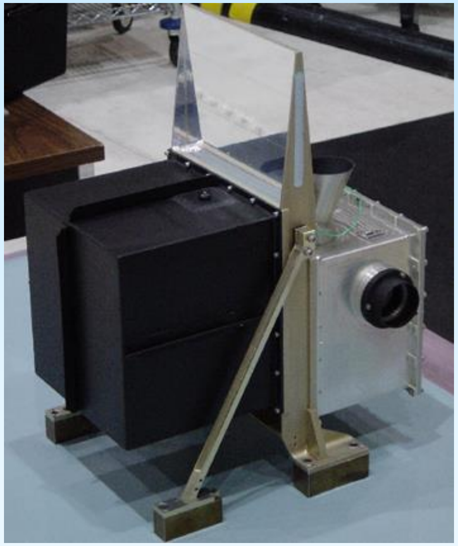
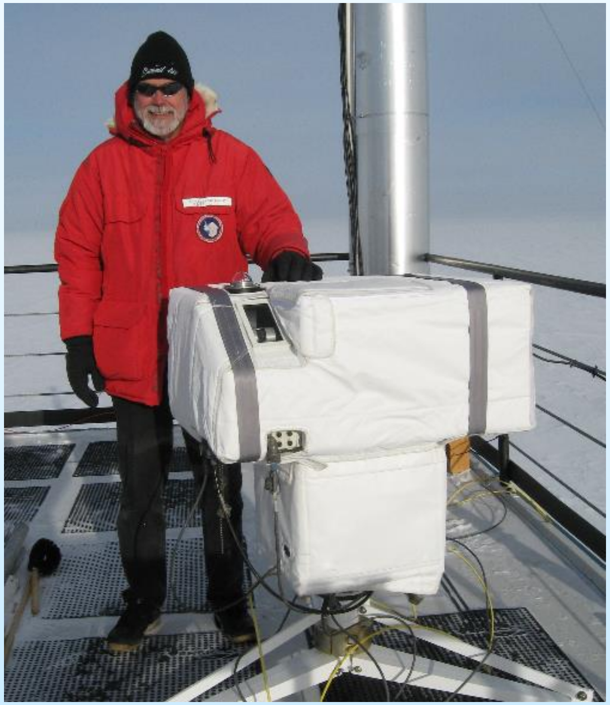


Instrumental stray light in UV visible spectrometers

C.T. McElroy

York University

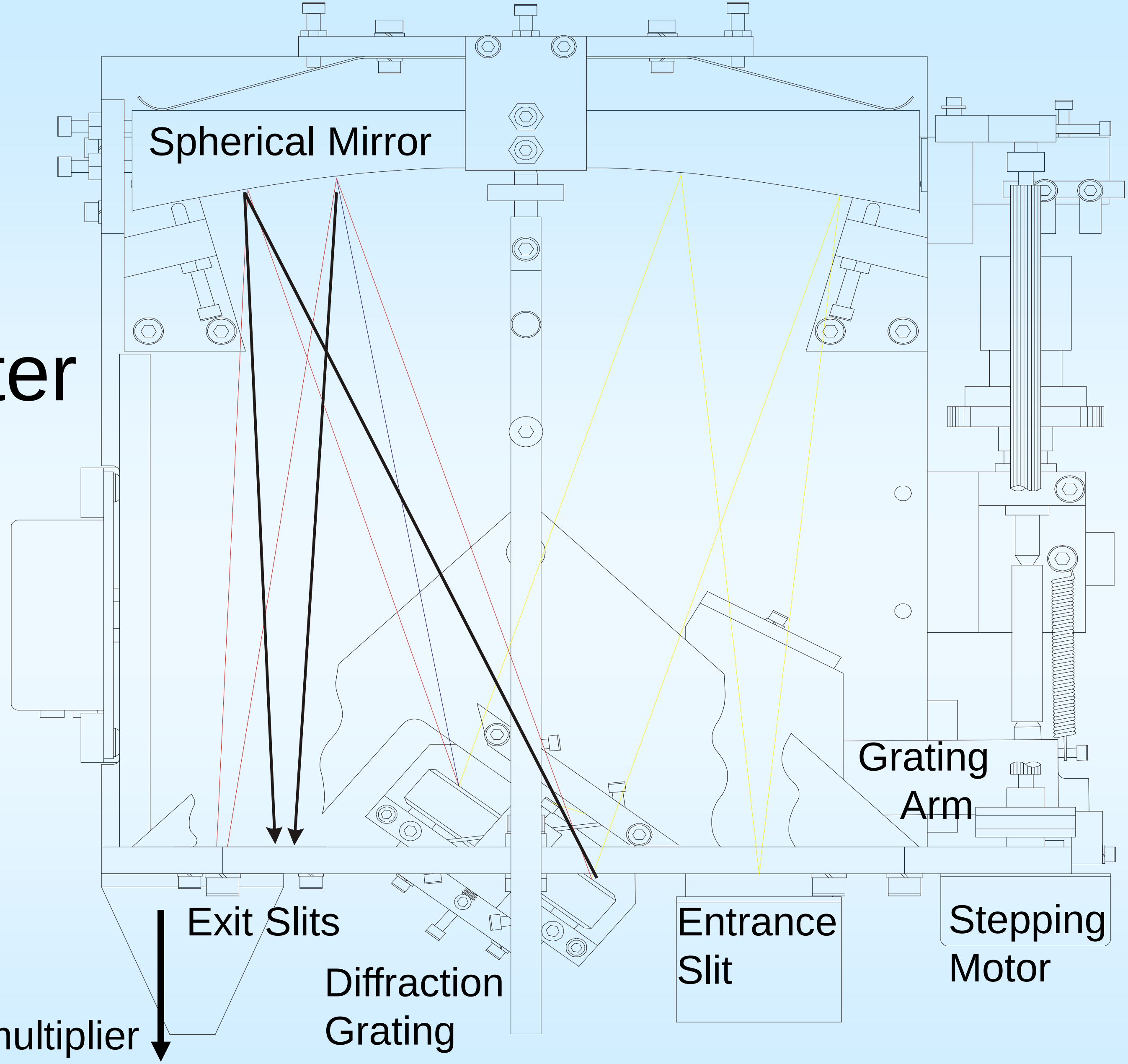


Stray Light & Linearity

- Brewer Spectrophotometer and Stray Light
- SunPhotoSpectrometer and Stray Light
- MAESTRO and Stray Light

