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NARROW PASSBAND IMAGERY OF COMETS

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Abstract

During an emission-line survey of the Milky Way, Comet West was accidently imaged through four different narrow passbands with a wide-field, image-intensified camera. Three passbands recorded very similar head plus tail structure. The fourth passband shows an additional large, diffuse component around the head. It was serendipitous that such was recorded as the filters, being selected for studies of emission nebulae, are not particularly suited for studies of comets. However the imagery, plus subsequent studies, encourages us to suggest that much can be learned about the structure of comets using narrow passband imagery simultaneously with long slit spectroscopy.

Introduction

Imaging through narrow passband filters is certainly not a new concept in astronomy. Monochromatic photographs in astronomy of bright planetary nebulae and bright H II regions were recorded nearly thirty years ago. Moreover wide-field imaging and image-intensified photography are used often. However, we have recently combined all three concepts into one instrument that has been used to produce an emission line survey of the galactic plane. This nearly uniform sample is being used to study a variety of problems concerning the structure of the interstellar medium. Just as this Wide Field Camera (WFC) has proven to be very useful in the studies of very faint galactic emission nebulae, it also has the potential of providing new information on the large-scale structure of comets.

In this paper we describe the instrument and its capabilities. The WFC and/or its filters can be used with other instruments. We have tried simultaneous spectroscopy and direct imagery and find the combination to be a powerful diagnostic. We are able to use the large interference filters with large format image intensifiers on longer focal length telescopes. With a set of filters optimally selected for cometary studies, much new and exciting information should be obtainable on dusty structures, plus neutral and ionic distributions.

The Instrument

Narrow passband imagery is normally done at the Cassegrain focus of telescopes, as moderately narrow passbands will not be significantly detuned in slow f-ratio optical beams (T. R. Gull, Optical and Infrared Telescopes for the 1990's, p. 373). Moreover most optically-flat interference filters are limited to five centimeters in diameter due to manufacturing difficulties and the associated costs. Until recently, the observer was limited to small field of view ($< 15'$), to low flux rates ($\ll 1$ photon/sec/resolution element), and with insufficient telescope time, to small areas of the sky.

While such small fields are reasonable for small, bright, well-defined objects (such as most planetary nebulae), many galactic nebulae are very large (degrees in extent) and their boundaries may not be well defined. A wide field-of-view, narrow passband, fast-focal-ratio telescope is needed to image the ionization structure of such nebulae. Moreover, as most currently available information of such nebulae came from radio surveys, arcminute angular resolution was considered to be very adequate for survey work. Narrow passband photography suddenly became possible when it was realized that a very small aperture, fast focal ratio telescope would be provided for sub-arcminute angular resolution even when matched with image-intensifier resolution. The major limitations then became finding the largest optically flat interference filters commercially available and finding the largest aperture, fastest focal ratio camera lens that fitted behind the filters. (The radiation passed by the filter is indeed well collimated and the incident angle is small.) The final solution proved to be 125 mm aperture interference filters matched to a Nikon 300 mm f.l., f/2.8 lens. The intensifier was the 2-stage, magnetically focussed (CIT Direct) system as supplied by Kitt Peak National Observatory or by Cerro Tololo Inter-American Observatory. Photographic plates with IIIaJ emulsion were hypersensitized to maximum sensitivity by baking in forming gas (2 percent H_2, 98 percent N_2). The imaging properties are listed in Table I.

Table I.
Properties of the Wide Field Camera

7.3 degrees field of view
15 to 30 arcseconds angular resolution
Gain over photographic plates ~ 50 to 100 at a transfer lens setting of f/2.0
Exposure times: $\Delta\lambda$ = 28Å at 5010Å to D_{sky} ~ 0.5 to 0.8 in 20 minutes

The Wide Field Camera has been used at Kitt Peak or Cerro Tololo since 1976 and over 3000 plates have been recorded by it. Much of the plate material is published as an Atlas (An Emission Line Survey of the Milky Way, NASA SP 434, R. A. R. Parker, T. R. Gull and R. P. Kirshner, 1979). With the camera, three supernova remnants have been identified optically, many interstellar bubbles and bowshocks have been noted, and many superbubble structures have been traced throughout the galactic plane. Moreover, the ionization structure of these nebulae has been studied by passbands isolating continuum, emission lines of neutrals, and emission lines of singly-, doubly-, and triply-ionized elements. The currently available filters are summarized in Table II.

