FAQ for CHIRON on the CTIO/SMARTS 1.5m

DeAndre X. Lesley
Hodari-Sadiki James
Leonardo A. Paredes
Wei-Chun Jao
Todd J. Henry

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1 CHIRON Specifications and Capabilities

1.1 What is CHIRON?

CHIRON is an optical, fiber-fed, high-resolution echelle spectrometer located at the CTIO 1.5m telescope that is operated by the SMARTS Consortium. A key reference for CHIRON can be found at [Tokovinin et al. (2013) PASP 125, 1336]. Additional details are available in the manual found at [Tokovinin (2012)].

1.2 What is CHIRON’s wavelength coverage?

There is a fixed spectral range of 4150–8800 Å.

1.3 What are the specs of the CCD?

The detector is a CCD231-84 device manufactured by Teledyne e2v and has dimensions 4096 (horiz.) × 4112 (vert.) with square pixels 15 µm in size.

1.4 What resolution options (and corresponding efficiencies) does CHIRON provide?

There are four instrumental setups available for CHIRON. Most programs use the Fiber or Slicer mode, as they are the most efficient and are appropriate for stars with magnitudes of $V \sim 6$ to 15. For brighter stars, the Slit and Narrow modes are sometimes used.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Binning (Horiz. × Vert.)</th>
<th>Spectral Resolution</th>
<th>Relative Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>4 × 4</td>
<td>27,400</td>
<td>1.0</td>
</tr>
<tr>
<td>Slicer</td>
<td>3 × 1</td>
<td>79,000</td>
<td>0.82</td>
</tr>
<tr>
<td>Slit</td>
<td>3 × 1</td>
<td>95,000</td>
<td>0.25</td>
</tr>
<tr>
<td>Narrow</td>
<td>3 × 1</td>
<td>136,000</td>
<td>0.11</td>
</tr>
</tbody>
</table>

1.5 What is the velocity resolution per pixel for each resolution mode?

In Fiber mode, the element size is 4,000 m/s and for the remaining three modes it is 1,000 m/s.

1.6 How faint can I observe?

Figure 1 shows the brightnesses and corresponding SNR for K dwarfs observed with 900 sec exposures taken in Slicer mode. Although only targets as faint as $V = 12$ are shown, CHIRON has been used to observe objects as faint as $V = 17$, with consequently poorer
SNR and radial velocity precision (if that is the intent of the program). For targets with \( V > 12 \), the PI is encouraged to contact the CHIRON team.

Figure 1: SNR calculated from CHIRON’s exposure meter (EM) versus RV uncertainty for individual spectra of K dwarfs, color-coded by stellar \( V \) magnitude. Each of the 1784 data points represents a single spectrum. The dashed line is described by Equation (1) and is derived using observations with exposure times of 900 sec. The slight overabundance of points at \( SNR = 100 \) is the result of observations that were stopped before 900 sec, when \( SNR \) reached 100.

### 1.7 What RV precision can be achieved using CHIRON for an individual exposure?

As a rule of thumb, to obtain a single measurement error in radial velocity (RV) of \( \sim 5 \text{ ms}^{-1} \), it is necessary to reach a signal-to-noise ratio \( SNR \sim 100 \) at 5500 Å. This is possible for K dwarfs brighter than \( V \sim 9 \text{ mag} \) in 900 sec exposures in Slicer mode. Overall, for stars like K dwarfs, the RV precision for a single spectrum is represented by the dotted line in Figure 1, and can be predicted using:

\[
\sigma_{RV} \sim \frac{10000}{SNR^2} + 4 \text{ ms}^{-1}
\]  

(1)

The following are representative of typical values for 900 sec exposures for K dwarfs:
Table 2

<table>
<thead>
<tr>
<th>V (mag)</th>
<th>SNR</th>
<th>$\sigma_{RV}$ (ms$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>130</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>25</td>
<td>20</td>
</tr>
</tbody>
</table>

1.8 What RV precision can be achieved using CHIRON for a series of exposures over months?

CHIRON is a relatively stable instrument. Again, for K dwarfs of various brightnesses observed for 900 sec in Slicer mode, the RV precision is typically 5–20 ms$^{-1}$, as summarized in Figure 2.

