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Interactive on-line archive for short-period variable stars

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ABSTRACT

We report initial results from a project to design an interactive on-line data archive for short-period variable stars. Our goal is to provide an easily accessible set of web pages for use by a researcher at the telescope. The first step is to provide the researcher with convenient access to data archives for a variety of short-period variable stars. In addition to the basic data archive, there is a page for each star that contains positional information, the most recent epoch and period data, basic physical parameters, and a set of helpful journal references. We also include a page for each of the program variables with a finder chart and a selection of comparison stars for use in differential photometry. Additionally, one entry point in the system is a phase calculator that will sort through the data and return a list of stars that are observable from various user input locations during a variety of time periods.

The current system has a partial data set in place for over one hundred short-period variable stars. We intend to continue to expand this set to include a large number of complete data files. We are also considering a similar archive of galaxy images for comparison use in student conducted supernovae searches. We find this system improves the scientific return from our two small telescopes at the West Mountain Observatory. We believe this model can also be employed to optimize data management and scientific return for a wide variety of projects from the new generation of large ground-based telescopes.

Keywords: archive, user interface, variable stars, finder charts, phase calculator

1. INTRODUCTION

When securing data for projects involving time series observations, a problem that is often encountered is how to best utilize the telescope time so that optimum phase coverage of the target objects is achieved. A common practice for an observer is to generate a new list of objects along with the time period that they should be observed for each night at the telescope. This is often a time consuming and repetitious procedure. Furthermore, many of the variable stars that have been cataloged have not been observed often. As a result there are often inadequate finder charts for many variable stars. It is also difficult to keep track of the many references to the various physical properties that have been determined in previous investigations if there are a large number of objects in a given class of stars. The interactive on-line data archive described in this paper is one solution to many of the problems an observer often faces during this type of research.

Web access is now common at many observatories. With the workstation now being a part of most telescope control rooms, we decided to base our archive around a series of web pages that can be accessed from a variety of locations. This structure allows us to continually update the data set while the archive remains active for a large number of observers around the world. The links from page to page are self-explanatory, permitting an observer to make use of this system on the very first visit. Since so many astronomers are now familiar with resources on the web, we concluded that this type of archive would be especially useful in conjunction with the observing aids detailed above.

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We have a long history of variable star research at Brigham Young University. For the past several decades, there have been many investigations into the fundamental properties of dwarf Cepheids and SX Phoenicis stars. Our experience with these short-period intrinsic variables led us to conclude that they would provide an excellent initial data set for this project. At present, we have entered a partial data set for approximately one hundred short-period variable stars. This has been done to test the feasibility and usefulness of different sections of our proposed system.

This first data set contains all of the SX Phoenicis stars, a majority of the high-amplitude delta Scuti stars (dwarf Cepheids), and a selection of ordinary delta Scuti stars. Most of the first data set information is adopted from Rodriguez et al. 1994[1]. The next step in this project will be to update the data files for all of the stars presently in the archive. This will include making sure that finder charts are available for each star in the archive, assembling complete lists of times of maximum light for all variables, and completing the literature search for each star in the data set to insure that the most recent period, epoch, and list of fundamental parameters are provided in the archive. Once this first step is complete, we plan to expand the archive to include all known short-period variable stars, along with a large selection of easily observable RR Lyrae stars and classical Cepheids. It was suggested at the January 1998 meeting of the American Astronomical Society that the data archive expand to include the lambda Bootes type variable stars. This suggestion has been adopted and we are now adding stars included in a recent paper by Paunzen et al. 1997[2] that details this interesting class of short-period variables.

We find that we can make use of this system whether we are observing with the telescopes of the Brigham Young University West Mountain Observatory or utilizing a remote facility. The ability to rapidly sort the observing lists based on magnitude, period, or amplitude, in conjunction with position in the sky, adds dramatically to the overall effectiveness of an observing run. Another area where this type of system would be useful is where a quick comparison of images from one night to the next is needed. For example, we have considered compiling an archive of galaxy images secured at the plate scale of our telescopes that will allow students to visually inspect subsequent images for transient events such as a nova or supernova. We believe that this system enhances the efficiency and utilization of our small telescopes. Furthermore, we believe that similar systems based on this model would be useful for any observer pursuing a wide variety of time-critical observations. The ready availability of these resources will greatly enhance the effectiveness and productivity of the observer when using valuable telescope time.

