# The 10th VLTI School of Interferometry

## Practice session I

## Interferometry basics with ASPRO

# Corrections

## 2 Our first model : the uniform disk

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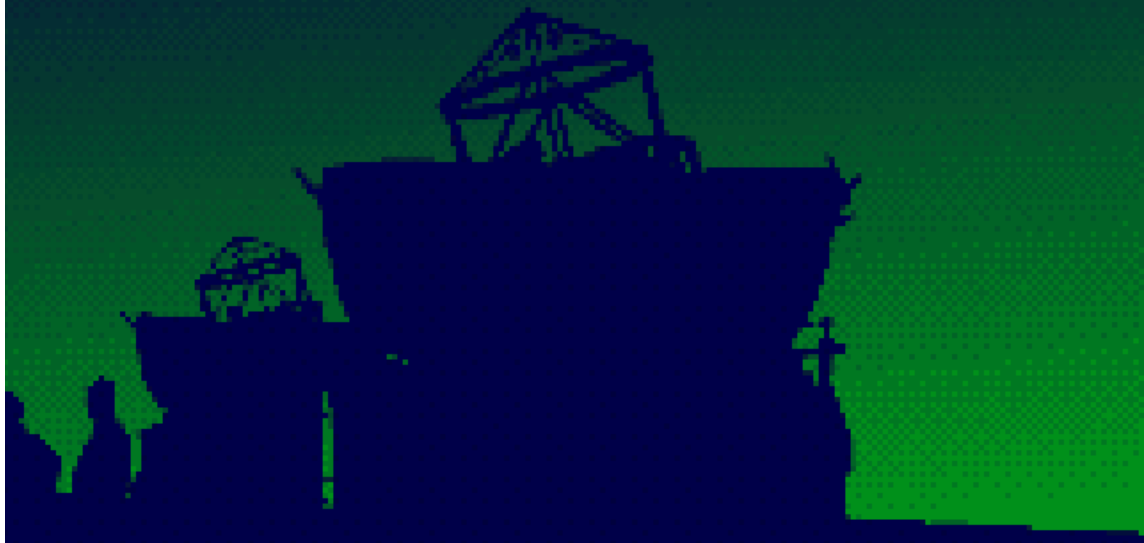

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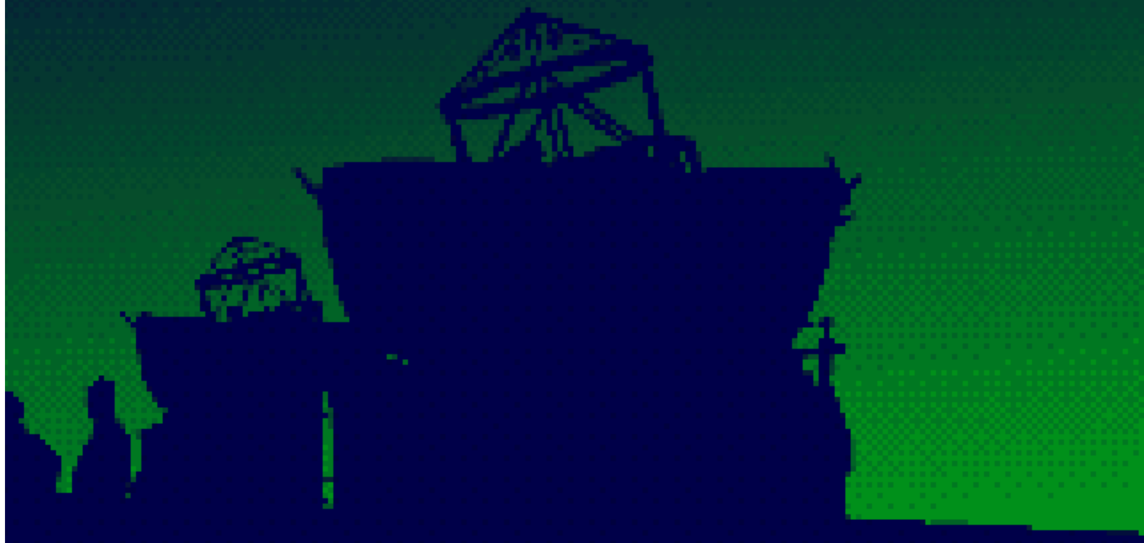

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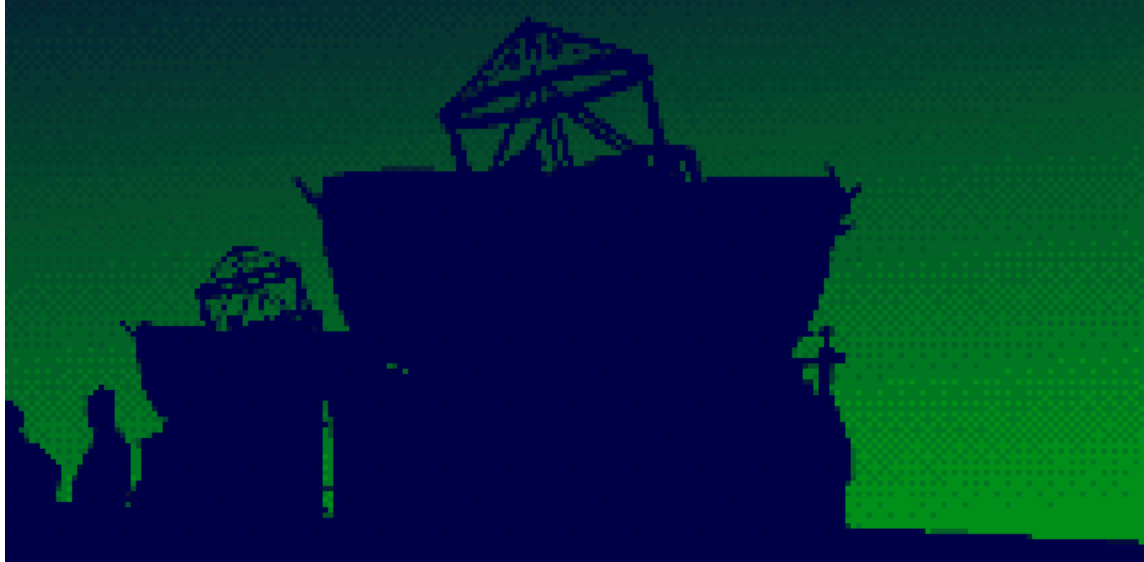

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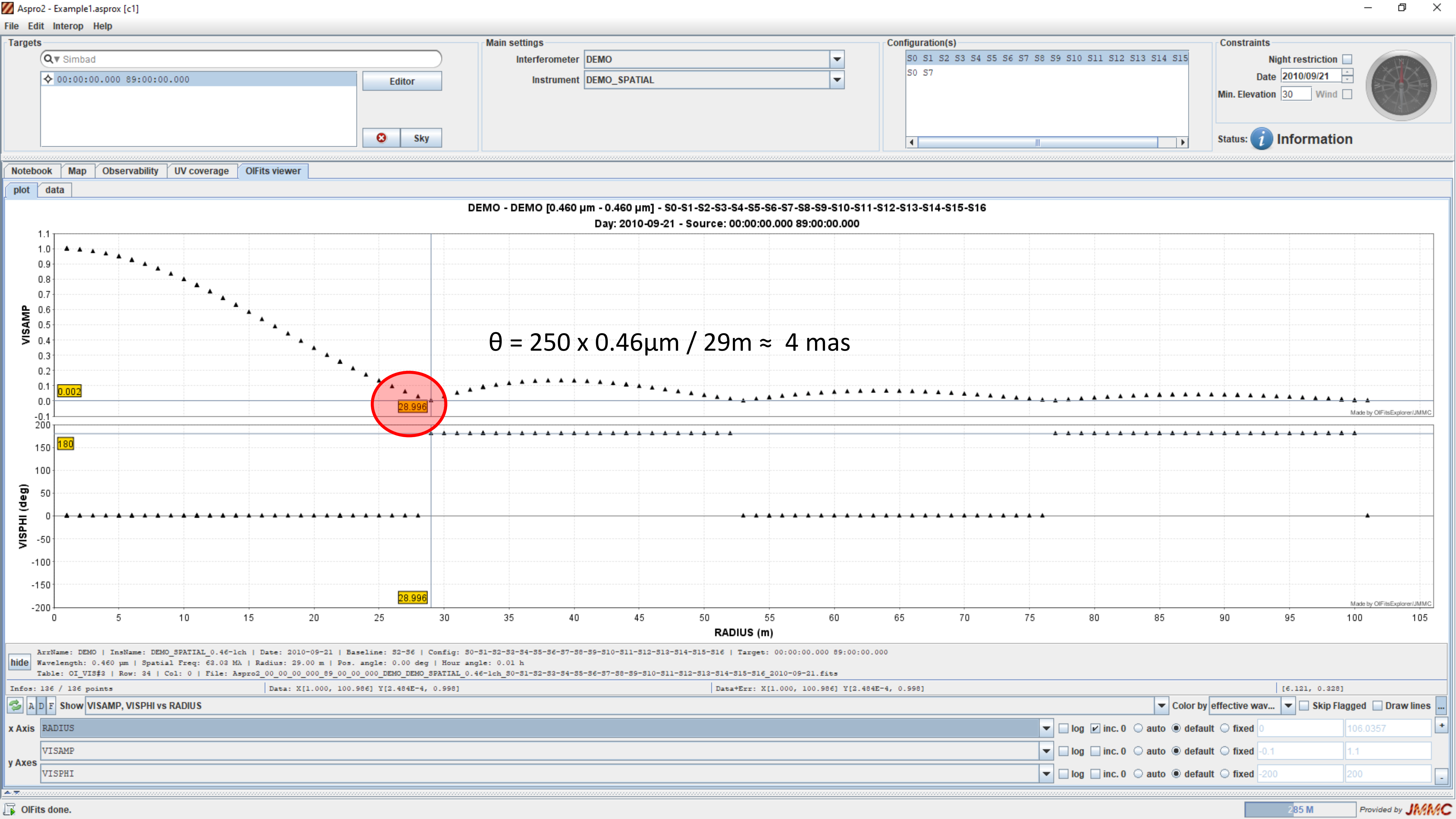
Aspro2 - Example1.asprox [c1]
File Edit Interop Help
Targets
Simbad
00:00:00.000 89:00:00.000
Editor
Sky
Main settings
Interferometer DEMO
Instrument DEMO_SPATIAL
Configuration(s)
S0 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15
S0 S7
Constraints
Night restriction
Date 2010/09/21
Min. Elevation 30 Wind
Status: Information
Notebook Map Observability UV coverage OIFits viewer
plot data
DEMO - DEMO [0.460 µm - 0.460 µm] - S0-S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16
Day: 2010-09-21 - Source: 00:00:00.000 89:00:00.000
VISAMP
θ = 250 x 0.46µm / 29m ≈ 4 mas
0.002
28.996
180
VISPHI (deg)
28.996
RADIUS (m)
Made by OIFitsExplorer/JMMC
ArrName: DEMO | InsName: DEMO_SPATIAL_0.46-1ch | Date: 2010-09-21 | Baseline: S2-S6 | Config: S0-S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16 | Target: 00:00:00.000 89:00:00.000
Wavelength: 0.460 µm | Spatial Freq: 63.03 MA | Radius: 29.00 m | Pos. angle: 0.00 deg | Hour angle: 0.01 h
Table: OI_VIS#3 | Row: 34 | Col: 0 | File: Aspro2_00_00_00_000_89_00_00_000_DEMO_DEMO_SPATIAL_0.46-1ch_S0-S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16_2010-09-21.fits
hide
Infos: 136 / 136 points
Data: X[1.000, 100.986] Y[2.484E-4, 0.998]
Data+Err: X[1.000, 100.986] Y[2.484E-4, 0.998]
Show VISAMP, VISPHI vs RADIUS
Color by effective wav...
Skip Flagged
Draw lines
x Axis RADIUS
y Axes
VISAMP
VISPHI
log inc. 0 auto default fixed
OIFits done.
Provided by JMMC

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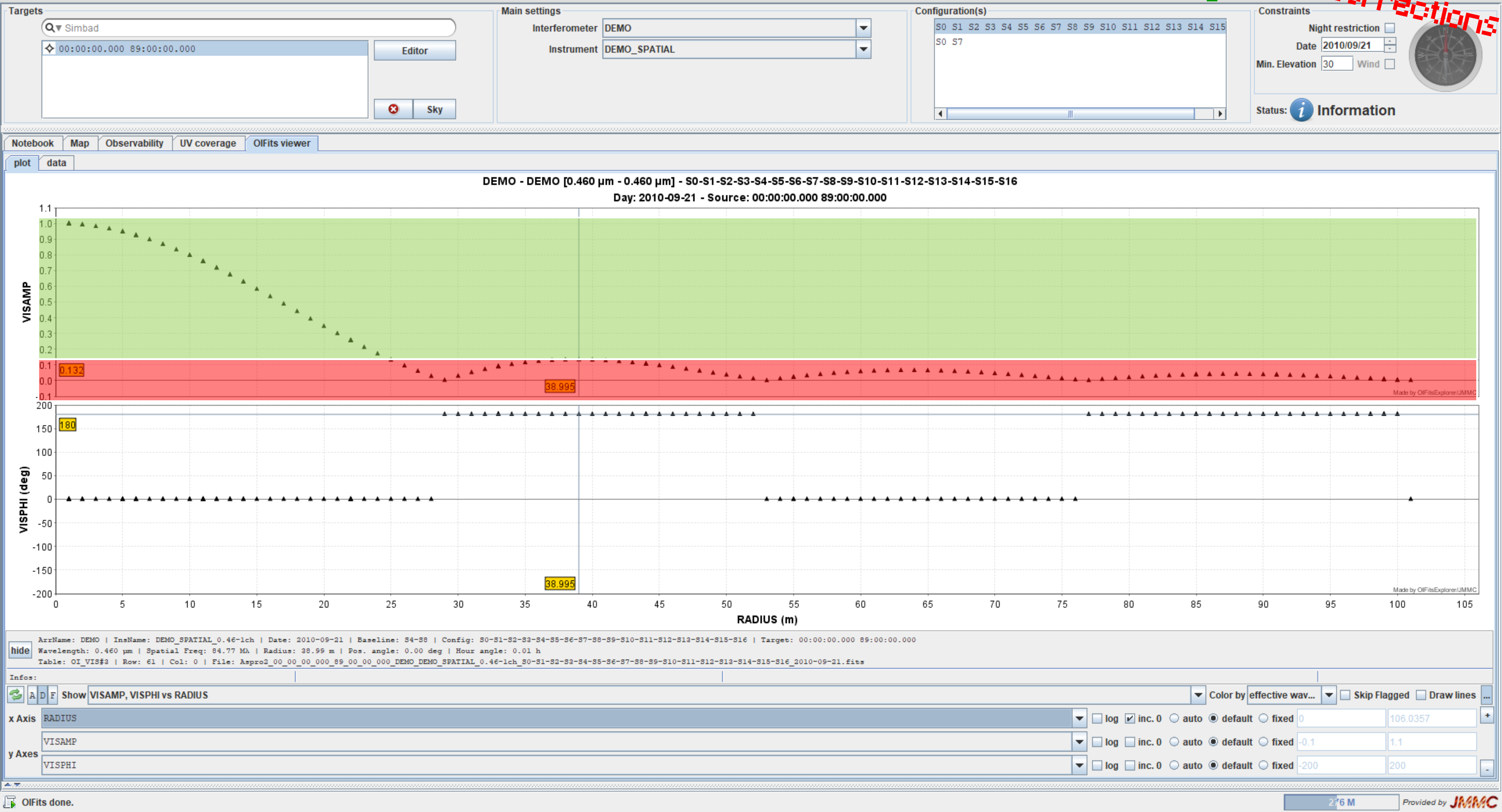

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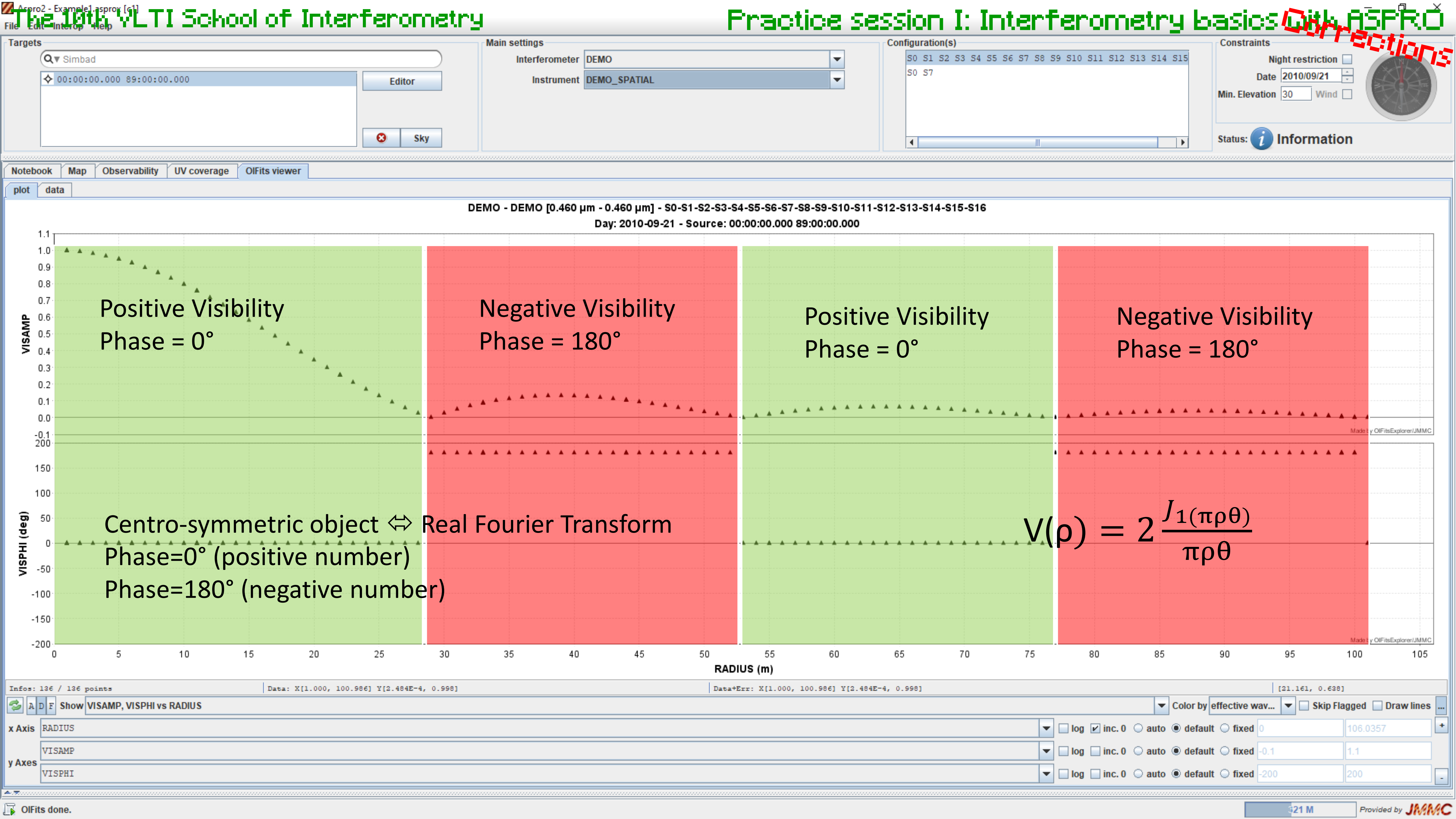


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The object is centro-symmetric
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Its Fourier Transform is Real
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B(V=0) ≈ 29m
Amplitude ≈ 0.132

# 3. Few other 1D distributions

### 3.1 Limb darkened disk

**Question : Note the baseline length corresponding to the first zero of visibility and the second-lobe amplitude.**

Now imagine you would estimate the size of this 4mas limb-darkened star by measuring the position of the first zero of visibility and using the formula determined for a uniform disk in the previous section.

**Question : Does the star appears bigger or small than its real size? Explain why.**

**Question : How can you discriminate between the uniform disk and the limb darkened disk?**

### 3.2 Gaussian distribution

Change the model to a "gaussian" (remove previous), and click on Add. Look at the new set of parameters shown in the bottom part of the window. This model has also four parameters, i.e. *flux_weight1*, *x1*, *y1* like for all models, and *fwhm1*, the full width at half maximum of the Gaussian distribution. Let's set this value to 4 mas and then click on **Ok** to close the window.

**Question : What is the Fourier transform of a Gaussian distribution?**

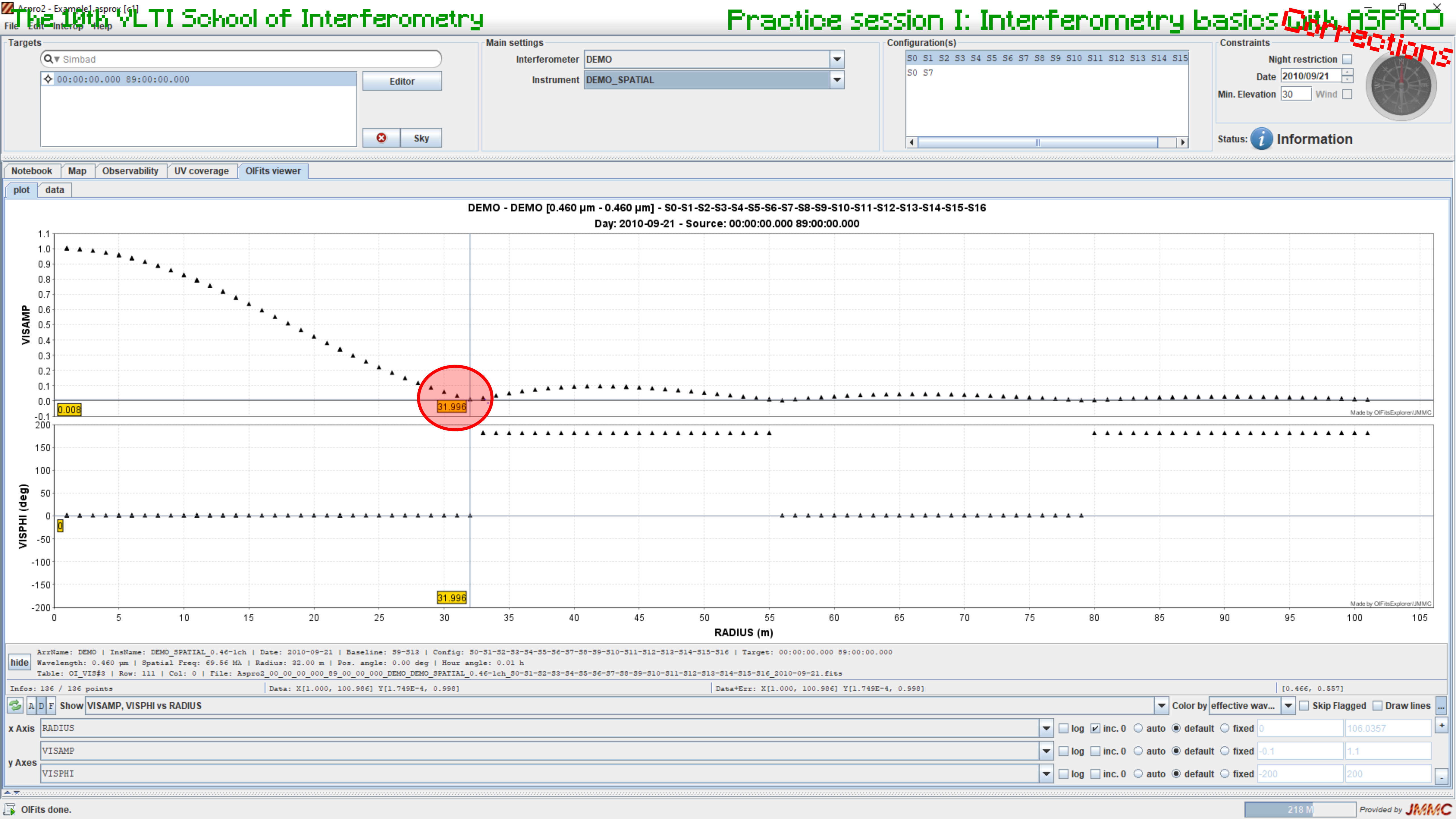
**Question : Compare the phase signal to that of the uniform disk.**

**Question : What is the baseline length corresponding to a visibility of 0?**

### 3.3 Ring

Open the **Target editor** again, **Remove** the Gaussian model and **Add** a Ring model instead. This time the model has 5 parameters : *flux_weight1*, *x1*, *y1*, a diameter like the uniform disk, and also a width. Let's consider the case of a 4 mas infinitely-thin ring : *diameter1*= 4, and *width1* = 0.

