(11) Science concepts. The student knows basic components of a CCD (Charged Coupled Device) camera. The student is expected to

(a) Define and explain with an illustration the three main parts of a CCD camera.

(b) Compare the efficiency of the light gathering power of a CCD to photographic film.

(c) Describe and explain the three main phases in image formation of the CCD (clearing, exposure and readout)

(d) Illustrate a pixel array and;

(e) Describe what is meant by pixel size full well capacity

(f) Describe the use of binning to decrease read noise

(g) Explain dark current and what a CCD can do to minimize this flow of electrons

(12) Science concepts. The student knows the macro steps in planning an observation. The student is expected to:

(a) Appraise the atmospheric conditions and temperature using current website such as the National Weather Service

(b) Indicate the latitude, longitude, and elevation of the local observatory or place of observation.

(c) Recommend a target star and find and record location in the sky using Stellarium software or

(d) Access the Minor planet Center and navigate successfully to decide on an other than star celestial object to observe at the proper latitude and longitude.

(e) Apply correct terminology and order for entering data to the minor planet center to print an ephemeris for a particular celestial object and;

(f) Print an ephemeris with the correct UT time and date considering daylight savings time

(g) Identify the meanings of the heading across the top of the ephemeris.

(13) Science concepts. The student knows the micro steps to preparing the telescope. The student is expected to

(a) Operate the lowering of the shutter and dome movement safely and ensure cover to telescope is carefully removed after opening.

(b) Demonstrate steps to power the telescope including turning on the CCD camera and checking lights for confirmation (including computers).

(c) operate appropriate software such as Maxim DL and Cartes du Ciel

(d) Open camera control and connect camera

(e) Discover the current ambient temperature and adjust the cooler to the camera to reflect a difference of 25 to 30 degrees C colder. Confirm power to cooler less than 70% after reaching target temperature.

(f) Open telescope under cartes du ciel and connect to software to telescope.

(g) Set up chart coordinate to mean J-2000

(14) Science Concepts. The student knows the steps to align the telescope. The student is expected to:

(a) Describe all safety precautions when operating the telescope.

(b) Properly use the handset to move telescope to polar alignment of zero (base) and 90 degrees (telescope)

(c) Comply with the hand set commands to align scope with Polaris and fine-tune align with the viewfinder

(d) Comply with handset commands to find next brightest star

(e) Create a 1 second exposure of the star and align with crosshairs to center of screen (let camera continue to take pictures)

(g) Focus image with focus control

(15) Science Concepts. The student knows how to slew telescope to the target. The student is expected to:

(a) Properly apply coordinates to the software and slew the telescope safely

(b) Create single exposure practice images to adjust binning and exposure time

(c) Identify the field and center the image keeping star references in the FOV.

(d) Re-adjust the focus if needed

(e) Use of control and ensure that the target and the reference stars do not exceed the linearity limit.

(16) Science Concepts. The students knows the process used to take a series of images. The student is expected to:

(a) Set the image path and choose appropriate binning

(b) Create a new file with name of observation for auto save

(c) Choose the appropriate filter and exposure time

(d) Assess the length of observation time and decide number of exposures

(e) Create images and monitor telescope for drift and dome position

(17) Science concepts. The student knows how to process images. The student is expected to:

(a) Calibrate the images using the appropriate software

(b) Reduce the images using the appropriate software.

(c) Stack images with correct software

(d) Identify the correct target in the images

(e) Perform an astrometry on the images using the correct software

(f) Prepare a report for submission to the MPC (minor planet center) after verifying the quality or accuracy of the observation

(g) Analyze images by doing photometry and making a light curve with fotodiff software

(h) Interpret light curve results related to wave pattern, velocity, period of rotation, and magnitude.

CHAPTER III

RECOMMENDED RESOURCES

Lesson Sources

The following primary sources are free and written by many authors who have contributed to the work. The information is very comprehensive and complete. The sites also direct student to other resources.

Free Books and Notes Online

A. https://cnx.org/contents/LnN76Opl@13.86:_45u6IpQ@4/Introduction

B. http://www.astronomynotes.com/index.html

C. http://www.sixdayscience.com/curriculum/textbook/

Websites and Books

A. https://www.jpl.nasa.gov/

B. Lecture-Tutorials for Introductory Astronomy, 3rd Edition 3rd Edition by Edward E. Prather (Author), Slater Timothy F (Author), Jeff P. Adams (Author), Gina Brissenden (Author)

C. Astronomy and Astrophysics ‘A Instructor's guide’ by Sarah Salviander PhD UT

D. Learner-Centered Astronomy Teaching: Strategies for ASTRO 101 1st Edition by Timothy F. Slater (Author), Jeffrey P. Adams (Author

B.https://www.nasa.gov/offices/education/programs/descriptions/CenterforAstronomyEducation.html

Software Specifications

The following software is mostly free or very inexpensive to purchase a site license. The software is to be used to familiarize students with the celestial sphere and help with doing image processing.

Maxim DL (diffraction limited)-- https://diffractionlimited.com/help/maximdl/MaxIm-DL.htm

a. MaxIm DL is specifically designed for astronomical imaging and other low-light level applications. It operates scientific-grade CCD cameras, DSLR cameras, low-cost CCD imagers, and webcams and other video sources. It also controls filter wheels, focusers, autoguiders, telescopes, focal plane rotators, and observatory domes. A wide variety of hardware is supported through both ASCOM drivers http://ascom-standards.org and proprietary and third-party plug-in drivers. MaxIm DL also includes a wide variety of image processing and analysis features.

Carte du Ciel—sky chart (free)- https://www.ap-i.net/skychart/en/start

a. This program enables you to draw sky charts, making use of the data in many catalogs of stars and nebulae. In addition the position of planets, asteroids and comets are shown.
b. The purpose of this program is to prepare different sky maps for a particular observation. A large number of parameters help you to choose specifically or automatically which catalogs to use, the colour and the dimension of stars and nebulae, the representation of planets, the display of labels and coordinate grids, the

superposition of pictures, the condition of visibility and more. All these features make this celestial atlas more complete than a conventional planetarium.

Stellarium – free open source- http://stellarium.org/

a. Stellarium is a free open source planetarium for your computer. It shows a realistic sky in 3D, just like what you see with the naked eye, binoculars or a telescope.

Poth - http://ascom-standards.org/FAQs/POTH.htm

a. POTH is an incredibly useful tool for both testing and routine observing. It started out as a "plain old telescope handset" (hence the acronym), but it has grown a lot since then. We can thank Jon Brewster for POTH. Let's look at a block diagram of a typical usage:

Fotodif - http://www.astrosurf.com/orodeno/fotodif/

a. The objective of this program is to provide the necessary tools for the production of long photometric serrations, both of relative and absolute magnitude, which can extend several hours. It also has two sections devoted to the search of short period variables and the analysis of periods.
b. FotoDif is able to track mobile objects through the field, so it is also useful for studying, for example, the rotation of asteroids. In the rest of the manual, the reference to variables is applied indistinctly also to asteroids.

Astrometrica - http://www.astrometrica.at/

a. Astrometrica is a interactive software tool for scientific grade astrometric data reduction of CCD images, focusing on measurements of the minor bodies of the solar system (asteroids, comets and dwarf planets).

Find orb-- https://www.projectpluto.com/find_orb.htm#group

a. Find Orb can take a set of observations of an asteroid, comet, or natural or artificial satellite, given in the MPC (Minor Planet Center) format or the NEODyS or AstDyS formats, and find the corresponding orbit.

