OH Mira Masers
Lyons Homeschool Group

1 Introduction

The objective for this project will be to detect OH masers around old Mira stars, which in the Northern Hemisphere can be found around: U Her, S CrB, W Hya, and R Cas. For radio measurements, we'll have to use dark skies as a control measure of cold sky between 2 and 3 degrees off from these Miras. This will be a program for collecting data over 2 years. Mira stars are old variable red giants with an average period of 331 days. However, their magnitudes may vary from a visual minimum magnitude to greater than 4 or 5 magnitude increase (very bright). The hope is that we can detect their OH masers at 1.665GHz and 1.667GHz with circular polarization during the entire cycle of variability. If detection is possible with this receiver on the 18 meter dish[es], then data can be collected on the weekends or whenever the stars are above the horizon. Variable star observations are normally done in the optical, however these OH masers have been rated greater than 1 Jansky in flux. (AAVSO, ()). Previous calibrations with T-22's 1.420GHz receiver have shown that this is about the limit of sensitivity for our 18 meter dish[es]. However, with suitable tracking capability and dwell time, we may be able to detect these OH maser signatures. Should our data be statistically significant, the hope will be to submit our results to the American Association of Variable Star Observers (AAVSO) Mira program.

2 Physical Science Instruction

LHS physical science is taught using a variety of sources. One is a volunteer, practicing professional scientist. The volunteer (VPS) came to LHS as a result of the 2013 flood in Lyons. Post flood, the VPS was talking with the Lyons Depot librarian about volunteering, and the librarian suggested LHS. The VPS provided background and contact information to the librarian, who then passed them over to the LHS. LHS with the VPS, and a series of trial classes were designed beginning with simple machines. The LHS and VPS collaboration, beginning in May, 2014, is ongoing at the time of this paper.

The VPS reasons for teaching LHS students the physical sciences are:

1. Bring the experience of a practicing professional research scientist (formally, an astrostatistician) earlier in the education process

2. Use derived lessons needed for an actual research project rather than the tradition sequence of mathematics and science curricula.

3. Contribute to rebuilding the vitality of the Town of Lyons community.

2.1 Teaching Method

Astronomy, mathematics, physics, and statistics are taught as the students engage in an actual astronomical research project. This method involves the students in activities such as observation techniques, data collection and analysis, and the science these tools bring.

The research project the students are working is to see if the period of oscillation of a Mira variable star aligns with the period of oscillation of the OH radical maser resident in the gas medium surrounding the Mira variable star. The research question for the student to investigate is whether the Mira variability pumps (drives) the OH maser.

The research phases are given in 2.1. These phases are designed around the beginning ages of the students beginning in the equivalent of middle school through the equivalent of high school. Students are expected to queue in, through, and out of the project according to age and interest level. Those students interested in scientific research are expected to mature through the project, while those students with less science interest will learn to use and process telescopic images to produce photographic art, for example.

Table 1: Mira OH maser correlation study phases.

Phase	Year	Activity
1	1	Collect Mira IR (optical) data
	2	Collect OH radical maser data
2	3	Identify the periods and magnitudes of the Mira and OH maser oscillations
3	4	Test if the oscillation periods are random
4	5	Write papers and present at conferences

The science and mathematics subjects the students will have are in 2.1. The subjects are given by the phase of the research project.

2.2 Skynet Junior Scholars Collaboration

Classes in physics began in May of 2014. The parents provided the topics for the VPS to teach. The lessons progressed with "hands-on" activities and experiments to enable the students to feel physics as well intellectualize it. The VPS supplemented the lessons with examples from current scientific research.

The VPS felt that the lesson structure was too much what could be had in a typical classroom, and less about what science and scientific research were about. The VPS decided to find a research project that could span the middle and high school years that was not necessarily ground-breaking science, but was serious enough to warrant comment from the scientific community. The VPS's specialty was astrostatistics, and hence the search for a project was focused on astronomy.

During a joint meeting between the Little Thompson Obsservatory (LTO) and the Estes Park Memorial Observatory (EPMO), LTO members introduced the Skynet Junior Scholars (SJS) program that they were participating in. SJS is designed to engage young explorers in the study of the Universe using the same tools as professionals. The SJS web portal connects middle and

Table 2: Mira OH maser correlation study science subjects.

