Plasma Lensing

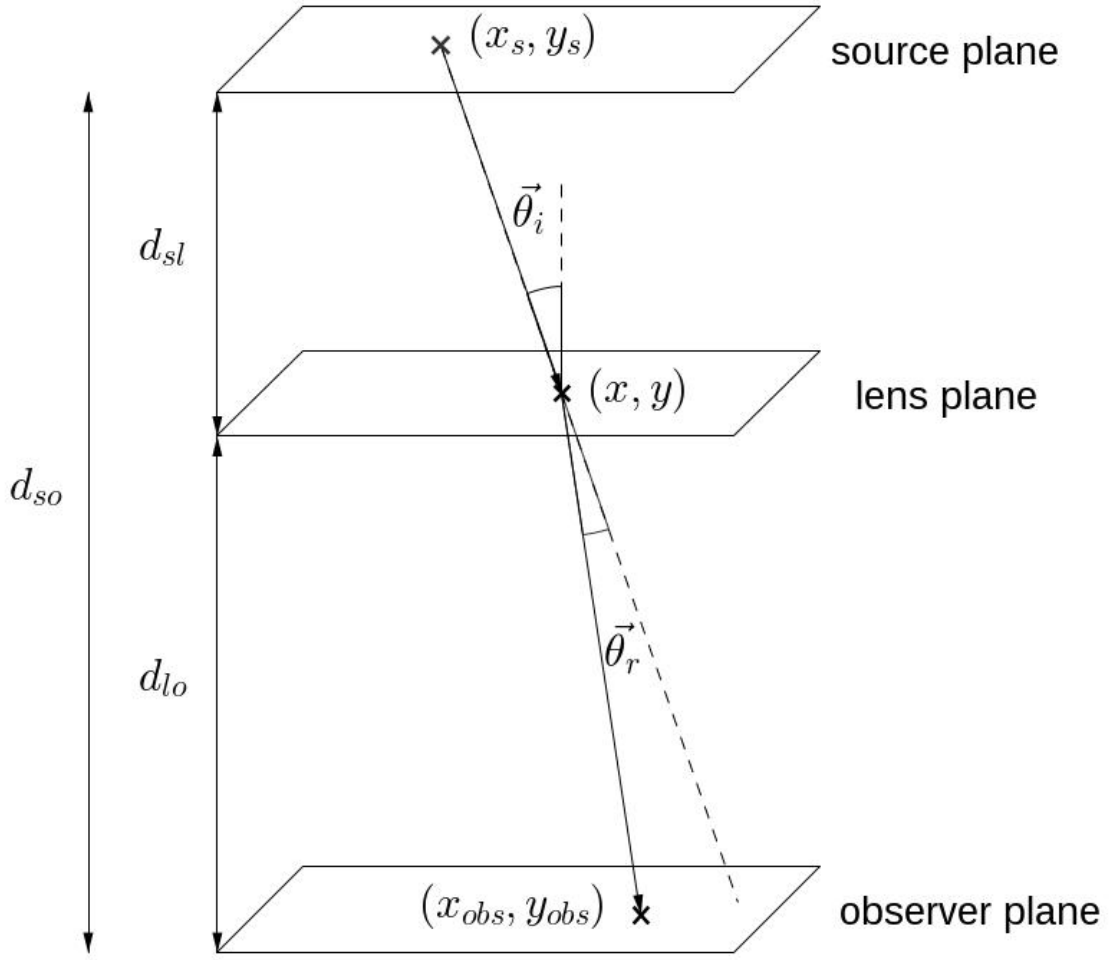
Motivations

- Population of small lensing events might be responsible for some of our residuals.

- Big events such as the ones seen in J1713+0747 might be a result of plasma lensing.

Geometry

- Mapping from source plane to observer plane altered by refraction due to lens.
- Can induce positive and negative TOA perturbations, changes in pulse shapes and intensities, generation of multiple images.

