THE BAA OBSERVERS' WORKSHOPS

Cambridge	Winchester	York
2003 February 15	2003 April 26	2003 September 6

In the next few issues of the* Journal *we will print some of the speakers' own transcripts of their talks at these very successful Workshops, so that members who were unable to attend can share their tips and expertise. We begin the series with Martin Mobberley, who delighted the Cambridge meeting with his unique combination of humour and technical accomplishment.

Imaging comets

by Martin Mobberley

Workshop No. 1:
The Institute of Astronomy, Cambridge
2003 February 15

Introduction

Imaging comets, especially from the UK, used to be nothing less than a battle against the insensitivity of photographic film and the inevitable arrival of cloud on those crucial moon-free nights when a bright comet was close to perihelion. In recent years the situation has changed considerably. On the positive side modern CCDs are twenty times more light-sensitive than the best photographic emulsions, and image processing is far easier than messing around for hours with revolting chemicals in a darkroom. On the negative side the modern lives of working people leave little room for learning new skills and the stress of the modern working day leaves little enthusiasm for a night-time battle with clouds and unfriendly equipment.

This author firmly believes that well-thought-out observatories and patient perseverance are the key to achieving success where imaging comets is concerned. Basically, anyone who has learned to use a computer can learn to take good comet images; it is all a question of surmounting the various hurdles in a systematic fashion.

Two inspirational observers

The BAA has had a long history of comet observing and comet photography. I have always thought that it is good to have a few 'hero figures' to look up to. In my early days in the BAA, like everyone else, I was inspired by Patrick Moore (as well as Henry Hatfield and Horace Dall) but as my interests slowly changed from the Moon and planets to comets, so I looked to other achievers. Who could fail to be inspired by George Alcock? A discoverer of five comets and five novae and the man who memorised some thirty thousand stars in patterns. Even today, if I see a partly cloudy sky and debate whether to go out or stay in, I often think 'George would have gone out'. It is often the only thing that forces me over that psychological barrier to abandon the warm cosy indoors for the freezing cold observatory. Harold Ridley is another iconic figure for me. A past President, Goodacre Medallist and lifelong meteor and comet observer; I often think when checking the sky 'If Harold had my equipment he would definitely have gone out'.

Others may not need heroes to inspire them, but I do!

What makes a good 'photogenic' comet?

The ultimate zero magnitude photogenic comets like Hale–Bopp and Hyakutake are very rare; such spectacles cannot be expected to appear every year. However, more modest comets like Ikeya–Zhang and the recent 2002 V1 (NEAT) which reach, say, third to fifth magnitude are much more common, often an annual event in fact. Such comets do not require huge telescopes and long exposures to record them. As a very rough set of 'rules of thumb' any comet with an absolute magnitude of better than 7, a perihelion distance of less than 0.8 AU and passing within 1 AU of Earth should make a nice target as it closes in to perihelion. One could expect, at some point, a degree-long tail to develop on such an object even though, as David Levy once said 'Comets are like cats: they have tails and they do what they want!' Even a modest telephoto lens on a barn-door mount can be used to image such a comet using CCD equipment.

Software and Web information for finding comets

Whether you intend using photographic film or a CCD camera you will almost certainly want some software to calculate where the comet is going to be in the sky. Ephemerides can also be downloaded from various Web sites: the BAA Comet Section web page at http://www.ast.cam.ac.uk/~jds is the best place to start on the Web. Here you will find ephemerides for current comets as well as news on which comets are brightest at the present time.

Useful freeware can also be downloaded from the Comet Section site. The most useful package to be found here is Schwittek's CMTWIN32.EXE (Figure 1) which reads a text file in which you have typed the comet's orbital elements and produces a whole host of data on the screen. Basically it tells you where the comet will be in RA/Dec and altitude/azimuth at midnight or for various degrees of twilight. It will also plot the comet's altitude and azimuth for the coming weeks and months. This is essential data for planning at what point a comet will disappear behind your local trees and houses.

