SEARCHING FOR NOVAE: CCD IMAGERY OR PHOTOGRAPHY?

William Liller
Instituto Isaac Newton
Casilla 8-9, Correo 9
Santiago, Chile

Presented at the 87th Spring Meeting of the AAVSO, June 20, 1998

Abstract

Has the convenience and high quantum efficiency of CCDs made photography obsolete in the search for galactic novae? The performance of two Kodak area detectors, the KAF-1600 CCD and hypersensitized Technical Pan film, are considered and evaluated.

1. Introduction

MACHO, EROS, OGLE, DUO: these are some of the powerful new sky surveys that are discovering variable stars by the hundreds and on occasion, microlensing events towards rich star regions like the Magellanic Clouds. However, according to Paczynski (1998), the total area covered by all microlensing surveys is less than 0.1 percent of the entire sky. TASS, The Amateur Sky Survey, has successfully tested 135mm f/2.8 lenses equipped within expensive CCDs in fixed mountings. Each unit sweeps out a 3 degree-wide strip of sky during the night and can reach down to magnitude 14.5. (See Gombert and Droege 1998.) So far TASS has been used to monitor variable stars, but soon it will start concentrating on the search for near-Earth asteroids and comets and later, novae and supernovae.

Searching for galactic novae presents an interesting and special problem: the great majority occur within 10 or 12 degrees of the galactic equator over a range of galactic longitude of about ±120 degrees centered on the galactic center in Sagittarius. Thus, unlike near-Earth asteroids and faint comets which can be found anywhere in the sky, most galactic novae confine their brief moments of glory to a broad strip of sky centered on the Milky Way. Having been engaged in a nova-search program for the past 15 years, I frequently ask myself: Given a limited budget and modest facilities, what is the best search procedure?

In this paper I will review the properties of two popular area detectors available at not-unreasonable prices: the Kodak KAF-1600 CCD, incorporated in the ST-8 camera developed and manufactured by the Santa Barbara Instrument Group (SBIG); and Kodak's black-and-white Technical Pan (TP) film. The reasons I have chosen these two detectors will, I believe, become abundantly clear later in this article. Finally, I will draw conclusions about which is better for monitoring the Milky Way regions.

2. Basic detector properties

The KAF-1600 CCD, the heart of the ST-8, has a 9.2 x 13.8-mm sensitive surface with 9 x 9 micron pixels. When coupled with a high-performance PC, this detector can deliver and store stunning images even with short focal length lenses (see Figure 1 and Table 1). It takes no more than a minute or so, depending on the computer speed, to download and save an entire frame which usually delivers 10 to 15 million bytes of data to a hard disk for storage. Considerable post-exposure manipulation of images is made possible by several different and inventive computer programs. The very much larger KAF-1000 CCD is not especially useful for short-focal length systems because of its