2. PHASE CALCULATOR

The phase calculator is a tool we have added to the data archive that significantly increases the utility of the system when used in conjunction with an observing run. This section of the program allows the user to sort through the entire data set for possible target objects. The search parameters include period, pulsation amplitude, and average magnitude. In addition, the user can check for observable phase intervals for a single variable star if desired.

We have divided the phase calculator program into two sections. The first section is a program that is specific to the West Mountain Observatory operated by the Department of Physics and Astronomy at Brigham Young University. The second section consists of a program that functions as a general phase calculator for any user input observatory location. The user can specify the output of the phase determination to include either times of maximum light, half phase intervals, or quarter phase intervals. The output is currently set to cover a twelve hour period that starts after a user input time delay. One of the next additions to the program will be a routine that will calculate the actual times for observable hours at a general location. We also plan to include a new feature that will allow for the phase determinations to be made several weeks or even months in advance of an observing run. At present, the system only allows for a time delay of one day between the calculations and the observations.

The West Mountain Observatory phase calculator is designed to return search results from the variable star data set specifically for that location during the twelve hour interval set by the user. The program calculates the Julian date and the heliocentric correction for each of the requested phase points. These are output along with the universal time for each point. The output also includes the altitude, hour angle, and corresponding airmass for each phase point determined. This output is extremely helpful at the telescope as an aid in deciding the most suitable time periods for observation of a selection of target objects.

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Figure 1 is the output from a search on the data set for information on the star IP Virginis. There are four times of maximum light that can be observed inside the two airmass window at West Mountain during the specified time interval. For this request, data was returned for the time of each quarter phase during the pulsation cycle. Note that each page is clearly dated and that the observatory latitude and longitude are listed for the observer. Also, the variable star name for each target object is listed on the output along with the basic pulsation properties and the epoch 2000 coordinates.

Figure 2 is the output for the same search on IP Vir using the general phase calculator. For this search, the latitude and longitude are those of Cerro Tololo Interamerican Observatory. Note that the same phase points are found for the overlapping portion of the time interval. However, other than the different observing hours, the output for the two sites differs only in the calculations of the altitude, hour angle, and airmass. This feature allows the observer to determine the optimum observing interval for each target object.

3. GENERAL INFORMATION PAGES

Another useful tool that has been incorporated into the interactive data archive is the general information page for each of the stars in the data set. This page contains information on the position of the variable star, additional names, photometric values, data on the period and epoch of the pulsation cycle, abundance estimates, basic physical parameters for the variable, a list of recent references, and a set of comparison stars that match the finder chart for stars that have been observed at Brigham Young University. It is our goal to update these pages as new information is submitted to us or as we complete investigations on various groups of stars.

Figure 3 is a sample of one of the general information pages in the data archive. Once again, the star IP Vir has been selected for this example. IP Vir is well suited for this example since detailed observations have only been reported in two prior investigations. The data display is thus limited and easy to display in a small area. IP Vir was discovered to be variable in a survey of standard stars by Landolt[3]. Since the initial study, there has been a complete investigation published by Joner et al. 1998[4]. Those major references are given in the general information page in Figure 3. Also note that the page lists the stars that have been used as a comparison ensemble in the differential photometry of the most recent investigation. The information page also contains all of the major results from the 1998 publication along with the updated pulsation epoch and period. This feature of the data archive is helpful during an observing session when a quick decision is required and the observer needs to consult a convenient source of basic information.

We are working to continue to expand this portion of the archive so that this information is readily available to as many observers as possible. We have data available for most of the stars that have been observed at Brigham Young University and will continue to add additional data as it becomes available. Expansion and update of the archive will continue to be a significant challenge in the foreseeable future because of the volume of work that continues to be produced in variable star investigations.

4. FINDER CHARTS

It was only a few short years ago that locating and copying adequate finder charts and maps for faint target objects was a time consuming procedure. If there was not a published map in the literature, an observer would often have no other choice than to try and copy a finder chart from an atlas or sky survey plates. Before these sources were digitized, this part of preparing for an observing run could take hours of valuable time. We decided that it would be useful to include a finder chart for each of the variable stars in the data archive. These maps are extracted from the Space Telescope Science Institute Digitized Sky Survey[5]. After the field is extracted, we edit the image so that we can add labels to indicate the variable star, members of the comparison ensemble, and the north and east directions.