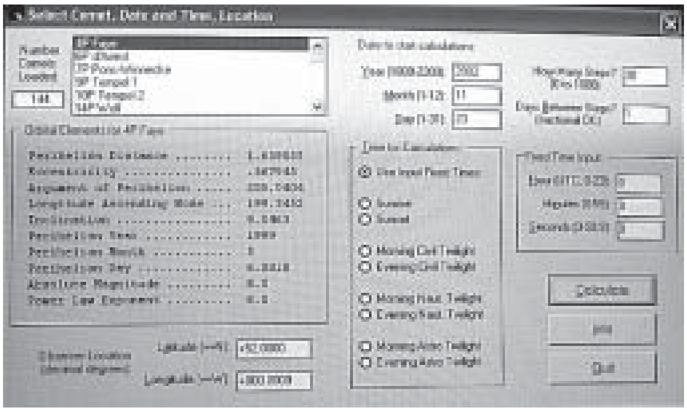

Figure 1. Schwittek's CMTWIN32.EXE freeware software.

The comet imager will often want to know how fast, and in what direction, a comet is moving. This information is not provided by CMTWIN32 but is provided on the Comet Section web page ephemerides. Take care! The units used by different organisations can vary! My personal preference is for arcseconds per hour, but there are plenty of other units in use. I frequently use the excellent software *Guide 8.0* published by Project Pluto (http://www.projectpluto.com). This contains a comprehensive list of comet elements discovered up to the time of issue and new elements can easily be added. Once the image of the comet is displayed against the background sky, right-clicking on it yields a host of data, including the comet's motion against the stars.

It is often highly useful to know what comets the leading experts are imaging and how the comets are developing, especially if you have been clouded out for weeks. Seeing others' images enables you to plan your own strategy. For example, if your standard set up has a 10 arcminute field and you see that the comet of interest already has a 6 arcminute head and a two degree tail you will want to use a telephoto lens with your CCD, not a telescope! Unfortunately, the standard comet magnitude law of the form:

Mag = Absolute mag + 5log (Earth distance) + 10log (Sun distance)

does not say much about tail length, which is often totally unpredictable even if the geometry of Sun, Earth and comet are taken into account. Ideally the Sun–Comet–Earth geometry should form a right angle for the optimum tail length, as shown in Figure 2. What the standard comet mag law does tell you is that a typical comet brightens with the inverse square of the comet's Earth distance and the inverse fourth power of the comet's Solar distance.

The Astronomer magazine Web page, maintained by Nick James, has a comprehensive Comet section which is usually updated every few days. If a comet is within amateur imaging range there will invariably be images of it on this web site, which is at: http://www.theastronomer.org/comets.html.

Disappointingly there are very few UK contributors to this page. Apart from myself the major UK contributors are Peter Birtwhistle, Nick James, Denis Buczynski and David Strange. What are the thousands of LX200s and CCD cameras in the UK used for?

The definitive source of up to date comet ephemerides is the CBAT/MPC Web site at: http://cfa-www.harvard.edu/iau/Ephemerides/Comets/index.html. New comet ephemerides are published on this site as soon as they are calculated. With brand new comets this is vital as the first orbit is often only approximate and the second orbit (typically issued within a week of the comet's discovery) is usually far more accurate.

Altitude vs twilight

Inevitably all really good comets run into problems because of low altitude and twilight. This is hardly surprising, as good comets get close to the Sun and the Sun needs to be below the horizon before it gets dark! The astronomical definition of the start of darkness (astronomical twilight) is when the Sun is 18° below the horizon. However, for really bright comets acceptable images can be obtained even in nautical twilight (Sun is 12° below the horizon). A typical scenario is shown in Figure 3. Thus, the comet imager usually ends up imaging bright comets in the dusk or dawn sky.