Phase	Subjects
1	Astronomy including stellar dynamics
	Optical and radio telescope operating and observing skills
	Sampling statistics (with concommitant mathematics)
2	Algebra
	Trigonometry
	Calculus
	Statistics
	Mira variable star physics
	OH maser physics
3	Time series statistical models
	Time series cross-correlation models
	Hypothesis testing
4	Writing scientific journal writing
	Scientific conference presentation skills

high-school aged youth with activities, resources and guidance to become scholars of the sky. SJS is funded by the National Science Foundation and targets 4-H programs and other out-of-school programs focused on STEM learning. The SJS is supported by the National Science Foundation under Grant Numbers 1223687, 1223235 and 1223345, and is administered by Sue Ann Heatherly (NRAO) and Vivian Hoetle, (University of Chicago Yerkes Observatory). See the SJS website for more information.

The LHS VPS investigated SJS and, upon being trained by the SJS leaders at the National Radio Astronomy Observatory at Green Bank, West Virginia at the behest of the LHS structure, formulated the Mira research project because of the capabilities of the SJS facilities.

3 Scientific Rationale

Develop observing procedures for using the SSP-4 Photometer to acquire H and J IR band observations of 4 Mira Stars. Develop a training program for use of the equipment for summer session.

Table 3: List of Targets.

Catalog No.	Other Designation	RA and Dec.	Magnitude
U Her	AAVSO 1621+19	16 25 47.4713 +18 53 32.867 IRCS	+7.6-12.3var
R Cass	AAVSO 2353+50	23 58 24.8725 +51 23 19.703 IRCS	+4.8-13.1var
W HYA	AAVSO 1343-27	13 49 01.9980 -28 22 03.488 IRCS	+7.7-11.6var
S CrB	AAVSO 1517+31	15 21 23.9556 +31 22 02.585 IRCS	+6.9-12.4var

3.1 Mira R Cas

Data inferred from the Hipparcos catalog
Distance: 107 ± 13 parsecs (348 ± 41 light-years)
Luminosity: 0.97 ± 0.23 times that of the sun
Absolute magnitude: 4.83 ± 0.25

J2000 position at current date (proper motion included)
Right ascension: $23^h\ 58^m.415610$ ($\pm$15.1 milliarcseconds)
Declination: $+51^\circ\ 23^m.3305$($\pm$14.0 milliarcseconds)

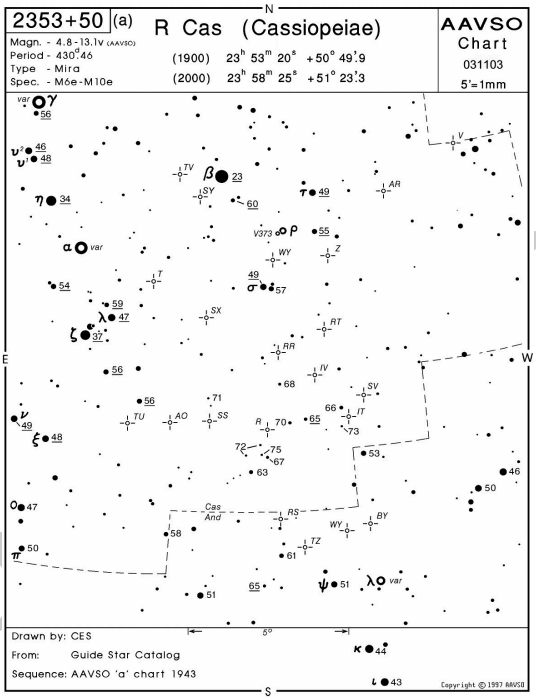

Figure 1: R Cas star chart.

Comments from the Hipparcos Variability Annex.
Spectral type: M6:e.
Periodic variable
Magnitude at maximum from curve fitting: 5.053
Magnitude at minimum from curve fitting: 9.293
Mean period: 431.3 days
A light curve exists for this star in Annex B of the full catalog.
Magnitude: 4.80
Proper motion in RA: +0.078 arcseconds/year
Proper motion in dec: +0.014 arcseconds/year

Proper motion total: 0.079 arcseconds/year
BD +50 4202
HR (Bright Star) catalog spectrum: M7IIIe
HR #9066 SAO #35938 HD #224490
Double/Multiple Companions optical.
Polarization: Polarization possibly due to circumstellar dust scattering.
Spectrum OH and H2O emission strong in infrared. IR spectra show water vapor. Variable M6e-M10e.
Variability ADS 17135A, M 4.7 - 13.5v, 430.46d.
Variable SiO maser source, indicating shell-like structure. Single cycle 6.45 to 11.25V, +1.31 to +2.66(B-V), -0.07 to +1.02(U-B).

