IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

Historic

From all the tests around the video camera and the effect on the accuracy in level and time, the synthesis target is to examine the possible improvement on the star occultation timing, by Moon or asteroid.
Those tests are only performed on occultation by asteroid, because the brightness of the Moon dark side disturbs the measurements.
Using the signal near the first diffraction fringe seems to give a good accuracy of the time.
There are two obstacles that hinder a little bit the project:
The knowledge of the Star diameter
The tremendous number of star flux measurement.
An algorithm from Eric Limburg has solved the first.
Using Limovie has solved the second
The records of the occultation from the media are first converted in .AVI files then analysed by LIMOVIE (Author Kazuhisa Miyashita). A recent version (9.30 beta received from the author) is able to perform analysis and diffraction calculations. Several tests has been done and reported to Mr Miyashita.

Operating process

The tests has been performed using the following steps:

Analysis of the video signal (LIMOVIE)

Saving the data in a .CVS file.

Diffraction fringes calculation taking into account the following parameters:

- Phenomenon speed
- Spectral response: camera, filter, star spectrum
- Star diameter
- Angle between displacement direction and tangent to the relief of the “occulter” body
- Distance Earth-Occulting body
- Integration on 40mS
- Drawing graphs

The Limovie measured values are plotted on the graphs.

Using LIMOVIE

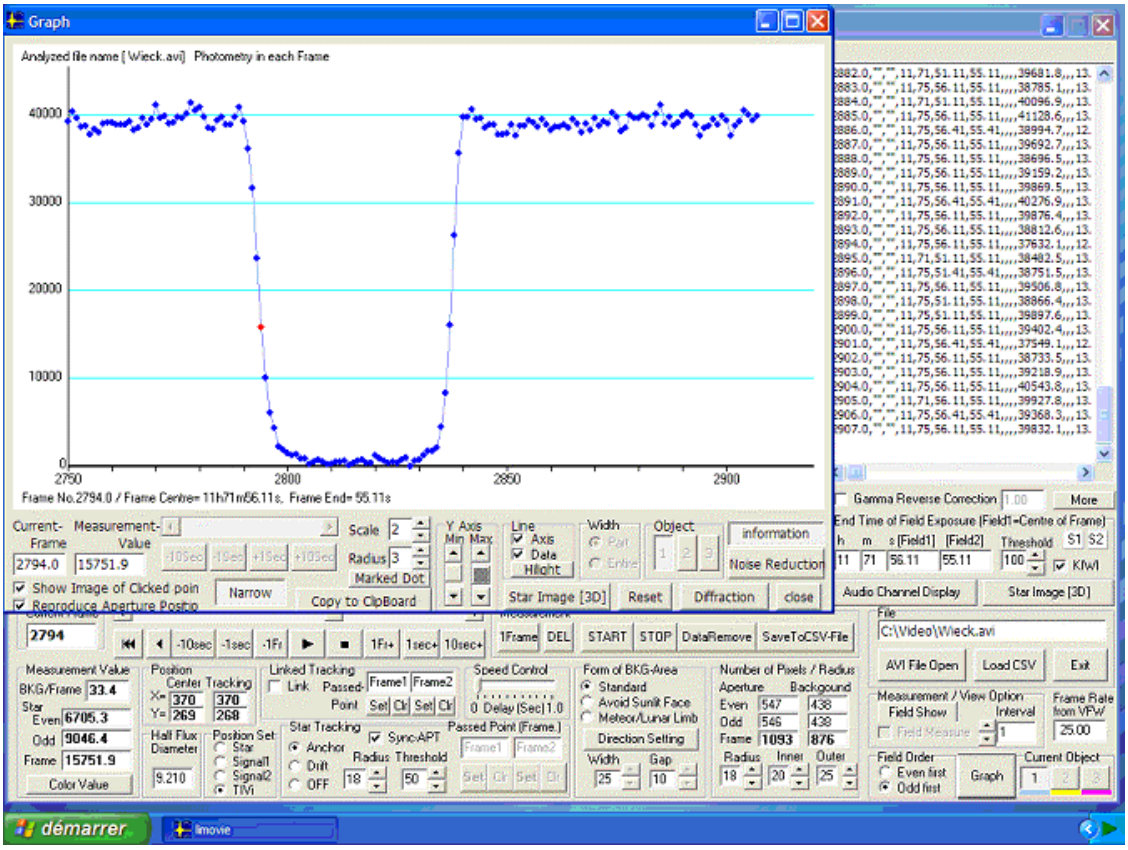
Despite uncertainties concerning the values fitted to the measurements one is able to use LIMOVIE to perform the analysis.
Nevertheless if one don’t waste a lot of time, the following data must be avelable:
The asteroid parallax in order to calculate the distance
The asteroid diameter, the duration of the phenomenon to calculate the speed of transit
The star name to know its diameter using OCCULT4 (if you have)

With LIMOVIE when you want to use the star diameter and or the angle between the moving direction and the tangent to the asteroid limb, the process time to fit the diffraction draw to light draw is very long (several minutes) and we’ll start again when one or other parameter are moved.

Using screen copy pictures here is the process:

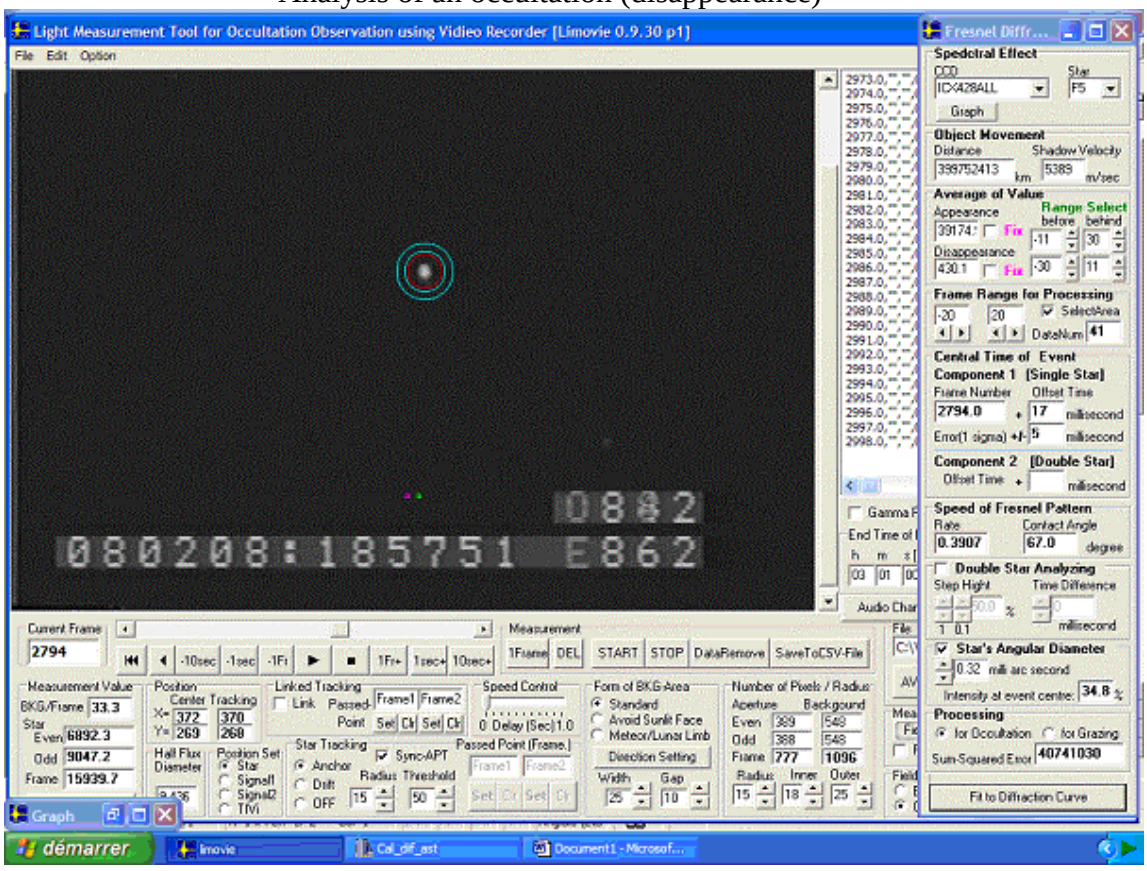
IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

Light graph



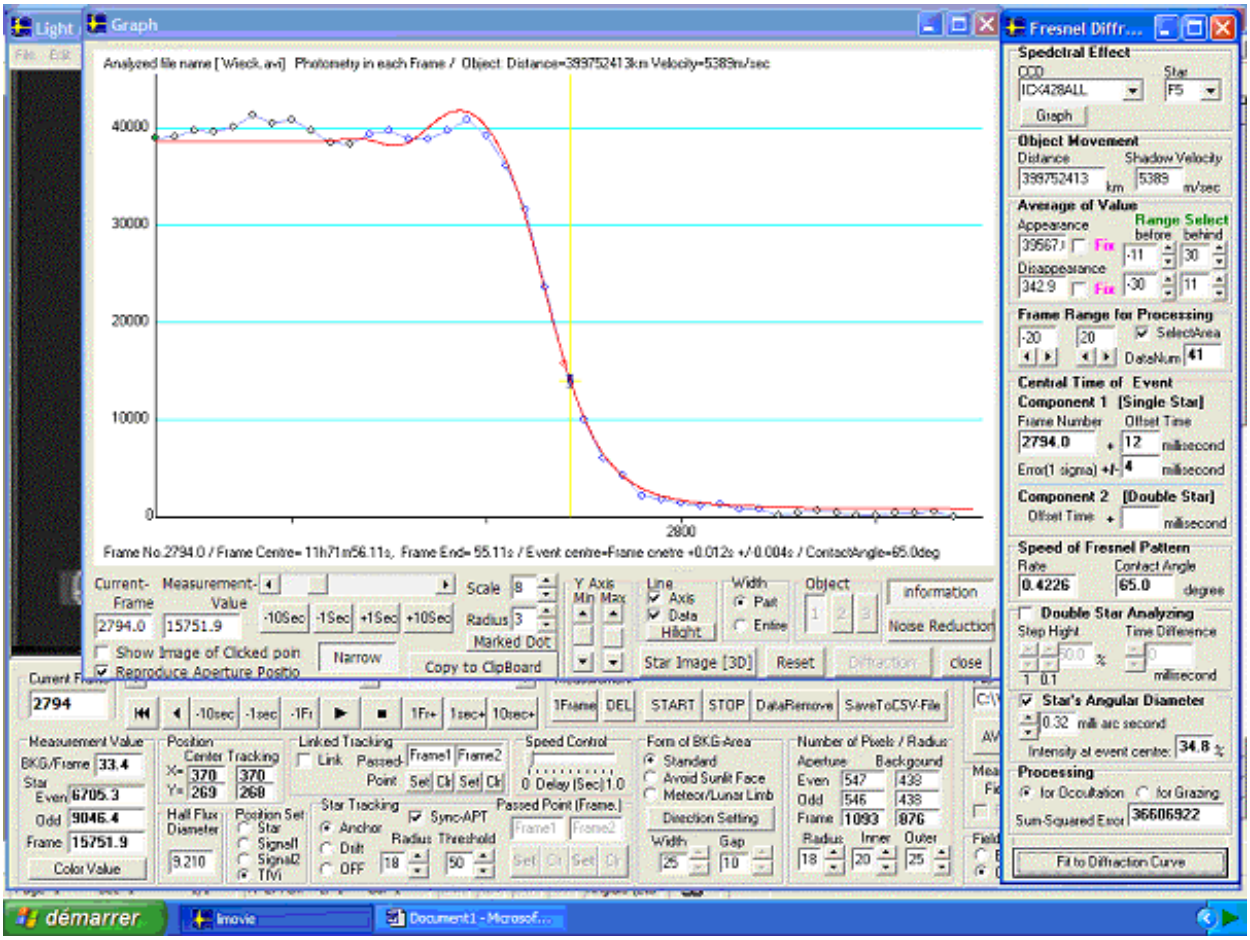
The going down time is 320mS and the going high 240mS. The phenomenon is not symmetric
The speeds are not the same for the disappearance and the reappearance.

Analysis of an occultation (disappearance)



IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

Fitting diffraction graph to light graph (disappearance)



Using those 3 windows we are able to get some elements:

842

Time on the picture: Picture number 2794 red dot on the graph: 18h57m51s862

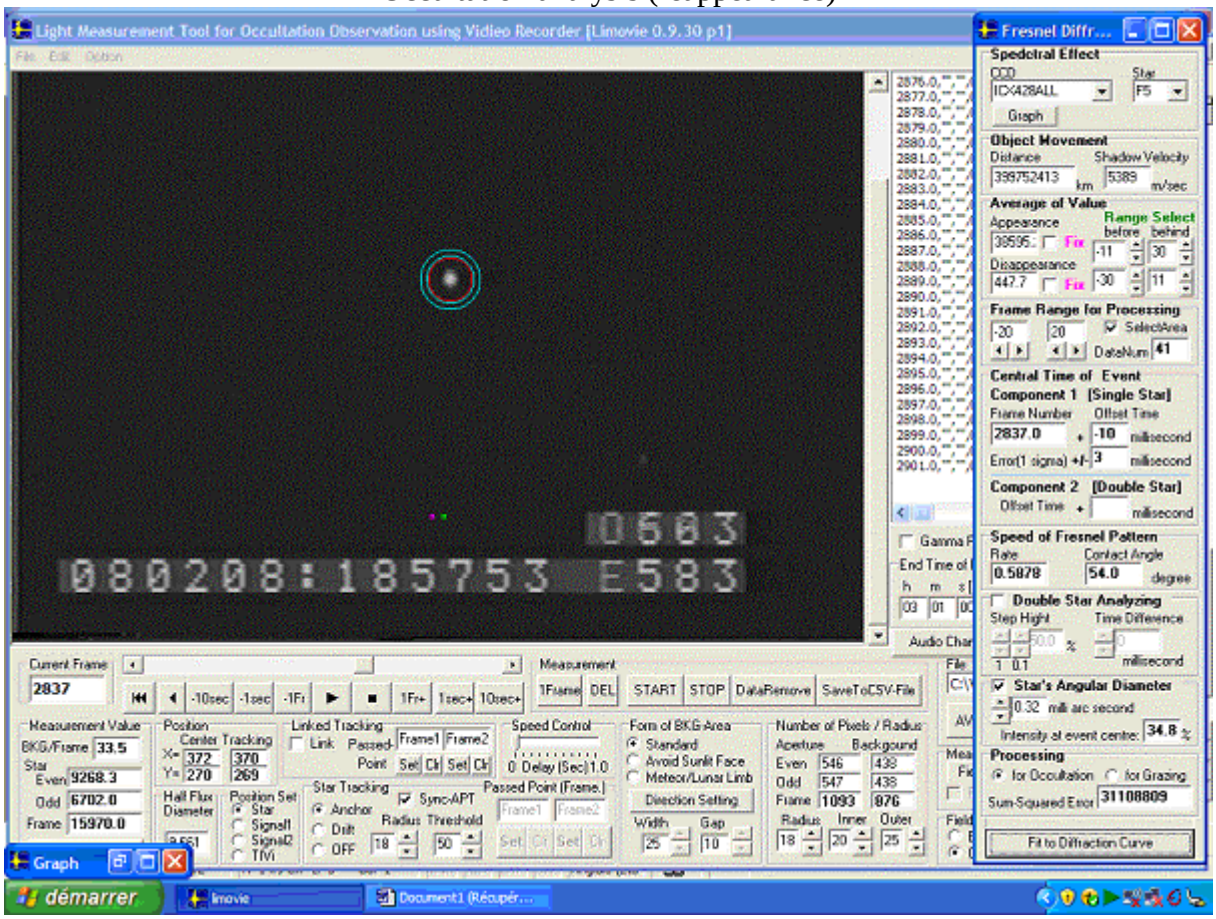
882

Asteroid distance 399,752,413 km
Speed 5389m/sec true speed 5389* 0.4226 with contact angle of 65°
Star Diameter 0.32m“

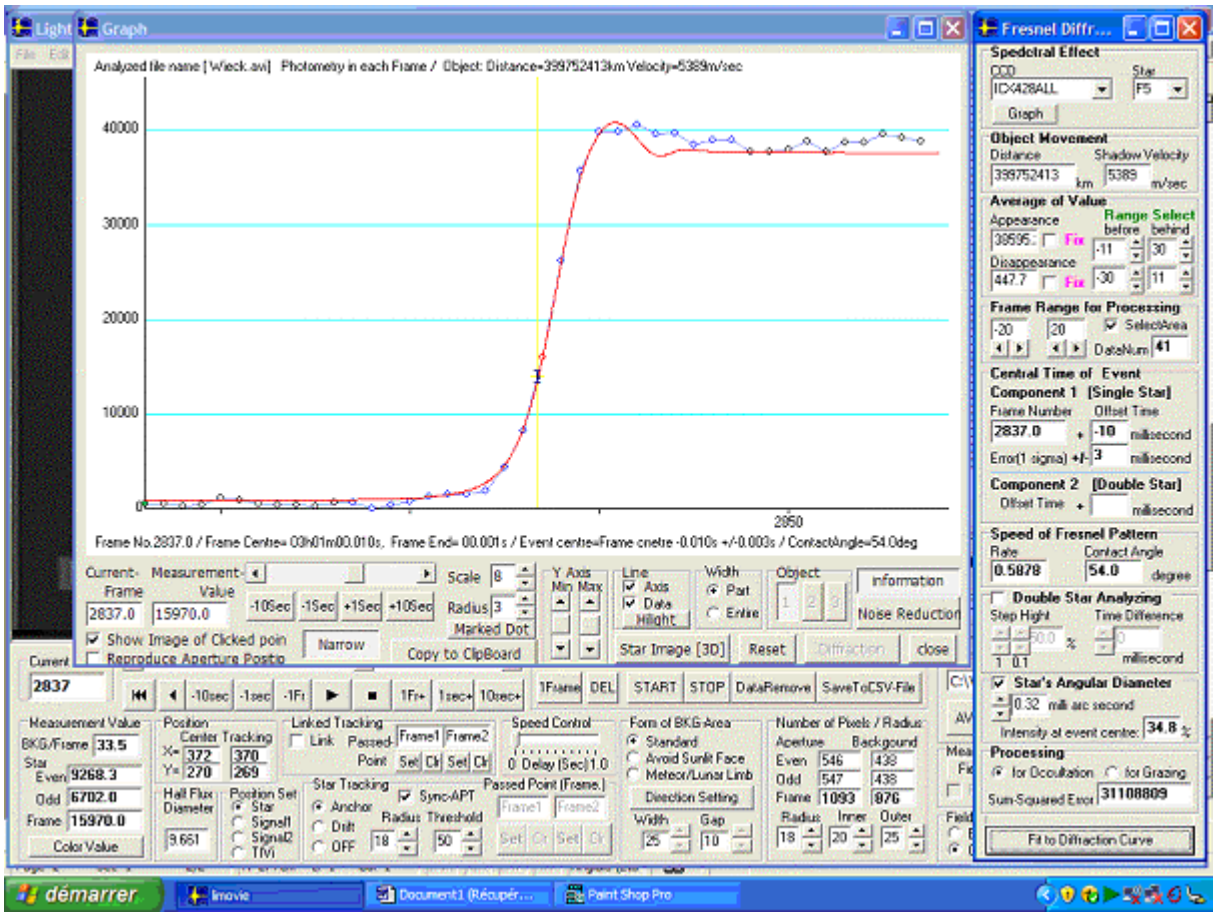
Time correction +12mS error +/- 4mS

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

Occultation analysis (reappearance)



