

## Catalina Sky Survey Telescopes and Instrumentation

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The Catalina Sky Survey (CSS) has regularly operated telescopes at four sites in Arizona and Australia. In Arizona, these are Mount Lemmon and Mount Bigelow in the Santa Catalina Mountains north of Tucson, as well as Kitt Peak in the Tohono O’odham Nation southwest of the city. Siding Spring Observatory in Australia was used from 2004 to 2013. All telescopes used by CSS to date aside from the Siding Spring Survey are owned by the University of Arizona<sup>2</sup> and operated by Steward Observatory<sup>3</sup> and CSS is grateful for their support. Access to these telescopes has been through both competitive per-semester observing proposals and negotiated long-term agreements.

### 1 Mount Bigelow 0.7-m Schmidt (703)



Figure 1 – The Catalina Sky Survey Schmidt telescope on Mount Bigelow, MPC code 703. This is the configuration of the telescope with its 4K x 4K CCD camera between 2003-2016. Catalina Sky Survey, L: 2008, R: 2009

The original Catalina Sky Survey used an earlier configuration of the Mount Bigelow Schmidt telescope. These photographic data are not (currently) considered for archiving in the PDS Small Bodies Node. Modern CSS operations began with the Schmidt in its current configuration of a 0.7-m primary and full-aperture corrector. This is a rather thick corrector and CSS has been funded to evaluate an upgrade to the optics of this telescope. If so, this would likely result in a new telescope and instrument context for PDS.

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MPC site	Aperture	Longitude	Latitude	Altitude	Datum
<b>703</b>	0.7-m	249.26736	32.417006	2516 m	WGS 84

The Minor Planet Center (MPC) site code for the Schmidt is 703, and data under this code have been submitted by two cameras pertinent to CSS data holdings in the SBN:

Dates	Name	Type	Pixel scale	FoV (deg <sup>2</sup> )	Description
2003-16	SI_600-277	imager	2.5"	8.1	Imager Labs 4K x 4K CCD, no filter, scroll shutter
2016 on	SN_110-108 /165685-06	imager	3.0" (bin 2x2)	19.4	Spectral Instruments 10K x 10K CCD, STA1600LN_10K detector, no filter, scroll shutter

## 2 Mount Lemmon 60" Survey Telescope (G96)



Figure 2 – The 1.5-m Catalina Sky Survey telescope on Mount Lemmon, MPC code G96. L: R. Kowalski, R: C. Scherer

The Catalina Sky Survey 60-inch survey telescope on Mount Lemmon, MPC code G96, has been a significant contributor to the annual Near-Earth Object discovery statistics since 2005. Indeed, as of 2020, G96 is the most prolific single telescope in the grand total of NEOs discovered (7,814) and NEO observations (178,966), as well as of incidental observations of asteroids of all kinds (45,715,932).

MPC site	Aperture	Longitude	Latitude	Altitude	Datum
<b>G96</b>	1.52-m	249.21128	32.442754	2789 m	WGS 84

During this period G96 has used two prime focus cameras with a major upgrade in 2016 of CCD camera and multi-element PF optics to significantly increase the field of view.

Dates	Name	Type	Pixel scale	FoV (deg <sup>2</sup> )	Description
2004-16	SI_600-386	imager	1.0"	1.2	Imager Labs 4K x 4K CCD, no filter, scroll shutter

2016 on	SN_110-106 /165685-06	imager	1.5" (bin 2x2)	5.0	Spectral Instruments 10K x 10K CCD, STA1600LN_10K detector, no filter, scroll shutter
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### 3 Siding Spring 0.5m Uppsala Schmidt (E12)



Figure 3 – Comet C/2006 P1 McNaught; photo taken from Swifts Creek, Victoria, Australia at approx. 10:10PM. Taken at f/4, ISO 800, 20 seconds and ~24 mm with post-processing in Photoshop to bring out details. Wikimedia Commons attribution: Fir0002/Flagstaffotos

From 2003 to 2013 Catalina Sky Survey operated the only major NEO survey telescope in the southern hemisphere in partnership with the Australian National University using the 0.5-m Uppsala Schmidt telescope at Siding Spring Observatory in New South Wales, Australia. The Siding Spring Survey operated under MPC code E12 and is credited with discovering 467 Near-Earth Asteroids as well as many comets, including Comet McNaught, the “Great Comet of 2007” (see figure 1).