Comments from the GCVS:
Cause(s) of variability: Long period variable (Mira type)
Photometric band: V
Maximum magnitude: 4.7
Minimum magnitude: 13.5
Epoch: JD 2444463. (Be aware that epoch data from the GCVS dates back so far that, for present-day use, it is not all that useful.)
Period of variation: 430.46 days
Spectral type: M6e-M10e
References: 00001 00002

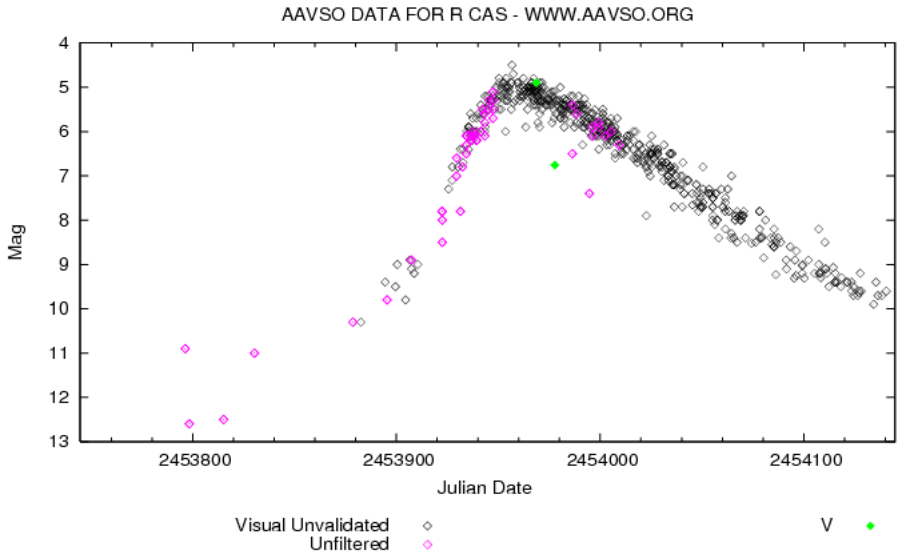

Figure 2: R Cas AAVSO light curve.

AAVSO designation 2353+50; available charts are:

a scale chart, made 1986; field of view is 18 degrees
b scale chart, made 1/94; field of view is 3 degrees
d scale chart, made 1/94; field of view is 1 degree
e scale chart, made 8/94; field of view is 30”

3.2 Mira R CrB

Data inferred from the Hipparcos catalog:
Distance: 530 ± 380 parsecs (1700 ± 1200 light-years)
Luminosity: 130 ± 190 times that of the sun
Absolute magnitude: -0.5 ± 1.6

J2000 position at current date (proper motion included)
Right ascension: $15^h\ 21^m.399183$($\pm$9.9 milliarcseconds)
Declination: $+31^\circ\ 22^m.0417$($\pm$14.8 milliarcseconds