Fitting the diffraction graph to the light graph (reappearance)

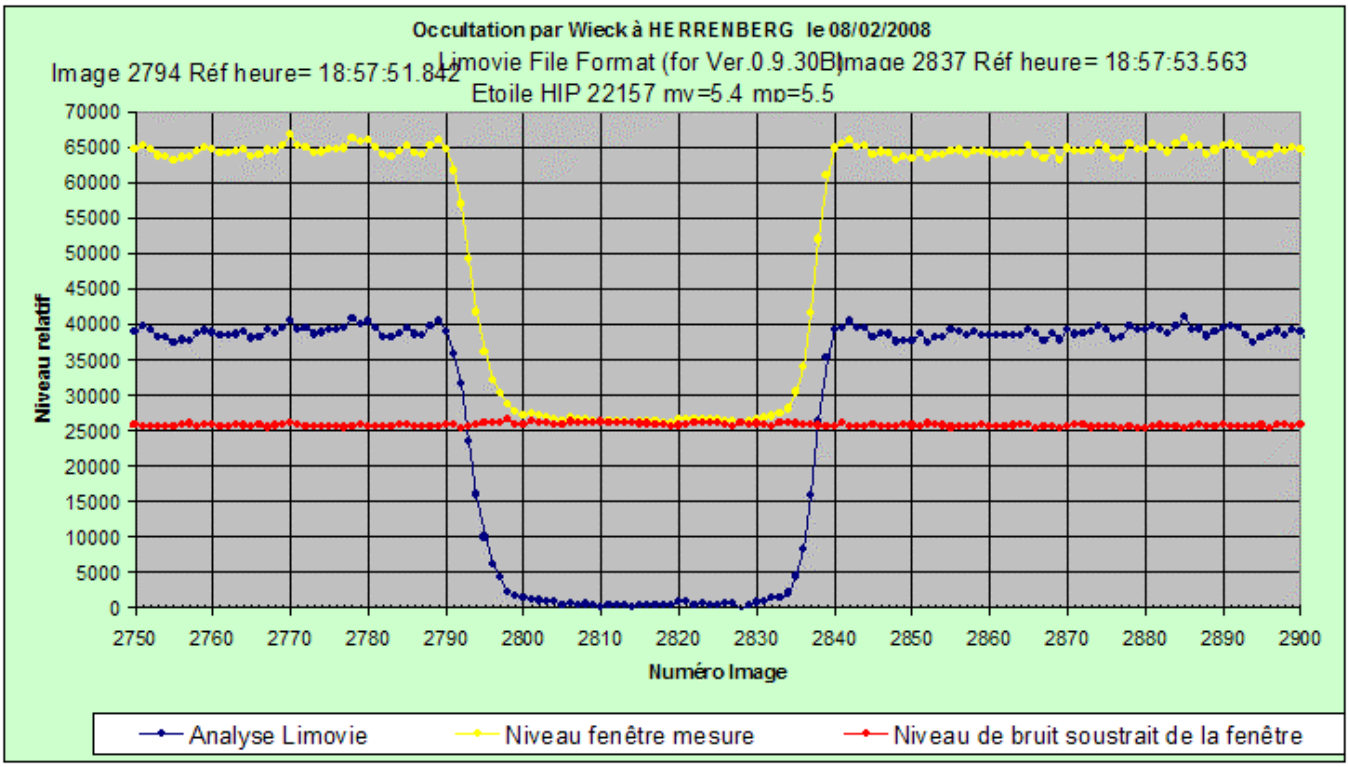


IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

The picture is the number 2837 the time is 18h57m53s583 (563 / 603)
The true speed approch is 5389*0.5878 the contact angle is 54°
Time correction –10mS
Time error +/- 3mS

One find the speed difference between disappearance and reappearance, its indicates that the movement is not perpendicular to the main axis of the ellipsoid

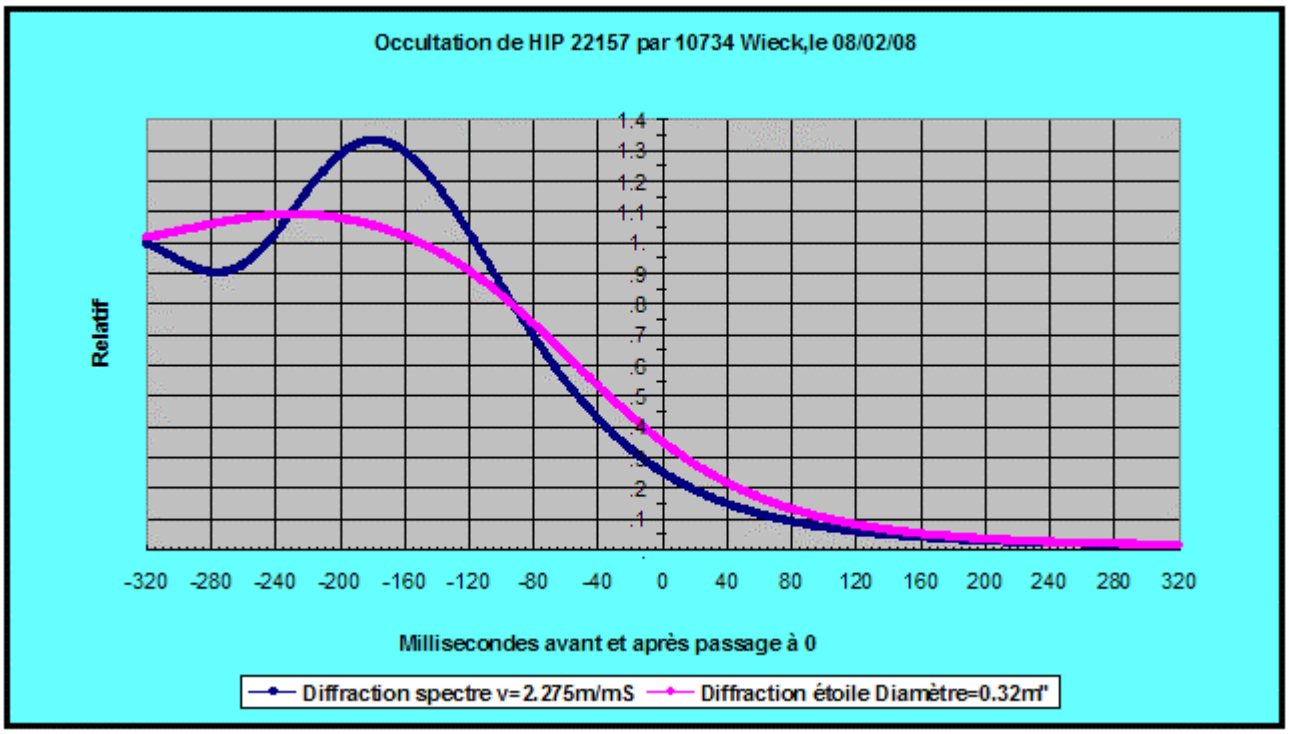
Using the « file ».CSV after transfer in an EXEL tabulator one can draw the following gaph to separate some data
The blue graph is the measured star flux by LIMOVIE
The yellow graph is the measurement in the red window (1093 pixels)
The red graph is the measurement in the ring limited by the blue circles (876 pixels), divided by 876 multiplied by 1093
The blue graph is the difference between the values of the yellow graph and those of the red graph for each value.
The average value of pixel is 26000/1093 let 23,78 ADU. The max value of a pixel is 255 the possible S/N is 10,72 but the result is only 65000/26000=2,5.
It is due to a compromise between the camera gain and the picture spreading to avoid saturation, and also to the size of the window measurement to prevent the picture turbulence.



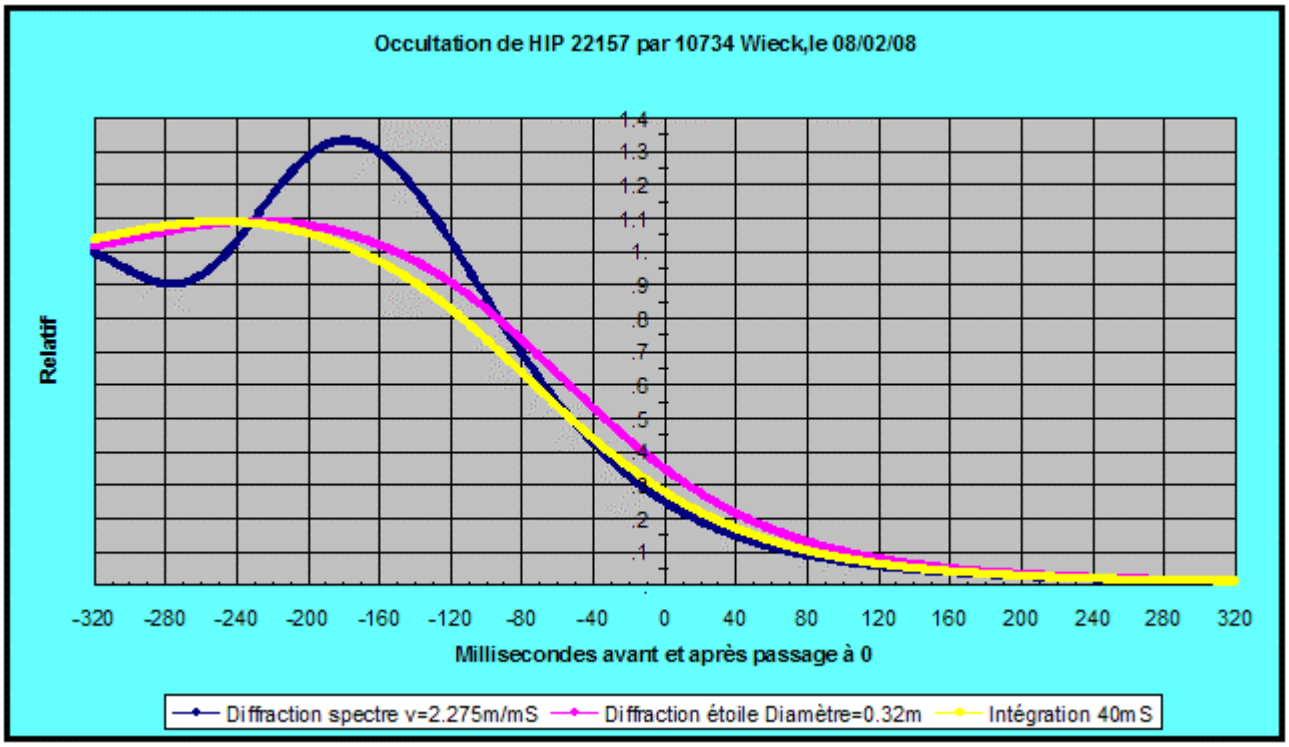
From those results we'll test another way using the measurements to compare them to the result from the diffraction after applying it the diameter effect and the integration time of 40 mS.

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

One is able to calculate a theoretical diffraction (disappearance or reappearance) using the responses of camera, filter, black body and the true approch speed of the two bodies star, asteroid, then the effect of the star diameter.



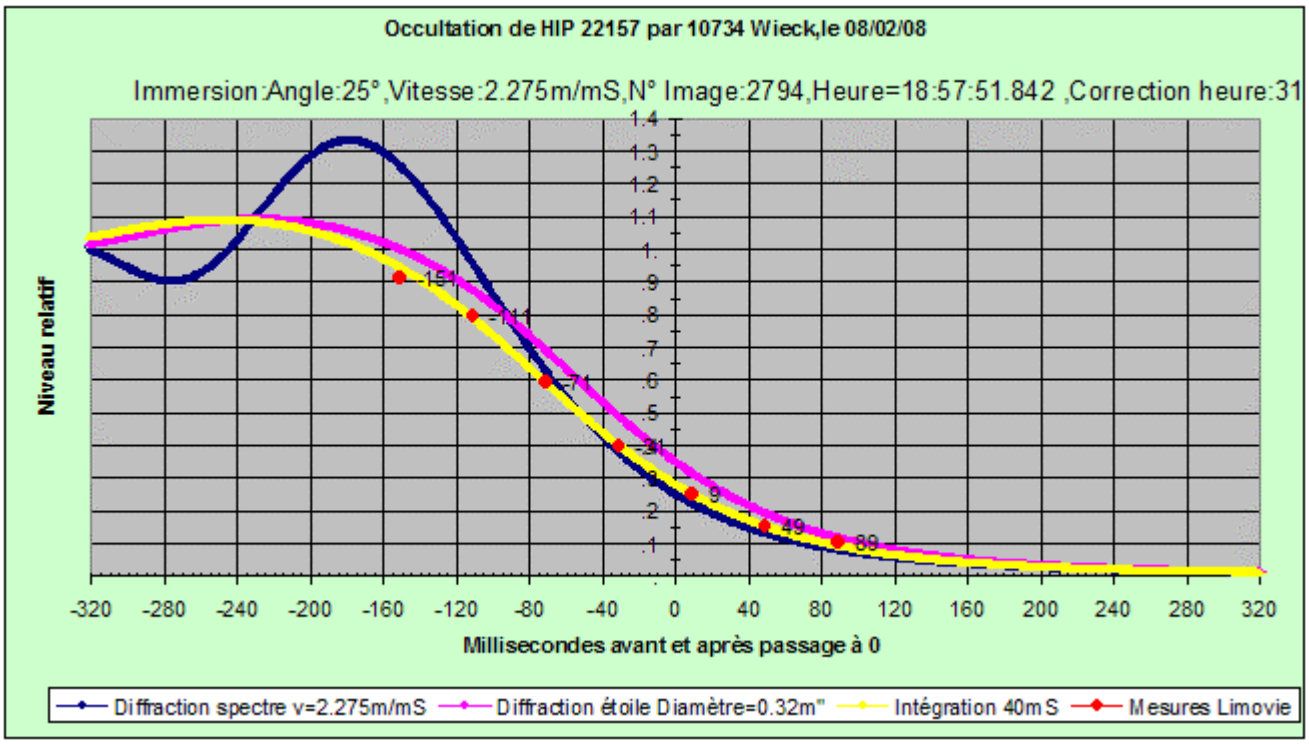
The next step is the calculation of the effect of 40mS integration



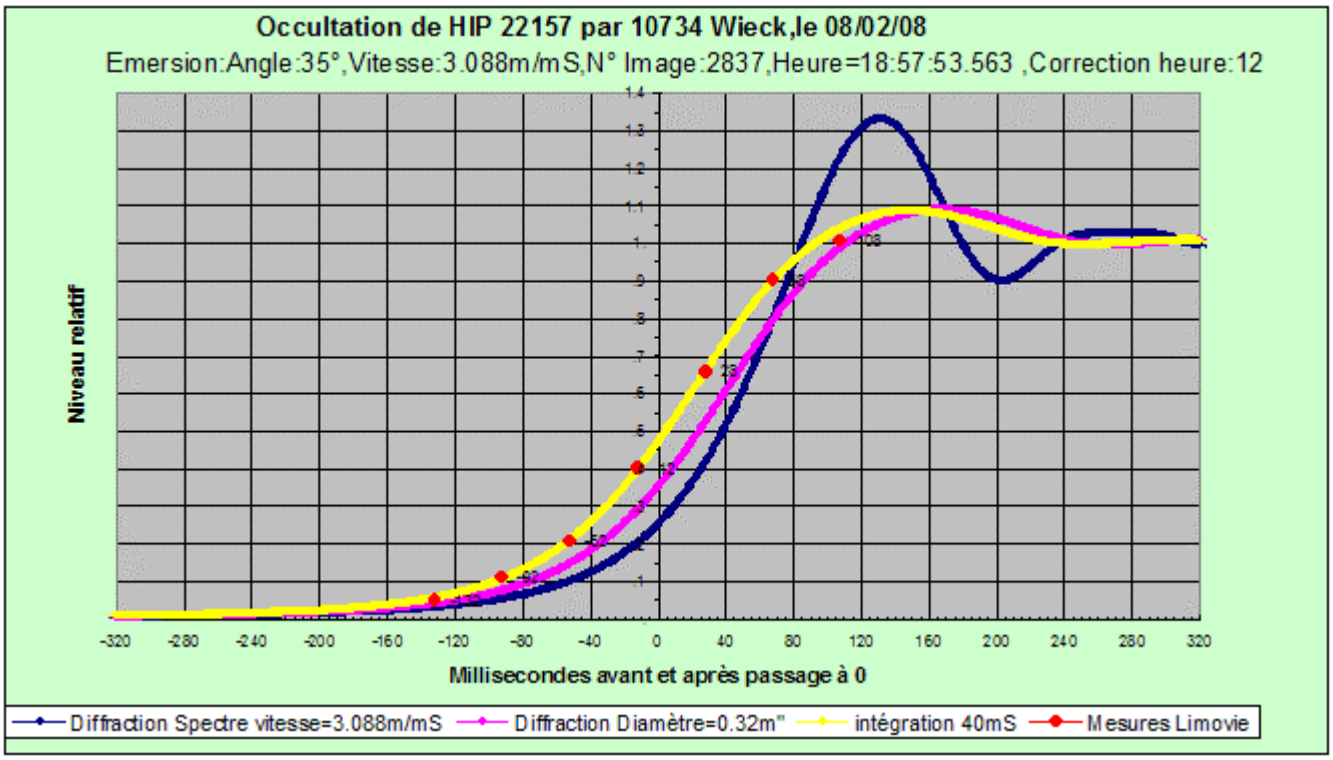
The way to obtain the yellow graph is for example for the time –120mS the value is the average of the sum values of the lilac graph from –120mS to –80mS. That is a figure of what append in a camera for an exposure time of 40ms.The same process is used for all times. The time label is the starting of the exposure time.

