

Thirty Years of Echelle Spectra Made Public

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Abstract. From December 1978 through May 2009, more than 250,000 high dispersion ($R \approx 36,000$ or 8.7 km/sec) optical spectra of bright stars ($V < 13$ on 1.5m, $V < 15$ on 6.4m) were recorded by the Smithsonian Astrophysical Observatory (SAO) on echelle spectrographs on the Tillinghast 1.5-meter reflecting telescope and MMT telescope on Mt. Hopkins in Arizona and the Wyeth 1.5-meter reflecting telescope in Harvard, Massachusetts. The spectra were obtained primarily to obtain radial velocities and stellar parameters. The spectra have been uniformly reduced and are being made public as a valuable resource in combination with Gaia proper motion and parallax measurements.

1. Introduction

For slightly over 30 years, from 1978 into 2009, the Smithsonian Astrophysical Observatory accumulated a uniformly-observed (Latham 1996), uniformly-reduced (Mink & Wyatt 1992) set of spectra using photon-counting intensified Reticon detectors (Latham 1982) on three telescopes in Arizona and Massachusetts. These spectra, most of which are of stars, were taken for a variety of purposes from studies of multiple star systems (Latham 1992) to cluster membership (Peterson & Latham 1989) to H α observations (Giampapa & Liebert 1986) to exoplanets (Latham 2014). All of these spectra, except for those of a few objects which are unpublished and still being observed, are being made public.

2. Instrument Description

The SAO echelle spectrographs, referred to as the "CfA Digital Speedometers" when used at the single order centered at 5187 Angstroms, were cross-dispersed echelle spectrographs using Reticon detectors (Davis & Latham 1979) (Latham 1979). Each photon-counting Reticon was a 2×936 pixel self-scanned photodiode array, coupled to a 3-stage image tube intensifier package, and then fed through the video amplifiers and electronics to the photon event discriminator, FIFO buffer, and computer. The Reticon was cooled to about -40°C from a Neslab chiller and re-circulating methanol bath.

Each spectrograph had an internal Thorium-Argon lamp for wavelength calibrations, and an internal incandescent lamp for flat field exposures.

Only one echelle order is viewed at a time by the Reticon detector. 204,000 of 253,000 spectra were taken at the order centered near 5187 Angstroms covering a 45 Angstrom bandpass, the standard setting used by most CfA radial velocity programs

and reduction routines. It is possible to set the spectrograph to view other orders though the system efficiency is poor in the blue.

Spectral resolution (R) is about 36,000 or 8.3 km/sec. Echelle spectrographs on 60" telescopes yield radial velocity precisions of down to 0.5 km/sec. These spectrographs can observe stars down to a visual magnitude of 13.0. On the MMT, stars as faint as 15.5 magnitude can be observed.

3. The Telescopes

The original Reticon echelle spectrograph was built for the Tillinghast 60-inch (1.5-m) reflector at Mt. Hopkins Observatory (now Frederick L. Whipple Observatory) in Arizona. Owned and operated by SAO and dedicated in 1970, this telescope continues to be used for both low and high resolution spectroscopy. 90,804 Reticon echelle spectra were taken on this telescope for over 30 years, from December 1978 to May 2009.

To observe fainter stars, a duplicate spectrograph was built for the Multiple Mirror Telescope, which at the time of these echelle observations was composed of six 1.8-meter mirrors, providing the effective aperture of a 4.5-meter mirror, or nine times the collecting area of each of the 1.5-meter telescopes. The MMT was dedicated in 1979 and converted to a single 6.5-meter mirror in 1998. 20,486 Reticon echelle spectra were taken on this telescope from April 1981 until the original MMT was shut down in January 1998.

Closer to SAO's headquarters in Cambridge, Massachusetts and owned by Harvard University, but operated by SAO, the 1.5-meter Wyeth telescope at the Oak Ridge Observatory, in Harvard, Massachusetts, was once the largest optical telescope in the U.S. east of Texas. It was built by Harvard in 1932 and in its later years, operated by SAO until it was shut down in August, 2005. 141,944 Reticon echelle spectra were taken on this telescope from July 1982 to May 2005.

4. The Spectra

Almost 37,000 different objects (by RA and Dec) have been observed between the three echelle spectrographs. As the purpose of these observations was often to observe how radial velocities varied over time to learn about multiple star systems, multiple observations were taken of many of the objects observed. Table 1 gives an idea of how many objects have multiple observations, and Table 2 lists the most frequently observed objects.

The first figure shows an unusual 6th-magnitude binary star, HR8210 or IY Peg, observed with the 1.5-meter Tillinghast reflector on Mt. Hopkins. Its radial velocity was fit using a template spectrum (Emley et al. 1996). The second figure is an MMT spectrum centered on the H α emission line of GL 406, a 13.5 magnitude M star (Giampapa & Liebert 1986).