It was decided early in this project to use a field of view that is twenty arc minutes square. The telescopes at West Mountain usually operate with a field about a quarter of that area. However, during our time series observations we have made frequent use of the Burrell Schmidt at Kitt Peak National Observatory, where we have usually used a field that is twenty arc minutes square. Thus, we have decided to make all of our maps to that scale. An effort has been made to locate suitable comparison stars within five arc minutes of all the variables.

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Figure 4 is a copy of one of the finder charts from the data archive. Once again, we use the delta Scuti variable star known as IP Vir as an illustration. Note that this map covers an area that is twenty arc minutes on a side. The directions north and east are clearly marked on the map. Also, the stars labeled one through seven are the same stars indicated on the general information page as members of the comparison ensemble. These stars have been used successfully during many nights of differential photometry on this object. They were found to be stable in all cases. These maps represent a great improvement over the days when observers would trace star patterns from the pages of an atlas. The use of these finder charts makes identification of unfamiliar fields at the telescope a routine matter.

5. DATA ARCHIVE

Our goal for the data archive is to assemble as much of the accumulated data as possible for intrinsic variable stars. While this final section of the program is not generally useful for investigators while they are in the process of securing observations, the archive will be a valuable resource for the researcher once the process of data interpretation has begun. Additionally, the archival data provides source material for the general information page, the phase calculator, and the finder chart subroutines within the program. The archive portion of the program is still being assembled, with a near term goal of completing the archival entries for as many of the stars in the initial data set as possible and a long term goal of collecting and updating as much data as possible into the archive for all classes of intrinsic variable stars.

Figure 5 is an output from the data archive file which contains all of the known times of maximum light for the variable star IP Vir. The star IP Vir was selected for illustration purposes in this paper because the total amount of data that has been secured for this star is still easily displayed on a single page. The times of maximum light are detailed from the two investigations previously mentioned. This is the same data set that was used to determine period changes in IP Vir since its discovery. At present the archive only contains average data points and times of maximum light. However, we hope to eventually archive individual data points for each star in the data set.

6. CONCLUSION

It is always a valuable tool for researchers to have data available to them in an archive. The value of the archive increases with the amount of data contained therein. While we are still in the beginning stages of this project, the initial steps thus far completed have demonstrated that we can utilize new technology to provide the researcher with convenient access to the type and amount of information that will be most useful during the observation process. This program has therefore established the feasibility of the next step, which allows researchers to extract data from the archive on a night by night basis and use that information to shape the observing program. Thus, the archive is not only valuable for data interpretation, but can be employed instantly to determine the most effective way to secure the observations.

Our program is designed around observations of short-period variable stars. For these stars, it is not only important to know when the object can be observed, but also to determine when each phase of the pulsation cycle can be observed. Thus, for our program the phase calculator is an extremely helpful tool for use at the telescope. Decisions can be made immediately, depending on which phase points are desired for any group of target objects. The on-line finder charts are also valuable to ensure that the same group of stars in a comparison ensemble are centered in the field from night to night. The general information pages can be very useful when an observer finds that there is a need to make changes in an observing program. At those times, there is no substitute for having as much information as possible at one's fingertips.

We believe that this model for an interactive data archive can be adapted to a wide variety of observing situations. It has a great potential for enhancing scientific return, not only for observers utilizing modest facilities but also for the next generation of observers at the largest ground-based observatories.

7. ACKNOWLEDGMENTS

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with whom we have corresponded and who have provided us with suggestions on ways to improve the utility of the archive. We would also like to thank Lisa Joner for editorial assistance during the preparation of this manuscript.

The Digitized Sky Surveys were produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.

8. REFERENCES

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Variable Stars Observable at BYU West Mountain Observatory Lat = 40.090 and Long = 111.840 W From UT 2:57 to UT 14:57 Starting on UT Date 2/28/1998

