Smithsonian Astrophysical Observatory (SAO)
Fred L. Whipple Observatory (FLWO)

FLWO Ridge Telescopes

The FLWO Ridge is at an elevation of about 7,800 ft (2,340 m).

The Ridge Telescopes are:

1. The Tillinghast 1.5m telescope (aka 60 inch) is an f/9.6 reflector with a spherical primary mirror. Because of its small usable field of view, it is used exclusively for spectroscopy. It has a German equatorial mount; it follows the apparent rotation of the sky because its long axis is parallel to the axis of rotation of the Earth. The design requires a large counterweight on the side of the polar axis opposite to the optical assembly. Its main advantage is that it allows for long instruments to hang below the primary mirror, but it does require a large dome.

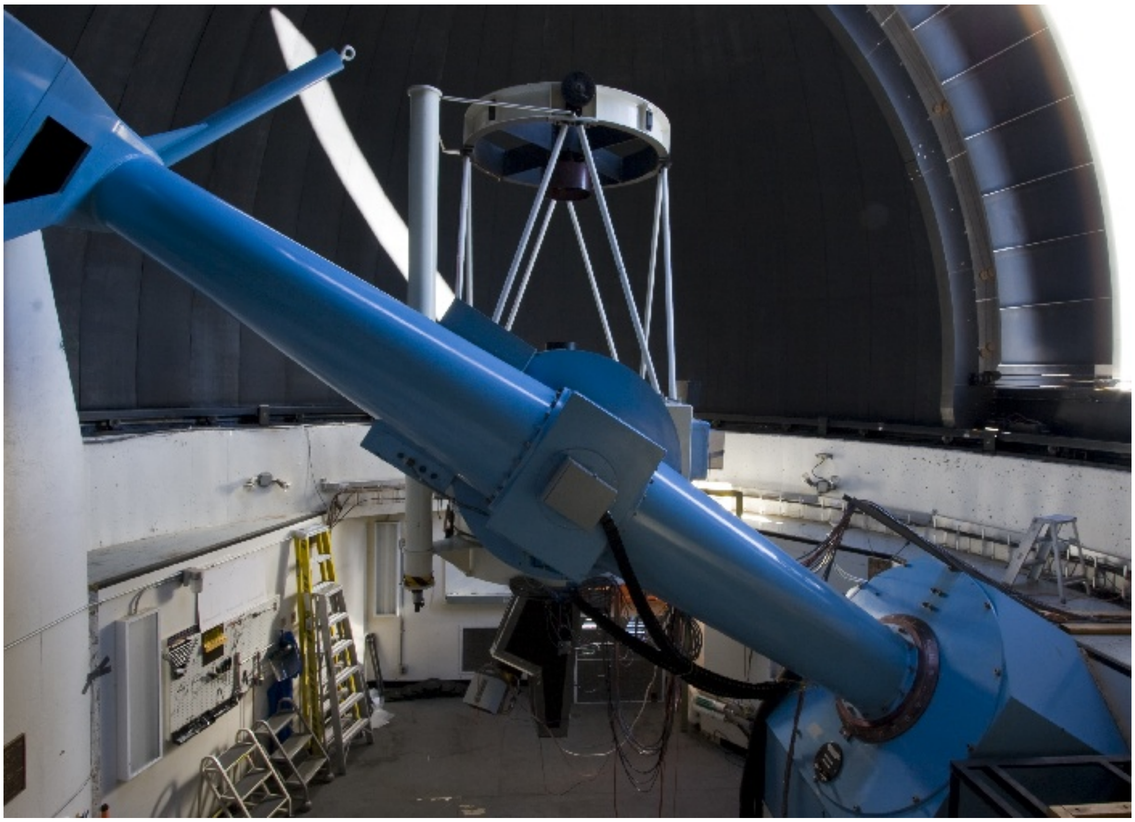

Fig. 1: The Tillinghast Telescope, viewed from the W side, with FAST mounted.