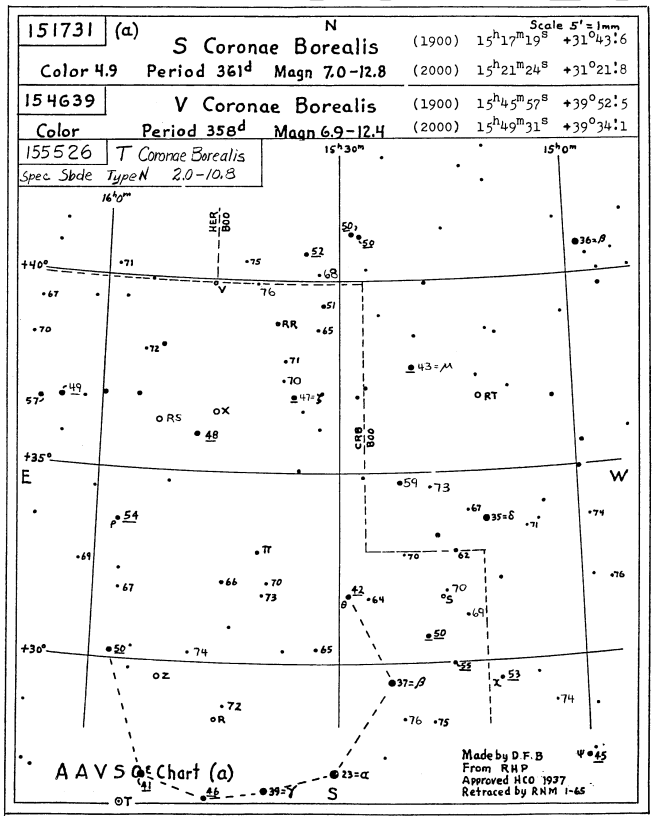

Figure 3: R CrB star chart.

Comments from the Hipparcos Variability Annex
Spectral type: M6e-M8e
Periodic variable
Magnitude at maximum from curve fitting: 6.469
Magnitude at minimum from curve fitting: 10.555
Mean period: 357.8 days
A light curve exists for this star in Annex B of the full catalog.

Comments from the GCVS
Cause(s) of variability: Long period variable (Mira type)
Photometric band: V
Maximum magnitude: 5.8
Minimum magnitude: 14.1
Epoch: JD 2444604.
Period of variation: 360.26 days
Spectral type: M6e-M8e
References: 00001 00002

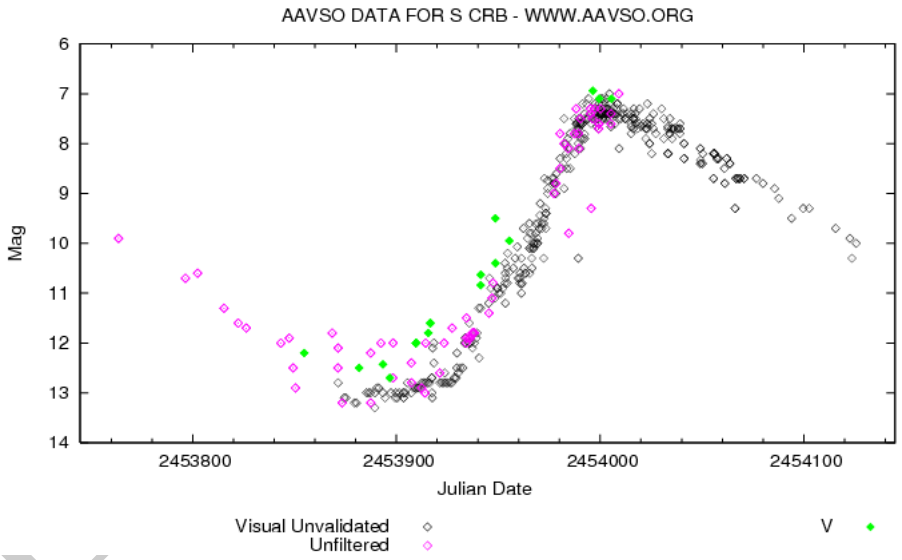

Figure 4: R CrB AAVSO light curve.

AAVSO designation 1517+31 ; available charts are
a scale chart, made 1986; field of view is 18 degrees
b scale chart, made 11/94; field of view is 3 degrees
d scale chart, made 12/94; field of view is 1 degree

3.3 Mira U Her

Data inferred from the Hipparcos catalog:
Distance: 610 ± 490 parsecs (2000 ± 1600 light-years)
Luminosity: 150 ± 230 times that of the sun
Absolute magnitude: -0.6 ± 1.7

J2000 position at current date (proper motion included)
Right ascension: $16^h\ 25^m.791047(\pm 13.0$ milliarcseconds)
Declination: $+18^\circ\ 53^m.5466(\pm 14.6$ milliarcseconds)

