Highly Variable Apparent Speed in the Quasar 3C 279

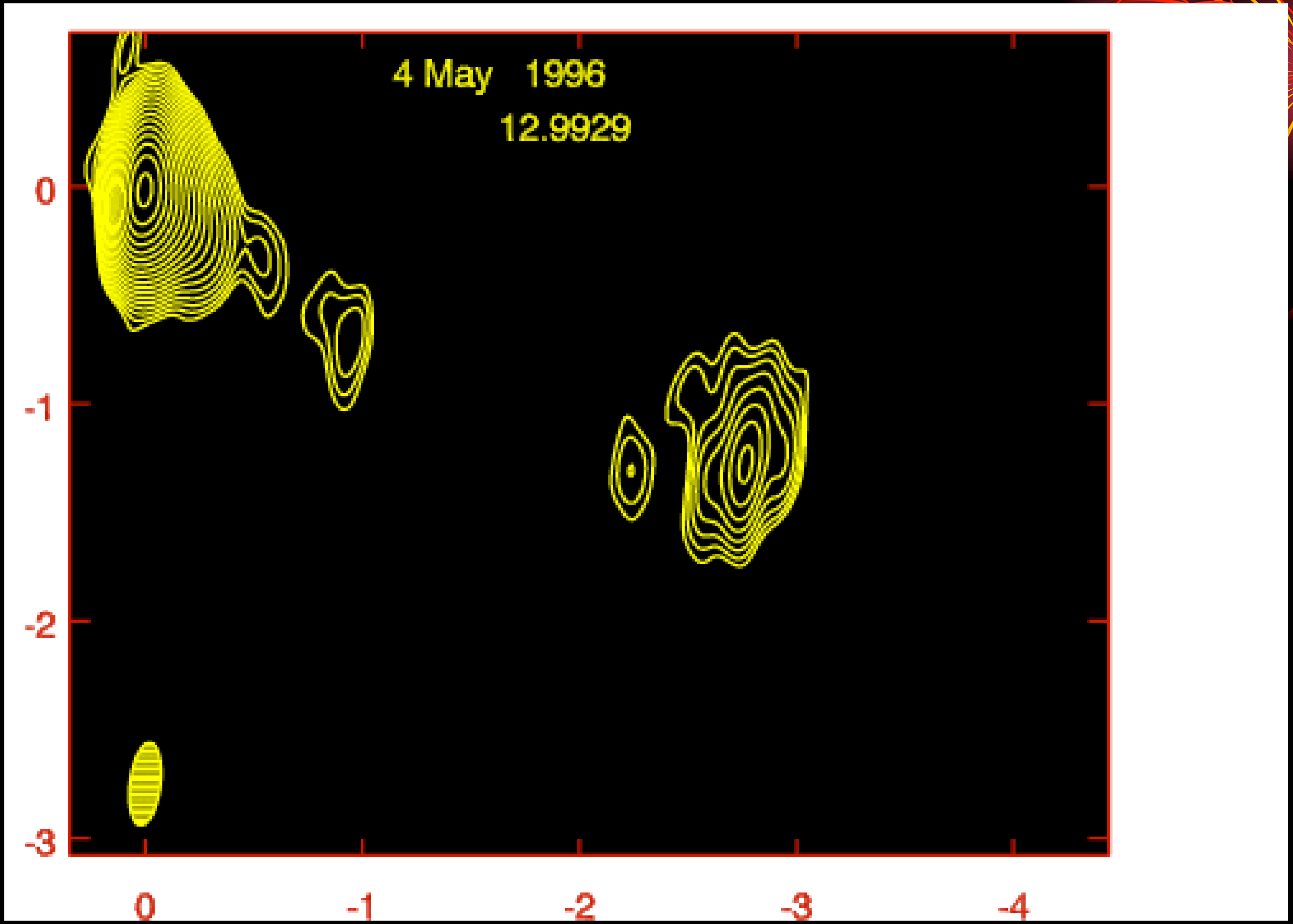
S. Jorstad / Boston U., USA
/St. Petersburg State U., Russia
A. Marscher / Boston U., USA
A. Stirling / U. of Manchester, Jodrell Bank Obs., UK
M. Lister / Purdue U., USA
T. Cawthorne / Central Lancashire U., UK
J.L. Gómez / IAA, Granada, Spain
D. Gabuzda / U. College Cork, Ireland
W. Gear / Cardiff U., UK
H .Teräsranta / Metsahovi Radio Obs., Finland
M. Tornikoski / Metsahovi Radio Obs., Finland

Observations:

We have obtained total intensity images of 3C 279 with the VLBA at 7 mm in 1995-1997 at 7 epochs (Jorstad et al. 2001)

