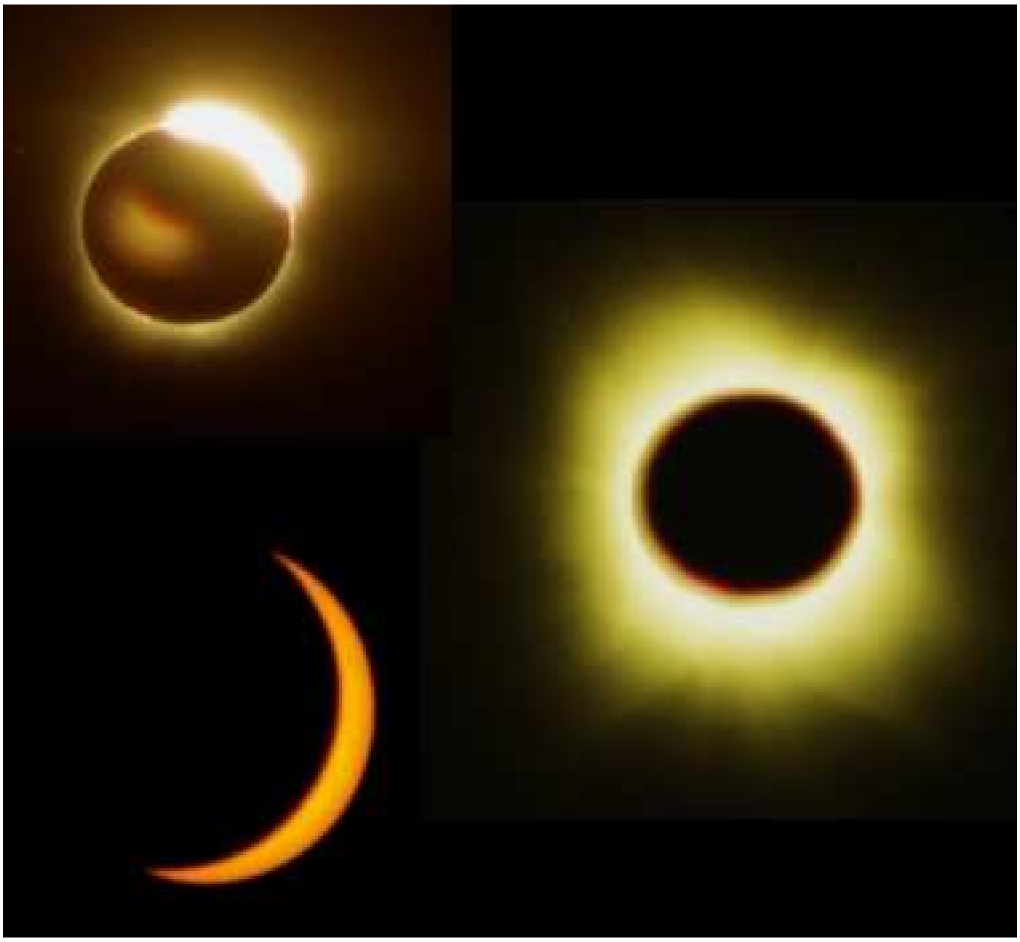
Totality 2002



Menaka Lashitha Bandara
lashi@lashitha.org

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Introduction

On 2nd December 2002, I set out with a group towards the town of Lyndhurst, South Australia in an attempt to capture the solar eclipse on film. The objectives were ambitious. I wanted good photographs of the corona, the *Diamond Ring* effect, and *Bailey's Beads*. All this was to happen in the 26.5 seconds of totality. These objectives were ambitious but I only failed on the last. All other effects were successfully captured - a total of 5 photographs during totality. This was my first total solar eclipse.

This document is a report that attempts to outline the equipment and procedure I employed to photograph the solar eclipse. I've attempted to elaborate on methodology, technical intricacies, and safety concerns when pointing optics at the sun.