- Two similar effects
  - Stray light
  - Charge carry-over

Brewer Ozone Spectrometer

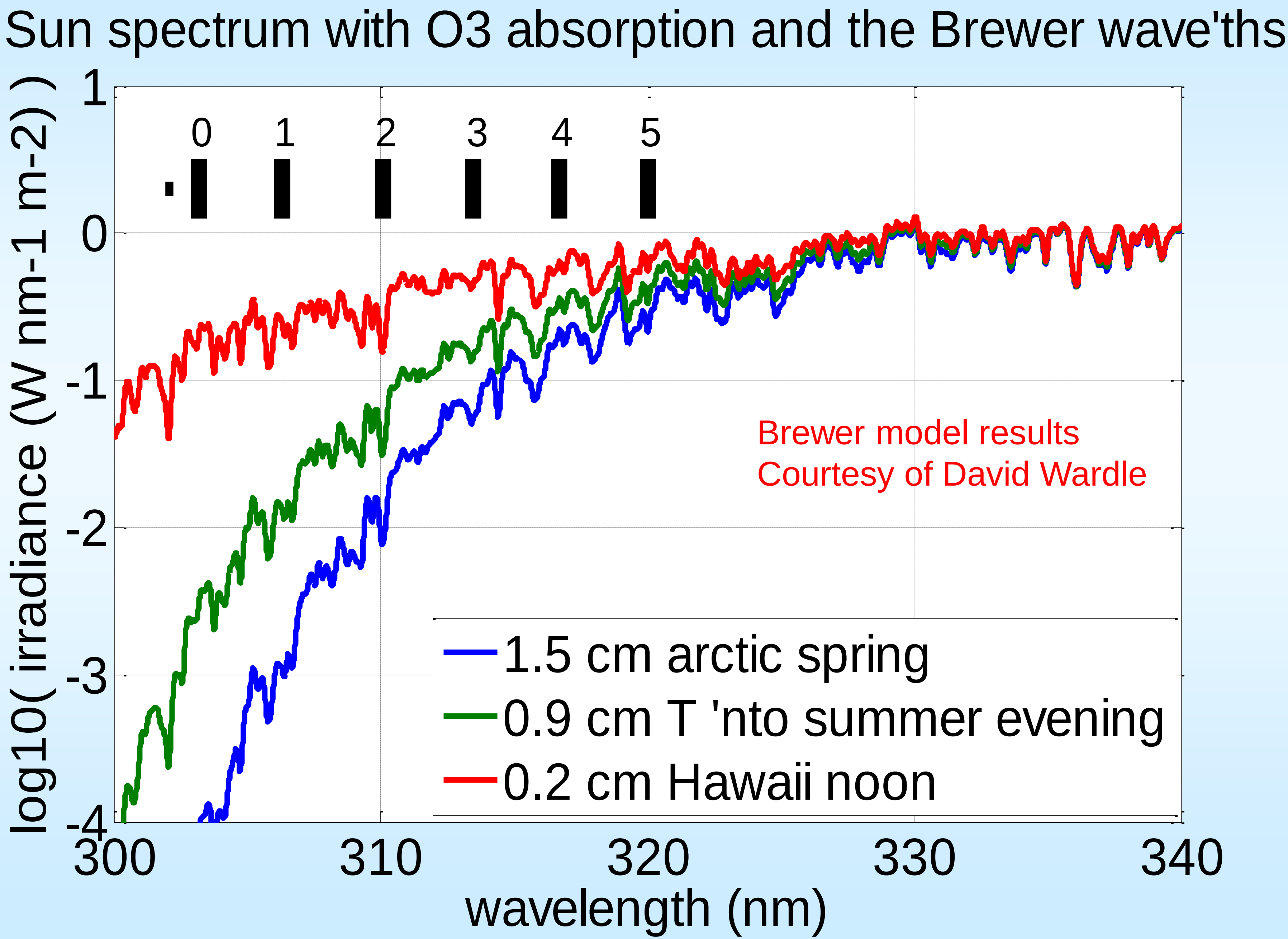


Modified Ebert spectrometer with multiple exit slits.

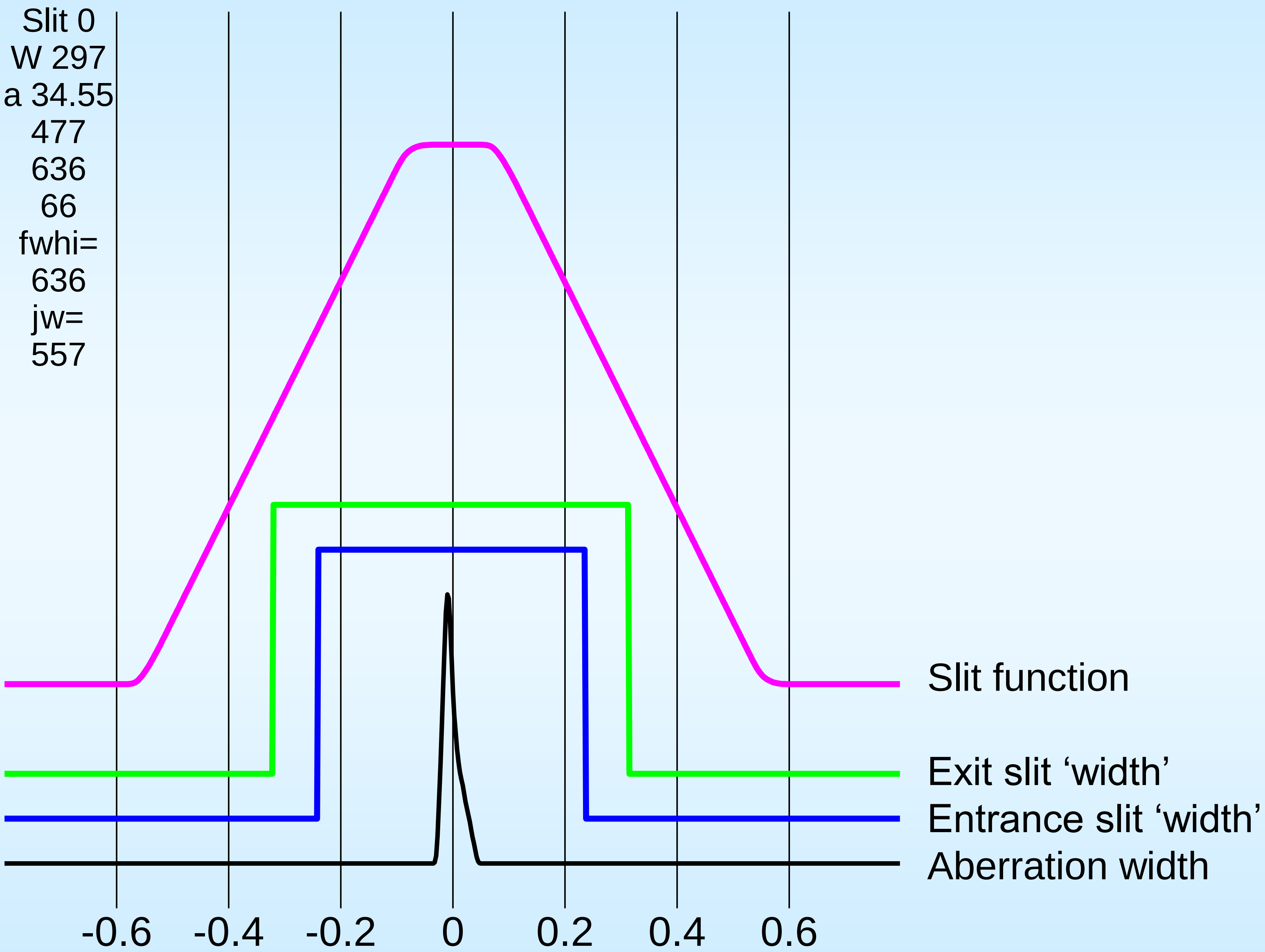
Serious Issues…

- Slit Function characterization
- Sensitivity, Etalonning & Pixel-to-pixel Gain
- Dynamic Range, Dark Count & Noise Level
- Stray Light, Linearity & Thermal drift (analog)
- Resolution, Free Spectral Range
- Wavelength Assignment

