From Observation to Simulation

Understanding surprising evolution in nova ejecta

Fiona Healy Tim O'Brien Robert Beswick

Science & Technology Facilities Council

MANCHESTER 1824
The University of Manchester

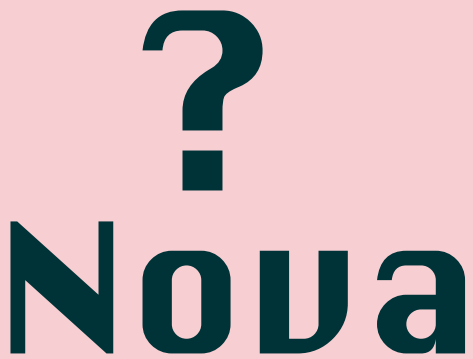
EVN Symposium 2016

St Petersburg

U959 Mon

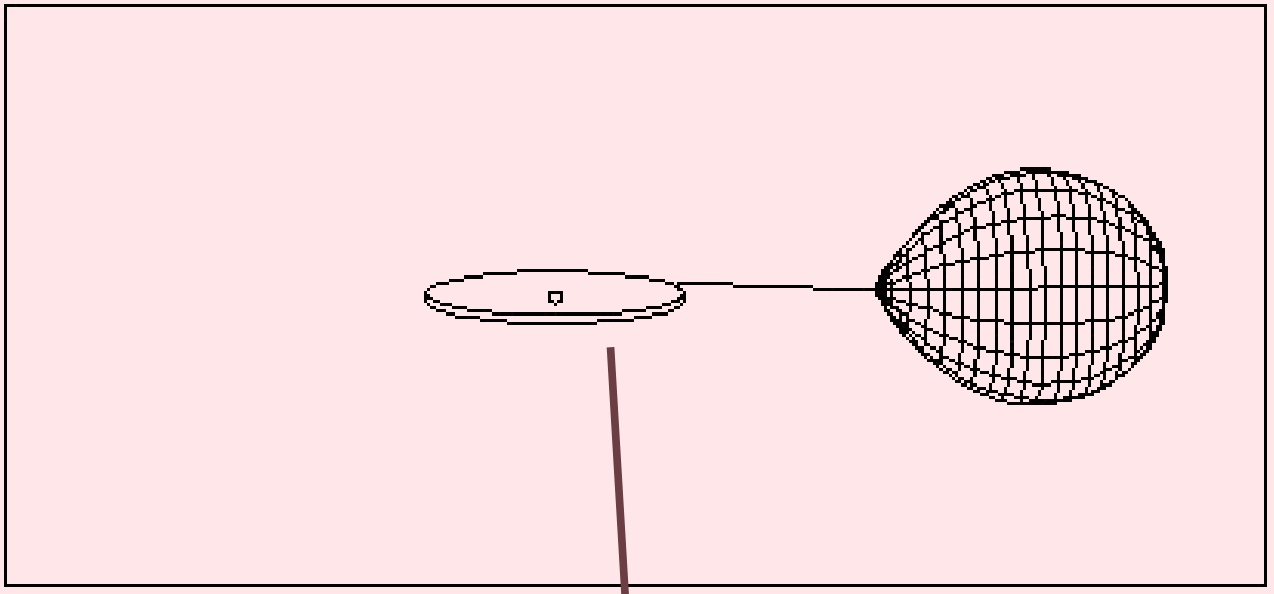
V959 Mon

Nova Mon 2012


?
Nova

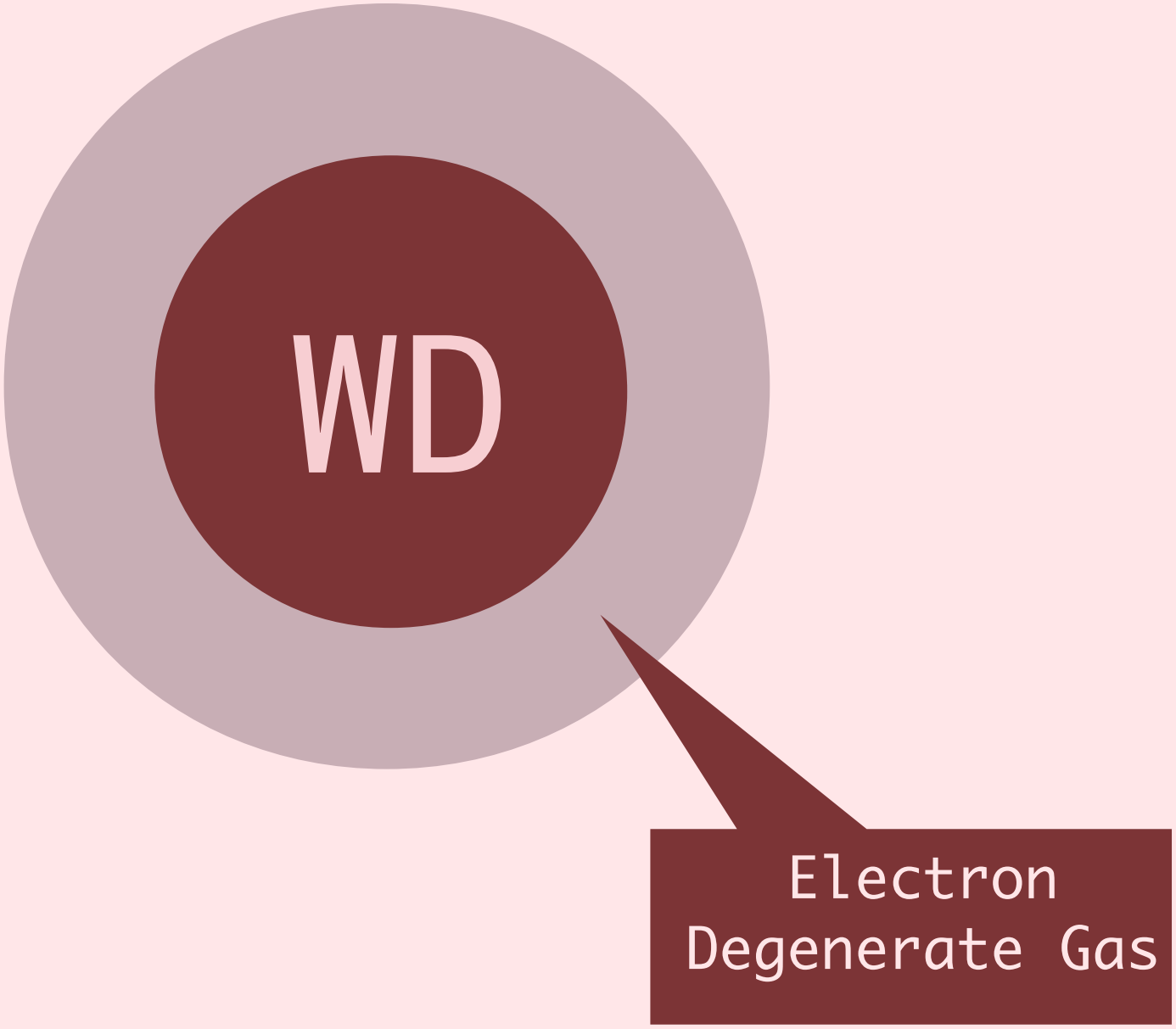
Cataclysmic Variable

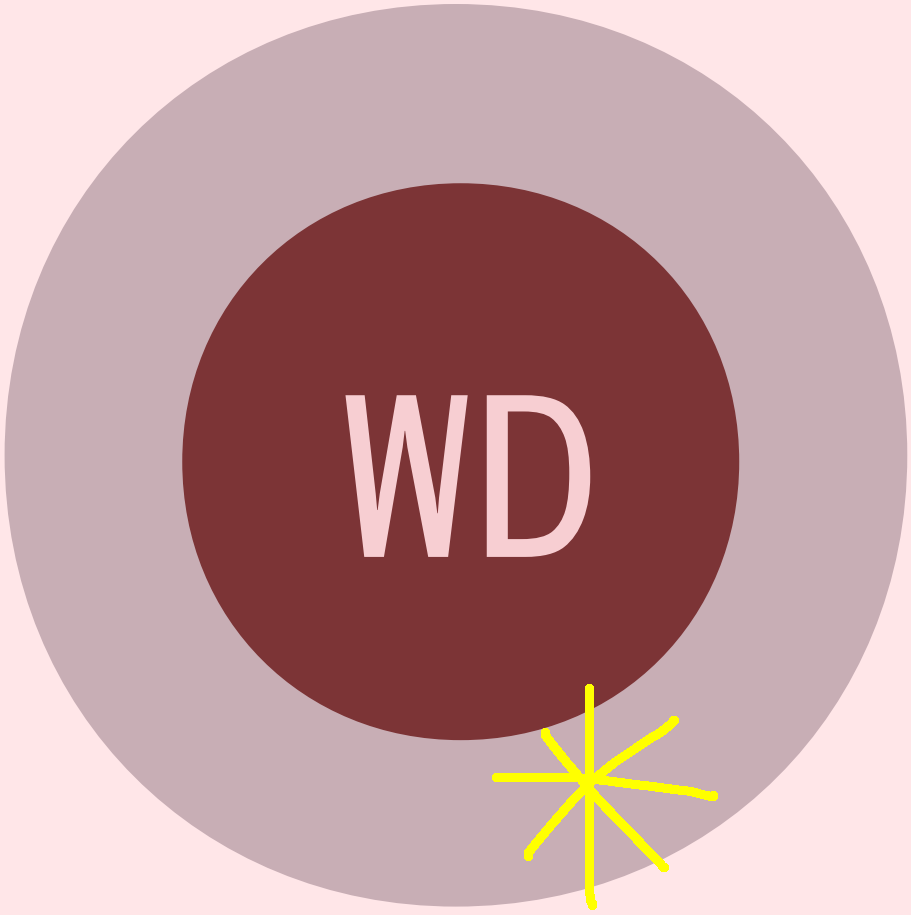
Cataclysmic Variable



White Dwarf

WD


WD
Electron
Degenerate Gas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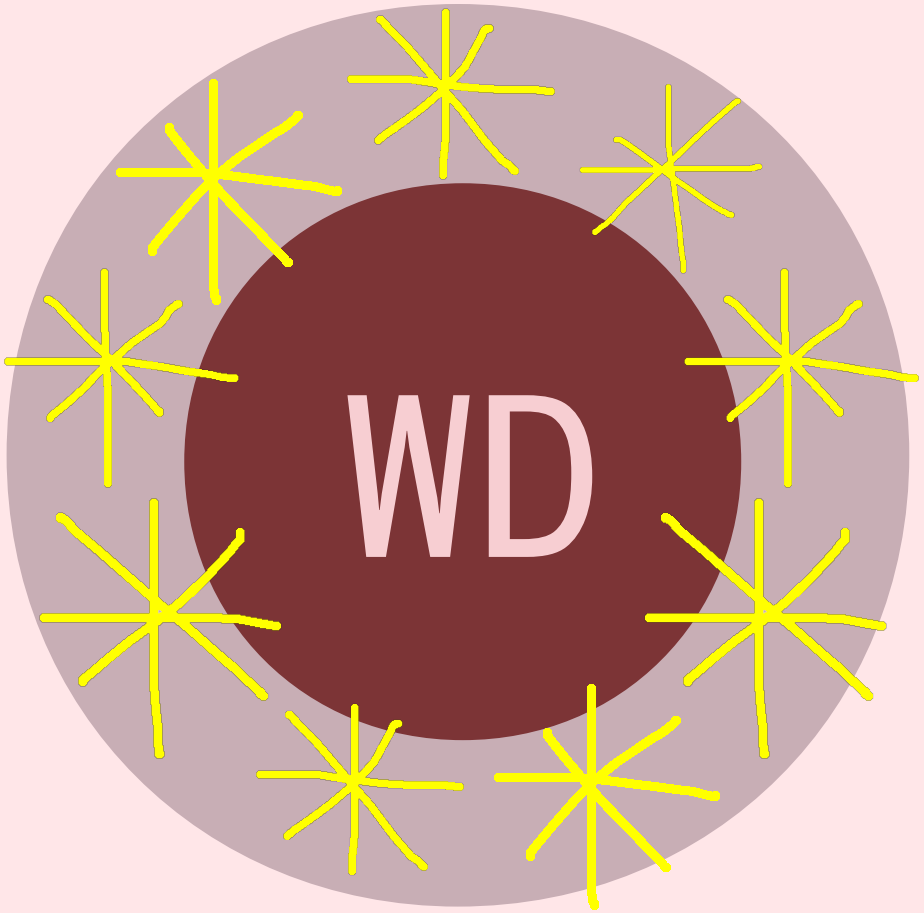
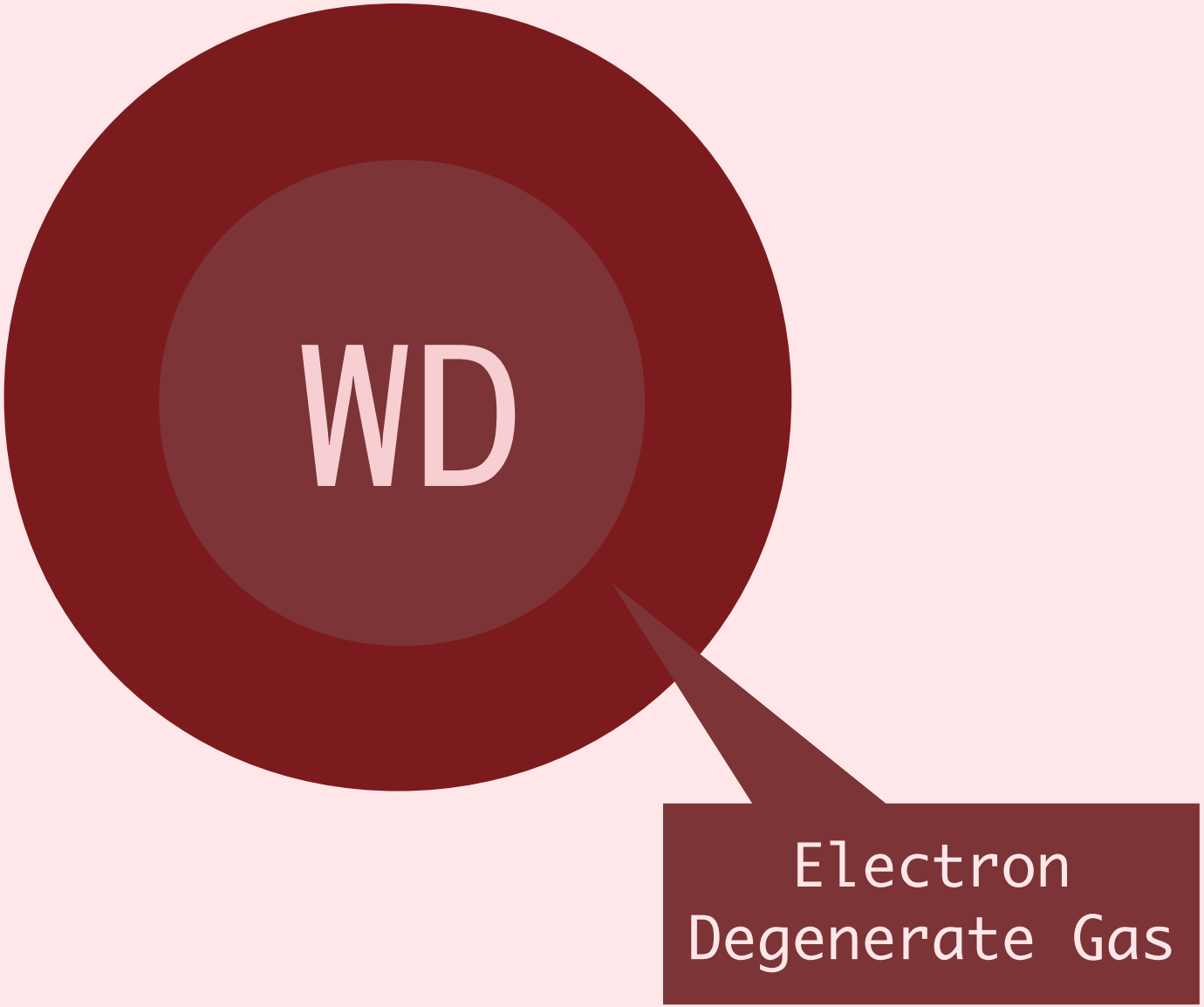
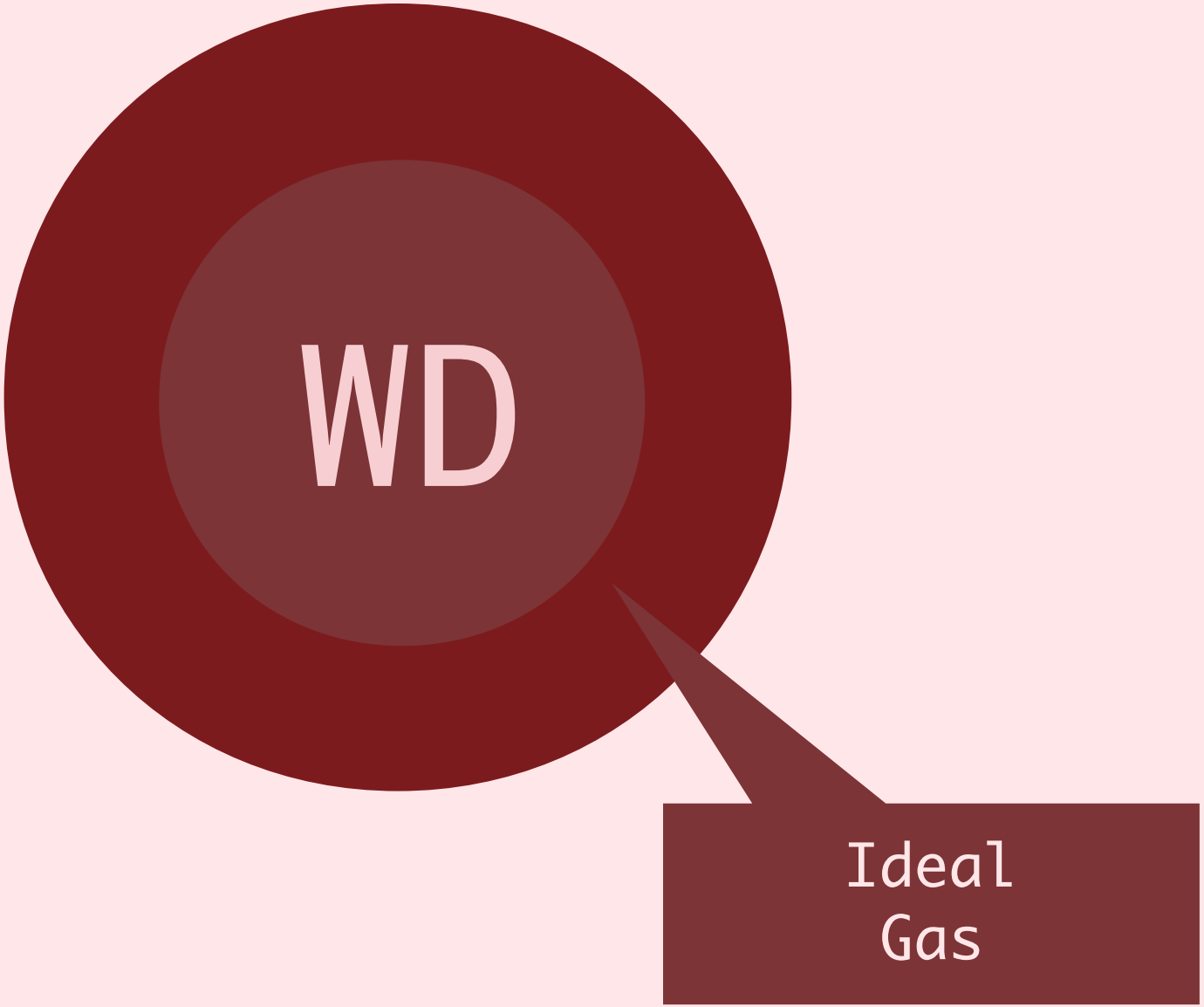