We have performed total and polarized intensity imaging of 3C 279 bimonthly from March 1998 to April 2001 at 7mm with the VLBA (Jorstad et al. 2004)

We have been monitoring the VLBI structure of 3C 279 in total and polarized intensity monthly from April 2001 until the present at 7mm with the VLBA


4 May 1996
12.9929
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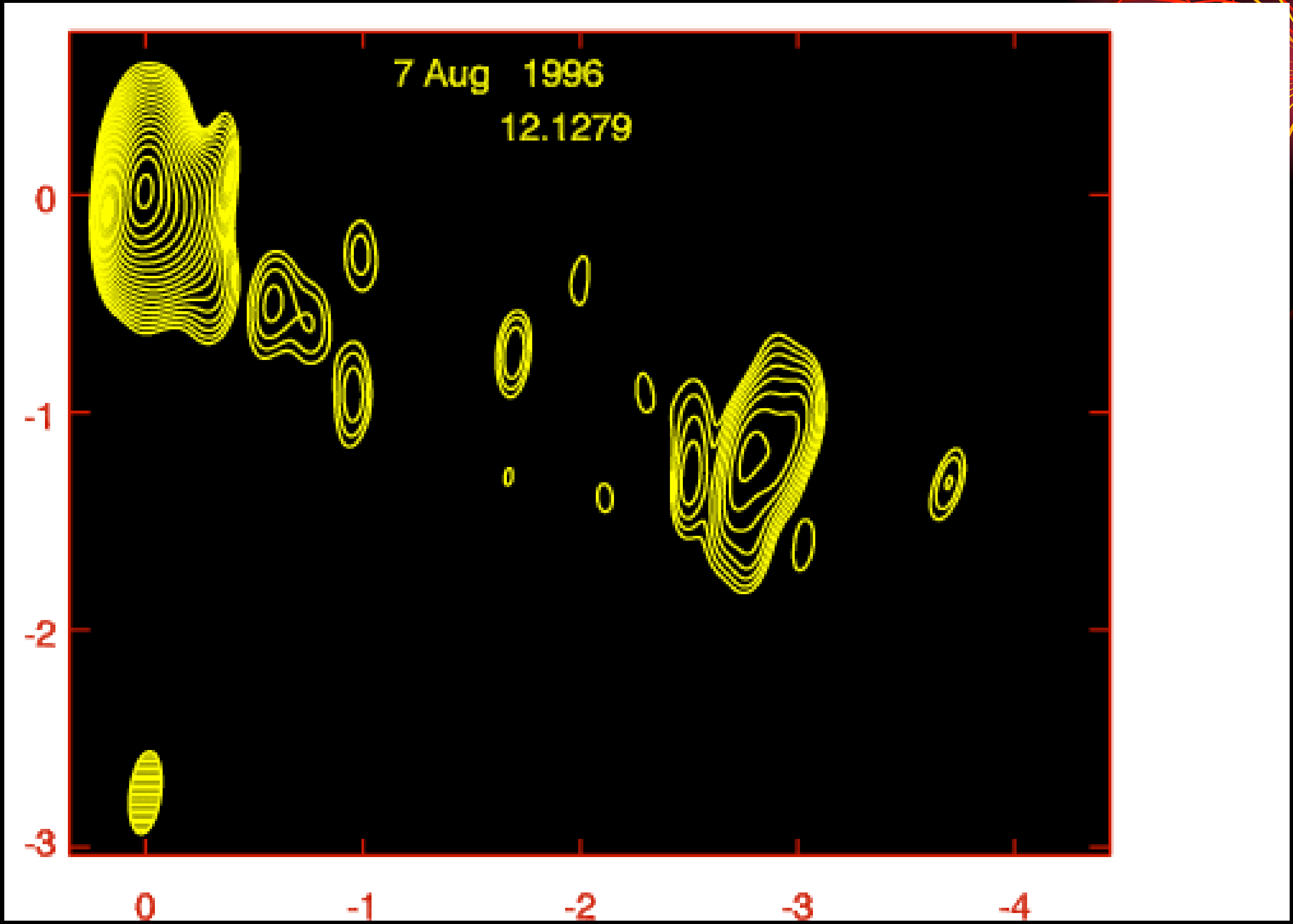
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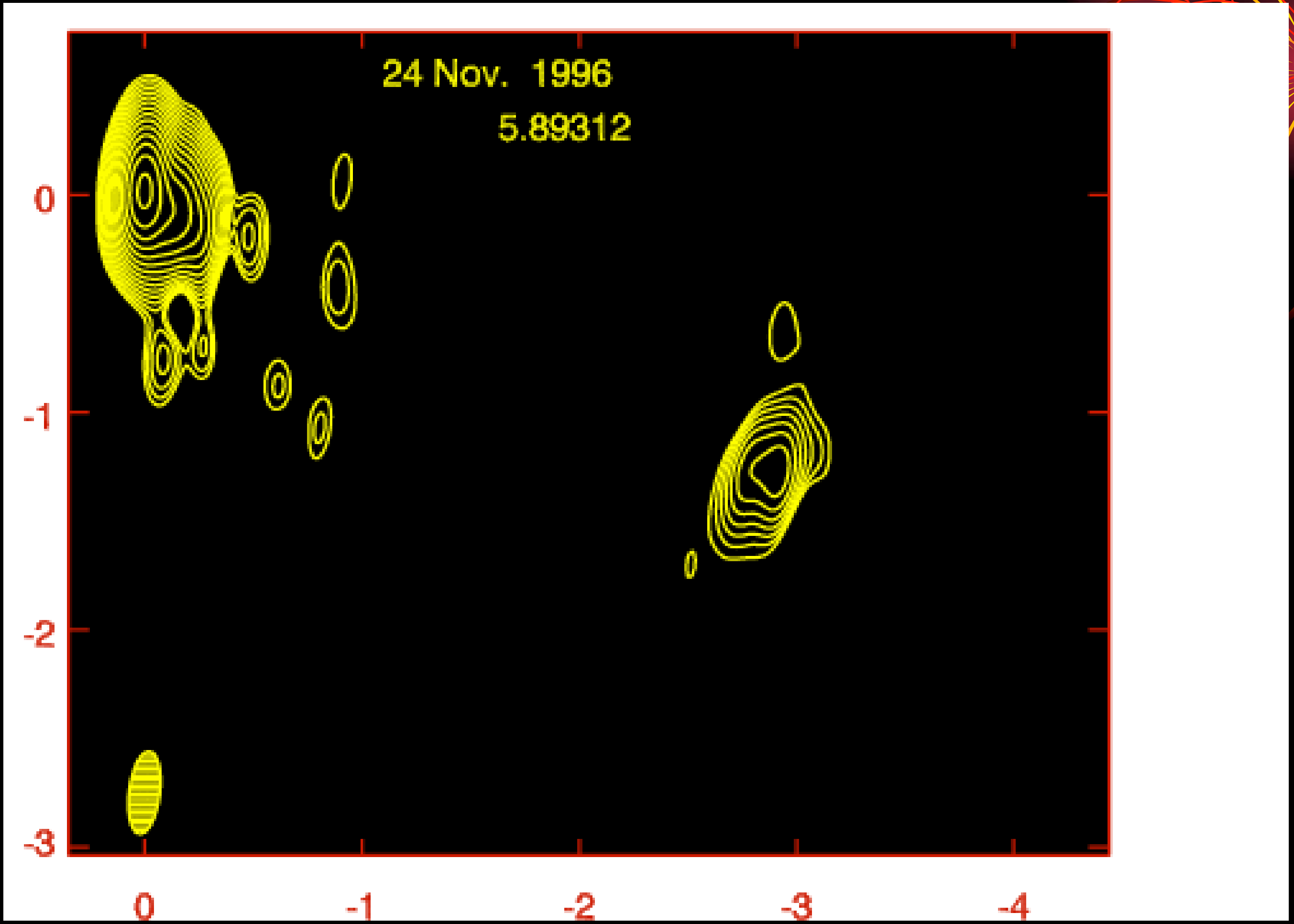