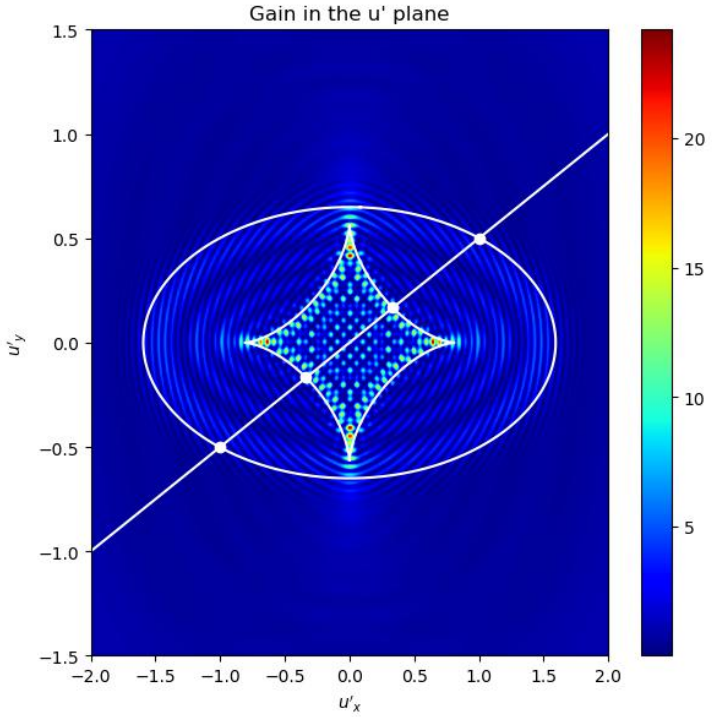


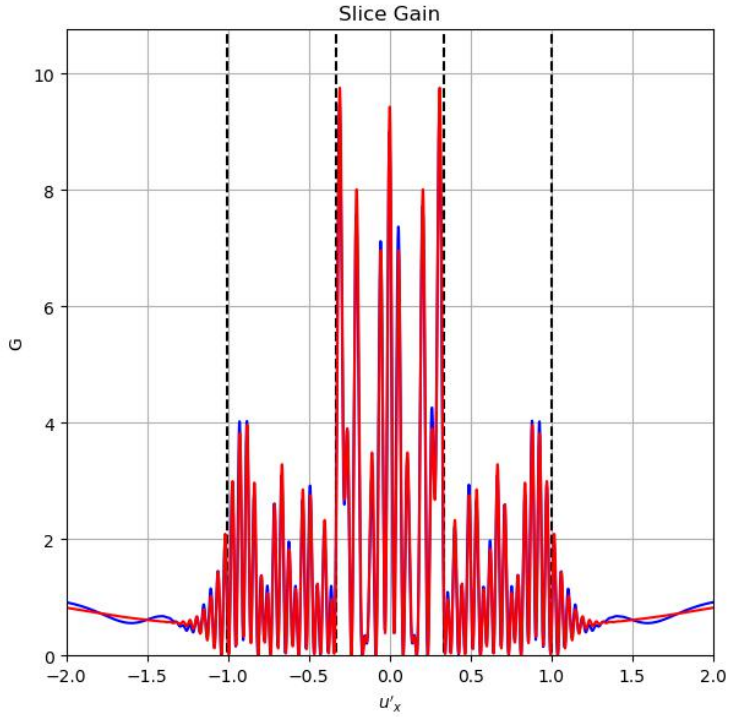
Methods

- Enhanced algebraic ray tracing, based on real and complex solutions to the lens equation, allow one to reconstruct the field and TOA perturbations due to a variety of lens shapes and parameters.

- Fast Fourier Transform techniques enable construction of the field for weak, small lenses of arbitrary shape.

Some Results



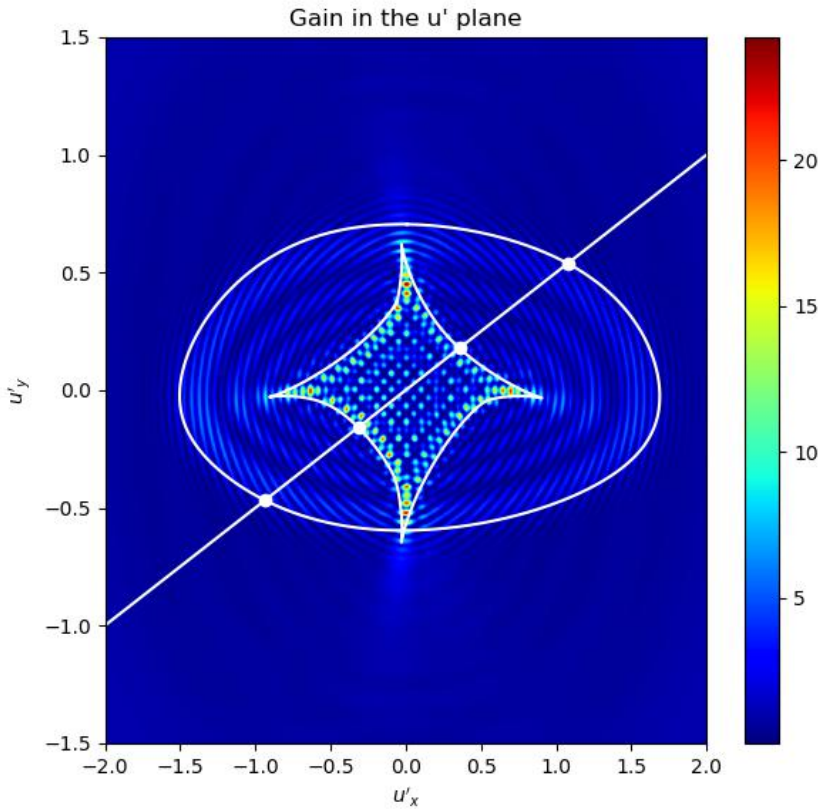


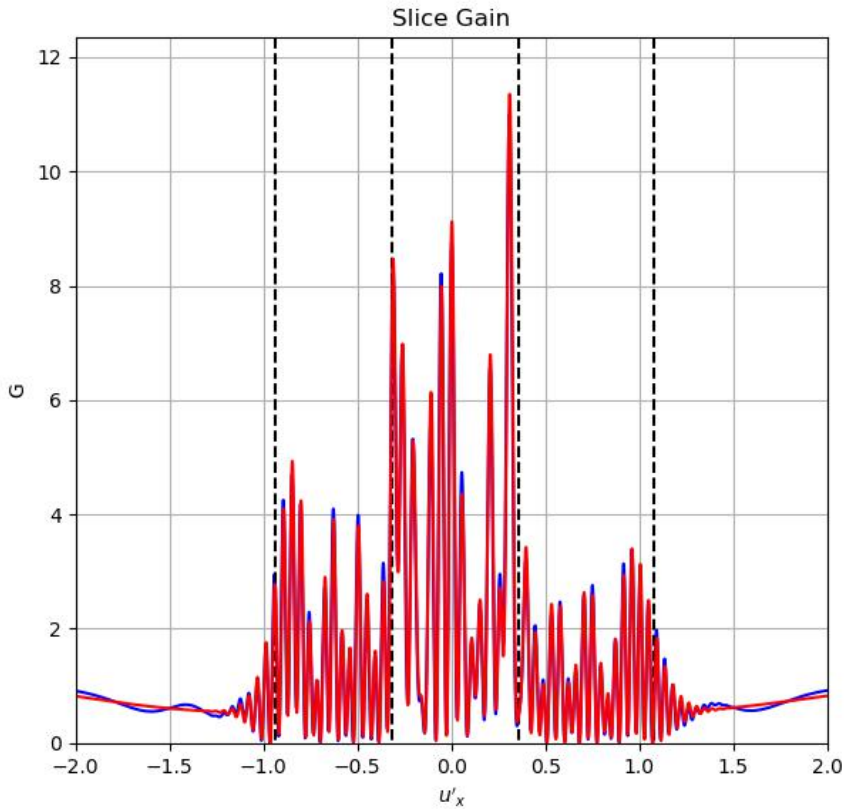
Blue line: Exact solution using FFT.

Red line: Solution using enhanced ray tracing.