WD

WD

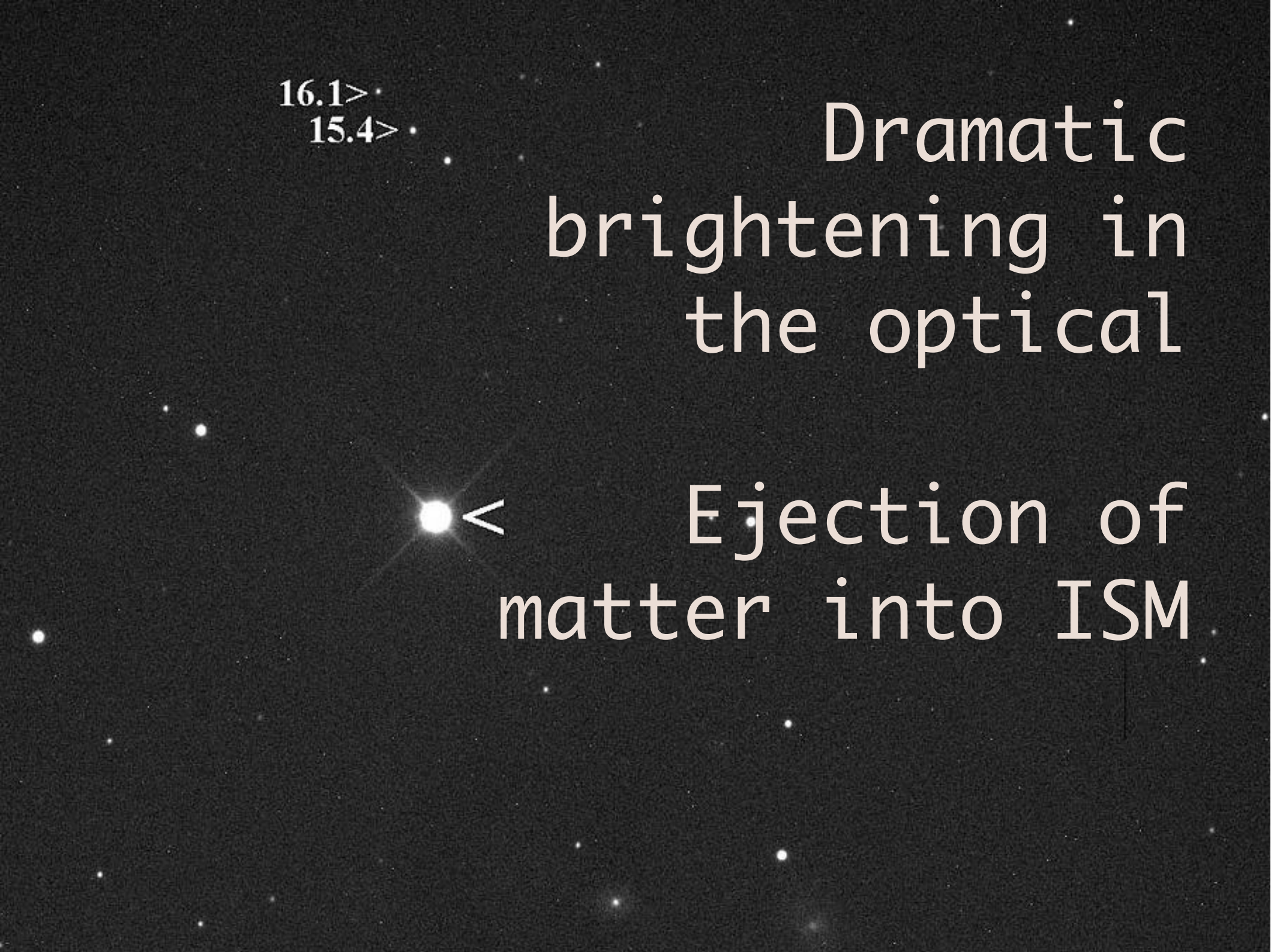
WD

WD


WD
Electron
Degenerate Gas


WD
Ideal
Gas

WD


16.1>
15.4>
Dramatic brightening in the optical
Ejection of matter into ISM

Radio Observations

Expanding shell of ejecta

Expanding shell of ejecta

Thermal bremsstrahlung

Expanding shell of ejecta

Thermal bremsstrahlung

Synchrotron if shocks present

Expanding shell of ejecta

Thermal bremsstrahlung

Synchrotron if shocks present

Radio flux increases with time, then decreases

Expanding shell of ejecta

Thermal bremsstrahlung

Synchrotron if shocks present

Radio flux increases with time, then decreases

Shell becomes optically thin (starting at higher frequencies) during expansion

Models assume:

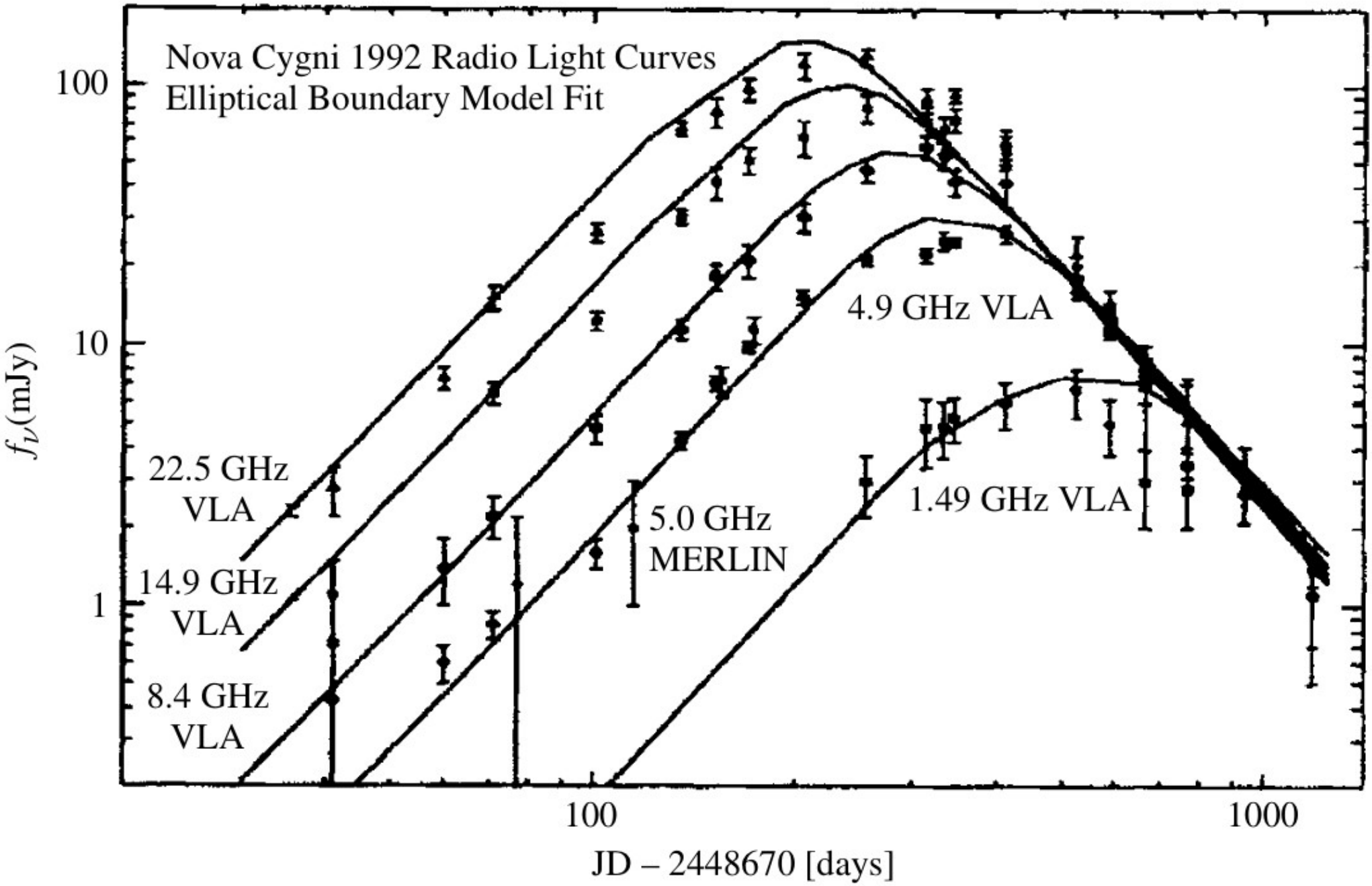
Models assume:

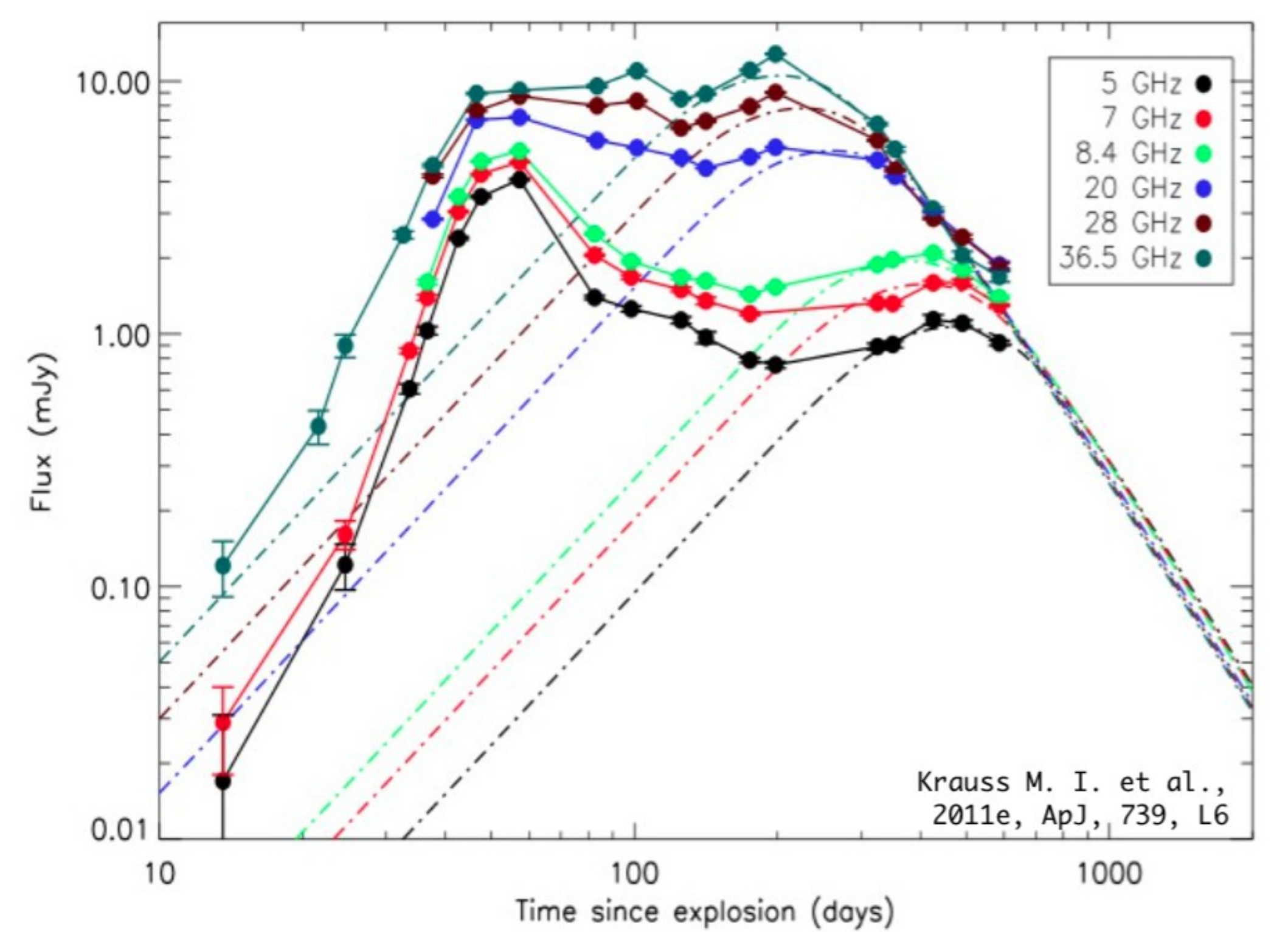
Density profile ~ $1/r^2$

Models assume:

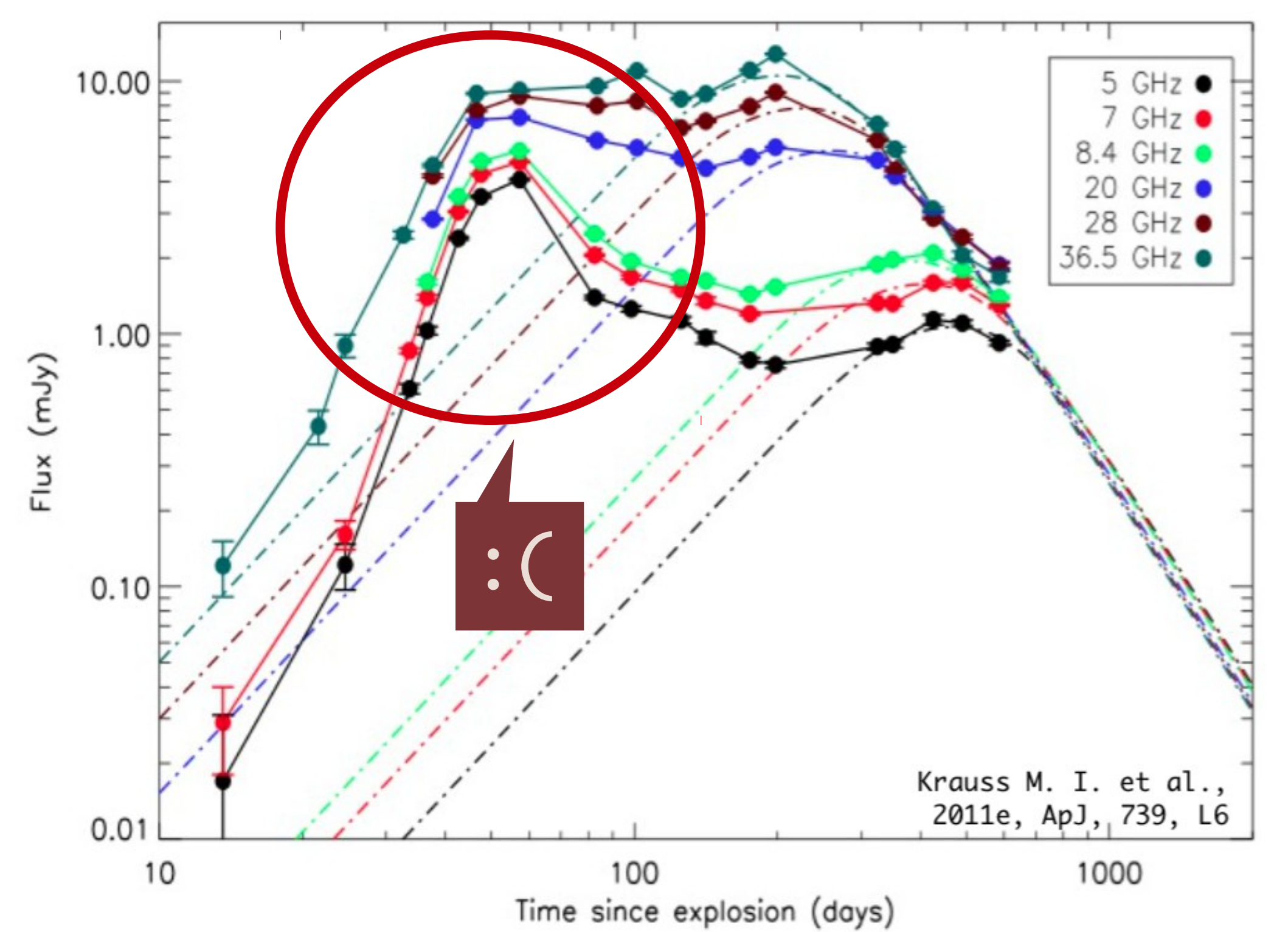
Density profile ~ $1/r^2$

Spherical shell of expanding material


Nova Cygni 1992 Radio Light Curves
Elliptical Boundary Model Fit
100
10
1
f_ν(mJy)
22.5 GHz
VLA
14.9 GHz
VLA
8.4 GHz
VLA
5.0 GHz
MERLIN
4.9 GHz VLA
1.49 GHz VLA
100
1000
JD – 2448670 [days]



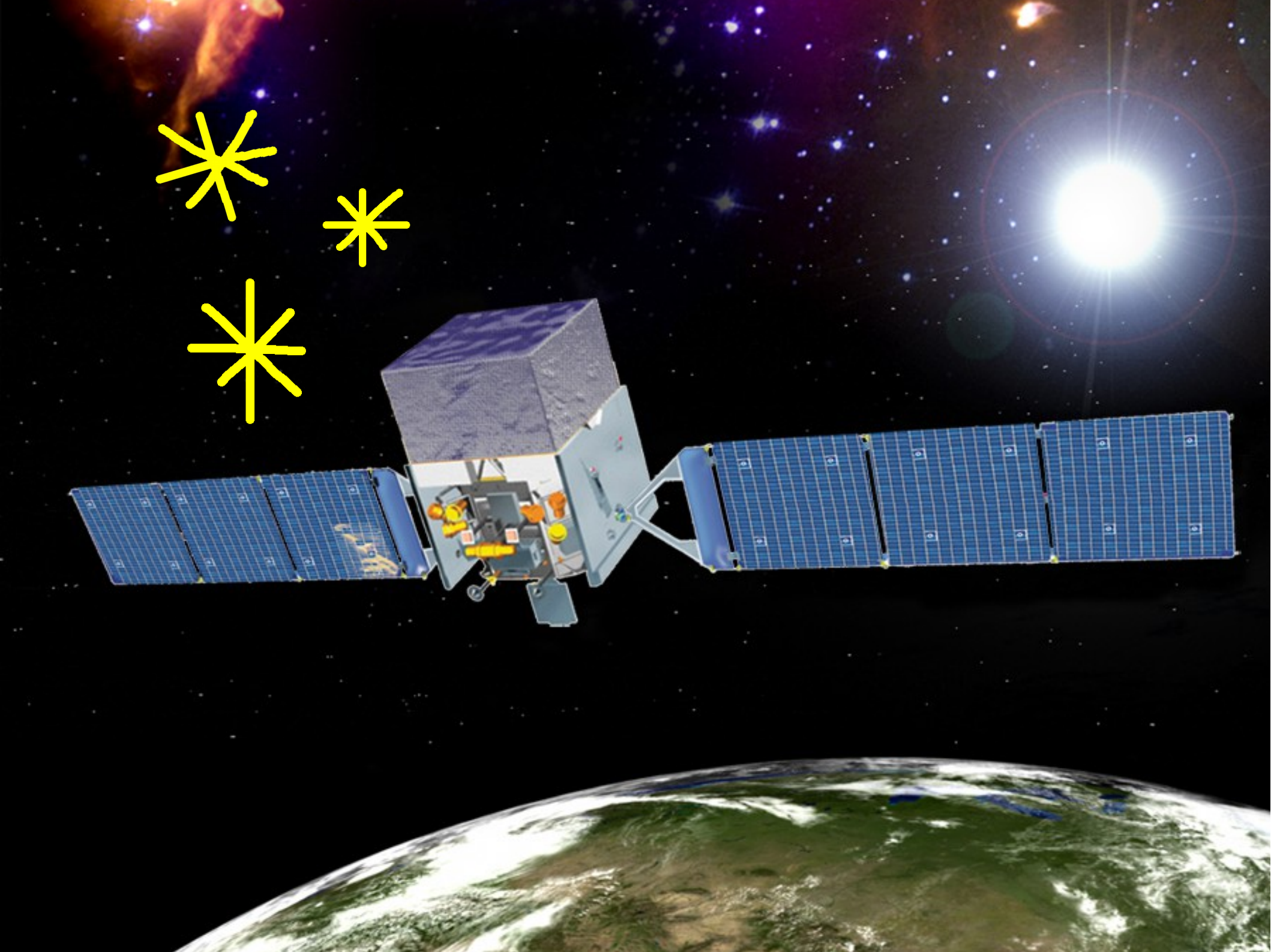
V1723 Acquilae

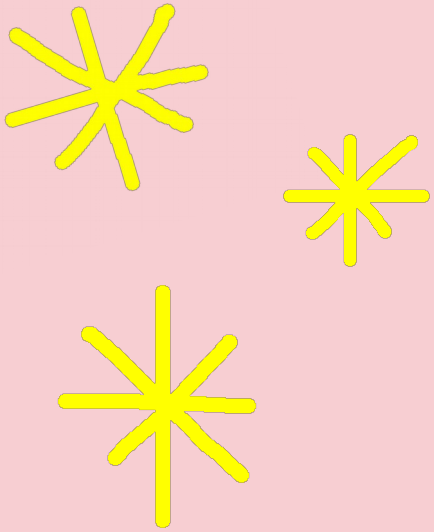


V1723 Acquilae

Nova Mon 2012

I'm a Unicorn

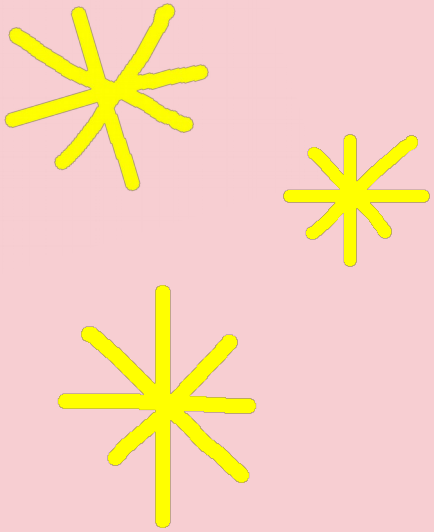




Nova Mon 2012

Discovered in Monocerotis by Fermi LAT as gamma ray source

Went behind sun for a while



Nova Mon 2012

Discovered in Monocerotis by Fermi LAT as gamma ray source

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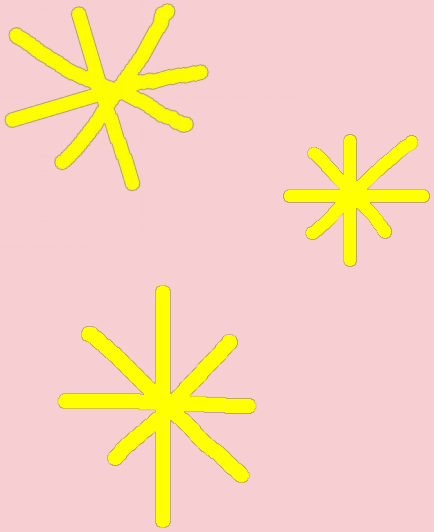
Observed in optical, discovered to be a nova



