Determination of the sun diameter from photometer measurements during the November 3, 2012 total solar eclipse in North Australia

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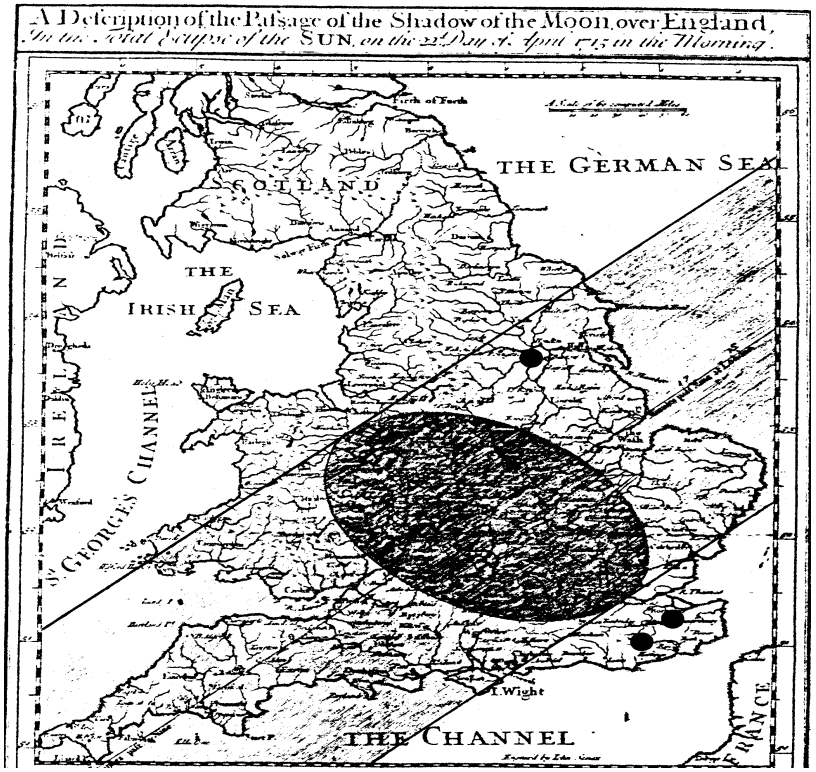
Philippe Lamy (LAM)
Patrick Rocher (IMCCE)

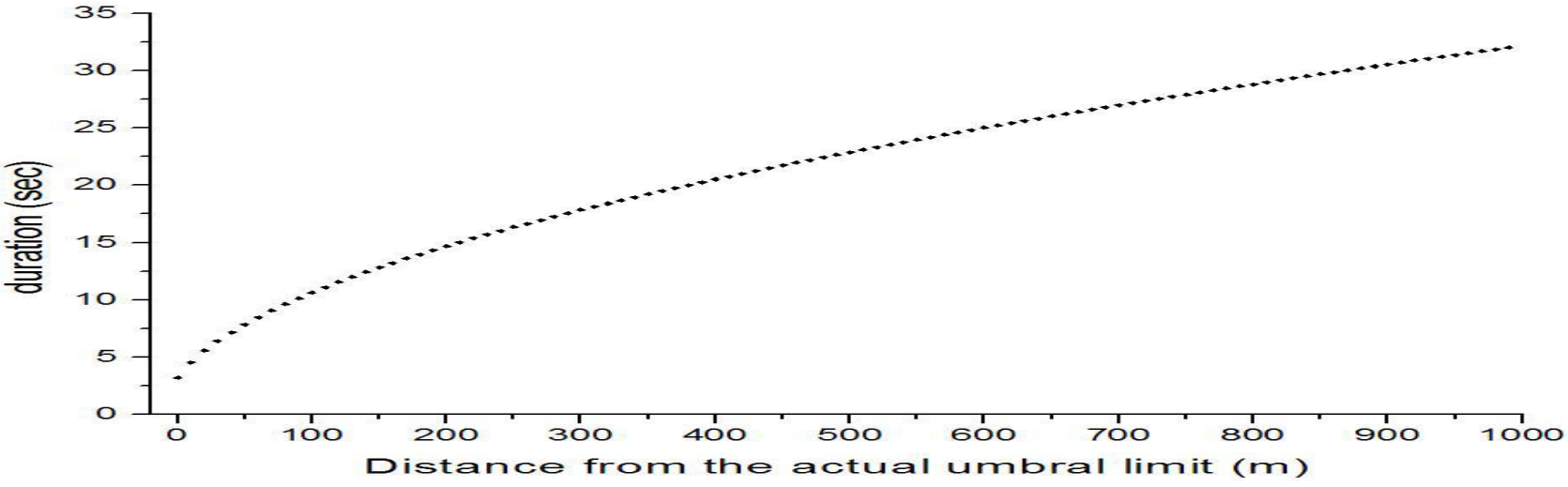
Third PICARD Workshop,
CNES HQ, 25th-26th Sept. '13

The origins of the timing method



Durée de totalité fonction de

Valeur de UT1 : position l'observateur (rotation de la Terre).
Valeur de UTC : échelle de temps utilisée pour l'observation.
Coordonnées de l'observateur.
Éphémérides de la Lune et du Soleil.
Paramètres physiques de la Lune : libration, direction du pôle de la Lune, écarts entre le centre de masse et le centre optique.
Paramètres liés aux limbes lunaires : rayon moyen, ellipticité et erreurs sur le profil.
Rayon du soleil.



1st campaign during the 11 July 2010 eclipse

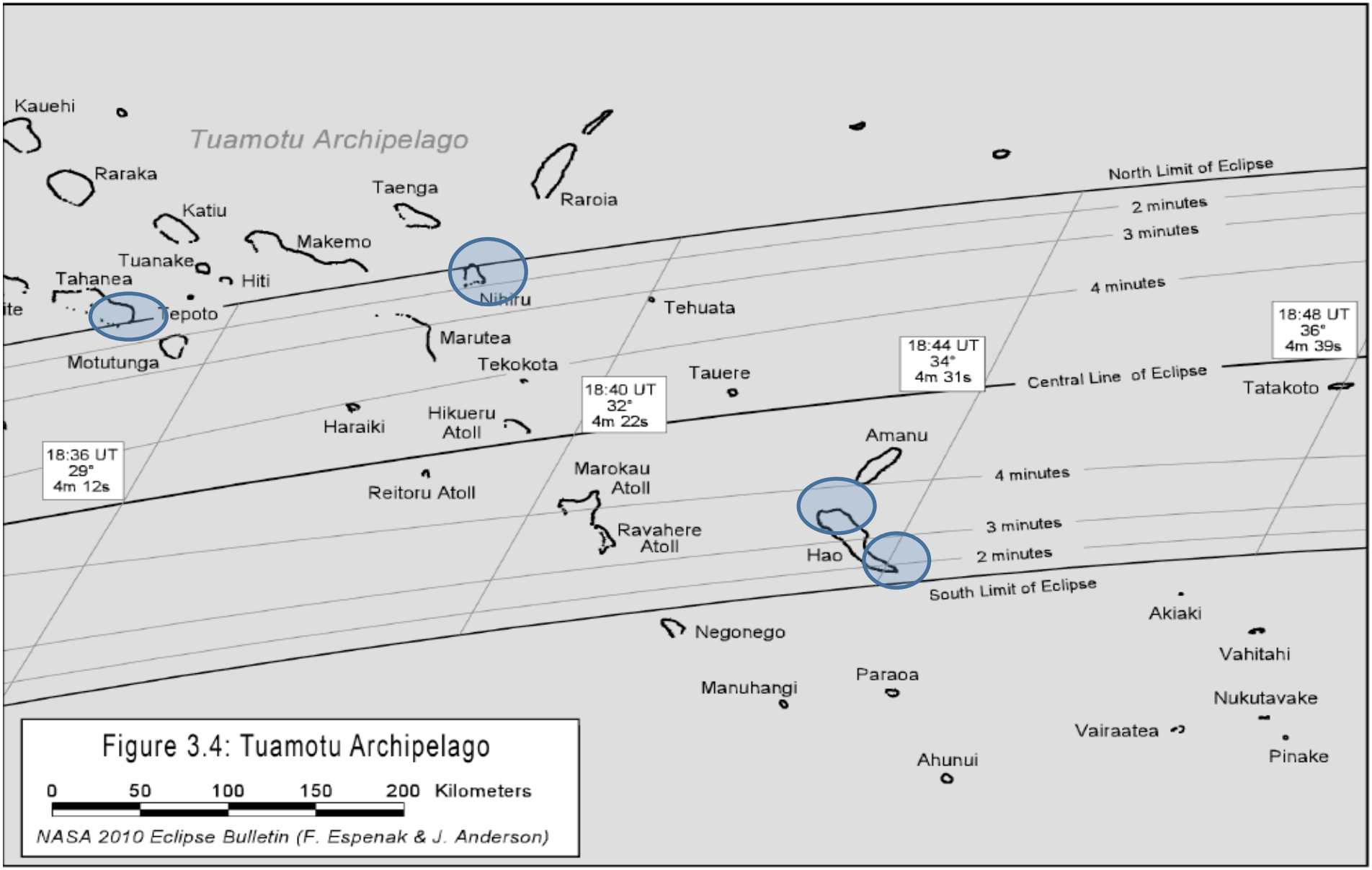
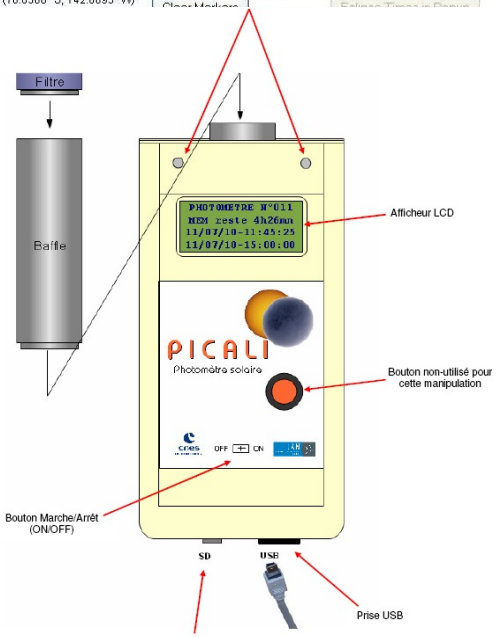
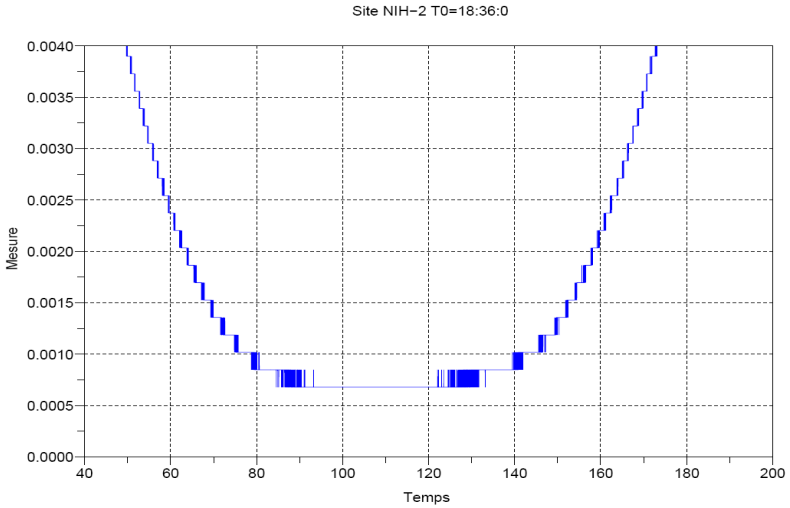