I hope that this document will be used as a reference point for those interested in eclipse photography. In such hope, equipment and preparation and procedure are discussed in detail. For those who know little or nothing about Solar eclipses, I have written first section in an attempt to spark enthusiasm for this subject.

Solar Eclipses

1.1 What is a solar eclipse

A total solar eclipse takes place when the Earth's moon positions itself between the Sun and the Earth precisely and casts a shadow on the Earth. Those who are standing within this shadow experience *totality*, since all of the Sun appears to be covered *exactly* by the moon. Outside of this shadow, an observer may see a *partial* eclipse, in which a part of the Sun is covered by the moon.

When the moon firstly appears to contact the Sun, it is known as *first contact*. The precise time at which totality begins is known as *second contact*, and when it ends, *third contact*. The time that the partial phase concludes is known as *fourth contact*.

Totality is a breathtaking experience. It allows us to see features of the Sun that are completely invisible otherwise. The most notable of these by the naked eye is the presence of the corona. This feature is dominated by the photosphere under normal circumstances. Eclipse photography makes this experience more profound, by revealing intricate details of the Sun that the eye cannot see.

1.2 The path of totality

It is important to remember that the moon is in motion around the Earth, and the Earth is spinning on it's axis. Thus, when the moon finally eclipses the Sun, it does so only briefly, and casts a shadow on the Earth. But simultaneously, the Earth is also spinning on its axis. This causes the shadow to move across on the Earth's surface. The line that is drawn by this shadow is called the path of totality. One needs to be within the width of this line in order to see a total eclipse. Just outside it, one can only see a partial eclipse.

The longest duration of totality one can observe it at the centre of this line (lengthwise). Those closer to the edge of the line can only experience a few seconds of totality.

The town of Lyndhurst in South Australia was located fairly close to the edge of this line. The duration of totality was 26.5 seconds. The thickness of the path of totality was approximately 30km.

1.3 Photography

The most useful feature of an SLR camera for an eclipse photographer is the fact that the exposure time (shutter speed) can be varied. There are various phenomena that can be captured on film during an eclipse. The easiest is probably the corona. Increasing exposures can capture a larger and larger corona. Shorter exposure times can capture solar prominences, such as flares. Shorter exposure times are also needed for transitional effects such as the *Bailey's Beads* and the *Diamond Ring*. Many of these effects cannot even be seen by the naked eye during an eclipse. Our eyes do not allow us to vary exposure, nor does it allows us to fully appreciate the transitional effects, which may last as short as 1 second. For this reason, solar eclipse photography is extremely important, scientifically and aesthetically.

Choosing the right location - Lyndhurst

2.1 Factors for choosing Lyndhurst

Choosing an optimal location for solar eclipse photography is a difficult task. There are many factors that can affect the visibility of an eclipse.

For the December 2002 eclipse, Lyndhurst, South Australia was one choice, and Ceduna, South Australia, was another. Lyndhurst was chosen over Ceduna for a number of reasons.

Primarily it is important to choose a location that lies in the path of totality. As explained in §1.2, one needs to be located within the width of this line in order to experience totality. Both Lyndhurst and Ceduna was located in the path of totality.

Rainfall statistics for December was reviewed closely between Ceduna and Lyndhurst. This information was accessed from both NASA and the Bureau of Meteorology of Australia. Ceduna's rainfall statistics were higher than that of Lyndhurst, but only slightly. Low rainfall statistics means that the chance of cloud cover are low, but not nil. In fact, a location may have low rainfall, but still experience cloud cover often.

The next consideration was that Ceduna was located closer to the ocean, whereas Lyndhurst was typical desert terrain. This gave a distinct advantage to Lyndhurst, because a location closer to the ocean has a typically higher risk of cloud cover. This was a key deciding factor and day's events demonstrated the truth of this theory.

