SIRIUS ASTRONOMER

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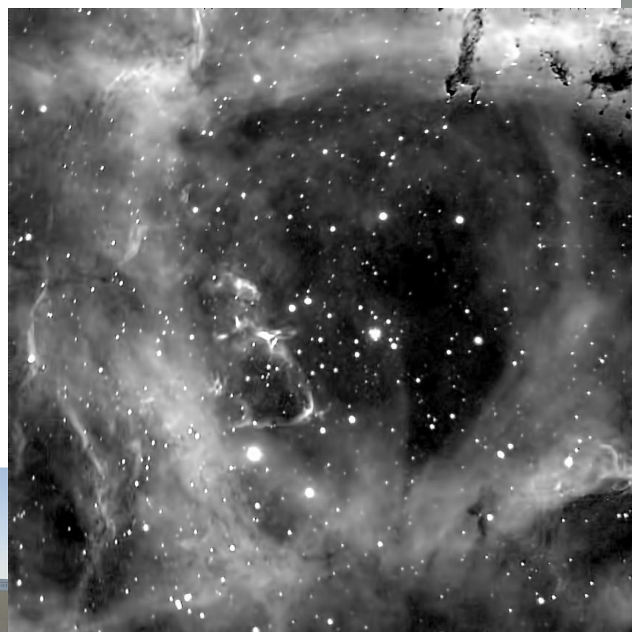
The Newsletter of the Orange County Astronomers

April 2016 *Free to members, subscriptions $12 for 12 issues* **Volume 43, Number 4**



OCA members Pat Knoll and Terry McGriff generated this image of the Rosette Nebula while doing an installation of a Meade LX200 at Eastlake High School in Chula Vista, CA (near San Diego). The image is in H-alpha and consists of 4-1200 second exposures using an Apogee C16M camera and a SBIG ST-I autoguider. Shown also are pictures of the observatory and the instrument itself. Whether it's public and educational outreach such as the effort shown here, or professional grade research as shown in the article on page 5, OCA members are at the forefront of amateur astronomy!

OCA CLUB MEETING

The free and open club meeting will be held April 8 at 7:30 PM in the Irvine Lecture Hall of the Hashinger Science Center at Chapman University in Orange. This month's speaker is Asanthra Coorae of UC Irvine speaking on Cosmic Light.

NEXT MEETINGS: May 13, June 10

STAR PARTIES

The Black Star Canyon site will open on April 30 and May 28. The Anza site will be open on April 9 and May 7. Members are encouraged to check the website calendar for the latest updates on star parties and other events.

Please check the website calendar for the outreach events this month! Volunteers are always welcome!

You are also reminded to check the web site frequently for updates to the calendar of events and other club news.

COMING UP

The next session of the Beginners Class will be held at the Heritage Museum of Orange County at 3101 West Harvard Street in Santa Ana on April 1 The following class will be held May 6.

GOTO SIG: contact Mike Bertin
Astro-Imagers SIG: Apr. 12, May 10
Remote Telescopes: contact Delmar Christiansen
Astrophysics SIG: Apr. 15, May 20
Dark Sky Group: contact Barbara Toy

AstroSpace Update

April 2016

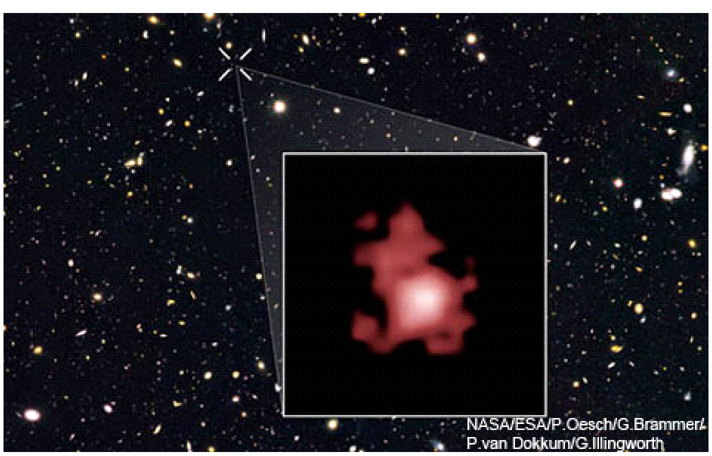
Gathered by Don Lynn from NASA and other sources

Fast radio bursts (FRBs) have been baffling astronomers since they were discovered in 2007, found in archived data from 2001. Only 16 of these had been detected before the current study, and none by a telescope with the resolution to tell exactly where they came from. FRBs last only a few milliseconds, are randomly distributed across the sky, and never repeat in the same location. An automatic warning system was developed to alert other telescopes to immediately look for an afterglow in the general area where an FRB is detected. An afterglow was seen after an FRB on April 18, and it was determined to be located in a galaxy about 6 billion light-years away. Only 1 theory fit an object this distant, and that is a pair of colliding neutron stars. It had long been suspected that FRBs were located at such great distances, because the different frequencies of the burst arrive slightly spread out in time, and this matched what passage through billions of light-years of intergalactic ionized hydrogen should do to a radio burst. The spread of this particular burst matched well with other measures of the amount of hydrogen between us and the galaxy with the afterglow. Mystery solved! Except … a few days later, other astronomers announced that they had discovered an FRB that repeated 10 times between November 2012 and June 2015. Colliding neutron stars destroy themselves, and so could not produce a repeat performance. The best theory for a repeating FRB is an extremely magnetic fast spinning neutron star. This is based on the repeater flipping between higher and lower frequencies, which some highly magnetic neutrons stars do. Also several objections were raised over whether the afterglow found in April was actually associated with the FRB. Some astronomers are now considering the possibility that there are 2 kinds of FRBs, a repeating and a non-repeating variety. Obviously more FRB observation is required. Fortunately, 3 new instruments designed to detect FRBs are scheduled to begin operations this year.