Videos

The following videos are free and are used in conjunction with a particular lesson. Worksheets with questions can be made to stimulate conversation and understanding.

. A. Television programs based on books by physicist Brian Greene. They aired on PBS and are now viewable for free on the PBS/NOVA website:

1. http://www.pbs.org/wgbh/nova/physics/elegant-universe.html
2. http://www.pbs.org/wgbh/nova/physics/fabric-ofcosmos.html

B. 4oo Years of the Telescope (about Galileo).

C. The Pluto Files from NOVA

D. Episodes of NOVA

E. Seeing in the Dark by Tim Ferris

F. The Cosmos reboot by Neil deGrasse Tyson

G.BBC's Wonders of the Universe with Brian Cox

Optional Publications

The following extended list of books and magazines is provided as a resource for students who wish to know more about some of the more popular topics in the course. All publications on this list are written at a popular, non-technical level.

A. Current Topics in Astronomy

B. Sky & Telescope magazine

C. From Clockwork to Crapshoot: A History of Physics by Roger G. Newton

D. Six Easy Pieces: Essentials of Physics Explained by Richard P. Feynman

E. Big Bang: The Origin of the Universe by Simon Singh

F. Alice in Quantum land: An Allegory of Quantum Physics by Robert Gilmore

G. Black Holes and Time Warps: Einstein's Outrageous Legacy by Kip S. Thorne

H. Dark Side of the Universe: Dark Matter, Dark Energy, and the Fate of the Cosmos by Iain Nicolson

I. The Goldilocks Enigma: Why Is the Universe Just Right for Life? by Paul Davies

J. The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory by Brian Greene

K.Flatland: A Romance of Many Dimensions by Edwin A. Abbott

Websites

These websites are very useful to supplement teaching and use directly in lessons. These are good to assign to students to do outside of class.

A. https://stardate.org/

B. http://www.minorplanetcenter.net/iau/mpc.html

C. https://apod.nasa.gov/apod/astropix.html

D. http://www.https://www.isro.gov.in/weather.gov/

E. https://www.universetoday.com/

F. http://oneminuteastronomer.com/

G. https://www.nasa.gov/missions

A. http://www.worldwidetelescope.org/webclient/

B. http://www.esa.int/ESA

C. http://global.jaxa.jp/

D. https://www.isro.gov.in/

CHAPTER IV

ACTIVITIES

The following activities are listed under the separate learning objectives in chapter one. The great majority of the activities are hands on and technology based and therefore computers and software are required.

(1-3) Safety and the Scientific Method

A. Review safety in general and specific to the course. Perform a simple experiment to illustrate the scientific method to finding scientific truth. All future work will involve a question, which will follow the format of the scientific method outline

B. A good question making activity (lab) which could be a standard for each new lesson. Student should generate questions before each lesson.

(4) Science Concepts. The student recognizes the importance and uses of astronomy in a historical context. The student is expected to:

A. Students will do online research of a particular historical person in astronomy and present findings on a PowerPoint, video or other method of presentation. (Cooperative)

B. Students will start an observation notebook and will be required to observe and record positions of certain celestial objects visible to the eye area of the sky at night in a designated area for an extended period. Students can use sky view app on their phone to locate the object.

5) Science Concepts. The student knows the earth's place in distance, time and motion in the universe. The student is expected to:

A. Students will make 3 dimensional scaled model using materials of their choosing to demonstrate size and distance comparatively of selected celestial objects and present to class.

B. Construct a time scale of the universe based on the 80-year average human lifespan

C. Construct a time scale of the universe based on a 24-hour day

(6) Science Concepts. The student develops a familiarity with the night sky and is able to locate a celestial object. The student is expected to:

A. Will use globes of the celestial sphere and Stellarium software to complete assignments and various practice labs to become familiar with the present and past sky from different parts of the world.

(7) Science Concepts. Students understand concepts of light and various ways light carries information. The student will be able to:

A. View various types of light with a spectrometer or diffraction grating and record emission lines.

B. Speed of light with chocolate lab.

C. Speaking through a laser light lab.

(8) Science Concepts. The student knows basic optical concepts related to how telescopes work. The student is expected to:

A. Research and view actual telescopes. Use binoculars as an example of refraction type telescope and analyze the image produced.

B. Student to watch “hunting for the edge of Space and ask 5+ good questions.

C. Optics lab with lenses and mirrors (Image formation)

(9) Science Concepts. The student knows the basic concepts of the properties of stars which influence the images recorded by telescopes. The student is expected to:

A. Use light meters to verify the invers square law of brightness

B. Kepler's 3rd law activity with ellipse

C. Color-Magnitude Diagram with IRSA Data:

D. Color-Magnitude Diagram with SDSS Data:

(10) Science Concepts. The student knowsways to discover the properties of stars from an observation. The student is expected to:

A. View and record the spectral lines produces by various gasses using a spectrometer with calibrations and tubes filled with various gasses.

B. Measuring the mass of Jupiter lab using its moons

C. Discover the mass of a star using its exoplanets and a spreadsheet

(11) Science Concepts. The student knows basic components of a CCD (Charged Coupled Device) camera. The student is expected to:

A. Using cups to demonstrate pixel filling and overfilling

B. Using preexisting data and graphs of images to calculate orbital time, distance, and size

(11) Science Concepts. The student knows the macro steps in planning an observation. The student is expected to:

A. Use of the national weather service and the minor planet center website to do preliminary steps in planning an observation.

(12) Science Concepts. The student knows the micro steps to preparing the telescope. The student is expected to:

A. Activities will be done at the observatory however; video of the procedure can also be shown in class. All students will demonstrate safe procedure in dome operation

(13) Science Concepts. The student knows the steps to align the telescope. The student is expected to:

A. All students will demonstrate proper technique and language in aligning the telescope.

(14) Science Concepts. The student knows how to slew telescope to the target. The student is expected to:

A. All students will be able to slew to celestial target of choice using proper language and proper use of software.

15) Science Concepts. The students knows the process used to take a series of images. The student is expected to:

A. All students will construct a record of their observation in the proper folder with the correct name. Students will successfully take a series of images with the correct settings

B. Hour of Code - Calibrating Astronomical Images:

. (**16) Science Concepts**. The student knows how to process images. The student is expected to:

A. All student will be able to process their images with the software and produce a level of accuracy and light curve.

(17) Other Labs: from the University of Nebraska and activities, this can be modified for your classroom.

A. NAAP labs

1. Solar System Models: http://astro.unl.edu/naap/ssm/ssm.html
2. Basic Coordinates and Seasons: http://astro.unl.edu/naap/motion1/motion1.html
3. Rotating Sky: http://astro.unl.edu/naap/motion2/motion2.html

4. Motions ofthe Sun: http://astro.unl.edu/naap/motion3/motion3.html

5. Planetary Orbits: http://astro.unl.edu/naap/pos/pos.html

6. Lunar Phases: http://astro.unl.edu/naap/lps/lps.html

7. Atmospheric Retention: http://astro.unl.edu/naap/atmosphere/atmosphere.html

8. Exoplanets: http://astro.unl.edu/naap/esp/esp.html

9. Habitable Zones: http://astro.unl.edu/naap/habitablezones/habitablezones.html

10. Blackbody Curves and Filters: http://astro.unl.edu/naap/blackbody/blackbody.html

11. Hydrogen Energy Levels: http://astro.unl.edu/naap/hydrogen/hydrogen.html

12. Hertzsprung-Russell Diagrams: http://astro.unl.edu/naap/hr/hr.html

13. Cosmic Distance Ladder (actually 3 in one):

http://astro.unl.edu/naap/distance/distance.html

CHAPTER V

ASSESSMENTS

The following assessments can be applied as the educator feels is best for that particular activity. The observation notebook is essential since this is an observational class. It is recommended that small steps should be tested to ensure good scaffolding of material.