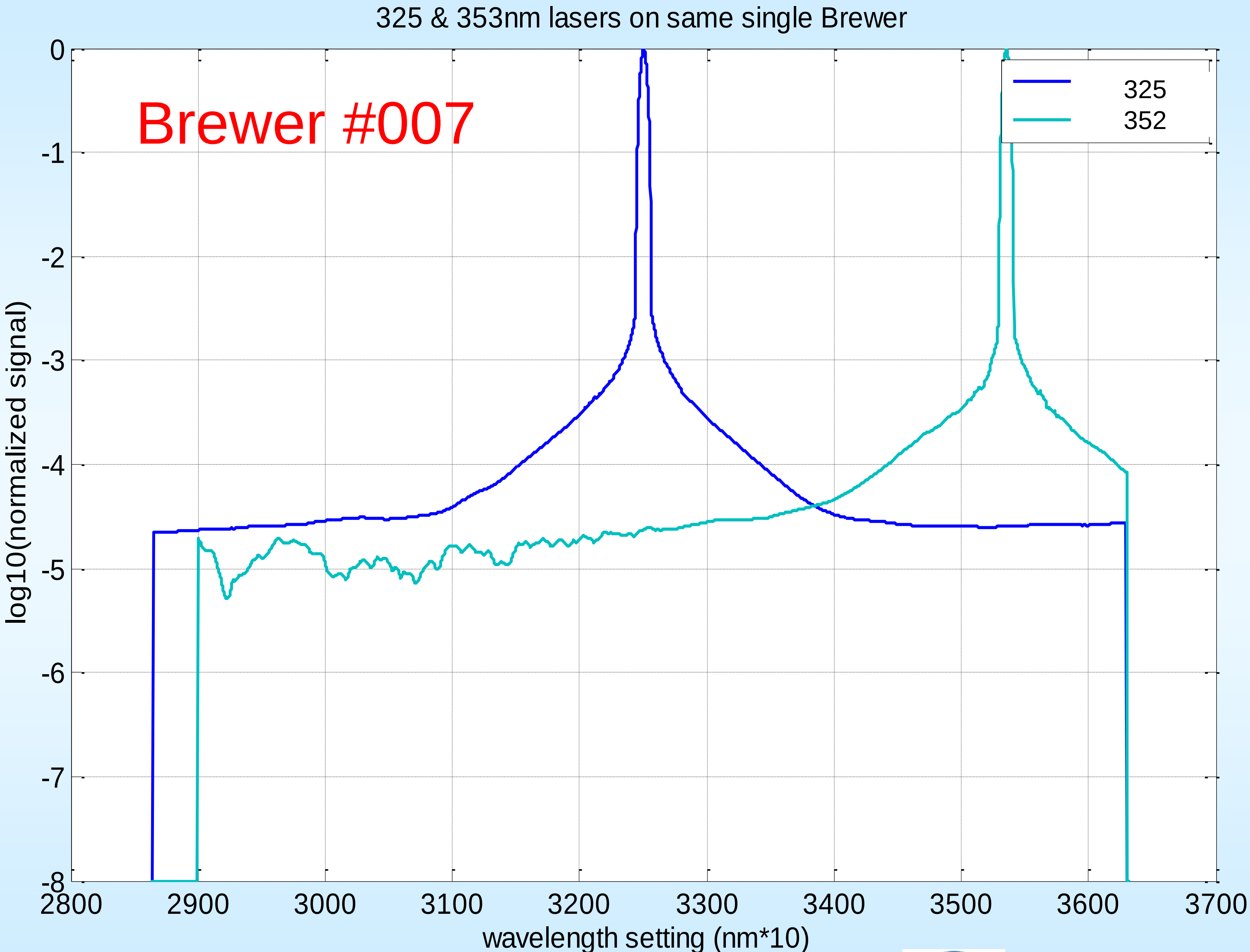
Solar spectrum and Brewer wavelengths



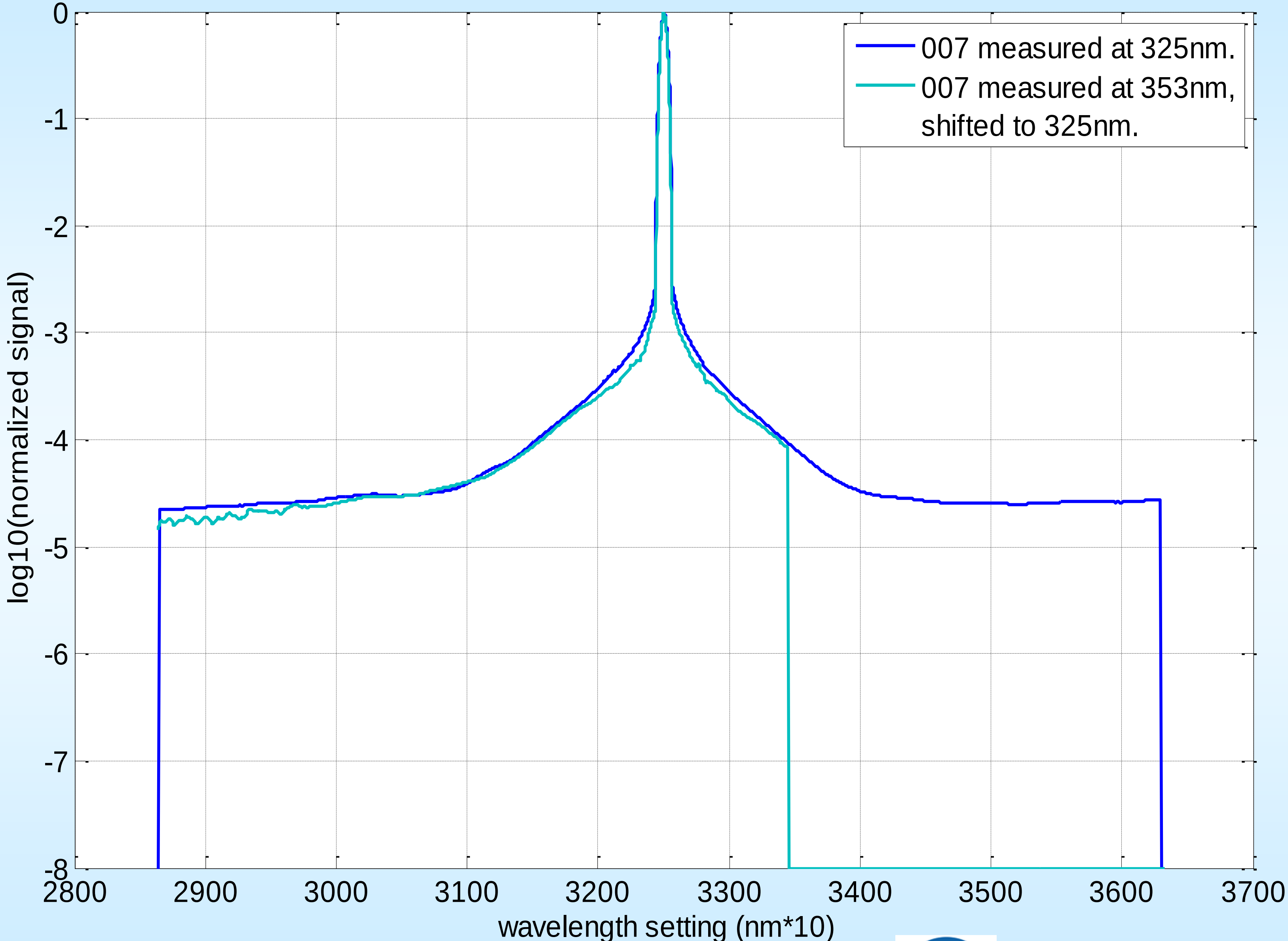
Slit #0 “slit function”



