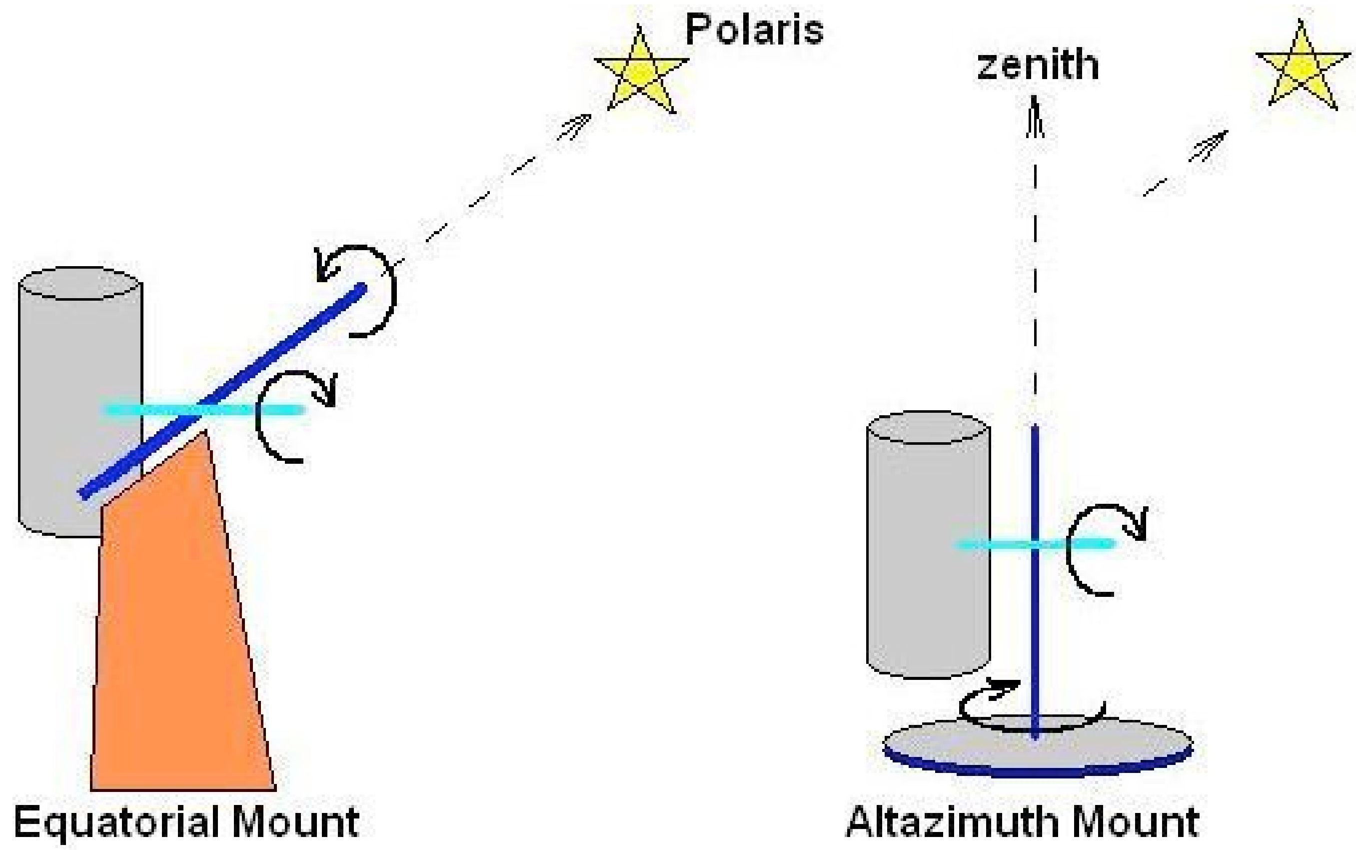
Telescopes & Spectrographs

Doug Finkbeiner, Astronomy 16 .
Adapted from lectures by John P. Oliver,
University of Florida

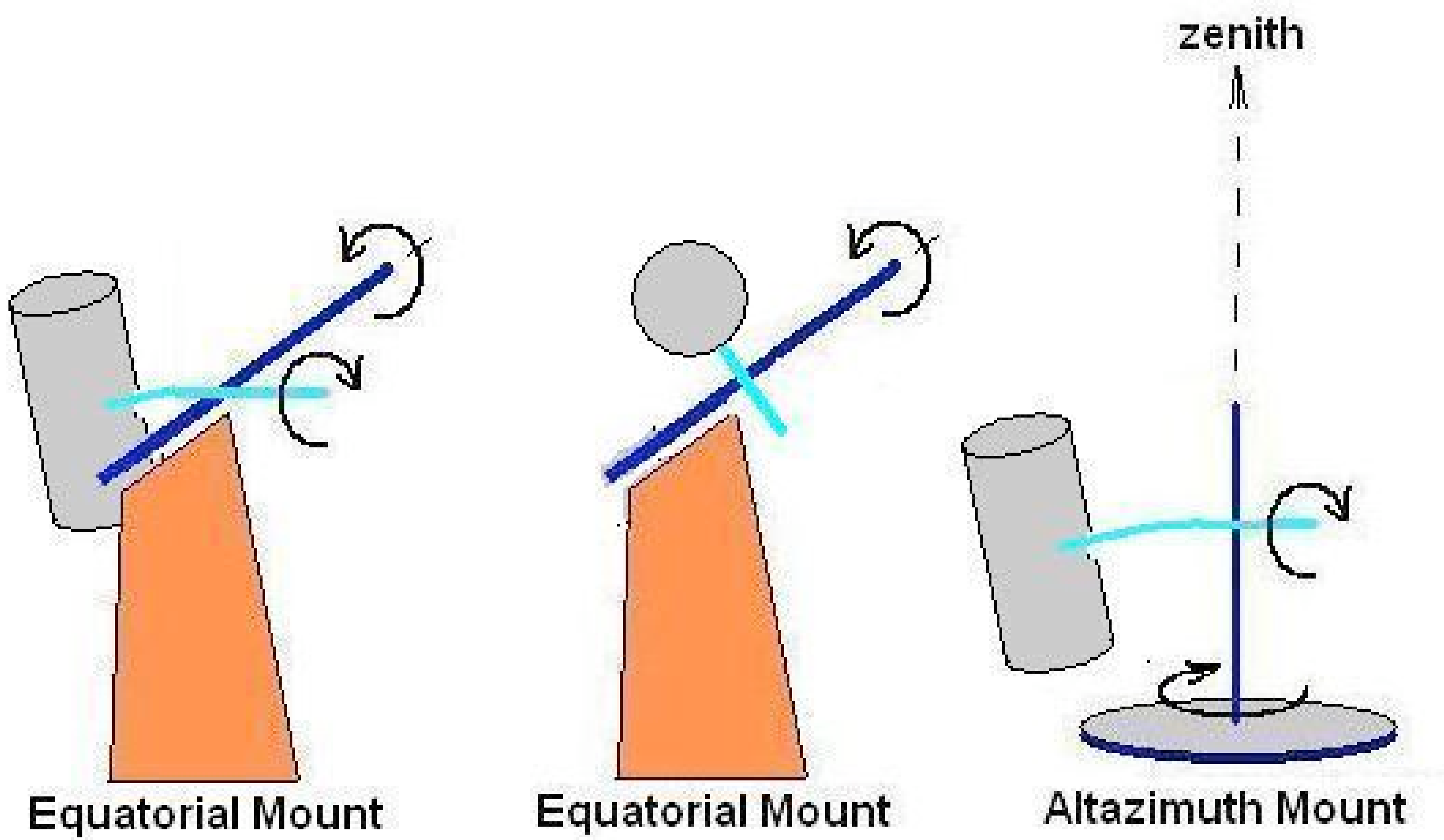
- Telescope Mounts
  the telescope mount allows the telescope to point anywhere in the sky and to track stars as they rise and set
- Balancing
  Proper balance is important if the telescope is to track the stars in all parts of the sky without drifting
- Polar alignment
  It is necessary that an equatorial mount be closely aligned on the pole to ensure accurate tracking



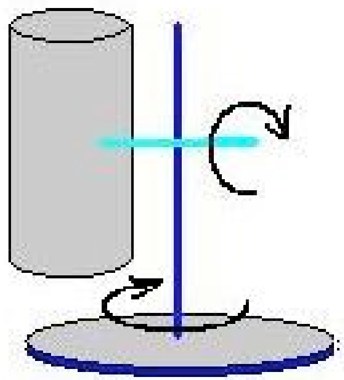
Equatorial Mount

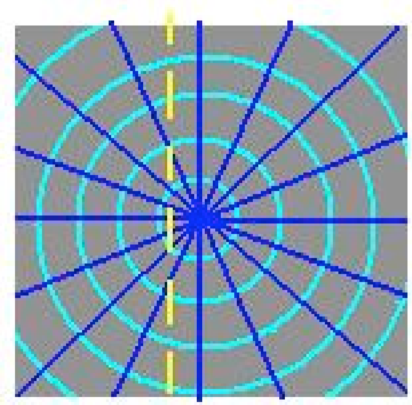
two axes: a polar axis is aligned with the Earth's axis, allowing diurnal tracking; a perpendicular declination axis