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

As the time inserted in the camera pictures is also the starting of the exposure time one is able to fit the measurement values to the yellow graph and to get the exact time of the concerned picture.



Time of the picture number 2794 18h57m51.842s correction +31mS before crossing 0 then that time occurs at17h57m51.873s then we got accurate time for the star centre crossing 0



For the reappearance picture number 2837 at 18h57m53.563s let 12mS before crossing 0 true time at 17h57m53.575s

One can notice than for crossing 0 the blue and lilac draw have the same values on the both graph but those values are different for the yellow graphs.

Between the two process the timings are different by 20mS. I think that: in LIMOVIE the measurement are fitted to the diameter graph not to the integrated one.

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

Sofware Cal_dif_Ast

To obtain that result the existing software has been modified in order to enlarge the diffraction calculated field to + /- 1200mS from the crossing 0, to take into account the star diameter and the phenomenon speed.

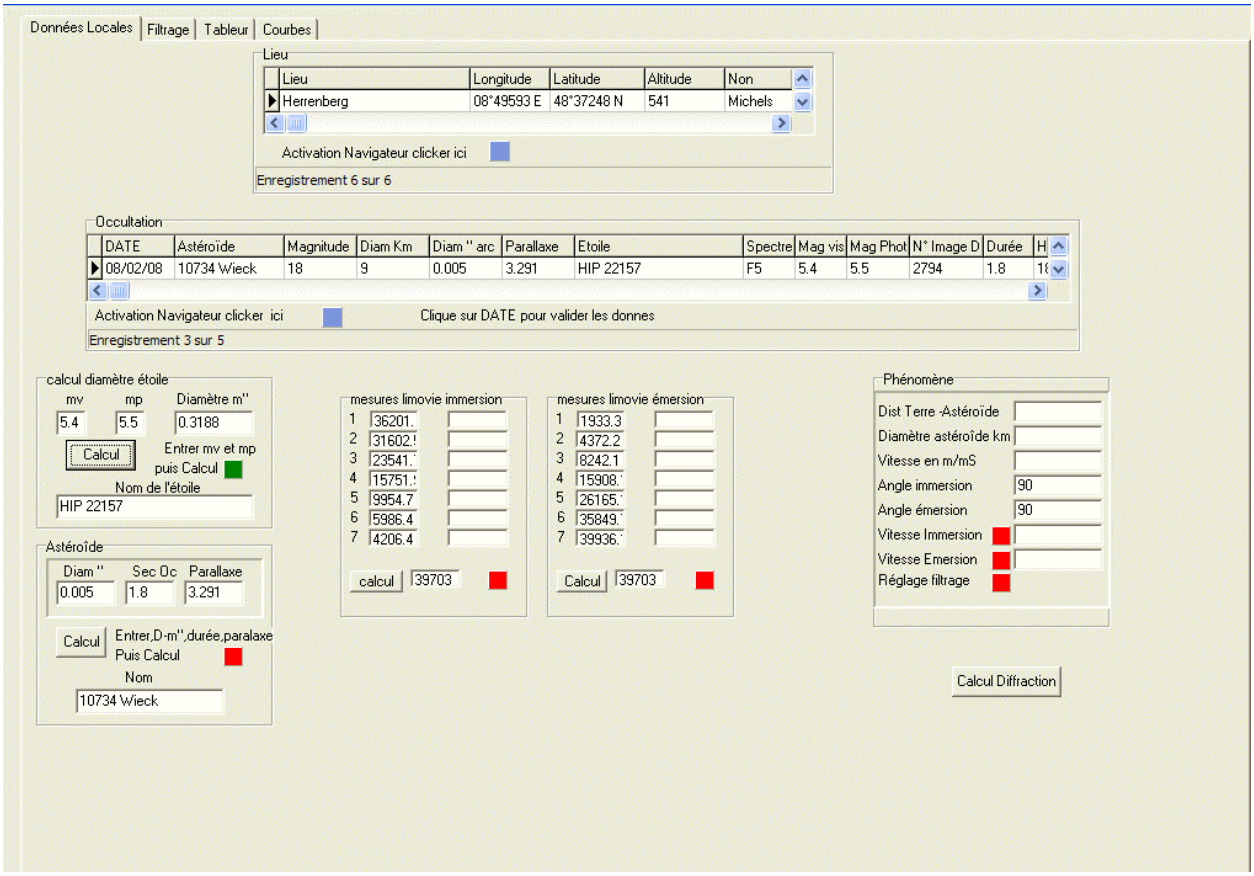
In fact the diameter and integration graphs are for the star centre for a defined time. On the above graph, the measurement corresponds to what appends for pictures in the field between –320mS and +320mS in relation with the geometrical occultation. The use of that graph is limited to the part where they are going to or from the maximum level to 0.
The measured values using LIMOVIE are converted in the same unit to the graph's ones by dividing those values by the value in the window "appearance" of LIMOVIE. Then using a value near of the halfway on the integration graph, this dot is fitted for the best on that graph. Following their timing the other values are positioned every 40mS on the same graph. To fit for the best for the other values the angle of the approch direction with the asteroid limb is modified while a good fitting is reached.
As it is a testing software, to an easier use all the data are in data base files:

- Observatories: place, longitude, latitude, altitude, operator
- Data concerning the occultation reduction
- Spectral response of some video camera CCD
- Spectral response of some filters
- Bodies temperature function of spectral classification
-

The software has 4 panels:

- Local Data (Données Locales)
- Filtering (Filtrage)
- Graphs (Courbes)
- Work Sheet (Tableur)

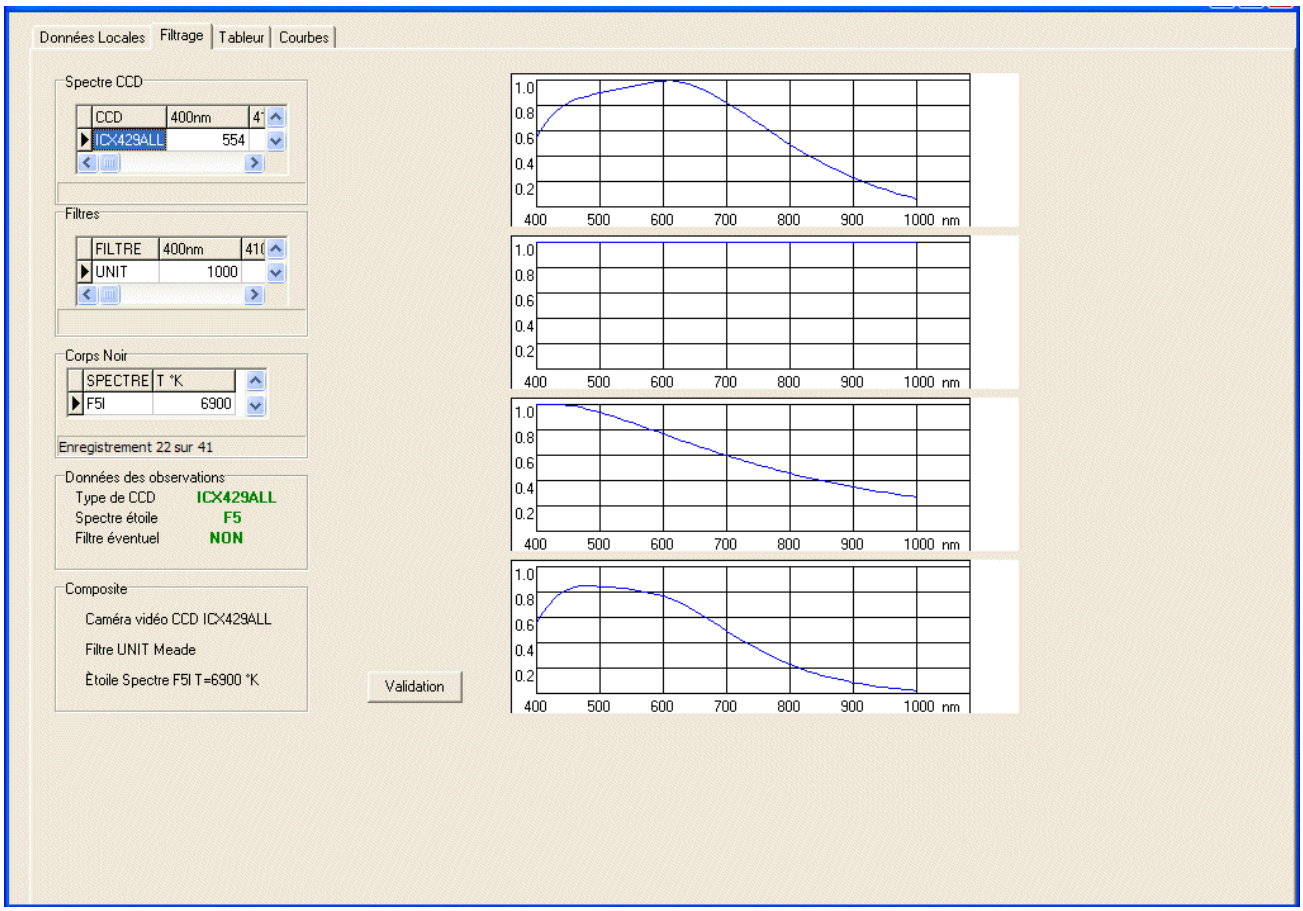
Those different displays are for calculus and operations described using the picture tabs.



On that tab there are some panels:

- **Lieu**: choice of the location
- **Données de l'occultation :** occultation choice. Click on **DATE** to validate the data
- **Calcul diamètre étoile** :Star diameter from mv and mp, click on "**calcul"** button to do that
- **Astéroïde** : do the calculation of distance Earth-Asteroid, asteroid diameter, speed on the diameter, using the "**calcul"** button the first 3 cells of the **Phénomène** are enabled
- **Mesures limovie immersion** a click on "**calcul"** puts in right place the values normalized
- **Mesures Limovie émersion** a click on "**calcul"** puts in right place the values normalized.
- **Phénomène** in it there are: Earth Asteroid distance, Asteroid diameter, radial speed of the phenomenon , choice for the disappearing and reappearing angles. A click on the white cells "Vitesse Immersion" and "Vitesse Emersion" makes the calculus and the red square go to be green. a click on the red square "réglage filtrage" moves to the tab "Filtrage".

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS



Following the indications of the panel ”Données des observations “ on the data windows you must choose the adequate values

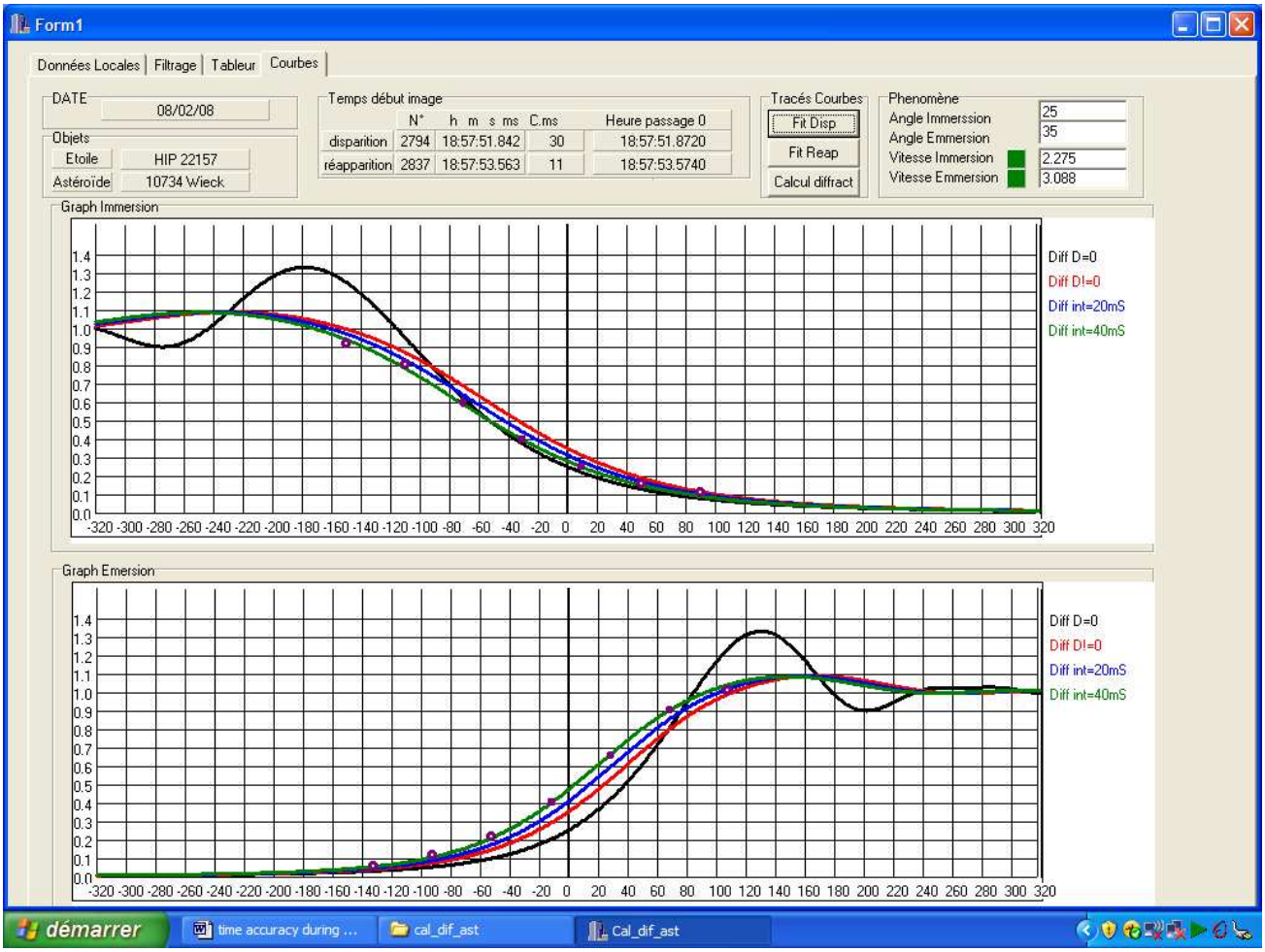
The 4 graphs give the following responses:

- CCD camera
- Filter: On that picture the response is flat and equal to 1, (no filter)
- Response of the black body of the chosen spectrum
- Composite response

A click on the "Validation" Button, moves to the tab "Données locales" and shift the “réglage filtrage” square to green.

A click on "Calcul diffraction" displays the panel "Courbes"

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

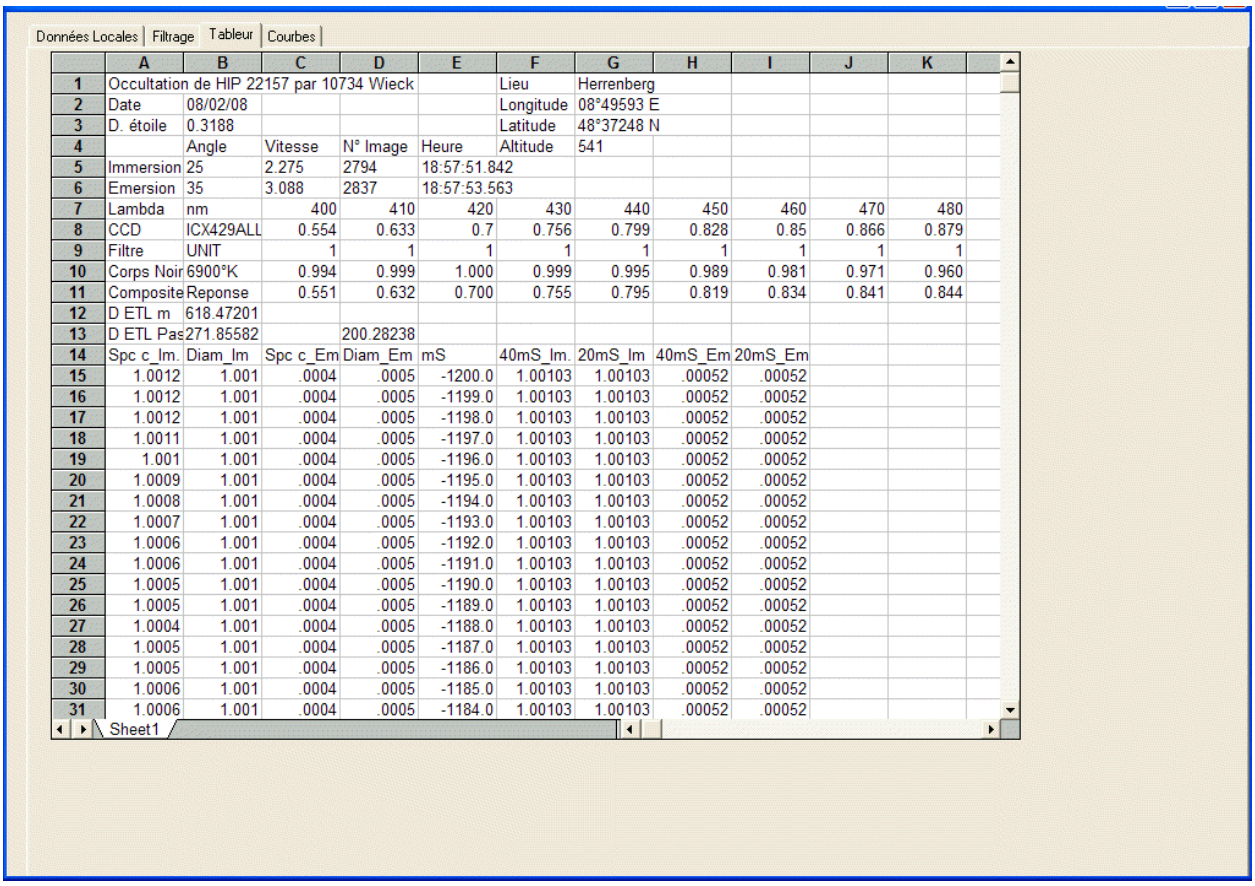


That tab reproduces:

- The date
- The star number
- The number and name of the asteroid
- The pictures number and hours of starting exposures
- The time correction to be done
- The crossing 0 hours
- The adjustment of the disappearing and reappearing angles, every time the angles are changed the corresponding square shift to red. You must click on the corresponding window to return to green.
- A button "Calcul de diffract "
- Two buttons "Fit disp» and "Fit reap"