Gravity waves – 0.4 seconds after the 1st ever detection of a gravity wave (reported here last month), the Fermi gamma-ray space telescope detected a gamma-ray burst in the same general area of the sky (exact location of the gravity wave is not known). The only theory that would produce both a gravity wave and a gamma-ray burst: A single very massive star rotating extremely fast, at the end of its life, collapsed into a black hole, but the spinning broke this collapse into 2 black holes, only thousands of miles (km) apart. Those 2 black holes spiraled into each other, still inside the uncollapsed parts of the star, causing the gravity wave. Much of the remaining star collapsed a fraction of a second later into the merged black hole, causing a gamma-ray burst. Astronomers will continue to look for gamma-ray bursts or other phenomena that correlate with gravity waves.

Exoplanet atmosphere – Observations with the Hubble Space Telescope analyzed with new computer software yielded the composition of the atmosphere of exoplanet 55 Cancri e. The software separated the spectrum of the planet's atmosphere from that of the star. The atmosphere consists mostly of hydrogen and helium, and had no indications of water. There are hints of hydrogen cyanide, which has been predicted as a product of a carbon-rich atmosphere. The planet orbits its star in only 18 hours, and is so close to its star that its temperature is estimated at 3600°F (2000°C). The planet is a super-Earth, that is, larger in diameter than the Earth, but smaller than Neptune. Super-Earths are found to be the most common size of planet in the Kepler spacecraft data, though none exist in the Solar System. Hubble has tried to analyze the atmosphere of 2 other super-Earths, but no spectral features were found.

Hyades planet – Astronomers have discovered a transiting exoplanet orbiting a red dwarf star named K2-25 located in the Hyades, the open star cluster closest to us. Only a handful of exoplanets are known in open star clusters. The Kepler spacecraft, now in its K2 mission, imaged the transit, and it was found by 2 amateur astronomers examining the K2 data. The planet, known as K2-25b, is about 3.5 times the size of Earth and orbits its star every 3.48 days. There are other known exoplanets in the Hyades, but this is the only transiting one (passes in front of its star). This is the largest planet known orbiting a Type M red dwarf. The discoverers think it may be puffed up from the star heating the planet's atmosphere. The K2 mission has also observed the Pleiades and Beehive clusters, so more exoplanets in open clusters may be found soon.

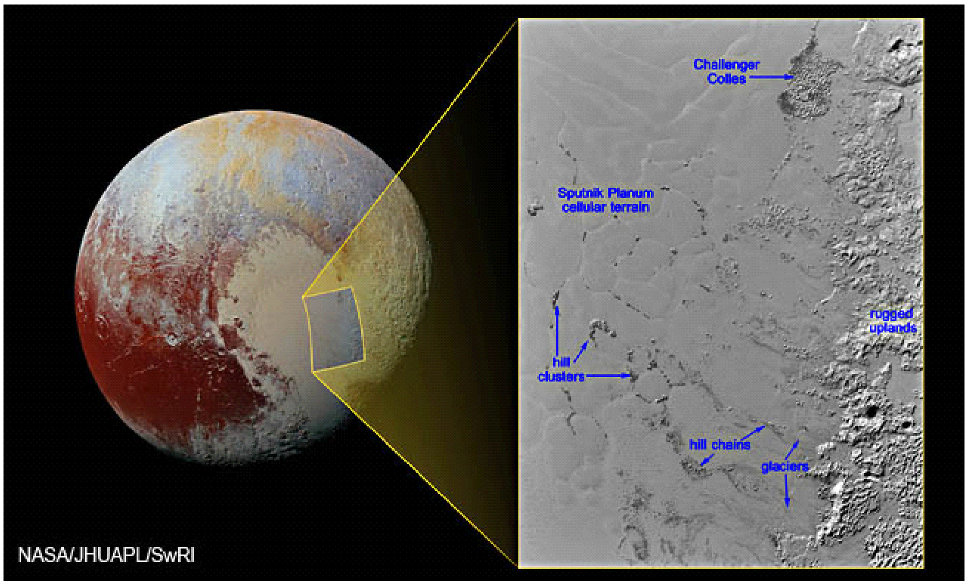


Most distant galaxy (again) – The Hubble Space Telescope has measured the redshift (11.1), and therefore distance to, a galaxy that was found to be the most distant known. Its light left there just 400 million years after the Big Bang. The galaxy has been dubbed GN-z11. It was found to be forming stars furiously.

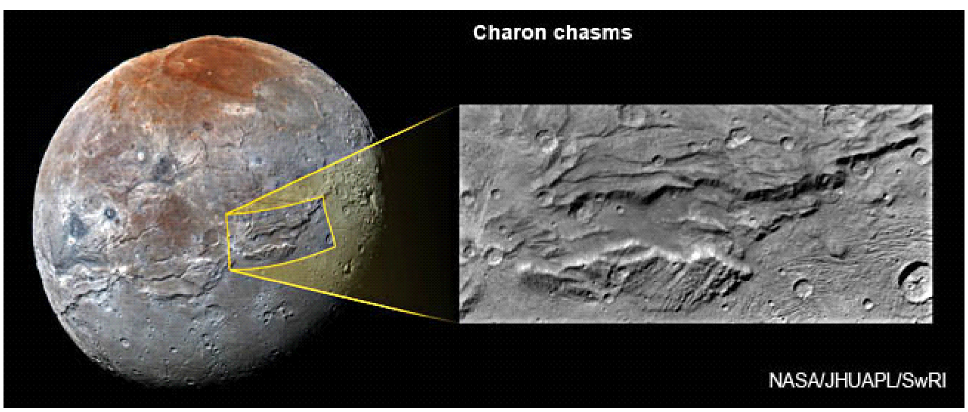
Milky Way halo – Astronomers took advantage of a recent study of the Andromeda Galaxy made by the Hubble Space Telescope to search for stars lying in the halo of the Milky Way, between us and Andromeda. 13 stars were found and studied, measuring their motions in 3 dimensions. The stars were found to be about 65,000 light-years from the Milky Way center. The motions found implied that they were remnants of a collision with a dwarf galaxy billions of years ago. The astronomers are planning a much larger study of Milky Way halo stars, targeted to find hundreds of them.

