Re: Planetary imaging with fast Newtonian

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- *From*: Chris L Peterson <clp@xxxxxxxxxxxxxxxxxx>
- *Date*: Tue, 18 Oct 2005 06:55:12 GMT

On Tue, 18 Oct 2005 04:13:58 +0000 (UTC), brian@xxxxxxx (Brian Tung) wrote:

>I sense a circular discussion. I'm not familiar with imaging issues,
>so let me ask some questions that I hope will clarify things. I'm
>asking both you and Jon, specifically, though all might answer:
>
> 1. For two scopes of the same focal *ratio* but different
> aperture, is there anything that they share?

Two scopes of the same focal ratio will share the same physical diffraction disk size (but not the same angular size).

> 2. For two scopes of the same focal *length* but different
> aperture, is there anything that they share?

As you observe, the two scopes share the same image scale.

>Obviously, the answer to #2 includes image scale. What I want to know
>is if there is anything else to it, and whether there is anything at
>all to #1. I would have thought that exposure time for DSOs would be
>correlated pretty strongly with focal ratio; is that entirely out of
>scope for this question? Are we asking only about the planets?

No, the exposure time is not correlated with focal ratio (with the possible exception of film imaging, which I'll hit in a moment). With digital imaging, there is usually no issue of under or over exposure (saturation excepted). What determines a "correct" exposure is a high S/N ratio. S/N continues to improve with exposure time, although one reaches a point of diminishing returns.

Consider two cases. A 10" f/10 telescope and a 10" f/5 telescope are used to image an object, each for a one minute exposure. Both telescopes collect and deliver the same number of photons to their image planes. On first glance, it would seem that the signal would be higher with the f/5 instrument, since the object dimensions are twice as small, and therefore the photon density is four times higher. And indeed, an individual pixel mapped to some point on the target will have four times as many photoelectrons stored as the same pixel on the f/10 instrument. But it turns out that doesn't mean much. If you take the data from the sensor on the f/10 scope and bin it− combine the value of blocks of four pixels− you will end up with new data at the same scale, and with the same signal count. The statistical noise component, which is equal to the square root of the signal, is also the same in both cases. If you bin the pixels before reading them out of the sensor, the readout noise is the same in both cases. That leaves only dark current noise. Dark current is proportional to area, so it is four times higher across the four pixels of the f/10 sensor, making the dark current noise twice as high. But in practice, this is seldom significant since dark current noise is usually only a small fraction of the total noise. What all of this boils down to is that the data quality is very nearly the same, regardless of the focal ratio.

For very short exposures, such as encountered when imaging with a webcam, dark current noise is usually insignificant. The major noise sources are readout noise and statistical image noise. The first has a fixed value per pixel, so changing the pixel scale changes its relative impact. But the readout noise is still only a fraction of the total noise, so the relationship of S/N to focal ratio is not at all linear.

For very long exposures, such as those used for capturing DSOs, saturation has to be considered. Normally images are broken into shorter subexposures, which allows an arbitrarily large number of photons to be collected without saturation. Long exposures are always limited by sky noise and object noise, and the effects of focal ratio reduce to zero.

The analysis is a little more complex with film because of its non−linear response. CCDs are photon counters− it doesn't matter what the actual accumulation rate is. Film has a threshold of sensitivity related to photon flux, however. Below a certain level the response is very poor, and reciprocity failure enters into the equation. Because of this requirement for a certain minimum brightness, there is some merit in considering focal ratio (although it is by no means necessary to do so).

Stan Moore has a more rigorous discussion of this material at http://home.earthlink.net/~stanleymm/f_ratio_myth.htm .

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- ***References***:
  - ***Re: Planetary imaging with fast Newtonian***

- ◊ *From:* David Nakamoto
- ♦ ***Re: Planetary imaging with fast Newtonian***
  - ◊ *From:* jonisaacs@xxxxxxx
- ♦ ***Re: Planetary imaging with fast Newtonian***
  - ◊ *From:* Chris L Peterson

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