Nova Mon 2012

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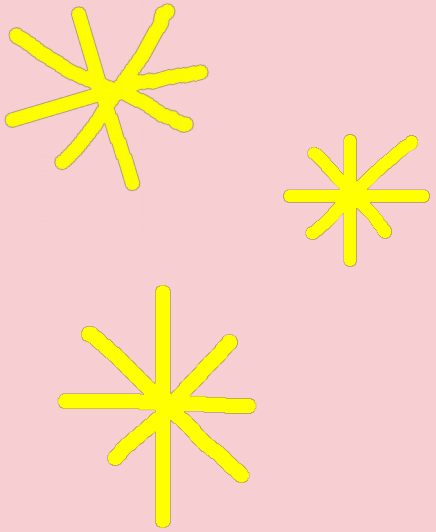
Nova Mon 2012



Discovered in Monocerotis by Fermi LAT as gamma ray source

Went behind s for a while

Obse scovered e a nova

Explosion not energetic enough?

Nova Mon 2012

Not the only one

Discovered in Monocerotis by Fermi LAT as gamma ray source

Went behind s for a while

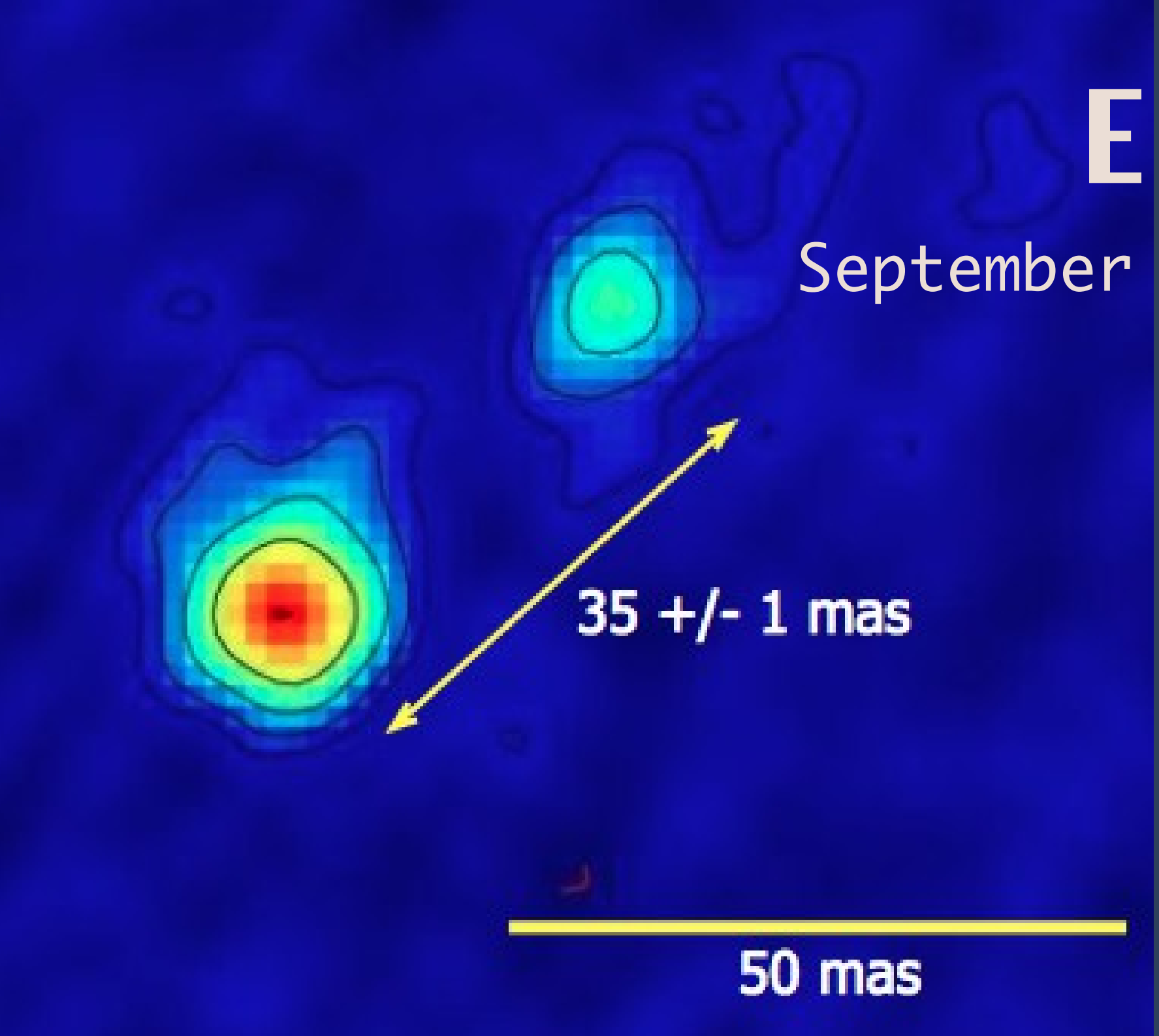
Obse scovered e a nova

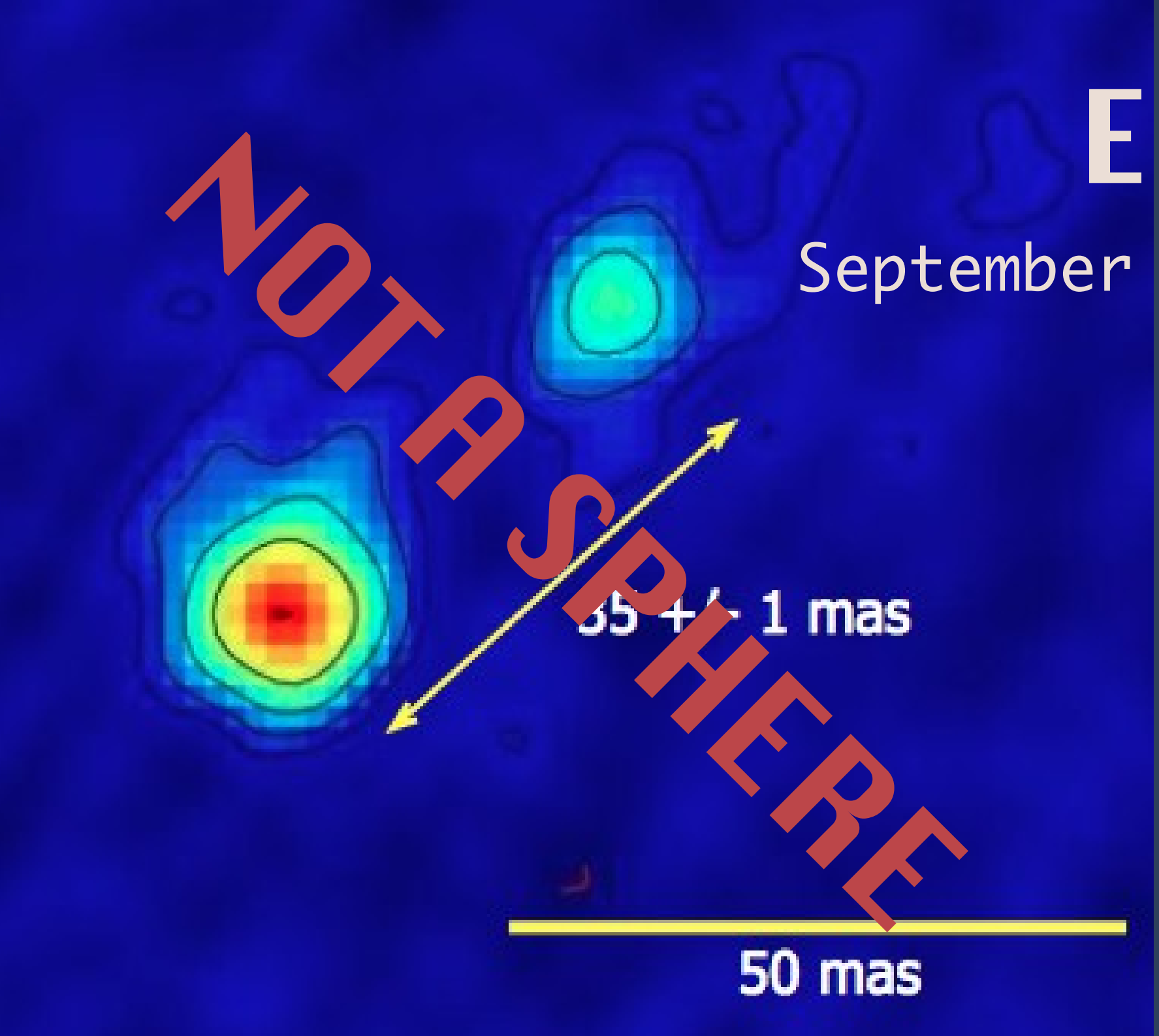
Explosion not energetic enough?

EUN Observations

EVN

September 2012



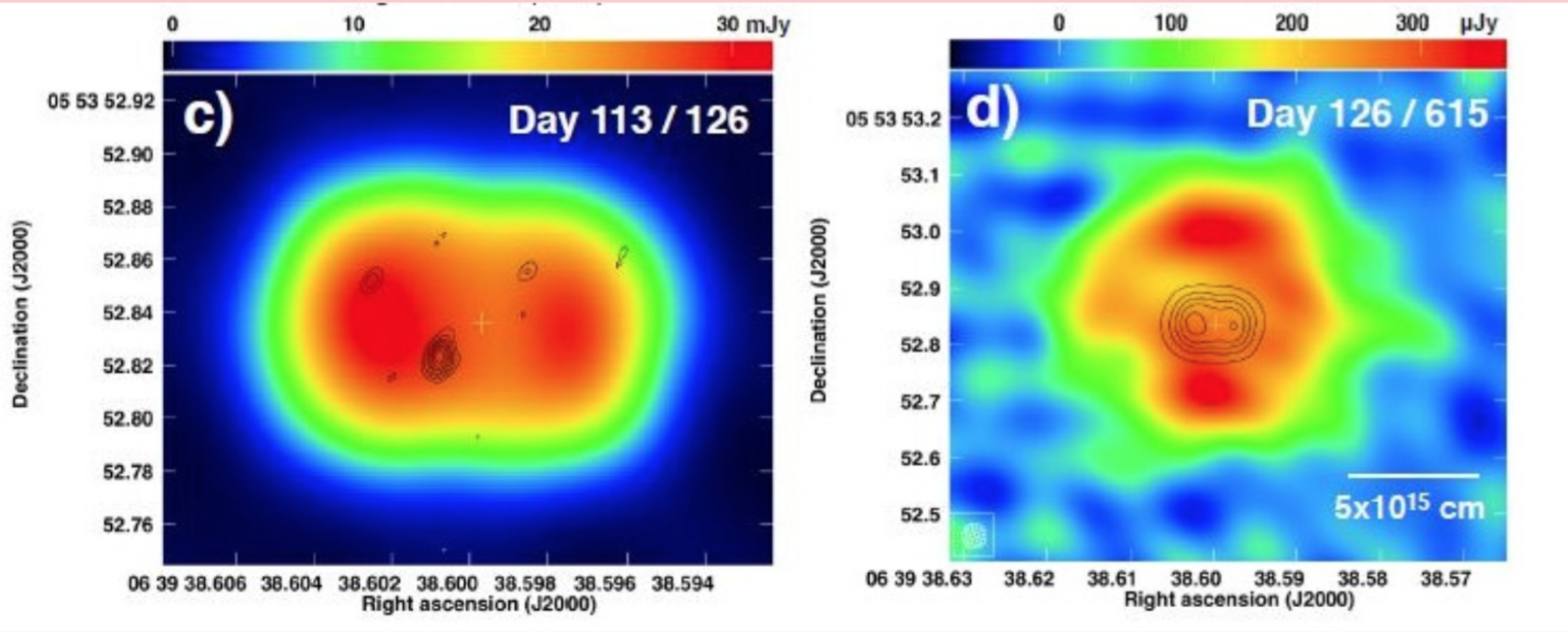


EUN

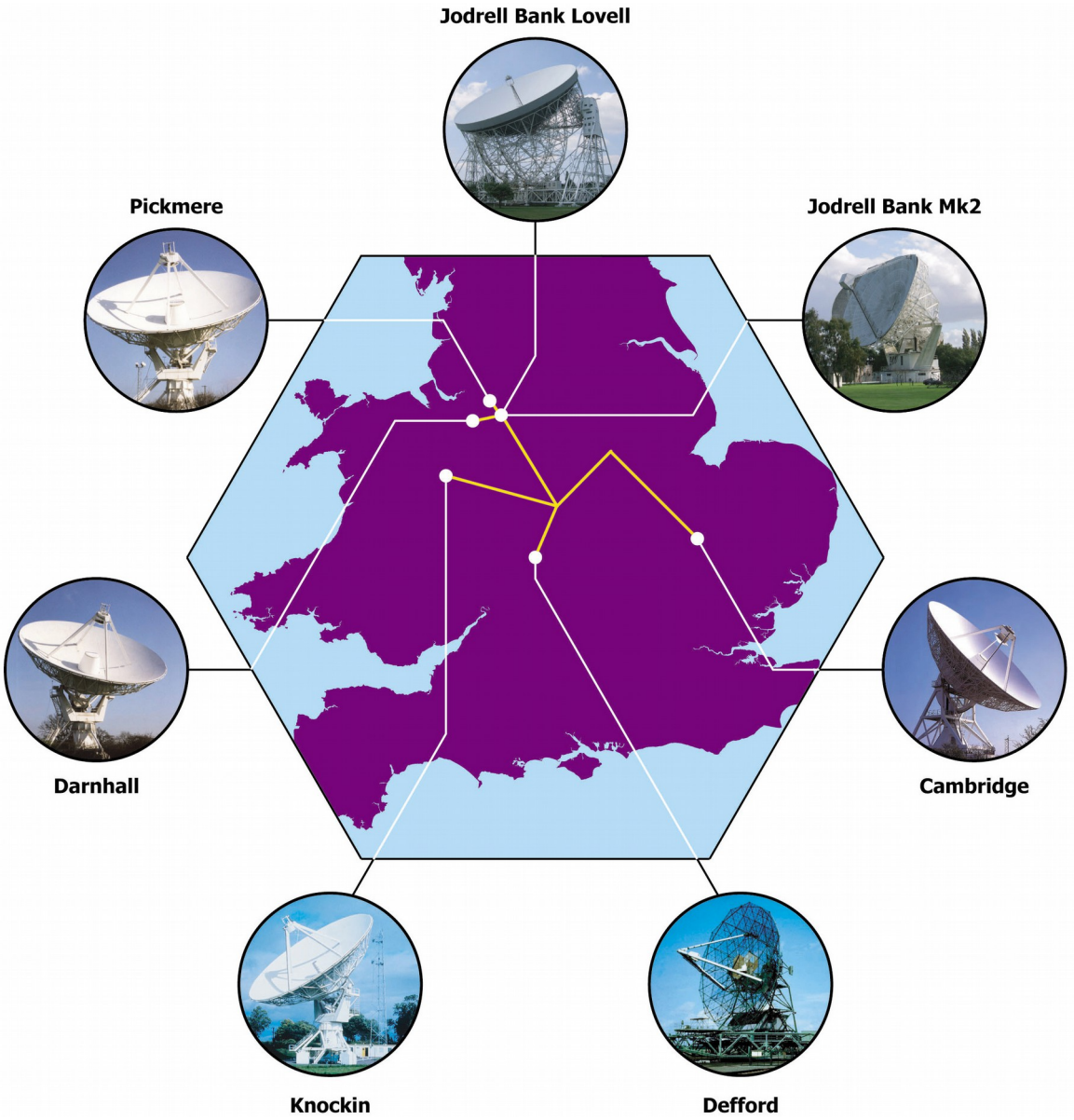
September 2012

VLA Observations

Ejecta change elongation from east-west to north-south



Things we did


Jodrell Bank Lovell
Pickmere
Jodrell Bank Mk2
Darnhall
Cambridge
Knockin
Defford

e-MERLIN

Reduced 6 epochs of eMERLIN observations of Nova Mon 2012

Reduced 6 epochs of eMERLIN observations of Nova Mon 2012

(7^{th} on the way)

Reduced 6 epochs of eMERLIN observations of Nova Mon 2012

(7^{th} on the way)

C Band (4 – 8 GHz)

Reduced 6 epochs of eMERLIN observations of Nova Mon 2012

(7^{th} on the way)

C Band (4 – 8 GHz)