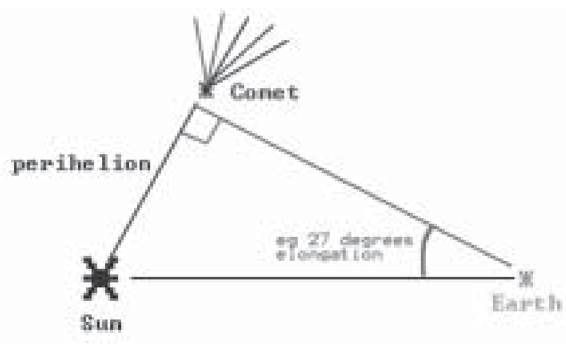

Figure 2. The optimum tail length viewing situation for a comet at a specific distance from the Sun.

Sometimes, when a comet passes north of the Sun (for the northern hemisphere observer) the imager will have the advantage of the comet being available in both dawn and dusk skies. Schwittek's CMTWIN32. EXE will show you with a few key-strokes if this is the case. There are pros and cons of dawn and dusk imaging. Getting up in the chilly pre-dawn hours is a major psychological problem for all but the hardiest individuals, especially in winter when a snug bed is far more tempting then a freezing observatory. In addition, this observer has found that there is a much greater tendency for mist and thin cloud to materialise at dawn, which is very demoralising when the equipment has just been set up. The advantage of dawn observing is that the observer has plenty of time in a dark sky to focus and check the equipment as the comet rises out of the murk. In addition, temperature changes and subsequent focus shifts are rarer at dawn than at dusk.

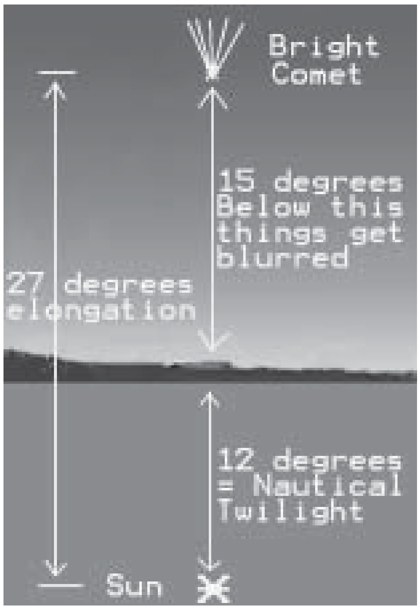

Figure 3. In nautical twilight, a comet elongated only (for example) 27° from the Sun, may still be 15° above the horizon and a possible target.

A lot simply depends on the observer's own horizon problems. In an ideal world all comet observers would live on top of hills with no trees or buildings above the telescope. In practice this is never possible, but some serious planning before siting a telescope can save years of frustration. The comet observer will tend to want the eastern and western horizons to be obstruction free, but in the UK winter this will translate to south-eastern/south-western and in the UK summer to north-eastern and north-western. Remember, bright comets will generally peak throughout the year where the sun rises or sets. In 1991 the author purchased a bungalow specifically with comet imaging in mind. The bungalow was at the top of a south-facing slope with excellent east,

Figure 4. Although the house roof cannot easily be removed, the tree can, enabling (in this case) Comet Kudo–Fujikawa to be followed for many more days.

west and south views. The house obstructed the north horizon, but, being a bungalow, only to an altitude of 17°. A close-to-optimum situation.

It is vital to know instinctively where your obstructions lie in an azimuth/altitude sense. Years ago I prepared a long sellotaped-together strip map of my whole horizon and marked the altitude and azimuth of every obstruction on it. I now know exactly whether I can get a comet image or not, without having to go out to the telescope and see what happens. Needless to say, a chain saw and powerful clippers can be a vital accessory for the comet observer surrounded by bushes and small trees (Figures 4 and 5).

Of course, even if your horizon is flat, the comet will, inevitably, sink into the murk and once objects drop below about 15° altitude the star images become bloated and swollen, unless you are using a very short focal length system.

