A POSSIBLE TECHNIQUE FOR COMETARY STUDIES WITH HIGH ANGULAR AND SPECTRAL RESOLUTION

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Abstract

The echelle spectrographs, designed for and used at the Cassegrain stations of the KPNO and CTIO 4-meter telescopes, are capable of cometary spectroscopy with seeing-limited angular resolution along the slit and with spectral resolving power ($\lambda/\Delta\lambda$) ranging from 10^4 to 10^5. Various gratings, cameras and detectors can be used in combination for specific studies in the 3000Å to 10,000Å range.

Introduction

High-dispersion spectroscopy coupled with high angular resolution is a challenging problem that requires large telescopes and special spectrograph designs. One solution, worked out for the KPNO and CTIO 4-meter telescopes, has been a Cassegrain-mounted echelle spectrograph. Two identical spectrographs are in regular use on these twin telescopes and are proving to be very useful in, not only stellar spectroscopy, but also nebular and extragalactic studies. With careful planning these spectrographs should be applicable to bright comets in line identifications and velocity studies in the cometary head region.

The Instrument

The echelle spectrograph is a result of initial design studies by D. J. Schroeder and follow-on studies by T. R. Gull and D. J. Schroeder. It is modular in design having red- and blue-optimized optics, several echelles and several cross-dispersers and three cameras. Photographic plates, image intensifiers and, more recently, CCD cameras have been routinely used as detectors. The optics as diagrammed in Figure 1 use a 125mm diameter f/8 collimator, a near-Littrow mounted echelle, cross-disperser grating and any of several cameras.

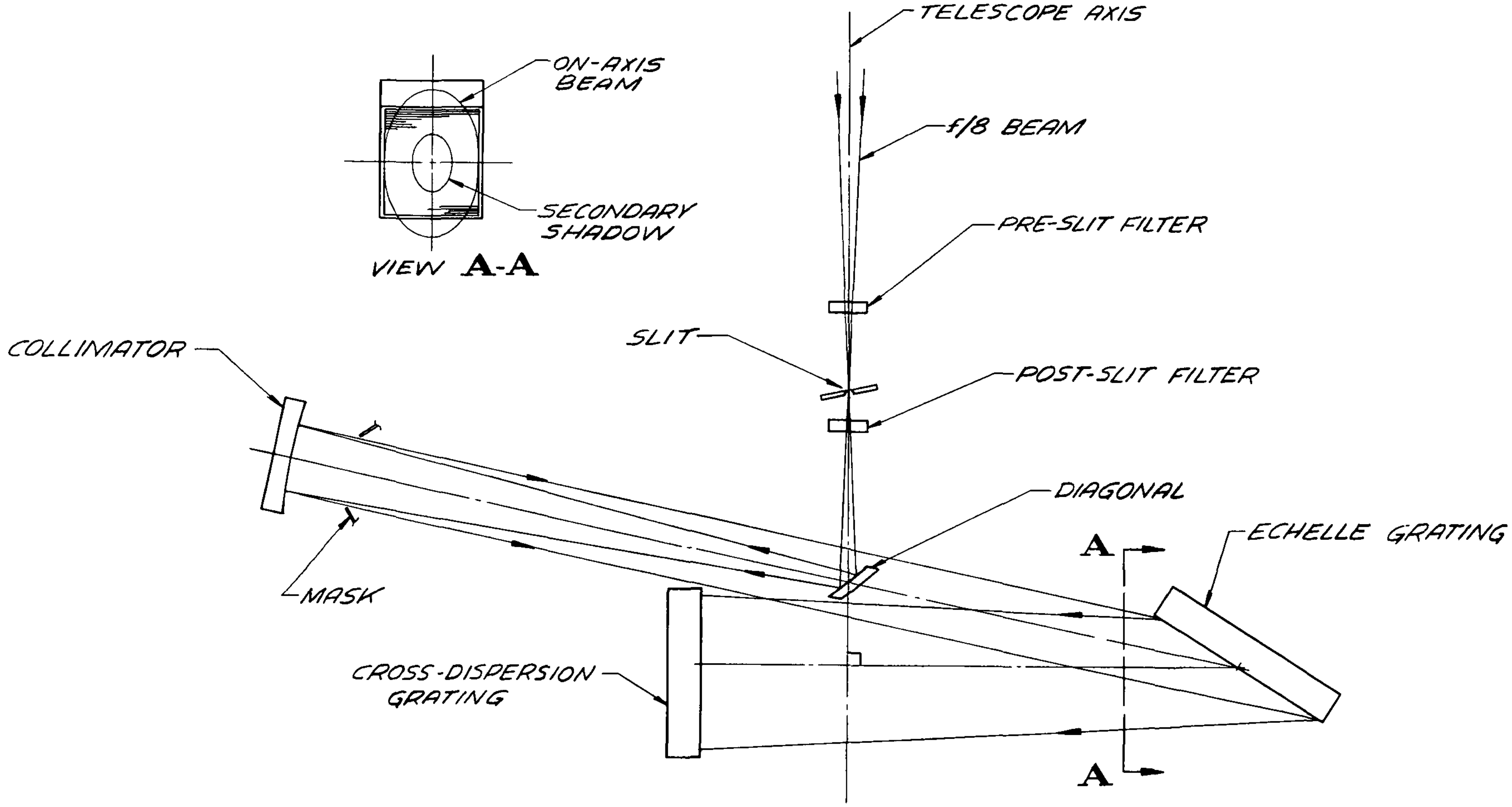
The modular design permits mounting of two cameras plus detectors at any given time. The cross-disperser is easily flipped 180° to permit properly blazed radiation into both camera ports.