Furthermore, the Bureau of Meteorology hosted a page on the Internet for weather patters and maps of the path of totality. These pages were updated daily at 1600H EST (Eastern Standard Time). Lyndhurst and Ceduna were of particular focus and were monitored closely in detail. As the day of the eclipse arrived, Lyndhurst was predicted to have much better visibility than Ceduna. However, there was still one large uncertainty in the visibility of the eclipse, that could not be eliminated until minutes before the eclipse. The eclipse was to take place 5° above the horizon at Lyndhurst. At such an acute angle, not only could clouds cause a problem, but atmospheric conditions could introduce substantial refraction that maybe invisible to the eye, but may show on film.

One may also need to consider the duration of totality when choosing the location. Ceduna had an advantage of about 1 second over Lyndhurst. This advantage was negligible in the light of other considerations. There were many other places that lie in the path of totality which had an advantage of about about 2 seconds over Lyndhurst. However, these locations were remote and was seen as potentially fatal due to the burning sun of the desert.

2.2 Considerations for hassle-free photography

The eclipse was photographed approximately 5km north of the town of Lyndhurst. One reason was because this is closer to the the centre of the line of totality (widthwise). Secondly dust storms brought on by erosion and desert wind could potentially make the visibility of the eclipse poor and also hinder the process of photographing the eclipse.

This spot was chosen as prime from a list of spots investigated. It contained more shrub which effectively decreased dust particles being suspended. Furthermore, the soil was soft, which meant that the tripod could be "rooted" to the ground, to minimise movement during photography. Furthermore, just below the spot was a valley. This meant that it was easier to take photographs of the partially eclipsed sun setting, and furthermore, it decreased any possibility of a dust storm emerging from the non-shrubby terrain.

Photographing the eclipse

3.1 Apparatus

The following is a list of apparatus that was used in the photography of the eclipse. Each item's use is explained.

- **Mamiya SLR 500 Camera**
  This was the camera that was used to capture the images of the eclipse. It has variable exposures (set) between 2 seconds to $\frac{1}{500}$ seconds. It contained an appropriate threaded socket to mount it onto a tripod.
- **Remote Trigger**
  This piece of equipment is essential for photographing something delicate as an eclipse. It allows the photographer to release the trigger without being in contact with the camera. This ensures minimal movement of the camera.
- **200mm Lens**
  An ordinary 50mm is extremely ineffective at capturing even the faintest details of an eclipse. The recommended starting size is a 500 - 600mm lens. Although a 200mm lens was used, it was used in conjunction with a $3\times$ teleconverter (below).
- $3\times$ **teleconverter**
  A teleconverter simply increases the focal length by a given amount. The teleconverter used for capturing the eclipse increased image size by a factor of 3. It is important to note that a teleconverter reduces resolution and light intensity slightly, and therefore, a large teleconverter should not be used.
- **Home made filters**
  Filters are not important during totality. However, they are vital leading up to totality. Since the duration of the eclipse was only 26.5 seconds, it would be impossible to aim, wind and shoot the camera at the moment totality began. Rather, the filters were used for two purposes. Firstly, to track the motion of the sun across the sky, so that at the precise defining moment of totality, the filter could be removed and the sun would be in focus. Secondly, so that photographs of the partial phase could also be captured.
- **Telescopic Tripod**
  With the exposures and lens used for photographing the eclipse, the photographs would experience blur if a tripod is not used. A telescopic tripod was essential because it has one extra feature over a normal tripod. It contains a tracking mechanism. As explained before, during the partiality phase, the motion of the sun was tracked across the sky with the two easy knobs on the telescopic tripod.
- **Eclipse Eyewear**
  These are eye glasses that can be purchased for a few dollars to wear when glaring at the sun. These were essential to establish first contact.
- **Stopwatch**
  Time the eclipse from second contact in order to ensure that no one is looking through the viewfinder at third contact.

3.2 Method of photography

The following are the steps that were taken during the photography of the eclipse.