Provides a resolution of 40 milliarcseconds

18th Sept 2012

12th Nov 2012

22nd Nov 2012

26th Feb 2013

11th Oct 2013

21st Feb 2014

18th Sept 2012

12th Nov 2012

22nd Nov 2012

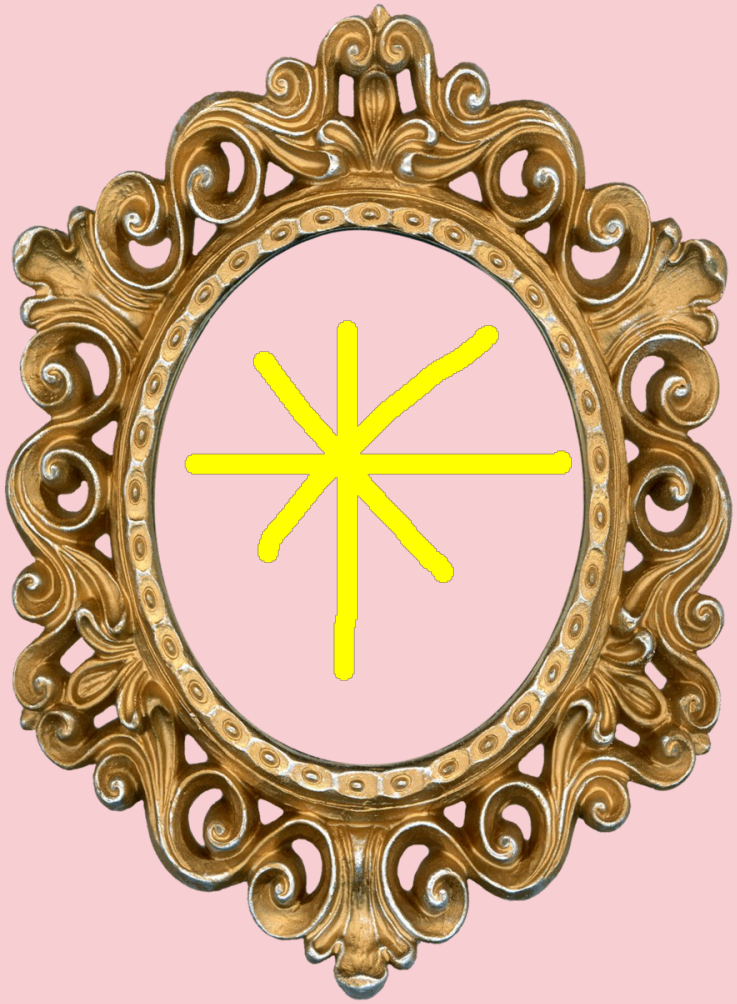
26th Feb 2013

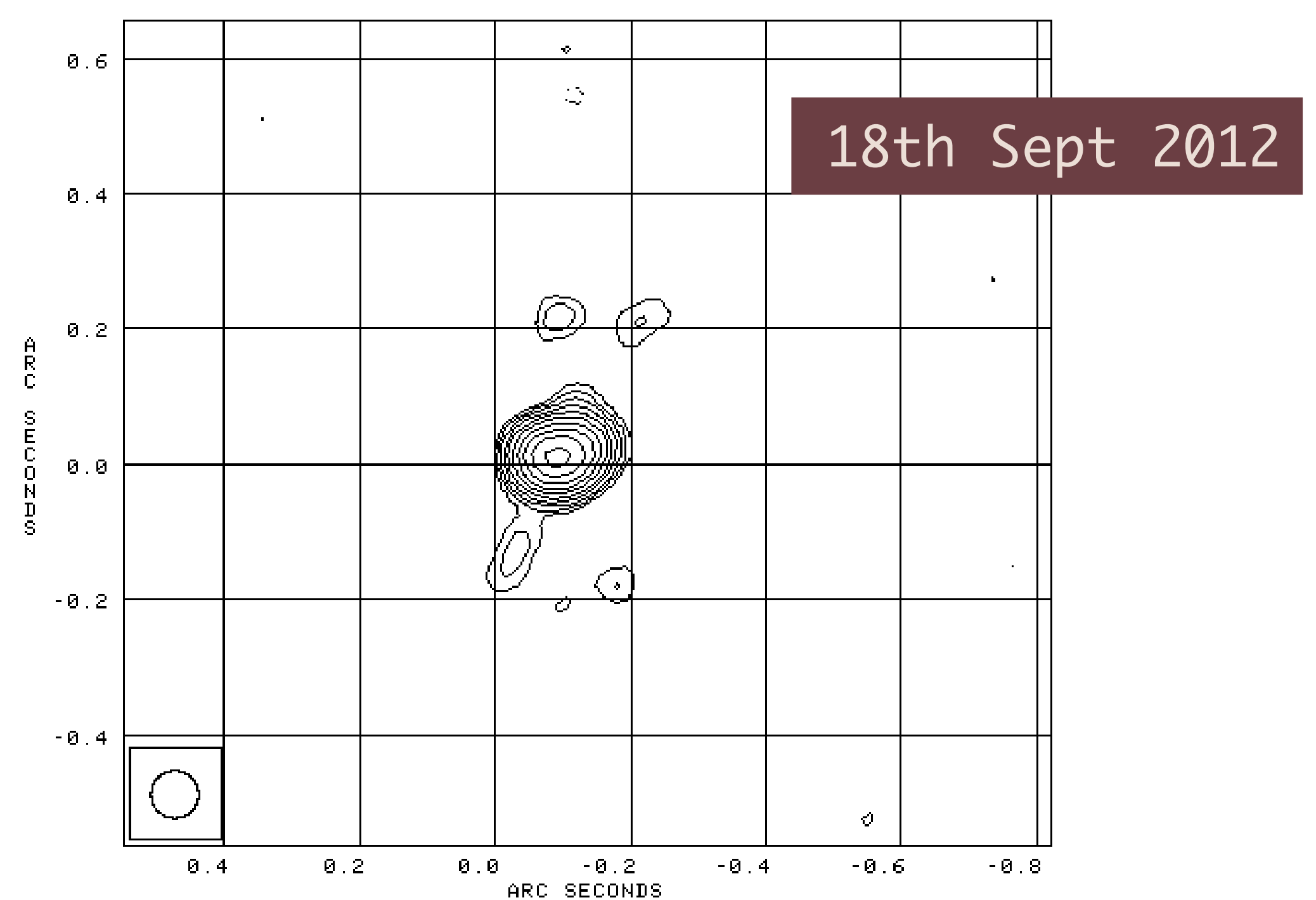
11th Oct 2013

21st Feb 2014

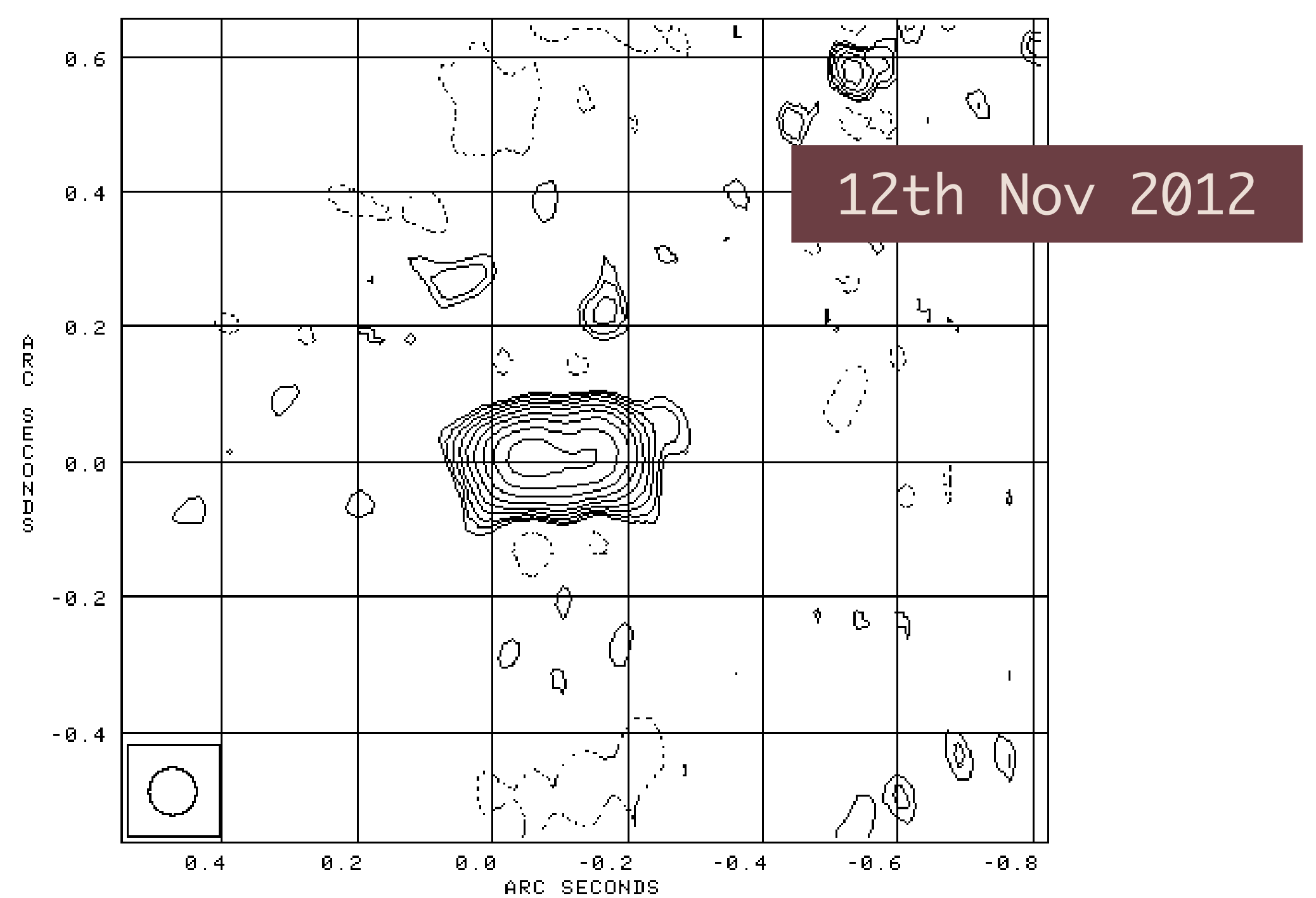
From ~ 80 days to
~ 600 days post
Fermi discovery

IMAGES





CENTER AT RA 06 39 38.60600 DEC 05 53 52.8300
PEAK CONTOUR FLUX = 5.2883E-03 JY/BEAM
LEVS = 7.029E-05 * (-3, 3, 4.240, 6, 8.485, 12,
16.97, 24, 33.94, 48, 67.88, 96)



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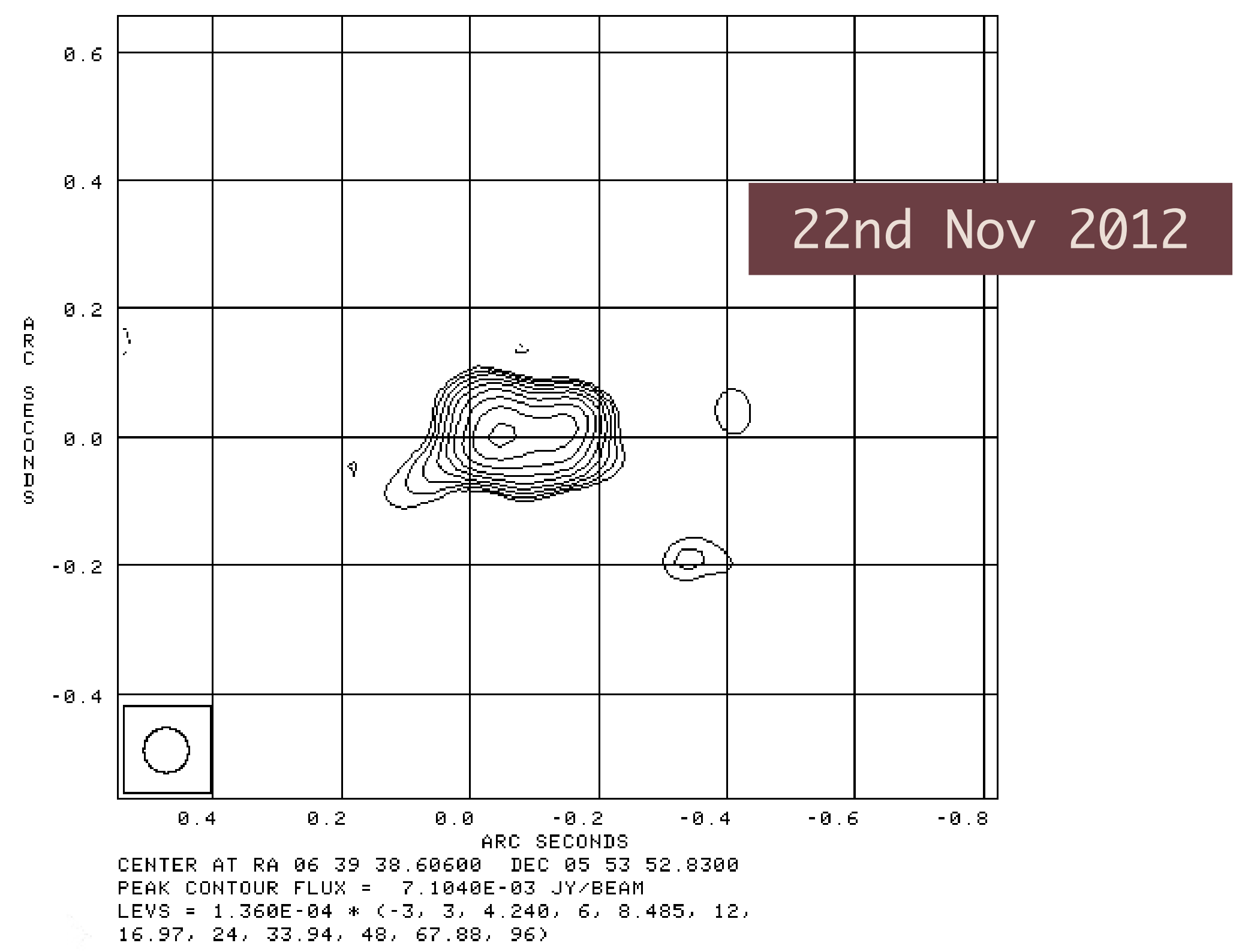
22nd Nov 2012
0.6
0.4
0.2
0.0
-0.2
-0.4
DECLINATION
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
ARC SECONDS
CENTER AT RA 06 39 38.60600 DEC 05 53 52.8300
PEAK CONTOUR FLUX = 7.1040E-03 JY/BEAM
LEVS = 1.360E-04 * (-3, 3, 4.240, 6, 8.485, 12,
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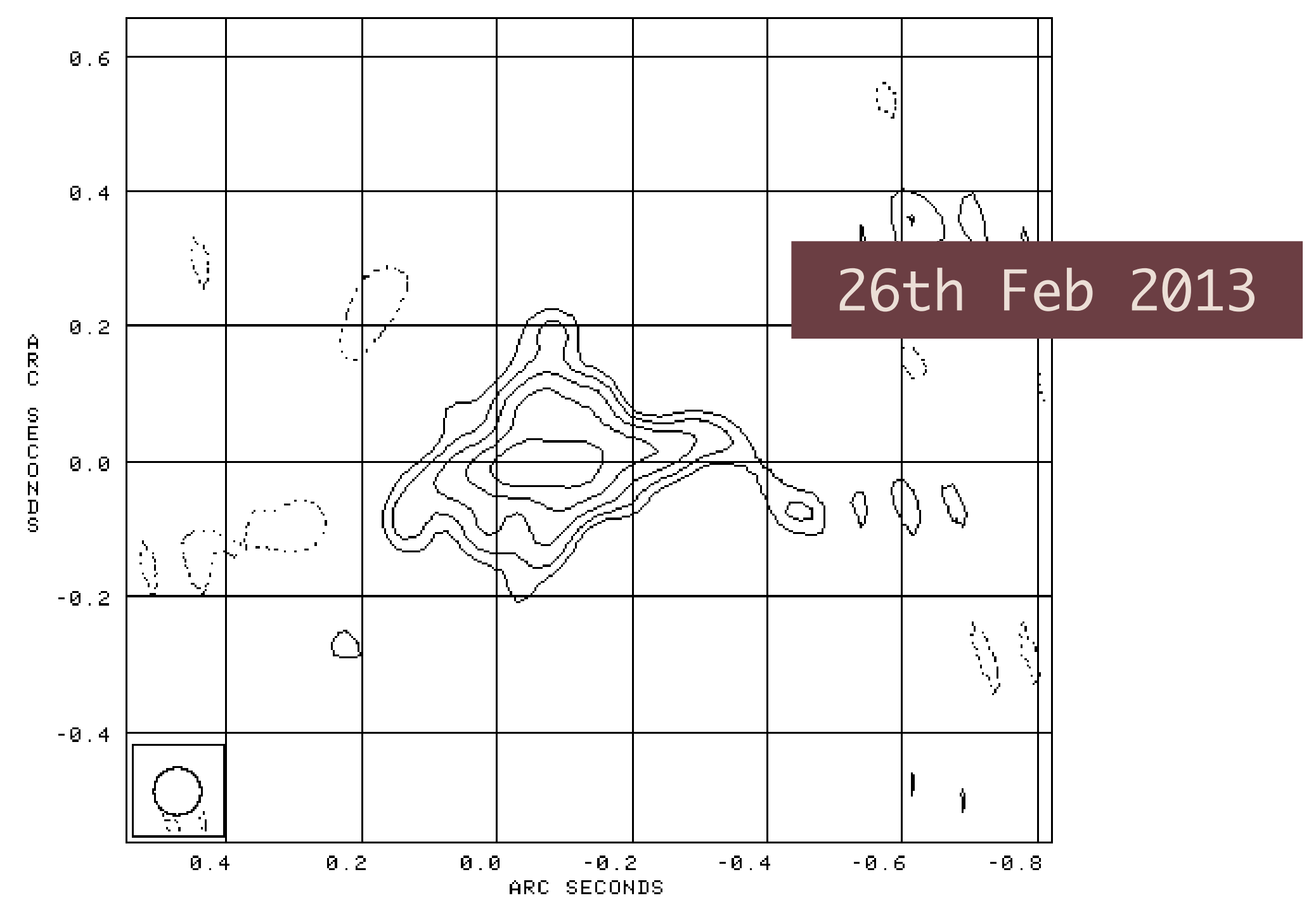

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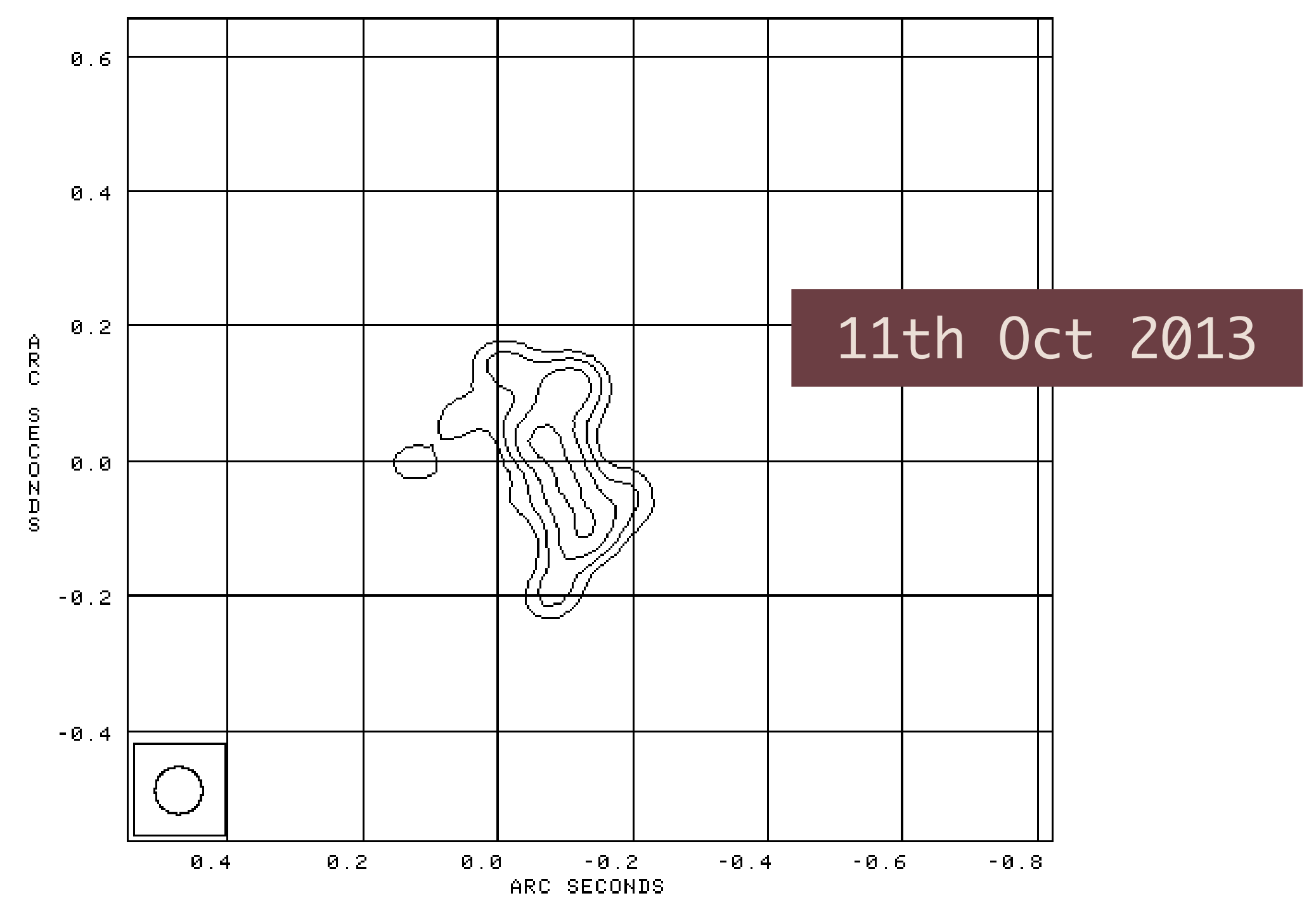
16.97, 24, 33.94, 48, 67.88, 96)



