Steve Conard
Bruce Holenstein
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High Speed Observing Plans for Regulus-163 Erigone Event

Goals

- Use available EMCCD cameras, supplemented with typical low light video cameras to:
  - Detect the white dwarf companion of Regulus
    - Probable that this could be achieved
  - Attempt to measure the angular size of Regulus
    - Questionable how good the data quality would be using the available telescopes
  - Contribute to size and shape measurement of Erigone (video)
    - “Easy”

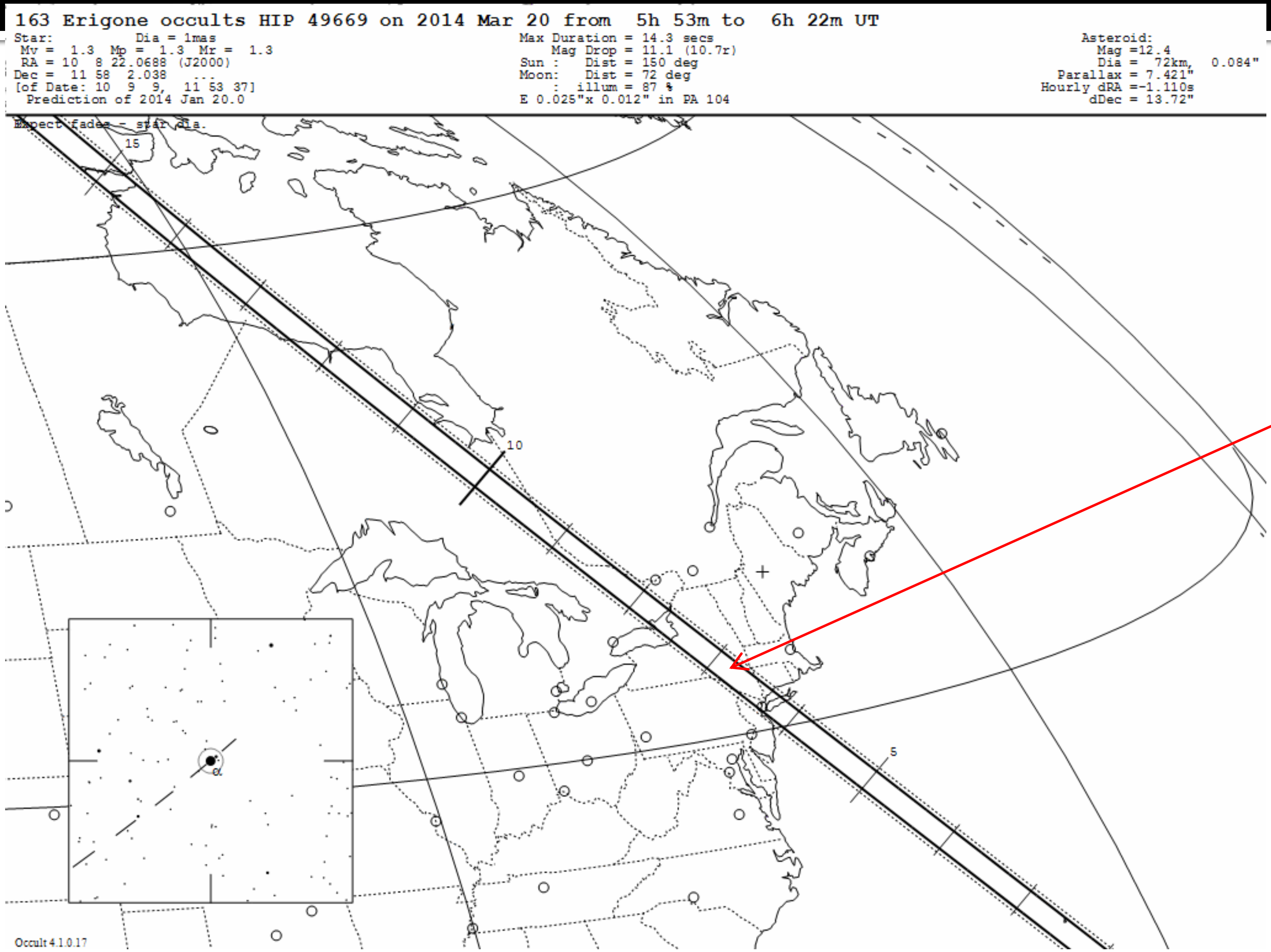
Observing Location

- Initially we were going to observe from several locations
  - We decided to scale back to all observing at a single location, in order to maximize the chances that we'd have at least partial success (more hands available for troubleshooting, spare hardware)
- We traded off several ideas for our observing location
  - Bring our own equipment, try to set-up in a known location
    - Bruce has relations along the predicted path, and Steve was raised in the Catskills
  - Find existing private, club, or college observatory to use
    - Steve has had excellent luck on getting positive responses for observing time at college observatories in the Northeast US (Alfred College, Randolph College, UMBC, JHU)
    - It was decided to pursue this path

Observatory Selection

