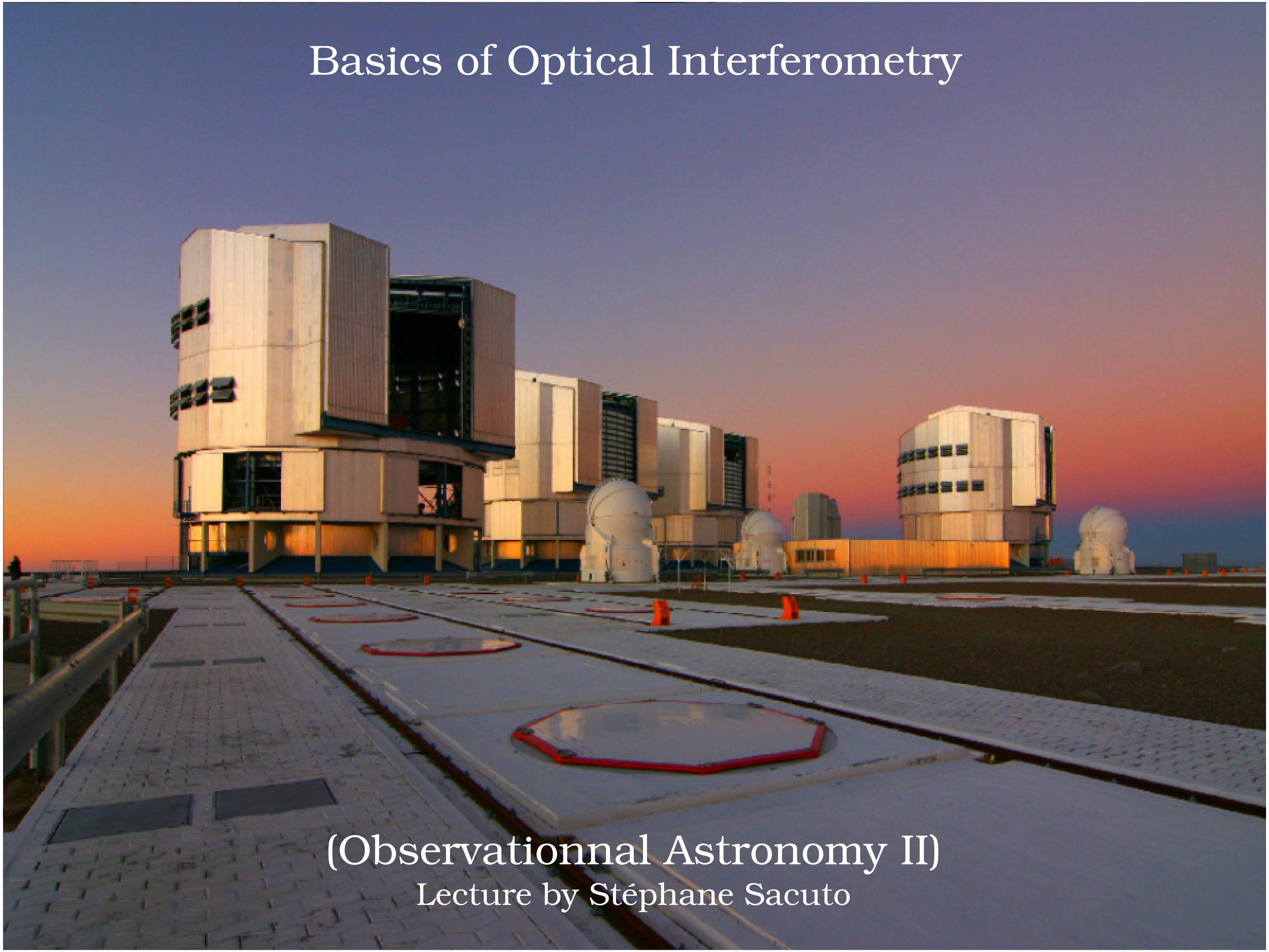
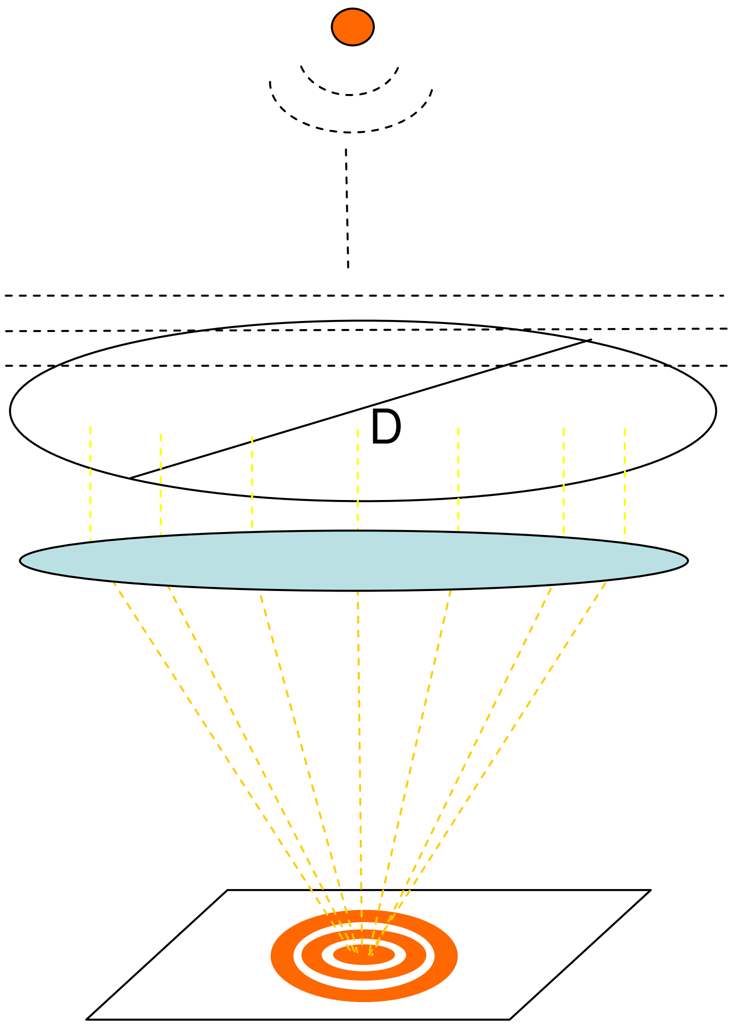
Basics of Optical Interferometry



(Observationnal Astronomy II)

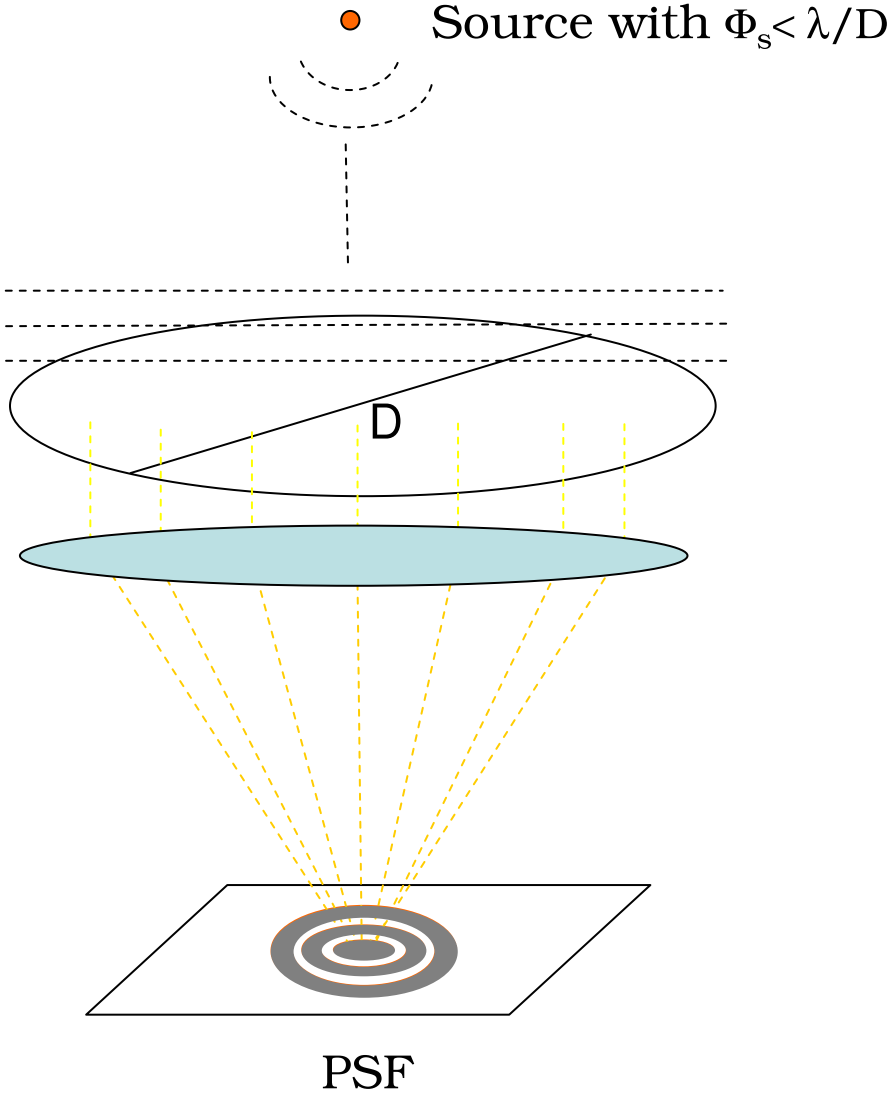
Lecture by Stéphane Sacuto

Power of Resolution and need for High Angular Resolution



$PSF \otimes I_{Obj}$

Power of Resolution and need for High Angular Resolution



The information on your object is lost.
You NEED more spatial resolution from your instrument.

Required monolithic telescope diameters

Objects	Wavelength (µm)	Angular size (mas)	Telescope diameter (m)
Circumstellar envelope around o Ceti (M star)	11	50	45
Volcanoes of Io (Jupiter satellite)	5	10	100
Nucleus of NGC 1068 (AGN)	2.2	< 1	> 400
Spots on the photosphere of a Cen (Solar type)	0.5	0.07	1500

Those structures are not resolved with monolithic telescopes
even with the ELT

We need something else

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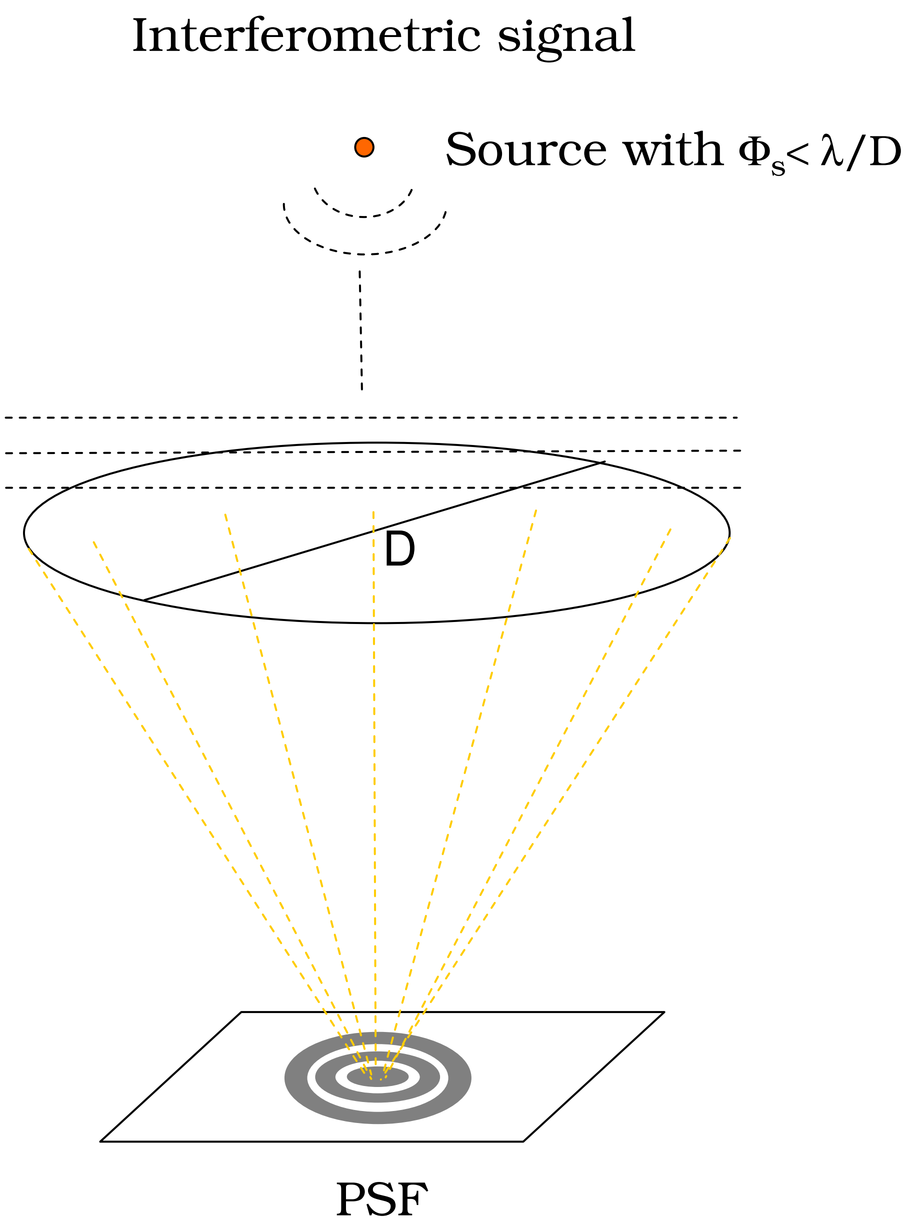
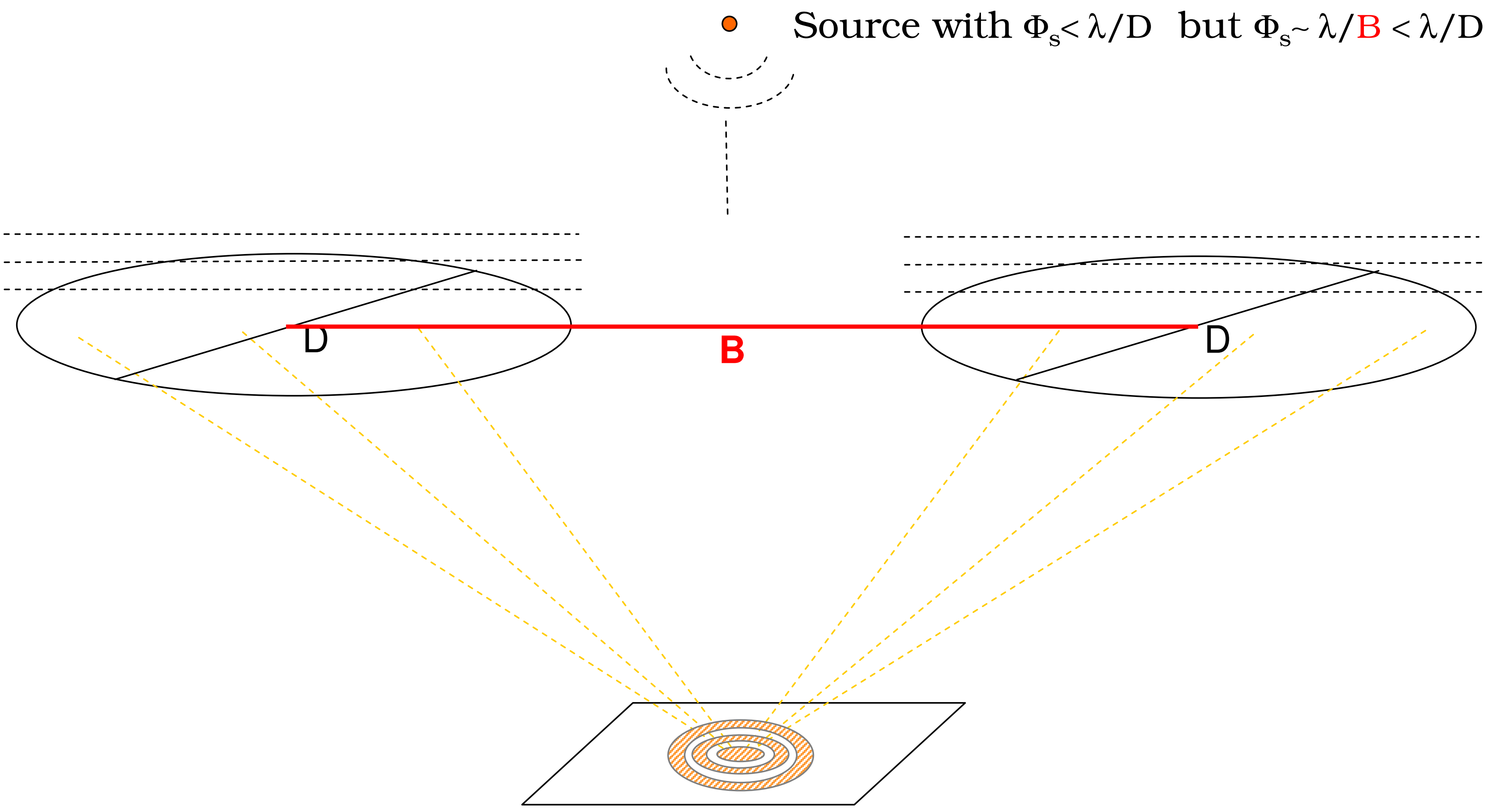
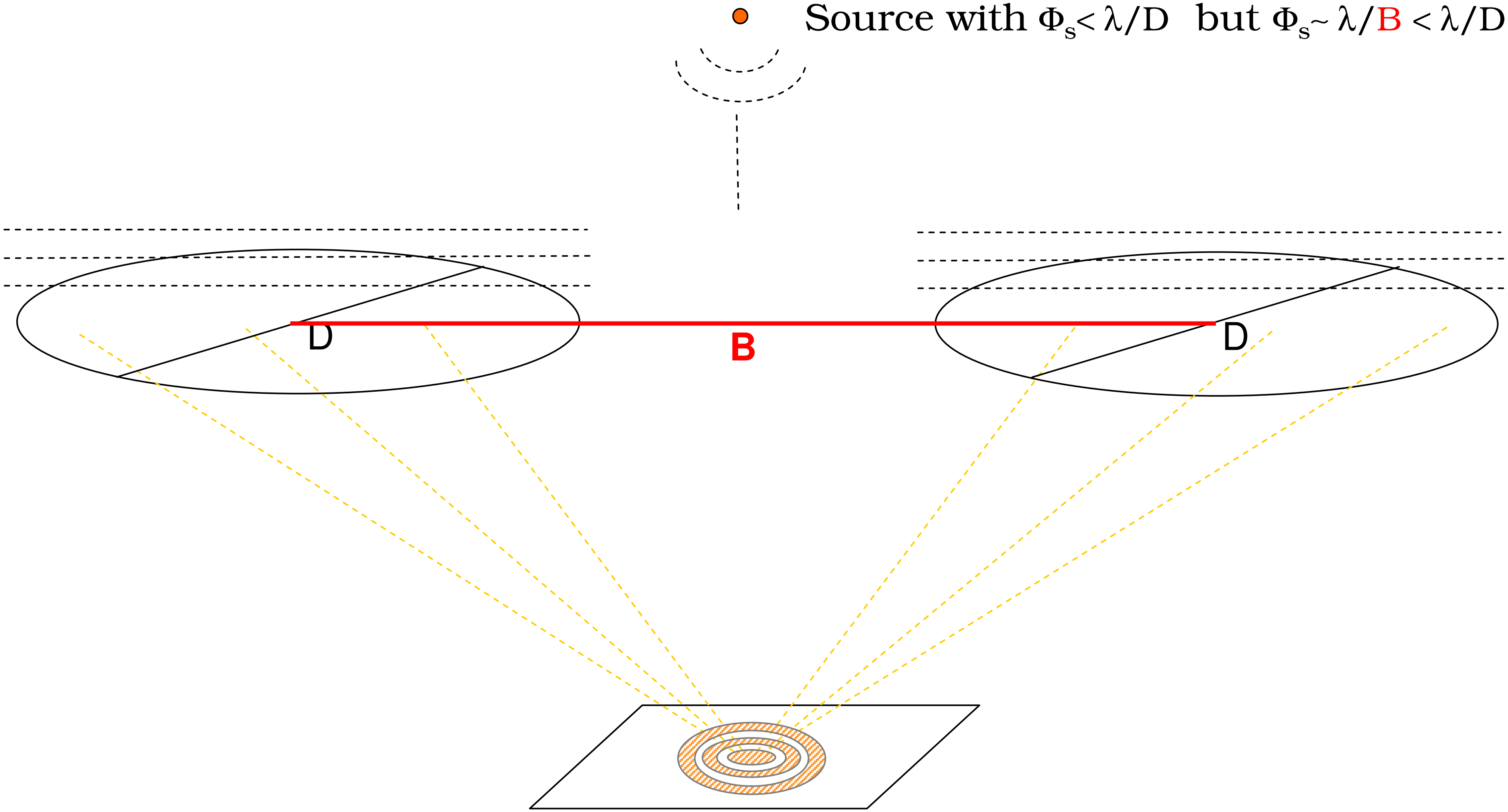
INTERFEROMETRY


Interferometric signal
Source with $\Phi_s < \lambda/D$
D
PSF

Interferometric signal

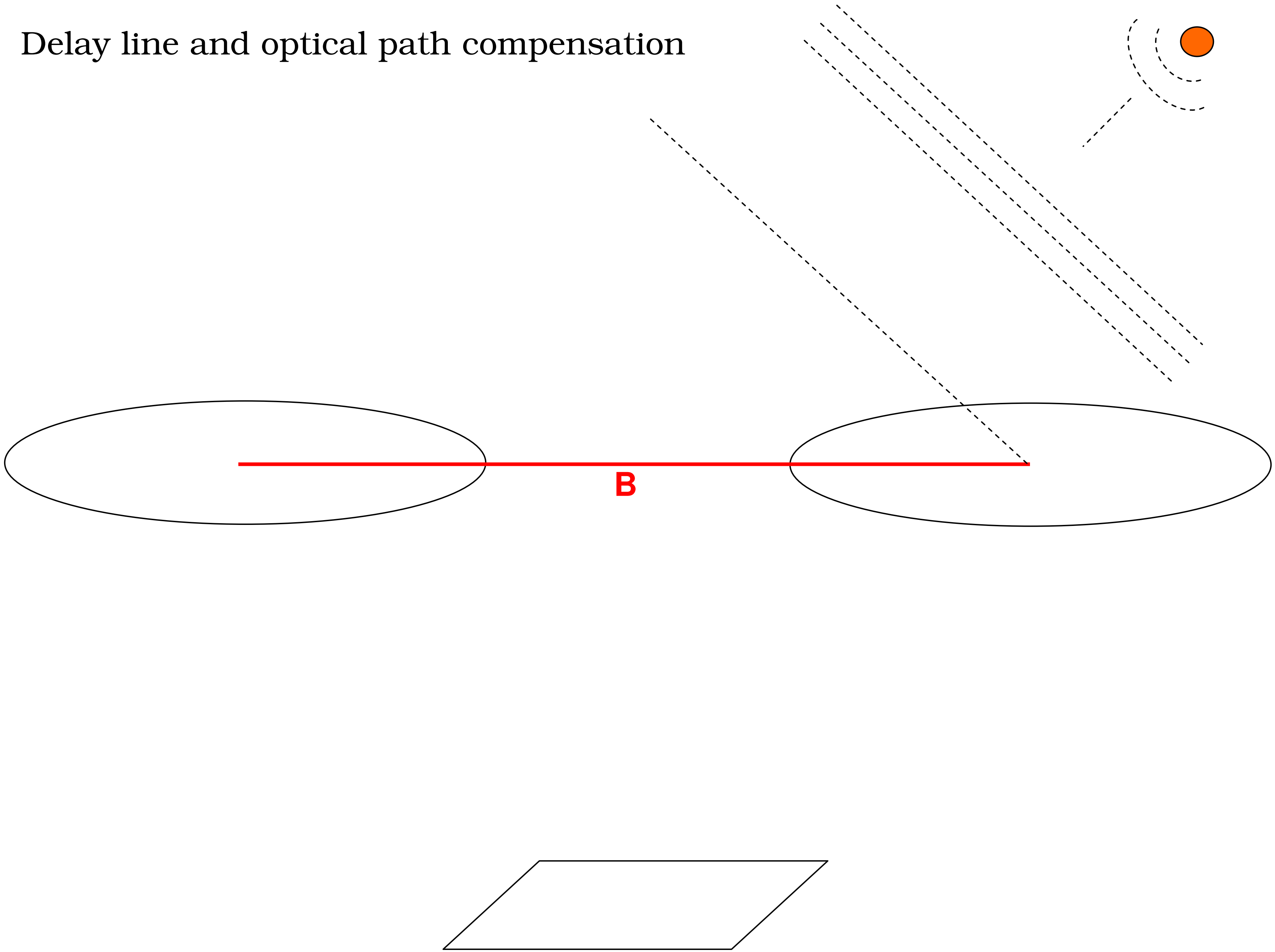


Interferometric signal



The signal of the source is found again but under the appearance of fringes

Delay line and optical path compensation



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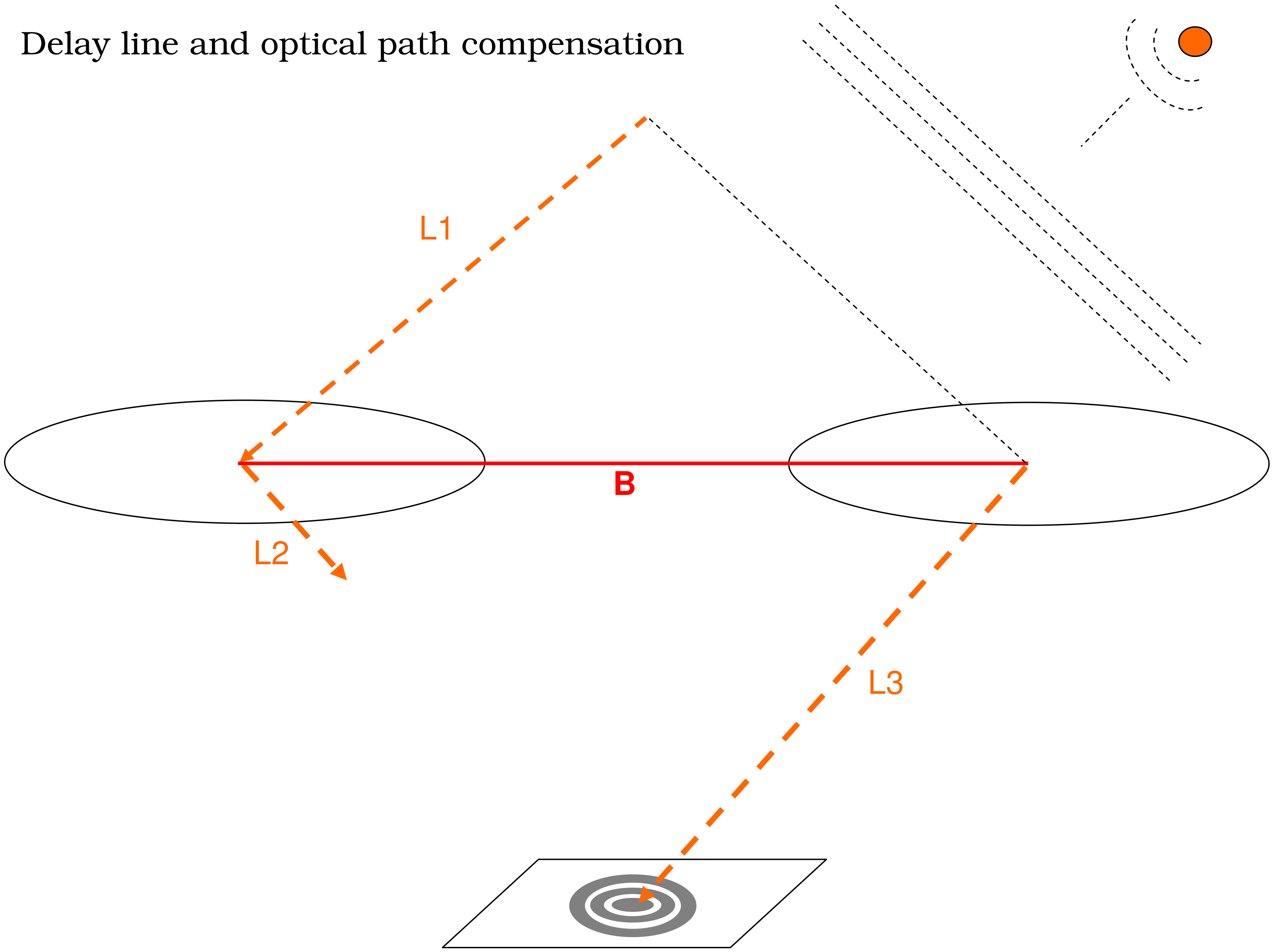

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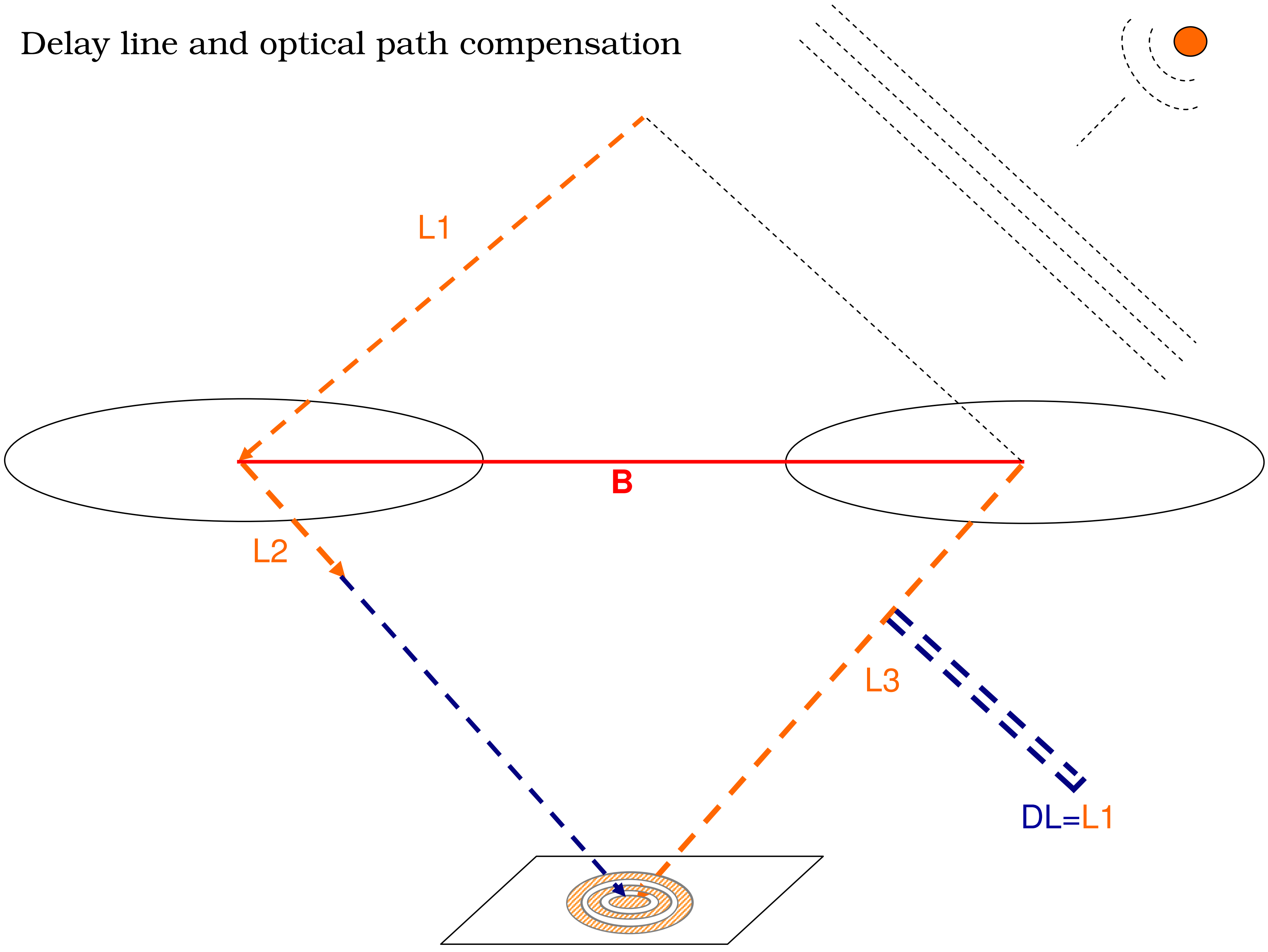

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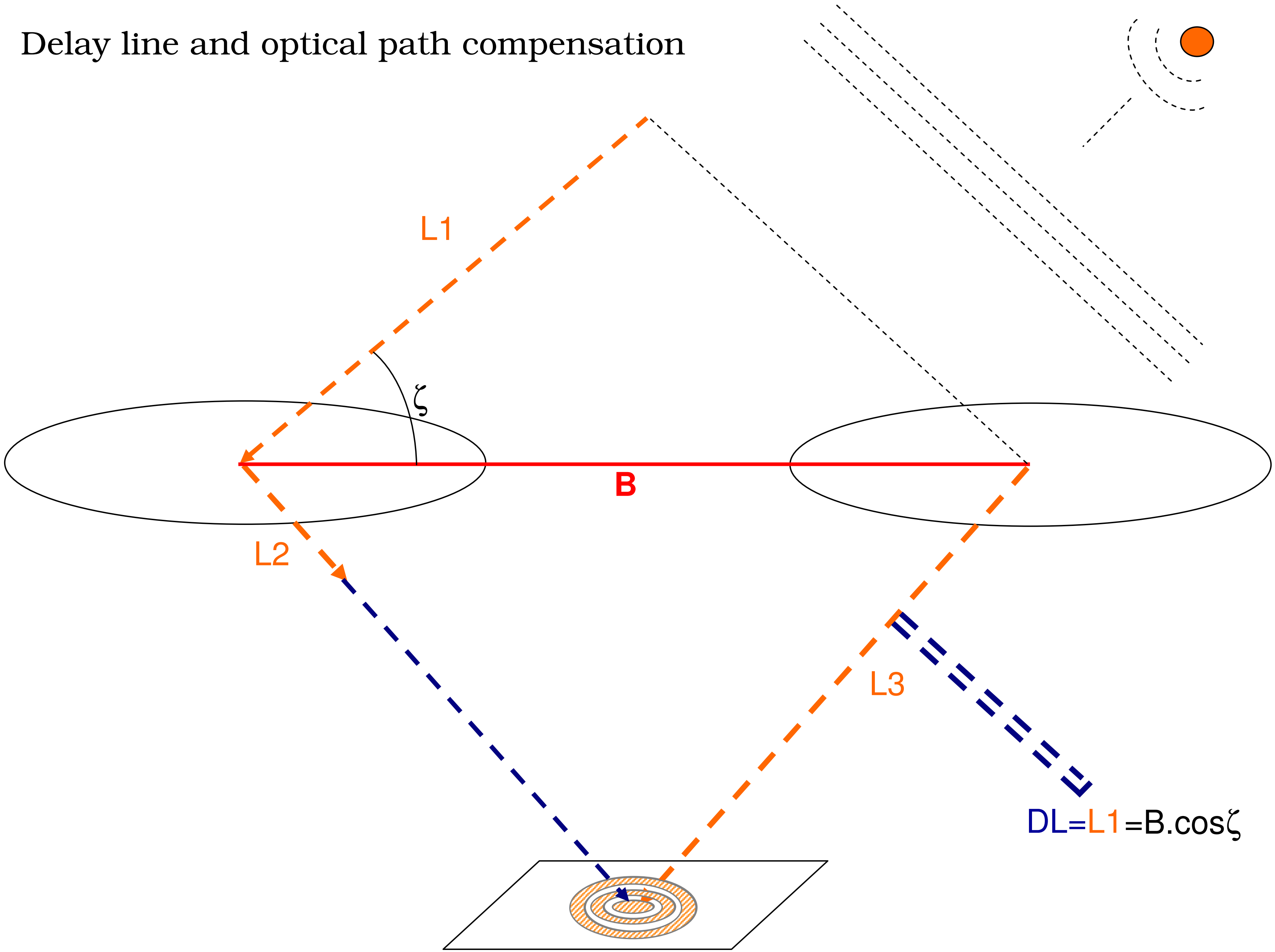

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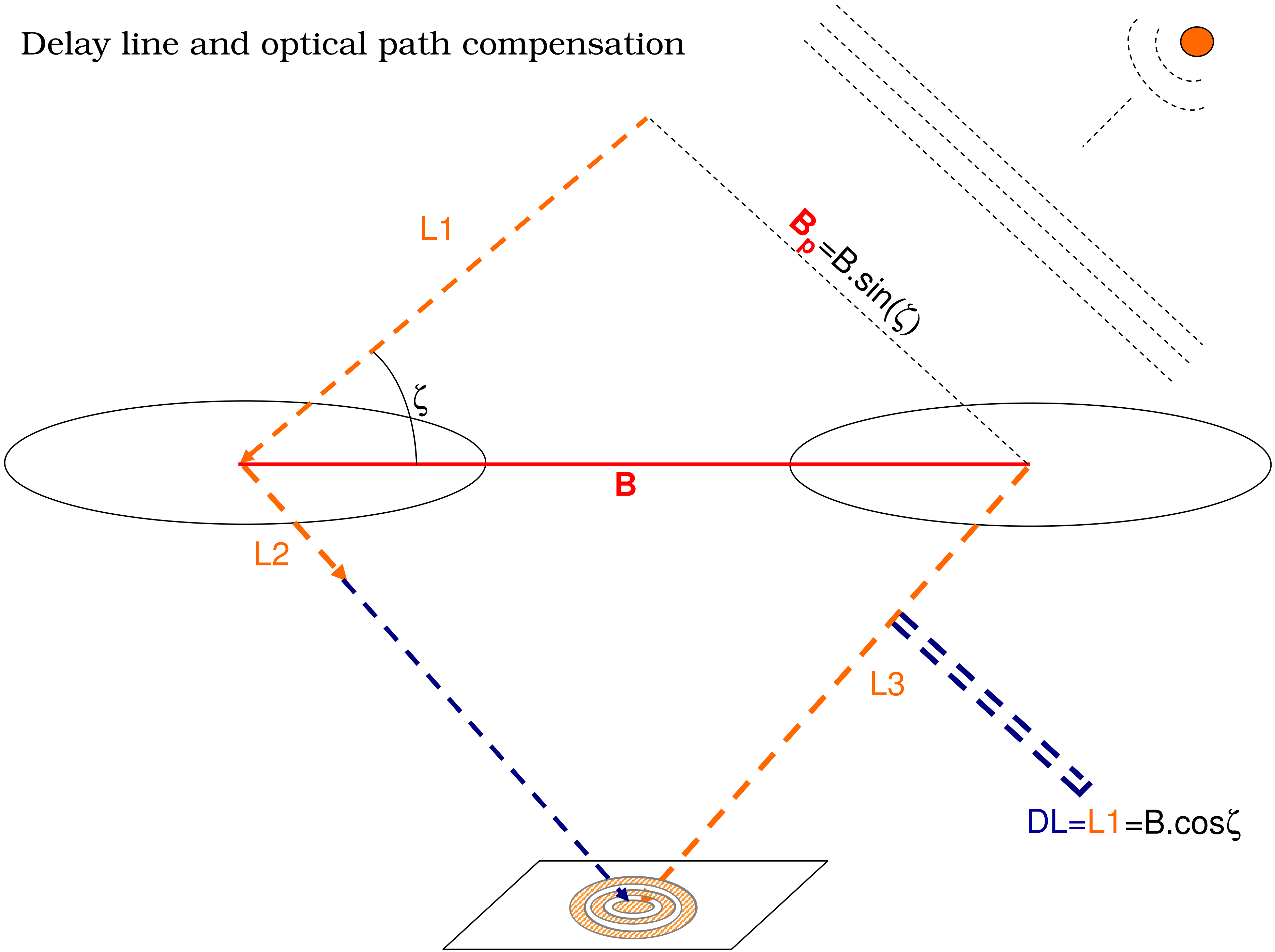
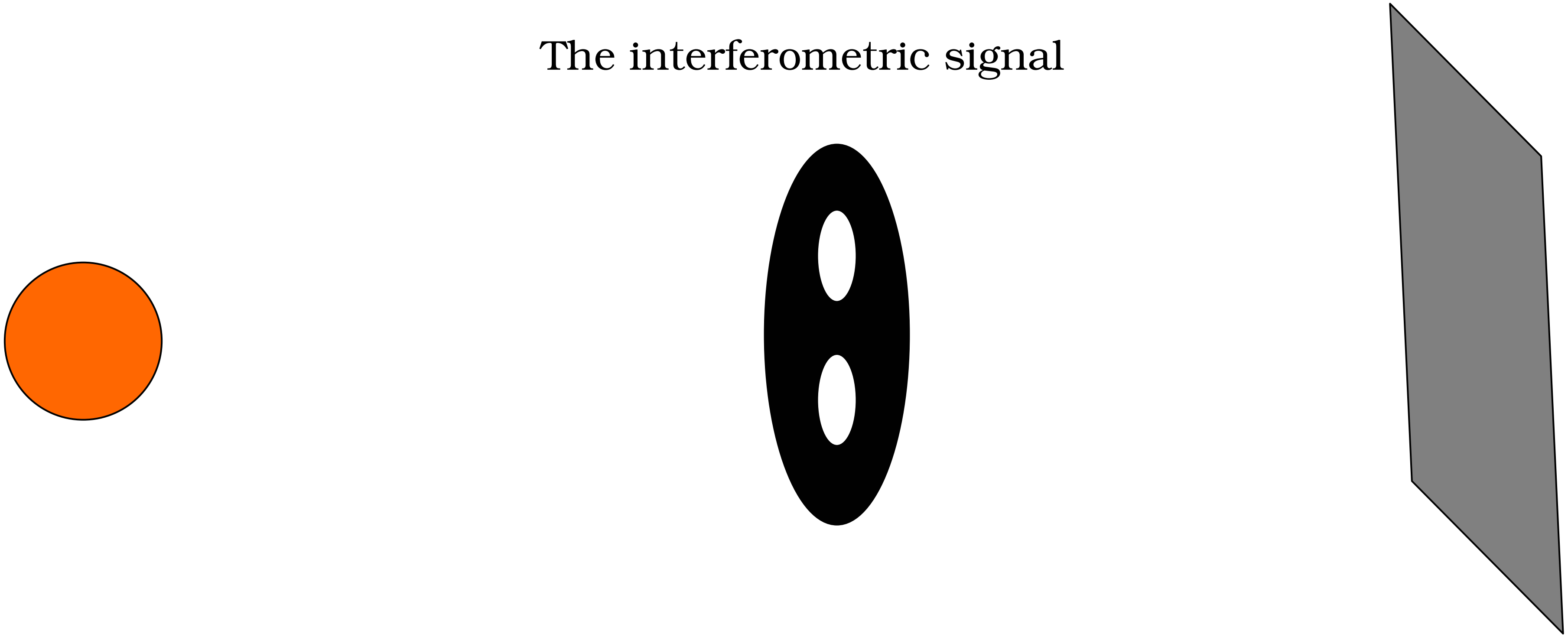


The interferometric signal



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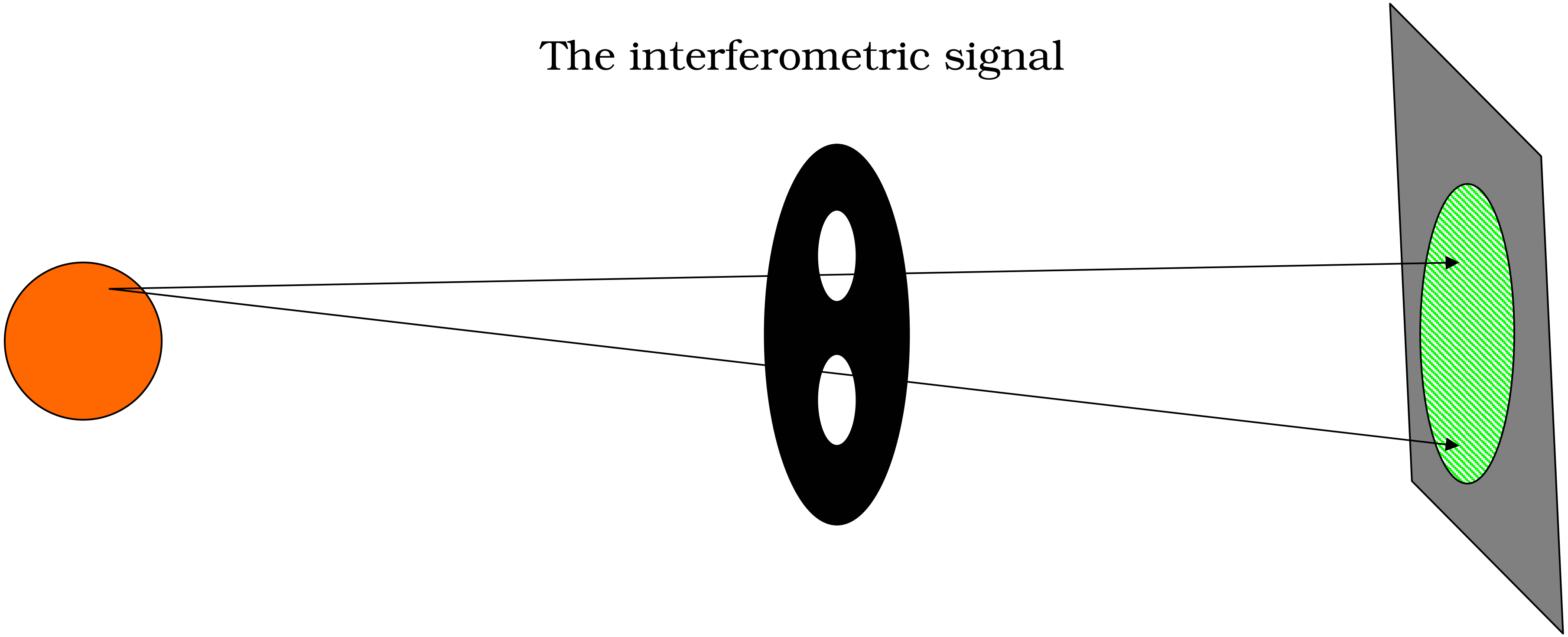

