REVISING THE APPROACH TO THE MEASUREMENT OF SOLAR DIAMETER WITH THE ECLIPSE OBSERVATIONS

Andrea Raponi

SUMMARY

1. Problems with the Classical Method

2. Understanding the Light Curve of the Bead

3. An application of the revised method

The **Classical Method** measures the solar radius considering Baily's beads like **on-off events** ➜ the luminosity profile of the solar limb is a **step function**: when the beads appear (or disappear) the step has overcome the lunar edge in a lunar valley.
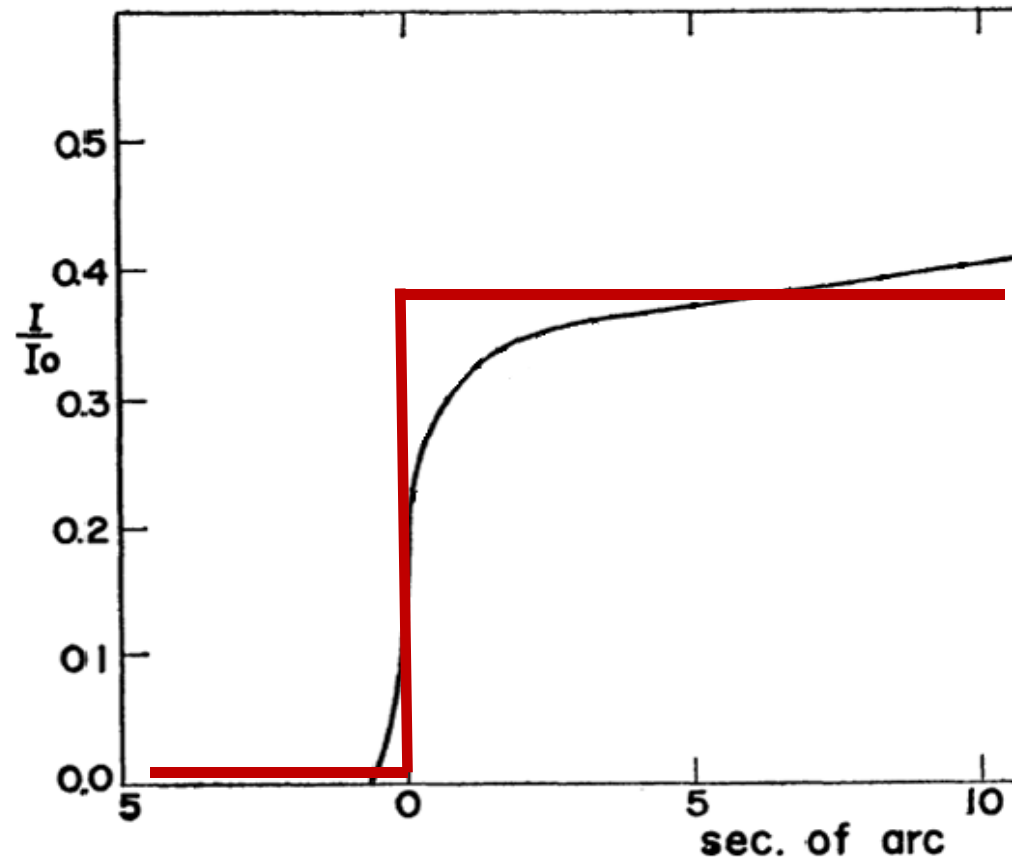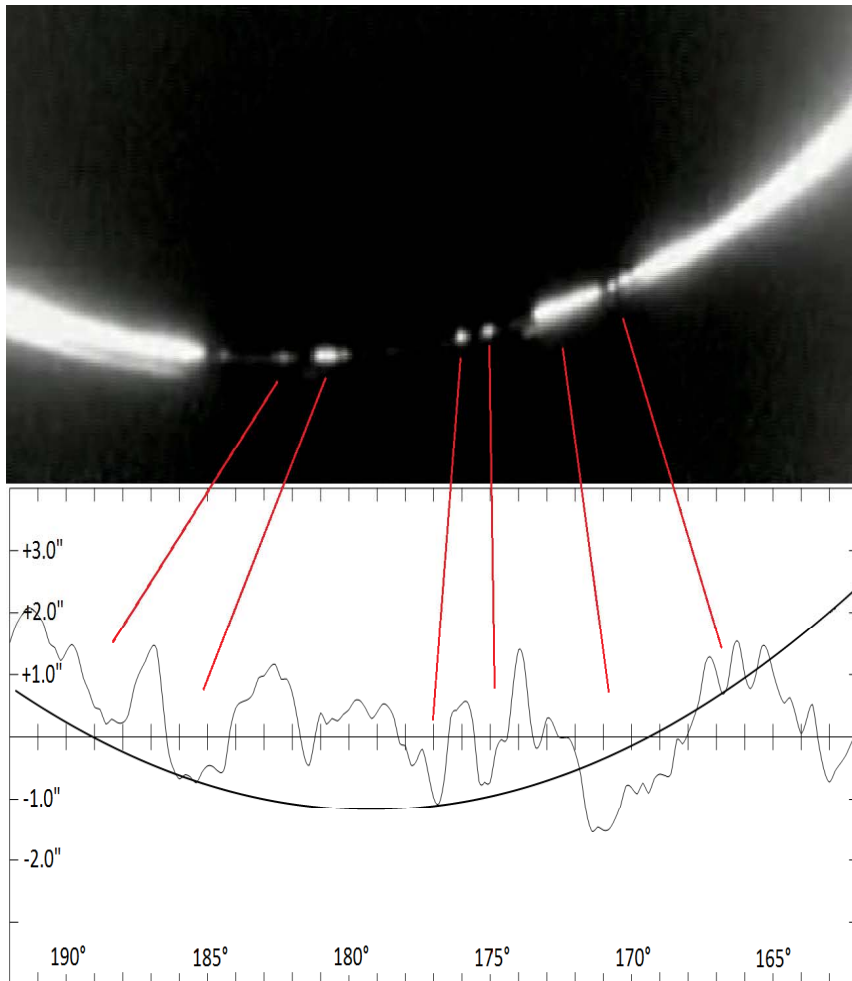
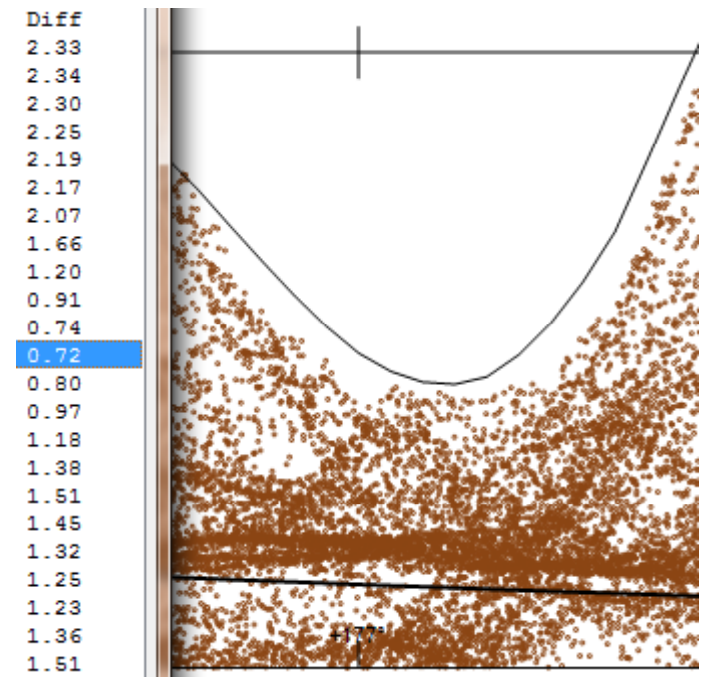**The limb profile like a step function.. always reasonable?**
Example: bead at AA = 177° during eclipse on 15 Jan 2010
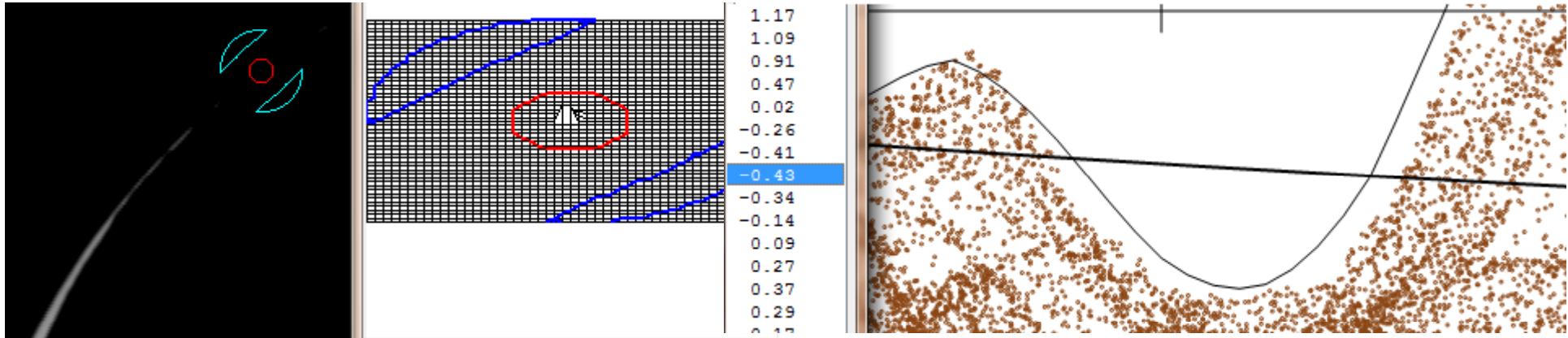
A. Tegtemeier, India: the bead appears when the
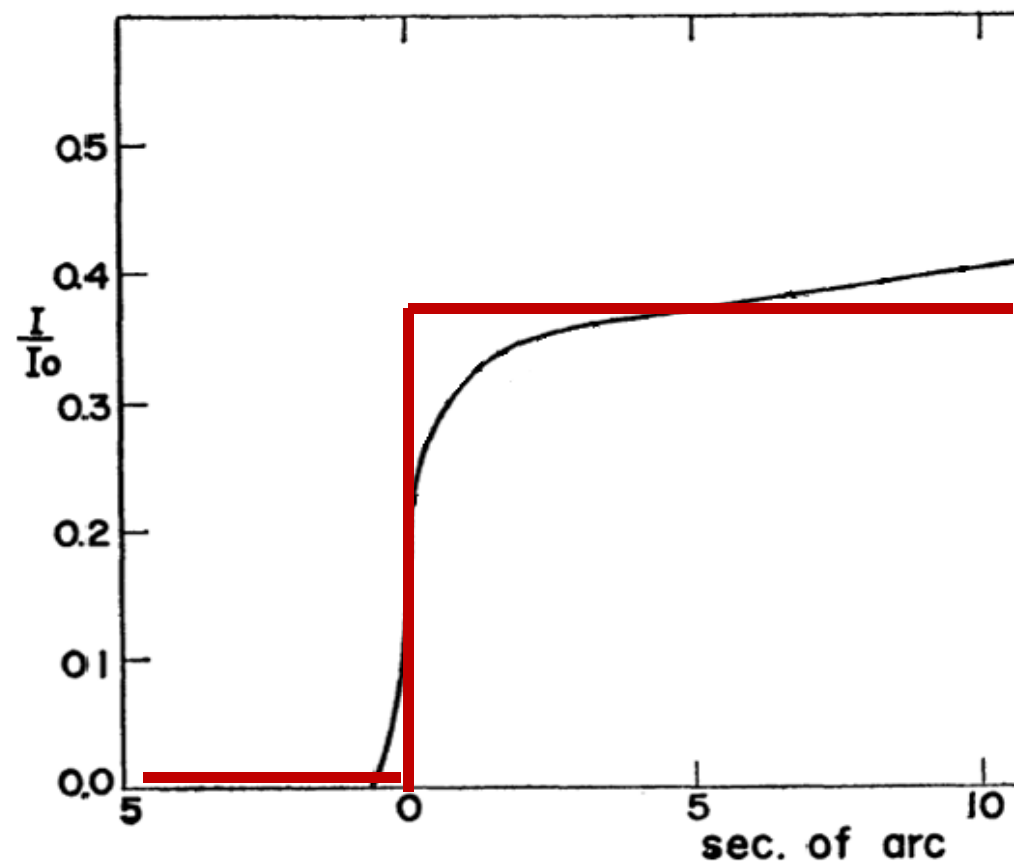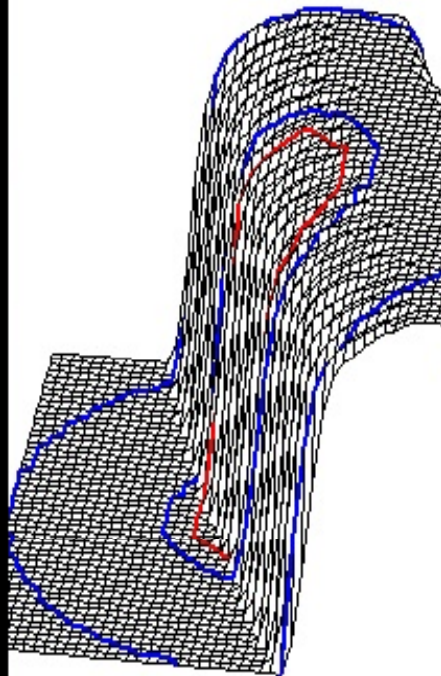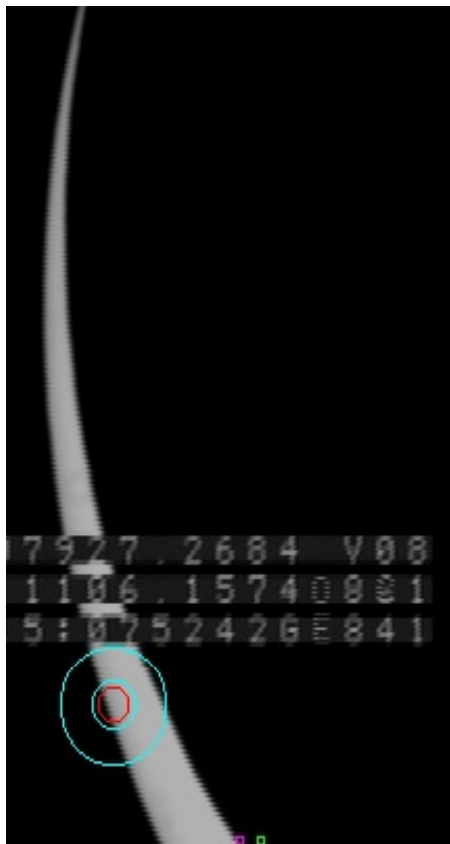standard limb is **0.43 arcsec over** the mean lunar limb