Figure 3.4: Tuamotu Archipelago

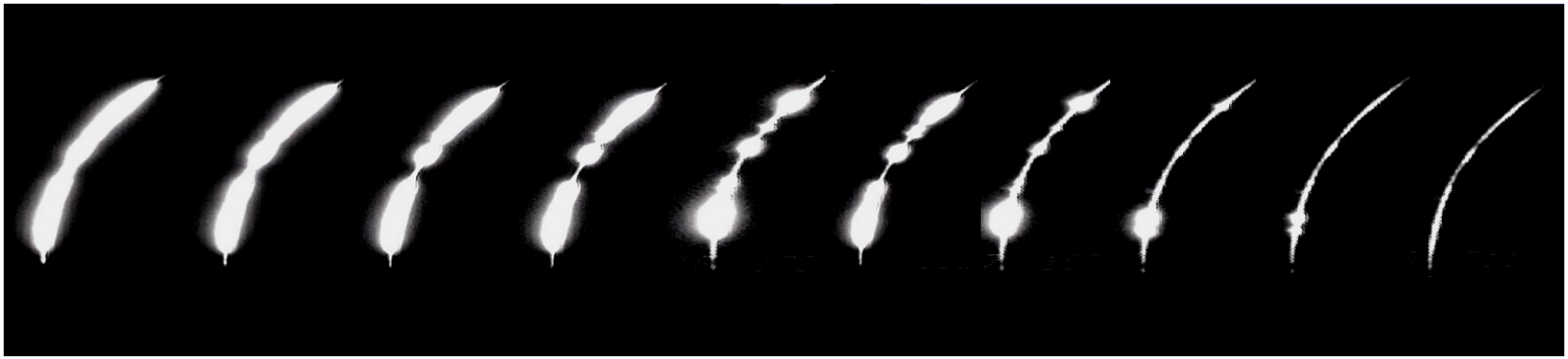
Example of setting





Sensitivity improved by x100 for the 2012 campaign

Baily's Beads



C2-10s ---------- → HAO Nord

Crédit Nugent – IOTA Observation

Nom du lieu : Nihiru (NIH-1/P009)
Latitude : 16° 39' 21.042" sud, -16.6558450°
Longitude : 142° 52' 17.040" ouest, -142.8714000°
Altitude : 0m.

Phase de l'éclipse	UT	P_sol	Z_sol	P_lune	Z_lune
Premier contact extérieur	17h 21m 9.131s	276°10' 5.689"	32°21'48.035"	97°11'12.899"	213°41'10.218"
Premier contact intérieur	18h 37m 43.799s	18° 4'30.413"	145°42'21.888"	18° 1'27.099"	145°39' 6.597"
Dernier contact intérieur	18h 38m 8.579s	3°16'29.724"	130°58'49.748"	3°25'31.380"	131° 7'31.126"
Dernier contact extérieur	20h 6m 20.852s	105°21'44.792"	253°38'14.152"	285° 3'42.250"	72°36'15.685"

Durée de la phase centrale : 0m 24.780s.
Instant du maximum : 18h 37m 58.916s
Obscuration : 100.0%
Magnitude : 1.000502

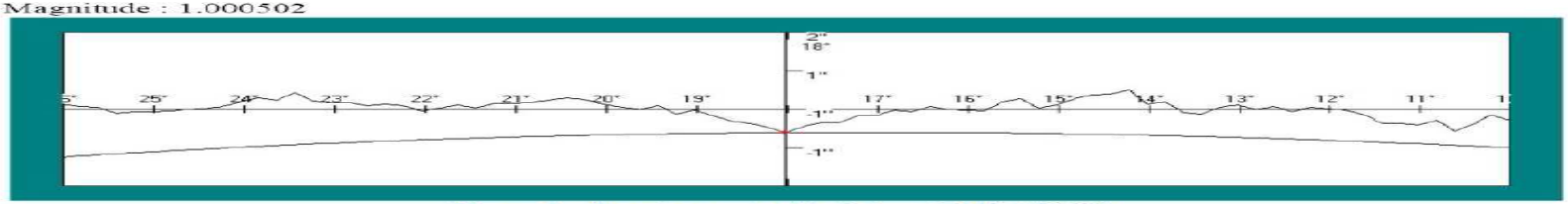


Figure 1 : Premier contact intérieur (NIH-1/P009)

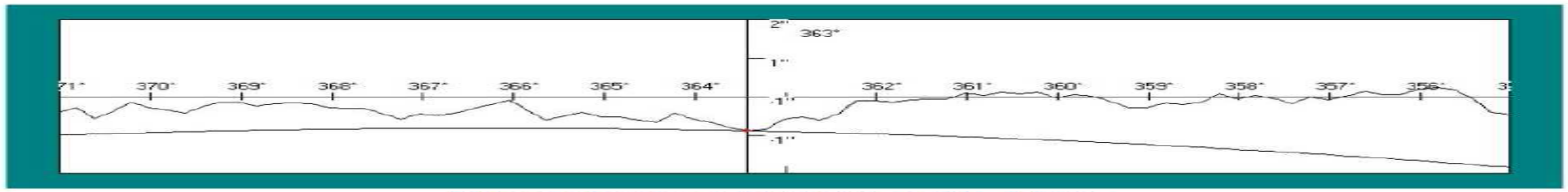


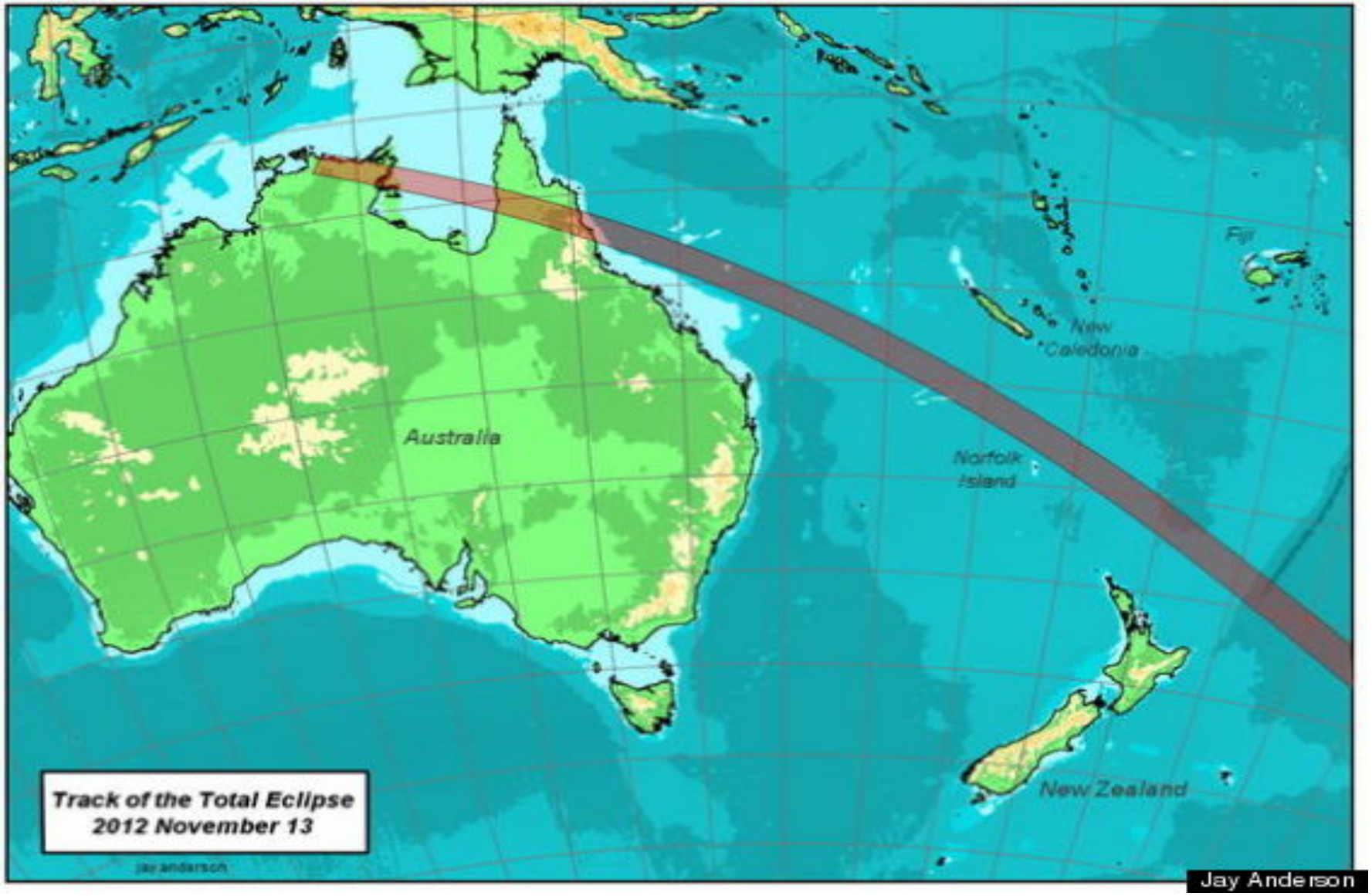
Figure 2 : Dernier contact intérieur (NIH-1/P009)

Attention, sur ces graphes l'axe des ordonnées est dilaté d'un facteur 3600 (l'échelle est la seconde d'arc) par rapport à l'axe des abscisses (l'échelle est le degré).