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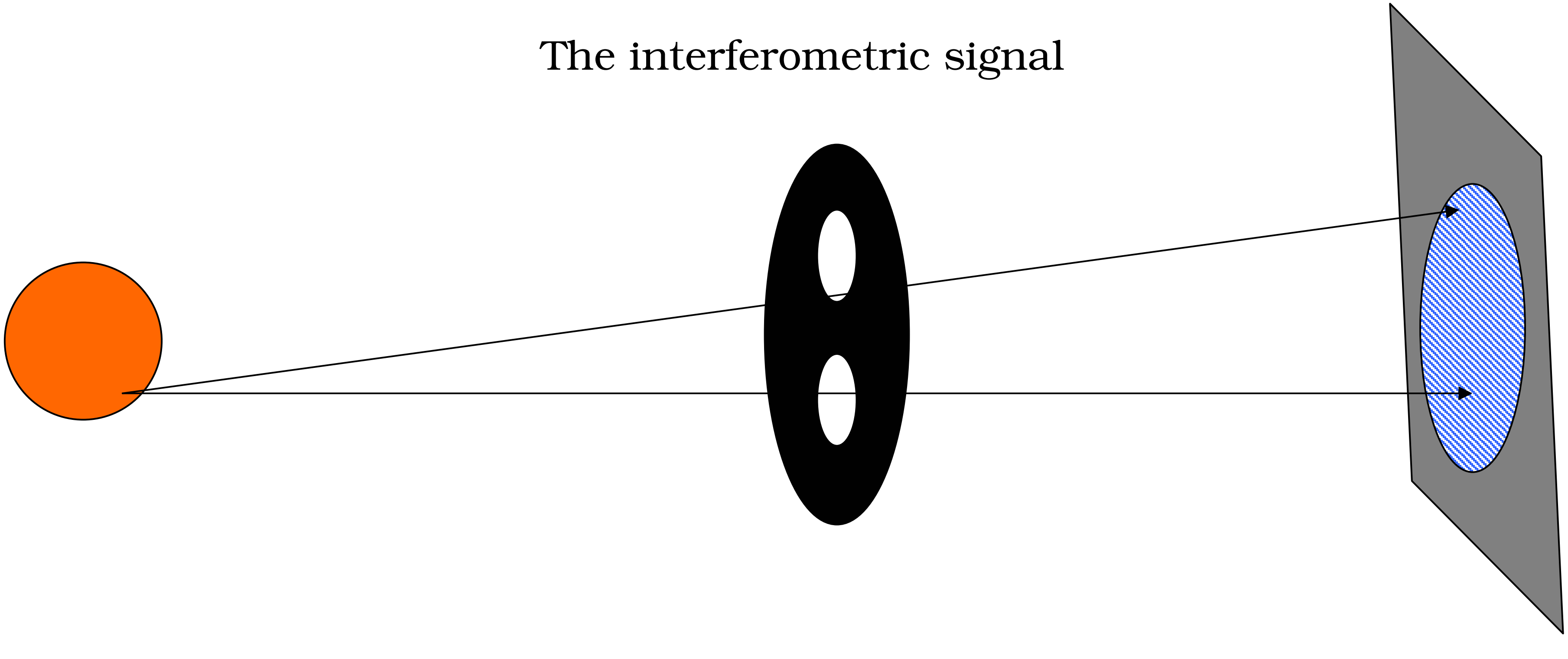

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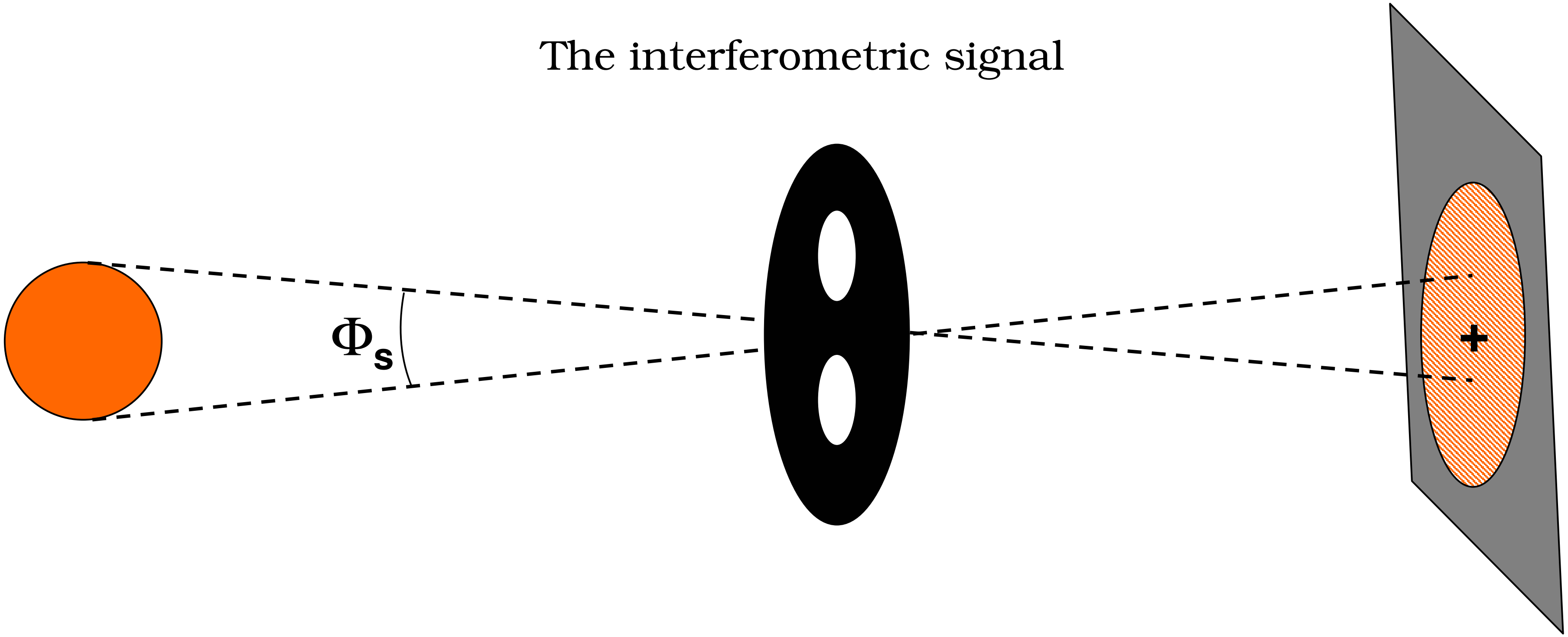

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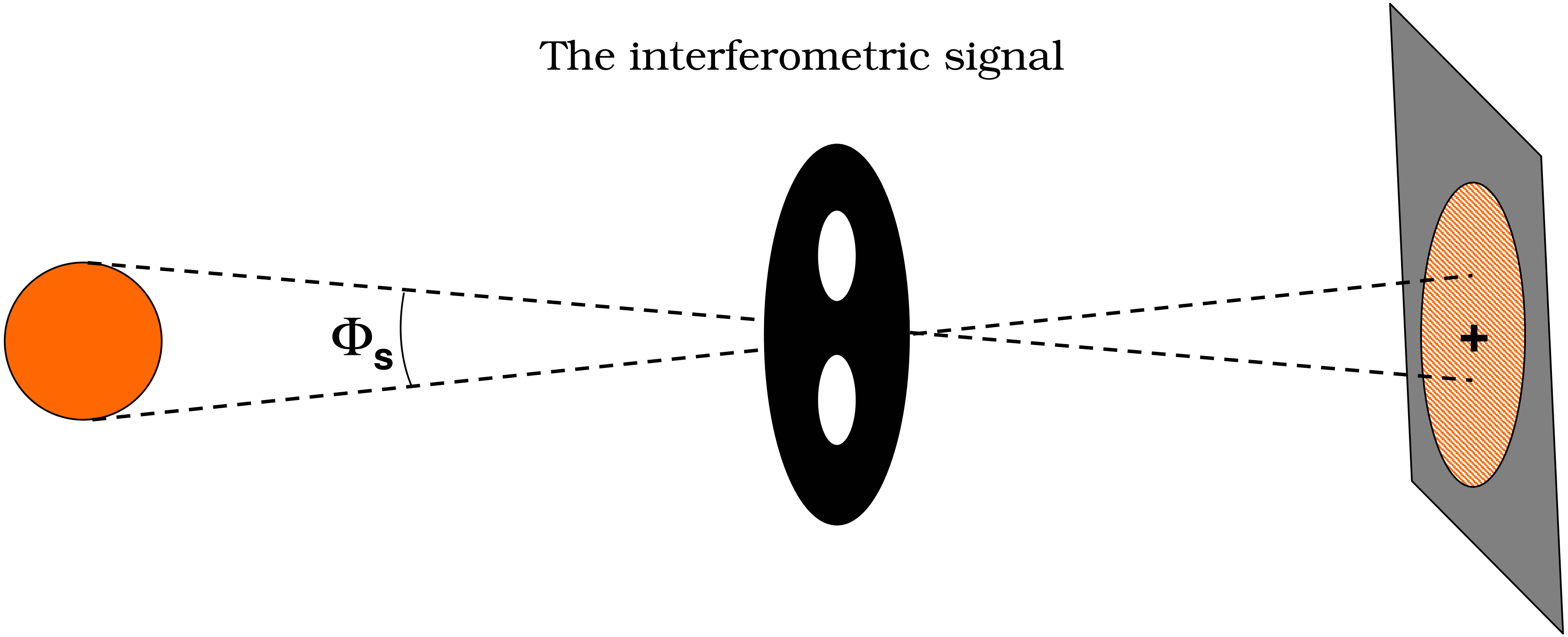
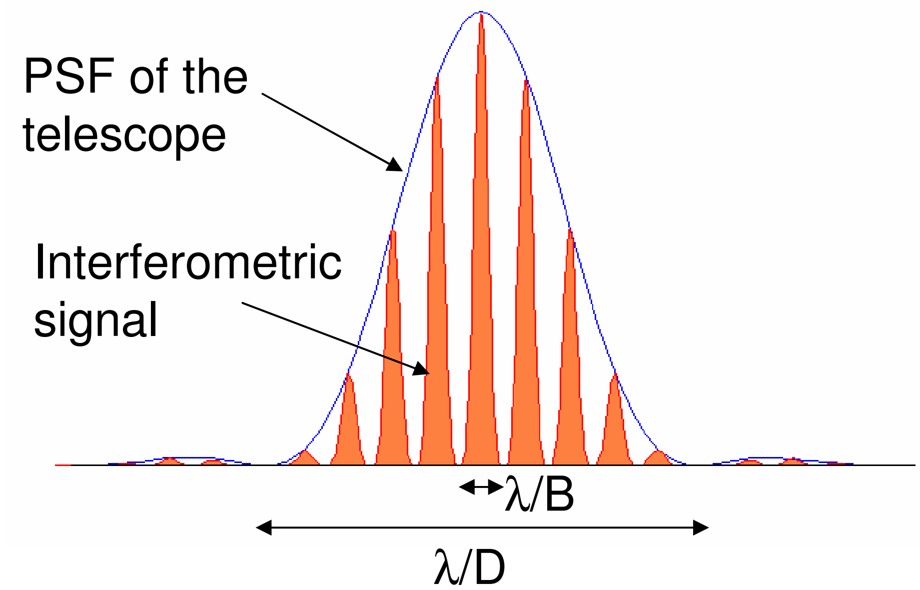


An Interferometer is measuring the contrast of the total fringe pattern :

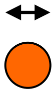
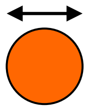
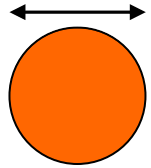


Fringe contrast is given by :

$$\boxed{V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}}$$

The fringe contrast (part I)

- For a given baseline length B and for different sizes of the source Φ_s

Small source ($\Phi_s << \lambda/B$)	Mid source ($\Phi_s \sim \lambda/B$)	Large source ($\Phi_s \sim \lambda/D$)
		

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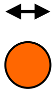	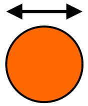	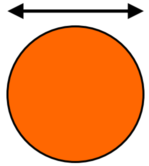
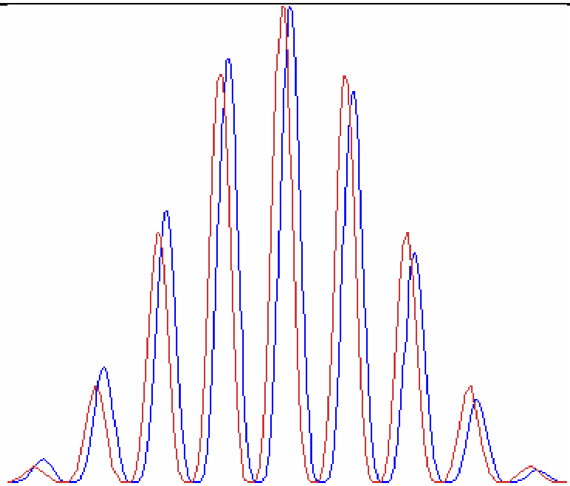	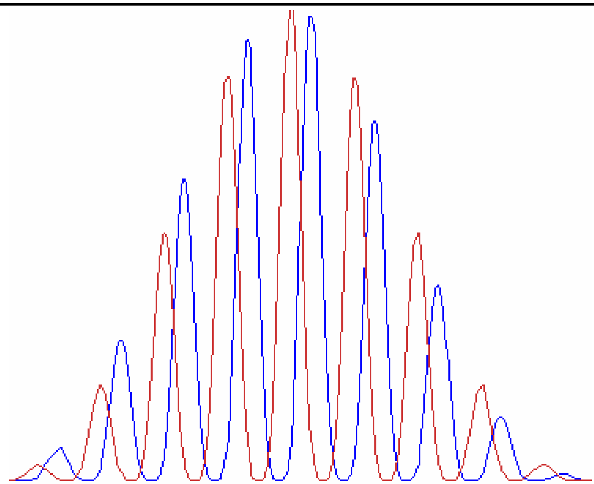	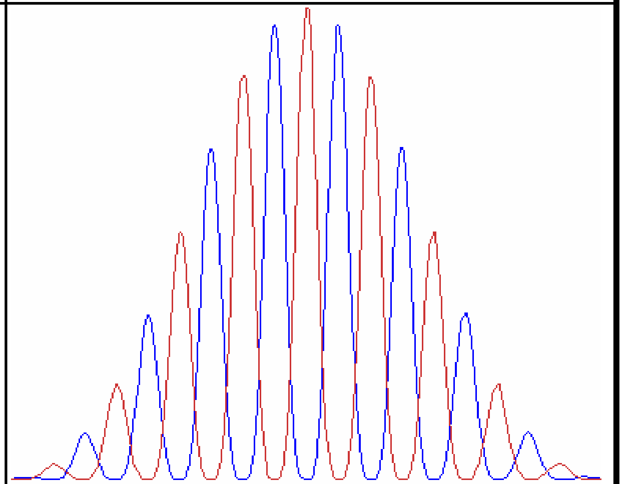

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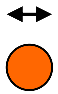
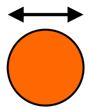
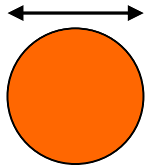
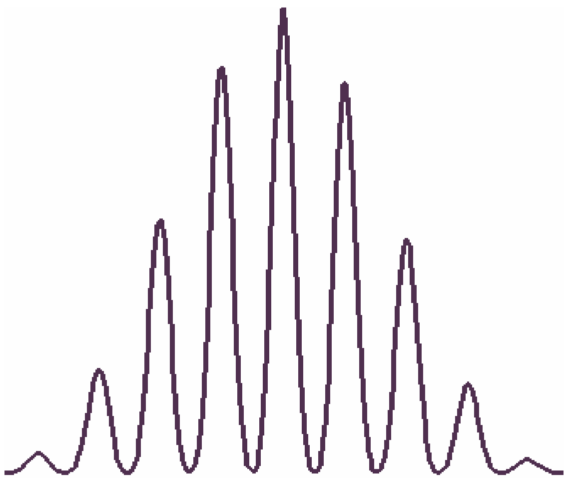
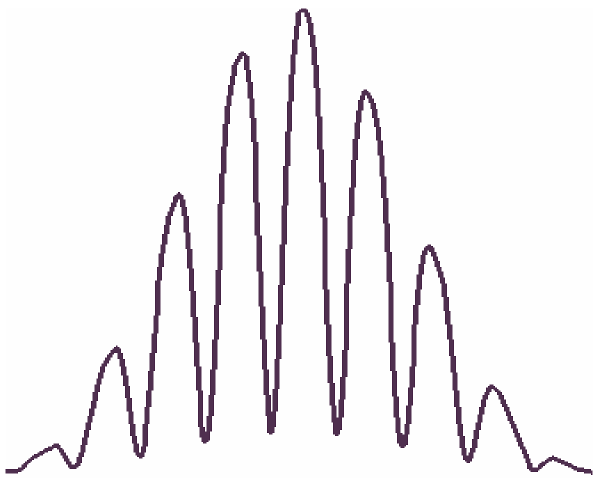
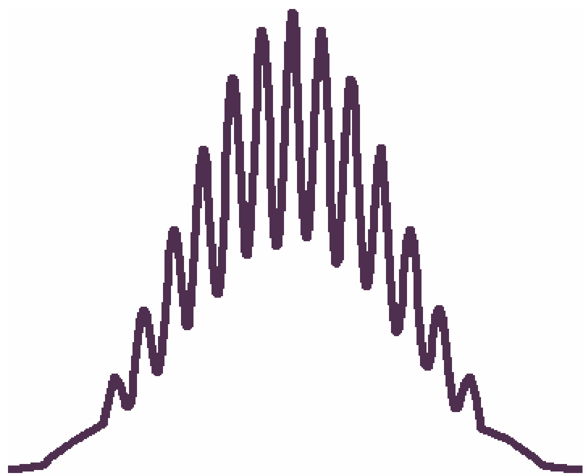
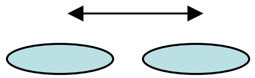
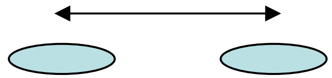
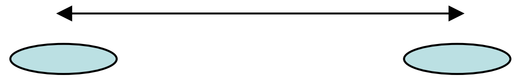
		
		
High contrast	Mid contrast	Low contrast
V~1	**V~0.6**	**V~0.2**

The fringe contrast (part II)

- For a given dimension of the source Φ_s and for different baseline lengths B

Small base ($B << \lambda/\Phi_s$)	Mid base ($B \sim \lambda/\Phi_s$)	Large base ($B >> \lambda/\Phi_s$)
		

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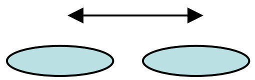	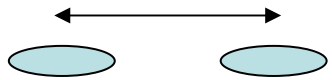	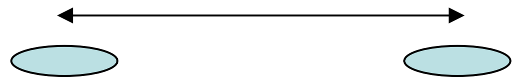
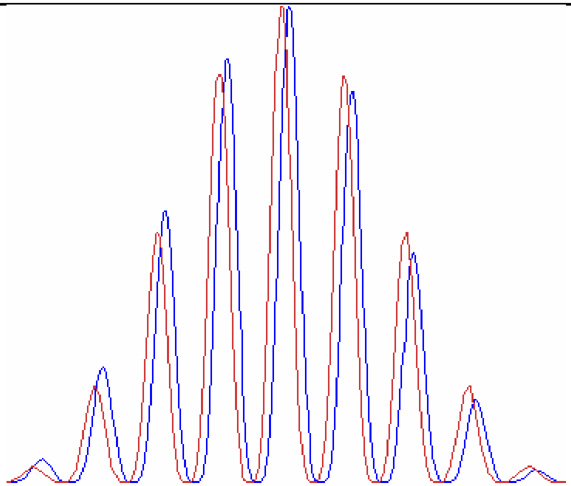	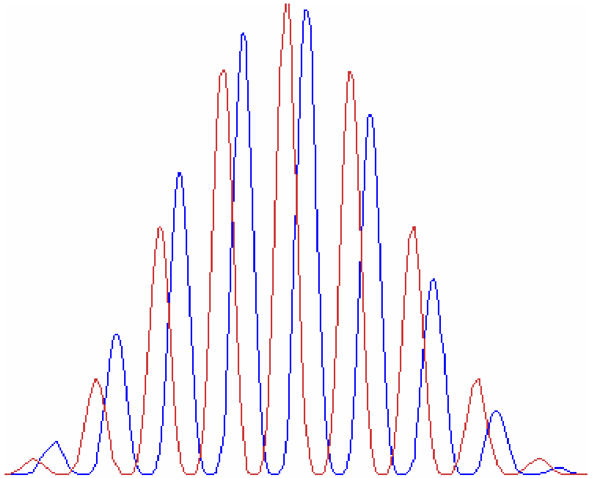	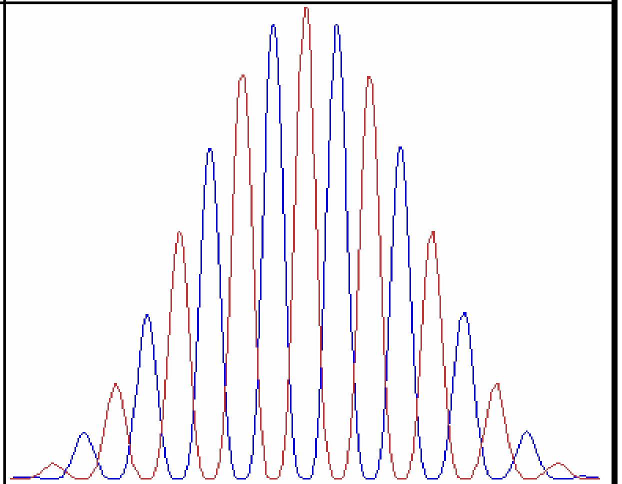

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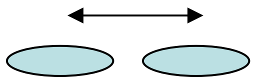	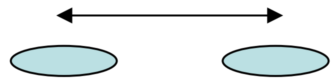	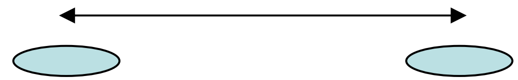
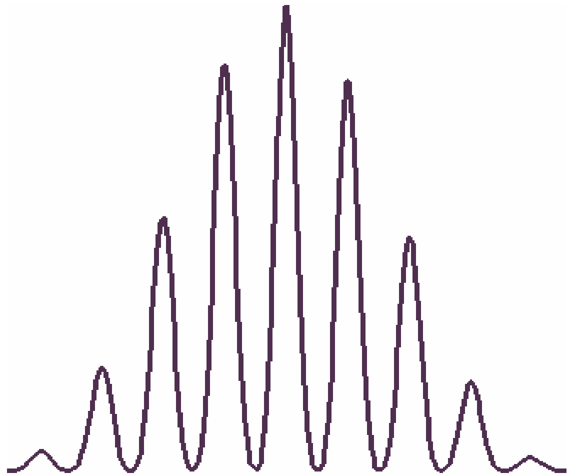	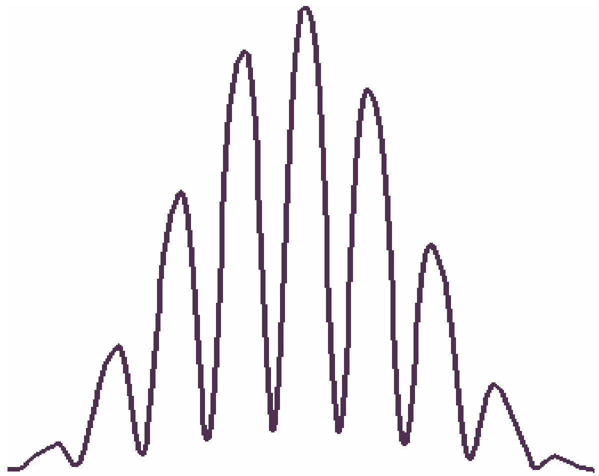	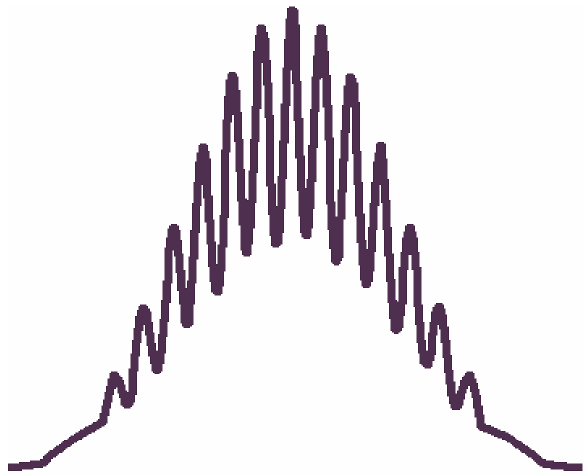
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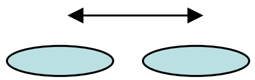	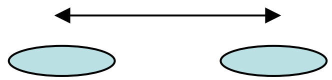	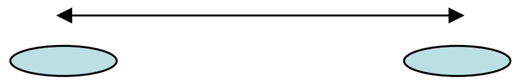
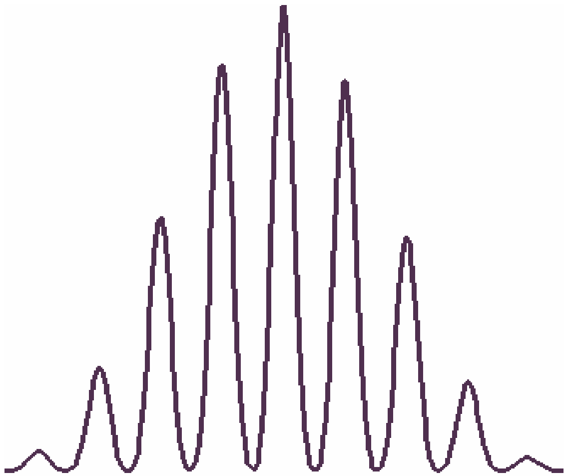	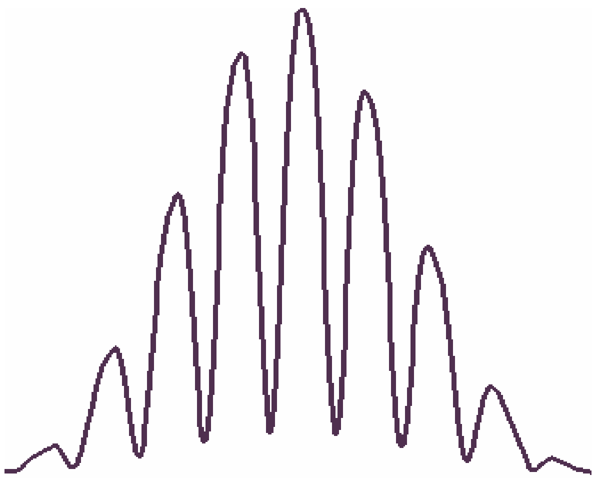	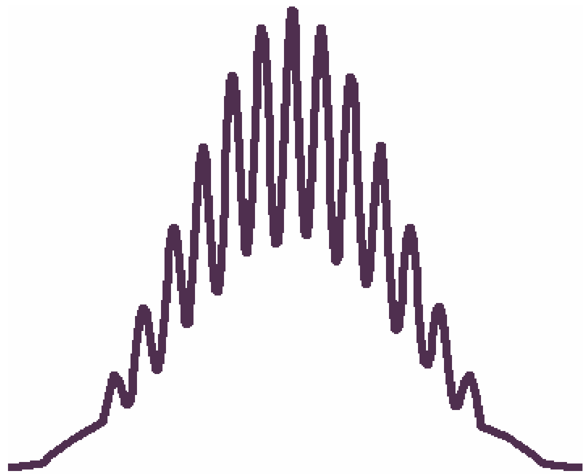
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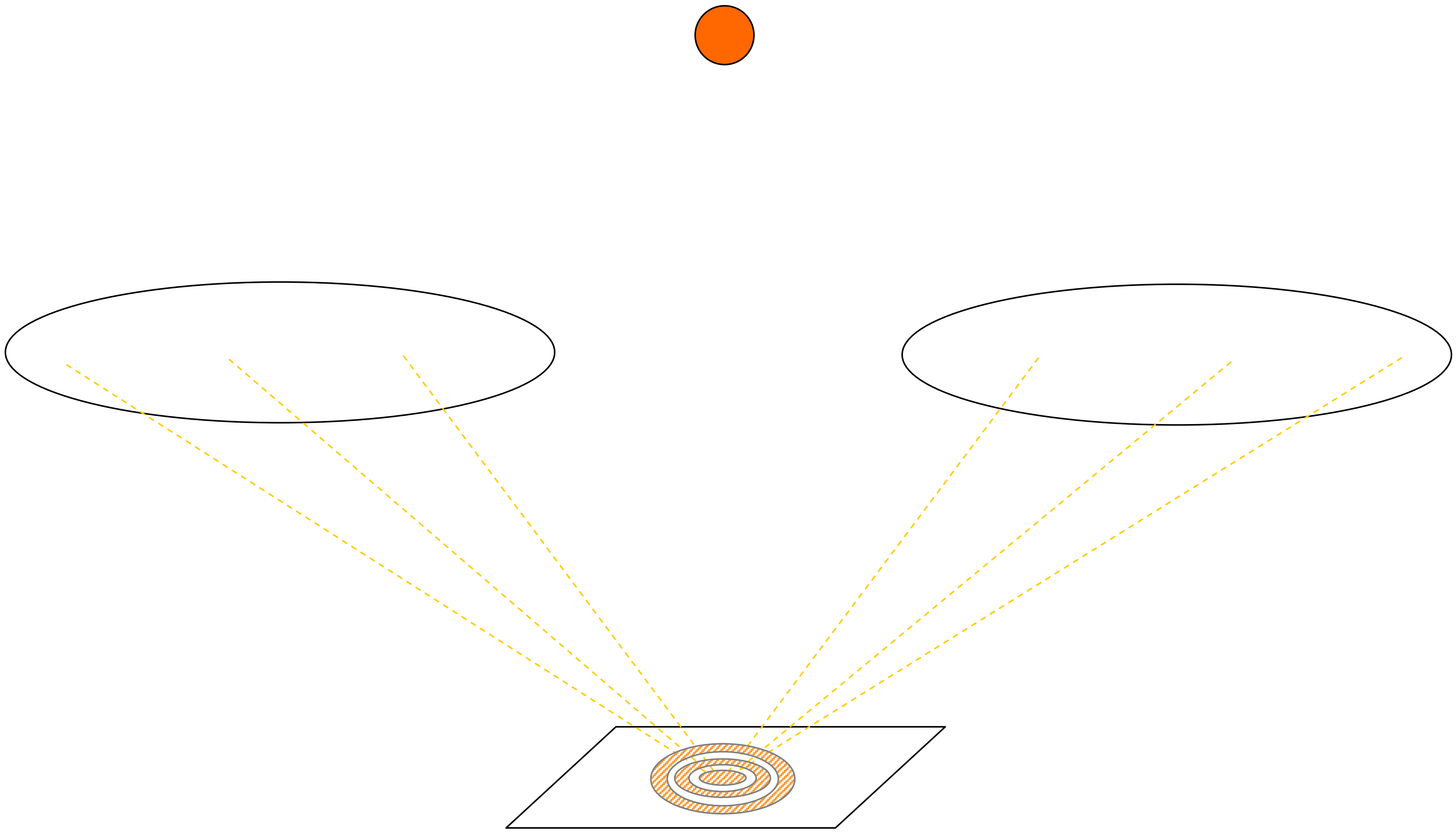
Object-Contrast Relation
The Van Cittert and Zernike theorem



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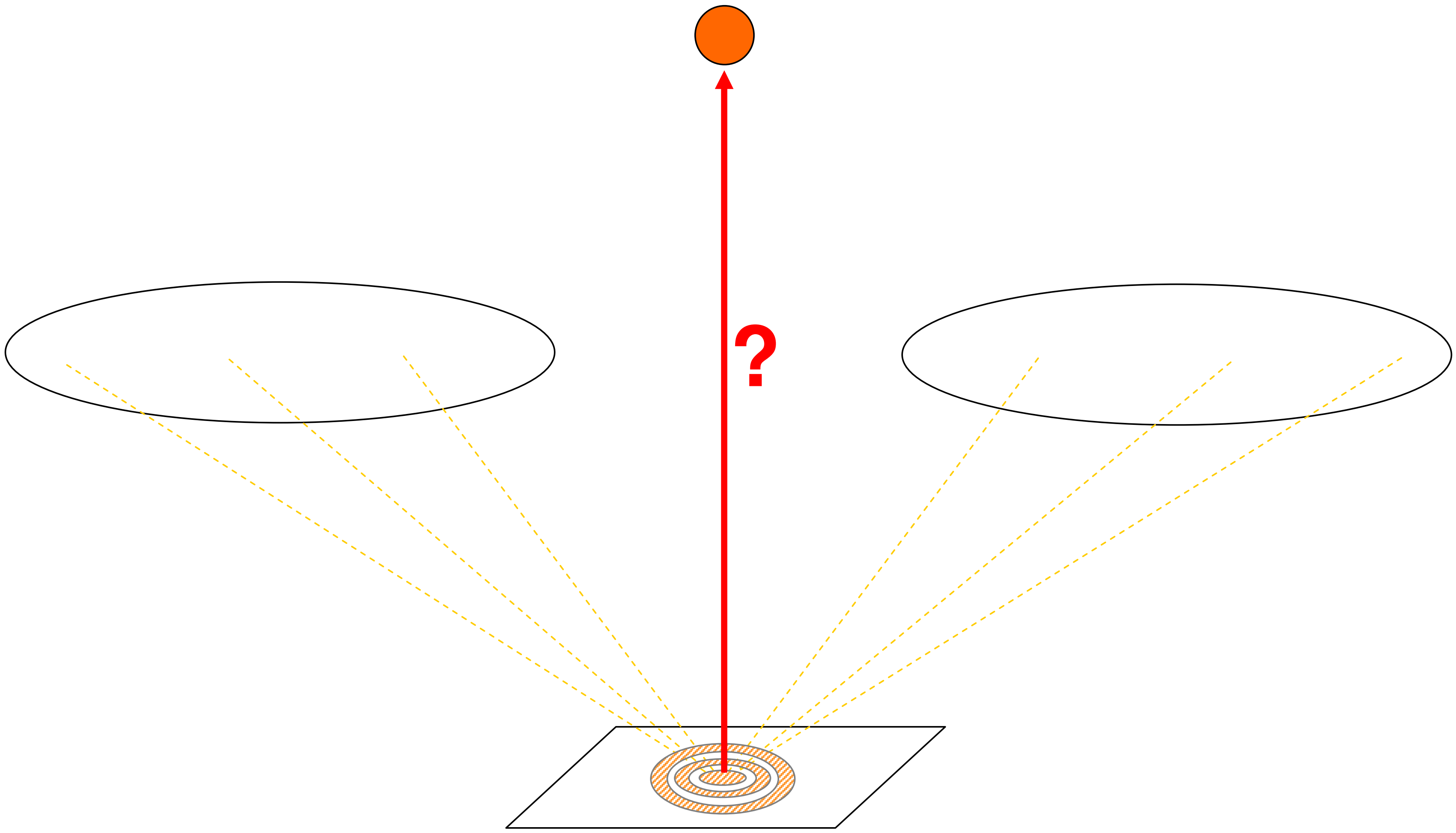

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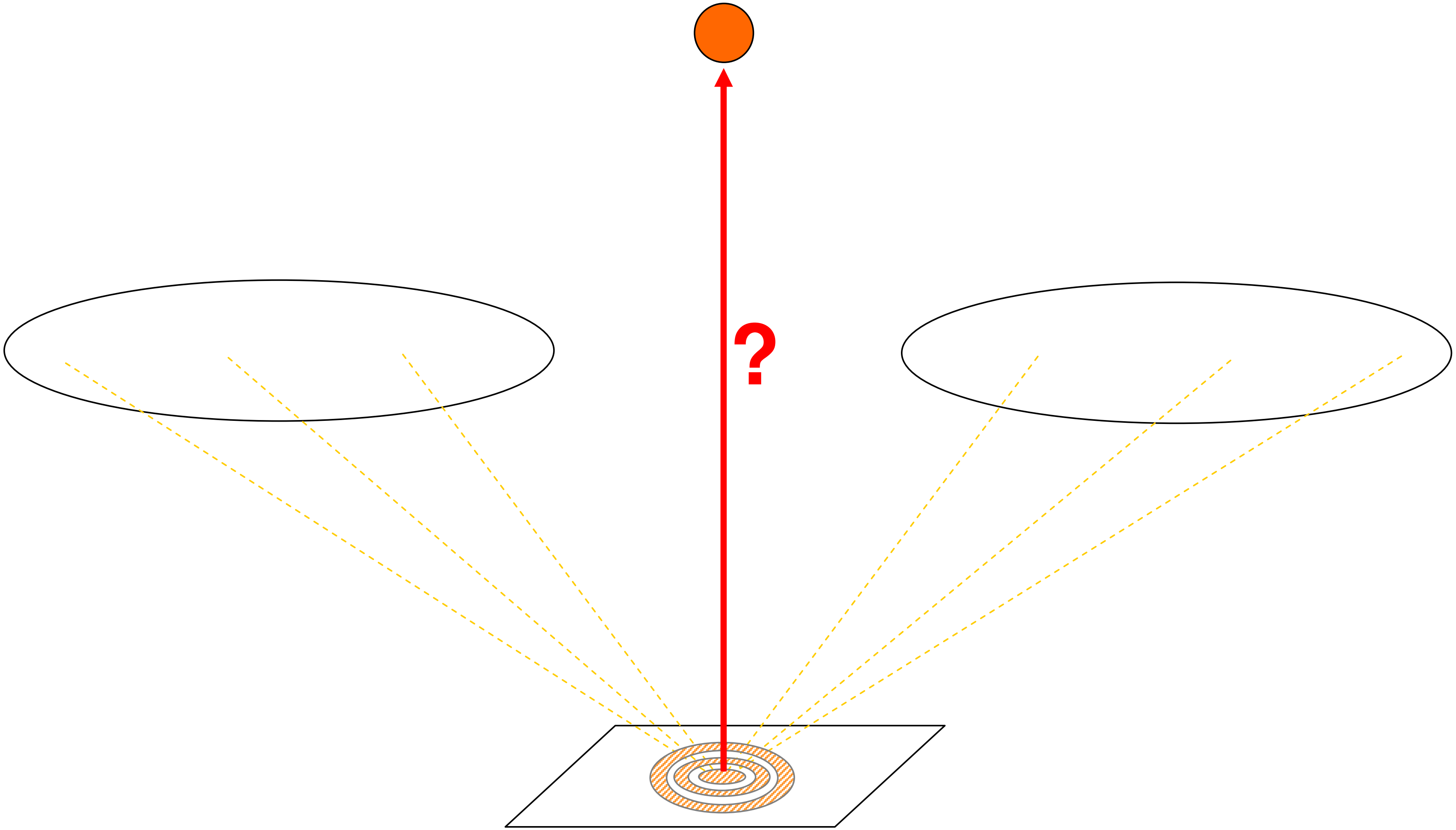

$$V = \left| \hat{\mathcal{O}}(u,v) / \hat{\mathcal{O}}(0,0) \right|$$

The Van Cittert and Zernike theorem

The fringe contrast of a source of emissivity ***O*** *is equal to the modulus of the Fourier Transform of* ***O*** *at a given spatial frequency normalized by the FT of* ***O*** *at the origin.*

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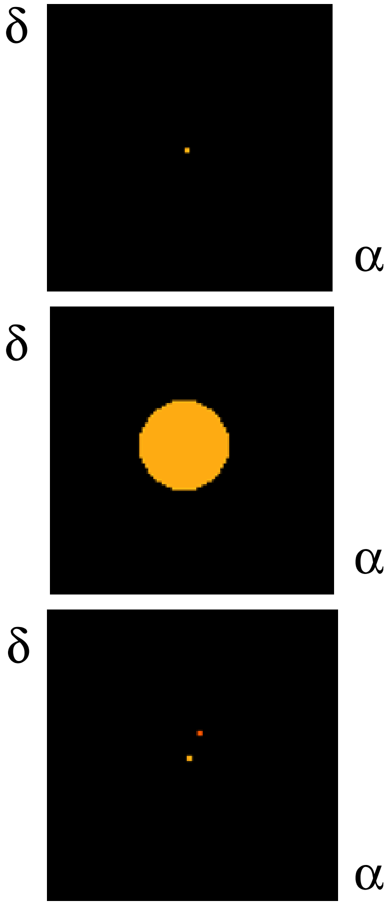
Direct Space $O(\alpha,\delta)$



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Fourier space/uv-plane/
spatial frequencies plane
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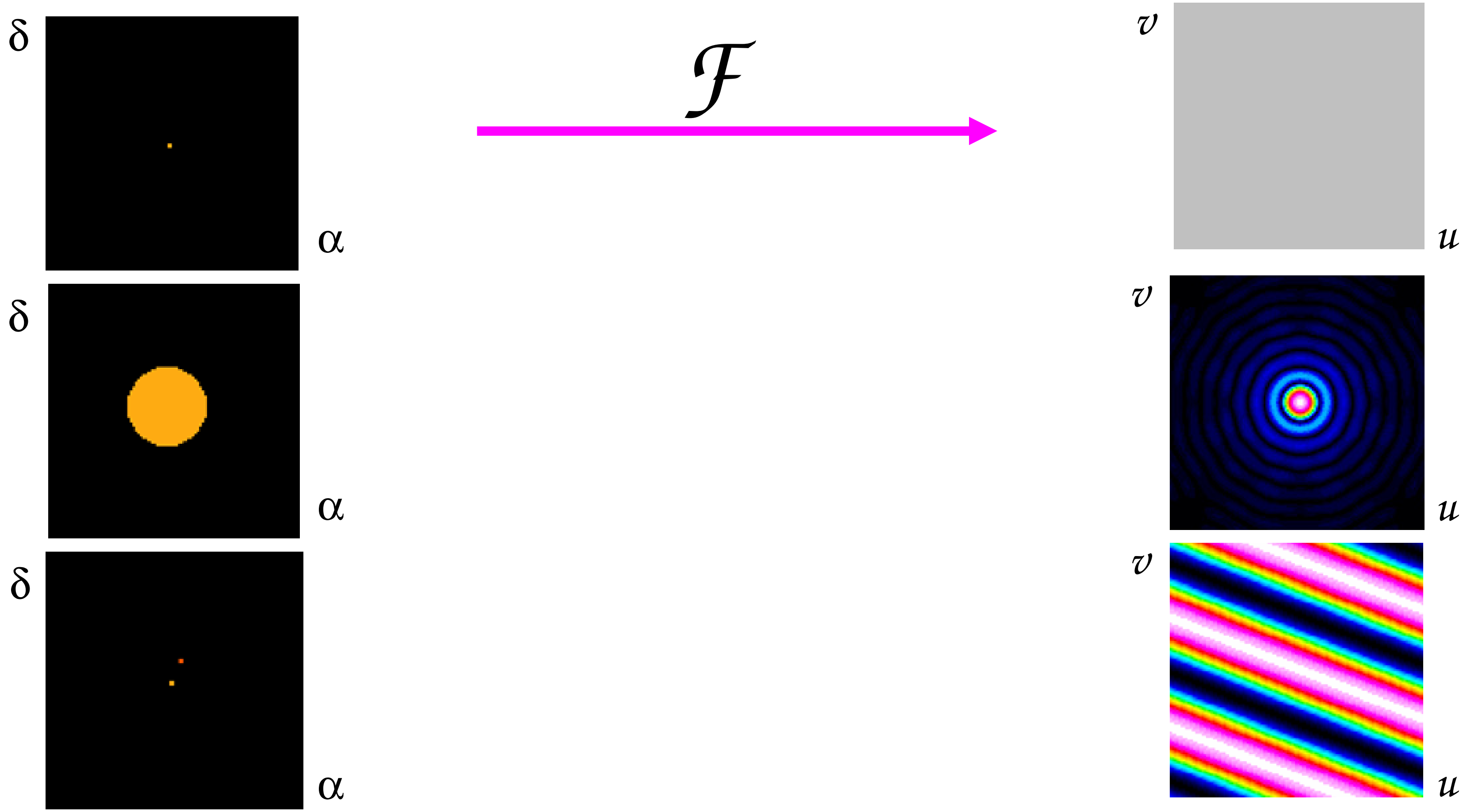

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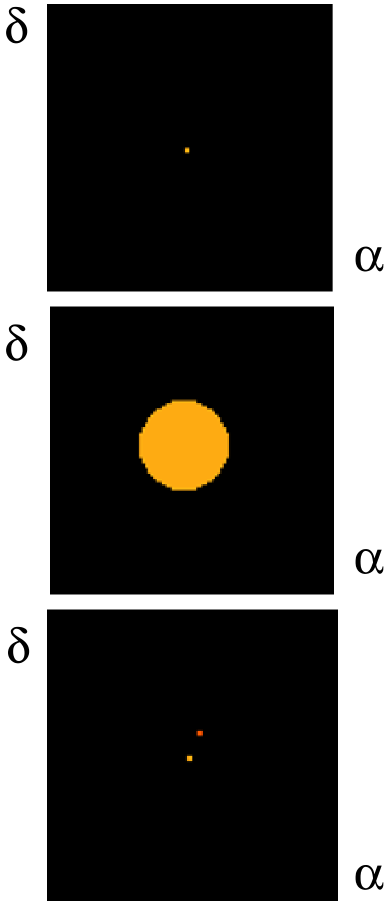
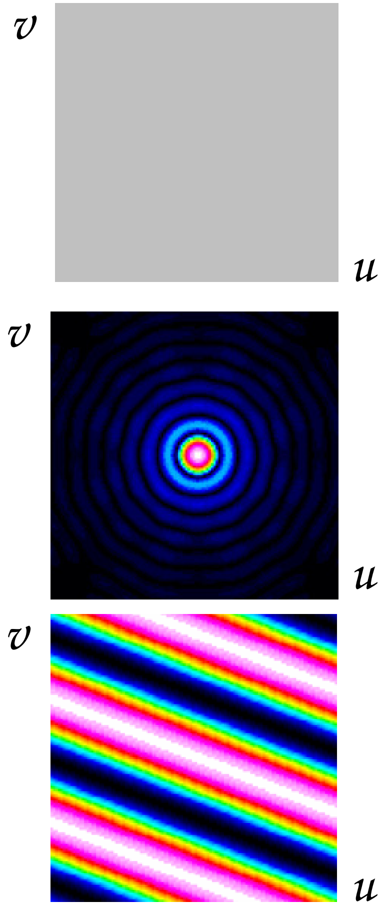


$$\mathcal{F}$$

$$\left| \frac{\iint O(\alpha,\delta)\ .\ \exp[-i.2\pi\ (u\alpha + v\delta)].\ d\alpha\ d\delta}{\iint O(\alpha,\delta)\ .\ d\alpha\ d\delta} \right|$$

Does someone recognize this denominator?