Table II.
Interference Filters Used by the Wide Field Camera

λ_c	$\Delta\lambda$	Bandpass of Interest
4224	60Å	Continuum
4770	25Å	Continuum
4860	28Å	Hβ 4816Å
5010	28Å	[O III] 5007Å
6300	10Å	[O I] 6300Å
6570	75Å	Hα 6563Å and [N III] 6548Å and 6584Å
6736	50Å	[S II] 6717Å and 6731Å

An additional lens (135 mm focal length, F/2.0) has also been used with the filters and intensifier. Nearly twenty degrees field of view is accomplished with arc minute resolution. Over 1500 plates have been recorded with the Extra Large Field (ELF) camera in an emission line survey of the northern two-thirds of the celestial sphere.

The Comet West Imagery

During the initial phase of the emission line survey, Comet West happened to be in one selected field. Indeed the cometary structure was not identified as such until it was noticed that the nebulosity appeared to be moving on successive nights. The plates of interest are reproduced in Figure 1. Information on the plate exposures is listed in Table III.

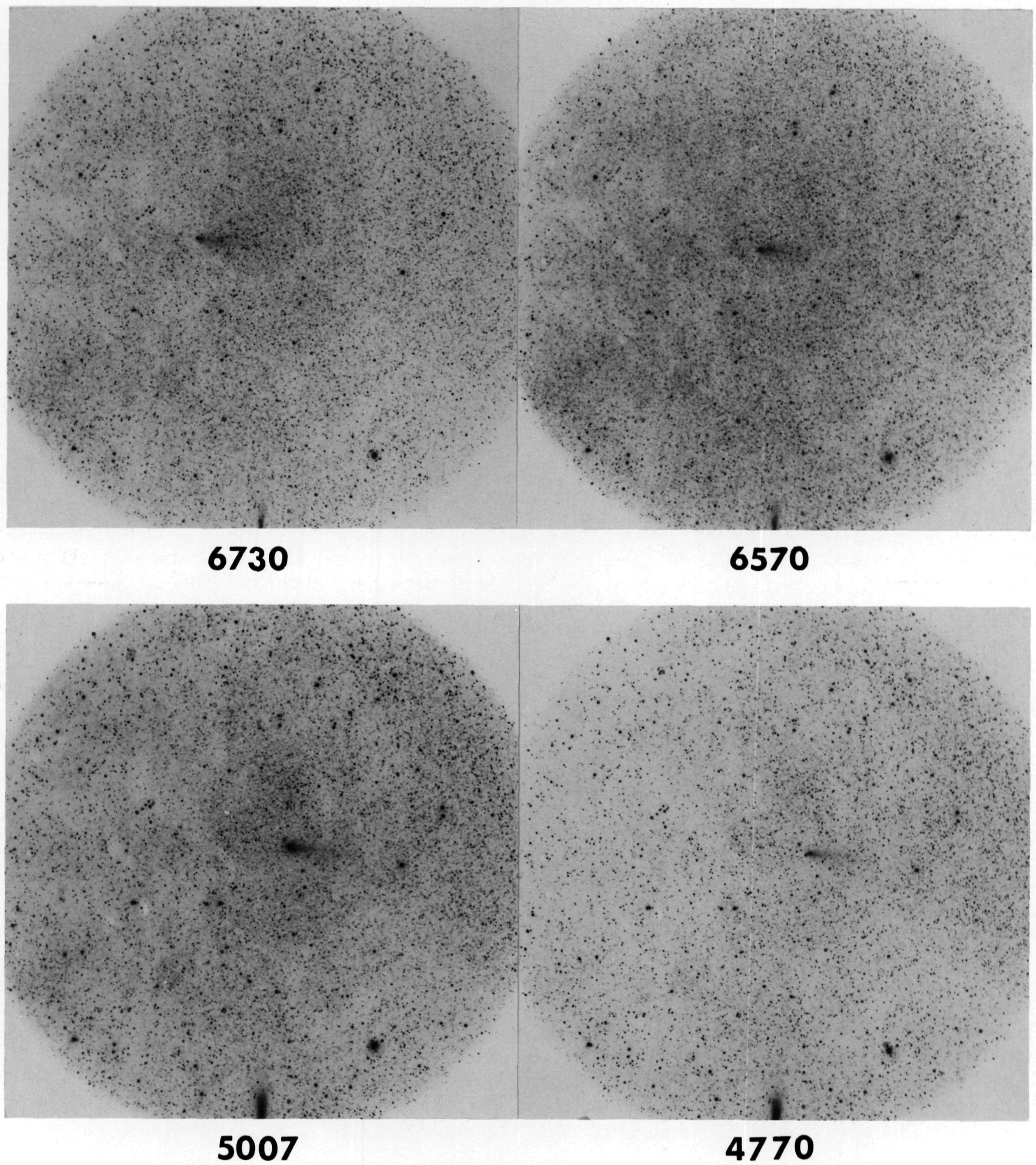

Figure 1. Narrow passband imagery of Comet West. Field of view is about 7 degrees with plate scale ~ 270"/mm.