A click on "Tableur" displays the calculation results

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

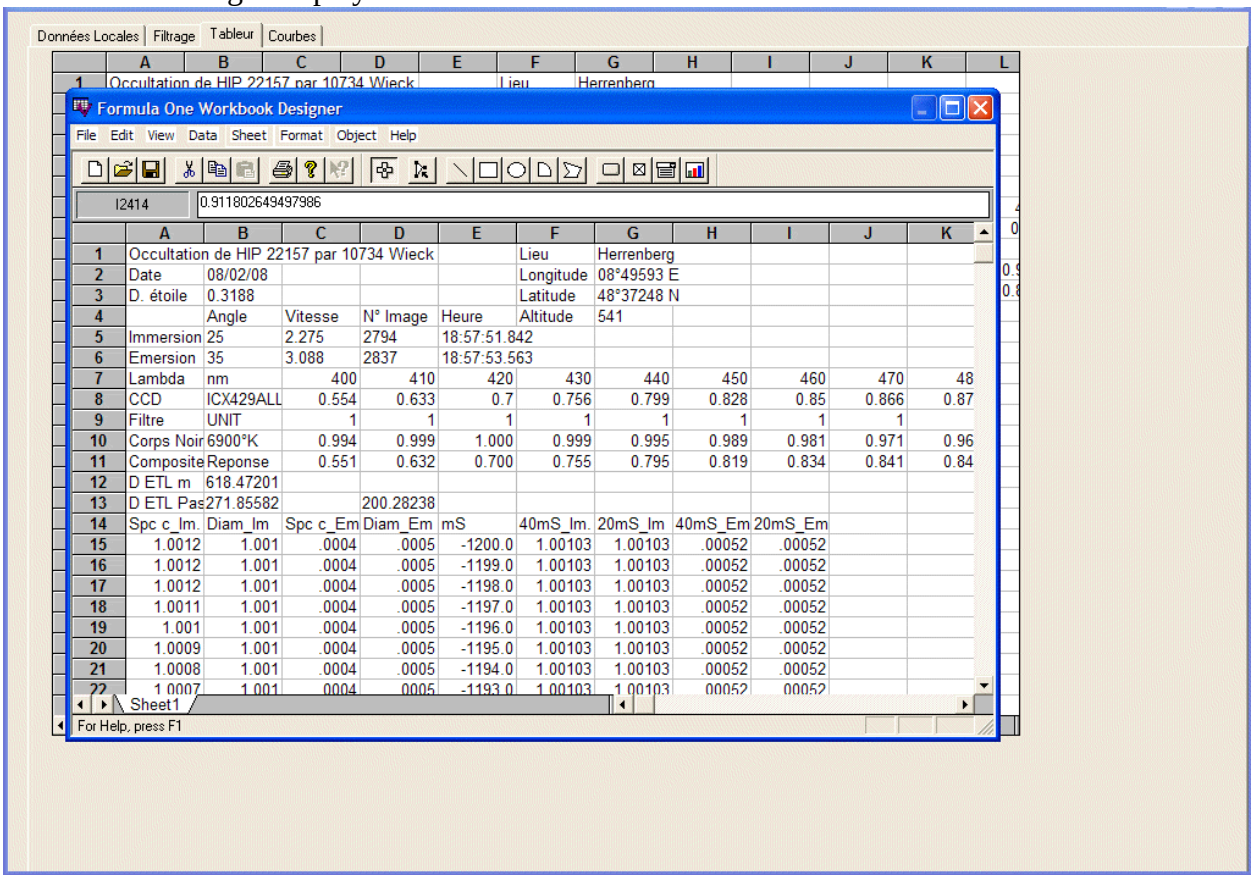


Données Locales | Filtrage | Tableur | Courbes

	A	B	C	D	E	F	G	H	I	J	K
1	Occultation de HIP 22157 par 10734 Wieck					Lieu	Herrenberg				
2	Date	08/02/08				Longitude	08°49593 E				
3	D. étoile	0.3188				Latitude	48°37248 N				
4		Angle	Vitesse	N° Image	Heure	Altitude	541				
5	Immersion	25	2.275	2794	18:57:51.842						
6	Emersion	35	3.088	2837	18:57:53.563						
7	Lambda	nm	400	410	420	430	440	450	460	470	480
8	CCD	ICX429ALL	0.554	0.633	0.7	0.756	0.799	0.828	0.85	0.866	0.879
9	Filtre	UNIT	1	1	1	1	1	1	1	1	1
10	Corps Noir	6900°K	0.994	0.999	1.000	0.999	0.995	0.989	0.981	0.971	0.960
11	Composite	Reponse	0.551	0.632	0.700	0.755	0.795	0.819	0.834	0.841	0.844
12	D ETL m	618.47201									
13	D ETL Pas	271.85582		200.28238							
14	Spc c_Im.	Diam_Im	Spc c_Em	Diam_Em	mS	40mS_Im.	20mS_Im	40mS_Em	20mS_Em		
15	1.0012	1.001	.0004	.0005	-1200.0	1.00103	1.00103	.00052	.00052		
16	1.0012	1.001	.0004	.0005	-1199.0	1.00103	1.00103	.00052	.00052		
17	1.0012	1.001	.0004	.0005	-1198.0	1.00103	1.00103	.00052	.00052		
18	1.0011	1.001	.0004	.0005	-1197.0	1.00103	1.00103	.00052	.00052		
19	1.001	1.001	.0004	.0005	-1196.0	1.00103	1.00103	.00052	.00052		
20	1.0009	1.001	.0004	.0005	-1195.0	1.00103	1.00103	.00052	.00052		
21	1.0008	1.001	.0004	.0005	-1194.0	1.00103	1.00103	.00052	.00052		
22	1.0007	1.001	.0004	.0005	-1193.0	1.00103	1.00103	.00052	.00052		
23	1.0006	1.001	.0004	.0005	-1192.0	1.00103	1.00103	.00052	.00052		
24	1.0006	1.001	.0004	.0005	-1191.0	1.00103	1.00103	.00052	.00052		
25	1.0005	1.001	.0004	.0005	-1190.0	1.00103	1.00103	.00052	.00052		
26	1.0005	1.001	.0004	.0005	-1189.0	1.00103	1.00103	.00052	.00052		
27	1.0004	1.001	.0004	.0005	-1188.0	1.00103	1.00103	.00052	.00052		
28	1.0005	1.001	.0004	.0005	-1187.0	1.00103	1.00103	.00052	.00052		
29	1.0005	1.001	.0004	.0005	-1186.0	1.00103	1.00103	.00052	.00052		
30	1.0006	1.001	.0004	.0005	-1185.0	1.00103	1.00103	.00052	.00052		
31	1.0006	1.001	.0004	.0005	-1184.0	1.00103	1.00103	.00052	.00052		

Sheet1

A double click right displays a tabulator



Données Locales | Filtrage | Tableur | Courbes

Formula One Workbook Designer

File Edit View Data Sheet Format Object Help

I2414 0.911802649497986

	A	B	C	D	E	F	G	H	I	J	K
1	Occultation de HIP 22157 par 10734 Wieck					Lieu	Herrenberg				
2	Date	08/02/08				Longitude	08°49593 E				
3	D. étoile	0.3188				Latitude	48°37248 N				
4		Angle	Vitesse	N° Image	Heure	Altitude	541				
5	Immersion	25	2.275	2794	18:57:51.842						
6	Emersion	35	3.088	2837	18:57:53.563						
7	Lambda	nm	400	410	420	430	440	450	460	470	48
8	CCD	ICX429ALL	0.554	0.633	0.7	0.756	0.799	0.828	0.85	0.866	0.87
9	Filtre	UNIT	1	1	1	1	1	1	1	1	
10	Corps Noir	6900°K	0.994	0.999	1.000	0.999	0.995	0.989	0.981	0.971	0.96
11	Composite	Reponse	0.551	0.632	0.700	0.755	0.795	0.819	0.834	0.841	0.84
12	D ETL m	618.47201									
13	D ETL Pas	271.85582		200.28238							
14	Spc c_Im.	Diam_Im	Spc c_Em	Diam_Em	mS	40mS_Im.	20mS_Im	40mS_Em	20mS_Em		
15	1.0012	1.001	.0004	.0005	-1200.0	1.00103	1.00103	.00052	.00052		
16	1.0012	1.001	.0004	.0005	-1199.0	1.00103	1.00103	.00052	.00052		
17	1.0012	1.001	.0004	.0005	-1198.0	1.00103	1.00103	.00052	.00052		
18	1.0011	1.001	.0004	.0005	-1197.0	1.00103	1.00103	.00052	.00052		
19	1.001	1.001	.0004	.0005	-1196.0	1.00103	1.00103	.00052	.00052		
20	1.0009	1.001	.0004	.0005	-1195.0	1.00103	1.00103	.00052	.00052		
21	1.0008	1.001	.0004	.0005	-1194.0	1.00103	1.00103	.00052	.00052		
22	1.0007	1.001	.0004	.0005	-1193.0	1.00103	1.00103	.00052	.00052		

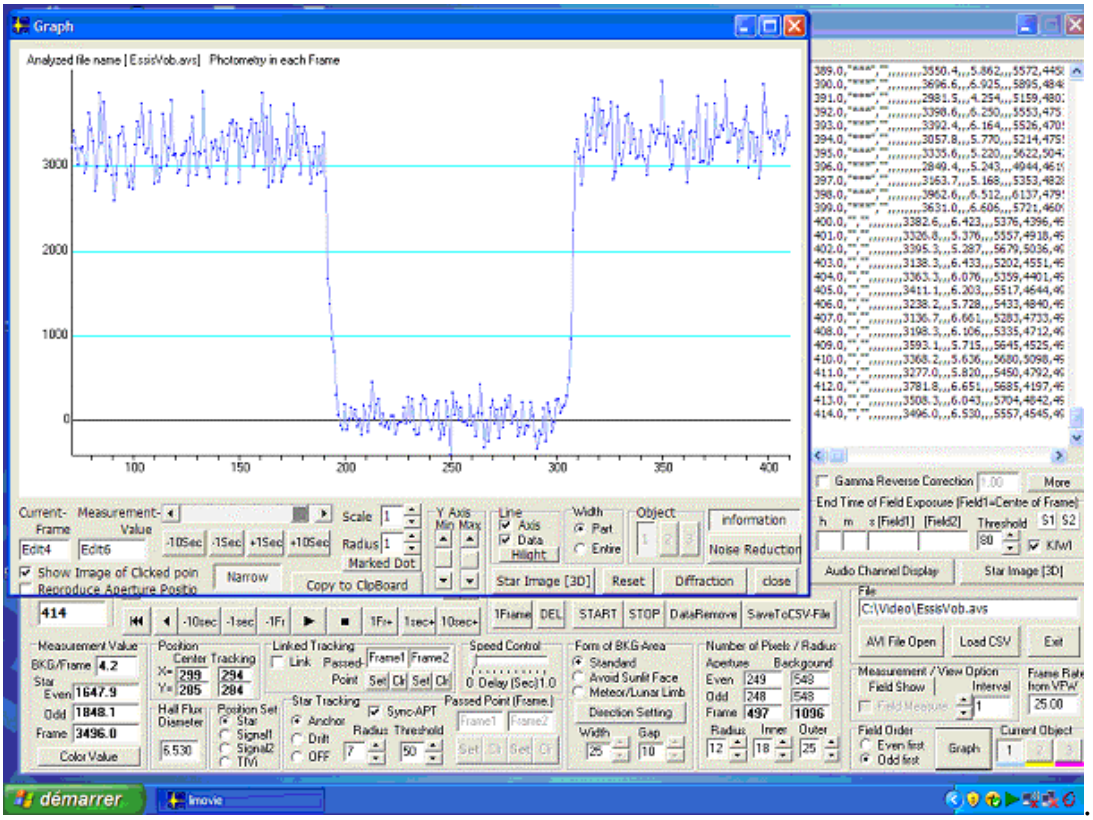
Sheet1

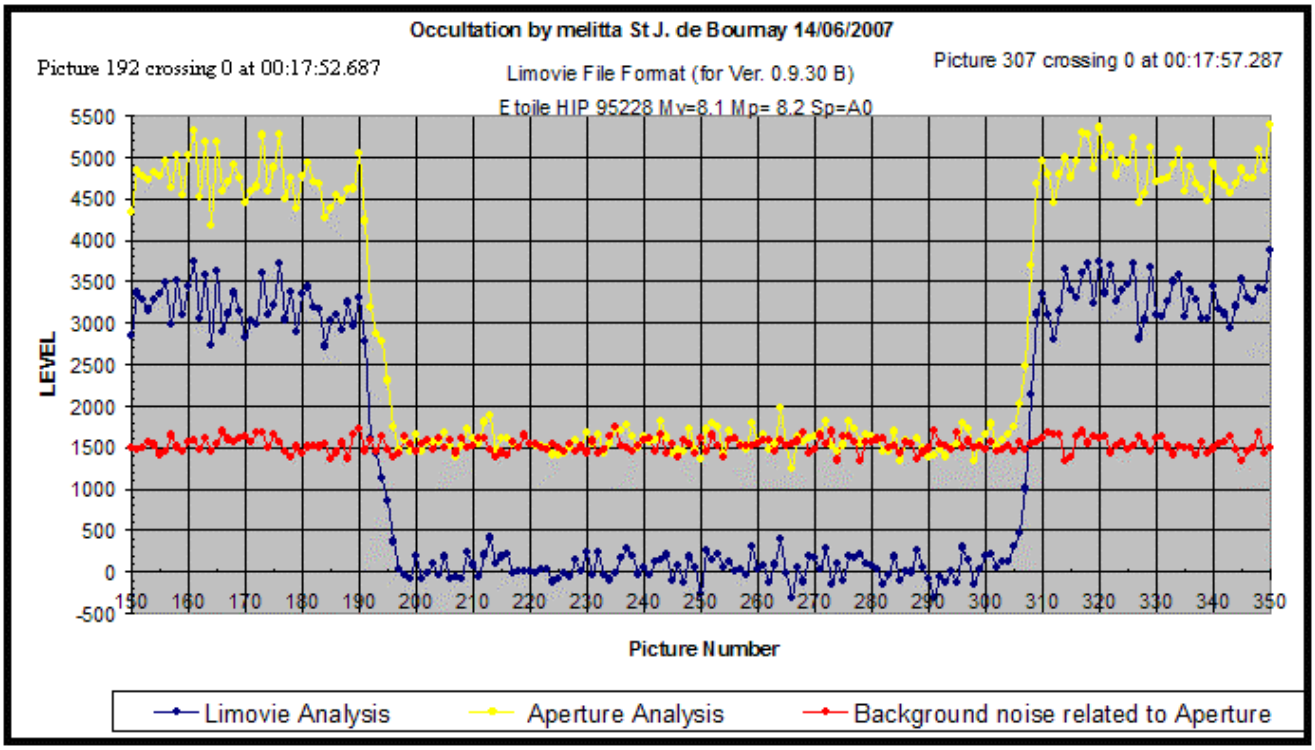
For Help, press F1

Could be saved in an EXEL tabulator, one is able to draw some graphs.
As that the way seems to be promising we test it on 3 other occultation's