![Figure 2: RV MAD (Mean Absolute Deviation) vs. V-magnitude](image)

1.9 How do I estimate exposure time in different modes?

The estimated $SNR$ per pixel reached at wavelength 5500 Å for a single exposure time $t$ of a target of magnitude $V$ is described in [Tokovinin et al. (2013) PASP 125, 1336], and in the manual found at [Tokovinin (2012)], and is given by:

$$SNR(t) = \frac{\epsilon F_0 10^{-0.4V} t}{\sqrt{\epsilon F_0 10^{-0.4V} t + KR^2}},$$  \hspace{1cm} (2)$$

where $\epsilon = 0.05$ is the total system efficiency (conservative estimate), $F_0 = 3.4 \times 10^5$ photons/s/pix is the flux of a $V = 0$ mag star’s outside atmosphere per pixel size, and $R = 5.5$ is the CCD
readout noise in electrons. The number of binned pixels across the order is \( K = 9 \) for the \( 3 \times 1 \) slicer mode and \( K = 2.5 \) for the \( 4 \times 4 \) fiber mode. Note that a better SNR can be achieved with multiple exposures.

Using this information and the plot shown in Figure 3 below, an estimate of \( t \) can be determined.

![Figure 3: Estimates of the SNR per pixel vs. \( V \) magnitude in Slicer and Fiber modes.](image)

(a) Slicer mode, \( 3 \times 1 \) binning, fast readout, Resolution = 79000

(b) Fiber mode, \( 4 \times 4 \) binning, normal readout, Resolution = 27400

2 The CTIO/SMARTS 1.5m Telescope

2.1 What are the telescope’s pointing precision and magnitude limit when using CHIRON?

The acquisition/guider camera has a field of view of \( \sim 3 \) arcmin, so we recommend that your target be positioned 1.5 arcmin within the field of interest. Targets brighter than \( V = 12 \) are acquired routinely; fainter targets take a bit more work, and sources as faint \( V = 17 \) can be identified and placed on the CHIRON fiber with the help of an appropriate finder chart.

If your target is a high proper motion star and its coordinates are in epoch 2000, please provide a finder chart. These targets have shifted a significant amount since being measured. Otherwise, please provide its coordinates in epoch 2020.

2.2 What are the RA and DEC limits of the 1.5m telescope?

The CTIO/SMARTS 1.5m telescope is mounted on an asymmetric, off-axis mount and is used on the east side of the pier. It is not possible to reverse the telescope over the pier. The range of telescope pointing values is listed in Table 3 below.
Table 3: Chart of sky accessibility for the 1.5m that shows, for various declinations, how far the telescope can point east/west in hour angle (hours:minutes) and the corresponding airmass.