R. Nugent, Uganda: the bead disappears when the
standard limb is **0.72 arcsec under** the mean lunar limb
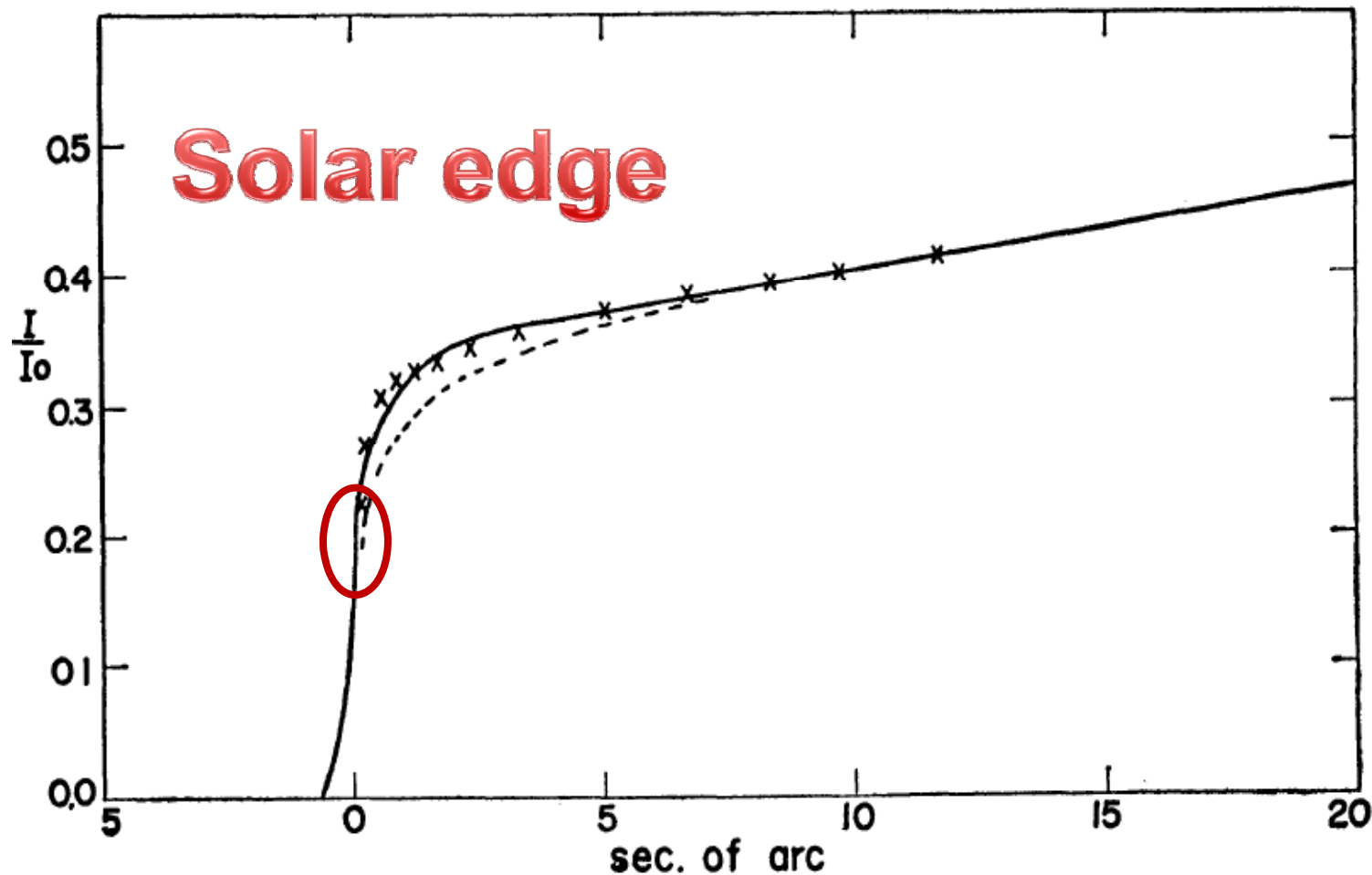
Explanation:

➢ Different optical instruments have different sensitivity and different Signal / Noise ratio