Observatory 'ease-of-use'

I have become more and more convinced over recent years that the most productive observers are simply those with the most user-friendly observatories. Numerous planetary observers use Schmidt–Cassegrains on balconies, patios or roof-tops; crucially, within feet of where they sleep. The psychological issue is critical here and should not be underestimated. If all you have to do to get an image is roll out of bed, open a French window and take a tarpaulin/roll a small cover off the telescope, then you will do it. Conversely, if you have to walk a hundred feet down the garden and trundle a half-ton shed off a giant Newtonian and battle with an infinity of cables and trip-wires, you will not do it. The telescope and observatory should be ready to use in minutes and permanently mounted in the observer's back garden. There is, of course, a conflict between having a telescope close to the house and the house being an obstruction, but, nevertheless, my message is that an easy-to-use telescope/observatory may be used every clear night whereas a hard-to-use telescope/observatory may be used for the first few months of its existence and then abandoned. It is a sad fact, but true. As I have said before, up and down the UK there are thousands of LX200s, but who uses them?

My personal preference is for a small run-off shed that is only just big enough to house the telescope (Figure 6). My LX200 shed is a pleasure to use and has dimensions of 1.2 × 1.2 (width × length) × 2 metres (height). The run-off sheds for my larger telescopes are twice this width and length and a hundred times harder to roll back. There comes a point, when a run-off shed weighs more than two hundred kilograms or so, where it will be a real battle to run back, especially if the rails are not straight and the shed not rigid. Similarly, if a shed is more than 2 metres long it will, with floor missing and door open, flex wildly when pushed back. An

Figure 6. The author's compact run-off shed and 30cm LX200 Schmidt–Cassegrain telescope.

associated problem is that a shed with a width greater than 1.5 metres cannot easily be pushed back with a hand on each side of the door-frame, so pushing on one side only is the result, with flexing and jamming being the experience.

I find domes nice and cosy structures and a pleasant barrier against biting winter winds, but frustrating to the observer. I may want to look at several comets a night and not move the dome slit each time. I also want to see the night sky above me and any fireball that passes overhead. But, most important, I want to see any approaching cloud so I can change my strategy if I only have a few minutes to spare. My small run-off shed is a joy to use and any future sheds will copy this pattern. The shed construction was fully described in the Springer–Verlag book *More Small Astronomical Observatories*, published in 2002 (ISBN 1-85233-572-6).

A modern Schmidt–Cassegrain in a tiny run-off shed is a very user-friendly combination, but I would advise never using the fastest slew speeds on the larger LX200s if you want to prolong the period between breakdowns. 14,000 rpm and tiny

Figure 5. The author's father, advancing the cause of comet observing.

Figure 7. An observatory that is, perhaps, the ultimate in simplicity. A box covers the instrument when not in use. Karen Holland demonstrating her 25cm LX200.

motors and gears do not go together well. (After five motor failures, I speak from experience.) There are even simpler alternatives to a run-off shed, see Figure 7.

Comet motion

Years ago, before the CCD era, long photographic exposures were the norm. Typically, exposures of twenty or thirty minutes were undertaken. Apart from the sheer torture of guiding a telescope drive for this length of time, there was another issue – comets move against the background stars! Typically, nearby comets move at between 100 and 400 arcseconds per hour, but if they are passing very close to the Earth they can move MUCH faster. Their motion is, of course, a vector sum of the Earth's motion and the comet's motion. It doesn't take a genius to see that, with capturing detail of a few arcseconds being the aim of the telescopic comet imager, if you expose for longer than it takes for the comet to drift a few arcseconds, you will lose detail.

With thirty minute photographic exposures there was only one solution. You had a separate guide telescope and an illuminated reticle eyepiece/micrometer eyepiece and you tried to glide a nearby bright star along a calibrated track so the telescope followed the comet. This involved a huge amount of preparation beforehand and a period of utter misery during the actual exposure. Thankfully these days are now in the past for the CCD observer, though for eight years, from 1985 to 1993 I was an offset-guiding comet photographer (Figure 8). My last offset-guided photograph was of Comet Schaumasse on 1993 Feb 19, though I did guide on Hale–Bopp's nucleus in 1997. I am glad those days are over!