**Question : What are the baseline length corresponding to the first zero of visibility and the amplitude of the second lobe?**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Aspro2 - Example1.asprox [c1]
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Constraints
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Date 2010/09/21
Min. Elevation 30
Wind
Status: Information
Notebook
Map
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UV coverage
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plot
data
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VISAMP
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31.996
0
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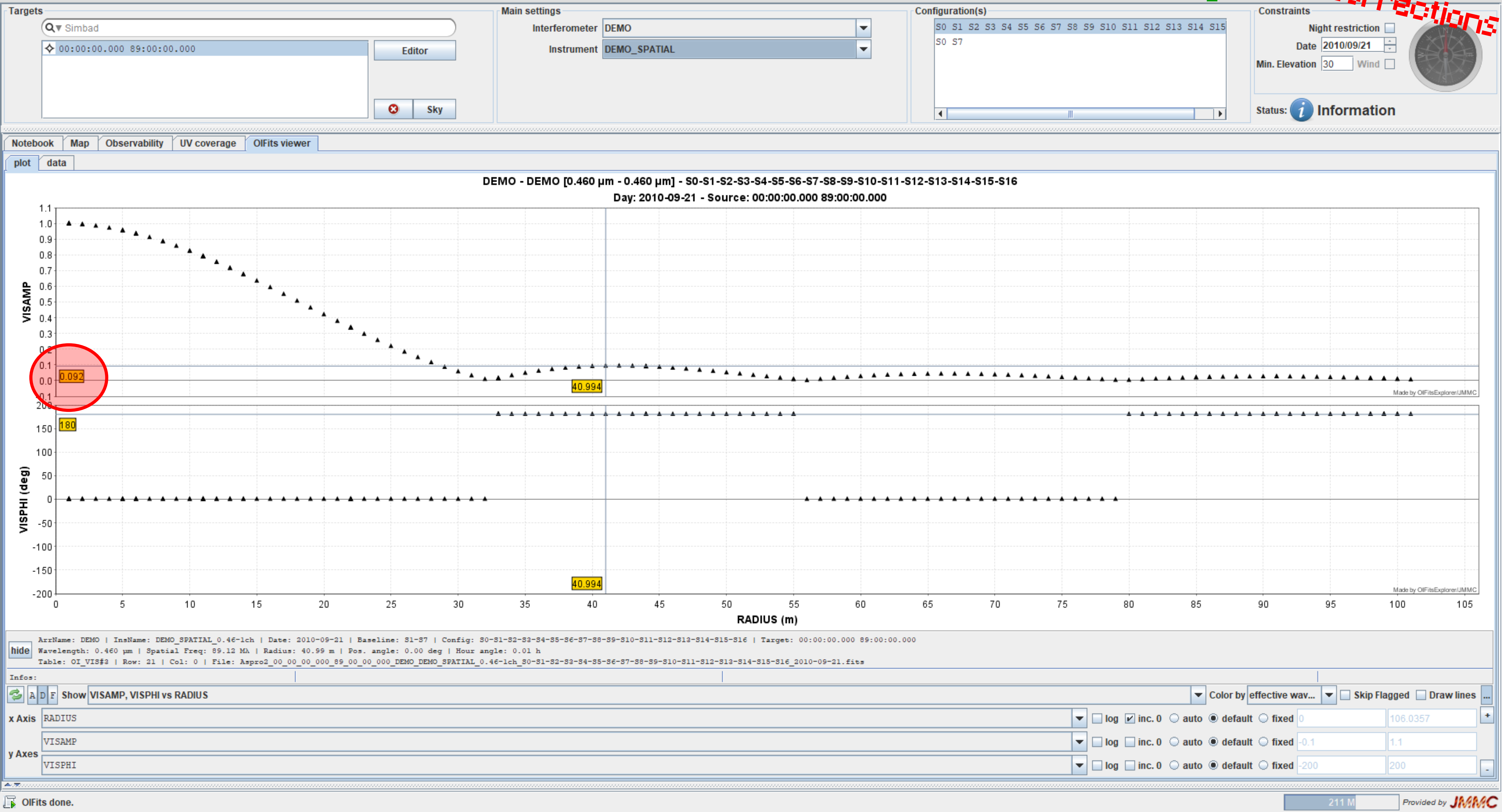
Made by OIFitsExplorer/JMMC
hide
ArrName: DEMO | InsName: DEMO_SPATIAL_0.46-1ch | Date: 2010-09-21 | Baseline: S9-S13 | Config: S0-S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16 | Target: 00:00:00.000 89:00:00.000
Wavelength: 0.460 µm | Spatial Freq: 69.56 MA | Radius: 32.00 m | Pos. angle: 0.00 deg | Hour angle: 0.01 h
Table: OI_VIS#3 | Row: 111 | Col: 0 | File: Aspro2_00_00_00_000_89_00_00_000_DEMO_DEMO_SPATIAL_0.46-1ch_S0-S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16_2010-09-21.fits
Infos: 136 / 136 points
Data: X[1.000, 100.986] Y[1.749E-4, 0.998]
Data+Err: X[1.000, 100.986] Y[1.749E-4, 0.998]
[0.466, 0.557]
Show VISAMP, VISPHI vs RADIUS
Color by effective wav...
Skip Flagged
Draw lines
x Axis RADIUS
y Axes VISAMP
VISPHI
log inc. 0 auto default fixed
0 106.0357
-0.1 1.1
-200 200
OIFits done.
218 M
Provided by JMMC

# The 10th VLTI School of Interferometry

# Practice session I: Interferometry basics with ASPRO

Corrections



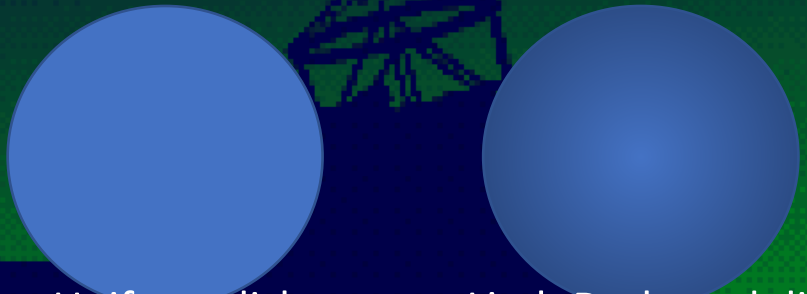
### 3.1 Limb darkened disk

**Question : Note the baseline length corresponding to the first zero of visibility and the second-lobe amplitude.**

B ≈ 32 m
Aplitude ≈ 0.092

Now imagine you would estimate the size of this 4mas limb-darkened star by measuring the position of the first zero of visibility and using the formula determined for a uniform disk in the previous section.

**Question : Does the star appears bigger or small than its real size? Explain why.**




**Question : How can you discriminate between the uniform disk and the limb darkened disk?**

### 3.2 Gaussian distribution

Change the model to a "gaussian" (remove previous), and click on Add. Look at the new set of parameters shown in the bottom part of the window. This model has also four parameters, i.e. *flux_weight1*, *x1*, *y1* like for all models, and *fwhm1*, the full width at half maximum of the Gaussian distribution. Let's set this value to 4 mas and then click on **Ok** to close the window.

**Question : What is the Fourier transform of a Gaussian distribution?**

**Question : Compare the phase signal to that of the uniform disk.**

**Question : What is the baseline length corresponding to a visibility of 0?**

### 3.3 Ring

Open the **Target editor** again, **Remove** the Gaussian model and **Add** a Ring model instead. This time the model has 5 parameters : *flux_weight1*, *x1*, *y1*, a diameter like the uniform disk, and also a width. Let's consider the case of a 4 mas infinitely-thin ring : *diameter1* = 4, and *width1* = 0.

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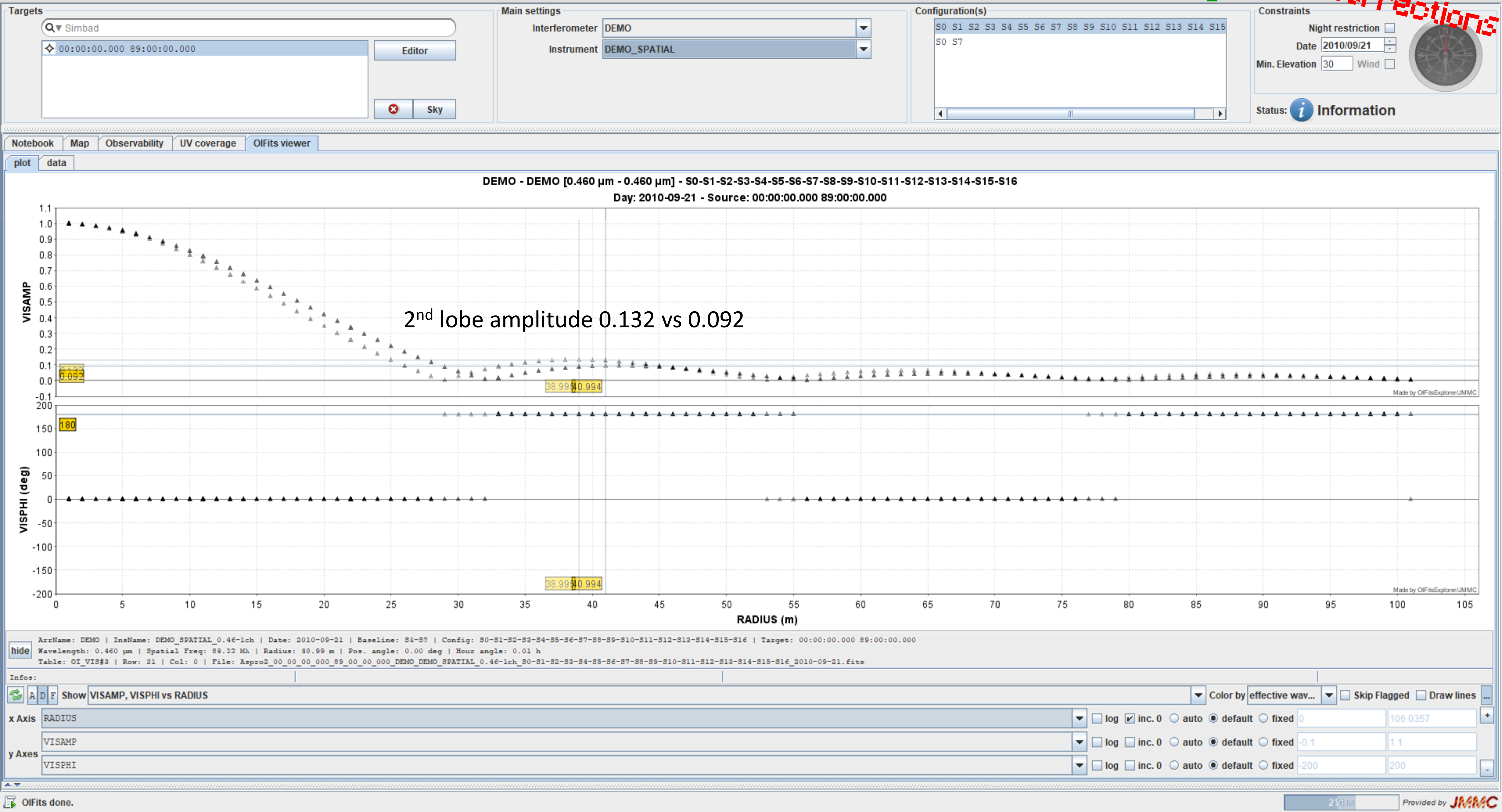


2nd lobe amplitude 0.132 vs 0.092

Corrections

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By measuring the $2^{nd}$ lobe amplitude

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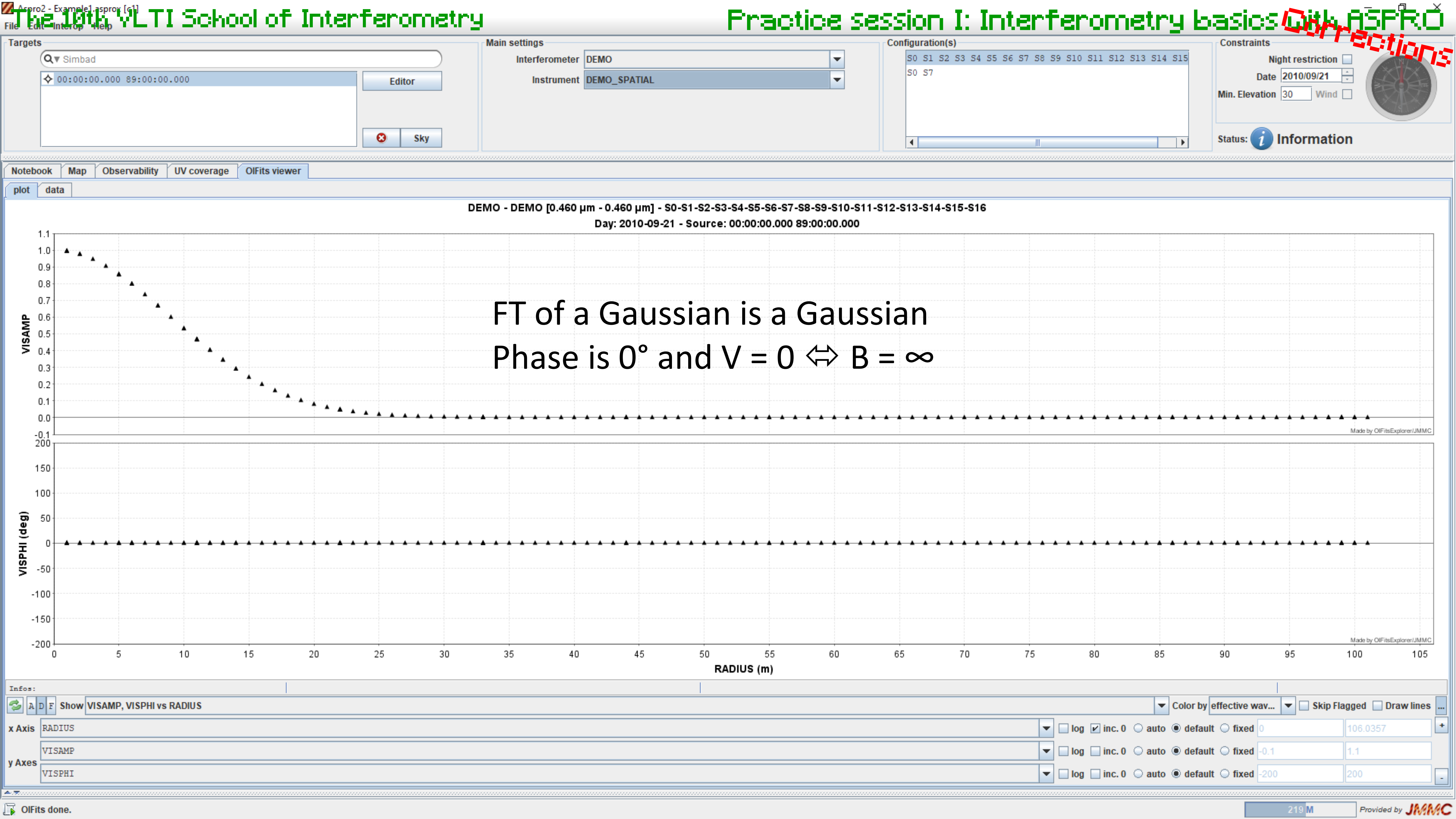


FT of a Gaussian is a Gaussian

Phase is 0° and V = 0 ⇔ B = ∞

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**Question : What is the Fourier transform of a Gaussian distribution?**

A Gaussian distribution

**Question : Compare the phase signal to that of the uniform disk.**

The phase is always 0

**Question : What is the baseline length corresponding to a visibility of 0?**

The zero is at the infinity

### 3.3 Ring

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# Practice session I: Interferometry basics with ASPRO

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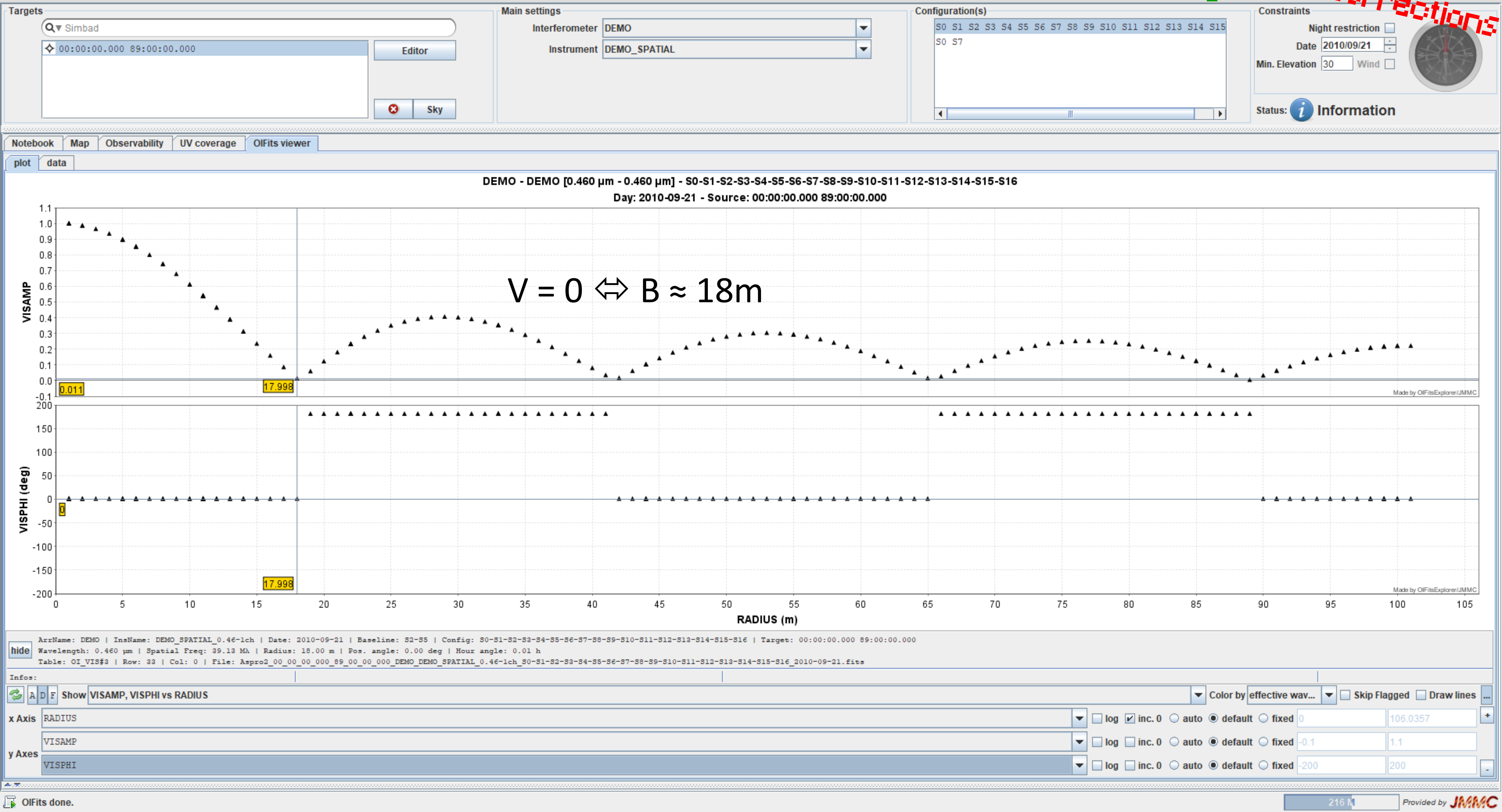
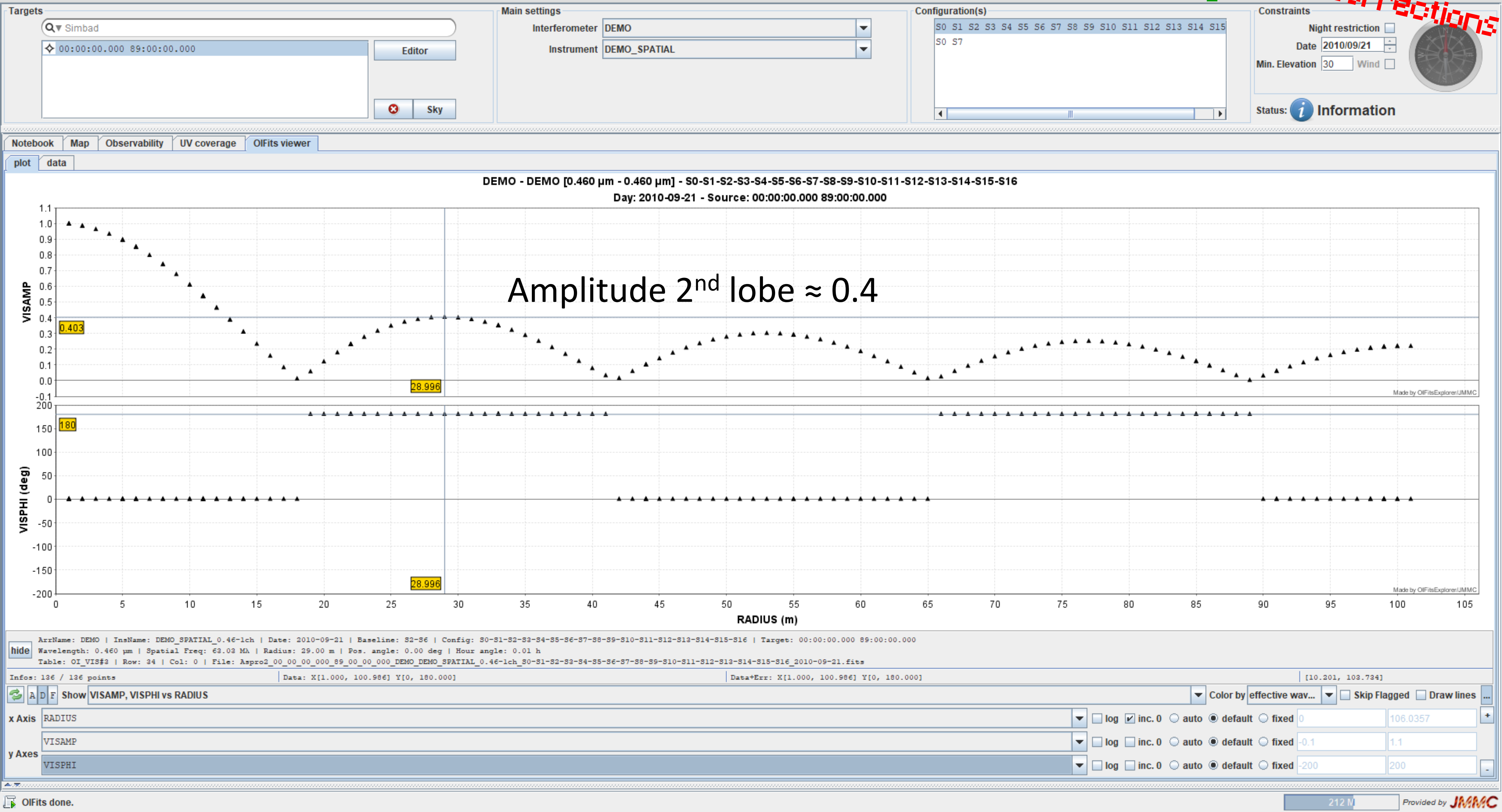



V = 0 ⇔ B ≈ 18m

The 10th VLTI School of Interferometry

# Practice session I: Interferometry basics with ASPRO

Corrections




Amplitude 2nd lobe ≈ 0.4

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**Question : What are the baseline length corresponding to the first zero of visibility and the amplitude of the second lobe?**

B ≈ 39m
Aplitude ≈ 0.4

### 3.4 Comparison of these models

In the previous sections you have build four models (uniform disk, Gaussian distribution, ring, and limb darkened disk) with a characteristic size of 4 mas. Their main difference is the smoothness/sharpness of their intensity distribution.

**Question : First, classify the models in term of sharpness/smoothness**

**Question : What is the relation between the distribution sharpness and the 2$^{nd}$ lobe amplitude ?**

### 3.5 Model confusion

If the interferometer largest spatial frequency (the ratio baseline length over wavelength) is not of the order of the typical size of your source, this may cause problems when you try to interpret your data.