➢ The Limb Darkening Function is **not** a **step profile**:
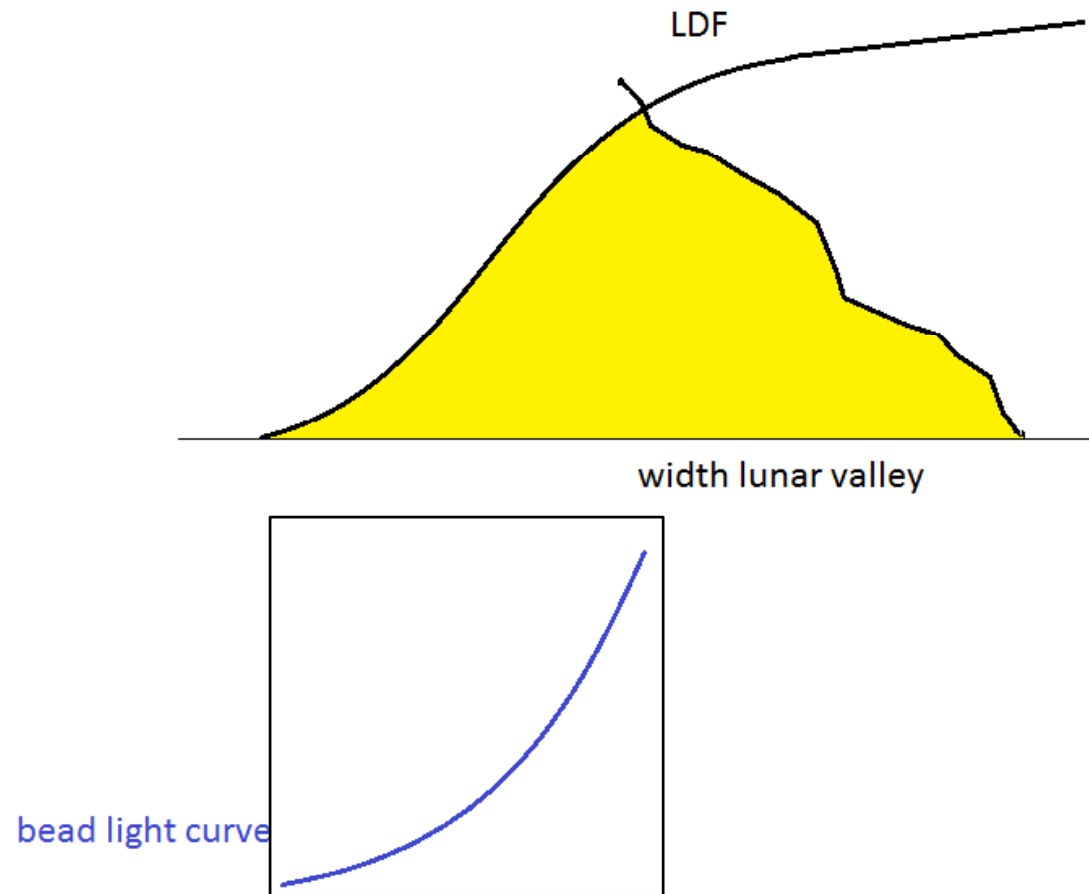we can not consider the bead as an ON-OFF signal

We have to take into account the whole shape of the Limb Darkening Function (LDF). The Inflection Point Position of the LDF is the definition of the solar edge.

We can consider the light curve of the bead as a convolution between the LDF and the width of the lunar valley ω:

LDF

width lunar valley

bead light curve

Bead Light Curve   Width of the Lunar Valley

$$L(y) = \int LDF(x)\, w(y - x)\, dx$$

Distance between lunar edge and standard solar edge

Obtaining the Limb Darkening Function from the Bead Light Curve is not straightforward because one has to analyze the shape of the Lunar Valley (the function ω) and perform the deconvolution.
But we can assume ω like a step function, namely the valley like a rectangle:

$$\omega = \begin{cases} 0 & for \ \ x < y \\ \\ k & for \ \ x > y \end{cases}$$

➔ *First Derivative*

$$L(y)' = k \cdot LDF$$

Linear transformation of the LDF, keeping its shape and thus its Inflection Point Position.

Summarizing up to here:

✓ We have to detect the Limb Darkening Function to obtain the Inflection Point Position: the LDF is not a step function.

✓ We assume the shape of the lunar valley like rectangular: ω is a step function. This assumption does work!

✓ We assume the light curve of the bead forged solely by the LDF. Namely there are not instrumental or atmospheric effects. This assumption has to be verified case by case.

✓ All we have to do to obtain the LDF is the first derivative of the whole light curve of the bead. If the inflection point is inside the LDF detected, we can infer a measure of the solar radius.

STEP 1/6 *Select the useful part of the light curve*

first frame: where the signal overcomes 5σ of the background noise
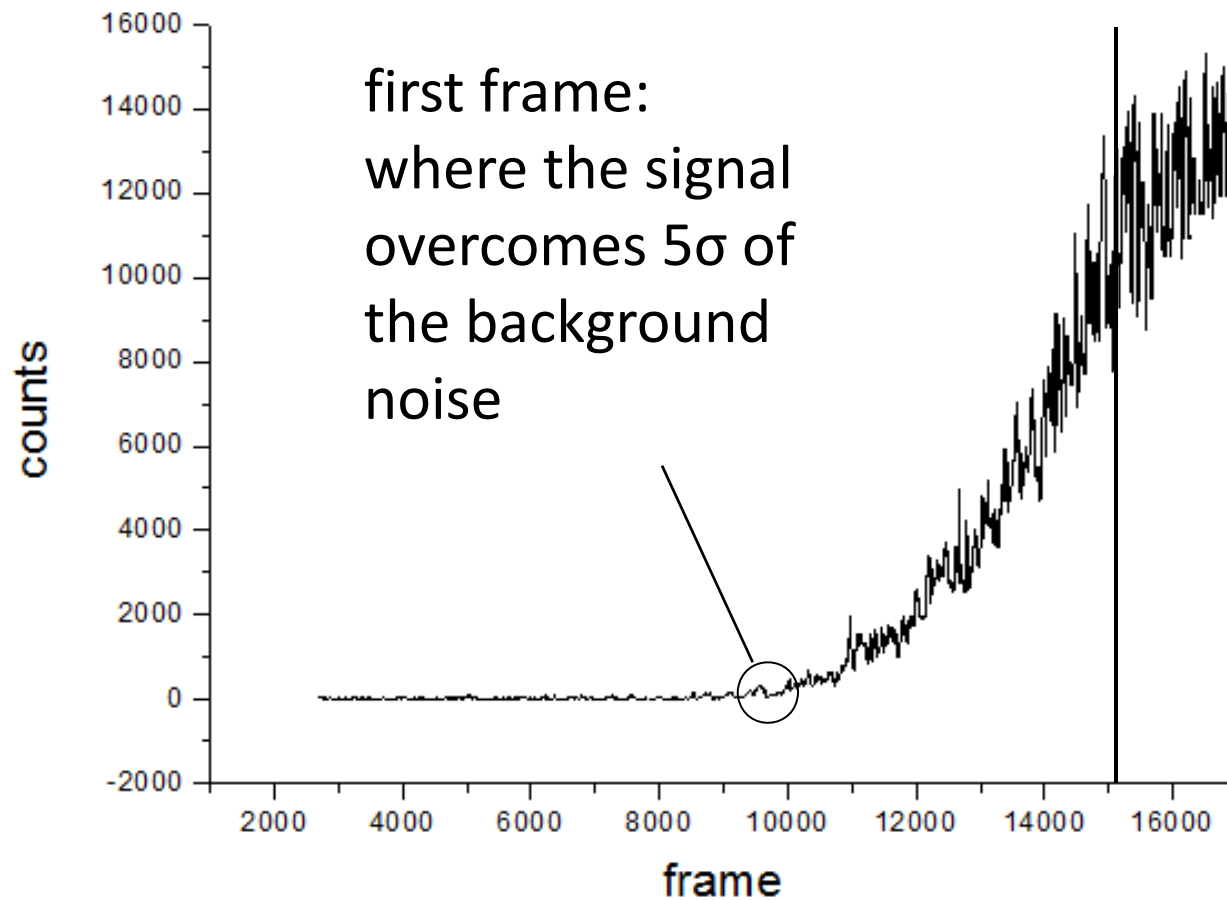
last frame: when the bell shape of the bead (3D window) reach its top
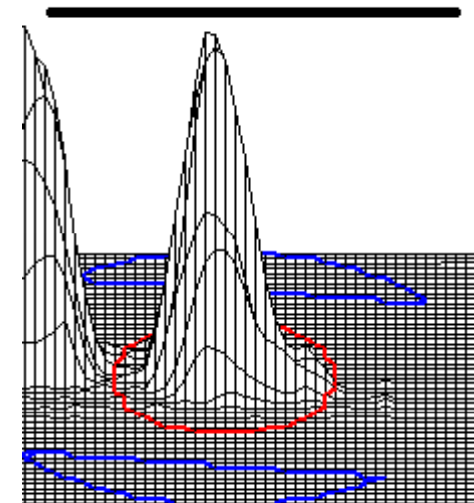
STEP 2/6 *Find the relation: Frame - UTC Time*