Fourier space/uv-plane/
spatial frequencies plane
$|\hat{O}(u,v)\ /\hat{O}(0,0)|$



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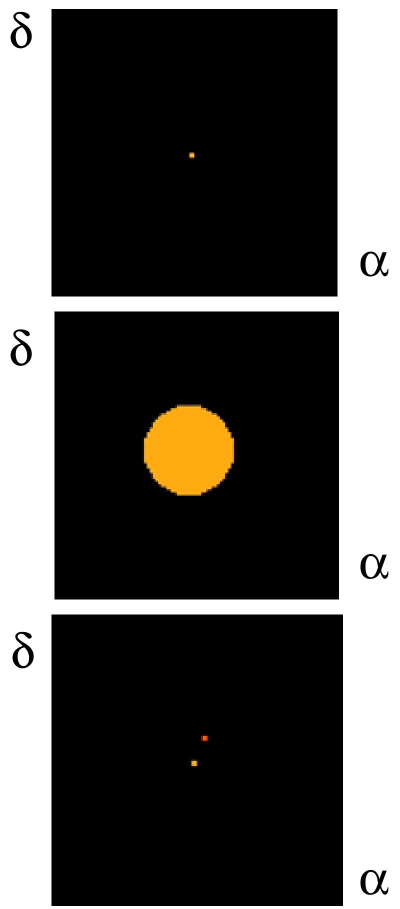

$$\xrightarrow{\mathcal{F}}$$

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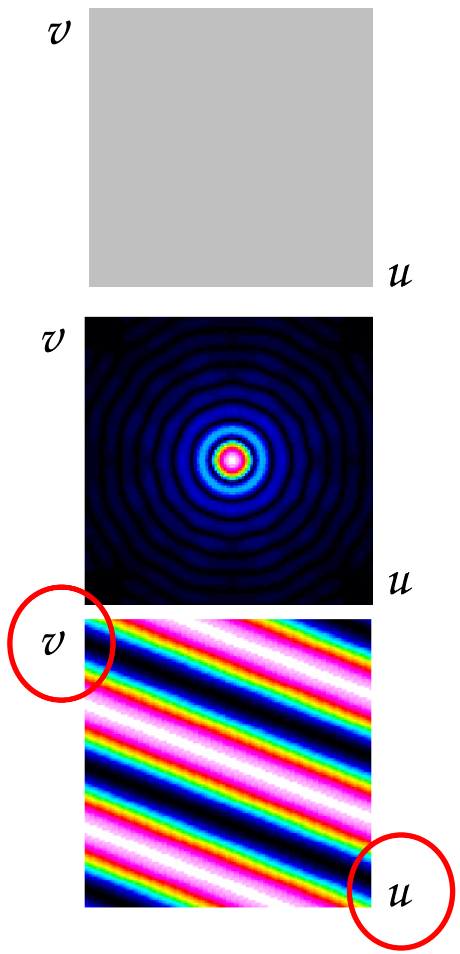
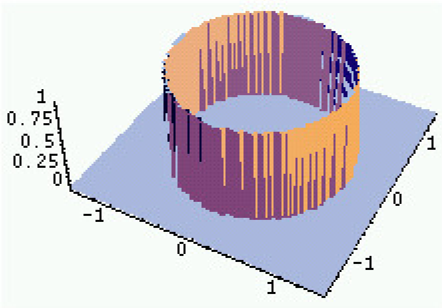
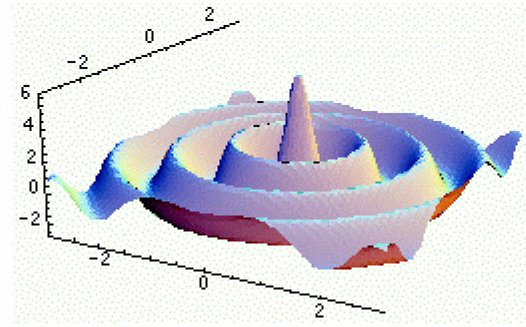
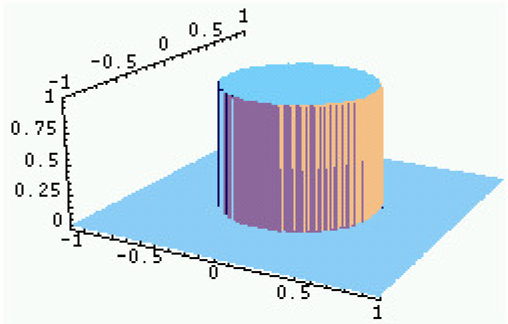
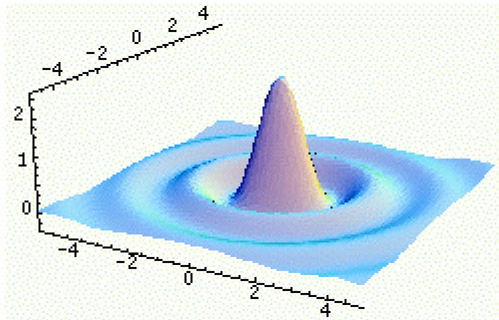
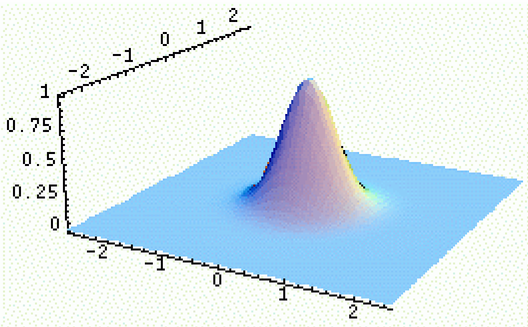
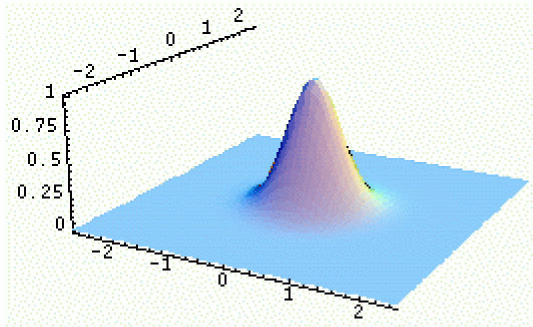
spatial frequencies plane
$|\hat{O}\,(u,v)\ /\hat{O}\ (0,0)|$



Some Fourier (Hankel) transformations

Fonction	Graphe de la fonction	Transformée	Graphe de la TF
$\delta(r-a)$		$2\pi a J_0(2\pi a q)$	
$\Pi\left(\frac{r}{d}\right)$		$2\left(\frac{\pi d^2}{4}\right) J_{1c}(\pi d q)$	
$\exp(-\pi r^2)$		$\exp(-\pi q^2)$	

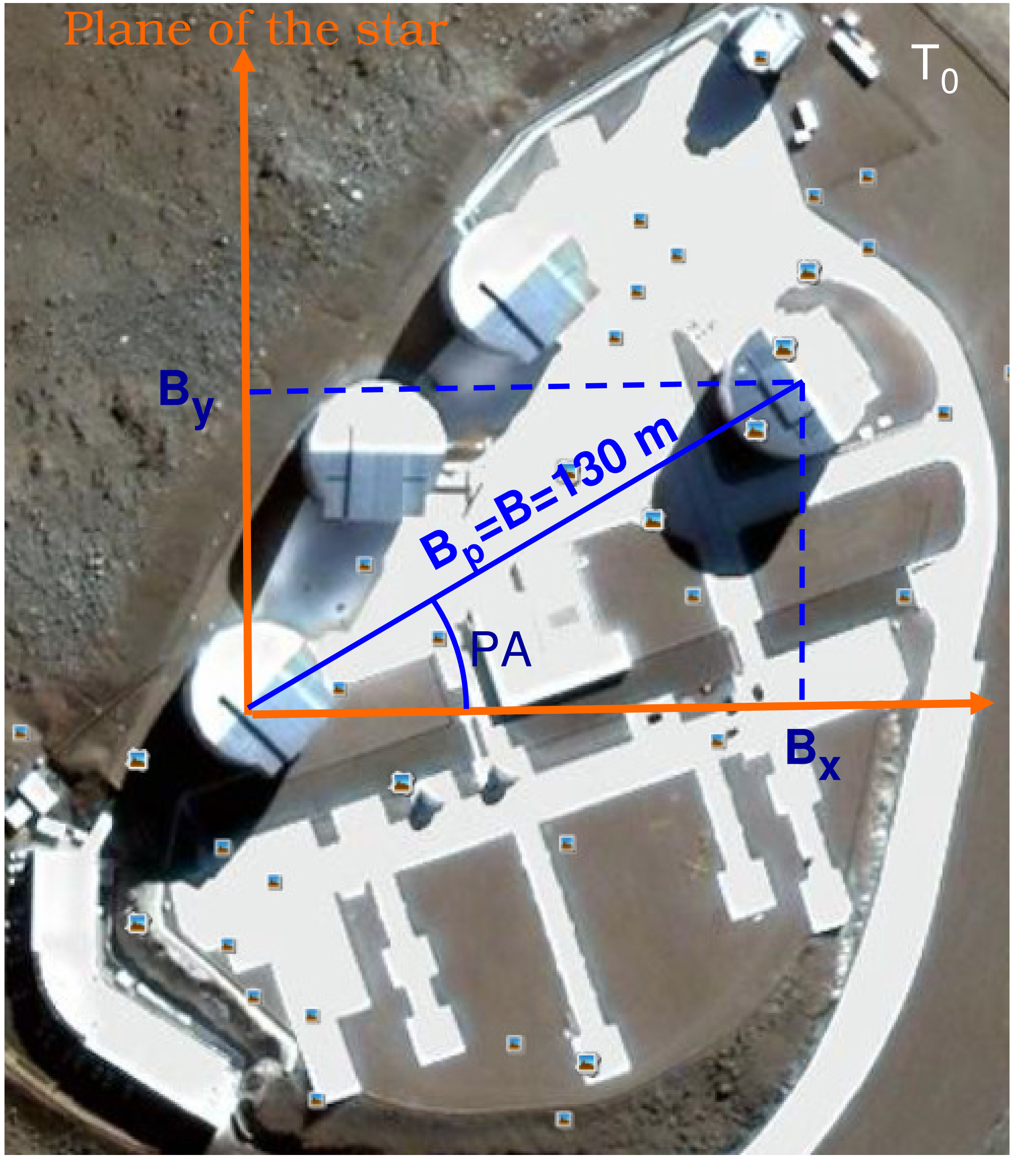
(*) $r = (\alpha^2 + \delta^2)^{1/2}$

(*) $q = (u^2 + v^2)^{1/2} = B_p/\lambda$

(**) $J_{1c}(X) = J_1(X)/X$

The uv-plane (part I)

spatial frequencies (u,v) : coordinates (B_x,B_y) of the projected baselines (B_p) seen from the star and divided by the observing wavelength (λ)



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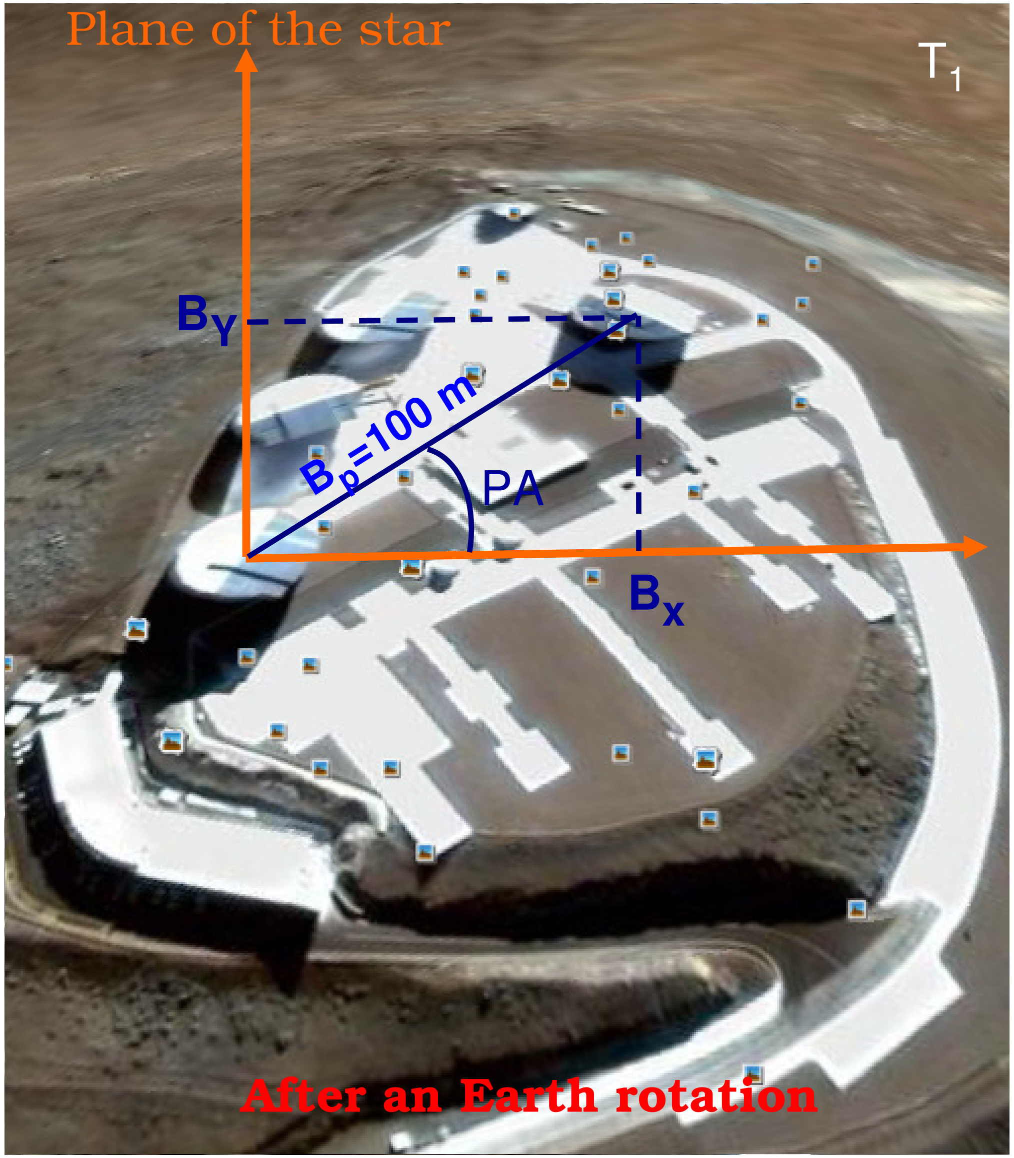

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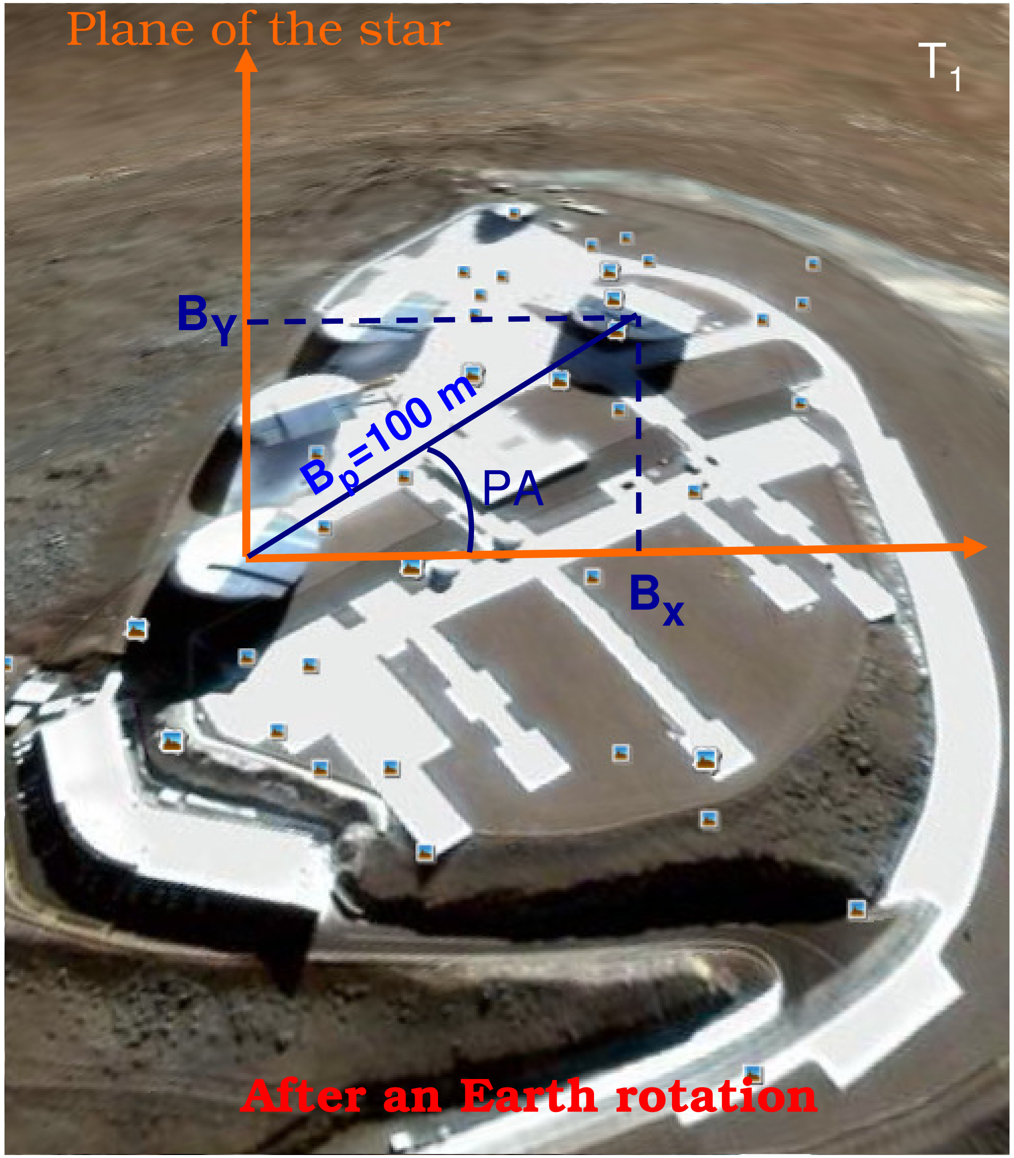
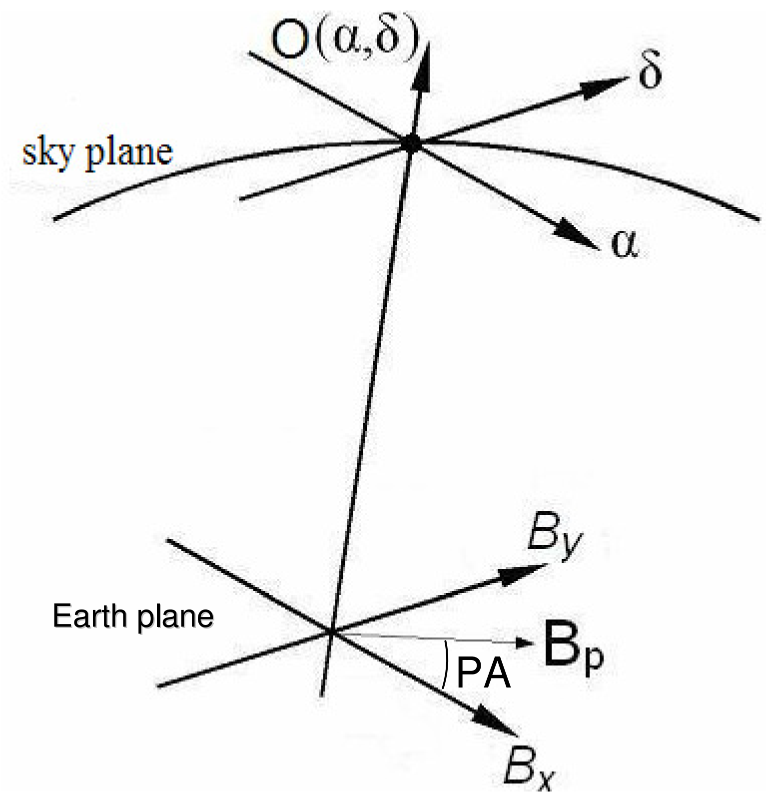


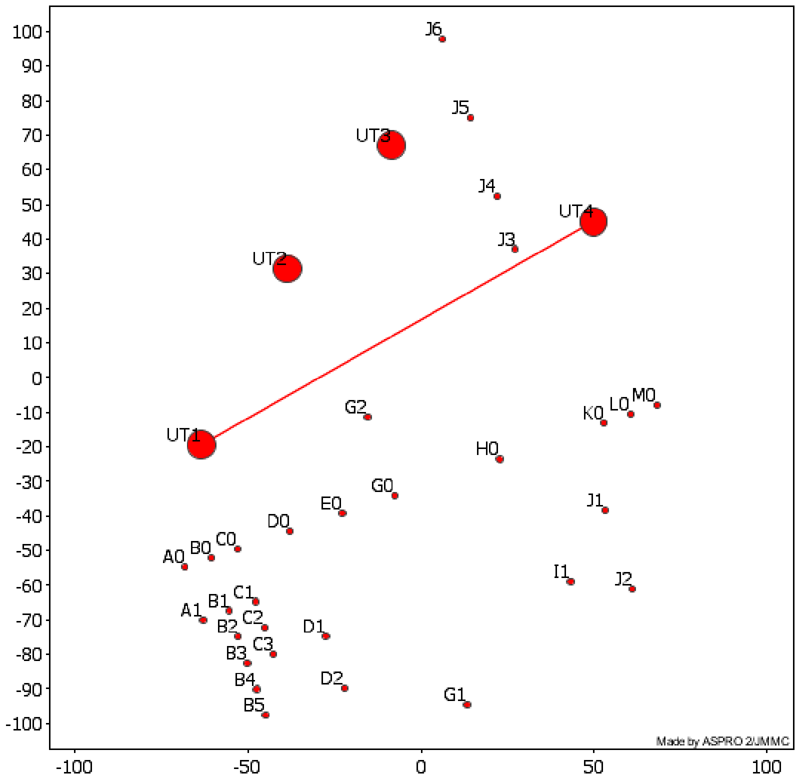


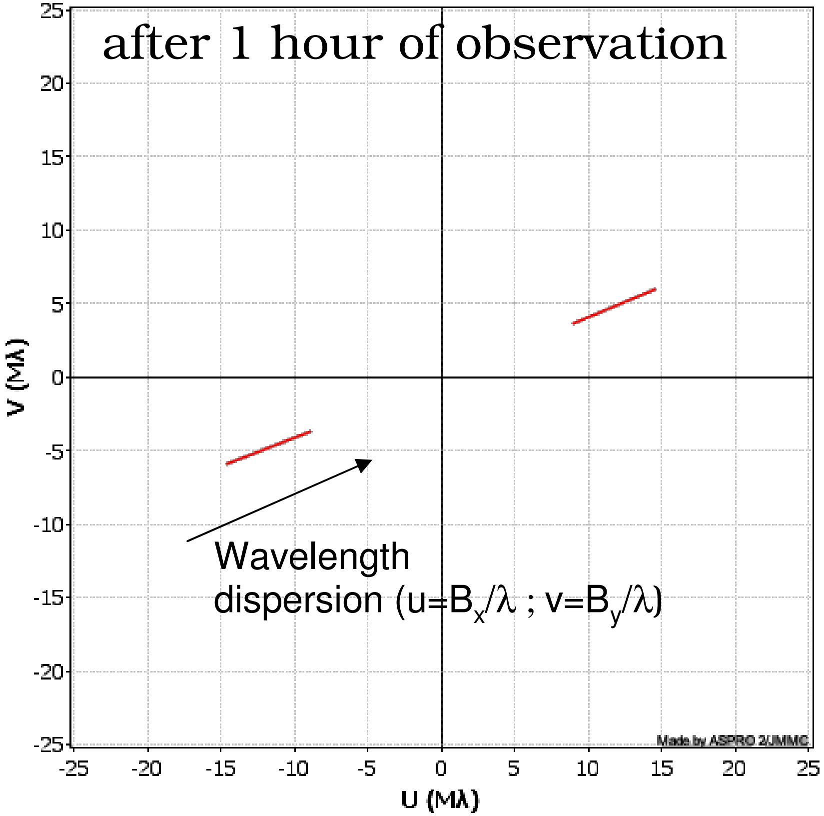
$$\begin{cases} u = B_x/\lambda = B_p.\cos(PA) / \lambda \\ v = B_y/\lambda = B_p.\sin(PA) / \lambda \end{cases}$$

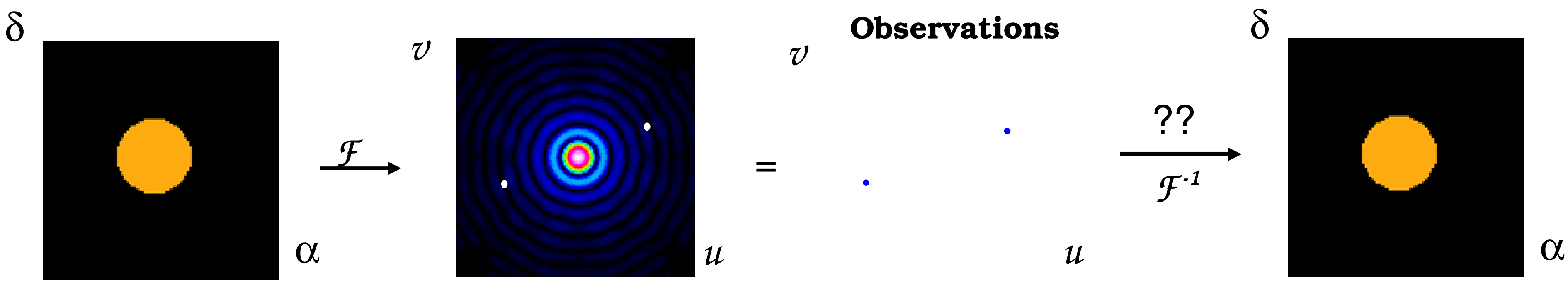
$$B_p/\lambda = \sqrt{u^2 + v^2}$$

The uv-plane (part II)

Observation of R Scl (α=01:26:58 ; δ=-32:32:35) at the date of 19 August 2011







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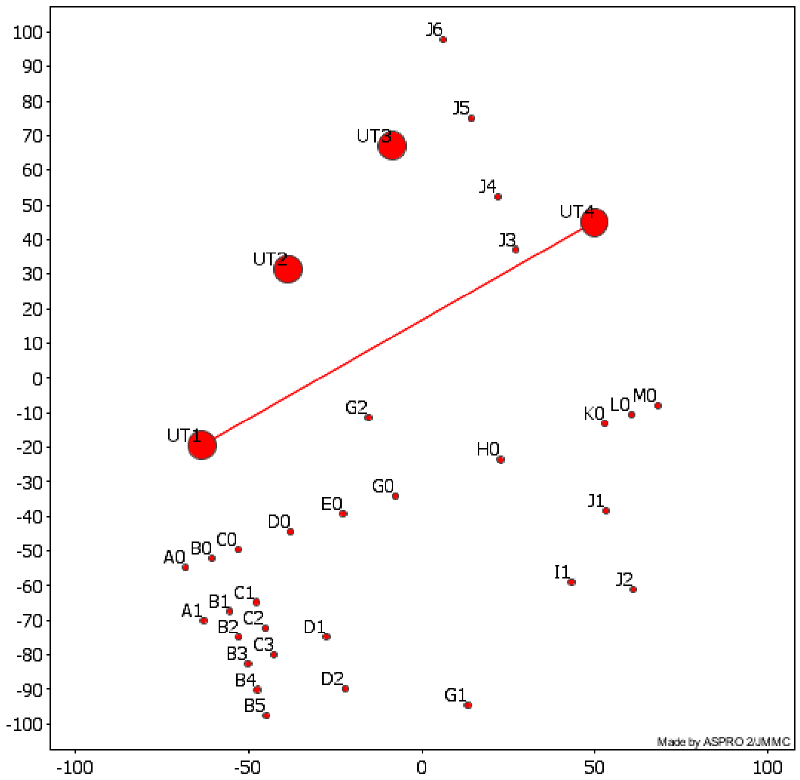

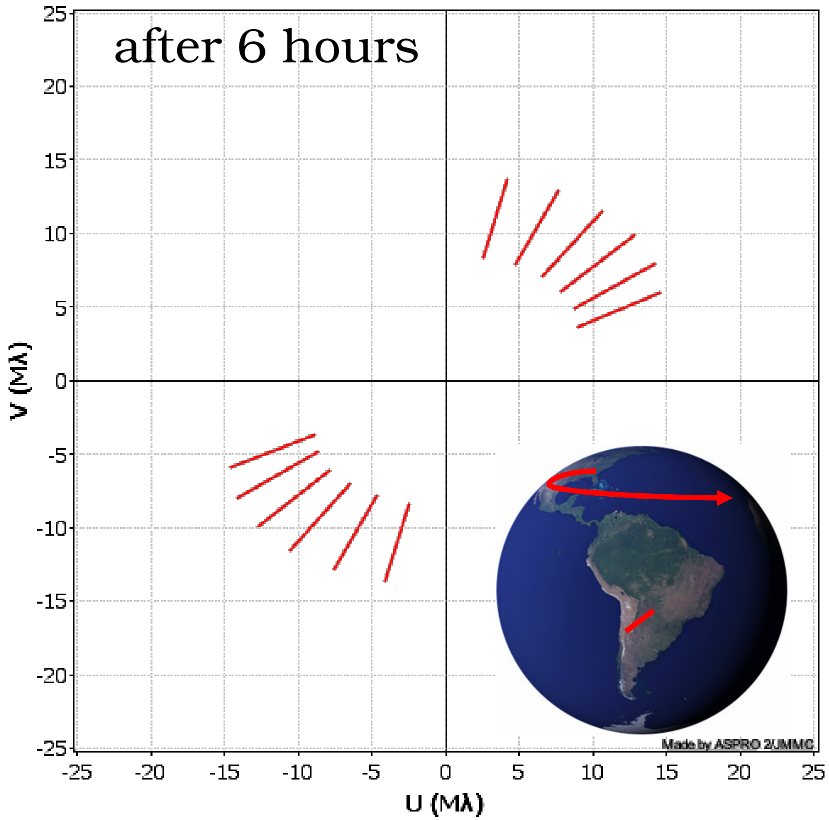

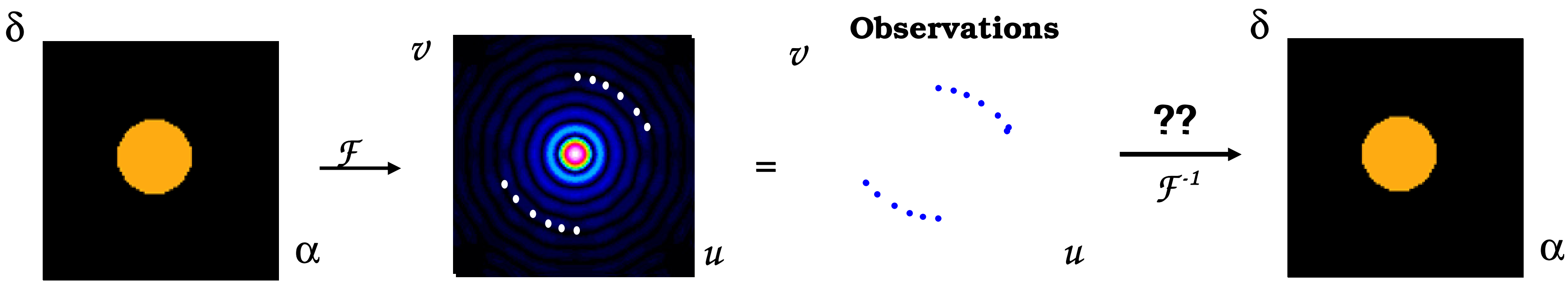

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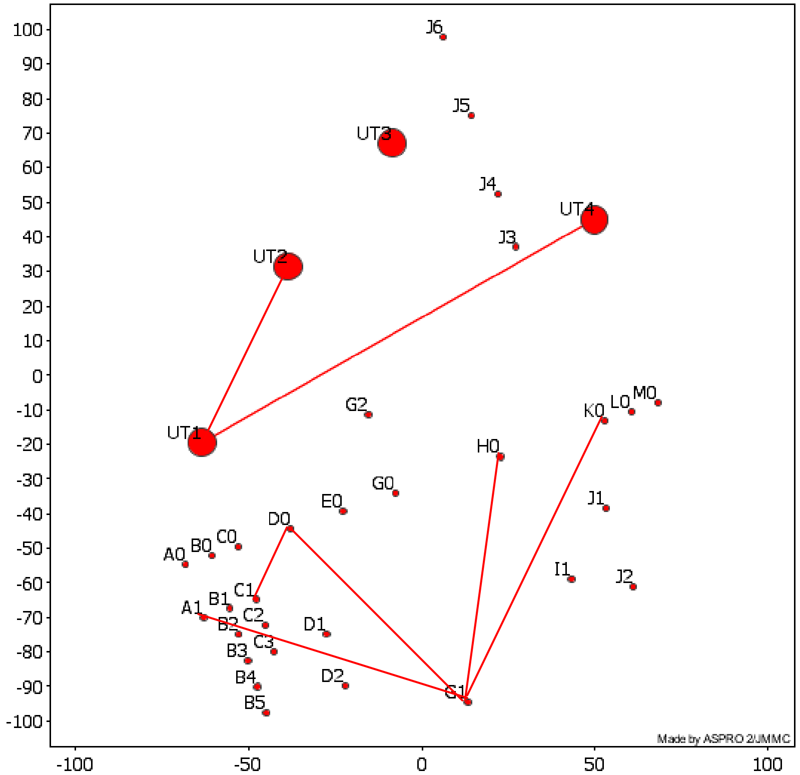

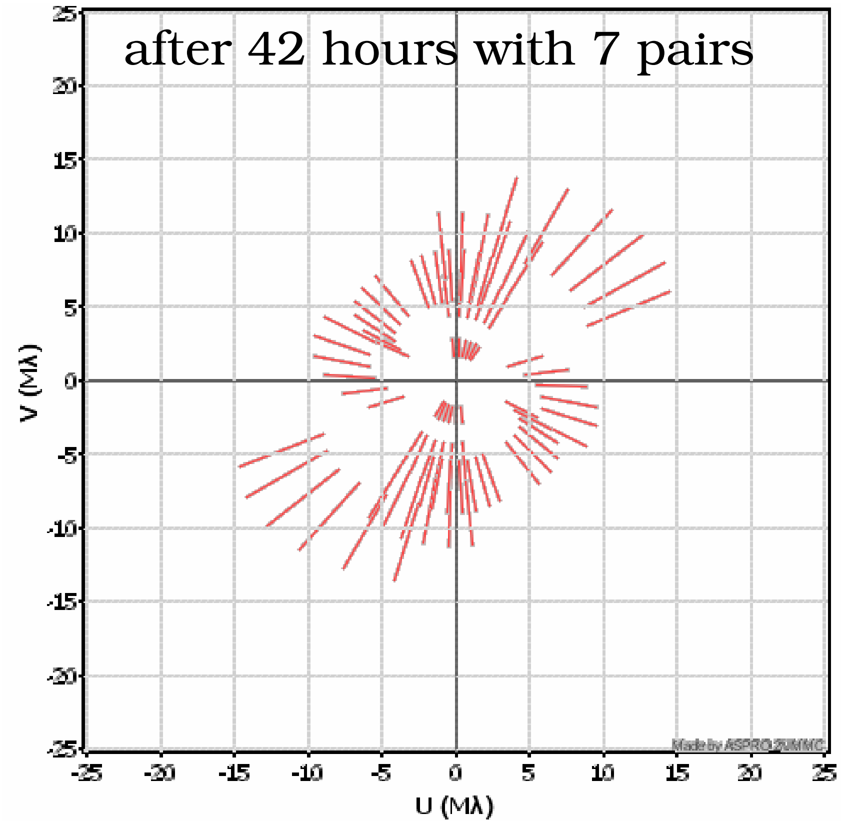

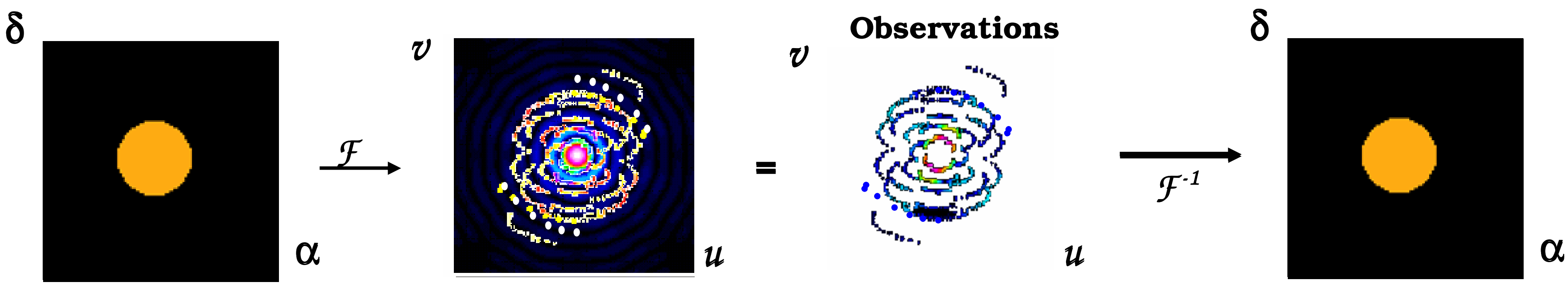

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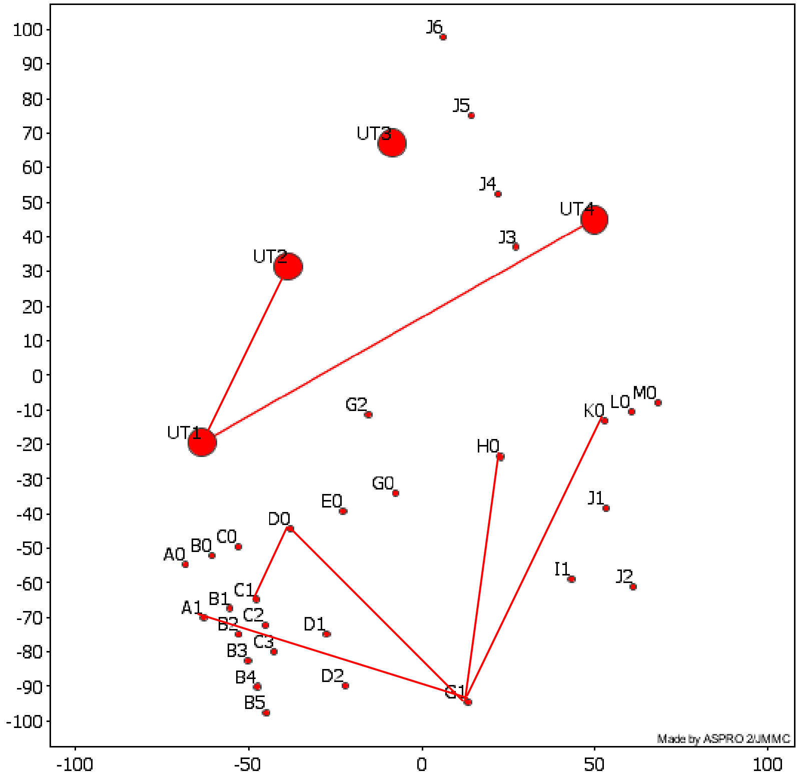

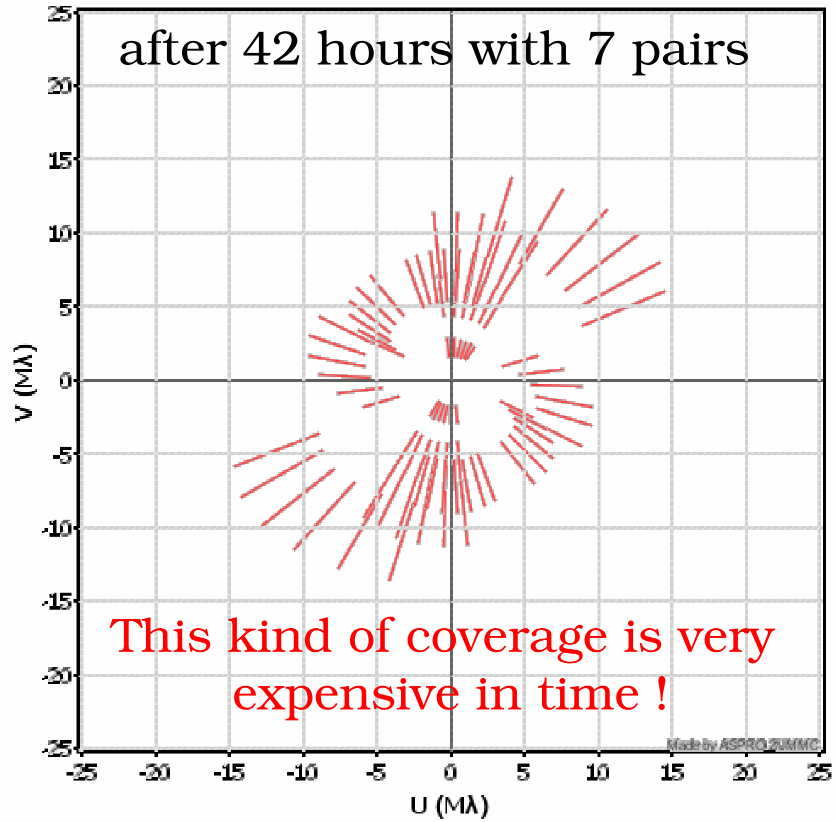

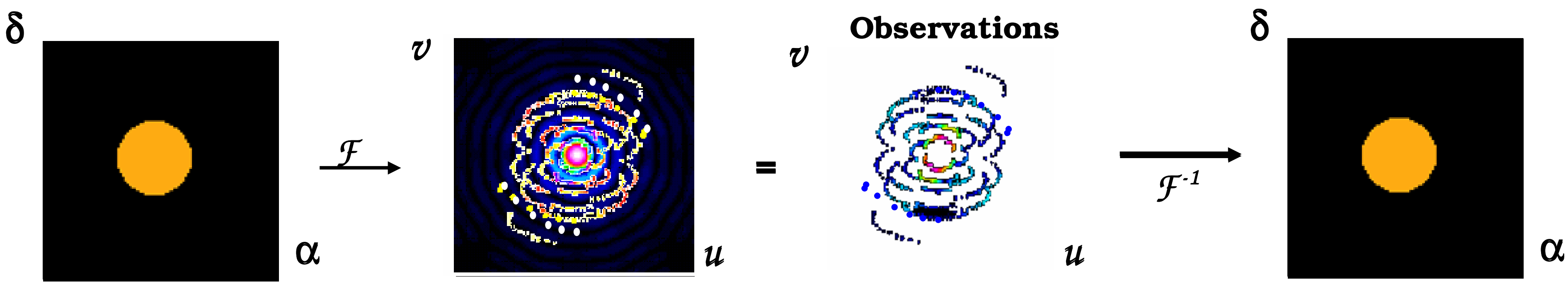

What is the appropriate uv coverage?

What is the appropriate *uv* coverage?

It depends on the complexity of the object

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Is it really necessary to get a very large uv-coverage for such an object?

[hot star]

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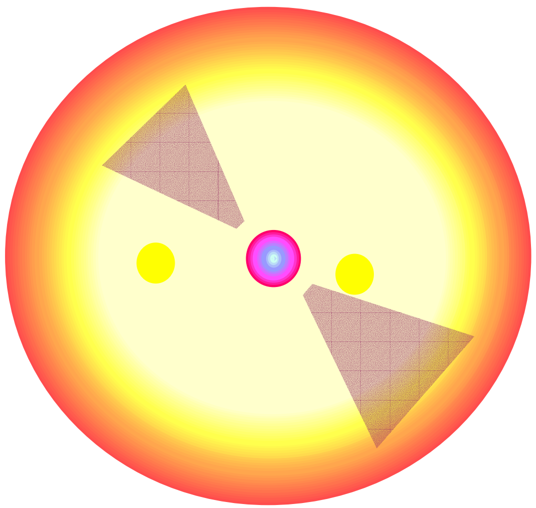
It depends on the complexity of the object

Is it really necessary to get a very large uv-coverage for such an object?

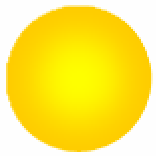
[hot star]

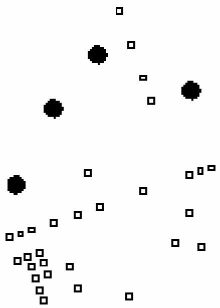
Is it necessary to get a very large uv-coverage for this one?