- advantage: one axis diurnal tracking
- disadvantage: asymmetry to gravity

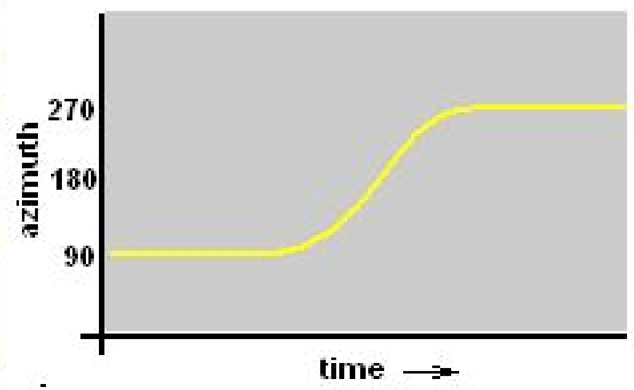


- Alt-azimuth Mount
  two axes: an azimuth axis aligned with the zenith; a perpendicular altitude axis
  - advantage: symmetrical to gravity
  - disadvantage: 2 axis tracking
    - "dead" zone at zenith
    - field rotation

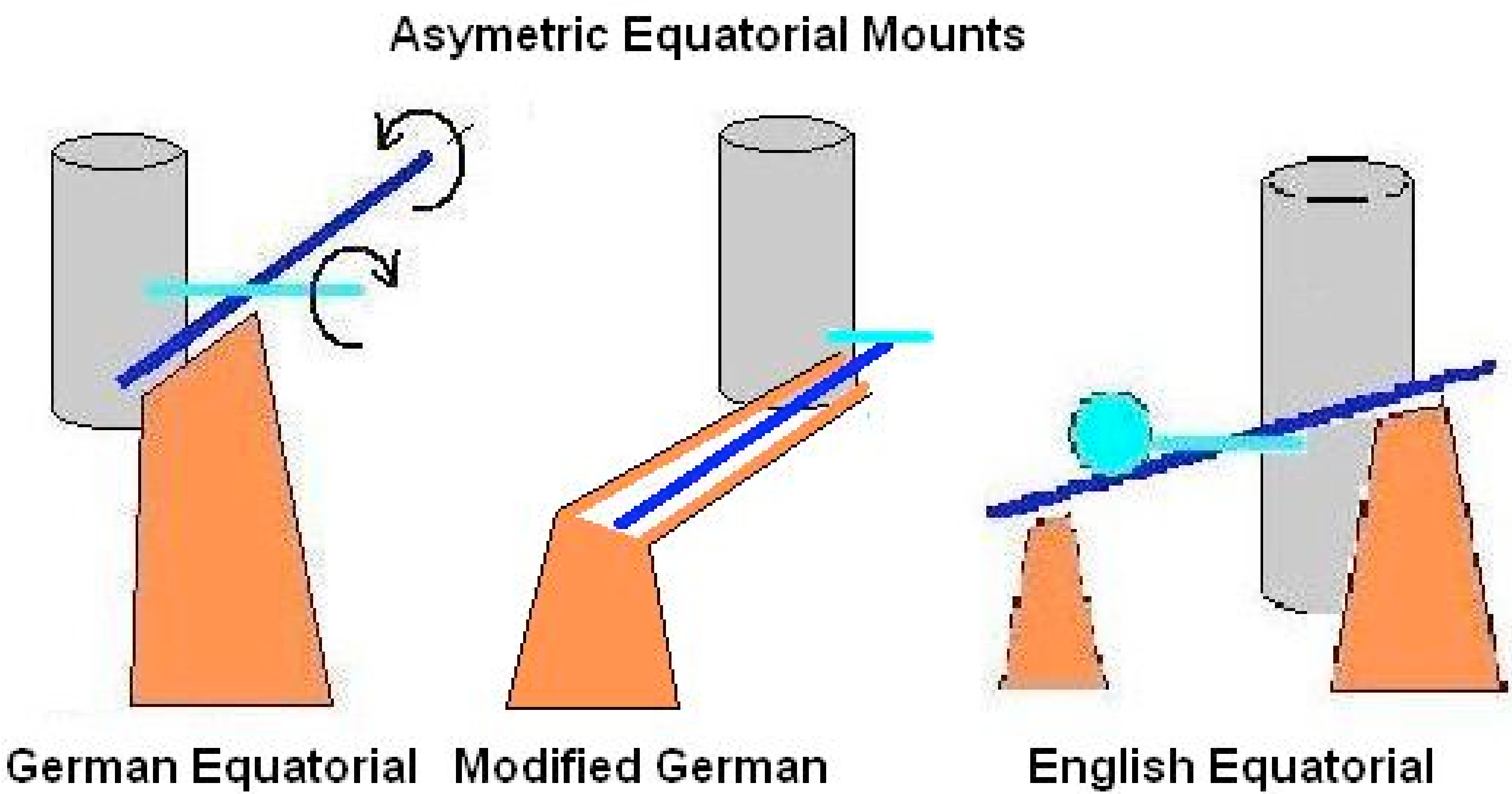




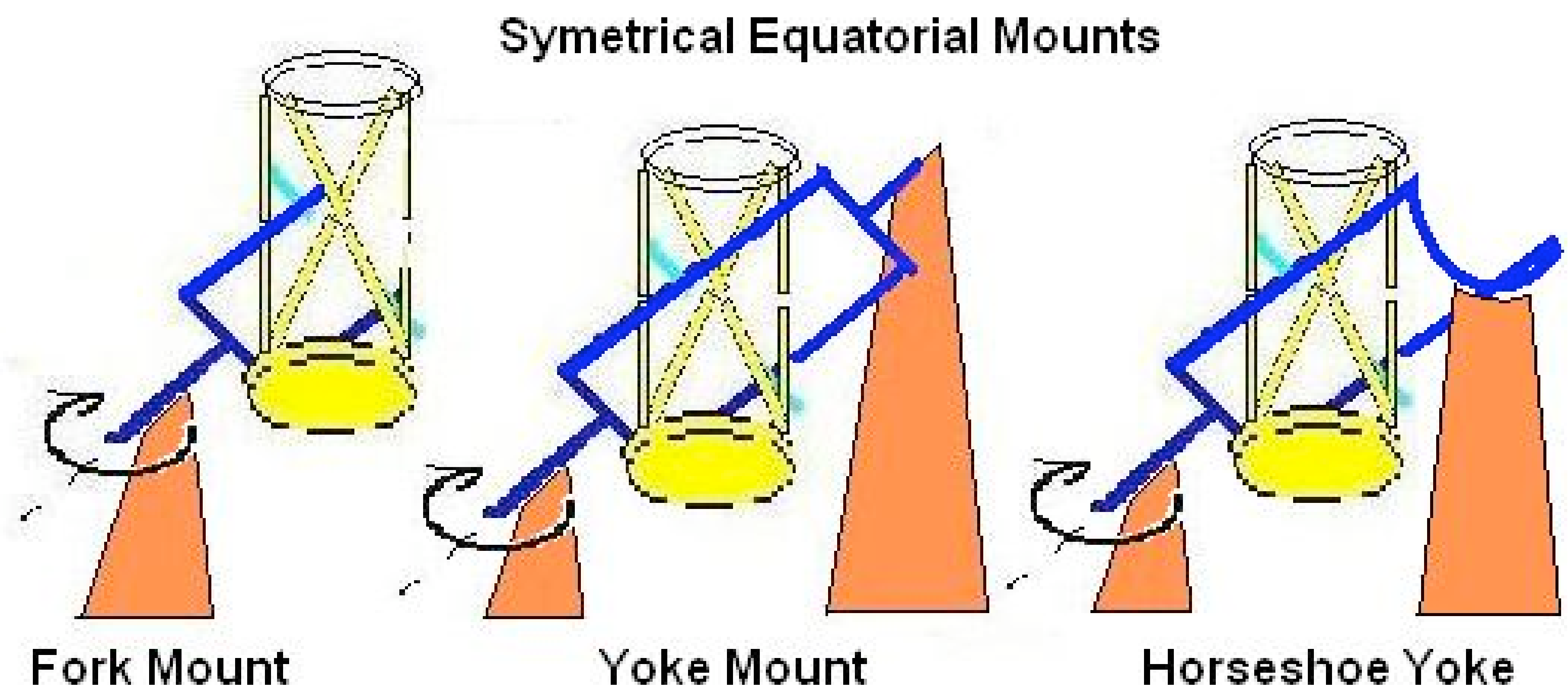
path of star near zenith



With an equatorial mount, the field seen in an eyepiece or camera is fixed in orientation (e.g. perhaps west to the right, north up, etc.). This is not the case with an alt-azimuth mount. Consider the case of tracking a star that passes near the zenith: as the zenith is passed the telescope must rotate nearly 180° in azimuth which means that a camera mounted rigidly to the telescope tube would rotate relative to the objects being imaged. Thus instruments on an alt-azimuth mounted telescope must be mounted on a bearing which must be rotated at the correct rate to compensate for field rotation.