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PEAK CONTOUR FLUX = 8.5520E-04 JY/BEAM
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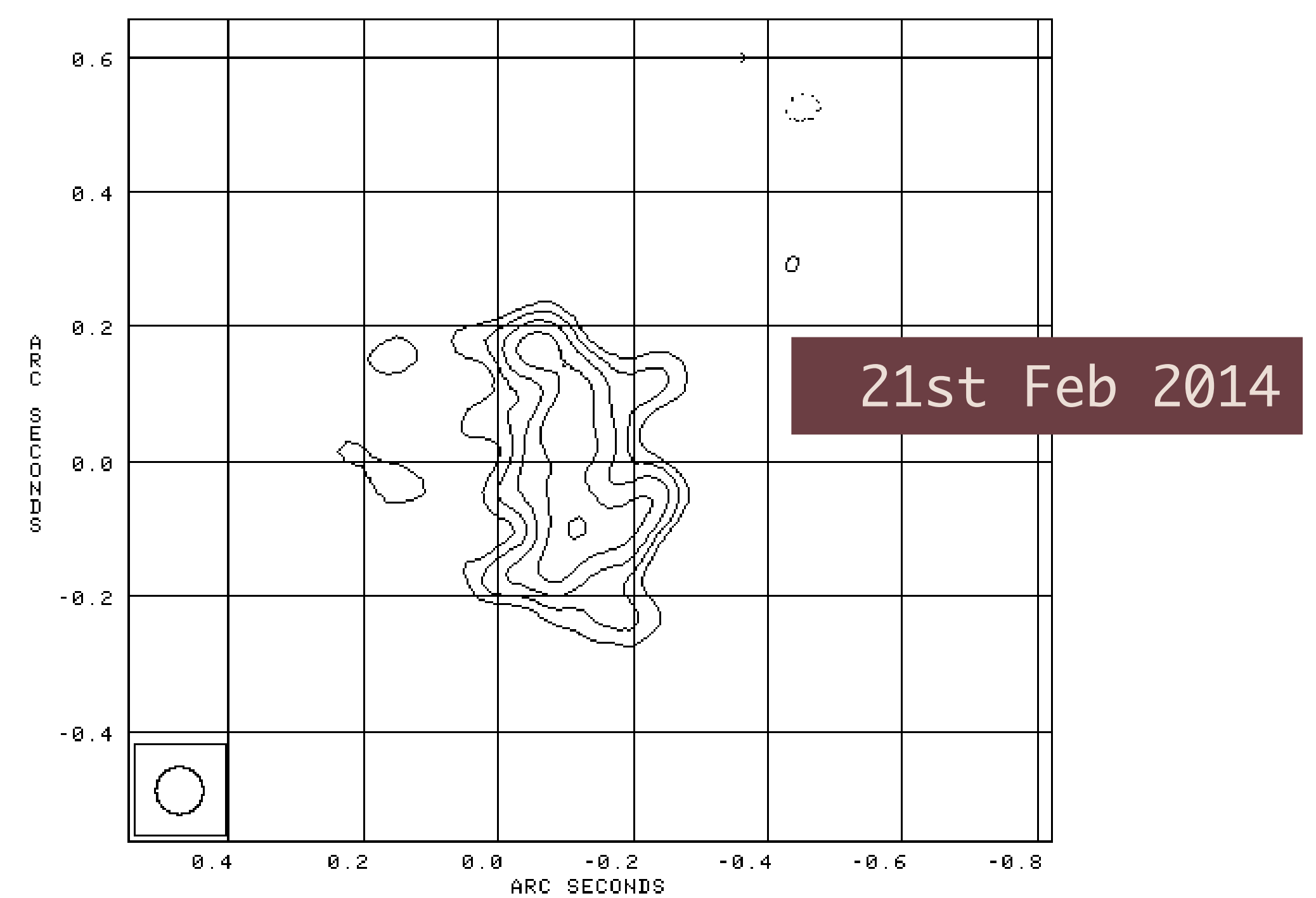

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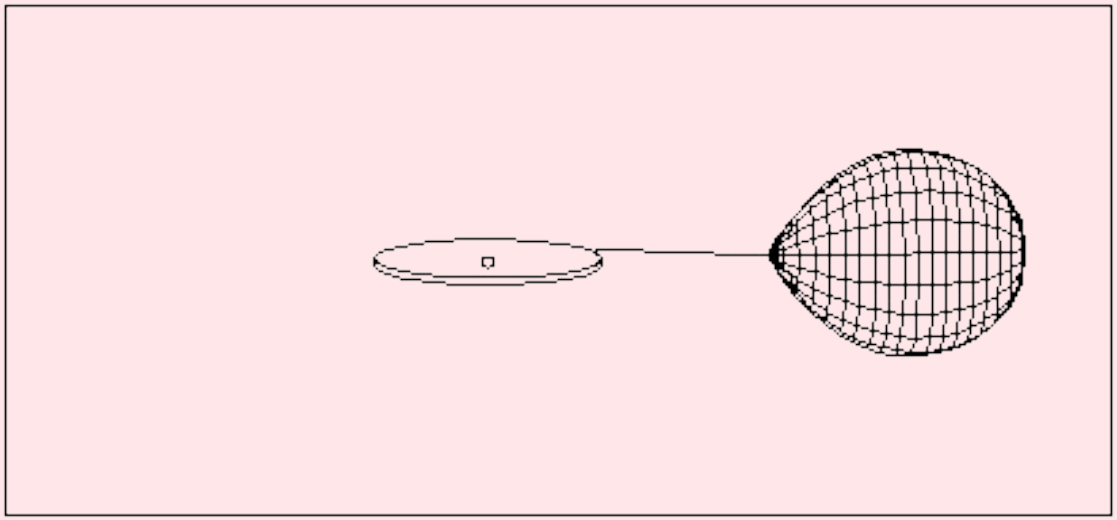
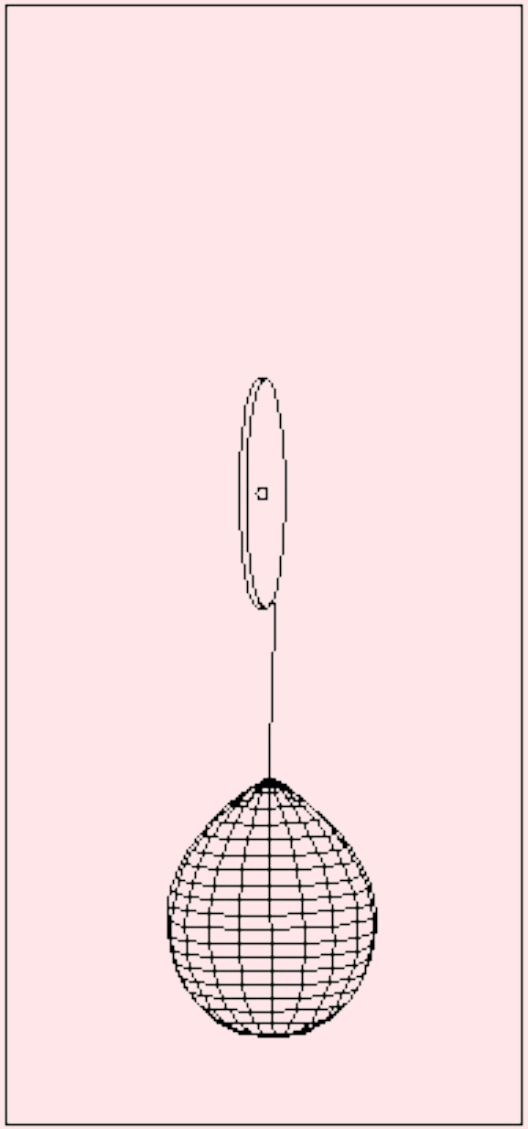
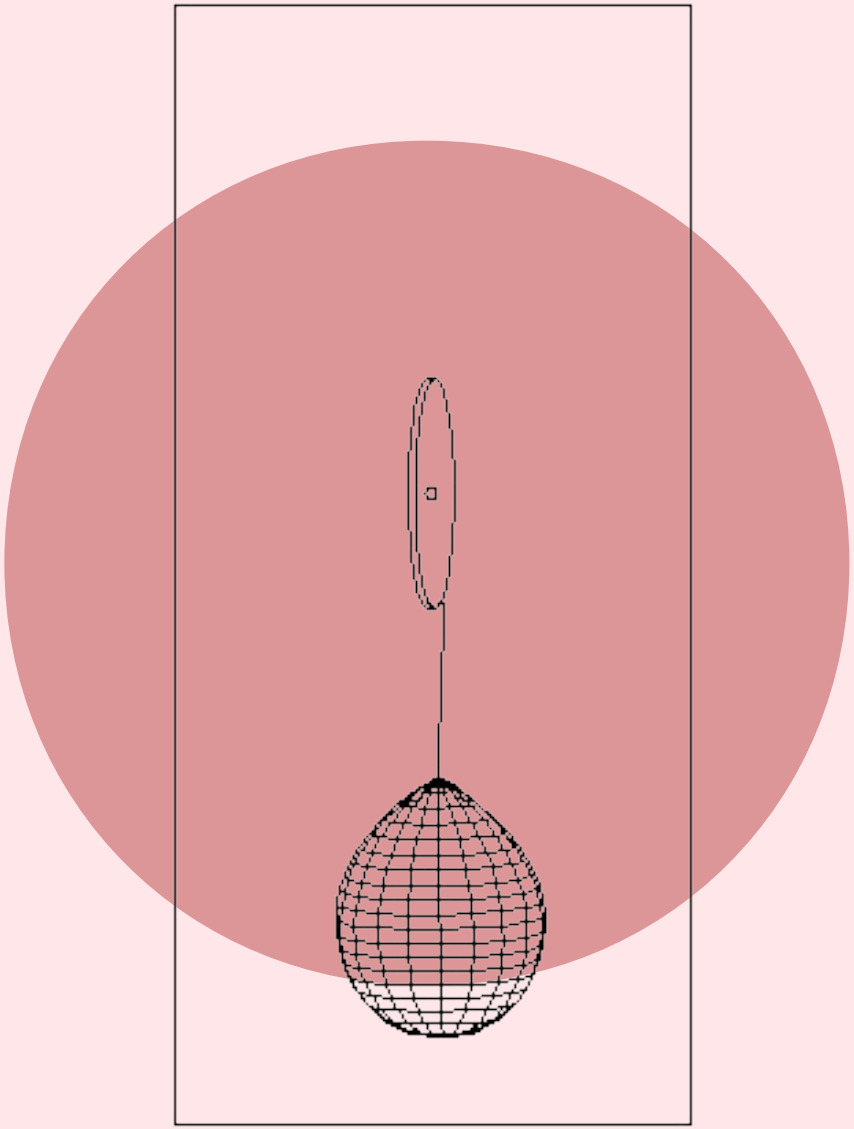
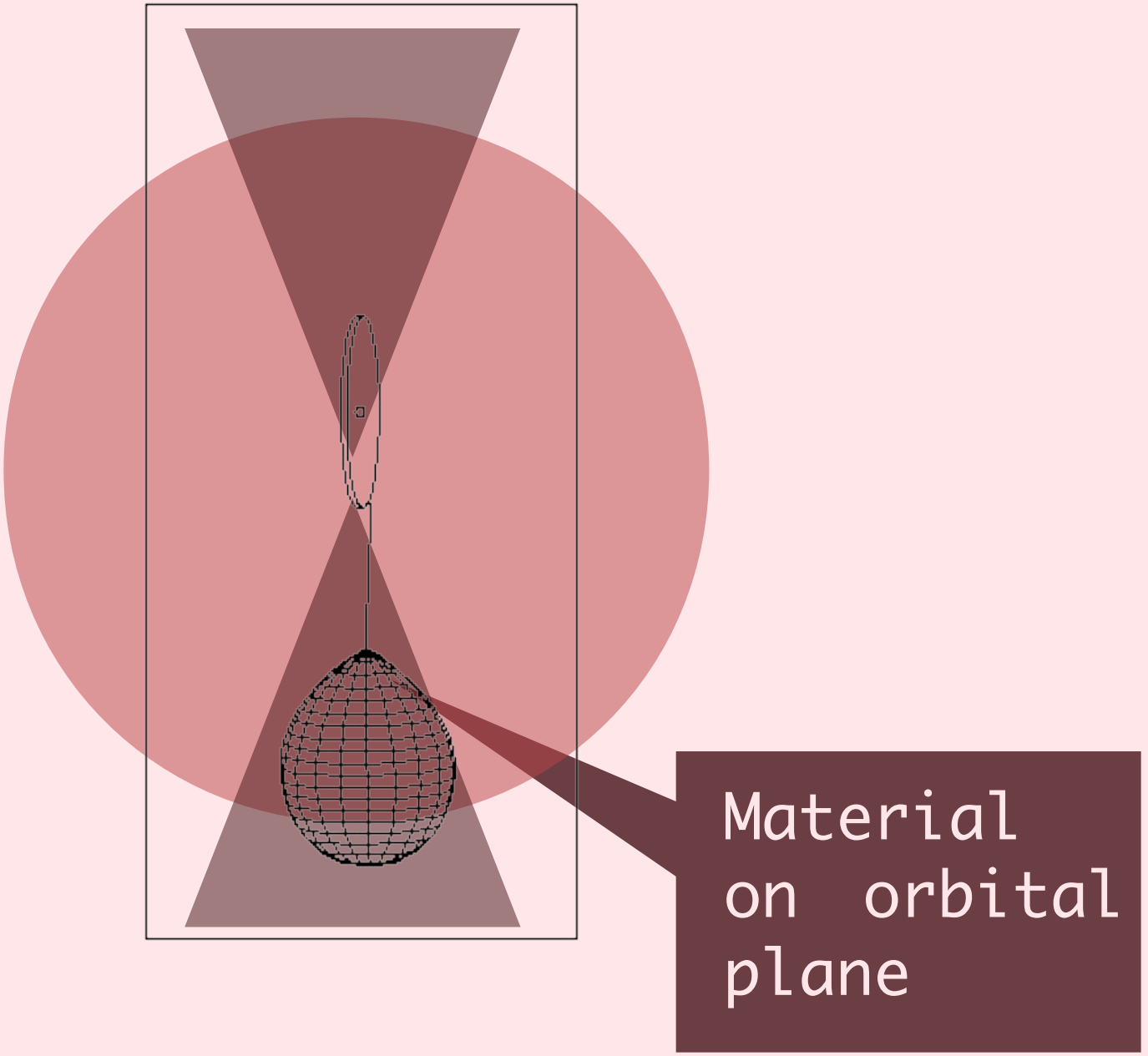


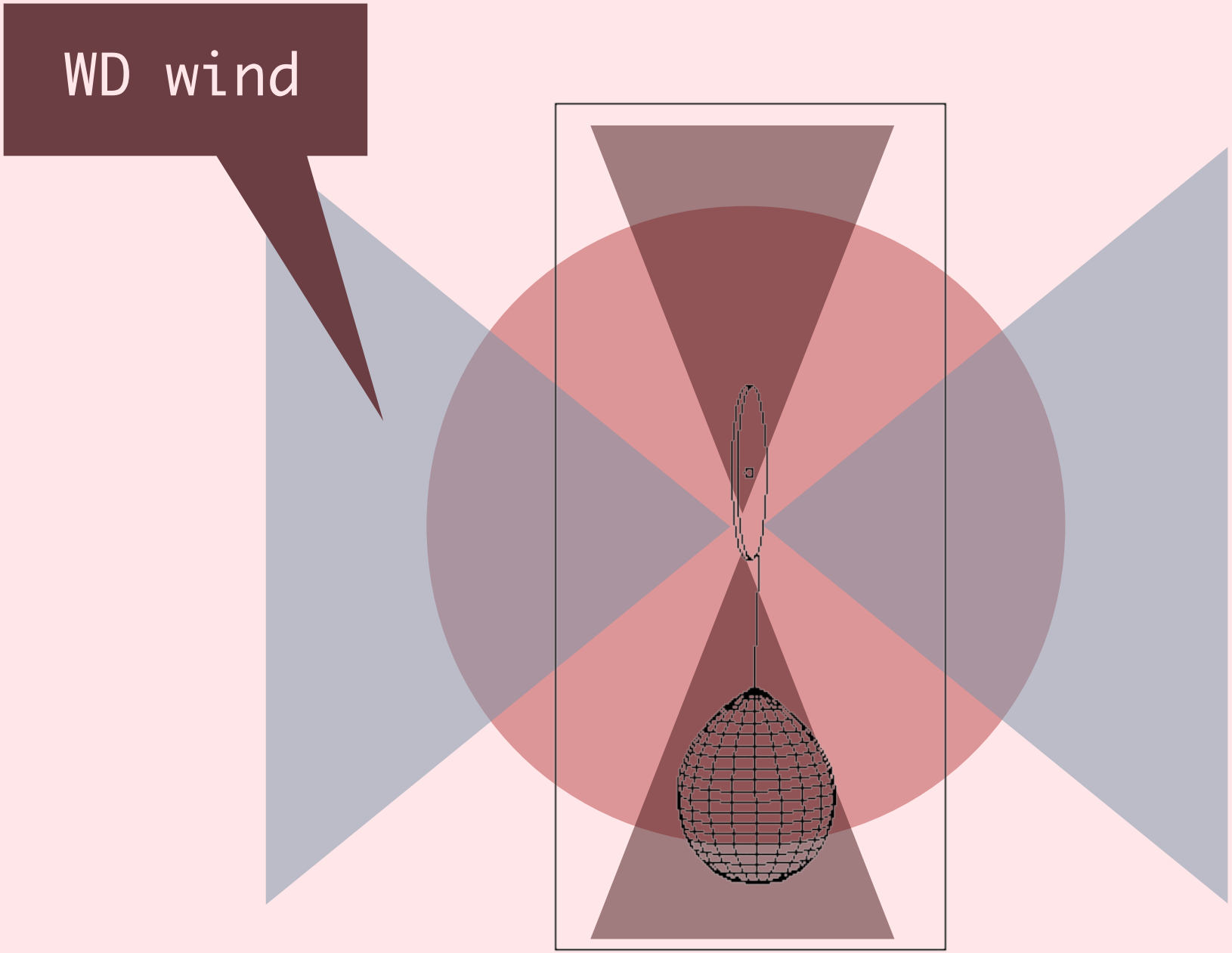
Chomiuk, L., et al., 2014, Nature,
514(7522), 339-342