5. Searching for Spectra

After the spectra were organized a search method was needed. Rather than stick the entire headers into a database before it was known how well their parameters could be trusted, a simple catalog was created and a search program was written. Table 3 shows

Table 1. Frequency of Observation

Number of Observations	Number of objects
1	12917
2	7745
3	5107
4	3784
5	3035
6	2534
7	2179
8	1865
9	1650
(...)	(...)
569	1

Table 2. Ten Most Frequently Observed Objects

Num	Object	RA	Dec
569	ALFBOO	14:17:02.799	+19:03:09.01
232	HD114762	13:12:21.777	+17:31:00.92
213	67-978	08:51:17.485	+11:45:24.3
188	RSBOO	14:33:36.131	+31:45:36.96
167	67-978	08:51:17.485	+11:45:22.31
153	HD136202	15:19:17.528	+01:46:21.31
151	HD146051	16:14:20.569	-03:41:31.91
149	EpsAur	05:01:58.105	+43:49:23.55
144	67-978	08:51:17.485	+11:45:24.29
135	ADLeo	10:19:39.689	+19:52:13.06

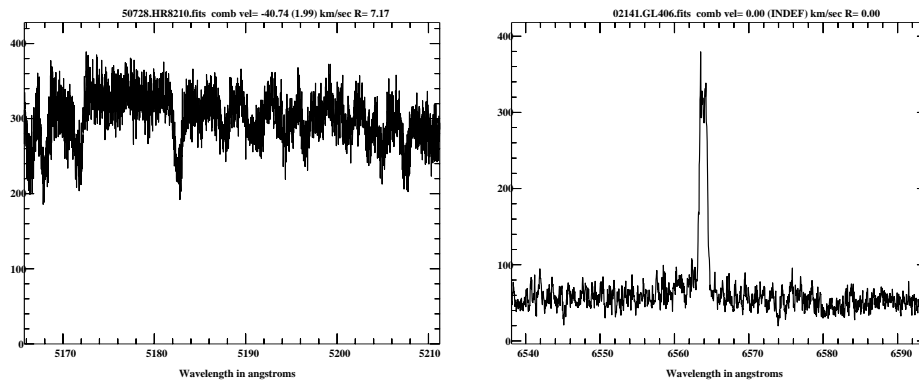


Figure 1. Typical Reticon echelle spectra *Left*: 1.5-meter spectrum of HR8210 (IK Peg) centered near Calcium H and K. *Right*: MMT spectrum of GL 406 centered on H α emission line.

the program listing its commands and two sample searches for the same object, with and without a specified line being required.

Table 3. Searching the Echelle Spectrum Archive with echsearch

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> echsearch
echsearch: Find entries for objects in the SAO reticon echelle database
Version 1.4 by Jessica Mink, SAO-TDC, August 11, 2016
Usage: echsearch [-v][-f][-e|o|m|a] object1 object2 ...
echsearch [-v][-f][-e|o|m|a] @object.name.list.file
echsearch [-v][-f][-e|o|m|a] hh:mm:ss.ss dd:mm:ss.ss
echsearch [-v][-f][-e|o|m|a] <Reduced File Number>
-a: Search for All reticon echelle spectra
-c: No column headers (default on)
-e: Search spectra from FLWO Tillinghast 60-inch Echelle (default)
-f: list object path names only (default off)
-l: list only objects containing the wavelength of this line (default off)
-m: Search only spectra from the MMT Echelle (default off)
-o: Search only spectra from the Oak Ridge Wyeth 60-inch Echelle
-s: set Search radius in degrees (default is 0.01)
-t: Search TRES observations, too (default is off)
-v: list object names as they are checked

> echsearch GL406
object rfn      ra      dec      hjdn      exp      w11      w12      vel      velerr  velr  prog  pi
-----
GL406 M02141 10:56:33.695 +07:01:41.96 2445121.66464 300.0 6538.11 6593.94 0.0 0.0 0.0 -2 GIAMPAPA
GL406 T18069 10:56:42.099 +07:03:09.51 2446896.74209 360.0 6371.94 6431.56 0.0 0.0 0.0 -2 S.KENYON
GL406 T18091 10:56:42.099 +07:03:09.51 2446897.67213 1500.0 6371.94 6431.56 0.0 0.0 0.0 -2 S.KENYON
GL406 T20806 10:56:42.099 +07:03:09.52 2447113.01414 2400.0 6371.94 6431.56 0.0 0.0 0.0 -2 S.KENYON
GL406 T21811 10:56:42.099 +07:03:09.52 2447167.86110 1200.0 6371.94 6431.56 0.0 0.0 0.0 -2 S.KENYON
GL406 T23226 10:56:32.095 +07:01:27.72 2447256.71154 2400.0 6371.94 6431.56 0.0 0.0 0.0 -2 S.KENYON
GL406 T23802 10:56:42.099 +07:03:09.52 2447312.66776 1500.0 5165.77 5211.23 20.77 0.928 4.21 45 S.KENYON
GL406 T27735 10:56:42.099 +07:03:09.52 2447607.73115 900.0 6371.94 6431.56 0.0 0.0 0.0 -2 S.KENYON
GL406 T29318 10:56:42.099 +07:03:09.52 2447666.69900 1200.0 6378.75 6438.92 0.0 0.0 0.0 -2 S.KENYON

> echsearch -l 5187 GL406
object rfn      ra      dec      hjdn      exp      w11      w12      vel      velerr  velr  prog  pi
-----
GL406 T23802 10:56:42.099 +07:03:09.52 2447312.66776 1500.0 5165.77 5211.23 20.77 0.928 4.21 45 S.KENYON
>

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