Rubrics- Three levels of completion prepared by teacher for all presentations, projects and observatory observations.

Peer Evaluation- Presentations and observatory observations should include peer evaluations.

Lab Notebook-An essential component of observations done individually

Participation - Completing weekly assignments and showing up to labs and observations.

Cooperative Learning- rubrics for team participation and cooperation

Tests-Periodic summative concept tests

Summative Grade -Completion of observation and image calibration (Astrometry and Photometry)

Recognition Points- Good questions, endurance, creative participation and thoughtful ideas.

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APPENDIX A

APPENDIX A

INSTRUCTIONS ON USE OF OBSERVATORY

(Manual)

NONPUEWENU OBSERVATORY

Instructions and Operations Manual

University of Texas Rio Grande Valley

(2017)

CONTENTS

Nonpuewenu Observatory

Fig. 1 Nonpuewenu observatory

Location: Las Palmas State Park, Olmito, TX

Contact Information: mariodiaz.org

Latitude: 25.9957917 West (262.4310500 East)

Longitude: 97.56899500 North

Altitude: 11 meters

Telescope and Dome

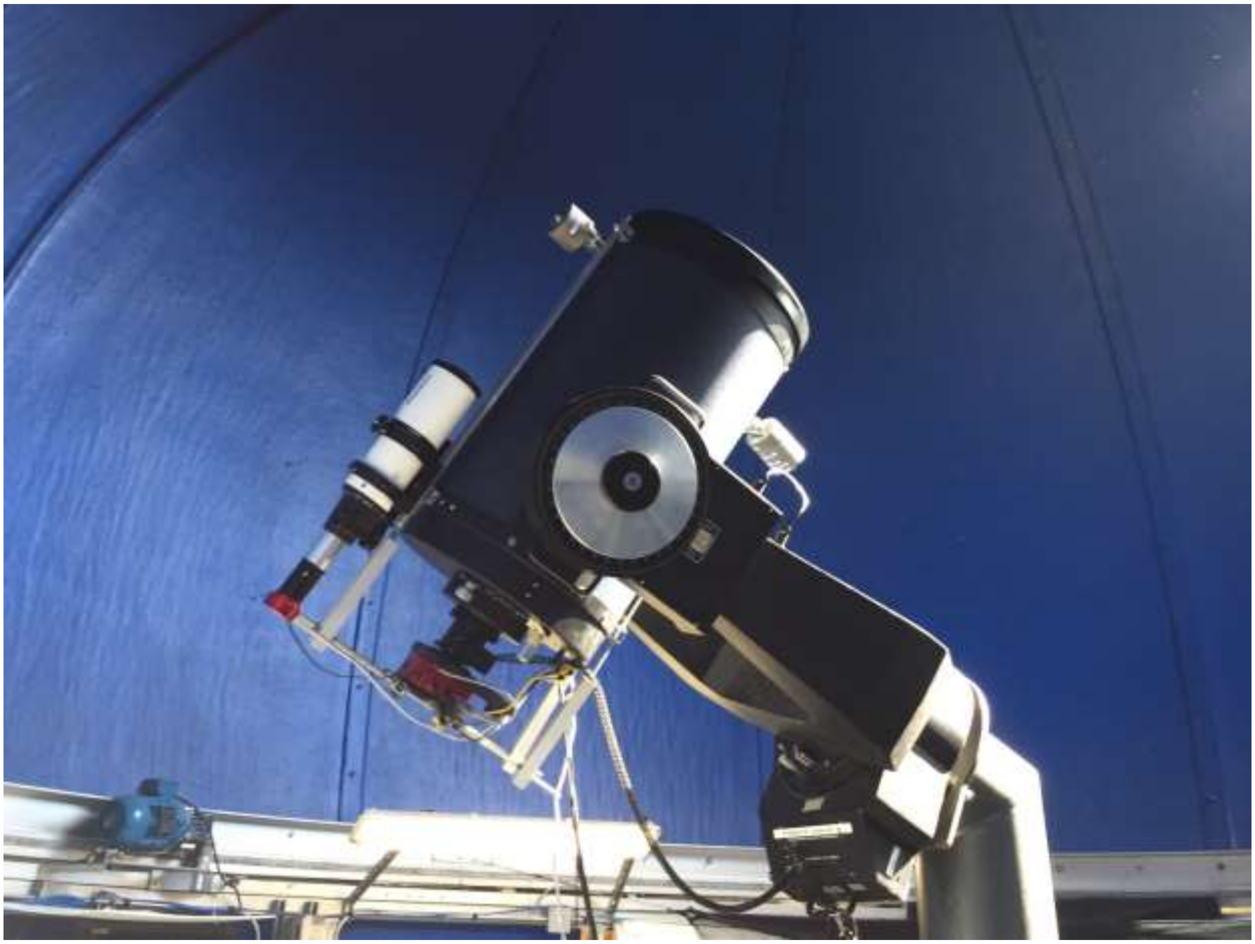


Fig. 2 Telescope and Dome

CWGA

Fig, 3 Dr. Mario Diaz

History of CWGA (Center for Wave Gravitational Astronomy)

The Center for Gravitational Wave Astronomy (CGWA), founded in 2003 through a grant from the NASA University Research Centers program, has been since its inception a member of the LIGO Scientific Collaboration -LSC- (UTRGV CGWA founders Joe Romano and Mario Diaz are members of LSC since 1998). On February 11, 2016, LSC jointly with the VIRGO collaboration (its European counterpart) announced in a press conference, that received worldwide coverage, its first detection of gravitational waves originated in the merger of two black holes located at more than a billion light years from us. The UTRGV CGWA has the largest group of gravitational-wave researchers in Texas and is one of the largest from the United States involved in the LIGO Scientific Collaboration global research effort. Its scientists and student researchers are key contributors to the first direct detection of gravitational waves.

Accolades and Recognition

Professors T. Creighton, M. Díaz, M. Rakhmanov, S. Mukherjee, V. Quetschke, J. Romano, C. Torres (deceased) and graduate students P. Daveloza, R. Stone, D. Tuyenbayev, and G. Valdes, are coauthors of the Physical Review Letters: Observation of Gravitational Waves from a Binary Black Hole Merger, a paper that was the third most cited scientific paper of 2016 (https://www.altmetric.com/top100/2016/). For their participation in this work they have received the 2016 Special Breakthrough Prize in Fundamental Physics, the 2016 Gruber Prize in Cosmology, the 2017 Princess of Asturias Prize from the King of Spain, and most recently the 2017 Group Achievement Award from the United Kingdom's Royal Astronomical Society. Mario Diaz was named Distinguished Visitor by his Alma Mater, the National University of Córdoba in Argentina and received an honorable mention by the Senate of the Argentine Republic.