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

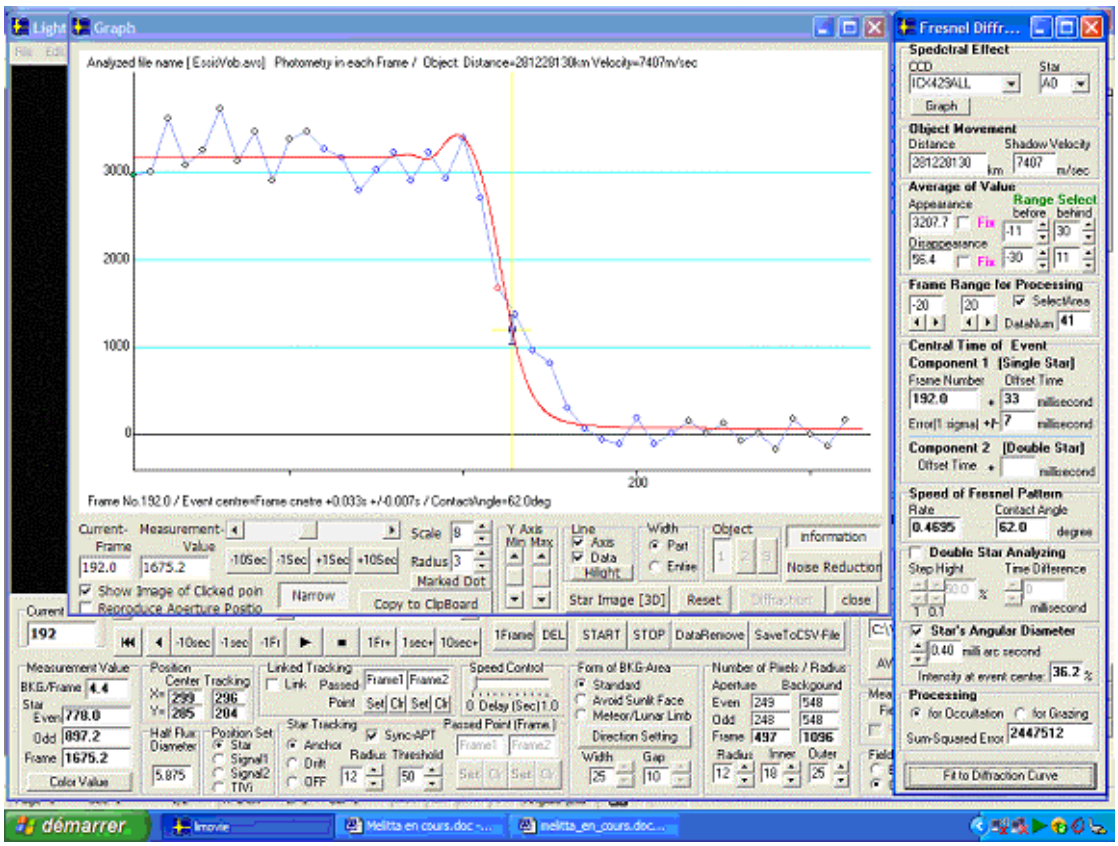
Occultation by Melitta

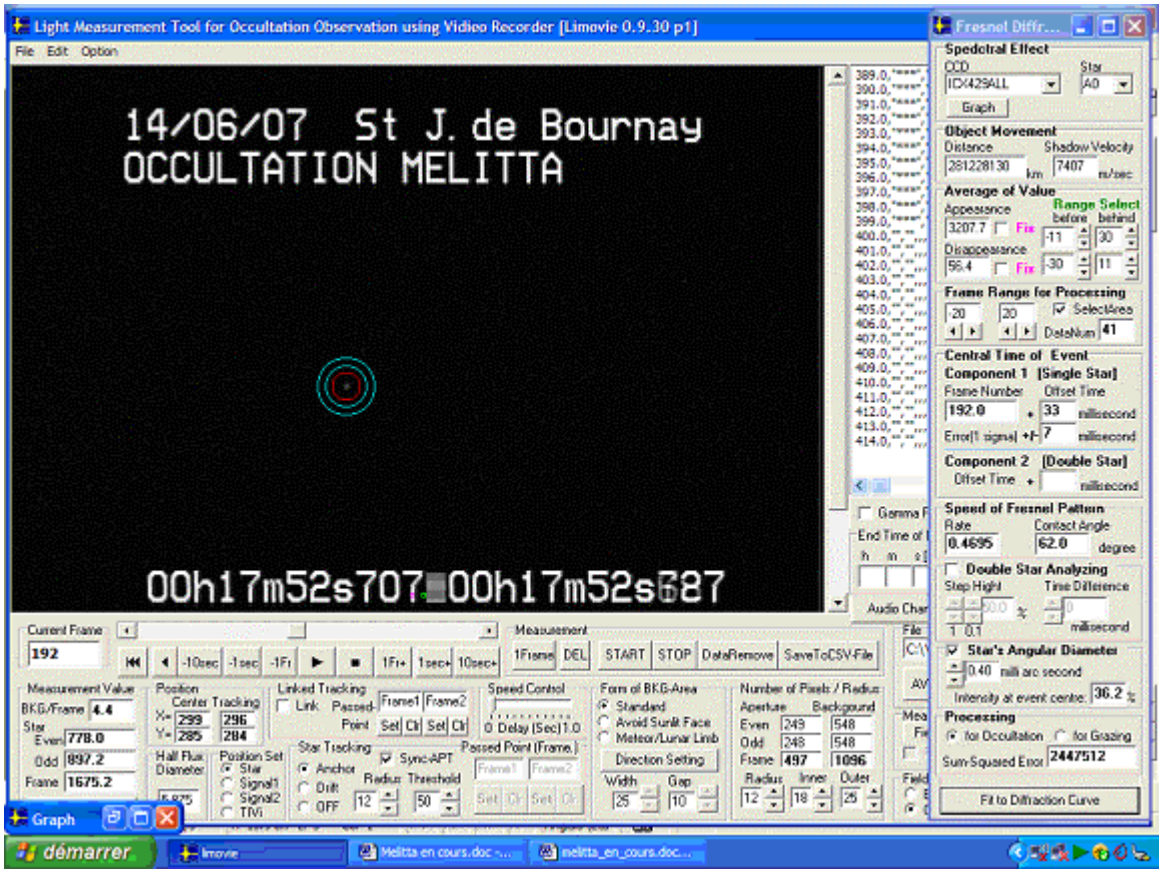




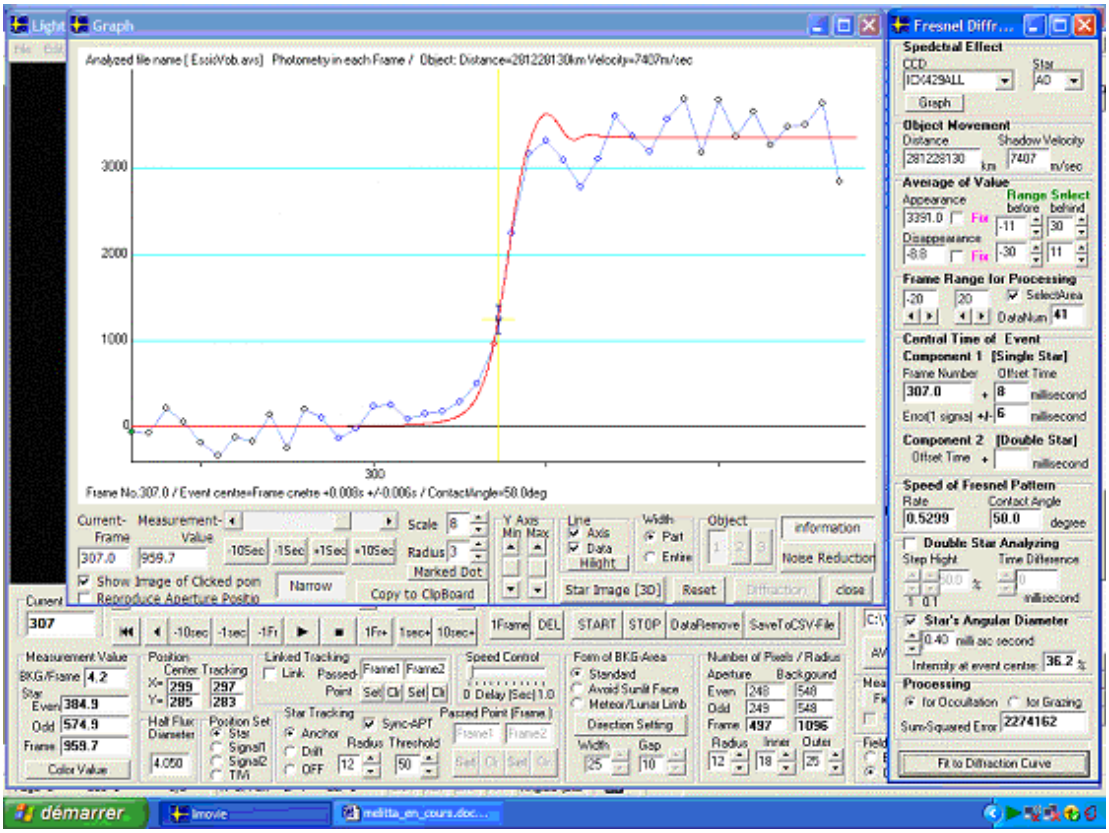
The noise by pixel is now 1500/497 let 3
As the max of a pixel is 255 then the S/N could be 255/3 let 85
The true value is 4700/1500 let 3,13

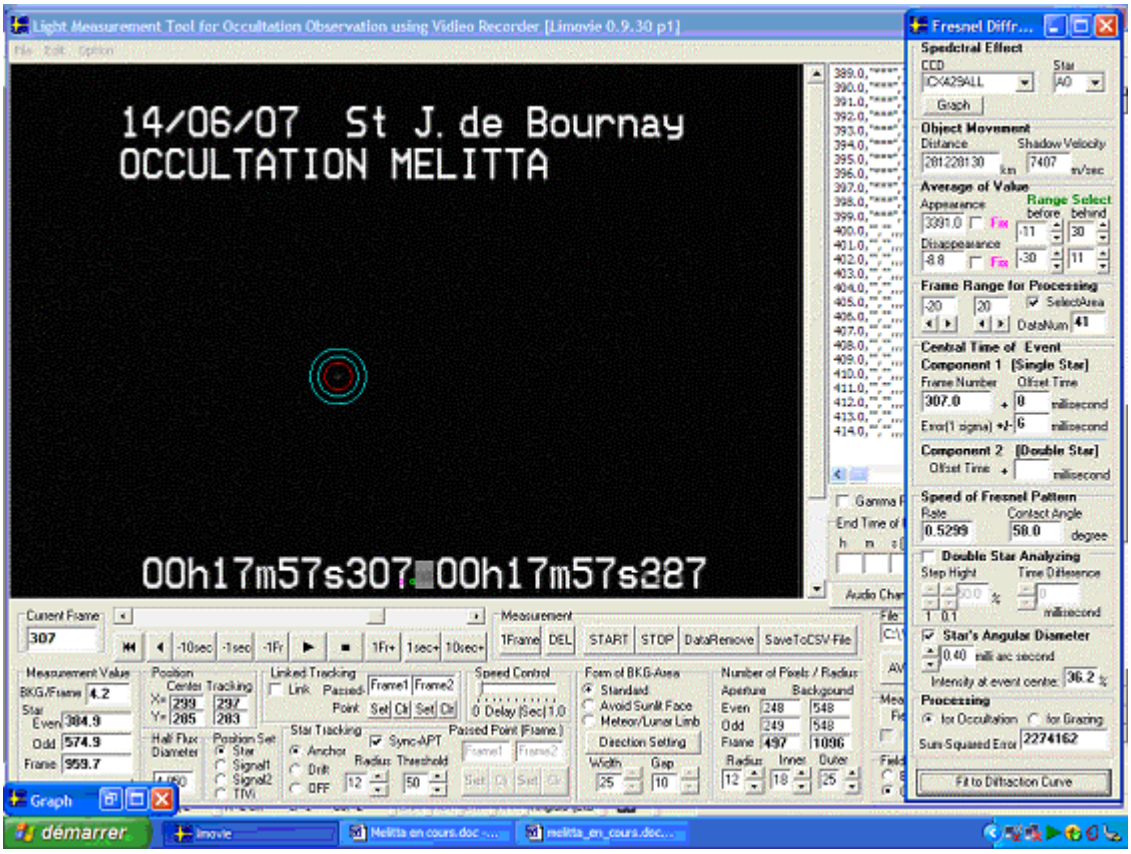
IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS



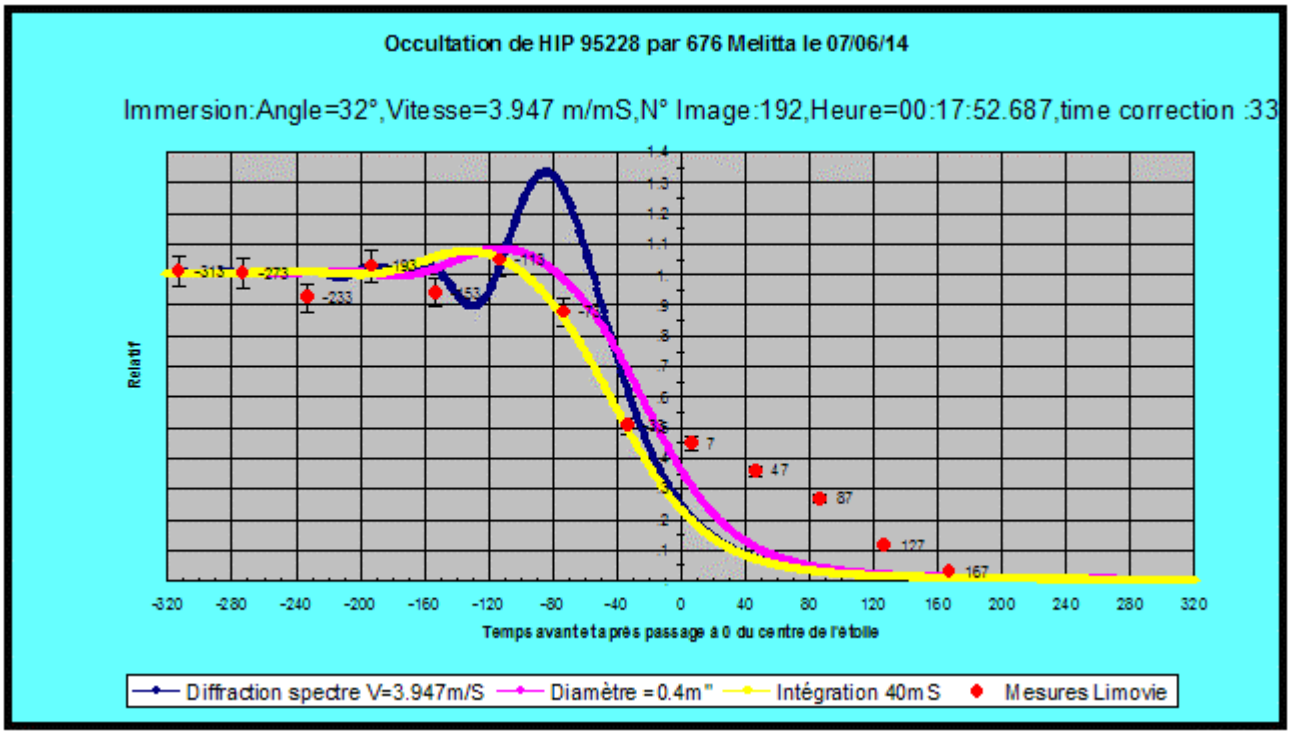


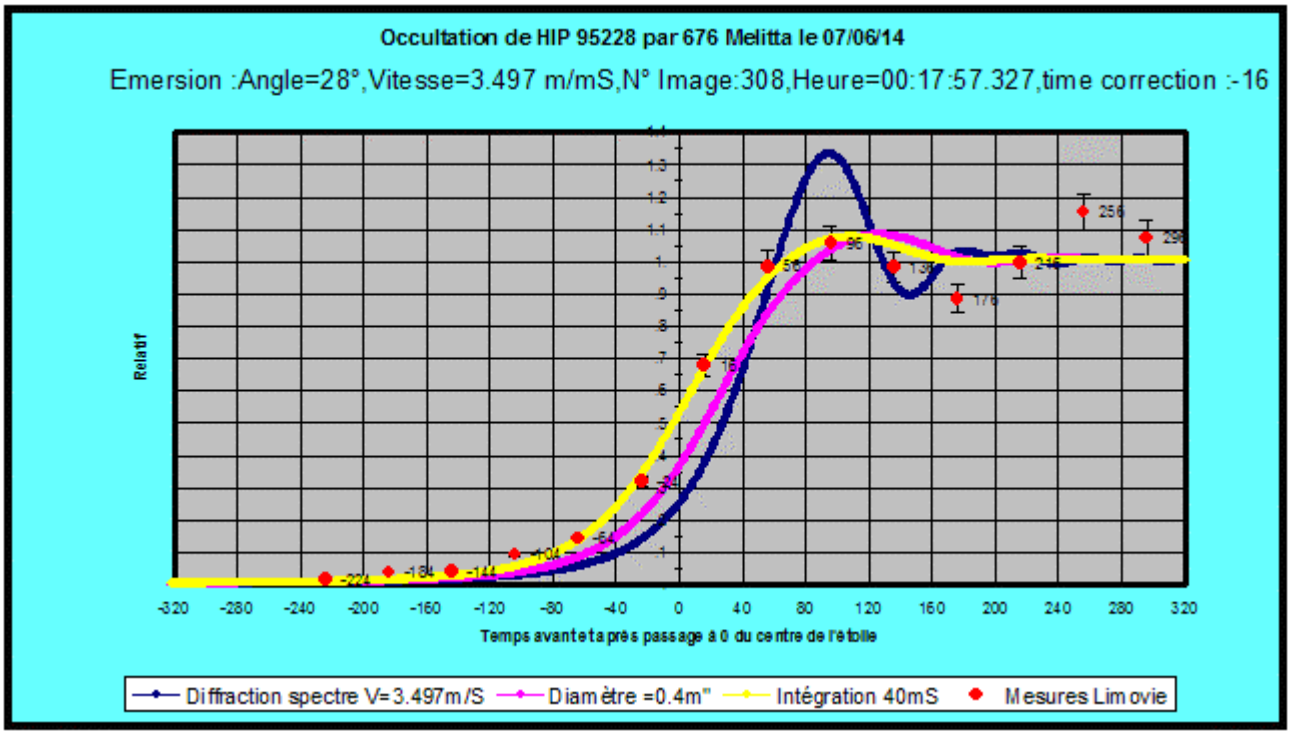
IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS





IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS



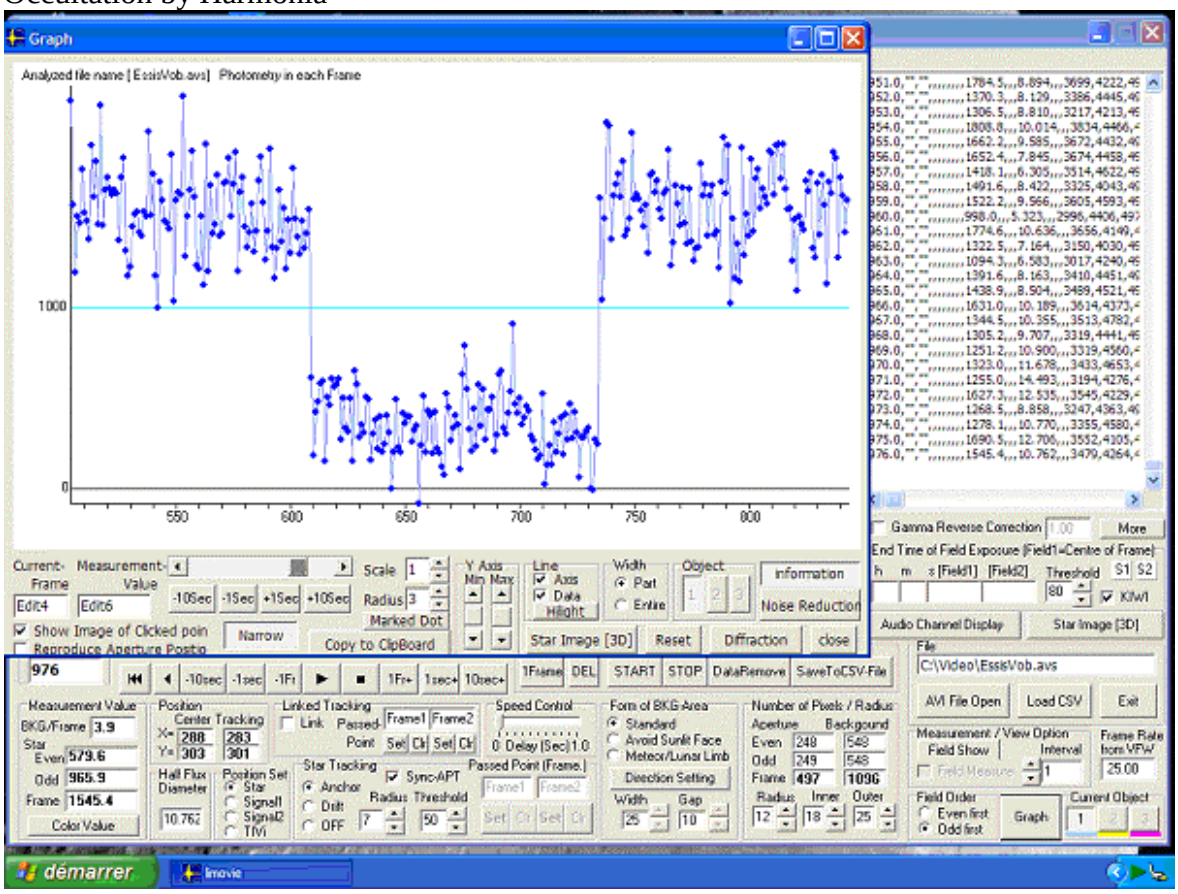


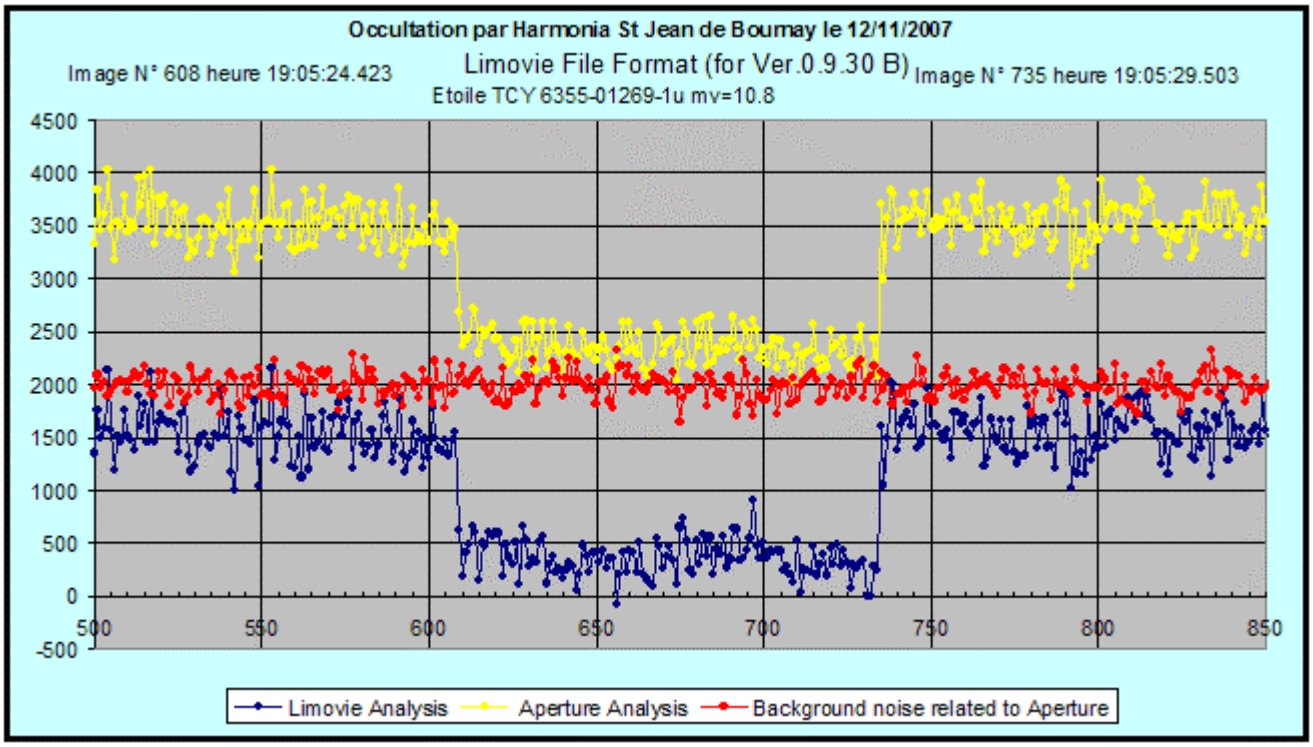
Results		Limovie		My self
Disappearing picture	192	0h17m52.720	192	0h17m52.720
Reappearing picture	307	0h17m57.295	308	0h17m52.311

On the disappearing there is a variation of the asteroid relief de the asteroid, or a double star
The calculated star diameter is wrong: the star is not on the main sequence of the HR diagram

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

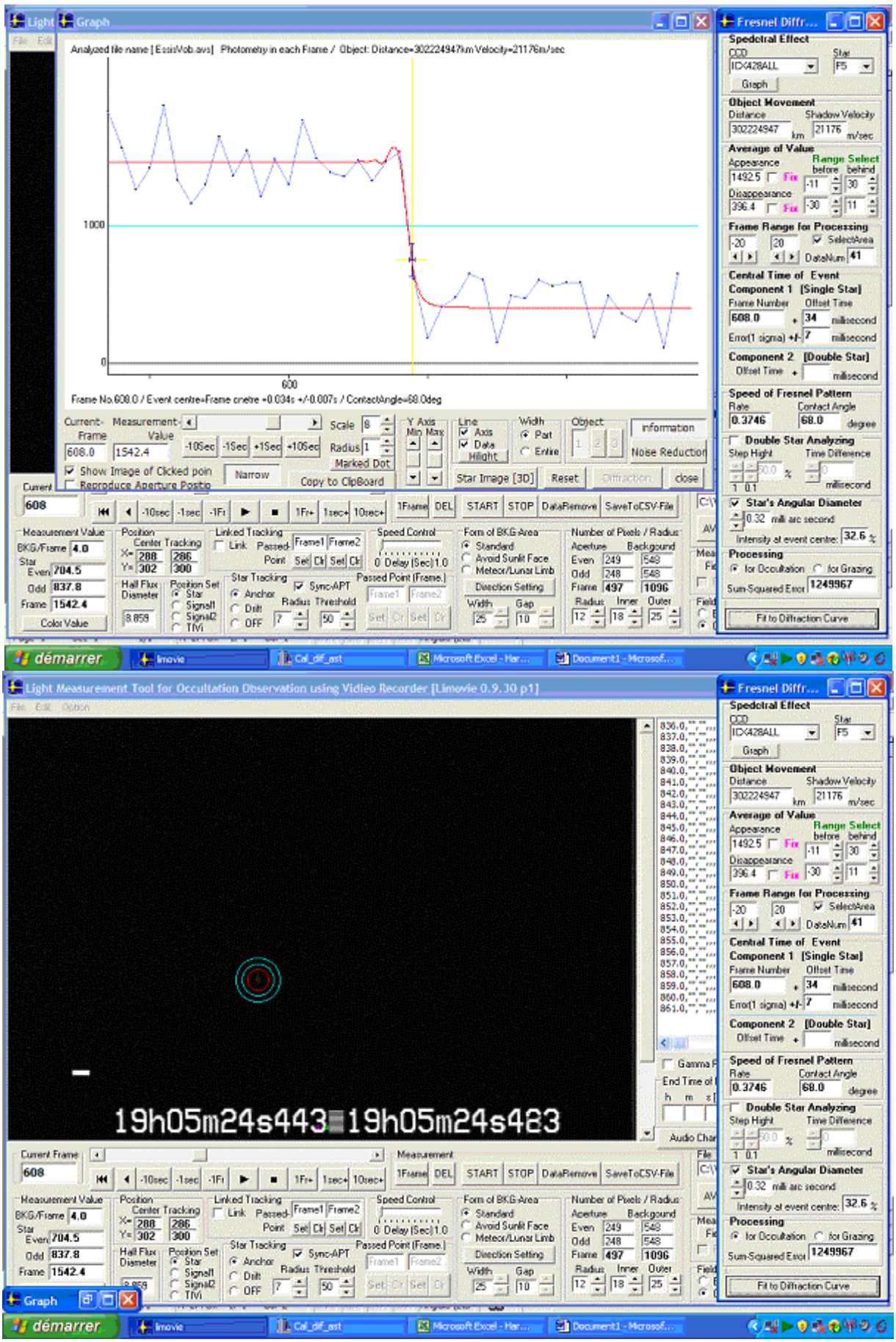
Occultation by Harmonia



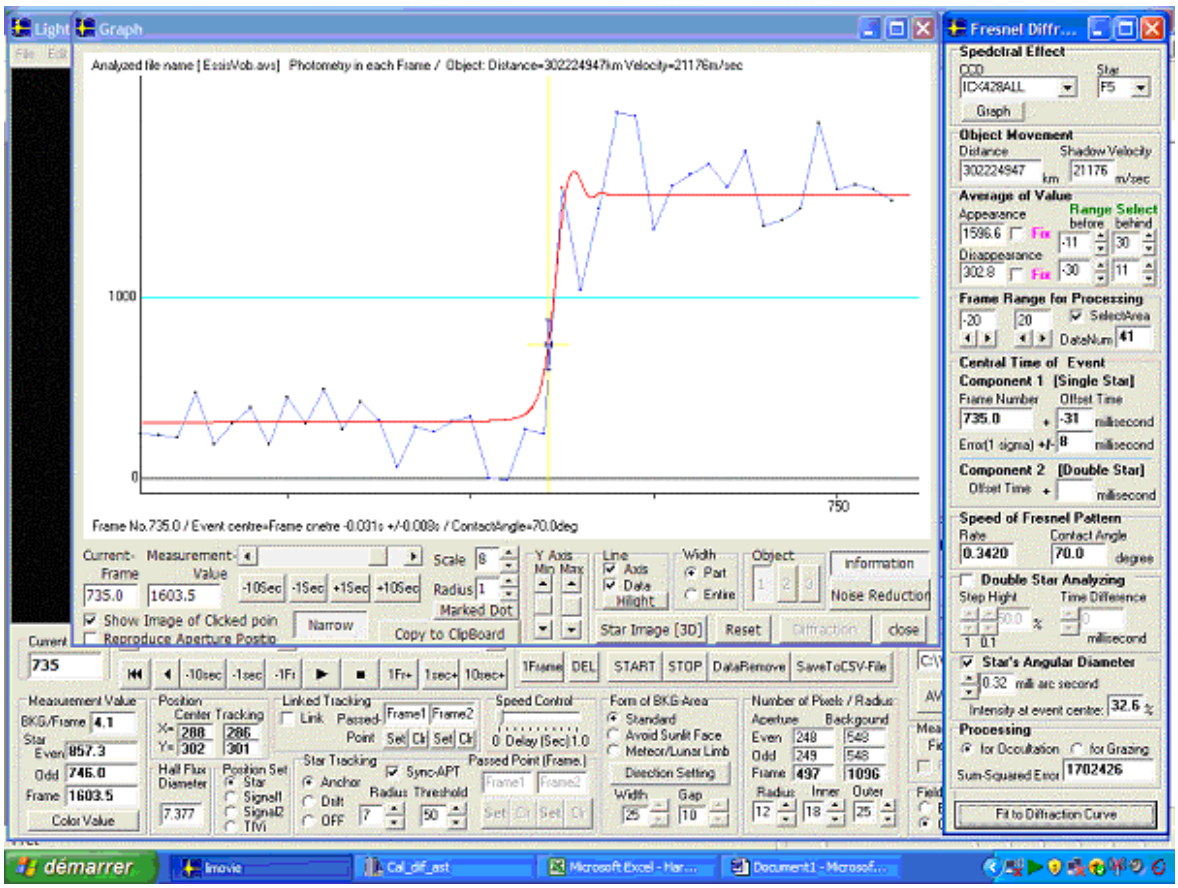


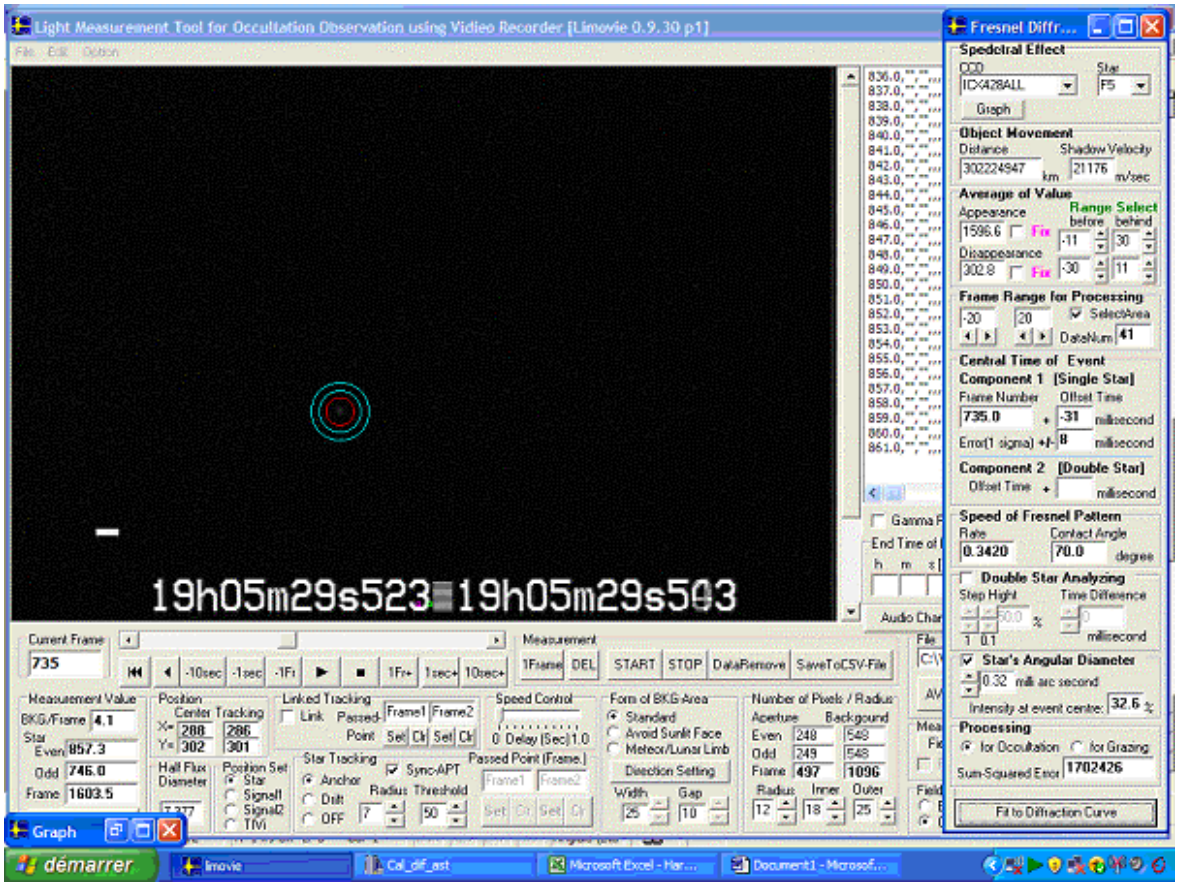
The noise by pixel is 2000/497 let 4
The max possible is255/4 let Signal/noise of 63
The true value is 3500/2000 let 1.75

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

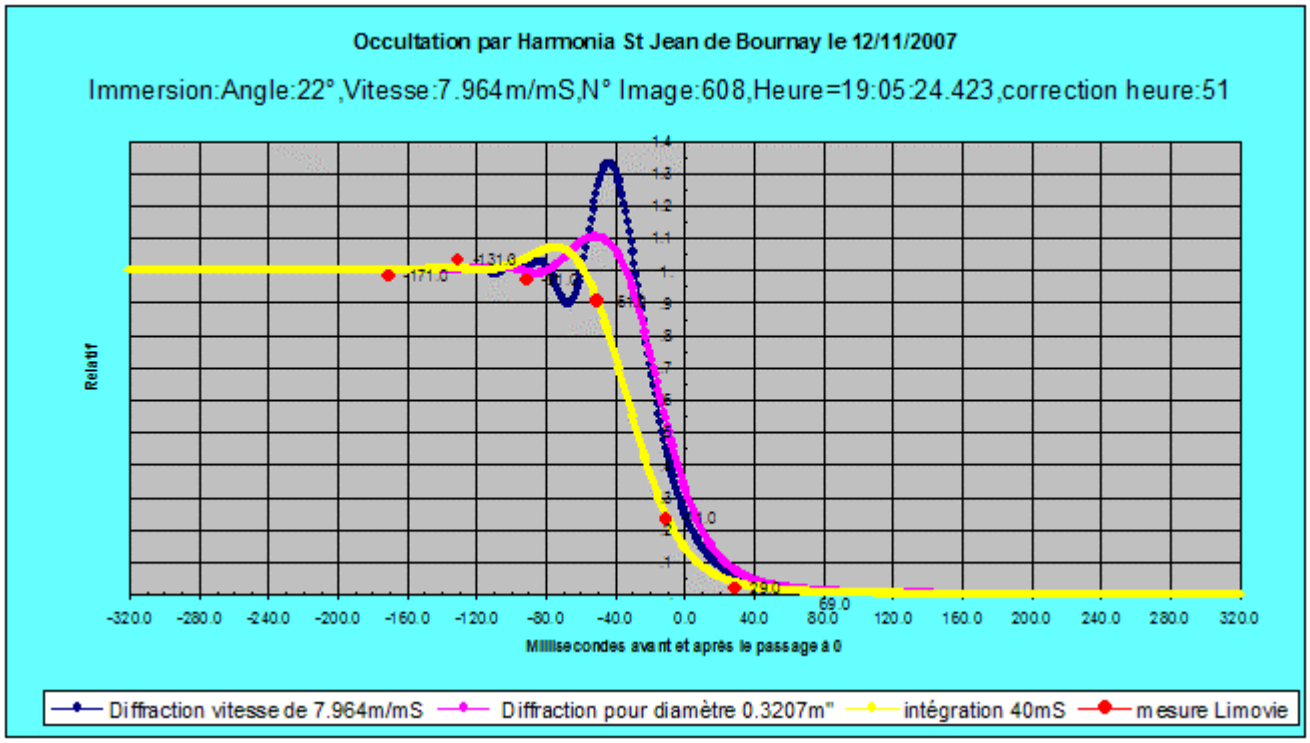


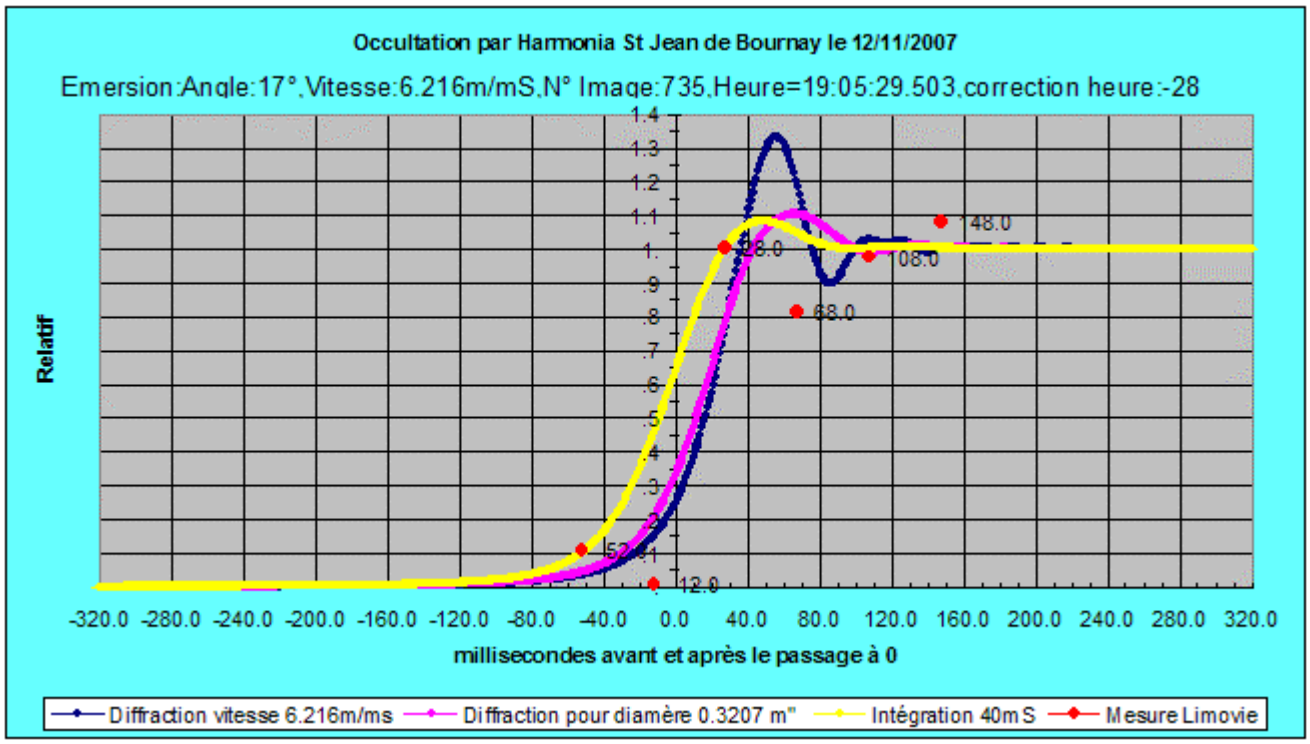
IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS





IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS



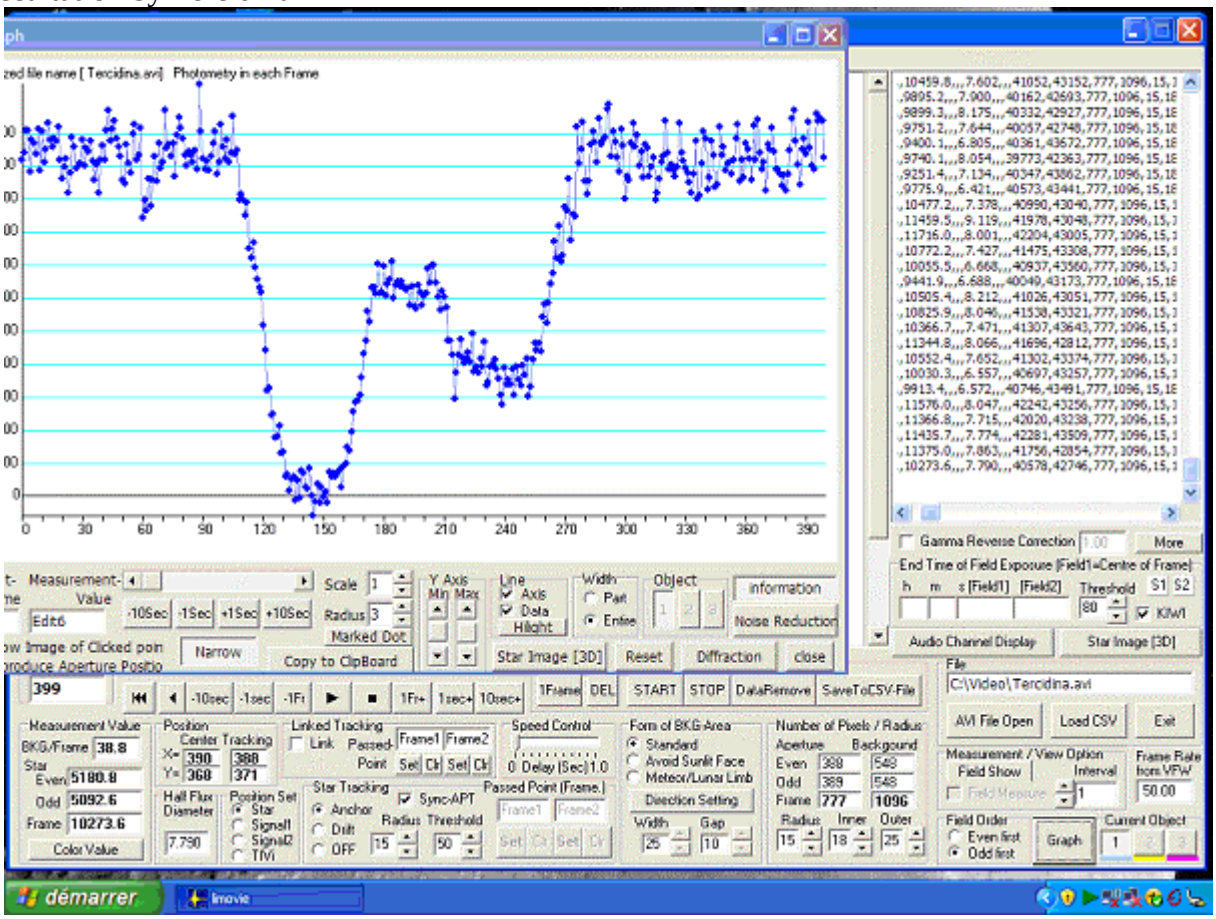


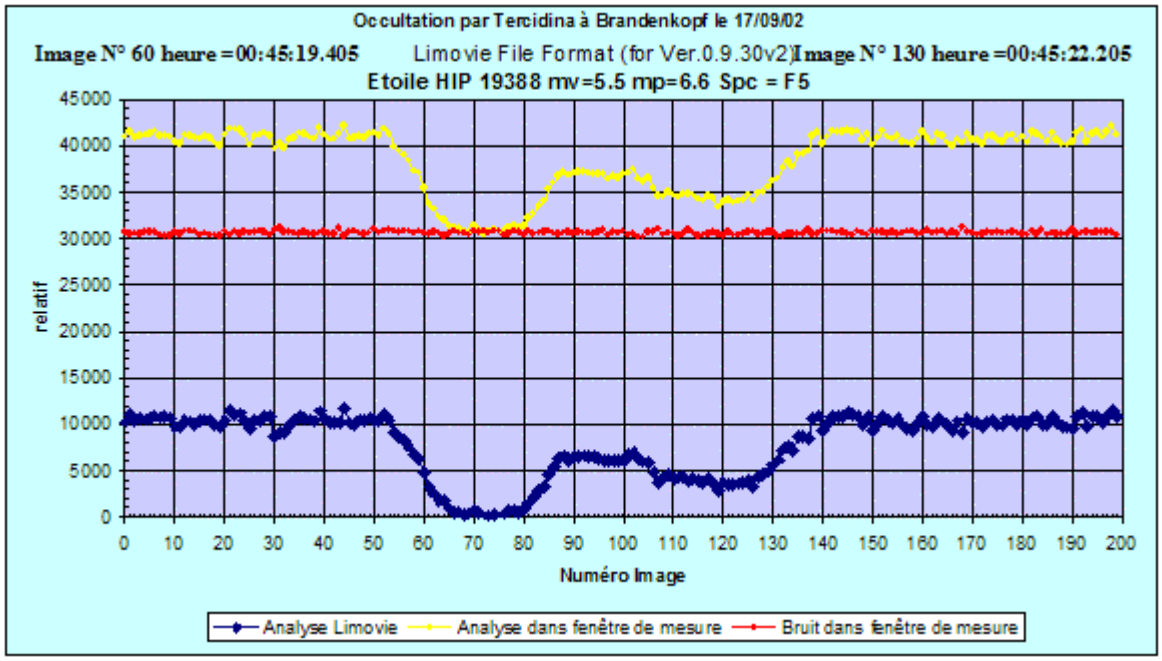
Results	Limovie		My self
Disappearance picture 608	19h05m24.457	608	19h05m24.474
Reappearance picture 735	19h05m29.472	735	19h05m29.475

As it is a speed phenomenon there are not enough values in the interesting zone then a poor accuracy, the reappearance is erratic.
The calculated diameter seems to be correct

IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

Occultation by Tercidina





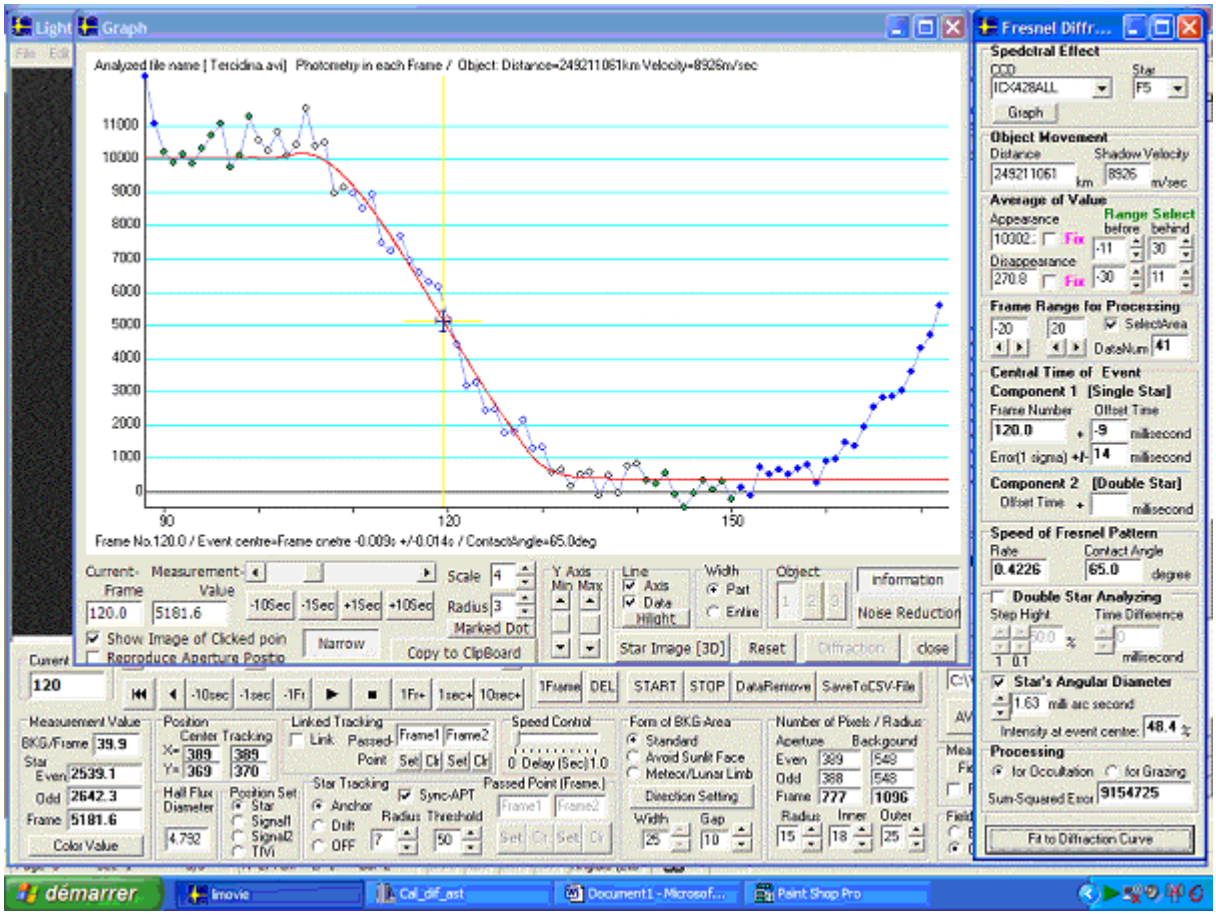
Those occultation it is a little bit pecular: the video record is composed as series of pictures built from the same video field . In order to return to true 40mS pictures, the values obtained by picture has been added 2 by 2 : picture 1+picture 2, picture 3+ picture 4…. The first one (blue) is the Limovie's values added in EXEL,