1. At the chosen location for shooting the eclipse three small holes were dug, as a frame for the legs of the tripod at full stretch. The legs of the tripod were placed into these holes. The tripod was more firmly rooted until it seemed stable.
2. The equipment was inspected for correct order. In particular, the filter was re-examined for scratches. It was also pointed at the sun without any lenses, to ensure that there was no light leaking into the filter.
3. The 200mm Lens was attached to the camera. The aperture was completely opened, and the focus set to maximum distance. Then the filter was placed on the lens, taking care not to alter any of the settings. Then, the camera was attached to the tripod, taking care to point it *away* from the sun.
4. 10 minutes before first contact was expected, the eclipse eyewear was worn, and the sun observed in intervals of about a minute in order to establish first contact.
5. When first contact was observed, the camera was aligned towards the sun. This was difficult as the sun appears dim in the viewfinder of the camera, due to the darkness of the filter.
6. The motion of the sun was tracked across the sky, about every minute. It was important to ensure that the sun was always in the viewfinder, since it can be difficult to see the sun as it's intensity decreases as totality approaches. This tracking time decreased to about 10 seconds from when more than $\frac{3}{4}$ of the sun was eclipsed. Photographs were also taken at various intervals, at exposures beginning at $\frac{1}{2}$ seconds up to 2 seconds with totality approaching. Care was taken not to knock any of the camera's tuning when the exposure time was adjusted. *Note: In the periods where the camera was not being used, a person was placed in front of the camera to block the sun as an extra safety precaution.*
7. Just prior to second contact, the first exposure time was set (2 seconds).
8. At second contact, the filter was removed, and a photo was taken. Then the film was wound, the new exposure time set and the camera alignment adjusted slightly prior to taking the next picture. Care was taken to minimise movement when winding the camera, and setting exposure time. This process was repeated for consecutive photographs.
9. Simultaneously, an assistant began timing the eclipse at second contact. This was to ensure that damage to eyes did not occur just after third contact. Photography was stopped with 5 seconds before third contact. At this mark, the exposure time appropriate for the *Diamond Ring* effect was set, and as third contact began, a photograph was taken in attempt to capture this effect.
10. The tripod was quickly moved in order to prevent damage to camera prism from focused sunlight.
11. Further photographs were taken (of third contact) after the filter was placed back on the camera, and realigned at the partially eclipsed sun.

Safety and Solar Filters

4.1 Safety Concerns

Solar filters are vital in eclipse photography. Filters are necessary to prevent damage to the eyes. The human eye does not have infra-red receptors. Thus, looking directly at sunlight is likely to result in permanent damage to the retina. It is important to understand that although the intensity of the visible light may be darkened by some material doesn't necessarily imply that the this material effectively filters at infra-red wavelengths.

Infra-red light can also damage camera equipment. A camera lens can gather much more light than the eye. Thus, focusing this light directly onto the prism could result in destroying the prism and burning the film. For this reason, it is important to make sure that the filter is much darker in all wavelengths than a material for standard use (ie, for naked eye observation of the sun).

In the light of these safety factors, it is important to either purchase professionally made solar filter or use a material for which the response curve for the light spectrum is known and available. The responsive curve should show sufficient responsiveness for the wavelengths just larger than visible light (infra-red).

WARNING: The filter should always be placed before the lens, and not between the camera and the eyes.

4.2 Solar filter material

Professional solar filters are expensive. The filter for a 200mm lens is approximately $200 at the time of writing. The alternative option was to construct a filter.

The first step in constructing a filter is to choose the right material. Response curves for various filter materials were obtained from the NASA handbook for the 2002 eclipse. An ideal material for this purpose seemed to be SN14 Welders glass. This glass, however, is not available in Australia. Be weary of anyone who claim that they stock this glass. The next ideal material seemed to be overexposed black-and-white negative. *It is important to note that colour negative is completely unsuited to the task - it has inadequate responsiveness within the infra-red band. Using this material will result in damage to eyes and camera*. An important note to make is that this material is a gross approximation to a good filter. The material scratches easily and needs to be handled with care.