- A web search resulted in a list of about a half-dozen college observatories within the predicted shadow in NY
  - This was down-selected to Vassar and SUNY-Oneonta based on closeness to centerline and available equipment, with a slight preference to SUNY-Oneonta
  - We contacted the observatory director at SUNY-Oneonta, Dr. Jason Smolinski, and he agreed to host our expedition

Map


163 Erigone occults HIP 49669 on 2014 Mar 20 from 5h 53m to 6h 22m UT
Star: Dia = 1mas
Mv = 1.3 Mp = 1.3 Mr = 1.3
RA = 10 8 22.0688 (J2000)
Dec = 11 58 2.038 ...
[of Date: 10 9 9, 11 53 37]
Prediction of 2014 Jan 20.0
Max Duration = 14.3 secs
Mag Drop = 11.1 (10.7r)
Sun : Dist = 150 deg
Moon: Dist = 72 deg
: illum = 87 %
E 0.025"x 0.012" in PA 104
Asteroid:
Mag =12.4
Dia = 72km, 0.084"
Parallax = 7.421"
Hourly dRA =-1.110s
dDec = 13.72"
Expect fades - star dia.
15
10
5
Occult 4.1.0.17
Approximate location of SUNY-Oneonta

Telescopes

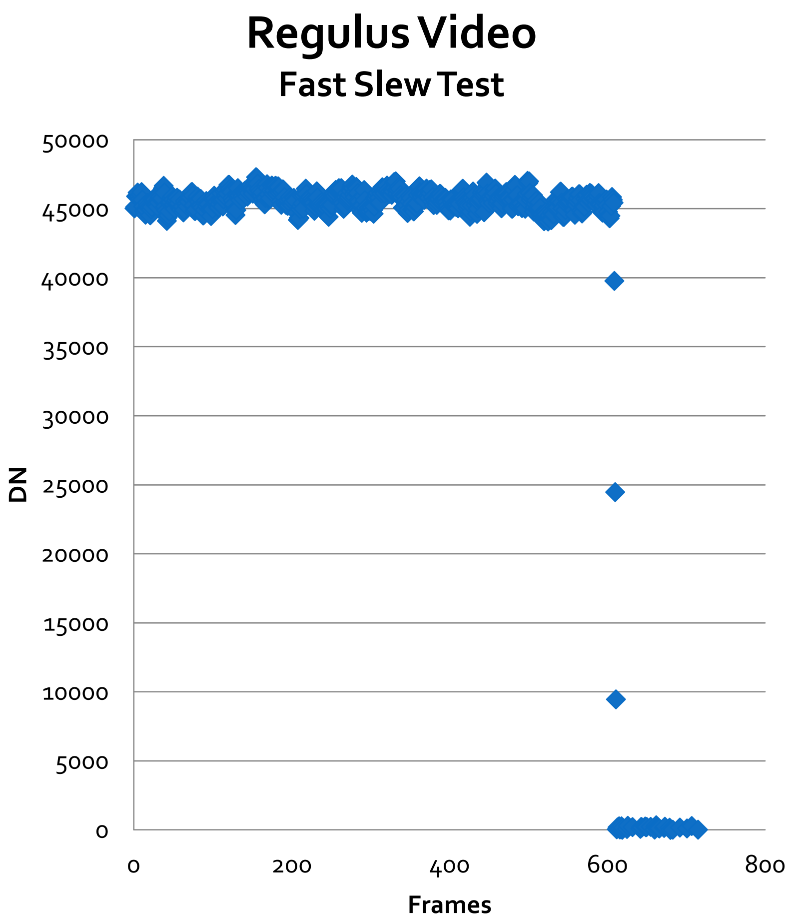
- SUNY-Oneonta has a well equipped observatory
  - 16" Meade SCT in dome—we planned to use a typical time-inserted video camera
  - 14" Celestron SCT in dome—we planned to use a 512B EMCCD tuned to detect the white dwarf companion
  - 1-m portable folded Newtonian—we planned to use a 128 EMCCD to measure angular size of Regulus
  - A number of smaller telescopes—did not plan to use
- Additionally, we planned to bring a 12" LX200 SCT belonging to Bruce that also would carry a 512B for redundancy