**Question : Compare the visibility obtained at 100m for a 0.9 mas uniform disk and a 0.5 mas Gaussian distribution.**

Now switch to the K band using the **UV-Coverage** tab and changing the **Instrument mode**.

**Question : Do the same comparison.**

Typical uncertainties on the visibility measurements are of the order of a few percent.

**Question : In which band(s) can you discriminate between these models and determine the object size?**

Go back to the B band, and compare the visibility at 100m from the 0.9 mas uniform disk and a 0.61 mas Gaussian distribution.

**Question : How can we discriminate between these two intensity distributions?**

### 3.6 Point source and flat field

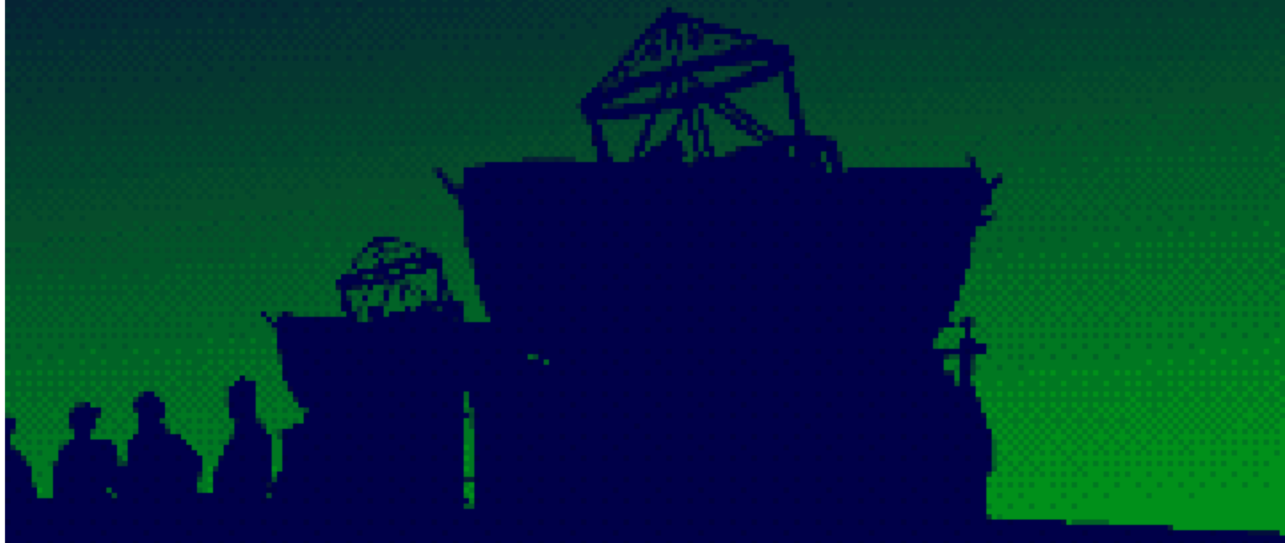
There is two additional intensity distributions that are widely used for modelling :

- the **point source** used to model a source too small to be resolved whatever by the interferometer
- the **flat field** used to represent the exact opposite, a fully resolved object.

Note that these models are useless on their own and are only used to build multi-component models described further down.

**Question : What are the point source and flat field visibility functions?**

In ASPRO2 point sources are modelled using the *punct* function. Flat field are not included, but can be modelled easily using a very extended uniform disk, for example with D≥250 mas.



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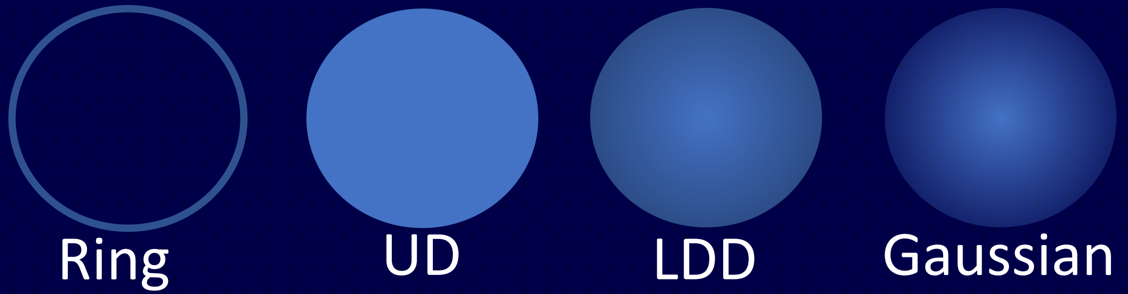

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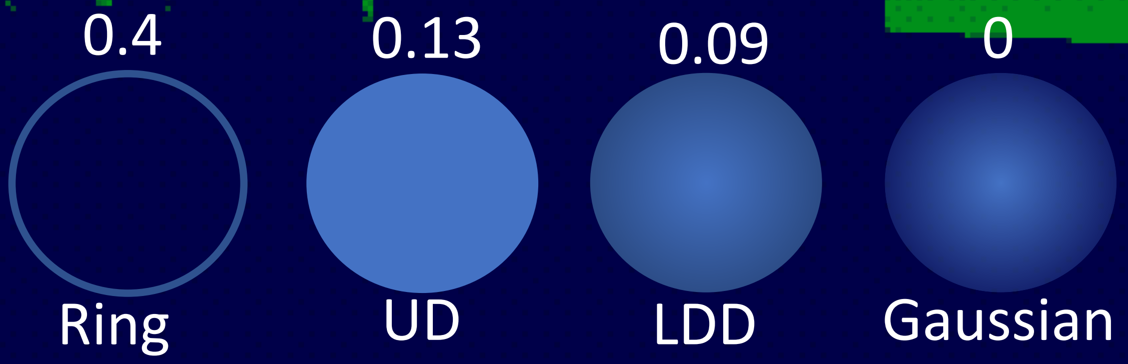
$2^{nd}$ Lobe Amplitudes



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Sharpness in image ⇔ higher lobes in FT
Ring = 0.4 UD = 0.13 LDD = 0.09 Gauss. = 0

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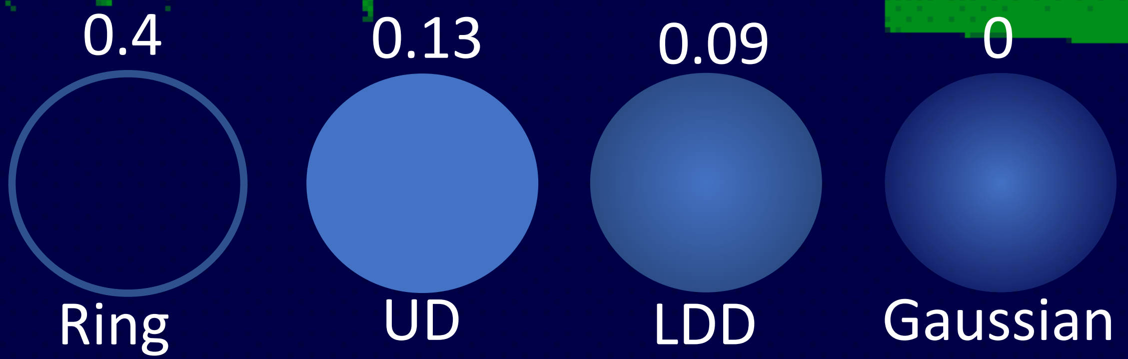

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0.9 mas UD ⇔ V = 0.233
0.5 mas Gaussian ⇔ V= 0.372

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0.9 mas UD ⇔V = V=0.958
0.5 mas Gaussian ⇔ 0.963

Corrections

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Now switch to the K band using the **UV-Coverage** tab and changing the **Instrument mode**.

**Question : Do the same comparison.**

0.9 mas UD ⇔V = V=0.958
0.5 mas Gaussian ⇔ 0.963

Typical uncertainties on the visibility measurements are of the order of a few percent.

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### 3.6 Point source and flat field

There is two additional intensity distributions that are widely used for modelling :

- the **point source** used to model a source too small to be resolved whatever by the interferometer
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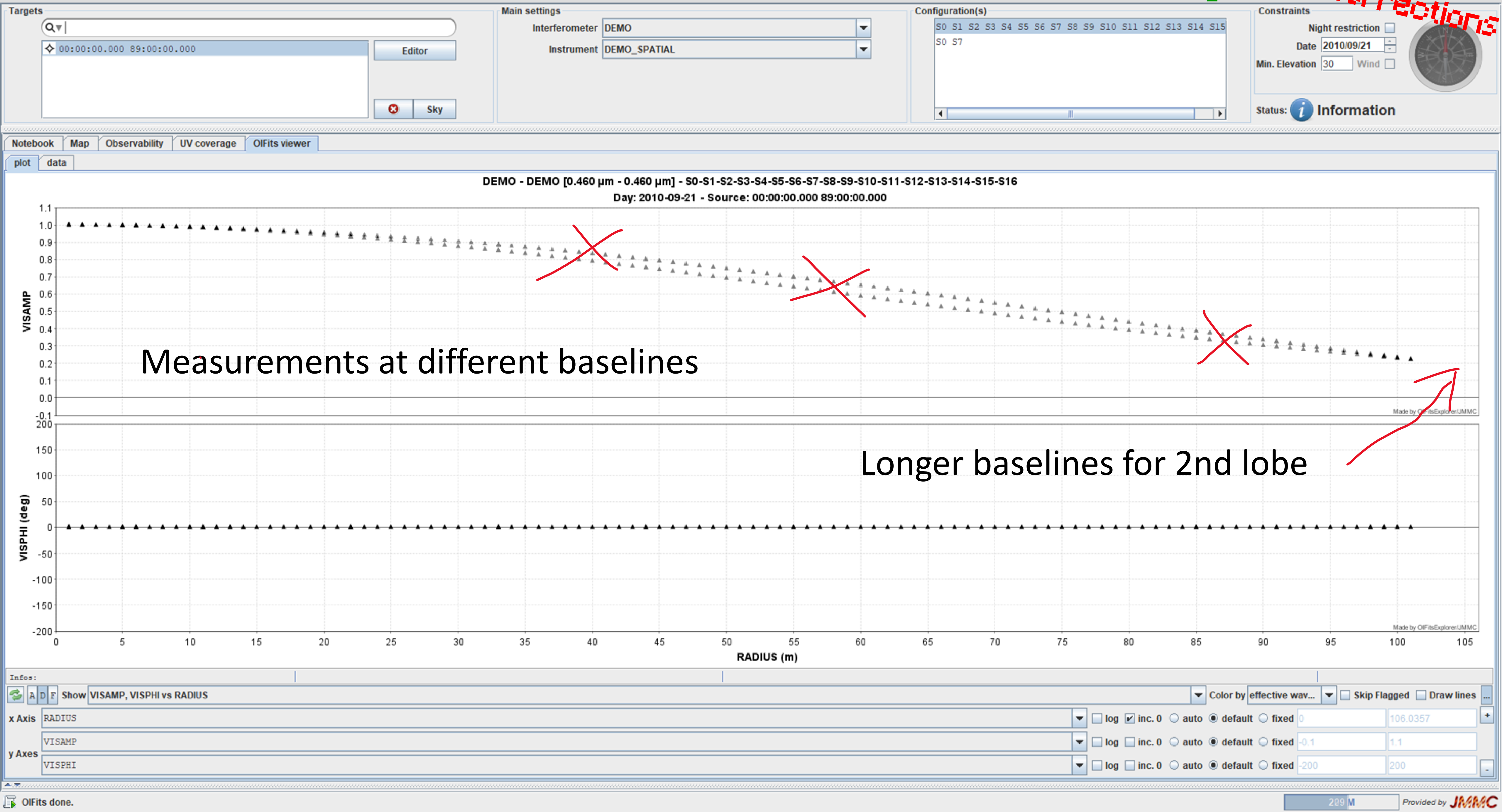
# Practice session I: Interferometry basics with ASPRO

Corrections



### 3.4 Comparison of these models

In the previous sections you have build four models (uniform disk, Gaussian distribution, ring, and limb darkened disk) with a characteristic size of 4 mas. Their main difference is the smoothness/sharpness of their intensity distribution.

**Question : First, classify the models in term of sharpness/smoothness**

> From the sharpest to the smoothest:
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**Question : What is the relation between the distribution sharpness and the $2^{nd}$ lobe amplitude ?**

> Sharpness in image ⇔ higher lobes in FT
> Ring = 0.4 UD = 0.13 LDD = 0.09 Gauss. = 0

### 3.5 Model confusion

If the interferometer largest spatial frequency (the ratio baseline length over wavelength) is not of the order of the typical size of your source, this may cause problems when you try to interpret your data.

**Question : Compare the visibility obtained at 100m for a 0.9 mas uniform disk and a 0.5 mas Gaussian distribution.**

> 0.9 mas UD ⇔V = 0.233
> 0.5 mas Gaussian ⇔ V= 0.372

Now switch to the K band using the **UV-Coverage** tab and changing the **Instrument mode**.

**Question : Do the same comparison.**

> 0.9 mas UD ⇔V = V=0.958
> 0.5 mas Gaussian ⇔ 0.963

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> FT(Point Source) : V = 1
> FT(flat field) : V = 1 if (B=0) and V = 0 otherwise

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# 4. Going 2D with flattened models

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Finally, put the disk major-axis at $45^o$.

**Question : Can you conclude on the extension measured by an interferometer?**

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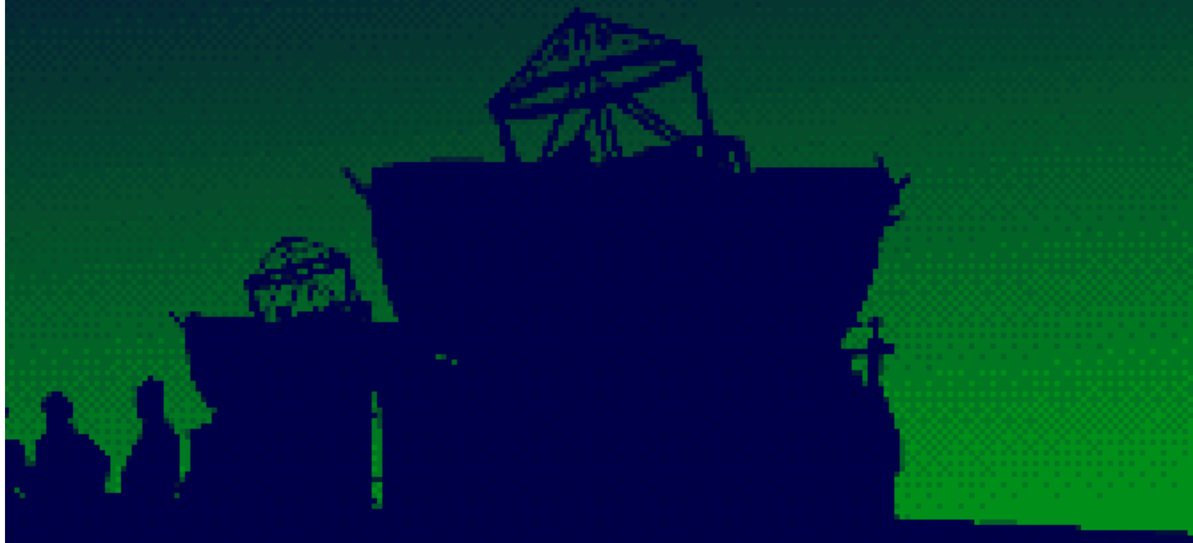

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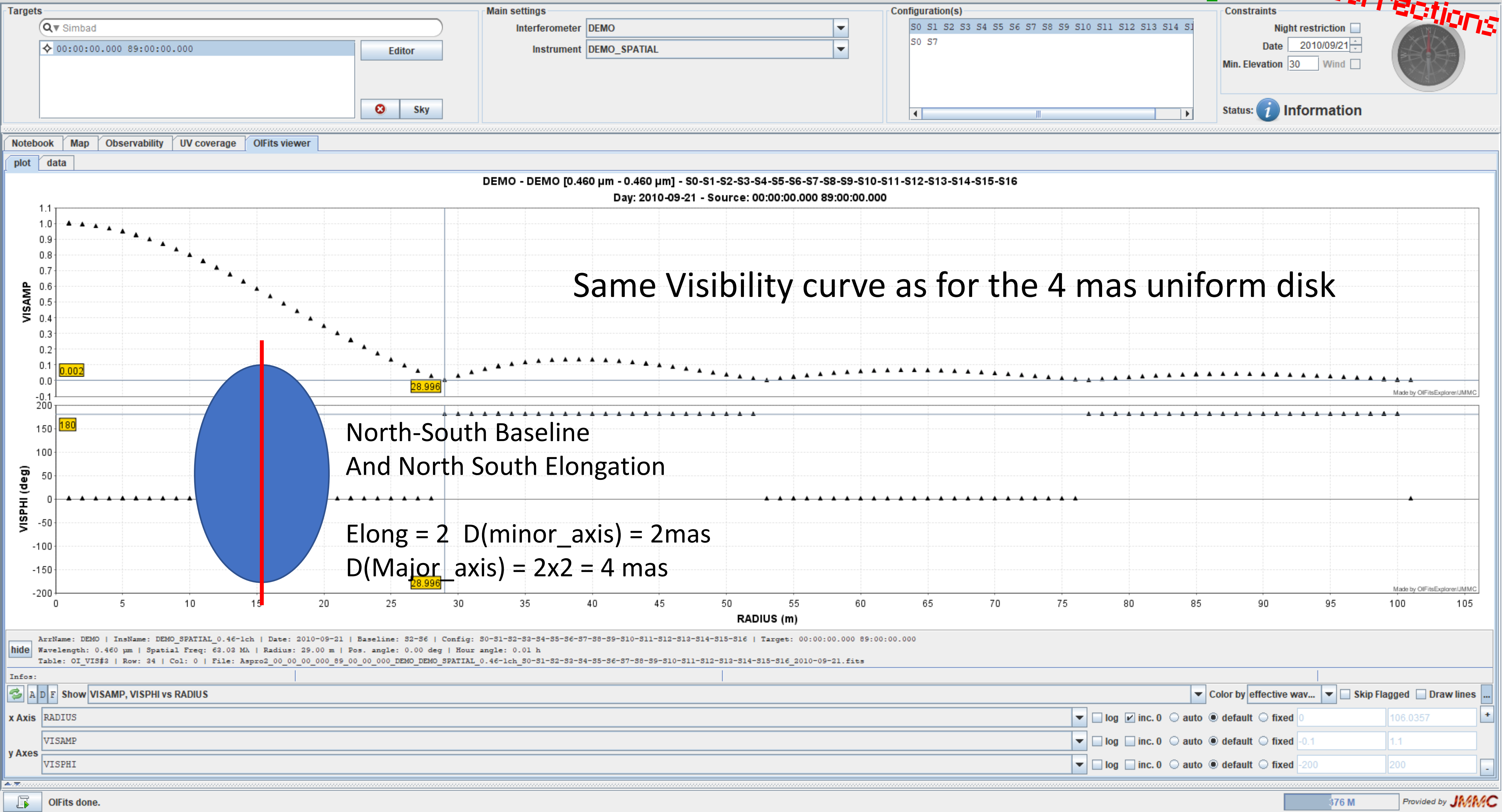

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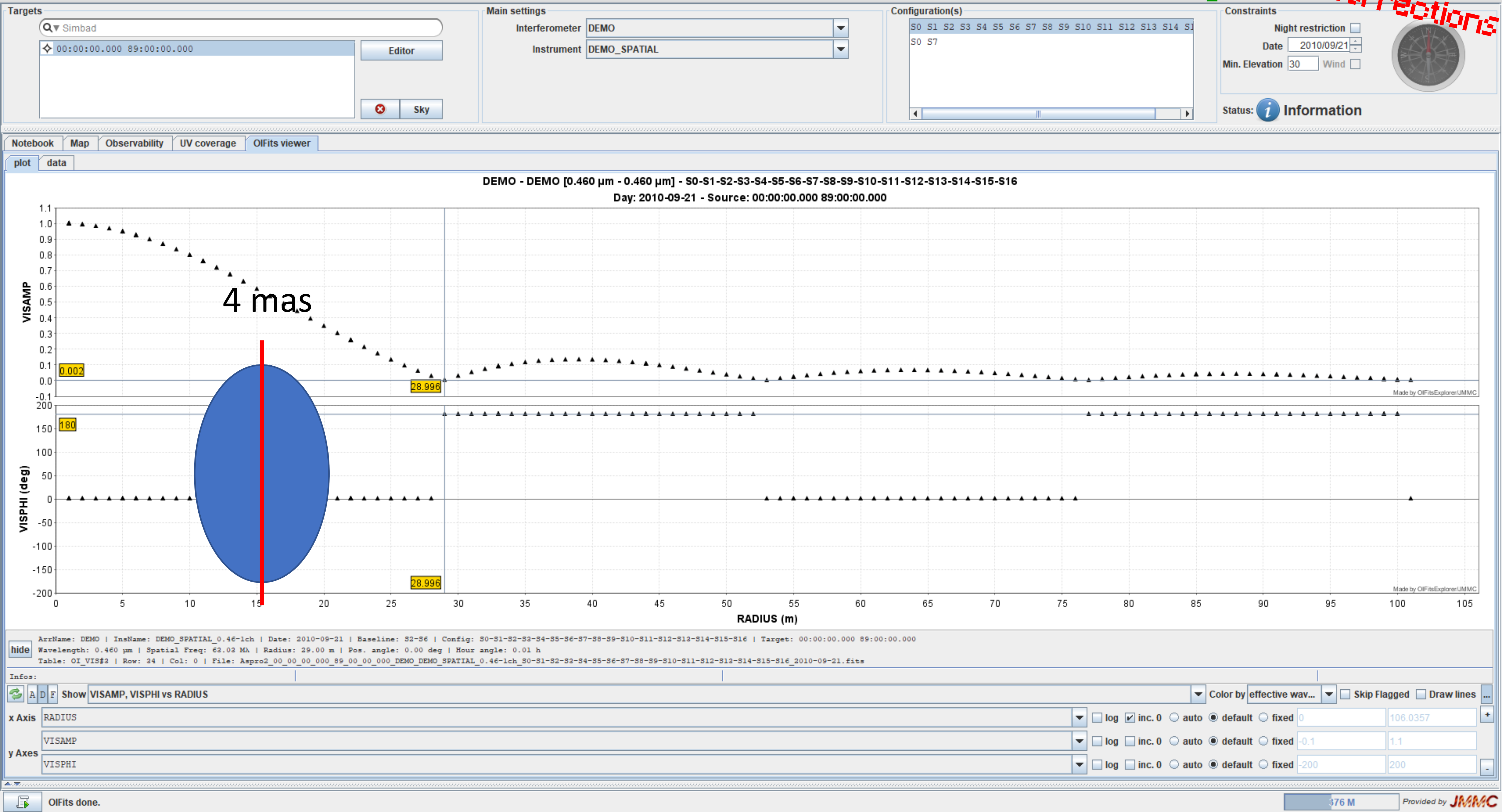