My strategy with CCDs is to try to take one single image of about 80 seconds duration, when I'm using the 30cm LX200 at a scale of about 2 arcseconds per pixel. I adopt this strategy because I vastly prefer to see the field in which the comet lies, complete with stars and maybe galaxies, as opposed to mere straight lines. Perfectly straight star trails used to be a 'badge of honour' amongst comet photographers, but with modern software there is no skill in this any more. My LX200 will track, unguided, for about 80 seconds when the Periodic Error Correction is well trained. Also, exposures of, say, 30 seconds, tend to be a bit noisy, especially from light-polluted sites. My ST9XE is capable of reaching mag 19 in 80 seconds (with perfect focus and transparency) so why would I want a longer exposure, for a bright comet, from my country site? If the comet is going to drift more than 3 or 4 arcseconds in this time (i.e. a faster drift than about 150 arcseconds per hour) I will usually reduce the exposure and stack the images, or I may not. A lot simply depends on experimentation for the particular comet, and on other factors. For example, if the comet is rapidly heading for a house roof, it is imperative to just get an exposure quickly, of any duration, and one exposure is often quicker than taking and saving many shorter ones.

Figure 8. A pleasing picture of Comet Swift–Tuttle taken on 1992 November 13 by the author, with his 36cm f/5 Newtonian and hypered 2415. Twentyfour minutes of sheer teeth-gritting, offset-guiding hell. Those days are now gone!

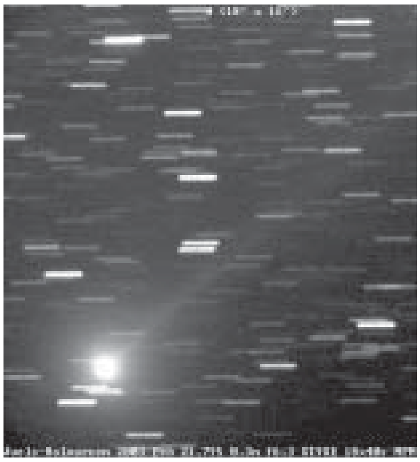

Figure 9. The modern way of following a comet. Eighteen 40-second images of comet Juels–Holvorcem, taken on 2003 February 18. Stacked in Richard Berry's AIP software. During each short exposure the comet drifted 3.3 arcseconds. 0.3m LX200 at f/6.3 with SBIG ST9XE CCD. Image by the author.

However, if the comet is moving faster than 400 arcseconds per hour I will tend to take multiple short exposures of 20 or 30 seconds duration and stack them, centred on the comet's centre of brightness. Numerous software packages (e.g. Berry's AIP, Maxim DL) will do this stacking trick and there are freeware packages which are worth hunting down too. There really are no hard and fast rules with regard to comet stacking and exposure duration; my advice would be 'see what works for you'. In general, stars on UK deep sky images are three or four arcseconds in diameter, so allowing the comet to drift three or four arcseconds between exposures will usually let you stack the images so the stars appear as continuous trails, rather than a line of dots (Figure 9).

Observers from town sites will want to stack more images than country observers, simply because their images will be noisy. Stacking tends to reduce noise proportional to the square root of the number of images stacked. Thus, a stack of sixteen images will only look about a quarter as noisy as a single image. When noise is reduced, a tail often emerges and stacked images can look nice and smooth.

Of course, advanced imagers may well want to stack multi-minutes worth of exposures up to get a decent image of a very faint comet. As long as you can see the comet, to reference the images to, simple stacking of images is possible. The difficulty comes when you can't see any image of the comet at all, but imaging such faint comets isn't really the point of this beginner's tutorial.

