Intro to Optical Measurements

Bruce Grossan

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5. Reduce to Measurement

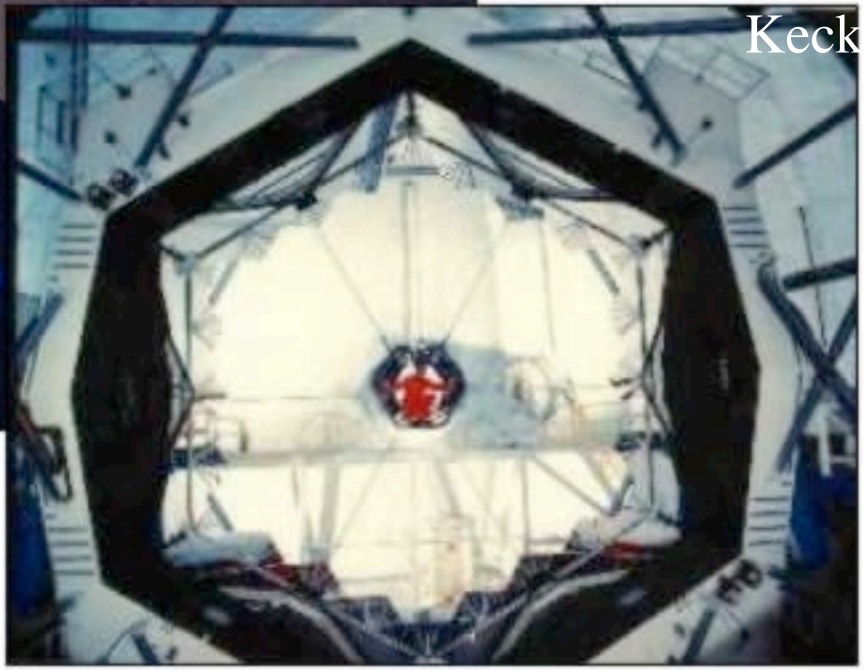
- Compare to Standard Stars

Collect Light

- BAT/UBAT = You can only get shadows
- XRT or Hubble or Keck all collect and focus light
  - Easier in the optical, just a shiny polished surface
    - ... but easiest in radio, because 1/4 lambda is big and easy to see and make. Can even use chicken wire!