Parameter	$d_{so}\,(kpc)$	$d_{sl}\,(kpc)$	$a_x\,(AU)$	$a_y\,(AU)$	$DM_l\,(pc\,cm^{-3})$	ν (GHz)	Slope	Offset
Value	1.1	0.55	0.03	0.04	-5.00E-6	1.0	0.5	0.0

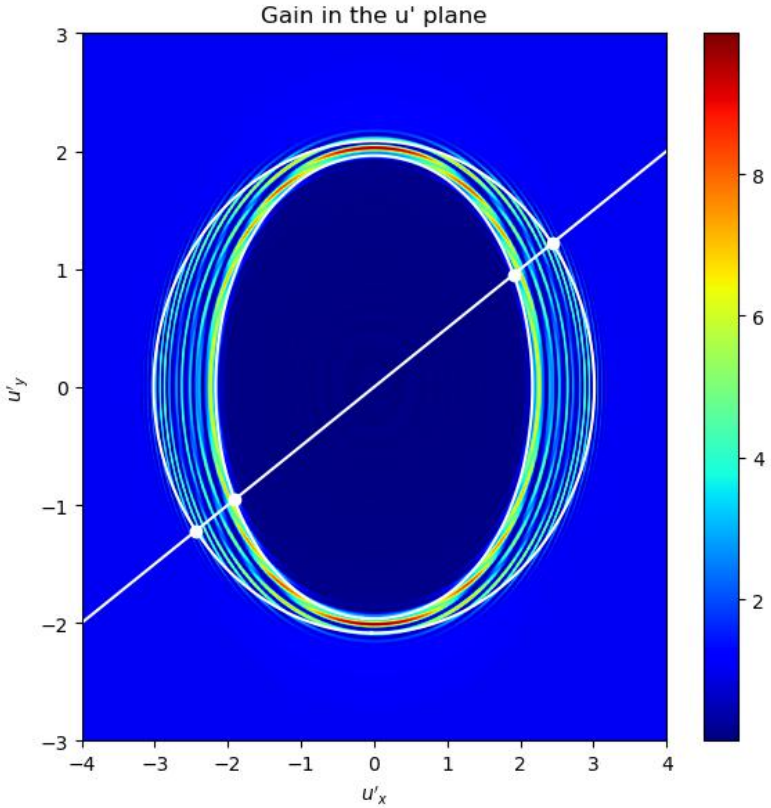
Lens shape	$e^{-u_x^2-u_y^2}$

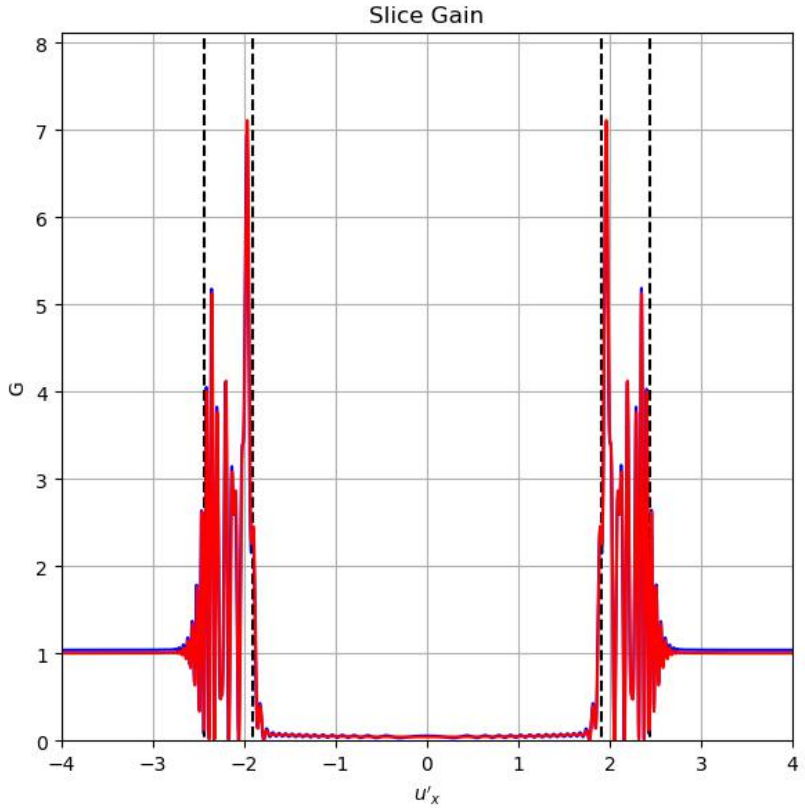




Parameter	$d_{so}\,(kpc)$	$d_{sl}\,(kpc)$	$a_x\,(AU)$	$a_y\,(AU)$	$DM_l\,(pc\,cm^{-3})$	ν (GHz)	Slope	Offset
Value	1.1	0.55	0.03	0.04	-5.00E-6	1.0	0.5	0.0

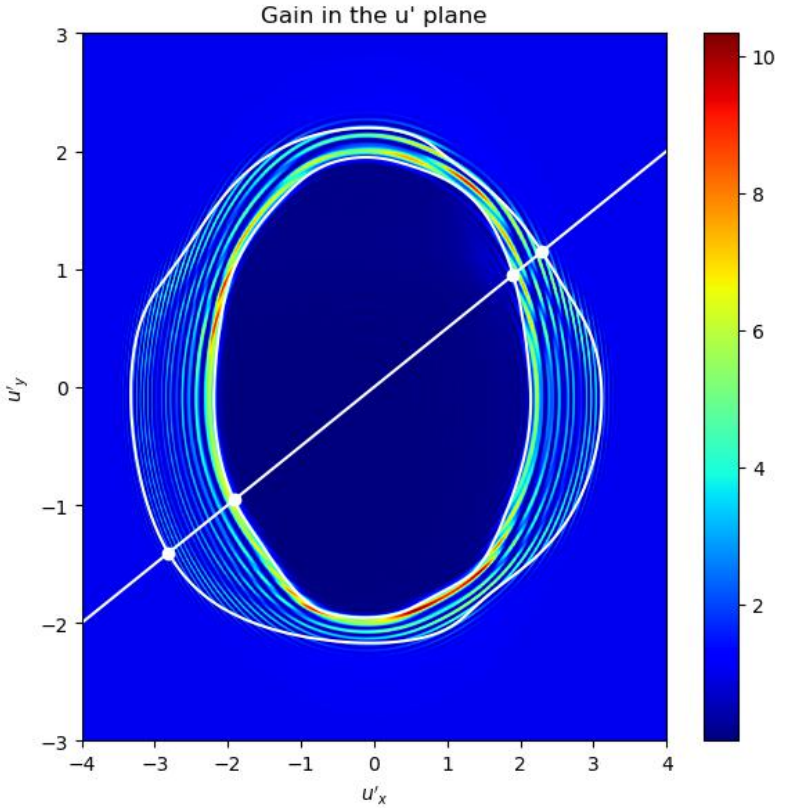
Lens shape	$(-0.01\sin(5u_x) - 0.01\sin(5u_y) + 1.0)e^{-u_x^2 - u_y^2}$