24 Nov. 1996
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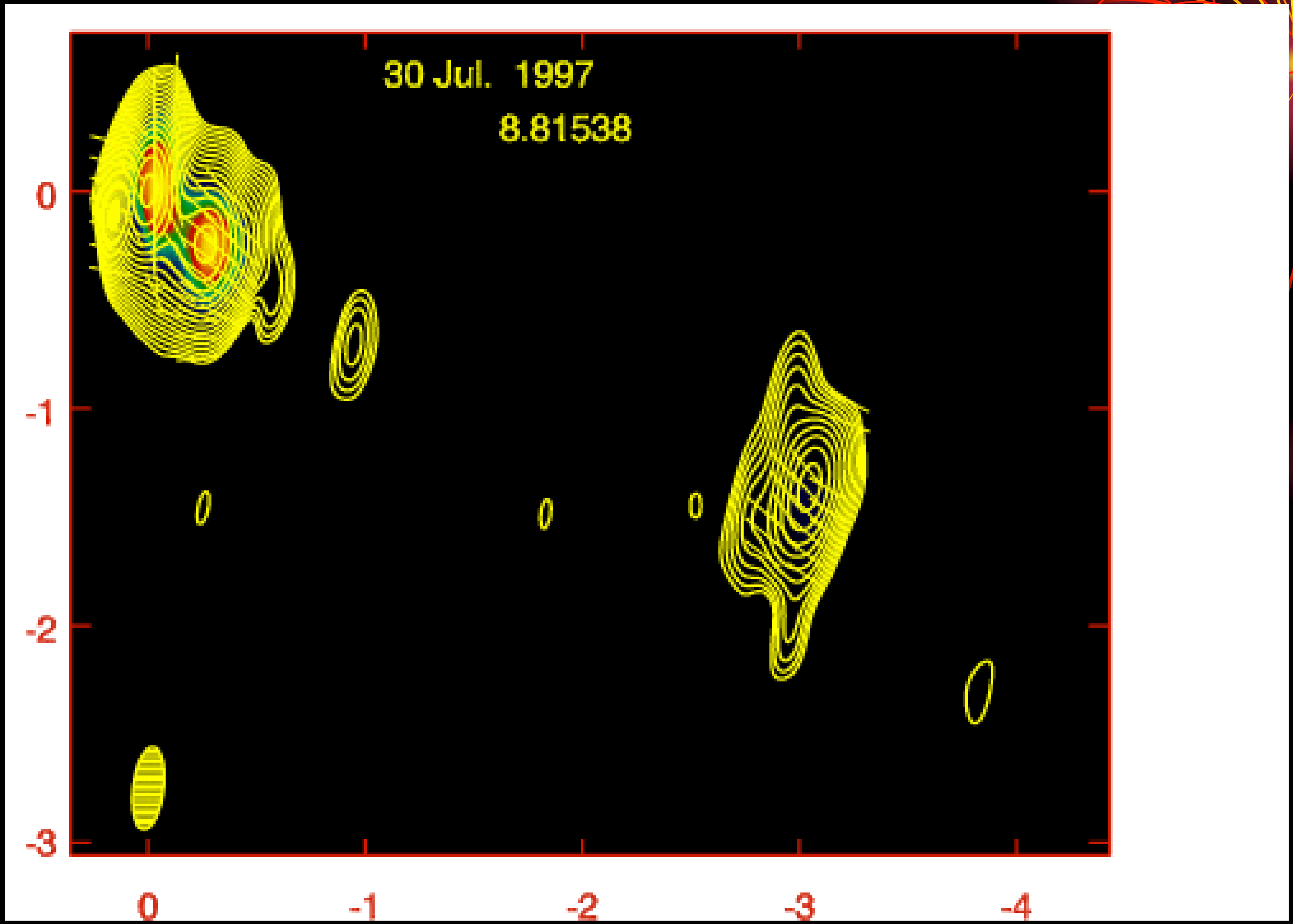
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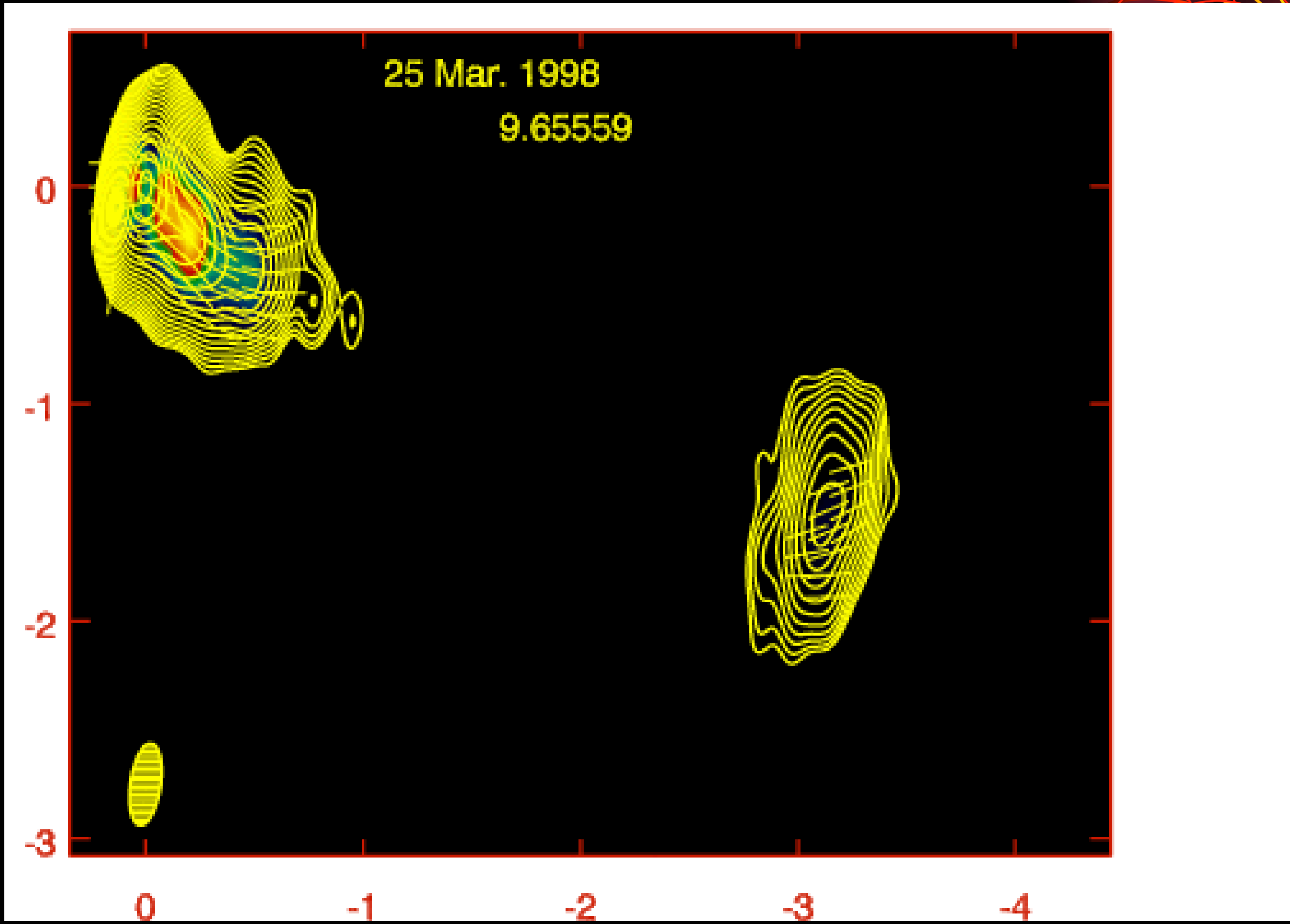
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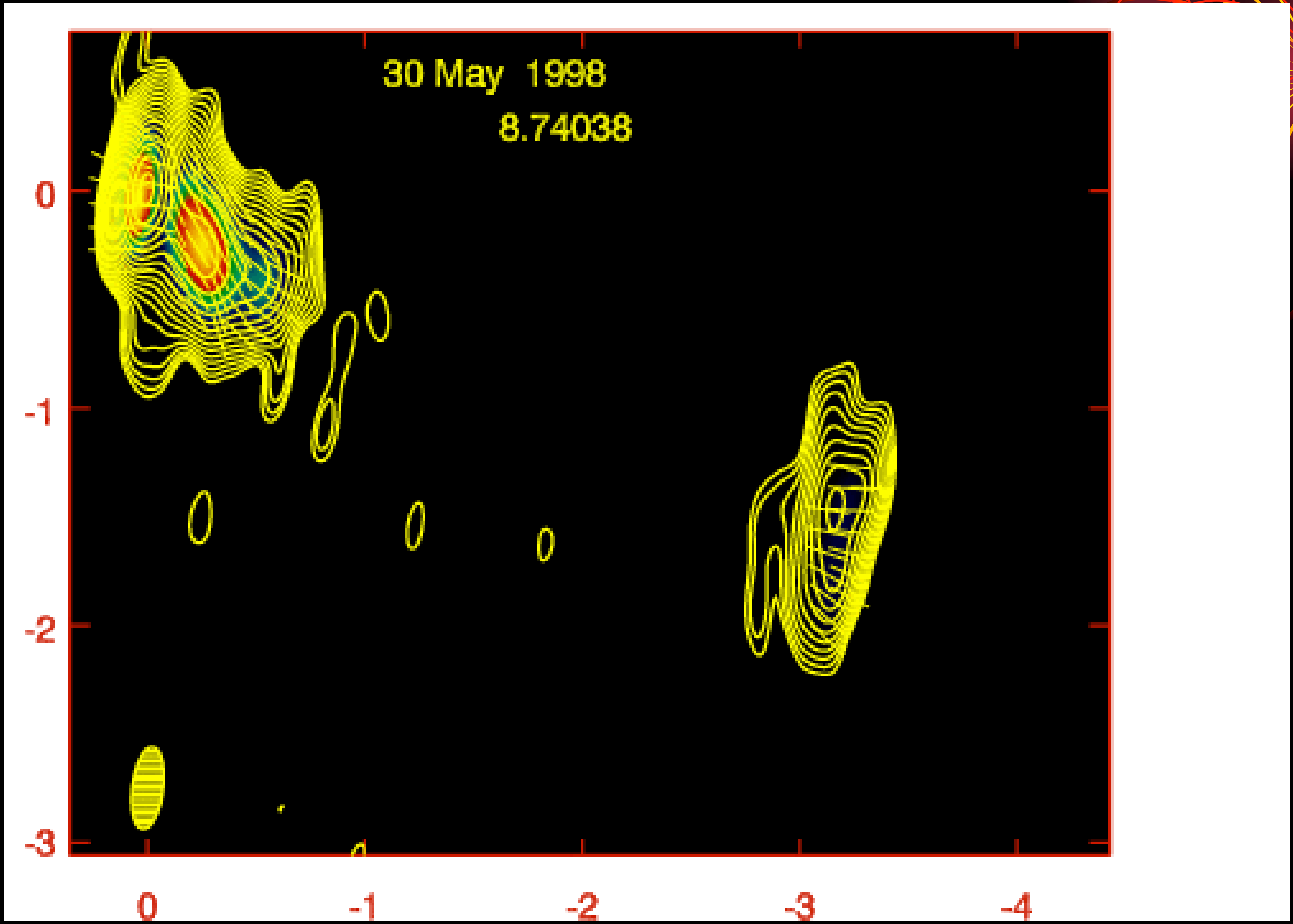
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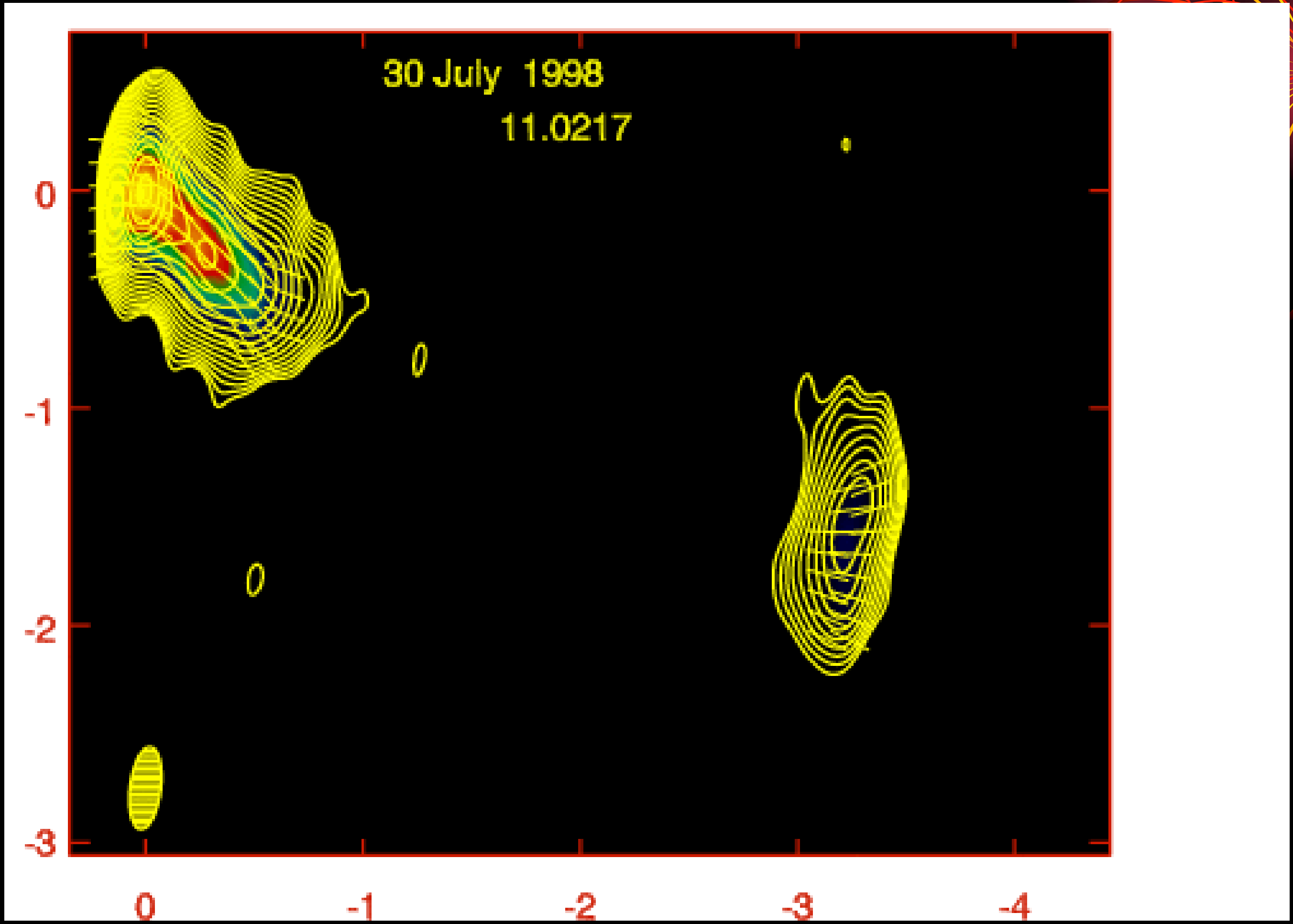

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11.0217
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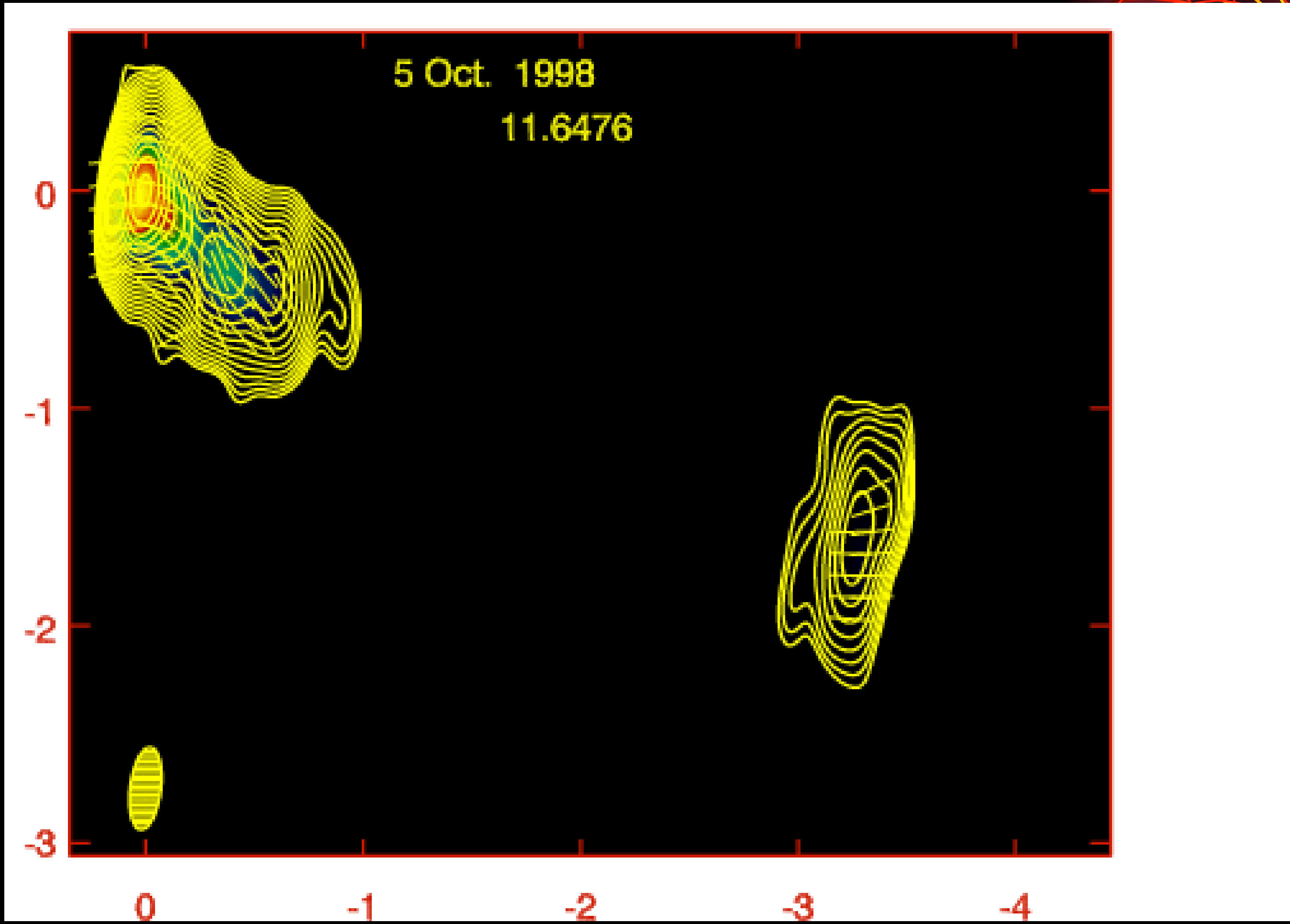