There have been 35 articles in peer review international scientific journals published by CGWA faculty and students The CGWA in addition to its current NSF CREST award received a supplement to support the work of the TOROS collaboration to detect gravitational waves. We definitely look forward to a new year of achievements and hard work. In a separate note, we report on the starting of operations of the UTRGV Astronomical Observatory at Resaca de la Palma.

MAILING ADDRESS and Other Contact Information and Map

For information about the observatory or events taking place ay the observatory, the contact information is below:

Mario Diaz- Director

University of Texas /Rio Grande valley

Center for Gravitational Wave Astronomy

Cavalry 105
Brownsville, Texas 78520
Email: mario.diaz@utrgv.edu
Phone: (956) 882-6690
Phone Alt: 956-882-5193
Fax: (956) 882 6722

Physical Address of Observatory

1000 New Carmen Ave. (off Hwy. 281 or FM 1732)
Brownsville, TX 78521
Latitude: 25.996275
Longitude: -97.5712694
View map and directions

(956) 350-2920

Google maps

https://www.google.com/maps/@25.9963419,-97.5725058,683m/data=!3m1!1e3

Fig. 4 Meade 16” LX200 Schmidt-Cassegrian telescope

Clear Aperture: 16" (406.4mm)

Optical Design: Advanced Coma Free (ACF)

Focal Length: 4,064mm

Focal Ratio: f/10

Telescope Mounting: Heavy-duty fork type; double-tine

Optical Coatings: Ultra-High Transmission Coatings

Resolving Power (Dawes Limit): 0.285 arcseconds

AutoStar Controller: Autostar II

Eyepiece: 26mm Series 5000 5-element Plossl

Diagonal: 1.25" diagonal prism

Pointing Precision (High-Precision Mode): 1-arc min.

Slew Speeds RA and Dec: 0.01x to1.0x sidereal, variable in

0.01x increments; 2x, 8x, 16x, 64x, 128x sidereal; 1°/sec. to

CCD

Fig. 5 CCD

SBIG STF-8300M (Monochrome) CCD Camera

Camera Specifications

The table below lists the specifications for the ST-8300 camera.

CCD Kodak KAF-8300

Pixel Array 3326 x 2504 pixels

Total Pixels 8.3 Megapixels

Pixel Size 5.4 x 5.4 microns

Full Well Capacity 25,500 electrons

Dark Current < 0.5e- at 0°C

Shutter Electromechanical

Exposure 0.1 to 3600 seconds, 10ms resolution

A/D Converter 16-bit with Correlated Double Sampling

Read Noise ~10e- RMS

Binning Modes 1x1, 2x2, 3x3

Full Frame Download

USB 2

USB 1.1

Up to 1,200,000 pixels per second

Up to 400,000 pixels per second

Cooling Single Stage TE, Active Fan, ~35C Delta

Temperature Regulation Closed Loop, ±0.1°C

Power Requirements 10 – 14.5 Volts DC at 3 Amp, Center-Positive

Backfocus Same as C-Mount, 0.690 inches

Dimensions 4 x 5 x 2 inches

Software Specifications

1. Maxim DL (diffraction limited)-- https://diffractionlimited.com/help/maximdl/MaxIm-DL.htm
   b. MaxIm DL is specifically designed for astronomical imaging and other low-light level applications. It operates scientific-grade CCD cameras, DSLR cameras, low-cost CCD imagers, and webcams and other video sources. It also controls filter wheels, focusers, autoguiders, telescopes, focal plane rotators, and observatory domes. A wide variety of hardware is supported through both ASCOM drivers http://ascom-standards.org and proprietary and third-party plug-in drivers. MaxIm DL also includes a wide variety of image processing and analysis features.
2. Carte du Ciel—sky chart (free)- https://www.ap-i.net/skychart/en/start
   c. This program enables you to draw sky charts, making use of the data in many catalogs of stars and nebulae. In addition the position of planets, asteroids and comets are shown.
   d. The purpose of this program is to prepare different sky maps for a particular observation. A large number of parameters help you to choose specifically or automatically which catalogs to use, the colour and the dimension of stars and nebulae, the representation of planets, the display of labels and coordinate grids, the superposition of pictures, the condition of visibility and more. All these features make this celestial atlas more complete than a conventional planetarium.
3. Stellarium – free open source- http://stellarium.org/

b. Stellarium is a free open source planetarium for your computer. It shows a realistic sky in 3D, just like what you see with the naked eye, binoculars or a telescope.

4. POTH - http://ascom-standards.org/FAQs/POTH.htm

b. POTH is an incredibly useful tool for both testing and routine observing. It started out as a "plain old telescope handset" (hence the acronym), but it has grown a lot since then. We can thank Jon Brewster for POTH. Let's look at a block diagram of a typical usage:

4. Fotodif - http://www.astrosurf.com/orodeno/fotodif/
   c. The objective of this program is to provide the necessary tools for the production of long photometric serrations, both of relative and absolute magnitude, which can extend several hours. It also has two sections devoted to the search of short period variables and the analysis of periods.
   d. FotoDif is able to track mobile objects through the field, so it is also useful for studying, for example, the rotation of asteroids. In the rest of the manual, the reference to variables is applied indistinctly also to asteroids.
5. Astrometrica - http://www.astrometrica.at/
   b. Astrometrica is a interactive software tool for scientific grade astrometric data reduction of CCD images, focusing on measurements of the minor bodies of the solar system (asteroids, comets and dwarf planets).
6. Find orb-- https://www.projectpluto.com/find_orb.htm#group
   b. Find_Orb can take a set of observations of an asteroid, comet, or natural or artificial satellite, given in the MPC (Minor Planet Center) format or the NEODyS or AstDyS formats, and find the corresponding orbit.

DIRECTIONS

I. Setting up the telescope for an observation.

A. Turn on:

a. General Control box: all switches.

.

Fig. 6 Control box

B. Turn on UPS

Fig. 7 UPS

C.. Turn on Computers.

Fig. 8 Computer

C. Telescope mount: (see below) turn on the ON switch.

a. Red led should be on.

b. Wait for a couple of minutes until fork positions itself.

c. The hand control will read “Welcome to AUTOSTAR”.

d. It will change once the initiation of the telescope is ready.

e. The CCD camera starts automatically through the UPS. Check for the fan noise and the red led to be on. (2nd pic)

Fig. 9 Telescope control switch

Fig. 10 Camera light indicator

II. Check all Connections: Verify the following:

a. Computer power.

b. Power to the mount: from the “18V-DC IN”.

c. CCD power.

d. CCD - USB.

e. Mount USB: from “RS232” connector on the mount to the pc.

f. Hand controller: from the “HBX” connector to the mount.

g. Focalizer: from the “Focus” connector to the mount.

III. Shutter: open it. (shutter control switch)

Fig. 11 Control for shutter

IV. Preparing Telescope

a. Remove the water proof cover of the scope.

b. Remove the tube cover slowly and carefully.