Collect Light

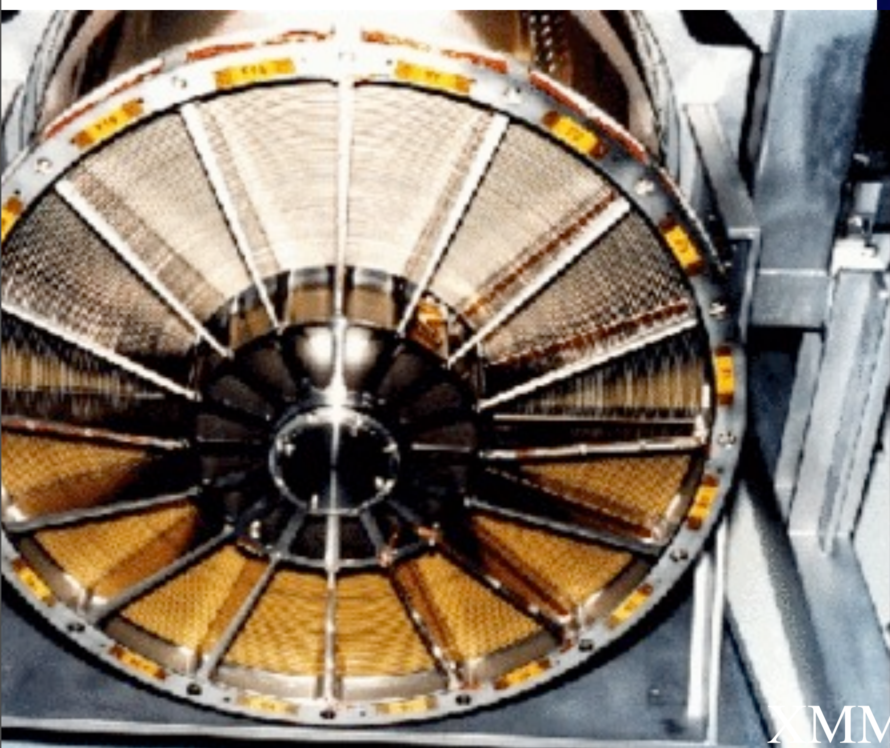
Keck I exterior

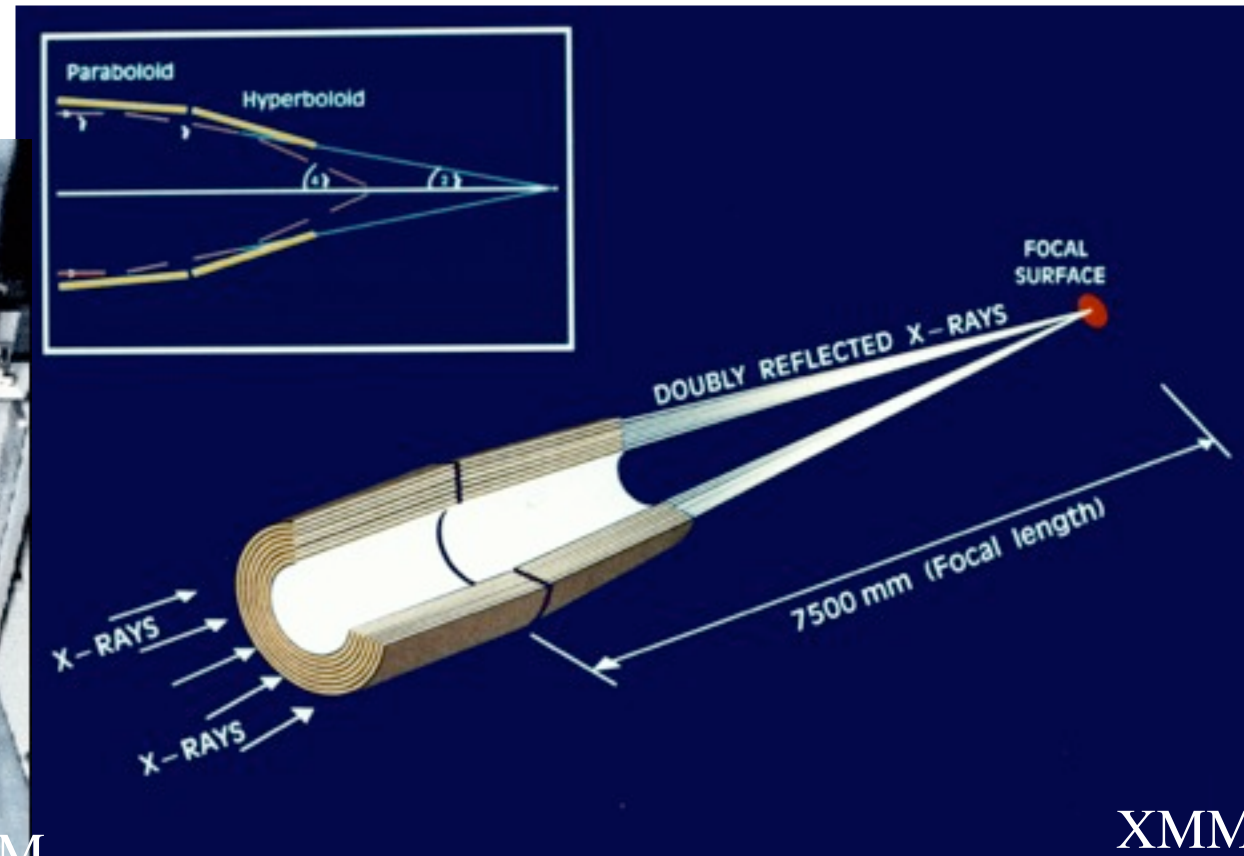


Close-up of primary mirror

X-ray mirror

- XMM telescope Wolter-I mirrors
- two bounces





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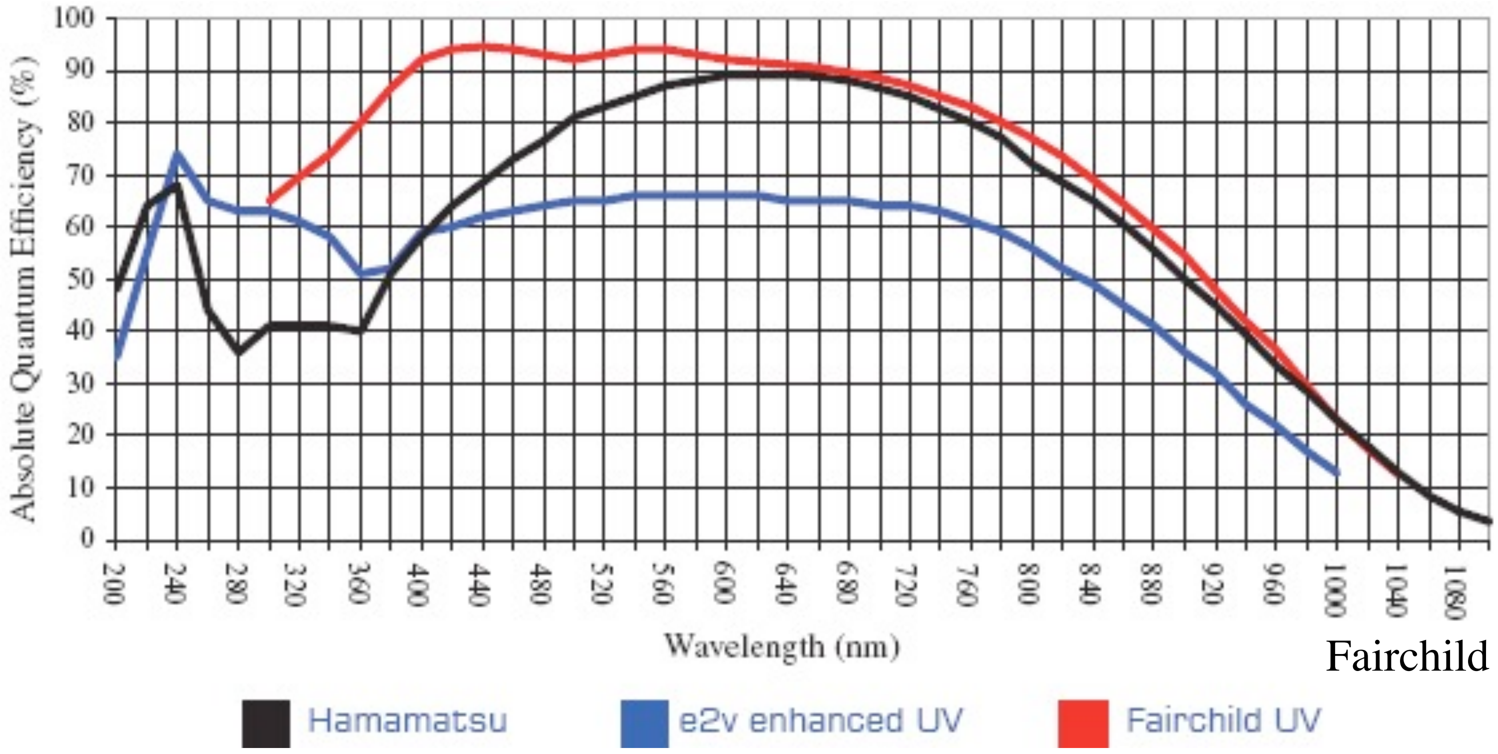
  - EMCCD

QE

- Back-SIde illuminated CCDs
  - This is just to give you an idea (this is a weird curve I found)



Bias Frames

- Take lots of zero time exposure frames, subtract them.

