Workshop on Automation and Robotic Operation of Moderate-Sized Telescopes for Speckle Interferometry

U.S. Naval Observatory

2-3 June 2014

Motivation

Continued advances in telescope design are now enabling robotic operation for a variety of observational programs. Heretofore, the small field of view and high magnification of speckle interferometry coupled with sensitivity of the technique to oversaturation have made robotic speckle interferometry a challenge, both from a software and hardware perspective. Advances in both equipment and techniques are now bringing automation of speckle observation within reach, however – with the promise of significant increases in data throughput enabling investigation of new avenues of research.

This workshop in intended for people with robotic experience, those developing and desiring to develop programs. There will be significant time set aside for discussion. The program details listed at the end of this document will provide possible relevant topics for discussion.

If you have a topic on which you would wish to present, please get in touch with the meeting organizers at wds@usno.navy.mil.

Program

***	**SUNDAY**	
1930-2300	Opening Reception. USNO Library.	
***	**MONDAY**	
0830-0845	Coffee.	
0845-0900	Welcome/Logistics. Fill out lunch form.	
0900-1030	Observing Programs appropriate for high-cadence, long-focus instruments. I. Optimizing Existing Observing Programs.	
1030-1045	Break.	
1045-1215	Observing Programs appropriate for high-cadence, long-focus instruments. II. New Observing Programs.	
1215-1300	Discussion.	
1300-1400	Lunch.	
1400-1530	Current Speckle Observing Programs. Procedures and “Best Practices”. What is scalable to high volume work?	

Program (continued)

1530-1615	Break / Discussion.
1615-1730	Camera (EMCCD, ICCD, CMOS, etc.) and Camera Systems (Filters, Risleys, etc.).
1730-1800	Discussion / Adjourn.
2000-2130	Tour.
2130-2300	Telescope and Observing demo.
***	**TUESDAY**
0630-0745	Leisurely (5 mph) six mile run through Rock Creek Park & National Zoo leaving South Gate. Optional.
0830-0900	Coffee / Logistics. Fill out lunch form.
0900-1015	Telescopes. I. Automating Existing Telescopes.
1015-1115	Telescopes. II. Adding Speckle to Existing Robotic Telescopes.
1115-1130	Break.
1130-1230	Telescopes. III. Dedicated New Robotic Telescopes for Speckle Interferometry.

Program (concluded)

1230-1300 Discussion.

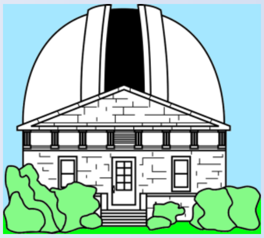
1300-1400 Lunch.

1400-1630 Software and Standards: Dealing with the data flow.

1630-1730 Discussion / Adjourn.

Proceedings

- A website will be set up for posting presentations. If desired, these can be scrubbed of embargoed material.
- LaTeX style files will be mailed in mid-June for electronic workshop proceedings.



Logistics

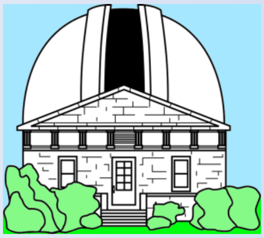
- To gain admittance to the US Naval Observatory, please submit name and DOB to "wds@usno.navy.mil" as per the dates on the following page.
- Arrive at USNO South Gate with photo identification (e.g., driver's license, passport) matching above data.
- For directions to the USNO please see: http://www.usno.navy.mil/USNO/tours-events/tour-information/travel-directions-to-the-u.s.-naval-observatory

- For accommodation and dining options, the south gate of the USNO is most convenient to the Glover Park neighborhood.
- Among the nearby restaurants are:
  - Angelico Pizzeria
  - Town Hall
  - Bourbon
  - Old Europe
  - Surfside
  - Heritage India
  - Shanghai Tea House
  - Subway
  - Chipotle
  - Rocklands BBQ
- Nearby hotels include:
  - Georgetown Hill Inn
  - Savoy Suites Hotel
  - Holiday Inn Washington-Georgetown

Deadlines

- 5 May : non-US citizens notify us of intent to attend meeting.
- 19 May : US citizens notify us of intent to attend meeting.
- 19 May : Title and abstract of contributed talk or poster along with preference for which you want to do. This will allow us time to finalize the program.

meeting email : wds@usno.navy.mil



Social Events

1. There will be a reception, Sunday 1 June, in the US Naval Observatory library at 7:30 p.m.

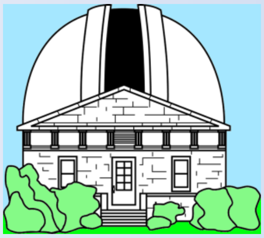
2. General tour of the Observatory on Monday 2 June at 8:00 p.m.