As all of the optics are of imaging quality, there is excellent resolution both along the slit and perpendicular to the slit. Laboratory tests of the optics showed resolution to be smaller than ten microns. The resolution at the telescope proves to be limited by detector resolution, slit width and seeing width. However, under long exposures (several hours) at extreme zenith angles, flexure can become noticable.

As the echelle spectrograph has seeing limited optics, a long slit and multiple slit options were incorporated. In Figure 2 a long slit spectrum of NGC2392 is presented. The seeing width is about 0"6, resolving power is about 4 x 10^4 and maximal velocity dispersion is 200 km/sec. Spectral coverage from 4800 to 6700Å is shown.

An example of multislit spectroscopy is illustrated in Figure 3. The Orion Nebula is sampled close of θ2 Ori. Each slit is about 2'3 long and with 26" separation. A high velocity structure near θ2 Ori is noticable, being 70 km/sec in blueshift.

The longslit and multislit modes have been successfully applied to nebular and extragalactic problems. T. R. Gull and R. A. R. Parker have multislit spectra of supernova remnants, including



SIDE ELEVATION OF 4 METER ECHELLE SPECTROGRAPH OPTICS

Figure 1a.

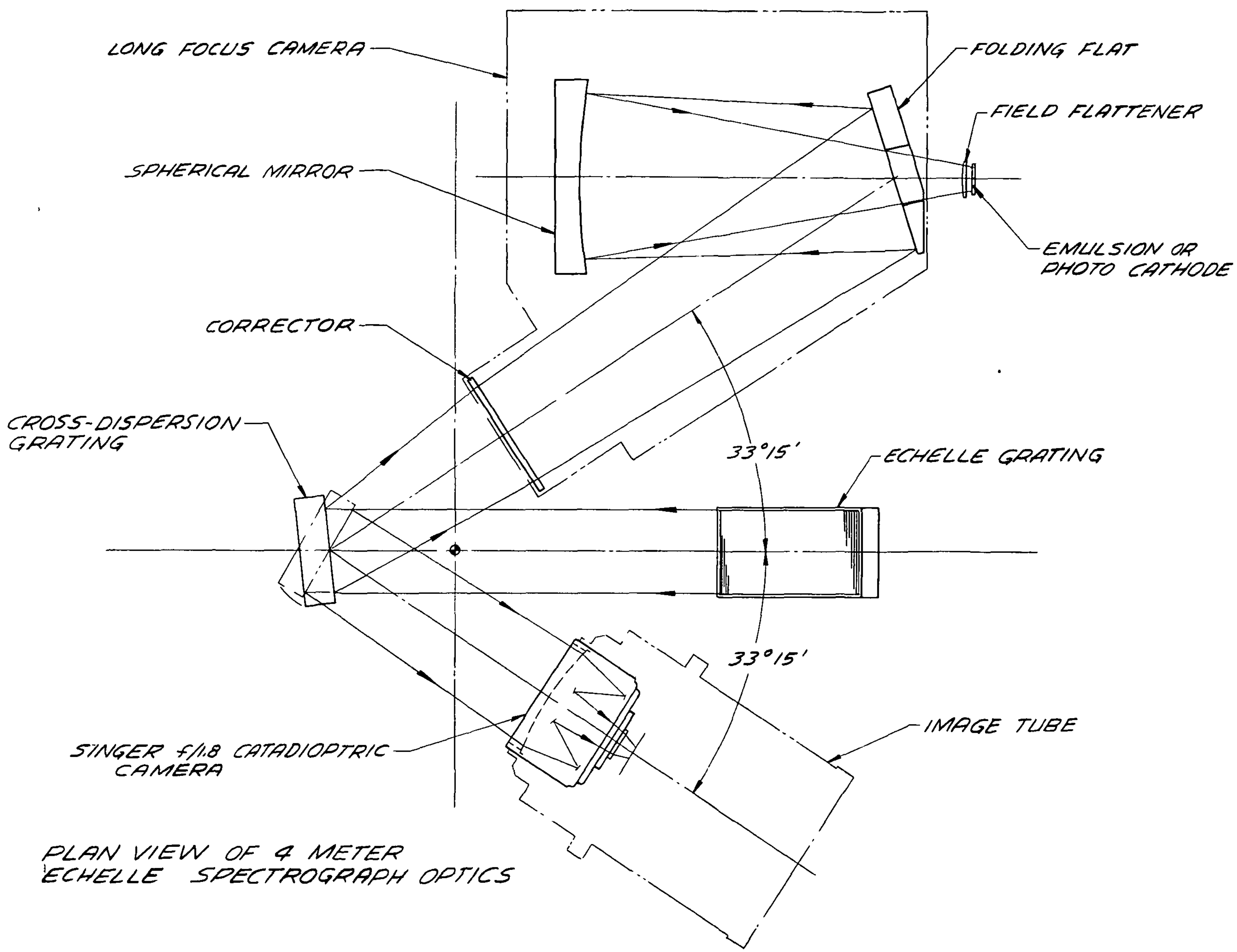

LONG FOCUS CAMERA
FOLDING FLAT
FIELD FLATTENER
SPHERICAL MIRROR
EMULSION OR
PHOTO CATHODE
CORRECTOR
CROSS-DISPERSION
GRATING
33°15'
ECHELLE GRATING
33°15'
IMAGE TUBE
SINGER f/1.8 CATADIOPTRIC
CAMERA
PLAN VIEW OF 4 METER
ECHELLE SPECTROGRAPH OPTICS

Figure 1b.

