Signal to Noise

Ast 401/580
Fall 2019

Signal to Noise (S/N)

The S/N is a way of quantifying how good an observation is. In a paper you would normally use this value to describe the data.

Discuss: What Limits the S/N?

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1) The number of photons in your "signal." You could improve this by increasing the exposure time and/or using a bigger telescope.

2) The noise can be affected by:

- ★ Sky-noise (observe in a dark site and when the moon is down)
- ★ Read-noise (use a better detector or bin)
- ★ Poor calibration: not enough bias frames or not enough signal in your flat field

How Do We Compute the S/N?

First we need to identify the signal (S). It's the part of the exposure you care about. It's what you have AFTER you've subtracted all of the additive stuff (overscan, bias, and sky).

How Do We Compute the S/N?

Second, we need to identify all of the noise components: photon-noise from the object, photon-noise from the sky, read-noise, etc.

How Do We Compute the S/N?

Best to do this all in terms of e- rather than ADUs, as we will want to compute photon-noise as sqrt(N).

Once you have the Signal and the Noise, you DIVIDE one by the other. The S/N is dimensional-less. It does NOT have units of ADUs or e- or light-years.

How Do We Compute the S/N?

You will also need some idea of error propagation (which you need to know in any of the sciences):

if you ADD or SUBTRACT two images (A and B) with errors σ_A and σ_B, the errors add in quadrature:

$f=A+B$ or $f=A-B$

$$\sigma_f^2 = \sigma_A^2 + \sigma_B^2$$

If you divide A by B, then

$$(\sigma_f/f)^2 = (\sigma_A/A)^2 + (\sigma_B/B)^2$$

How Do We Compute the S/N?

What happens if you add or subtract a constant to an image A? The value of A changes but the error doesn't! Remember how the standard deviation is defined:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \overline{x})^2},$$

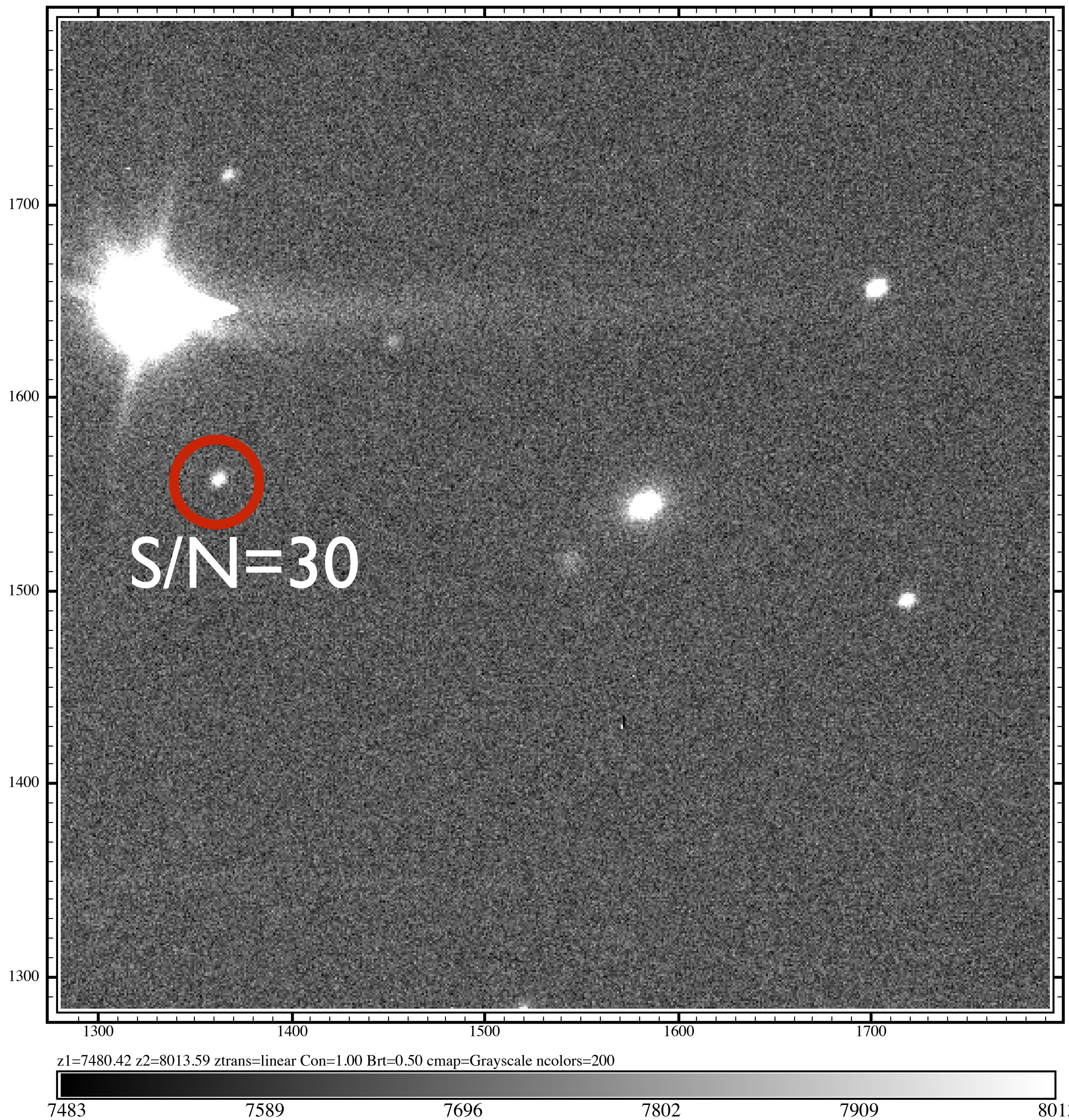
How Do We Compute the S/N?