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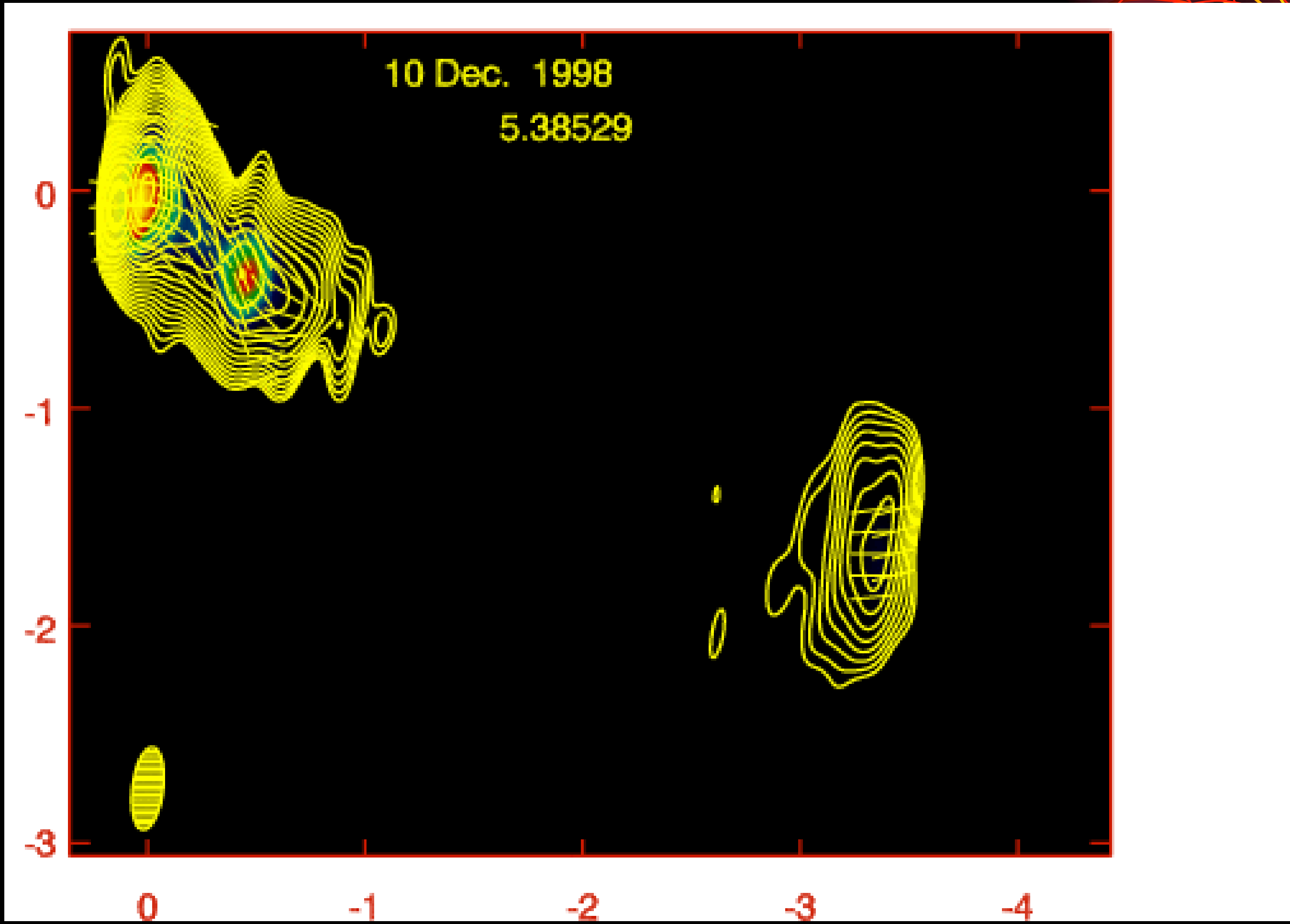

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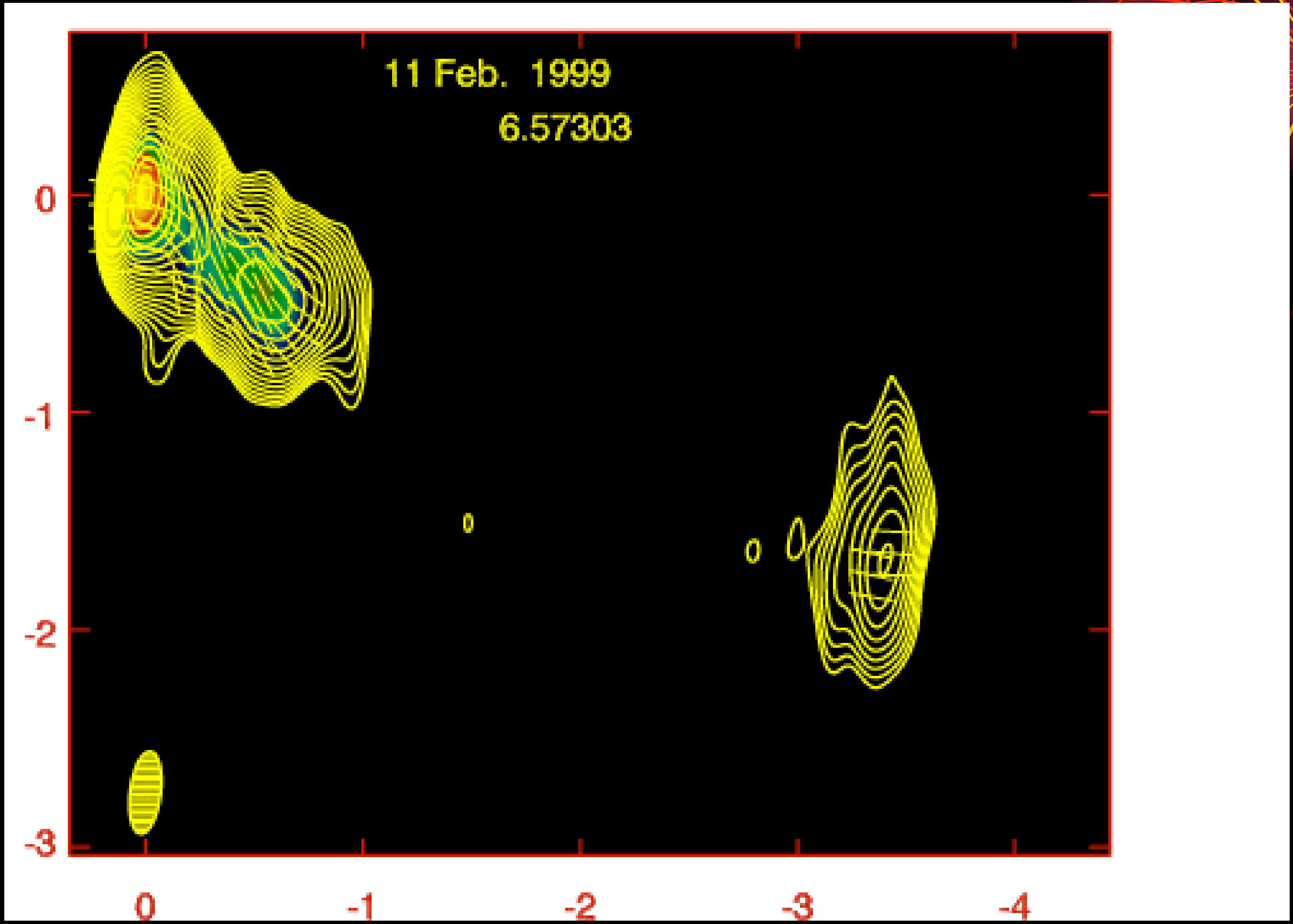

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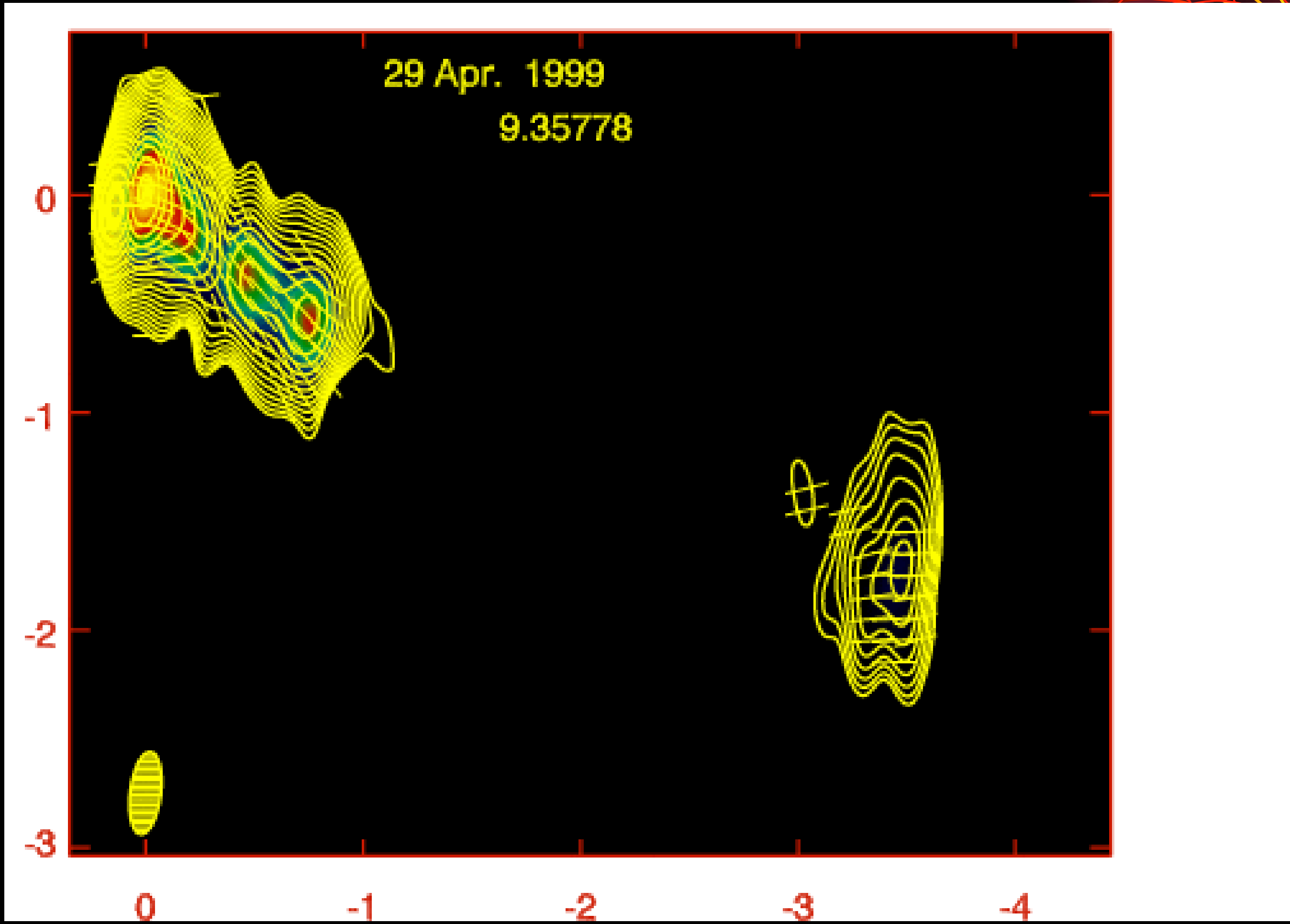
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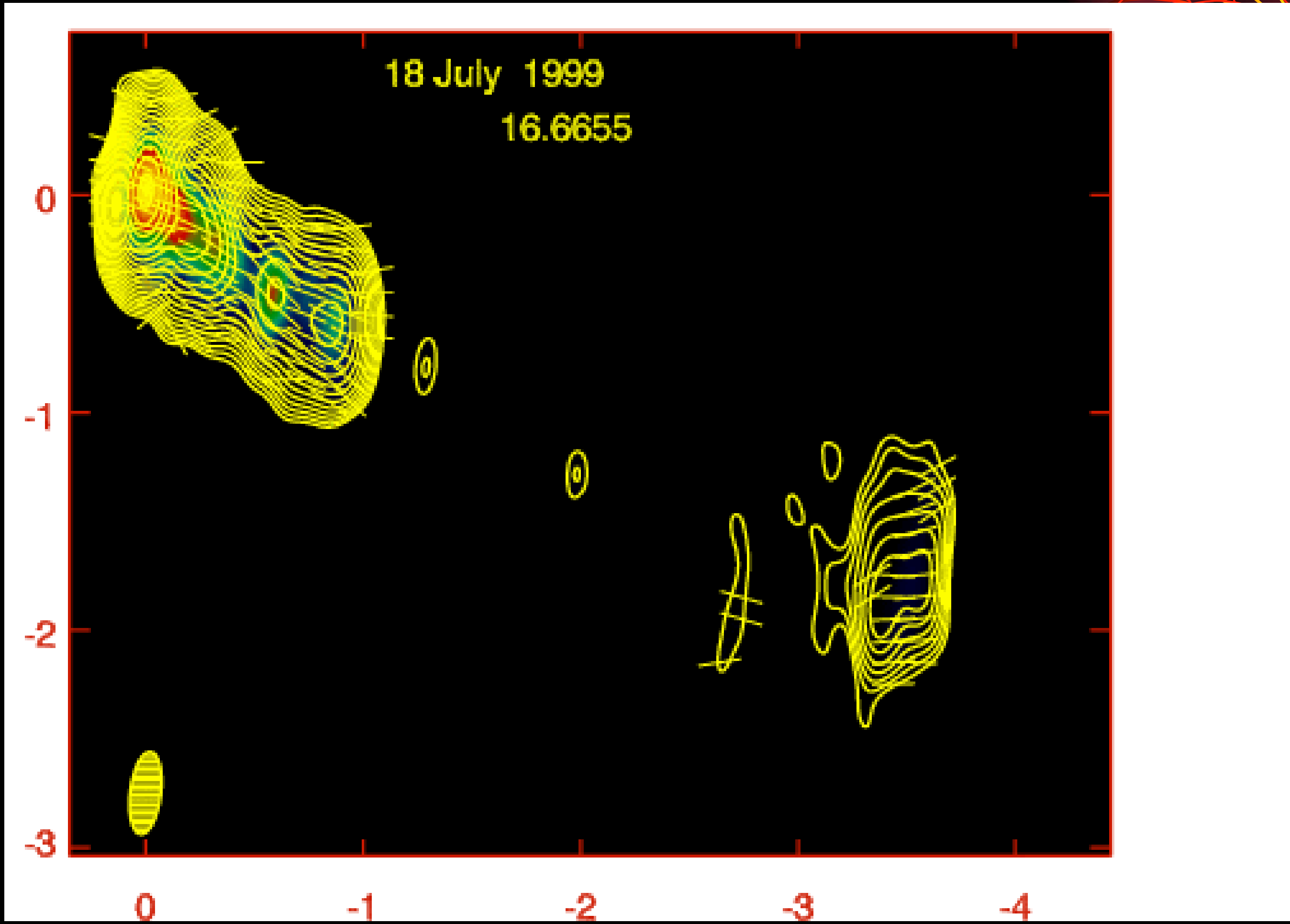
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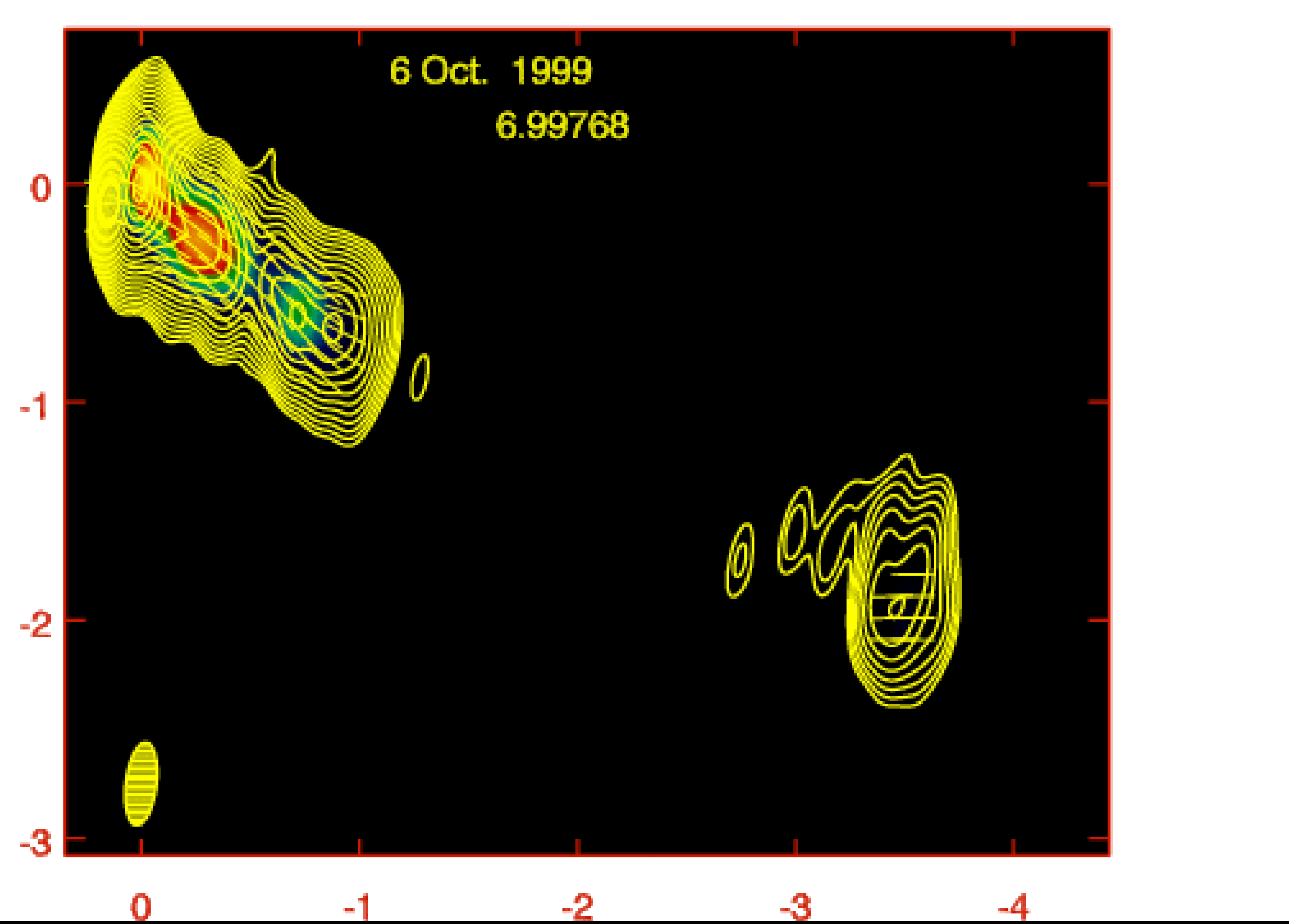
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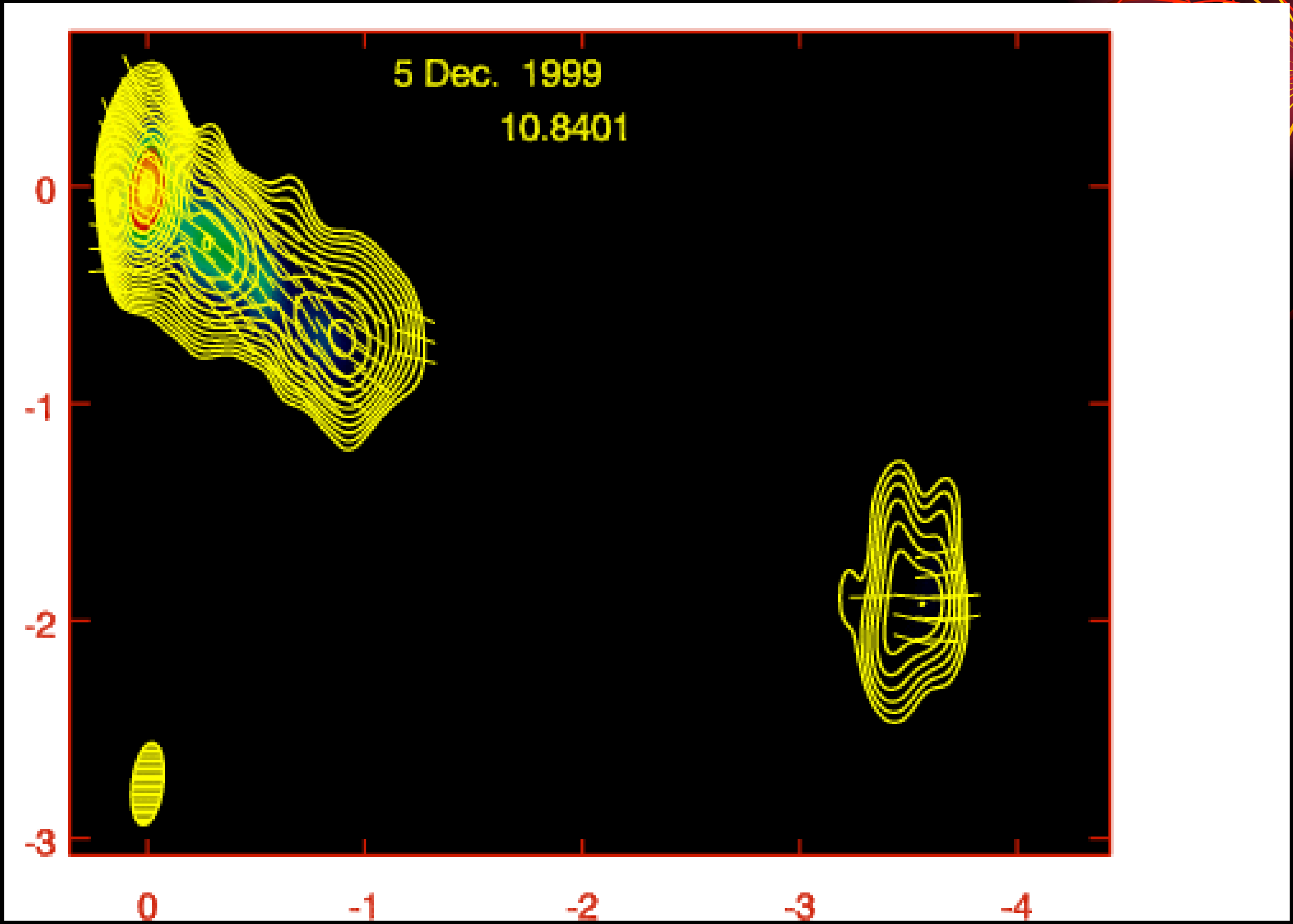