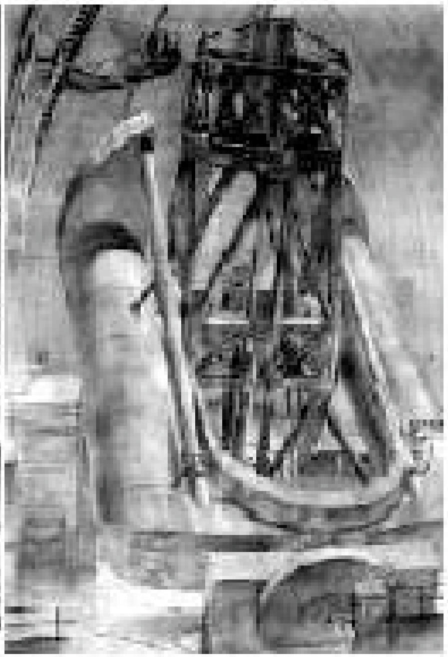
- German Mount: Most frequently used for refracting telescopes. Must be "reversed" to observe on both sides of the meridian.
- Modified German Mount: By extending the polar axis (and proving support at the far end) the tube can clear the pier without the need to reverse.
- English Mount: Must be "reversed" to observe on both sides of the meridian. Full support for both ends of the polar axis may restrict use near the pole.



- Fork Mount: most frequently used for reflecting telescopes. To reach pole, tube must clear fork.
- Yoke Mount: Added support for polar axis. Cannot reach pole.
- Horseshoe Yoke Mount: Allows reaching pole while providing support at both ends of polar axis.

RHO .76m
German Eq.