Flats

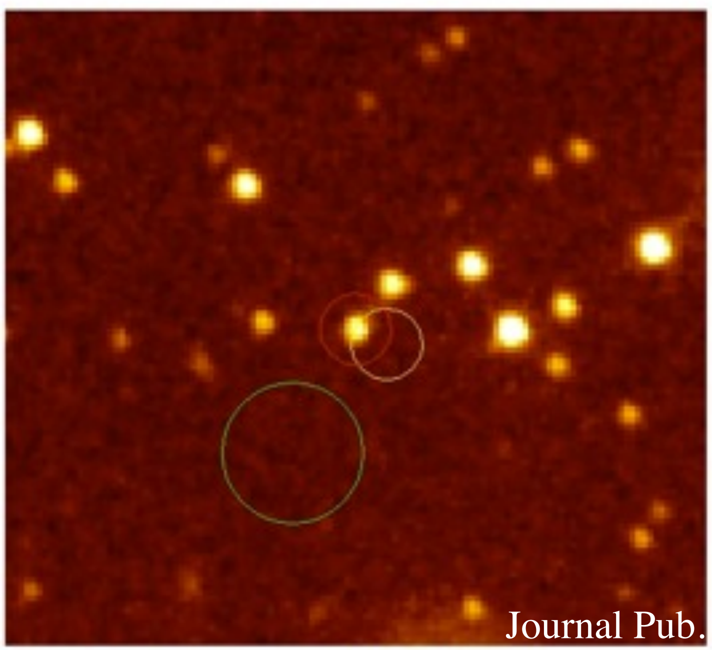
- Can try to observe a uniform source of illumination
  - Difficult in practice
    - (out-of-focus screens tend to have problems)
    - Fit a smooth 2-d surface to see response differences pixel-by-pixel
- SuperFlat-
  - Take all your images during the night, median them, rejecting saturated data
    - By medianing images, you reject stars, and only add in typical average brightness background. With many many images, this becomes an excellent flat illumination.
- Divide by the flat to make the correction
-

Noise - Really! Look at any Dark Frame

- Demo with Computer Camera

Imaging Measurements REALLY SIMPLE

- Measure (add up) all the light in an aperture.
- Subtract a background (by whatever method)
  - example method: annulus around your aperture
  - average a few background apertures nearby
  - Use CORRECT statistics to determine the background aperture sigma

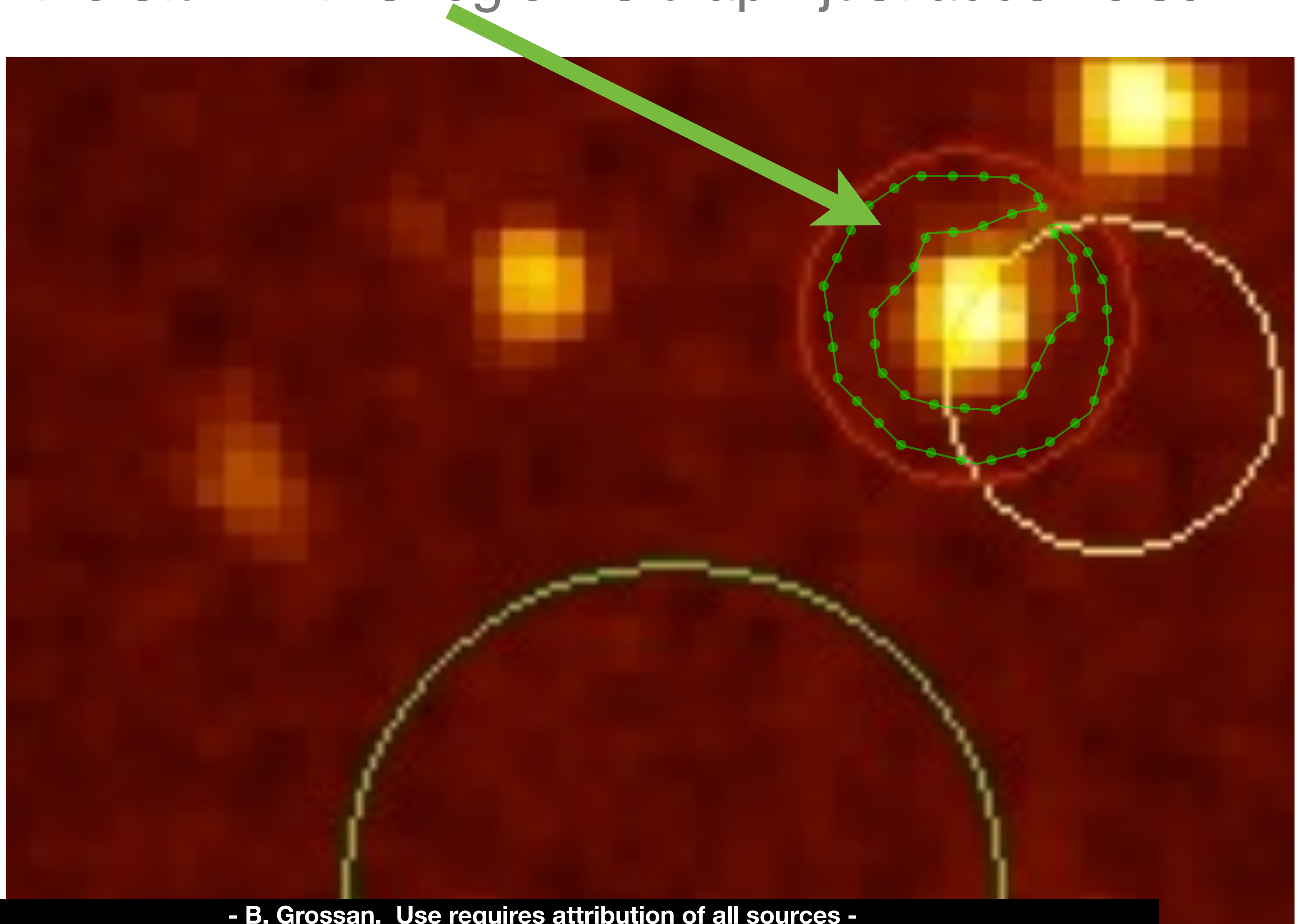


The above summed UVOT V-band image gives the XRT error position (yellow), the source counts extraction region (red), as well as th region used to extract the background level (green) for GRB 050525A.

- Good method for galaxies and other extended objects.