Crédit Patrick Rocher IMCCE

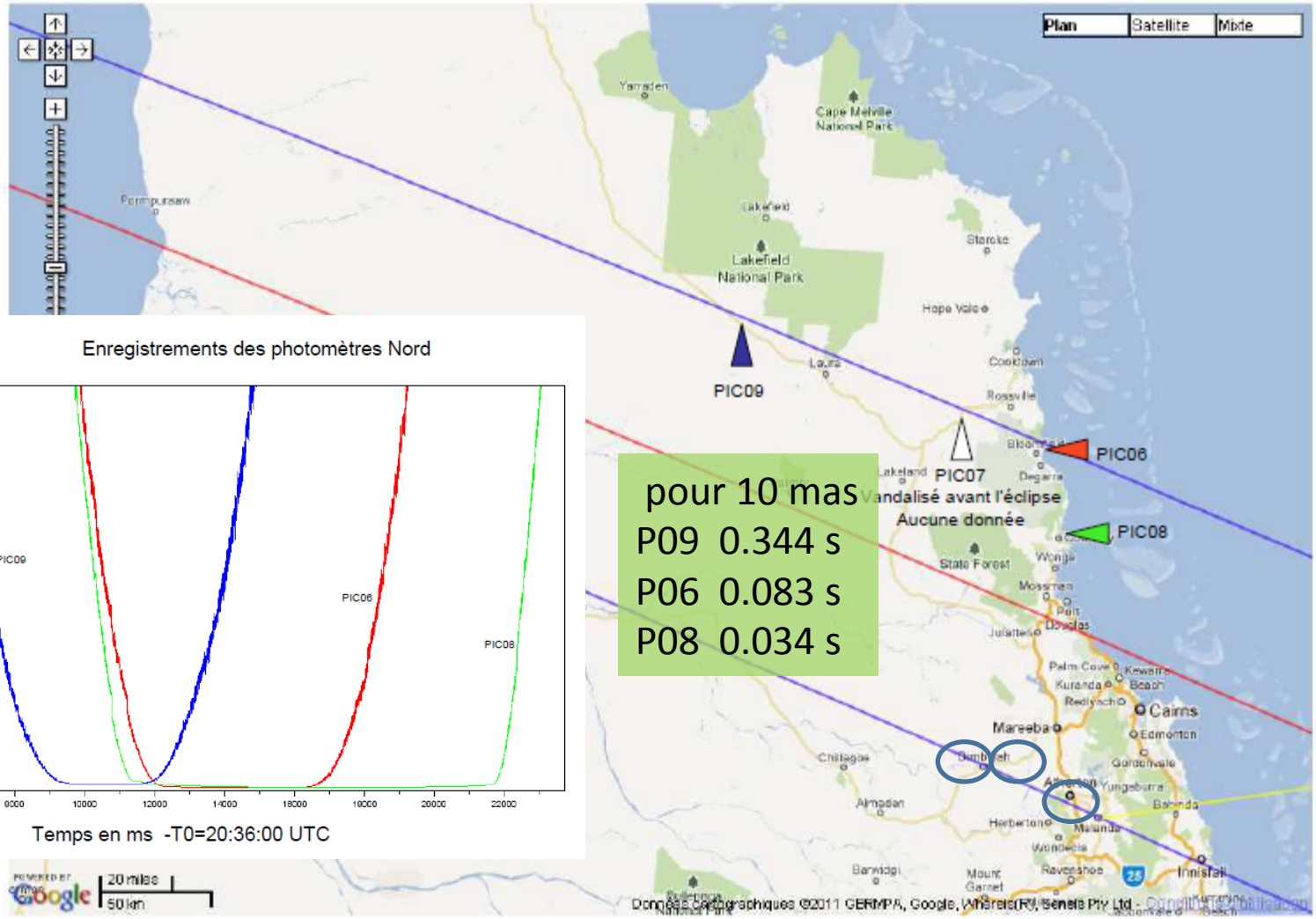
The total solar eclipse of 14 November 2012

Started on Nov 14 and ended on Nov 13…



PICALI data

Positionnement des photomètres Nord



Total Eclipse at Thornton Beach, North Australia on November 14, 2012

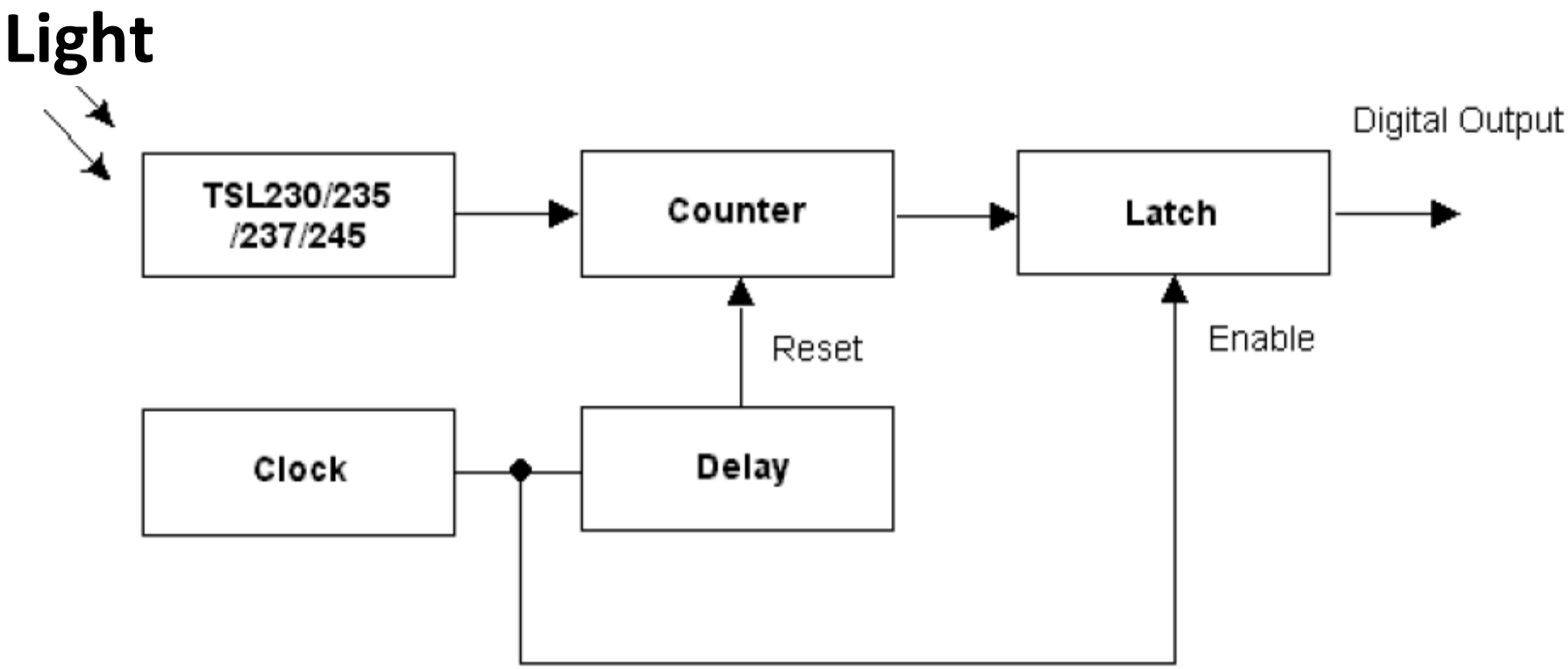
Thornton Beach Location

The weather was cloudy with small showers on Thornton Beach on the early morning of November 14, as seen of the photometric readings. Hopefully, the skies opened up for about half-an-hour at totality time.

Totality at Lakeland (close to Thornton Beach)