Mt. Wilson 2.5m
Yoke

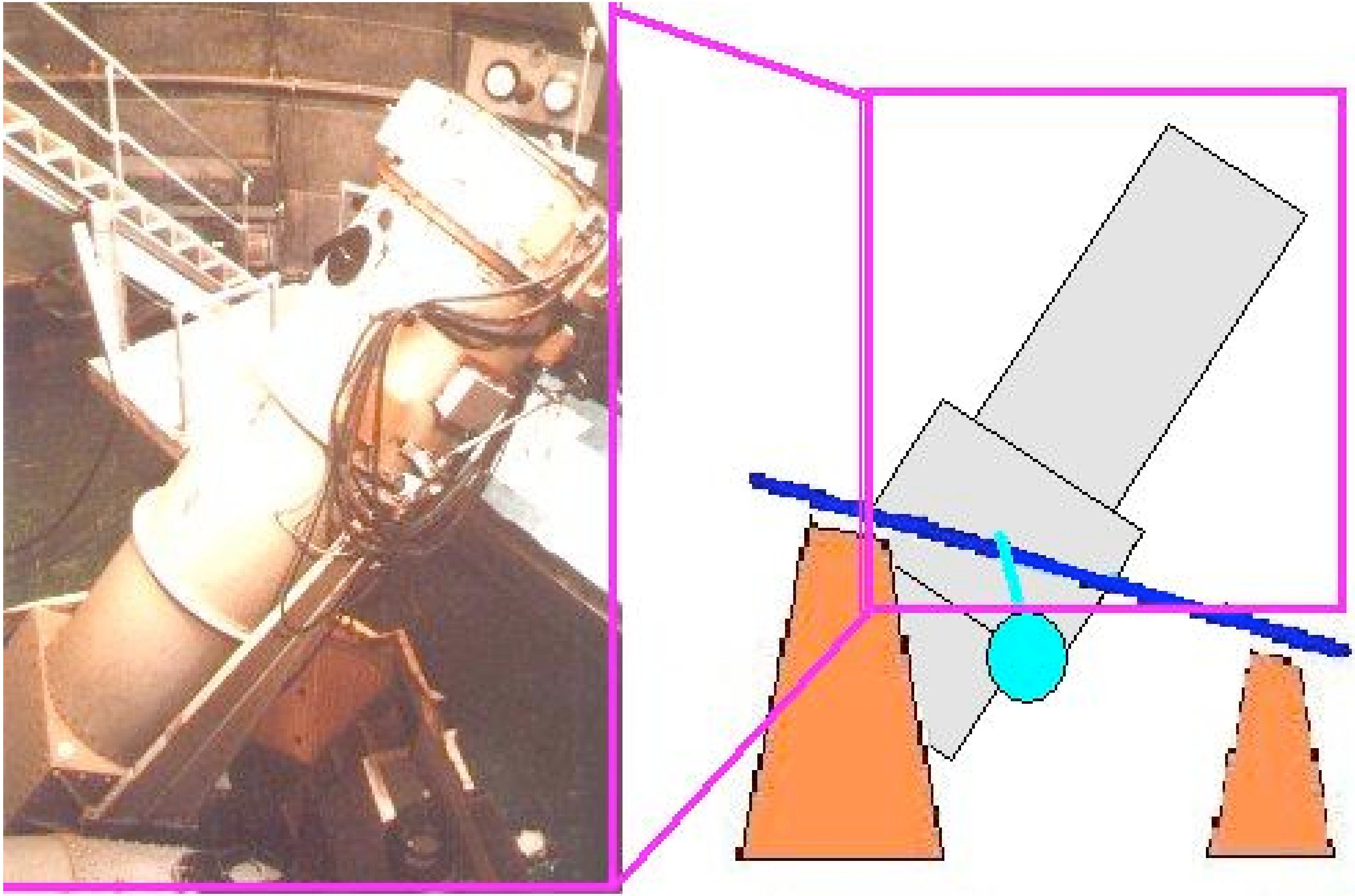


Palomar 5m
Horseshoe Yoke

RHO 0.46m
fork mount

Lick 3m
fork mount

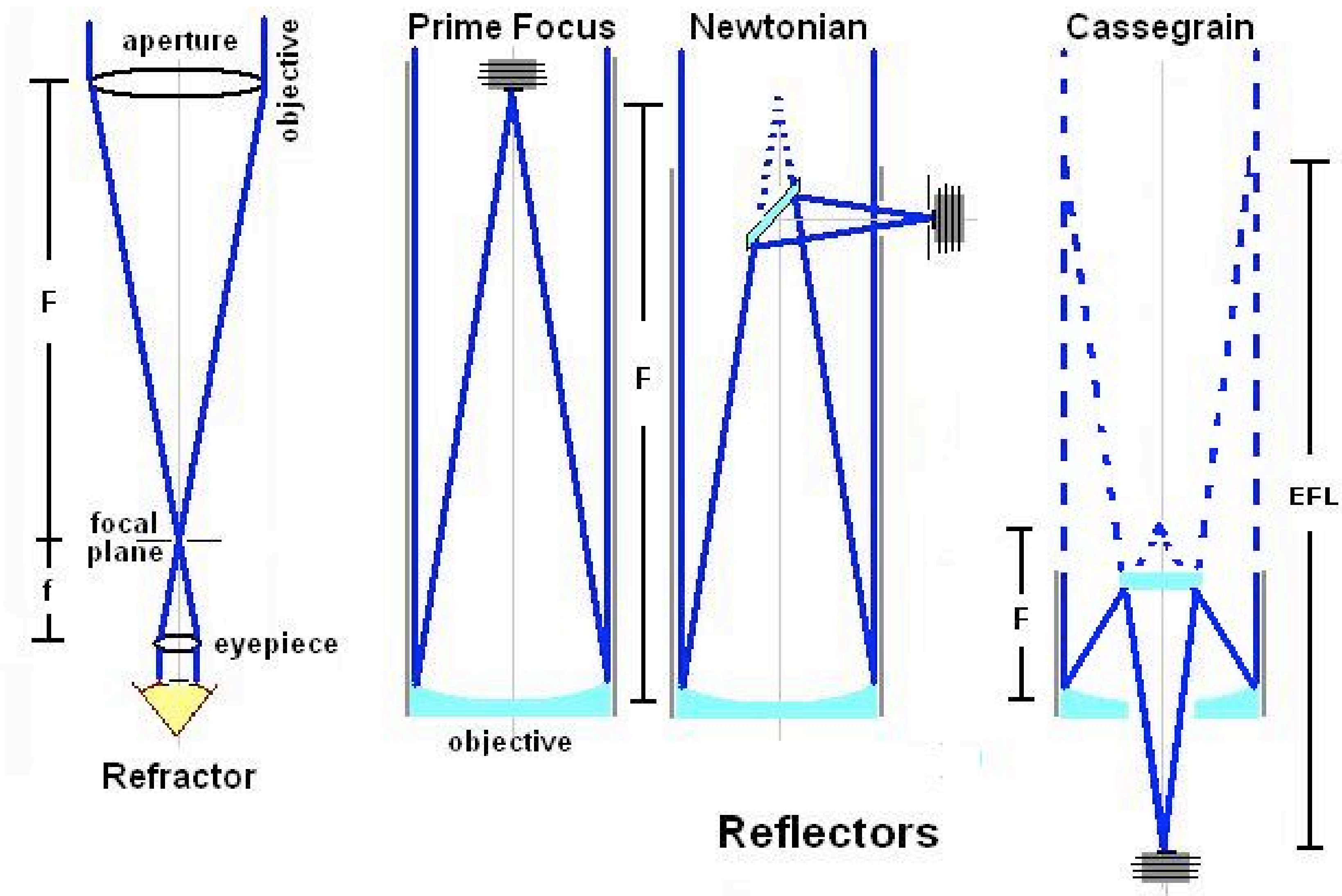
prime focus cage

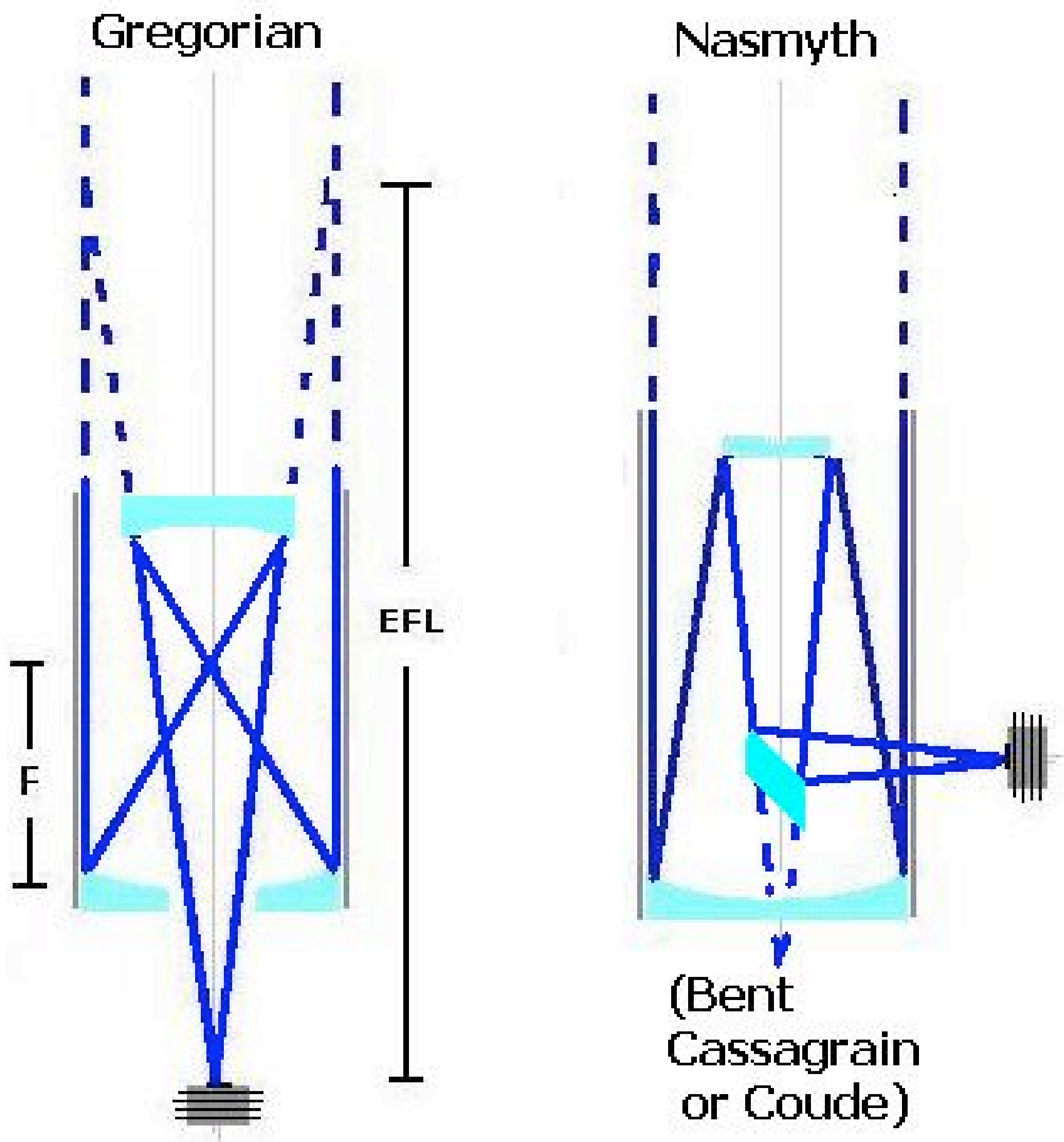


The Lick Observatory Crossley 0.91m - English Equatorial

Basic Telescope Optics

The four basic forms of telescope optics are shown in the figure below. Each of these has an objective that collects the light, bringing it to a focus.

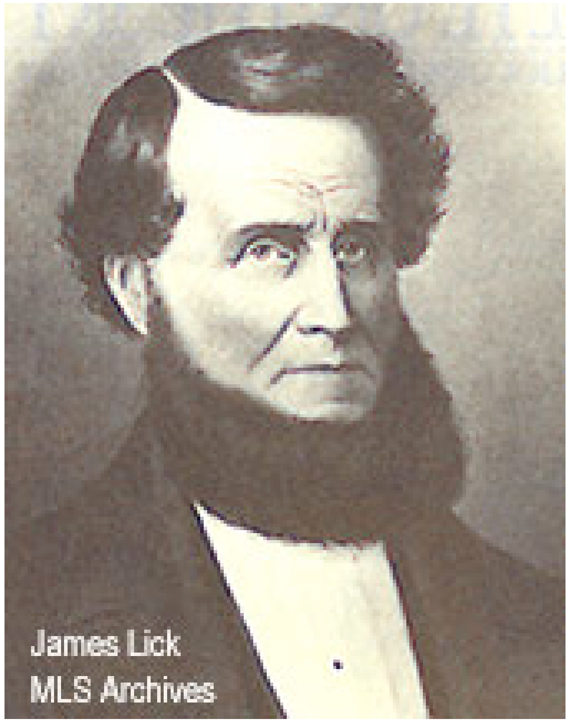



Gregorian
EFL
F
Nasmyth
(Bent
Cassagrain
or Coude)
Schmidt
Maksutoff

The Great Lick Refractor

Lick Observatory was built 1880-1888.

This was the largest telescope in the world.



Eccentric businessman and real estate magnate James Lick donated the $700,000 needed to build a "telescope superior to and more powerful than any telescope yet made." A self-made millionaire bachelor with a fondness for monuments, Lick was of the age and personality that he wanted his name and reputation to live on after his death. He first considered constructing statues of himself and his parents to stand as a memorial for posterity. Not just average statues, these would have been built on the coast on a scale large enough to be seen from ships at sea!

It was pointed out that such statues would likely be targets for shelling during any future wars. Lick then changed his mind and decided to build a huge pyramid, larger than the Great Pyramid of Cheops, on 4th and Market Streets in San Francisco.

Fortunately, scientific acquaintances persuaded Lick to change his mind again and endow a project which was monumental not only in physical size, but also in its ability to further scientific research and give astronomers a better look at the Universe: the world's largest and most powerful telescope.

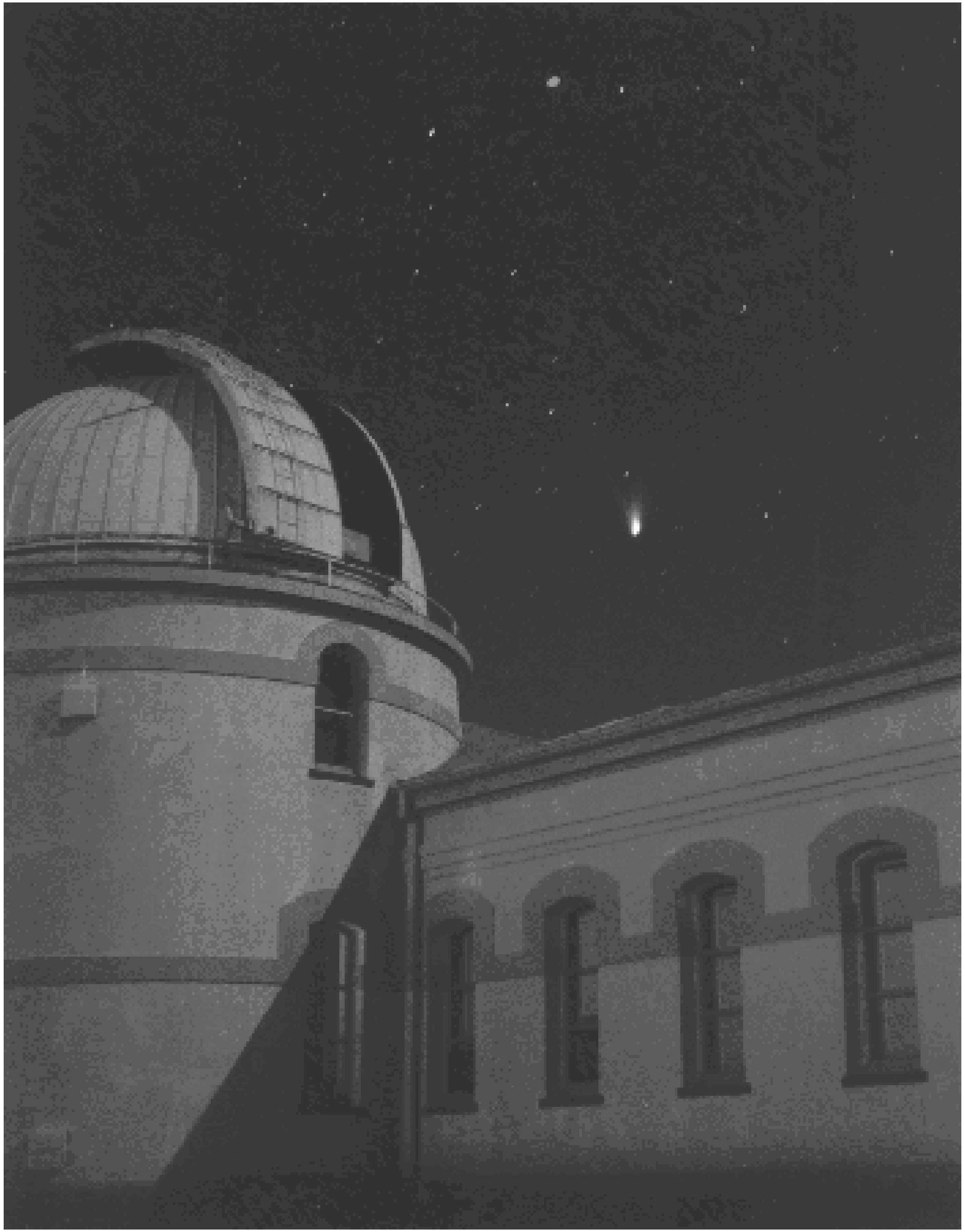
This picture was taken outside the 40 inch Nickel telescope at Lick Observatory on March 1, 1997.