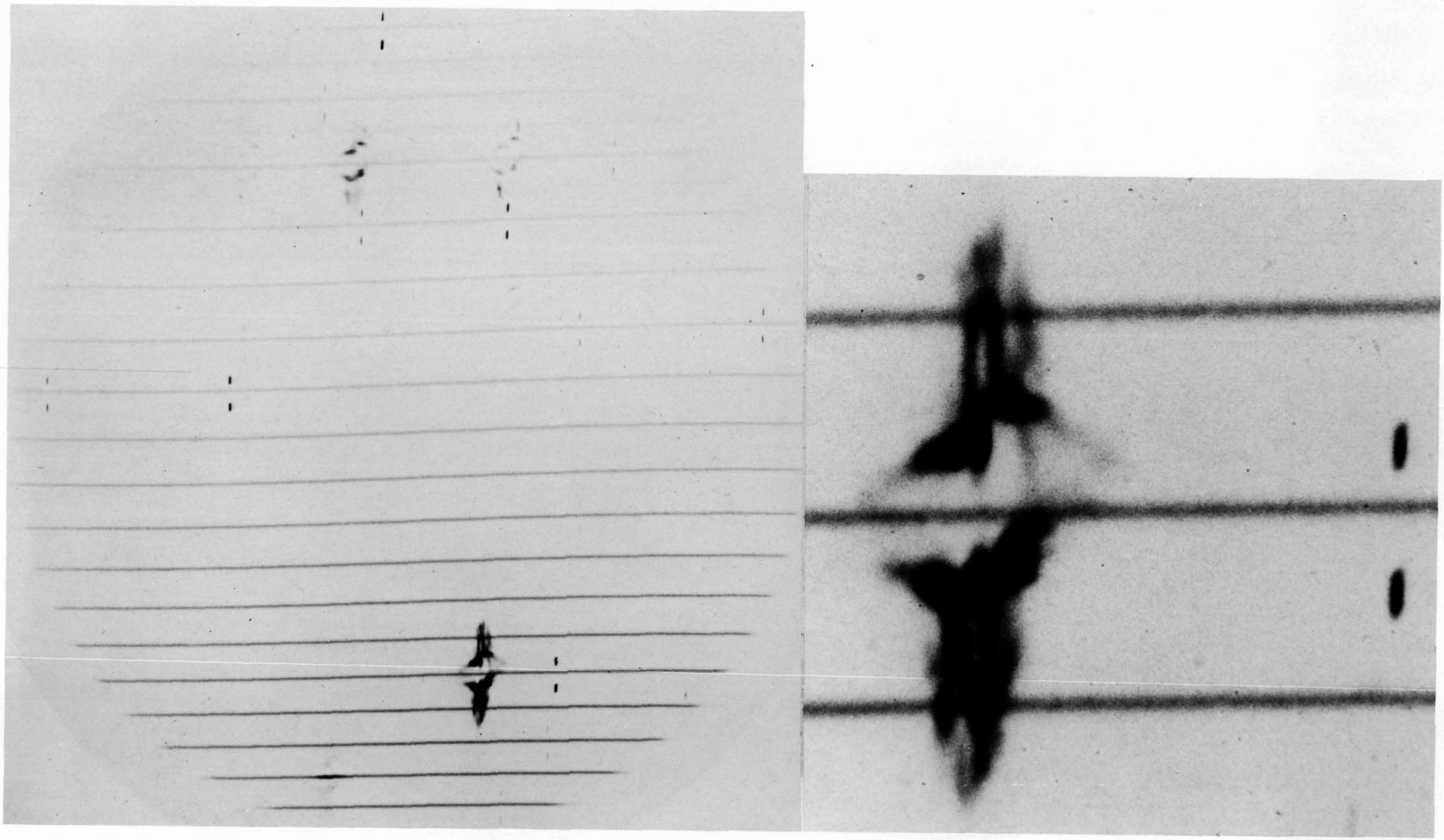


Figure 2. Echellogram of planetary nebula NGC2392. Original plate scale ~ 2.6Å/mm at 5000Å with seeing less than an arcsecond. The right portion is an enlargement of the 5007Å [OIII] line with velocity dispersion approaching 200 km/s.