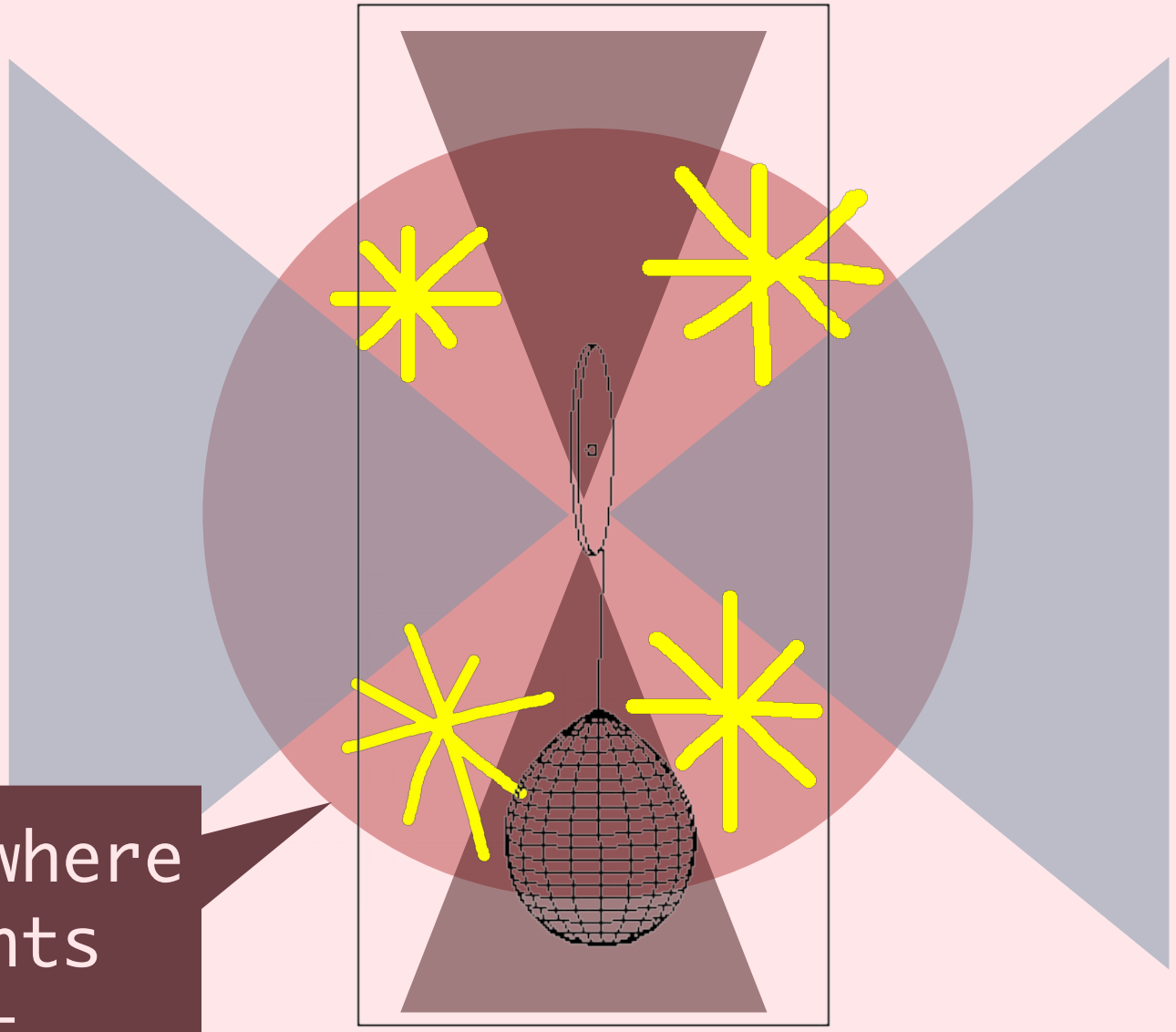


Ejecta



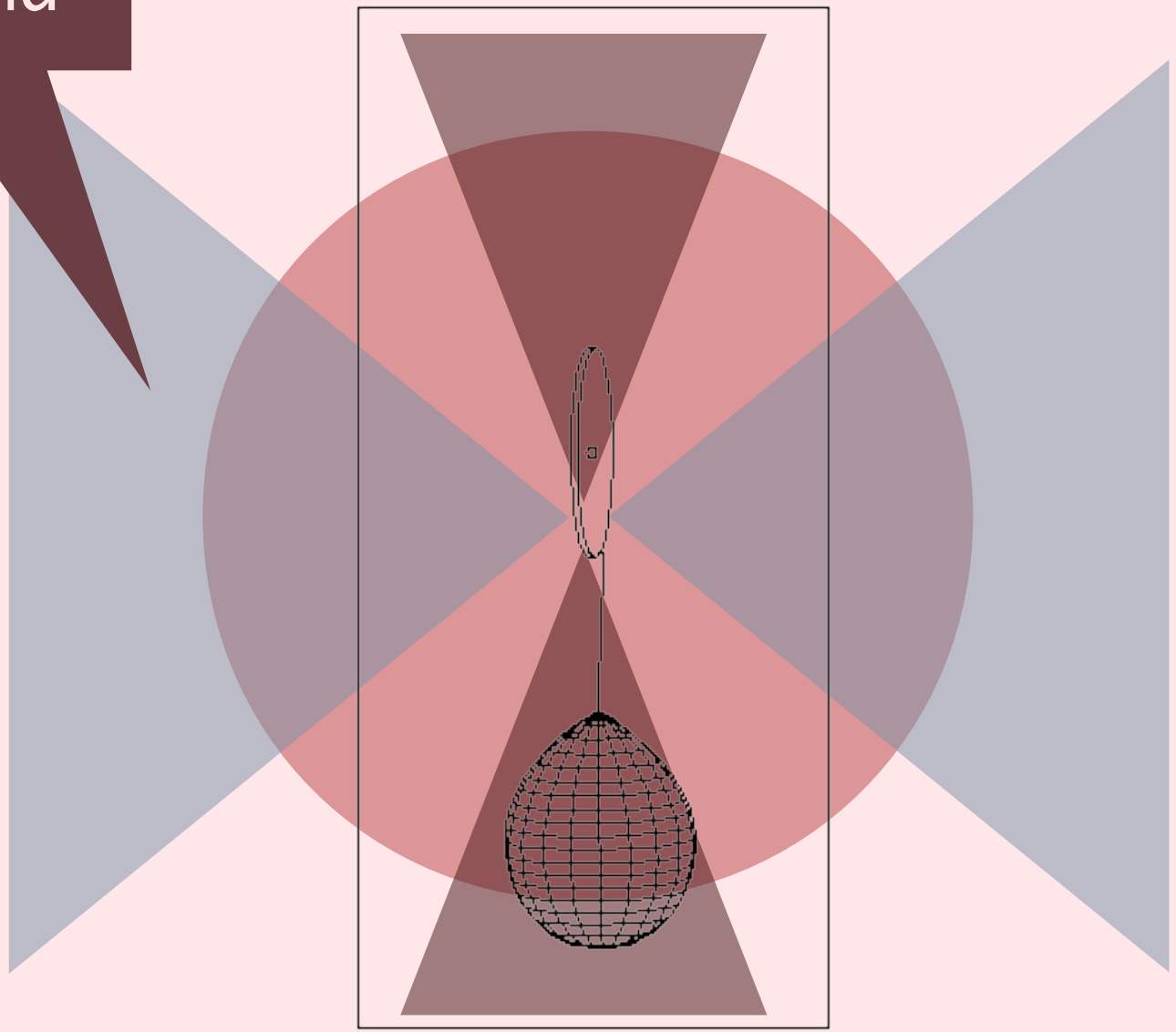

Material
on orbital
plane

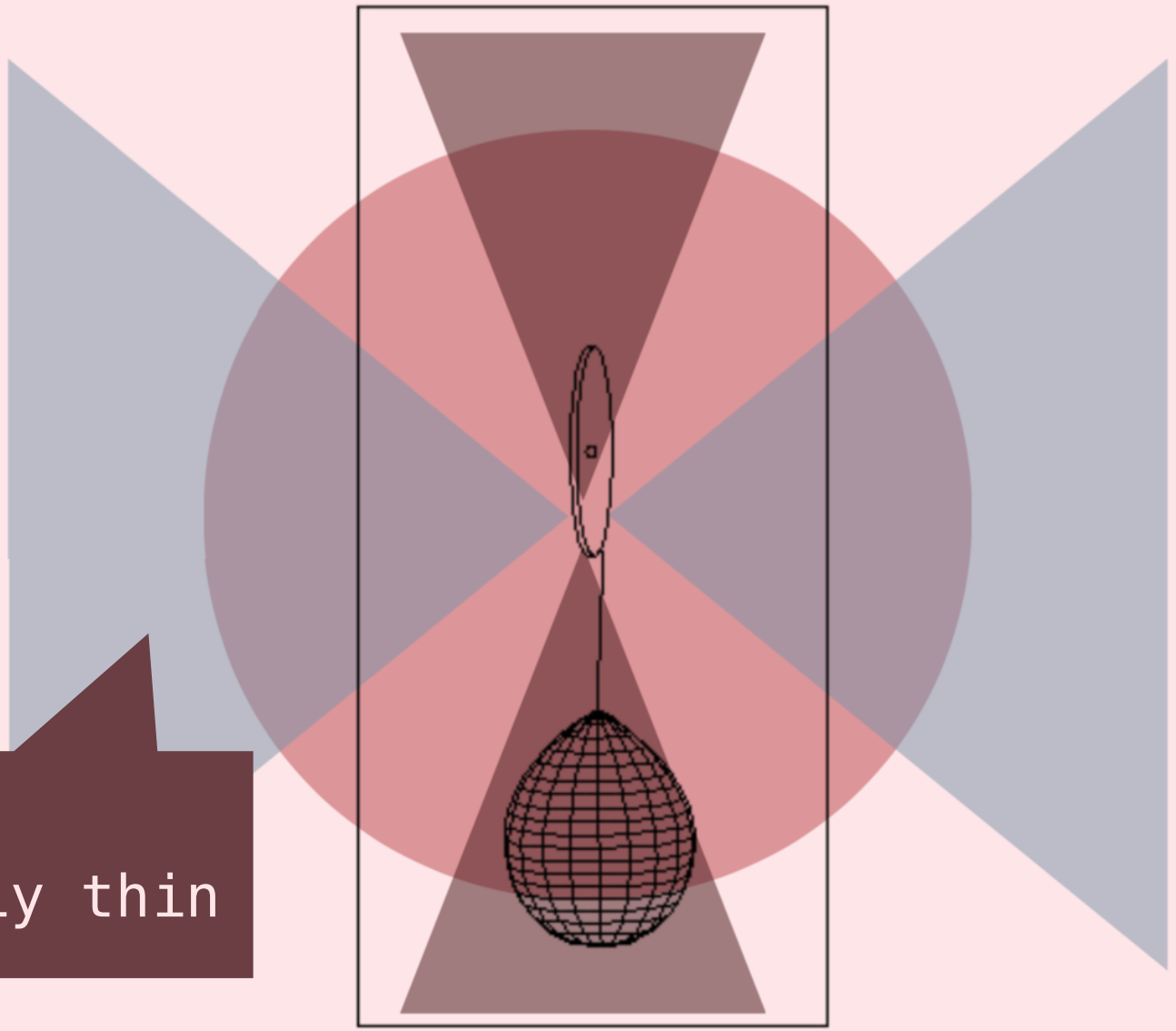

WD wind



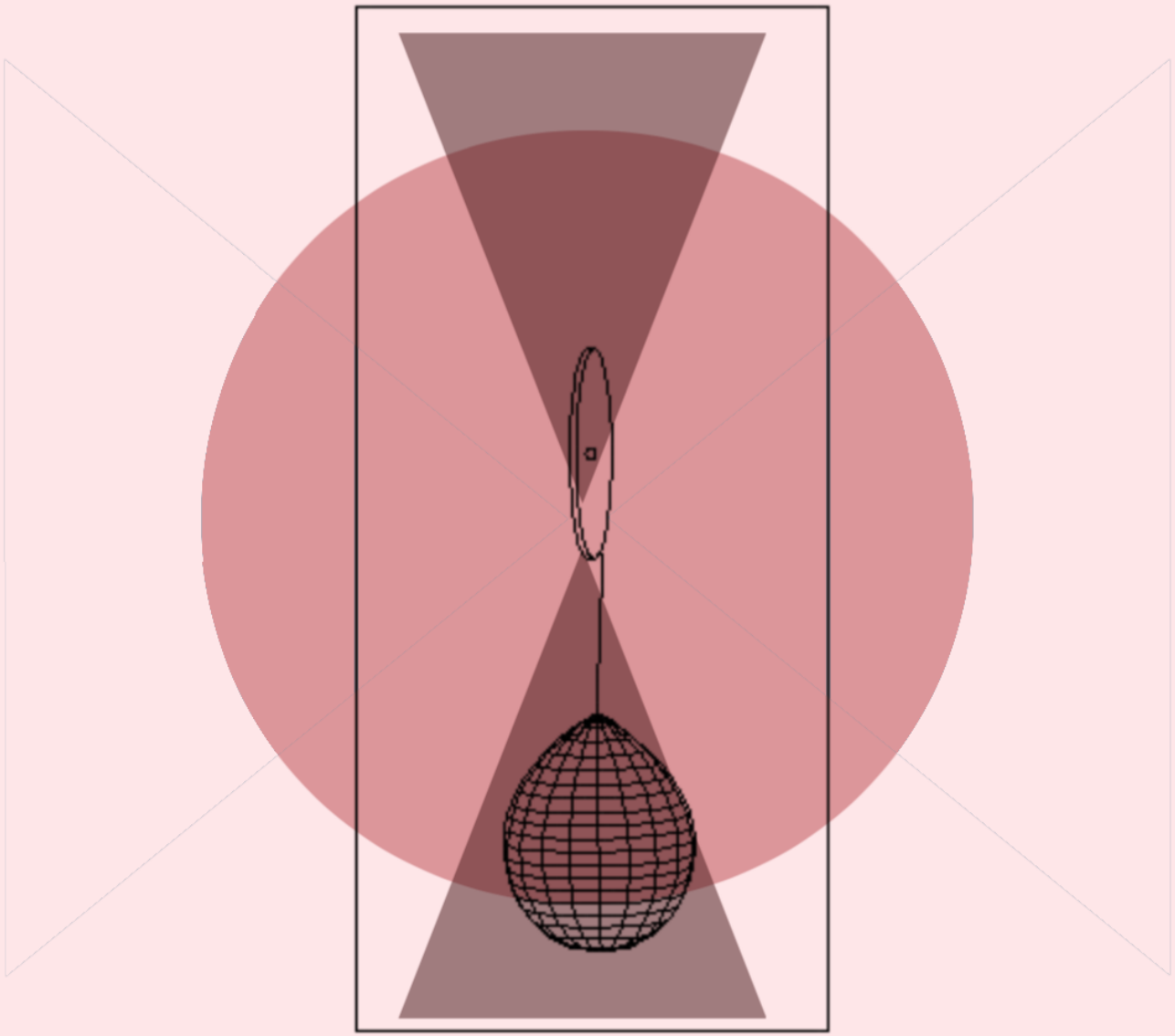
Shocks where components interact

Accelerated
by WD wind





Becomes
optically thin



Simulations

Simulations:

Radio emission model:

Simulations:

Radio emission model:

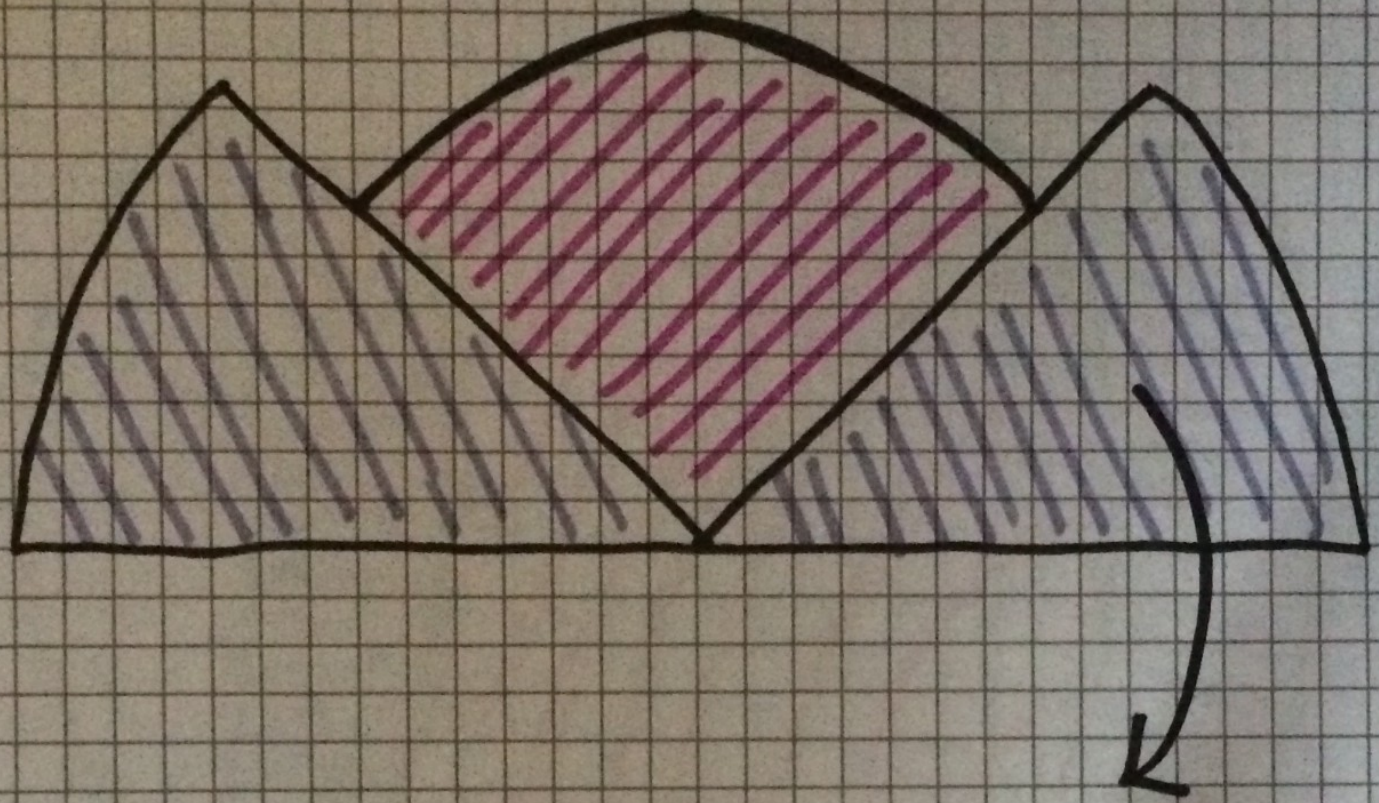
Insert density distribution

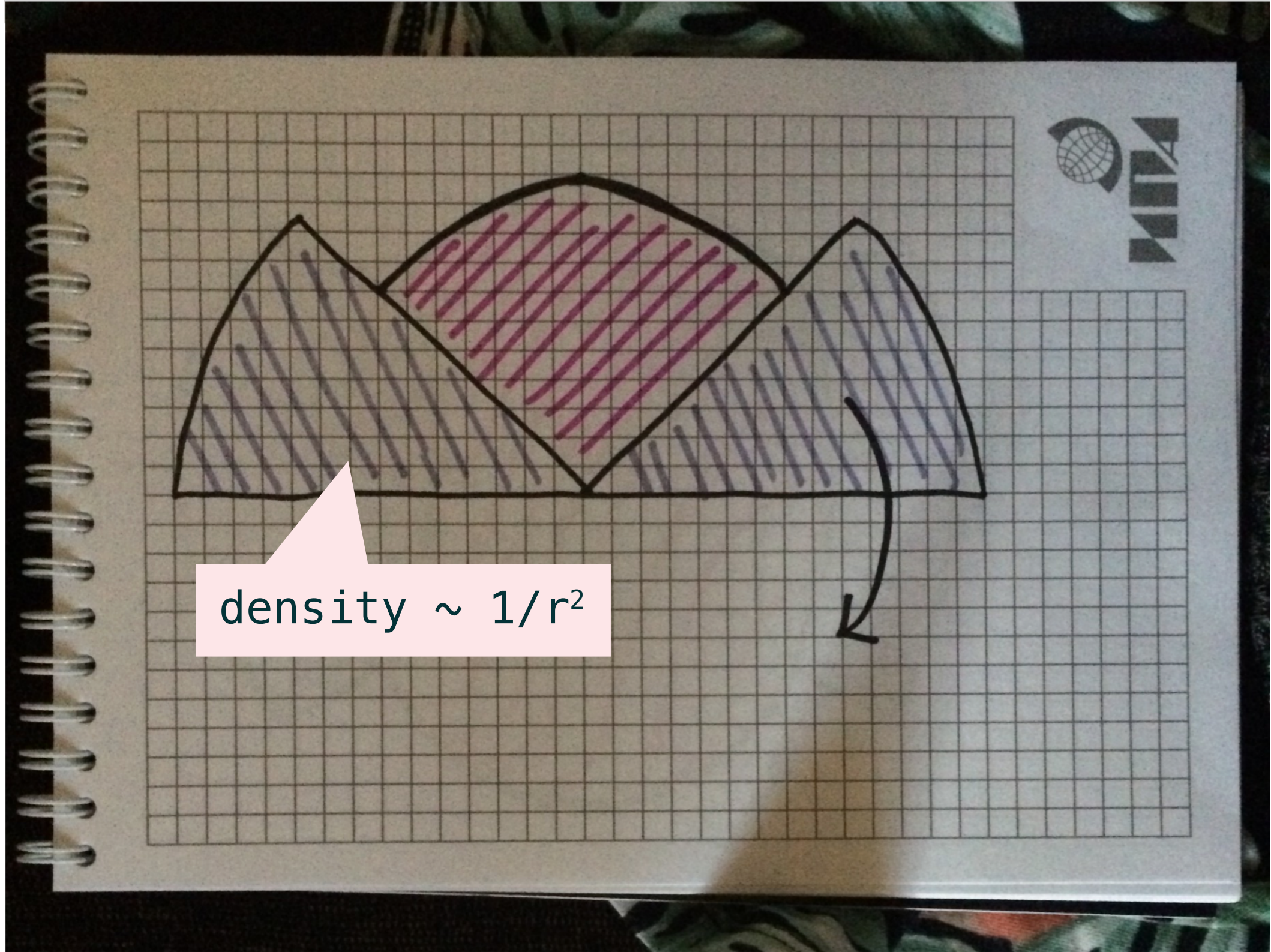
Simulations:

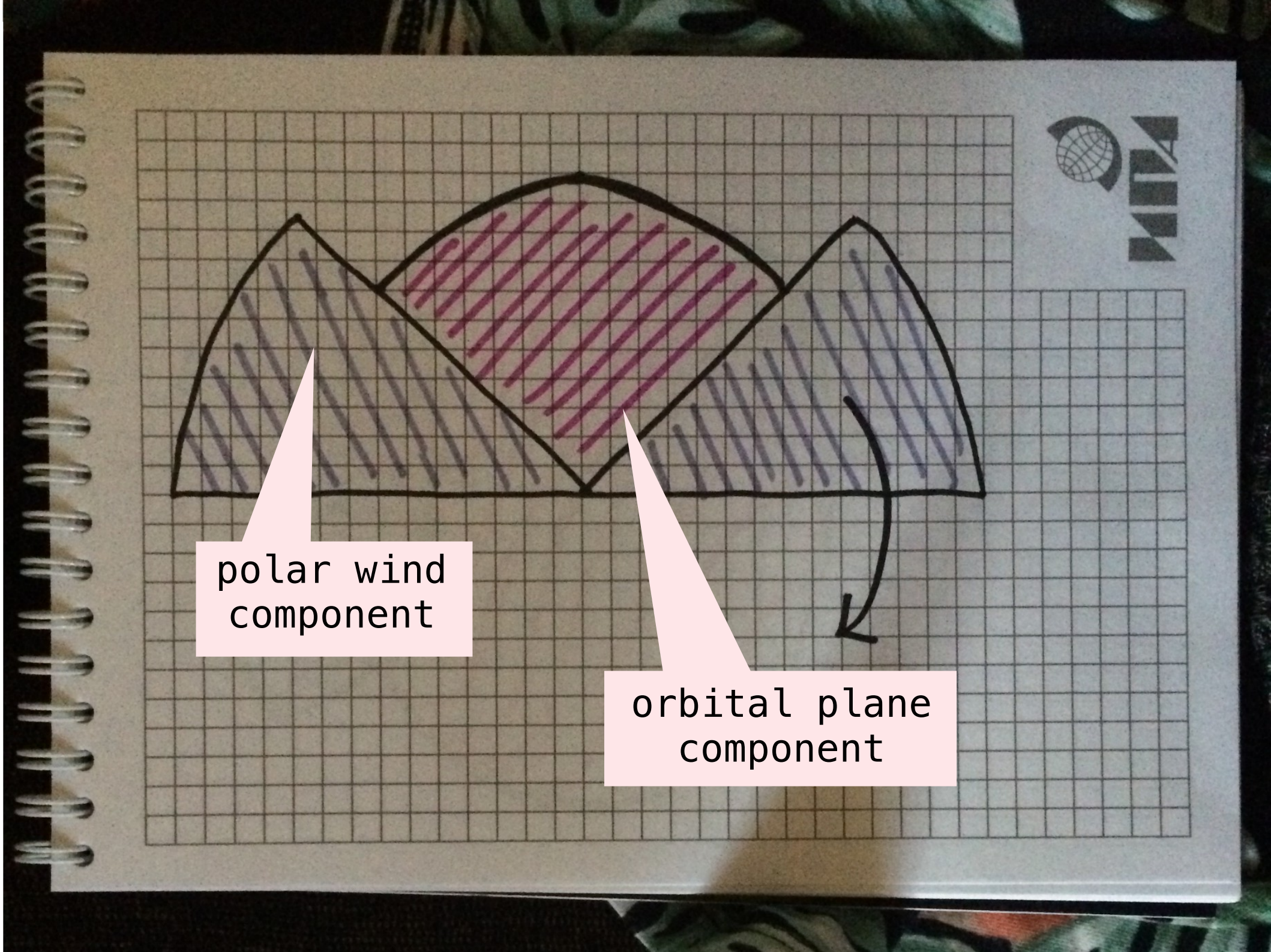
Radio emission model:

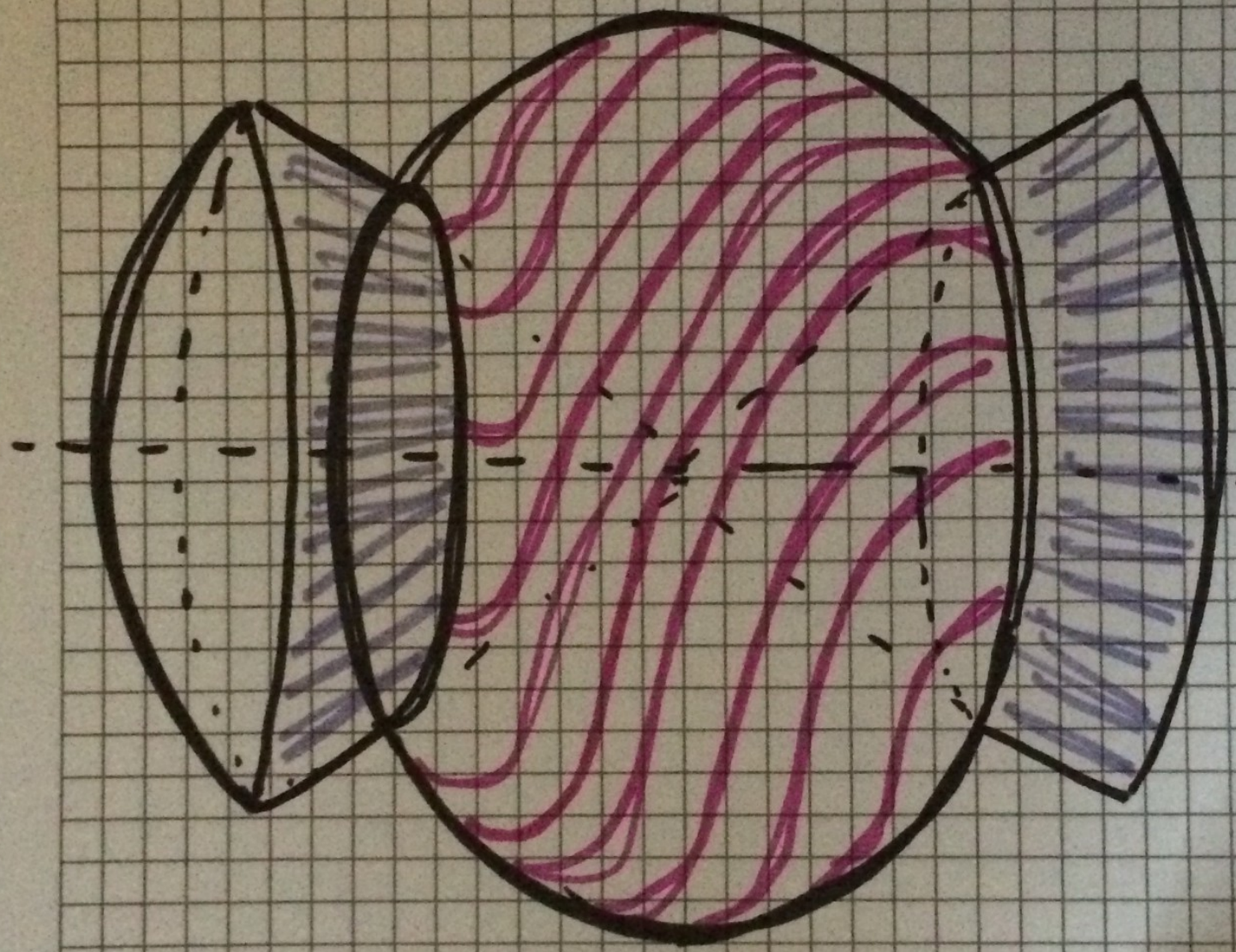
Insert density distribution

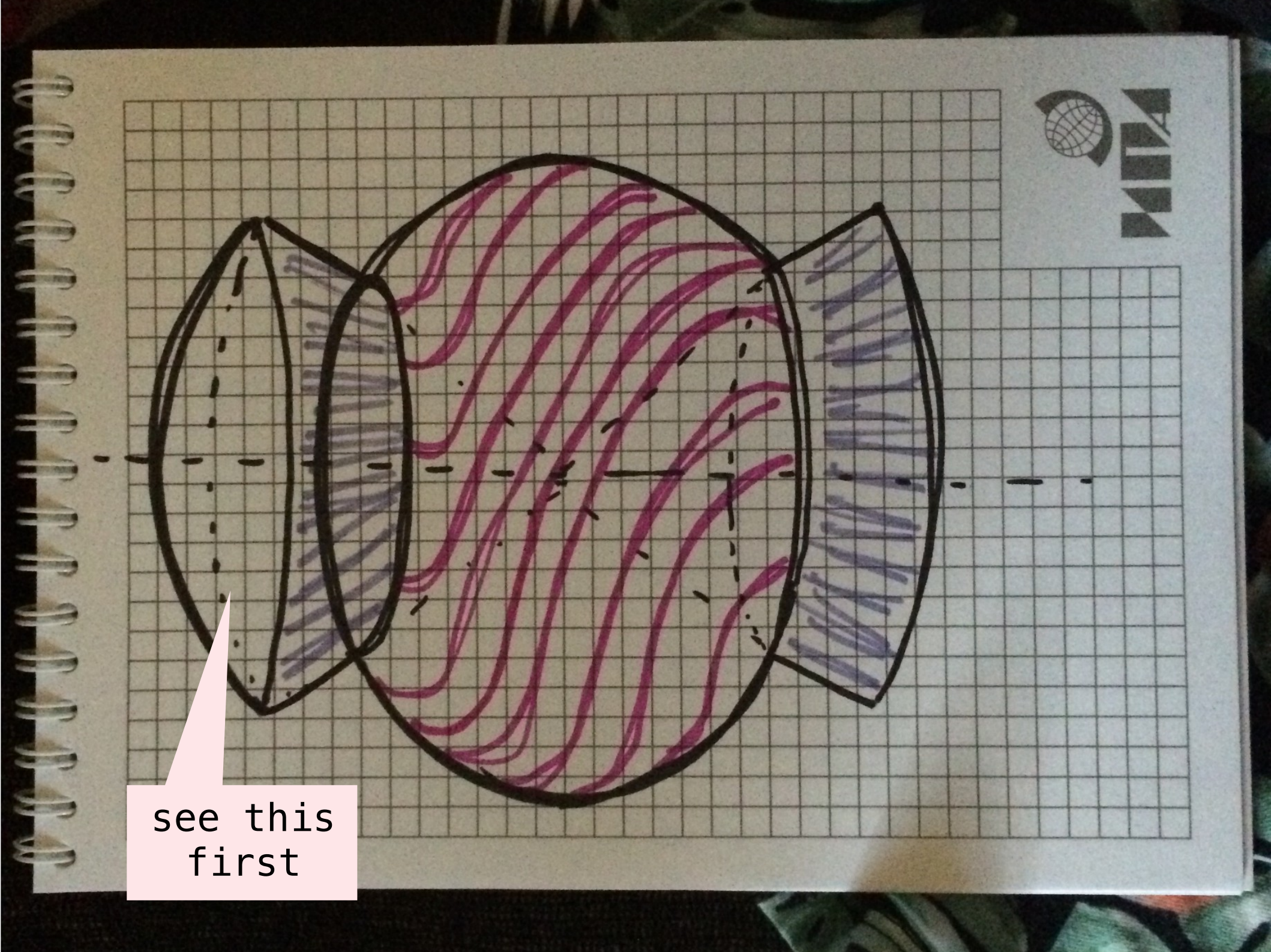
Returns simulated radio image

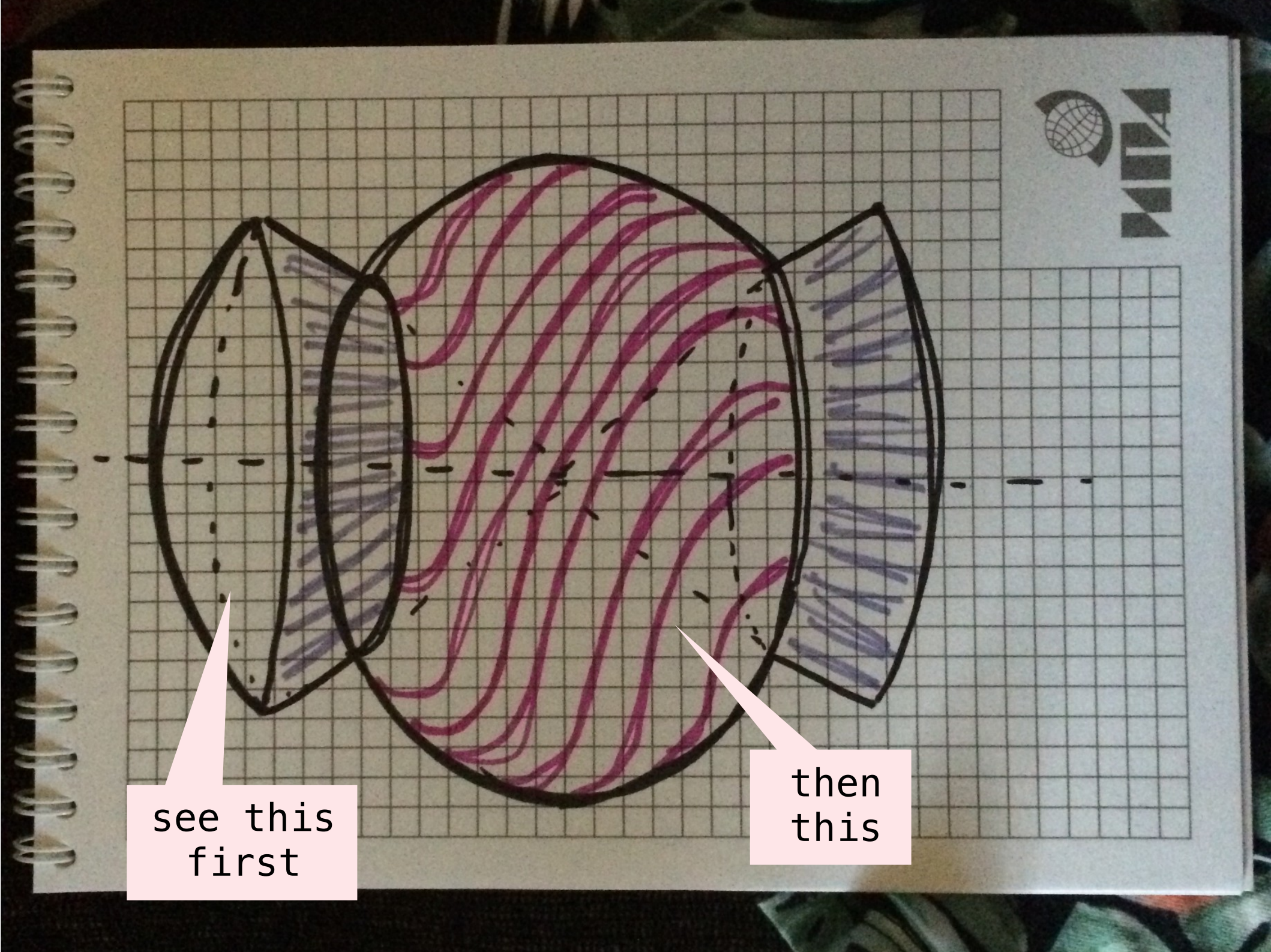



density ~ 1/r²


polar wind component
orbital plane component




see this
first


see this first
then this

Evolve radii of components over time to make light curve

Evolve radii of components over time to make light curve

Vary the ratio of the expansion velocities of the two components

Evolve radii of components over time to make light curve

Vary the ratio of the expansion velocities of the two components

Evolve radii of components over time to make light curve

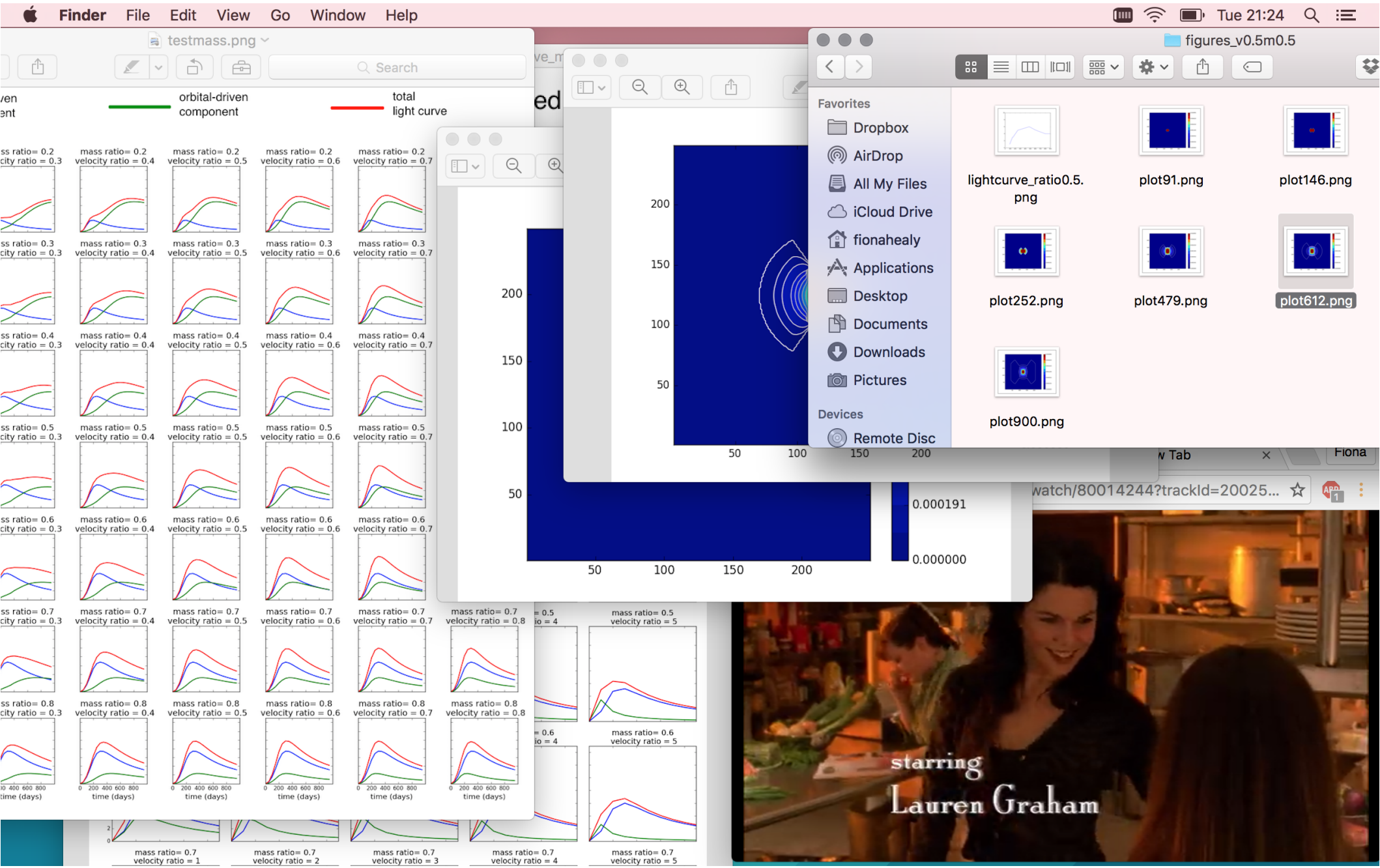
Vary the ratio of the expansion velocities of the two components