Record eclipsing binary – Astronomers have discovered an eclipsing binary star system with the longest eclipse known (3.5 years) and with the longest period between eclipses (69 years). Those records were formerly held by Epsilon Aurigae. The newly discovered system, known as TYC 2505-672-1, is nearly 10,000 light-years away. The most recent eclipse ended in 2014, and was well documented by observations by amateur astronomer members of AAVSO and a small telescope survey called KELT. 1432 images of the system were found in the Harvard image archives, including the previous eclipse 69 years earlier. The binary pair must orbit at about the distance between Uranus and our Sun. Like Epsilon Aurigae, the new discovery must have eclipses caused by a large dust cloud (nothing else would last for years). It appears the binary consists of 2 red giant stars, 1 of which has had its outer layers stripped off. The stripped material could be what formed the eclipsing cloud.

New Horizons (Pluto mission) images of Sputnik Planum (a huge plain on Pluto) show clusters of hills that stick up through the plain's surface. Astronomers say that they are probably the tips of icebergs (of water ice) floating in a frozen sea of nitrogen. The hills are up to a few miles (km) across. Likely they were broken off from the ice mountains that partially surround the plain.

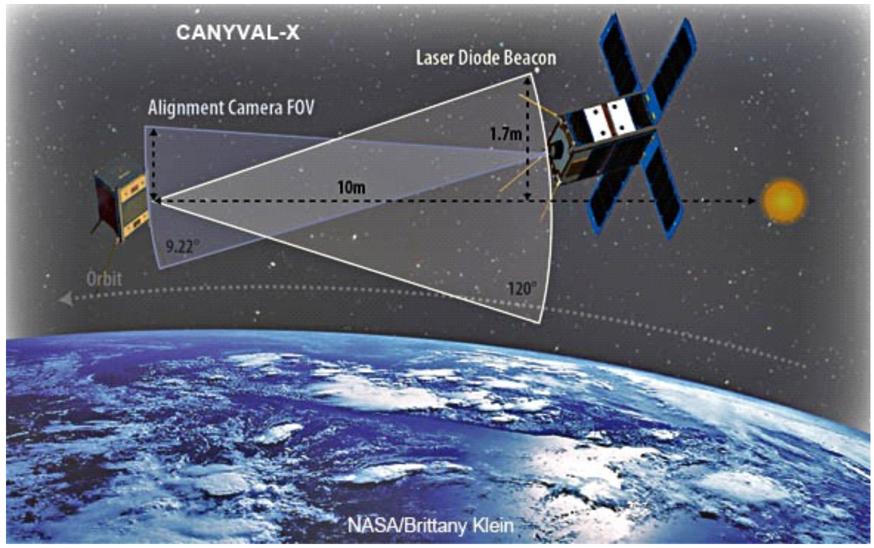


The side of Pluto's moon Charon imaged by **New Horizons** shows a system of tectonic faults that were pulled apart, including valleys reaching more than 4 miles (6 km) deep. The system of chasms is one of the longest seen anywhere in the Solar System, extending at least 1100 miles (1800 km) (probably longer, since it disappears around the back). Astronomers say that early in its history, Charon probably melted much of its water ice, due to heat from radioactive materials and the moon's formation. When the moon cooled, the liquid water froze and expanded, cracking the outer shell, creating the system of chasms.



WFIRST – NASA announced that, after years of design, work will begin on WFIRST (Wide Field InfraRed Survey Telescope), an infrared space telescope with the resolution of the Hubble Space Telescope, but 100 times the field of view. It is set to launch in the mid 2020s. Though WFIRST is much smaller than the James Webb Space Telescope, and therefore with poorer resolution, WFIRST is being considered a successor to both Hubble and Webb. WFIRST is the answer to the question: what do you do when a spy agency gives you a 2.4-meter (94-inch) space-qualified mirror they had laying around? WFIRST design includes a state-of-the-art coronagraph. A coronagraph allows studying objects quite close to a bright source, such as exoplanets very near stars. WFIRST is planned to operate at the L2 Lagrange point, a million miles away from Earth, as will Webb. High priority studies for WFIRST are dark energy (by measuring distant supernovas and gravitational lensing) and exoplanets (by measuring microlensing of planet transits).

CANYVAL-X is a pair of satellites to be launched in May this year, which will test precision formation flying of such objects. Together they will make up a coronagraph space telescope. One satellite carries the optics, the other the detector. The 2 components have been nicknamed Tom and Jerry.



Astronaut Scott Kelly and cosmonaut Mikhail Kornienko finished their "year-long" mission (actually 340 days), during which they participated in numerous studies of long-term effects of spaceflight. Kelly's health was continually compared with his twin brother on the ground. Kelly set the American record for total time in space (520 days), but it will be eclipsed by Jeff Williams during his current stay on the International Space Station. Kelly has announced he will retire soon.

Flood – On January 18, a Cambridge city 8-inch water main broke under Harvard College Observatory Hill, flooding the archives where over ½ million irreplaceable glass photographic negatives, taken over a century, are stored. The water rose about a yard (m) deep before it could be turned off, putting 1/8 of the archive under muddy water. The archive was already being scanned to make a digital copy, but none of the flooded glass plates had been scanned. They were frozen and are being separated from their paper envelopes, washed and dried. The process is expected to take over a year. Hopes are high that it can all be restored. Some of the scanning and computing equipment was also damaged, but it is being replaced. Insurance is paying for the plate restoration.