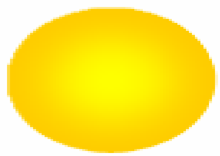


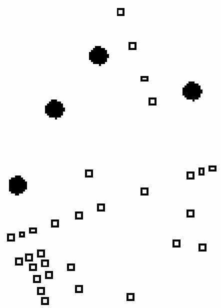
[Post-AGB (triple system + envelope + disk)]

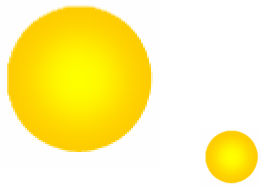
❖ Spatial information

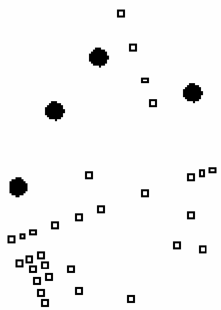


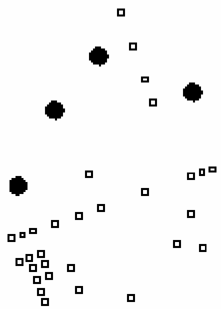












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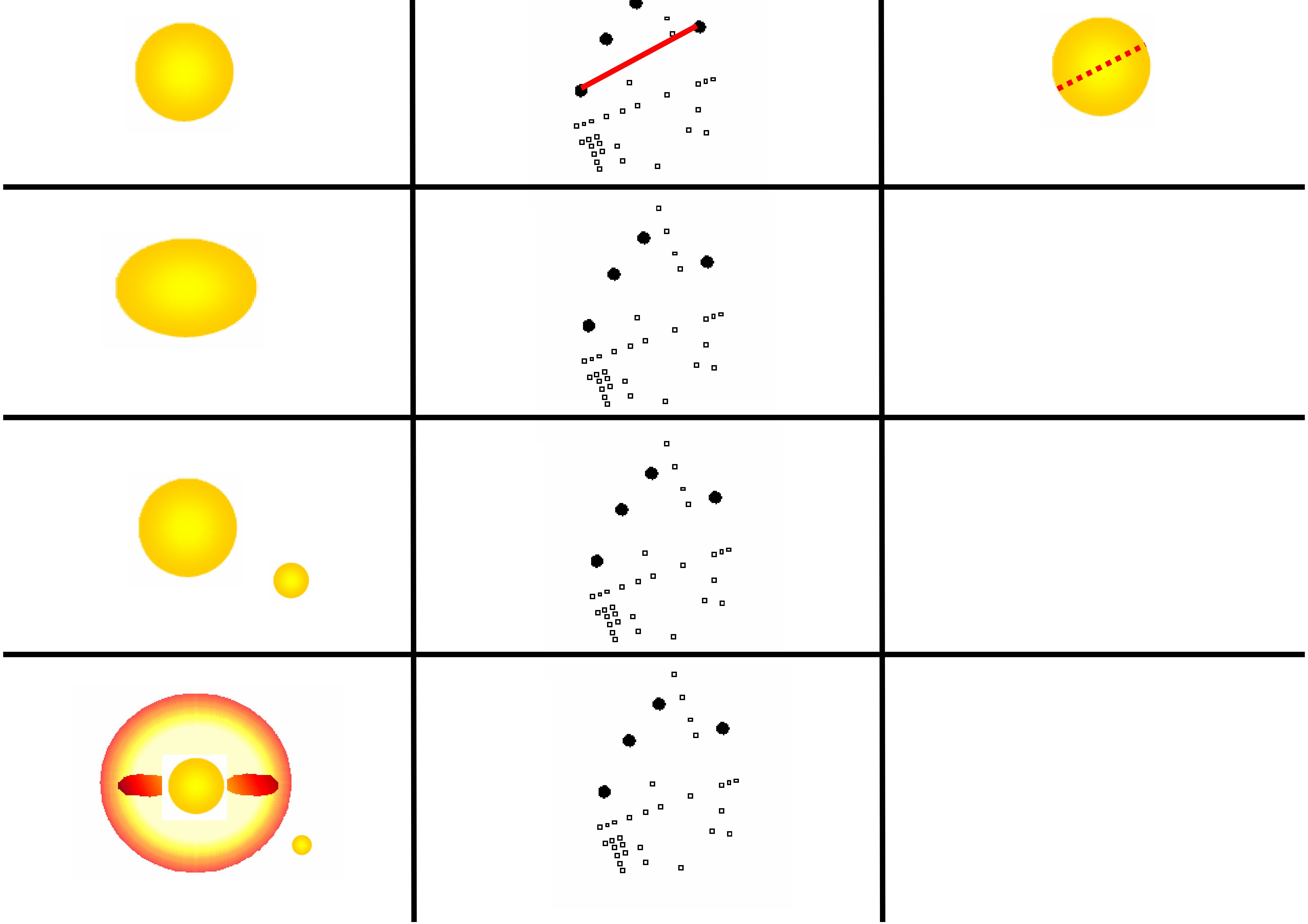

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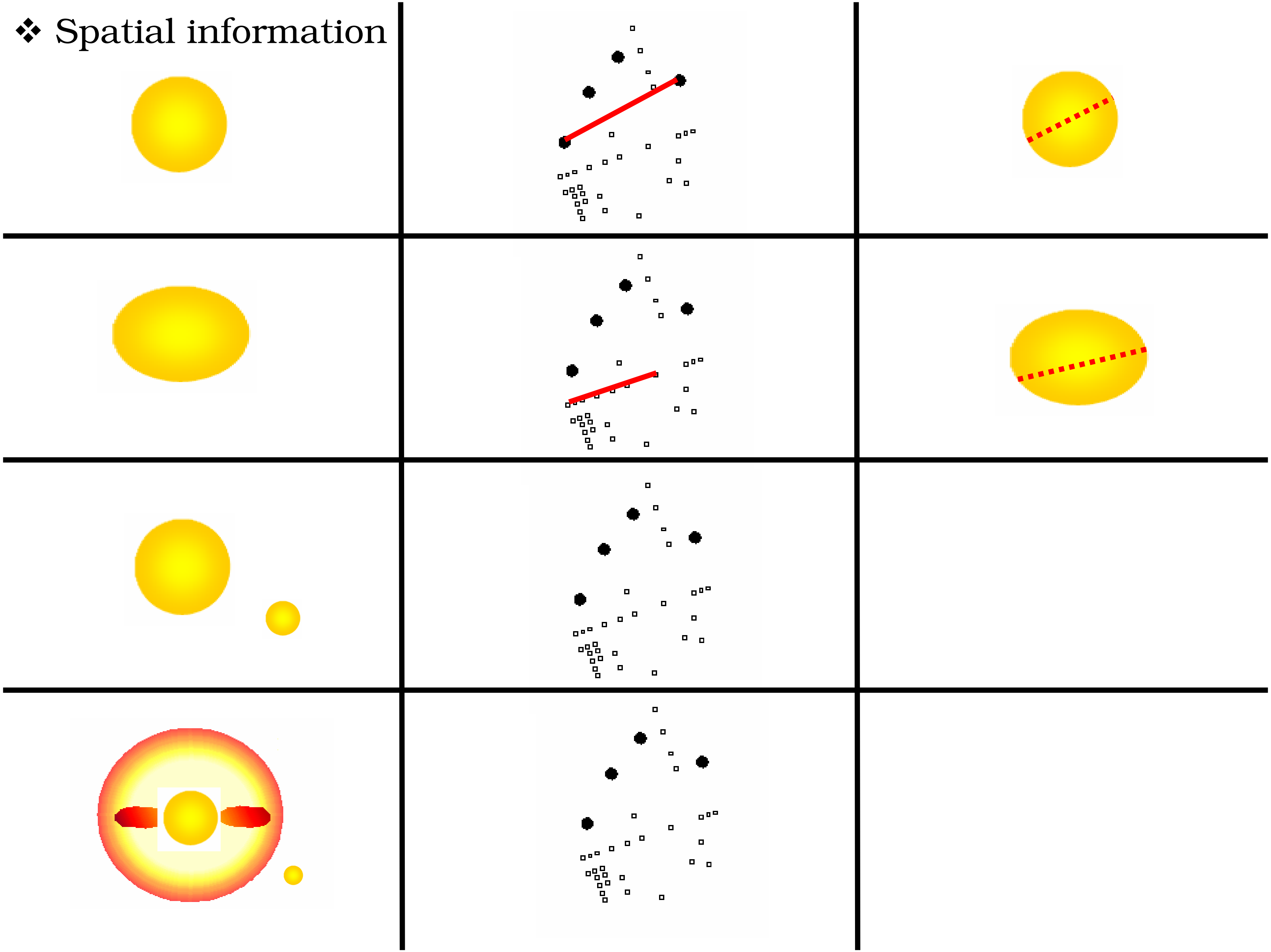

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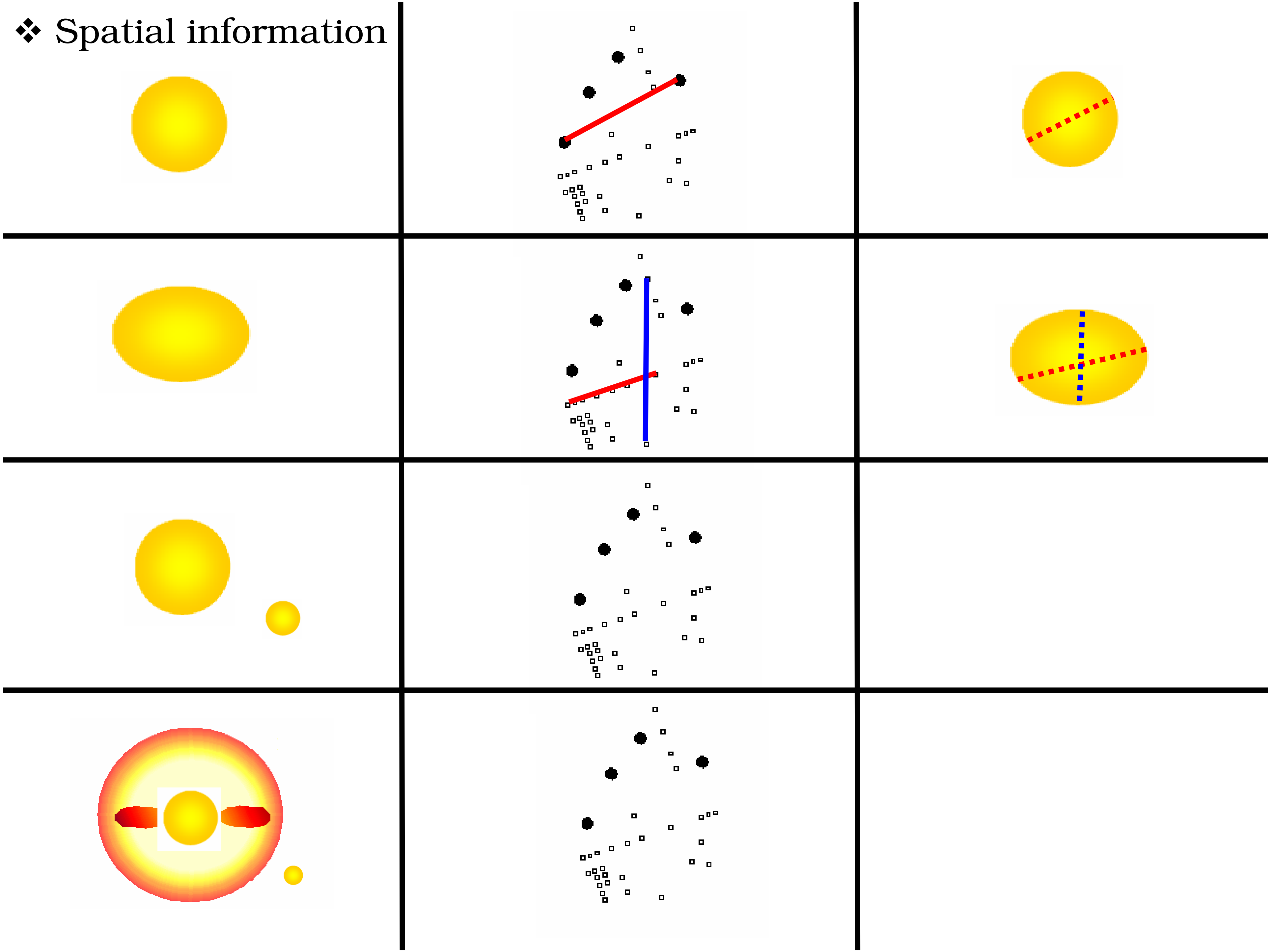

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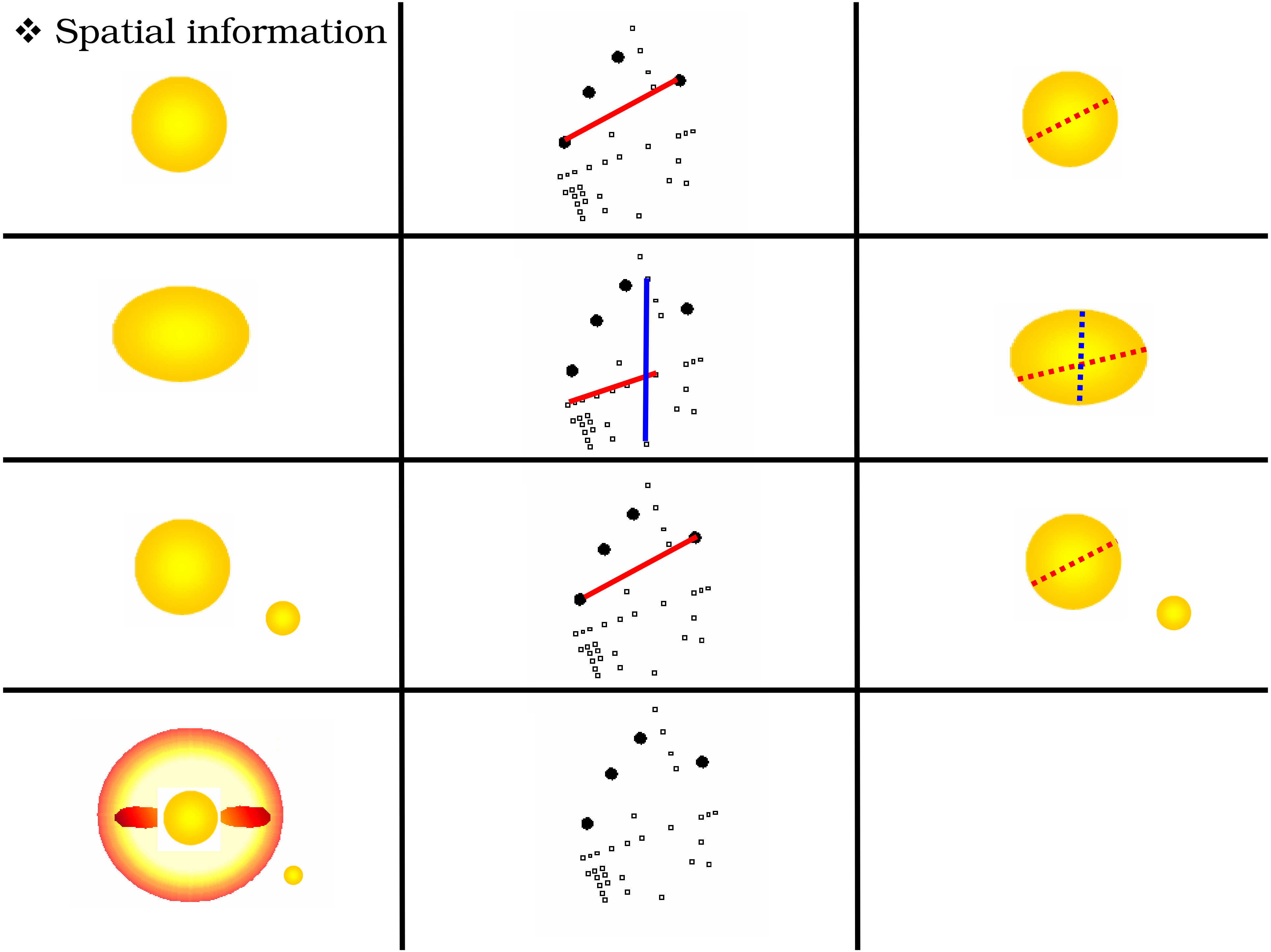

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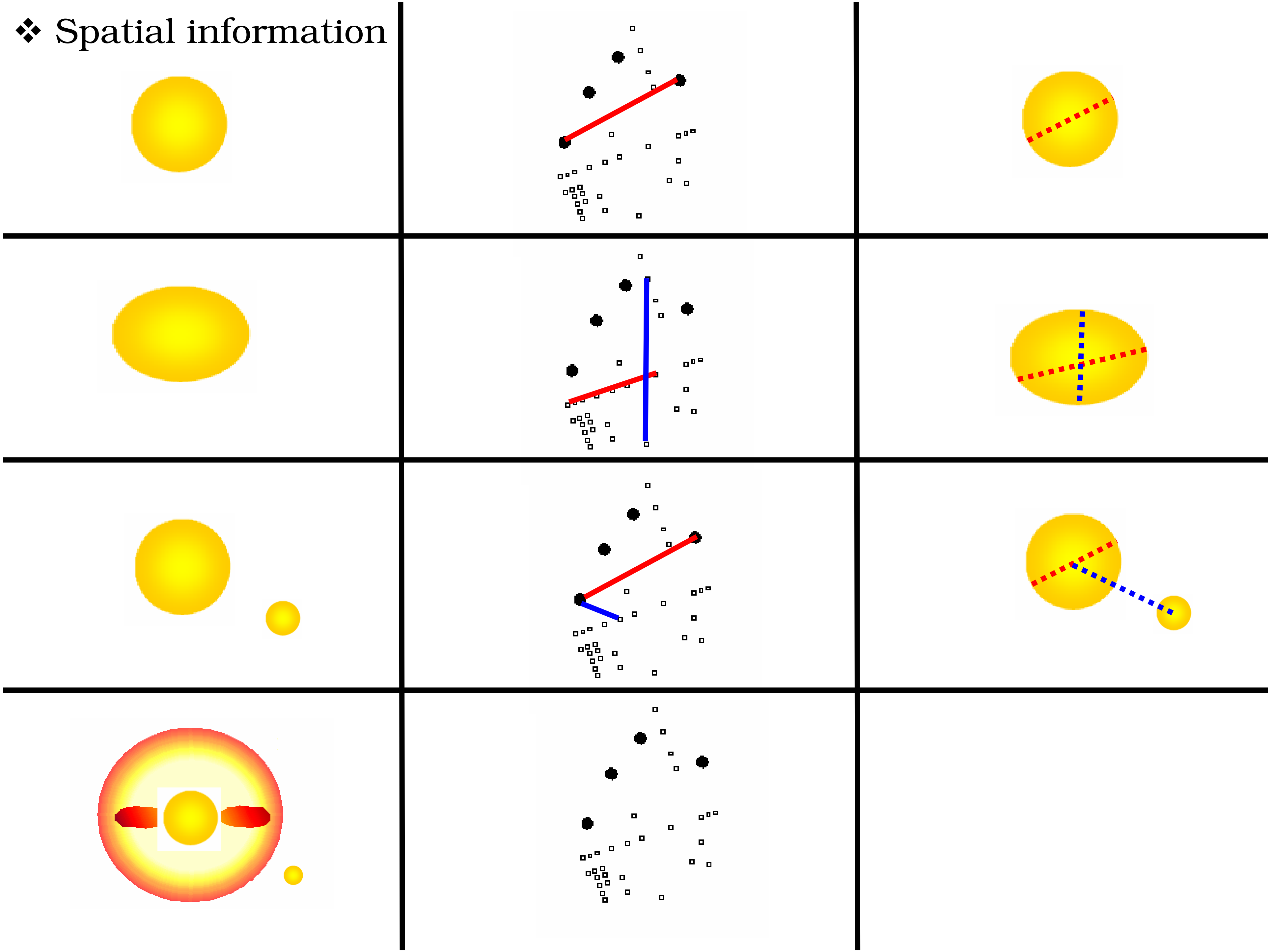

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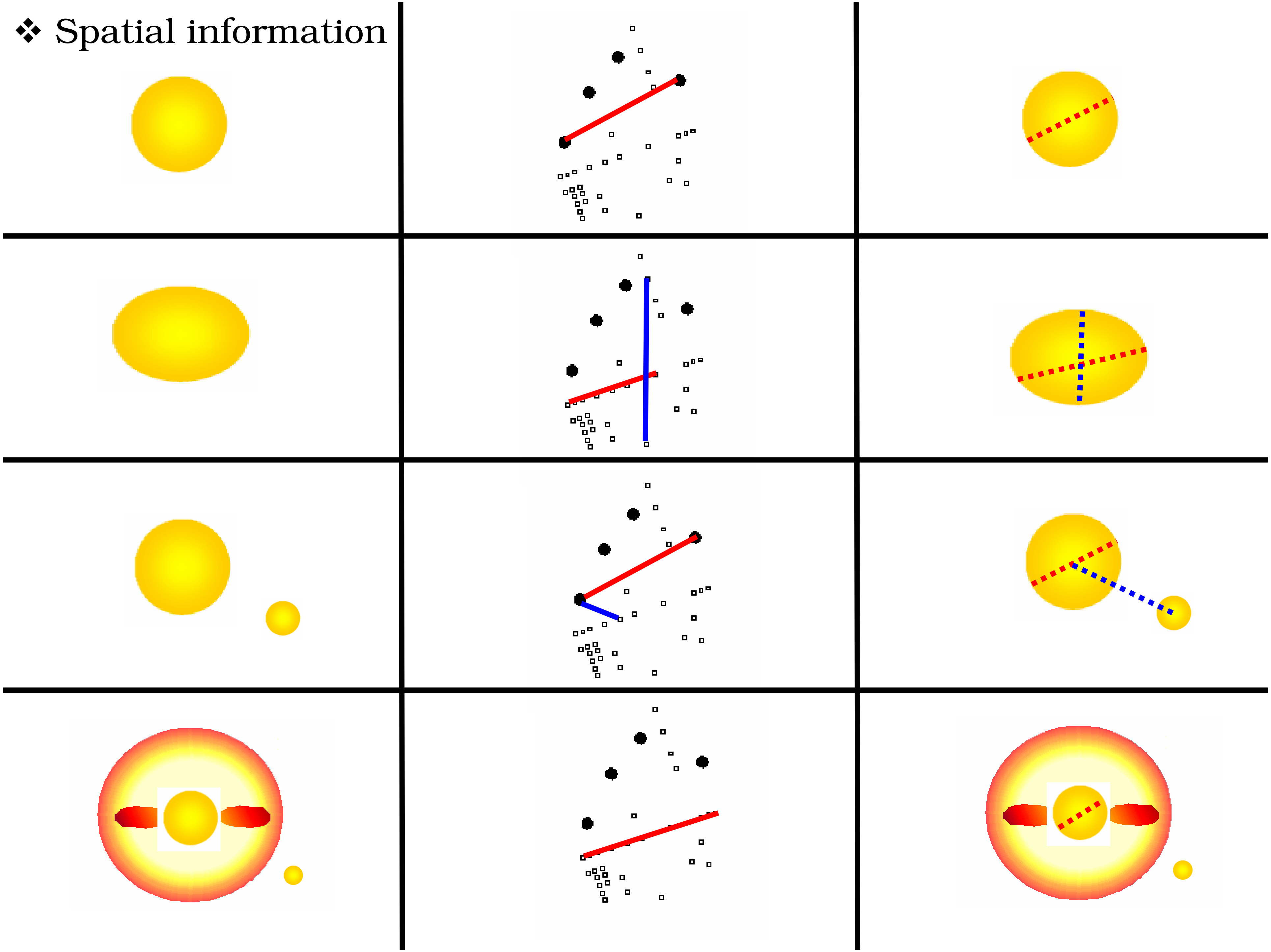

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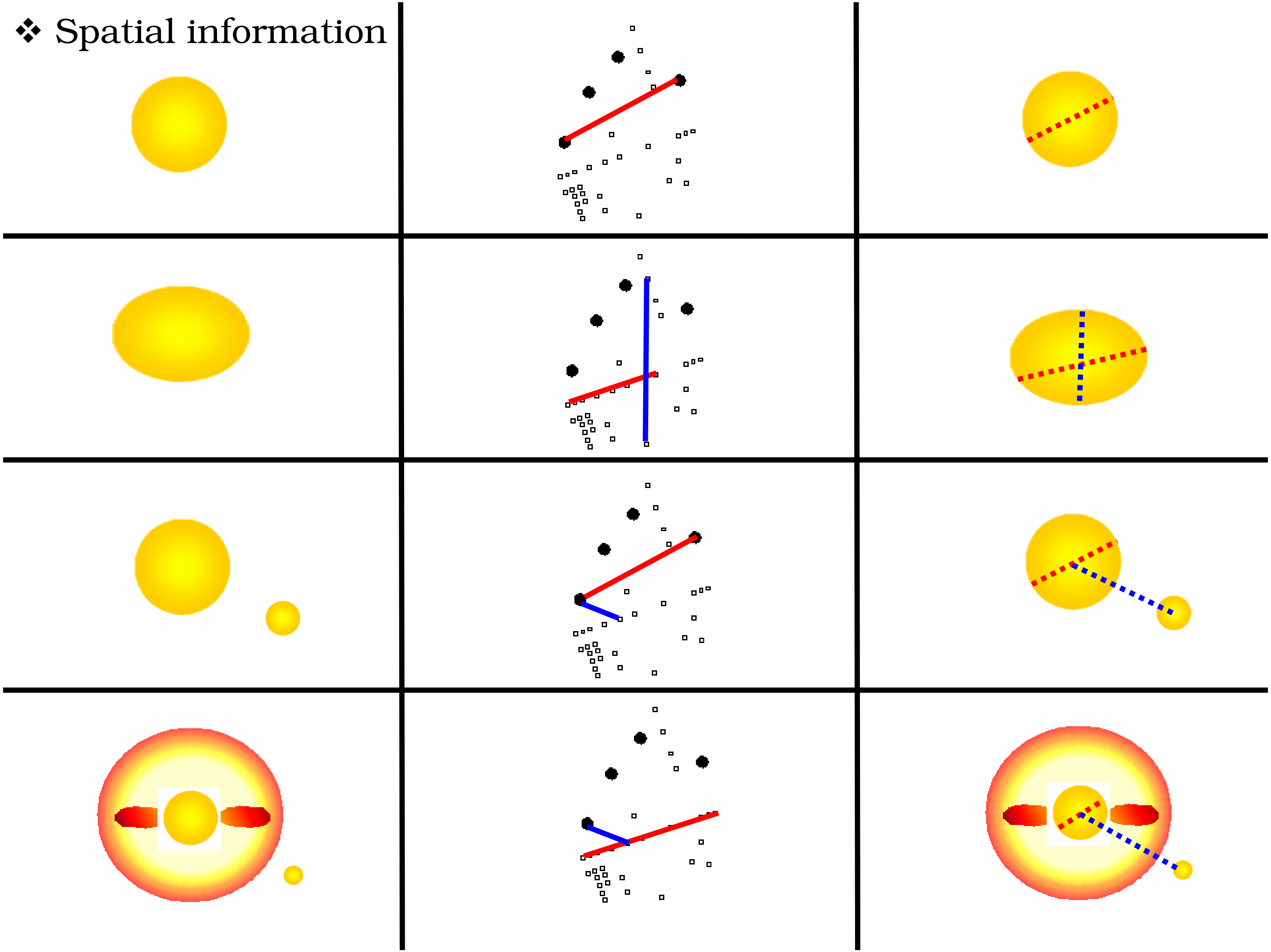

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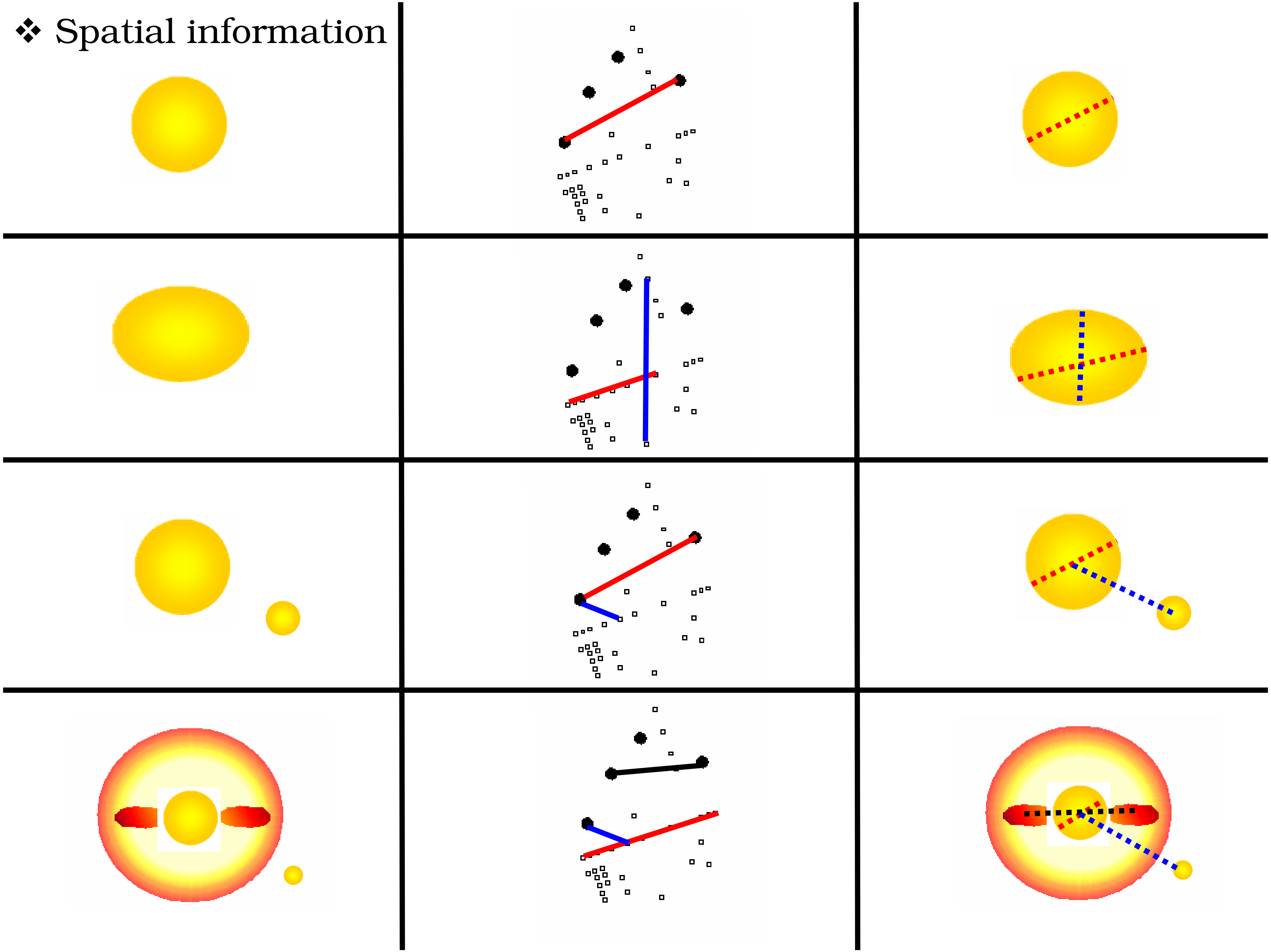

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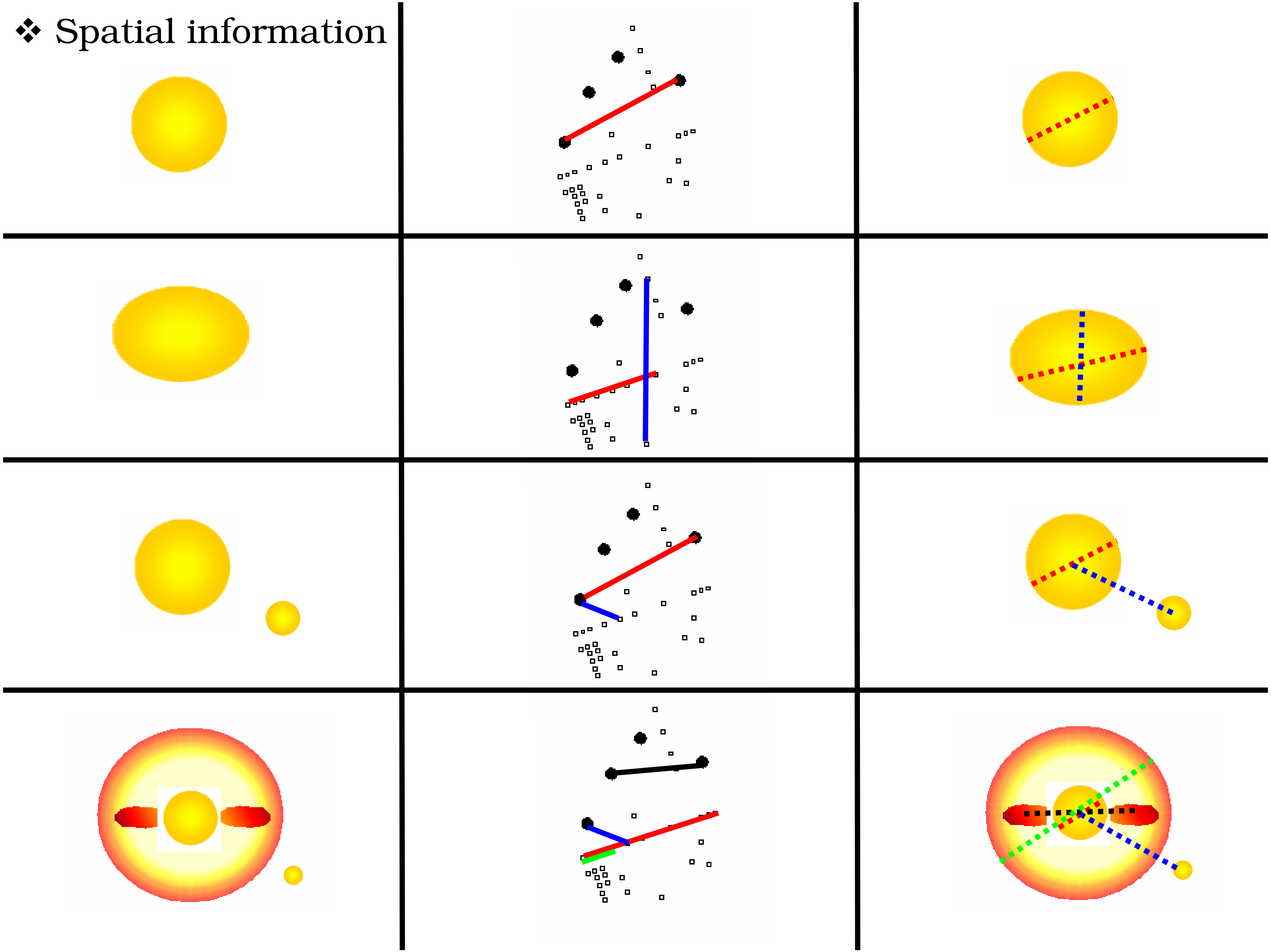
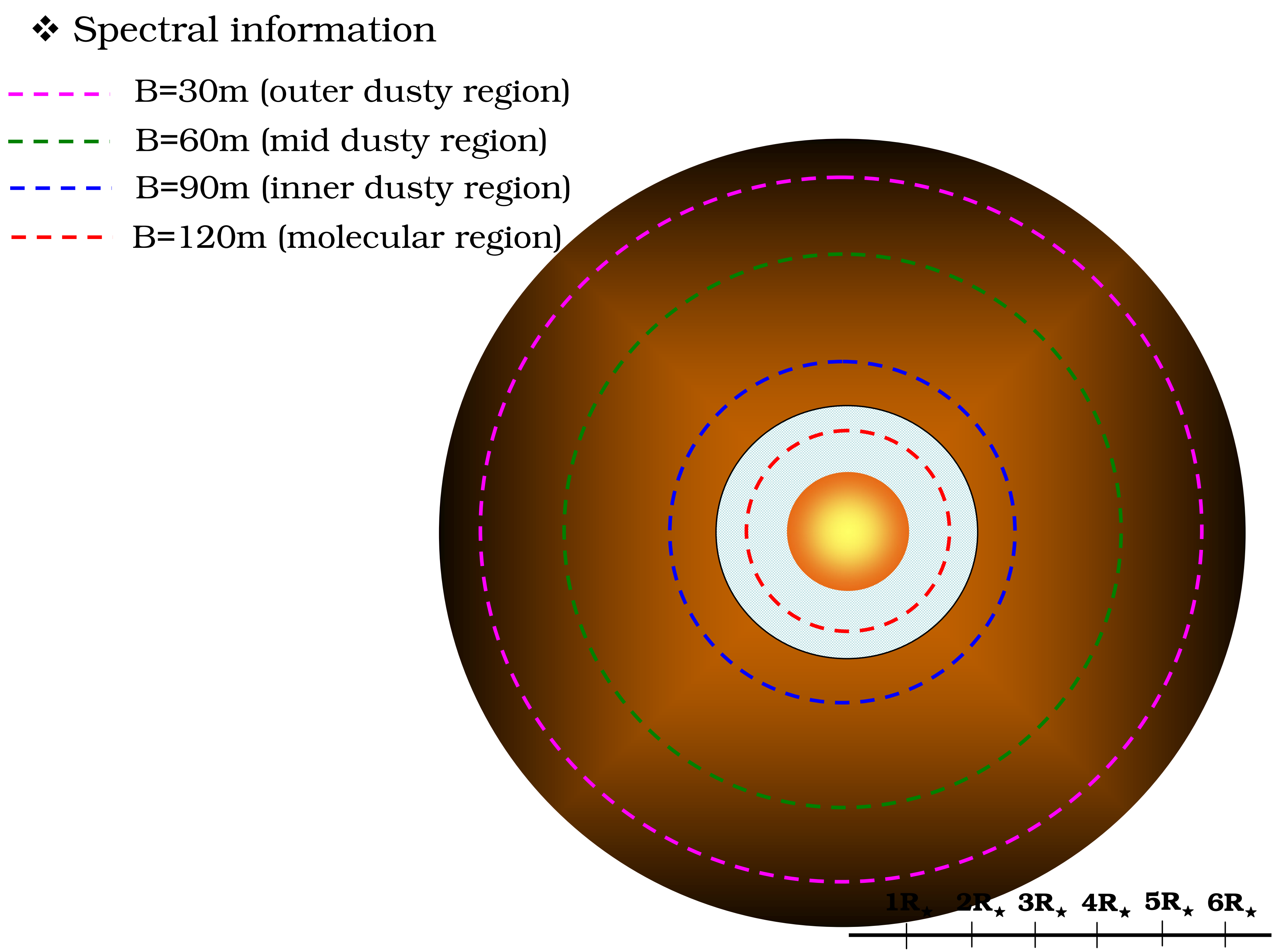
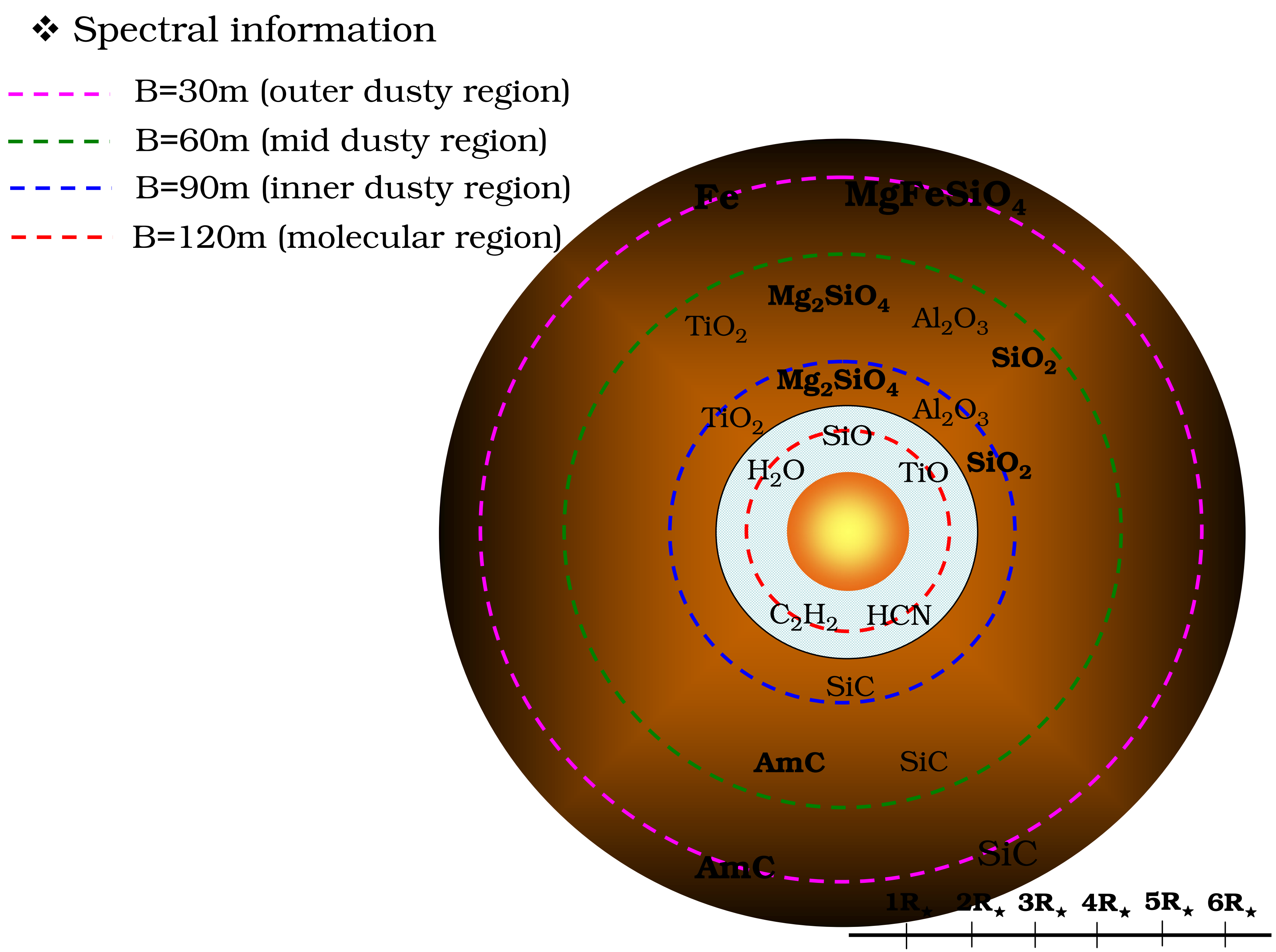
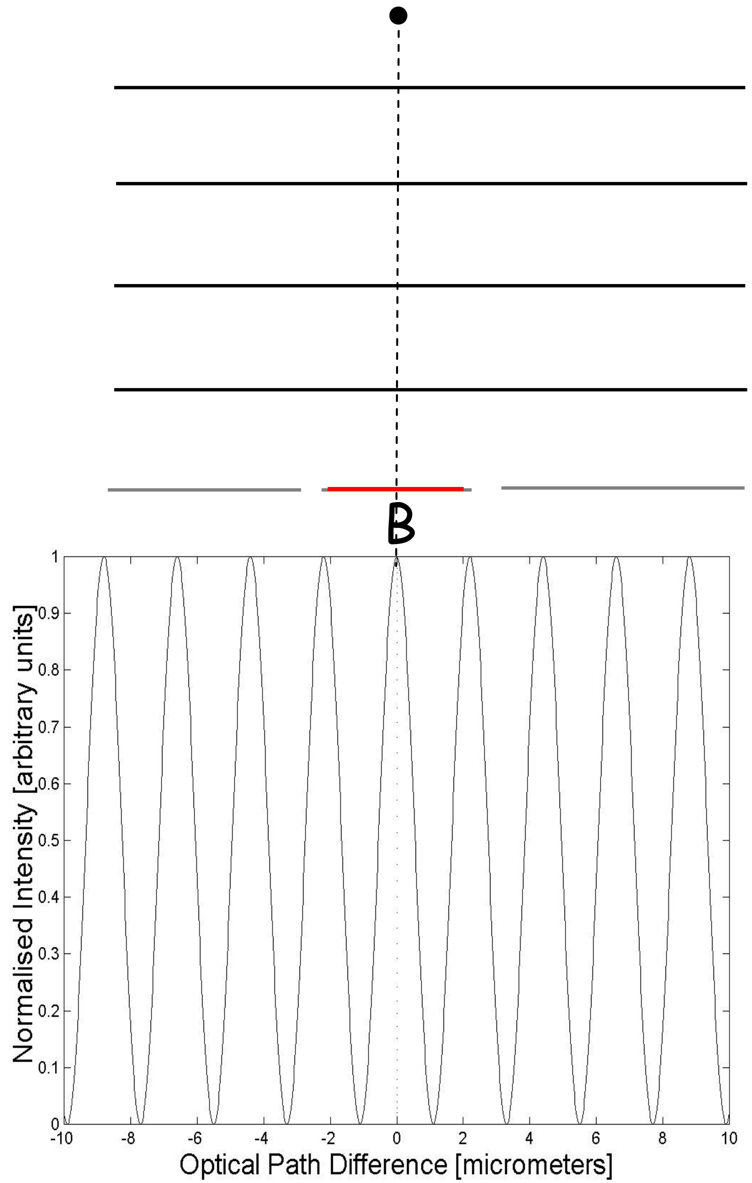



❖ Spectral information
B=30m (outer dusty region)
B=60m (mid dusty region)
B=90m (inner dusty region)
B=120m (molecular region)
1R⋆
2R⋆
3R⋆
4R⋆
5R⋆
6R⋆



❖ Spectral information
B=30m (outer dusty region)
B=60m (mid dusty region)
B=90m (inner dusty region)
B=120m (molecular region)
Fe
MgFeSiO4
Mg2SiO4
TiO2
Al2O3
SiO2
Mg2SiO4
TiO2
Al2O3
SiO2
SiO
H2O
TiO
C2H2
HCN
SiC
AmC
SiC
AmC
SiC
1R⋆
2R⋆
3R⋆
4R⋆
5R⋆
6R⋆