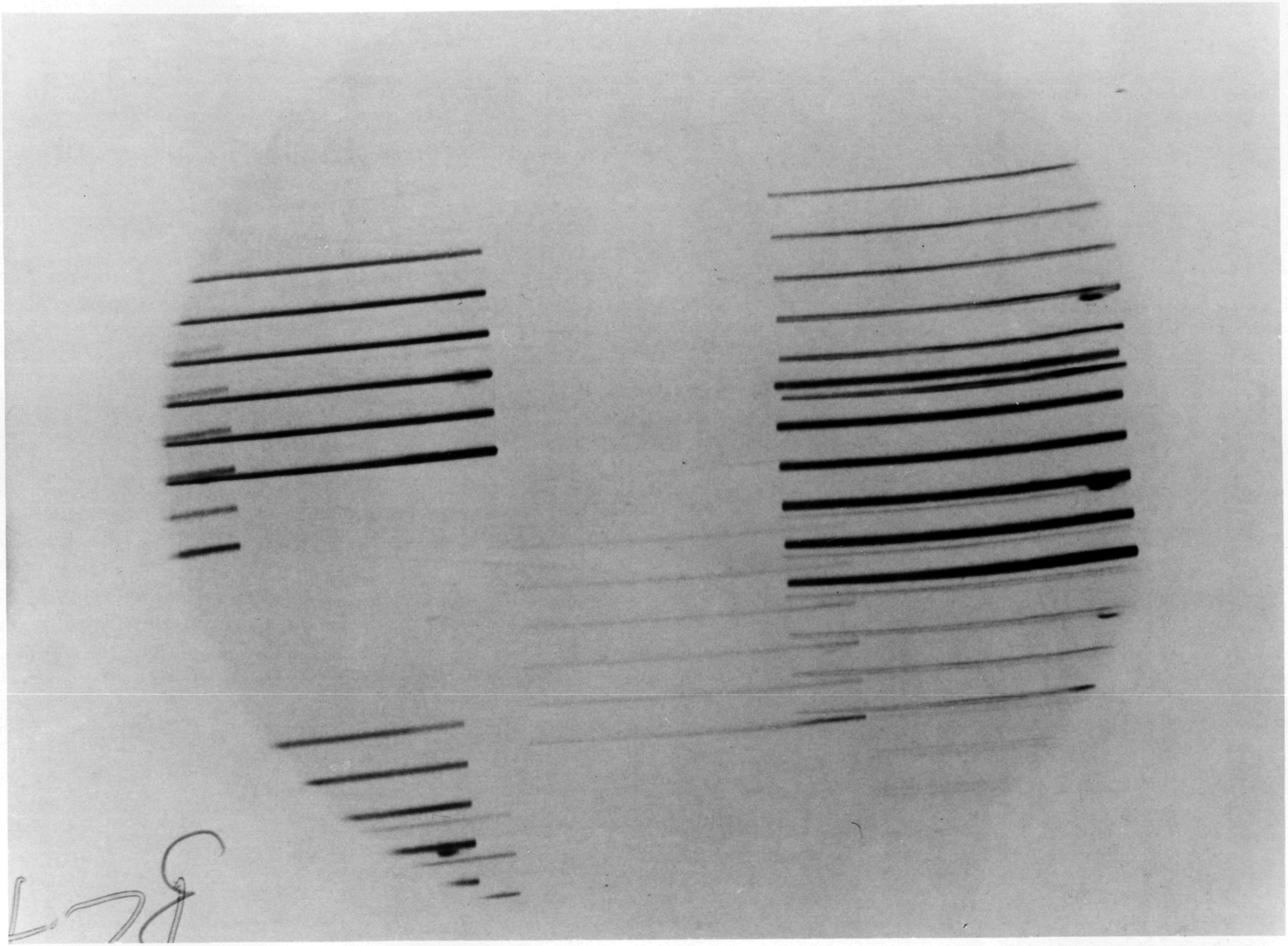


Figure 3. Multiple slit spectroscopy of the Orion Nebula done with the 4-meter echelle spectrograph. Each of six slits are 150 arcseconds long and 30 arcseconds separation. The line splitting in the [NII] (lower right) is less than 20 kilometers per second.

Cygnus Loop. This data is now in the final reduction stage and line widths are measurable leading to temperature estimates of blast waves. Long slit spectroscopy has been applied to galactic rotation studies by Vera Rubin. The 10"/mm plate scale along with 2.6 to 12.6Å/mm dispersion is most helpful.

Application to Comets

Several possible studies should be considered. For example, 10^4 resolving power, full spectral coverage from 4300 to 7000Å could be recorded of a 1" x 12" portion of the cometary head. A few cometary spectra of this nature already exist. Multiple slit studies of single emission lines such as [OI] 6300Å are indeed possible (if [OI] is significantly brighter than the night sky line). Band head studies with a long slit would be possible if a proper interference filter were used to isolate the single echelle order instead of the usual blocking glass filters. This technique has been done by Chris Anderson in time variable studies of stellar profiles.

Exposure times should be a few hours, or less, if image intensifers are used. Actual predicted exposure times are not given here as detector technology is changing rapidly. Reference exposures are best obtained from the astronomer in charge of the echelle spectrograph at KPNO or CTIO.

Final Remarks

The echelle spectrograph has great promise for cometary studies. Studies of non-periodic comets should be considered, and specific studies of Halley's Comet should now be planned.