To plot the light curve of the bead in function of the time

5:26:00   28

Current Frame   ◄   ►

1107 |◄◄| ◄ | -10sec | -1sec | -1Fr | ► | ■ | 1Fr+ | 1sec+ | 10sec+ |
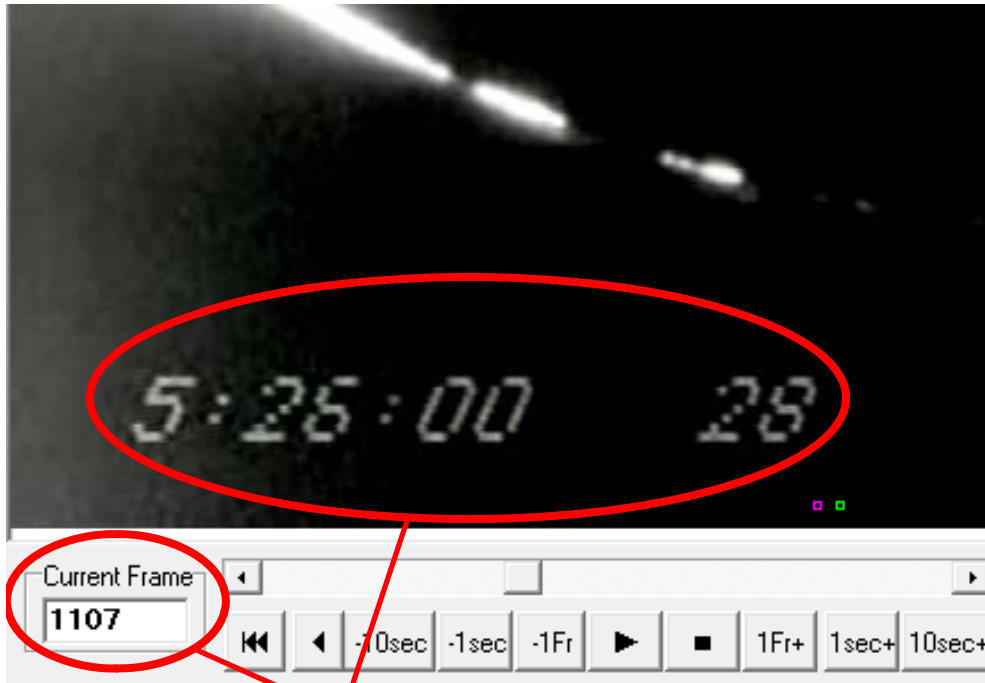
time = frame · m + q

m = (time2-time1) / (frame2-frame1)
q = time1 - frame1 · m

counts

frame ⇒ time
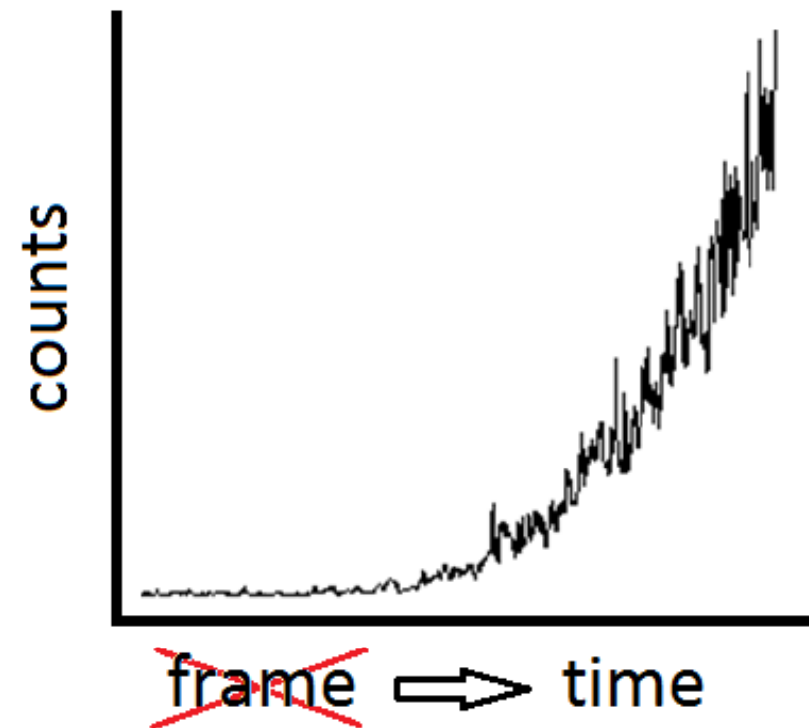
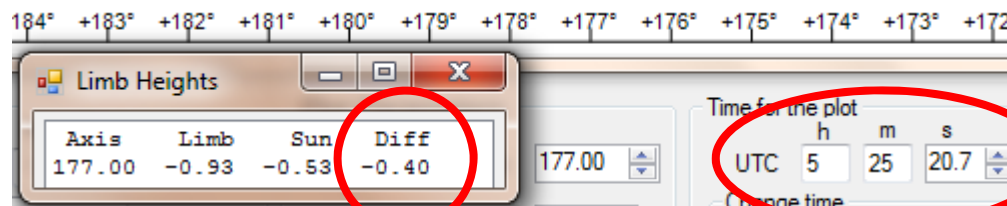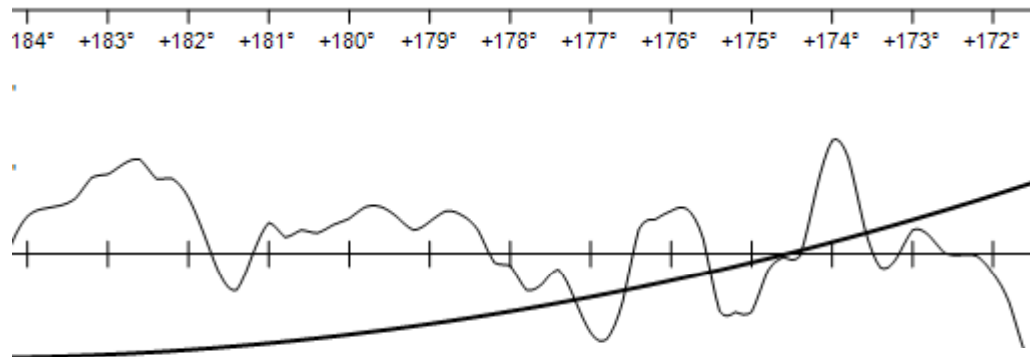## STEP 3/6 *Perform polynomial fits to flatten the noise*