Prior to the construction of the actual filter unit, a few different exposures of this material was developed by a professional photographer. From these materials the darkest was selected. These were tested in the following ways:

1. The sample was viewed against a background under normal sunlight. No filter should let through light under these conditions.

2. The sample was then held against a 60W light globe. Only the filament should be visible.
3. The sample was then held towards the sun directly, but without involving any optics. This was then compared with professional sun viewing glasses, that were available for around AUS$5. The sample should be darker than the eyewear.
4. The sample was then held up in front of the camera with a small lens ie, 50mm. The sun should appear extremely faint, almost impossible for the eye to see.
5. The 200mm lens was then used, and the sample tested against this. Once again, the sun should appear extremely faint.

WARNING: Make sure that when holding the filter in front of the camera that it is securely in front of the camera. If it is knocked away from the camera (ie, by wind), then permanent damage to eyes and camera could occur.

4.3 Constructing the filter

The chosen body for the solar filter unit was electrician's electrical roll base. This base detaches into two halves, and provided that the tunnel is large enough, it will slip onto the camera lens. However, it is important that this tunnel is not too large for the lens, since unwanted light could enter and make photography harder.

The following procedure was followed in constructing the filter. Figure 4.1 is an illustration of transforming the electrical roll housing into a solar filter.

1. The large circular base of the unit was cut to a size just larger than the tube section itself.
2. Then the solar filter material was cut to the exact size of the base of the filter.
3. The cut filter material was checked for scratches. A few were thrown out. The cutting process easily introduces scratches to the material.
4. A thin layer of "super-glue" was applied, and the material was pasted onto the base.
5. Tape was cut into tiny sections, and the filter was sealed by 3-4 layers of tape along the edge. This step also ensured that the filter was light sealed.

WARNING: It is not safe to simply use super-glue to hold the material on the base of the filter. The filter could easily detach itself and could cause permanent blindness and damage to camera equipment. The last step is imperative in ensuring the material is secured to the housing.

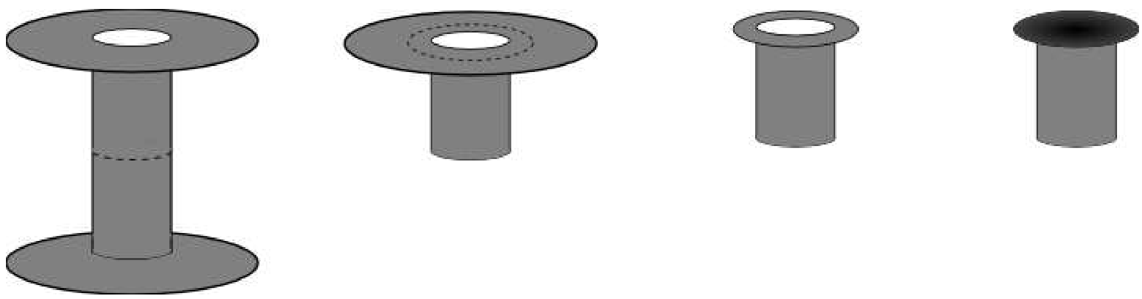

Figure 4.1: Transforming an electrical wire roll into a solar filter.

This unit was then tested according to this procedure:

1. The unit was pointed at a light bulb. It was verified that no scratches or leaks existed.

2. The unit was then pointed at the sun, in the absence of any optics. No scratches or leaks were detected.

3. The unit was then tested with camera and lens.

A few filters were made, in case filters acquired damage during transportation and handling. All materials for constructing filters were also taken, in case a filter needed to be constructed at Lyndhurst. Care was taken when handling the filters. The material was padded with cotton wool, and were never touched by the material part, only by the plastic housing of the filter.