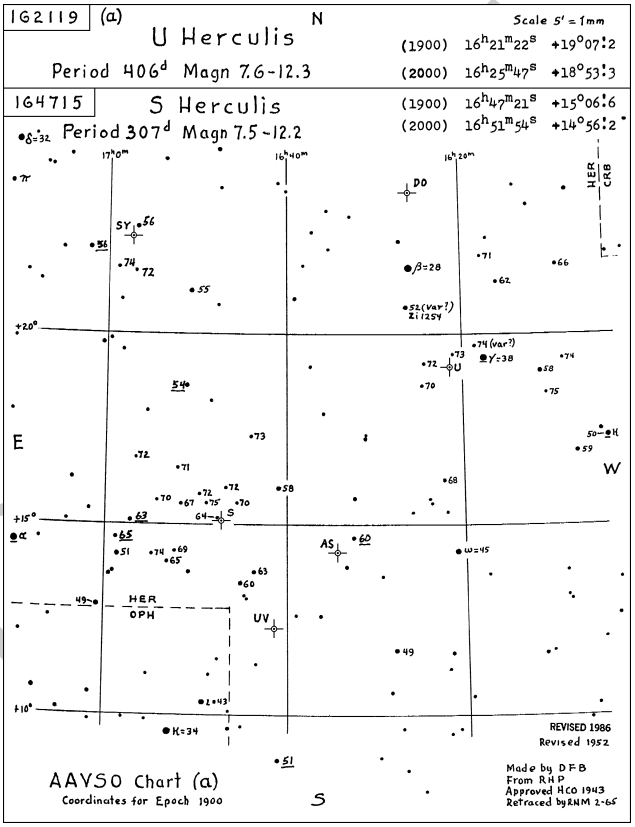

Figure 5: U Hur star chart.

Comments from the Hipparcos Variability Annex
Spectral type: M6.5e-M9.5e
Periodic variable
Magnitude at maximum from curve fitting: 6.419
Magnitude at minimum from curve fitting: 10.294
Mean period: 418. days

A light curve exists for this star in Annex B of the full catalog.
Comments from the GCVS
Cause(s) of variability: Long period variable (Mira type)
Photometric band: V
Maximum magnitude: 6.4
Minimum magnitude: 13.4
Epoch: JD 2444994.
Period of variation: 406.10 days
Spectral type: M6.5e-M9.5e
References: 00001 00002

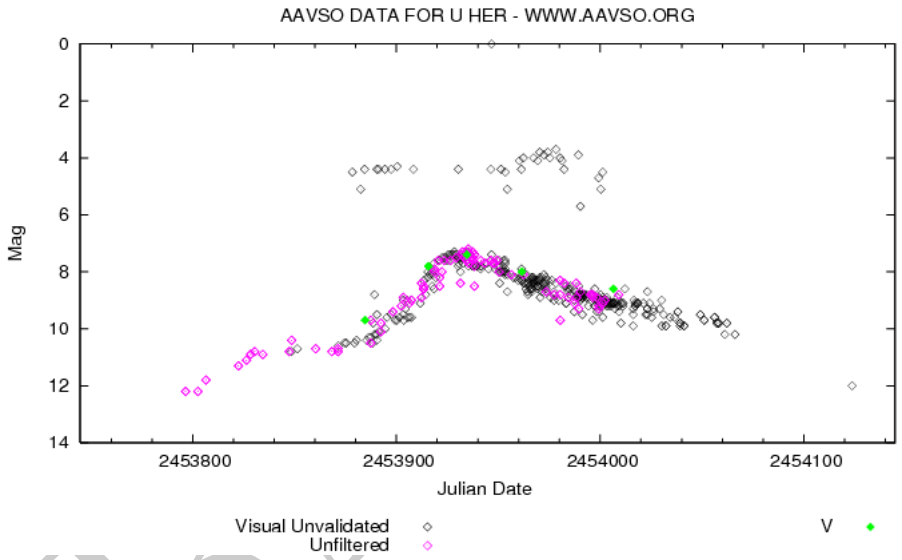

Figure 6: U Hur AAVSO light curve.