There are different functions that fit the light curve.
We can take polynomial functions from 3ᵛ to 9ᵛ grade.
Their differences are due to the electronic noise.
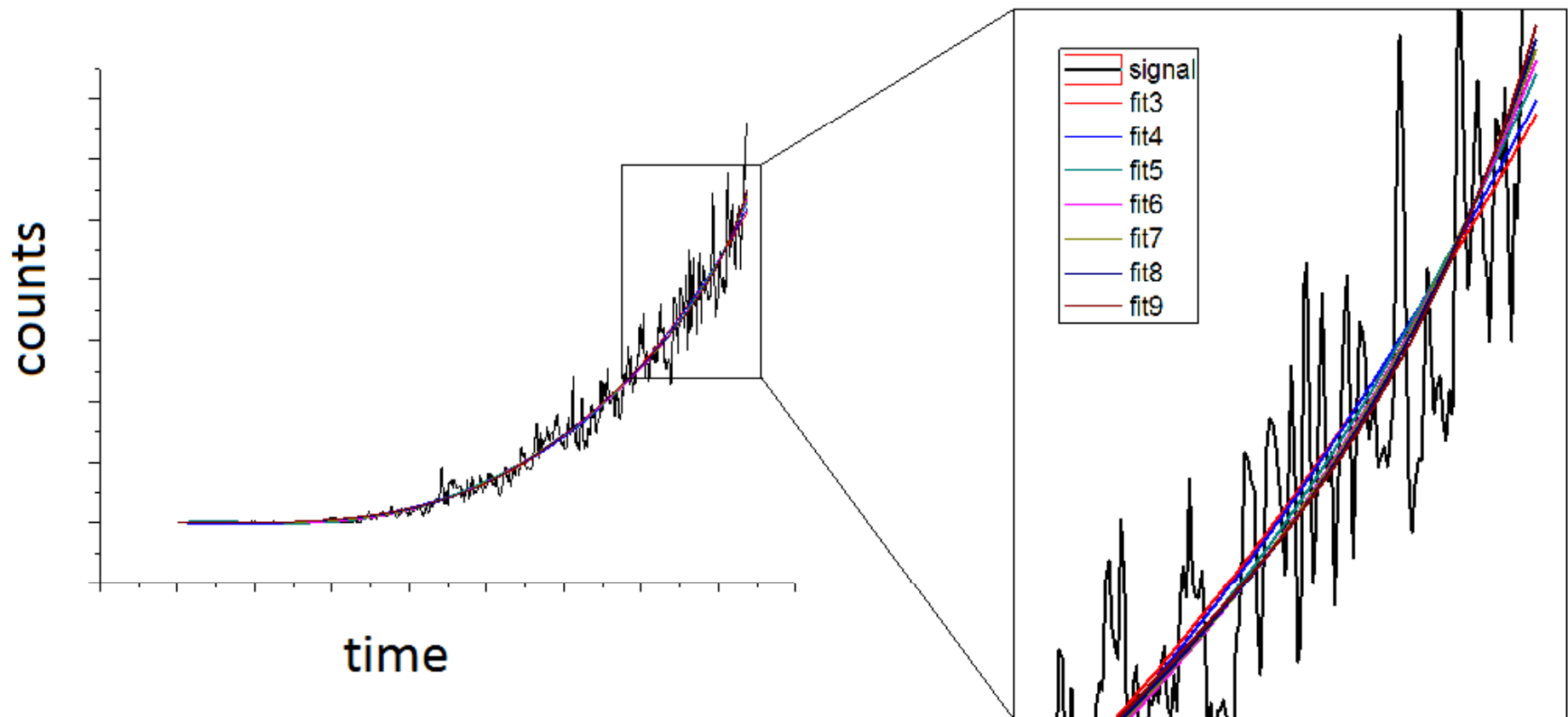
STEP 4/6 *Find the relation: UTC Time – y (ΔR)*
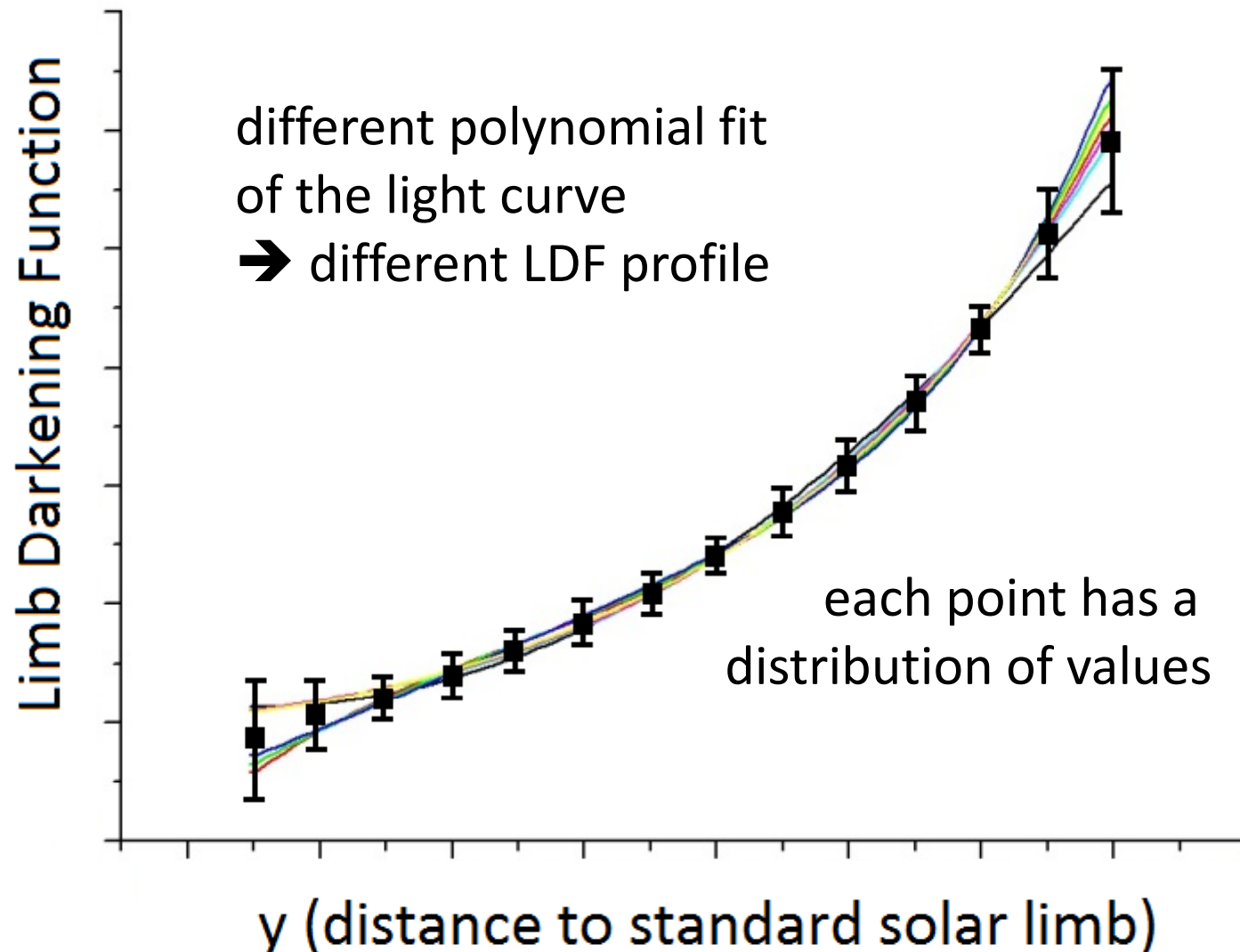
To plot the light curve of the bead in function of ΔR. At this point we have some polynomial fits instead of the signal detected.