<table>
<thead>
<tr>
<th>DECLINATION (°)</th>
<th>EAST HA LIMIT</th>
<th>EAST AIRMASS LIMIT</th>
<th>WEST HA LIMIT</th>
<th>WEST AIRMASS LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>+25</td>
<td>2:00</td>
<td>2.138</td>
<td>2:29</td>
<td>2.420</td>
</tr>
<tr>
<td>+20</td>
<td>2:00</td>
<td>1.876</td>
<td>2:29</td>
<td>2.099</td>
</tr>
<tr>
<td>+15</td>
<td>2:29</td>
<td>1.866</td>
<td>2:29</td>
<td>1.866</td>
</tr>
<tr>
<td>+10</td>
<td>2:45</td>
<td>1.805</td>
<td>2:59</td>
<td>1.928</td>
</tr>
<tr>
<td>+05</td>
<td>2:45</td>
<td>1.654</td>
<td>2:59</td>
<td>1.758</td>
</tr>
<tr>
<td>00</td>
<td>3:15</td>
<td>1.751</td>
<td>3:29</td>
<td>1.885</td>
</tr>
<tr>
<td>−05</td>
<td>3:15</td>
<td>1.632</td>
<td>3:29</td>
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<tr>
<td>−10</td>
<td>3:29</td>
<td>1.641</td>
<td>3:29</td>
<td>1.641</td>
</tr>
<tr>
<td>−15</td>
<td>3:45</td>
<td>1.681</td>
<td>3:59</td>
<td>1.812</td>
</tr>
<tr>
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<td>3:59</td>
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<td>−25</td>
<td>4:15</td>
<td>1.653</td>
<td>4:29</td>
<td>1.935</td>
</tr>
<tr>
<td>−30</td>
<td>4:15</td>
<td>1.714</td>
<td>4:29</td>
<td>1.845</td>
</tr>
<tr>
<td>−35</td>
<td>4:15</td>
<td>1.660</td>
<td>4:59</td>
<td>2.101</td>
</tr>
<tr>
<td>−40</td>
<td>4:40</td>
<td>1.816</td>
<td>5:04</td>
<td>2.063</td>
</tr>
<tr>
<td>−45</td>
<td>4:15</td>
<td>1.596</td>
<td>5:29</td>
<td>2.276</td>
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<tr>
<td>−50</td>
<td>4:30</td>
<td>1.671</td>
<td>5:29</td>
<td>2.167</td>
</tr>
<tr>
<td>−55</td>
<td>4:30</td>
<td>1.660</td>
<td>5:29</td>
<td>2.083</td>
</tr>
<tr>
<td>−60</td>
<td>4:30</td>
<td>1.662</td>
<td>5:29</td>
<td>2.021</td>
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<tr>
<td>−65</td>
<td>4:30</td>
<td>1.677</td>
<td>5:29</td>
<td>1.976</td>
</tr>
<tr>
<td>−70</td>
<td>4:30</td>
<td>1.705</td>
<td>5:29</td>
<td>1.948</td>
</tr>
<tr>
<td>−75</td>
<td>4:30</td>
<td>1.748</td>
<td>5:29</td>
<td>1.935</td>
</tr>
<tr>
<td>−80</td>
<td>4:30</td>
<td>1.807</td>
<td>5:29</td>
<td>1.936</td>
</tr>
<tr>
<td>−85</td>
<td>4:30</td>
<td>1.884</td>
<td>5:29</td>
<td>1.953</td>
</tr>
</tbody>
</table>

2.3 How can I be sure my target is isolated from another source?

The size of the fiber is 2.7 arcsec, so in order to isolate the incoming light of the target, a separation distance of approximately 3.5 arcsec between two sources is necessary, in seeing that is 1.5 arcsec or better. In poor seeing conditions, the separation will need to be correspondingly larger.

2.4 What is the typical seeing at the 1.5m?

The average seeing is ~1.0 arcsec, with a minimum of 0.7 arcsec and a maximum of reasonable conditions at 1.5 arcsec. Some programs for bright stars can be executed when the seeing is worse than 1.5m arcsec.
2.5 How are the observations made?

Observations are carried out by an on-site telescope operator at CTIO, which is located near La Serena, Chile.

3 Planning and Scheduling Observations

3.1 How do I set up my observations?

The CHIRON scheduling software is located here (https://chiron.astro.gsu.edu). You will be given a login and password if you purchase time on CHIRON, or are awarded time via the NOIRLab or Chile TACs. NASA time on CHIRON is awarded through the NOIRLab process as well. Your overall allocation is included in a Program, and you are able to make multiple Plans under your Program to carry out your science effort in an organized way.

3.2 How do I enter my targets on the website?

There are many permutations of how you might schedule your targets. You will need to determine which observing mode you want to use with CHIRON (usually Fiber or Slicer), what types of calibrations you need to accompany your observations (ThAr lamp, Iodine cell, or none), the number of exposures and integration times you want, and the cadence of visits to each target. You can assign particular windows for your observations — defined as the local night date in Chile — if timing is important. Please visit this video for step-by-step instructions on how to enter targets once you have logged in.

3.3 Is there a program to calculate when a star can be observed at the 1.5m with CHIRON on a given night, and for how long it can be observed on various nights throughout the year?

This webpage has a widget that allows you to enter a star’s coordinates and see how it moves in the sky. First, set Observatory = Cerro Tololo Observatory (Chile).

To see the visibility for a star on a given night:

a. Set Mode = Staralt
b. Enter coordinates of star(s)
c. Click on Retrieve
d. The result is a plot of visibility throughout the night.

To see the visibility for a star throughout the year:

a. Set Mode = Starobs
b. Enter coordinates of star(s)
c. Click on Retrieve
d. The result is a plot showing how long a star can be observed throughout the year.