Table III.
Data Pertaining to Plates of Comet West

	Date	Time	Filter	Exposure
1.	May 28, 1976	07:46 U.T.	6730Å	12m
2.	May 29, 1976	08:28 U.T.	6570Å	10m
3.	May 30, 1976	07:19 U.T.	5007Å	15m
4.	May 30, 1976	10:13 U.T.	4770Å	15m

The head and tail structure are very similar in the 6730, 6570 and 4770Å plates. However, the 5007Å plate shows a very diffuse structure around the head.

The source of the diffuse structure is uncertain. Time variability cannot be entirely ruled out. However, the structure is several hundred thousands kilometers in size. It is doubtful that a disturbance could be dissipated in 10^4 seconds, the approximate interval between exposures through the 5000Å the 4770Å filters. Moreover there is no evidence of solar wind disturbances that would correlate with such a disturbance (M. Niedner, private communication).

There are no bright cometary emission features known within the 5010 ($\Delta\lambda$ = 28Å) passband. Comet West did have exceptionally bright, extended CO^+ (S. Larson, private communication), and there are two CO^+ lines at 5040Å and 5068Å. However, the filter is a 3-period stack; its rejection of both lines should be at least 100 times the peak transmission. Little CO^+ emission should leak through the side of the filter profile. Comet West may have extended emission thought to be molecular in nature at or about 5000Å (S. Wyckoff, private communication). Such might be the origin of the extended feature.

We point out that the dimension of this structure is $\sim 2 \times 10^5$ km. In discussions with Ip (1980, Ap. J. 238, 388) and Combi and Delsemme (1980, Ap. J. 238, 38), this is approximately the dimension of the bow shock separation from the nucleus ($\sim 10^5$ to 10^6 km). The detected emission indeed may be originating from the volume bounded by the shock interface between the solar wind and evaporated material from the comet nucleus.

That shock phenomena might be revealed by narrow passband imagery is not too surprising. The many interstellar bubbles discovered in this survey (T. R. Gull and S. Sophia, 1979, Ap. J. 230, 782; F. C. Bruhweiler, T. R. Gull, K. G. Henize and R. Cannon, 1981, submitted to Ap. J.; J. C. Heckathorn and T. R. Gull, 1980, BAAS 12, 458; and J. C. Heckathorn, T. R. Gull and F. C. Bruhweiler, in preparation) are noted primarily by increased [O III] emission at the shock interface, i.e., emission lines that are sensitive to density changes.

More recent studies were attempted on Comet Bradfield this year. No strong, extended nebulosity was noted, but simultaneous spectroscopy by Steve Larson suggested few ions were present. We did, however, develop a valuable addition to the WFC capabilities. The WFC system is strapped upon a 40 cm telescope at KPNO or at CTIO much as a finder telescope is ordinarily mounted with the optical axes co-aligned. The spectrograph used by S. Larson (see his accompanying paper for description) was mounted at the Cassegrain focus of the No. 3 40 cm telescope permitting simultaneous, long-slit spectrophotometry and direct imagery.

We now have the capability of monitoring structural changes along with spectral changes. With proper choices of cometary passbands, we hope to monitor ions, neutrals and dust by this approach. We request advice and suggestions from the community on what filters should be added to those listed in Table II.

The currently available filters are now being used on larger telescopes with large-format image intensifiers. Two single-stage fiber-optics-output 144 mm diameter image intensifiers are being used at facilities located on the mountain at Kitt Peak. One intensifier, owned by Steward Observatory, is being used by Eric Craine with a 24-inch F/5 bent Cassegrain telescope. He and colleagues have nearly completed a near-infrared survey of the northern hemisphere. The same intensifier is occasionally used at the F/9 Cassegrain focus of the 90-inch telescope. An identical 144 mm intensifier, on loan from KPNO, is being used with the McGraw-Hill telescope (1.3 m, F/7.5) and is also mountable on the KPNO 2.1 meter telescope. Both systems have been successfully used with the 125 mm clear aperture interference filters to study supernova remnants and interstellar bubbles.

Final Remarks

In summary, interference filter photography of comets is possible and, coupled with extended slit spectroscopy, offers a very useful source of information on studies of various cometary constituents. We should include such in any major program to study Comet Halley.