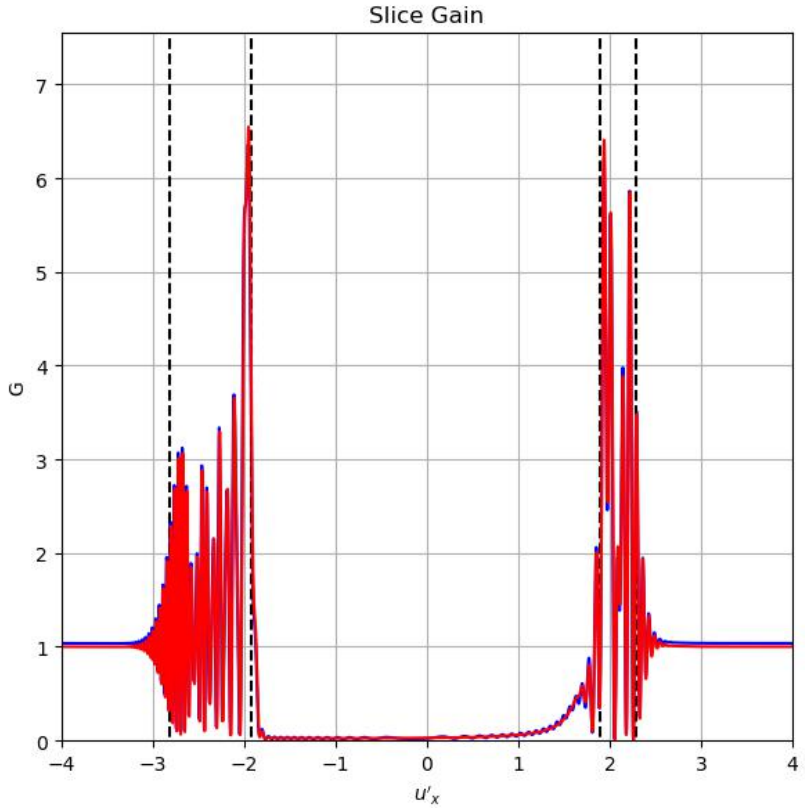




Parameter	$d_{so}\,(kpc)$	$d_{si}\,(kpc)$	$a_x\,(AU)$	$a_y\,(AU)$	$DM_l\,(pc\,cm^{-3})$	ν (GHz)	Slope	Offset
Value	1.1	0.55	0.03	0.04	5.00E-6	1.0	0.5	0.0