3. Following the Observatory tour will be a demonstration of the 26” telescope and the current state of our automation project. If cloudy, this will be a short event; however, if conditions permit the general speckle observing program will be demonstrated (FYI: Sunset 8:28 p.m. local).

4. Leisurely (5 mph) six mile run through Rock Creek Park and National Zoo leaving South Gate at 6:30 a.m.

Refreshment

- Lunch (sandwich,chips,cookie,drink) will be provided and delivered by Stargazer Café for $8.95. Menus will be distributed and collected each morning.



Lunch Menu

NAME:______________________________

Café

Lunch Selection

All sandwiches served with Soda, water, chips &cookies
please mark your selection clearly

Choice of Bread
☐ White Sub-roll ☐ Wheat Sub-roll ☐Wrap ☐ Croissant
☐ Mayonnaise ☐ Mustard Pasta Salad or Cole slaw
Choice of Cheese
☐ Swiss ☐ Provolone ☐ American
☐ *Garden Fresh Veggie*
Garden fresh lettuce, tomatoes, onions, green peppers, olives, shredded carrots, pickles, and cheese
☐ *Roast Beef Delight*
Sliced Roast Beef with lettuce, tomatoes and cheese
☐ *Turkey Delight*
Sliced turkey with lettuce, tomatoes and cheese
☐ *Tuna Salad*
Savory flaked tuna mixed with mayo and celery with lettuce and tomatoes
☐ *Chicken Salad*
Chicken breast mixed with mayo, celery with lettuce and tomatoes

Program Details

Observing Programs appropriate for high cadence, long focus instruments. I. Optimizing Existing Observing Programs.

Observing Programs appropriate for high cadence, long focus instruments. I. New Observing Programs.

Possible automated speckle telescopes in 1m, 2m, and 4m classes in both the Northern and Southern hemisphere could have significantly different but complimentary programs. For example, a northern hemisphere 1m class telescope (e.g., the USNO 26") could do little but improve the orbits or rectilinear elements of known systems. A 1m class telescope could confirm a fair number of Hipparcos/Tycho pairs in the southern hemisphere, while a 2m class telescope could probably do them all. To complete the Bright Star Catalogue speckle survey, a 4m class telescope would be required. For many of these systems (e.g., Gaia discoveries and nearby stars), the magnitude limit would restrict what could be done with EMCCD cameras, so conventional CCD or CMOS hybrids might be better. Potential observing programs include:

- Improve known orbits
- Improve known rectilinear elements
- Improve or add differential photometry
- Confirm Hipparcos or Tycho discoveries
- Observe short-arc binaries (small separations and short periods)
- Discover new doubles/binaries (Millions of Multiples/LSST follow up)
- Discover new doubles/binaries (large delta magnitudes requiring special equipment/procedures)
- Follow up to Gaia discoveries
- Follow up on various surveys with LSST, Pan-STARRS, etc.
- Special surveys of selected classes of double or binary stars

Program Details

Astrometric Precision and Accuracy

Automated speckle interferometry systems, especially on telescopes devoted full time to double star observations, might be able to reach new levels of both precision and accuracy. This could open up entirely new observational possibilities. Over a range of separations, magnitudes, and magnitude differences, how many observations would be needed for the variance to be minimized? What “calibration” observations should be made in a single night or over multiple nights, and if multiple nights, how many? These are questions that all programs (telescope + detector + reduction methodology) should address, but it should be a key project early in the automation program. Some of the portions of such a program may primarily be one-time and hence may not need to be repeated

Another way of increasing precision (and perhaps extending capabilities to fainter doubles or ones with larger delta magnitudes) is to make more extensive use of more carefully selected single reference deconvolution stars. Again, automation encourages such “luxuries.” A series of “observational experiments” has been planned to explore the use of reference deconvolution stars with an eye toward automation where one can use them more generously. Could one, for instance, bracket the double star observations with single star observations (much as is done with comparison stars in differential photometry)? Should we try to match the reference star spectral type to that of the primary double star?

Accuracy can be improved through more extensive and frequent calibrations, always using the same telescope and equipment in the same manner (such as observing along the meridian), and recording and applying possible influential variables (such as truss temperatures) and using them to make small adjustments in the results.

Differential Multi-band photometry

Observations of differential magnitudes of pairs in multiple colors are considerably easier than absolute photometry observations. While some double star speckle observations, such as Horch’s dual-channel observations, always include differential photometry, many other observers only report observations in one color band. Automation will allow routine differential photometric measurements to be gathered in a larger number of different color bands. Repeated observations over the years on multiple telescopes should improve both the precision and accuracy of color indices.