Vary the ratio of the masses of the two components

Evolve radii of components over time to make light curve

Vary the ratio of the expansion velocities of the two components

Vary the ratio of the masses of the two components


Finder File Edit View Go Window Help
Tue 21:24
testmass.png
Search
orbital-driven component
total light curve
mass ratio= 0.2 velocity ratio = 0.3
mass ratio= 0.2 velocity ratio = 0.4
mass ratio= 0.2 velocity ratio = 0.5
mass ratio= 0.2 velocity ratio = 0.6
mass ratio= 0.2 velocity ratio = 0.7
mass ratio= 0.3 velocity ratio = 0.3
mass ratio= 0.3 velocity ratio = 0.4
mass ratio= 0.3 velocity ratio = 0.5
mass ratio= 0.3 velocity ratio = 0.6
mass ratio= 0.3 velocity ratio = 0.7
mass ratio= 0.4 velocity ratio = 0.3
mass ratio= 0.4 velocity ratio = 0.4
mass ratio= 0.4 velocity ratio = 0.5
mass ratio= 0.4 velocity ratio = 0.6
mass ratio= 0.4 velocity ratio = 0.7
mass ratio= 0.5 velocity ratio = 0.3
mass ratio= 0.5 velocity ratio = 0.4
mass ratio= 0.5 velocity ratio = 0.5
mass ratio= 0.5 velocity ratio = 0.6
mass ratio= 0.5 velocity ratio = 0.7
mass ratio= 0.6 velocity ratio = 0.3
mass ratio= 0.6 velocity ratio = 0.4
mass ratio= 0.6 velocity ratio = 0.5
mass ratio= 0.6 velocity ratio = 0.6
mass ratio= 0.6 velocity ratio = 0.7
mass ratio= 0.7 velocity ratio = 0.3
mass ratio= 0.7 velocity ratio = 0.4
mass ratio= 0.7 velocity ratio = 0.5
mass ratio= 0.7 velocity ratio = 0.6
mass ratio= 0.7 velocity ratio = 0.7
mass ratio= 0.7 velocity ratio = 0.8
mass ratio= 0.8 velocity ratio = 0.3
mass ratio= 0.8 velocity ratio = 0.4
mass ratio= 0.8 velocity ratio = 0.5
mass ratio= 0.8 velocity ratio = 0.6
mass ratio= 0.8 velocity ratio = 0.7
mass ratio= 0.8 velocity ratio = 0.8
time (days)
mass ratio= 0.5 velocity ratio = 5
mass ratio= 0.6 velocity ratio = 5
mass ratio= 0.7 velocity ratio = 1
mass ratio= 0.7 velocity ratio = 2
mass ratio= 0.7 velocity ratio = 3
mass ratio= 0.7 velocity ratio = 4
mass ratio= 0.7 velocity ratio = 5
0.000191
0.000000
figures_v0.5m0.5
Favorites
Dropbox
AirDrop
All My Files
iCloud Drive
fionahealy
Applications
Desktop
Documents
Downloads
Pictures
Devices
Remote Disc
lightcurve_ratio0.5.png
plot91.png
plot146.png
plot252.png
plot479.png
plot612.png
plot900.png
watch/80014244?trackId=20025...
starring
Lauren Graham

Interesting results when:

Interesting results when:

Mass of wind component =
0.5 x total mass of system

Interesting results when:

Mass of wind component ~
0.5 x total mass of system

(i.e. components
have similar mass)

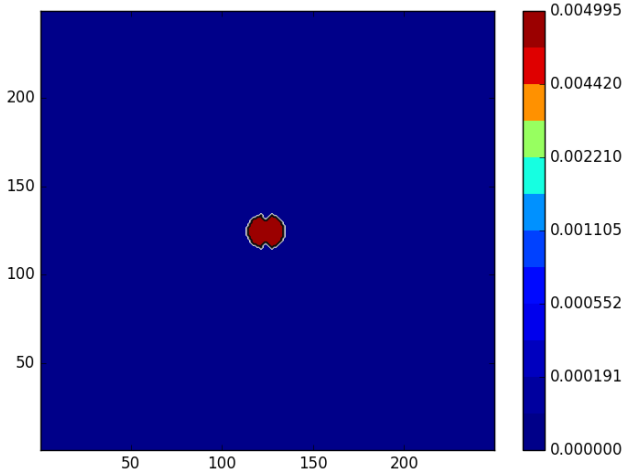
Interesting results when:

Mass of wind component ~ 0.5 x total mass of system

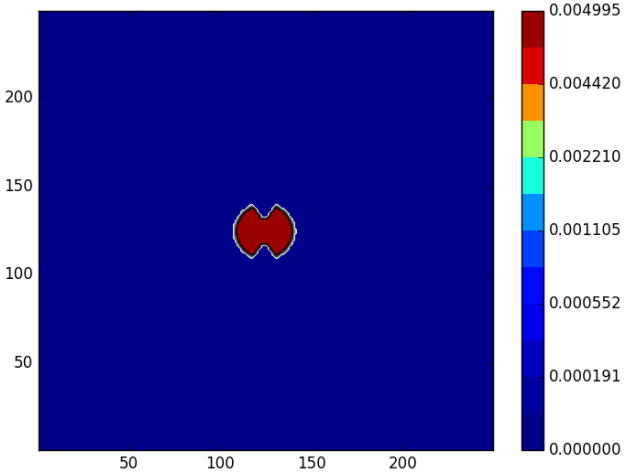
(i.e. components have similar mass)

Velocity of orbit component ~ 0.5 x velocity of wind component

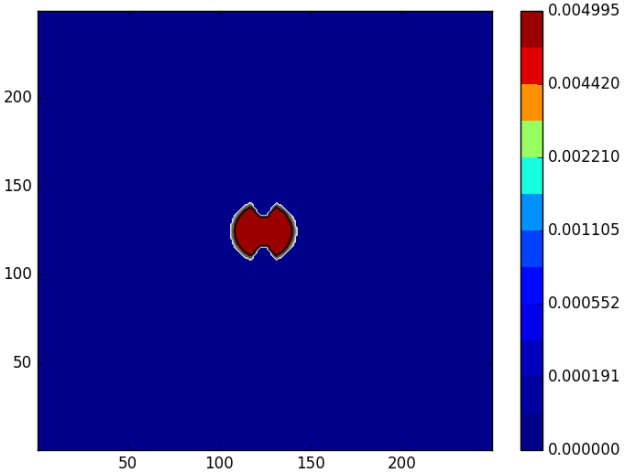
Simulated Radio Emission



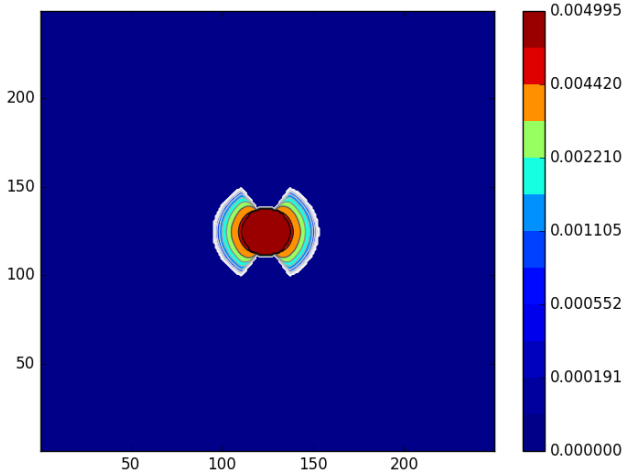
Day 91



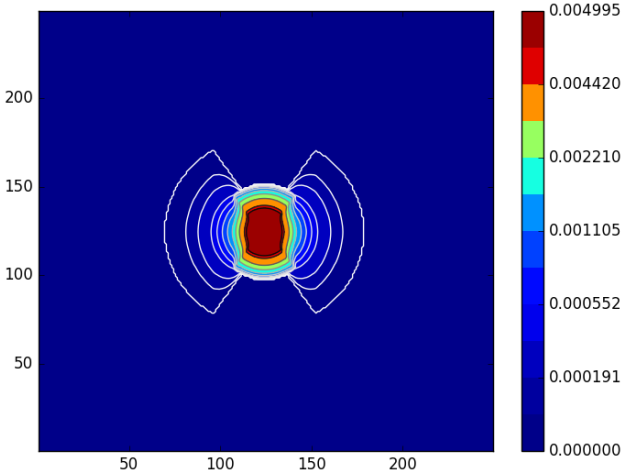
Day 146



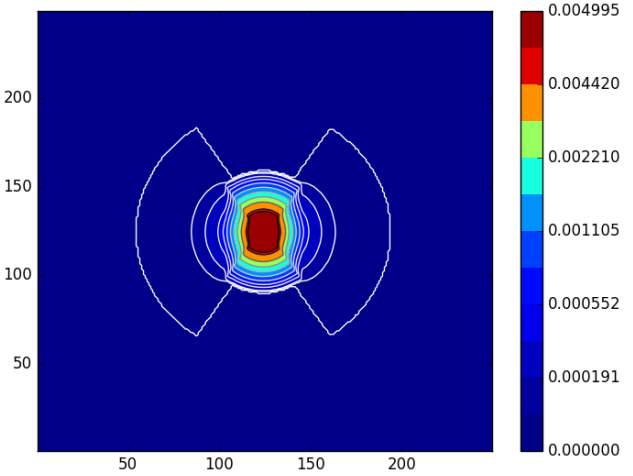
Day 156



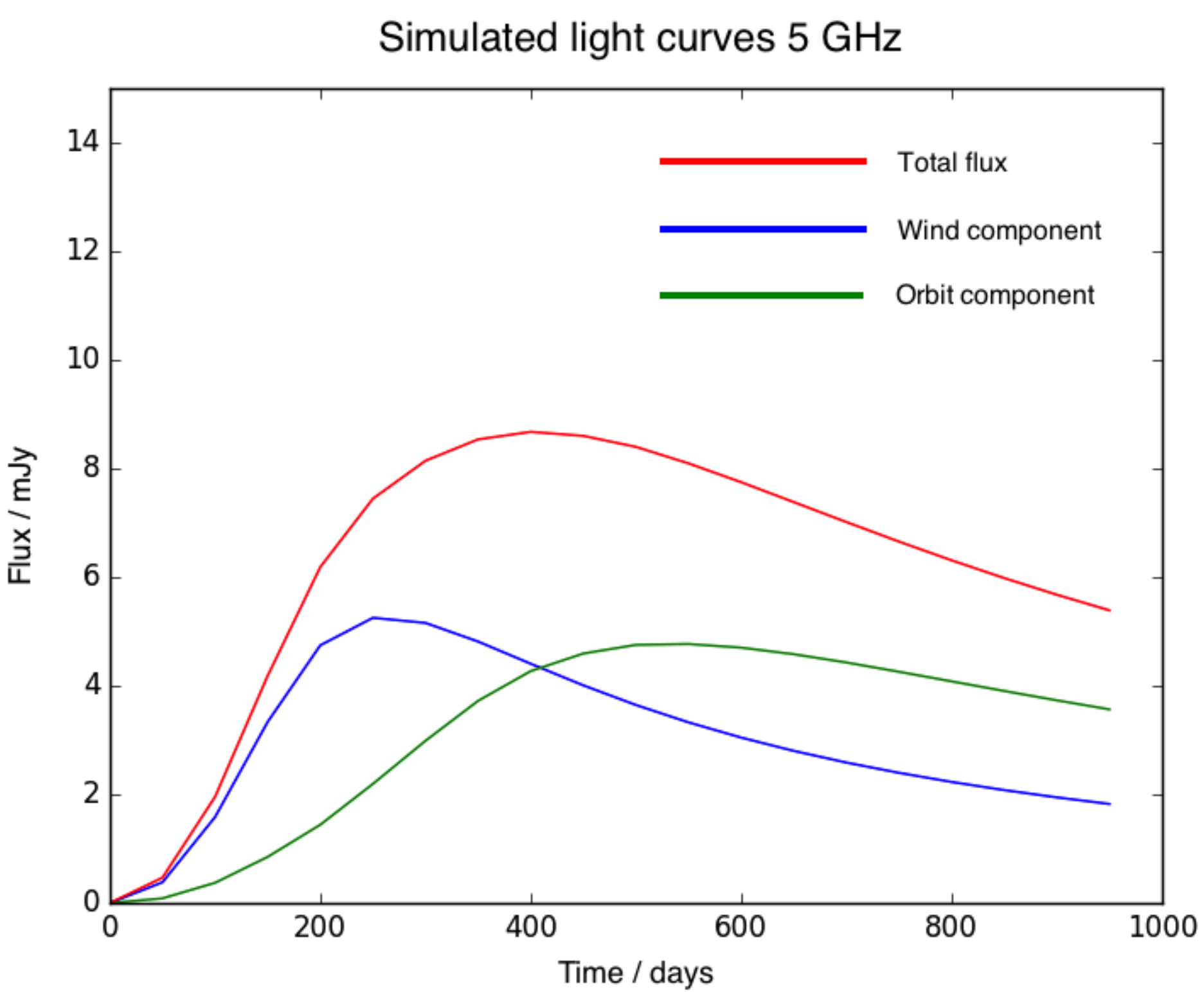
Day 252



Day 497



Day 612


Simulated light curves 5 GHz
Total flux
Wind component
Orbit component
Flux / mJy
Time / days
0
2
4
6
8
10
12
14
0
200
400
600
800
1000

Interesting results when:

Mass of wind component ~
0.5 x total mass of system

(i.e. components
have similar mass)

Velocity of orbit component ~ 0.5
x velocity of wind component

“interesting” = kind of looks
like observations

Next steps:

Next steps:

Fold simulated emission through eMERLIN UV filter to simulate eMERLIN images

Next steps:

Fold simulated emission through eMERLIN UV filter to simulate eMERLIN images

Make more realistic images and light curves

Next steps:

Fold simulated emission through eMERLIN UV filter to simulate eMERLIN images

Make more realistic images and light curves

Quantify similarity between observations and simulations by measuring residuals between simulated and observed images/light curves

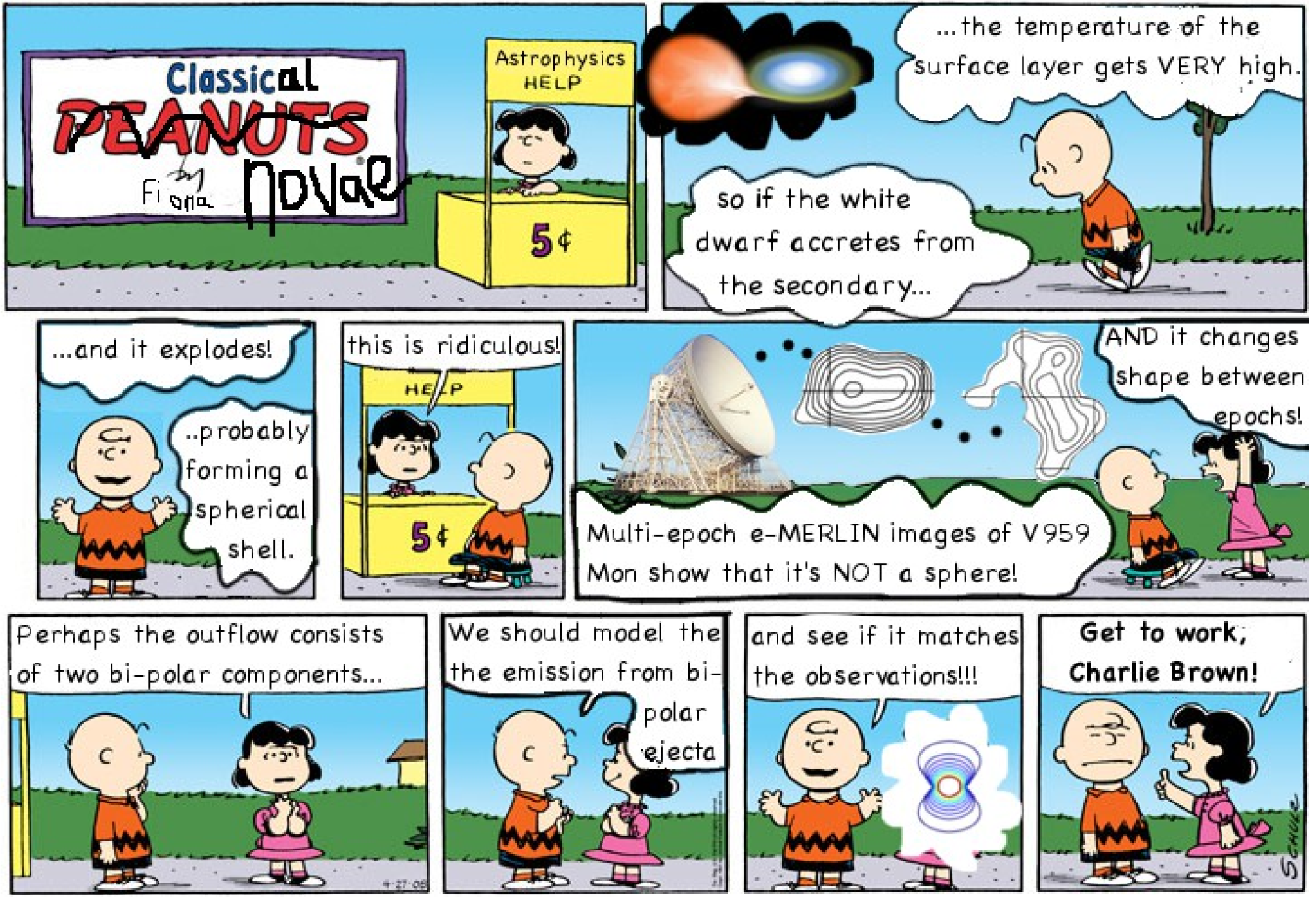
Next steps:

Fold simulated emission through eMERLIN UV filter to simulate eMERLIN images

Make more realistic images and light curves

Quantify similarity between observations and simulations by measuring residuals between simulated and observed images/light curves

More frequencies!


Classical
PEANUTS
by
Fiona Novae
Astrophysics
HELP
5¢
...the temperature of the surface layer gets VERY high.
so if the white dwarf accretes from the secondary...
...and it explodes!
..probably forming a spherical shell.
this is ridiculous!
HELP
5¢
AND it changes shape between epochs!
Multi-epoch e-MERLIN images of V959 Mon show that it's NOT a sphere!
Perhaps the outflow consists of two bi-polar components...
We should model the the emission from bi-polar ejecta
and see if it matches the observations!!!
Get to work, Charlie Brown!

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