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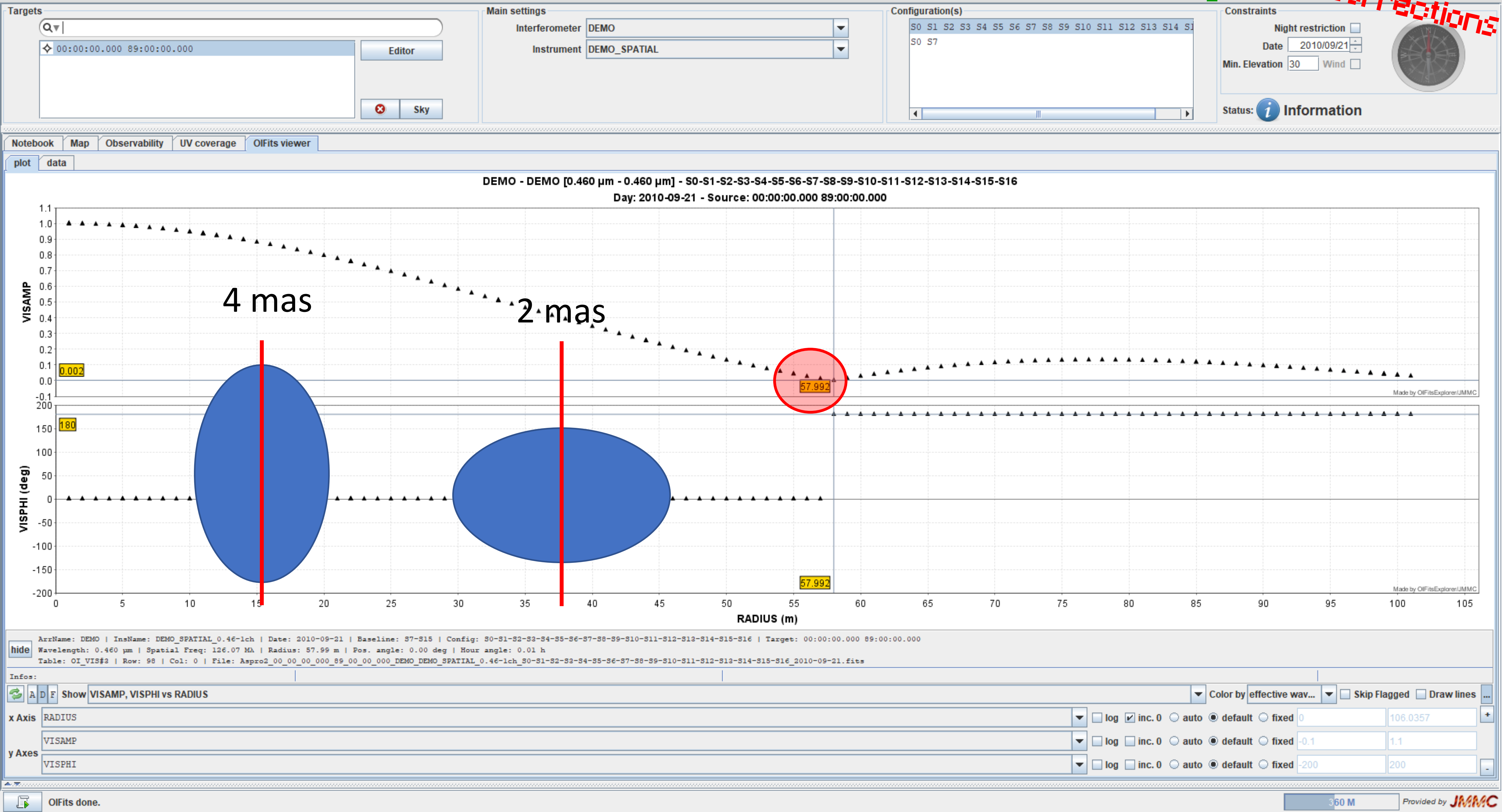

# The 10th VLTI School of Interferometry

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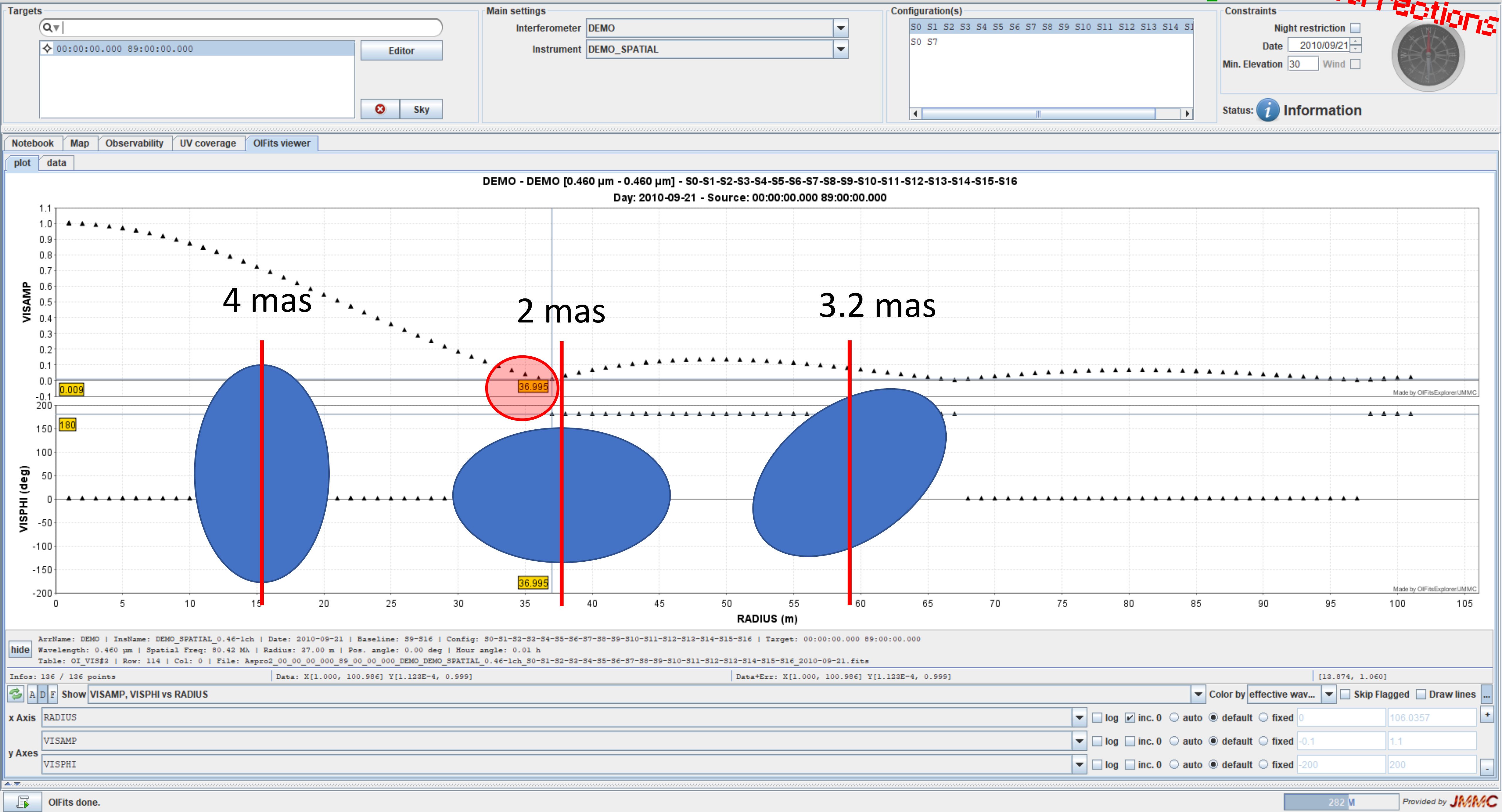

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Twice as far, i.e., B=58m
Now the baseline is oriented along the minor-axis

**Question : What uniform disk diameter does this correspond to?**

2mas

Finally, put the disk major-axis at 45$^o$.

**Question : Can you conclude on the extension measured by an interferometer?**

At 45° we found 3.1 mas, an intermediate value between the major and minor axes.
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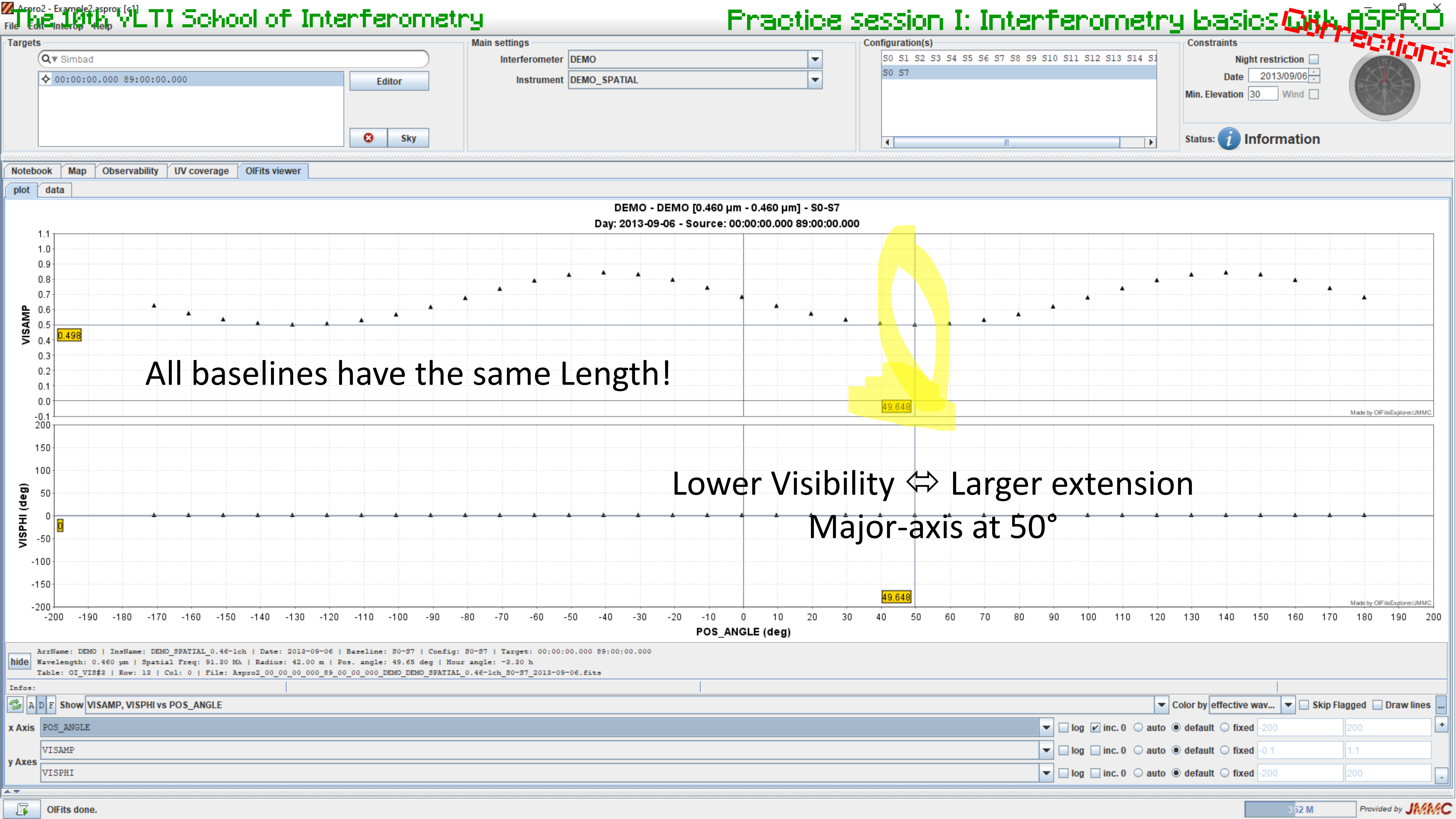
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Corrections
Targets
Main settings
Interferometer DEMO
Instrument DEMO_SPATIAL
Configuration(s)
Constraints
Night restriction
Date 2013/09/06
Min. Elevation 30
Status: Information
Notebook
Map
Observability
UV coverage
OIFits viewer
DEMO - DEMO [0.460 µm - 0.460 µm] - S0-S7
Day: 2013-09-06 - Source: 00:00:00.000 89:00:00.000
VISAMP
VISPHI (deg)
POS_ANGLE (deg)
All baselines have the same Length!
Lower Visibility ⇔ Larger extension
Major-axis at 50°
OIFits done.

Corrections

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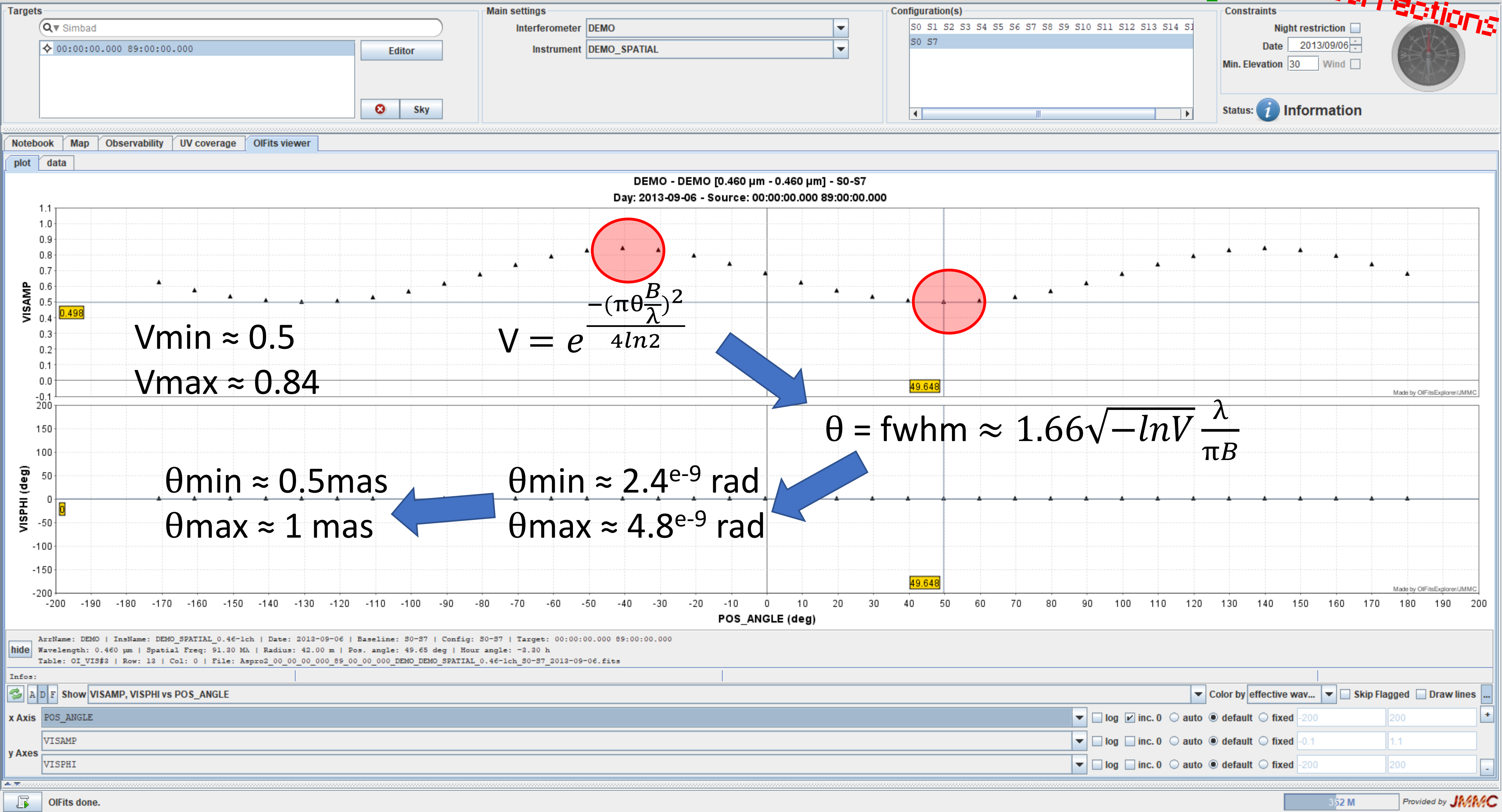


Vmin ≈ 0.5

Vmax ≈ 0.84

$$V = e^{\frac{-(\pi\theta\frac{B}{\lambda})^2}{4ln2}}$$

$$\theta = \text{fwhm} \approx 1.66\sqrt{-lnV}\,\frac{\lambda}{\pi B}$$

θmin ≈ 2.4e-9 rad

θmax ≈ 4.8e-9 rad

θmin ≈ 0.5mas

θmax ≈ 1 mas

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Using the FT given in the cheatsheet for the Gaussian

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> Elong = 1 / cos (inclination)

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## 4 Going 2D with flattened models

In the previous sections you learned about 1D functions to model interferometric measurements. Now it is time to take a look at two-dimensional intensity distributions.

### 4.1 Elliptical distributions

**Question :** Compare its visibility function to the one obtained for the 4 mas uniform disk.

Now modify the model so that the major-axis is oriented East-West.

**Question :** Where is the first zero of the visibility function?

**Question :** What uniform disk diameter does this correspond to?

Finally, put the disk major-axis at 45$^o$.

**Question :** Can you conclude on the extension measured by an interferometer?

Now, let's use a new set of baselines. Load the configuration file *Example2.asprox*. Look at the UV plan in the **UV coverage** tab. The baselines in the new set all have the same length, i.e. 42m, but they have different position angles, and cover all directions.

Go to the **OIFits viewer** tab and plot the Visibility (VISAMP and VISPHI) as a function of the position angle (POS_ANGLE).

**Question :** Without looking at the model can you determine the major-axis position angle?

**Question :** Assuming an elliptical Gaussian model what are the major and minor axes FWHMs?

### 4.2 Application to geometrically thin disk

Elliptical intensity distributions are widely used to model geometrically-thin circumstellar disks. In this case the flattening is due to the projection of the disk on the sky-plane, i.e., perpendicular to the observer line of sight. At an inclination angle of 0$^o$, i.e. pole-on, the disk is not flattened, and the elongation ratio (i.e. major-axis/minor-axis) grows with the inclination angle.

**Question :** Find the formula of the elongation ratio for this simple geometrically thin disk model

**Question :** Conclude on the inclination angle of our object.

---

It is extacly the same! (V=0 ⇔ B=29m)
The baseline is North-South oriented and so it ``sees'' The major-axis of the Elongated disk

Twice as far, i.e., B=58m
Now the baseline is oriented along the minor-axis

2mas

At 45° we found 3.1 mas, an intermediate value between the major and minor axes.
The interferometer only measures extension along the baseline orientation

yes, as there is some modulation, minimum is at 50°, which mean the longest dimension (the major axis) has a PA of 50°

Using the FT given in the cheatsheet for the Gaussian

$$\text{fwhm} \approx 1.66\sqrt{-lnV}\,\frac{\lambda}{\pi B} \Leftrightarrow fwhm = 1 \text{ and } 0.5$$

Elong = 1 / cos (inclination)

60°

# 5 Composed models

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Imagine that your model is a weighted sum of N components :

$$I_{tot}(x,y) = \sum_{i=1}^{N} f_i \, I_i(x,y) \tag{1}$$

where $I_i(x,y)$ is the intensity distribution of the i$^{th}$ component and $f_i$ its relative flux with $\Sigma f_i$=1.

**Question : What is the visibility function (i.e. normalized Fourier Transform) for this model?**

## 5.1 Star + circumstellar disk model

Let's look at a simple star + circumstellar disk example. First, load a new observation file : *Example3.asprox*. Go to the **UV coverage** tab and look at it (again remove the annoying **Plot rise/set uv tracks** option). It is composed two perpendicular strips of baselines : one North-South and one East-West. It will allow us to probe our object along these two perpendicular orientations.

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Plot the visibility amplitude and phase as a function of the baselines lengths.

**Question : Describe the visibility function.**

Change the flux ratio between the two components and look at the visibility function.

**Question : What has been modified? Can you explain why?**

Now imagine that you want to constrain the circumstellar environment extension and flattening.

**Question : What baseline lengths and orientations will you choose?**

**Question : Will these set of baselines give information on the stellar surface?**

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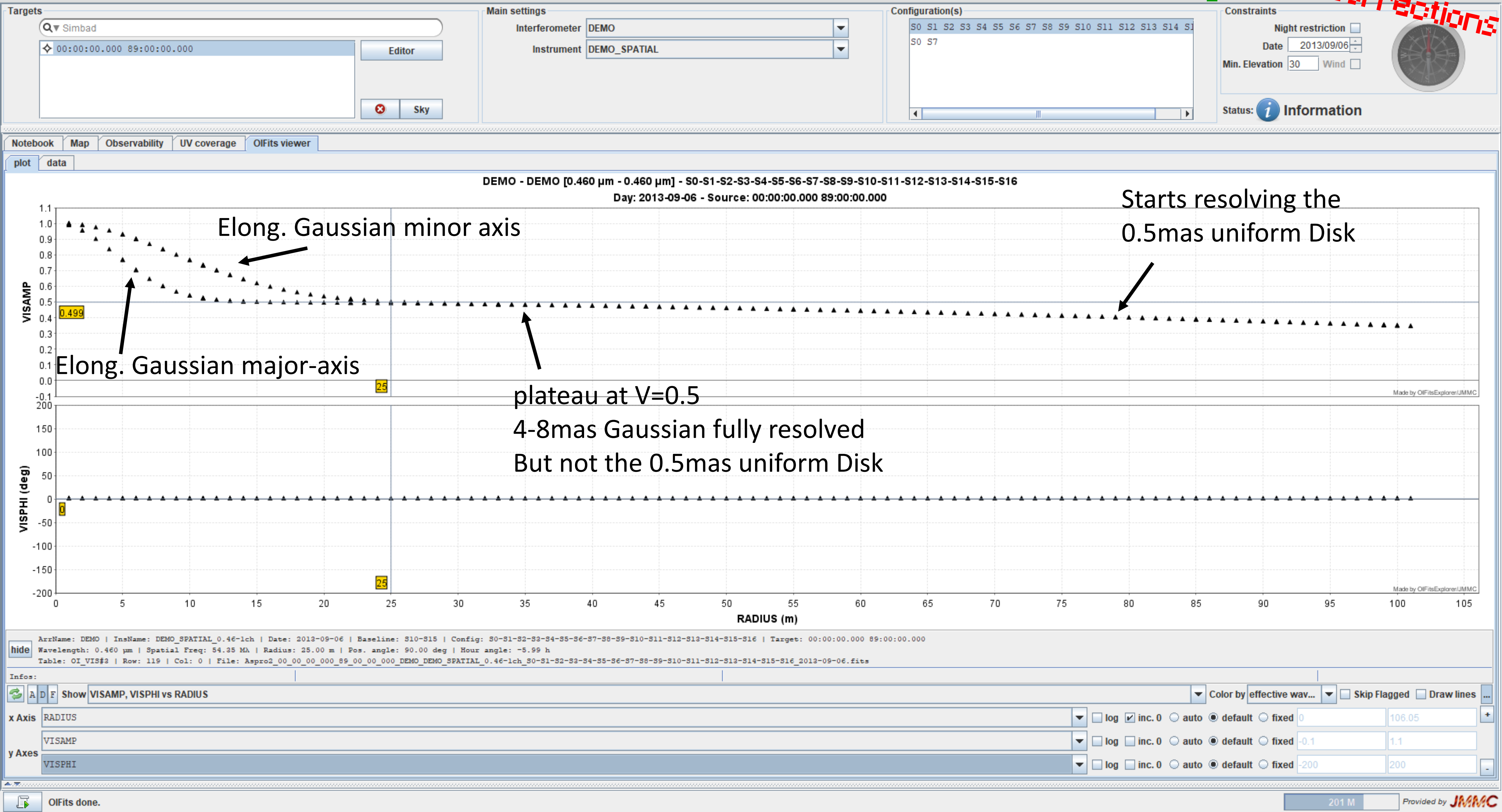
Corrections