The Tillinghast telescope has two spectrographs:

- FAST, a low-resolution spectrograph that covers the full optical range, between wavelengths λ=3700 and 9000 Å. It is able to disperse light with spectral resolution (λ/Δλ) between 1800 and 7000 in order of increasingly fine separation of wavelengths. It is used for projects ranging from measuring the redshifts of galaxies, to studies of supernovae, studies of a wide variety of stars of different sizes, ages and compositions, and studies of asteroids.

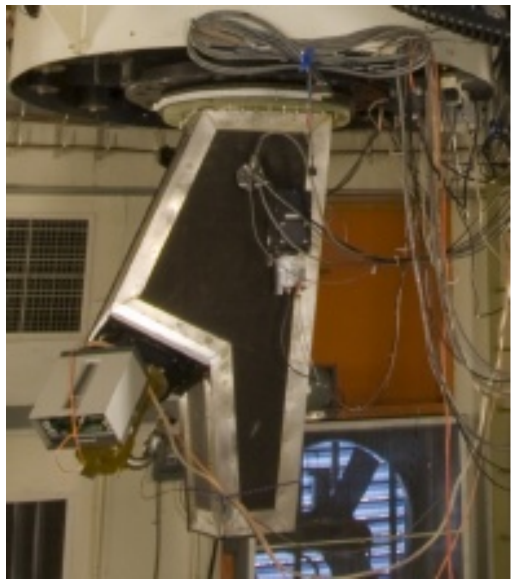

Fig. 2: FAST, mounted on the Tillinghast telescope.

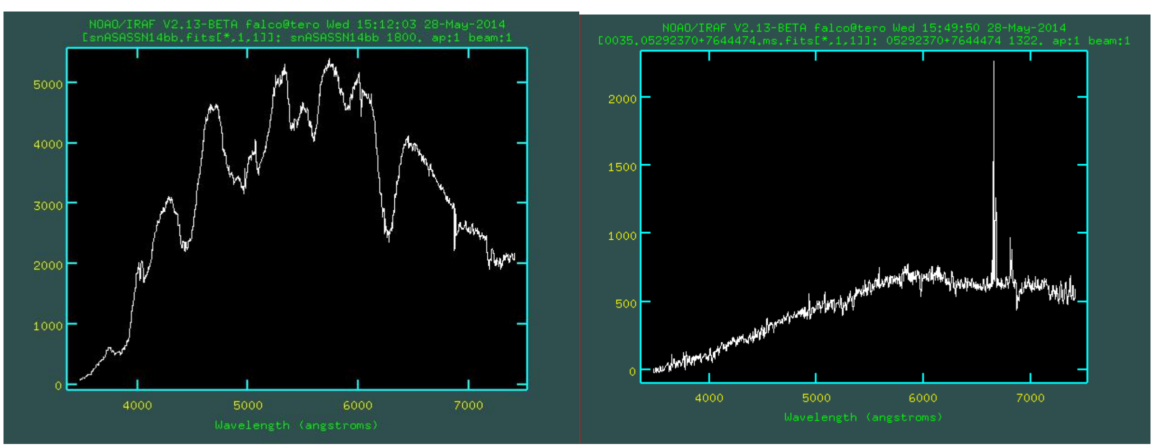

Fig. 3: 1.5m/ FAST spectra: SN14bb (left) and spiral galaxy 2MASS 0529+7644.

- TRES, a high-resolution spectrograph that also covers the optical range, but with spectral resolution between 30000 and 60000, about 20 times higher than for FAST. TRES is used intensively for radial velocity (RV) measurements of stars, to uncover exoplanets, or to refine the orbits of exoplanets discovered with the Kepler satellite or with other surveys such as HATs or MEarth. It is also used to measure the masses of eclipsing binaries and stars of various sizes, ages and compositions.