Cameras

- Bruce has a number of EMCCD cameras that he purchased used from sources such as eBay
- For the Regulus event, we chose to use 3 of them
  - (2) Photometrics Cascade 512B (512 x 512, 16 µm square pixels, capable of being read out at ~200 Hz in ROI/binned mode)
  - (1) Photometrics Cascade 128+ (128 x 128, 24 µm square pixels, capable of being read out at >3000 Hz in ROI/binned mode)
- These cameras have adapters to mate to a 2" standard eyepiece tube
  - Bruce had these adapters custom fabricated
  - They do not easily adapt to focal reducers typically used by IOTA

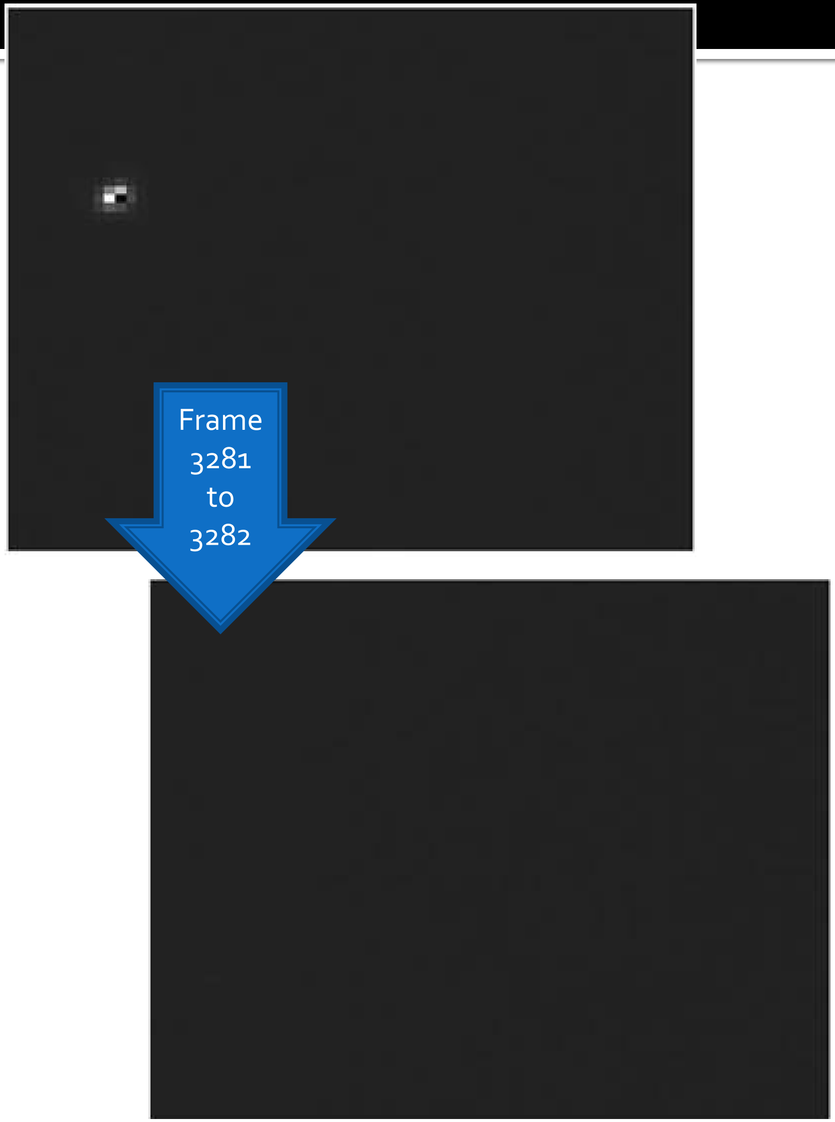
Advance Testing

- In order to estimate the data quality we could obtain, we did advance testing using Steve's 14" Celestron SCT
  - This telescope is identical to the one we planned to use at SUNY-Oneonta for the white dwarf detection
  - Used Dave Herald's suggested test of recording Regulus in the field, then slewing it out of the field as quickly as possible—to look for time for pixel recovery
    - Used a Stellacam EX video camera, found the signal level was essentially background in three frames or less (non-infinite acceleration of the mount contributed some)



Advance Testing

- A similar test was done using the Photometrics EMCCD
  - Done at ~167 frames per second
  - Went from a peak pixel of ~8000 to not detectable in a single frame
- SNR > 10



Software

- During advance testing, it was determined that the various software packages for the Photometrics EMCCD would not operate above about 90 Hz
  - We desired to get to about 200 Hz for the Regulus shape measurement attempt
- Dylan ended up writing his own software to allow us to approach 200 Hz
  - This development is discussed in a later talk