Film speed and exposure times

5.1 Film Speed

Film speed determines the amount of detail that can be captured on film. A lower film speed is better, since the granularity of the film is smaller (and hence resolution is higher). However, increasing film speed means that exposure time need to be increased, and it is not always possible to do so since it may introduce gross amounts of motion blur, which will in fact lead to a much worse photograph. Thus depending on circumstances, it is important to make a compromise for film speed.

Since the duration of totality for the 2002 eclipse was 26.5 seconds, *ASA400* film was used. This film is quick, but it allows moderate resolution. Increasing exposure time for a slower film would have decreased the total number of phenomena that could be captured (five photos), and introduce motion blur into the image.

5.2 Evaluating exposure time for partial phase

The partial phase of the eclipse is when the solar filter is employed in photography. It is impossible to assume that every filter is made in the same way, and will darken light by the same amount. Thus, optimal exposure times should be worked out by taking photographs with the filter in place. These were the steps taken in doing so:

1. The filter, camera, and equipment was taken to Jells Park (Wheelers Hill) on a sunny day.
2. To make photography close to eclipse conditions, it was made sure that the sun was approximately 5° from the horizon.
3. Photographs were taken at various exposures.
4. These were developed at a local photo shop.
5. The lowest exposure time of the sharpest set of images was used (to minimise motion blur).
6. The optimal exposure time was found to be $\frac{1}{2}$ second.

It is important to note that this evaluation is a gross approximation to the actual eclipse. When the eclipse takes place, the intensity of light decreases as it approaches second contact. Thus, it was important to increase exposure times to 1-2 seconds when the eclipse was minutes away from second contact. Since there were less focus on partial eclipse photography these exposure times were not determined systematically.

5.3 Exposure times during totality

There are a few factors which affect exposure time:

- *Film speed*
  Increasing film speed will decrease exposure time.
- *Focal length*
  Increasing focal length will decrease light intensity. This will demand a longer exposure time.
- *Features you wish to capture*
  Some phenomena (such as transitonal effects) have a corresponding exposure time.

NASA's report on the eclipse had standard exposure times table which showed the exposures necessary with film speed, feature, and focal length as the varying factors. Due to the teleconverter, the focal length of the lens was multiplied by 3. The value (larger) closest to this was used as an index to the table of exposure times. The times used are shown in the table below. Photographs were taken in this order.

Effect	**Time (seconds)**
Corona $8R_\odot$	2
Corona $4R_\odot$	$\frac{1}{2}$
Corona $2R_\odot$	$\frac{1}{4}$
Corona $1R_\odot$	$\frac{1}{8}$
Diamond Ring	$\frac{1}{125}$

The Photographs

6.1 Features captured

Of the five photographs taken, three photographs were aimed at capturing the corona at 8,4,2 and $1R_\odot$. The corona features were captured on film. However, the expected size of these features were hard to distinguish between the four photographs. Due to the similarity in these images, only the photographs of corona at 8 and $4R_\odot$ given by figures 6.1 and 6.2 respectively. From analysis of these images, it seems that the exposure times used were slightly larger than required.

The problem may lay in the calculation of the exposure times, where the focal length was simply multiplied by three and the next largest focal length appearing in the index of the table was used. Rather, it would have been more accurate to use the equation given by NASA to calculate the exposure times.

However, in having said that, the exposure time used for capturing the diamond ring effect (figure 6.3) seemed to have been accurate. Furthermore, the fourth image, in which $\frac{1}{8}$ second exposure time was used, also gave a greater than expected corona. The test photographs taken to evaluate optimal exposure time for the filter showed little difference between the larger exposure times. Thus, there may be mechanical error with the camera when using long exposure times.

Overall, the photographs were quite good. The corona photos demonstrated the size of the corona extending beyond the photosphere, and the diamond ring image revealed the presence of solar prominences.