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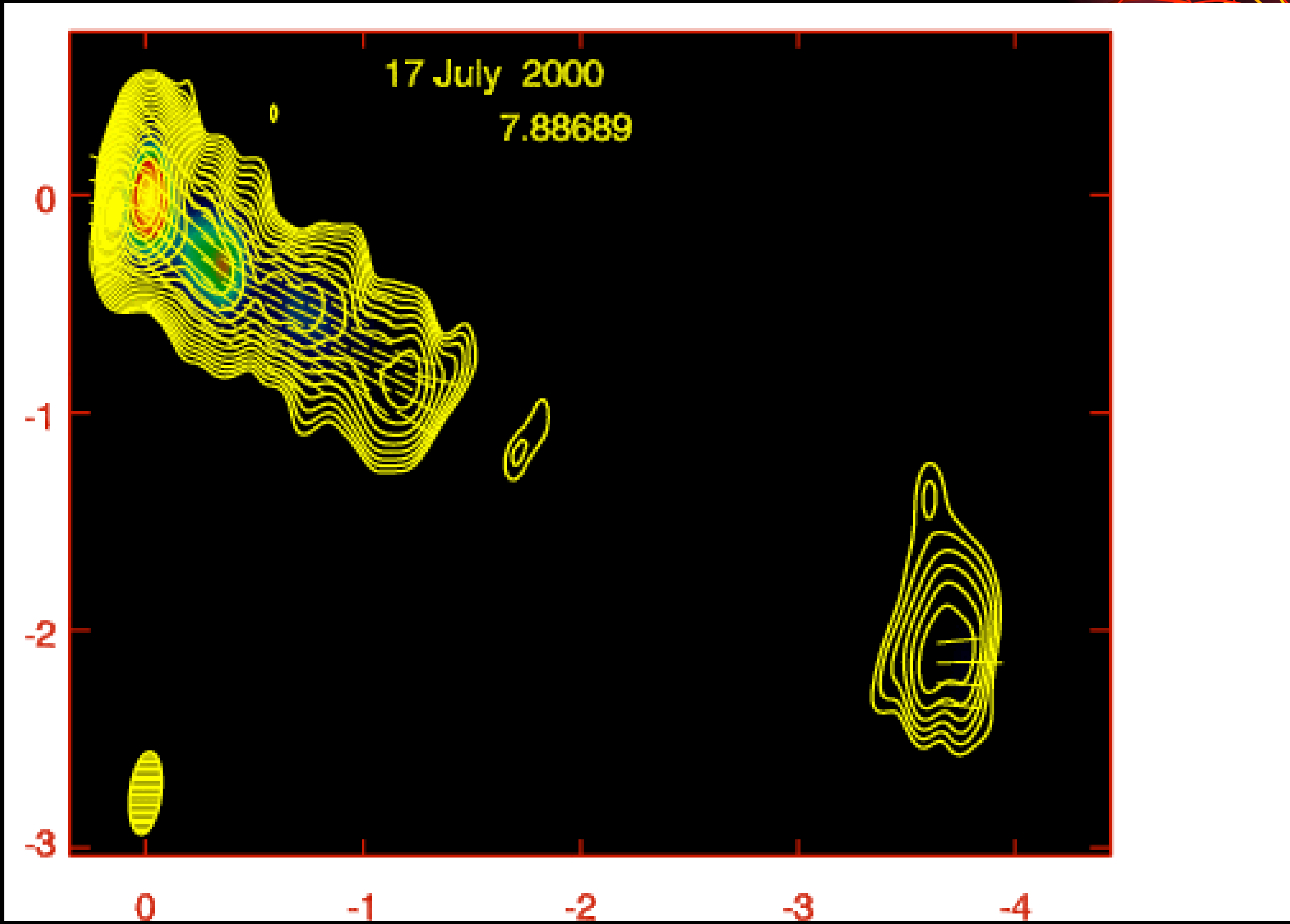
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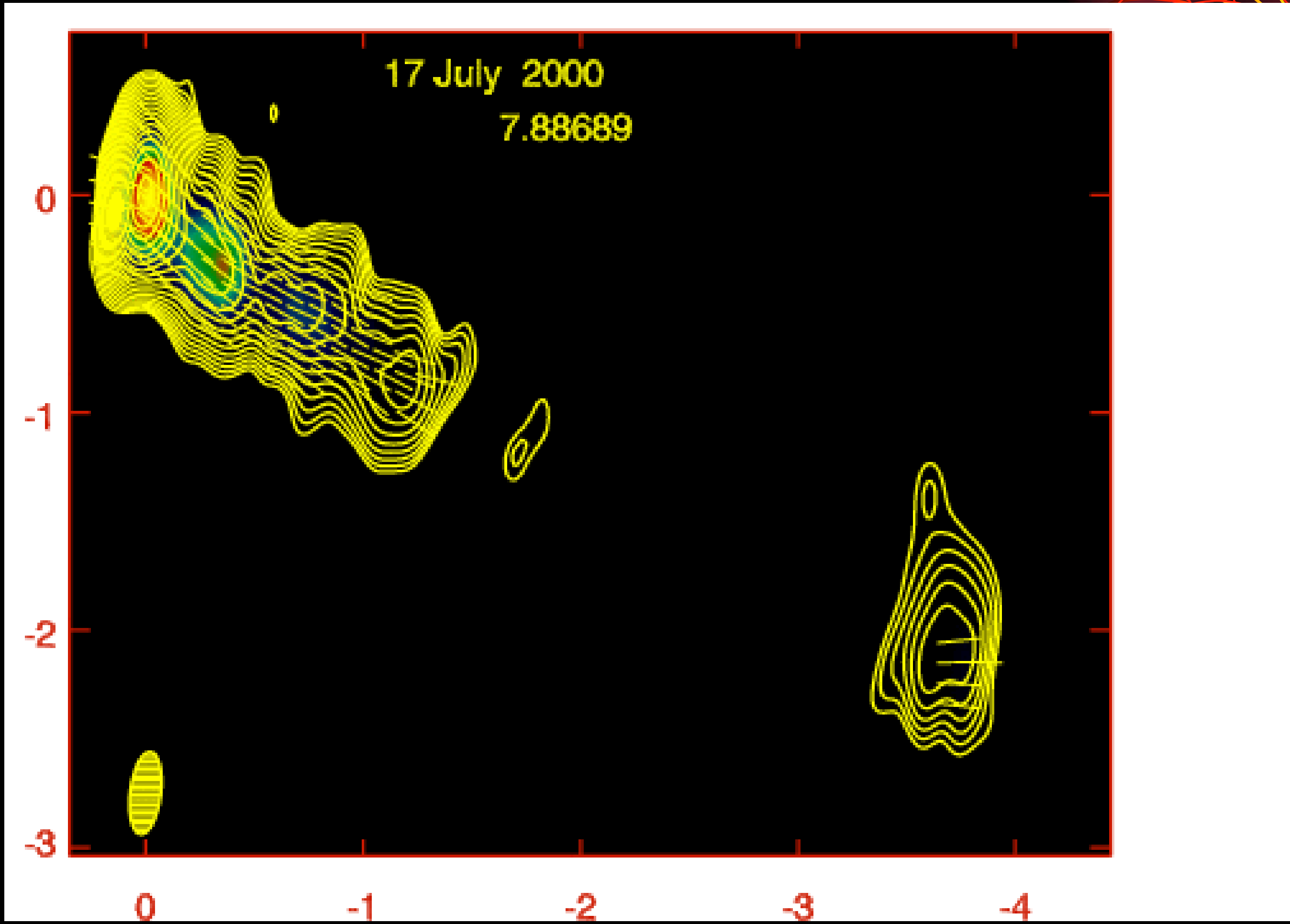
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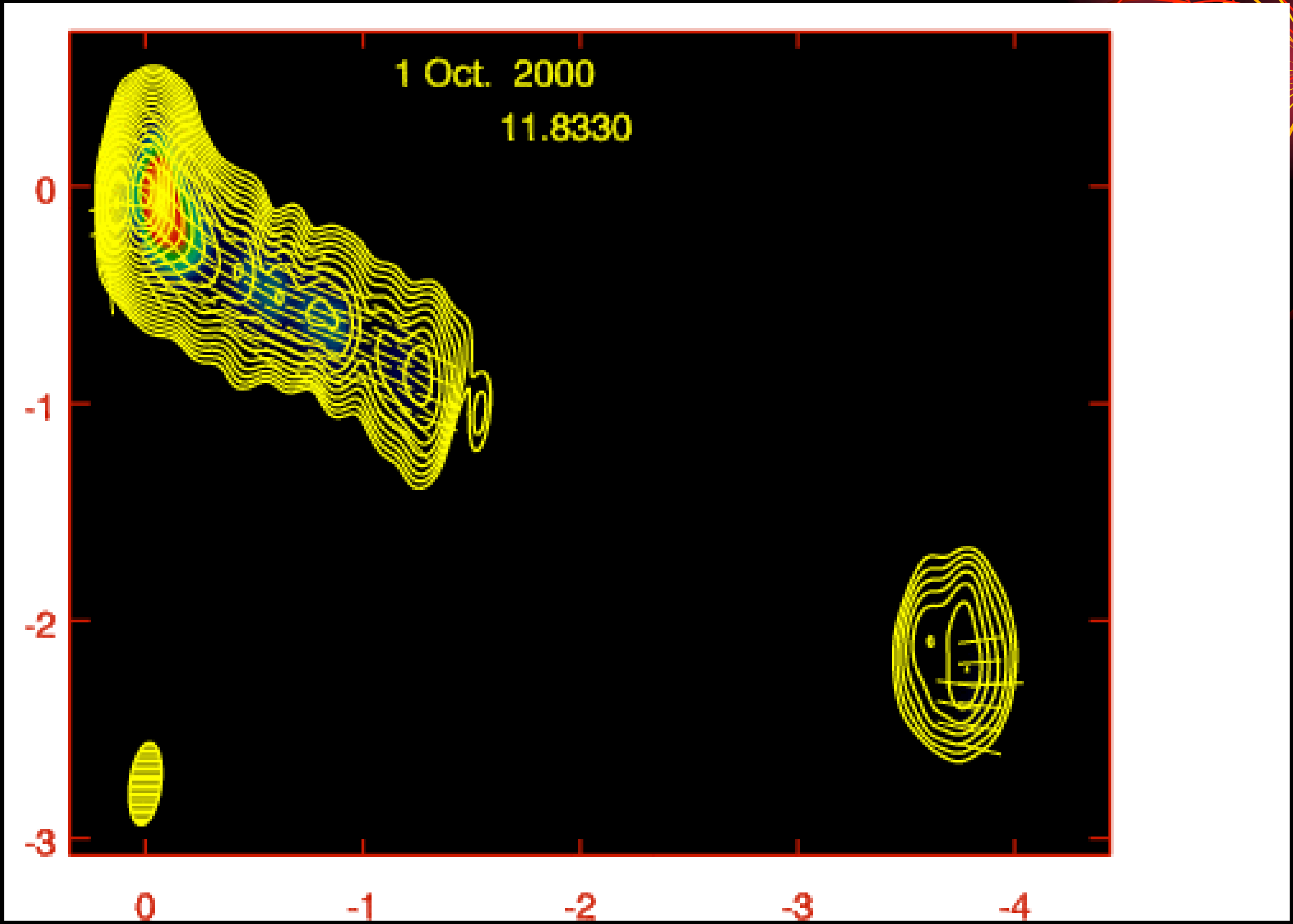

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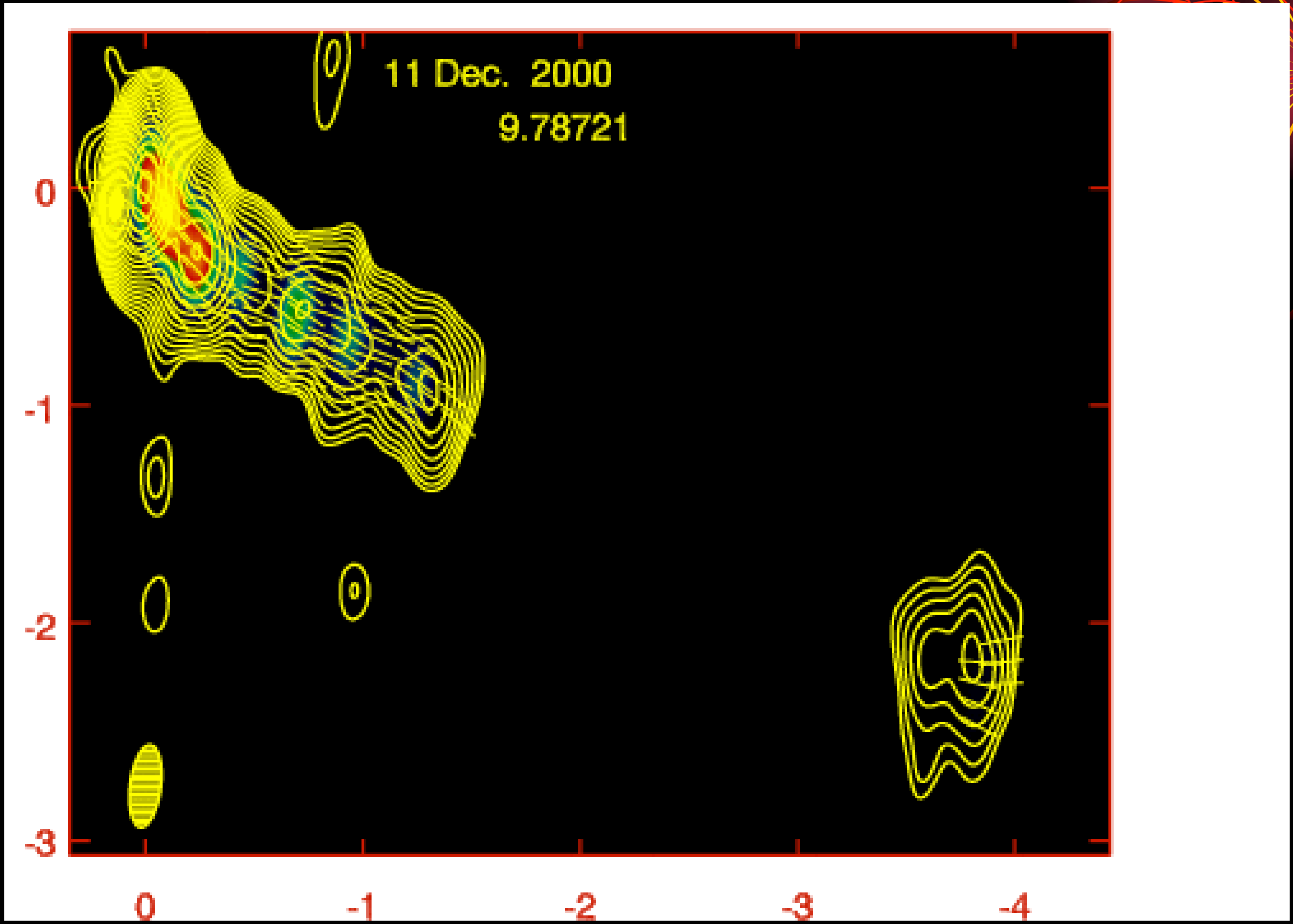
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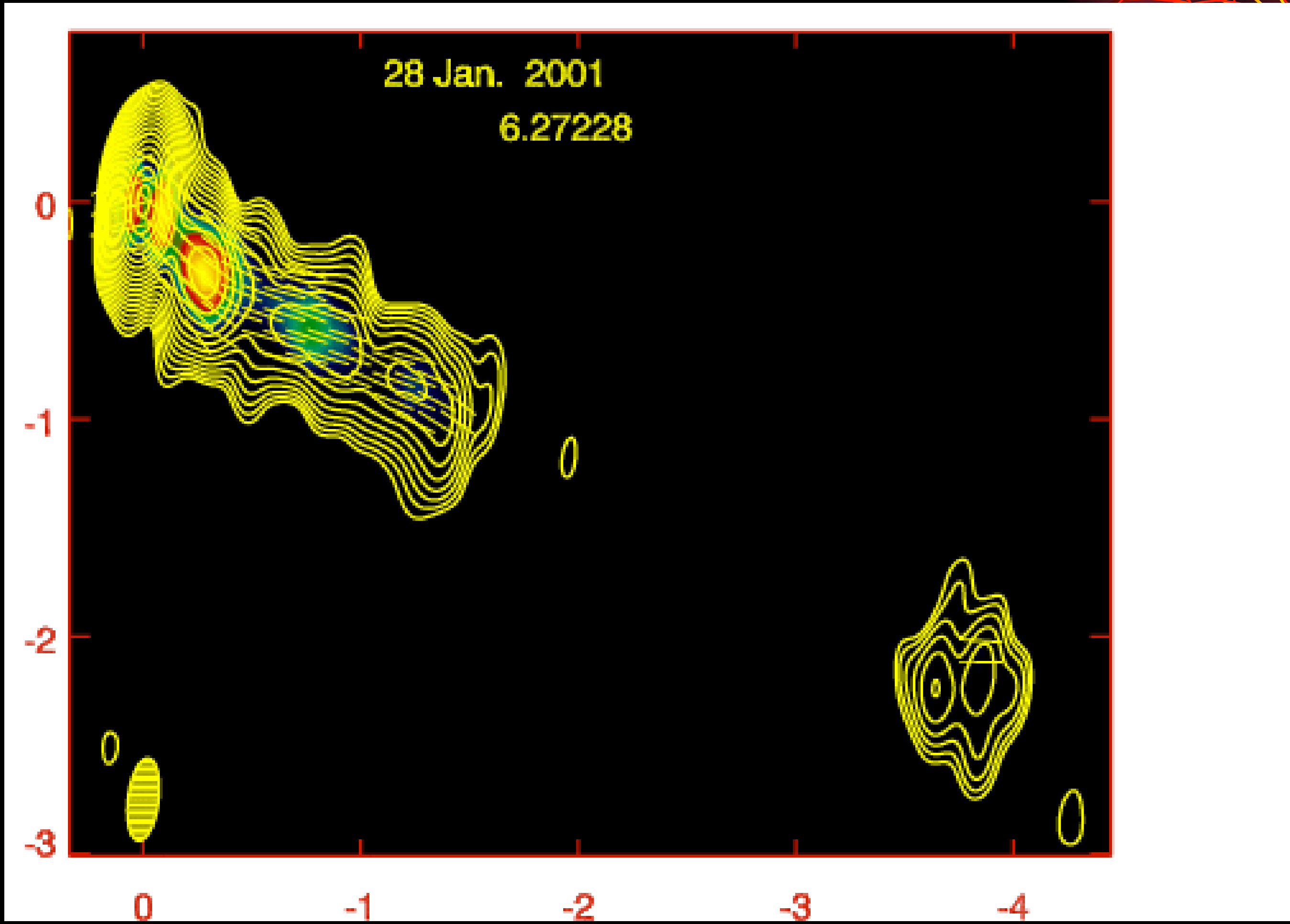
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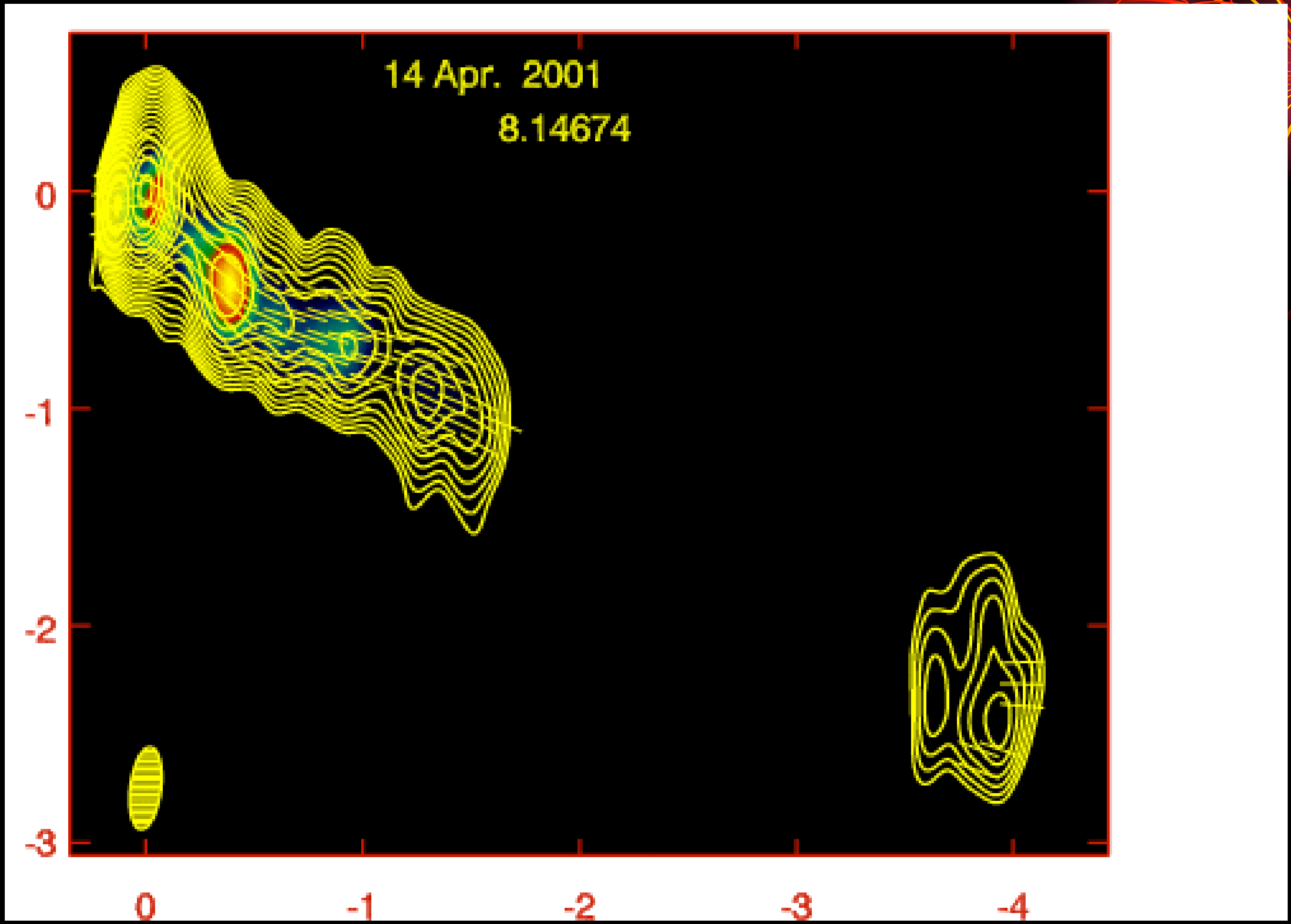