The Phase in Interferometry: $\boldsymbol{V} = V\, e^{-\mathbf{i}\phi}$

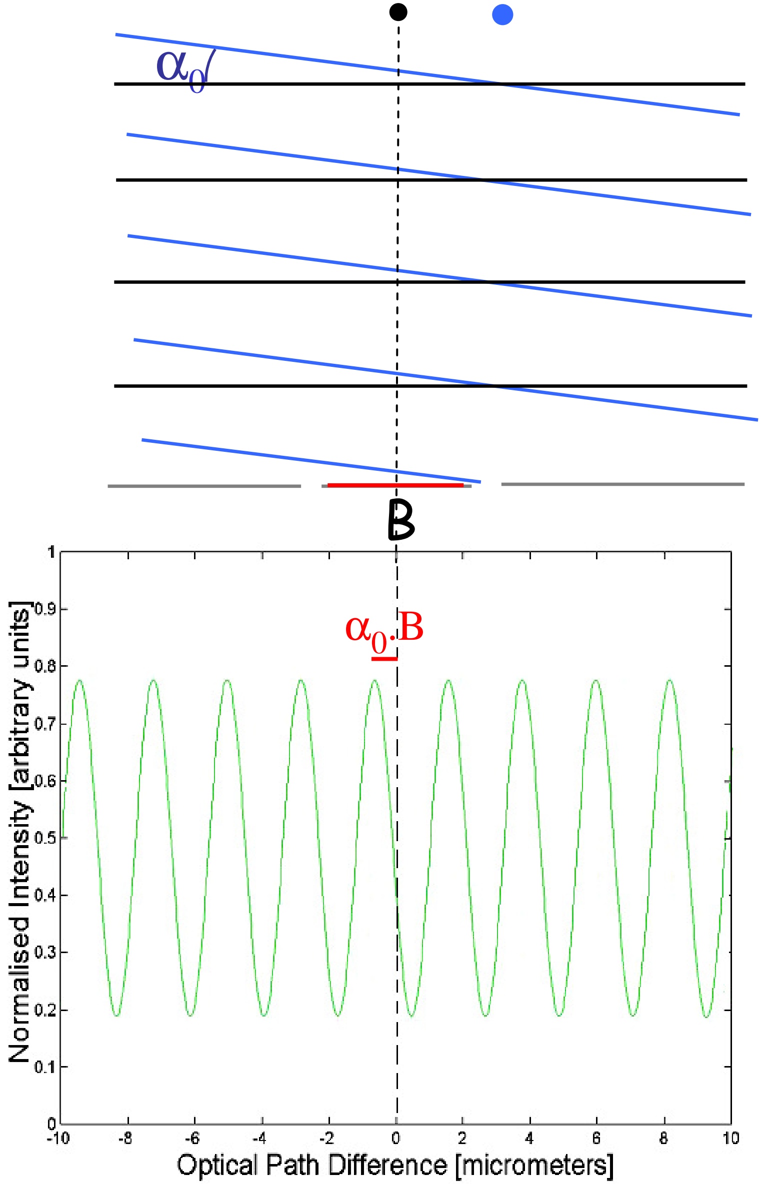


The Phase in Interferometry: $\mathbf{V} = V\, e^{-\mathbf{i}\phi}$

- Binary source at angle α_0 =>

displacement of the fringes by OPD = α_0.B

$$\phi = 2\pi \frac{OPD}{\lambda}$$



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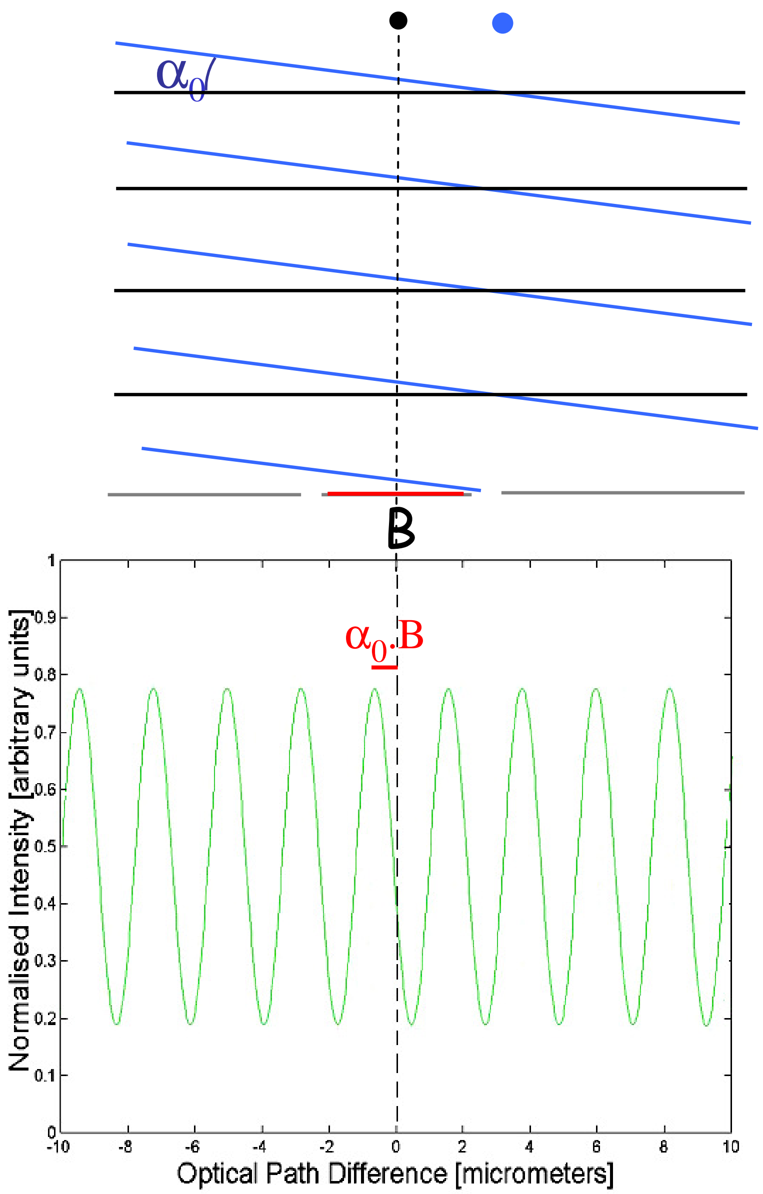
Van Cittert-Zernike theorem

$$\phi(u,v) = \arg[\hat{O}(u,v)] = atan\left[Im(\hat{O}) / Re(\hat{O}) \right]$$



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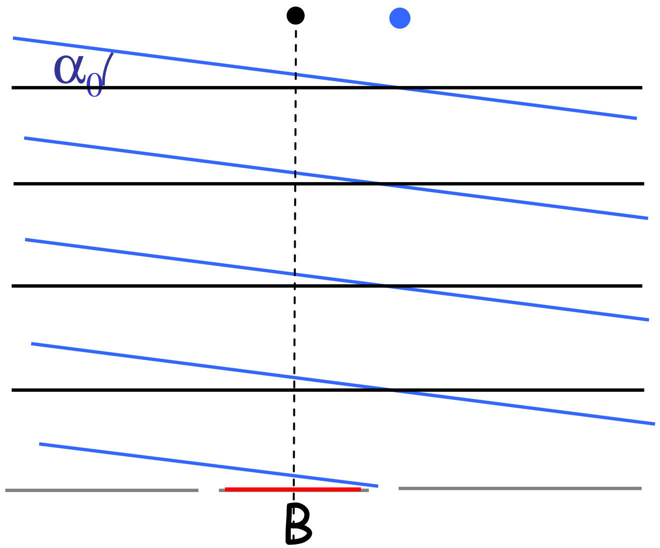
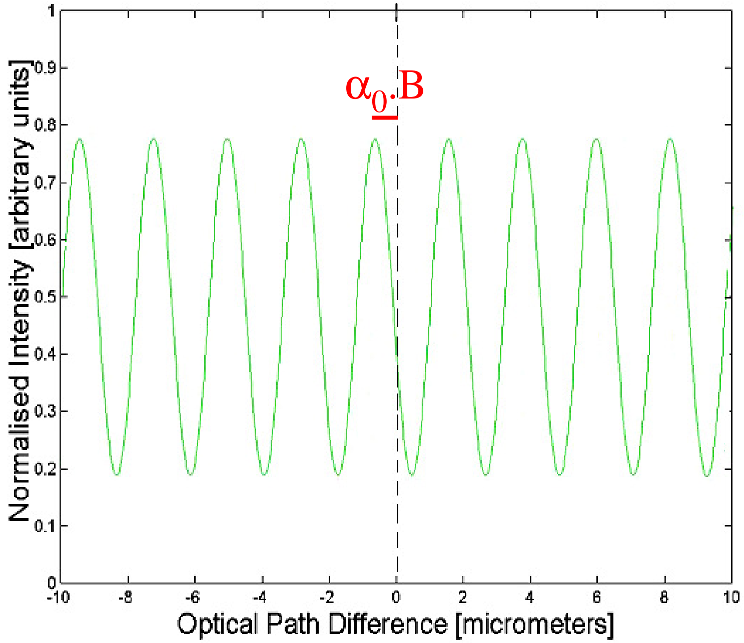
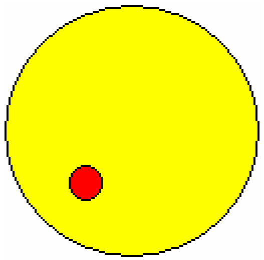




information on the asymmetries of an object



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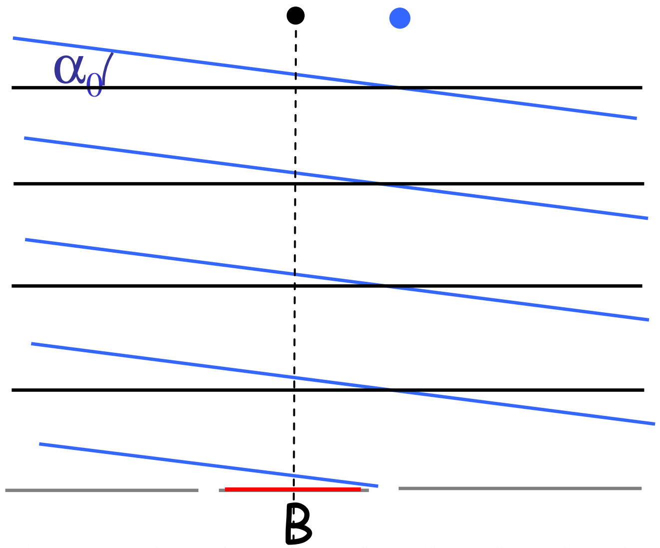

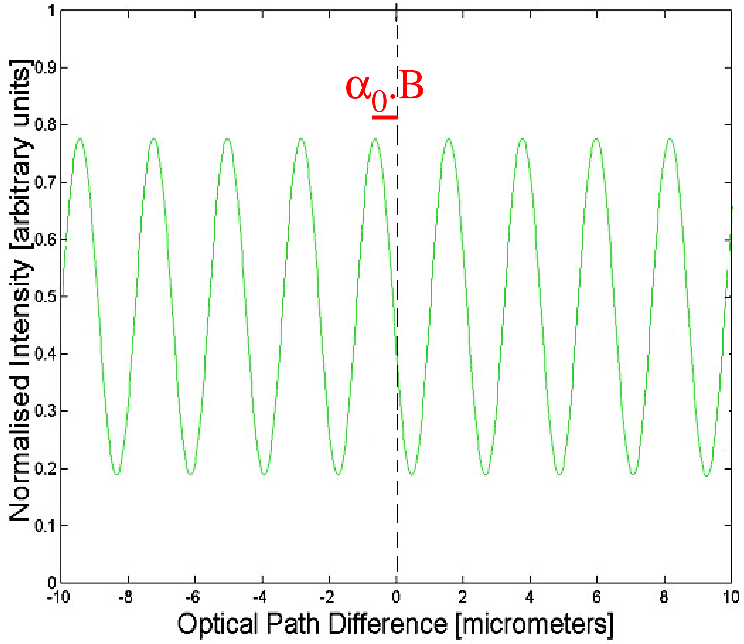

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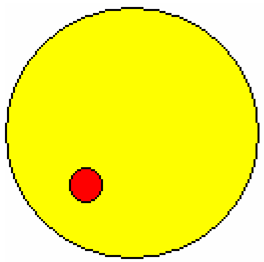


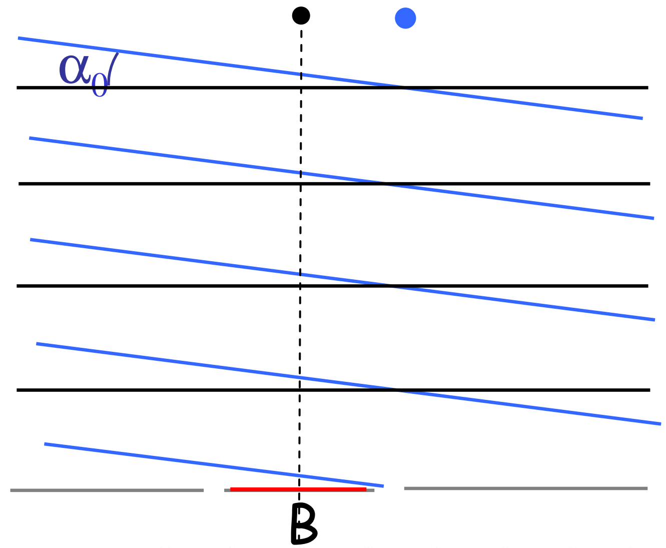
$$\phi^{12} = \phi^{12}_{obj} + \delta_2 - \delta_1$$

The Phase in Interferometry: $\boldsymbol{V} = V\, e^{-\mathbf{i}\phi}$

- Binary source at angle α_0 =>

displacement of the fringes by OPD = $\alpha_0 . B$

$$\phi = 2\pi \frac{OPD}{\lambda}$$



Van Cittert-Zernike theorem

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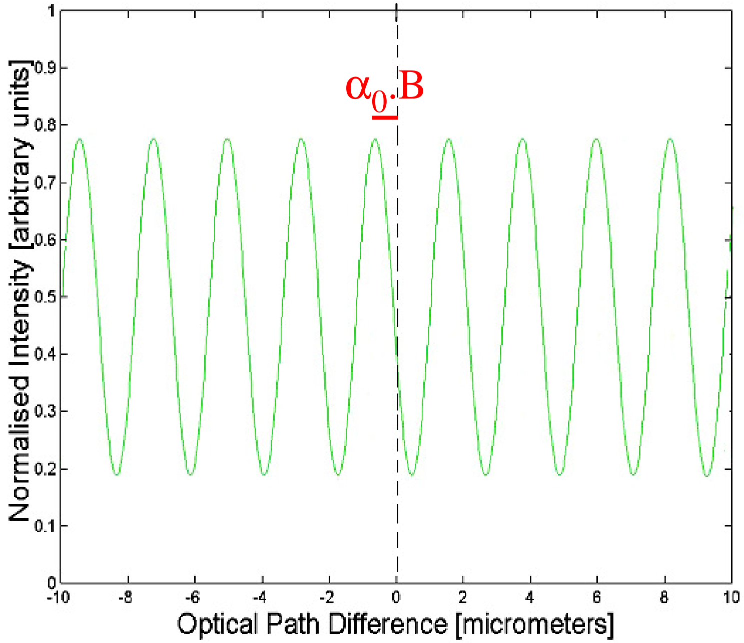
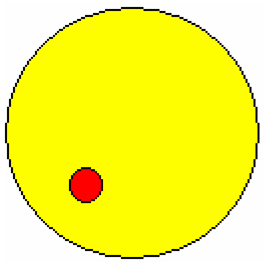


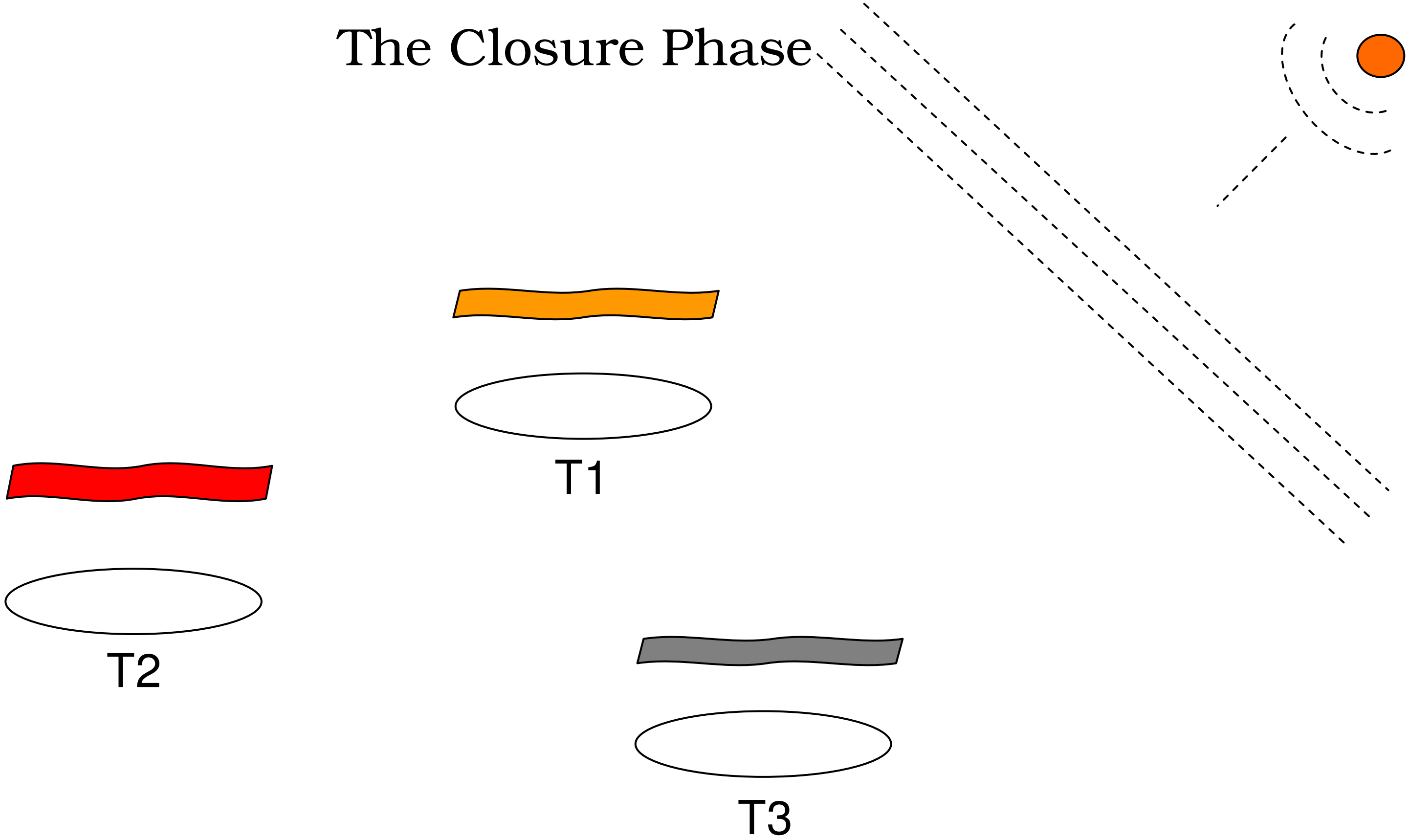
information on the asymmetries of an object



$$\phi^{12} = \phi^{12}_{obj} + \boxed{\delta_2 - \delta_1}$$

Atmospheric noise

The Closure Phase

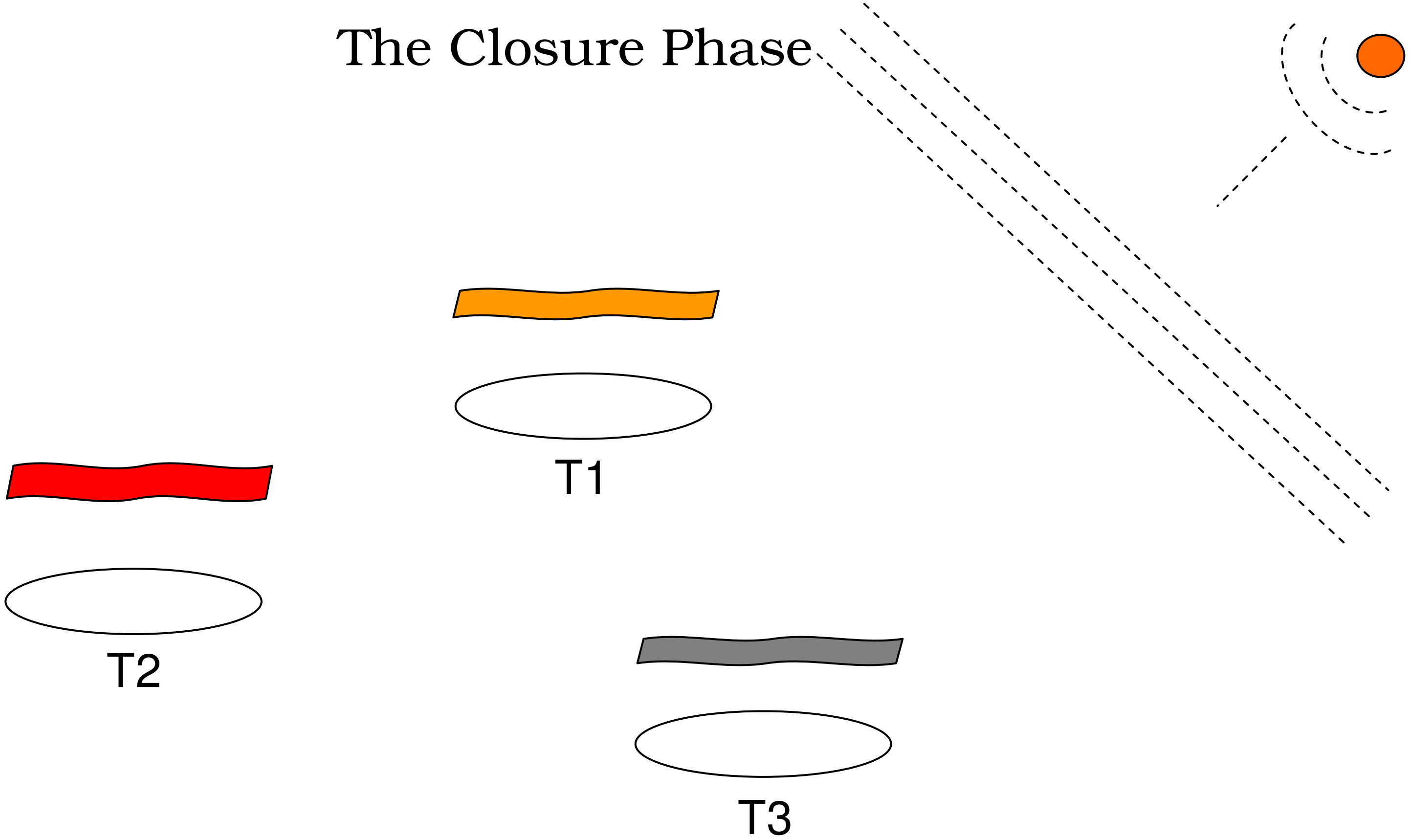


Observed	Object	Atmosphere

$$\phi^{12} = \phi^{12}_{obj} + \delta_2 - \delta_1$$
$$\phi^{23} = \phi^{23}_{obj} + \delta_3 - \delta_2$$
$$\phi^{31} = \phi^{31}_{obj} + \delta_1 - \delta_3$$

$$\phi_{123} = \phi^{12} + \phi^{23} + \phi^{31} = \phi^{12}_{obj} + \phi^{23}_{obj} + \phi^{31}_{obj}$$

The Closure Phase

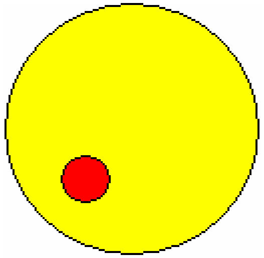


Observed	Object		Atmosphere
ϕ^{12}	$= \phi^{12}_{obj}$	$+$	$\delta_2 - \delta_1$
ϕ^{23}	$= \phi^{23}_{obj}$	$+$	$\delta_3 - \delta_2$
ϕ^{31}	$= \phi^{31}_{obj}$	$+$	$\delta_1 - \delta_3$

$$\phi_{123} = \phi^{12} + \phi^{23} + \phi^{31} = \phi^{12}_{obj} + \phi^{23}_{obj} + \phi^{31}_{obj}$$

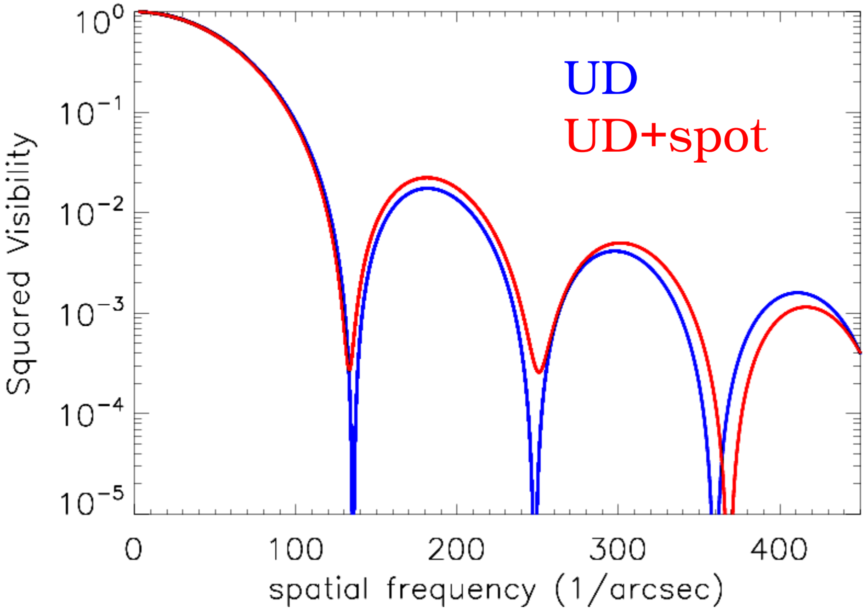
Object Only!!

An Example

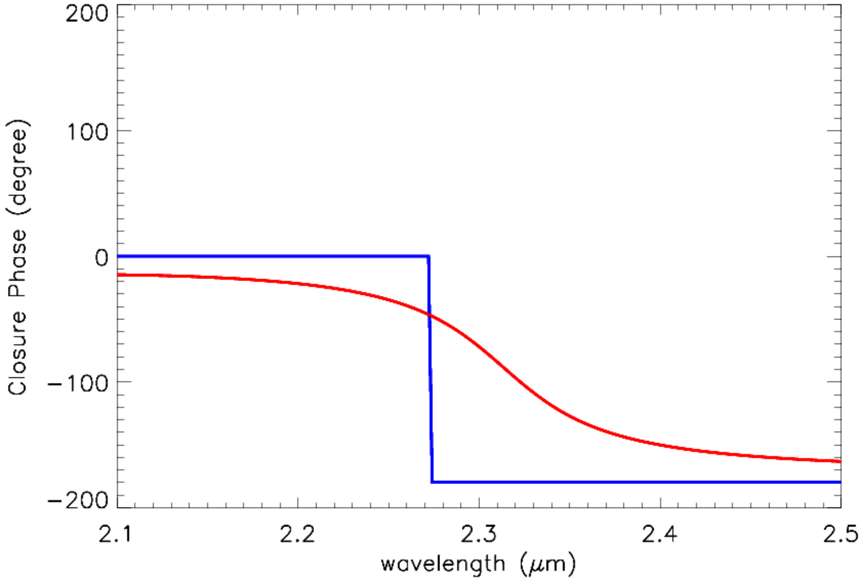


UD of 9 mas diameter with a spot of **2 mas** diameter on its surface representing **25%** of the total flux.

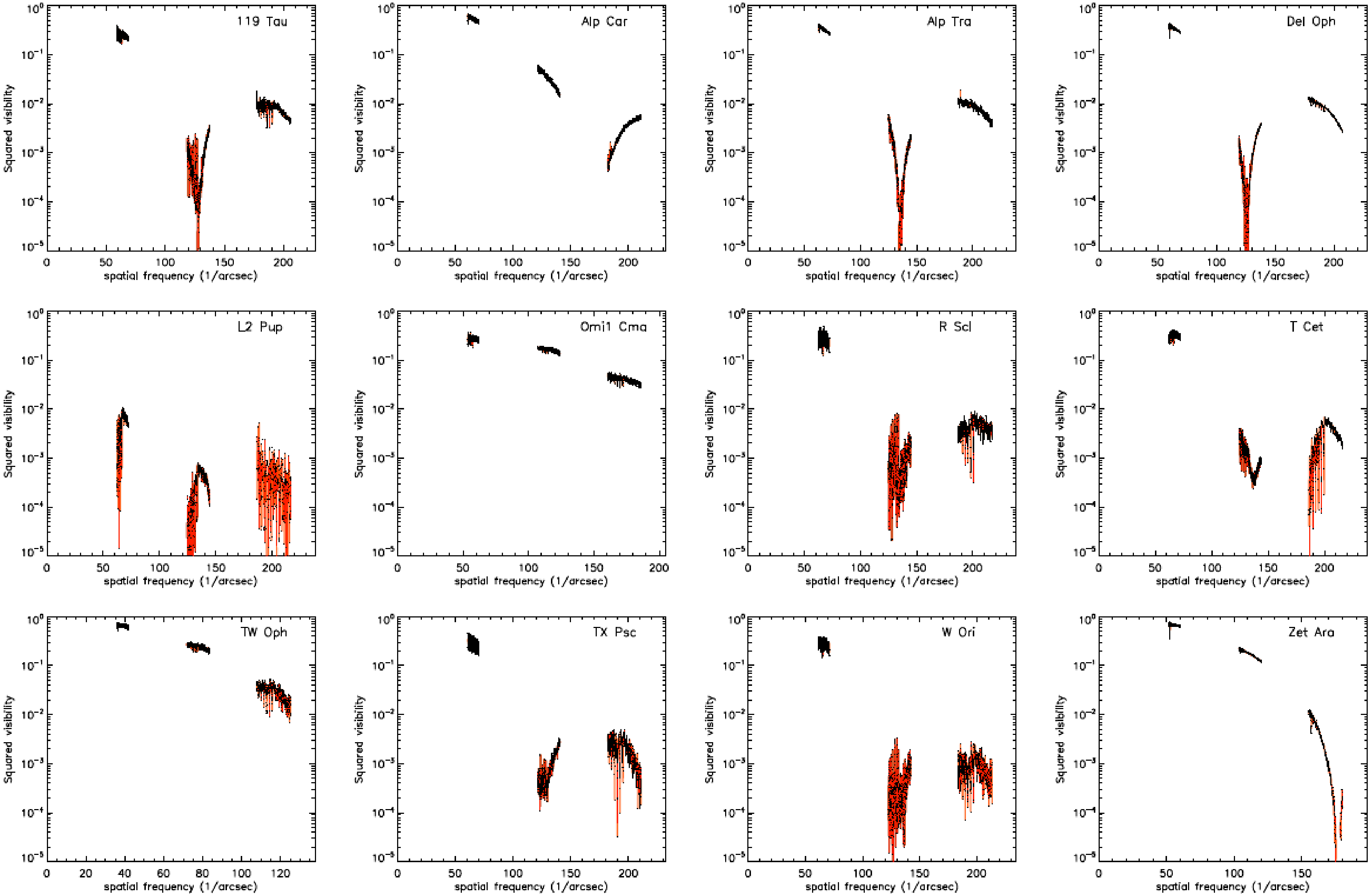
Fringe contrast



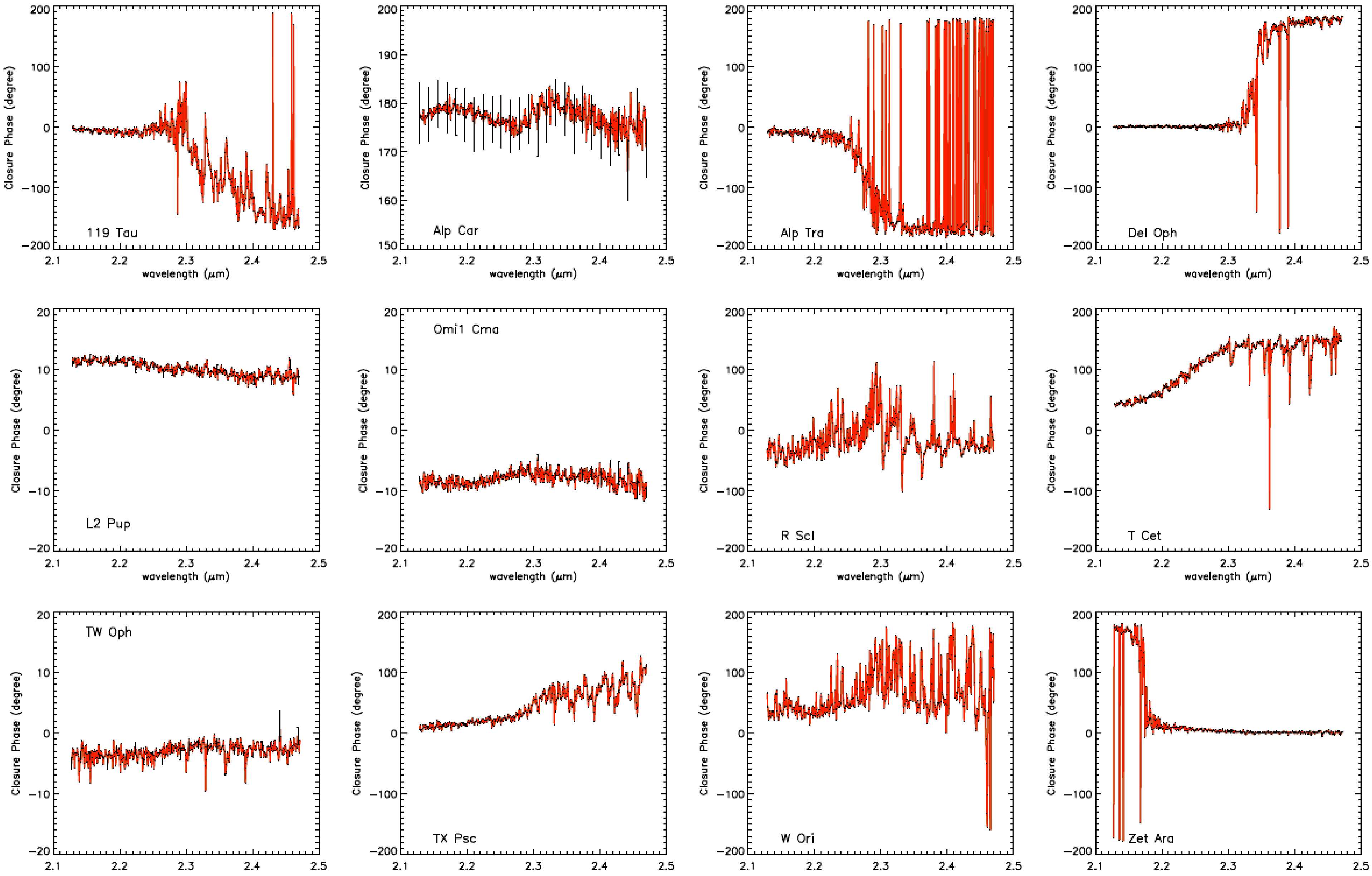
Closure Phase



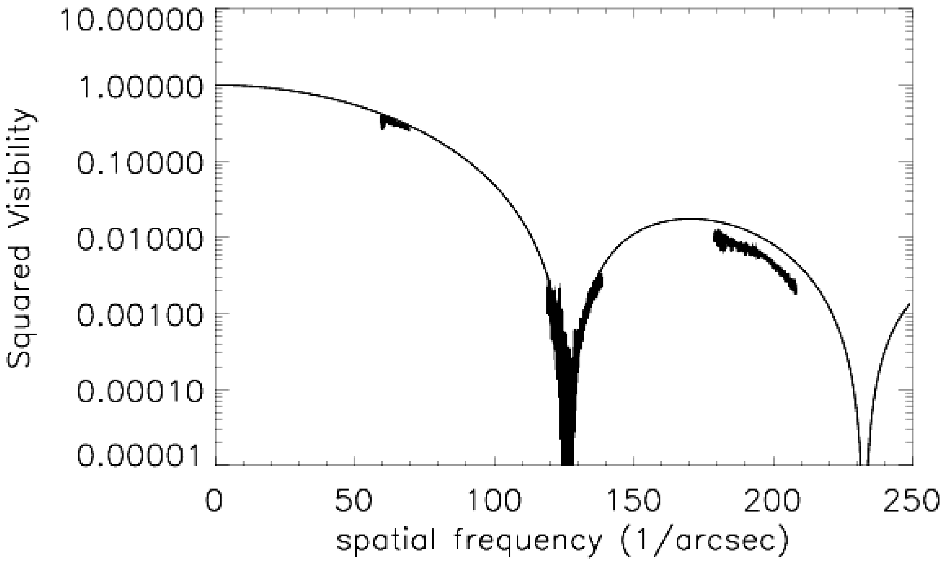
Real visibility data points (AMBER with 3 telescopes)



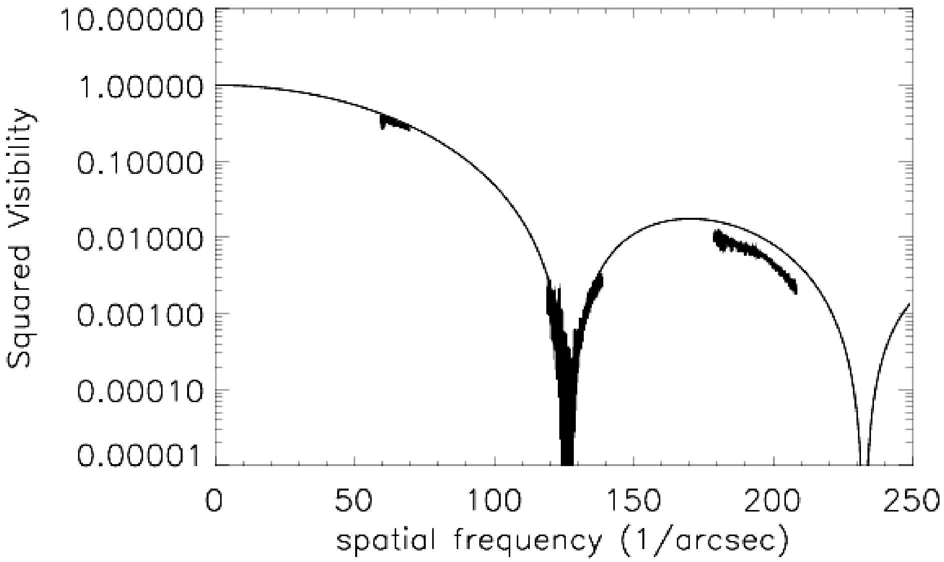
Closure Phase data

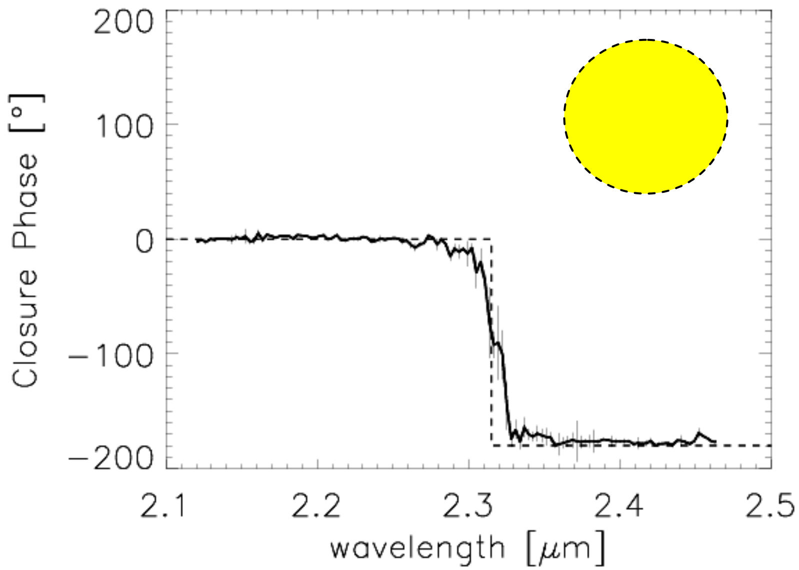


Model vs Data (part I)

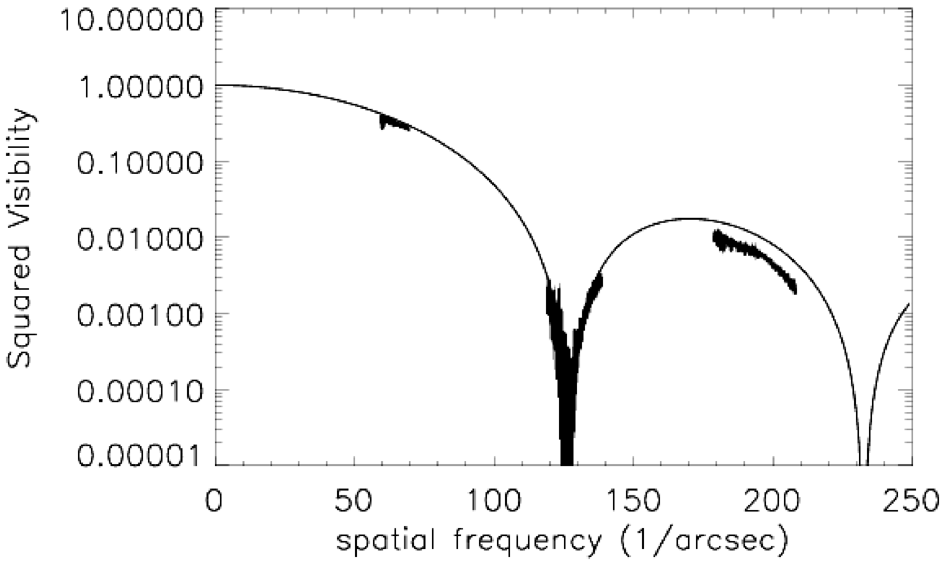


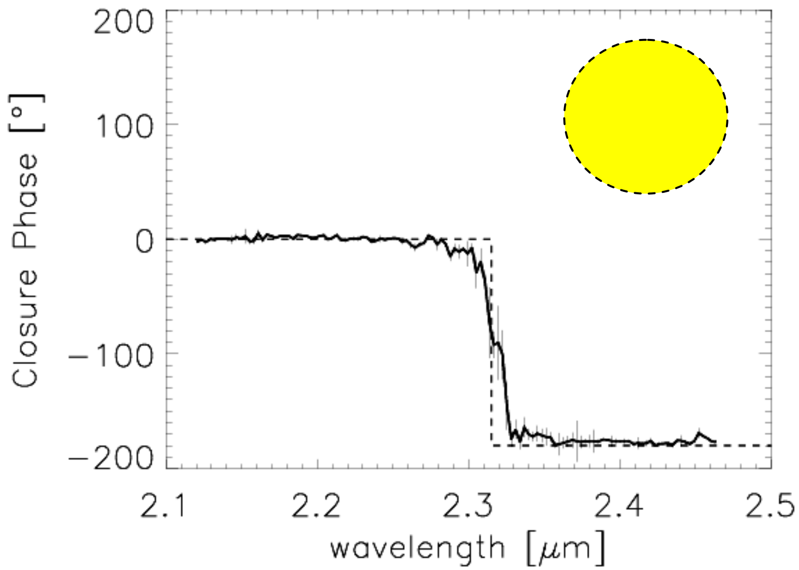
Model vs Data (part I)

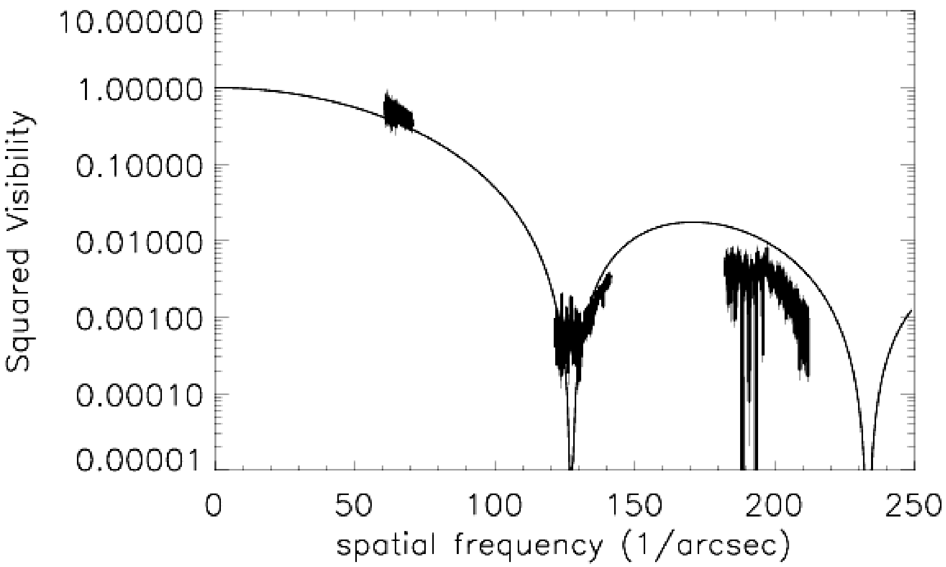




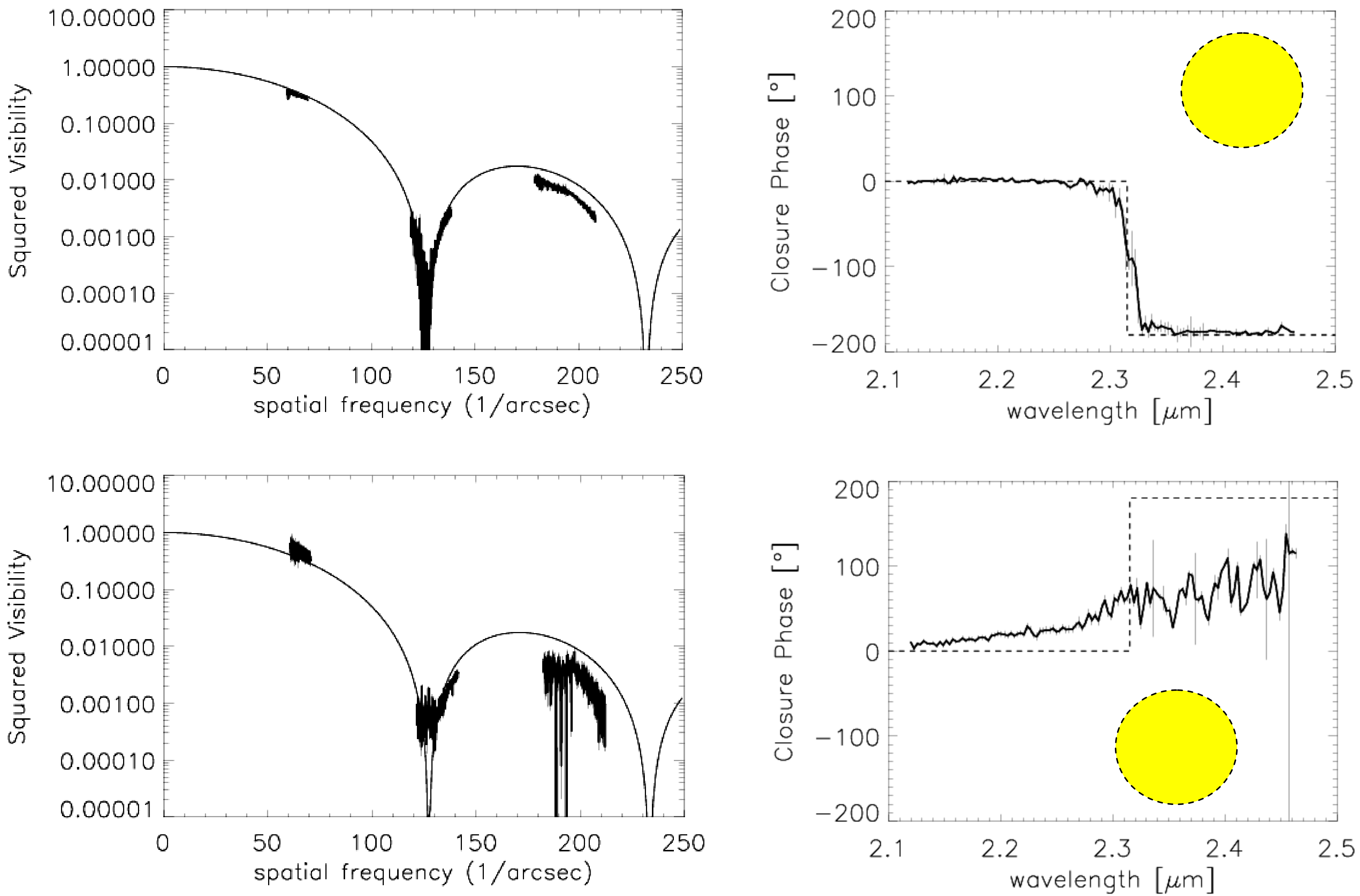
Model vs Data (part I)