Instant AstroSpace Updates

Astronomers working on **BOSS** (Baryon Oscillation Spectroscopic Survey) have discovered the largest known wall of superclusters of galaxies, and modestly named it the BOSS Wall. Its mass is 10,000 times that of the Milky Way, it stretches more than a billion light-years, and more than 800 galaxies can be seen in it, even at its distance of 5 billion light-years.

The Rosetta (comet mission) spacecraft team has declared dead the Rosetta lander, named **Philae**, though they have left the Rosetta-Philae receiver on, just in case. Radio contact has not been occurred since last July, and the temperatures on the comet have dropped to low enough to ruin parts of Philae.

Japan Space Agency JAXA launched **Astro-H**, also known as Hitomi, a new X-ray space telescope, covering at high resolution a very wide range of wavelengths, including many not observed by the 6 other X-ray space telescopes in operation. Its studies will include evolution of galaxy clusters and black hole growth.

InSight (mission to study the interior of Mars) has been rescheduled for launch in May 2018, landing in November 2018, following its postponement from launch this year, due to leaks in its primary instrument, a seismograph. The leaky instrument will be redesigned and rebuilt.

Speckle Interferometry:

Scientific Research with the OCA Kuhn 22" Telescope

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Introduction

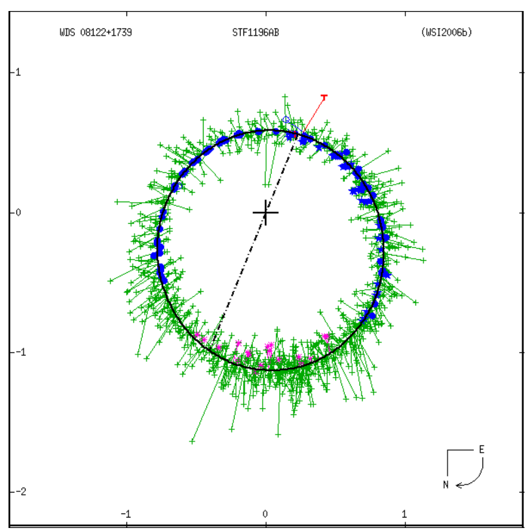
Membership in OCA, one of the largest and most active amateur astronomy clubs in the United States, has many privileges, not the least of which is access to the fine Kuhn 22-inch Cassegrain telescope, located at the club's Anza observing site, with fairly dark skies at 4300' elevation, in the hills about 20 miles east of Mount Palomar Observatory. OCA member William Kuhn led a volunteer effort of many OCA members in designing and building the telescope, named after him. The observatory became operational in 1984, and has been used occasionally for research, particularly discovery of supernovae and asteroids. It is open to all members and guests every month at new-moon star parties, for viewing all types of celestial wonders.

The Kuhn 22-inch telescope can also be reserved by OCA Star Members for special group events or private observing sessions. The combination of my long-time OCA membership, experience in observing double stars (Wasson 2014), and the convenient Anza site located only 37 miles from my home, seemed a natural fit to attempt a new type of research - Speckle Interferometry - which would benefit greatly from a larger aperture than my own 12-inch telescope.

Encouraged by a workshop on Speckle Interferometry presented by Russ Genet and Dave Rowe at the Society for Astronomical Sciences (SAS) meeting in June, 2015, I applied for Star Membership and began training later that month. Requirements for Star Membership include completion of an extensive training program, typically three sessions from instructor Barbara Toy, to learn how to operate the facility safely, and donation of a modest one-time $150 fee used for facility maintenance and upgrades. My training was completed in September 2015.

Speckle work doesn't compete with deep sky observing for nights near new moon, because stellar targets at high magnification are not seriously degraded by a bright sky background. However, I prefer to go to the Anza site when the moon is not too bright, just to enjoy the beautiful sky away from city lights.

From its inception in the 1970s until recently, Speckle Interferometry was practiced only by professional astronomers and graduate students, using specialized equipment at major observatories. The example shown in Figure 1 demonstrates the potential of Speckle Interferometry to improve measurement accuracy for close binaries, reducing uncertainty and producing a high-quality orbit solution.



The technological revolution in small, sensitive, fast, moderately-priced cameras, now used extensively by amateurs to make exquisite planetary images, has also opened the field of Speckle imaging to amateurs. The last piece of the puzzle, easy-to-use software for processing Speckle images, has only become available since 2010, making amateur Speckle Interferometry practical for the first time.

Why Observe Double Stars?

Everything we know about stars is based on observing their light with a range of instruments, to measure or derive their basic properties. The most fundamental property of any star is its mass, which determines how rapidly nuclear fusion proceeds in its core, and thus its intrinsic brightness and its life expectancy.

But the only direct way to determine the mass of stars is by observing them in binary systems. Orbital velocity (measured by Doppler shift) and period are driven by the stars' masses and distance apart. So we need to know the apparent size of the orbit and its distance from us, in order to find the true physical size of the binary star orbit. Distance is measured most accurately by parallax; the Hipparcos satellite of the 1990s made great improvements in distance accuracy, and the next-generation Gaia satellite is now in operation. That leaves the apparent orbit ellipse as the last measurement needed to define the stellar mass accurately.

Surprisingly, less than 60 binary star systems have *accurately* measured (definitive) orbits, so the quality of our models of stellar evolution hangs on this remarkably small sample! Many systems with large orbits are so slow that they have not completed a single orbit since measurements began (about 250 years ago by William Herschel), and many "fast" orbits appear so close together that they can only be resolved by very large telescopes. But many others, some having orbital periods of decades, are near enough that their separation can theoretically be resolved and measured by the Kuhn 22-inch aperture, for which the "Rayleigh limit" resolution is about 0.3 arc-sec; thus the Kuhn 22-inch telescope has the potential to help refine the accuracy of stellar masses – among the most fundamental properties in science!