AAVSO designation 1621+19; available charts are
a scale chart, made 1986; field of view is 18 degrees
b scale chart, made 2/65; field of view is 3 degrees
c scale chart, made 2/65; field of view is 2 degrees
d scale chart, made 2/65; field of view is 1 degree

3.4 Mira W Hya

Data inferred from the Hipparcos catalog:
Distance: 115 ± 14 parsecs (374 ± 47 light-years)
Luminosity: 11.3 ± 2.8 times that of the sun
Absolute magnitude: 2.17 ± 0.27

J2000 position at current date (proper motion included)
Right ascension: $13^h\ 49^m.032860$
Declination: $-28^\circ\ 22^m.0652$

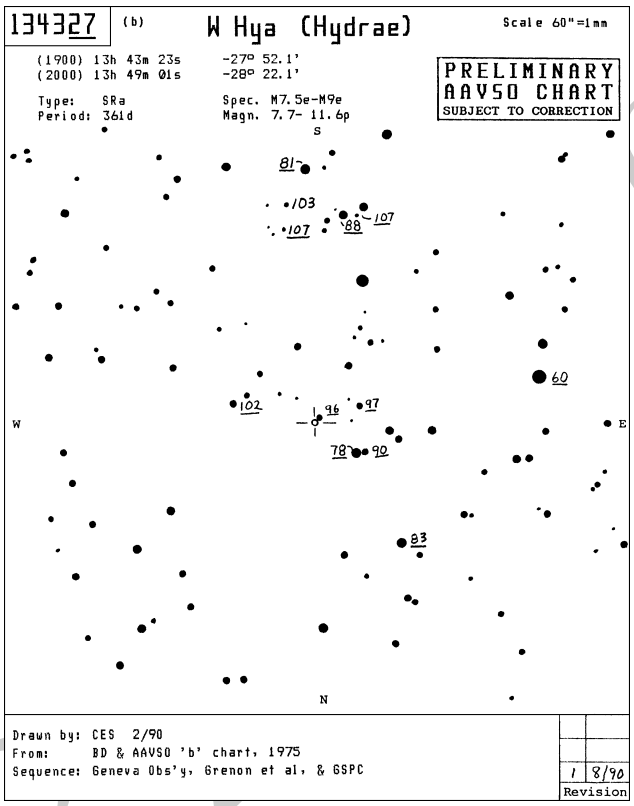

Figure 7: W Hya star chart.

Comments from the Hipparcos Variability Annex
Spectral type: M7e
Periodic variable
Magnitude at maximum from curve fitting: 5.319
Magnitude at minimum from curve fitting: 7.335
Mean period: 369. days
A light curve exists for this star in Annex B of the full catalog.

Comments from the GCVS
Cause(s) of variability: Semiregular long-period (Z Aqr type)
Photometric band: P
Maximum magnitude: 7.7
Minimum magnitude: 11.6

Epoch: JD 2443271.
Period of variation: 361. days
Spectral type: M7.5e-M9ep
References: 00001 08953

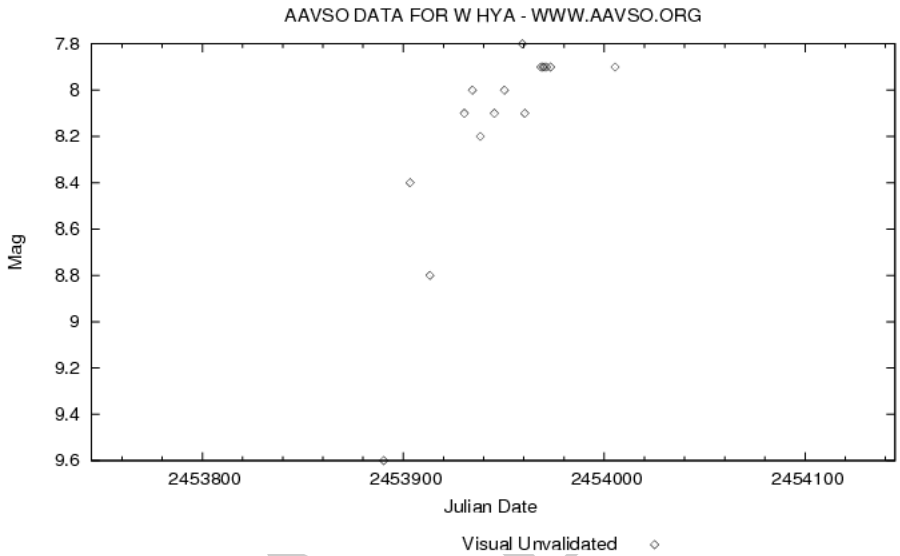

Figure 8: .

AAVSO designation 1343-27; available charts are
b scale chart, made 2/90; field of view is 3 degrees