Photometric observations at Thornton Beach

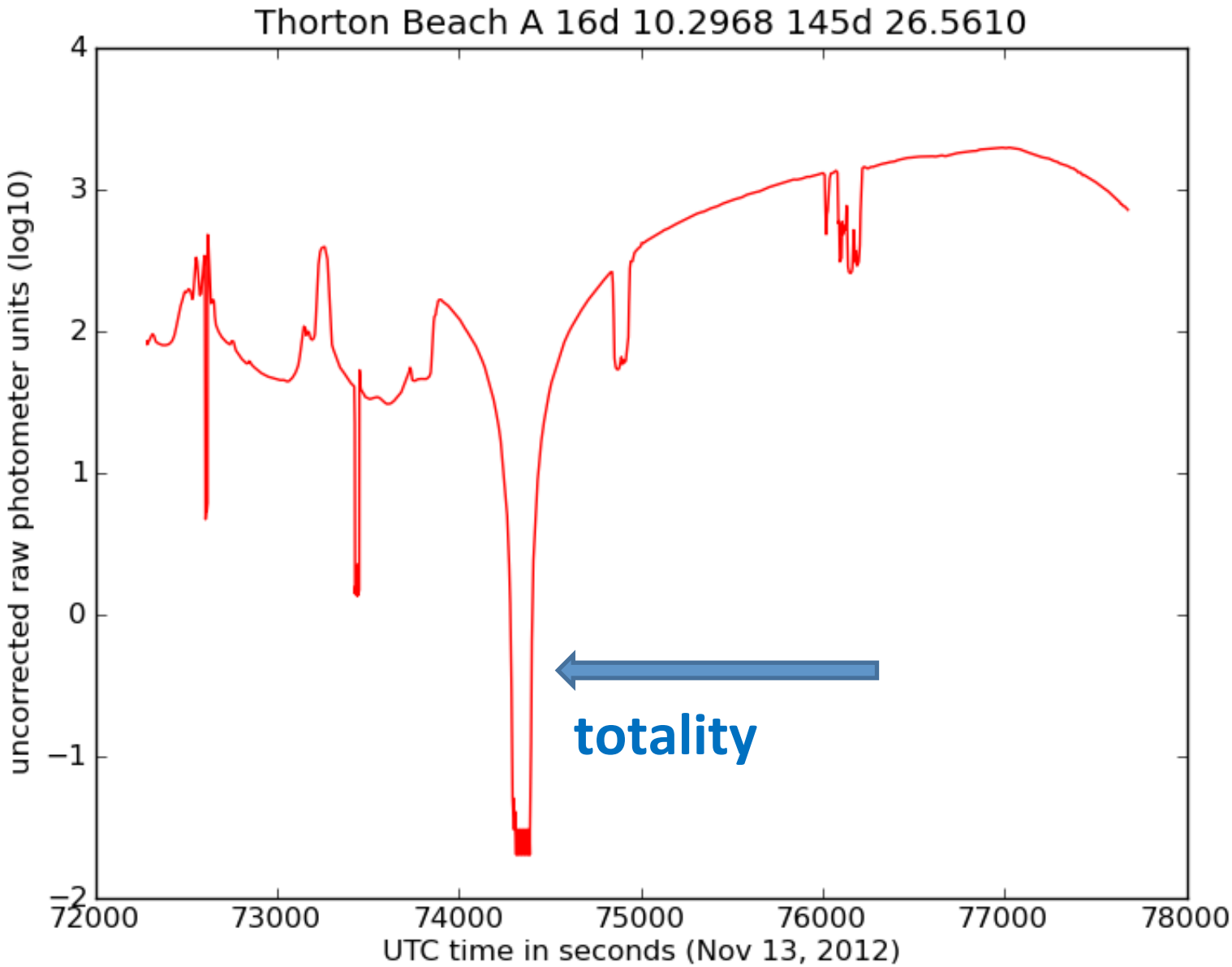
Close-up of photometers



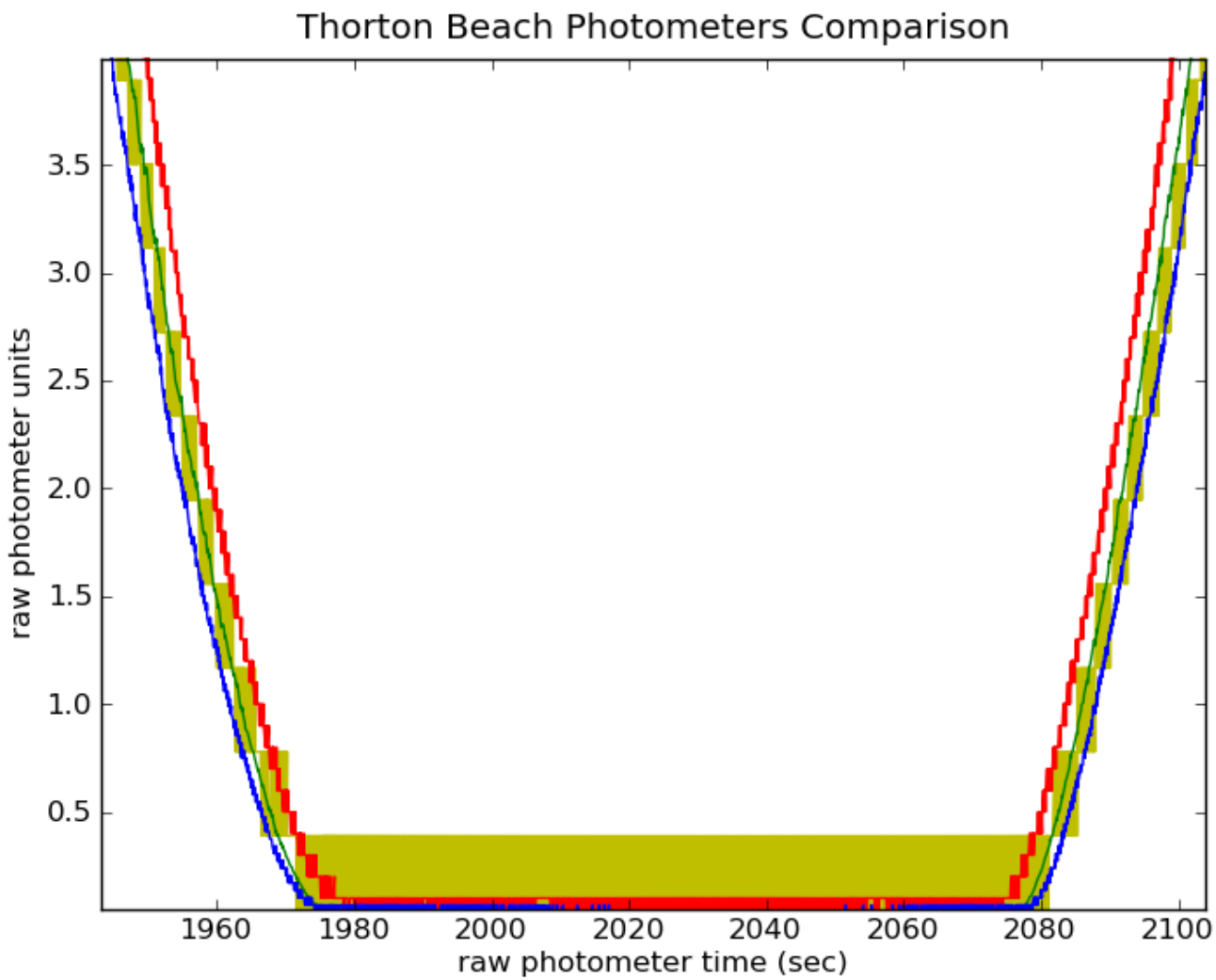
Light to Digital Converter

Photometer	Counting	Sensitivity	Filter	Latitude (S) 16°	Longitude (W) 145°	Color Curve (Figure 4)
A	50 ms	Variable 1-100	58A dark green	10.2968’	26.5610’	green
B	10 ms	10	58A dark green	10.2945’	26.5629’	yellow
C	10 ms	Variable 1-100	56 light green	10.2889’	26.5692’	red
D	10 ms	100	96-0.6 neutral	10.2866’	26.5720’	blue

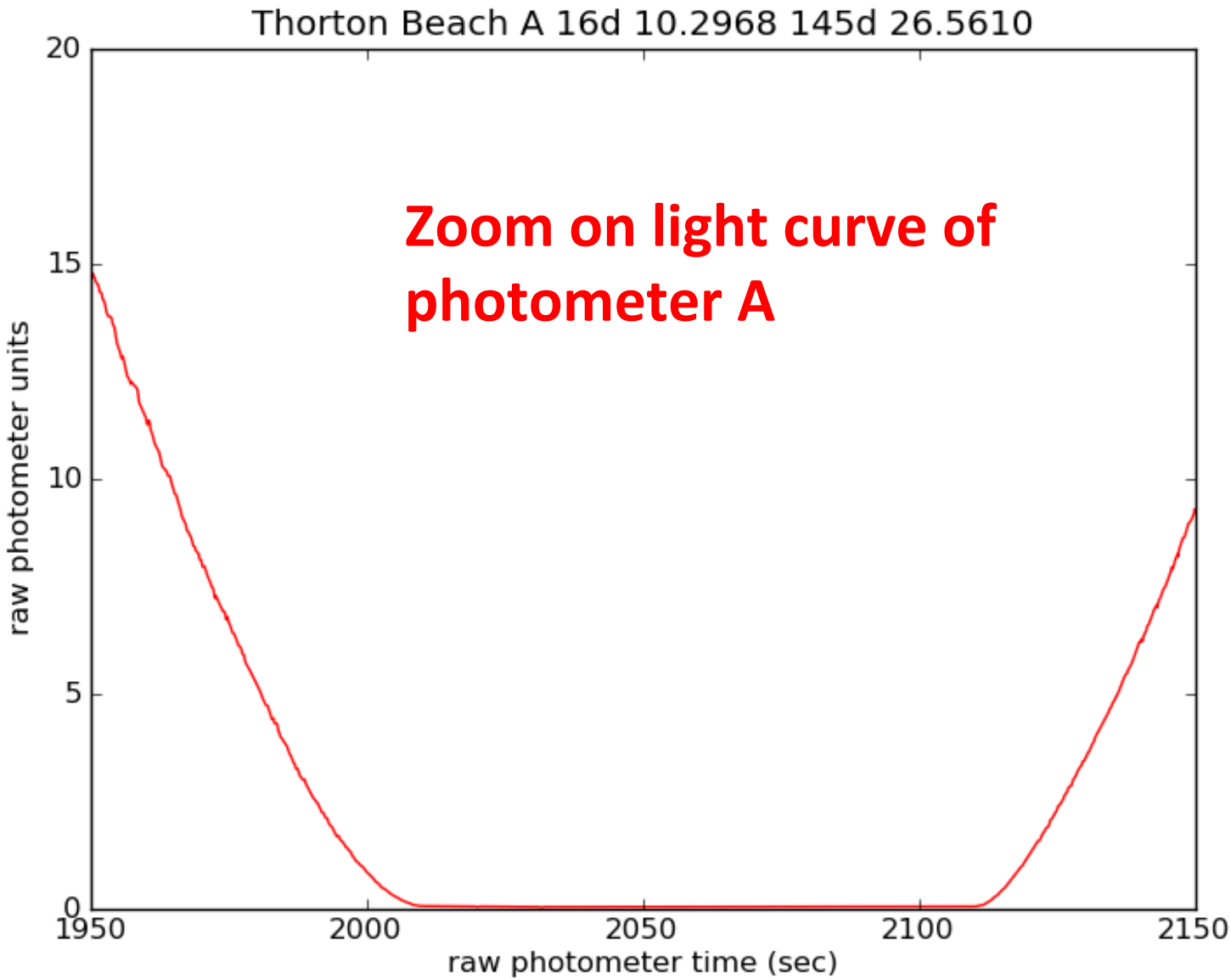
Set up of the four MPSP-1 photometers (A, B, C, D) deployed at Thornton Beach. Counting is the period of the frequency counter in milliseconds. Filters are identified by their Wratten number. The sensitivity is the number of active cells of the photodiode (electronic iris).



Photometer A Light curve in Log10 units



Comparison of the 4 photometer light curves taken at Thornton Beach. The light curves are embedded. This phenomenon is due to the different wavelength responses for each photometer.


Thorton Beach A 16d 10.2968 145d 26.5610
Zoom on light curve of photometer A
raw photometer units
raw photometer time (sec)
20
15
10
5
0
1950
2000
2050
2100
2150

Modeling the photometric observations at Thornthon Beach

Modeling the photometric observations

To be solved for (free parameters):

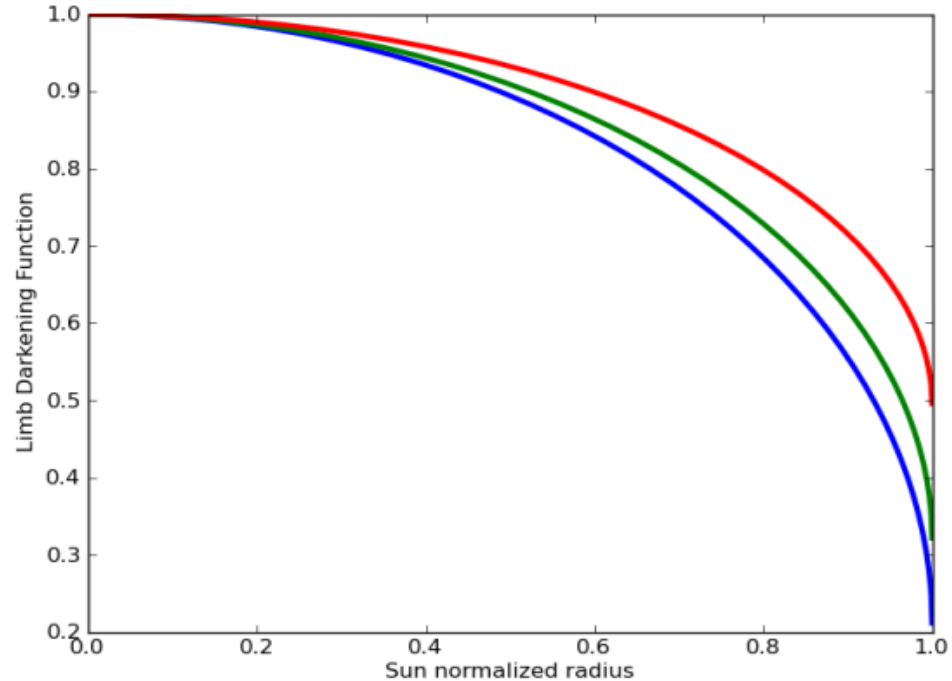
- **Radius of the Sun**
- **Marine Aerosols (salt particules)➔ Beer's Law [exp (-σ m)]**

As a function of (fixed parameters):

- **Equivalent radius of Moon limb (1736.645 km)**
- **Sun Limb darkening function**
- **Photometer calibration (laboratory)**
- **Photometer response (photodiode + optical filters)**
- **Sun/Moon ephemeris (IMCCE)**