Before leaving the subject of comet image stacking it is worth mentioning that, occasionally, dramatic changes in a comet's tail can occur when a comet is close to the Sun (i.e. 1 AU or less) and crossing a magnetic boundary in the inner solar system. On such occasions a tail may change direction, or material move away from the comet's head, at a dramatic rate. If multiple short exposures (say, of 60 seconds duration) are taken and animated into a movie, the result can be quite dramatic. The tricky part here is actually taking enough images over many nights to capture such an event, and to take a sequence lasting, say, thirty minutes or more, between twilight and the comet disappearing below the local horizon. Features can, occasionally, move down the tail much faster than the comet's motion against the stars, so short exposures are advisable for this kind of work.

Creating a mosaic

Comets come in all shapes and sizes, and the comet imager will often have a dilemma working out what focal length instrument is best for any one object. For the superb comet Hyakutake in March 1996, I found an 85mm lens and 35mm format film to be ideal; this gave a 23° × 16° field. For Hale–Bopp at its best, a field of about 10° was close to optimum, while for the 2002 comet Ikeya–Zhang, a field of two or three degrees would have been best. All these comets could easily be captured on film with a modest telescope, because they were bright enough that the relative insensitivity of film was not a hindrance. Indeed, they were all comets that showed distinctive colours, so colour film was at an advantage over a monochrome CCD. The only requirement with film is that you need to guide the exposure for maybe five or ten minutes. With a really bright comet you can guide on the nucleus, but for a comet like Ikeya–Zhang, guiding, or (horror of horrors) offset guiding on a nearby star is advised.

I suspect that most potential comet imagers will use amateur telescopes in the 15 to 30cm aperture range and, when coupled to a CCD camera, will have fields of 10 or 20 arcminutes to play with. But what do you do when your CCD field is, say, 20 arcminutes, but the comet's tail is over a degree long? My personal preference here is to produce a mosaic along the comet's tail. Positioning the telescope to take all the images may sound like a nightmare but, with a GOTO telescope with RA and Dec readout, this is not the case. The first priority is to totally familiarise yourself with which direction the N, S, E and W buttons on your hand controller move the stars on your monitor, and by how much. It is essential to know this precisely as, in the heat of the imaging moment, it is easy to get confused with directions. Also, bear in mind that, for example, at 60° declination, a minute of RA will correspond to 7.5 minutes of arc, not the 15 minutes of arc you get at 0° Dec.

The next step is to be prepared for which direction the comet's tail is pointing, either by looking at your own image from the previous night, or other images on the Web. You can then do a little sketch before going out to estimate the amount you need to move the scope between frames to follow the tail, but with plenty of overlap. If you get the planning right, taking a mosaic of frames only requires moving the scope in RA and Dec by a set amount for each frame. For my LX200, slowly creeping the scope to offset by the right amount is controllable to an accuracy of plus or minus one arcminute, which is enough accuracy if you allow a few arcminutes of overlap.

The next step, once indoors, is to equalise the background sky contrast and brightness of each image where it interfaces with the next image. There may be ways of doing this automatically, but I prefer to judge the degree of 'grayness' by eye. Unfortunately, if the comet is in twilight, which changes in brightness every minute, it will be very difficult to achieve a satisfactory mosaic, as even if the sky 'grayness' of adjacent images is matched, the comet's tail brightness will alter as it crosses the image boundary. Mosaicing is best achieved in a dark sky.

Once each image's 'grayness' has been adjusted they need to be aligned. My preference here is to put the comet's head image (image 1) into Paint Shop Pro and then enlarge the canvas size ready for the subsequent images. I prefer a black canvas background, but that is my choice. The next step is to call up image 2 and then, using Paint Shop Pro's 'clone brush' (and the preferred brush tip size), right-click on a star on the boundary of both pictures in image 2 and then left-click on the same star in image 1, and commence painting a clone of image 2 into image 1. This may not make much sense if you don't use Paint Shop Pro, but many people do and other packages have a clone brush feature too. The process is continued for the image 2/image 3 boundary, image 3/image 4 boundary and so on (Figure 10).