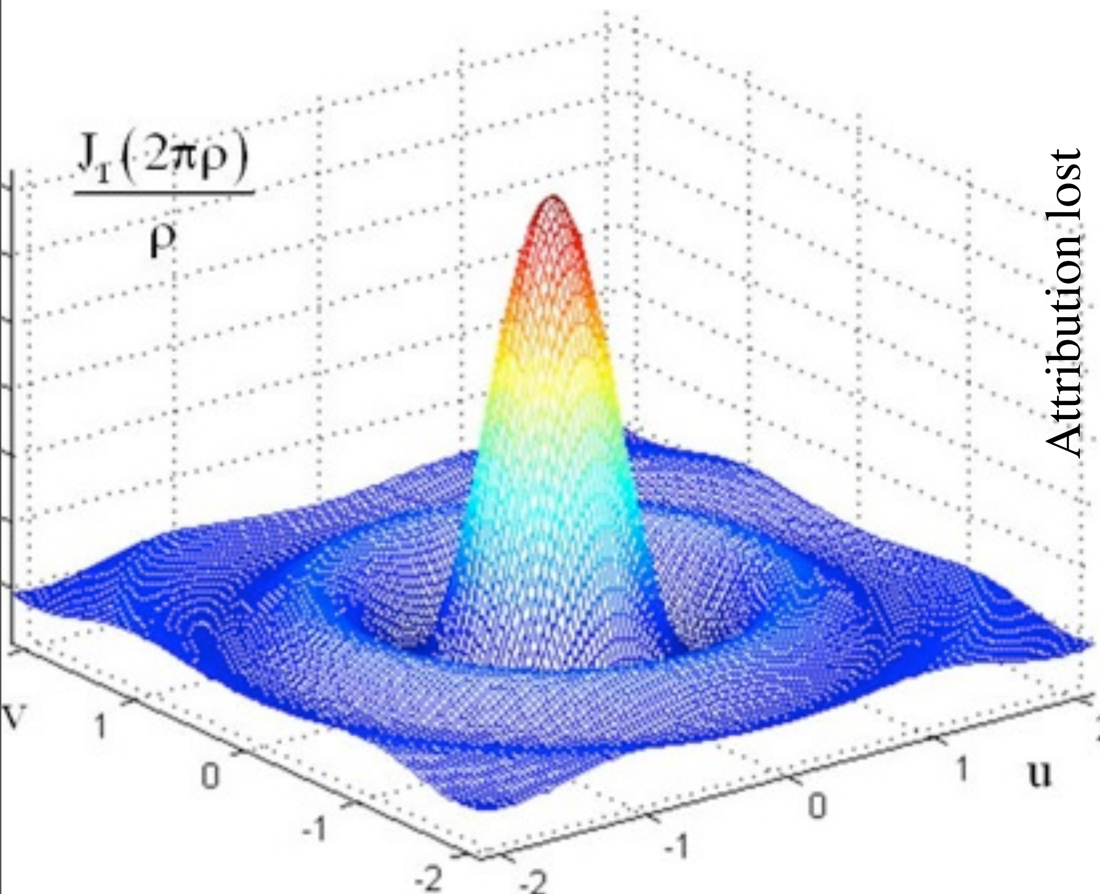
Problems with Really Simple

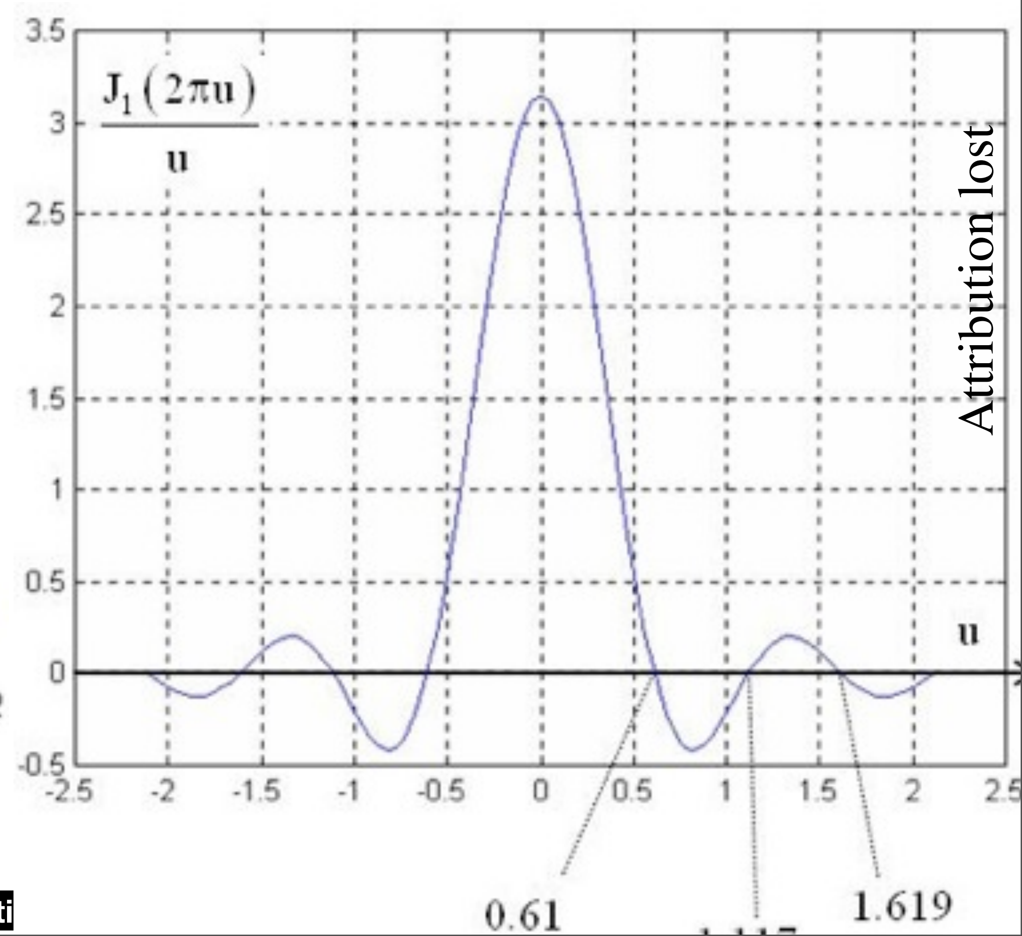
- All the stuff in this region is crap - just adds noise.