6.2 Quality of the photographs

The quality of the photographs were satisfactory. The ASA400 granularity proved fine enough to capture good quality images. This detail was particularly visible in the diamond ring photograph that showed the presence of solar prominences. However, this photograph experienced a slight reflection by the lens, and added a spot of light that should not be there.

The other photographs, however, did not present high quality and detail - although they were valuable corona shots. There was motion blur present in these shots. There are a number of inevitable reasons that contributed towards this. Firstly, the exposure times required to capture the corona were large. This was complemented by the fact that the images were taken from a location on the edge of the path of totality. Thus, the motion of the moon across the sun appeared much quicker, and longer exposures can capture this blur on film. This motion blur may have been reduced by using a shorter focal length, or by using a faster film - but at a cost financially and in quality. Furthermore, these images could be digitally enhanced by combining the shots that were taken at a shorter exposure time. This has yet to be done.

It is important to note, however, that although motion blur was present in the corona shots, it did not affect the objective of these photographs - to capture the presence of the corona.

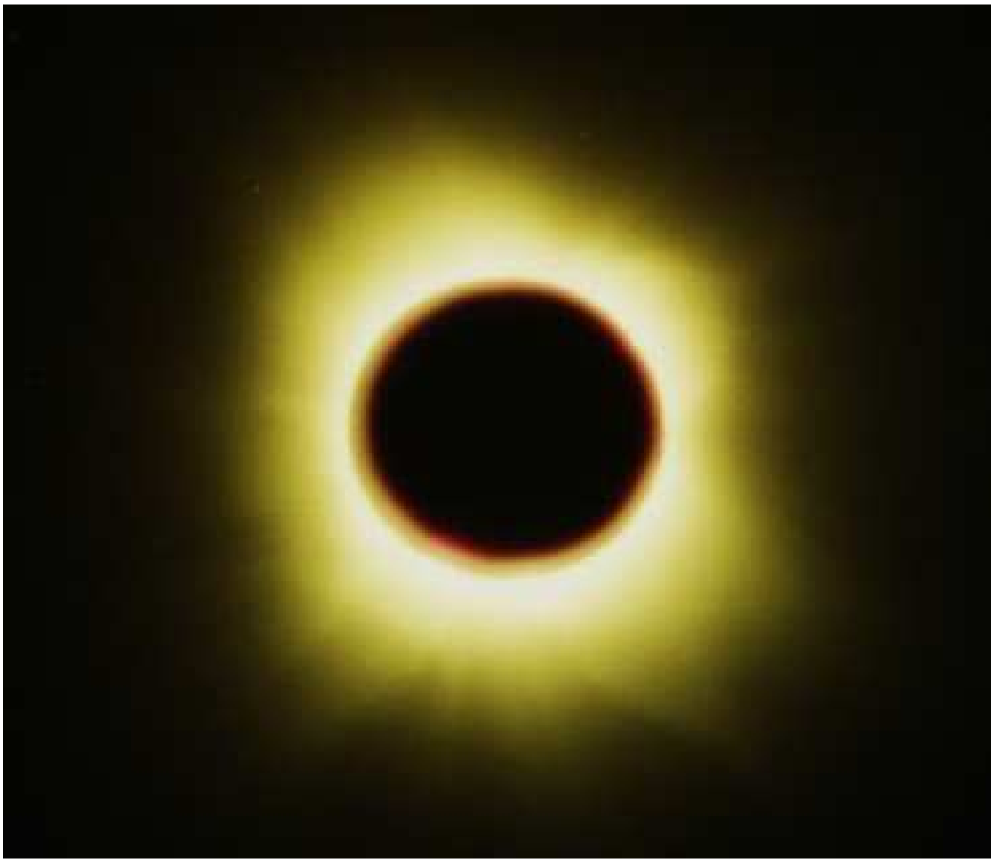