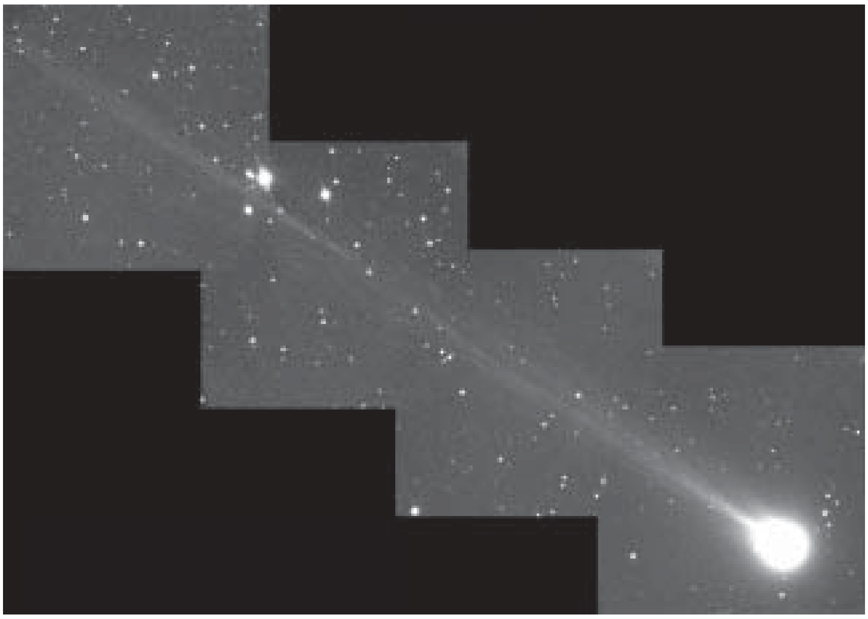

Figure 10. Mosaicing comet images. Four 80-second images of Comet 2002 V1 (NEAT) taken by the author, with a 0.3m f/6.3 LX200 on 2003 Jan 25. Each exposure was 80 seconds long and the images were taken every 120 seconds, i.e. telescope re-positioning took 40 seconds. The comet's nucleus would have moved 4.3 arcseconds between exposures. Images combined in *Paintshop Pro 5*.

Coping with the British weather

On average I find that on about one night in three, from East Anglia, I can do some useful work between gaps in cloud banks, gaps between cloud, or in a totally clear sky. Anyone familiar with living in the UK knows that the trend is for a lot of active weather fronts coming from the west, often with few cloud breaks; but when clear nights do arrive, they frequently come in a row. It must be terrible being the sort of UK based observer who specialises in observing time-critical phenomena! We all know that one-off solar eclipses, lunar eclipses, occultations and the peak nights of meteor showers are usually clouded out. Fortunately most bright comets are at their peak of activity for several weeks and so the chance of being clouded out for all of that time is low (but not impossible!)

With CCDs the half, gibbous, or even Full Moon is no longer an easy excuse for staying indoors, and the same applies to broken cloud. While 30 minute offset guided exposures on film were thwarted by any amount of cloud, 60 second exposures can be clinched between gaps in cloud. Indeed, for the past few years this has been my main strategy, and enables me to

Figure 11. A flat field with the 0.3m LX200 at f/6.3. Note the doughnuts and uneven illumination. 1/100th of a second with SBIG ST9XE in civil twilight.

average an image on as many as one night in three, when a good comet is about. Hanging around a telescope staring at broken cloud is about as exciting as watching paint dry, but it is worth it if a break of a few minutes enables you to secure a spectacular picture.