What happens if you multiply or divide image A by a constant "c"? Well, the errors also change by the same factor cA has the error $c\sigma_A$

Applications of the S/N

The S/N value allows you describe how good the data are to others. You would include it in any journal paper as a way of characterizing your data.

lmi.0188 - Asteroid Neugent



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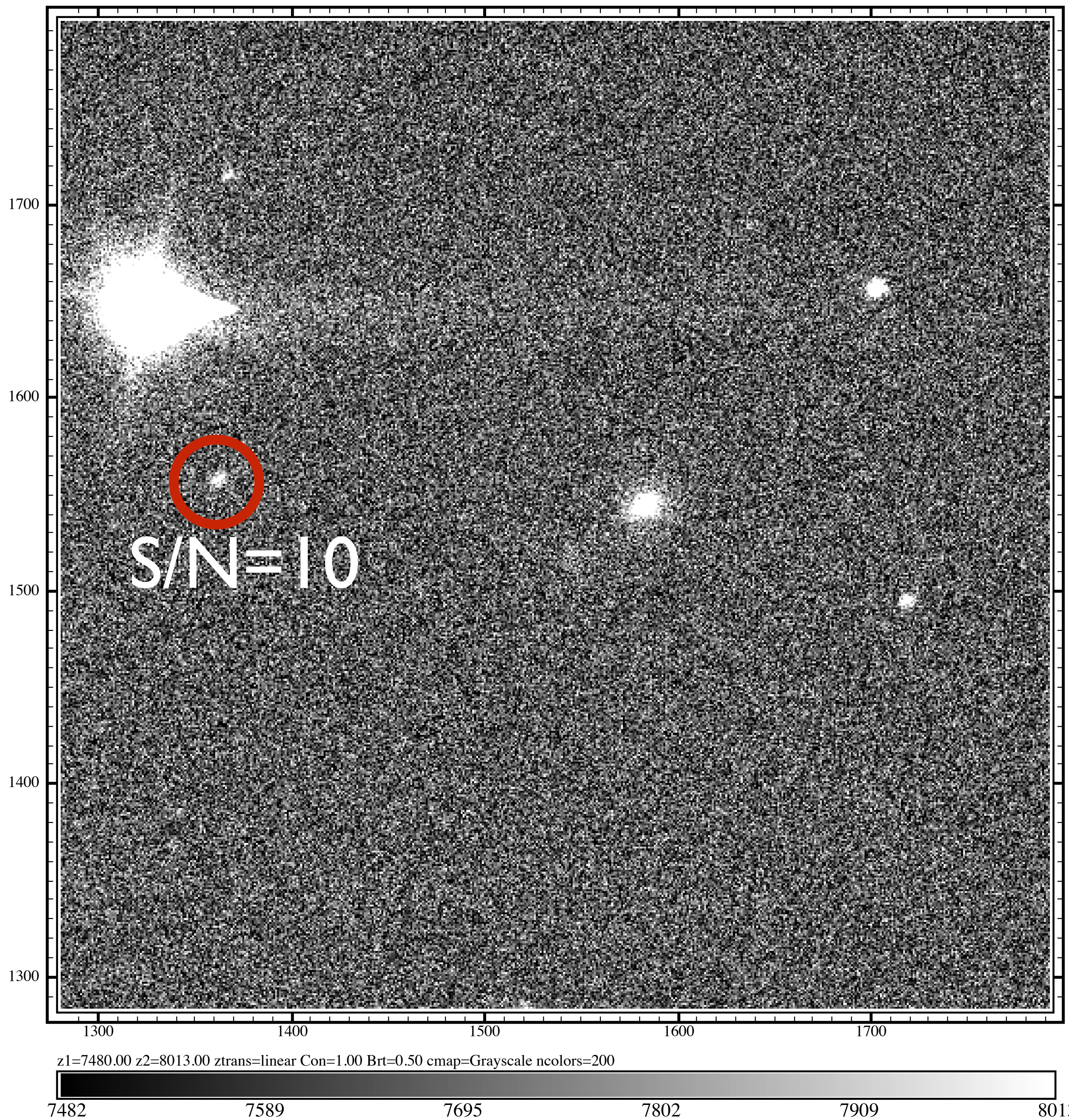