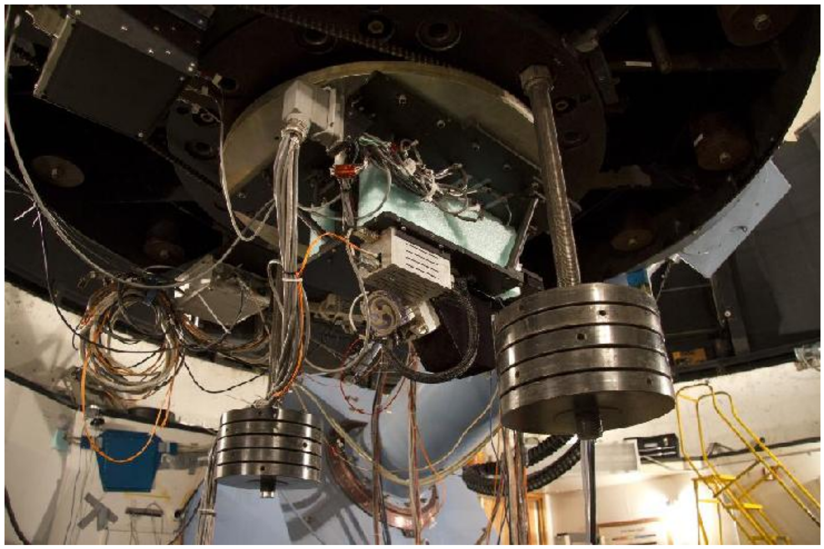

Fig. 4: TRES "head" mounted on the Tillinghast telescope.

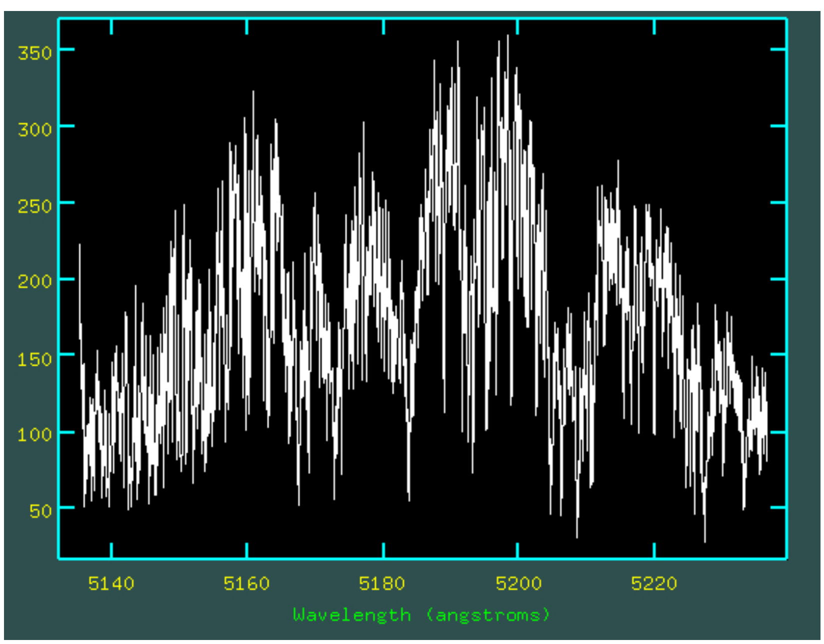

Fig. 5: 1.5m/ TRES spectrum: HAT54c exoplanet

2. The 1.2m telescope (aka 48 inch) is an f/8 Ritchey-Chrétien reflector, with a honeycomb borosilicate (Ohara E6) primary mirror. It is used exclusively for imaging at optical wavelengths. The telescope is used with Keplercam, a CCD camera with 4Kx4K pixels. The telescope is fully robotic.

Fig. 6: The 1.2m telescope, with Keplercam (inside the blue dewar, its LN2 vessel).

Fig. 7: 1.2/ Keplercam RGB image of the host galaxy for SNj1652.