184° +183° +182° +181° +180° +179° +178° +177° +176° +175° +174° +173° +172°

184° +183° +182° +181° +180° +179° +178° +177° +176° +175° +174° +173° +172°

Limb Heights

Axis	Limb	Sun	Diff
177.00	−0.93	−0.53	−0.40

177.00

Time for the plot

	h	m	s
UTC	5	25	20.7

Change time

$y = time \cdot m + q$

$m = (y2 - y1) / (time2 - time1)$

$q = y1 - time1 \cdot m$

counts

time ⟹ y
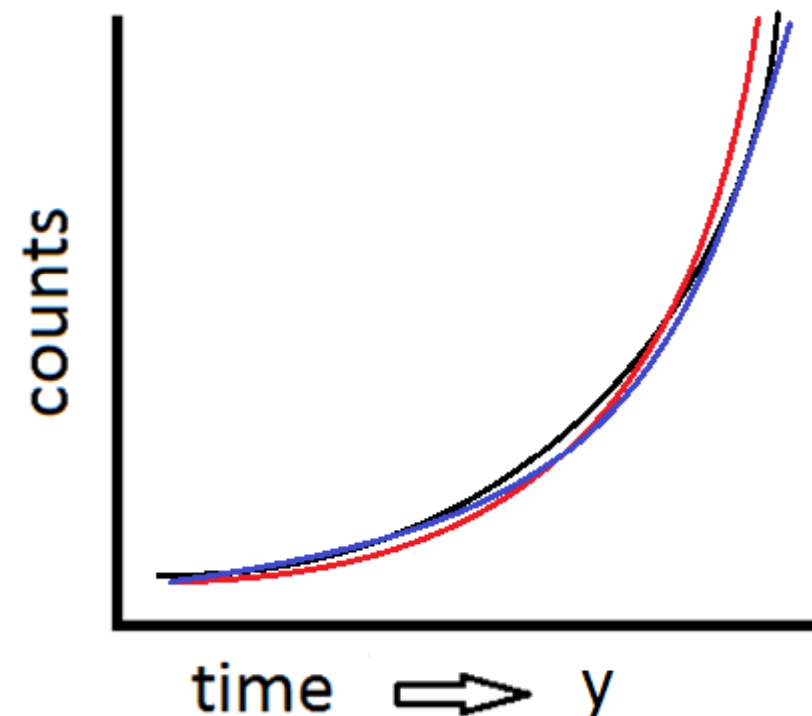
STEP 5/6 *Perform the first derivative to find the LDF*

different polynomial fit
of the light curve
➔ different LDF profile

each point has a
distribution of values

Limb Darkening Function

y (distance to standard solar limb)

STEP 6/6 *Infer the Inflection Point Position:*
8 bits dynamic range, diverse observations

Eclipse 15 Jan 2010

A. Tegtmeier, lunar valley AA = 171°

R. Nugent, lunar valley AA = 177°
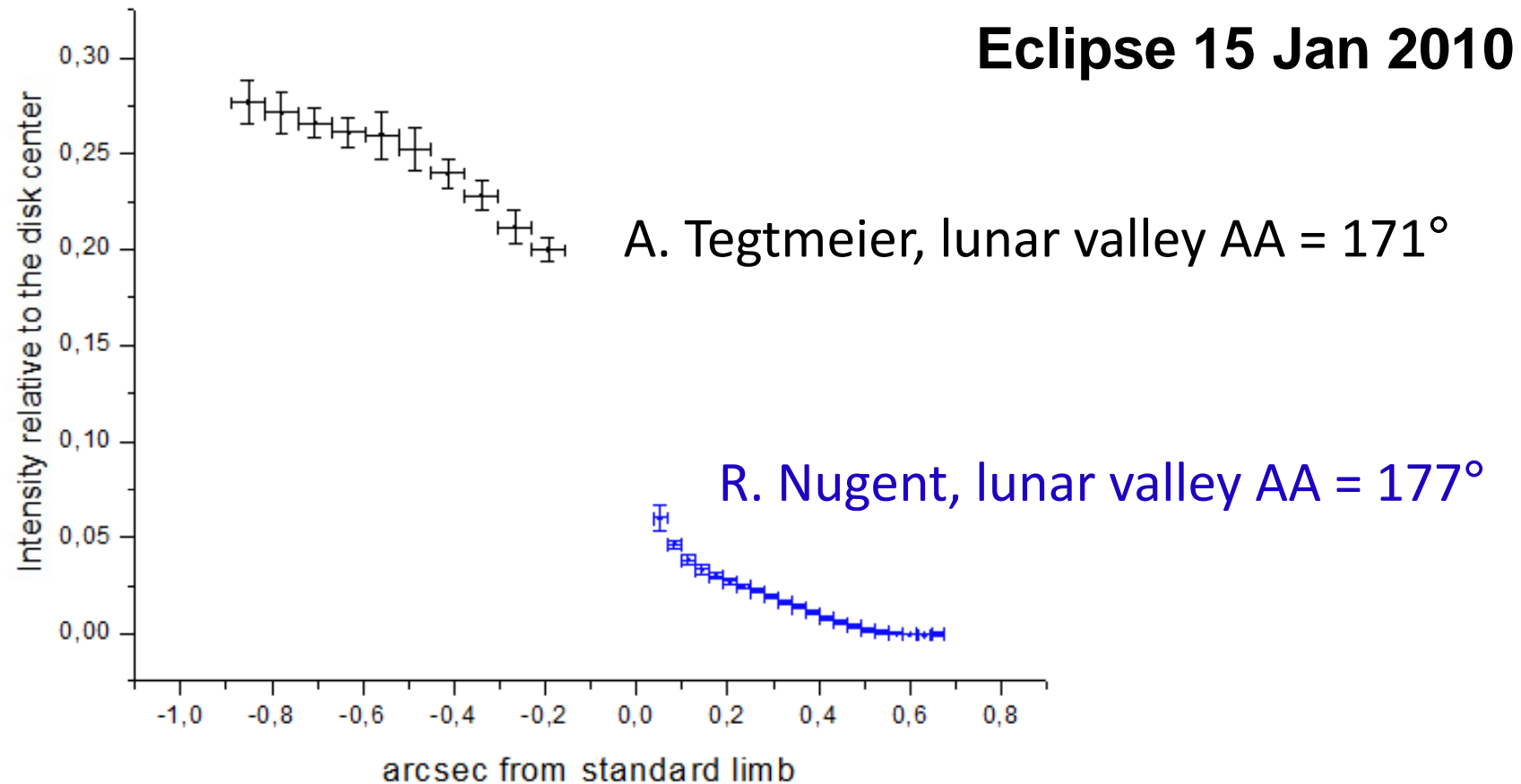
-0.19 arcsec < ΔR ($R_{real} - R_{standard}$) < +0.05 arcsec