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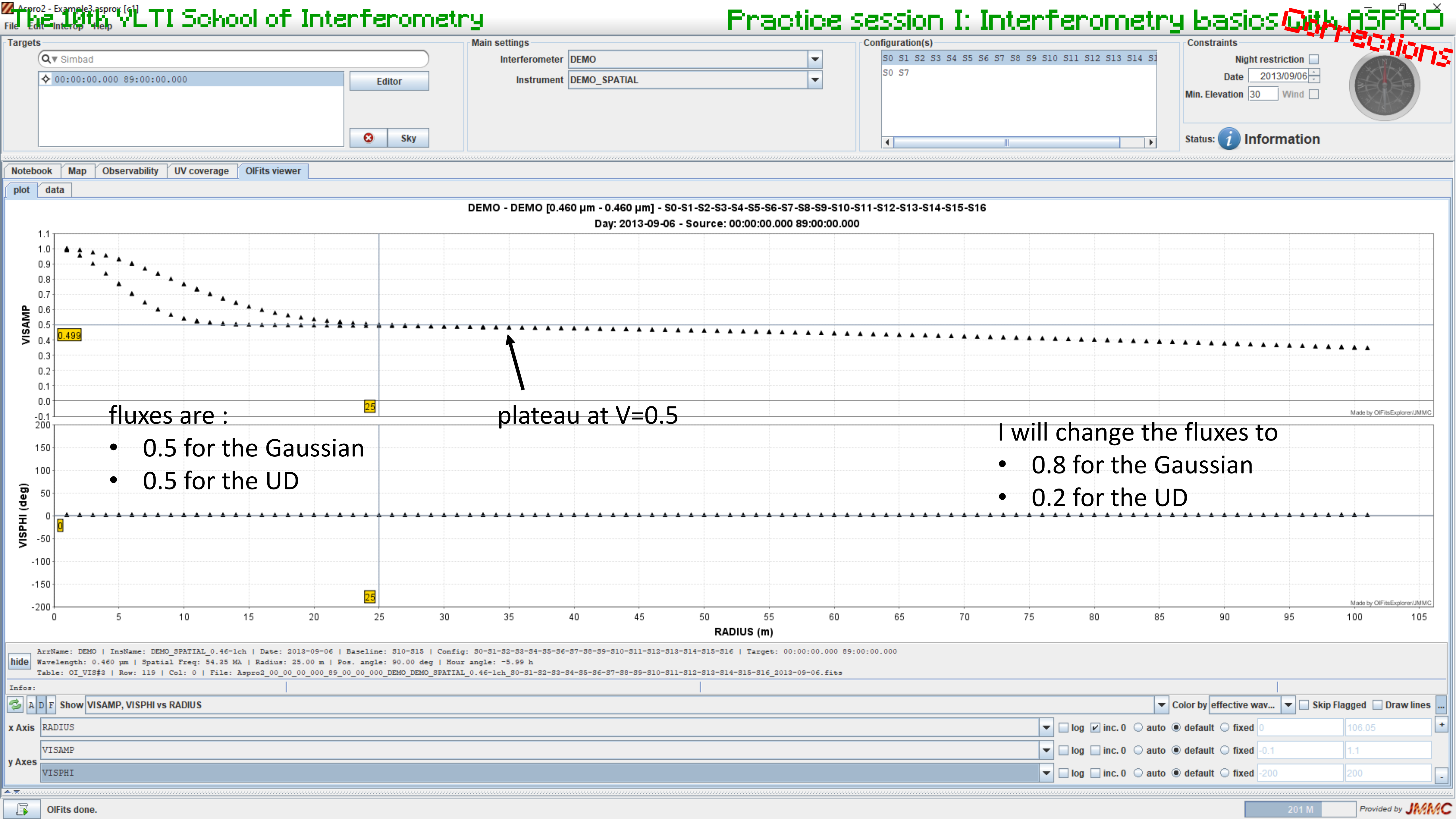


fluxes are :

- 0.5 for the Gaussian
- 0.5 for the UD

plateau at V=0.5

I will change the fluxes to

- 0.8 for the Gaussian
- 0.2 for the UD

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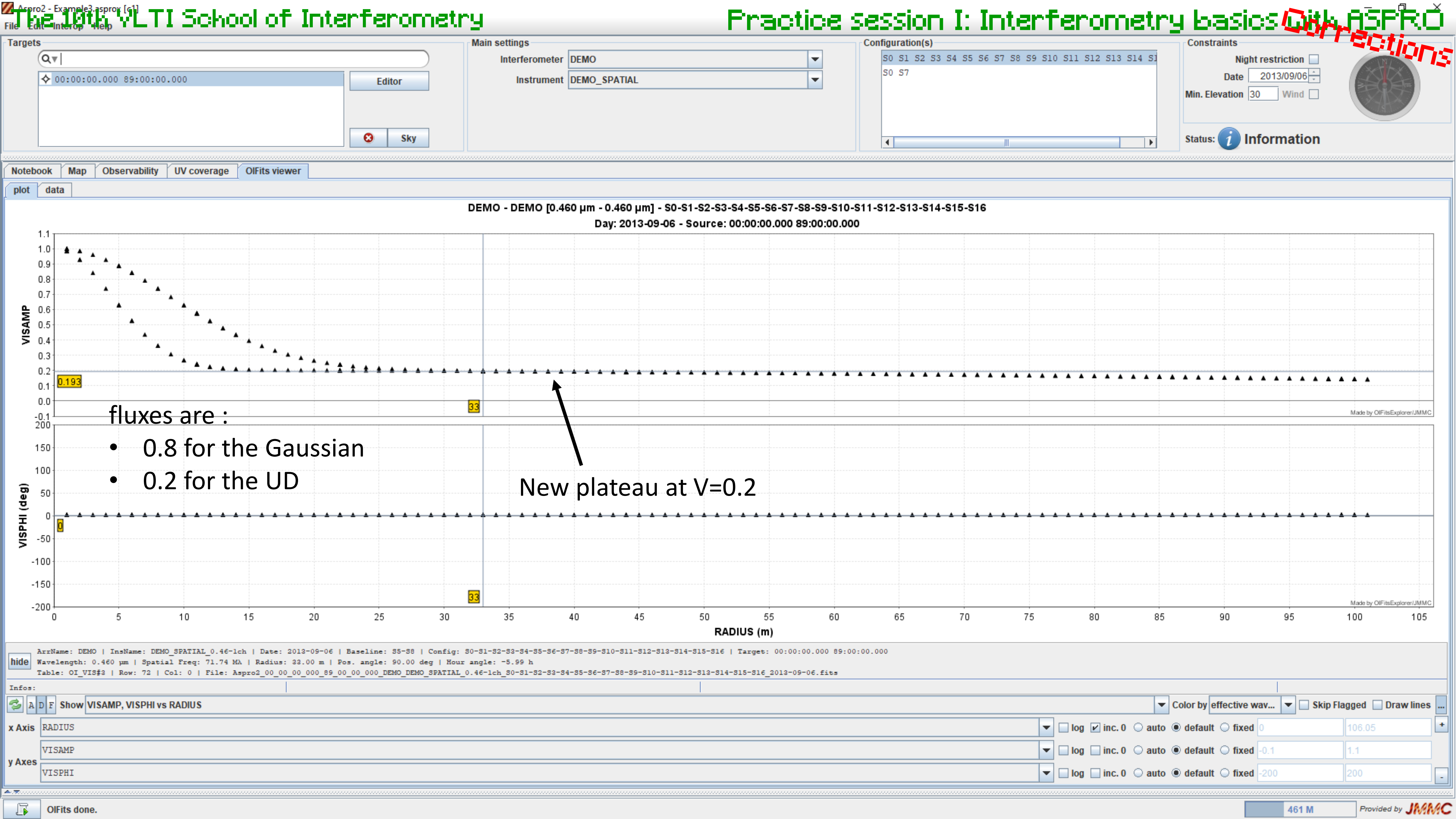
## Practice session I: Interferometry basics with ASPRO — Corrections

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New plateau at V=0.2

Corrections

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# Practice session I: Interferometry basics with ASPRO

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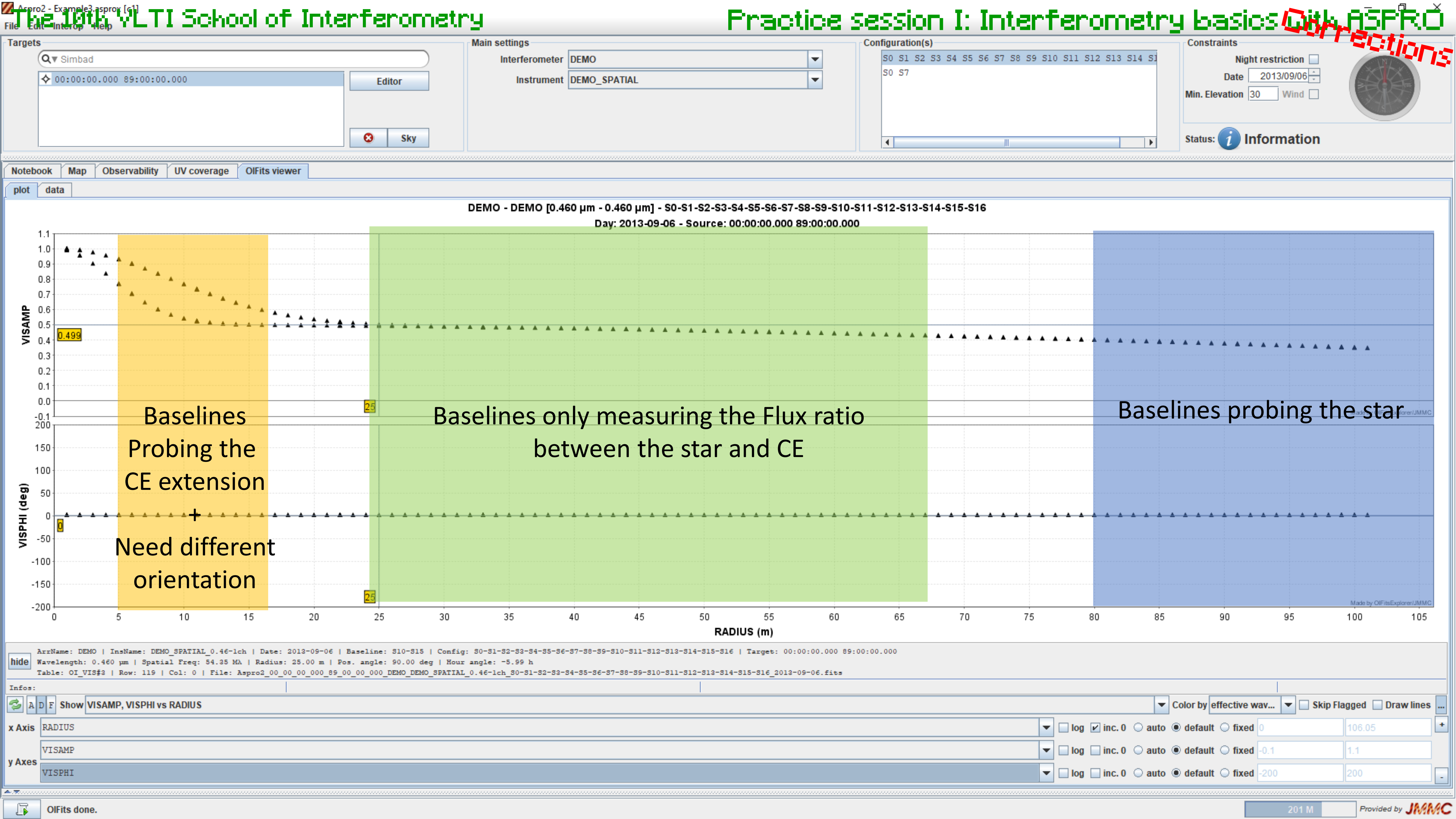

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**Question : What baseline lengths and orientations will you choose?**

Baselines shorter than the plateau : B < 20 m
Disk elongated ⇔ Baselines in many orientations.

**Question : Will these set of baselines give information on the stellar surface?**

No. The star start to be significantly resolved for baselines larger than 60 m.

## 5.2 Binaries

A second kind of very useful two components model is the binary model. We will use a single strip of North-South aligned baselines to exlpore this model. So, load the *Example1.asprox* file.

Then, open the **Target Editor** and create a model consisting of two point sources. Set their flux to 0.2 and 0.8. Look at the second component, the *x2* and *y2* parameters have been replaced by *sep2* and *pos_angle2*, i.e. polar coordinates. Choose *sep2*=5 and *pos_angle2*=0. This simulates two unresolved stars separated by 5 mas in the North-South orientation, i.e. aligned with our baselines.

**Question : Describe and explain the visibility function.**

Write down the amplitude of the sinusoidal modulation. Set the flux ratio to 0.1/0.9 and then to 0.5/0.5.

**Question : What is the link between the flux ratio and the amplitude of the binary modulation?**

Write down the modulation period in meter, and express it in B/$\lambda$ units (cycles/rad). Then set the binary separation, i.e. *sep2*, to 10 mas. and do this again.

**Question : Give the relation between the binary separation (in rad) and the modulation period (in cycles/rad).**

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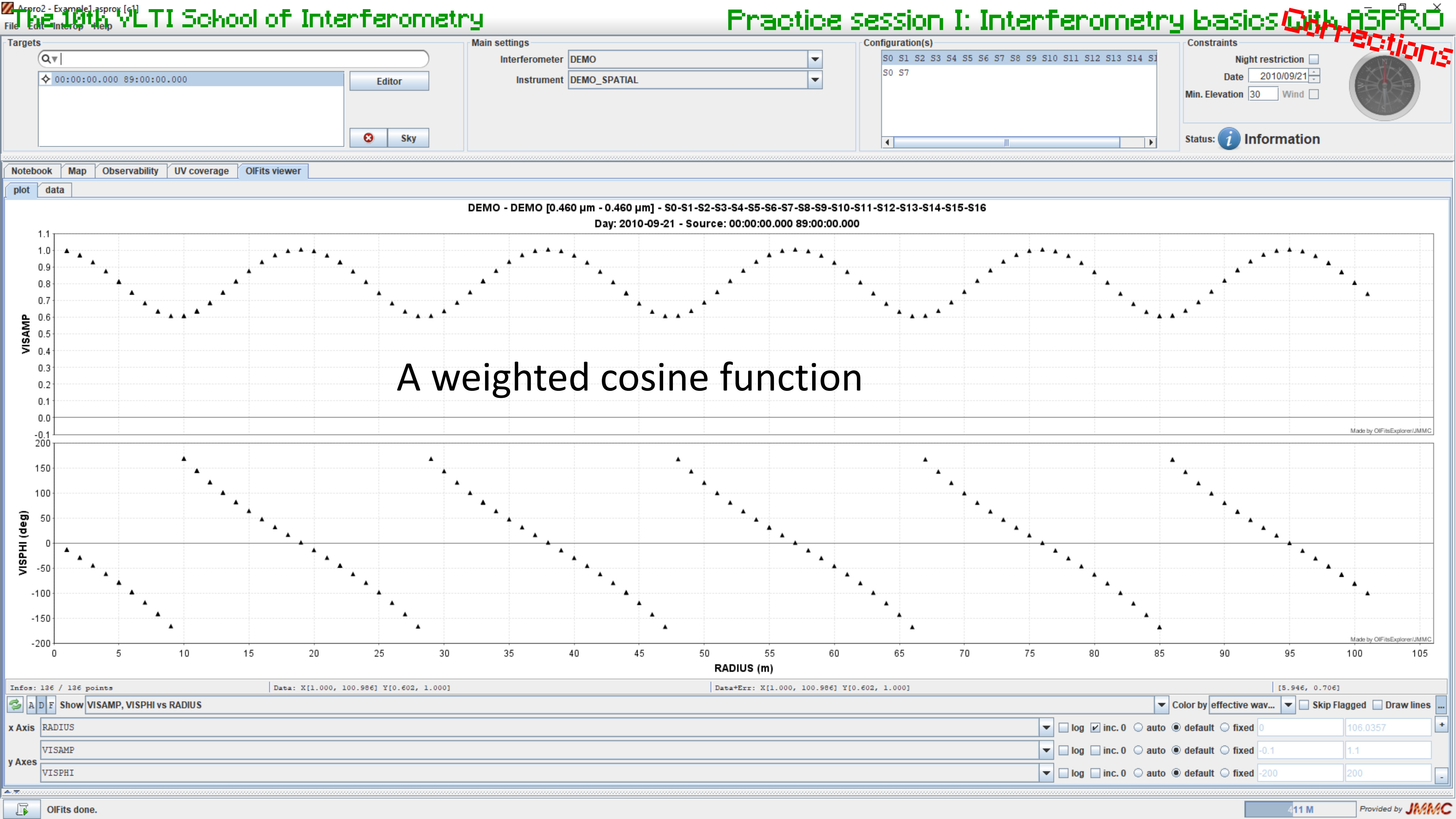


A weighted cosine function

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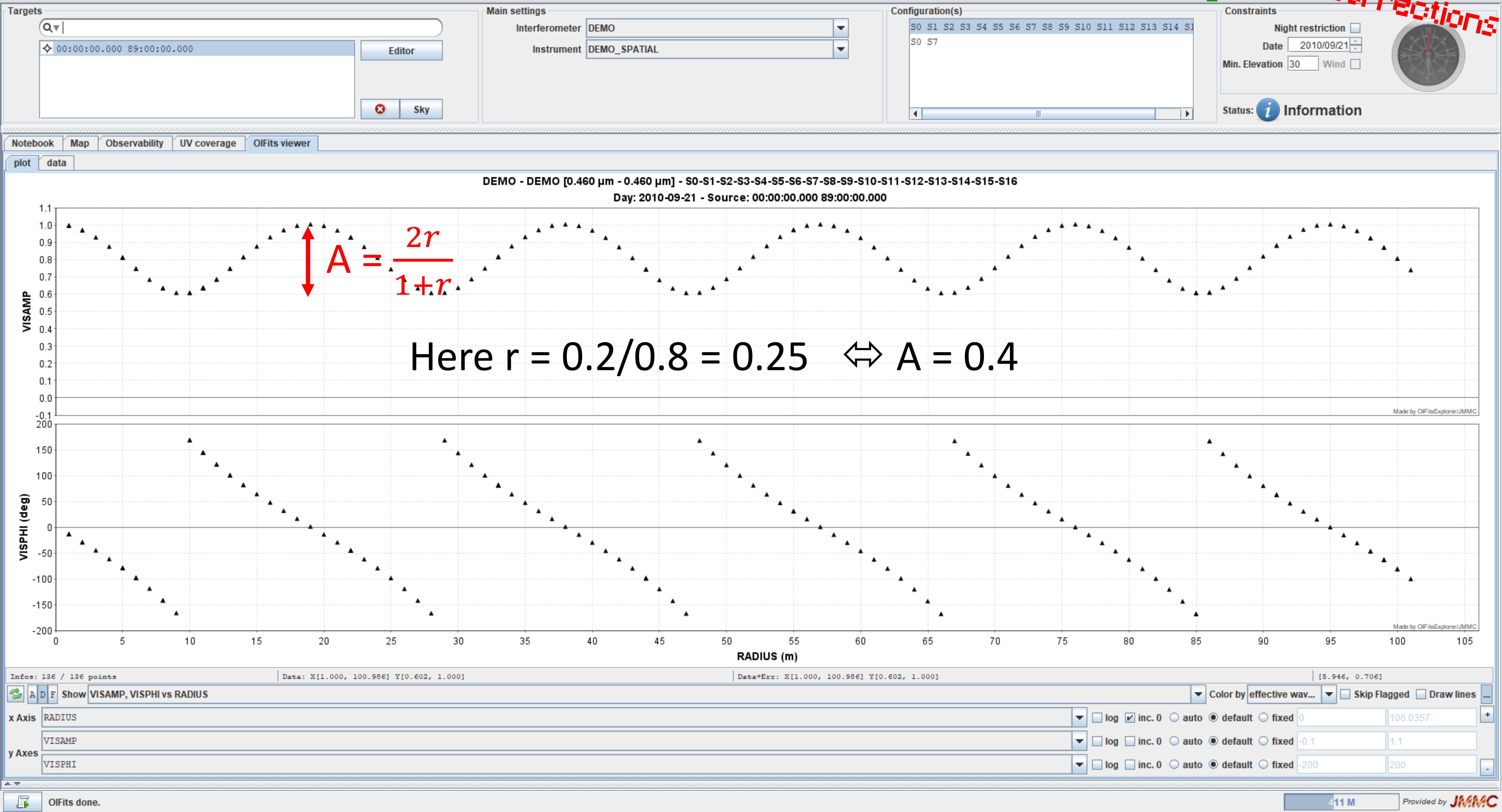

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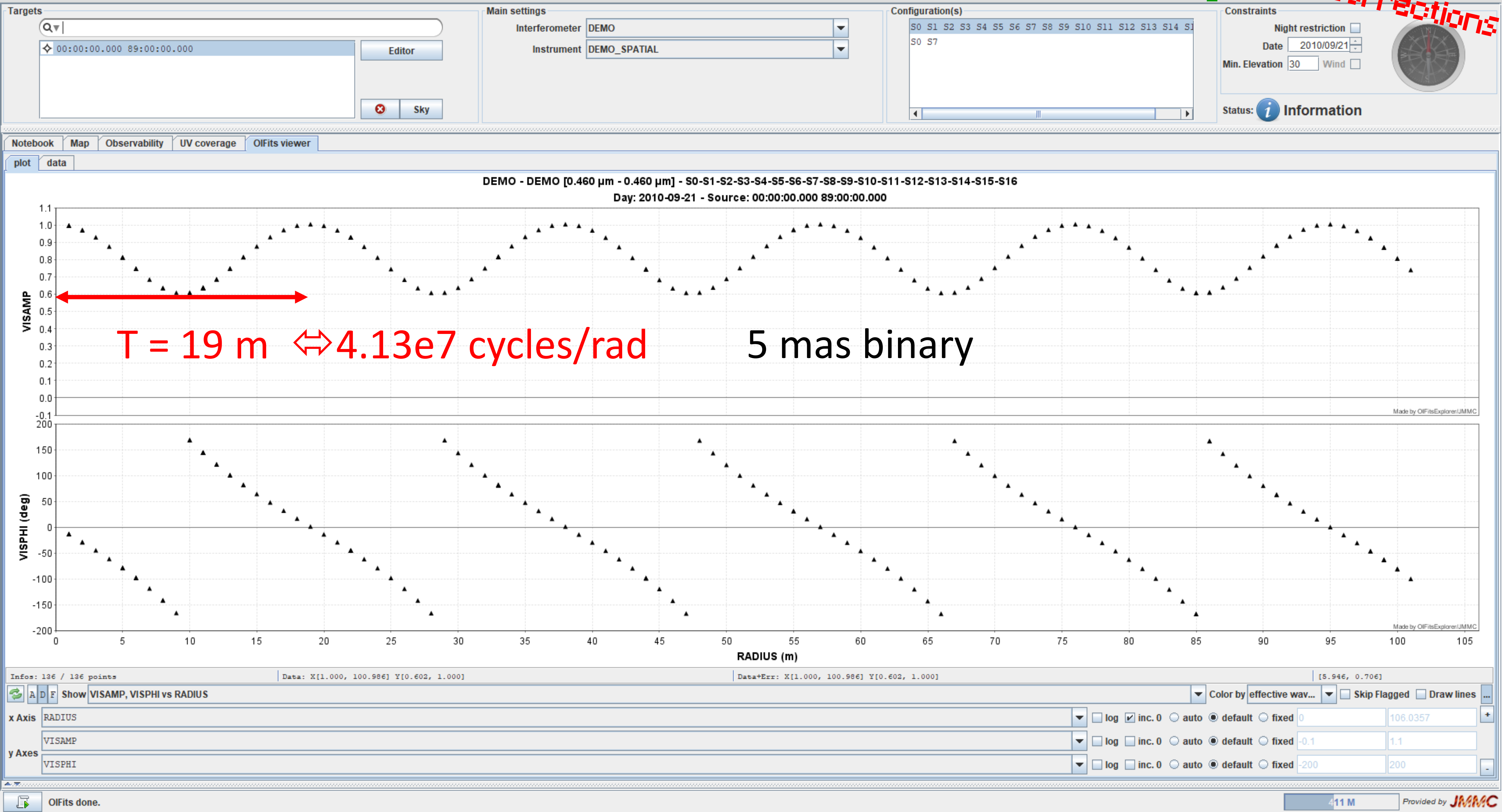

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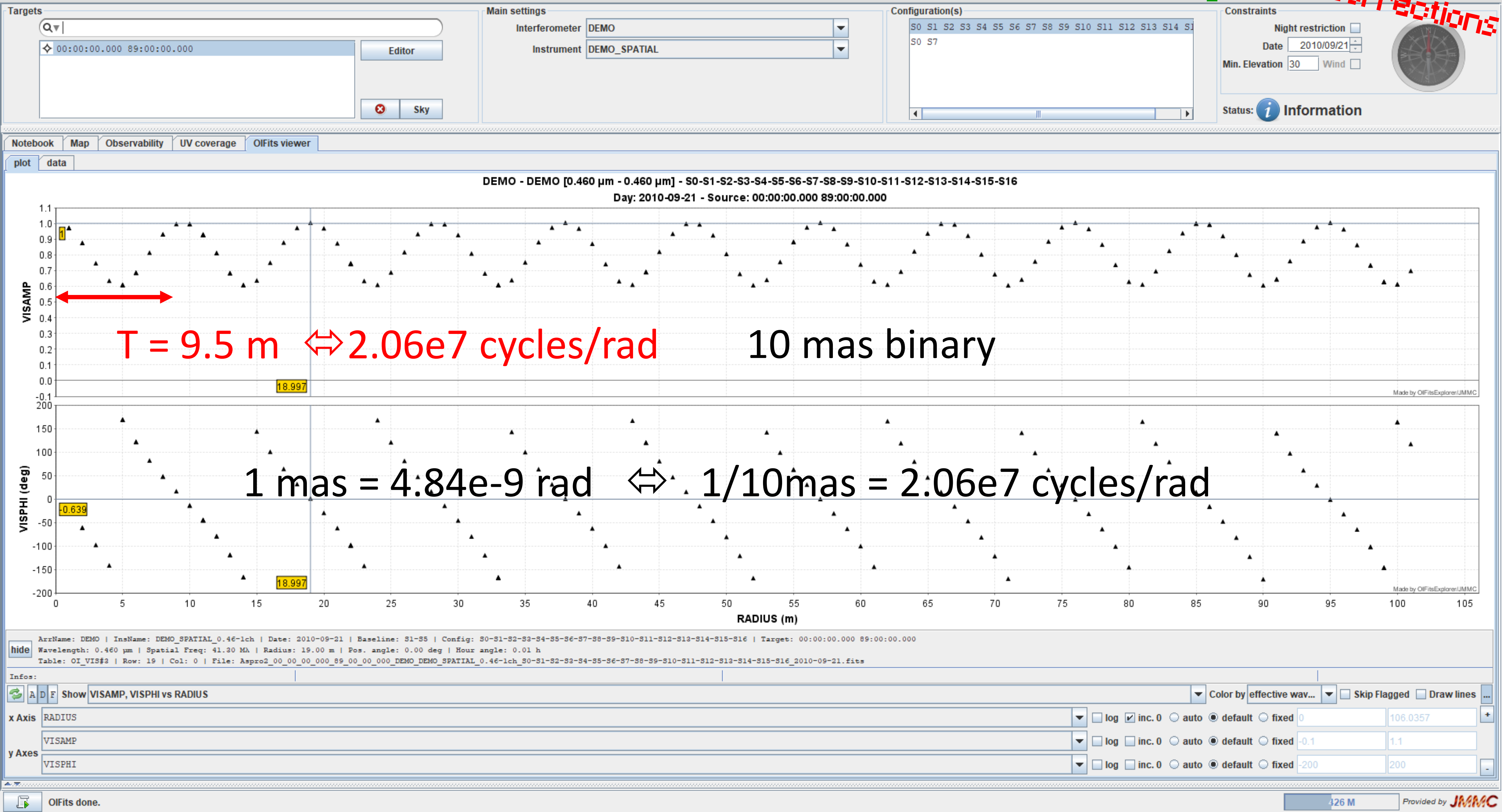

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- 5mas => 19m => 4.13e-7 cycles/rad
- 10mas => 9.5m => 2.06e-7 cycles/rad

The modulation period is equal to the inverse of the binary separation.