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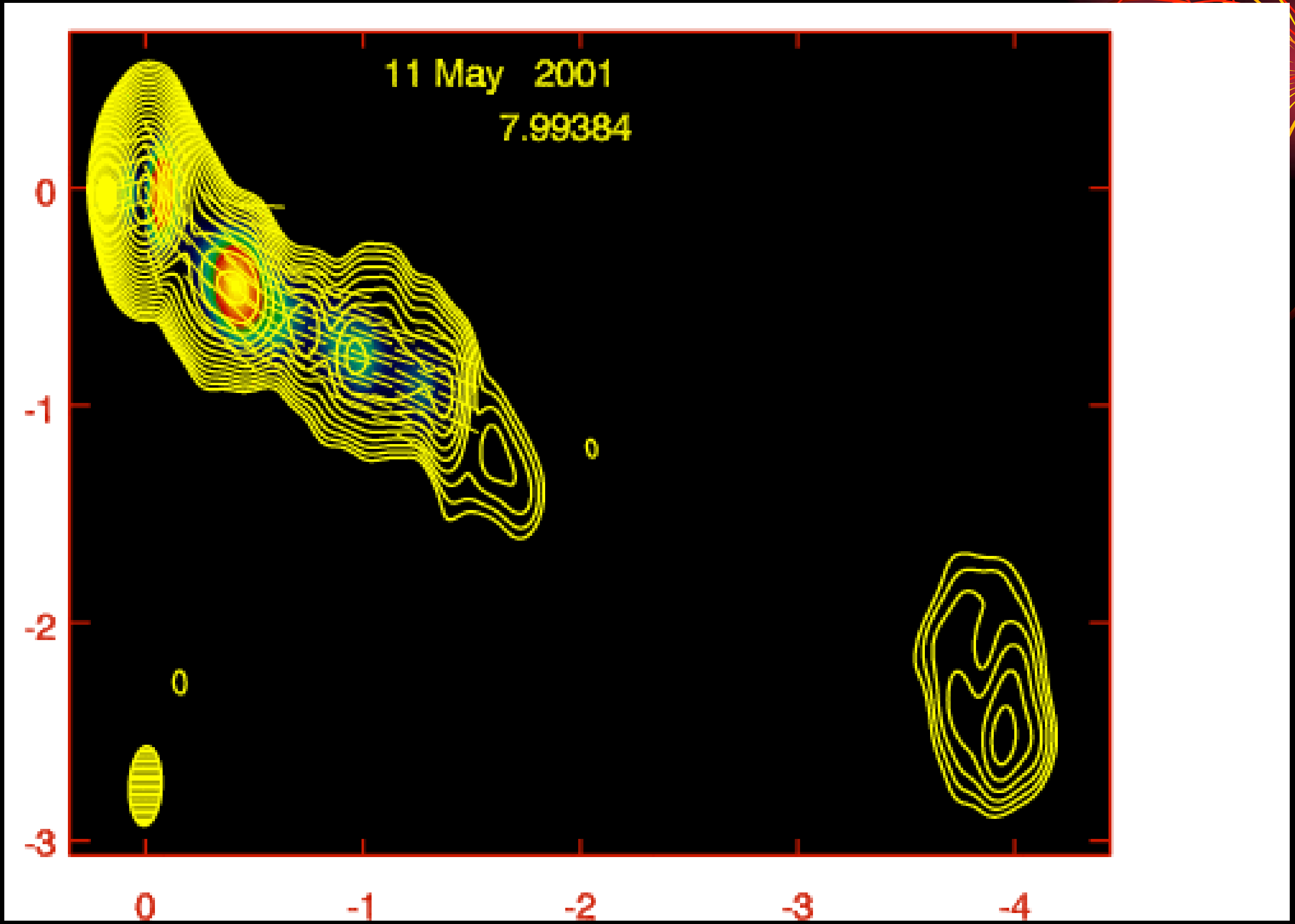
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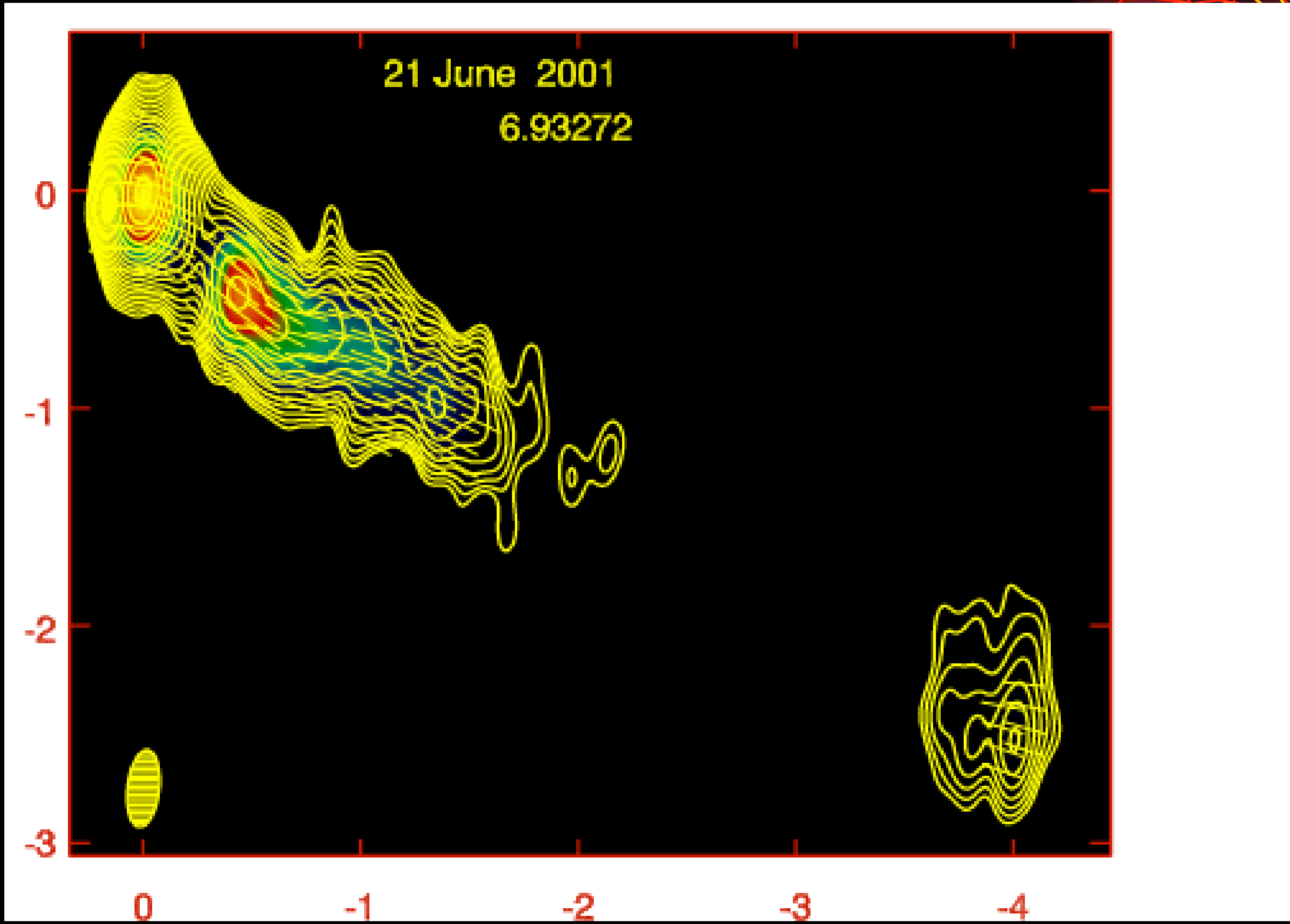
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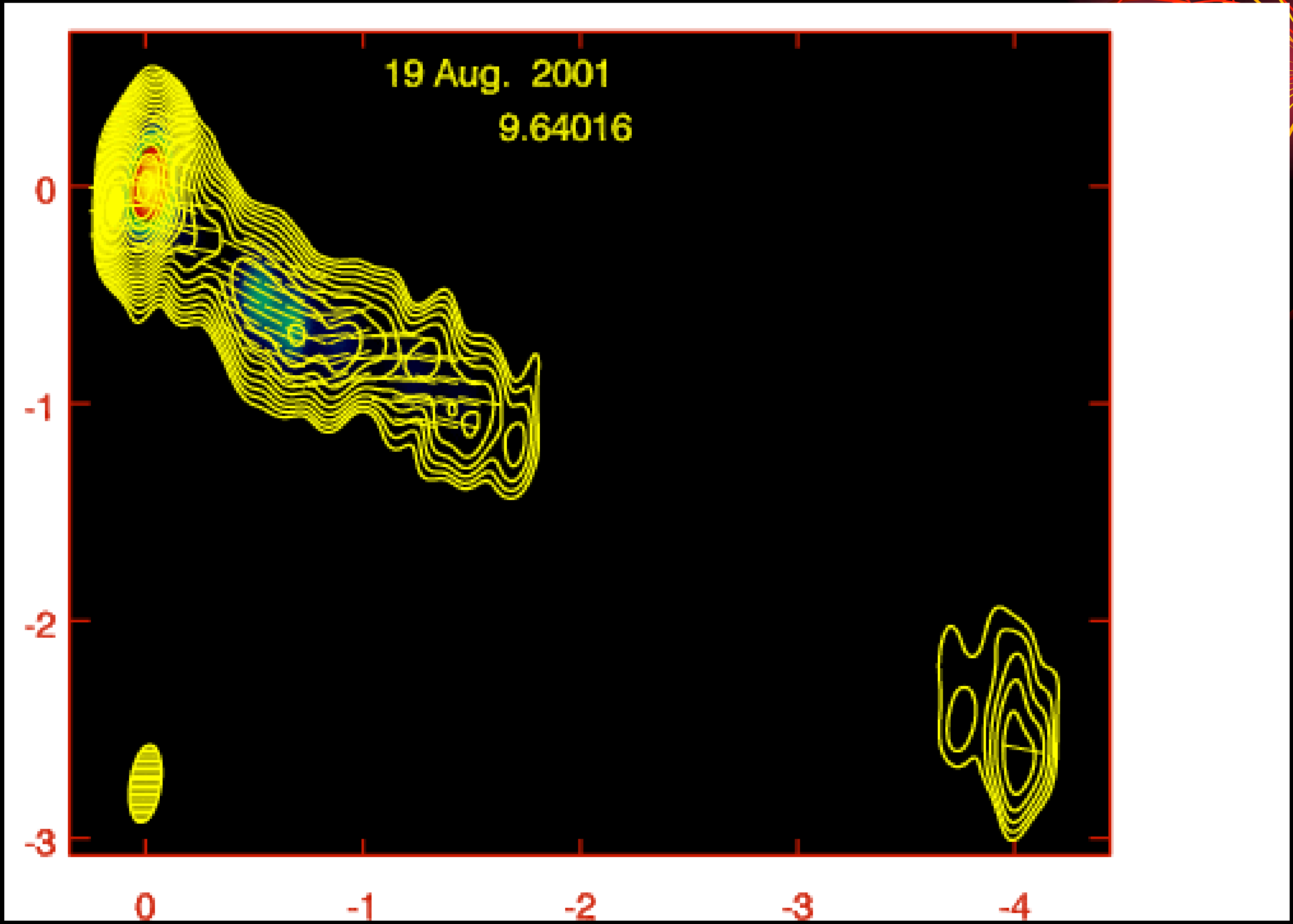
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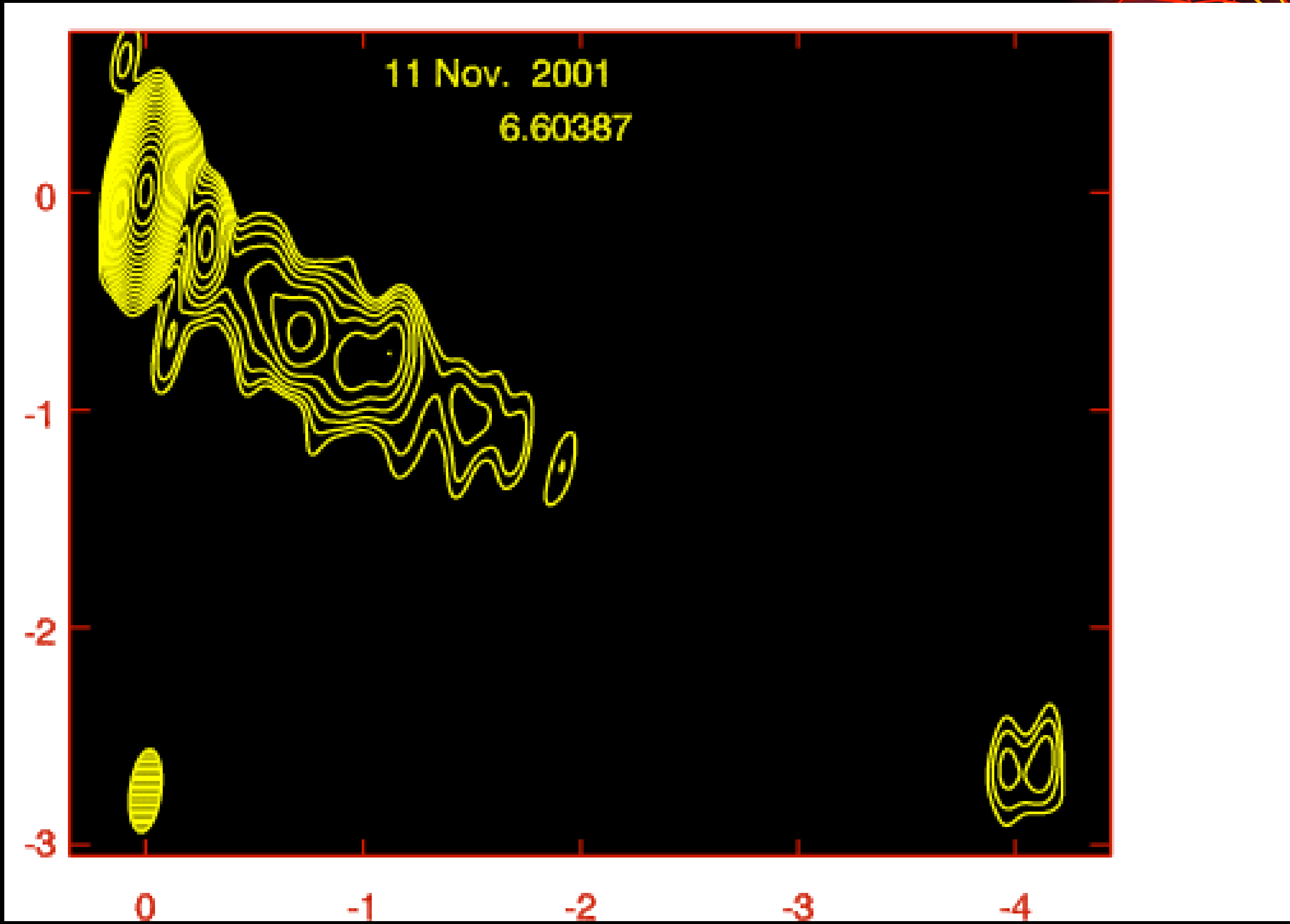
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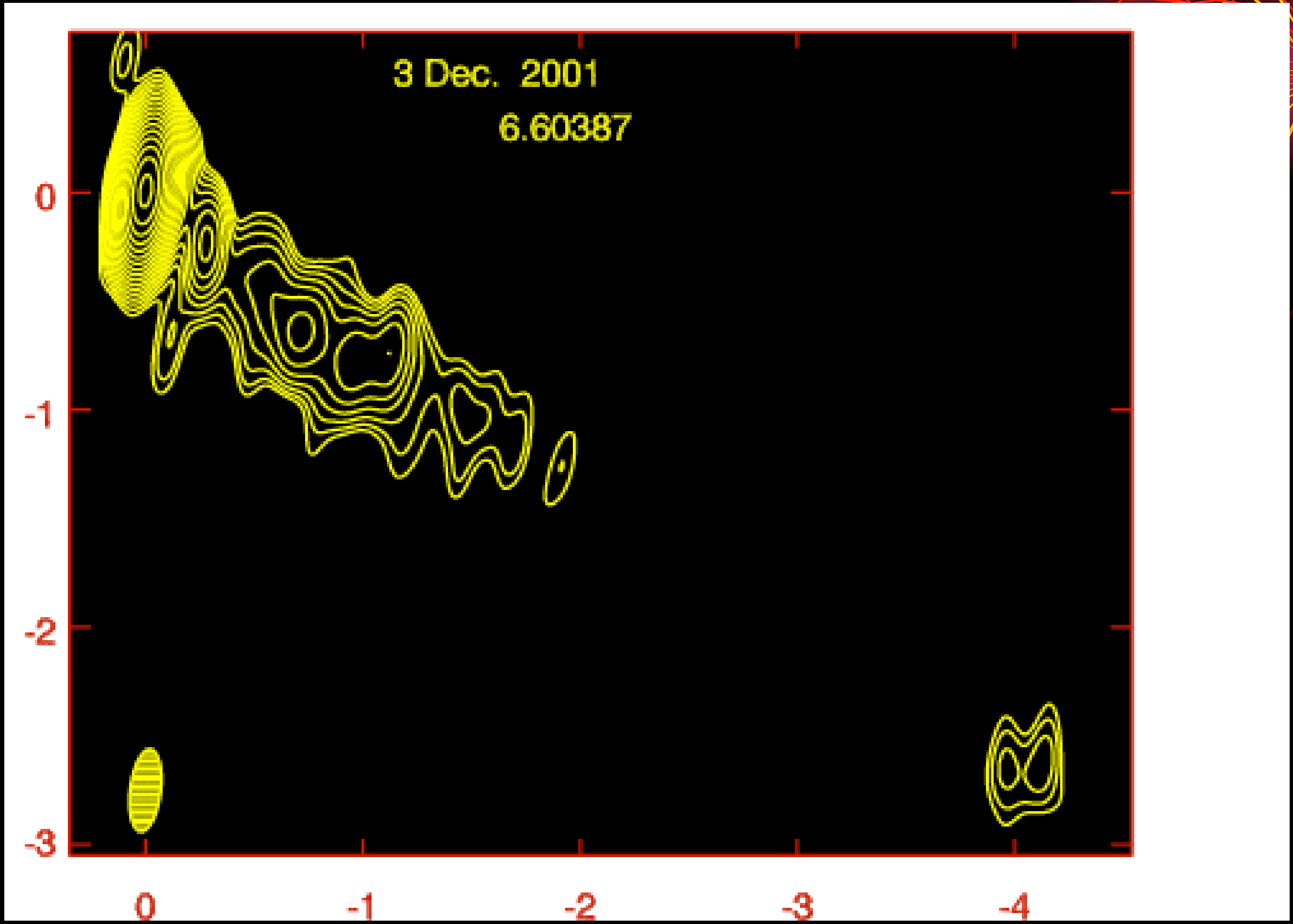

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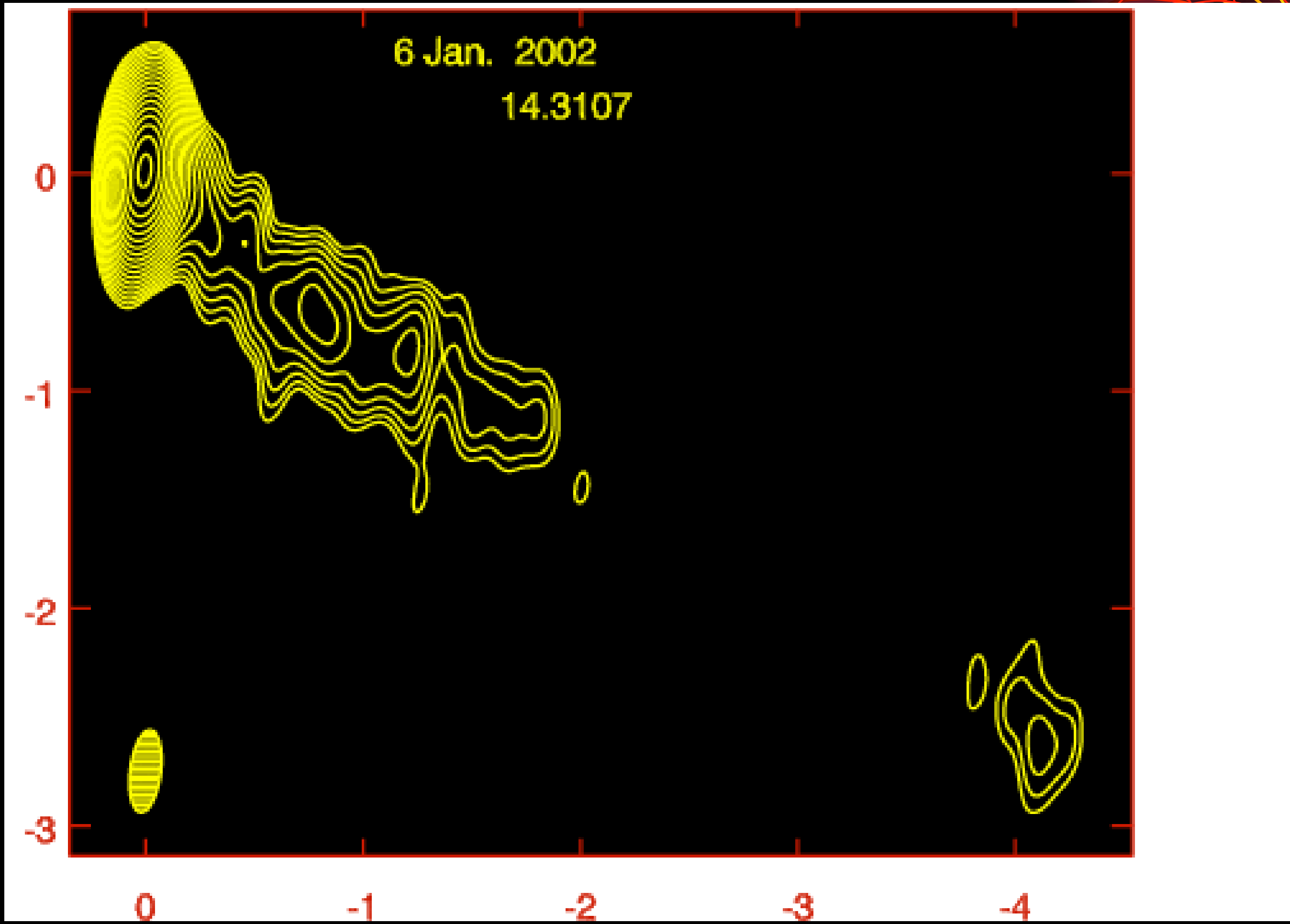