MPC site	Aperture	Longitude	Latitude	Altitude	Datum
<b>E12</b>	0.5-m	149.0642	-31.273455	1183 m	WGS 84

The CCD camera used for E12 data-taking was a near clone of the 4K x 4K cameras used during the same period on CSS telescopes in the northern hemisphere.

Dates	Name	Type	Pixel scale	FoV (deg <sup>2</sup> )	Description
2003-13	SI_600-263	imager	1.8"	4.2	LORAL_9607-114 4K x 4K CCD, no filter, scroll shutter

#### 4 Mount Lemmon 40" Follow-up Telescope (I52)



Figure 4 – CSS remote observing console at the Lunar and Planetary Laboratory on the campus of the University of Arizona in Tucson. This is a frequent station for the observer for Catalina’s 1-m follow-up telescope, I52. G. Leonard

Catalina Sky Survey realized a significant addition to its NEO discovery capabilities with the commissioning of the 1.0-m astrometric follow-up telescope on Mount Lemmon, MPC code I52. By offloading same-night and subsequent follow-up responsibilities from the survey telescopes, these are freed to generate even more candidate NEOs for follow-up. The combination of I52 and later V06 (below) have become the most productive follow-up telescopes for NEOCP follow-up and arc extensions. A major prime focus upgrade to I52 is nearing completion. I52 was also the first CSS telescope to be operated fully remotely from the University of Arizona campus as well as from the control room of our other telescopes and has served as the pilot for such capabilities to remotely operate our other telescopes, including from our observers’ homes during the COVID pandemic.

MPC site	Aperture	Longitude	Latitude	Altitude	Datum
<b>I52</b>	1.0-m	249.21108	32.442547	2789 m	WGS 84

NEO follow-up telescopes do not require the same wide field of view of NEO survey telescopes and a smaller and less expensive CCD camera suffices to this task.

Dates	Name	Type	Pixel scale	FoV (deg <sup>2</sup> )	Description
2012 on	SI_800-594	imager	1.0"	0.3	Spectral Instruments 2K x 2K CCD, E2V_42-40_041831905 detector, no filter, iris shutter