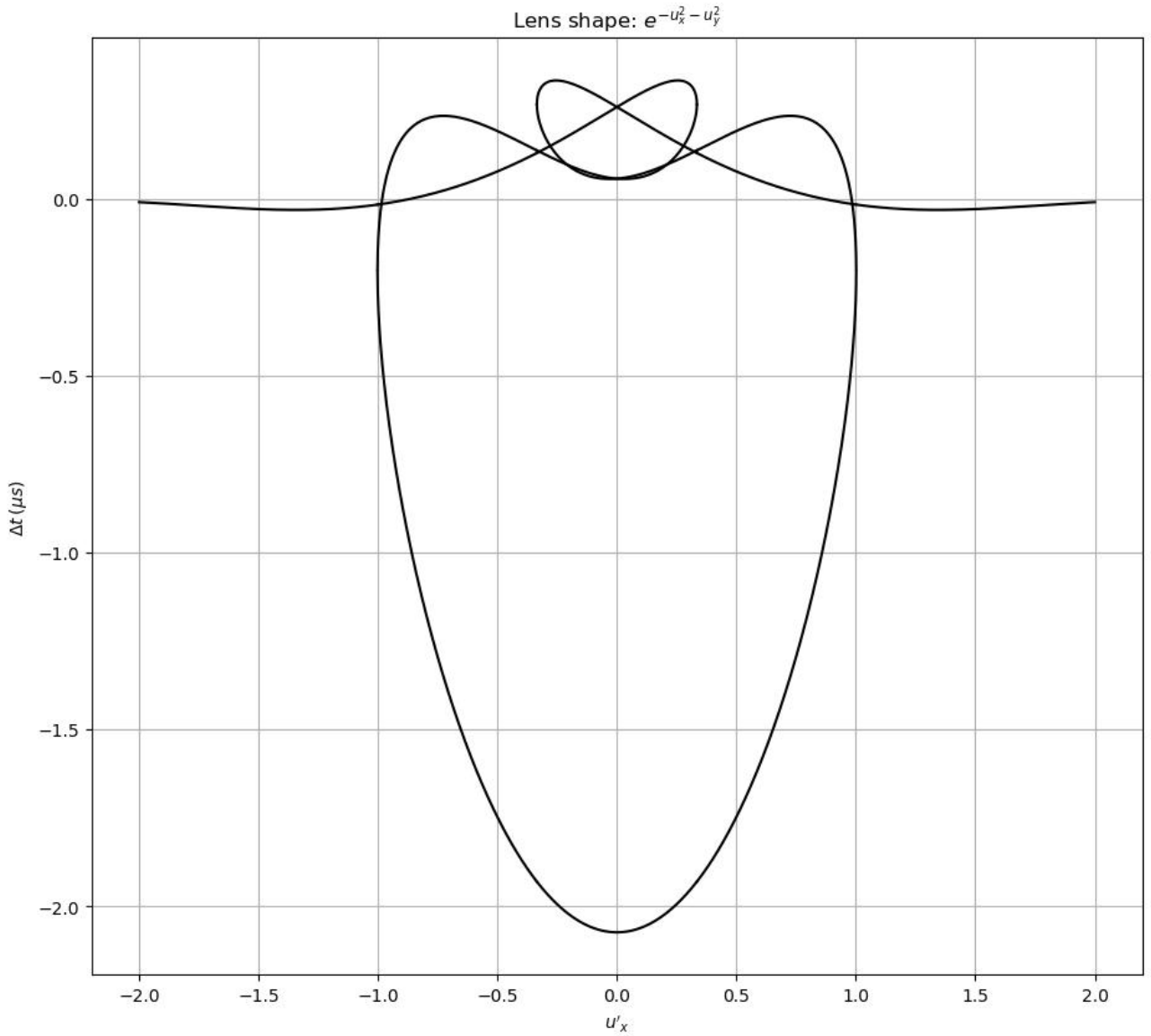
Lens shape	$e^{-u_x^2-u_y^2}$

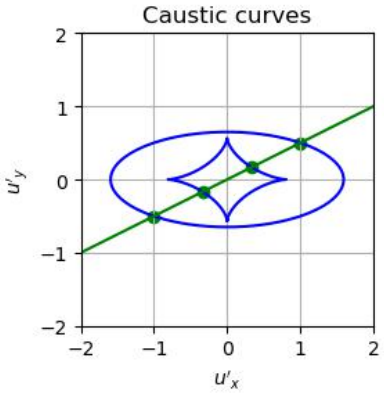




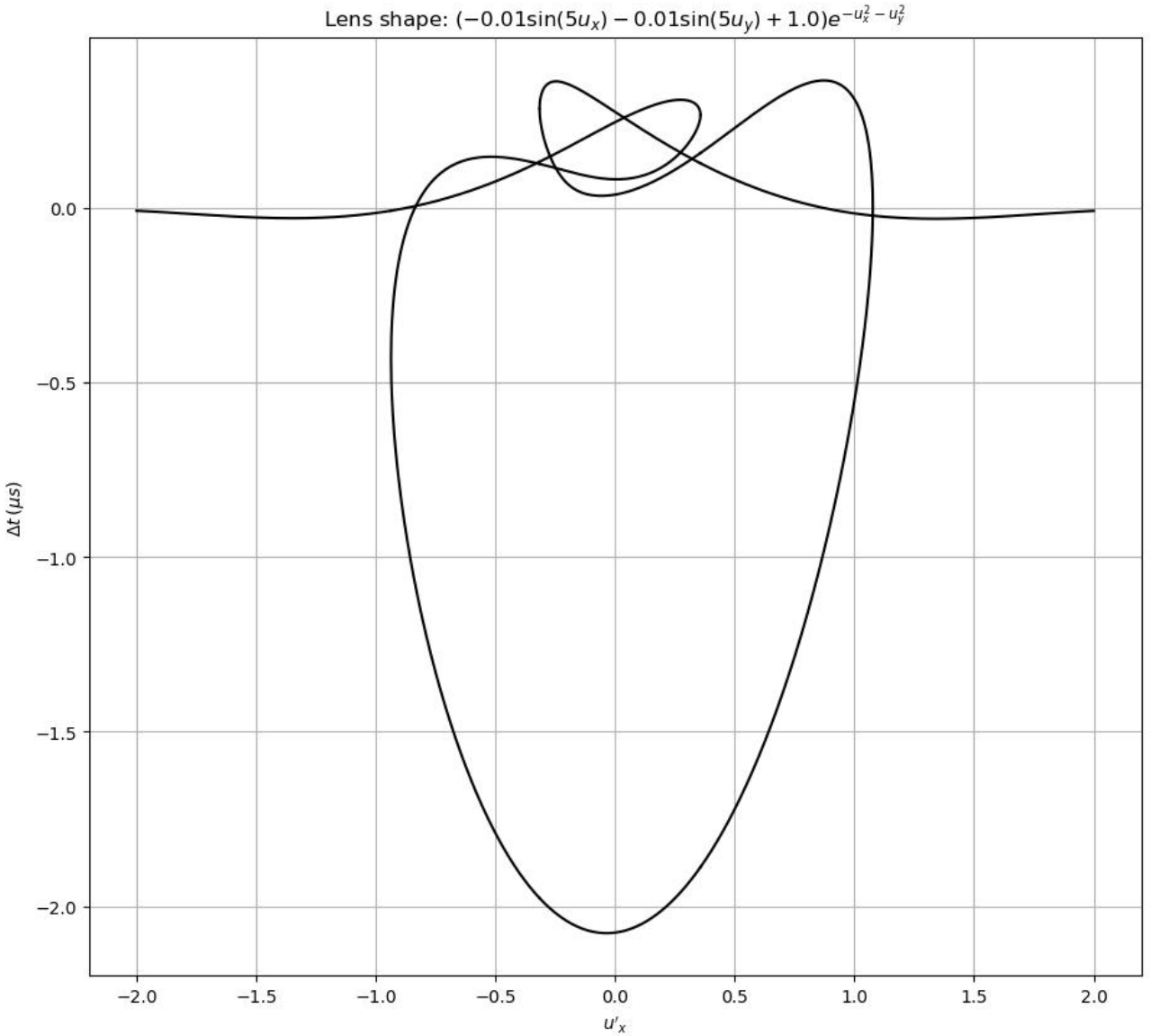
Parameter	$d_{so}\,(kpc)$	$d_{si}\,(kpc)$	$a_x\,(AU)$	$a_y\,(AU)$	$DM_l\,(pc\,cm^{-3})$	ν (GHz)	Slope	Offset
Value	1.1	0.55	0.03	0.04	5.00E-6	1.0	0.5	0.0

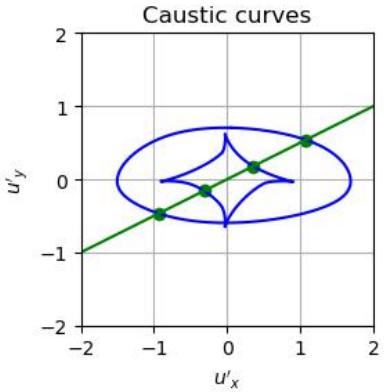
Lens shape	$(-0.05\sin(5u_x) - 0.05\sin(5u_y) + 1.0)e^{-u_x^2 - u_y^2}$