Fig. 12 Telescope with Cover

V. Initiating software

A. Turn on Maxim DL

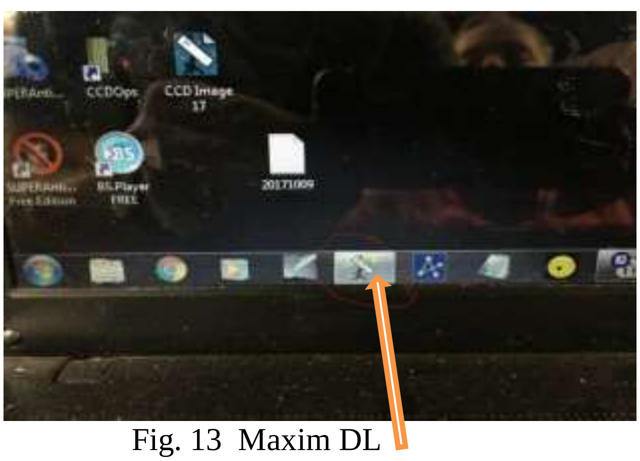


Fig. 13 Maxim DL

B. Open camera control window View → “Camera Control Windows” (click).

Camera control icon

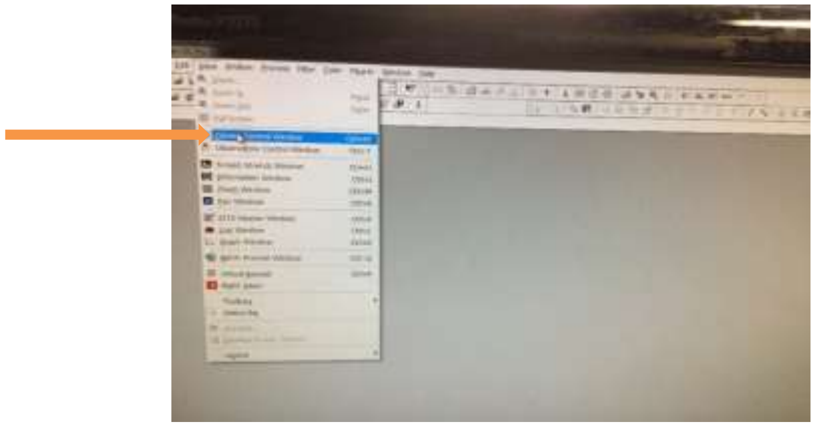


Fig. 14 Camera control tab

VI. Turning on cooler

A. Setup → “Connect” (click). In: Coolers “On” (click).

B. Wait for CCD cooler temperature to indicate the Set point value. Set Temp at 25 c below ambient temperature. Make sure power is below 75% after reaching desired temp.

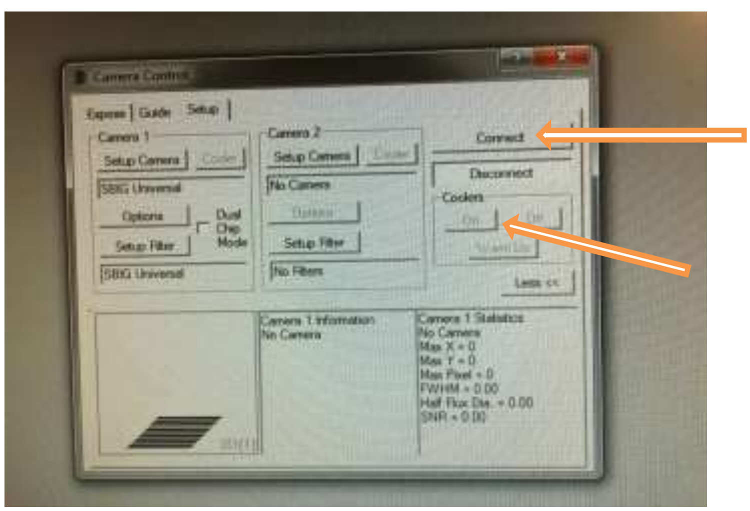


Fig. 15   Camera control window

VII. Telescope alignment.

a. It is done when the scope requests it or when necessary.

b. When aligning: the telescope will move and rotate to make all the necessary adjustments. Keep a reasonable distance from the tube and check that no cables or ancillary material obstruct its motion.

c. There are two possible situations:

➔ 1. The telescope was properly parked the previous night utilized, In that case follow this procedure:

a) On the hand controller you will see: “Select item: Object”.

Fig. 16 Hand Controller

b) Select a bright star, isolated and close to culmination. Find it visually before displacing the telescope. Suggested examples: Vega (Alfa Lyr), Deneb (Alfa Cyg), Caph (Beta Cas), Capella (Alfa Aur), Castor (Alfa Gem), Arturo (Alfa Boo).

c) Hit “Enter“, select the desired star. Select Go to.

d) The controller will show “Taking GPS Fix”. (GPS is correcting date and time).

e) The scope will go to the selected star.

f) Center the star using the hand controller. Look for: “Center an object in the CCD” later in this manual.

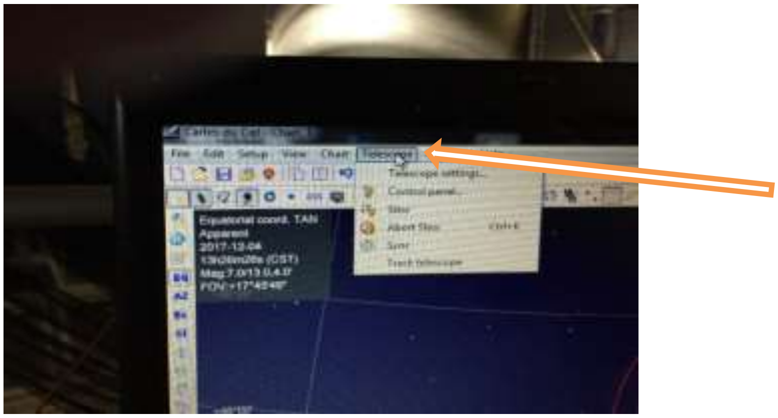


Fig. 17 Telescope tab

g) Connect the telescope with Cartes du Ciel:

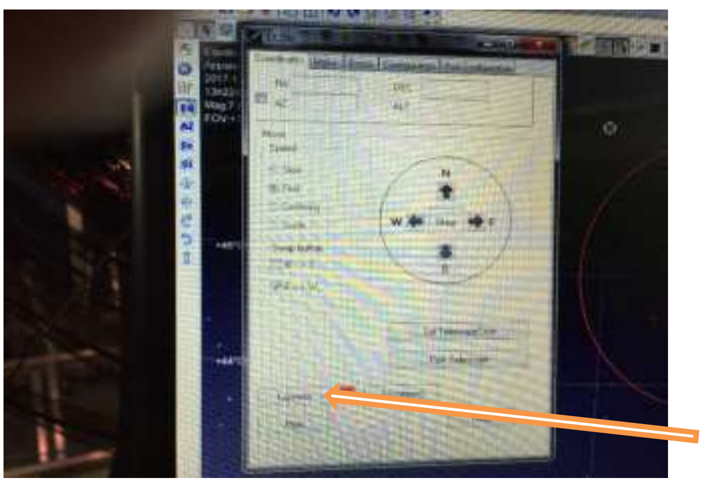


Fig. 18 Telescope control window

(How to Connect the virtual hand controller in the application from)

a) Telescope→ Control panel →connect.

b) The color of the square (visualization frame) on the celestial chart will change: red -> green.