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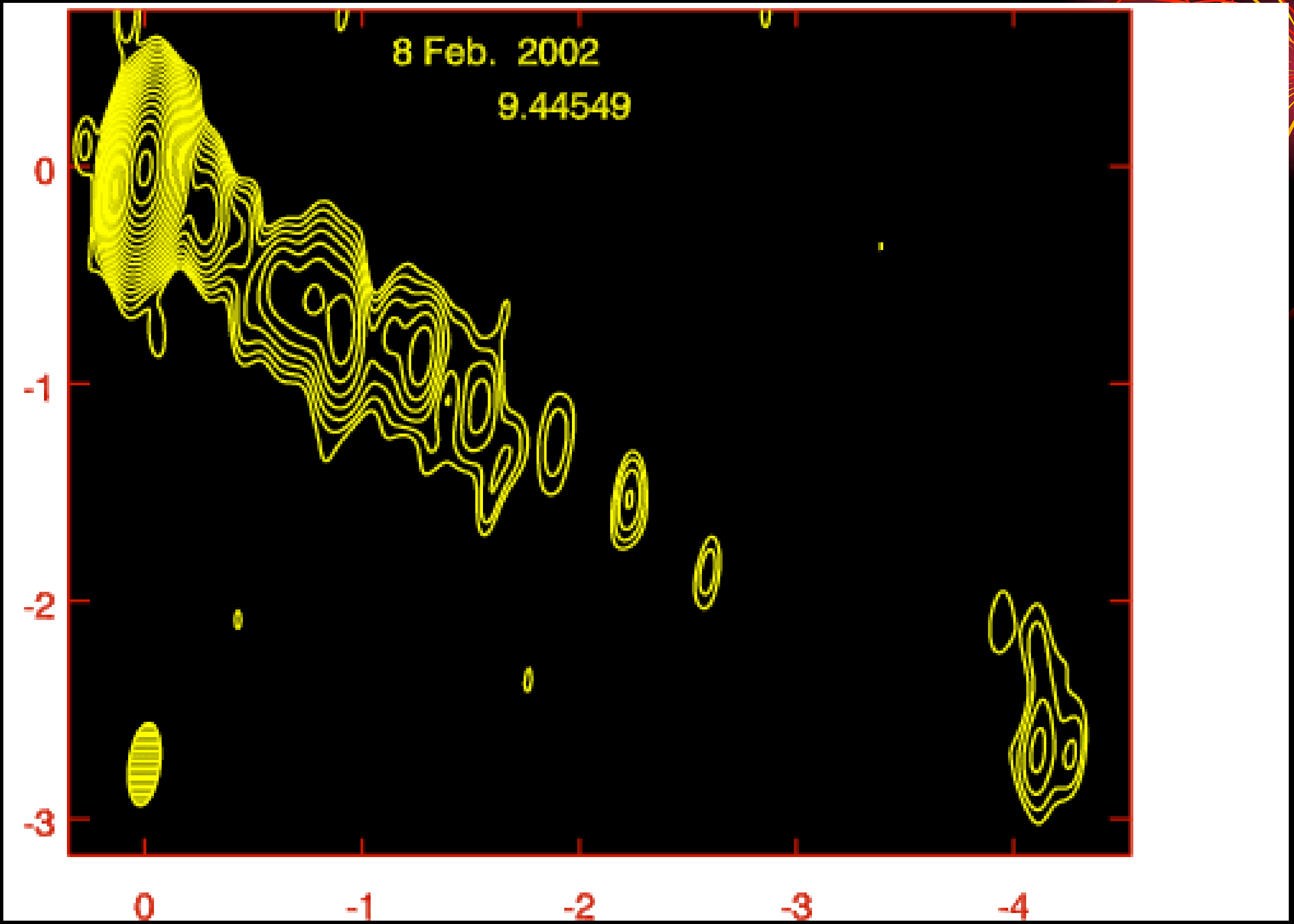
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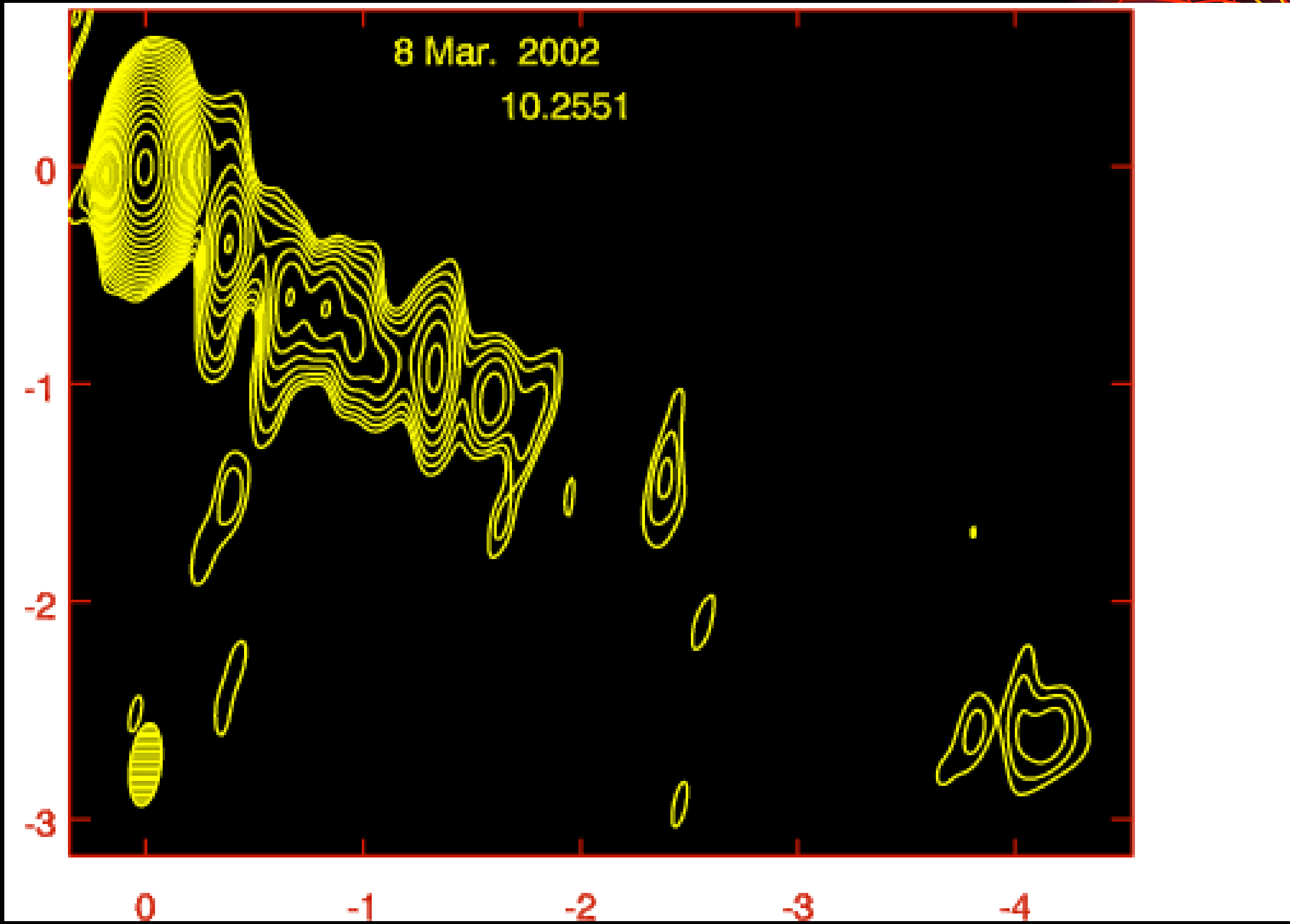
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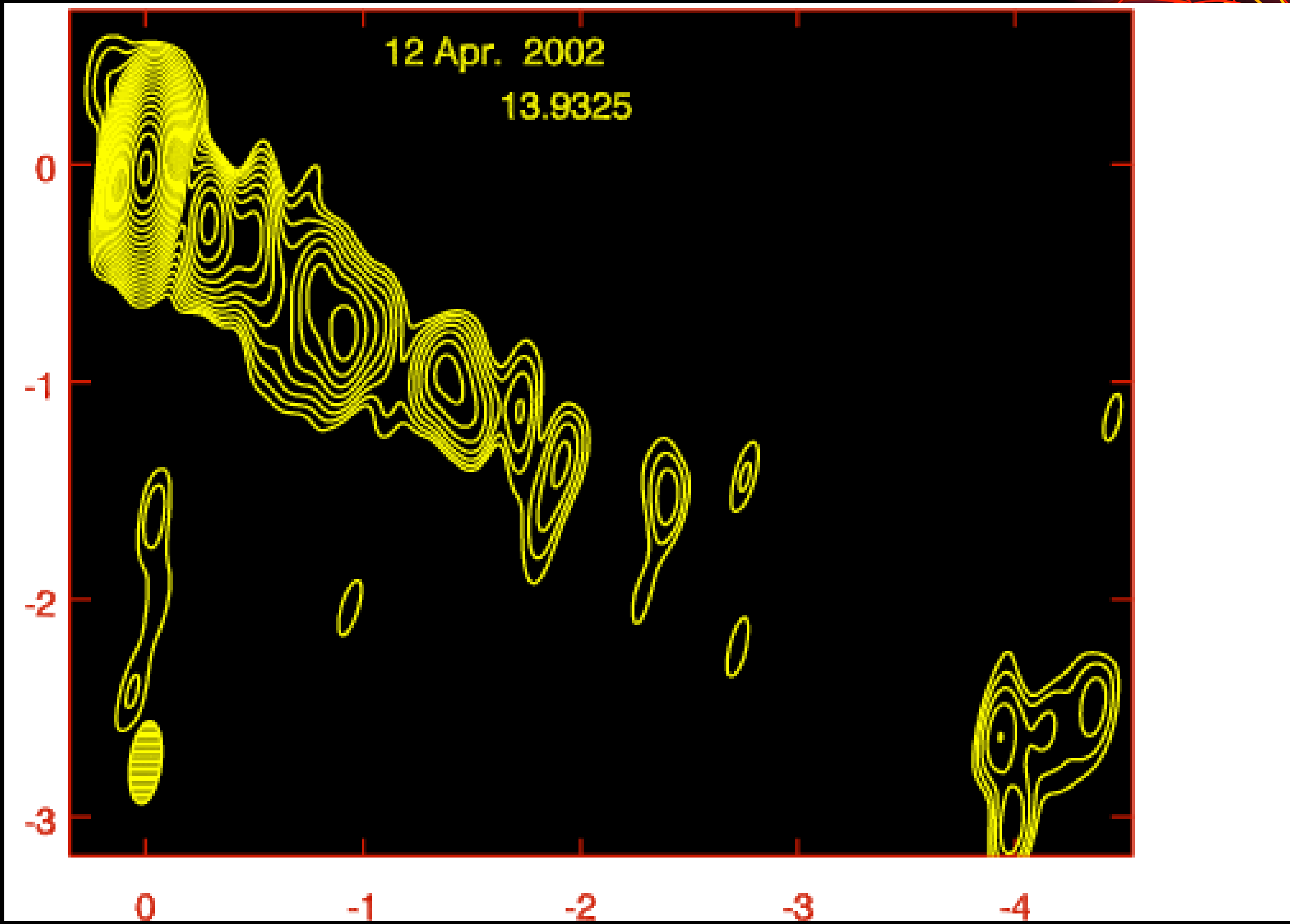
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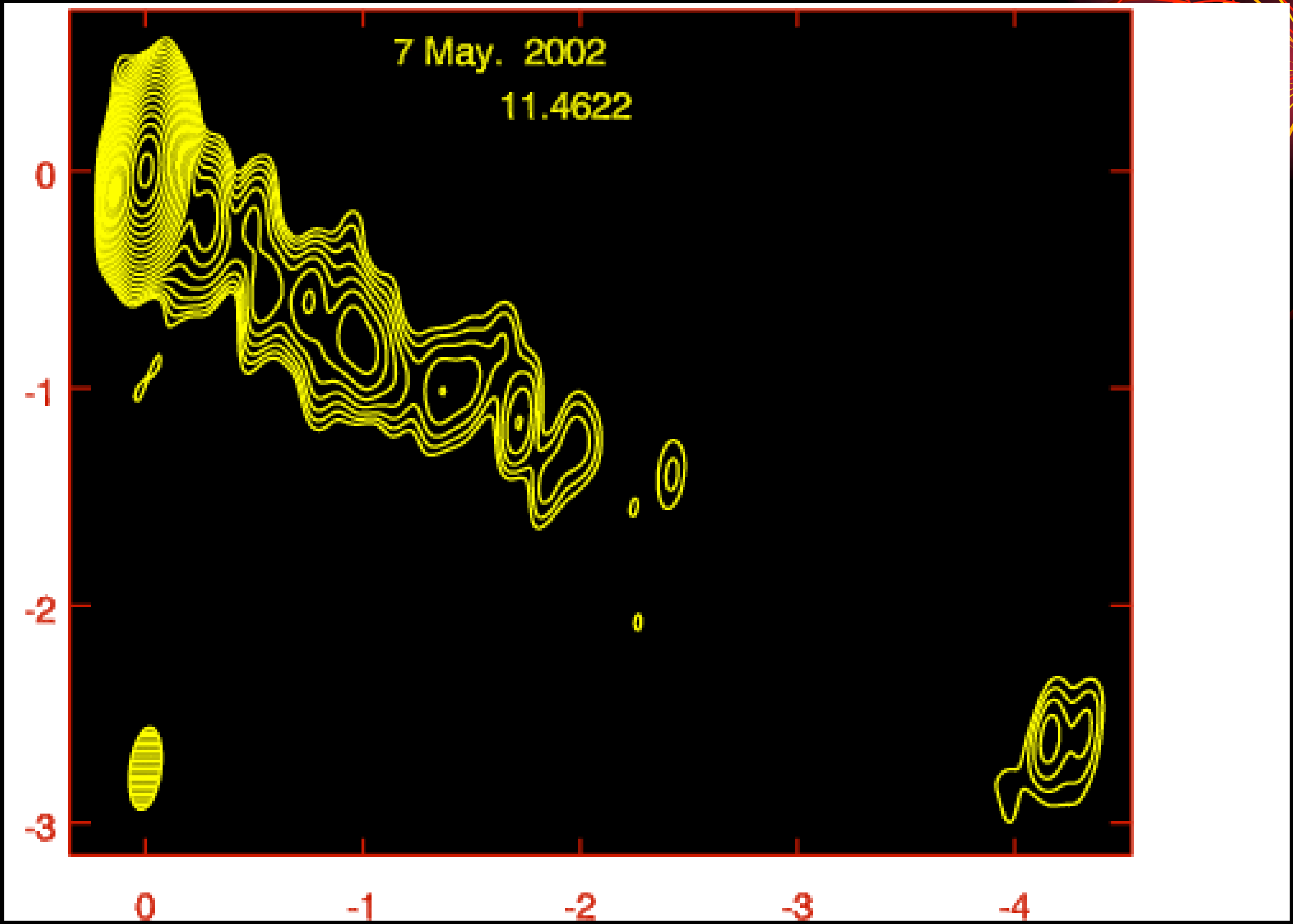

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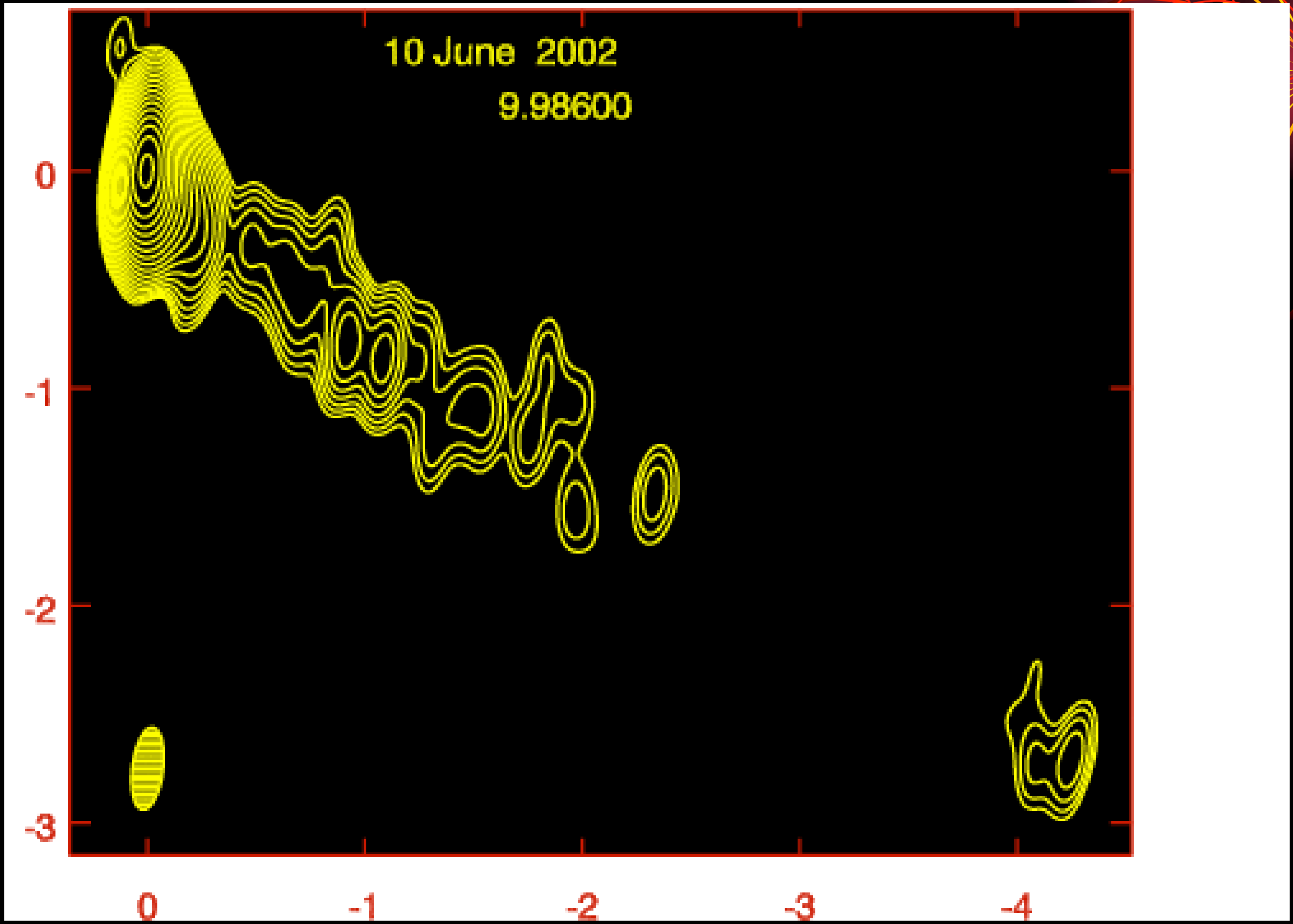
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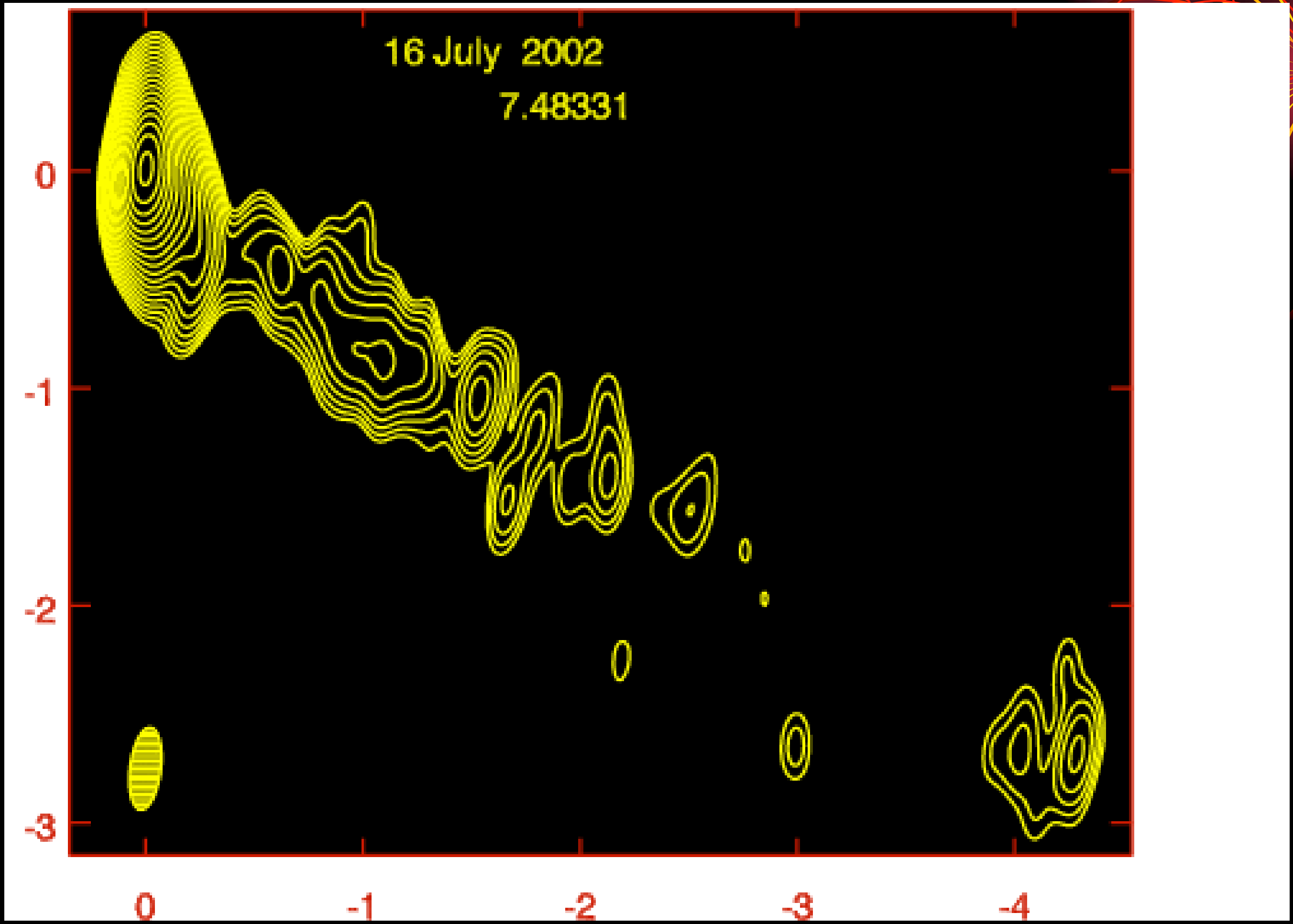