➔ least-squares observed/computed

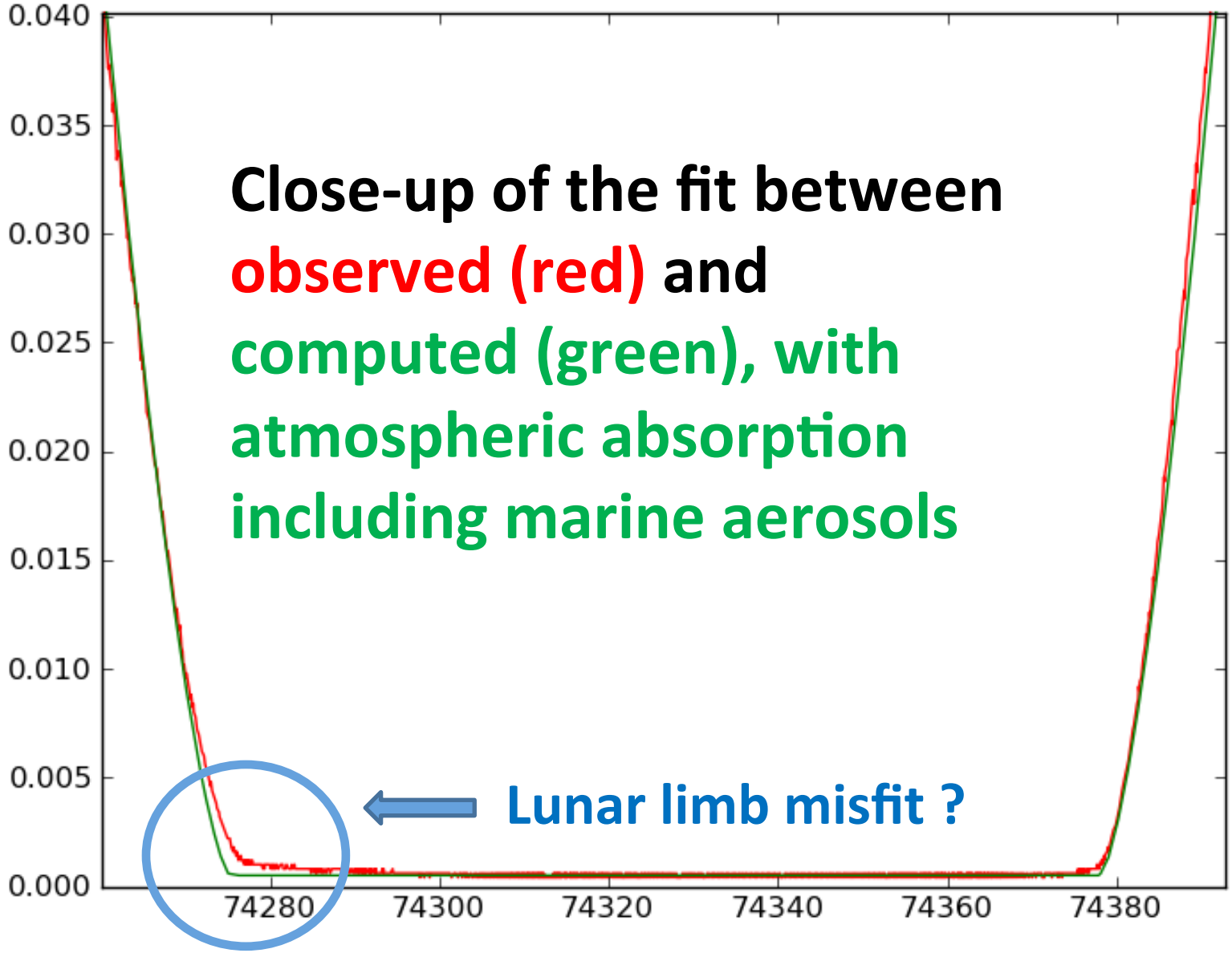
Sun limb darkening function used to reduce the observations

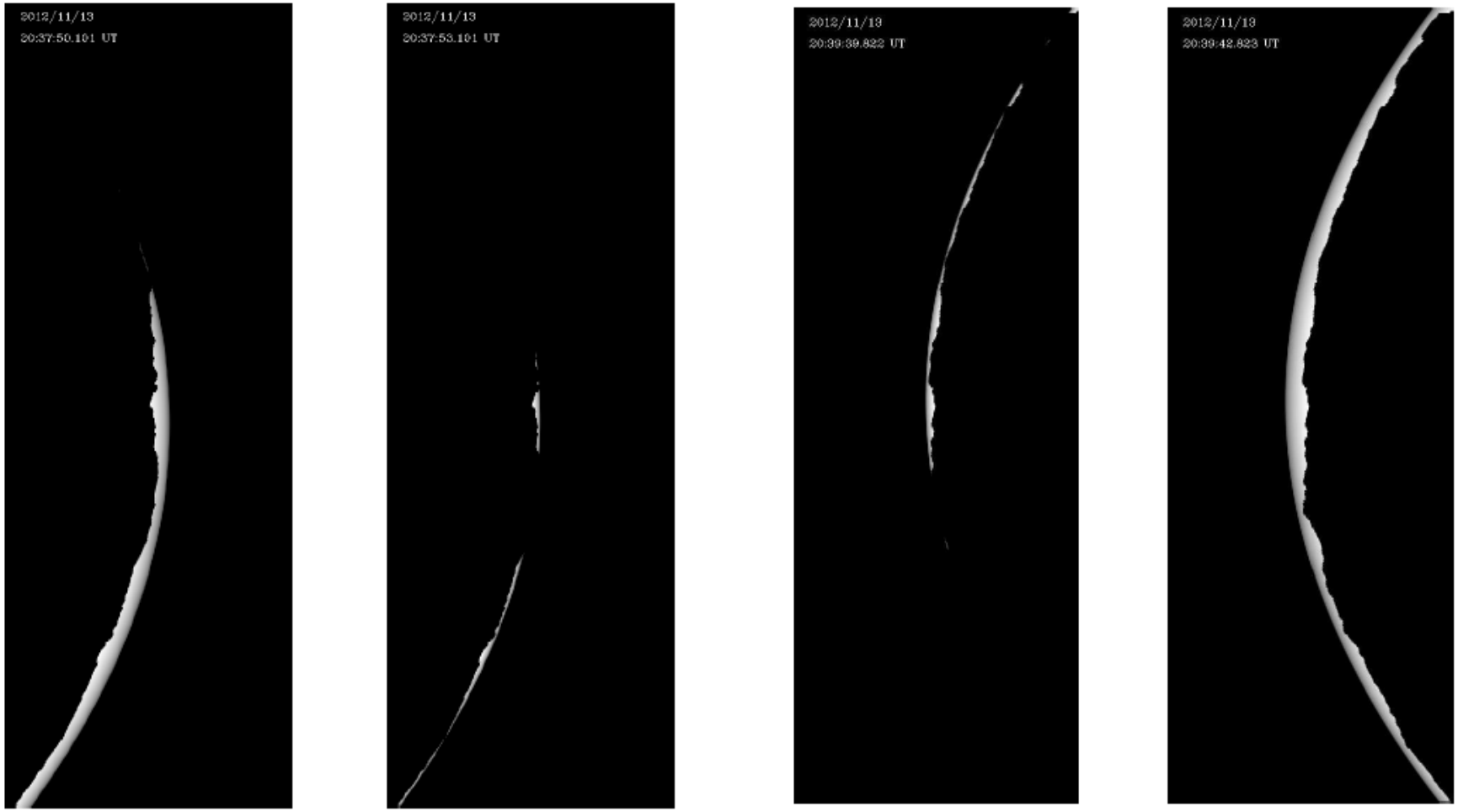


We used for the limb darkening function (LDF) of the Sun the formula first given by Waldmeier (1941), and also used by Scheffler (1974) and Koepke et al. (2001),

$$LDF(R_S, \lambda) = \frac{I_\lambda}{I_\lambda^0} = \frac{1+\beta_\lambda\sqrt{1-r^2}}{1+\beta_\lambda} \text{ with } \beta_\lambda = \frac{3hc\sqrt[4]{2}}{8k\lambda T_S}$$

where $0 \leq r \leq 1$ from the center of the disk of the Sun to its border. I_λ denotes the intensity coming from a point at a distance r from the center of the solar disk, I_λ^0 denotes the intensity coming from the center itself, λ is the wavelength, *h* the Planck constant , *c* the speed of light, *k* the Boltzmann constant and T_S the temperature of the Sun surface. The relative radius r is by definition $r = R/R_S$ where R_S is the quantity we are looking for, the radius of the Sun.


0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
74280
74300
74320
74340
74360
74380
Close-up of the fit between
observed (red) and
computed (green), with
atmospheric absorption
including marine aerosols
Lunar limb misfit ?



Geometry of the contacts (courtesy Faury, Lamy LAM / Rocher, IMCCE)

Sun Radius: Results

Photometer	Filter	Sun radius (km)	Formal Error (km)	Sun radius (“)	Formal Error (“)
A	58A dark green	695,845	18	959.42	0.08
B	58A dark green	Too noisy	-	-	-
C	56 light green	696,585	21	960.44	0.09
D	96-0.6 neutral	695,374	20	958.77	0.09

C (narrowband) compatible with Emilio et al. (2012): 960.12” ± 0.09”
A (wideband) compatible with PICARD BOS (2013): 959.41" ± 0.11“
D very large wideband

What's next?

The processing of the 2012 campaign is not complete
-Still on going PICALI data analysis at LAM (Philippe Lamy) by comparison between observed and theorical light curves based on Kaguya altimetry data to reconstruct the lunar limb as seen by the instruments
- comparison of the results from the 6 photometers located at Thornton Beach (4 from UPF, 1 'old' PICALI, 1 x100 PICALI) yet to be done
- then processing of the other photometers which have yielded reliable observations: 3 on the Northern edge, 1 in the South

Then revisit of the 2010 data taking into account the expertise aquired for the 2012 data analysis

On going preparation of the forthcoming Total Solar Eclipse (Gabon,3 November) for cross comparison of photometer data (UPF, PICALIs) high resolution image timing

Submission of a proposal (J.P. Barriot, E.Quemerais,P. Lamy) to PNST for supporting this approach taking into account that the CNES support in connection to PICARD will not be extended

Conclusions

The origin of the attempts to monitor the solar diameter through total solar eclipse photometry was to use the PICARD SODISM as a reference for an absolute value of the solar radius and calibrate the eclipse observation data against them in order to initiate a long term serie of solar radius records

The SODISM anomaly prevents to maintain this approach

The main question now is:

can this method provide a significant improvement for the monitoring of the solar radius change on a long term scale?

and then, if positively answered,

which improvements in instrumentation and data analysis should be supported ?