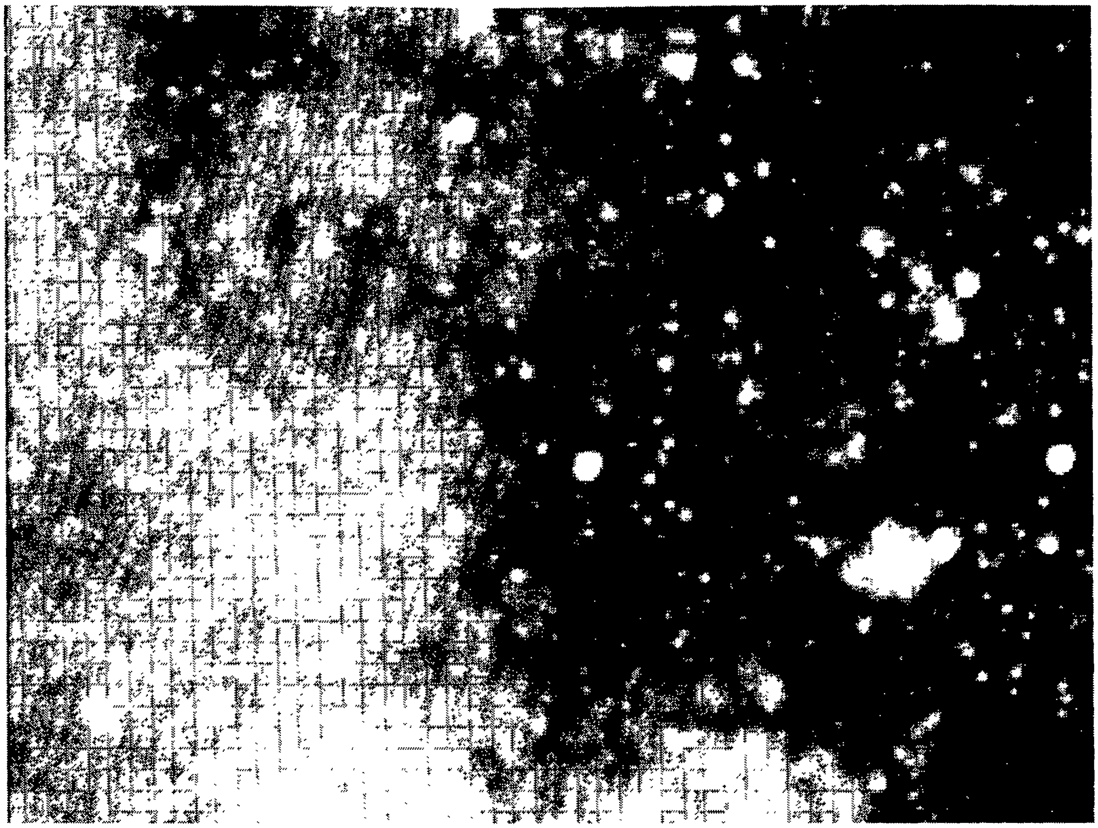

Figure 1. A region in Sagittarius as imaged by a 28mm f/5.6 lens and an SBIG ST-5 CCD camera with 10-micron square pixels. The bright star near the center is 11 Sgr, and the bright irregular blob to the right and slightly below is the Lagoon Nebula, M8. The faintest stars visible on the right are around magnitude 9.5. The frame measures 6.4 x 4.8 degrees; north is up, east to the left.

much larger pixel size: 24 x 24 microns. (See diCicco 1997 for a good discussion on this point.)

Kodak's Technical Pan (TP) film employs an extremely fine-grain black-and-white emulsion and comes in a variety of sizes. When used straight out of the package, it is slow—ISO 25—but it is easily hypersensitized to ISO speeds of 200 or more when used with a high-contrast developer such as Kodak D-19. The resolving power is listed as 320 lines/mm (Schaub 1992), which I will assume corresponds to a pixel size of about 3 microns. Table 2 summarizes the characteristics of photographs made with 35mm film and short focal length lenses.

3. Comparing performance

To the eye, the most obvious difference between these two detectors is the area of the sensitive surface: 8.64 cm^2 for the 35mm film and 1.27 cm^2 for the CCD, or a ratio of 6.80 in favor of the film. The higher resolution of the film with a resolution element area one-ninth that of the CCD is also an important consideration in many search or survey programs (see below).

CCDs are far more sensitive. The detective quantum efficiency of a typical CCD averages 25 or 30 percent over the full range of wavelength response, while hypersensitized TP film is at best a few tenths of a percent. Therefore, in principle, my standard photographic exposure of 2.5 minutes could be reduced to 1.5 seconds with a CCD.

Table 1. Characteristics of the Kodak KAF-1600 CCD when used with short focal length lenses.

Focal length (mm)	*Pixel size (arcsec)*	*Field of view (degrees)*	*Area of Field (sq. deg.)*
28	66	19 x 28	532
50	37	10.5 x 15.8	167
85	22	6.2 x 9.3	57.7
135	14	3.9 x 5.9	22.9
300	6.2	1.8 x 2.6	4.6

However, this assumes that we are talking about stars in an uncrowded field with little or no foreground or background nebulosity. Figure 1 shows a region in Sagittarius as imaged with a CCD with 10-micron pixels—SBIG's ST-5 (TC-255)—and a 28mm lens. Stars down to a bit fainter than ninth magnitude can be discerned on the right side of the frame, but in some places on the left, because of the crowding, it is impossible to see any individual stars.

When it comes to processing exposures, CCD observers have it easier. A series of "flat fields" should be made every night or two, and dark frames are needed for each exposure time used. After that, the computer can process each exposure in a minute or two in a well-lit room during day or night. To hypersensitize TP film, photographers must first bake the emulsion in a hydrogen gas mixture for a number of hours. (It can then be stored for months in a standard food freezer.) Following exposure, the film is taken to the darkroom where it is loaded into a film tank, developed, fixed, washed, dried, and mounted in the usual way, a process that consumes perhaps a couple of hours. However, darkness and the human presence are not needed for all that time, and usually a number of exposures, typically (for me) ten or twelve, are developed together.

4. Searching

On a given night, a nova search will typically cover a swath of sky measuring some 20 or 25 degrees wide and perhaps 150 degrees long, or about 3400 sq. deg. Standard 35mm film used with an 85mm focal length lens can carry out the task with ten well-aimed exposures. To do the same with a CCD would require around 64 exposures, albeit of far much shorter duration. Even with a camera that has an automatic pointing facility, the time to move the camera from point to point in the sky would add up; assuming 5 seconds for pointing anew, 5.25 minutes would be consumed by a CCD system just in moving from field to field. However, because fields are farther separated, photographic re-pointing might use up a minute following each exposure.

Table 2. Characteristics of Kodak Technical Pan 35mm film when used with short focal length lenses.