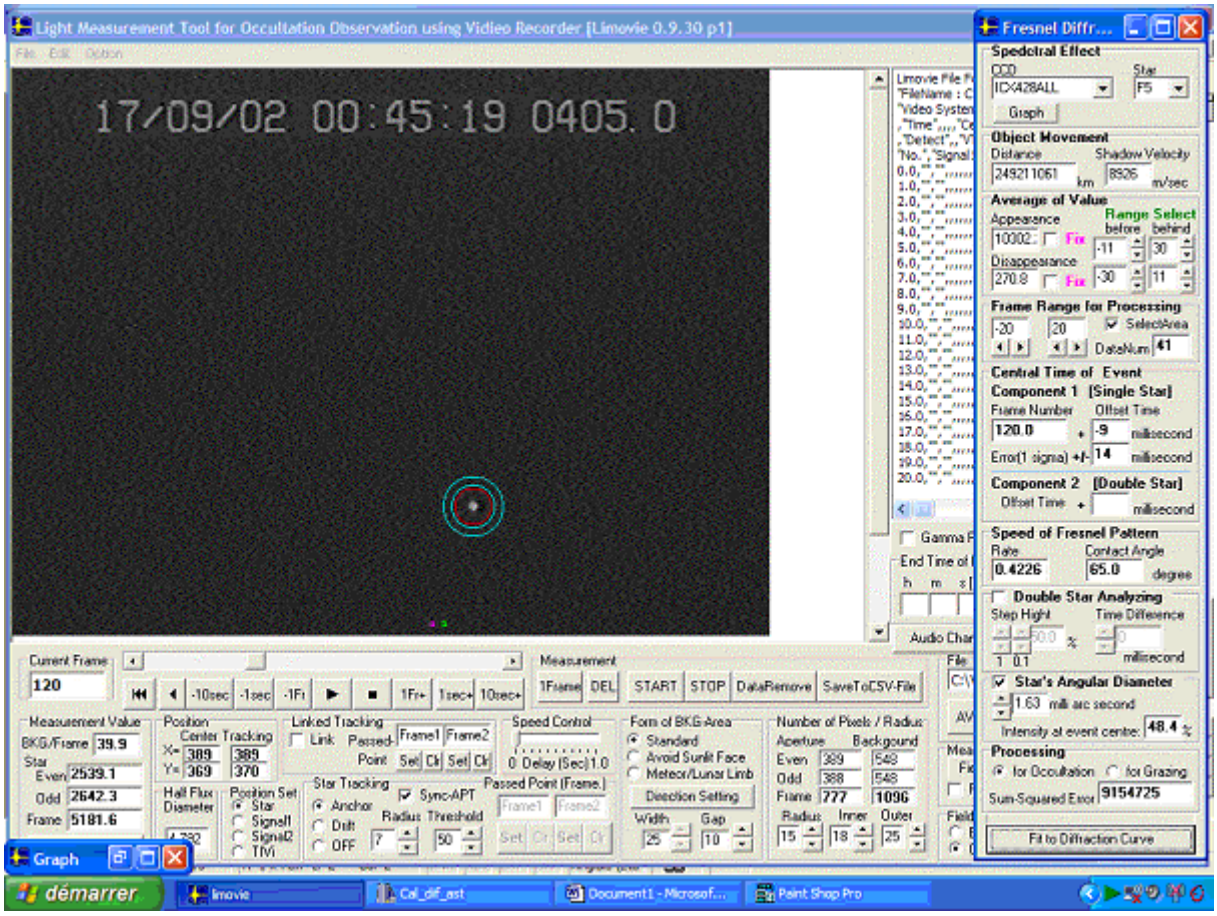
The noise by pixel is 30000/777 let 39

The max possible is 255/39 let a Signal/noise of 6,5

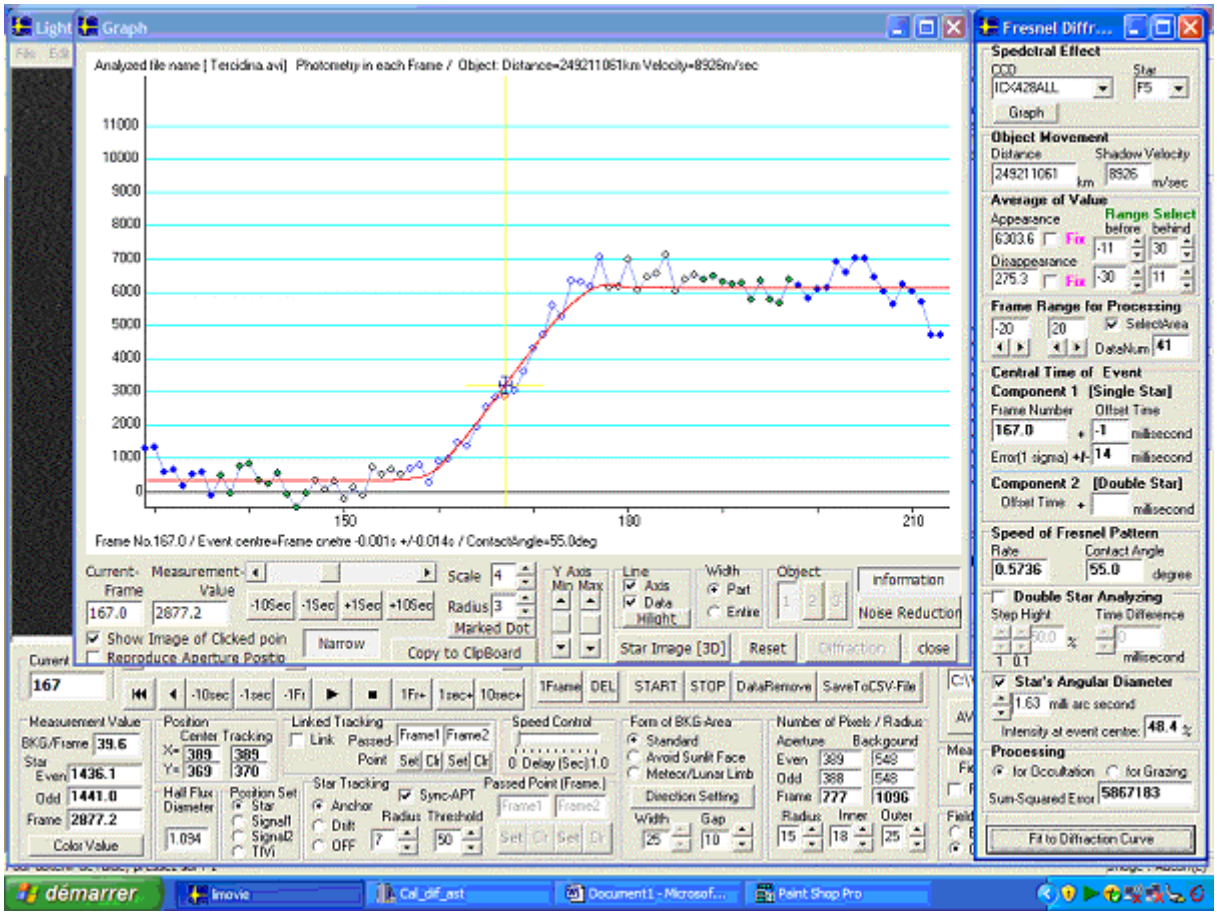
The true value is 40000/30000 let 1.33

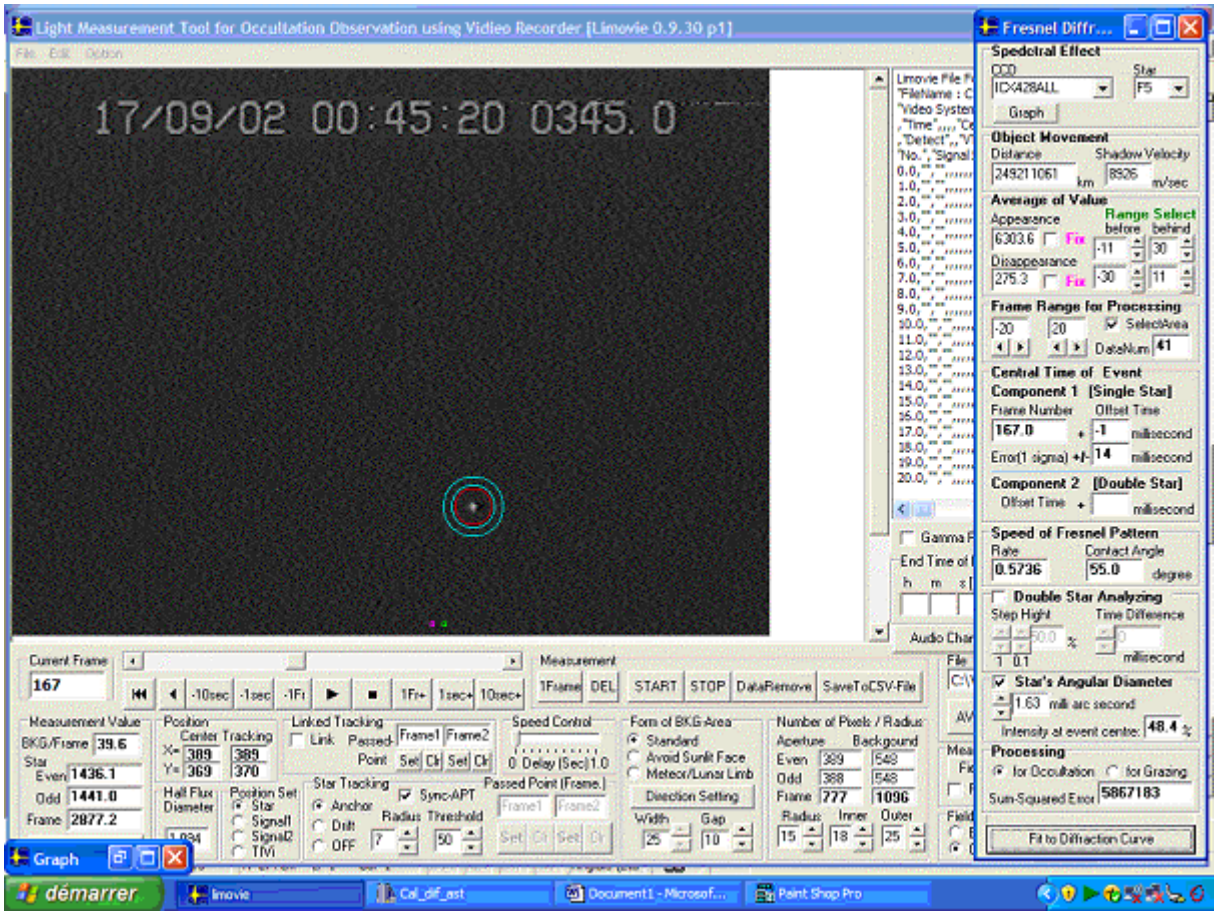
IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS



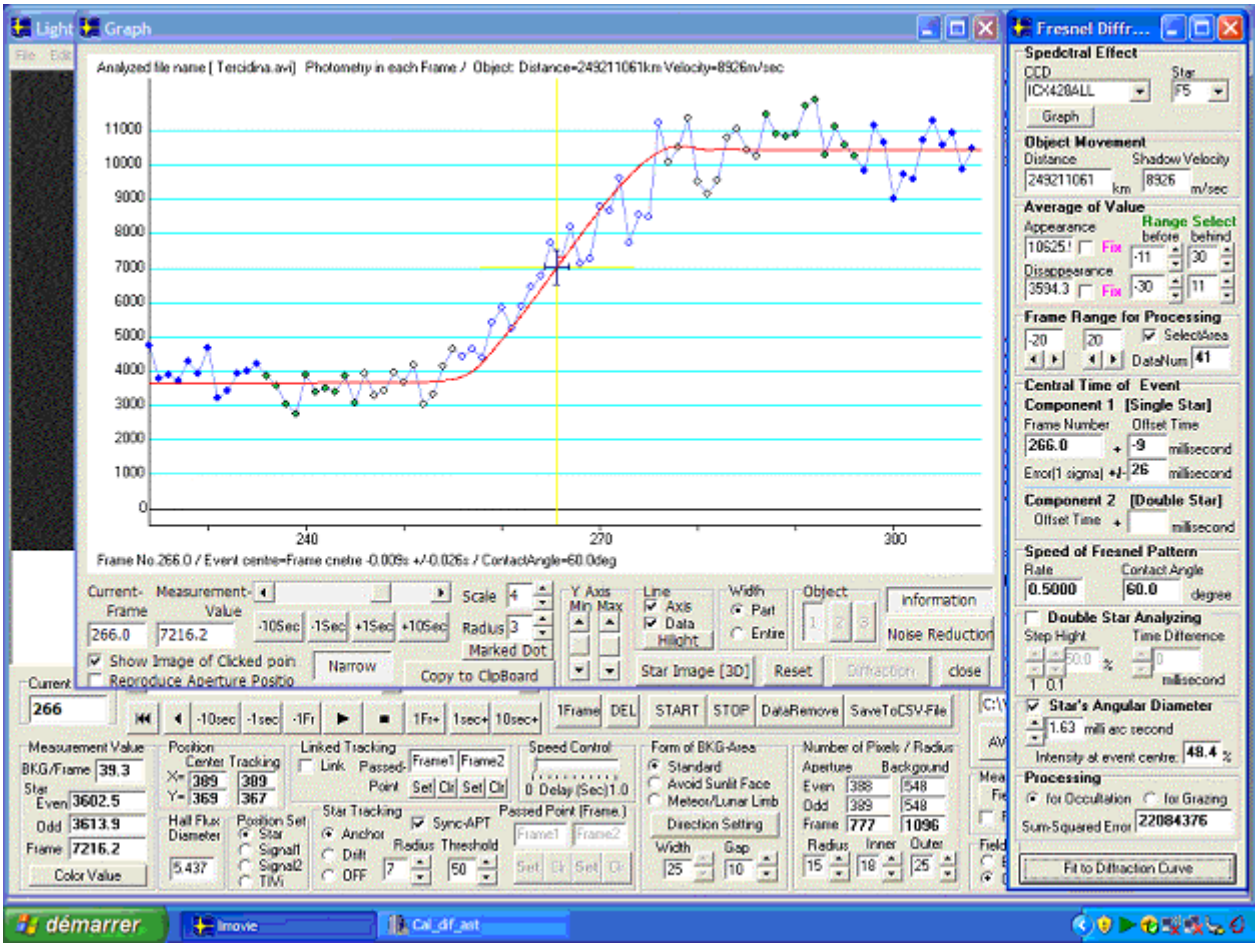


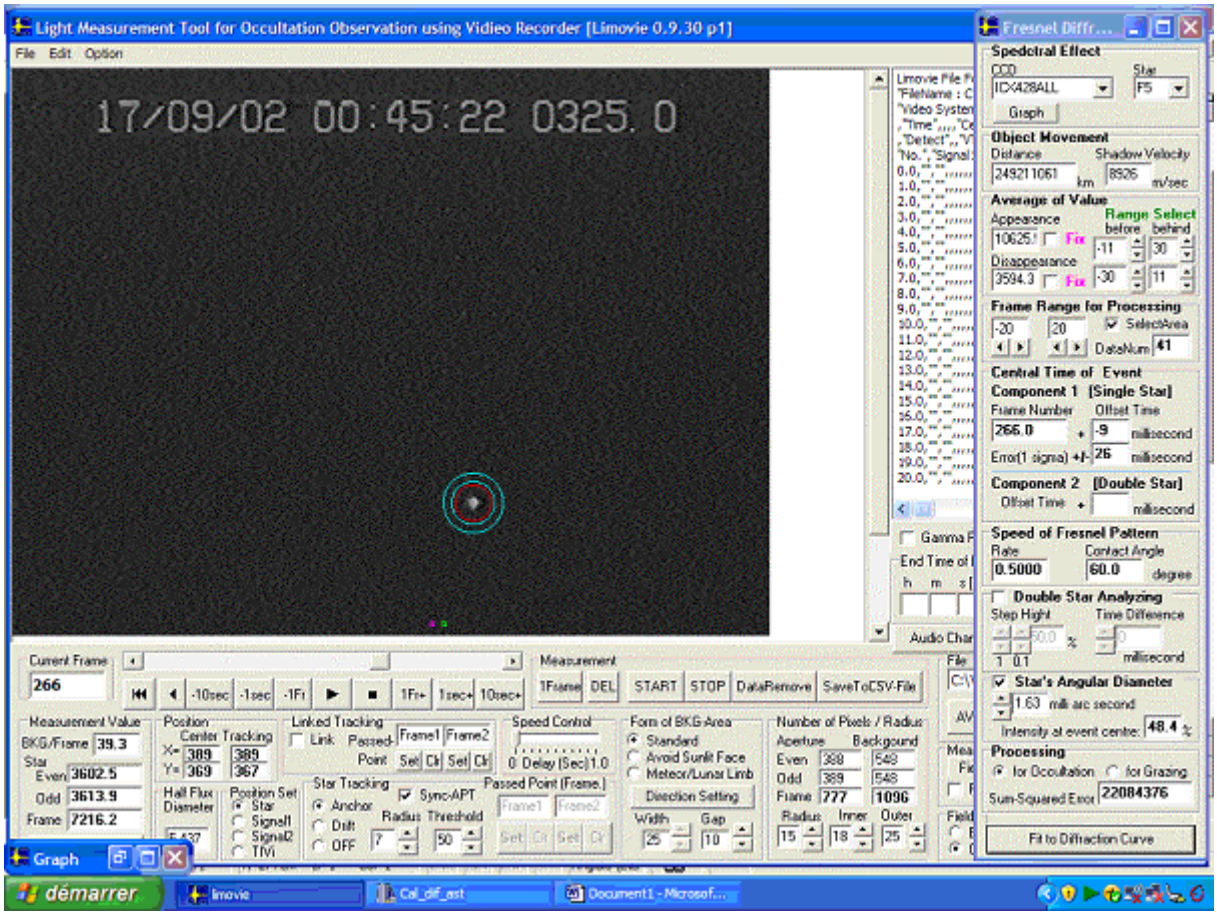
IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS



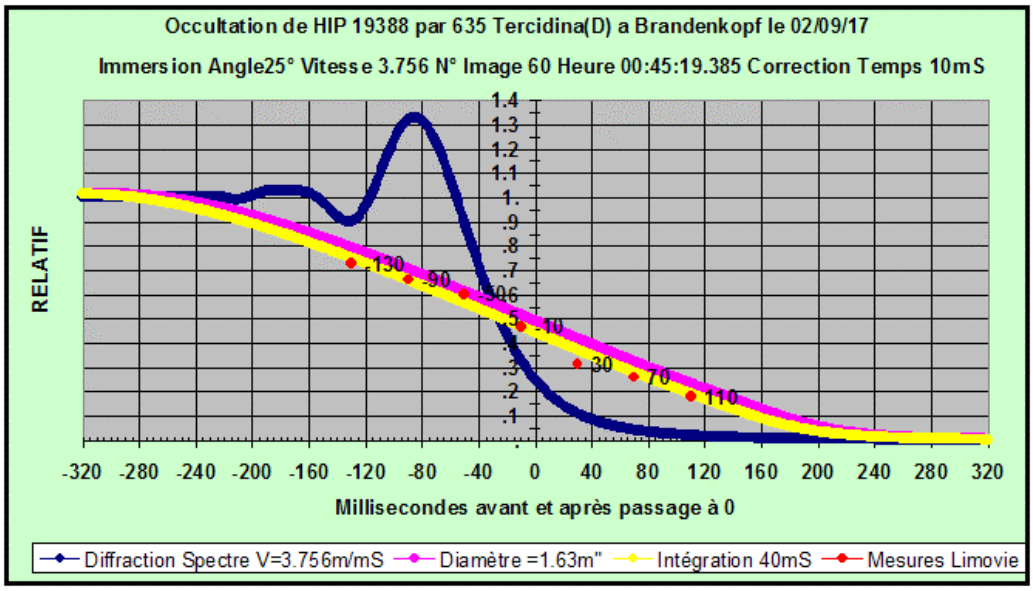


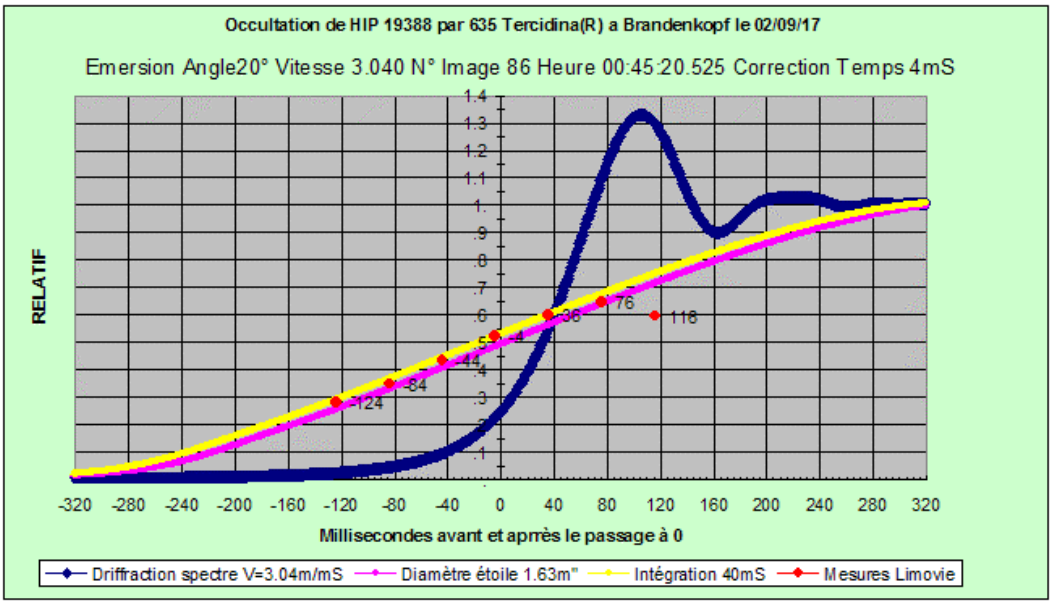
IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

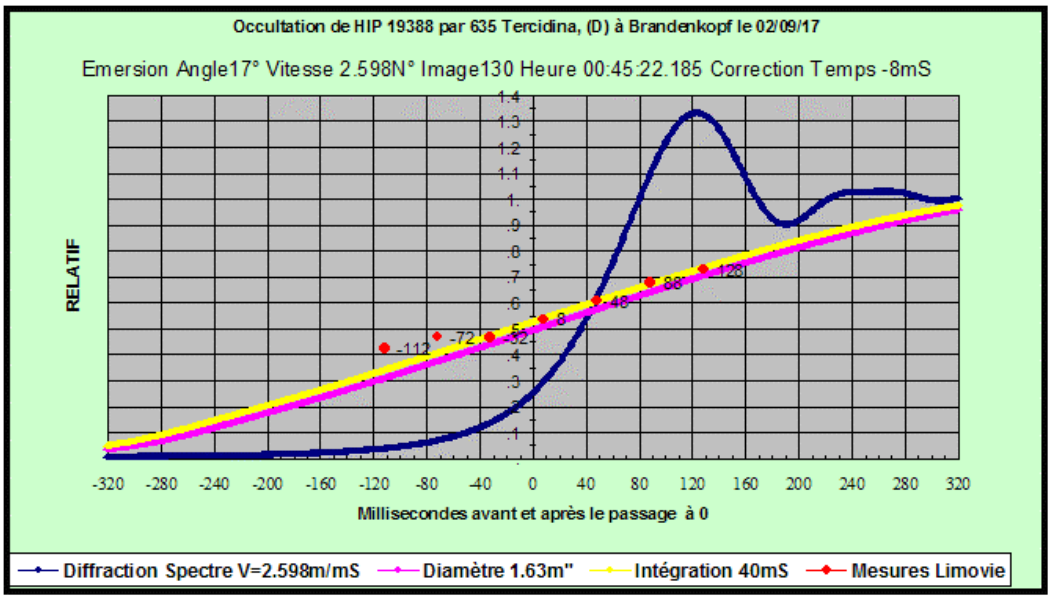




IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS







IMPROVEMENT OF TIME ACCURACY DURING STAR OCCULTATIONS

Résults		Limovie		My self
Disappearance	picture 60	00h45m19.396	60	00h45m19.395
Partial reappearance	Picture 83	19h05m20.344	86	00h45m29.529
Final reappearance	Picture 133	00h45m22.316	130	00h45m22.177

The graphs are very flat there are 2 causes:
The star diameter is very large then the values are increasing or decreasing slowly.
As the displacement angle is very small the diameter and the integration graph are near together.
For the disappearance the result are rather the same.
For the reappearances there is a difference:
Limovie treats them as diffraction fringes
While the software as part of fringes then several dots are out of the drawing.
Another thing is the noise on the record there is a spray of white dot on the picture; it is the result of colour sub-carrier of the VTR

Now a day those tests are stopped because I have no other records to analyse.

If a serial of occultations are enough to draw a profile of an asteroid it may be interesting to compare the angle of contact calculated by that way to the draw of the chords

Thanks to:

CALA (Club astronomique Lyon Ampère) for Melitta and Harmonia records
Andreas Eberle for Wieck record
Oliver Klöes for Tercinida record

Thomas Flatrès membre of :
SAF (société astronomique de France)
SAR (Société d'astronomie de Rennes)
IOTA-ES (International Occultation Timing Association European Section)

thomas.flatres@wanadoo.fr