325 & 352 nm laser scans…………………



325 & shifted 353 laser scans…………………



Brewer Stray Light Corrections

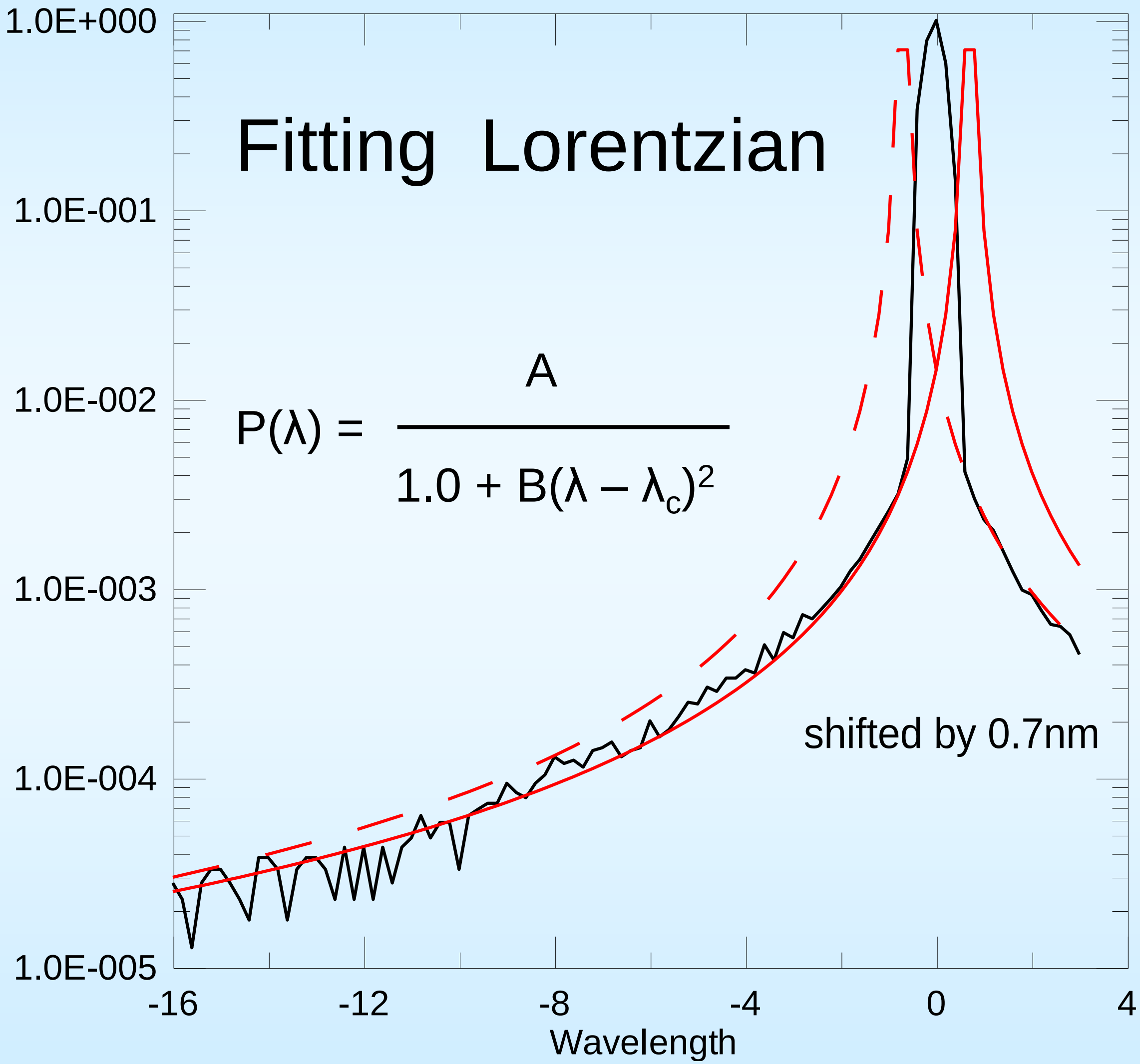
- Zero order correction:

  - counts between 290 and 292.5 averaged and subtracted from all other wavelengths

- Vitali Fioletov's somewhat better correction

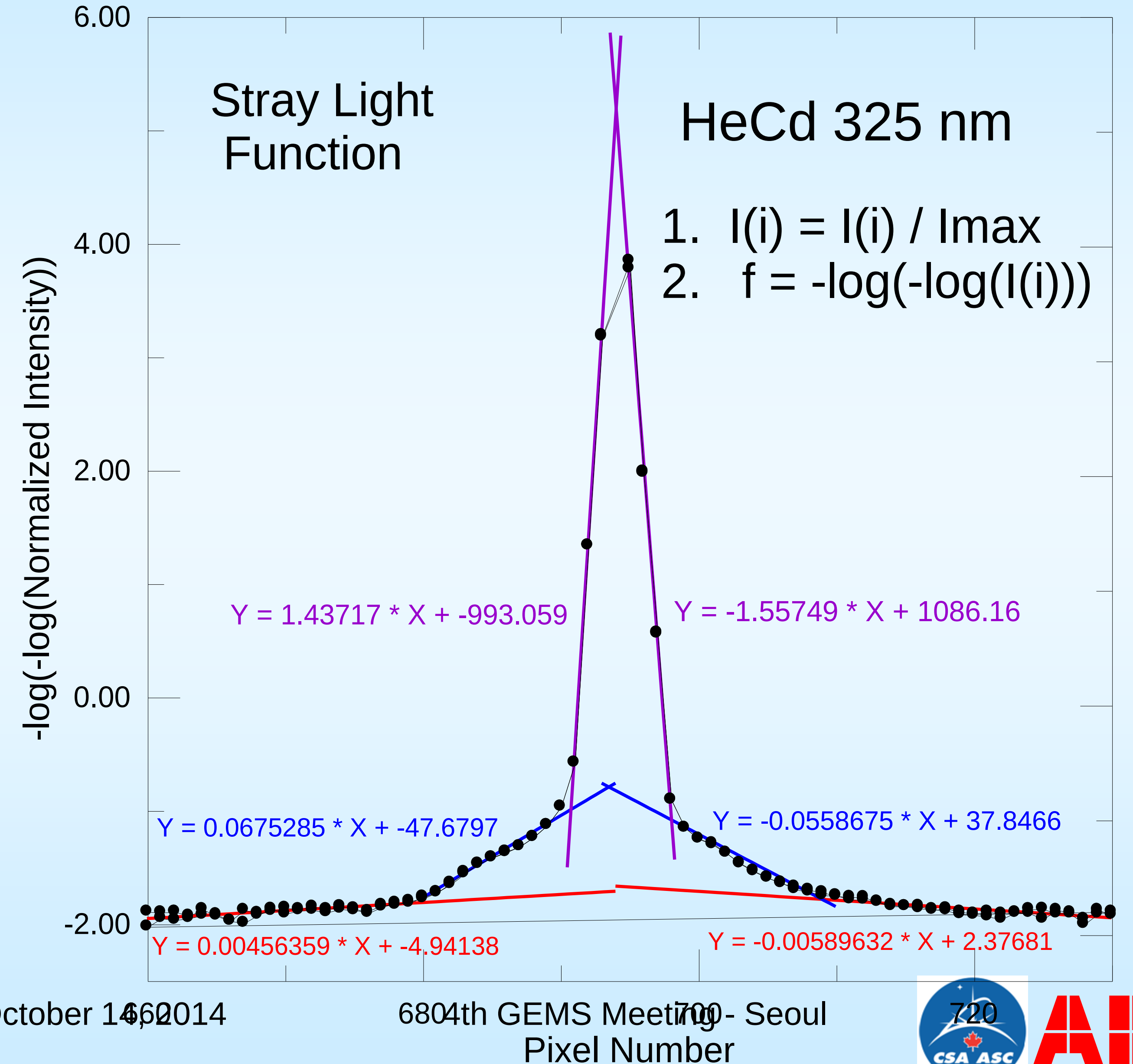
  - a theoretical correction made by convolving a spectrum with the stray light function scaled to match the value at 290 and then subtracted