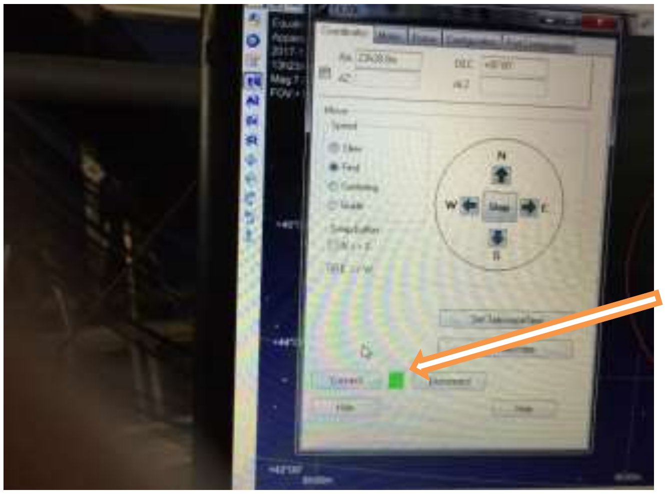


Fig. 19 Telescope control window

c) Center the star in Maxim FOV, using the virtual hand controller.

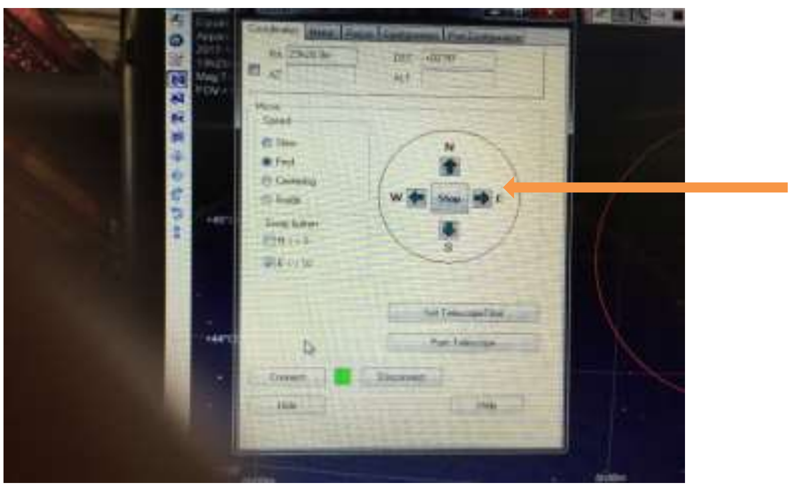


Fig. 20 Virtual hand controller

d) Right click on the mouse. Go to Telescope and check: follow telescope.

e) The star will show up in the visualization frame in Cartes du ciel.

f) If star is not inside the FOV frame Cartes du ciel, select the star in Cartes du Ciel. Go to Telescope → Synchronize. The star will be centered in the FOV frame.

2. The telescope was not parked last time used:

a) You'll see on the hand controller: “Press 0 to align or MODE for Menu”. Select 0.

b) Choose: “Polar Align”.

The true Decl = 90 was already determined: It is NOT necessary to find it in spite of the hand controller request. The mount has already been put in station: DO NOT move it.

c) With the hand control: take the scope to Decl = 90° y HA=0.

Fig. 21 Mount Alignment

Fig. 22 Fork alignment

d) Press “Enter“. You'll see: “Taking GPS Fix”. Let it do it.

e) The scope will go to Polaris.

DO NOT center it: just verify that it is close enough with the viewfinder.

f) Select “Enter": It will move for a few seconds to an object.

g) Center the object using the hand controller with the N, E, S y W arrows. Press “Enter“.

h) Eventually you will see: “Select ítem: Object”.

i) Connect the scope with Cartes du Ciel:

j) Connect the virtual hand from: Telescope → Control pannel → connect.

K) The small button will change from red to green.

l) Rick click your mouse. Go to: Telescope and check on: Follow telescope.

m) The star will show up in the visualization frame In Cartes du ciel.

n) If star is not inside the FOV frame Cartes du ciel, select the star in Cartes du Ciel.

Go to Telescope → Synchronize. The star will be centered in the FOV frame.

X. Hand controller utilization

a. ”ENTER “is like in the pc. It will implement our selection in the menu.
b. The MODE key is similar to (Escape) key. It cancels the most recent selection and it goes to the next level.
c. Once Cartes du Ciel is open, do not use the hand controller.
d. When hand controller is used without synchronizing with Cartes du Ciel, the coordinate are the one that corresponds to the date.
e. TO find out which coordinates the scope is pointing to: press and maintain “Mode” for 2 seconds and then release.
f. Once giving an instruction to the scope wait until it stops completely before entering a new command. While slewing the hand controller will show that it is performing

such action. Once the action is not shown any longer it is a good indicator of having stopped completely

XI. Slewing speed (with hand controller):

a. It can be modified at any time.

b. Press the key “1 Speed” and the “Up” and “Down” buttons.

c. The following is a summary of the different speeds that can be achieved:

XII. To search for a star with the hand controller

a. “Select Item: Object“ → “Star“ → “Named“

b. When entering “Named star move across options, with the “Up“ and “Down“ arrows.

c. “Enter“→ the options include star names and constellation name.

d. “Go to“→ scope will slew to the star.

XIII. Centering and object in the CCD images:

a. In Maxim “Camera Control”: change to the “Expose” tab and select: “*Find Star”.

b. Click in “Continuous”.

c. Select A low exposure time (i.e.: 1 sec).

d. Click on “Start”: you will get a series of images.

e. Right click on the image: → “Crosshairs” → it will become visible. Crosshairs will appear.

f. Center the crosshair. Move the crosshairs following the star.

g. Displacements can be made with the hand controller or using Cartes du Ciel.

XIV. Fine tuning focus with the micro focuser:

a. With the hand controller:

a. Press the 4 key FOCUS. Display will show "Focus Speed Fast".

b. Press the up-down keys to select one of the possible focuser speeds.

c. Press “ENTER“ to select desired speed.

d. Adjust focus with one of the four displacement buttons.

b. With Cartes du Ciel:

e. Select the focus tab. Select GPS Auto star.

f. There also four speeds. #1 is the slowest.

g. You can also adjust intermittently with "pulses" instead of continuously. Pulses duration can be configured as well.

XV. Record a series of images: (Once the object is centered)

a. “Expose” tab. Click Options → No calibration (no dark, only the image).

b. Click on Autosave → “Autosave setup” window will open.

c. Name the file. Slot1 (click) → Complete: Type (Light, Dark…), Exposure, Binning, Readout Mode, Repeat (for a given number of images).

d. Options (click) → “Set image save path...” → choose folder → Ok (click).

e. Start (click), it will be begin the recording of images.

XVI. Park the telescope.

a. Before parking the telescope: synchronizing with cartes du ciel with FOV centered star. This will provide a better saving of the alignment data.

b. IN the virtual hand controller, select “ (Park the telescope)".

c. A window will appear: ‘do you really want to park and disconnect the telescope’.

d. Select: (Yes). A message will appear: (Parking and disconnecting the telescope).

e. When finalizing motion: (accept).

f. Disconnect the virtual Cartes du Ciel hand controller.

g. Close Cartes du ciel.

Another option: parking with the hand controller.

a. Disconnect the virtual controller in Cartes du ciel.

b. Go to the main menu selecting MODE.

c. With the vertical arrows, select Utilities → Park Scope → “Enter“.

d. The telescope will be parked and you will see on the display “Scope parked. Turn scope off”.

XVII. Returning CCD to ambient temperature

a. Window: “Camera Control”: Setup → Cooler “Warm up” (click).

b. Wait until temperature is above or about 0 (cero) Celsius (32 °F) and the cooler works at 10%.

c. Select "Off". Select "Disconnect -

d. Close MaxIm.

XVIII. Telescope storage

a. Cover with the scope tube.

b. Cover the telescope with the waterproof cover.