Point Spread Function - from Fourier optics

- The fourier transform of a circle is a bessel function
- core is often approximated as gaussian

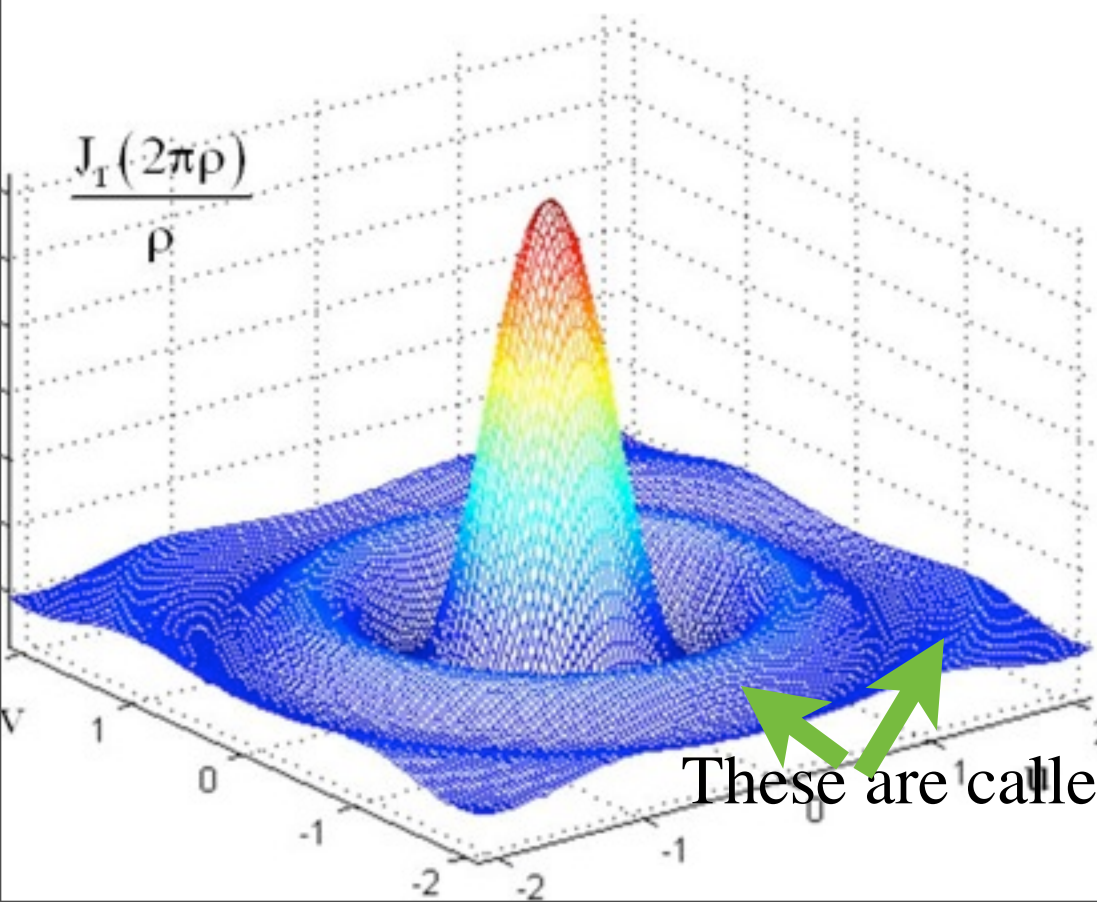




- B. Grossan. Use requires attributi

PSF

- Any source smaller than the PSF or resolution will have the PSF profile
  - like stars, GRBs, satellites at great distances, etc.
  - Profile of extended objects can be thought of as a superposition of PSFs; more properly the profile is a convolution of the source and the PSF.

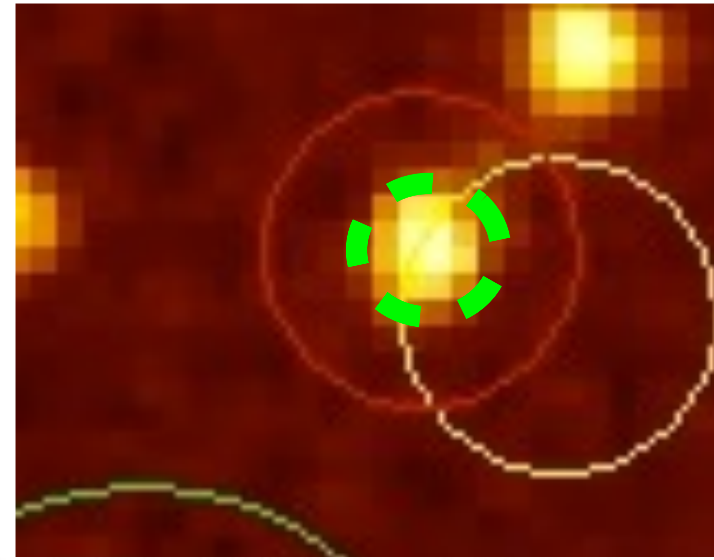


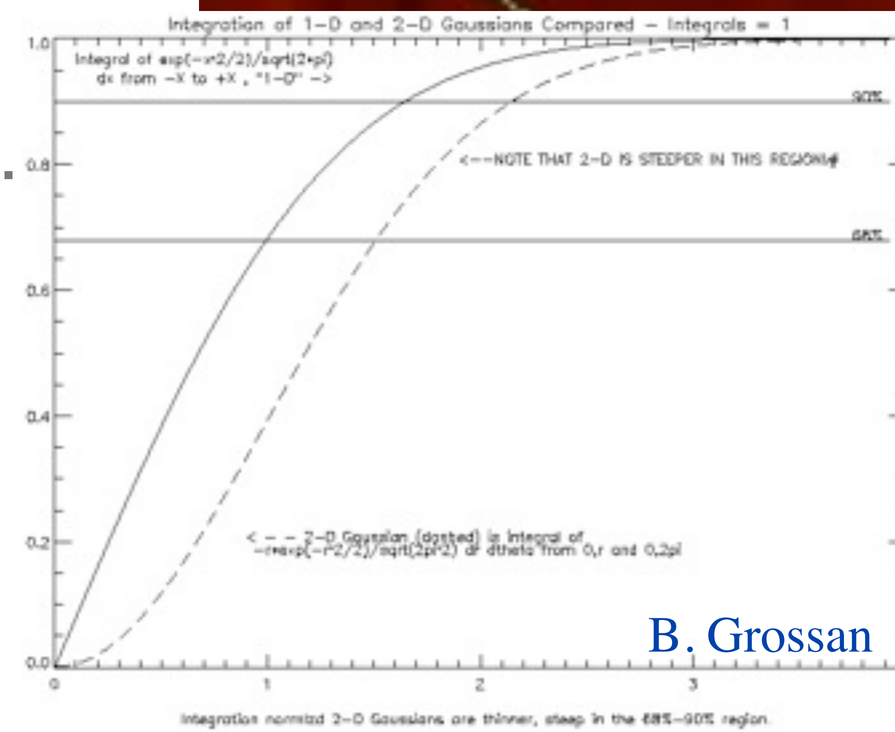
These are called Airy Rings

ion of all sources -

Better: Aperture Corrections

- If you KNOW your source to be point-like, just use the BRIGHTEST part of the source, then correct for the light you didn't get, but would have.
- In the approximation at left, you multiply by 1/0.68 for aperture radius=1.5 times the core width.