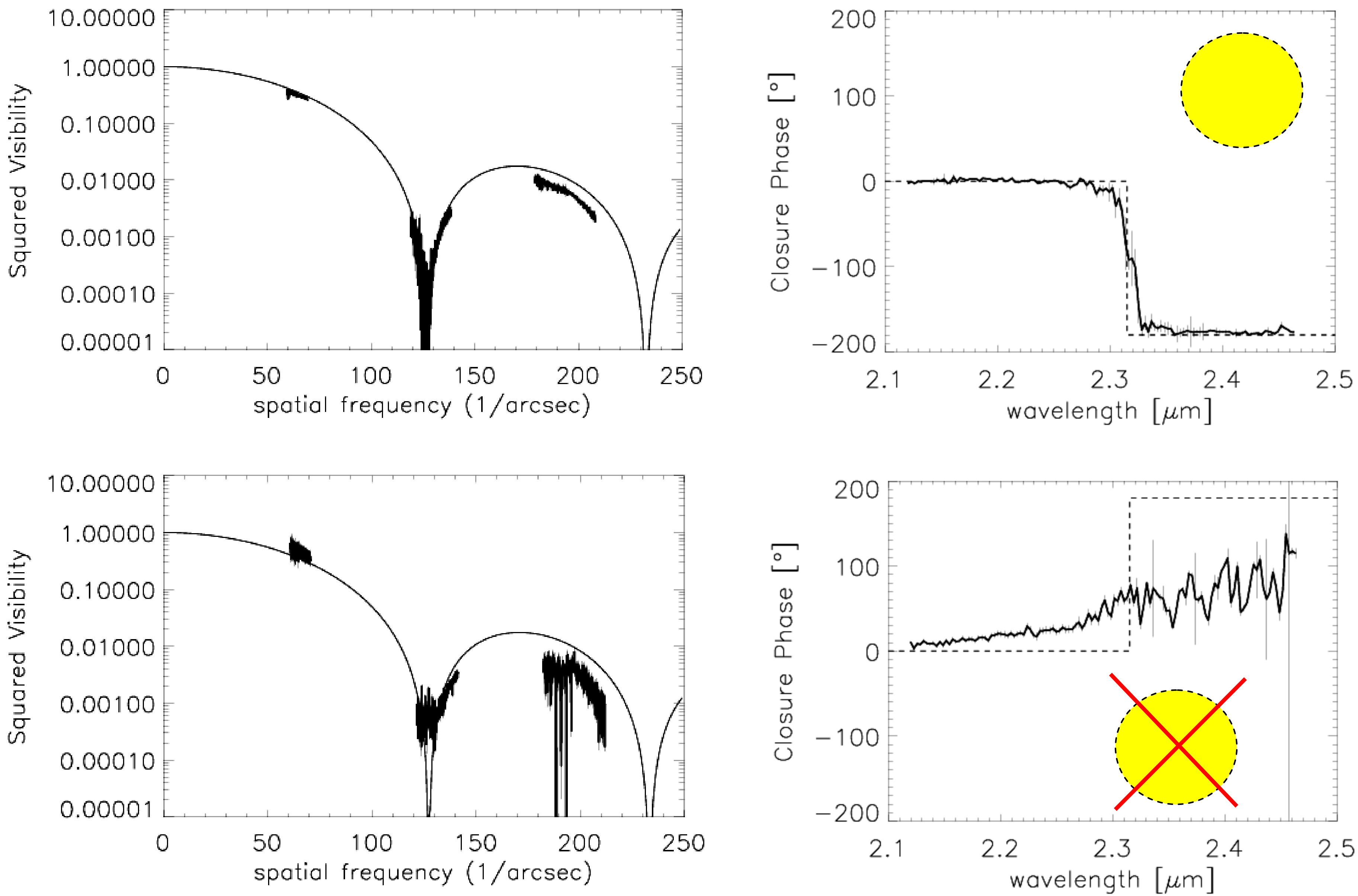




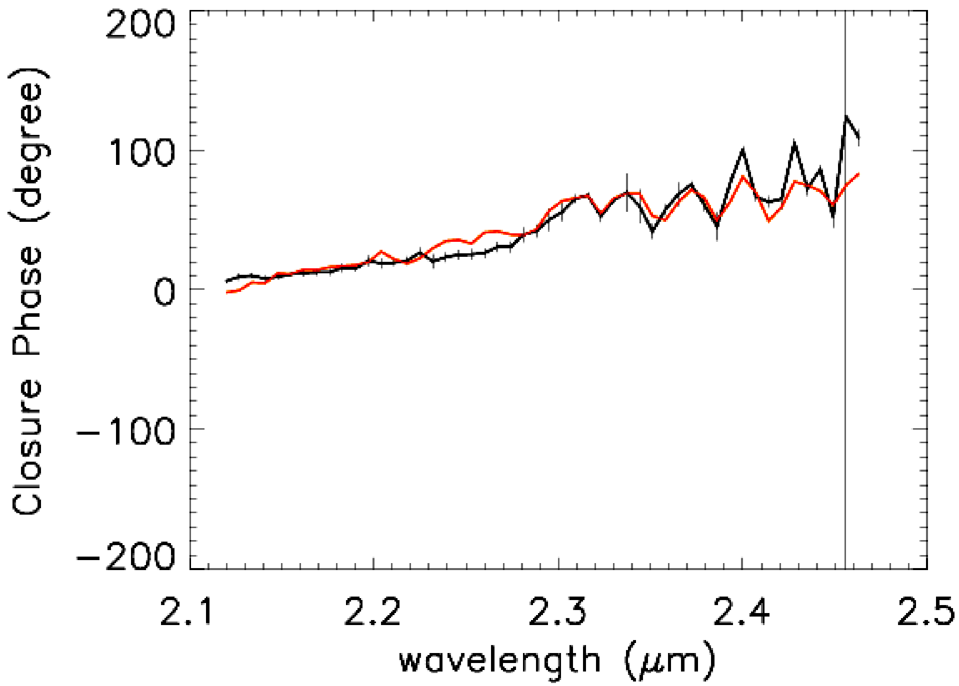
Model vs Data (part I)

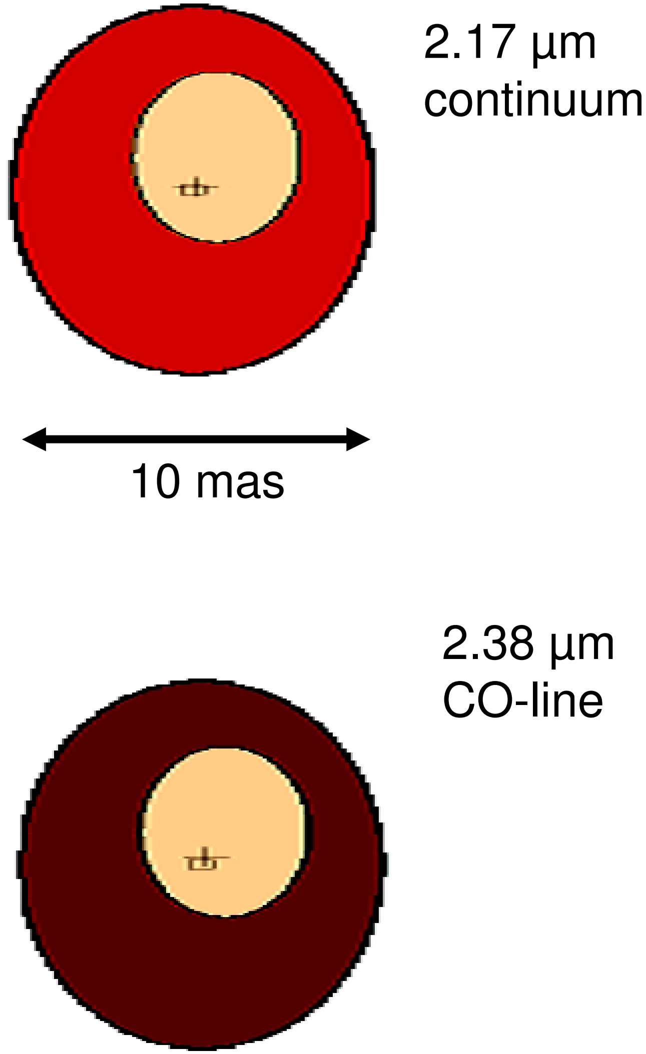


Model vs Data (part I)



Model vs Data (part II)





The calibration in Interferometry

The need for accurate determination of the calibrator diameters

Calibrated visibility | *System response*

$$V = \frac{V_{\mathrm{sci,raw}}}{R_{\mathrm{V}}}$$

where

$$R_{\mathrm{V}} = \frac{V_{\mathrm{cal,raw}}}{V_{\mathrm{cal,model}}}$$

The need for accurate determination of the calibrator diameters

Calibrated visibility — *System response*

$$V = \frac{V_{\mathrm{sci,raw}}}{R_{\mathrm{V}}} \quad \textit{where} \quad R_{\mathrm{V}} = \frac{V_{\mathrm{cal,raw}}}{V_{\mathrm{cal,model}}}$$

Unresolved calibrator

$$V_{\mathrm{cal,model}} = 1$$

Error on visibility solely due to uncertainty on the calibrator diameter

$$\frac{\Delta V}{V} = 0$$

The need for accurate determination of the calibrator diameters

Calibrated visibility *System response*

$$V = \frac{V_{\mathrm{sci,raw}}}{R_{\mathrm{V}}} \quad \textit{where} \quad R_{\mathrm{V}} = \frac{V_{\mathrm{cal,raw}}}{V_{\mathrm{cal,model}}}$$

Unresolved calibrator

$$V_{\mathrm{cal,model}} = 1$$

Error on visibility solely due to uncertainty on the calibrator diameter

$$\frac{\Delta V}{V} = 0$$

The need for accurate determination of the calibrator diameters

Calibrated visibility *System response*

$$V = \frac{V_{\mathrm{sci,raw}}}{R_{\mathrm{V}}} \quad \textit{where} \quad R_{\mathrm{V}} = \frac{V_{\mathrm{cal,raw}}}{V_{\mathrm{cal,model}}}$$

Unresolved calibrator

$$V_{\mathrm{cal,model}} = 1$$

Resolved calibrator

$$V_{\mathrm{cal,model}} = 2\left|\frac{J_1\left(\pi\phi_{\mathrm{cal}}\frac{B_{\mathrm{p}}}{\lambda}\right)}{\pi\phi_{\mathrm{cal}}\frac{B_{\mathrm{p}}}{\lambda}}\right|$$

Error on visibility solely due to uncertainty on the calibrator diameter

$$\frac{\Delta V}{V} = 0$$

$$\frac{\Delta V}{V} = \frac{\pi B\phi_{\mathrm{cal}}}{\lambda}\frac{J_2\left(\frac{\pi B\phi_{\mathrm{cal}}}{\lambda}\right)}{J_1\left(\frac{\pi B\phi_{\mathrm{cal}}}{\lambda}\right)}\frac{\Delta\phi_{\mathrm{cal}}}{\phi_{\mathrm{cal}}}$$

The need for accurate determination of the calibrator diameters

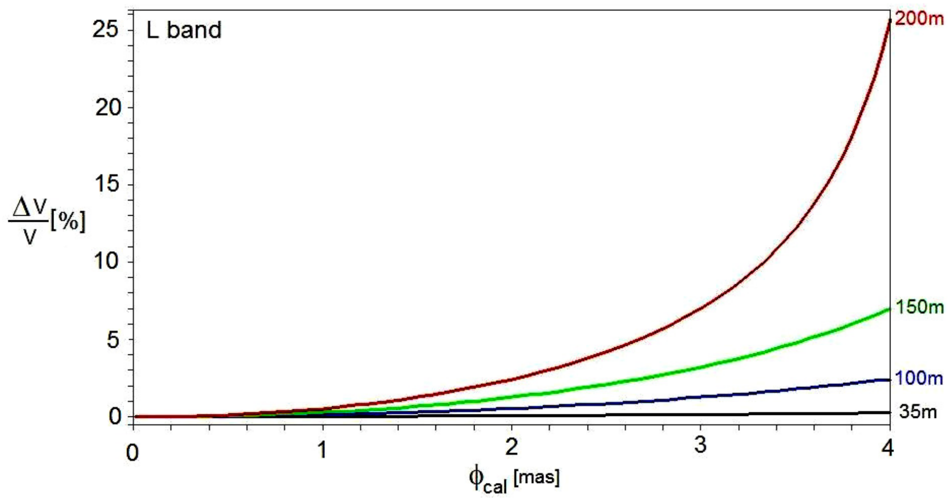
Calibrated visibility | *System response*

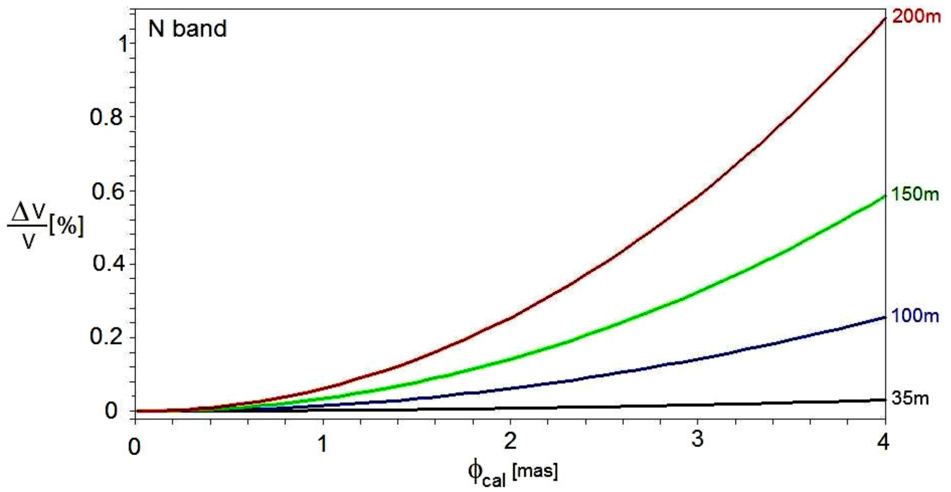
$$V = \frac{V_{\mathrm{sci,raw}}}{R_{\mathrm{V}}} \quad \textit{where} \quad R_{\mathrm{V}} = \frac{V_{\mathrm{cal,raw}}}{V_{\mathrm{cal,model}}}$$

Unresolved calibrator	***Resolved calibrator***
$V_{\mathrm{cal,model}} = 1$	$V_{\mathrm{cal,model}} = 2\left\lvert \dfrac{J_1\left(\pi\phi_{\mathrm{cal}}\frac{B_{\mathrm{p}}}{\lambda}\right)}{\pi\phi_{\mathrm{cal}}\frac{B_{\mathrm{p}}}{\lambda}} \right\rvert$
Error on visibility solely due to uncertainty on the calibrator diameter $\dfrac{\Delta V}{V} = 0$	$\dfrac{\Delta V}{V} = \dfrac{\pi B\phi_{\mathrm{cal}}}{\lambda} \dfrac{J_2\left(\frac{\pi B\phi_{\mathrm{cal}}}{\lambda}\right)}{J_1\left(\frac{\pi B\phi_{\mathrm{cal}}}{\lambda}\right)} \dfrac{\Delta\phi_{\mathrm{cal}}}{\phi_{\mathrm{cal}}}$

Effects of diameter uncertainties on the visibility accuracy

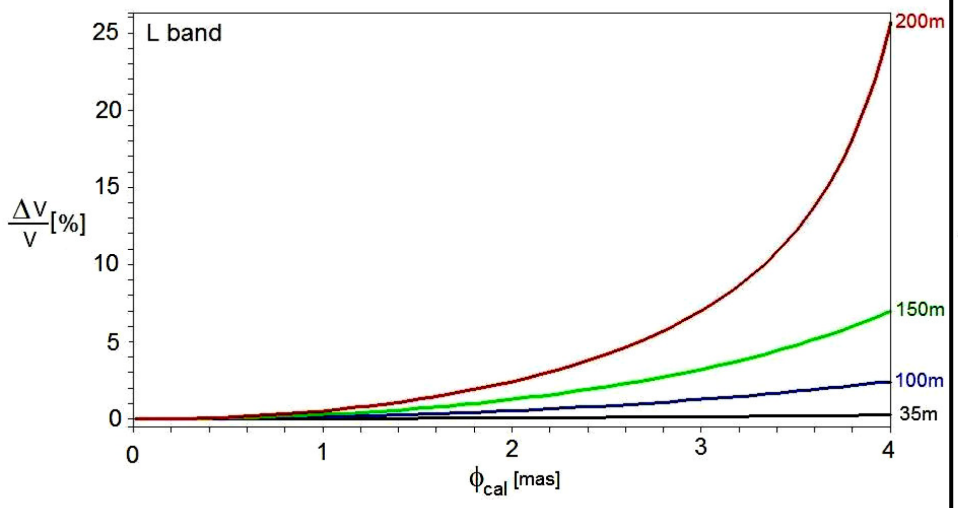
$\Delta\phi_{cal}/\phi_{cal} = 3\%$

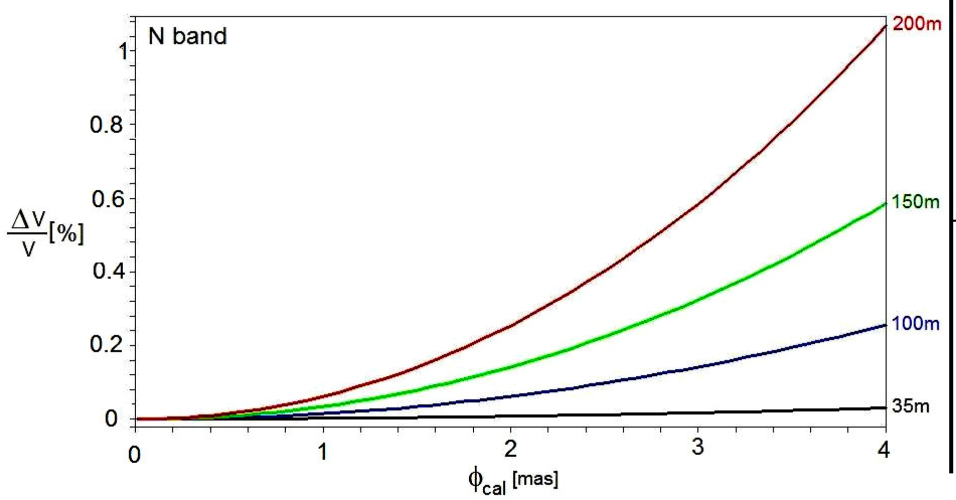




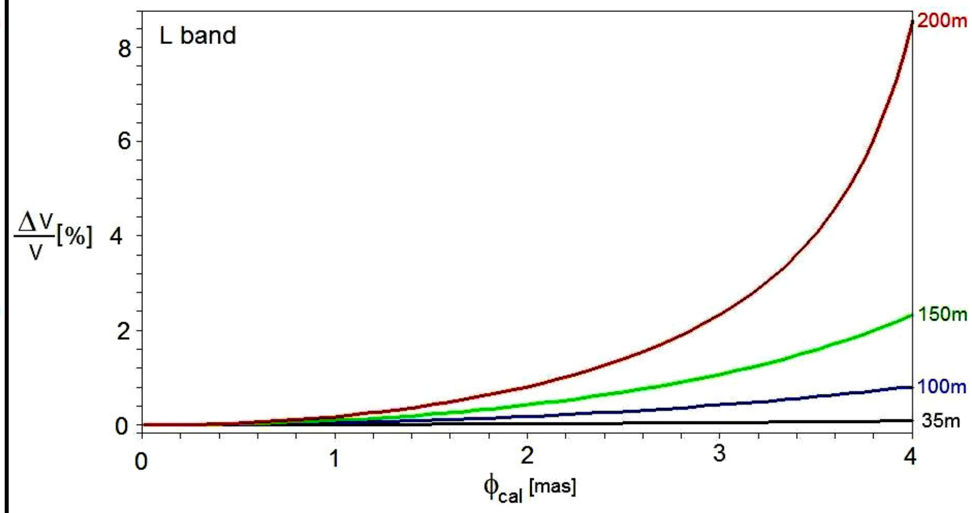
Effects of diameter uncertainties on the visibility accuracy

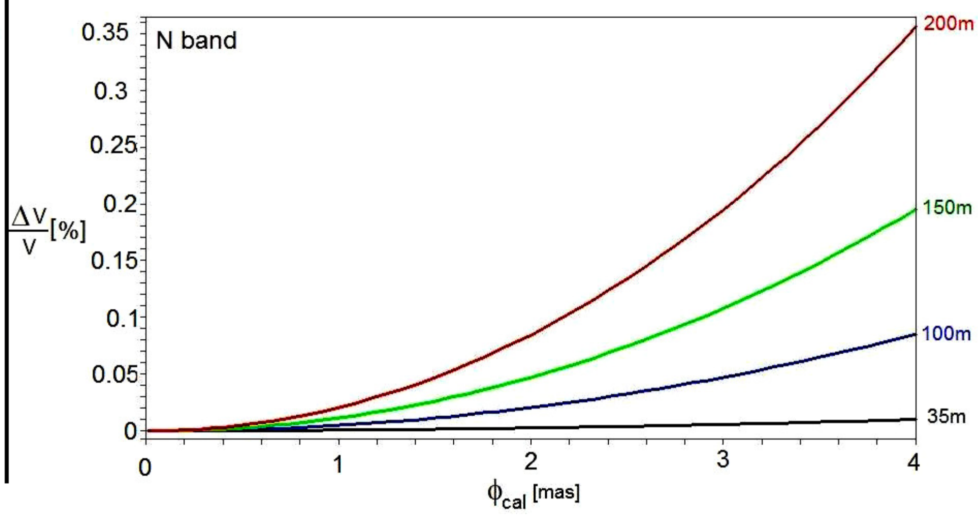
$\Delta\phi_{cal}/\phi_{cal}$= 3%





$\Delta\phi_{cal}/\phi_{cal}$= 1%





ASPRO

The Astronomical Software to PRepare Observations

How to launch ASPRO in the web?

http://www.jmmc.fr/aspro_page.htm

JMMC

JEAN-MARIE MARIOTTI CENTER
Infrared and Optical Interferometry for Astronomy

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  - Partners
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  - VLTI proposals
- Data processing
  - VINCI
  - MIDI
  - AMBER
- User support
- Site map
- Development

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ASPRO:
The Astronomical Software to PRepare Observations

ASPRO is a complete software suite developed and maintained by the JMMC that allows to prepare interferometric observations with the VLTI or other interferometers. It allows in particular to simulate the projected baseline evolution during the observations (supersynthesis), derive the visibilities for a given object (single star, binaries, user defined FITS image,...), and offers many additional useful functions. A description of the JMMC Working Group on the developement of ASPRO can be found on this page.

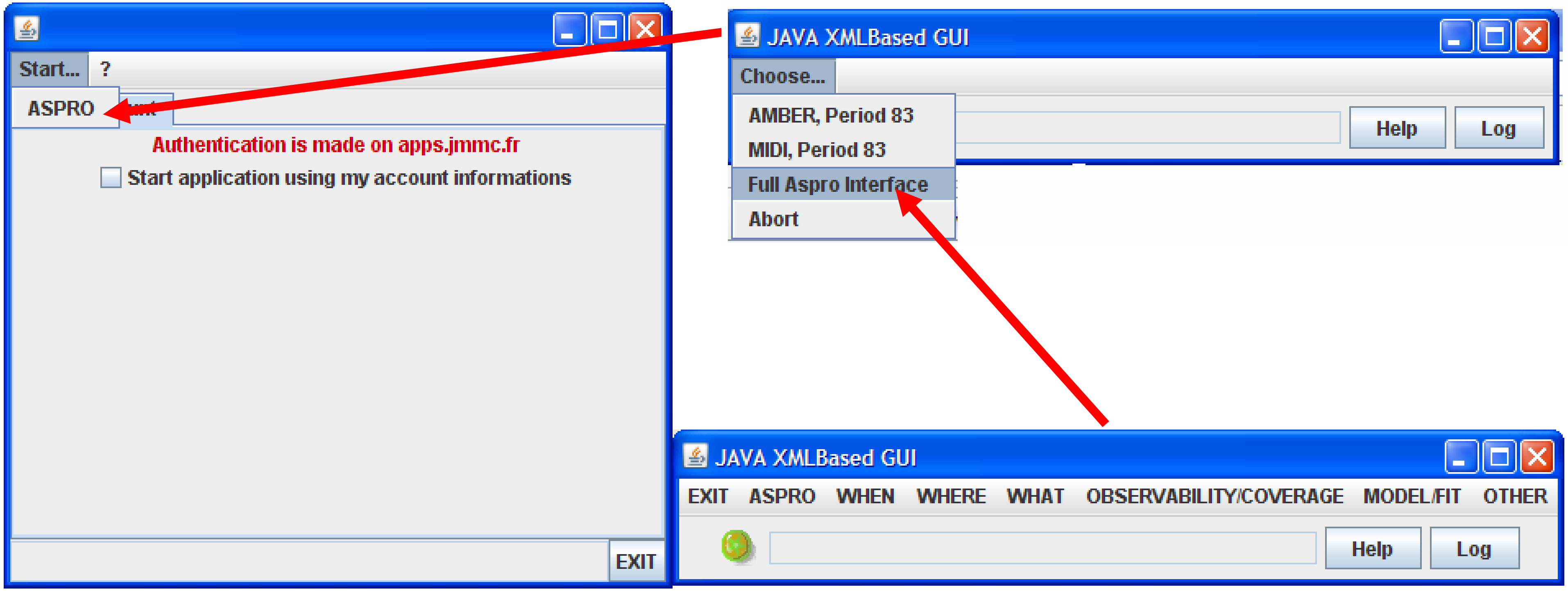
You can access the JMMC shared softwares running on our servers through Java applications

aspro WebStart

Java WebStart Application

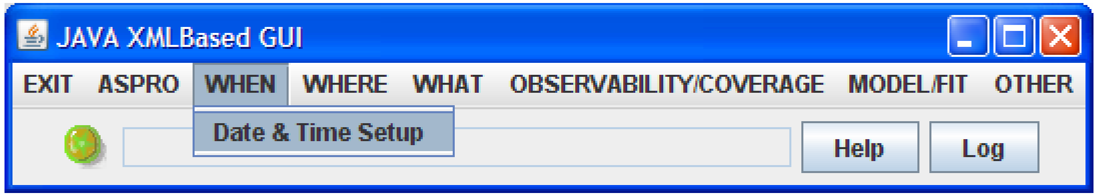
The java software used run ASPRO requires java web start. **For more information about the installation of Java for your platform and the associated configurations, please refer to this page**. If you can't use java web start, please contact User support to find an issue with your configuration.

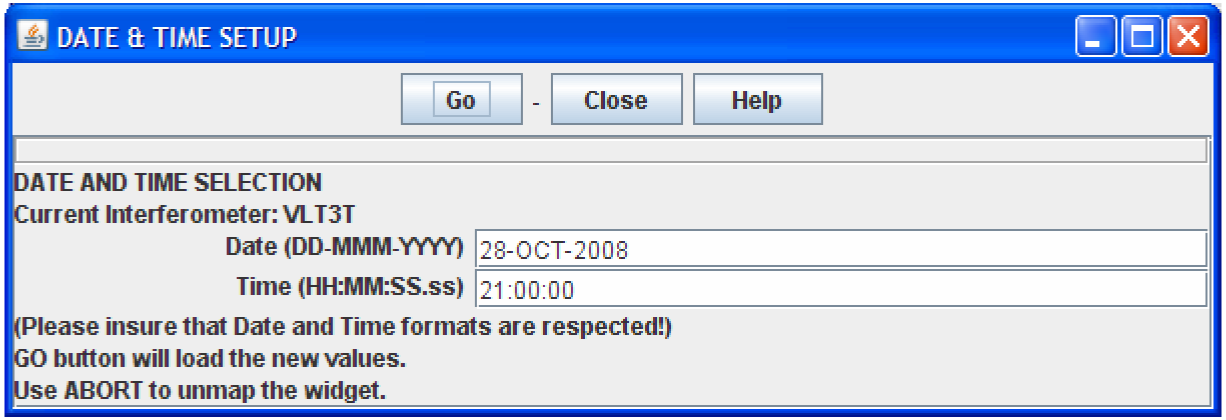
The interface



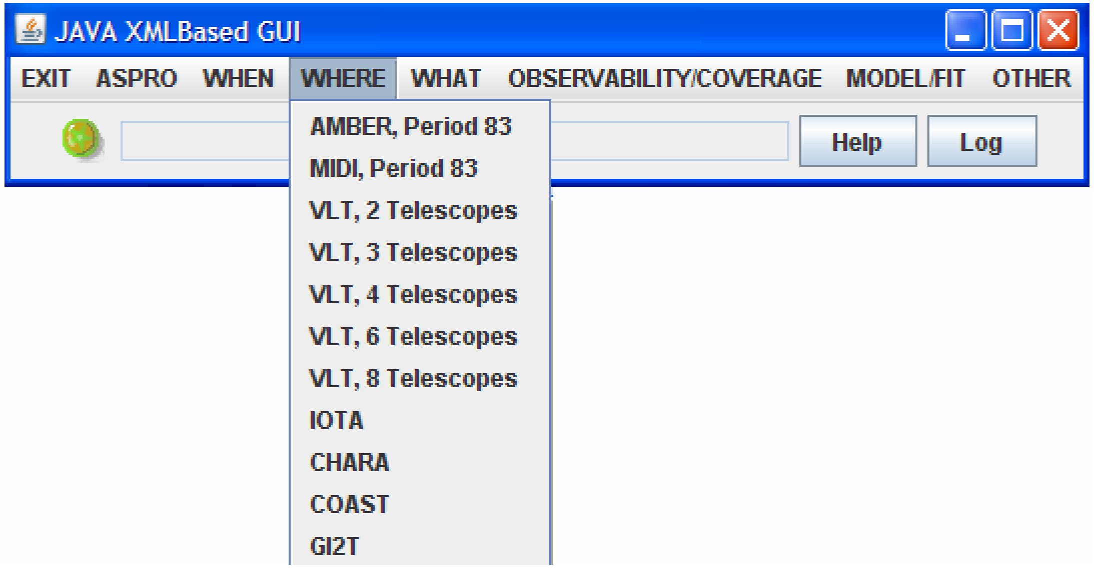
- **WHEN:** to define the date and time of the simulated observation
- **WHERE**: to select the interferometer (VLTI, IOTA, CHARA, …) and the number of telescopes
- **WHAT**: to define the target properties (name, coordinates, brightness);
- **OBSERVABILITY/COVERAGE**: to define the VLTI configuration to be used for the observations
- **MODEL/FIT**: to calculate and plot interferometric observables and their associated uncertainties according to the chosen model (UD, LD, Binary, …) and the corresponding baseline configuration.

When

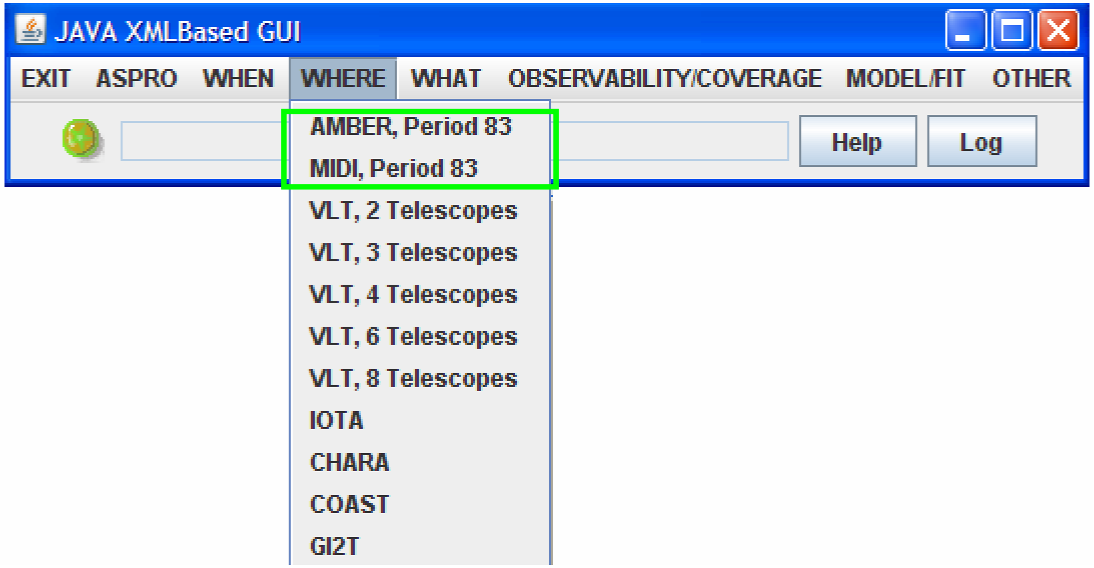

JAVA XMLBased GUI
EXIT
ASPRO
WHEN
WHERE
WHAT
OBSERVABILITY/COVERAGE
MODEL/FIT
OTHER
Date & Time Setup
Help
Log


DATE & TIME SETUP
Go
-
Close
Help
DATE AND TIME SELECTION
Current Interferometer: VLT3T
Date (DD-MMM-YYYY)
28-OCT-2008
Time (HH:MM:SS.ss)
21:00:00
(Please insure that Date and Time formats are respected!)
GO button will load the new values.
Use ABORT to unmap the widget.

Where


JAVA XMLBased GUI
EXIT
ASPRO
WHEN
WHERE
WHAT
OBSERVABILITY/COVERAGE
MODEL/FIT
OTHER
Help
Log
AMBER, Period 83
MIDI, Period 83
VLT, 2 Telescopes
VLT, 3 Telescopes
VLT, 4 Telescopes
VLT, 6 Telescopes
VLT, 8 Telescopes
IOTA
CHARA
COAST
GI2T

Where


JAVA XMLBased GUI
EXIT
ASPRO
WHEN
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WHAT
OBSERVABILITY/COVERAGE
MODEL/FIT
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AMBER, Period 83
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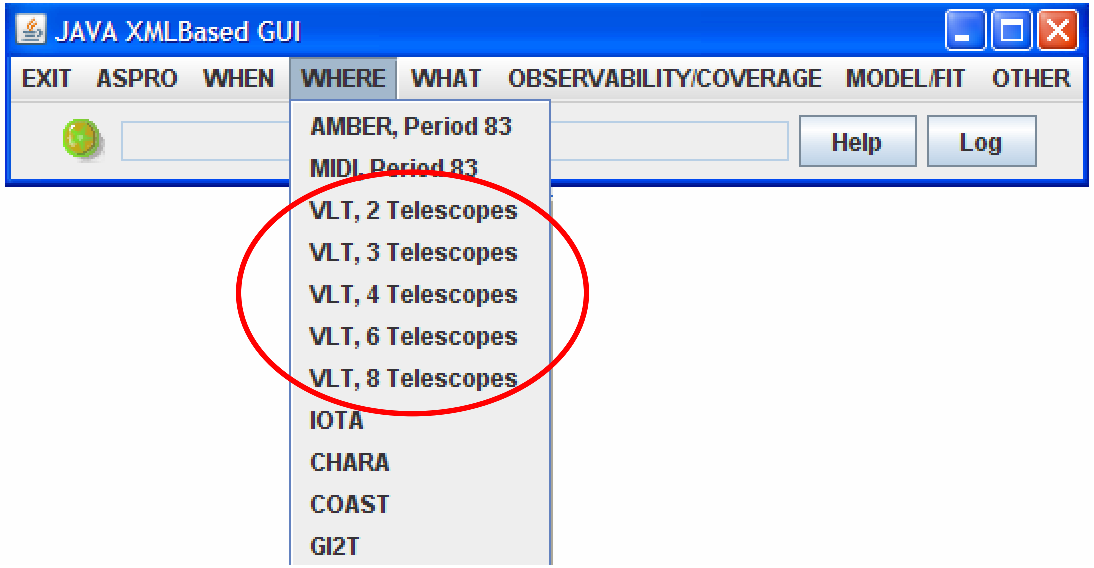
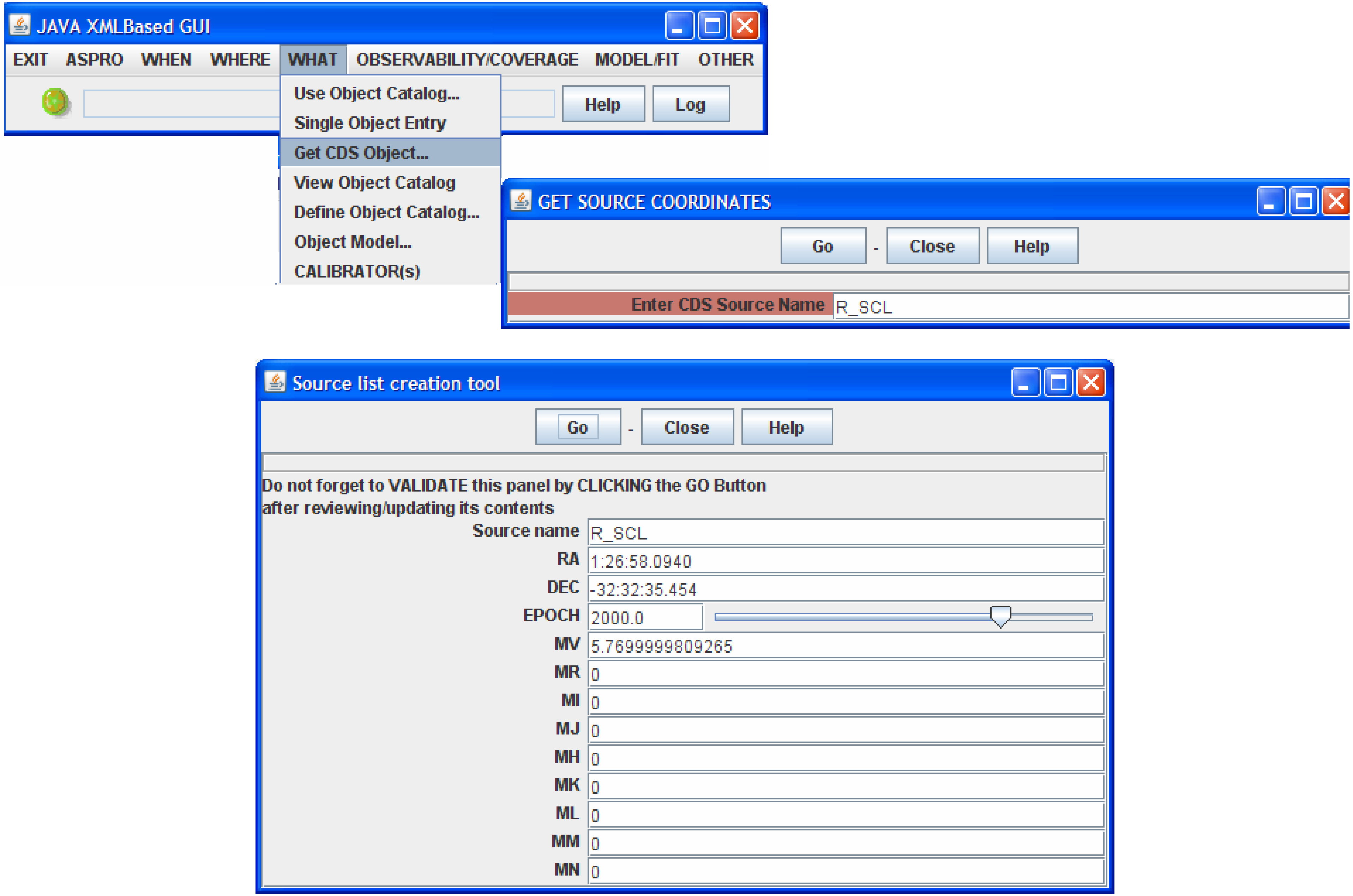
VLT, 2 Telescopes
VLT, 3 Telescopes
VLT, 4 Telescopes
VLT, 6 Telescopes
VLT, 8 Telescopes
IOTA
CHARA
COAST
GI2T

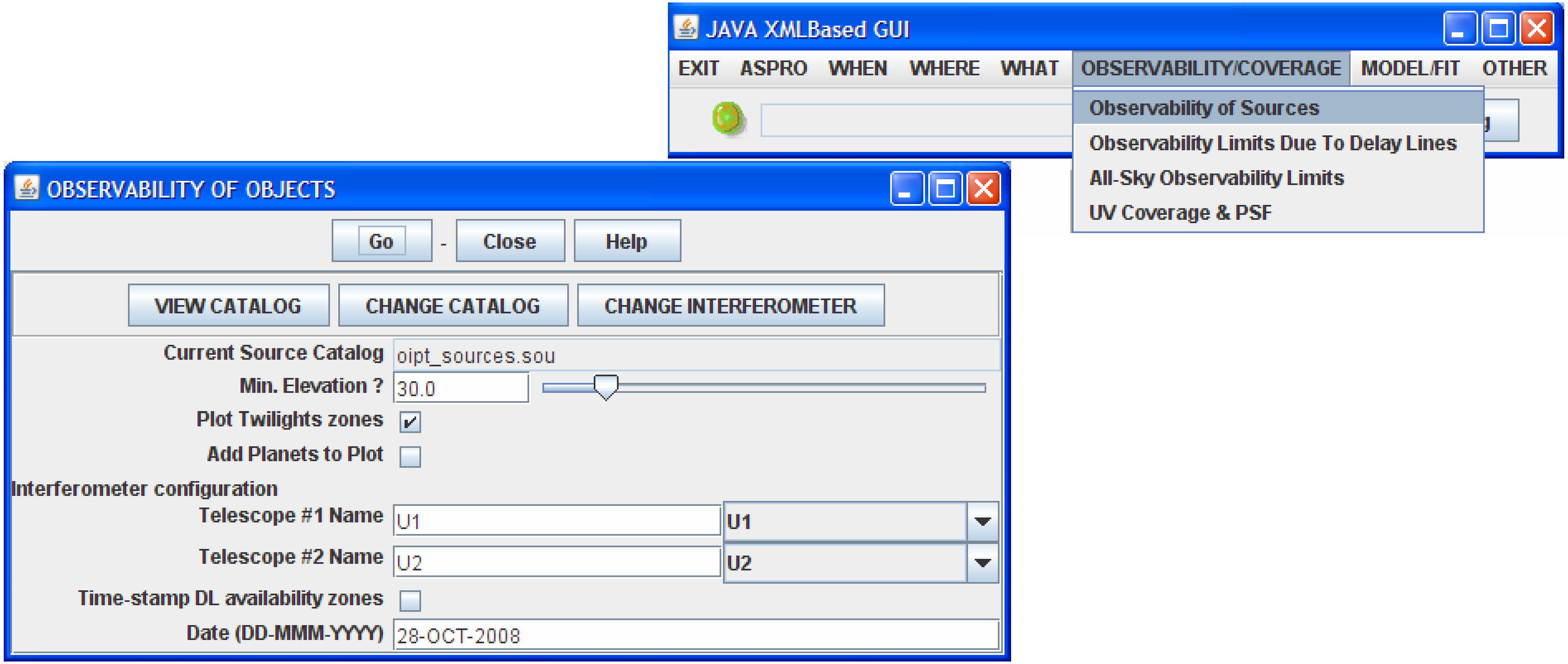
Where


JAVA XMLBased GUI
EXIT
ASPRO
WHEN
WHERE
WHAT
OBSERVABILITY/COVERAGE
MODEL/FIT
OTHER
Help
Log
AMBER, Period 83
MIDI, Period 83
VLT, 2 Telescopes
VLT, 3 Telescopes
VLT, 4 Telescopes
VLT, 6 Telescopes
VLT, 8 Telescopes
IOTA
CHARA
COAST
GI2T