Predicted SNR
(to capture the full event with one camera)

- The Cascade 512 are 16bit EMCCDs with 200k electron wells.
- Use a small amount of EM gain (~25x) to reduce the read noise to around 1 electron.
- At 100 frames/sec on a 16 inch scope, an unfiltered Regulus will produce about 8M photo electrons x 25 = 200M electrons from the CCD registers.
- Defocus so the PSF is spread over a region ~50 pixels in diameter to avoid saturation.
- Predicted SNR for Regulus photometry will be **5.7 per frame**, 100% scintillation bound.
  - Lower than measured SNR during testing phase
- A 13.5th magnitude companion will then produce a SNR of **2.0 per frame**, 80% read noises, 11% scintillation, and the rest shot noise. EM gain is essential since just 5% of the pixels will hold photoelectrons. Adding more EM gain to reduce the read and quantization noises risks saturation on Regulus.
- Another idea we considered briefly was to programmatically increase the camera gain after the flux level falls off a certain percentage.

Event Plans

- SUNY-Oneonta had planned the following in conjunction with this event
  - A planetarium show for interested attendees
  - Guests invited from an observatory in Albany (off the predicted path)
  - Students observing and assisting in our observations
- Several telecons held to discuss our observations
  - A "Data Collection Event Plan" written with a timeline and responsibilities

Data Collection Plan

Draft 2
14 March 2014

Regulus-Erigone Occultation Event Plan
IOTA High Speed Imaging Team
SUNY-Oneonta Observatory

Attendees

From SUNY-Oneonta
Jason Smolinski (host)
Mike Faux (Department Chair)
Students

From Dudley Observatory
Ron Barnell
Others?