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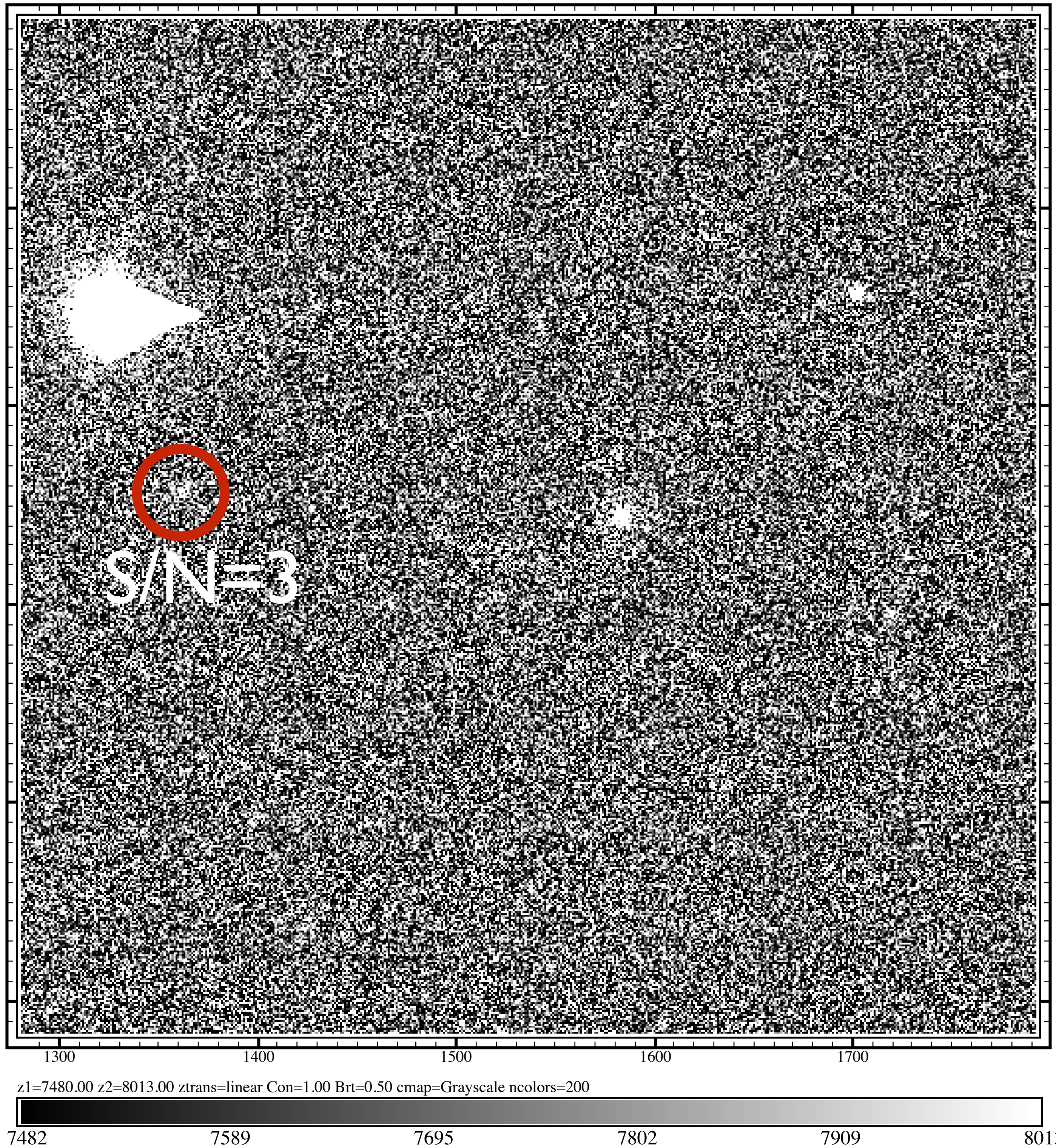

Signal to Noise (S/N)

Depending upon your application....

S/N of 3 is "barely detectable" [a 3 sigma result]

S/N of 30 is "respectable"

S/N of 50 is "pretty good"

S/N of 100 is "good"

S/N of 200+ is "excellent"

Applications of the S/N

You would also need to talk about this in any good observing proposal; Time Allocation Committees not only want a defense of why you need a particular S/N, they then want you to justify the amount of observing time you are asking for in terms of the time you'll need to achieve this S/N.

Applications of the S/N

It's also a convenient way of estimating what your error [in magnitudes] will be: sigma_mag = 1/(S/N).

Okay, it's actually 1.08/(S/N)

Wait, what? How can the uncertainty in magnitude just be 1./(S/N) in magnitudes?

sigma (mag) = -2.5 log ((S ± N)/S))=-2.5 log(1+N/S)

$$\begin{aligned}\sigma(m) &= \pm 2.5\log(1+\tfrac{N}{S}) \\ \sigma(m) &= \pm\tfrac{2.5}{2.3}[\tfrac{N}{S} - \tfrac{1}{2}(\tfrac{N}{S})^2 + \tfrac{1}{3}(\tfrac{N}{S})^3 - \ldots] \\ \sigma(m) &\approx \pm 1.0875(\tfrac{N}{S})\end{aligned}$$

The fact that 2.5 is very similar to Euler's number e once again saves us