The "Seeing" Problem

Angular resolution of any telescope depends only on the wavelength of light and the telescope aperture - the larger the aperture, the smaller and closer are details which can be resolved. But for telescopes larger than about 4 inches, atmospheric "seeing" begins to limit the resolution that can actually be achieved, a problem all too familiar to us amateur astronomers.

The problem, of course, is that the sharp, theoretical image is continuously chopped up, shifted and smeared in random ways by small atmospheric cells of variable temperature, density and refraction index, creating an image that is blurred into the "seeing disk." Those cells act like many small lenses filling the big telescope aperture, but each lens is continuously changing size, moving around in the aperture and rotating and tilting slightly with respect to all the others. The length over which the wave front is plane (like the size of each small lens) is called the Fried parameter, typically about 5-20 cm (2-8 inches). The angular size of each "isoplanatic patch" (where atmospheric turbulence is constant) is typically only a few arc seconds, so the double star separation where speckle interferometry can give an accurate measurement is limited to this small angle.

A most remarkable fact was discovered and demonstrated by Anton Labeyrie in 1970: the full-resolution information of a star image still exists in the scrambled "seeing" disk! The image is blurred by the rapid seeing motion, but if very short exposures are taken to "freeze" the motion, each frame shows a pattern of small "speckles." These are actually the interference pattern of all the small lens images superimposed upon each other, swirling within the seeing disk – we see a patch where light from two or more small lenses adds together as a bright "speckle." The dark spaces are where the interference cancels. Picture the moving pattern of light and dark "speckles" on the bottom of a swimming pool, created by the wavy surface acting like a bunch of small, moving, tilting lenses.

The power of Speckle Interferometry is to recover the image information contained in a perfect image formed by the full telescope aperture, by analyzing the speckle patterns of many frozen images. Quality is enhanced by also observing a single reference star, nearby on the sky and near in time. These images are used in Fourier Transform processing, to remove distortions which are common to both the single and double star images.

Equipment

The Kuhn 22" telescope is an f/8 classical Cassegrain design on an equatorial fork mount. It has encoders on both axes, and "Go-To" capability using an older version of TheSky software (www.bisque.com). Although it was built decades ago, club members have upgraded and maintained it well. It can find most objects within a few arc minutes, well within a medium power eyepiece field. Although it does not track accurately enough for long exposure photography, it does track well enough at high magnification for Speckle Interferometry; tracking errors from frame to frame are usually smaller than the seeing movements caused by the atmosphere, which are stopped anyway by taking short exposures (typically 10 to 40 milliseconds).

I use a Point Grey (https://www.ptgrey.com) BlackFly 23S6M-C high-speed monochrome camera, having a Sony IMX249 CMOS detector with 5.86µ square pixels in a 1920 x 1200 array, and global shutter. This camera was chosen because of its large detector (11.2mm x 7.0mm), advertised low read noise (7e- rms), high Quantum Efficiency (82% peak at 500nm), high speed USB3.0 interface (more than 30 fps full frame), and moderate price ($495). A larger-than-usual detector was considered important for the following reasons:

1. Prior experience with my 12-inch Go-To Dobsonian telescope at home had shown that it may be difficult to acquire and track faint stars at high magnification required for speckle work, and the finding and tracking performance of the 22" was unknown to me at the time.

2. I planned to investigate the sidereal drift method to calibrate images for orientation and plate scale (discussed in detail below).

High magnification is required in Speckle Interferometry, so that details of the distorted star images can be seen; individual speckles, which are comparable in size to the Airy disk, should each cover at least several pixels. A red filter has been used to minimize color dispersion of the speckles.

I have had success with plate scales of about 0.07 arc-sec/pixel. Magnification is accomplished by eyepiece projection, with a Baader Hyperion 10mm eyepiece, T2 threaded couplers on the eyepiece and camera, and 30mm T2 projection tube, to reach approximately f/30 (the Airy Disk spanning about 8 pixels). A flip mirror and 23mm illuminated reticle eyepiece are used to find and center target stars. A 3-meter USB3.0 cable carries data to my laptop computer and supplies 5VDC power to the camera. My setup ready for speckle interferometry is shown in Figure 1.

Preparing for a Speckle Run

Double star targets were chosen by scrolling through the on-line Washington Double Star (WDS) catalog, containing a single line of summary information for all known double star components. Maintained by the U.S. Naval Observatory, the catalog provides information for over 130,000 double star systems, so finding targets can be a rather tedious process. For each selected star, the WDS data line was copied into a spreadsheet, which was then printed to act as both a target list and log for hand-written notes at the telescope. Stars with the following characteristics were selected as Speckle candidates:

Fortunately, a *very much easier* way to comb the WDS catalog for suitable targets has recently been developed by Tom Bryant (2015), by way of his on-line web site.

I have found that the easiest way to identify target stars at the telescope is as SAO stars, so the SAO number of each potential target, and a nearby reference (deconvolution) star, were added to the spreadsheet. This way no time is lost in choosing or locating targets. The general faint limit of about 10^{th} magnitude for SAO stars seems well suited to the 22" for my camera and magnification; fainter stars are often buried in the noise, and there are plenty of suitably bright targets.

At the Telescope

After following the checklist for opening the OCA observatory and preparing the Kuhn telescope and control computers, the Speckle Interferometry optical train is screwed together and installed in the Cassegrain 2-inch focuser. The telescope is slewed to a bright star, then centered and "synced," to be sure TheSky software knows accurately where the telescope is pointing.

The cable from the camera is plugged into the USB3.0 port on the laptop, and the data acquisition software FireCapture (Edelmann, 2015) is started. This program, designed primarily for planetary imaging, is used because it can handle many types of cameras and can output frames as FITS files, which is a convenient format for Speckle data reduction. The highly-magnified, turbulent image of the moderately bright star is focused until speckles become clearly visible on the laptop screen.