Best - PSF fitting

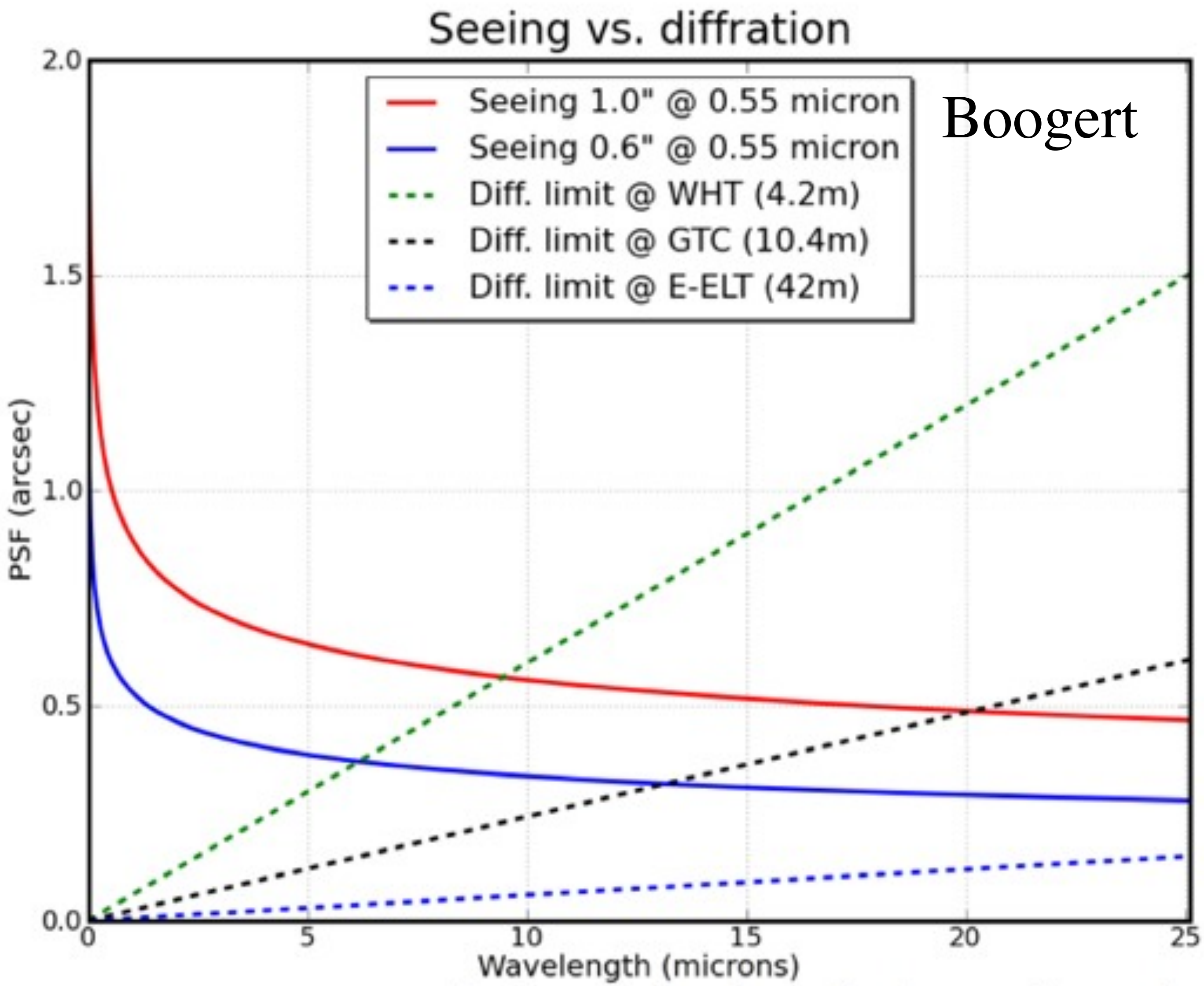
- Fit an empirical PSF by averaging over all the bright stars on the field
- Fit this PSF function to your faint, noisy target
  - You fit only for a multiplicative scale factor A and position x0,y0
  - You include any information in the “wings” of the PSF, away from the core, but they ***do not add noise*** because they are weighted by the uncertainty. This is closer to an optimal fitting process.
- This is where imaging really wins over non-imaging; you use more information, add no unnecessary noise.
  - Don’t forget; you need to ***fit*** some kind of background 2-D surface underneath the source to subtract the background.
  - Done by programs like DoPHOT, and SeXtractor.

PSF Width Choice?

- What is best, 90% of light within one pixel?
- Why not 100 pixels / FWHM, so you can have as much information for fitting as possible?
- Answer: For FAINT imaging, you need to find the optimal point,
  - >1 FWHM/ pix you collect too much background
  - ~ 1 FWHM/pix your PSF varies too much as you move across pixel boundaries and you do not get good fit results
  - <<1FWHM/pix too many pixels, too much read noise;
- typically ~ 2.5 pix / FWHM
- Why is SMT ~ 4 FWHM / pix?

What is Seeing?