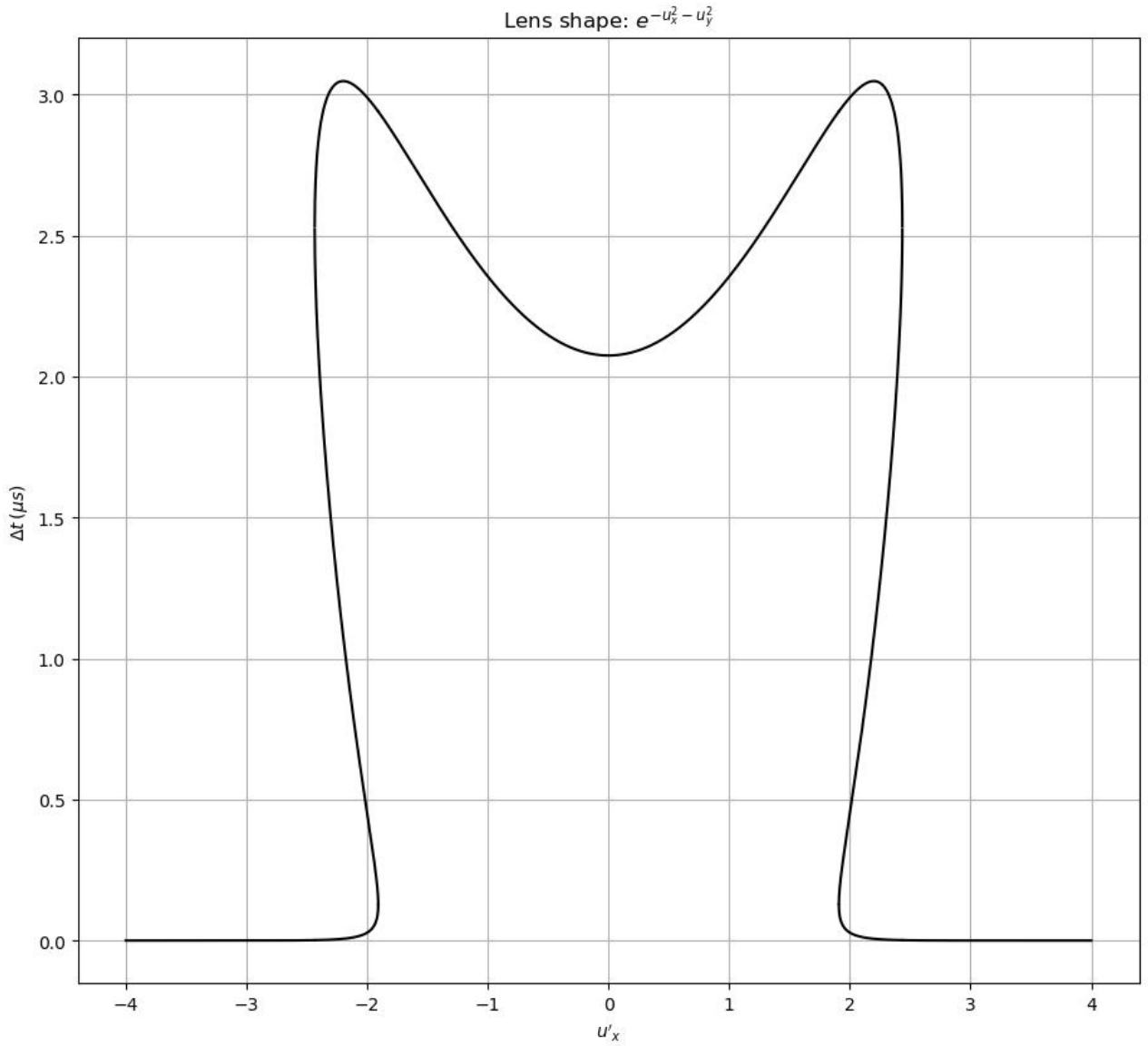


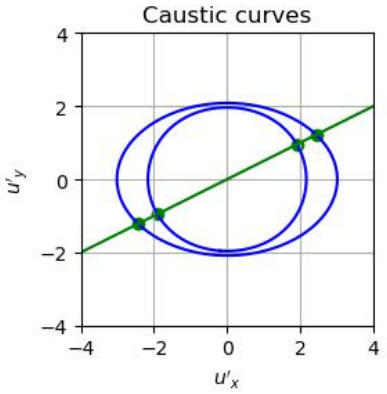
Parameter	Value
$d_{so}\,(kpc)$	1.1
$d_{sl}\,(kpc)$	0.55
$a_x\,(AU)$	0.3
$a_y\,(AU)$	0.4
$DM_l\,(pc\,cm^{-3})$	-5.00E-4
ν (GHz)	1.0
Slope	0.5
Offset	0.0