Thanks

Jean Mouette, Serge Koutchmy, Cyril Bazin IAP

Lydie Sichoix UPF

Alain Perret ex CNES

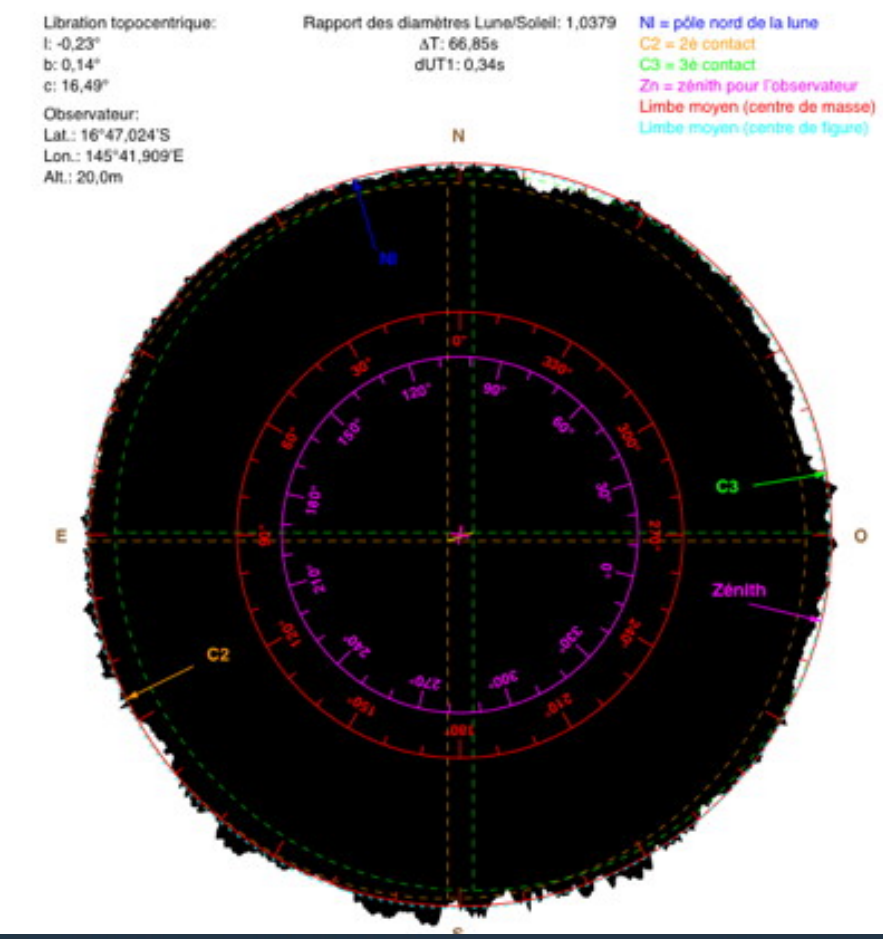
Jean Louis Raynaud LAM

Frédéric Bouchart, Gonzague Bosch TENUM

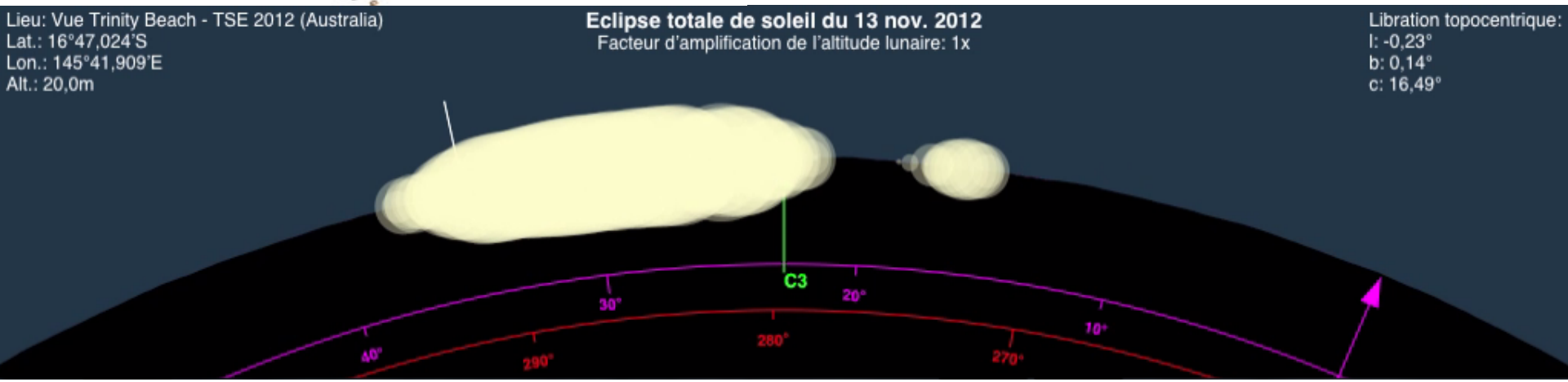
Patrick Martinez and the ADAGIO observers in HAO

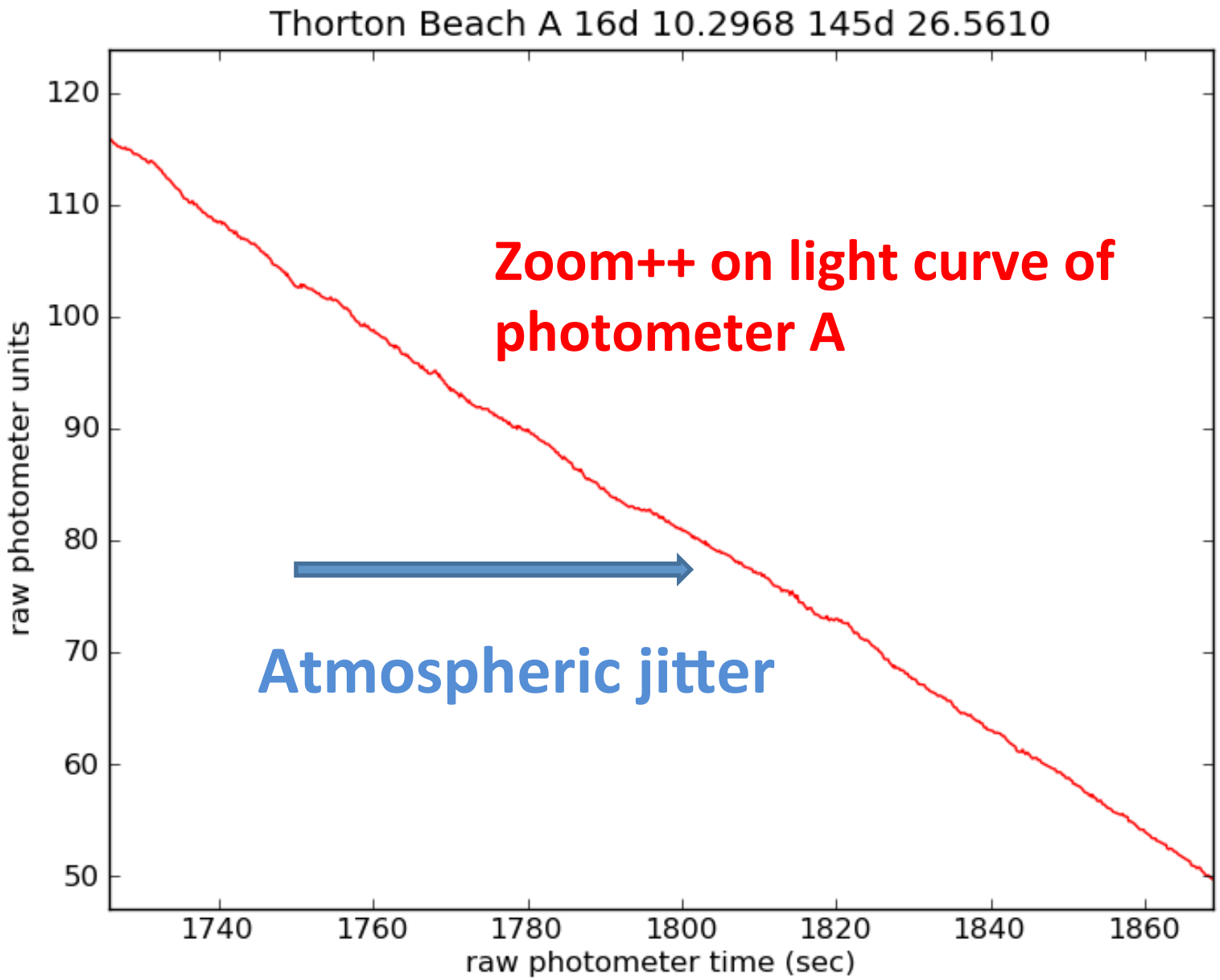
Photometers set-up on Thornton Beach, November 14, 2012, 5 am