Figure 6.1: Corona at 2 second exposure

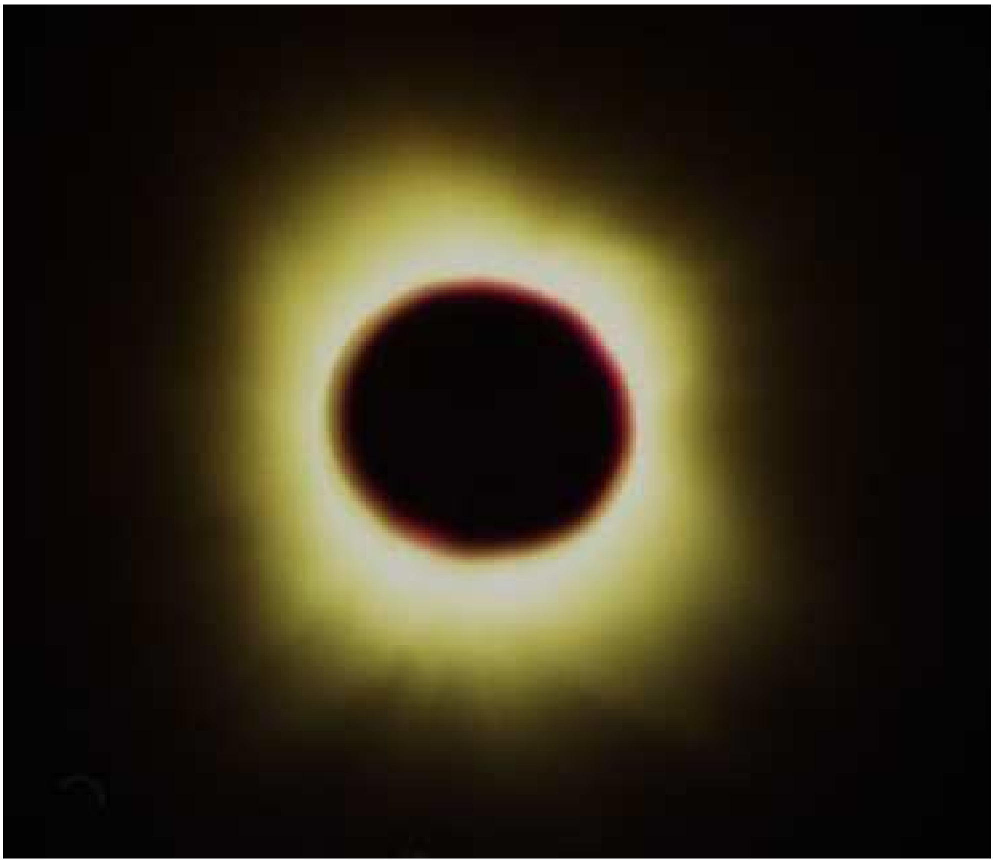

Figure 6.2: Corona at $\frac{1}{2}$ second exposure

Figure 6.3: The diamond ring

Thanks

I would like to firstly thank *Susan Feteris* (School of Physics and Materials Science) for her assistance. Without her help, I would not have had the necessary equipment to capture the eclipse. She authorised the use of the University's camera, lens, and she introduced me to NASA's documentation on this eclipse which I used as a primary resource.

Keith Bambery (School of Physics and Materials Science) also deserves much credit. He gave me valuable technical advice and a vital piece of equipment - the telescopic tripod.

Furthermore, *Steve Morton* (Scientific Imaging) gave me invaluable assistance in constructing the solar filters. The use of black and white negative was his idea, and he kindly created the material which became the final filter.

On the same note, thanks to my father *Adikari Bandara* for kindly donating his electrical wire roll for the housing of the filter.

I would also like to thank *David Wolf* who assisted by timing eclipse to make sure I didn't blind myself at third contact.

Thanks to *Grahame Price* who assisted me when photographing the sun at Jells Park to determine exposure times.

Last but not least, I'd like to thank *Adrian Lucas*, *Cait MacKenzie* for helping me transport the equipment.

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