From IOTA:
Steve Conard, Johns Hopkins Applied Physic Laboratory
Bruce Holenstein, Gravic
Dylan Holenstein, Gravic
Jack Gross, Randolph College
Hart Gillespie, Randolph College

Approximate Schedule

~4:30 p.m. - High speed imaging team (HSIT) arrives at observatory
~4:30 to 7:30 p.m. - Observatory setup and dinner
8:00 p.m. - Dudley group arrives; Roundtable introductions and coffee
8:30 p.m. - Planetarium show, some of HSIT returns to observatory and begins data collection test runs
9:30 p.m. - Observatory tour
2:00 a.m. - Occultation
3:00 a.m. - Equipment breakdown, return to hotel

Goals
(In order of importance)
1. Obtain one GPS time inserted 30-Hz chord to support the 2-D mapping of Erigone's shape
2. Obtain one GPS time inserted 30-Hz chord to support detection of possibly white dwarf companion of Regulus
3. Obtain at least two ~100-Hz chords from same location to allow coadding of data to reduce scintillation noise

Data

Data collected from goal 1 above will be reported and shared with all interested parties. This will be done via the North American Coordinator for IOTA. Data from 2 and 3 above will be evaluated by the HSIT and SUNY-Oneonta prior to release to any other parties, and after that step the group will determine if and how the data will be released to others--and with what conditions.

Equipment and Personnel Matrix

Telescope	Camera	Computer/Timing	Lead	Primary Goal Supported
SUNY-14" SCT	Photometrics 512B [b]	WOO Laptop [b], GPS [a], PVCamRecorder	Conard	3
SUNY-16" SCT	Stellacam EX [b]	SCORE Box [b], Canon Recorder [b]	Gillespie	2
SUNY-1m Newt*	Photometrics 512B [a]	Gravic TBD [a], GPS [a], PVCamRecorder	B Holenstein	3
Gravic - 20" Newt [a]	Photometrics 128 [a]	Gravic TBD [a], GPS [a], PVCamRecorder	D Holenstein	3
C-mount Lens [b]	Watec 902 Ult [b]	SCORE Box [c], Canon Recorder [b]	Gross	1

* If the 1m Newtonian is not available, a 10" SCT from Gravic will be used or we'll delete that station
[a] carried by Holenstein
[b] carried by Conard
[c] carried by Gross/Gillespie

Significant Open Issues

Will 1-m telescope be useable? Jason reports he will know by Monday’s call.
How will Photometrics camera be installed on 1-m (off-loading mass from focus tube, balancing telescope)? Jason reports the telescope has additional weight plates for balancing

Comments

Several of the SUNY students are experienced with the 16" SCT--we'll assume one or two will be working with Hart on collecting that data.
If the 1m is available, Jason will be assisting with that telescope.
The brightness of the white dwarf is unknown and estimates have ranged from mag 8 to 14. We will optimize the camera on the 16" SCT for the faint end of that range (if it is brighter, many of the other IOTA systems deployed elsewhere will detect it.

Results

- Weather forecasts from several days in advance looked dismal
- About 24 hours in advance, we "tentatively" canceled
  - Members of the observing team had one-way drives of 4 to 10 hours, and were missing work or classes to travel
- Later in the day, Dylan and Bruce decided to travel in any event
  - While there ended up being some "sucker holes" in the area, there were none near Regulus at event time
  - After arriving, they were told the observatory site was too muddy to allow visitors so they observed in the hotel parking lot.

Observing in Oneonta, NY

L to R: Hotel worker, Dylan, and Jason

Lessons Learned

- Use of private/club/college observatories is often easy to obtain, especially for interesting potential event such as Regulus/Erigone
  - Past experience has shown that it can sometimes spark an interest in the host to observe future events—reference Hart Gillespie's talk about the Randolph College program
- Initial plans for new types of observations are often too grandiose, and as a result are too risky
  - Developing plans that can be gracefully descoped can be the most practical way to proceed
- Dry run testing is critical
  - It revealed that although the EMCCDs were rated to run at ~200 Hz, the available software did not support that
  - Early testing gave us the opportunity to develop the required software

Future High Speed Observing Campaigns

- Bright asteroid occultations are rare, so we are looking for other opportunities to observe
  - We have been looking for opportunities to try high speed lunar occultations, but have been thwarted by weather and availability of people
    - Stray light will be a limiting factor
    - Steve is working on design of a lunar light trap for use on these cameras using FRED
    - Concept is to use 3-D printing to fabricate them once the design is complete
  - While not high speed, the EMCCD camera have shown they can detect very faint stars on a C-14 with <1 second exposures, and will be useful for future TNO events