3.4 How are requested visits scheduled?
The CHIRON team in Atlanta assembles the queue for every night. Questions and urgent requests should be directed to chironhelp@astro.gsu.edu.

4 Data from CHIRON

4.1 How do I retrieve my data?
We have an ftp server located in Atlanta to which access is granted by the CHIRON Team to certified users. Users should expect an email with further instructions.

4.2 What is the data processing procedure like?
Following the observations, the data are transferred to Atlanta computer servers, where frames are processed and grouped by program before being distributed to each user in a secured storage location.

4.3 How soon can I expect to receive my processed data?
A typical turno (one week’s worth of observations) at the 1.5m runs from Wednesday night through the following Tuesday night. Data are retrieved automatically at the end of each night’s observations. Data are processed after the completion of two consecutive turnos. We distribute data on the Thursday following the end of these two turnos, resulting in a 14-day distribution schedule.

However, please contact the CHIRON Team if you need data turnaround on a faster schedule, and we may be able to accommodate your request.

4.4 What data products are provided by the CHIRON Team?
CHIRON users will receive spectra in tabular form, with wavelengths and fluxes. The images have been (a) flatfielded, (b) bias subtracted, and (c) wavelength calibrated. This pipeline is described in further detail in Tokovinin et al. (2013) and Paredes et al. (2021, submitted). Note that radial velocities are not provided for such programs, as most investigators have their own techniques for extracting velocities for different types of stars observed with CHIRON.
4.5 How many echelle orders are created in each CHIRON setup, and which orders are contaminated by telluric lines?

In Fiber mode there are ??? orders. ???

In Slicer mode there are 59 orders. Orders past 35 contain telluric absorption lines. The two most prominent of these are the $O_2$ A band located in order 50, and the $O_2$ B band located in order 42. Spectra in these regions typically aren’t useful because they are corrupted by the Earth’s atmospheric lines.

In Slit mode there are ??? orders. ???

In Narrow mode there are ??? orders. ???

4.6 How are the files named for raw and reduced data?

Each .fits file header contains information about the telescope, time, instrument setup and other useful information.

The chi*.fits files are the raw data = the 2-D images of the echelle spectra.

The achi*.fits files are the respective reduced counterparts of the chi*.fits files that contain the extracted orders into 1-D arrays, with fluxes given in photoelectrons and wavelengths in Angstroms. These reduced files are bias-subtracted, flat-fielded, and wavelength-calibrated using the closest ThAr frame taken that night.

The data arrays are formatted as [order, pixel, wavelength/flux] and are of sizes:

Fiber mode is [???,???,???]
Slicer mode is [59x3200x2]
Slit mode is [???,???,???]
Narrow mode is [???,???,???]

4.7 How often are calibration frames acquired?

A full set of calibrations for all setups is taken twice a day, in the afternoon at 3:00 PM local Chile time and at the conclusion of a night’s observing.

For improved RV precision, users are encouraged to take a ThAr lamp or Iodine cell exposure after each science exposure. If in pursuit of extreme precision better than 5 ms$^{-1}$, ThAr or Iodine exposures might also be taken before the science exposure.
4.8 Where can I find the raw calibration data?

Calibration files can be found at smarts@ftp.chara.gsu.edu:chiron.cals/. This directory can be accessed using normal (not sftp) ftp as follows:

a. ftp ftp.chara.gsu.edu 2997

b. user: insert username \textit{(given privately)}

c. pass: insert password \textit{(given privately)}

d. cd chiron.cals

4.9 What is the most precise timestamp of the spectrum available to be used in barycentric corrections?

The .fits header contains multiple timestamps. The most precise timestamp is given by the header key ‘EMMNWOB,’ which is the photon-weighted middle point of the observation.

4.10 Where can I find old archival CHIRON data?

Archival data of CHIRON can be available after 1.5 years of proprietary time at the NOIRLab Data Archive. Brief tips on how to acquire archived data can be found at .

4.11 How do I cite use of CHIRON?

Please refer to the two papers that provide the fundamentals needed to understand operation of CHIRON: Tokovinin et al. (2013) and Paredes et al (2021, submitted).