Satellite pictures are a great way of checking what the weather is doing, but some care is needed. The visual picture is the best indicator but, for obvious reasons, at night, it is as useful as an inflatable dartboard. The infrared satellite picture is available all day and night via the Internet or, for example, Sky News, but some care is needed. The infrared view is a record of the temperature of cloud tops or of the ground. It does not show fog or thin cloud and frozen ground looks like cloud, so caution is necessary. The best type of weather for the comet imager occurs following the passage of a cold front from north to south across the country. The cold northern air is always dry and crystal clear and, by day, a superb pure blue sky at the zenith will fade into a lighter shade of blue at the horizon, but without a trace of the milky haze that ruins transparency.

In such a sky, good CCD images of naked eye comets can be taken even at Full Moon, provided the comet and the Moon are on opposite horizons. Remember, many comets peak in nautical twilight when the sky is as bright as a moonlit sky anyway. Hazy skies are the worst for the comet imager. They often coincide with a high pressure system that has been around for too long, or humid air coming up from the South. I prefer total cloud cover to a hazy sky; at least with total cloud cover you know it is not worth bothering. With a hazy sky I usually make the effort, but then wonder why I did.

Flat fields

For a perfect comet picture flat-fielding your CCD is essential. Apart from in the precision field of photometry, there is no other area where flat-fielding is more important, than in comet work. This is simply because bright comets are often imaged in twilight and the twilight illumination will enhance every horrible dust-speck and source of vignetting in your system. Specks of dust on the CCD window are a real pain for the CCD imager, but a lot depends on your f-ratio and how far away the dust mote is. At f/3 and f/4 the fat light cone tends to suffer more from vignetting caused by the telescope drawtube cutting the light cone or by a secondary mirror that is too small.

At the typical Schmidt–Cassegrain f-ratio of 10, dust specks will be obvious, appearing as small doughnut shapes on the image (Figure 11). My favourite way of creating a flat field is simply shooting an image at the shortest exposure possible (e.g. 1/100th of a second) in civil twilight when the Sun is about 6° below the horizon. This is best done with the telescope drive off and with an exposure that fills, say, half the dynamic range of the CCD. Obviously if the sky is too bright the CCD will saturate. If you wait too long and the sky is too dark, bright stars may be recorded on the field. This can happen more often than you might think, even in strong twilight.

Every modern CCD camera's proprietary software will have a Flat-Field command. You simply load your comet image, select the 'apply flat field' command, click on the flat-field image and your vignetted and doughnut-riddled image suddenly becomes evenly illuminated and doughnut-free. It is important to maintain the same camera orientation when using a flat-field from a previous night.

Some observers will stress that you need to obtain flat-fields every night because the telescope is never quite the same from night to night. However, there comes a point when perfectionism will simply kill new observers' enthusiasm. Comet imaging, like all astronomy, is something best learned a bit at a time. I have found that dust specks on the glass window above the CCD can stay in exactly the same position for months, despite others advising differently.

In passing, it goes without saying that, for a good image, the telescope should be critically focused. With Schmidt–Cassegrains, this can be a tiresome procedure as mirrors can 'flop' as the telescope changes position and tubes can expand or contract with temperature. I have also found that dew heater bands, while essential for long observing periods in the UK climate, can easily alter the telescope focus as they heat up. If you are going to use a dew heater it should be switched on half an hour *before* you try focusing the telescope, so everything reaches equilibrium early on.

Conclusions

Like anything in astronomy, or in life itself, practice makes perfect. Over the past twenty years I have taken far more grotty comet pictures than good ones, but these have all been part of the learning process. Ultimately, the results one gets depend on a number of factors, not least distractions from tedious work and family commitments which tend to coincide with the clearest nights.

But possibly the most important factor is simply a stubborn but patient single-mindedness to surmount all the obstacles placed in the comet imager's way in the form of physical tiredness, other commitments, trees, light pollution, cloud, cold, dew, equipment failures and financial restrictions. With modern equipment, imaging comets is far less of a battle than it used to be and, hopefully, this article might inspire others to take up the challenge.

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