Coordinates of comet Hale-Bopp
at 1 March, 1997, 0h UT
RA = 21 21 dec = +33 17 (J2000)

Distance: 1.067 A.U. = 159 million km

Camera: Rolleiflex
Film: Ilford HP5
400 speed, pushed to 1600(?)
Exp: 20 seconds
Dev: Kodak D76
Paper: Ilford Multigrade IV RC

Photographer: Douglas Finkbeiner



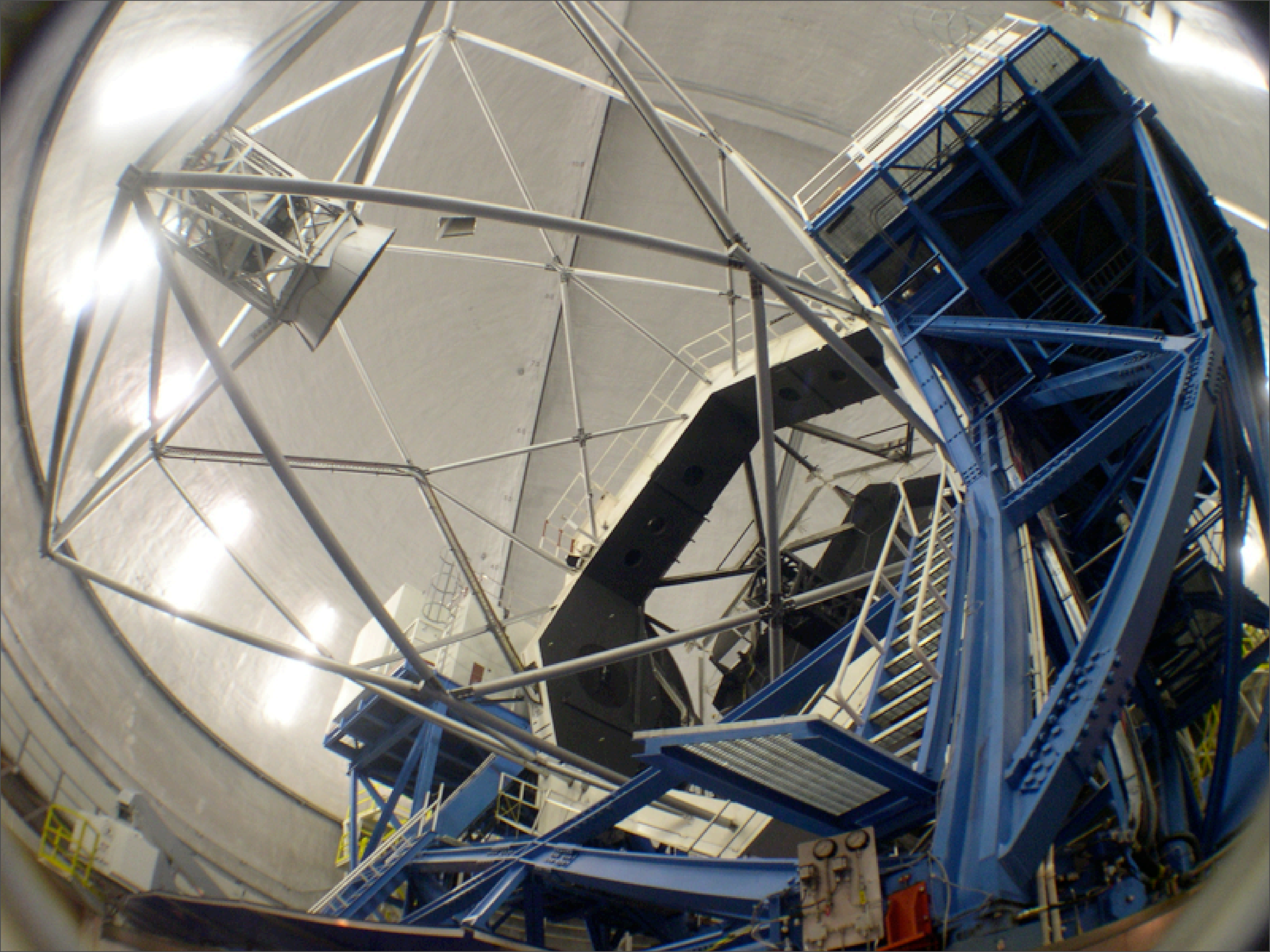
Professor Kyle Cudworth near the telescope at Yerkes Observatory (40 inch refractor)

1897

The 200-inch Hale Telescope

(1930s)

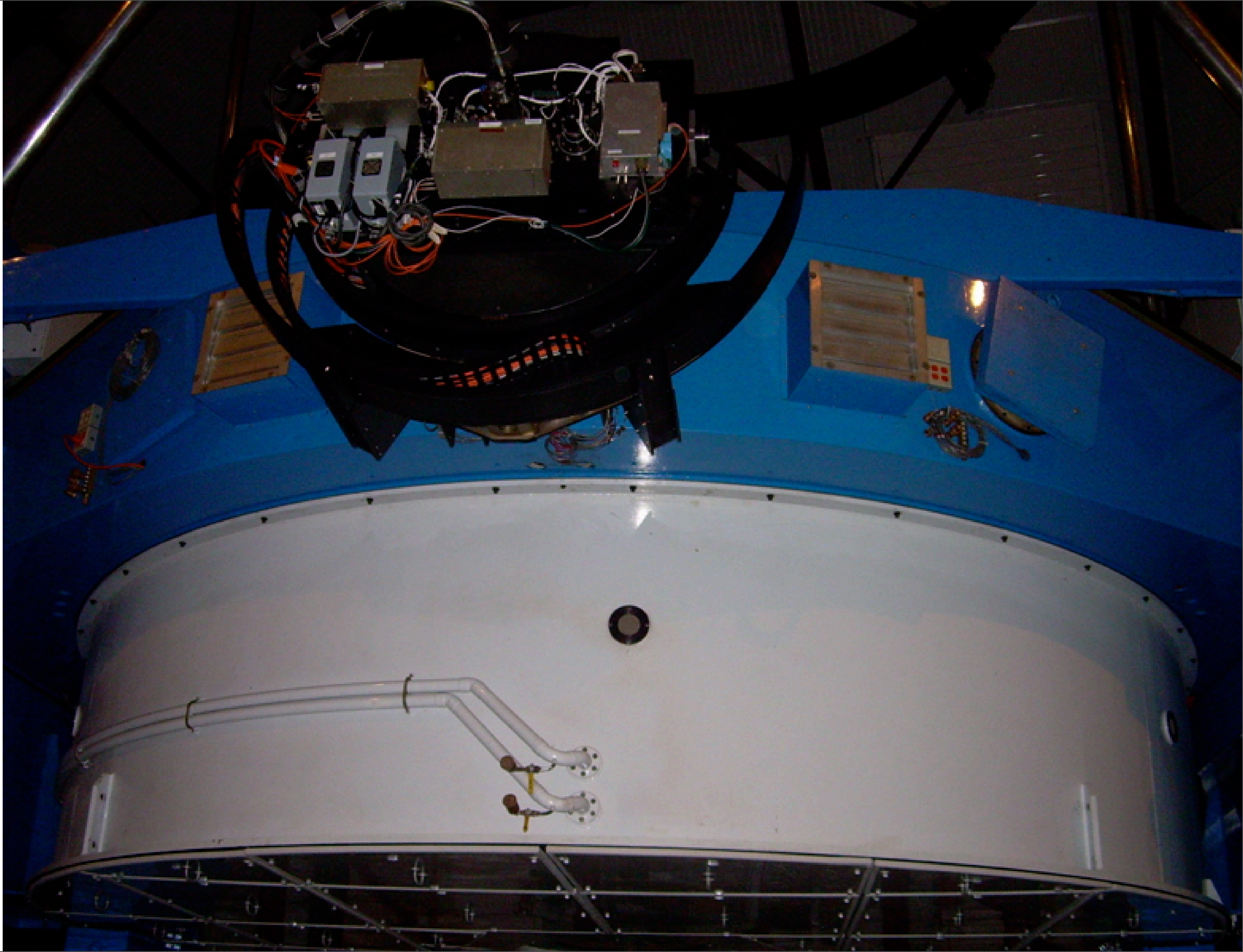
Keck telescopes (each 10 m aperture), Mauna Kea, Hawaii (1990s)