- Seeing is the time-varying distortion of the optical path (“shimmering”; twinkling) of rays through atmosphere
- Telescope size not limit in O-IR



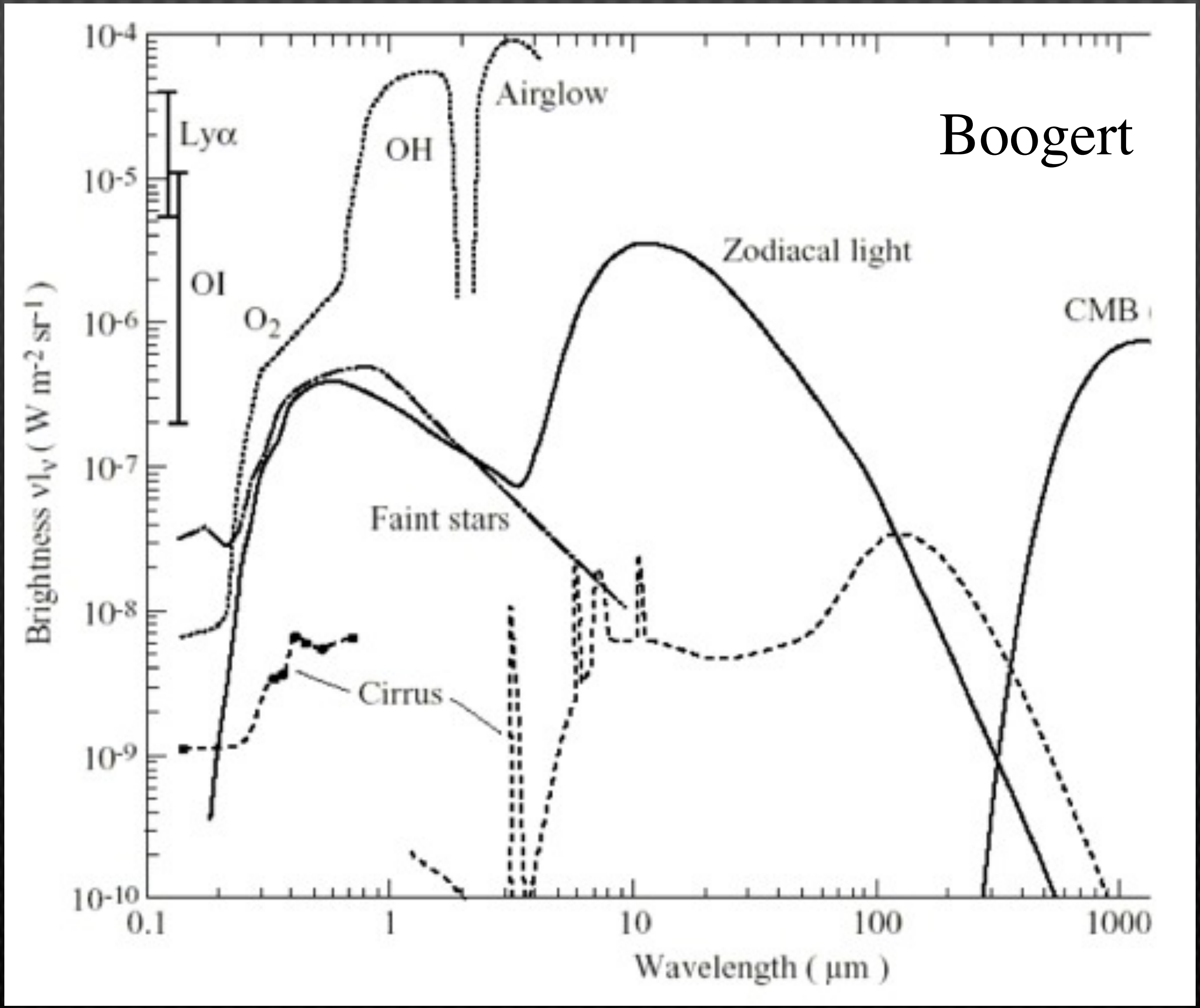
source: www.gtc.iac.es/en/media/canaricam/

AO - adaptive optics for ground

- Shift-and-add is majority of gain
  - fast-image recording often done on small devices in IR
- Wavefront sensors
- Deformable mirrors
- Laser Guide Stars ---
  - http://www.youtube.com/watch?v=3BpT_tXYy_I

Observing from Space

- Compare Space and Ground background
- Which would you rather have?
- **Now add-in seeing as well!!!**



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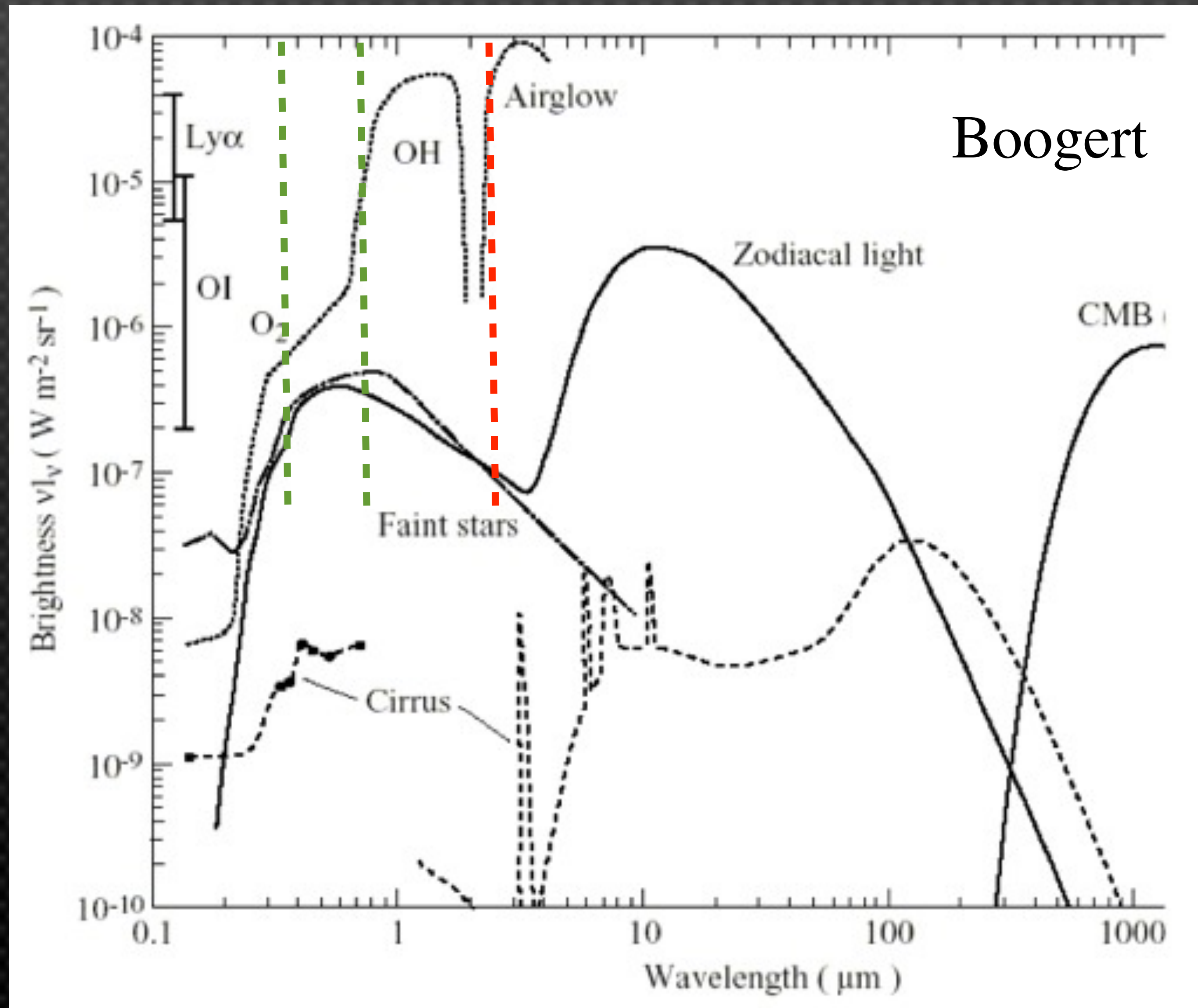