STEP 6/6 alternative *Infer the Inflection Point Position: 12 bits dynamic range, single observation*

First derivative of the LDF
(second derivative of the light curve)
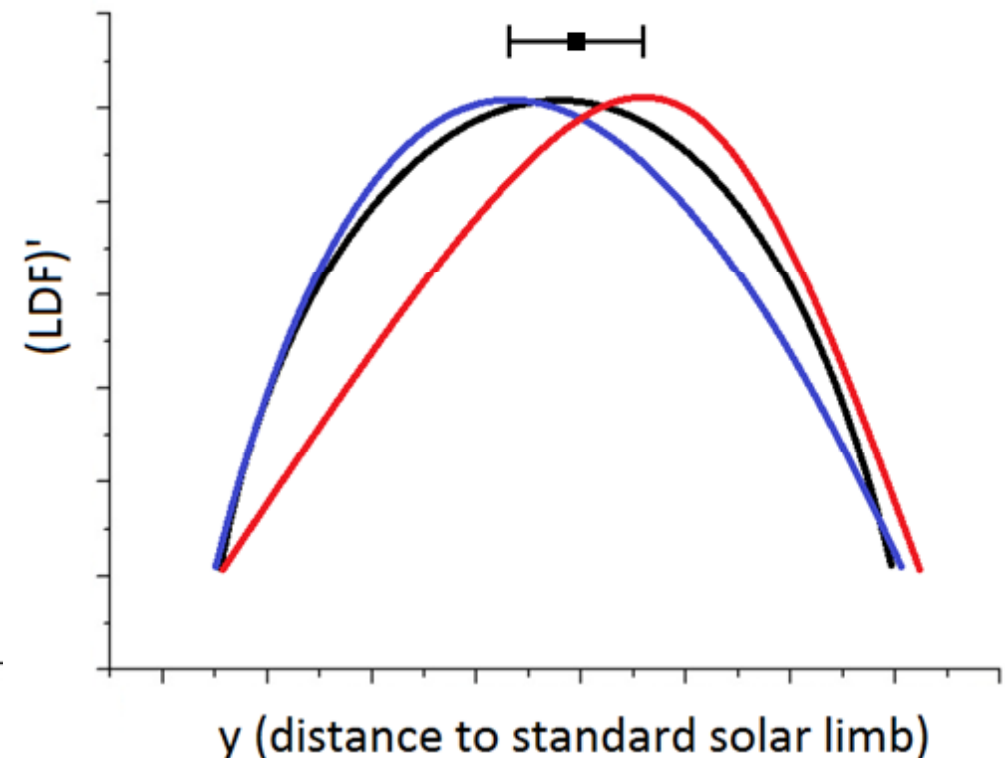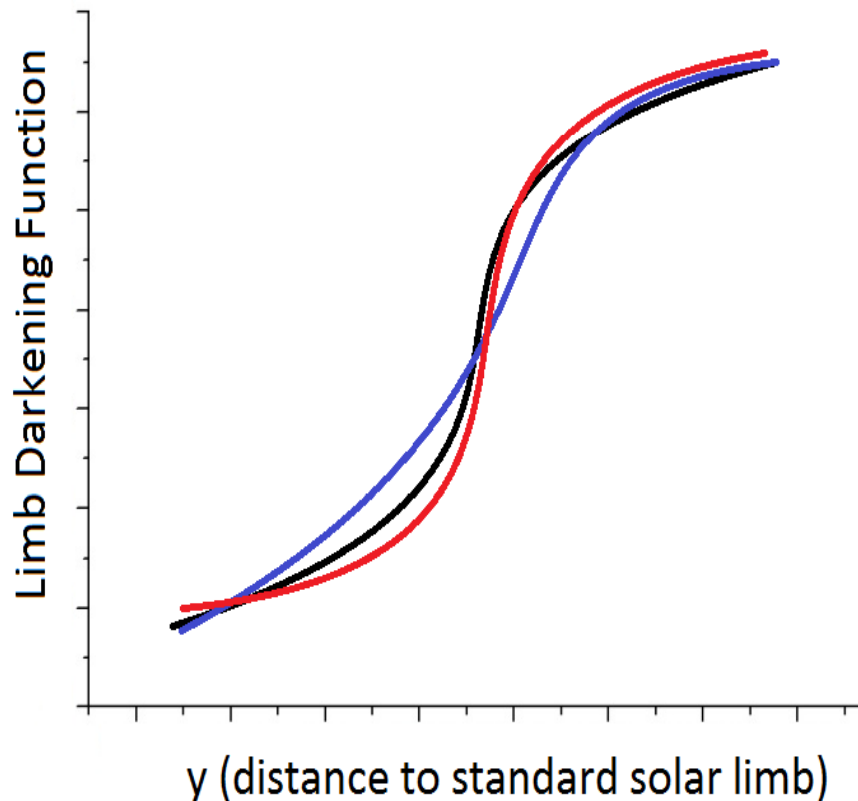
andr.raponi@gmail.com

Thank you