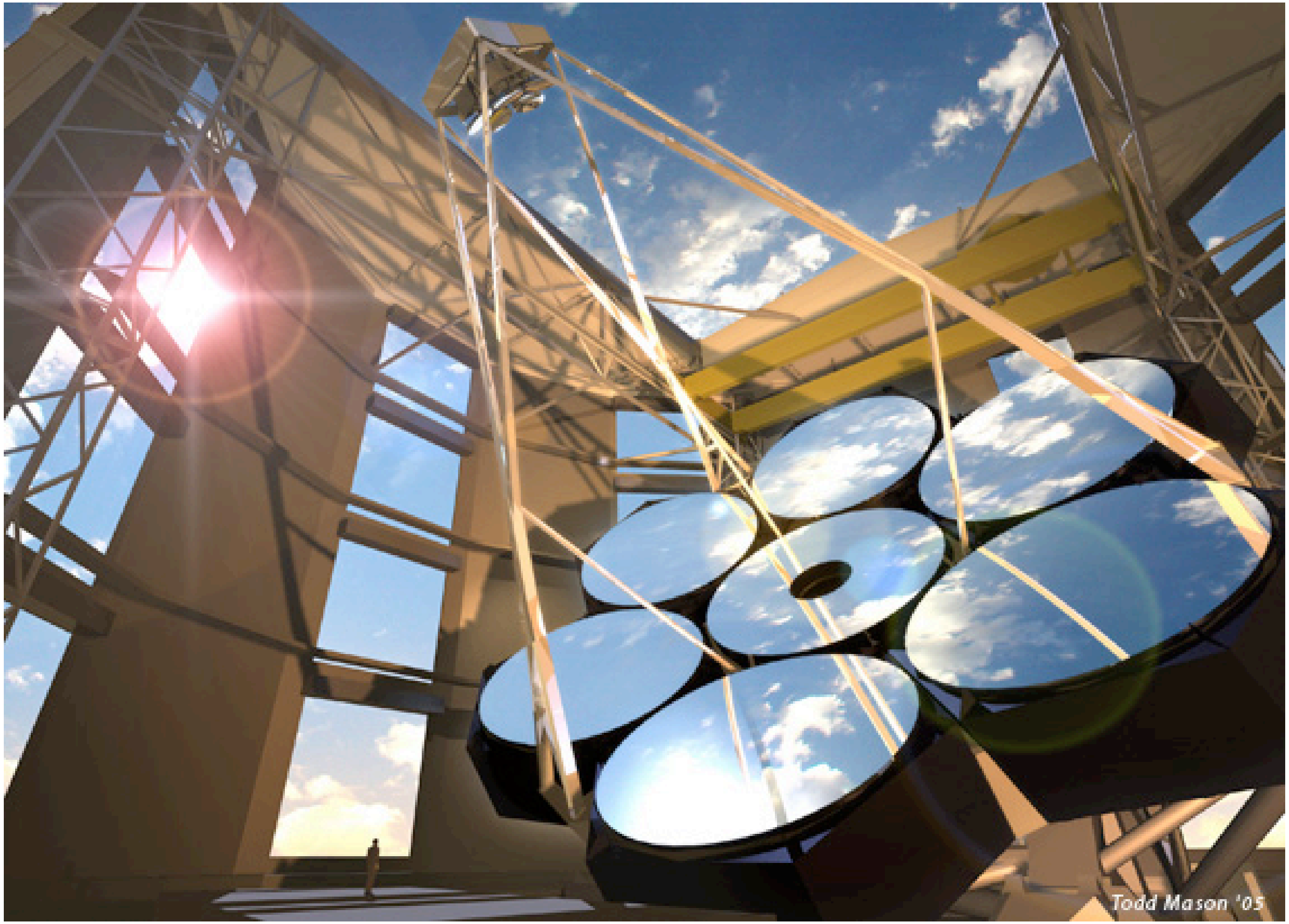


Magellan telescopes at Las Campanas, seen from Mamalluca Peak.

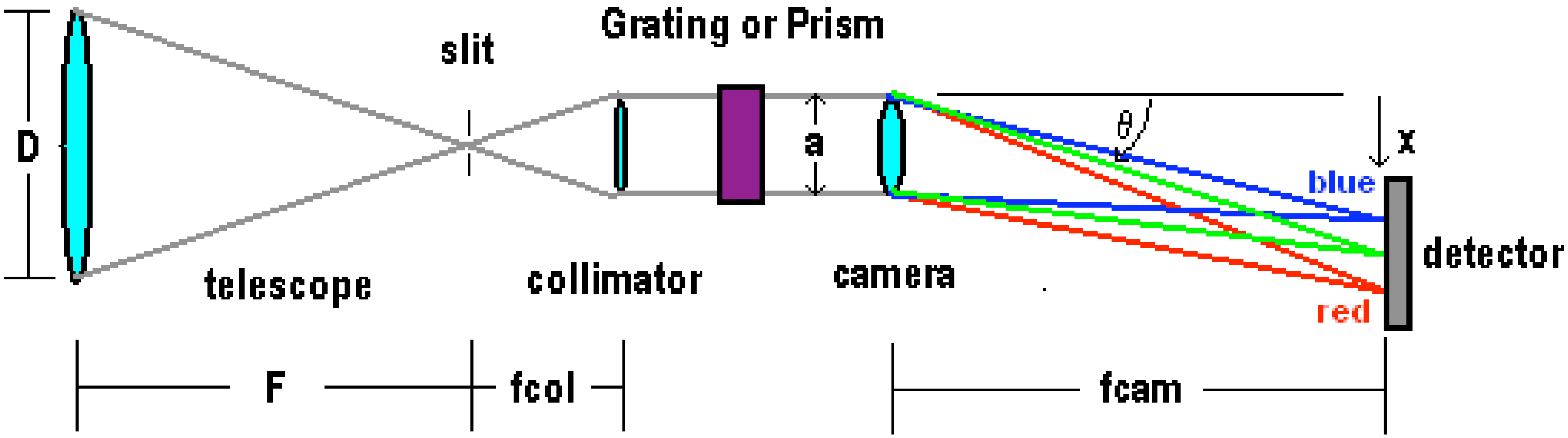
(Harvard undergrad shown for scale)

Closer view: Two 6.5m telescopes



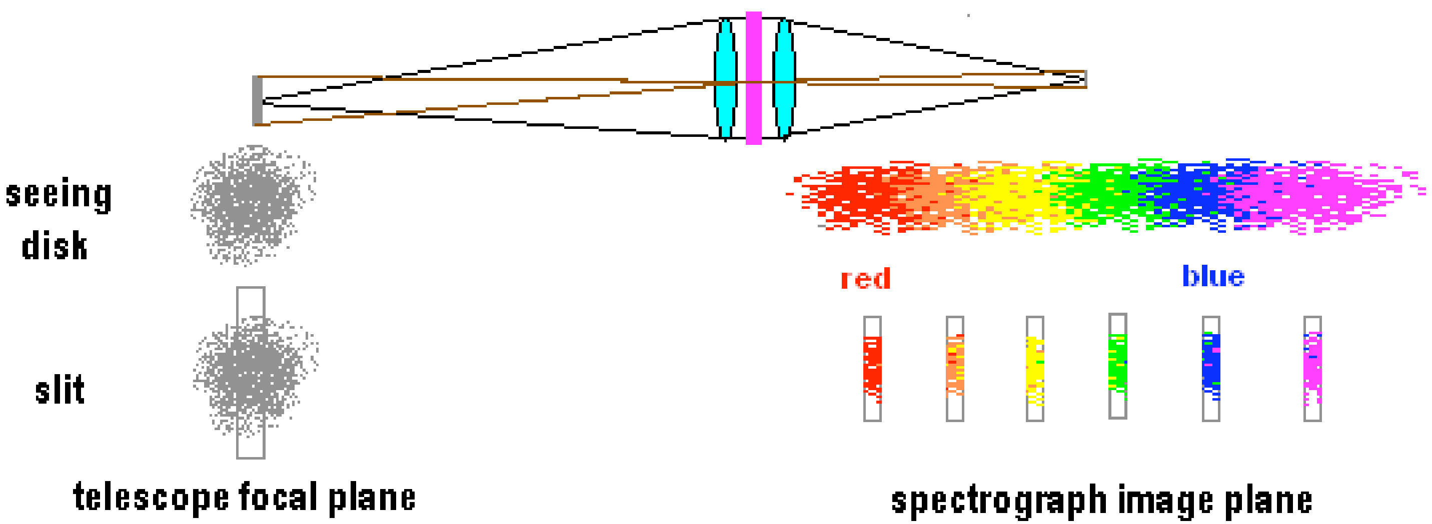


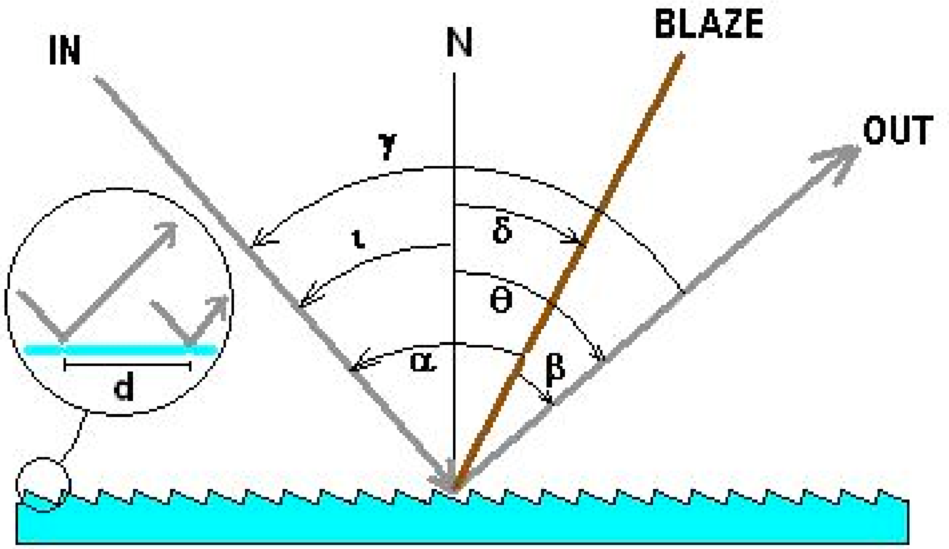
The Giant Magellan Telescope (GMT)—the product of more than a century of astronomical research and telescope-building by some of the world's leading research institutions—will open **a new window on the universe for the 21st century.** Scheduled for completion around 2016, the GMT will have the resolving power of a 24.5-meter (80 foot) primary mirror—**far larger than any other telescope ever built**.