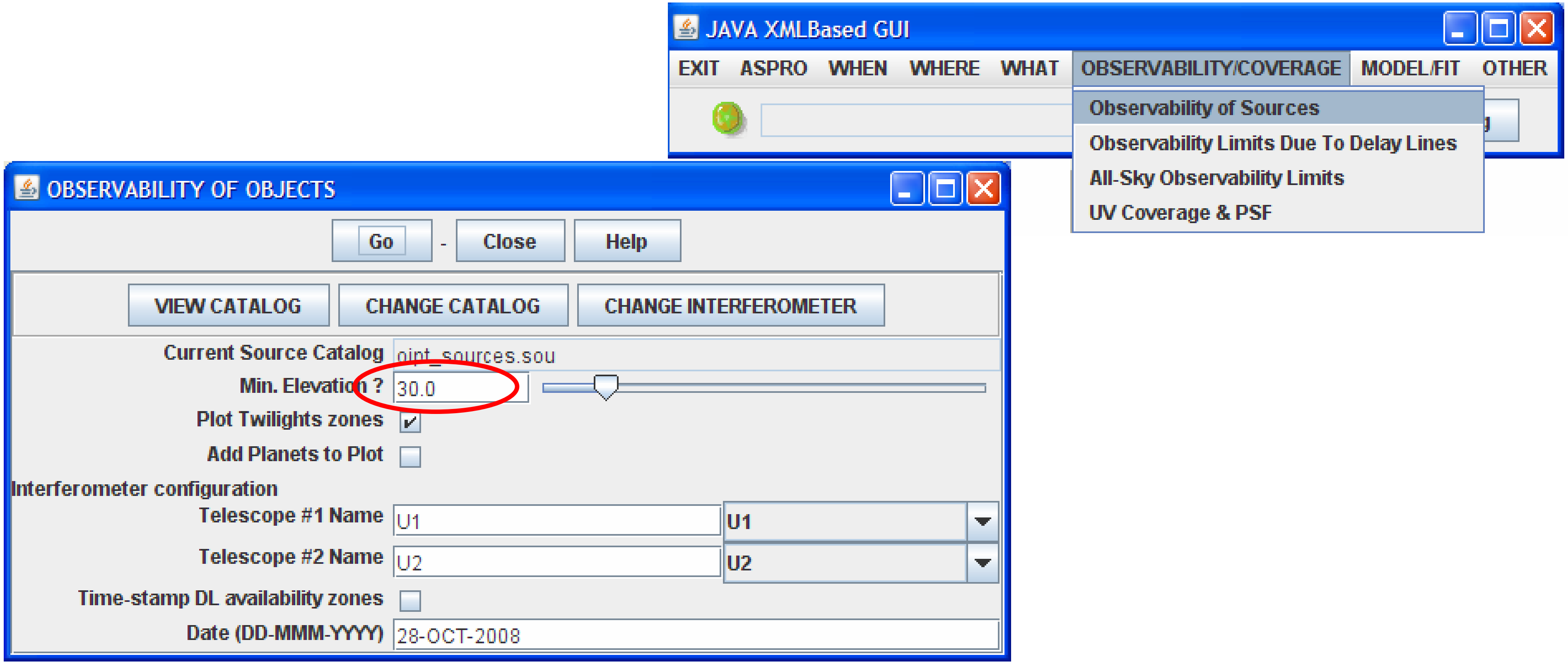
What


JAVA XMLBased GUI
EXIT
ASPRO
WHEN
WHERE
WHAT
OBSERVABILITY/COVERAGE
MODEL/FIT
OTHER
Help
Log
Use Object Catalog...
Single Object Entry
Get CDS Object...
View Object Catalog
Define Object Catalog...
Object Model...
CALIBRATOR(s)
GET SOURCE COORDINATES
Go
Close
Help
Enter CDS Source Name
R_SCL
Source list creation tool
Go
Close
Help
Do not forget to VALIDATE this panel by CLICKING the GO Button
after reviewing/updating its contents
Source name R_SCL
RA 1:26:58.0940
DEC -32:32:35.454
EPOCH 2000.0
MV 5.7699999809265
MR 0
MI 0
MJ 0
MH 0
MK 0
ML 0
MM 0
MN 0

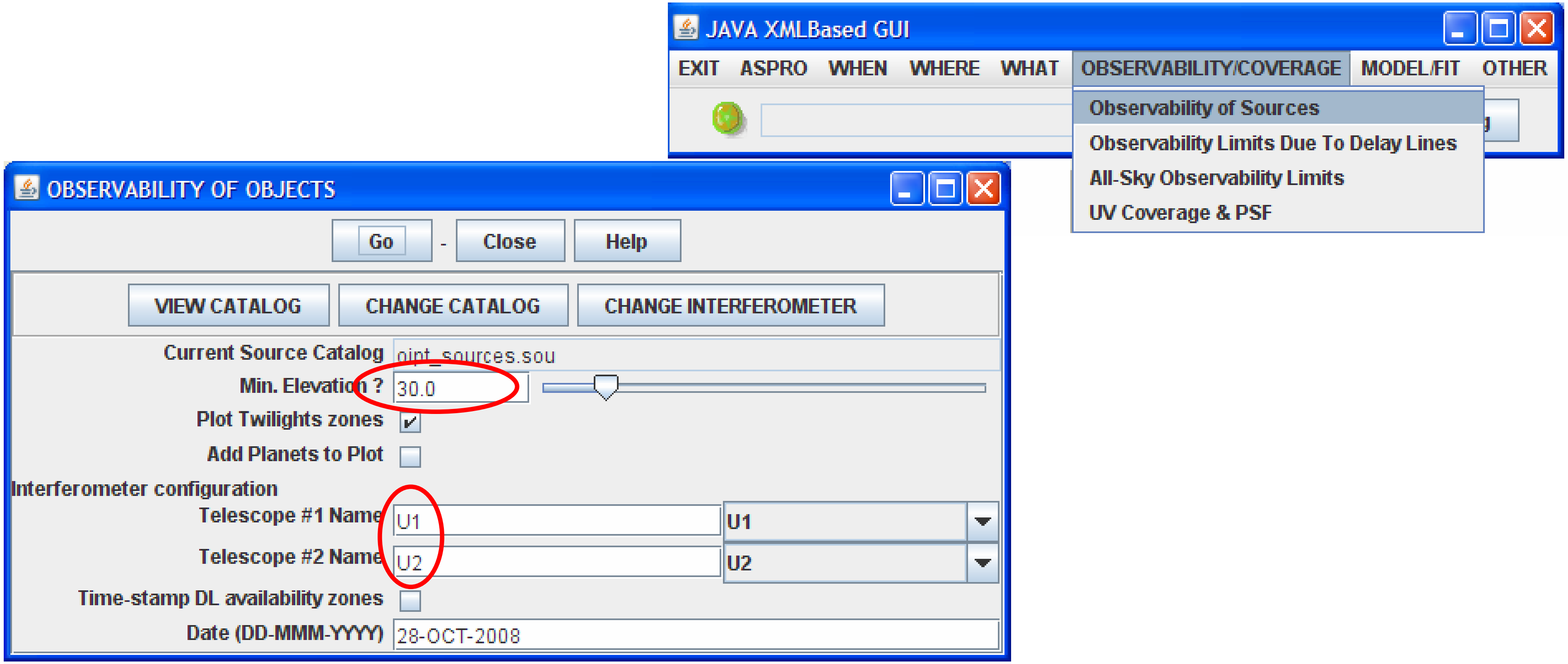
Observability



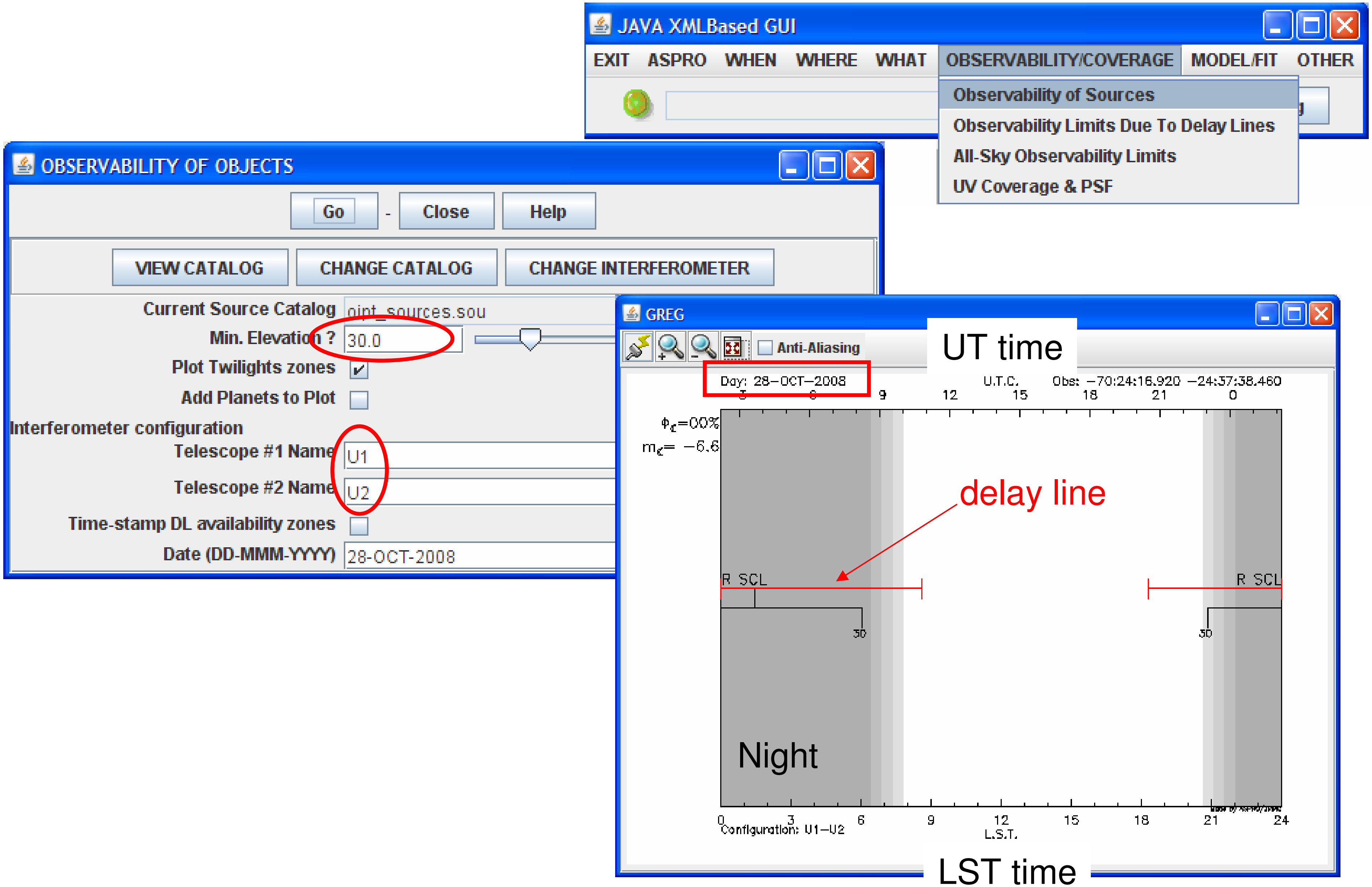
Observability



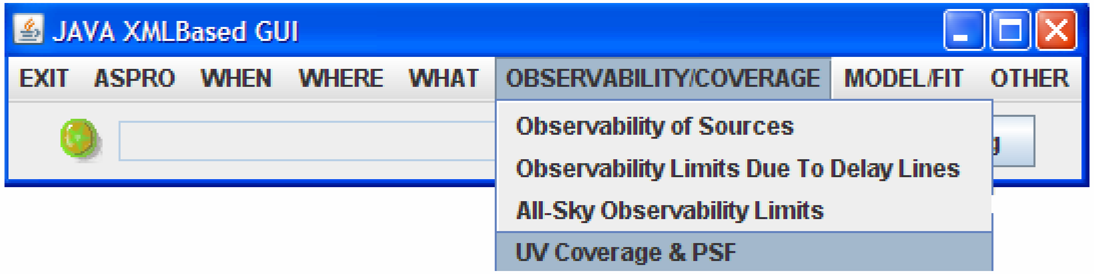
Observability

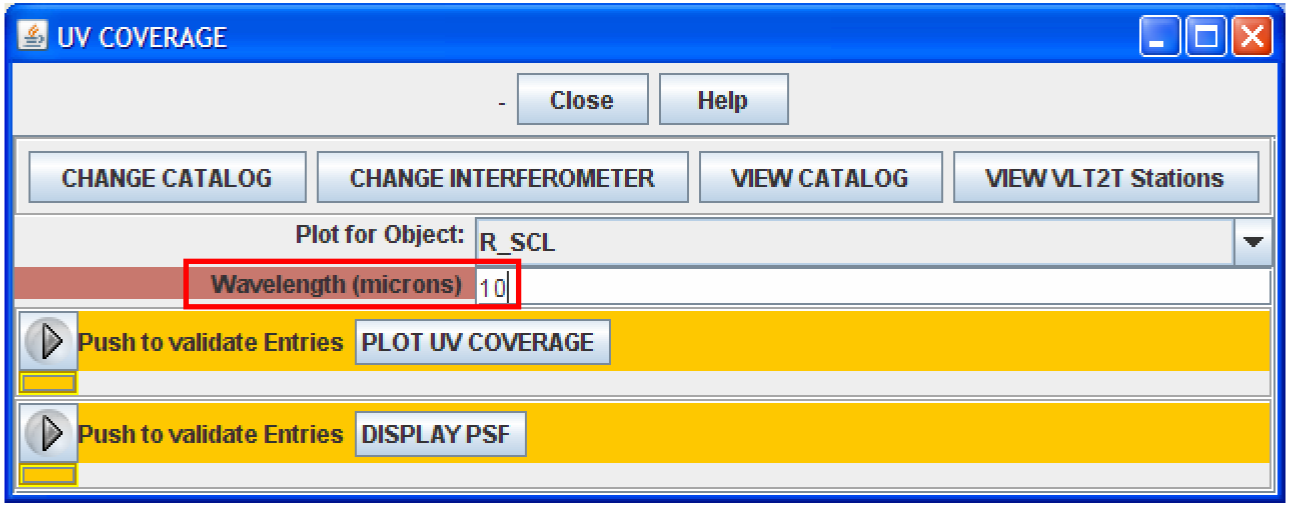


Observability

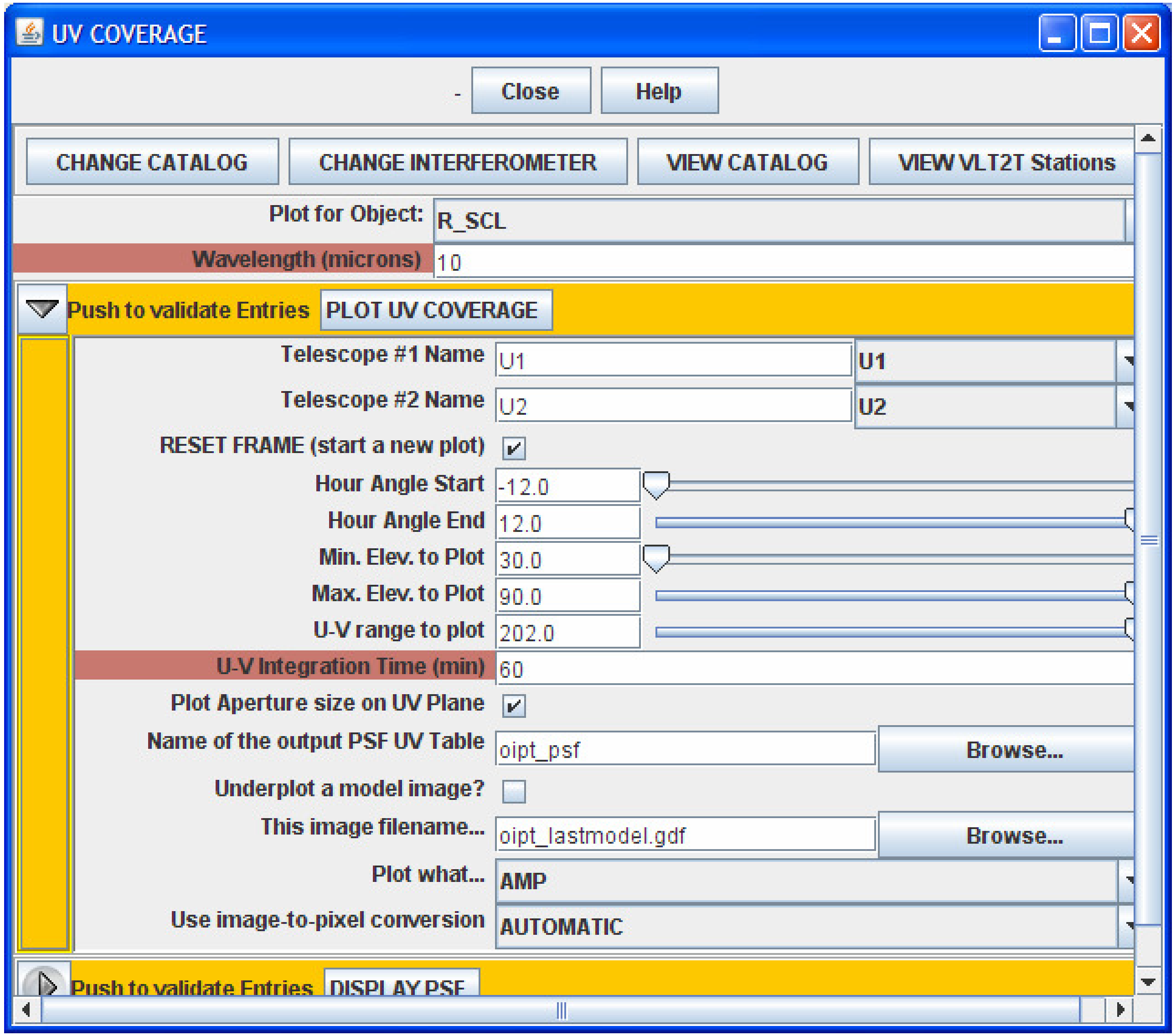


uv-coverage (part I)

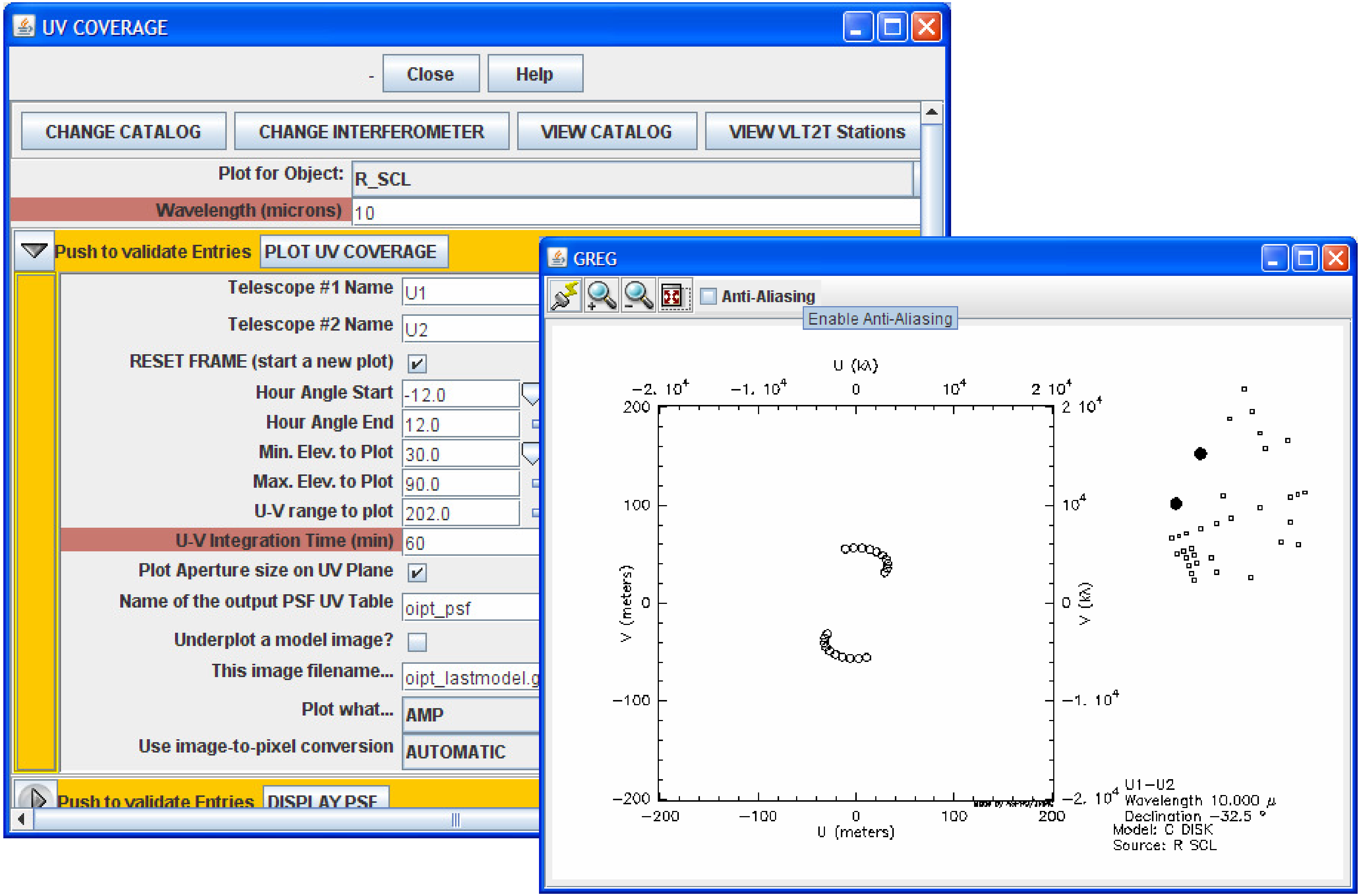




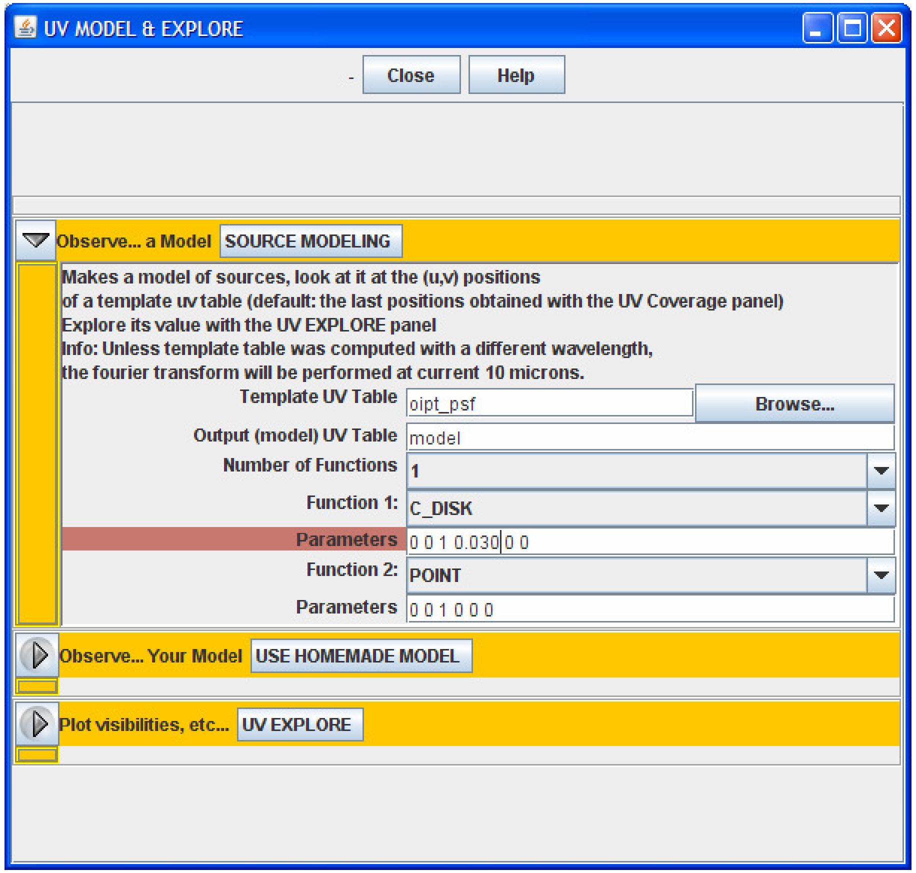
uv-coverage (part II)



uv-coverage (part II)



Model/Fit (part I)



Model/Fit (part I)

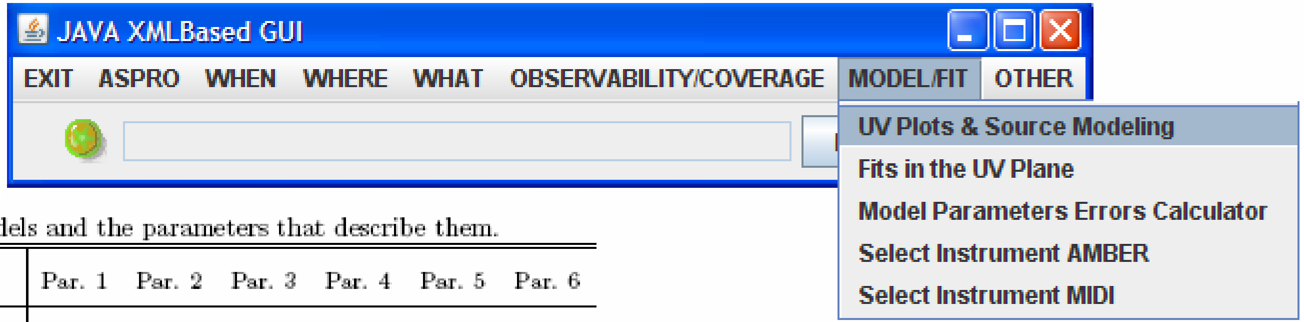
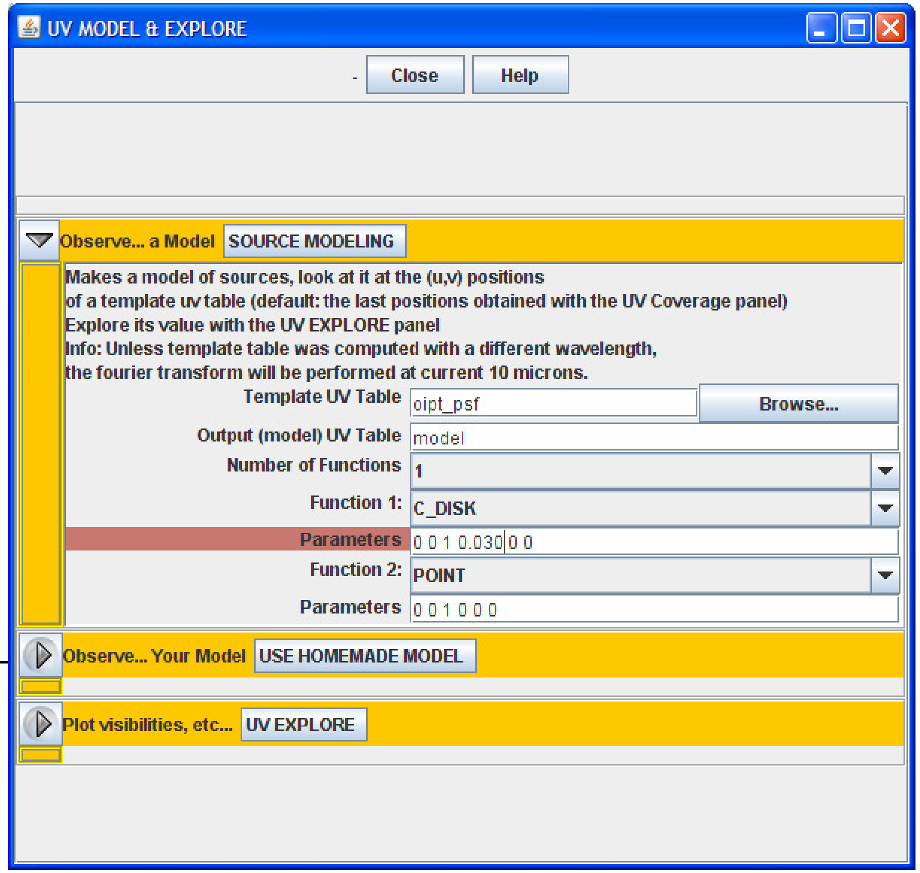
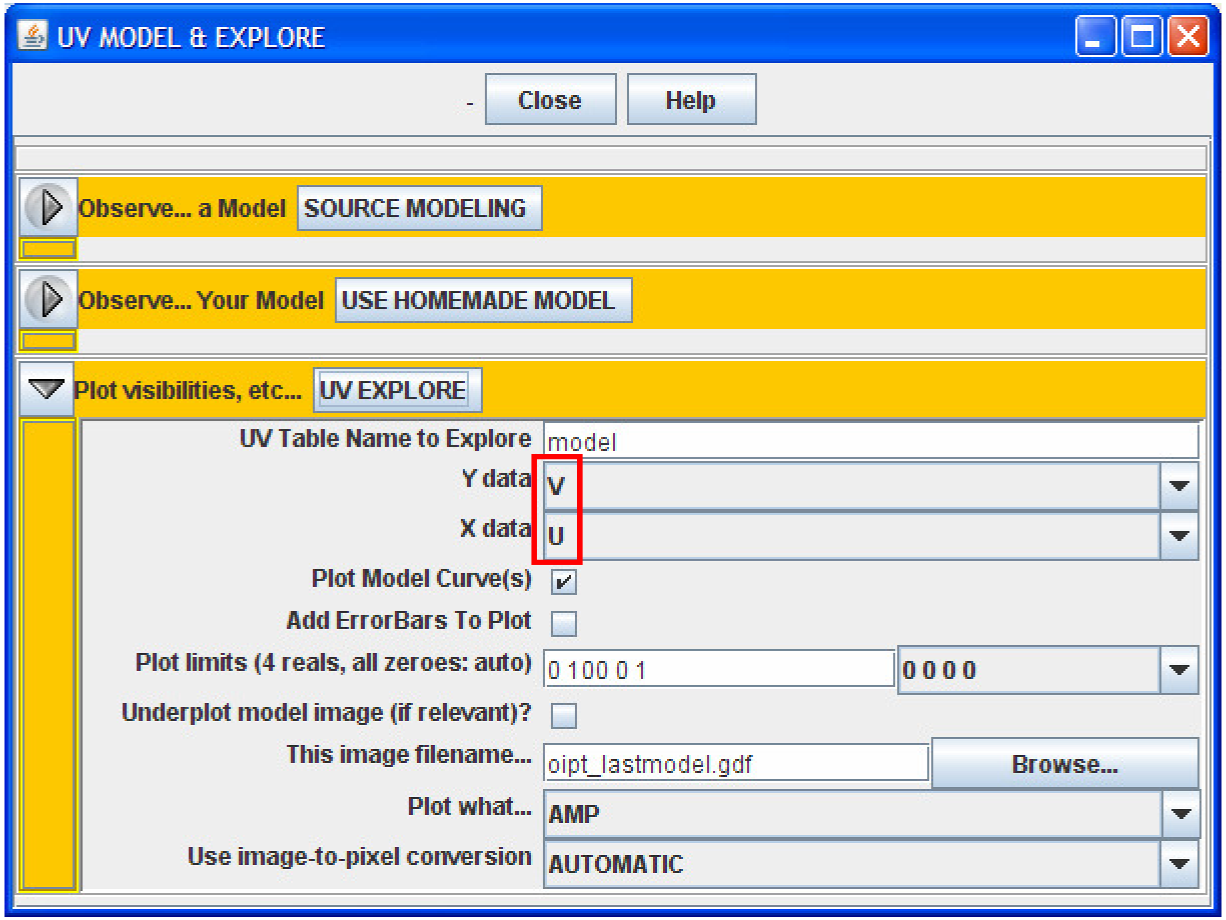


Table 1: List of available analytical models and the parameters that describe them.

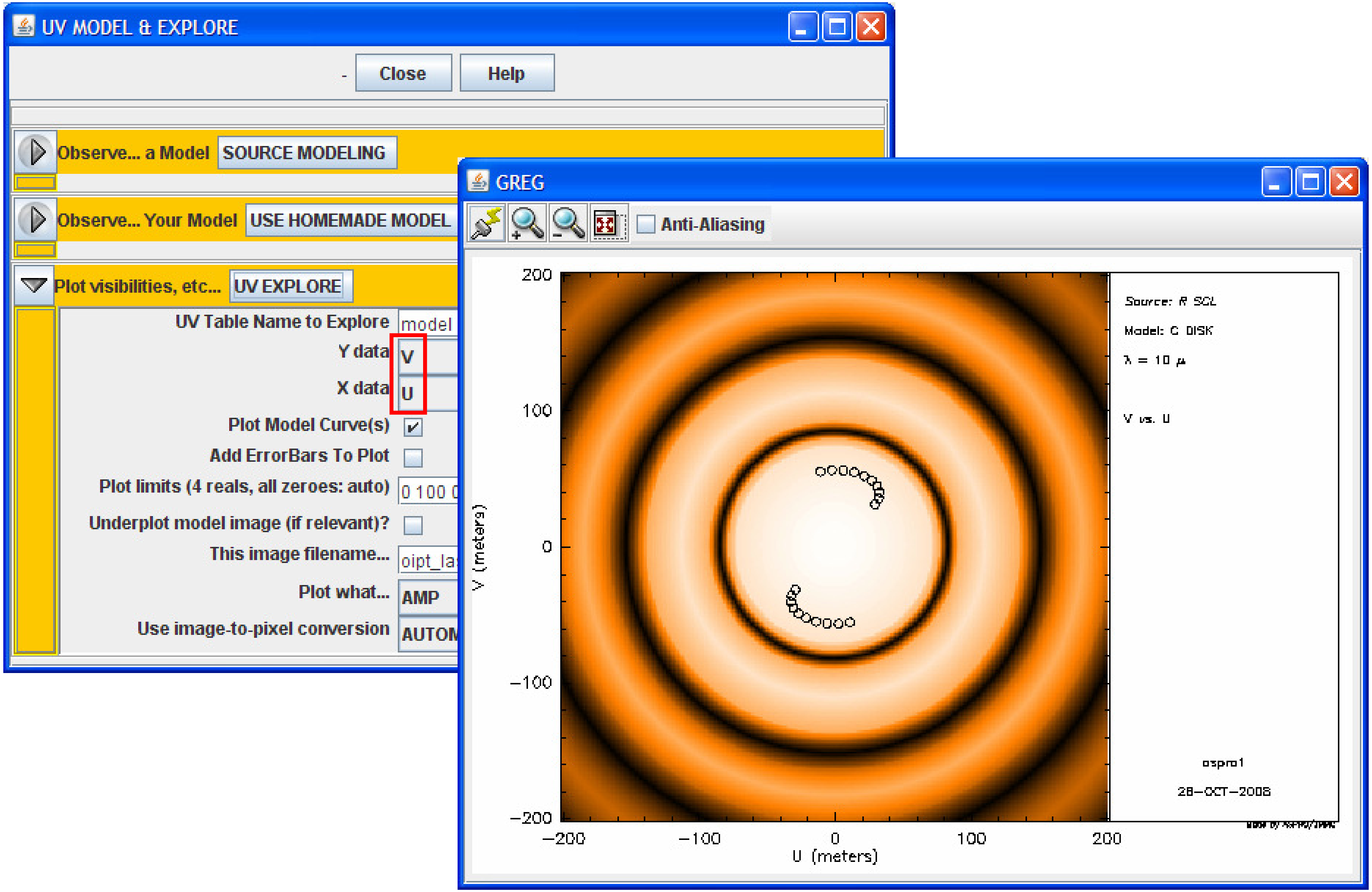
Name	Description	Par. 1	Par. 2	Par. 3	Par. 4	Par. 5	Par. 6
Point	Point Source (Dirac function)	$\Delta\alpha$	$\Delta\delta$	F_ν	–	–	–
C_Gauss	Circularly symmetric Gaussian distribution	$\Delta\alpha$	$\Delta\delta$	F_ν	$D^{1/2}$		
E_Gauss	Elliptical Gaussian distribution	$\Delta\alpha$	$\Delta\delta$	F_ν	$D^{1/2}_M$		
C_Disk	Circular disk (a.k.a. uniform disk)	$\Delta\alpha$	$\Delta\delta$	F_ν	D		
E_Disk	Elliptical uniform disk (i.e., inclined C_Disk)	$\Delta\alpha$	$\Delta\delta$	F_ν	D_M		
Ring	Uniform ring with finite width	$\Delta\alpha$	$\Delta\delta$	F_ν	D_i		
U_Ring	Unresolved (infinitely narrow) ring	$\Delta\alpha$	$\Delta\delta$	F_ν	D		
Exp	Exponential brightness distribution	$\Delta\alpha$	$\Delta\delta$	F_ν	$D^{1/2}$		
Power-2	$1/r^2$ brightness distribution	$\Delta\alpha$	$\Delta\delta$	F_ν	$D^{1/2}$		
Power-3	$1/r^3$ brightness distribution	$\Delta\alpha$	$\Delta\delta$	F_ν	$D^{1/2}$		
LD_Disk	Limb-darkened disk (resolved star)	$\Delta\alpha$	$\Delta\delta$	F_ν	D		
Binary	Binary point source	$\Delta\alpha$	$\Delta\delta$	F_ν	FR		



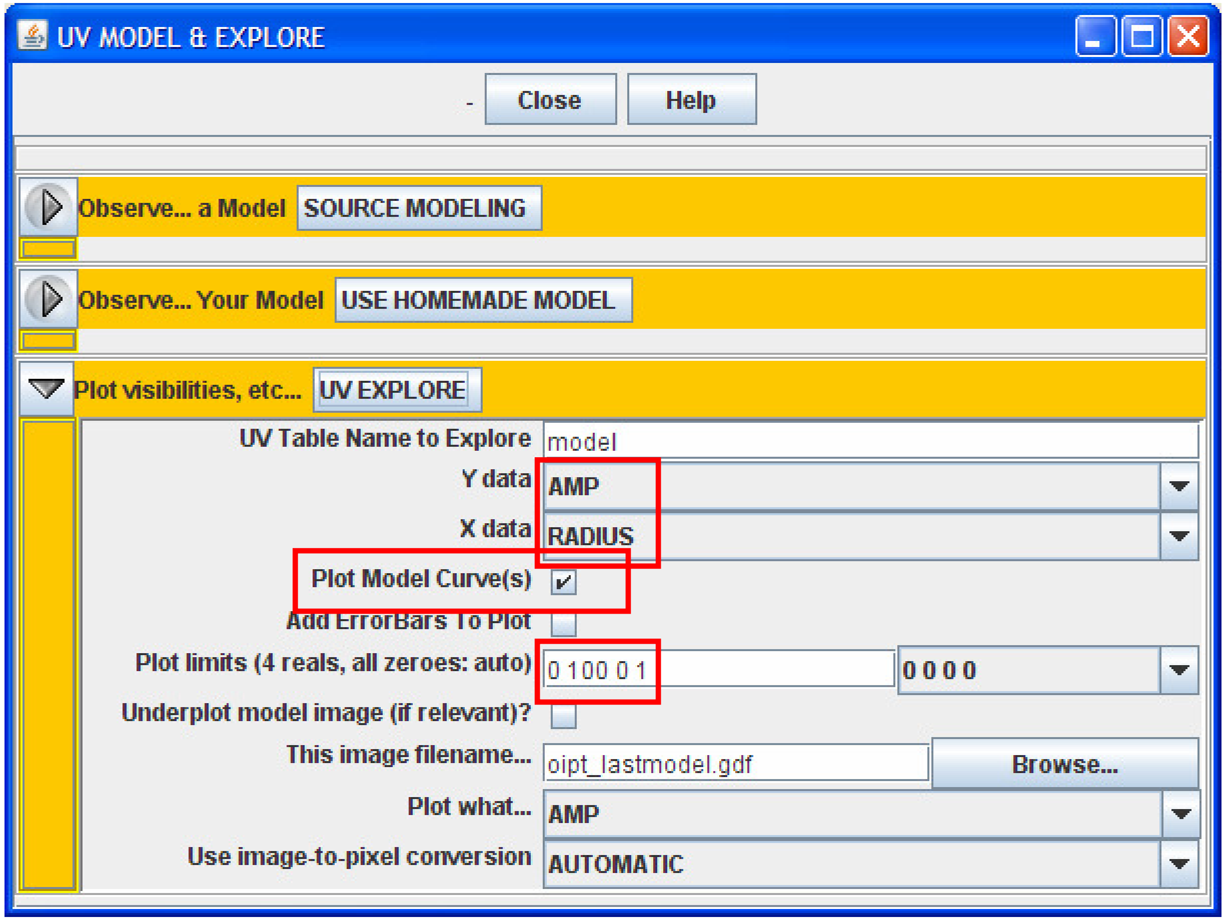
Model/Fit (part II)



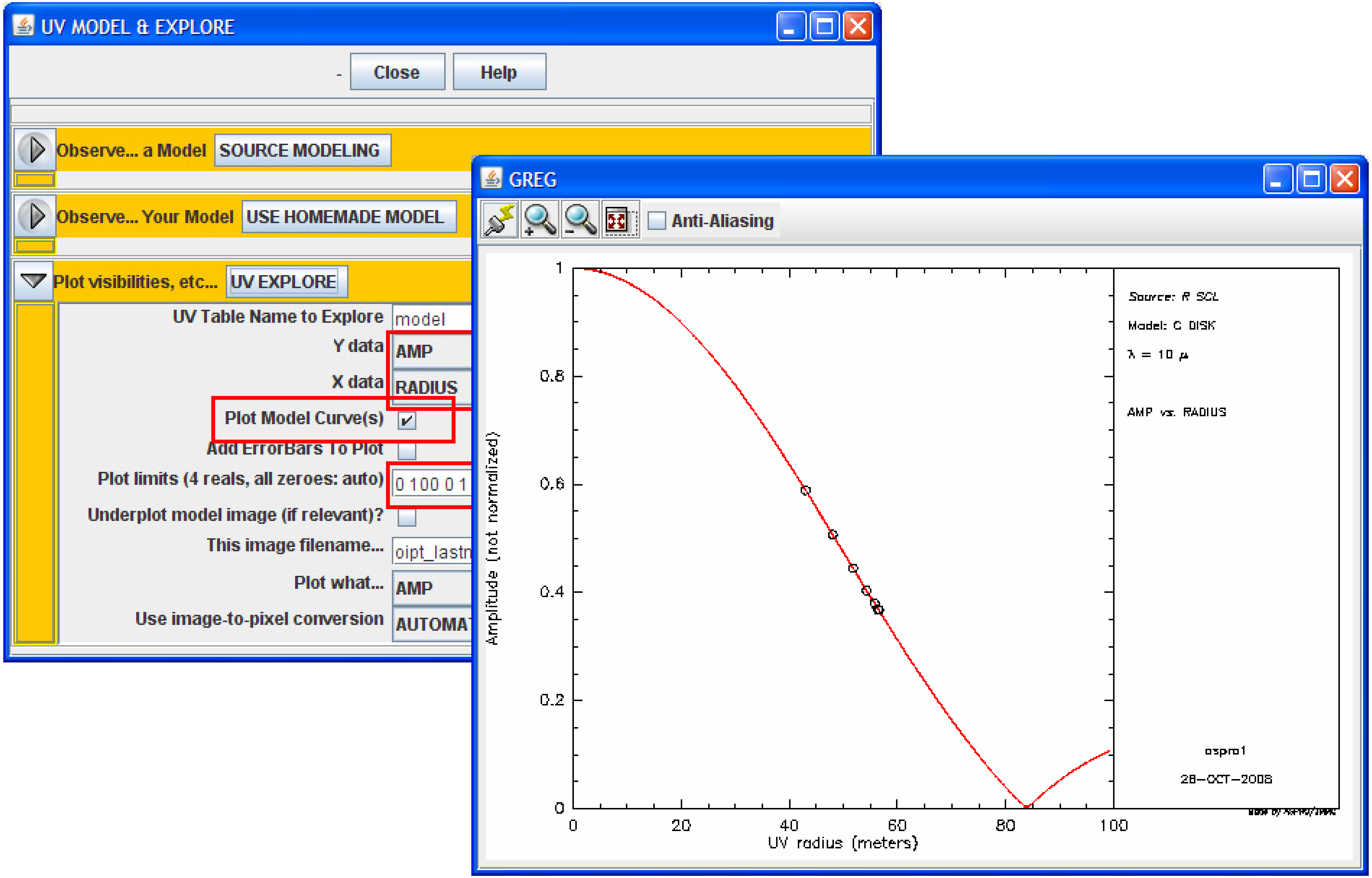
Model/Fit (part II)



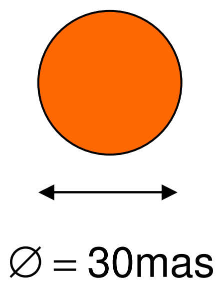
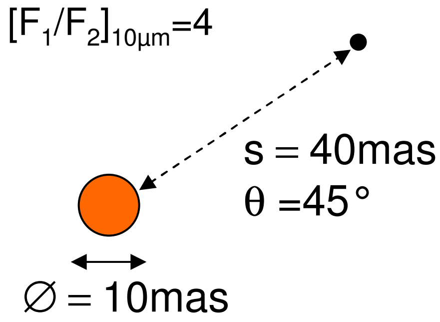
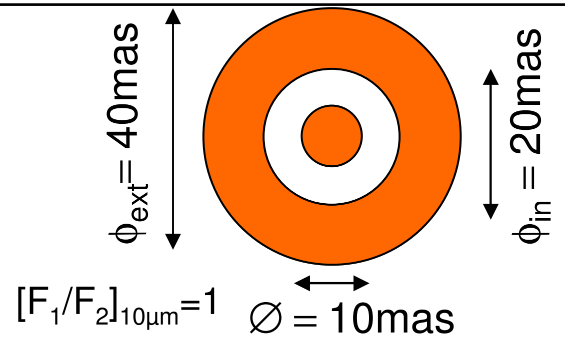
Model/Fit (part III)