XIV. Dome shutter: close it.

XV. Turn off:

a. The computer.

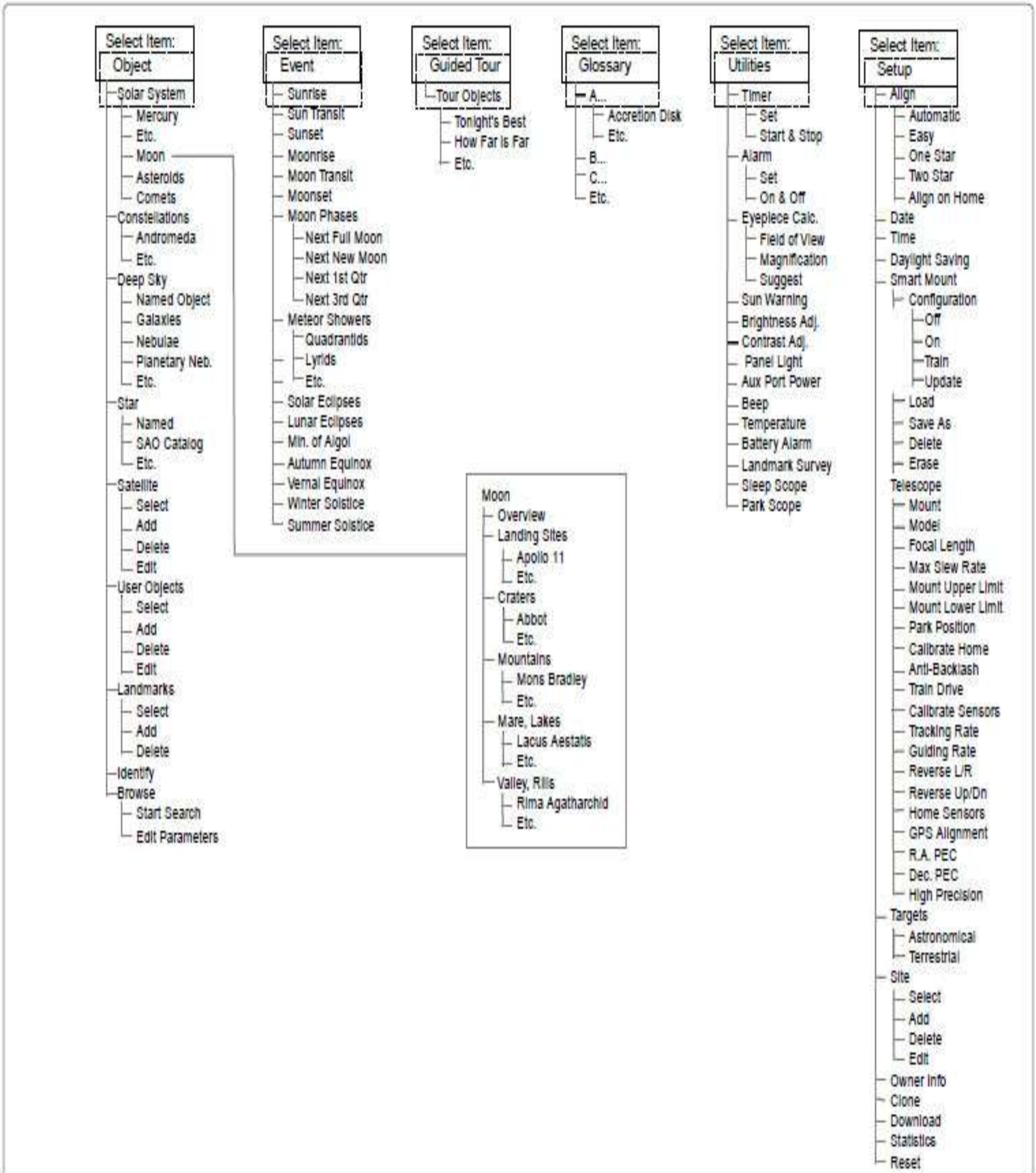
b. The CCD will shut off automatically with the UPS once this one is unplugged.

c. The mount with the “OFF" button on the mount.

d. UPS unit.

e. Main control switches: all except 2 which is the exit lights.

Hand controller menu map



General Directions for Doing an Astrometry

A) Download the software Astrometrica : http://www.astrometrica.at

(It's probably better to install it using the full zip file) or download the exe file right below this set of instructions: link—Setup-Astrometrica.exe the executable for direct download.

B) Configure the program:

1. In the menu: "File/Settings/Open", select the image file form your file of images taken

2. In the tab Program select "UCAC4" in the square Star Catalog .

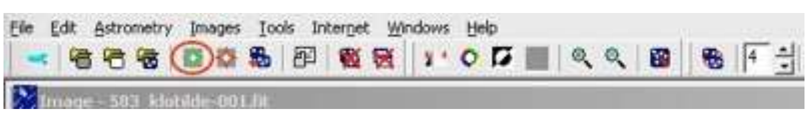
3. Go to the environment tab and in the directories box select the directories were you put the files.

4. Select "VizierR" as an option for all in the tab "Catalogs".

5. Save all your changes, close the program and open it again (you need to do this to force the program to read the configuration)

C) Image reduction

1. open one image from the subdirectories containing the images for each asteroid (you can open several at once). Click on the button astrometric data reduction (Ctl+A).The button is circle in red in the image below



2. With this button, you would need to provide the coordinates of the center of the image. Alternatively, if you know the object you expect to localize in the images you loaded you can enter its name in object line, which opens when you click on astrometric data reduction.

3.If you don't know the name of the object, neither the coordinates, you can do the following: go to Images -> Edit Image Parameters. The date will appear in the box and the time of the middle of the exposure. With that information (the ephemerides) you can obtain the coordinates from the Minor Planet Center (MPC) database.

.4 .Reduce the images by aligning the red circles with objects (stars) in your image. You do this by clicking on the arrows that appear in the box “Aligning Reference Stars”. Notice that in addition to clicking on the arrows you will need to also change “Position Angle” and “Focal Length”. Eventually you will need to correct the information in the tab CCD on the File->Settings menu.

.5 .After clicking OK on the astrometric reduction button red circles will appear in your images. These red circles represent the position of know stars and objects in the field of view of your image based on the coordinates entered. (notice that depends on the configuration adopted and the CCD characteristics). Reduce all images.

6. Verify the cardinal points read in the images reading the RA and DEC while following the cursor over the reduced images.

7. Detect the asteroids using the “Blink” button. Astrometry of Image” obtained from the menu ˙: “File/View Log File”.

8.Find the asteroids with the names contained in the files, for each field using the blink function over the sequence of images. Take note of the direction in which they move estimating the angle (from North to East).

9. Select File-> Reset File in the menu.

10.Select the asteroid. Verify that SNR is larger than 7 and that the measure magnitude is similar to the theoretical one. Enter the abbreviated name of the object in the blank space in object designation (after clicking on it to select). If the object exist in the catalog it should appear in the list of objects close to the center of the image when clicking browse. Selecting from the list will show the abbreviated name. Accept after verifying. A pink circle will appear surrounding the object.

11Add one astrometry line in File->View MPC report file.

12.Perform the other astrometries avoiding those images where the asteroid appears superimposed with stars or with low SNR. It is convenient to have astrometries separated in time.