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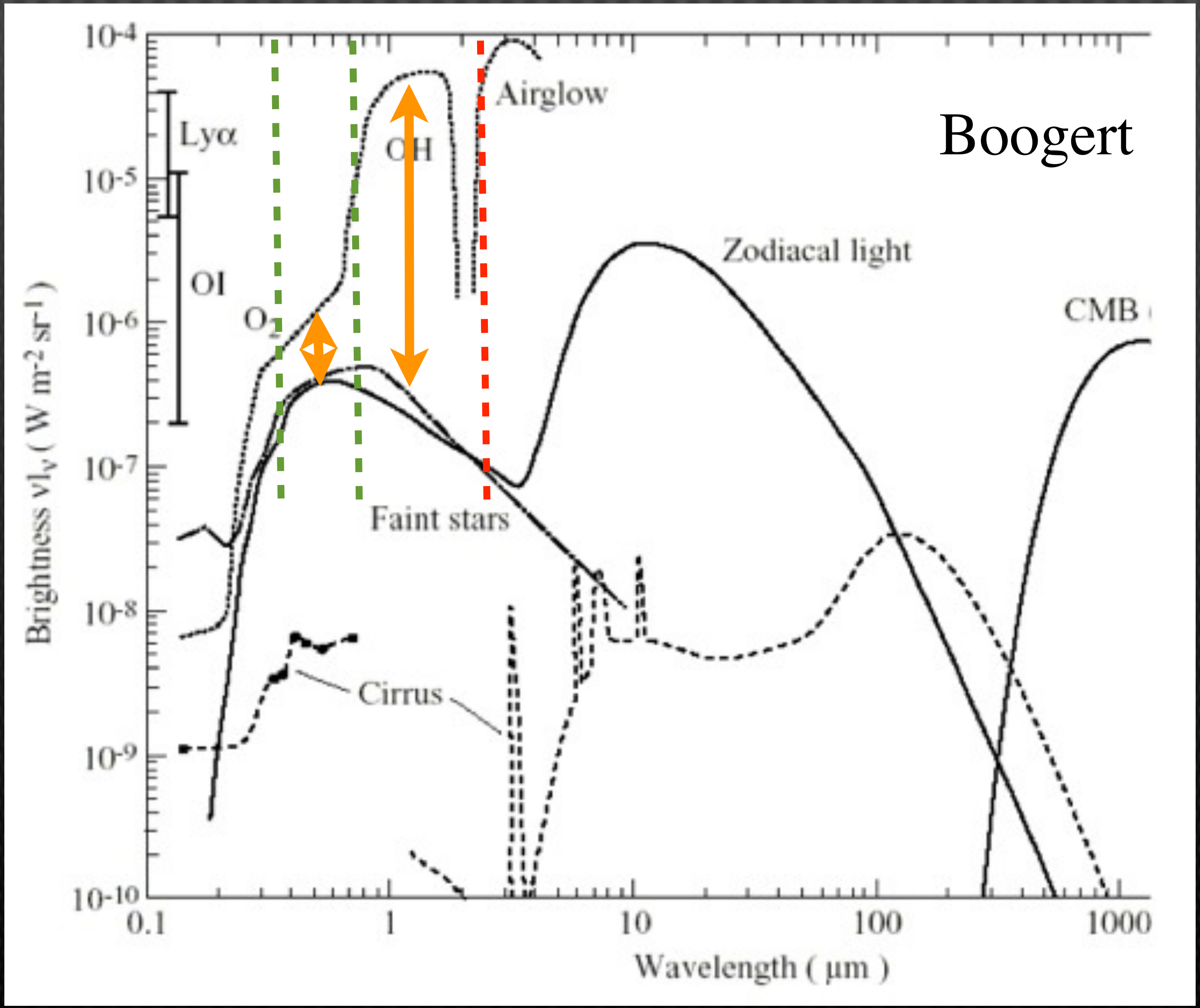

Still More to Do...

- There is still lots more to do in fitting absolutely the most precise estimate of the object flux... full analysis may include non-gaussian errors and so may need more complex analysis than chi-square.
- Imaging complex structures at low flux may require e.g. maximum likliehood or bayesian analysis to recover the structure
- Imaging techniques recover more and more information beyond optical resolution limit - has to do with using information about the response of system, information (or assumption) about possible structure, de-convolving image.

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    - Which one will you be?

Your Observing

- Observing is a skill which you can take much pride in.
- Berkeley is about as good a place to observe from as Moscow;
  - write proposals to VLT! Don’t be shy.

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