Program Details

Speckle observations are often made in a single band, with the observer having to choose between observing more doubles in less color bands or vice versa. Automation would allow a greater number of observations to be made in different color bands, significantly increasing the astrophysical significance and value of all observations, including those made in single color bands.
With dedicated speckle systems, transformations to standard photometric systems (and to the “Tycho system”) could be achieved through more extensive observations of “standard” double stars.

Variable Star Differential Photometry

Full automation would provide the observing time needed to investigate the variability of selected components.

Current Speckle Observing Programs. Procedures and “Best Practices”. What is scalable to high volume work?

Learning from Existing Manual Speckle Programs

What can we learn from the information/data flow on existing manual speckle interferometry programs that we could apply to automation? Are there standards, or at least best practices, that we could apply to automated speckle programs? Possibilities for consideration:

Generation of target lists
Selection of targets on nights of observation
Format of recorded observations / FITS header information / other recorded information
Preparation of data for reduction
Reduction of data including calibration
Dissemination of data to users (often multiple requestors of data)
Publication of observations
Incorporation of observations in appropriate catalogs
Achieving of data and observations for posterity

Program Details

Camera (EMCCD, ICCD, CMOS, etc.) and Camera Systems (Filters, Risleys, etc.).

Cameras

What is the current camera technology and economics? Where might it go in the future? Technical breakthroughs could allow us to reach fainter magnitudes or larger delta magnitudes, while an economic breakthrough might help bring double star intensity interferometry to many more observatories. Possible topics include;

Currently available new EMCCD cameras (overview of all the suppliers)
Used market for EMCCD cameras
Future of front-illuminated EMCCD chips and cameras
NuVu super low clock-noise EMCCD cameras
sCMOS cameras and other possibilities
Uncooled, non-EM CCD cameras for use on smaller telescopes and brighter, wider doubles

Camera systems

Of course there is more to speckle interferometry cameras than just EMCCD cameras. Other components include magnification, filters, Riseley prisms, etc. How will these be automated? What camera systems are currently automated? Possible topics include:

New USNO EMCCD camera system
Live observing demos both Monday and Tuesday night of the USNO camera (weather permitting)
California Polytechnic State Univ. camera system
Atmospheric distortion correction tutorial/principals

Program Details

Telescopes. I. Automating Existing Telescopes.

Telescopes (automate existing telescopes)

As a supplement or alternative to building new telescopes dedicated to speckle observations of double stars, existing telescopes (besides the USNO refractor) could be automated. Possibilities include:

McMath-Pierce 0.9-m East Auxiliary Telescope. Discussions are under way with Matt Penn and Mark Giampapa at the National Solar Observatory about automating this telescope for double star observations either for the entire year or at least for long segments of the year. A trial, non-automated run is scheduled for this April. Speckle camera system can be put on an optical bench of the 0.8m East Auxiliary Telescope. This telescope is controlled by TheSky6. The main 1.5-meter telescope would be another possibility, switching the beam in the spectrograph room to a speckle camera.
Big Bear Solar Telescope. This 1.5-meter telescope might be automated for night-time speckle interferometry.
Kitt Peak 2.1-m telescope. This spring is the last semester of operation for this telescope after operating continuously for decades. NOAO is hoping to form a user's consortium. The consortium may try to automate or at least provide real-time remote access of the telescope. If they do, perhaps occasional blocks of time (say twice a year) might be used for speckle interferometry. Discussions are under way with Lori Allen, the Kitt Peak Director.
NOFS 1-meter Ritchie telescope. This historic telescope could be used for dedicated speckle observations for a month or two twice a year. It might be a candidate for automation.
Lowell Observatory/JPL Table Mountain Observatory 1-meter telescope. This Boller & Chivens telescope has been reconditioned and moved out of storage at Lowell Observatory and installed at JPL's Table Mountain Observatory. It will be operational later this year. Lowell and JPL will share time 50/50. Discussions are underway with Lowell's Director, Jeff Hall, and Gerard van Belle.

Program Details

Telescopes. II. Adding Speckle to Existing Robotic Telescopes.