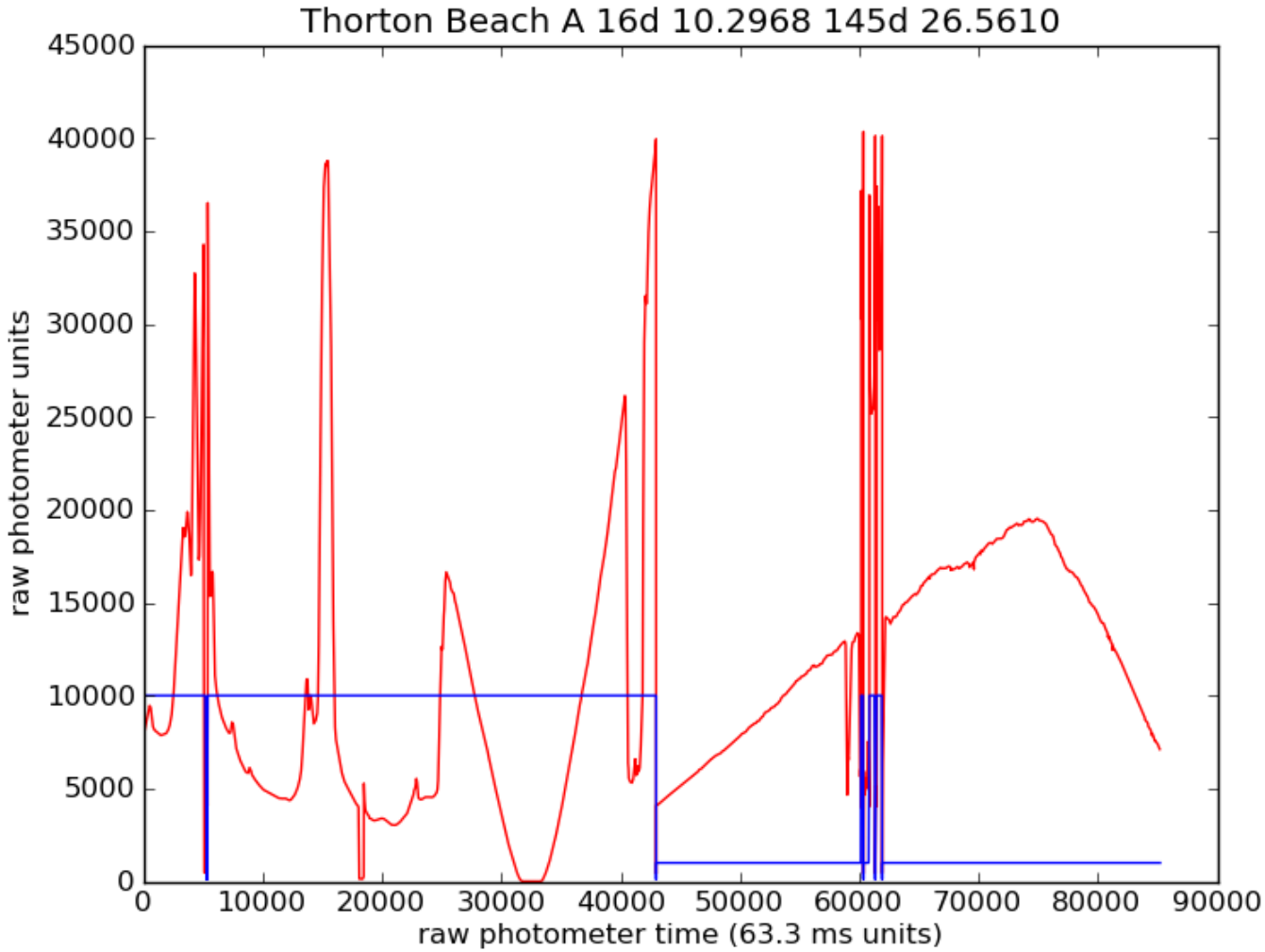

Thornton Beach



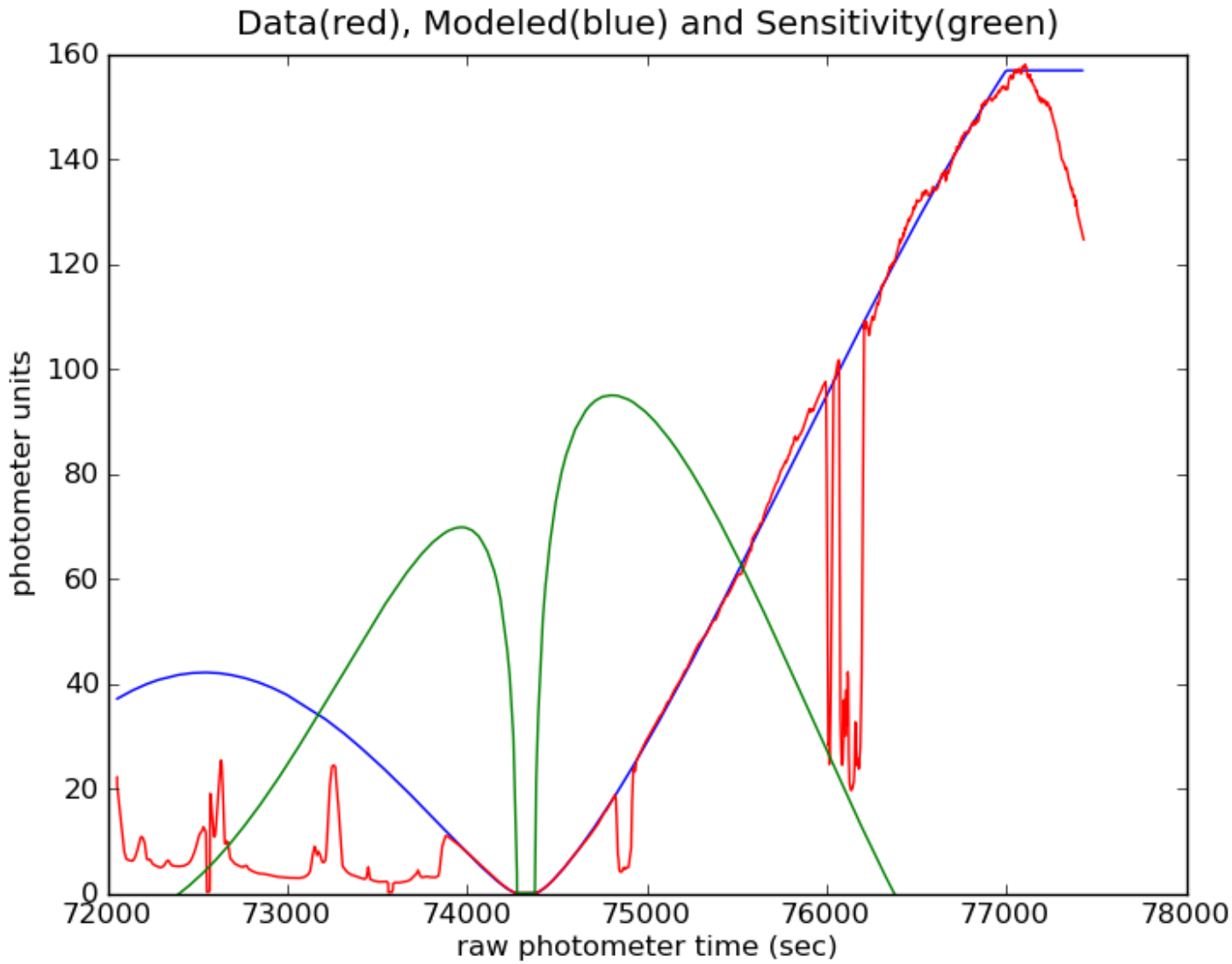
Geometry of the eclipse at Thornton Beach (courtesy X. Jubier)




Thorton Beach A 16d 10.2968 145d 26.5610
raw photometer units
raw photometer time (sec)
120
110
100
90
80
70
60
50
1740
1760
1780
1800
1820
1840
1860
Zoom++ on light curve of photometer A
Atmospheric jitter

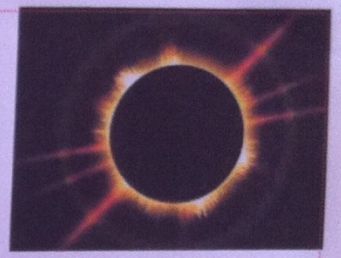


Light curve at Thornton Beach with the photometer A facing the sea.
Red curve: raw reading, Blue curve: electronic iris switching. Local times for the contacts were: 5:44:10 (first), 6:37:55 (second), 6:38:46 (third), 07:39:18 (fourth). Approximate duration of totality was 102.5 seconds.



Sensitivity (green) of the theoretical light curve (blue) to the radius of the Sun (red: observed)

The Lakeland Downs Hotel



Solar Eclipse

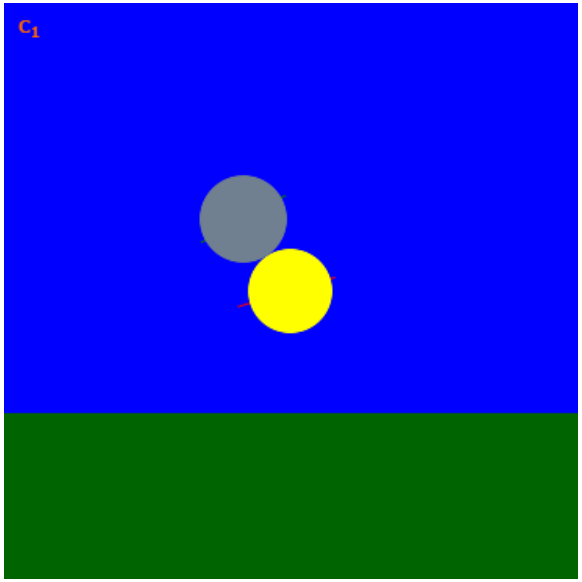
Wednesday 14th November 2012

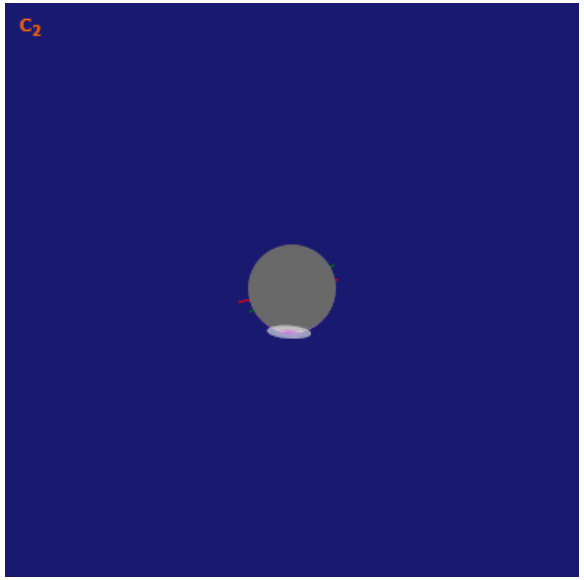
*** THE 'HILLYBILLY GOATS' LIVE!!**

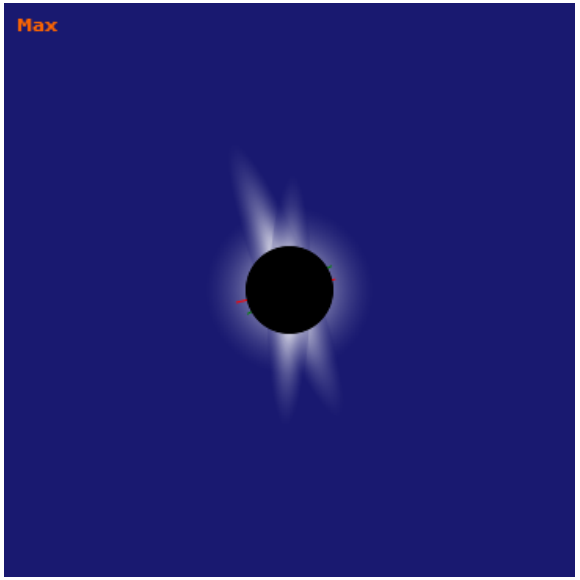
***BBQ BREAKFAST**
***COLD BEVERAGES**
***SOLAR GLASSES**
***MEMORABILIA**

Share this
Once-in-a-lifetime experience with
The Lakeland Downs Hotel

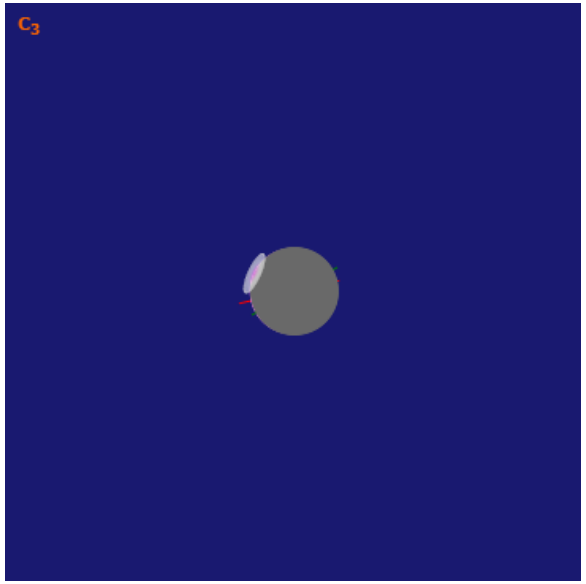
Start of Partial Eclipse	5:44am
Start of Total Eclipse	6:37am
Duration	1minute 32seconds
End of Total Eclipse	6:39am
End of Partial Eclipse	7:39am