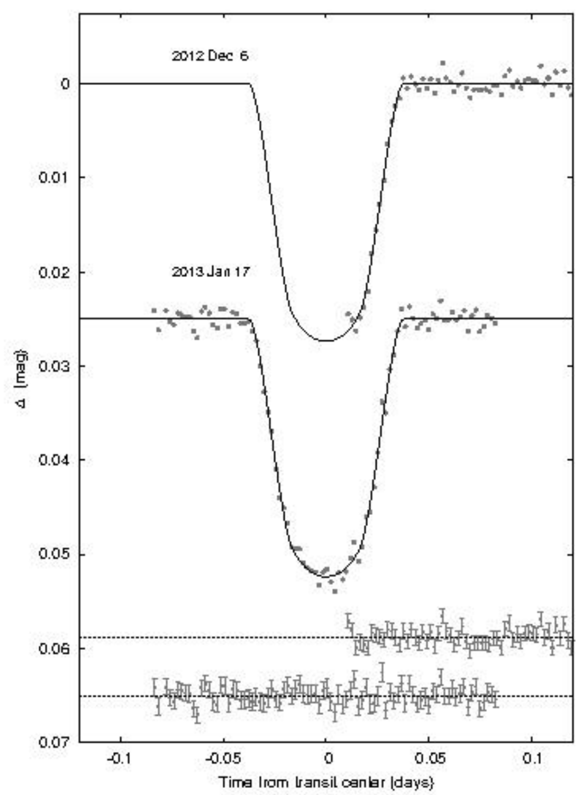

Fig. 8: 1.2/ Keplercam lightcurves of HTR265-005, showing the transit of an exoplanet.

