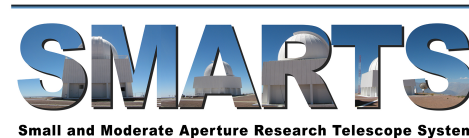# FAQ for CHIRON on the CTIO/SMARTS 1.5m

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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 $\mathring{A}$.

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 1

Mode	Binning (Horiz. × Vert.)	Spectral Resolution	Relative Efficiency
Fiber	4 × 4	27,400	1.0
Slicer	3 × 1	79,000	0.82
Slit	3 × 1	95,000	0.25
Narrow	3 × 1	136,000	0.11

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.
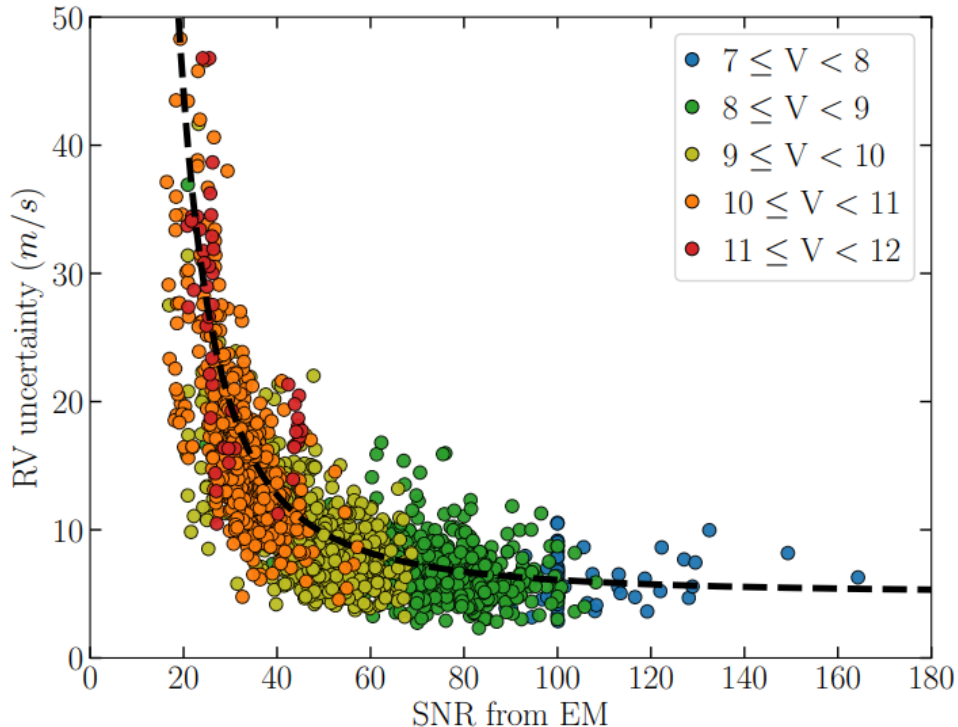
Figure 1: SNR calculated from CHIRON's exposure meter (EM) versus RV uncertainty for individual spectra of K dwarfs, color-coded by stellar V magnitude. Each of the 1784 data points represents a single spectrum. The dashed line is described by Equation (1) and is derived using observations with exposure 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 $\sim 5\,\mathrm{ms}^{-1}$, it is necessary to reach a signal-to-noise ratio $SNR \sim 100$ at 5500 Å. This is possible for K dwarfs brighter than $V \sim 9\,\mathrm{mag}$ 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:

$$\sigma_{RV} \sim \frac{10000}{SNR^2} + 4\,\mathrm{ms}^{-1} \tag{1}$$

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

Table 2

V (mag)	SNR	$\sigma_{RV}(\,\mathrm{ms}^{-1})$
7	130	5
9	50	10
11	25	20

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.
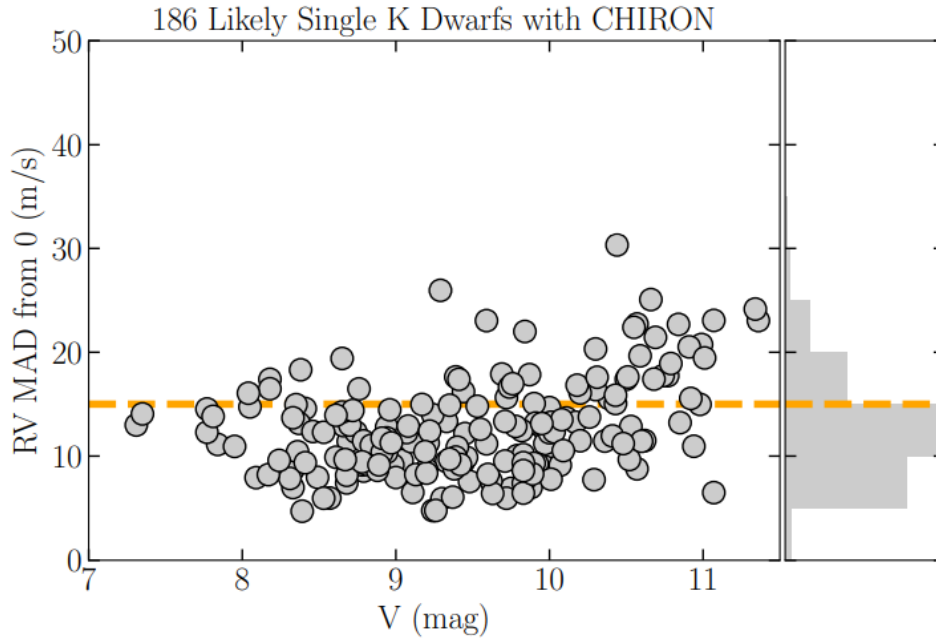
Figure 2: RV MAD (Mean Absolute Deviation) vs. V-magnitude

1.9 How do I estimate exposure time in different modes?

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

$$SNR(t) = \frac{\mu \epsilon F_0 10^{-0.4V} t}{\sqrt{\epsilon F_0 10^{-0.4V} t + K R^2}}, \tag{2}$$

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, and $R = 5.5$ is the CCD

readout noise in electrons. In the 3×1 slicer mode, pixel size $\mu = 1$ and the number of binned pixels across the order is $K = 9$. For the 4×4 fiber mode, $K = 2.5$ and the spectral pixel is larger by a factor of $\mu = 4$. 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.

(a) Slicer mode, 3×1 binning, fast readout, Resolution $= 79000$

(b) Fiber mode, 4×4 binning, normal readout, Resolution $= 27400$
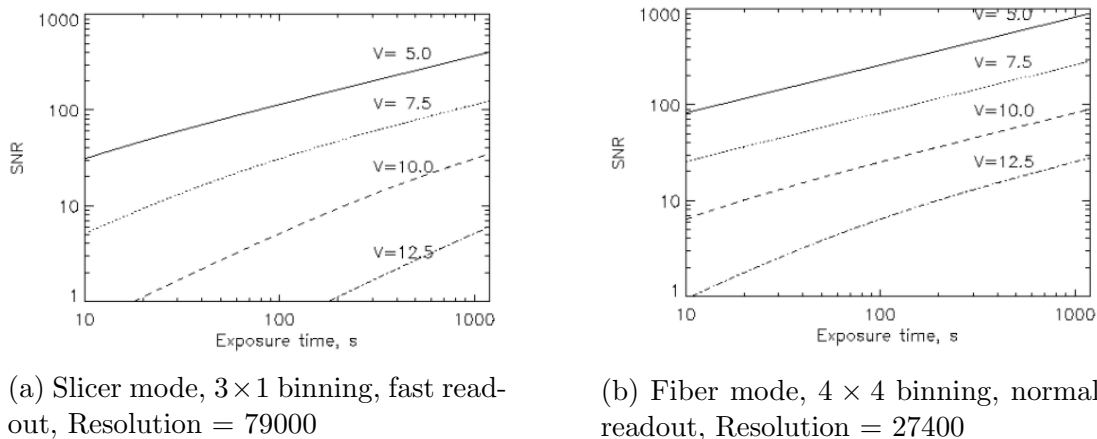
Figure 3: Estimates of the SNR per pixel vs. V magnitude in Slicer and Fiber modes.

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 ~ 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.

DECLINATION (°)	EAST HA LIMIT	EAST AIRMASS LIMIT	WEST HA LIMIT	WEST AIRMASS LIMIT
1.5-M TELESCOPE POINTING LIMITS				
+25	2:00	2.138	2:29	2.420
+20	2:00	1.876	2:29	2.099
+15	2:29	1.866	2:29	1.866
+10	2:45	1.805	2:59	1.928
+05	2:45	1.654	2:59	1.758
00	3:15	1.751	3:29	1.885
−05	3:15	1.632	3:29	1.758
−10	3:29	1.641	3:29	1.641
−15	3:45	1.681	3:59	1.812
−20	3:45	1.602	3:59	1.718
−25	4:15	1.653	4:29	1.935
−30	4:15	1.714	4:29	1.845
−35	4:15	1.660	4:59	2.101
−40	4:40	1.816	5:04	2.063
−45	4:15	1.596	5:29	2.276
−50	4:30	1.671	5:29	2.167
−55	4:30	1.660	5:29	2.083
−60	4:30	1.662	5:29	2.021
−65	4:30	1.677	5:29	1.976
−70	4:30	1.705	5:29	1.948
−75	4:30	1.748	5:29	1.935
−80	4:30	1.807	5:29	1.936
−85	4:30	1.884	5:29	1.953

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.