IP Vir	Period = 0.0652	Amp = 0.10	Mag = 11.58	RA = 14:40:07.6	Dec = +00:01:45.2

Cycle #	HJD	JD	UT	Altitude	Hour Angle	Airmass
33430.25	2450872.8528	2450872.8483	08:21	30.47	-3:14	1.97
33430.50	2450872.8691	2450872.8646	08:45	34.28	-2:50	1.77
33430.75	2450872.8854	2450872.8809	09:08	37.83	-2:26	1.63
33431.00	2450872.9017	2450872.8972	09:32	41.08	-2:03	1.52
33431.25	2450872.9180	2450872.9135	09:55	43.93	-1:39	1.44
33431.50	2450872.9343	2450872.9298	10:18	46.33	-1:16	1.38
33431.75	2450872.9506	2450872.9462	10:42	48.17	-0:52	1.34
33432.00	2450872.9669	2450872.9625	11:05	49.39	-0:29	1.32
33432.25	2450872.9832	2450872.9788	11:29	49.92	-0:05	1.31
33432.50	2450872.9995	2450872.9951	11:52	49.73	0:17	1.31
33432.75	2450873.0158	2450873.0114	12:16	48.85	0:41	1.33
33433.00	2450873.0321	2450873.0277	12:39	47.30	1:04	1.36
33433.25	2450873.0484	2450873.0440	13:03	45.16	1:28	1.41
33433.50	2450873.0647	2450873.0603	13:26	42.52	1:51	1.48
33433.75	2450873.0810	2450873.0766	13:50	39.46	2:15	1.57
33434.00	2450873.0973	2450873.0929	14:13	36.04	2:39	1.70
33434.25	2450873.1136	2450873.1092	14:37	32.35	3:02	1.86

Fig. 1 - Output from West Mountain phase calculator for quarter phase intervals on the variable star IP Vir. Input location is the BYU West Mountain Observatory.

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Variable Stars Observable at Lat = -30.166 and Long = 70.816 W From UT 2:57 to UT 14:57 Starting on UT Date 2/28/1998

IP Vir	Period = 0.0652	Amp = 0.10	Mag = 11.58	RA = 14:40:07.6	Dec = +00:01:45.2

Cycle #	HJD	JD	UT	Altitude	Hour Angle	Airmass
33428.50	2450872.7387	2450872.7342	05:37	34.79	-3:14	1.75
33429.00	2450872.7713	2450872.7668	06:24	43.71	-2:27	1.45
33429.50	2450872.8039	2450872.7994	07:11	51.48	-1:40	1.28
33430.00	2450872.8365	2450872.8320	07:58	57.23	-0:53	1.19
33430.50	2450872.8691	2450872.8646	08:45	59.77	-0:06	1.16
33431.00	2450872.9017	2450872.8972	09:32	58.29	0:40	1.18
33431.50	2450872.9343	2450872.9298	10:18	53.29	1:27	1.25
33432.00	2450872.9669	2450872.9625	11:05	45.97	2:14	1.39
33432.50	2450872.9995	2450872.9951	11:52	37.30	3:01	1.65

West Mountain Observatory of Brigham Young University

Fig. 2 - Output from the general phase calculator for half phase intervals on the variable star IP Vir. Input location is for CTIO.

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IP Virginis - Delta Scuti Variable Star

RA : 14:40:08 Dec : +00:01:45 Epoch : 2000.0

Other Names :SA 106-1024, GSC0032601010

Photometric Information:

Filter : V

Avg. Mag : 11.58

Amplitude: 0.10

Period : 0.0652d

Equation for Times of Maximum Light :

HJD(max) = 2448692.8545 + 0.065210352 E

Other Information:

[Fe/H] : -0.33 Reference : Joner et al. 1998, PASP, 110, April Pub.

Spectral Type : Reference :

Important References :
Landolt 1990, PASP, 102, 1382
Joner, Hintz, and Collier 1998, PASP, 110, April Publication

Ensemble 1 Stars :1,2,3,4,5,6 Ensemble 1 Average :

Ensemble 2 Stars :5,7 Ensemble 2 Average :

Comments:
log(g) = 3.89, T(eff) = 7400 K, P1/P0 = 0.774, E(b-y) = 0.008

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Fig. 3 - Output of the general information page for the variable star IP Vir.