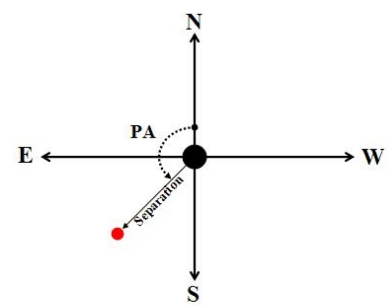
After selecting a target star, typing in its SAO number, and clicking the “slew” command, the big telescope comes to life, majestically but quietly “humming” its way toward the target, which is almost always seen in the eyepiece of the flip mirror. After centering in the illuminated reticle eyepiece, the star is always close to the center of the camera CMOS chip displayed on the laptop. The double star target is centered and a small “Region of Interest” (ROI) selected in Fire-Capture, usually a 512x512 pixel patch (about 40x40 arc-sec) near the center of the chip. Then FireCapture is ordered to record 1000 frames, and I watch as the star boils and dances for about 30 seconds, to be sure it doesn’t drift too near an edge of the ROI field. Only bright and well-separated double stars (more than about 1 arc-sec) are obviously seen as double; a tight and/or faint companion is invisible in the seeing mess, but it is still there!

The next target is a “deconvolution” star, which is a nearby *single* star, later used as a reference in data reduction. All the same optical imperfections that affect the double star are captured in the reference star as well, including even focus and some atmospheric effects. By Fourier Transform “deconvolution,” these small effects are cancelled from the double star data, greatly improving and sharpening the Autocorrelation end product.

Although only one sequence is required for a speckle measurement, several sequences may be taken, to provide statistical samples for defining uncertainty of the final measurement.

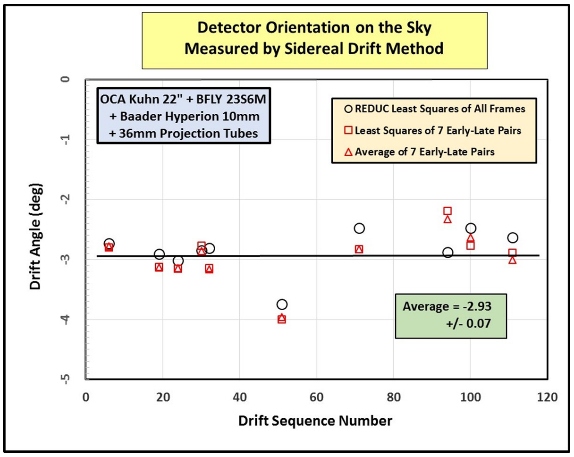
Calibration

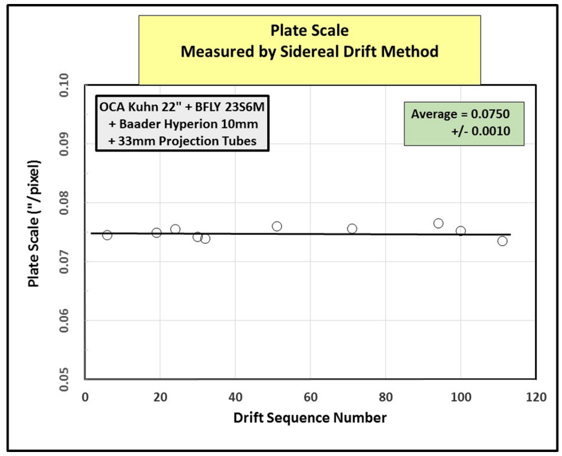
The end products of any double star measurement are simply two quantities: Separation (arc-seconds) and Position Angle (degrees), as shown in Figure 2. In order to maximize accuracy of the measurement, two calibration factors must be determined: Pixel Scale or “Plate Scale” (arc second/pixel) and orientation of the camera on the sky. A simple but accurate way to calibrate the setup is by making several “Calibration Drifts” throughout the night. This method applies only to equatorially-mounted telescopes, and no adjustments can be made which could change the magnification or rotate the camera.



To make a Calibration Drift sequence, a moderately bright star is moved to the east edge of the full field, then a smaller ROI is selected having full frame width (about 2½ arc-minutes) but only 300 pixels in height; this speeds up the frame rate and reduces hard drive storage space. The recording sequence is started and at the same time the circuit breaker powering the telescope drive motors is turned off. When the star has drifted at the sidereal rate from the eastern to the western edge of the field, the breaker is turned back on. The telescope is driven west with the hand paddle control until the star is again centered, and TheSky is “synced” once more to re-establish accurate telescope pointing. A drift typically takes about 10 seconds near the equator, and longer at higher declination.

The sidereal drift path of the star describes the true east-west direction, distorted slightly by the star bouncing around in the seeing disk. Each frame has the computer clock time written to the FITS header by the FireCapture acquisition software. The exposures are short enough to stop the sidereal motion in each frame, as well as the seeing motion. Thus the sequence records several hundred star positions (star image centroid in pixels) at known times. The slope of the star positions calibrates the rotation angle of the camera relative to the true east-west direction. Changes in star position versus time, and the known sidereal rate (a function only of star declination) are used to calculate the pixel scale calibration constant (arc-sec / pixel). This process was originally done in a spreadsheet, but Dave Rowe (chief technical officer of Plane Wave Instruments) has added it to his Speckle Tool Box data reduction program, making it *very much* easier and faster. Figure 3 is an example of one night’s calibration data.