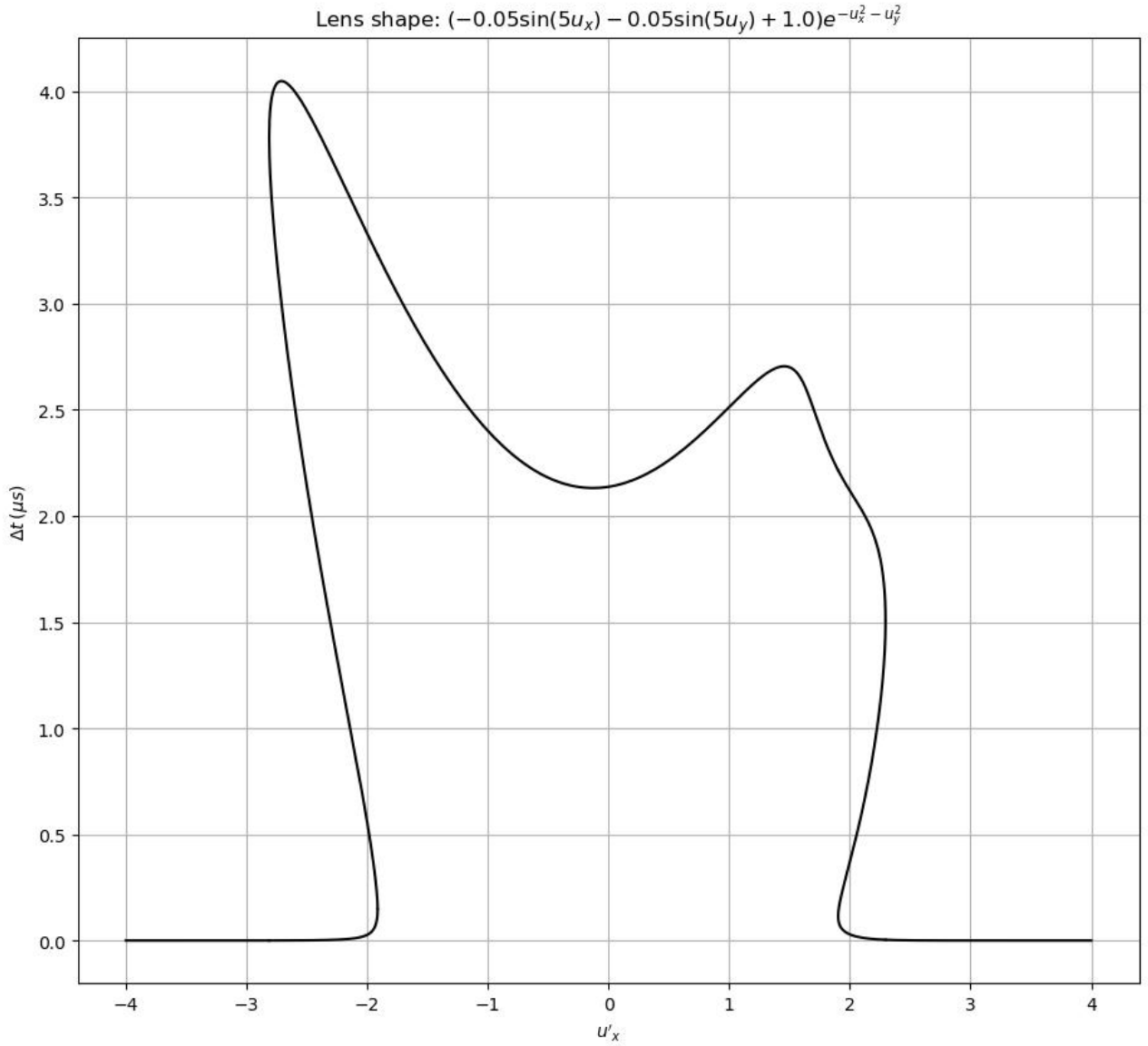


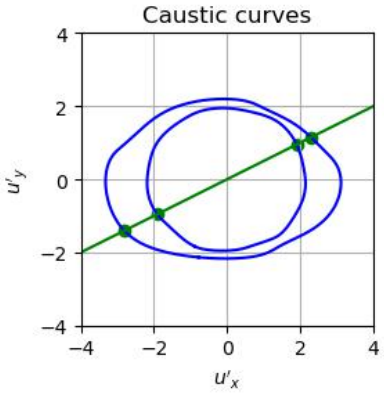
Parameter	Value
$d_{so}\,(kpc)$	1.1
$d_{sl}\,(kpc)$	0.55
$a_x\,(AU)$	0.3
$a_y\,(AU)$	0.4
$DM_l\,(pc\,cm^{-3})$	-5.00E-4
ν (GHz)	1.0
Slope	0.5
Offset	0.0





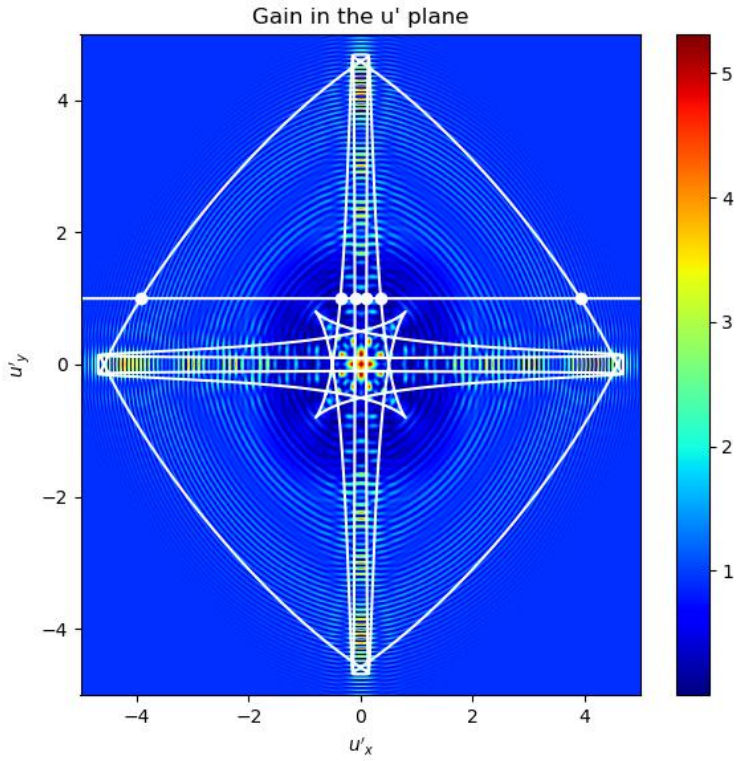
Parameter	Value
$d_{so}\,(kpc)$	1.1
$d_{sl}\,(kpc)$	0.55
$a_x\,(AU)$	0.3
$a_y\,(AU)$	0.4
$DM_l\,(pc\,cm^{-3})$	5.00E-4
ν (GHz)	1.0
Slope	0.5
Offset	0.0