13. Copy all astrometries and save them in a file with “lastname_name.txt”

Instructions to Evaluate the Quality of the Astrometry’s using FINF-ORB

1. In this first step you will download astrometries for previous targets:

2. Search for them in: http://www.minorplanetcenter.net/db_search

In the "Data about an object:" slot enter the asteroid name.

3.Download the file indicated "These data are available for download"" from Observations".

4. Paste all the observations from the same asteroid in a txt file.

5. Delete all the observations from older than six months more recent than the observations you have.

6.Save the data in a file with the following name: LastName_FirstName_observations_XXXXX.txt

replacing XXXXX with the corresponding asteroid’s name.

7.Copy all the astrometries you performed Paste them after the observations obtained following point 1) in your corresponding txt file.

8.Save the files.

9. Install the software Find_Orb": http://www.projectpluto.com/find_orb.htm. Click on "Downloads" to download the file to your computer (notice if you are running crossover for Mac download the 32 bit version).

10. After downloading and installing the file run it and

11. Open LastName_FirstName_observations_XXXXX.txt

12. Select "All perturbers Off" and repeat a few times "Full step" until the mean residuals don't vary any longer.

13. Verify that all residuals in RA y DEC from your astrometries are lower than 1 arcsecond. If you have some residuals larger than that discuss what could be the origin and interpret the result.

14. Save the report by clicking on "Save Residuals.."

- The file should be named: LastName_FirstName_residuos_XXXXX.txt

Stacking of Images

When observing a very dim object stacking of the images obtained is a very useful method to enhance the Signal to Noise ratio of the image. Remember that asteroids are moving objects. A fast and dim asteroid is particularly hard to track.To performing this exercise you will need to download the following subdirectories and unzip them in the directory you use to work with **Astrometrica.**

1. Open Astrometrica and be sure it reads the MPCORB.dat file (reading the MPCORB database).
2. Open the file XXX...YYYY...ZZZ_datos.txt that corresponds to the first asteroid.
3. Load one of the images from the directory that corresponds to the above asteroid.

4. Click on the Astrometric Data Reduction button. When the window asking for the object pops up, go to the text file and copy from it the coordinates to enter in the objects name/coordinates window.
5. As the red circles come up move them until they align with the stars in your field.
6. Perform a second reduction of the same image. The program will register the coordinates of the center of the image to use in the other images.
7. verify the cardinal points in the image (which is N, E, etc) and make a note of them. Close the image.
8. Click on the Stack Images button. Look up and select images in the directory you are working with (with add button). Enter the information about the asteroid velocity and direction of motion. Click OK. The images will be stacked with stars leaving traces and the asteroid becoming a still object in the resulting image.
9. Perform another stacking with the rest of the images following the sequence in the directory.

10.Use the blink button to detect the asteroid. Verify that the asteroid moves parallel to the star traces. Check that the direction in which your candidate is moving corresponds to the data file

12.In the File menu select File/Reset File. Select the asteroid. Verify that the SNR is larger than 7 and that the magnitude is similar to the theoretical one.

13.Click on the object. The Object verification will pop up. Enter the object name in the blank slot where it reads “object designation”. Accept after verifying the identification. A magenta circle will come up with the object name.

14..A new astrometry line will appear shall be added in "File/View MPC Report File”.

15.If it doesn’t be sure you have the blinking image closed.

16.Perform the astrometries of the other images avoiding those in which the asteroid is too close to stars or where SNR is too low. It is convenient to have astrometries separated in time (why?).

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17.Copy the astrometries of all objects and save them in a file Lastname_name_XXXX.txt.

18.In each of the downloaded subdirectories there is a file XXX...YYYY...ZZZ_observ.txt. This file contains the observed astrometries for the asteroid you are working with. Paste your astrometries (saved in Lastname_name_XXXX.txt) after the data in the XXX...YYYY...ZZZ_observ.txt file. Save the file with your changes.

19.Open the software Find_Orb. Open the saved files XXX...YYYY...ZZZ_observ.txt

20.Select all perturbers off and run it several times including a few with Full step until the mean residuals don’t change any longer.

21.Check that the residuals are smaller than 1 arcsec.

22.Save the residuals in a file name Lastname_name_Residuals_XXXX.txt.

Photometry Light Curves with Fotodiff

1) Install the windows software fotodif (Spanish Language) change language as needed : http://www.astrosurf.com/orodeno/fotodif/

2) In "Configuracion" (configuration) open "Sistema Optico" (optical system) :enter equipment resolution (pixel scalel).

For límite de linealidad (linear limit) , accept the value 50000, if you don’t know the actual one.

3) In "Configuracion" open "Fotometría" (Photometry) : radio de apertura (aperture radius) should cover tightly the brightest star in your field. It can be estimated performing an astrometric reduction with Astrometrica: in the Object verification window select Centroid and modify radius until you select a circle adjusted to the basis of the star profile.The background inner radius is defined avoiding stars within it.

4) En "Configuracion" open "Observatorio": enter the observatory coordinates.

5) We can enter groups of images which we will call series: enter the first one.

6) Open a window where you complete the coordinates for the center of the image. It is better, in general to enter the coordinates for the object you plan to measure. Verify that the observatory location and pixel scale are correct.

7) Select the object to measure. Use the magnifying glass to see it better. Resize the aperture circle to the desired (and appropriate) radius. The maximum counts for the profile should not exceed the limit of linearity (i.e. the default provided by the software is 50000). If it is the object to be measured select variable. The name can be written over the **Var-1**.

8) Select the reference stars and the control one. They must have amilar number of counts to the object under study. Check again that the linearity limit is not exceeded and that you don’t have contaminating stars in the aperture circle nor in the background circle.

9) When finalizing star selection: Save the image selecting "Guardar como". (save as)

Save the star positions. it could become useful later.

10. Select "Proceso": (process) then select :"Gráfico". (graph)

11. In "Configurar" (configure) we will options for the plot and the report

12.In "Resumen y comentarios" (comments) we can check plot statistics and add notes. The plot can be saved in "Guardar como...".(save as)

13. Save the data with "Guardar datos...". (save data) It can be become handy to reconstruct the plot.

14. Select "Informe" to configure the columns in the data table. Save the report with the

NOTE:

The processing of a series could be interrupted due to several reasons: equipment jerk, partial obstruction by clouds, etc. Take note of the object's name and inspect it in reference to the previous and posterior images. The process should be done with the images that correspond to stable weather conditions and sky position.

Necessary information to perform the photometries:

Latitude: 25.9957917 West (262.4310500 East)

Longitude: 97.56899500 North altitude 11 m

BIOGRAPHICAL SKETCH

The graduate's name is Alan Wayne Hendrick and lives at 801 Balboa Rd. Rancho Viejo, Texas, 78575. He completed a Bachelor's of Science program of study from The University of Texas at Arlington and a Master's in Curriculum and Instruction with an emphasis in science from the University of Texas at Brownsville. He has recently completed a Master's of Science in Interdisciplinary Studies with an emphasis in physics from the University of Texas/ Rio Grande valley. For the past 19 years, Mr. Hendrick has taught high school science and is currently teaching physics at Veterans memorials High. He was a Vietnam veteran who earned a nursing degree during his service and currently practices part time as a nurse with special needs children.

He is presently developing and has submitted an innovative astronomy class for adoption by the state of Texas to teach high school students. The course teaches students how to do an astronomical observations and how to work in a real research facility in collaboration with the University of Texas/ RGV.