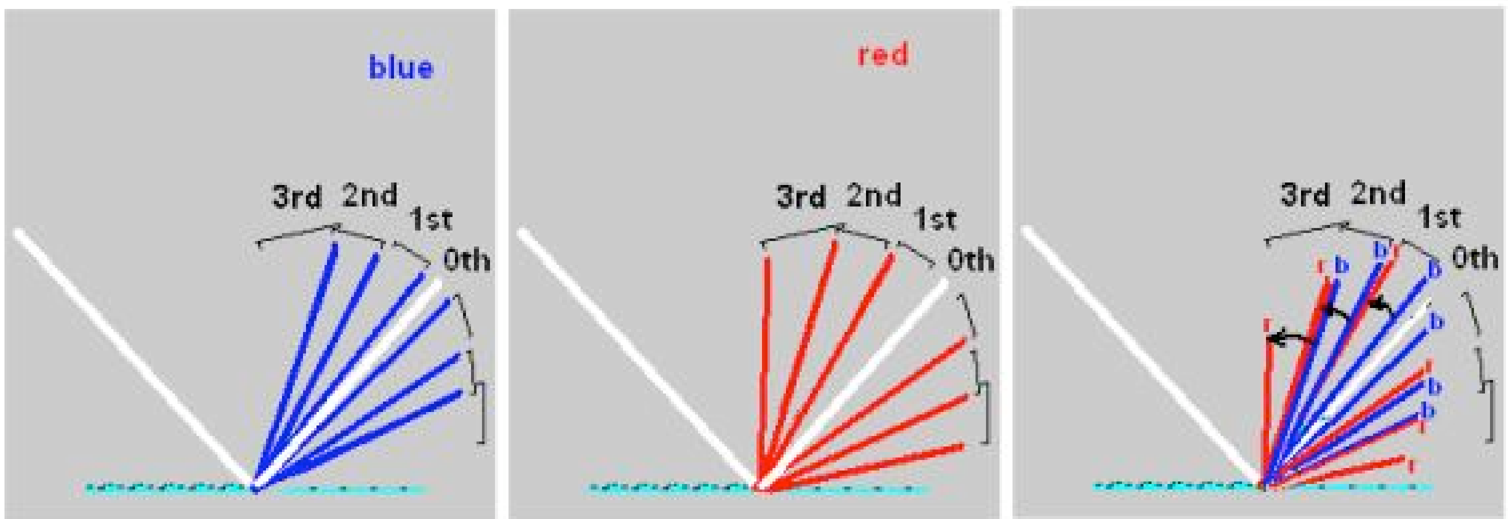
The basic astronomical spectrograph is comprised of a slit, collimator, a dispersing element (typically a diffraction grating or prism), a camera, and a detector.

- Slit: isolates portion of sky that is imaged in a single wavelength
- Collimator: makes beam parallel
- Dispersing element: disperses light as a function of wavelength
- Camera: forms image of object (star or slit) on detector


seeing
disk
slit
telescope focal plane
red
blue
spectrograph image plane

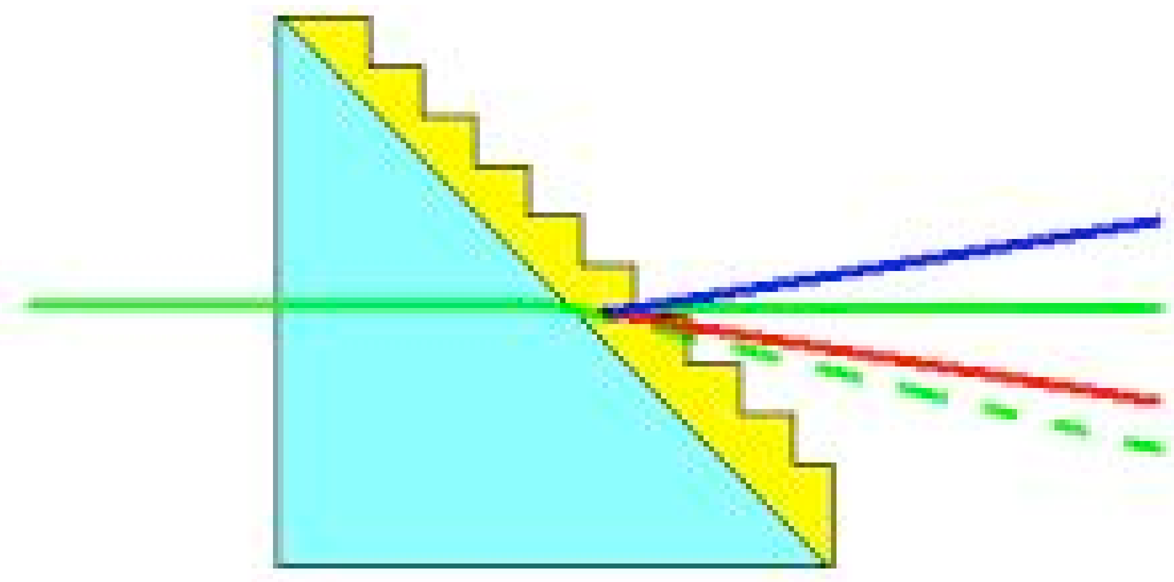


A reflection diffraction grating has a series of closely spaced grooves so that light reflects off of the grating surface as though there was a series of narrow parallel mirrors. Constructive interference between the reflected beams of light at specific angles for a given wavelength and not for other wavelengths results in the creation of a spectrum. Setting the path difference between adjacent rays equal to a multiple of whole wavelengths (thus achieving constructive interference) sets up the grating equation and the dispersion equation. The beam is dispersed into multiple orders. The 0^{th} order is not dispersed (white light).