Add Speckle Interferometry to Existing Automated Telescopes

Full automation of telescopes and observatories has now become routine. There are many telescopes that are already fully automated but do not make speckle double star observations. Including speckle interferometry may be as simple as adding a speckle camera or, in some cases, both a camera and an instrument selector. Perhaps some of the owners of these robotic telecopes could be enticed to include speckle interferometry in their capabilities. These telescopes include:

LCOGT All of the many Los Cumbres Observatory telescopes are automated. Most of them are equipped with EMCCD cameras. They have two 2-m telescopes, and will have over a dozen 1-m telescopes and over a dozen 0.4-m telescopes. Currently, magnification for speckle is not included, but they are planning on a magnification capability with Andor Luca cameras on their 1-meter telescopes in the future. Joe Tufts at LCOGT has been working on adding this capability.
Fairborn Observatory They now have 14 fully automated telescopes operating at a fully automated observatory. All this is taken care of by one on-site person, Lou Boyd. This is easily the planet's most efficient observatory. Primarily automated photometry, but also a 2-meter automated spectroscopy telescope with meter/sec radial velocity capability (double temperature control, etc.). Adding speckle interferometry might not be out of the question.
Winer Observatory Mark Trueblood manages a large roll-off roof observatory in Sanoita, south of Tucson. Winer Observatory is probably more of a place to site a telescope than latching on to an existing telescope.
Sierra Stars Observatory Network Rich Williams runs a network of telescopes, including 0.6-m and 0.8-m telescopes in California and Arizona (Mt. Lemon). This totally automated, queue-observing network is places emphasis on scientific research, including student research.

Program Details

Telescopes. III. Dedicated New Robotic Telescopes for Speckle Interferometry.

Develop new telescopes dedicated entirely to speckle interferometry of double stars

Depending on the circumstances, a specialized telescope can cost considerably less to purchase and operate than a general-purpose telescope. It is not entirely clear whether not this will be the case for speckle interferometry, but is worth considering and discussing. Possible topics include:

Type of mount Meridian, quasi-meridian, and all-sky telescopes of various sorts are being considered. The cost differences at small apertures may not be large but can be significant at 2m and beyond.
Pointing accuracy The field-of-view of speckle cameras is so small—just a few arc seconds across—it can help the efficiency of speckle observations if the double star (or single reference star) can be brought directly into the science camera's fov without having to go through a wide-field initial acquisition process. The combination of affordable Renishaw optical tape encoders, advanced pointing models, such as PointXP, and excellent mechanics (such as all-bearing systems) may provide a pointing accuracy on small, affordable telescopes significantly better than 5 arc seconds, especially in a local areas after observing a single reference star.
Slewing-to-target times Speckle interferometry observations can be very short. For instance, 1000 frames taken at 10 ms each is only takes 10 seconds. Of course 2000 frames at 30 ms/frame for four color bands is much longer, namely 4 minutes. In any event, moving rapidly (and accurately) between targets could significantly improve overall observational efficiency. To this end, the new, relatively affordable, direct drive system from Sidereal Technology would be worth considering.
Large-aperture, low cost, dedicated speckle telescopes A group of astronomers and engineers in the "Alt-Az Initiative" have been exploring low cost meter-class mirrors and telescopes for the past seven years. What they have learned could apply to the development of meter-class speckle interferometry telescopes. For instance, a dedicated 2-meter, quasi-meridian telescope might employ a spherical primary and a low-frequency (essentially DC) active (adjustable) secondary mirror. For any given week of operation, the telescope could observe doubles in a 10° x 10° field of view centered on the meridian at the start of the week. The telescope's pointing model could be tweaked for this small field, and the secondary mirror (perhaps a Pressman-Carmichael) could be adjusted to minimize distortions of the thin, spherical, low-cost primary mirror. Since there would only be roughly 5° of movement from the "tweaked" center of the field, the pointing model and mirror adjustments might be good for the week. Proper, consistent and constant image rotation will be *essential* in alt/az systems.

Program Details

Software and Standards: Dealing with the data flow.

Developing and fielding a number of totally automatic double star speckle interferometry systems will greatly increase the flow of observational requests, data reduction, and data archiving. Handling this flood in a manner efficient for all will require the development of shared software, the standardizing of data transfer protocols, and specifying uniform FITS headers, etc. Without doubt, this will be the most challenging task on the path toward total automation of a number of systems. The flood of data from these automated instruments will require new automated reduction, or at least automation of the preliminary reduction.
A number of reduction programs have been developed that have worked well for their using institutions, but are were intended for wider, public use. Examples include the reduction programs at the USNO, Elliott Horche's, and Andre Tokovinin's. Two reduction programs have been developed with the intent of providing user-friendly software for a wide range of users. These are:

Florent Losse's REDUC Florent has developed a double star reduction program intended for widespread use (which it has seen). It has a nice speckle interferometry capability, although not intended for differential photometry or full automation.
Dave Rowe's PlateSovle 3 Dave has completed the initial development of a reduction program that can reduce data semi-automatically but should be able run fully automatically in the near future. It is well documented and was developed with an eye toward widespread public use.