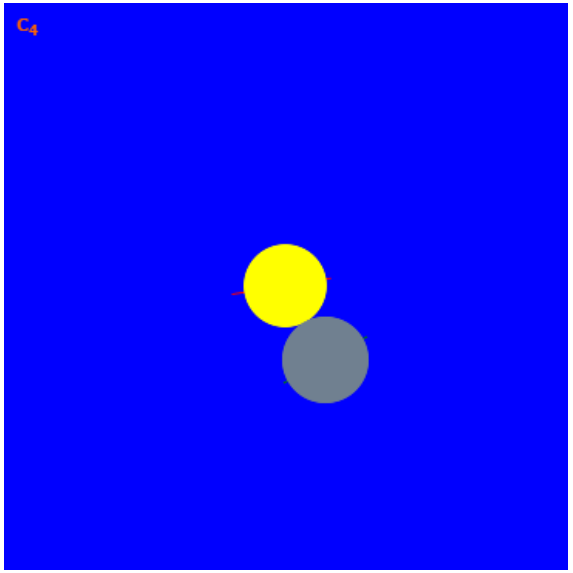






Geometry of the eclipse at Thornton Beach





Coordonnées géographiques de l'observateur

(saisissez votre localisation [Convertisseur Lat/Lon DMS<->DD] et fuseau horaire)

Recherchez votre lieu par nom Recherchez votre fuseau horaire (page Internet)

Latitude :	16 °	10.2968 ′	S	—> -16,17161°	
Longitude :	145 °	26.561 ′	E	—> 145,44268°	
Altitude :	0	mètres			
Fuseau horaire :	10 :	00	E	(Heure d'hiver / normale)	

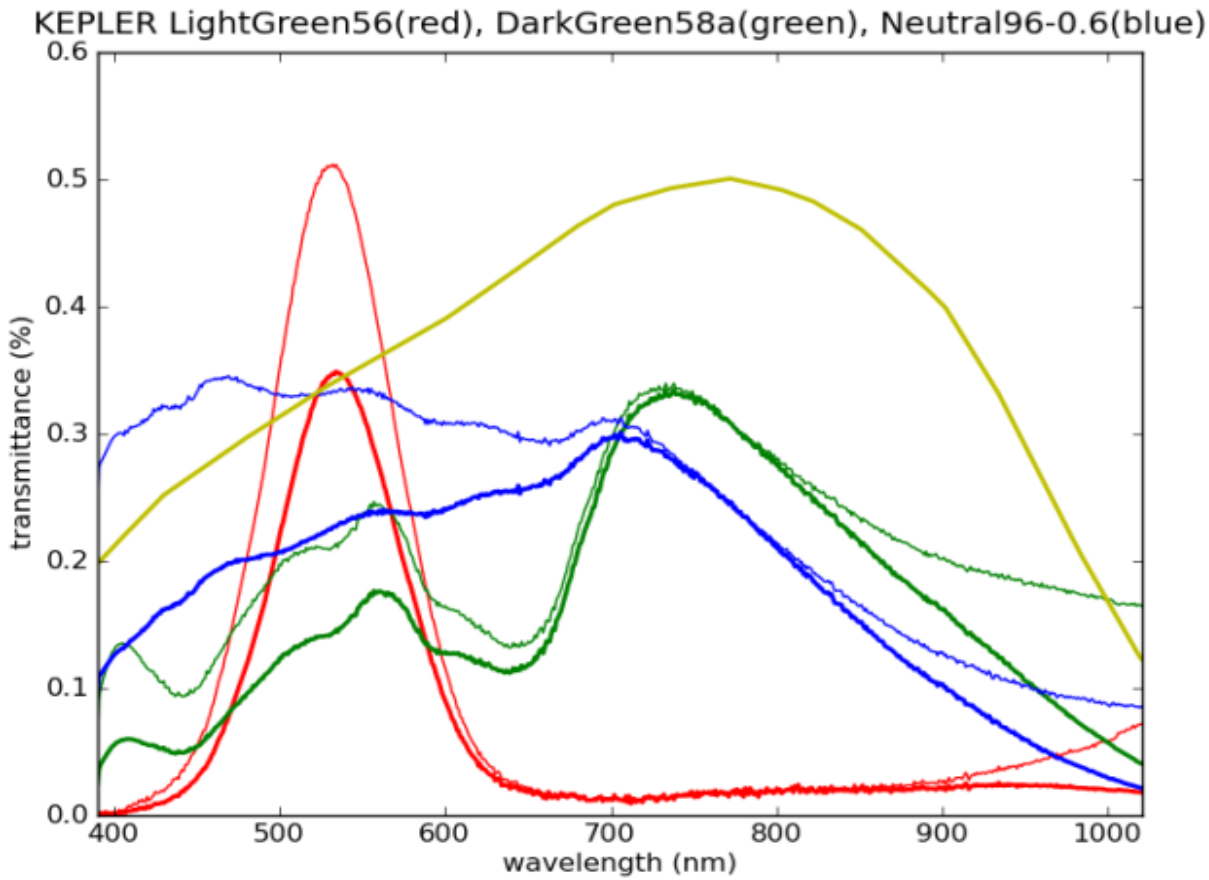
Calculer les circonstances de l'éclipse

Prédiction des circonstances locales de l'éclipse

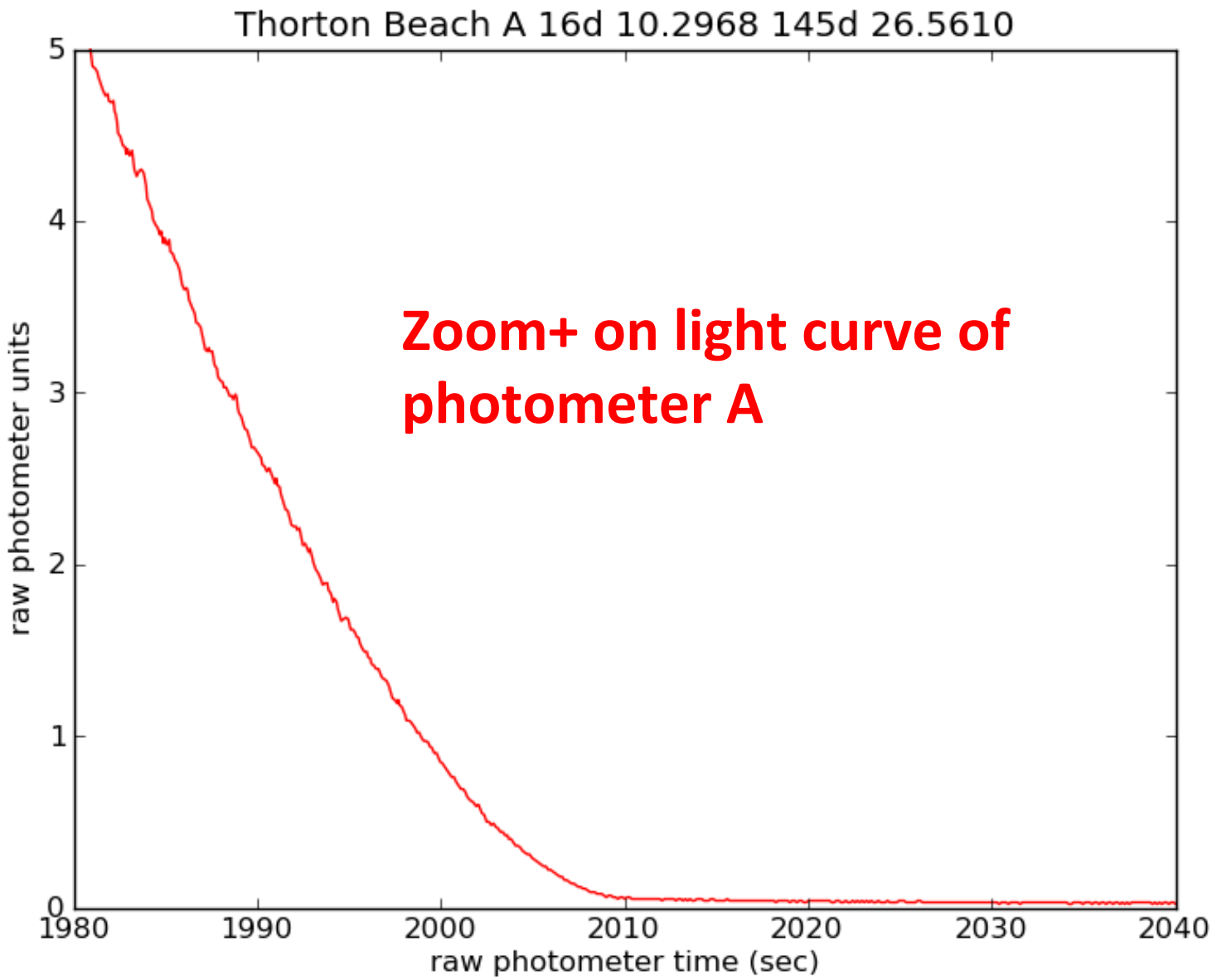
(pour les coordonnées ci-dessus avec ΔT=66,9s)

Phase	Date	Heure	Alt	Azi	P	V	CL
Début de l'éclipse partielle : (1er contact)	14/11/2012	05:44:10,3	+00,8°	108,8°	286°	10,8	
Début de l'éclipse totale : (2nd contact)	14/11/2012	06:37:55,4	+13,1°	105,5°	073°	06,1	
Maximum de l'éclipse :	14/11/2012	06:38:46,4	+13,3°	105,4°	198°	02,0	
Fin de l'éclipse totale : (3ème contact)	14/11/2012	06:39:37,8	+13,5°	105,4°	322°	09,8	
Fin de l'éclipse partielle : (4ème contact)	14/11/2012	07:39:18,5	+27,4°	102,5°	109°	05,1	

Type d'éclipse :	Totale	Durée :	1m 42,5s	[2m 03,8s]	Degré d'obscuration : 100,00%
Grandeur de l'éclipse :	1,00797	Rapport Lune/Soleil :	1,03690	Afficher le profil du limbe lunaire	
Pénétration dans l'ombre :	43,2%	Libration lunaire l :	-12,50°	b : -0,12°	c : 16,18°



Yellow: ***spectral response of the photodiode;*** ***Bold blue:*** ***joint response of the Kepler Neutral filter 96-0.6 and the photodiode;*** ***Bold green:*** ***joint response of the Kepler Dark Green filter 58A and the photodiode;*** ***Bold red:*** ***joint response of the Kepler light Green filter 56 and the photodiode***


Thorton Beach A 16d 10.2968 145d 26.5610
raw photometer units
raw photometer time (sec)
0
1
2
3
4
5
1980
1990
2000
2010
2020
2030
2040
Zoom+ on light curve of photometer A