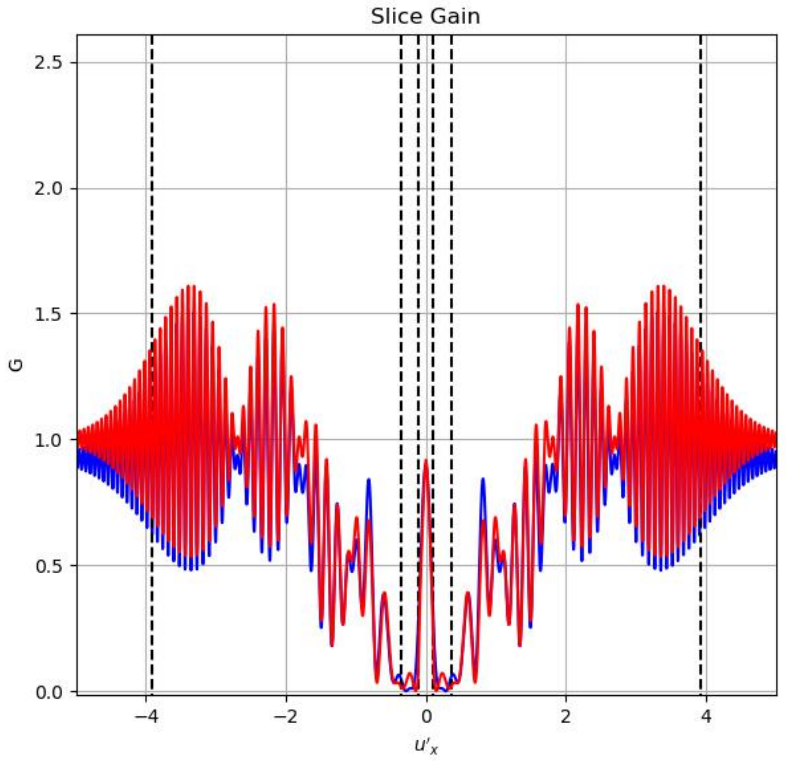




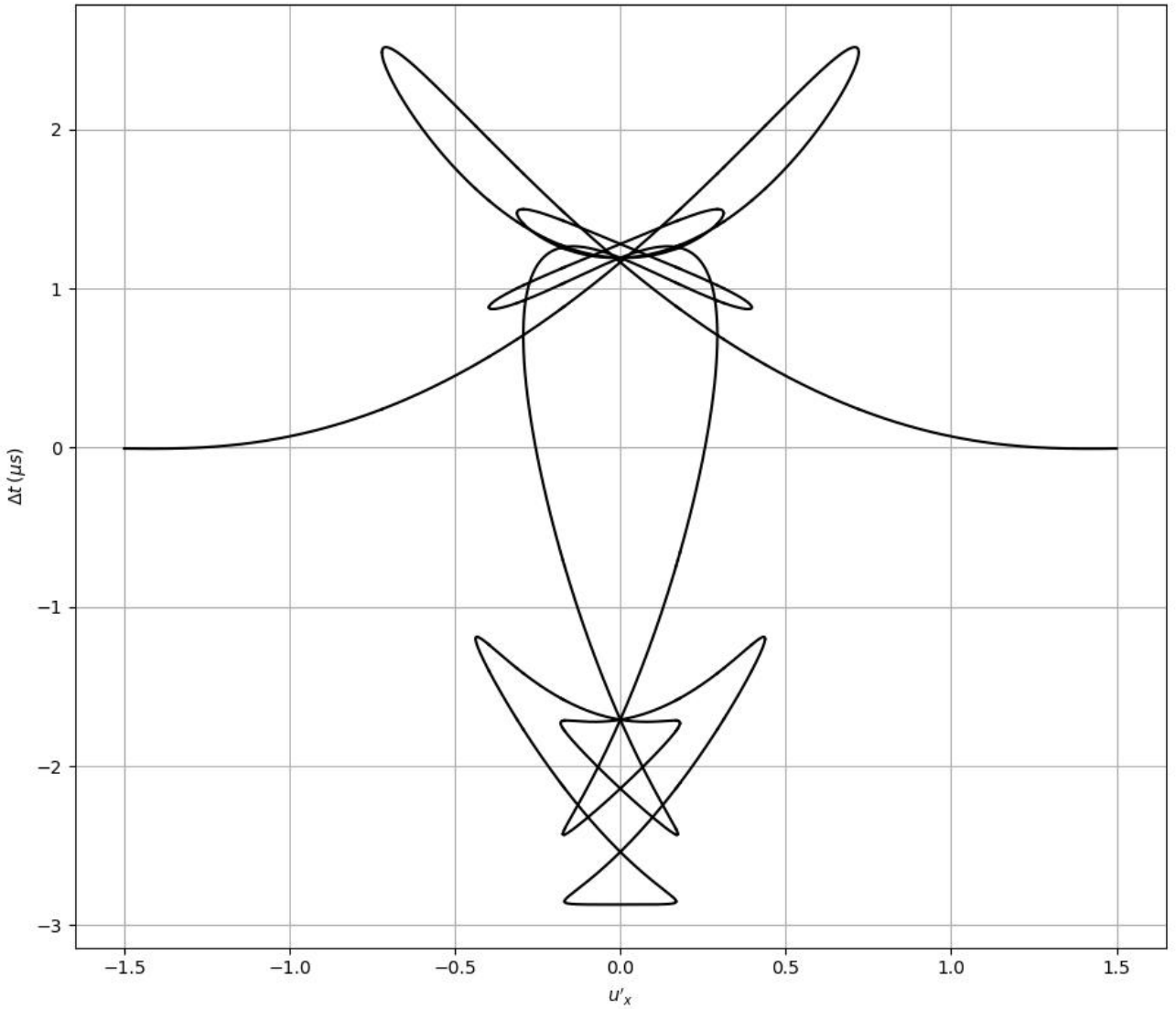
Parameter	Value
$d_{so}\,(kpc)$	1.1
$d_{sl}\,(kpc)$	0.55
$a_x\,(AU)$	0.3
$a_y\,(AU)$	0.4
$DM_l\,(pc\,cm^{-3})$	5.00E-4
ν (GHz)	1.0
Slope	0.5
Offset	0.0

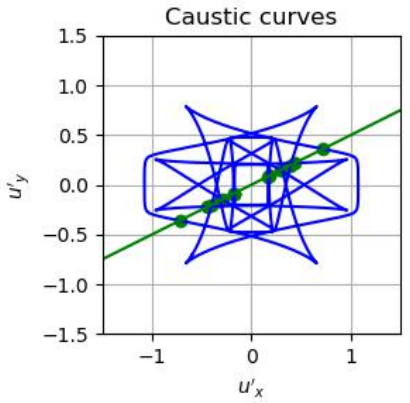
A fancy one...





Parameter	$d_{so}\,(kpc)$	$d_{sl}\,(kpc)$	$a_x\,(AU)$	$a_y\,(AU)$	$DM_l\,(pc\,cm^{-3})$	ν (GHz)	Slope	Offset	Lens shape
Value	1.1	0.55	0.02	0.02	-2.00E-6	0.8	0.0	1.0	$e^{-ux^4-uy^4}$





Parameter	Value
$d_{so}\,(kpc)$	1.1
$d_{sl}\,(kpc)$	0.55
$a_x\,(AU)$	0.5
$a_y\,(AU)$	0.6
$DM_l\,(pc\,cm^{-3})$	-5.00E-4
ν (GHz)	0.85
Slope	0.5
Offset	0.0
Lens shape	$e^{-u_x^4-u_y^4}$

Future work

- Combine multiple image TOAs to predict altered pulse shapes, TOAs as measured by the telescope.
- Find lens parameters that can reproduce J1713+0747 event observations.
- Average over frequency bands.

Code, more detailed exposition available at github.com/ggrillo93