### 5 Mount Bigelow 61" Kuiper Telescope (V06)

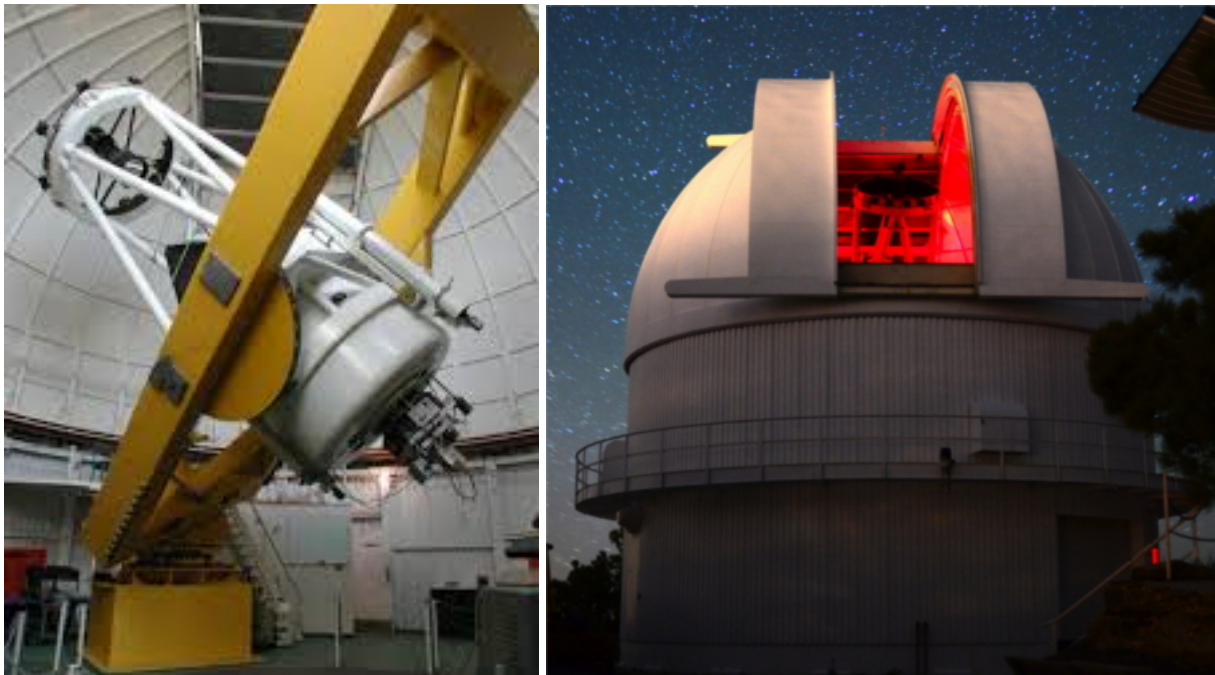


Figure 5 – Steward Observatory's 61-inch Kuiper telescope on Mount Bigelow. Courtesy Steward Observatory.

Astronomers face the perennial challenge of gaining access to useful amounts of telescope time. In recent years CSS has been allocated about one week per month of competitively allocated time on Steward Observatory's 61-inch Kuiper telescope. The Kuiper is sited next to the Catalina Schmidt on Mount Bigelow. When used by CSS for astrometric follow-up, the Kuiper telescope has MPC code V06. With its larger aperture and excellent optics, V06 can acquire significantly fainter asteroids than I52, including the most difficult NEO candidates produced by our flagship survey telescope, G96.

MPC site	Aperture	Longitude	Latitude	Altitude	Datum
V06	1.54-m	249.26745	32.416847	2520 m	WGS 84

Commissioning operations on the Kuiper telescope also provided the challenge and opportunity of supporting CSS-style data-taking using a CCD camera not developed specifically for the job of observing Near-Earth Asteroids. Support for the MONT4K imager has enabled support for other non-CSS cameras on future telescopes.

Dates	Name	Type	Pixel scale	FoV (deg <sup>2</sup> )	Description
2017 on	MONT4K	imager	0.6" (bin 4x4)	0.03	University of Arizona Imaging Technology Laboratory 4K x 4K CCD, no filter, iris shutter