Double Brewer Stray Light



Courtesy
C. McLinden

CPFM Stray Light Function



Stray Light Correction Algorithm

Write measured spectrum as: $I_m(w) = I_t(w) + I_s(w)$

Calculate $I_s(w) = \int I_g(w') \, q(w, w') \, dw'$

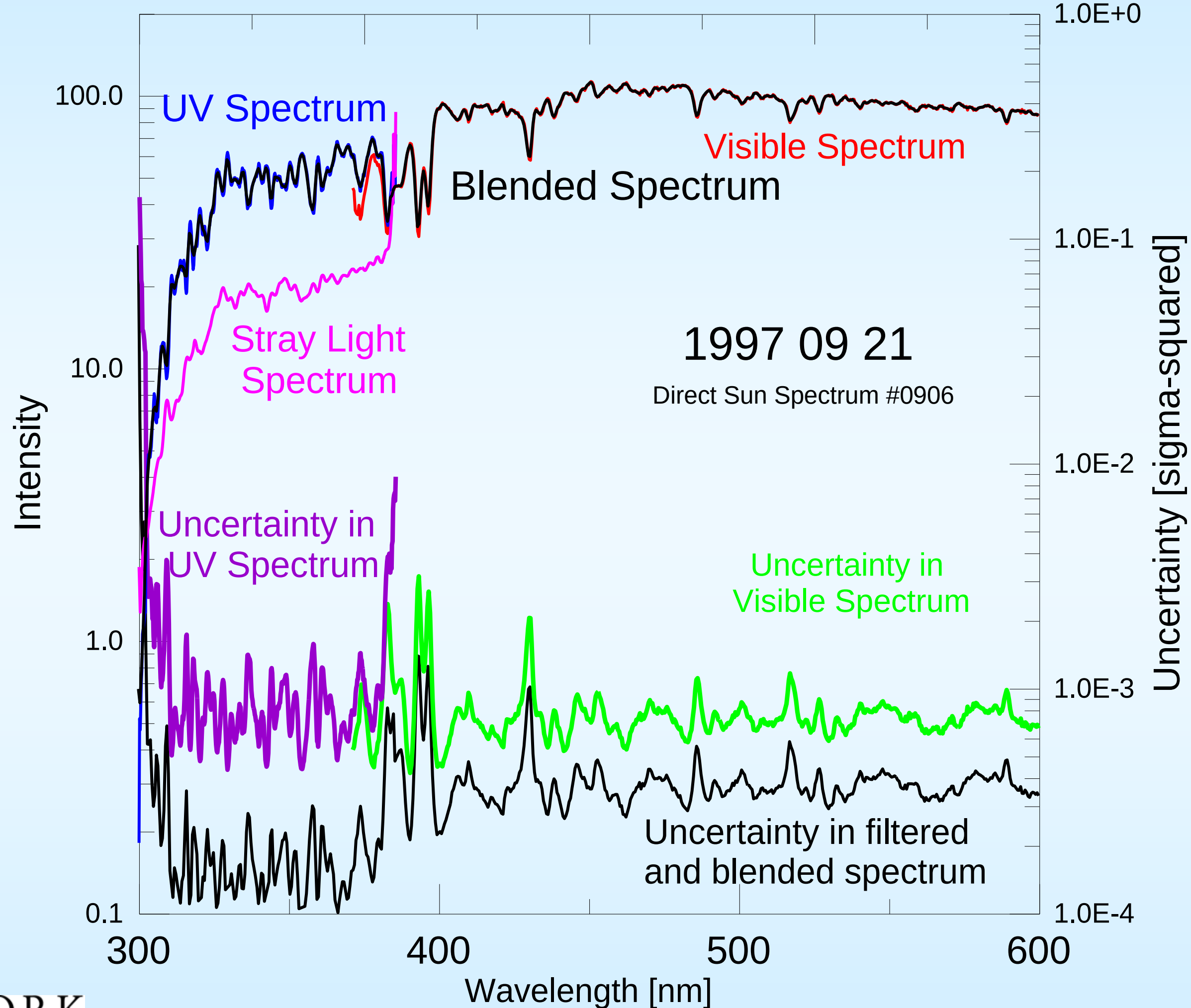
Using a ‘guessed’ $I_g(w) \sim I_m(w)$ to generate a better estimate of the true spectrum:

$$I_e(w) = I_m(w) - I_s(w)$$

It converges in a few iterations

Can be combined with a dark correction

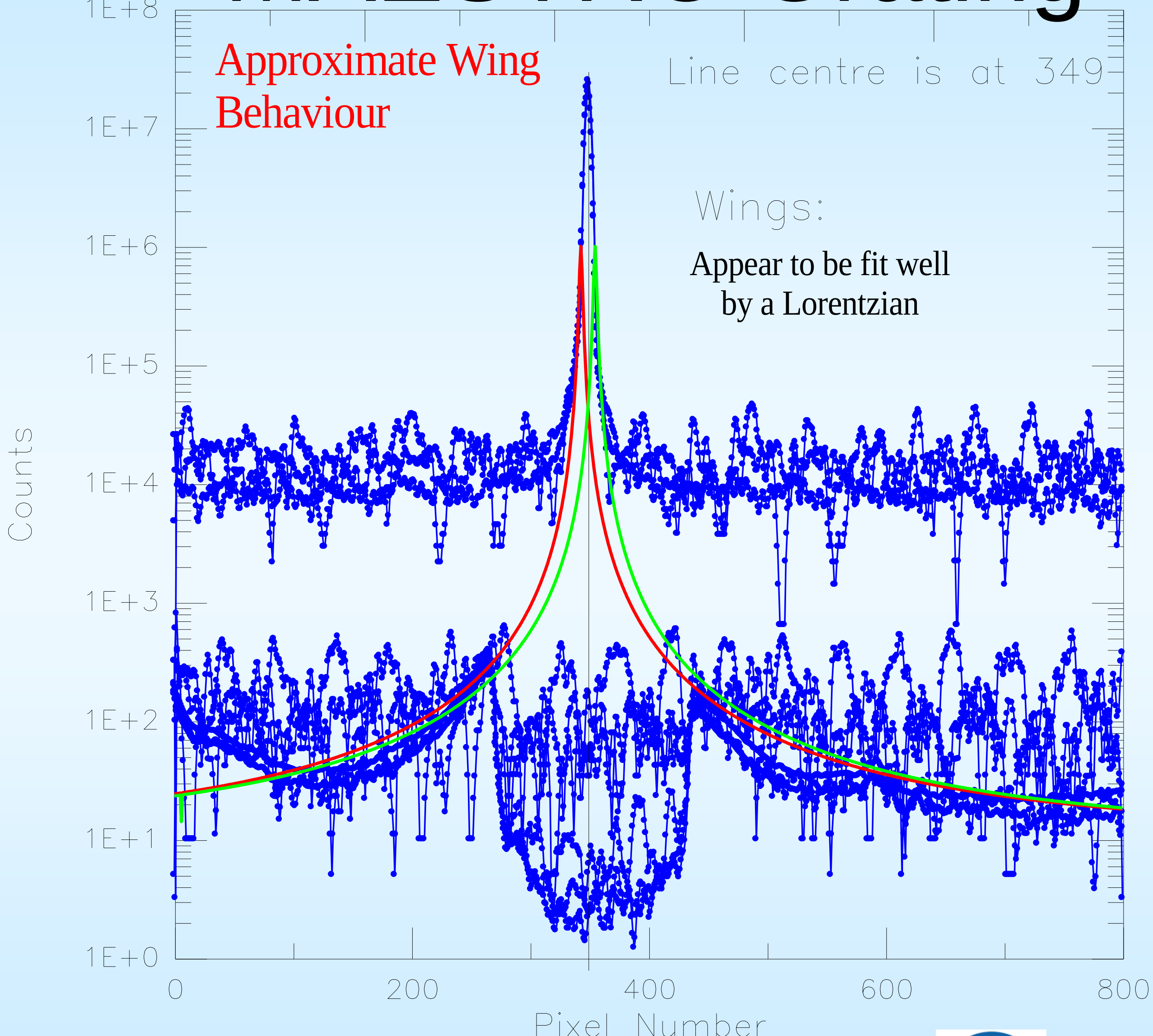
Sample Spectrum



The uncertainty in the combined spectrum is lower because some smoothing is applied and the smoothing function is wider in the UV to better match the resolution between the UV and visible.