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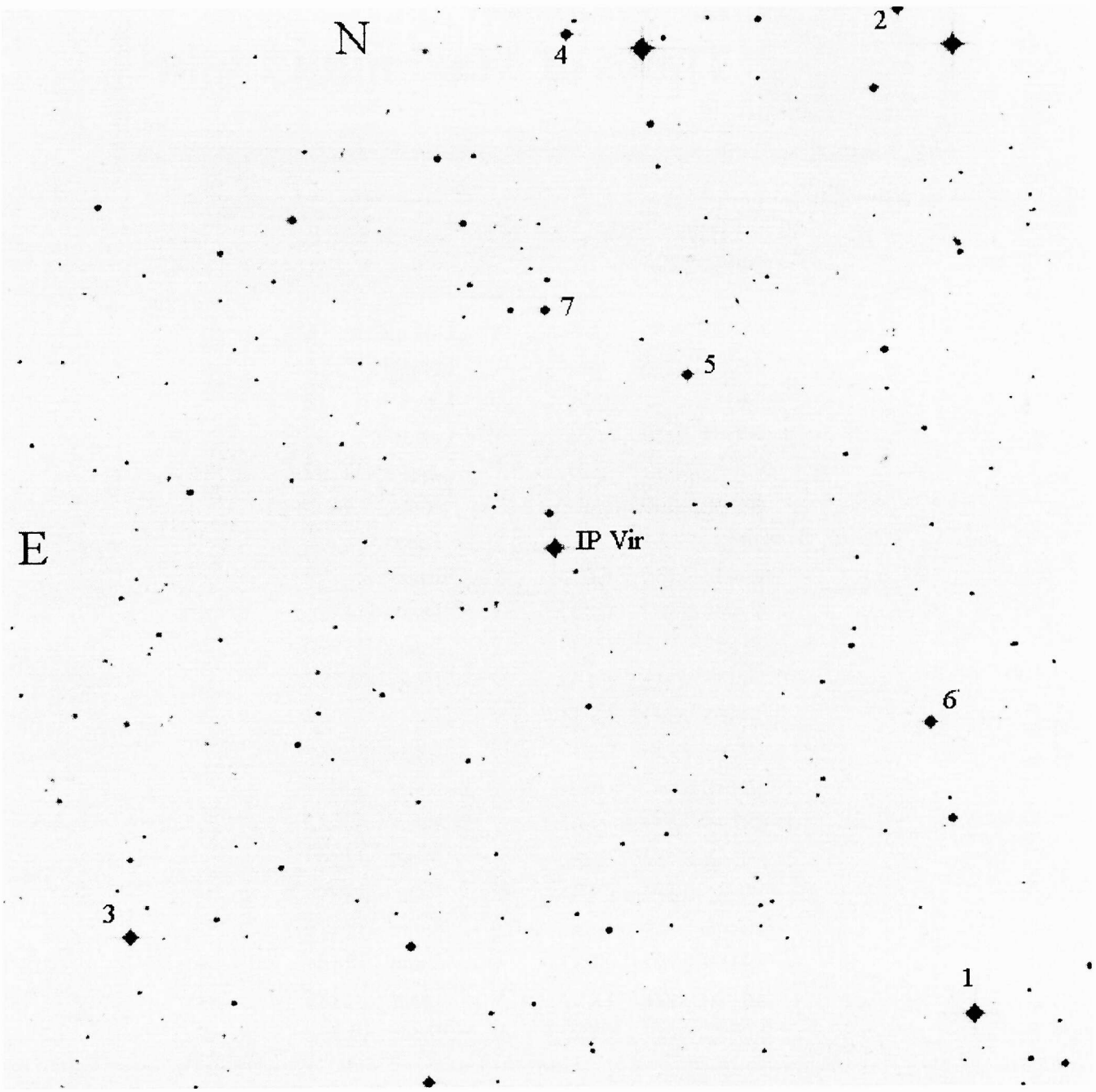


Fig. 4 - Finder chart for the variable star IP Vir. The numbered stars are members of the comparison ensemble.

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IP Virginis
Times of Maximum Light

HJD 2400000.0+	Detector	Filter	Obser.	Cycle
48051.6364	pm	V	Landolt	0
48051.7005	pm	V	Landolt	1
48054.6382	pm	V	Landolt	46
48054.7029	pm	V	Landolt	47
48057.6359	pm	V	Landolt	92
48692.8549	pm	V	Joner	9833
49127.7424	pm	V	Joner	16502
49439.9036	CCD	V	Joner	21289
49439.9682	CCD	V	Joner	21290
49445.8381	CCD	V	Joner	21380
49445.9042	CCD	V	Joner	21381
49445.9699	CCD	V	Joner	21382
49791.7790	CCD	V	Joner	26685
50138.8285	pm	V	Joner	32007
50141.8299	pm	y	Joner	32053
50142.8712	pm	y	Joner	32069
50144.8289	CCD	V	Joner	32099
50146.7829	pm	y	Joner	32129
50169.9350	CCD	V	Joner	32484
50170.0001	CCD	V	Joner	32485
50582.8459	CCD	V	Joner	38816

Landolt : Landolt 1990, PASP, 102, 1382
Joner : Joner, Hintz, and Collier 1998, PASP, 110, April Publication.

Fig. 5 - Output from the data archive for all known times of maximum light for the variable star IP Vir.

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