1 mas = 4.84e-9 rad

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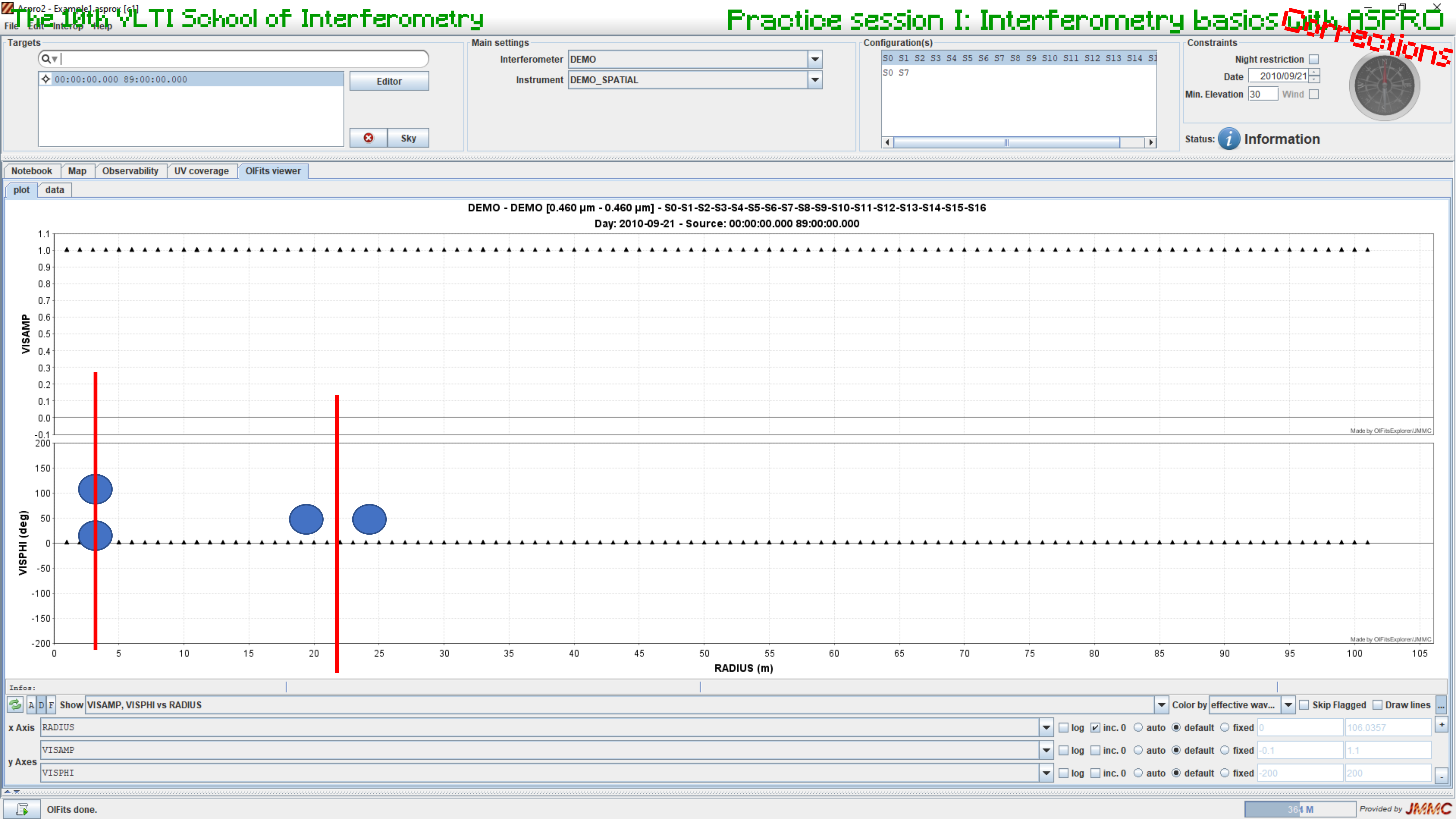

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> 1 mas = 4.84$^{e-9}$ rad
>
> 4.13$^{e-7}$ = 1/5 mas 2.06$^{e-7}$ = 1/10 mas

Now change *theta2* to 90$^o$ : binary in the East-West orientation.

**Question : Describe and explain the visibility function.**

> There is no modulation anymore as the baseline samples perpendicular to the binary direction.
> V = 1 as the interferometer ``sees” an unresolved object in the baselines orientation.

Do the same but with *theta2* equal to 30$^o$, 45$^o$, and 60$^o$.

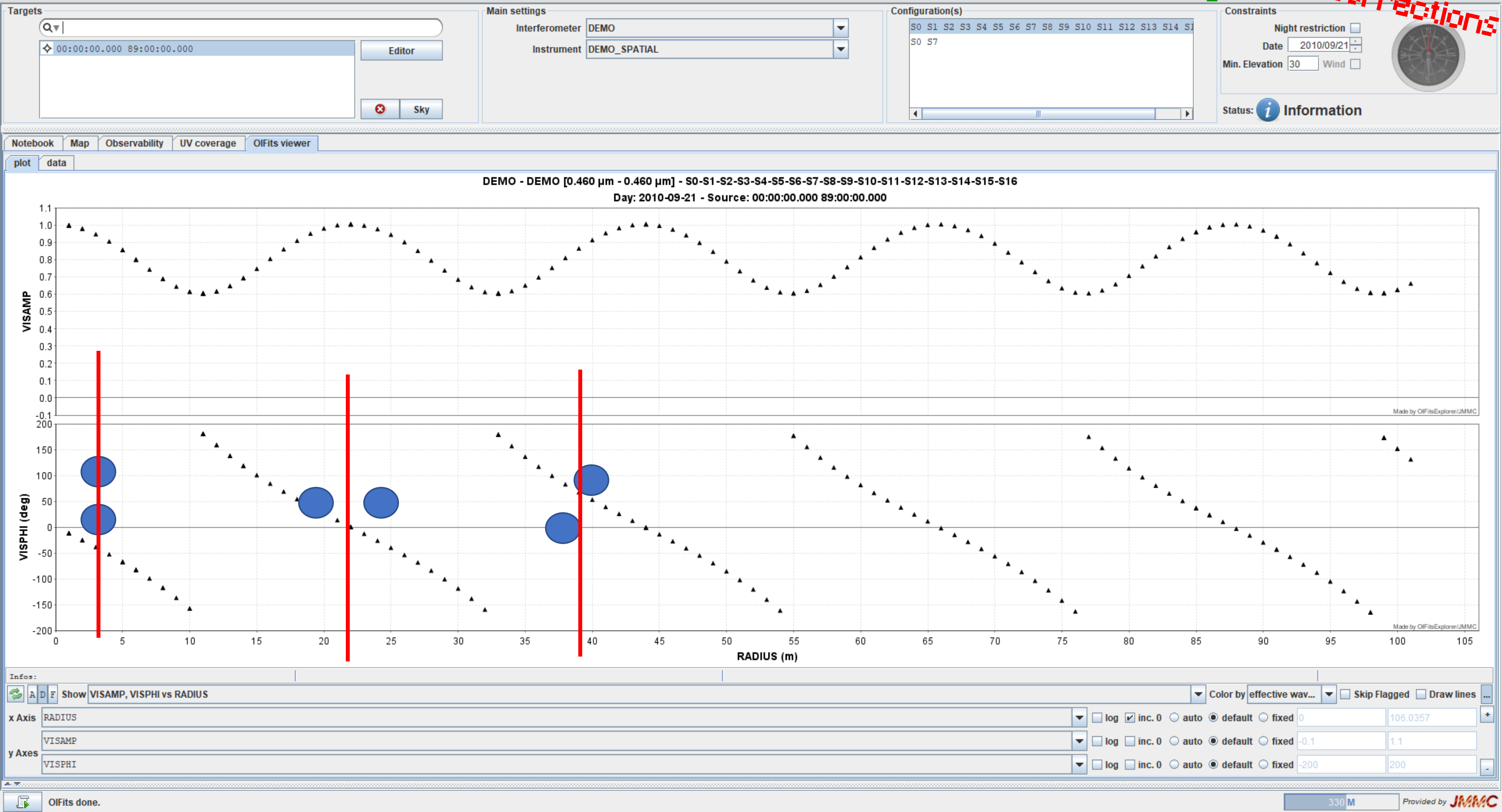
**Question : How does this affect the visibility function? Why?**

Finally replace the components by uniform disks and try various diameters between 0 and 2 mas, for each component, separately.

**Question : What is the effect of resolving one component on the visibility function?**

# Practice session I: Interferometry basics with ASPRO

Corrections



# The 10th VLTI School of Interferometry

## Practice session I: Interferometry basics with ASPRO

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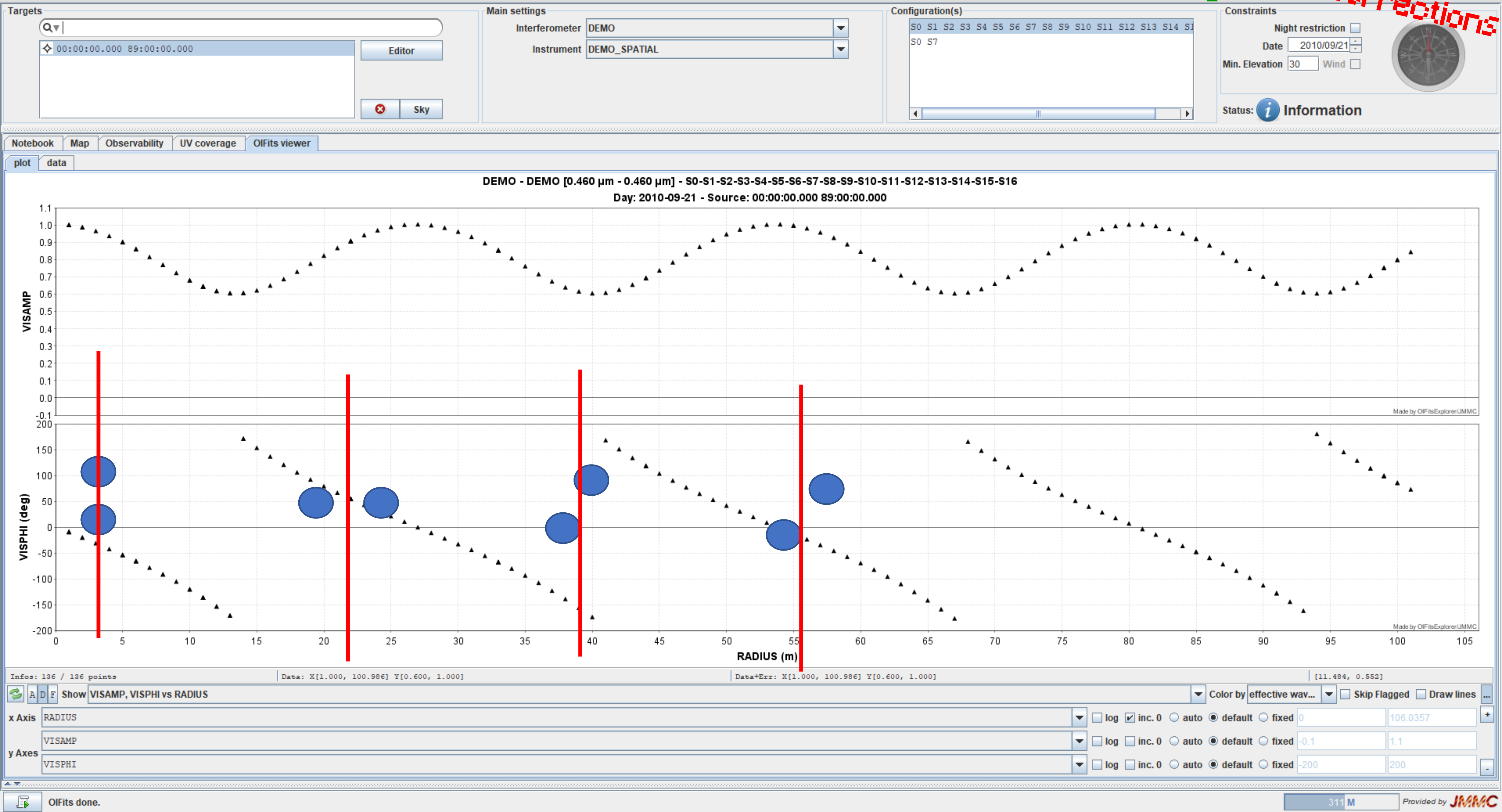

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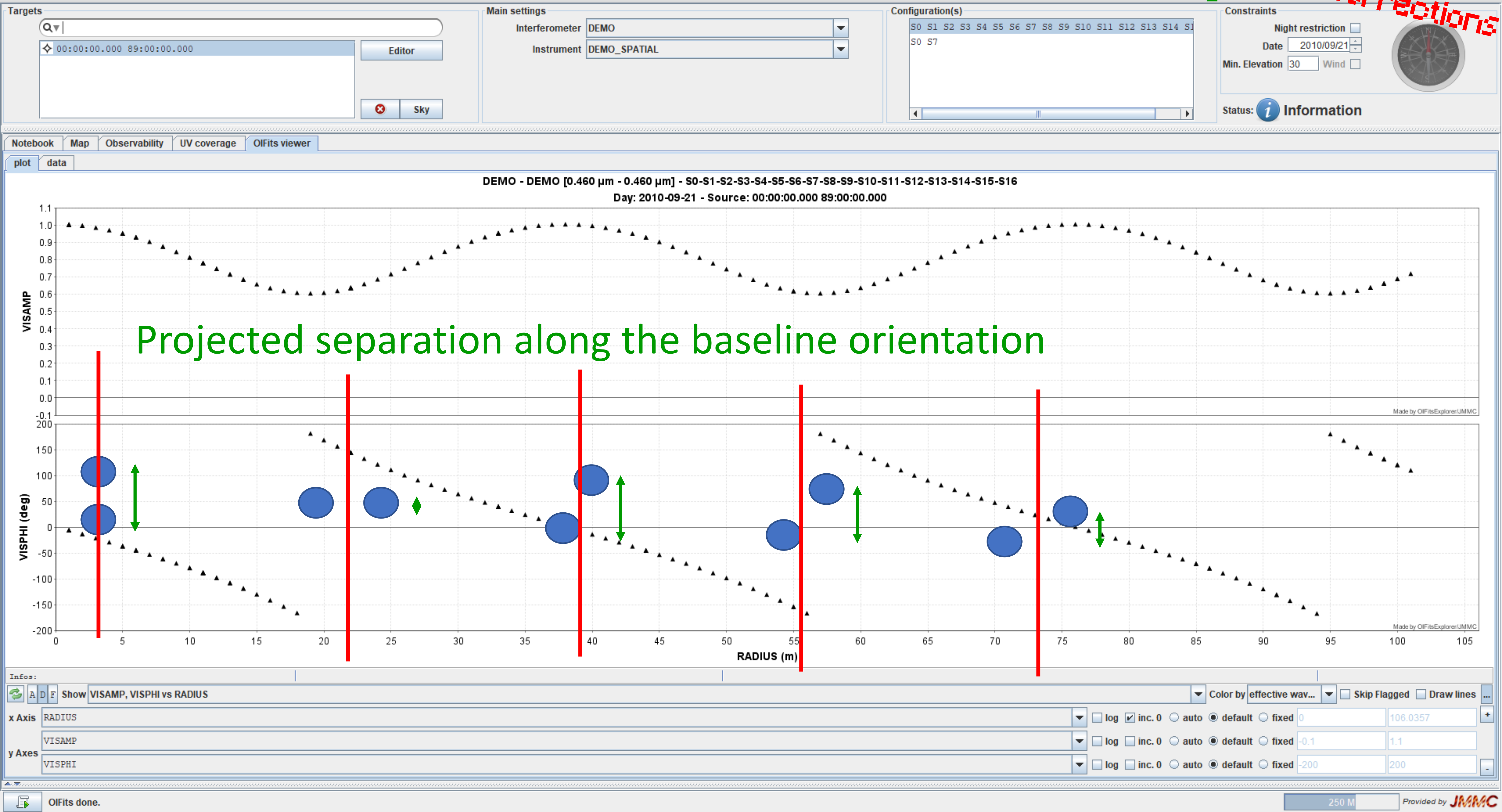

## 5.2 Binaries

A second kind of very useful two components model is the binary model. We will use a single strip of North-South aligned baselines to exlpore this model. So, load the *Example1.asprox* file.

Then, open the **Target Editor** and create a model consisting of two point sources. Set their flux to 0.2 and 0.8. Look at the second component, the *x2* and *y2* parameters have been replaced by *sep2* and *pos_angle2*, i.e. polar coordinates. Choose *sep2*=5 and *pos_angle2*=0. This simulates two unresolved stars separated by 5 mas in the North-South orientation, i.e. aligned with our baselines.

**Question : Describe and explain the visibility function.**

Write down the amplitude of the sinusoidal modulation. Set the flux ratio to 0.1/0.9 and then to 0.5/0.5.

**Question : What is the link between the flux ratio and the amplitude of the binary modulation?**

Write down the modulation period in meter, and express it in B/$\lambda$ units (cycles/rad). Then set the binary separation, i.e. *sep2*, to 10 mas. and do this again.

**Question : Give the relation between the binary separation (in rad) and the modulation period (in cycles/rad).**

Now change *theta2* to 90$^o$ : binary in the East-West orientation.

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Do the same but with *theta2* equal to 30$^o$, 45$^o$, and 60$^o$.

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Finally replace the components by uniform disks and try various diameters between 0 and 2 mas, for each component, separately.

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The visibility function corresponding to a binary is a weighted cosine function.

If r is the flux ratio between the components (r<1), the amplitude A of the modulation is given by :

$$A = \frac{2r}{1+r}$$

- 5mas => 19m => $4.13^{e-7}$ cycles/rad
- 10mas => 9.5m => $2.06^{e-7}$ cycles/rad

The modulation period is equal to the inverse of the binary separation.

1 mas = $4.84^{e-9}$ rad

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There is no modulation anymore as the baseline samples perpendicular to the binary direction.
V = 1 as the interferometer ``sees” an unresolved object in the baselines orientation.

The interferometer samples the projected separation of the binary along the baseline orientation

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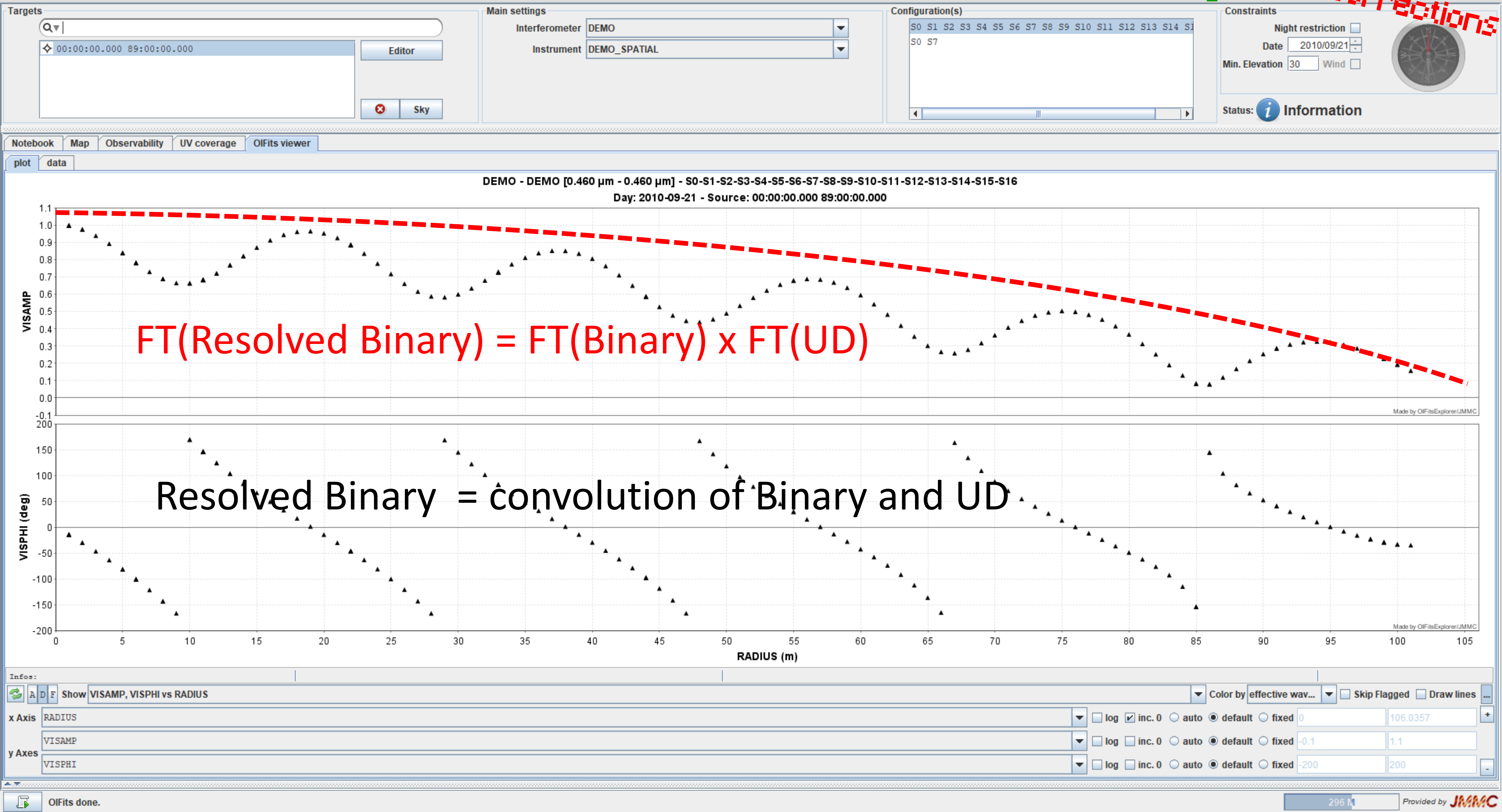

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The interferometer samples the projected separation of the binary along the baseline orientation

Finally replace the components by uniform disks and try various diameters between 0 and 2 mas, for each component, separately.

**Question : What is the effect of resolving one component on the visibility function?**

It is a convolution of two distributions in the image plane, so in the Fourier plane it amounts to a mutiplication of the binary pattern with the FT of a disk, i.e., a Bessel function

## 5.3 Home-made models

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**Question : what is the field of view (the size) of this image?**

Play with the zooming and the color scale.