Stray light becomes 60%
Of the total signal at 300 nm.

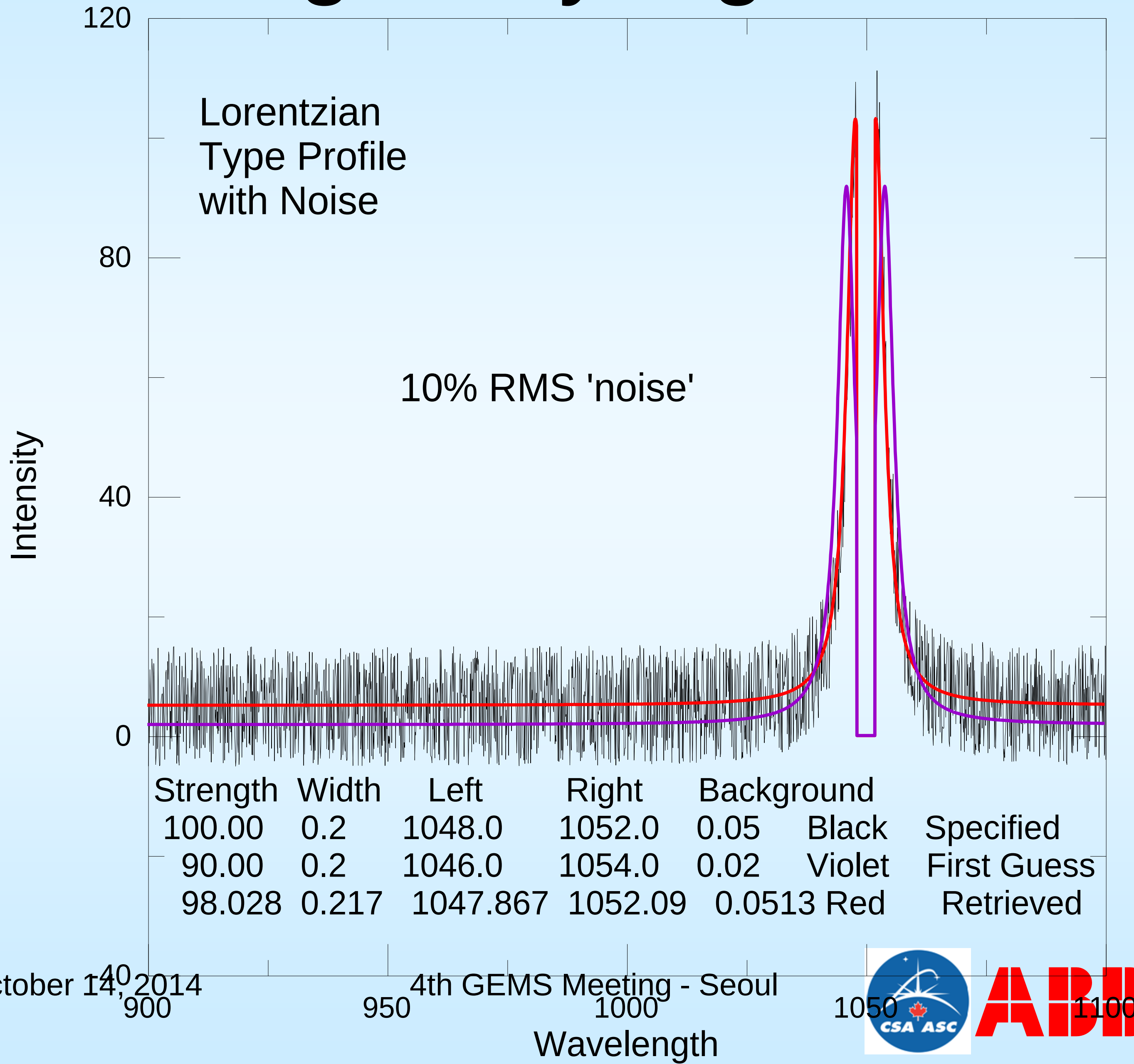
MAESTRO Grating



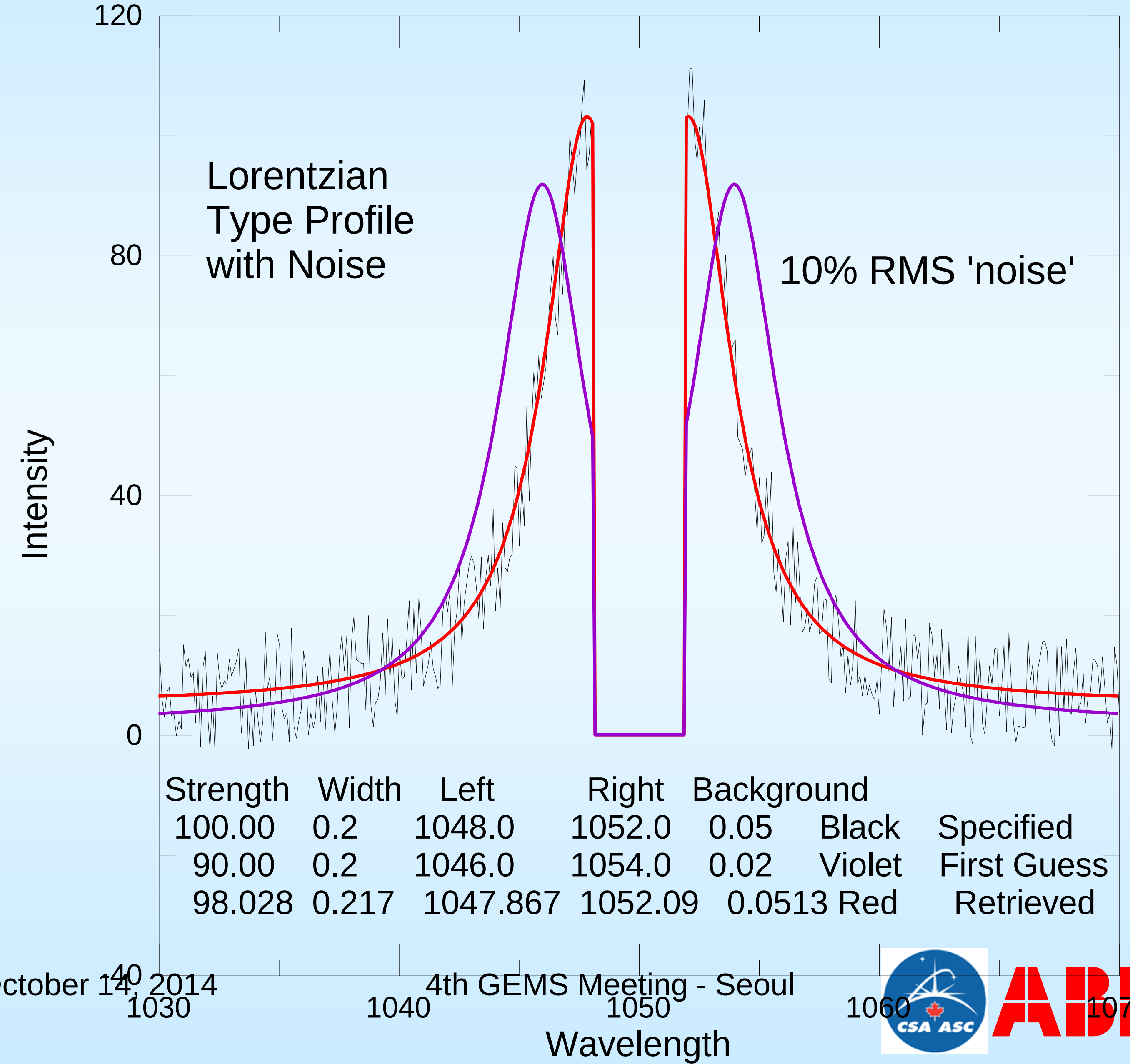
Full laser illumination

Centre of line blocked

Grating Stray Light - Wide



Grating Stray Light Function



Strength	Width	Left	Right	Background		
100.00	0.2	1048.0	1052.0	0.05	Black	Specified
90.00	0.2	1046.0	1054.0	0.02	Violet	First Guess