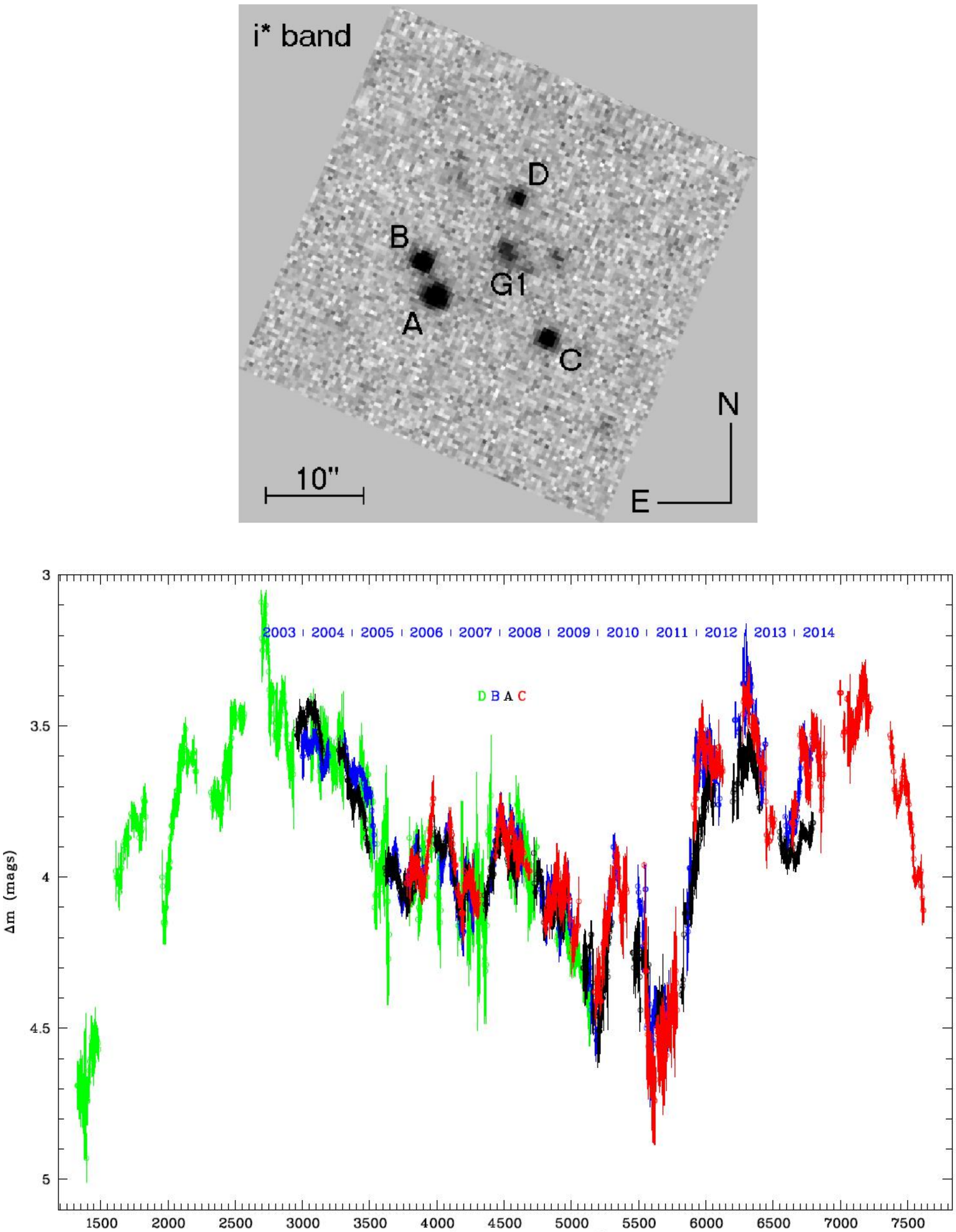

Fig. 9: (Top) 4 images of the gravitationally lensed quasar SDSSJ1004+4112, from the SDSS survey. (Bottom) lightcurves of the 4 images above, shifted by their respective time delays. All observations were acquired with the 1.2m. The longest delay is 7.1 years, which is also the longest delay ever measured, thanks to patient monitoring over the 11 years up to the year 2014.

3. HATNet is a network of six 11cm diameter telescopes, wide-field (8x8 degrees), fully-automated "HAT" telescopes. The goal of the project is to detect and characterize exoplanets (planets orbiting stars other than the Sun), and also to find and monitor bright variable stars. There are two main stations, one at FLWO and the other at the Submillimeter Array (SMA) site of SAO atop Mauna Kea, Hawaii. The HAT acronym stands for Hungarian-made Automated Telescope, because it was developed by a small group of Hungarian students and engineers. Since the start of operations in 2005, as of May 2014, HATNet has discovered 54 exoplanets.

Fig. 10: 5 HAT clamshell enclosures, just North of the Tillinghast

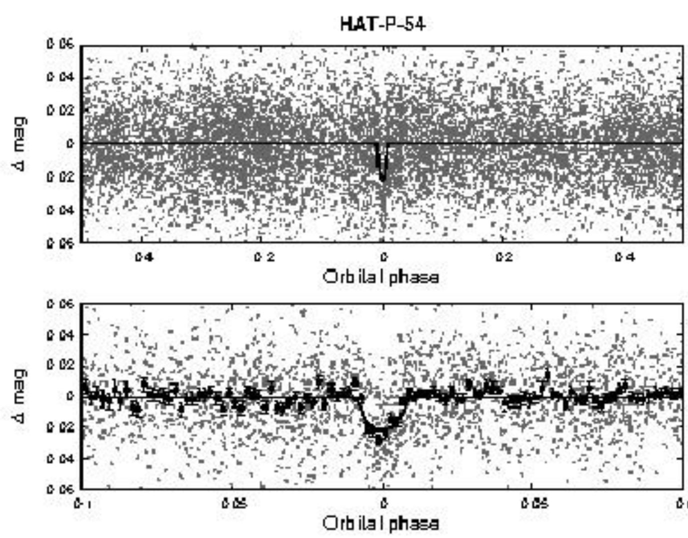

Fig. 11: HAT lightcurves of HT54, with HT54c exoplanet.

4. MEarth (pronounced “mirth”) is an astronomical survey that uses robotic telescopes in the Northern and Southern hemispheres to observe nearby M dwarf stars in search of new Earth-like exoplanets. MEarth-North at FLWO consists of 8 identical telescopes. On each telescope, a 40cm primary mirror focuses starlight onto a CCD camera that records the infrared brightness of each star. By measuring the brightness of a star many, many times, MEarth searches for dips in the star’s light (known as transits) caused by planets blocking some of the star’s light. Eight telescopes allow observations of that many stars at once.