Focal length (mm)	*Grain size (arcsec)*	*Field of view (degrees)*	*Area of Field (sq. deg.)*
28	22	49 x 74	3,618
50	12	28 x 41	1,135
85	7.3	16 x 24	393
135	4.6	10.2 x 15.3	156
300	2.0	4.6 x 6.9	31.5

Table 3. Summary of times needed to image 150 degrees of the Milky Way using an 85-mm f/1.4 lens.

Detector	KAF-1600	Tech Pan
Exposure time	1.5 sec	150 sec
Download/Film advance	60 sec	2 sec
To point anew	5 sec	60 sec
Time/exposure	66.5 sec	212.0 sec
No. of exposures	64	10
Grand totals	70.8 min	34.3 min

Adding up times, an observer equipped with a KAF-1600 CCD, an 85mm f/1.4 lens, and, one would hope, an automatic pointing system can expect to take, on a given search night, 64 1.5-second exposures, each downloaded in, say, 60 seconds, with 5 more seconds needed to re-aim. 64 x (1.5 + 60 + 5) – 5 seconds = 70.8 minutes. Using TP film in a similar setup, the old-fashioned but intrepid nova hunter would need ten 150-second exposures, no downloading time, 2 seconds to advance the film, and an estimated 60 seconds to re-aim. 10 x (150 + 2 + 60) – 60 seconds = 34.3 minutes. The ratio of these two times: 2.06. This arithmetic is summarized in Table 3.

Could a shorter focal length camera be used effectively with the CCD? I seriously doubt it. In my own experience I have found that 85mm is about right for a photographic search to 10th magnitude. (I thank AAVSO member Phil Dombrowski for noting the availability of this lens with a focal ratio of 1.4.) However, because of the coarser "grain" of the CCD, longer, not shorter, focal lengths are indicated; the resulting smaller fields would then require many more exposures. My experiments with the focal lengths listed in Tables 1 and 2 show that a 135mm lens is about right, and the developers of the TASS program have reached the same conclusion. With this lens, some 154 CCD images would have to be taken to cover the assumed area. The estimated time to complete a night's run: 170.6 minutes, or 5.0 times as long as doing it photographically.

Finally, each new frame, CCD or photographic, must be compared in some manner with an archival image taken under similar conditions. Many different search techniques have been employed, but most boil down to either image subtraction or a "blinking" method of some kind. With a computer, image subtraction seems to me to be the quickest and easiest method. The same can be done photographically, but it involves returning to the darkroom to make a positive print on which the archival negative is placed and aligned (see Hoffleit 1997). Blinking is standard procedure for photography, and many ingenious blinking devices have been invented during the last 100 years or so. (The author prefers, for various reasons, a stereoscopic comparison of photographs. For further discussion, see Liller 1992.)

As for the actual searching for novae, most people would obviously prefer sitting in front of a computer monitor to squinting through a microscope, but one's stamina and the time involved are other matters to consider. Reviewing over 150 CCD frames seems to me to be a daunting task even if image substraction is perfect or nearly so. At something like one minute to prepare and review each frame, some 2.5 hours would be needed for a complete CCD search. As for photography, in my experience, to search carefully a single frame takes about 15 minutes. Ten frames: 2.5 hours. In other words there would seem to be no clear time advantage of one method over the other. In either case splitting the task between two nights would be my recommendation.

5. Additional considerations

With a large budget, there are at least two straightforward ways to overcome the relatively small size of the KAF-1600: Buy larger, small-pixel CCDs, and mount several of them together in a mosaic. A much more powerful computer to handle the increased data processing and storage would be essential and clearly, the added expense would be considerable. Further comment is not considered appropriate in this short communication.

The photographic exposure times assumed above are what I have found convenient to search to tenth magnitude. In reality, stellar images one or two magnitudes fainter can be detected on film, but in practice, the search goes much more quickly and efficiently if one is looking for stars well above the detection limit.

6. Summary

As of this writing, the price of the CCD system described above costs something less than $10,000 including the computer. As superior and useful as it is for many purposes, it still is unable to compete with the described photographic system. Considering that for a CCD search a 135mm lens would be best, as opposed to an 85mm lens for a photographic search, the latter wins out by a factor of about five. During the last fifteen years, I have taken approximately 5,000 photographs of the Southern Milky Way in my nova search program. With an estimated total cost of the film and chemicals of $1,000 and with 25 nova discoveries or co-discoveries, that comes to about $40 per nova. My intention is to continue, at least for awhile longer, with this antiquated but efficient—and economical—way of finding galactic novae.

References

di Cicco, D. 1997, *Sky & Telescope*, **93**, 38.
Gombert, G., and Droege, T. 1998, *Sky & Telescope*, **95**, 42.
Hoffleit, D. 1997, *J. Amer. Assoc. Var. Star Obs.*, **25**, 135.
Liller, W. 1992, *The Cambridge Guide to Astronomical Discovery*, Cambridge Univ. Press, ch. 7.
Paczynski, B. 1998, *Sky & Telescope*, **95**, 46.
Schaub, G. 1992, *The Amphoto Book of Film*, Watson-Guptill Publications, New York.