98.028	0.217	1047.867	1052.09	0.0513	Red	Retrieved

EG&G Reticon Detector - Details

- Commercial detector
- Used by ESA's GOME(2) & SCIA
- Large dynamic range
- High resistance to non-linearity
- <u>No blooming</u>
- Randomly addressable
- UV-enhanced Si photodiodes
- Electrometer amplifier
- 16 bit A/D input
- Controlled by soft-programmable FPGA (XILINX)

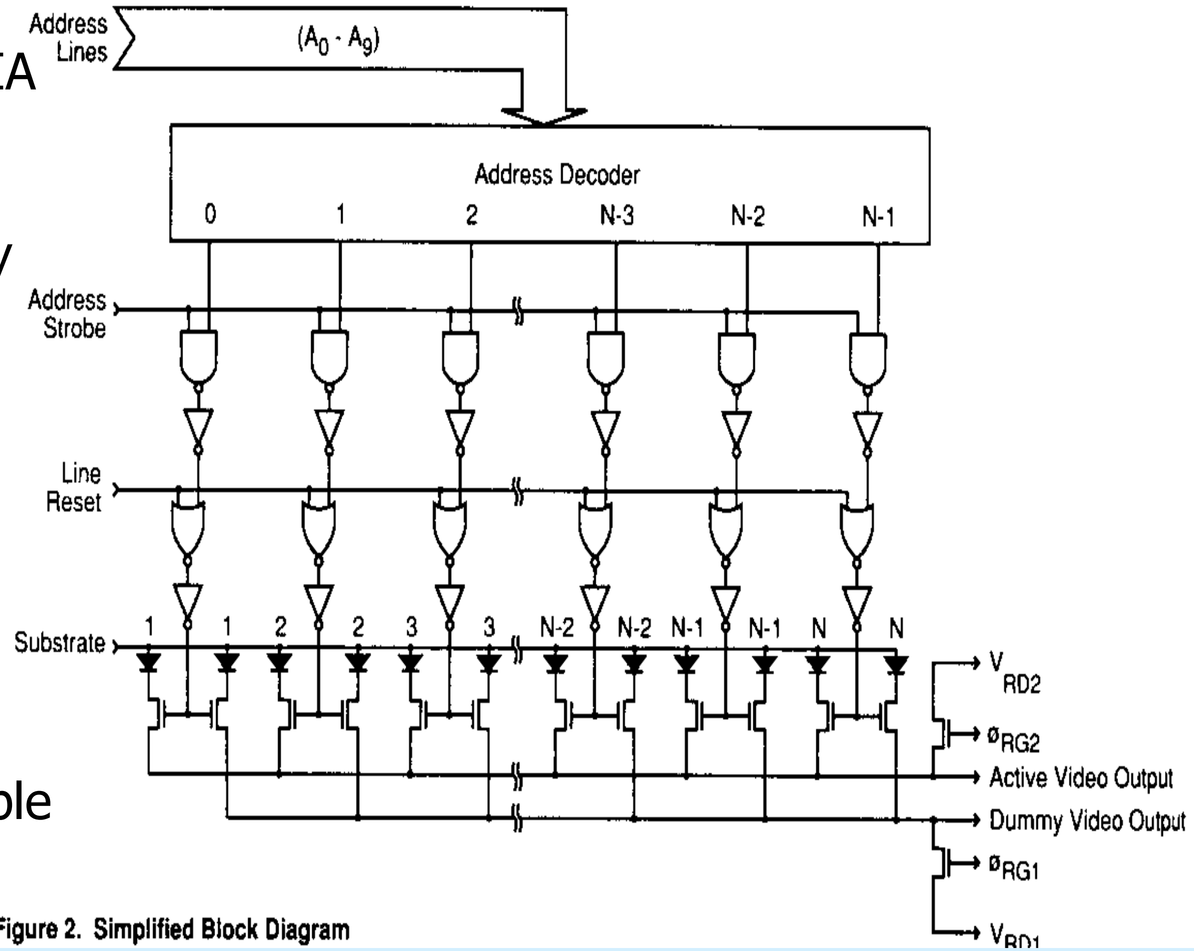
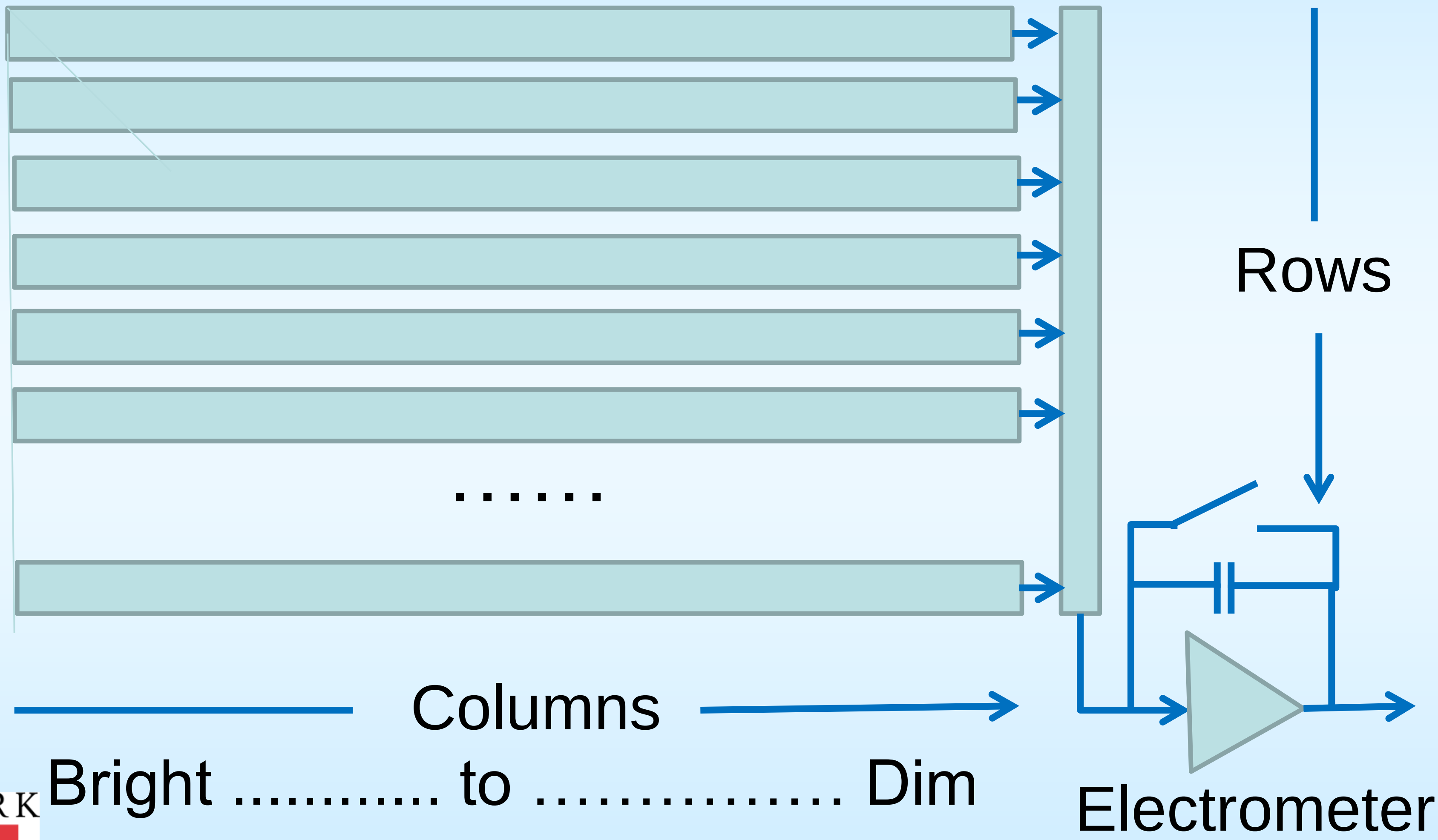