2.6 What are the observing overheads when using CHIRON?

1. Science Observations
   (a) 5.5 minutes to slew/acquire/start guiding
   (b) 18 seconds to read out

2. Calibration Observations
   (a) 1.5 minutes to reset fiber
   (b) 18 seconds to read out

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.

To schedule your observations, you must first create your online account. Then refer to the scheduling instructions.

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.

3.5   What is the difference between the box for Comments/Notes on a Plan page the box for Comments* for individual targets?

The Comments/Notes box for each Plan is **for your overall program** in that Plan, in which you might want to point out to schedulers (and remind yourself) what your overall goal for that Plan is. Examples include (a) RV monitoring to determine stellar spectroscopic orbits, and (b) Hα measurements of 2019 novae.

The Comments* box for a given target is used to indicate special considerations **for that target** such as specific timing and number of observations.

3.6   Once I have built my program in the CHIRON Scheduler, how do I know what has happened?

In the "Flags" column, you can hover your mouse over these letters to see associated dates:

T = time window — You have requested specific dates between which the object should be observed.

S = scheduled — Our nightly observing list is usually created by noon each day, so there is a chance you will see the "S" flag on your target because it is scheduled for that night.

When a target is scheduled, it is locked.

O = observed — The observation is complete and data will be delivered, typically every other Thursday. You cannot delete this observation from your Plan. Only targets with a "pencil" symbol on the left can be edited/deleted.

3.7 If my queued observation in the CHIRON Scheduler is in red, what do I do?

This means that your preferred window has closed for the observation. If you still want your target(s) observed, you will need to update the time constraints in order for us to reschedule it. Occasionally, we send out reminder emails to ask PIs to update their windows, but you can do updates at any time.

3.8 How much time do I have left to use in my CHIRON allocation?

Your remaining time (in hours) is calculated based on all the uploaded targets under your program, even if they are not yet observed. Your requested time includes the exposure time for science+calibration frames and telescope overheads (pointing+readouts), so the **remaining time** is your **awarded time minus your requested (not observed) time**. You may create as many plans as you like under your program, and all of them will share the same remaining time.

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 How soon can I expect to receive my processed data?

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.

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.

4.3   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.

4.4   How many echelle orders are created in each CHIRON setup, and which orders are contaminated by telluric lines?

In Fiber mode there are 62 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 62 orders.

In Narrow mode there are 62 orders.

4.5   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 [62x801x2]
Slicer mode is [59x3200x2]
Slit mode is [62x3200x2]
Narrow mode is [62x3200x2]

4.6 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.

4.7 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 (*given privately*)

c. pass: insert password (*given privately*)

d. cd chiron.cals

4.8 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.

4.9 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. To acquire this data, please see the following instructions:

1. Go to https://astroarchive.noao.edu/

2. Click "Web search".

3. Click "Clear Search" if this is not your first time to use this site.

4. In the box called "Image & Telescope / Instrument", find the "Telescope & Instrument" tab. Select both "ct15m, chiron" **AND** "ct15m, echelle" in the pull down menu. Be sure to leave all other entries as their default values or blank.

5. Click "Search" and the first 100 entries will appear. There are roughly 800,000 observations from 2010-2020 in the Archive.

6. Now that you have the basics, you can:

(a) Go back one page and enter in various quantities to search by (Name, RA/DEC, etc.)

(b) Stay on the page and use the filters on the left side to find frames you need. In particular, you can choose the time of observations via "Observations Per Year" and the kind of observation via "Observation Type" — likely to be "object", for which you will then need the various corresponding calibration frames, as all the data are raw frames. You can sort by RA to find particular objects.

There are no pipelined data available from CHIRON observations before October 2017. At this time, the RECONS team does not have the resources to resurrect and re-reduce old data, but, of course, a user can extract the raw data from the NOIRLab Archive and work with them.

4.10   How do I cite use of CHIRON?

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

We ask that you acknowledge the CHIRON Team in your papers. This may be particularly worth doing if we have contributed extra effort to secure your data, e.g., large target lists that needed extra support or tricky timing during observing — both are indicated by many back-and-forth emails. If you would like to acknowledge the CHIRON Team, you may use something similar to the following:

"This research has used data from the CTIO/SMARTS 1.5m telescope, which is operated as part of the SMARTS Consortium by RECONS (www.recons.org) members Todd Henry, Hodari James, Wei-Chun Jao, and Leonardo Paredes. At the telescope, observations were carried out by Roberto Aviles and Rodrigo Hinojosa."