Fig. 12: The 8 MEarth telescopes in their open enclosure.

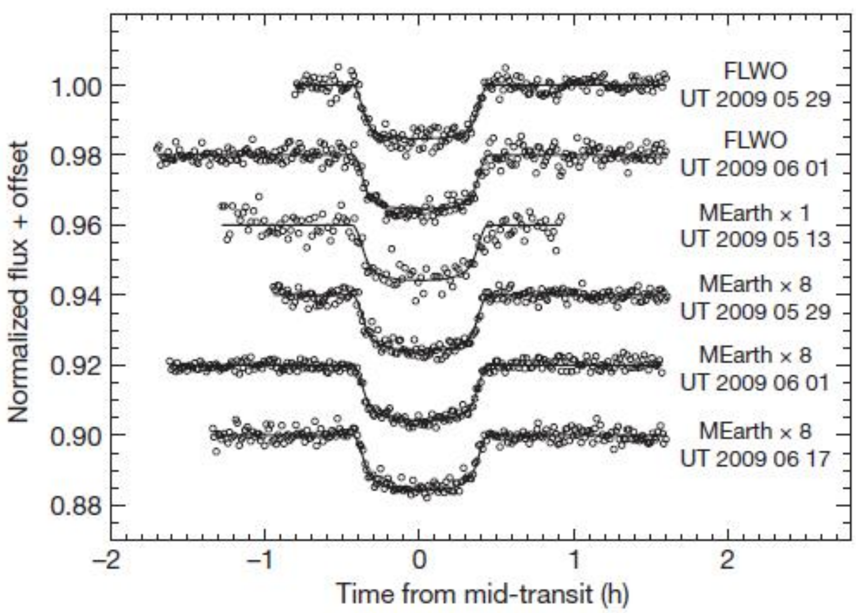

Fig. 13: MEarth and 1.2m (top 2) lightcurves of GJ1214, showing transits of exoplanet GJ1214c.

5. *Minerva* (MINiature Exoplanet Radial Velocity Array) is a new array of robotic telescopes, each a reflector with a 70-cm primary mirror. The telescopes are all of the same type, and will be outfitted for both photometry and high-resolution spectroscopy. The project is now expanding, with the addition of Minerva Red, at first a single telescope for spectroscopy (the same type as the first 4) in its own separate dome, and possibly two more such telescopes. The light collected with the main Minerva spectrograph and with the Minerva Red spectrograph will be transported via fiber optic cables into the control building where the spectrographs will be housed. These require a stable environment (especially regarding temperature) to achieve the highest possible sensitivity.

   The primary goal of *Minerva* is to discover Earth-like planets in close-in (less than 50-day) orbits around nearby stars, and super-Earths (3-15 times the mass of Earth) in the habitable zones of the closest Sun-like stars. A secondary goal is to look for transits of known and newly-discovered exoplanets, which provide information about the radii and interior structures of the planets. This second goal employs the proven method used by the *Kepler* Mission, and the unique design of the *Minerva* observatory allows the pursuit of both goals simultaneously.

   The dedication ceremony took place on May 18, 2015. The 5 telescopes in the 3 enclosures shown in Fig. 14 are now operational. Fig. 15 is an example of the imaging possible with MINERVA.

Fig. 14: Two telescopes are seen in each of the long enclosures (dubbed Aqawans) in the background. A fifth telescope is seen in the Minerva Red Astrohaven round dome (photo by Cullen Blake).

Fig. 15: M51 taken with an Andor camera mounted on MINERVA's T3 (2nd telescope on the left of the enclosure on the right) on May 6, 2015.

The modifications of a room in the control building to house the spectrographs were completed in December 2015. The main spectrograph was installed, and as of February 2016, it is being tested. Image of a representative spectrum coming soon…