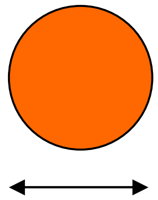
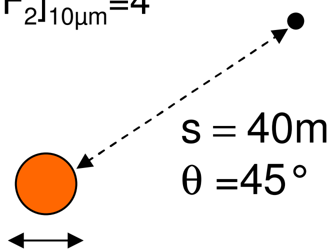
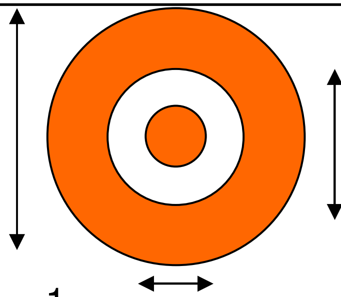
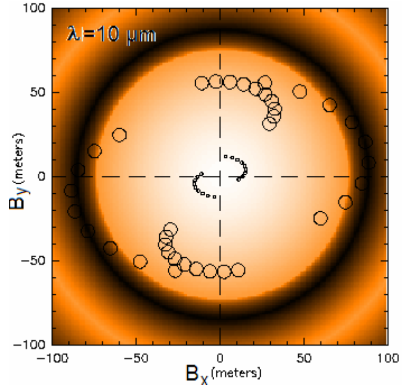
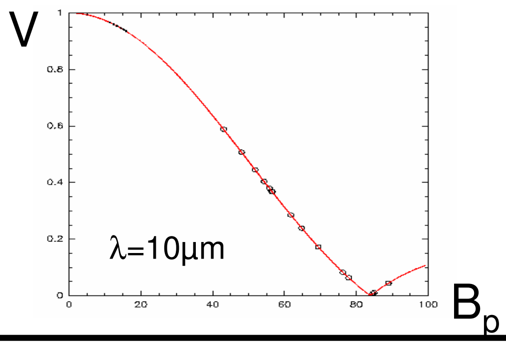
Model/Fit (part III)



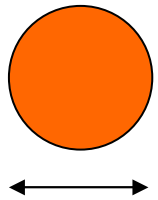
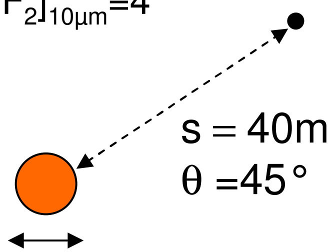
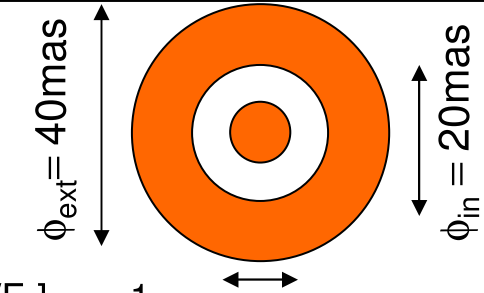
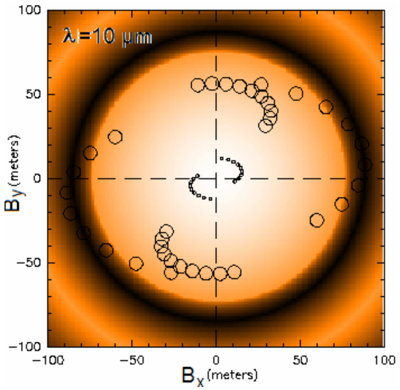
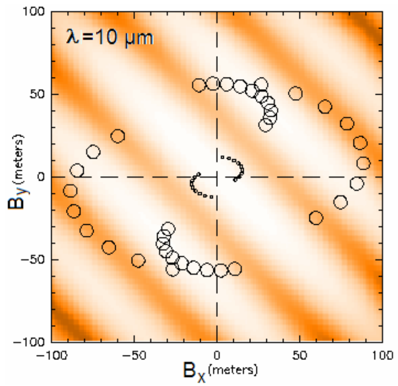
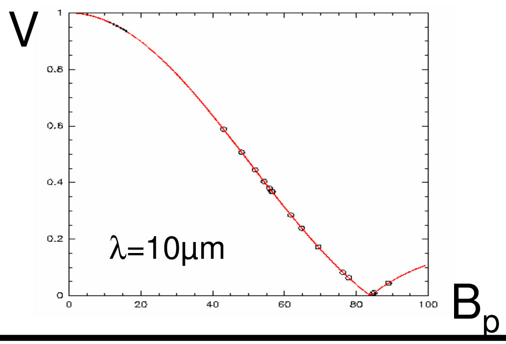
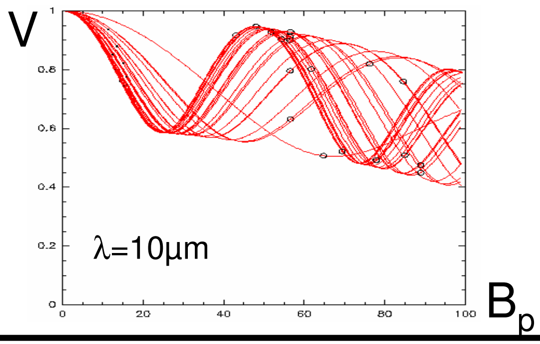
Model/Fit (part IV)

	Uniform disk	Resolved binary	Uniform disk + Uniform ring
DIRECT			
FOURIER SPACE			

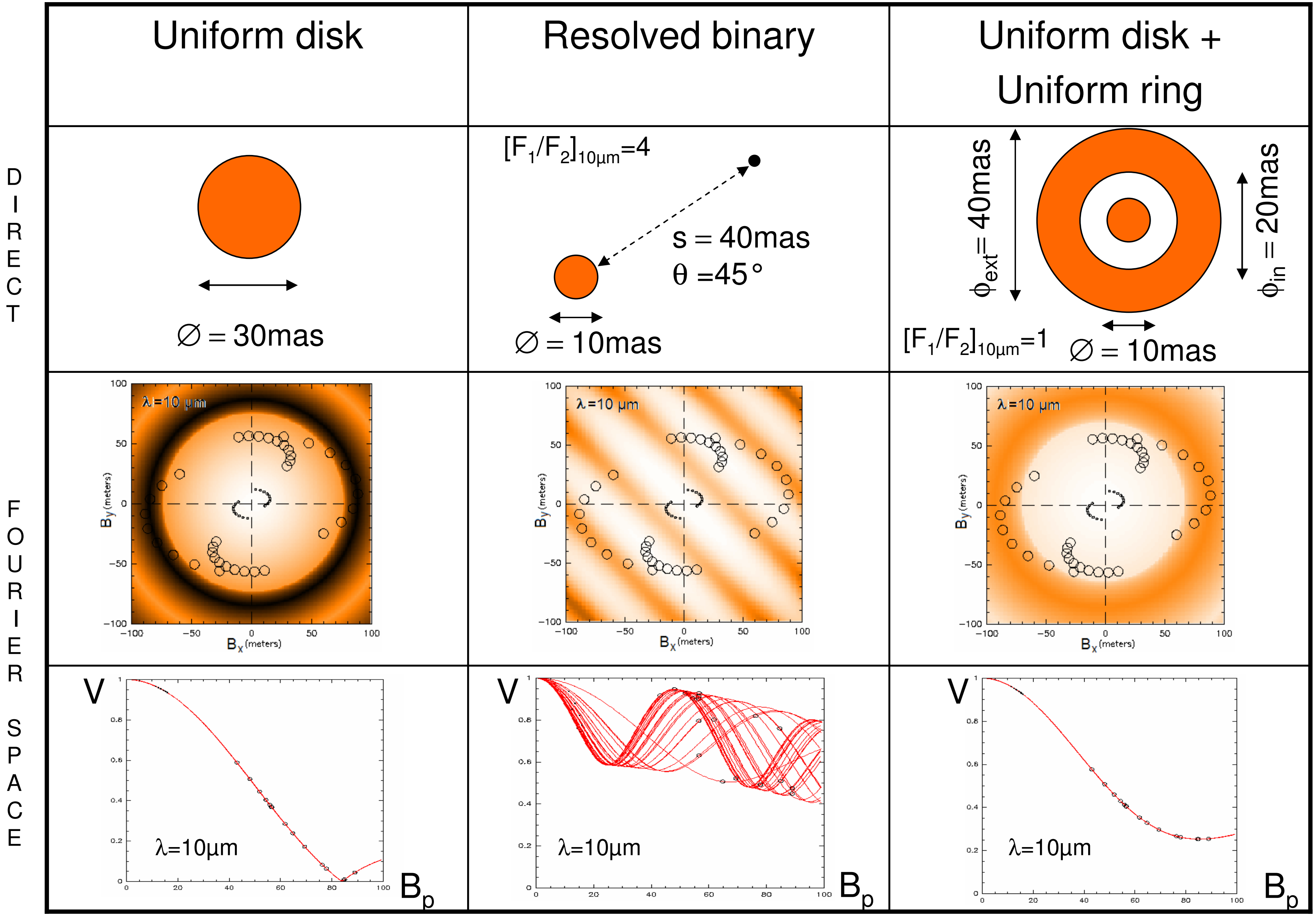
Model/Fit (part IV)

	Uniform disk	Resolved binary	Uniform disk + Uniform ring
DIRECT	 $\varnothing = 30$mas	$[F_1/F_2]_{10\mu m}=4$  $s = 40$mas, $\theta = 45°$, $\varnothing = 10$mas	 $\phi_{ext} = 40$mas, $\phi_{in} = 20$mas, $[F_1/F_2]_{10\mu m}=1$, $\varnothing = 10$mas
FOURIER			
SPACE			

Model/Fit (part IV)

	Uniform disk	Resolved binary	Uniform disk + Uniform ring
DIRECT	 $\varnothing = 30$mas	$[F_1/F_2]_{10\mu m}=4$  $\varnothing = 10$mas	 $[F_1/F_2]_{10\mu m}=1$ $\varnothing = 10$mas
FOURIER SPACE			
			

Model/Fit (part IV)

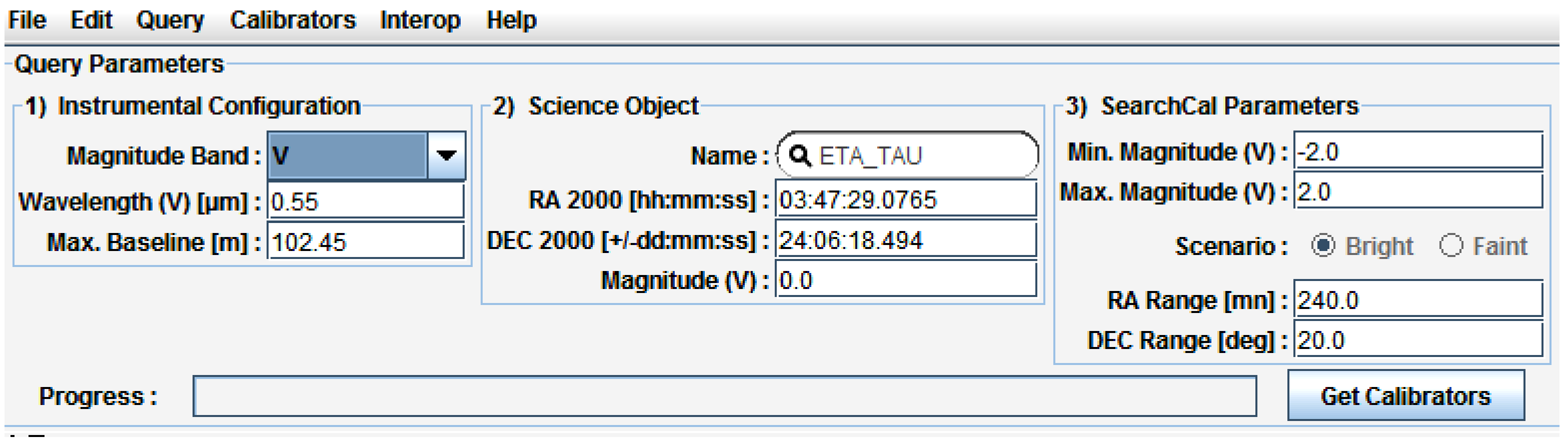


DEFINE THE BEST CALIBRATOR

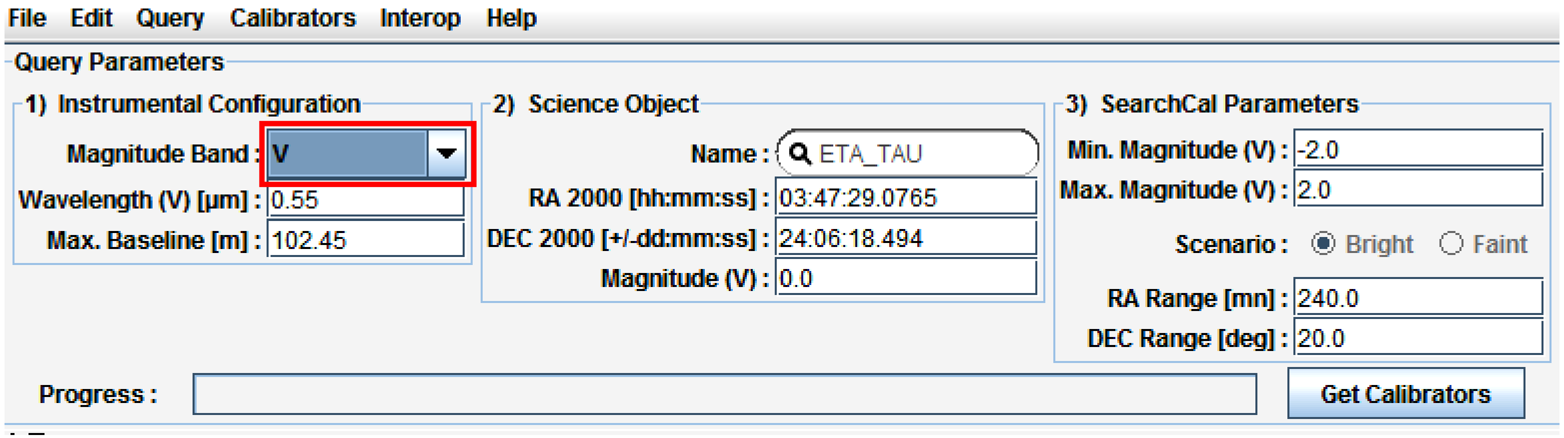
http://www.jmmc.fr/searchcal_page.htm

How to launch SearchCal in the web?

CALIBRATORS

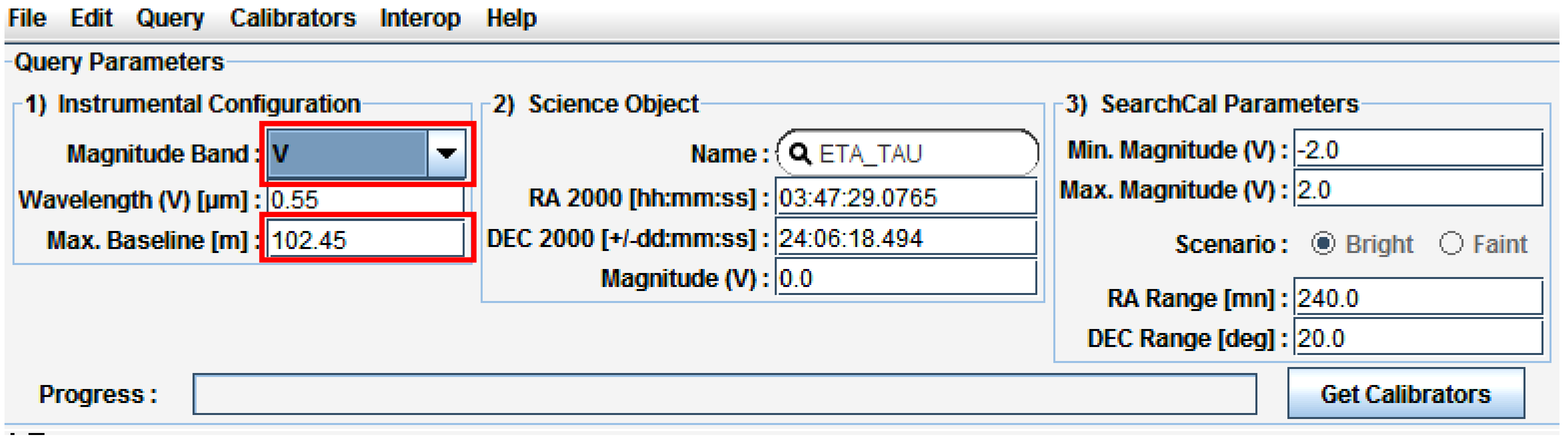


CALIBRATORS



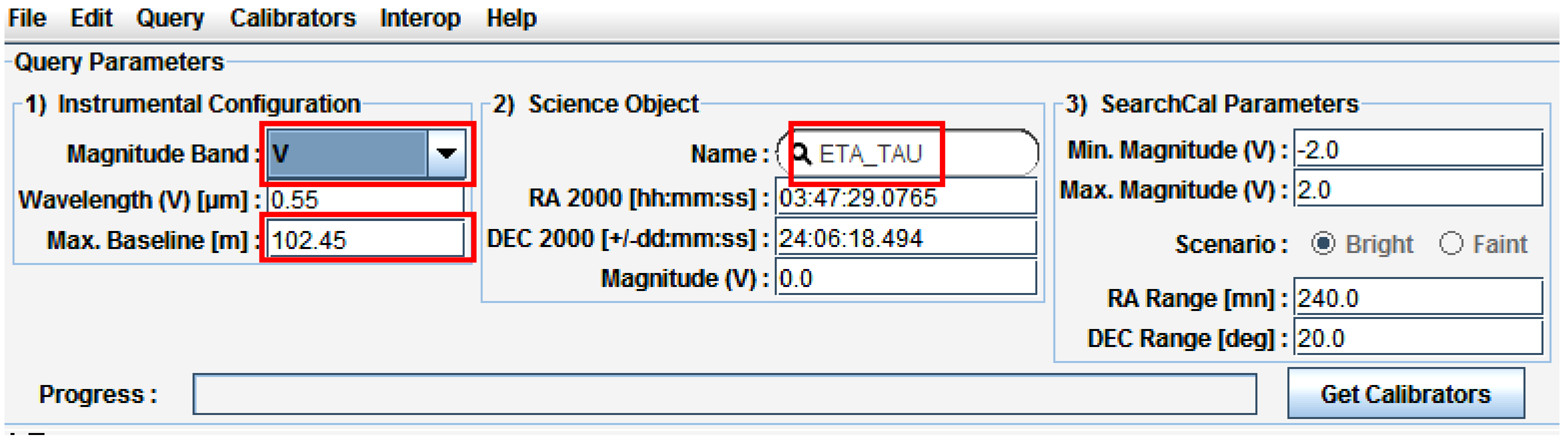
❖ Choose your observing wavelength (AMBER-H/K or MIDI-N)

CALIBRATORS



- ❖ Choose your observing wavelength (AMBER-H/K or MIDI-N)
- ❖ The maximum baseline of your observation (*limit of sensitivity*)

CALIBRATORS

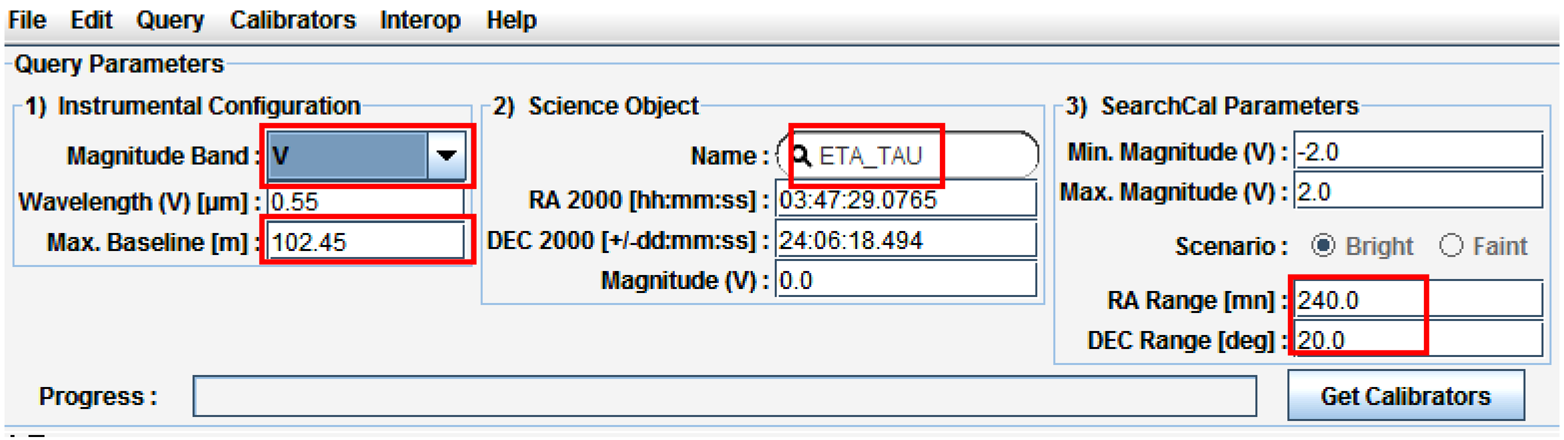


❖ Choose your observing wavelength (AMBER-H/K or MIDI-N)

❖ The maximum baseline of your observation (*limit of sensitivity*)

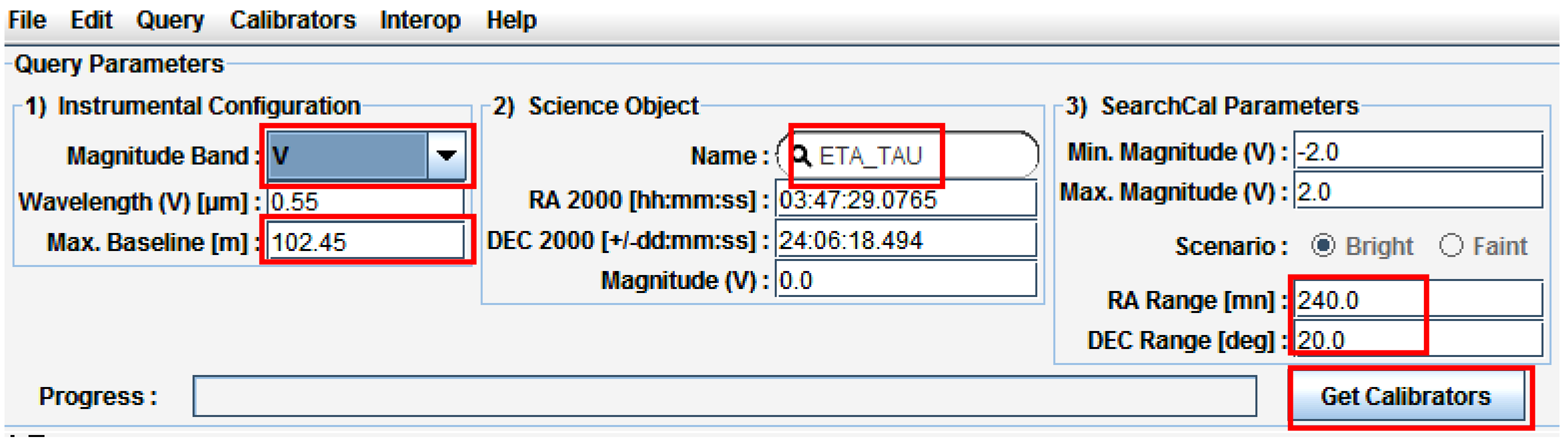
❖ The science target

CALIBRATORS



- ❖ Choose your observing wavelength (AMBER-H/K or MIDI-N)
- ❖ The maximum baseline of your observation (*limit of sensitivity*)
- ❖ The science target
- ❖ The maximum location around the science target (*close enough to avoid atmospheric biases*)

CALIBRATORS



- ❖ Choose your observing wavelength (AMBER-H/K or MIDI-N)
- ❖ The maximum baseline of your observation (*limit of sensitivity*)
- ❖ The science target
- ❖ The maximum location around the science target (*close enough to avoid atmospheric biases*)
- ❖ And get your calibrators (*from the various catalogs existing*)

Table

Index	dist	HD	RAJ2000	DEJ2000	vis2	vis2Err
1	**0.0**	**23630**	**03 47 29.076**	**+24 06 18.48**	**0.892**	**0.014**
2	0.46	23408	03 45 49.607	+24 22 03.89	0.978	0.0030
3	4.445	25604	04 04 41.715	+22 04 54.93	0.612	0.043
4	6.745	26162	04 09 09.966	+19 36 33.18	0.847	0.02
5	8.08	27382	04 20 21.216	+27 21 02.71	0.667	0.039
6	8.266	27482	04 21 15.258	+27 21 00.89	0.522	0.01
7	8.807	19637	03 10 27.046	+26 53 46.44	0.806	0.0050
8	8.89	27934	04 25 22.166	+22 17 37.94	0.973	0.0040
9	8.995	28024	04 26 18.464	+22 48 48.89	0.95	0.0070
10	9.049	21110	03 25 23.920	+31 43 51.95	0.874	0.016
11	9.395	19787	03 11 37.764	+19 43 36.03	0.657	0.039
12	10.118	26526	04 12 58.443	+32 31 57.82	0.646	0.01
13	10.535	19460	03 08 21.109	+18 47 42.19	0.627	0.0060
14	10.782	26311	04 10 59.020	+33 35 12.44	0.678	0.0070
15	13.153	28100	04 26 36.373	+14 42 49.62	0.72	0.034
16	14.253	17361	02 47 54.541	+29 14 49.63	0.61	0.01
17	15.476	30454	04 49 12.847	+31 26 14.55	0.692	0.036
18	16.048	31553	04 57 48.647	+23 56 54.80	0.814	0.024
19	19.234	15176	02 27 27.772	+31 48 04.61	0.823	0.0040

Table

Index	dist	HD	RAJ2000	DEJ2000	vis2	vis2Err
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- Separation from the science target in degree

Table

Index	dist	HD	RAJ2000	DEJ2000	vis2	vis2Err
1	**0.0**	**23630**	**03 47 29.076**	**+24 06 18.48**	**0.892**	**0.014**
2	0.46	23408	03 45 49.607	+24 22 03.89	0.978	0.0030
3	4.445	25604	04 04 41.715	+22 04 54.93	0.612	0.043
4	6.745	26162	04 09 09.966	+19 36 33.18	0.847	0.02
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7	8.807	19637	03 10 27.046	+26 53 46.44	0.806	0.0050
8	8.89	27934	04 25 22.166	+22 17 37.94	0.973	0.0040
9	8.995	28024	04 26 18.464	+22 48 48.89	0.95	0.0070
10	9.049	21110	03 25 23.920	+31 43 51.95	0.874	0.016
11	9.395	19787	03 11 37.764	+19 43 36.03	0.657	0.039
12	10.118	26526	04 12 58.443	+32 31 57.82	0.646	0.01
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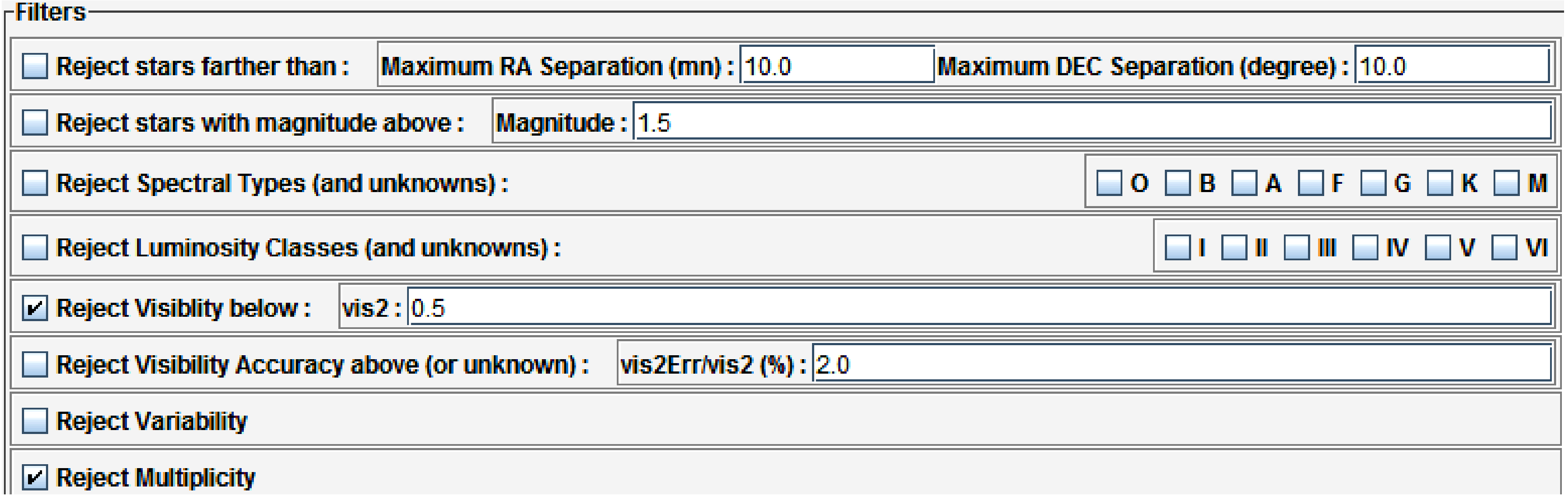
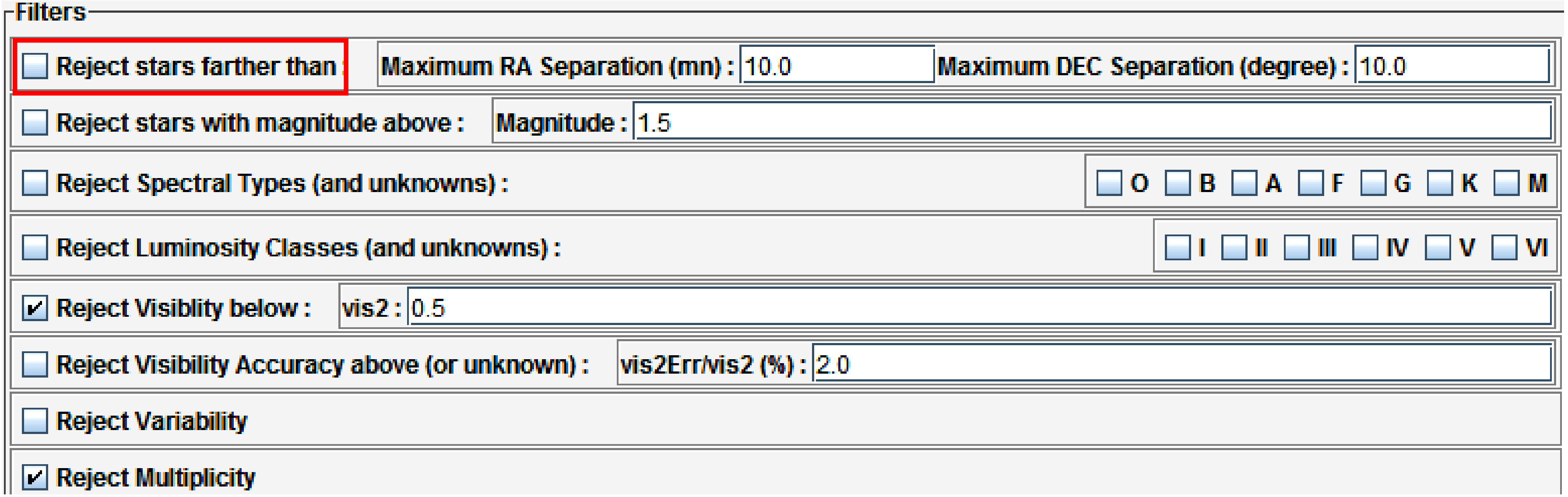
18	16.048	31553	04 57 48.647	+23 56 54.80	0.814	0.024
19	19.234	15176	02 27 27.772	+31 48 04.61	0.823	0.0040

- ❖ Separation from the science target in degree
- ❖ Evaluation of the corresponding equivalent UD visibility value

Selection criteria

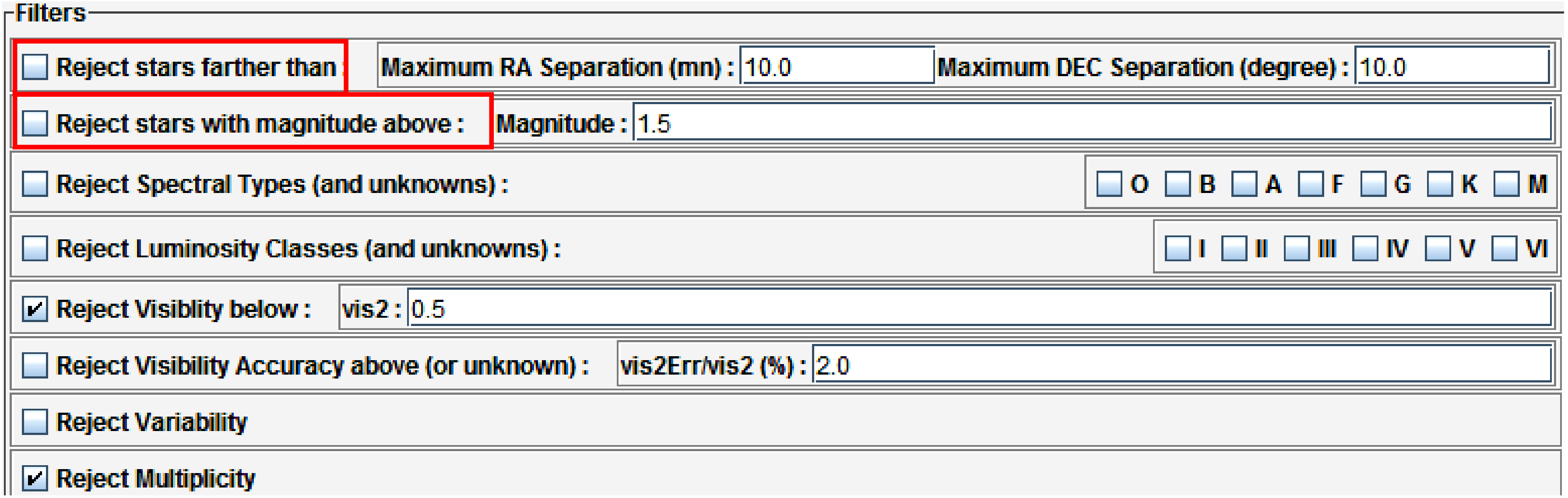


Selection criteria



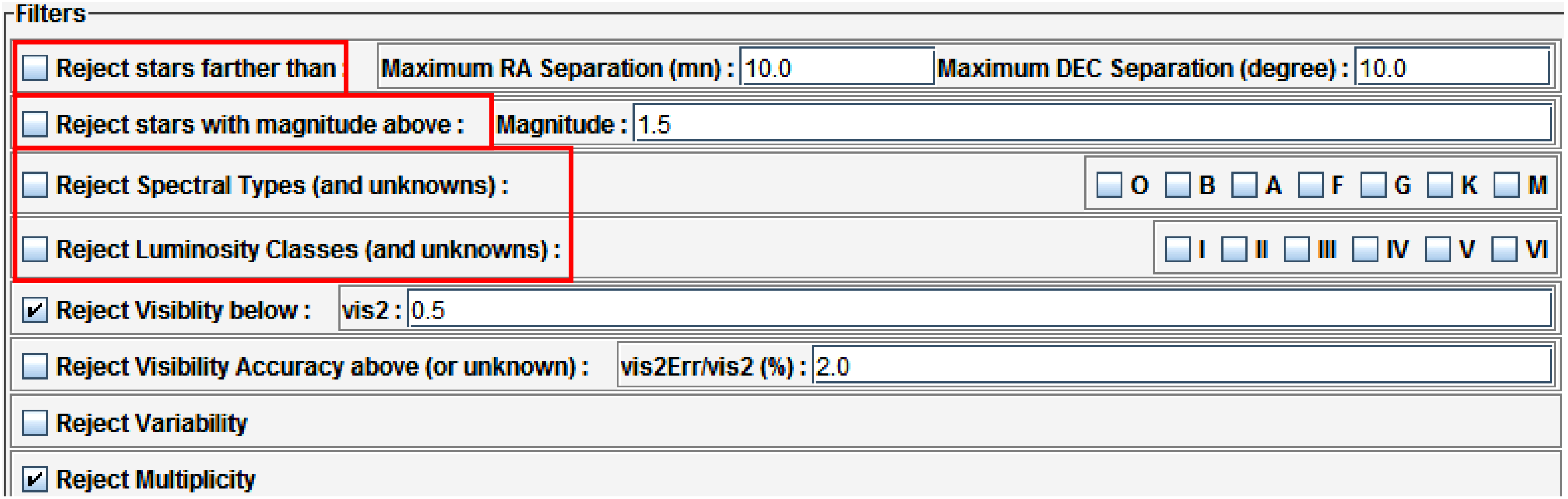
❖ location of the calibrator (*as close as possible*)

Selection criteria



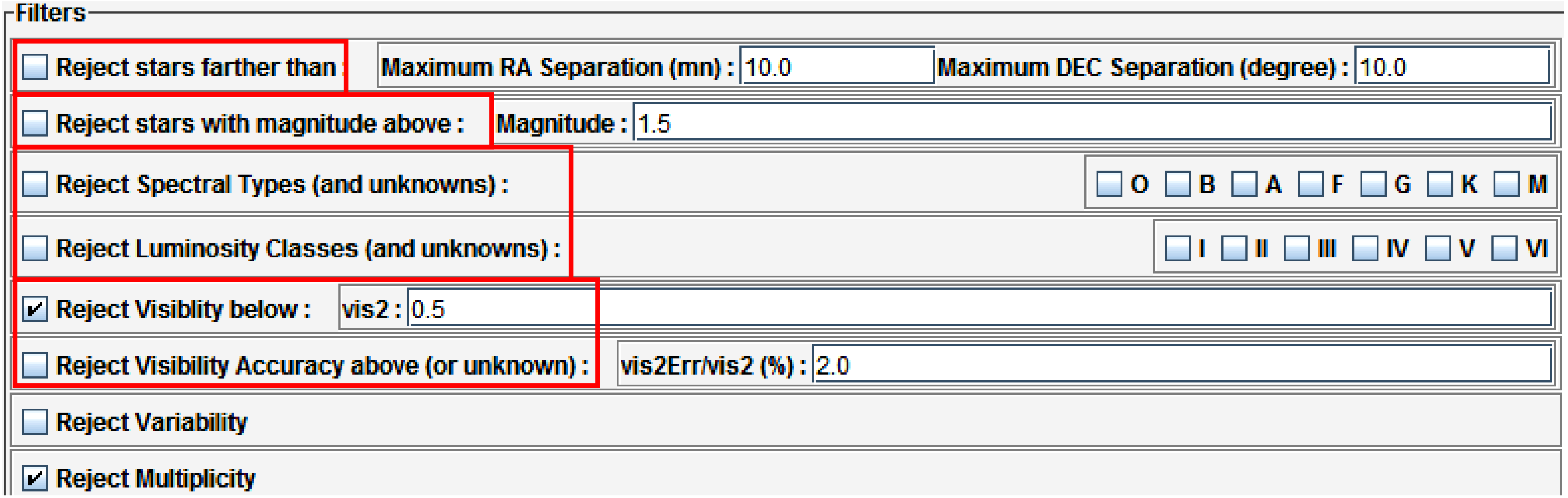
- ❖ location of the calibrator (*as close as possible*)
- ❖ brightness (*as bright as possible to get a high Signal to Noise ratio*)

Selection criteria



- location of the calibrator (*as close as possible*)
- brightness (*as bright as possible to get a high Signal to Noise ratio*)
- spectral type and luminosity (*avoid complex object like cool stars*)

Selection criteria



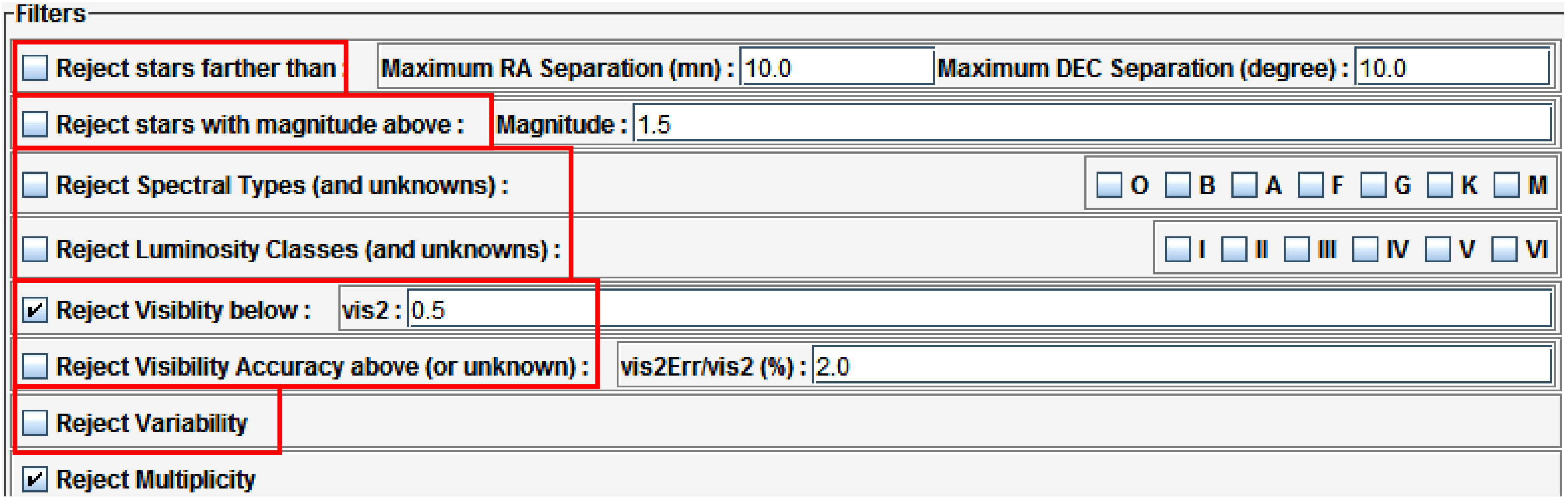
❖ location of the calibrator (*as close as possible*)

❖ brightness (*as bright as possible to get a high Signal to Noise ratio*)

❖ spectral type and luminosity (*avoid complex object like cool stars*)

❖ visibility and accuracy (*avoid too large objects -> V small -> poor S/N ratio*)

Selection criteria



❖ location of the calibrator (*as close as possible*)

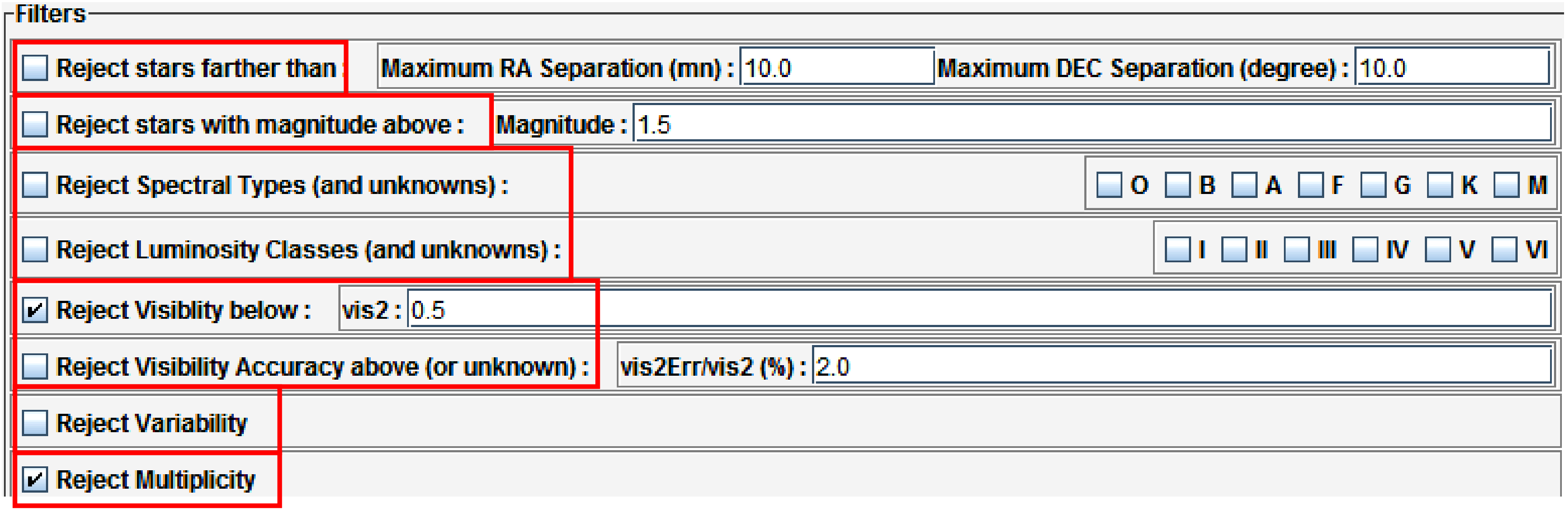
❖ brightness (*as bright as possible to get a high Signal to Noise ratio*)

❖ spectral type and luminosity (*avoid complex object like cool stars*)

❖ visibility and accuracy (*avoid too large objects -> V small -> poor S/N ratio*)

❖ variability (*avoid to use variable objects that may lead to temporal biases in the calibrated measurements*)

Selection criteria



❖ location of the calibrator (*as close as possible*)

❖ brightness (*as bright as possible to get a high Signal to Noise ratio*)

❖ spectral type and luminosity (*avoid complex object like cool stars*)

❖ visibility and accuracy (*avoid too large objects -> V small -> poor S/N ratio*)

❖ variability (*avoid to use variable objects that may lead to temporal biases in the calibrated measurements*)

❖ multiplicity (*avoid multiple object that may lead to a wrong interpretation of the calibrated measurements*)

DEFINE THE BEST CALIBRATOR

Found Calibrators (63 sources, 61 filtered)

Index	dist	HD	RAJ2000	DEJ2000	vis2	vis2Err	diam_vk	e_diam_vk	UD_V	U
1	**0.0**	**23630**	**03 47 29.076**	**+24 06 18.48**	**0.892**	**0.014**	**0.947**	**0.065**	**0.914**	**0.933**
2	22.544	35497	05 26 17.513	+28 36 26.82	0.893	0.014	0.946	0.065	0.913	0.932

HD35497

Filters

- [x] Reject stars farther than : Maximum RA Separation (mn) : 100.0 Maximum DEC Separation (degree) : 5.0
- [x] Reject stars with magnitude above : Magnitude : 2.5
- [x] Reject Spectral Types (and unknowns) : [ ] O [ ] B [ ] A [ ] F [ ] G [ ] K [ ] M
- [x] Reject Luminosity Classes (and unknowns) : [ ] I [ ] II [ ] III [ ] IV [ ] V [ ] VI
- [x] Reject Visiblity below : vis2 : 0.7
- [x] Reject Visibility Accuracy above (or unknown) : vis2Err/vis2 (%) : 2.0
- [x] Reject Variability
- [x] Reject Multiplicity