**Question : Can you explain the shape of the intensity distribution?**

Close the **Target Editor** window, and go to the **UV Coverage** tab to select the **N** band. Look at the 2D Fourier transform of the image overplotted on the UV Coverage plot.

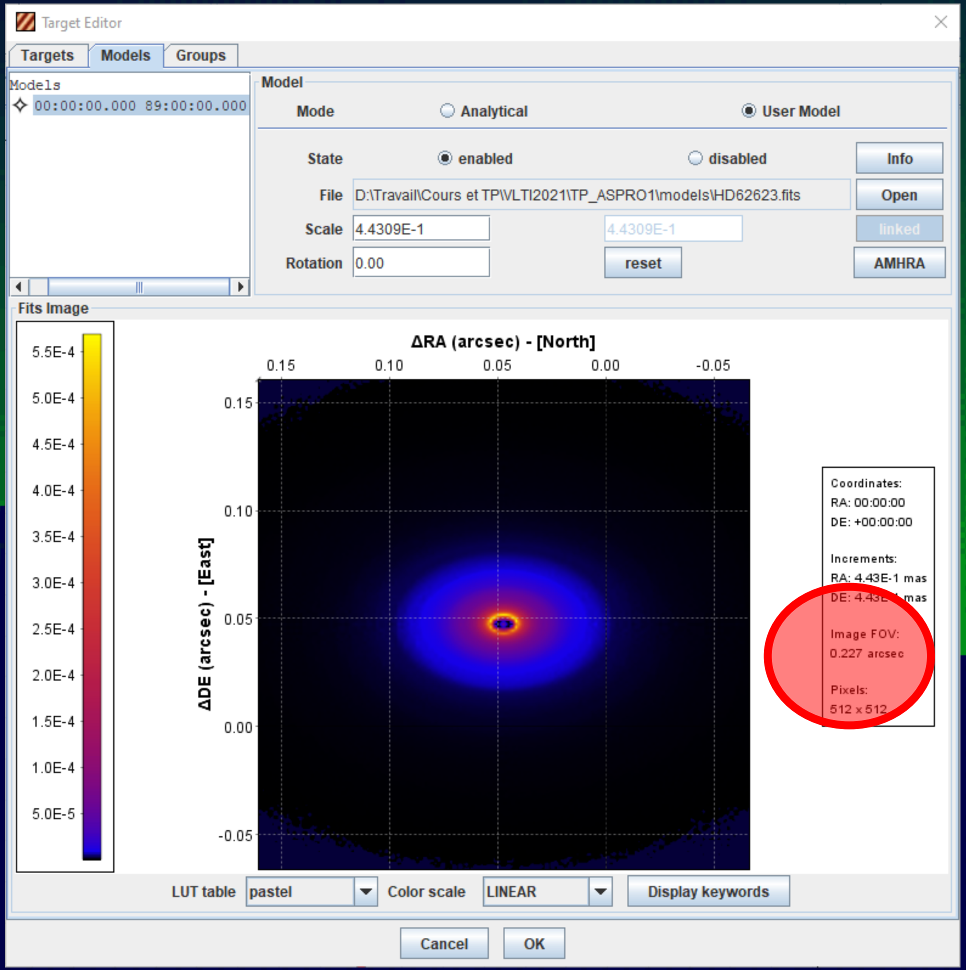
Finally, go back to the **OiFits viewer** tab to see North-South and East-West cuts of the 2D-visibility function. As before, plot VISAMP & VISPHI as a function of RADIUS.

**Question : Is the visibility function closer to that of a Gaussian distribution or uniform disk?**

**Question : What are the values of the visibility in the two orientations for a 20 m baseline?**

**Question : Using these values estimate the objects extension in the North-South and East-West orientations.**

**Question : Assuming that the disk is geometrically thin what is the object inclination angle?**



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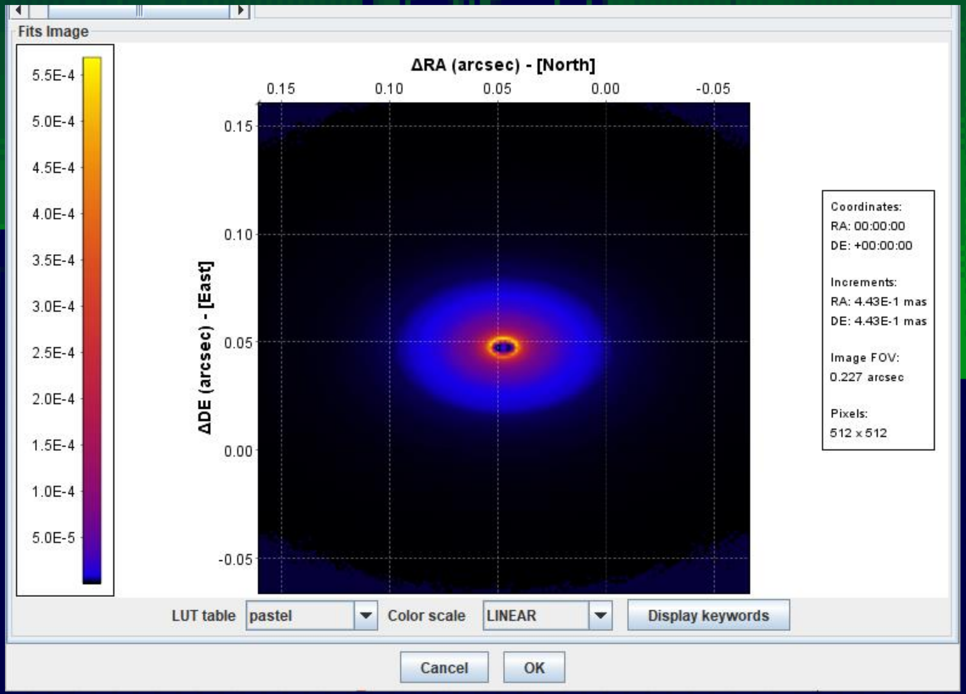

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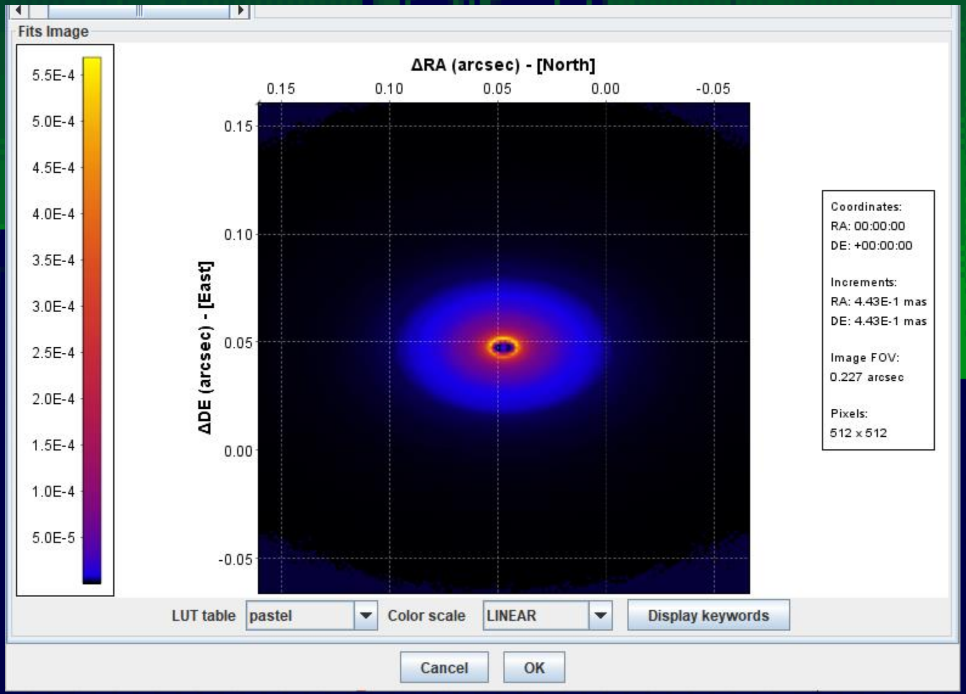

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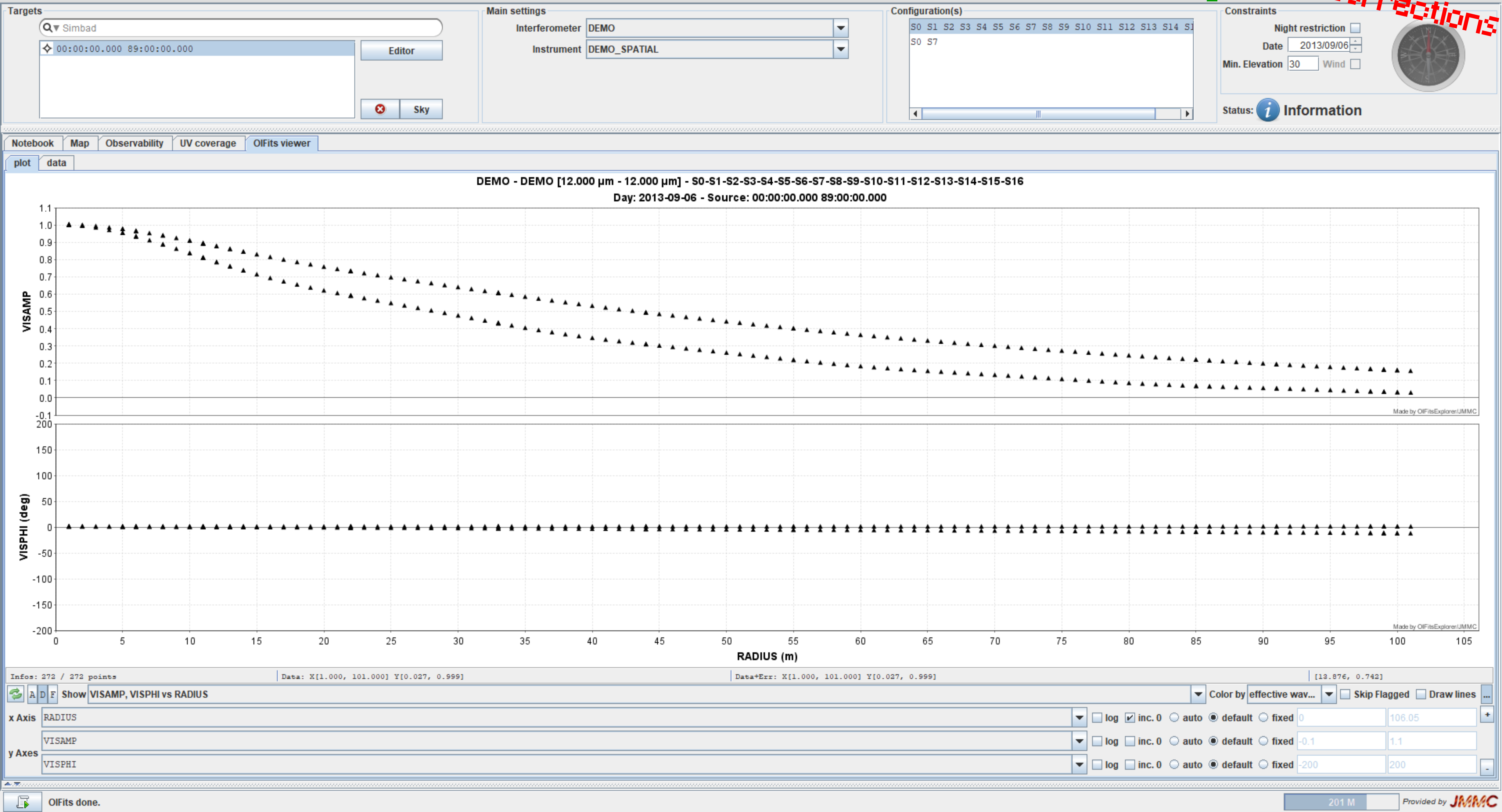

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As the object intensity distribution has no sharp edge beside the inner rim that is very small compared to the object extension, its visibility function is closer to that of a Gaussian distribution.

**Question : What are the values of the visibility in the two orientations for a 20 m baseline?**

V= 0.755
V= 0.618

**Question : Using these values estimate the objects extension in the North-South and East-West orientations.**

**Question : Assuming that the disk is geometrically thin what is the object inclination angle?**

Corrections

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$$\text{fwhm} \approx 1.66\sqrt{-lnV}\,\frac{\lambda}{\pi B}$$

B = 20m λ = 12µm

fwhm ≈ 34.7 mas
fwhm ≈ 45.4 mas

Question : Assuming that the disk is geometrically thin what is the object inclination angle?

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B = 20m  λ = 12µm

fwhm ≈ 34.7 mas
fwhm ≈ 45.4 mas

Elong = 1 / cos (incl.)
Elong = 45.4/34.7 = 1.31
Incl ≈ 40°

# 6 Effect of the Wavelength

# 6 Effect of the observed wavelength

## 6.1 Achromatic objects observed at various wavelengths

The spatial resolution of an inteferometer strongly depends on the observing wavelength. Imagine that our North-Pole interferometer is able to observe in any photometric band between 0.46$\mu$m (B) and 12$\mu$m (N).

**Question : Which band will give the highest resolution?**

To change the observing wavelength go to the **UV Coverage** tab. You can select a photometric band between B and N in the **Instrument mode** list.

**Question : Give the ratio between the resolutions in N and B bands**

Let's assume a 0.05 uncertainty on our visibility measurement and three baselines of 50, 70 and 100 m.

**Question : In which band should we observe a 1 mas star?**

**Question : Should we observe a 5 mas star with the same configuration?**

Now, let's do a multi-wavelength observation. First load the *Example4.asprox* file. It contains a 3 telescopes (S0-S5-S16) configuration of baselines. Unlike for the other exercices the observing wavelength is not fixed to one band but ranges between 0.1$\mu$m to 10$\mu$m, the "Wide" (and fake) instrument mode of the UV Coverage panel.

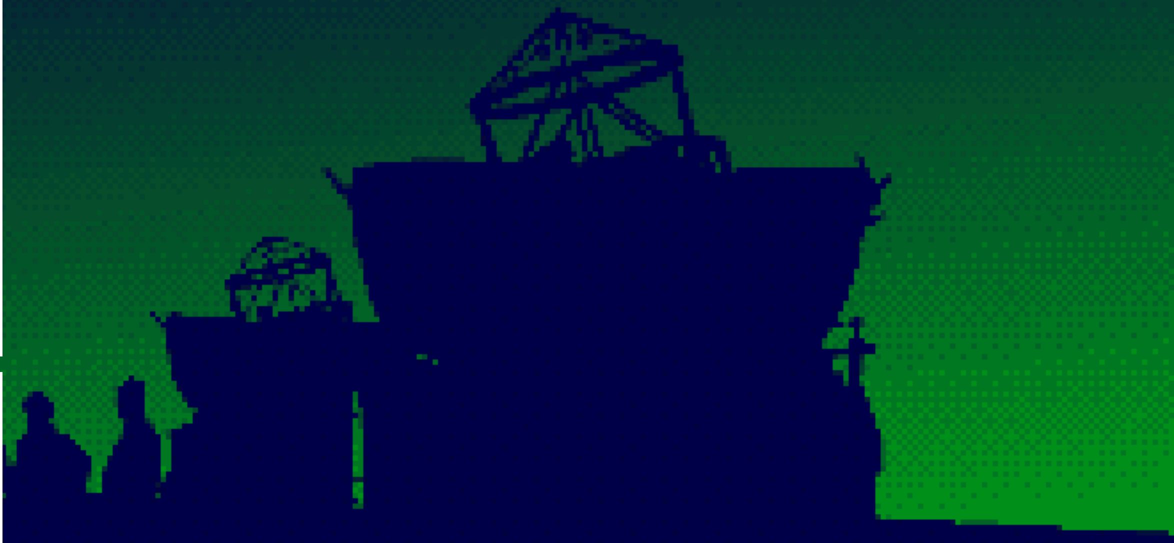
Note that for this observation we use a 1 mas uniform disk model.

First plot the visibility and phase as a function of the baseline length to see the visibility of the three baselines.

**Question : Explain why we obtain a large range of values for the visibility of each baseline.**

Now plot the visibility as a function of the spatial frequency B/$\lambda$ (SPATIAL_FREQ). The different colors correspond to different wavelengths from purple for the smallest one (0.1$\mu$m) to red for the largest one (10$\mu$m).

**Question : For this achromatic model case, conclude on the effect of observing at multiple wavelengths.**



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Smaller λ higher resolution

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12/0.46 = 26

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Resolution ⇔ B/λ
Smaller λ higher resolution

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Corrections

Aspro2 - Example3.asprox [c1]

Targets: 00:00:00.000 89:00:00.000

Main settings — Interferometer: DEMO — Instrument: DEMO_SPATIAL

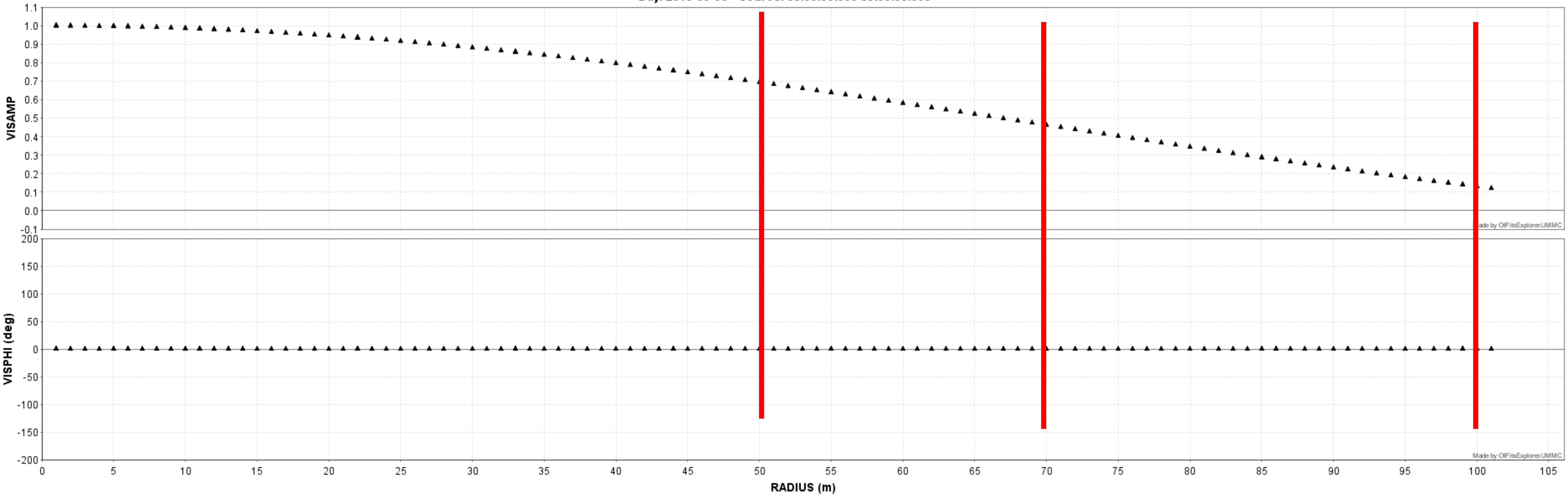
Configuration(s): S0 S7

Constraints — Date 2013/09/06 — Min. Elevation 30

Status: Information

Notebook | Map | Observability | UV coverage | OIFits viewer

DEMO - DEMO [0.460 µm - 0.460 µm] - S0-S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11-S12-S13-S14-S15-S16
Day: 2013-09-06 - Source: 00:00:00.000 89:00:00.000




Infos: 272 / 272 points — Data: X[1.000, 101.000] Y[0.121, 1.000] — Data+Err: X[1.000, 101.000] Y[0.121, 1.000]

Show VISAMP, VISPHI vs RADIUS — Color by effective wav... — Skip Flagged — Draw lines

x Axis: RADIUS — y Axes: VISAMP, VISPHI

OIFits done.

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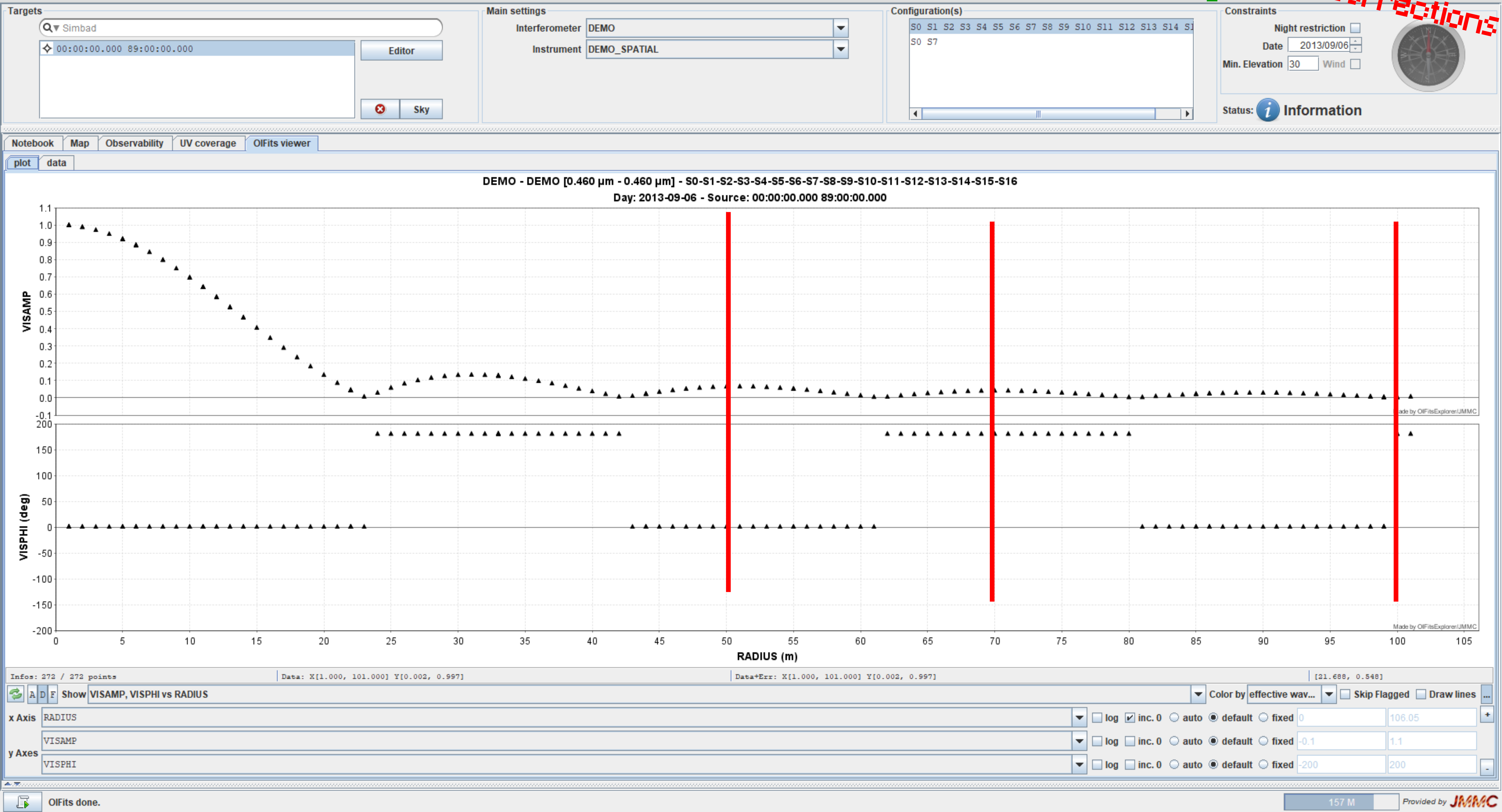
The 10th VLTI School of Interferometry