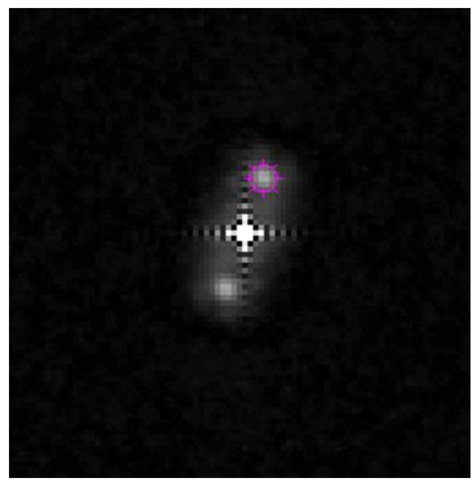




Data Reduction and Speckle Analysis

The details and mathematics behind Speckle Interferometry are beyond the scope of this article. Briefly, Speckle Interferometry data reduction is accomplished by Fourier Transform mathematical analysis of dimensional frequency information, that is, the spacing and orientation of the speckle patterns in each frame. It requires some intense "number crunching!"

Processing includes taking Fourier Transforms of all 1000 individual frames in the binary star sequence, and the same operations for the sequence of single "reference" star frames. In "deconvolution," these transforms are averaged and divided, tending to cancel the optical aberrations and atmospheric distortions that are common to both sets. The cancelled errors include optical aberrations (central obstruction, mirror imperfections, etc.), and even some atmospheric effects!

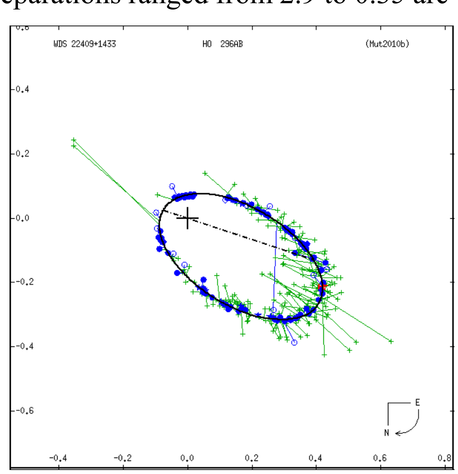


In the last step of processing, an inverse Fourier Transform is taken to give an "Autocorrelogram." It is no longer a real image of the stars, but still contains the near-diffraction-limited information from which measurements are made. An example is shown in Figure 4.

Fortunately, the "heavy lifting" of Fourier Transform mathematics tailored to speckle image processing has been implemented already, and is transparent to the user. At least three freeware programs for Speckle data reduction are available on-line to amateur astronomers, by request of the authors: REDUC (Losse, 2015), PlateSolve3 (Rowe and Genet, 2015), and Speckle Tool Box (Rowe, 2016).

First Speckle Results – Does It Work?

From September through December 2015, I made five Speckle runs on the Kuhn 22" telescope, including a "shakedown" run. A total of 59 close binary stars were observed and measured. Separations ranged from 2.9 to 0.35 arc-seconds, and secondary magnitudes from 5.5 to 9.9.

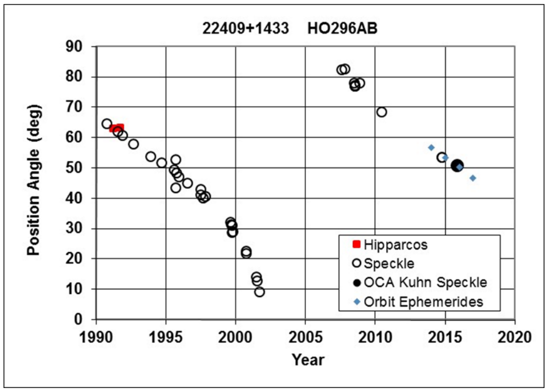


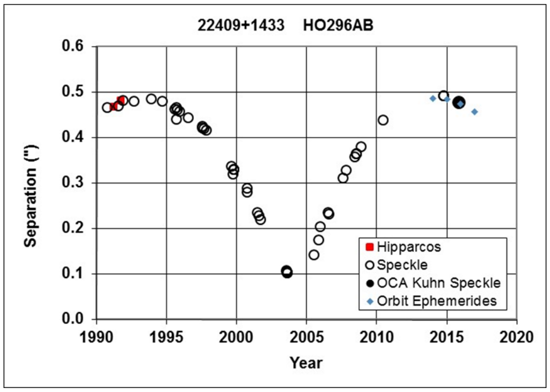
The binary HO296AB was observed in November 2015, chosen as a bright but challengingly close object having a separation (WDS catalog) of only 0.5 arc-sec. Not until after I reduced the data and compared my measurement with the historical data of others, did I realize what a challenge I had inadvertently assumed. Figure 5 shows the WDS apparent orbit plot of all data through 2010.

HO296AB is one of the few binaries which has a "Grade 1" definitive orbit solution, meaning it has numerous accurate measurements over at least one full orbit. The period is 20.83 years, so the orbit has been fully covered by speckle measurements, begun in 1979 by Dr. Harold McAlister on the Kitt Peak 4-meter Mayall telescope. Almost all the other speckle observations were also made by professional astronomers with telescopes including the Kitt Peak 2.1m, WIYN 3.5m, Mt.

Wilson 2.5m (100"), and the Discovery Channel 4.3m. In addition, near periastron, where the separation is less than 0.1 arc-second, measurements have been made with the Russian 6m telescope (speckle in 1983) and with the Palomar Test Bed Interferometer (2003 through 2008).

An outstanding example of Kuhn 22" Speckle results, compared with the measurements of other observers, is shown in Figure 6. The Kuhn 22" data, both Position Angle and Separation, are consistent with all the other speckle data and with the Grade 1 (definitive) orbit predictions. However, it is fortunate that my observation was made near apastron, where the separation is greatest; near periastron, the separation is less than 0.1 arc-sec, requiring the resolution of a much larger telescope.





I plan to publish these results, along with all the other Speckle measurements made with the Kuhn 22" telescope during 2015, in the *Journal of Double Star Observations (JDSO)*. This on-line journal, begun in 2005, particularly encourages publication of all amateur and student measurements. Unlike many professional publications, there are no "page" charges or membership requirements. Double star measurements have no scientific value unless they are published, and become part of the ongoing permanent archive of historical measurements. All *JDSO* observations are regularly reviewed by the staff of the U.S. Naval Observatory for inclusion in the WDS Catalog, the official permanent archive.