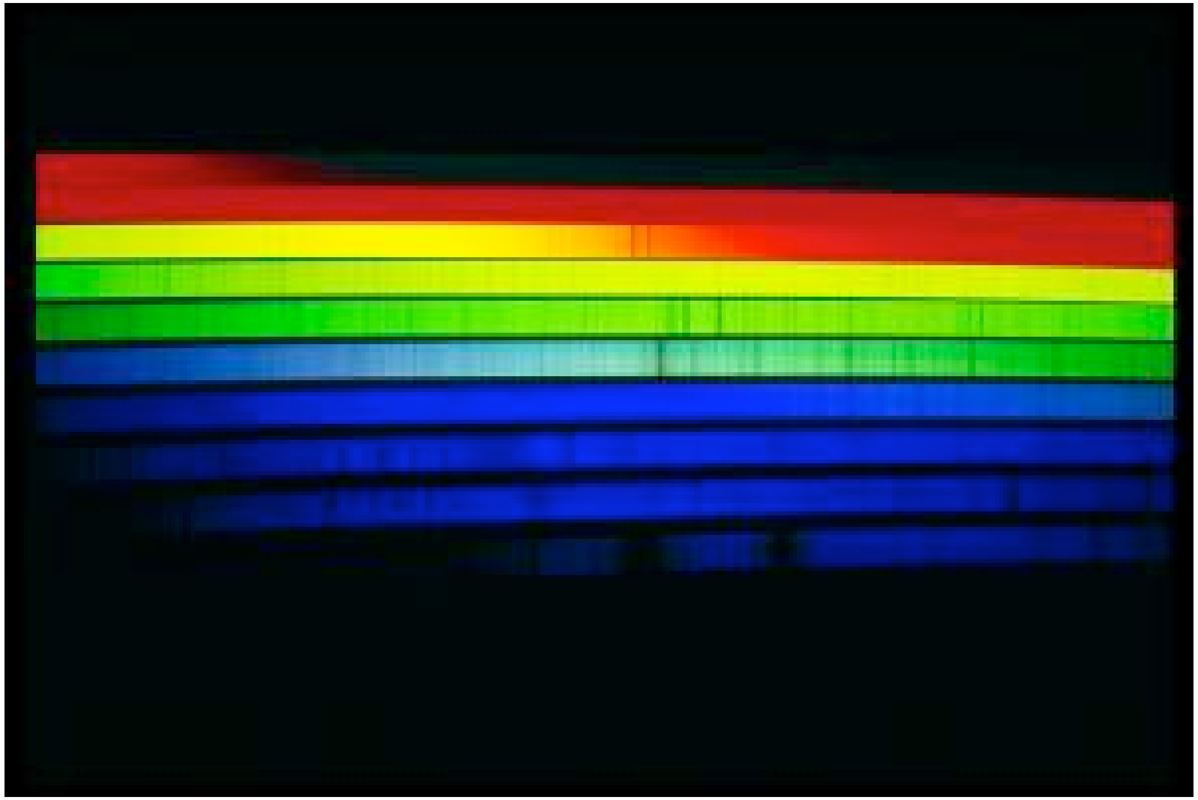


No Blaze

Blazed

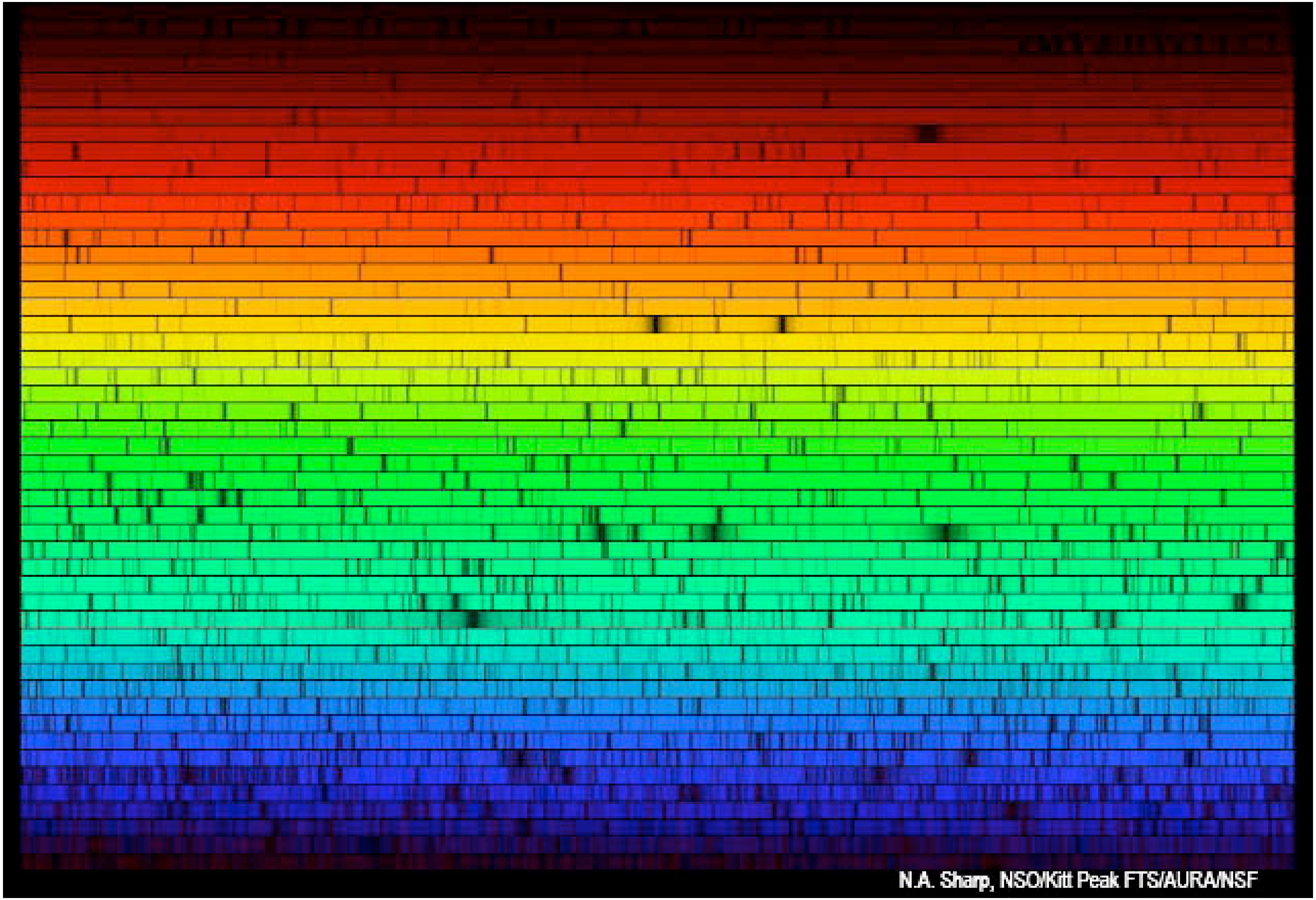


Most modern spectrographs use a diffraction grating or a combination of a diffraction grating and a prism termed a ***grism***. Here a grating has been bonded to the surface of a prism. The deviation of the beam by the prism is compensated by the deviation of the central wavelength in the grating resulting in a spectrum centered on the system optical axis.

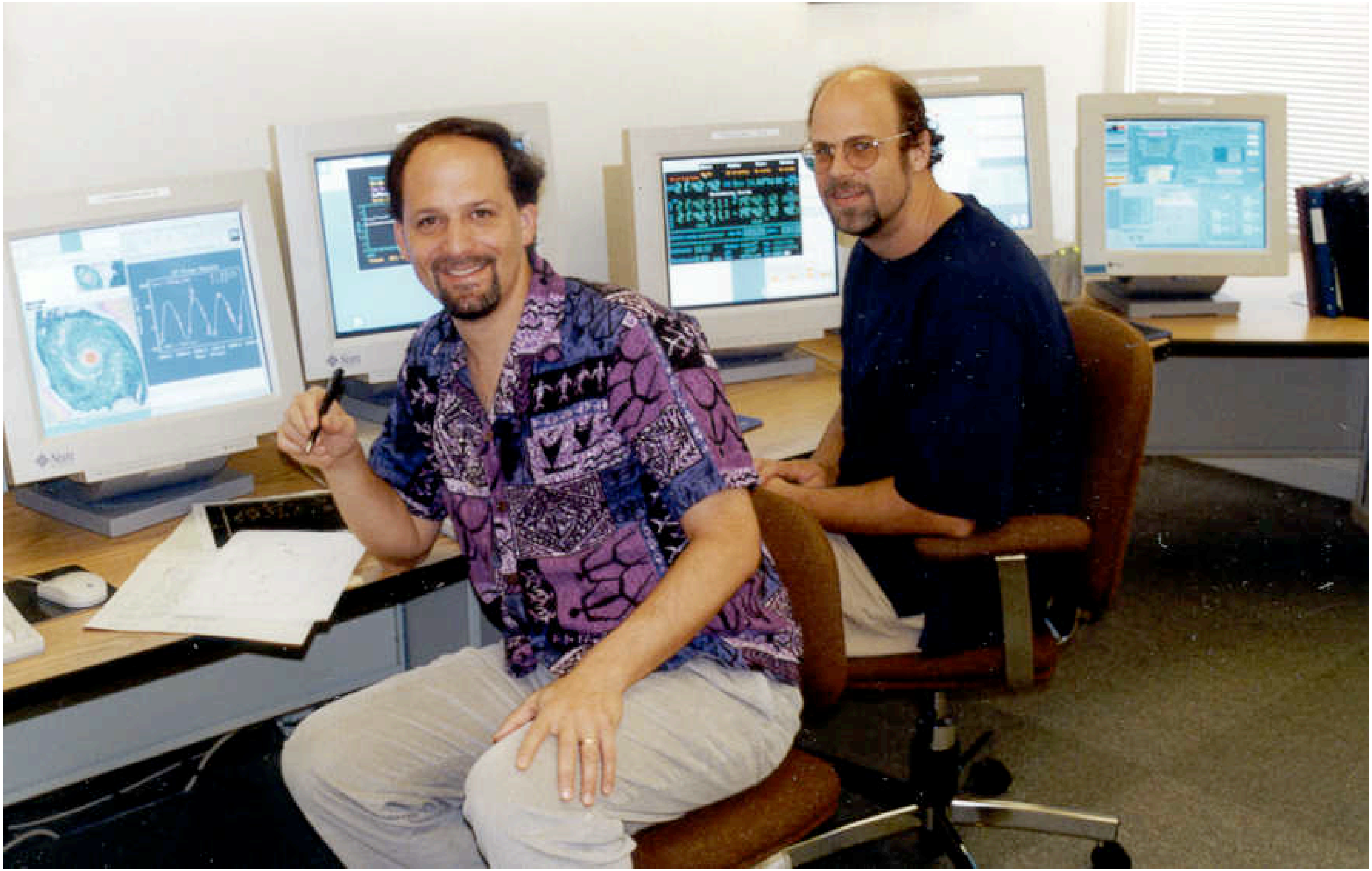


Echelle

To increase the resolution of a grating one can either decrease the spacing between groove **d**, or increase the order m. One kind of spectrograph that adapts well to two-dimensional detectors is the *echelle* spectrograph. Here a grating with a relatively coarse pattern of grooves (so large d) is used at a very high order (typically more than 50). A weak prism is mounted with its dispersion perpendicular to the echelle dispersion, displacing the orders so that they do not overlap.


N.A. Sharp, NSO/Kitt Peak FTS/AURA/NSF

Geoff Marcy and Paul Butler, planet hunters



(and users of the Hamilton echelle at Lick Obs.)

Doppler shifts: Star radial motion shows up as periodic variation; Very effective [speed is now measured to within 10 ft/s!], has given us most of the candidates, and about 1000 stars are being monitored.