## 6 Kitt Peak 90" Bok Telescope (V00)

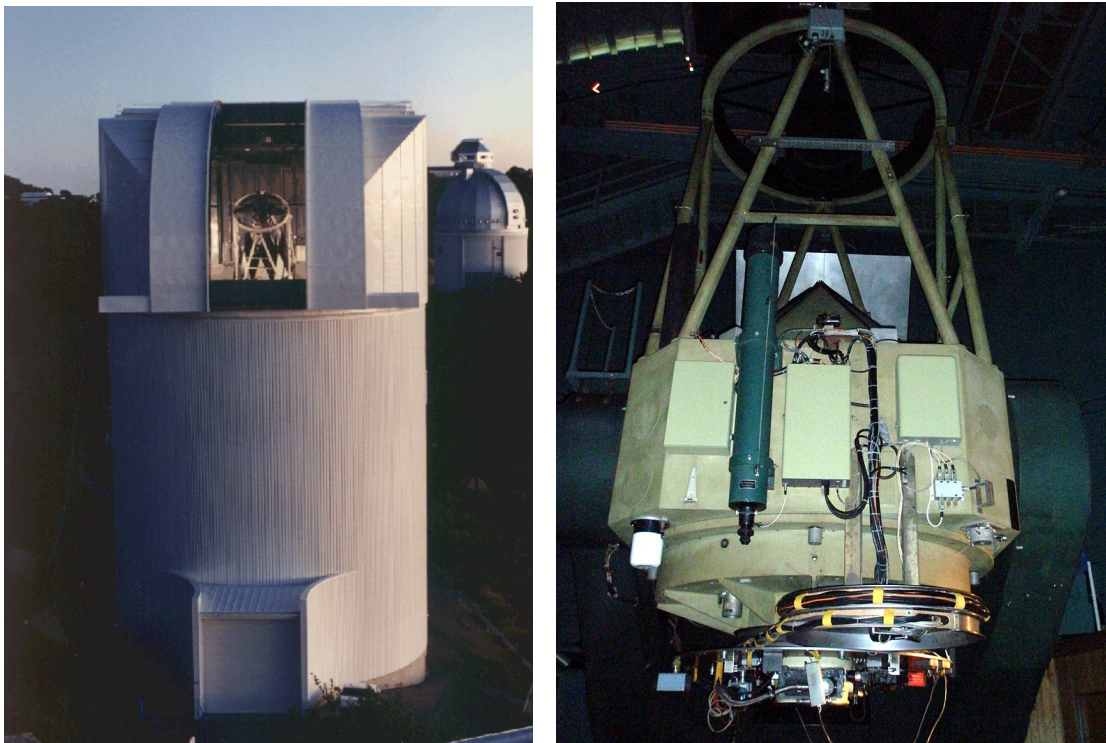


Figure 6 – Steward Observatory's 90-inch Bok telescope on Kitt Peak. Courtesy Steward Observatory.

Catalina Sky Survey has also commissioned operations on the 2.3-m Bok survey telescope on Kitt Peak, in partnership with Spacewatch and the University of Minnesota. This collaboration (MPC code V00) has been awarded several nights per month for a deep survey near-sun in the evening and morning hours and for drilling deep into opposition during the darkest hours of the night. The larger aperture has already demonstrated its value in the discovery of a large and nearby Potentially Hazardous Asteroid during engineering for the new facility.

MPC site	Aperture	Longitude	Latitude	Altitude	Datum
<b>V00</b>	2.29-m	248.39981	31.963127	2031 m	WGS 84

The Bok collaboration has also presented the chance to commission CSS-style observing using the Bok's workhorse wide-field 90Prime camera, a mosaic of CCD detectors. Steward Observatory is building a new-and-improved version of 90Prime and Catalina staff have advised on features that should benefit NEO surveying and follow-up observations.

Dates	Name	Type	Pixel scale	FoV (deg <sup>2</sup> )	Description
2019 on	90PRIME	imager	0.9" (bin 2x2)	1.1	Steward Observatory 90prime CCD mosaic, no filter

## 7 Other Telescopes



Figure 7 – Mount Lemmon SkyCenter and the 0.8-m Schulman telescope. Courtesy Steward Observatory.

CSS is always looking for access to new, or new-to-us, telescopes. In the near future this will include the 0.8-m Schulman telescope of the Mount Lemmon SkyCenter<sup>4</sup>, which is MPC code G84 when used for astrometric follow-up. We have been funded by NASA to provide a new camera and will receive a significant amount of telescope time in return. The Schulman will be used for astrometric follow-up to offload brighter objects from Catalina Sky Survey's nearby 1.0-m I52.

MPC site	Aperture	Longitude	Latitude	Altitude	Datum
<b>G84</b>	0.8-m	249.21084	32.442529	2781 m	WGS 84

<sup>4</sup> <https://skycenter.arizona.edu>

Mount Lemmon SkyCenter staff will also benefit, and vice versa, from increased access to Catalina Sky Survey facilities and data, including through the CSS PDS holdings, in their public programs.