The results presented here demonstrate that the OCA Kuhn 22" Telescope is capable of excellent Speckle Interferometry observations, when coupled with a modern camera, computer and software. Amateur astronomers can now make scientific contributions that, less than a decade ago, were restricted to professional astronomers using the world's largest telescopes! I encourage other OCA members to join me in doing Speckle Interferometry, to make a genuine contribution to science by using the excellent club resource of the Kuhn 22" Telescope.

Acknowledgements

The author is grateful to OCA Past President Barbara Toy for her dedication and expertise in instructing new Star Members, and her custodianship of the Kuhn 22-inch Telescope, and to members of the Orange County Astronomers for support and maintenance of the Anza site facilities. He also thanks Bob Buchheim and Russ Genet for their review, comments and corrections.

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory, and the author particularly thanks Brian Mason for providing all previous observation data for target stars.

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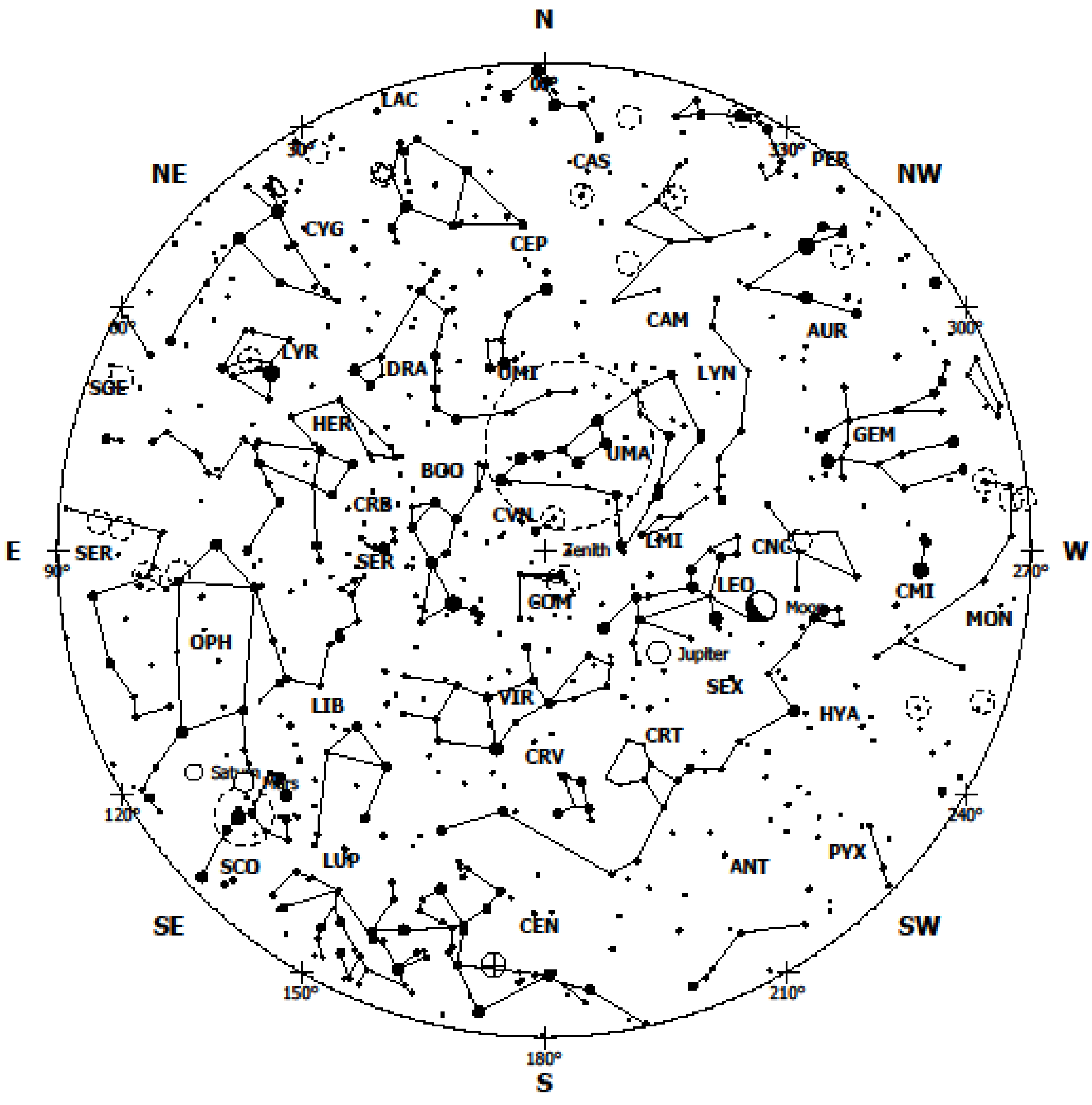
April Whole Sky



Symbols		
Galaxy	Bright nebula	Antisolar point
Quasar	Dark nebula	Asteroid
Globular cluster	Planetary nebula	Comet
Open cluster	Supernova remnant	Meteor shower

Magnitudes

-6 -5 -4 -3 -2 -1 0 1 2 3 4 5

Location	Time	View
United States, CA, Long Beach	Local time: 2016-04-16 00:00:00	Field of view: 200° 00′ 00″
Lon: 118° 11′ 18″ W, Lat: 33° 46′ 01″ N	Universal time: 2016-04-16 07:00:00	RA: 12h 46m 40.28s, Dec: +33° 46′ 01.0″
Time zone: GMT-08:00	Julian date: 2457494.79167	Azi: 180° 00′ 00.0″, Alt: +90° 00′ 00.0″
Elevation: 29 feet above sea level	Sidereal time: 12h 46m 40s	Constellation: Canes Venatici

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