# Practice session I: Interferometry basics with ASPRO

Corrections



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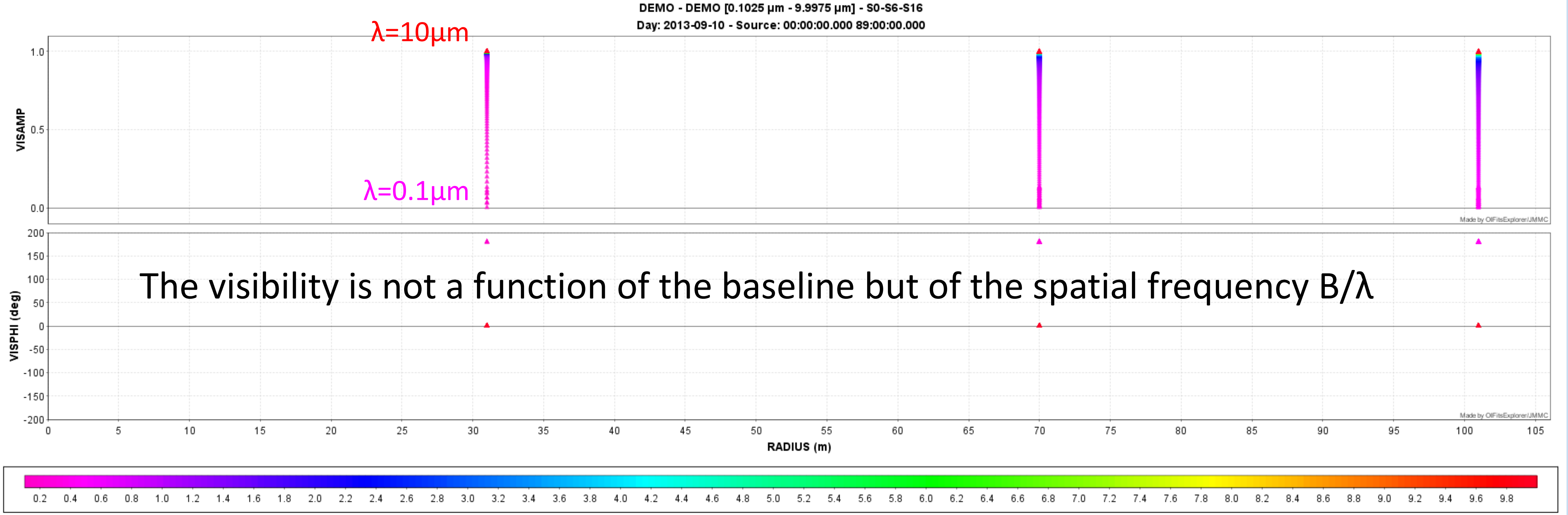


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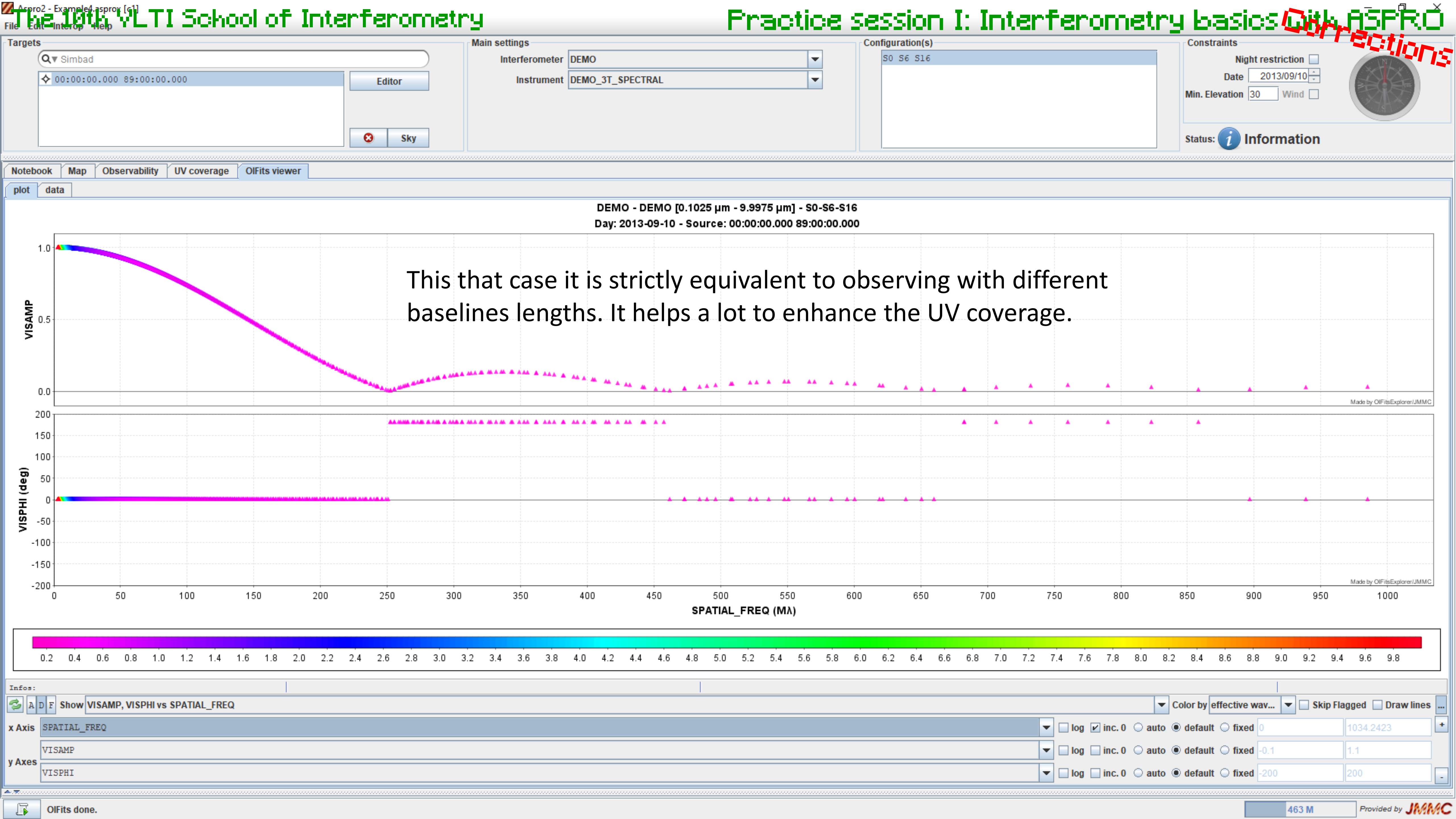


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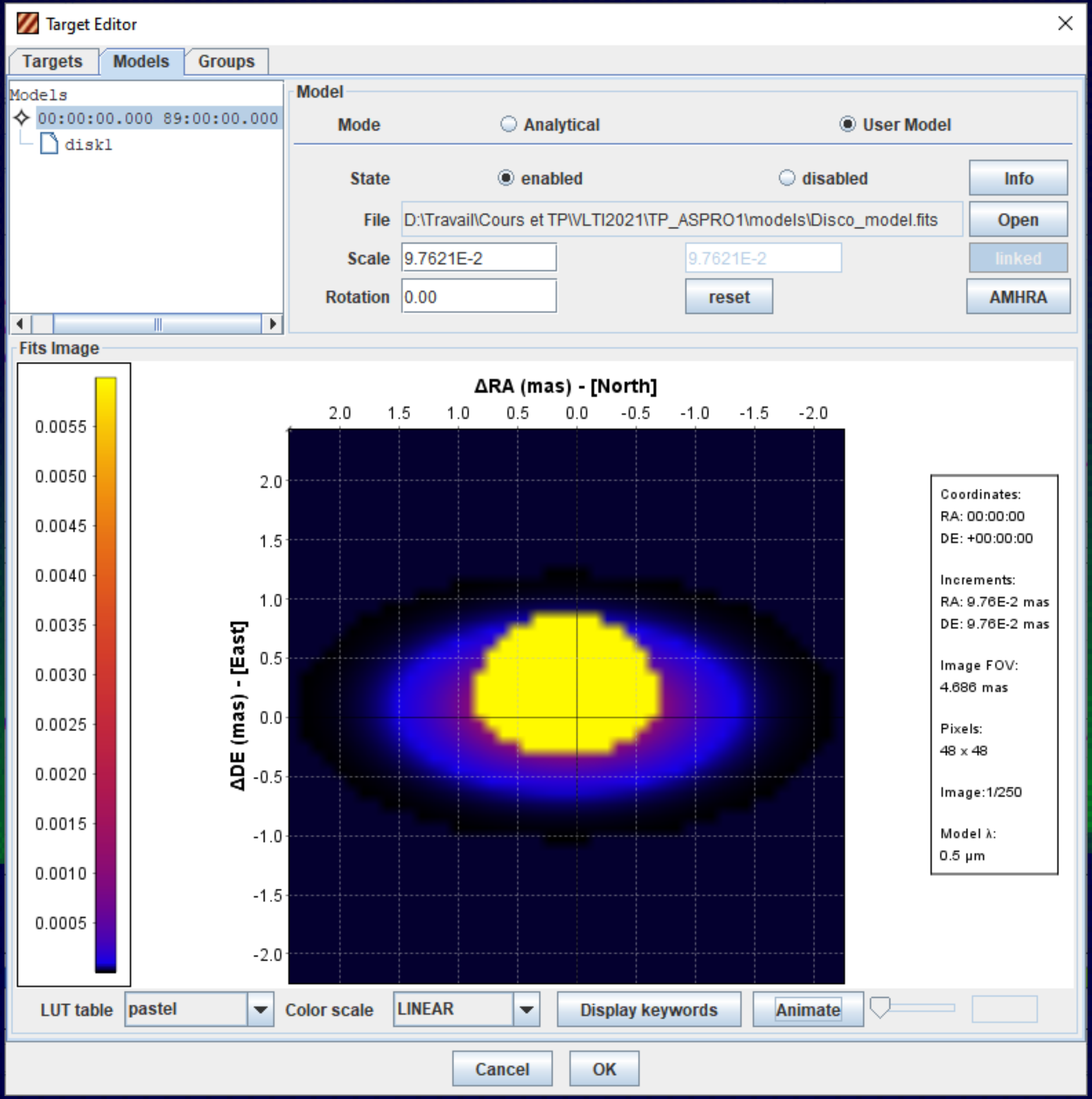


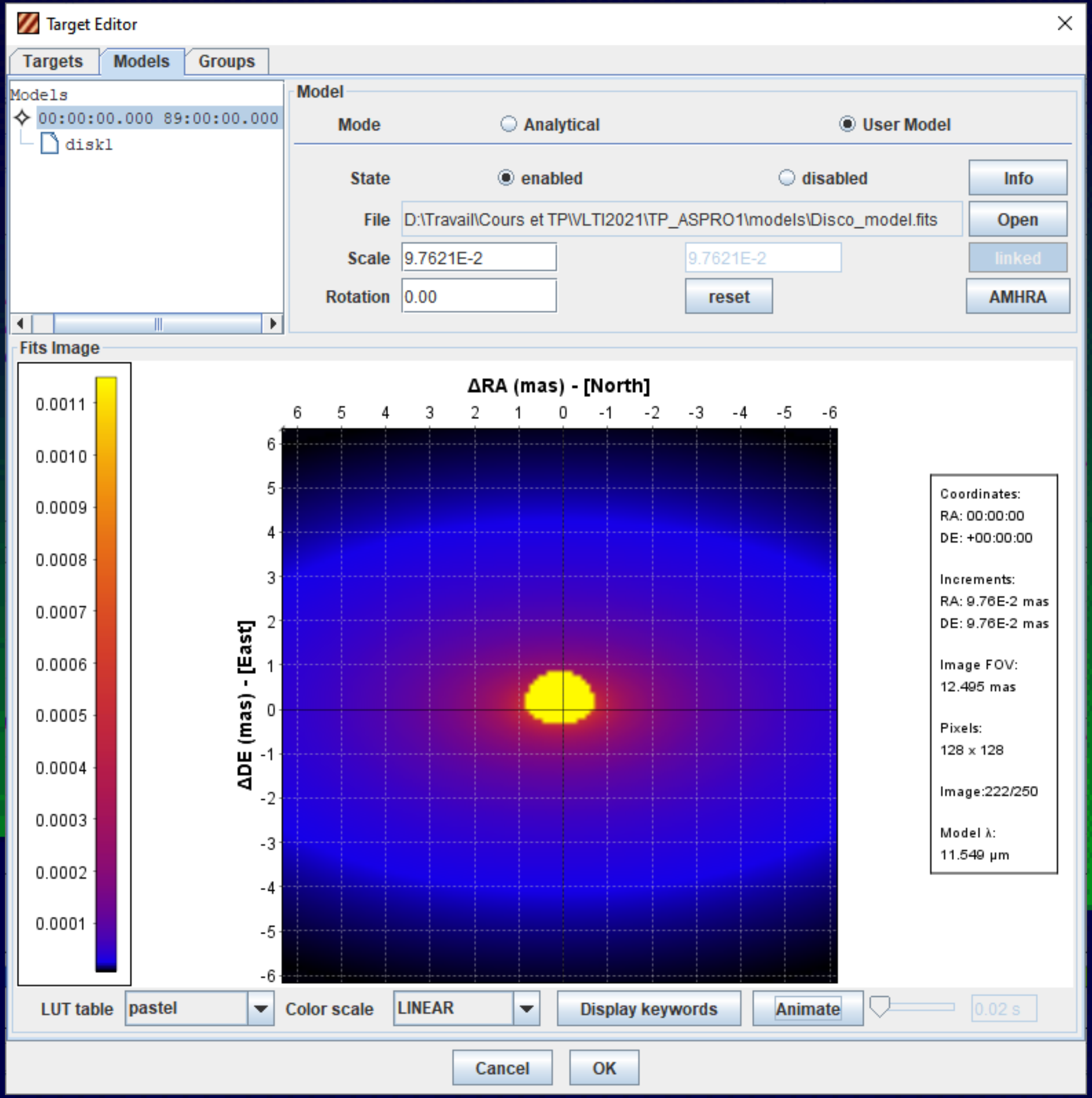


DISCO model taken from the AMHRA website https://amhra.oca.eu/AMHRA/disco-gas/input.htm

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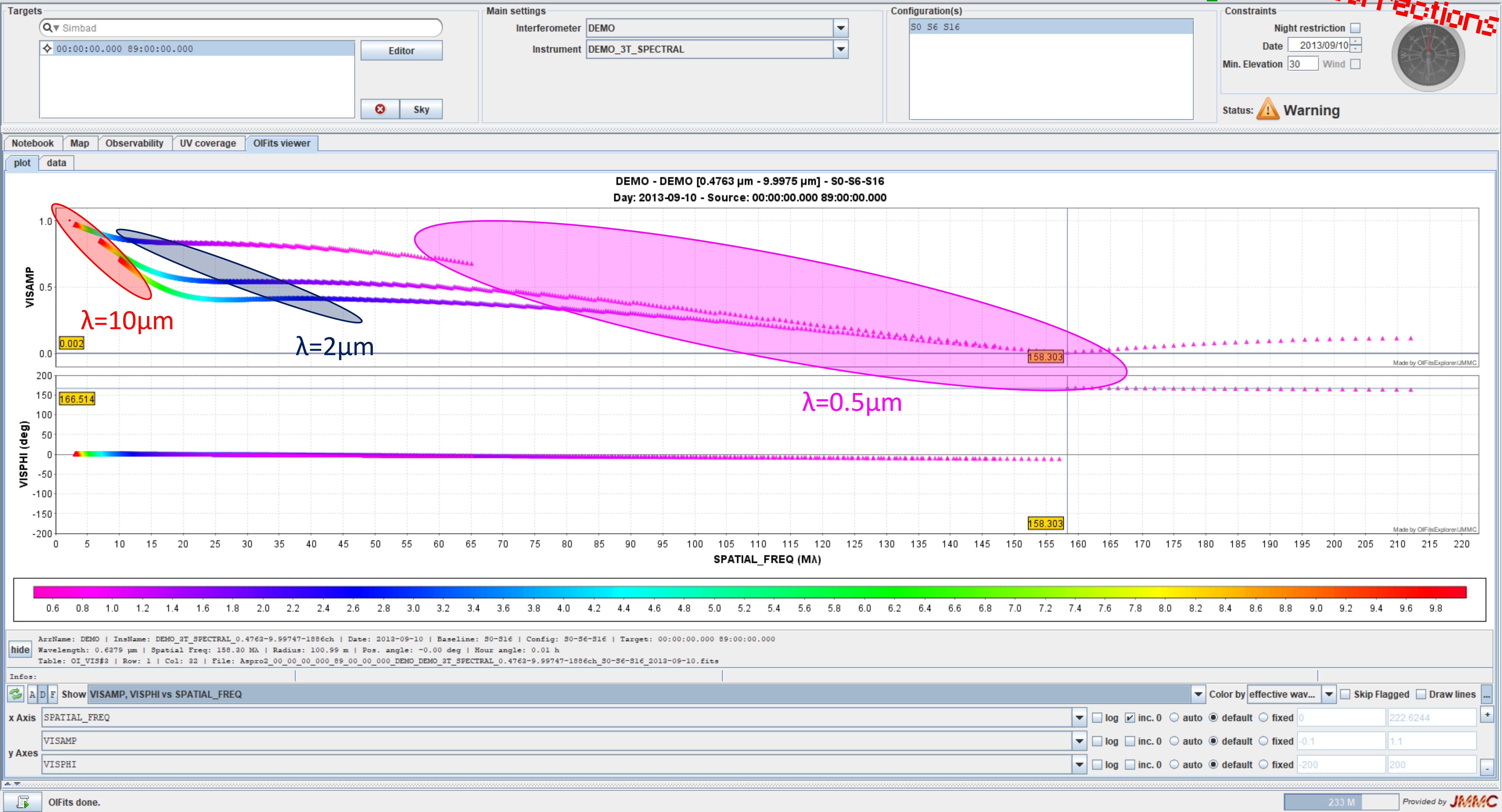

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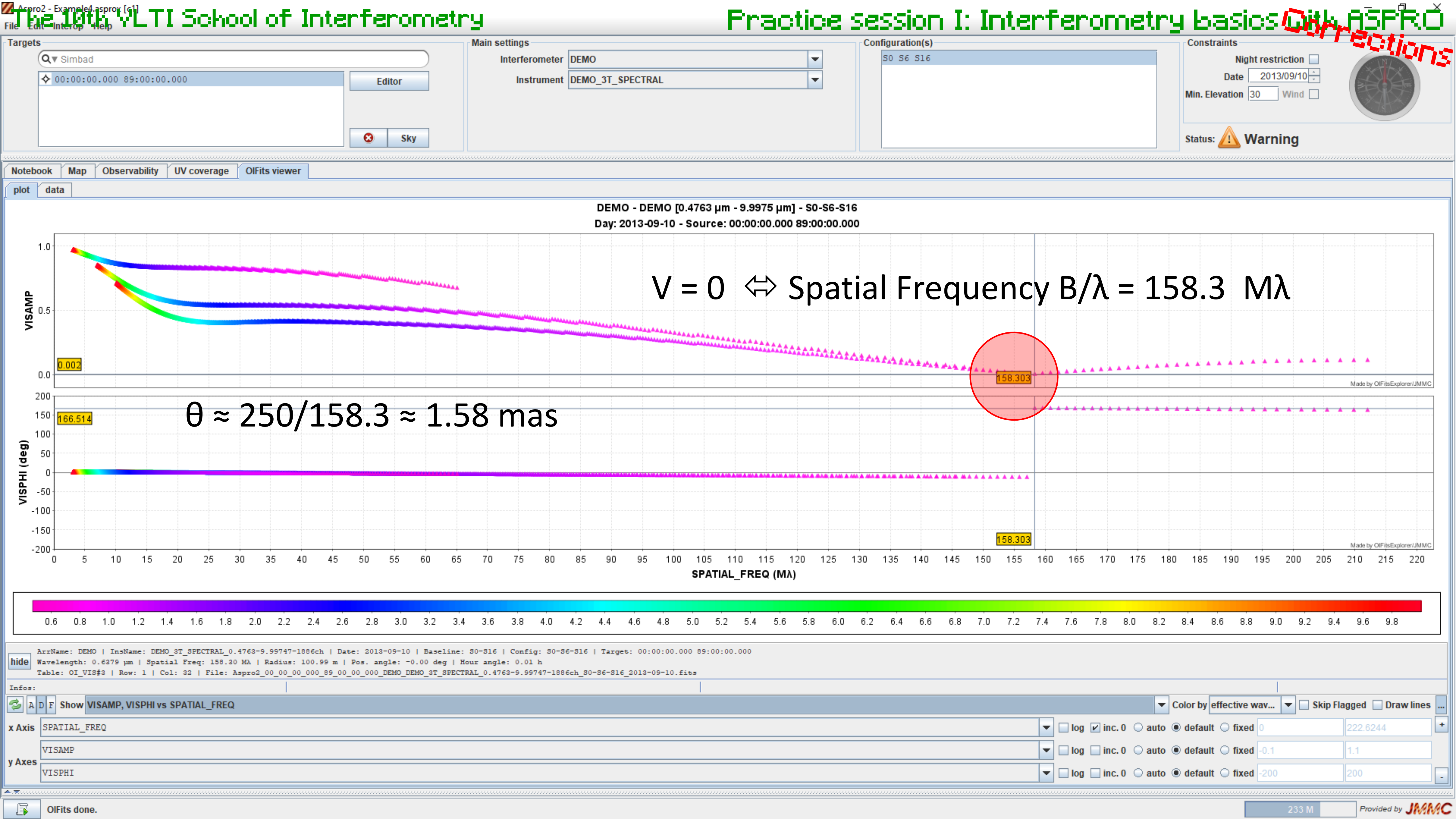
Aspro2 - Example4.asprox [c1]
File Edit Interop Help
Targets
Simbad
00:00:00.000 89:00:00.000
Editor
Sky
Main settings
Interferometer DEMO
Instrument DEMO_3T_SPECTRAL
Configuration(s)
S0 S6 S16
Constraints
Night restriction
Date 2013/09/10
Min. Elevation 30 Wind
Status: Warning
Notebook Map Observability UV coverage OIFits viewer
plot data
DEMO - DEMO [0.4763 µm - 9.9975 µm] - S0-S6-S16
Day: 2013-09-10 - Source: 00:00:00.000 89:00:00.000
V = 0 ⇔ Spatial Frequency B/λ = 158.3 Mλ
θ ≈ 250/158.3 ≈ 1.58 mas
VISAMP
VISPHI (deg)
0.002
158.303
166.514
SPATIAL_FREQ (MΛ)
Made by OIFitsExplorer/JMMC
ArrName: DEMO | InsName: DEMO_3T_SPECTRAL_0.4763-9.99747-1886ch | Date: 2013-09-10 | Baseline: S0-S16 | Config: S0-S6-S16 | Target: 00:00:00.000 89:00:00.000
Wavelength: 0.6379 µm | Spatial Freq: 158.30 MΛ | Radius: 100.99 m | Pos. angle: -0.00 deg | Hour angle: 0.01 h
Table: OI_VIS#3 | Row: 1 | Col: 32 | File: Aspro2_00_00_00_000_89_00_00_000_DEMO_DEMO_3T_SPECTRAL_0.4763-9.99747-1886ch_S0-S6-S16_2013-09-10.fits
hide
Infos:
Show VISAMP, VISPHI vs SPATIAL_FREQ
Color by effective wav...
Skip Flagged
Draw lines
x Axis SPATIAL_FREQ
y Axes VISAMP
VISPHI
log inc. 0 auto default fixed
OIFits done.
233 M
Provided by JMMC

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1'' = 1au at 1 pc.
1au ≈ 107 Dsol
Rstar ≈ 0.107 x distance (in pc) x θ (in mas)
Rstar ≈ 10 Rsol

# 7 Bonus

## 6.3 Bonus : play with the models from the AMHRA service

You can go to the AMHRA service web page, download models and load them on ASPRO2. Currently, AMHRA gives access to the following models:

- **Kinematic Be Disk** : Model of the geometry (size and shape) and kinematics (rotation and expansion) of circumstellar disks, especially of Be stars observed at high spectral resolution (R>1000). It is not adapted to our DEMO interferometer that does not have a high spectral resolution mode. But you might test it with GRAVITY (in Brγ line) or MATISSE (in Brα line)
- **Disk and stellar Continuum DISCO** : we already used it, but you might want to compute model with different paramters.
- **Evolved stars (Red Supergiants and AGBs)**: Stellar surface maps of evolved stars computed from 3D hydrodynamical simulation with CO5BOLD-OPTIM3D
- **Binary spiral model** : Phenomenological model mimicking the shock caused by the collision between the winds from massive stars (e.g. the WR and OB stars)
- **Supergiant B[e] stars with HDUST** : Grid of models for B[e] supergiants, i.e. hot stars surrounded by gaseous and dusty circusmtellar disk.
- **Limb-darkening with SAtlas** : Grid of models providing realistic intensity maps for spherically symmetric stars, showing the limb darkening effect.