Figure 2. Simplified Block Diagram

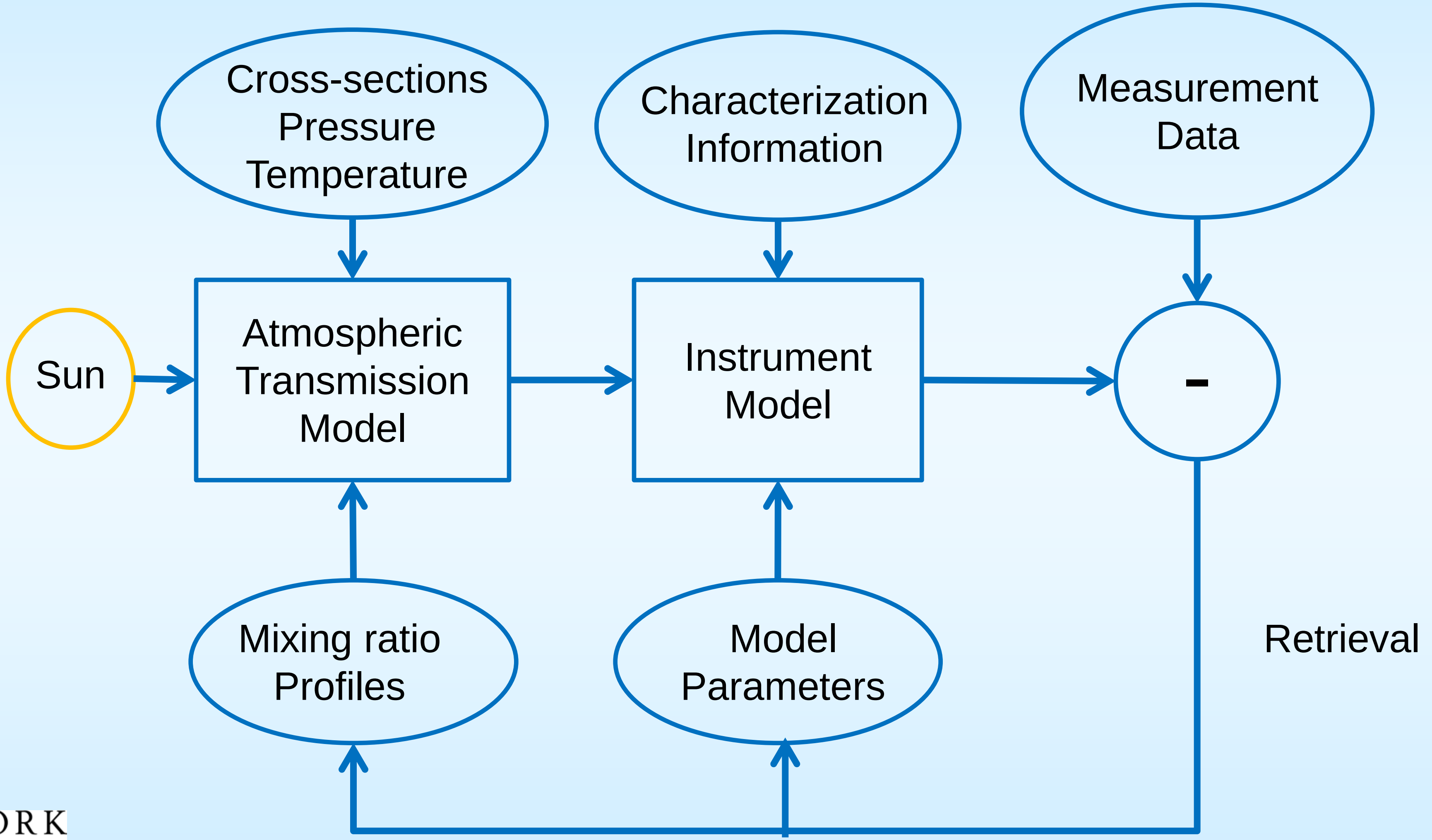
True CCD Detectors



Random Addressing

A detector like the HAS-2 with random addressing
Can be read out continuously
Each pixel is only contaminated by nearby pixels
Nearby pixels will have very similar signal levels
Much smaller correction problem

Forward Model Includes Instrument



Requirements

- Develop a model for the electronic offset

  (Extrapolate to zero integration time)
- Model dark count spectrum (key to dark pixels)
- Correct for imperfect detector reading

  (Charge carry-over – fit pixels with no ‘real’ light)
- Correct for stray light
- Include a representation of all of these effects in the instrument forward model. Then the parameters may be – at least partially – retrieved using on-orbit data. For example by reading detectors that are not illuminated and at very short wavelength

Retrieving Model Parameters

- Different types of measurements for different purposes
- Long integration times test linearity of signal processing
- Laser measurements for stray light at different wavelengths (wavelength dependence of slit function and stray light?)
- Blocked line centre measurements to separate electronic offset from stray light
- Glass filters can also be used for this

(They look like ozone)

- Laser light can be added on top of white light background for testing

YORK U UNIVERSITÉ UNIVERSITY

Consider how much can be done on orbit to track changes…


Thank you!
ACE Arctic Campaign
Sunrise 2007
Photo by
P. Fogal

Basic system

For a single wavelength input to a spectrometer we can write

Signal = intensity of input * $f(\lambda, \lambda_s)$

where λ is the wavelength of the input radiation
& λ_s is the wavelength setting.
$f(\lambda, \lambda_s)$ is a response function converting intensity to count rate
Note: the dispersion function is λ_s = F(steps or pixels)

We often do a line scan in which we
use a constant input λ, and vary the setting λ_s.
(What is more relevant is changing the input λ given a constant setting.)

Stray light continued………………..

For a spectrum of input radiation:

$$Signal(\lambda_s) = \int P(\lambda)*f(\lambda, \lambda_s)*d\lambda$$

Where $P(\lambda)$ is the spectral irradiance (watts m^{-2} nm^{-1})

Most spectrometer users assume the above can be simplified to:

$$Signal(\lambda_s) = \int P(\lambda)*R(\lambda)*q(\lambda - \lambda_s)*d\lambda$$

R may be called the responsivity and q the “slit function,” and q(0)=1.

Not entirely correct.