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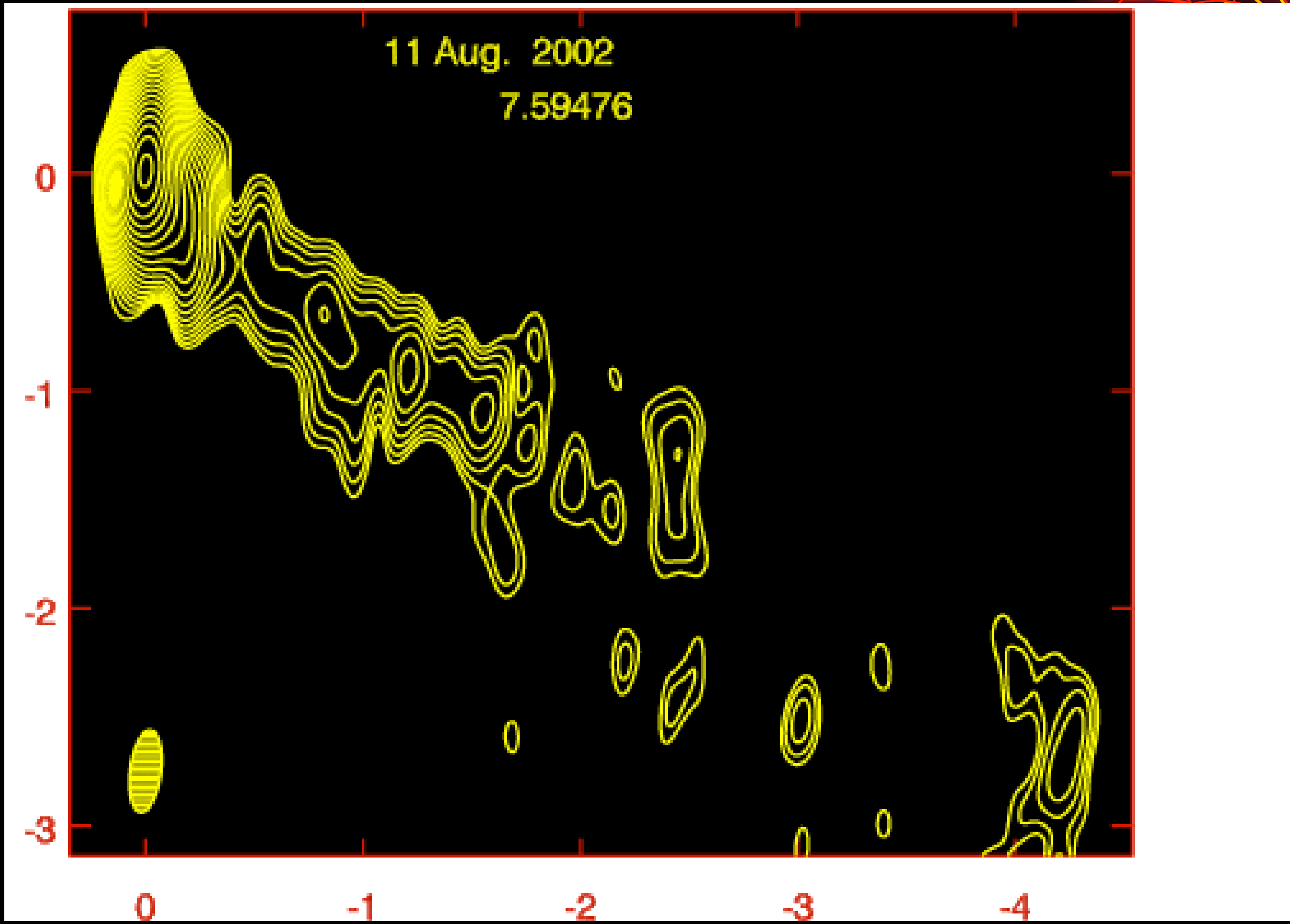
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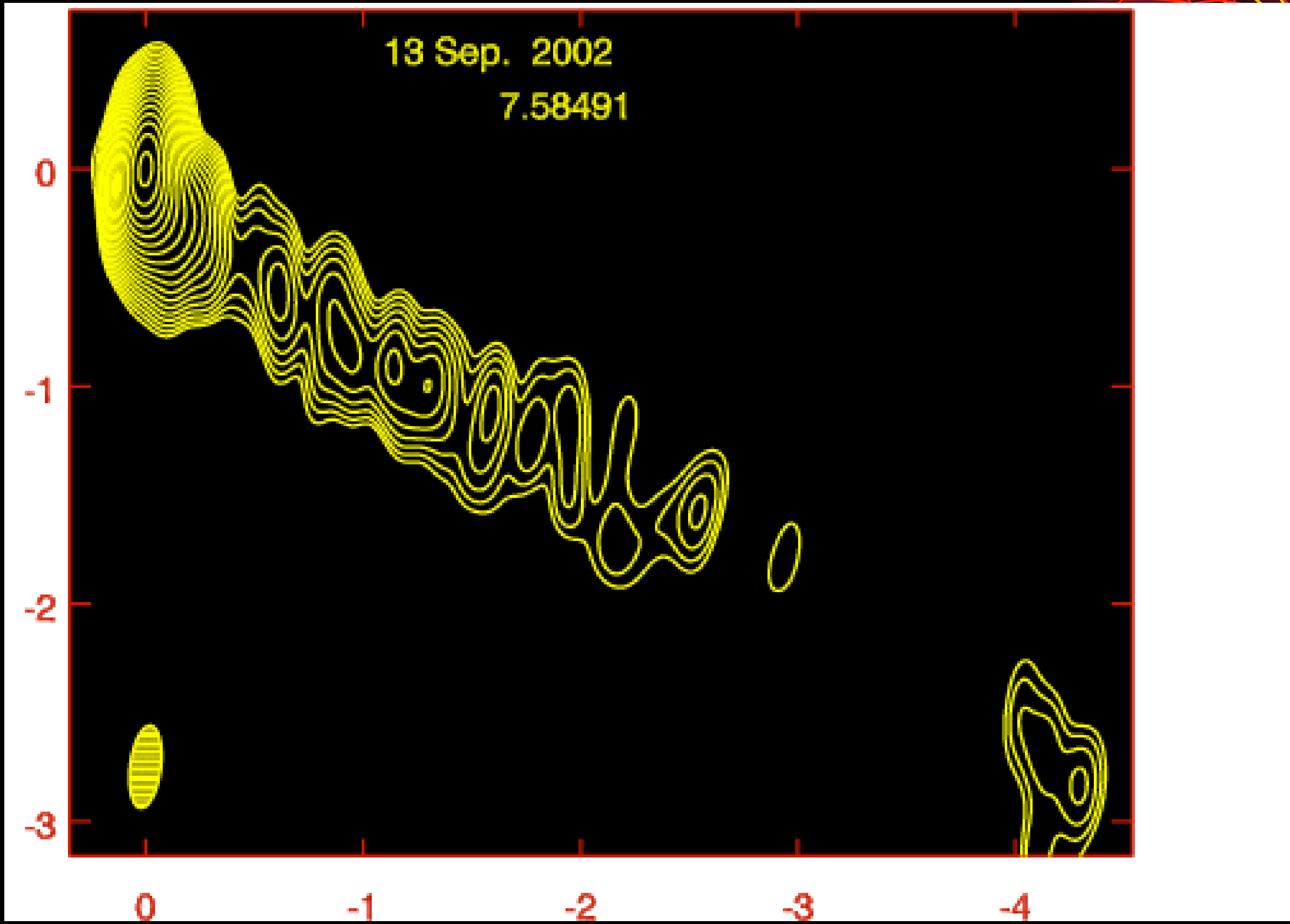
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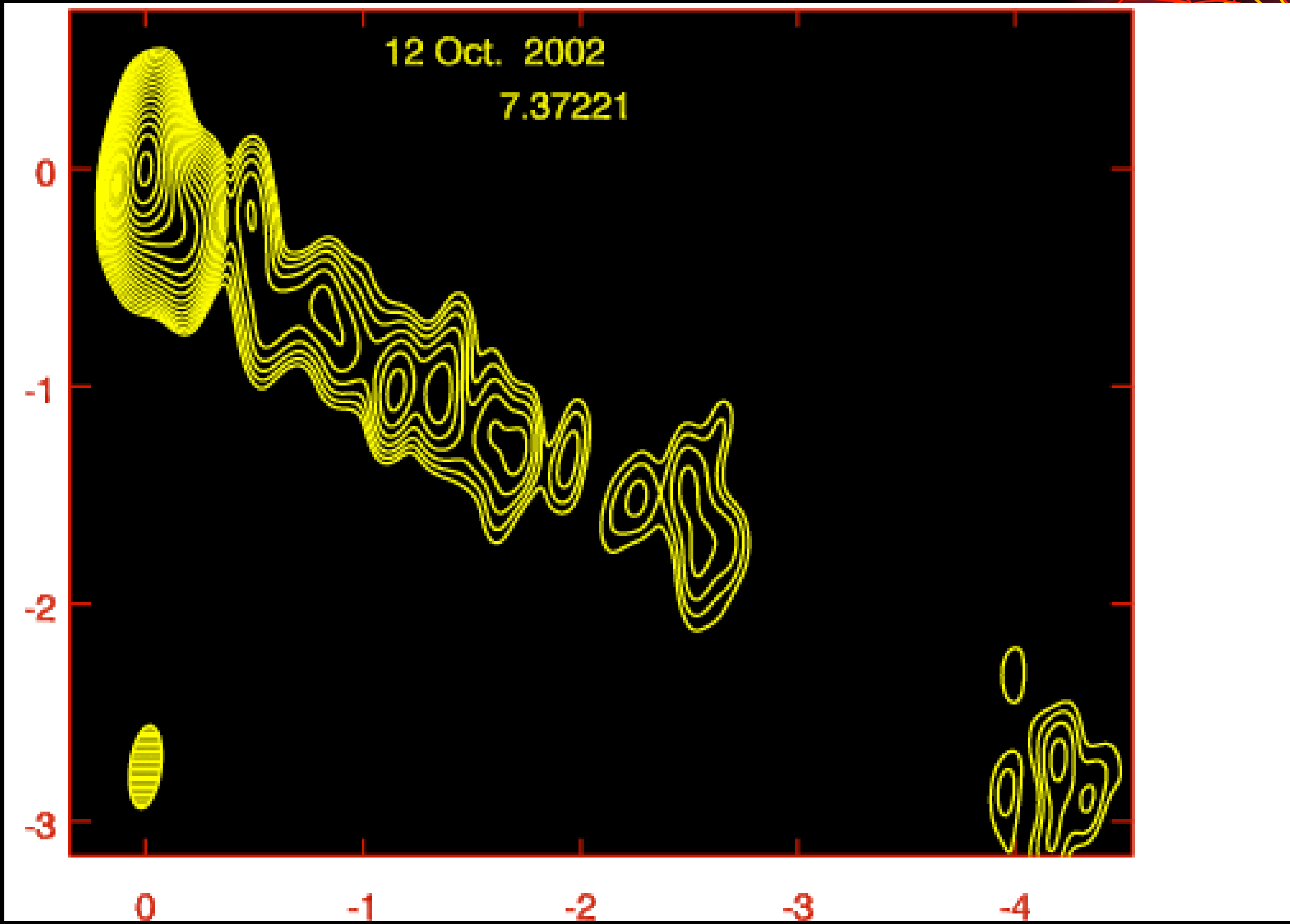
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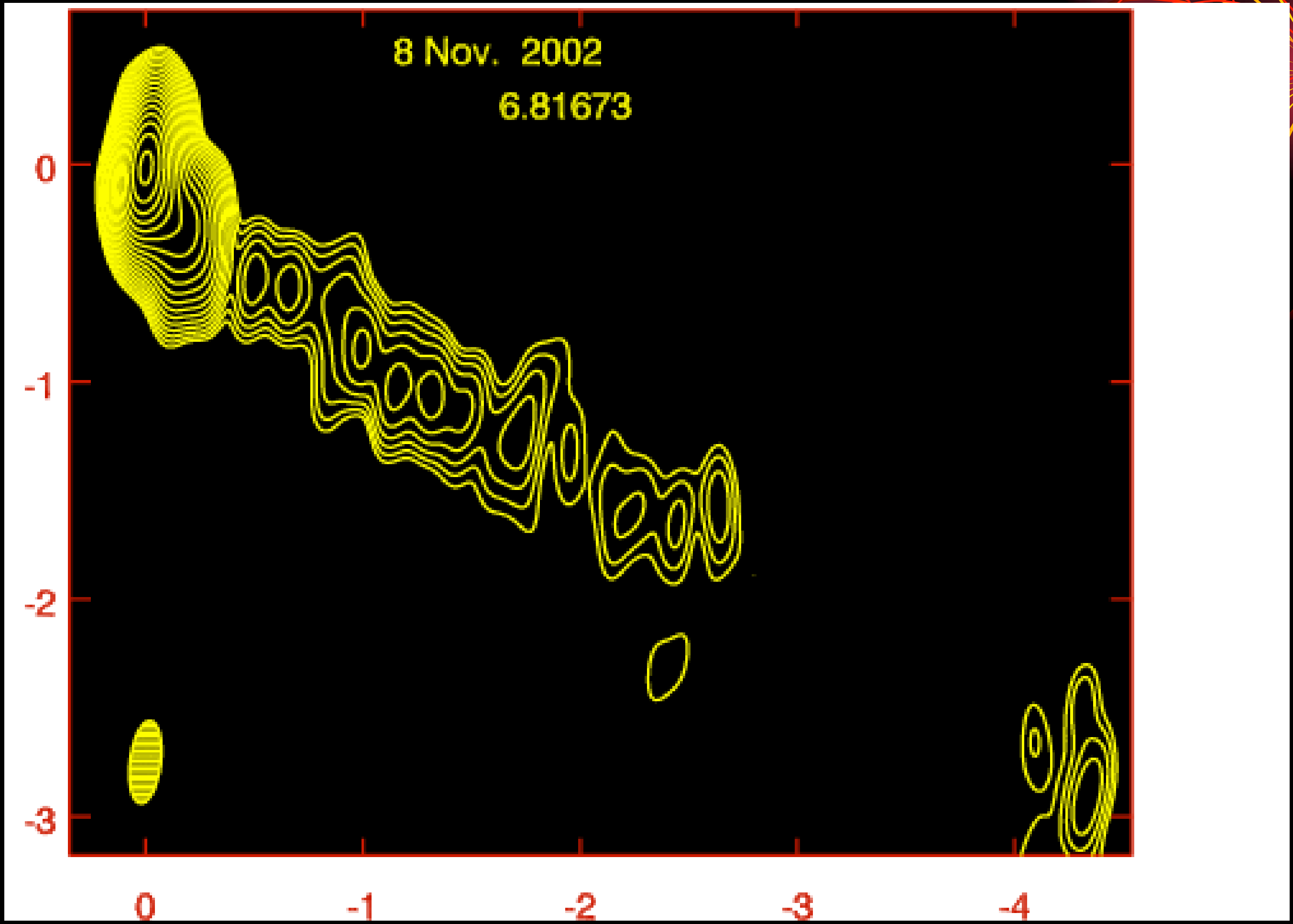
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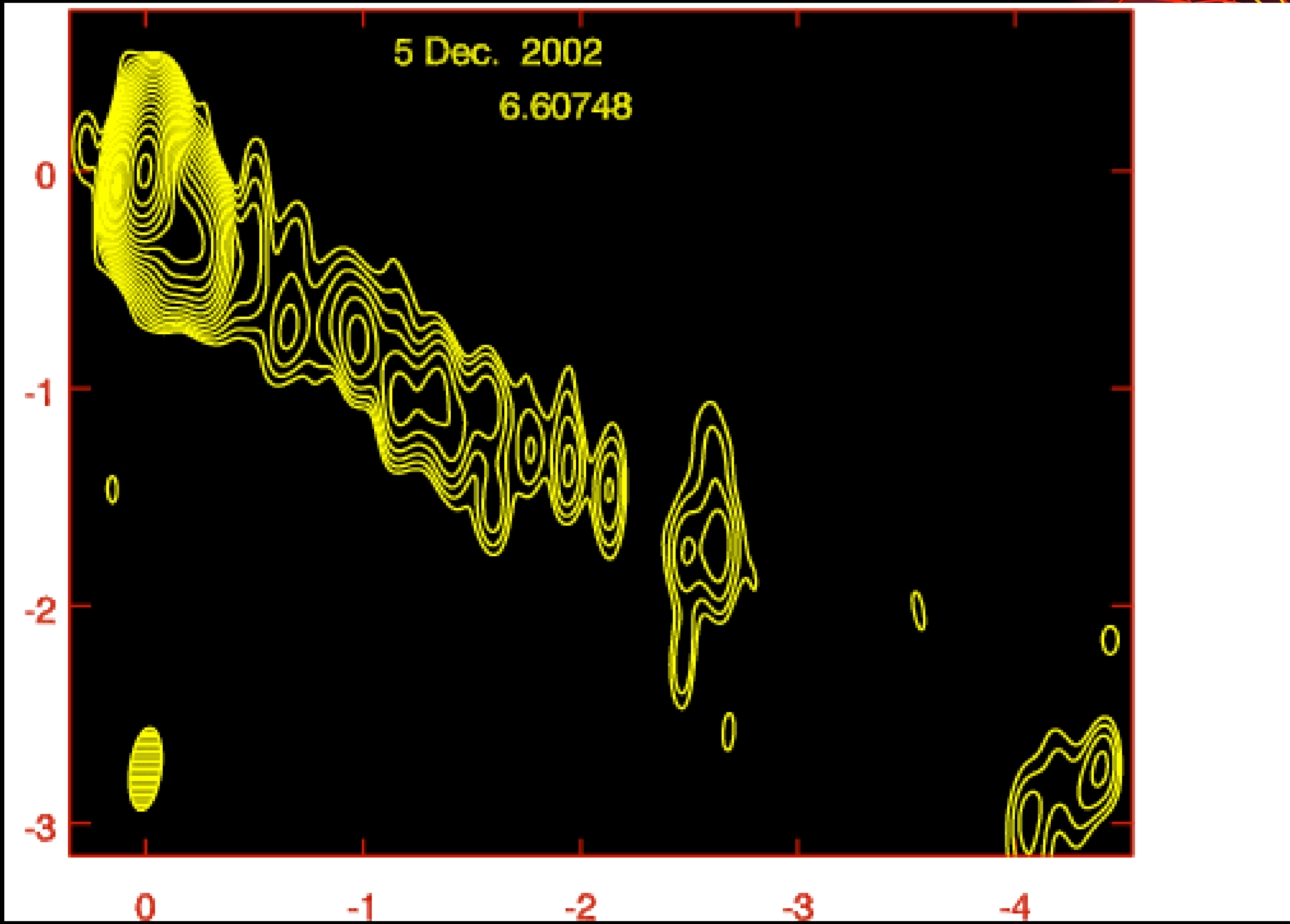
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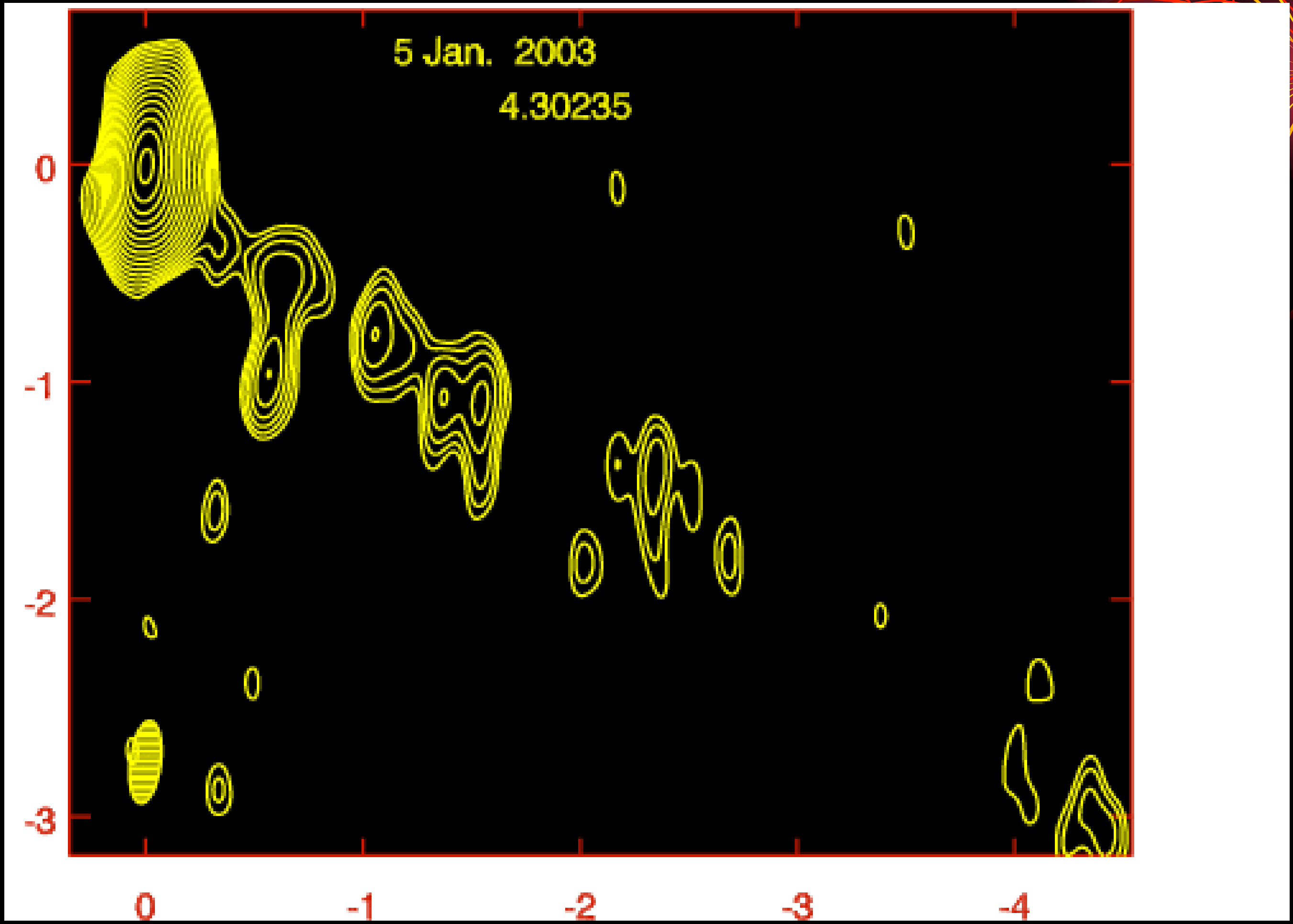
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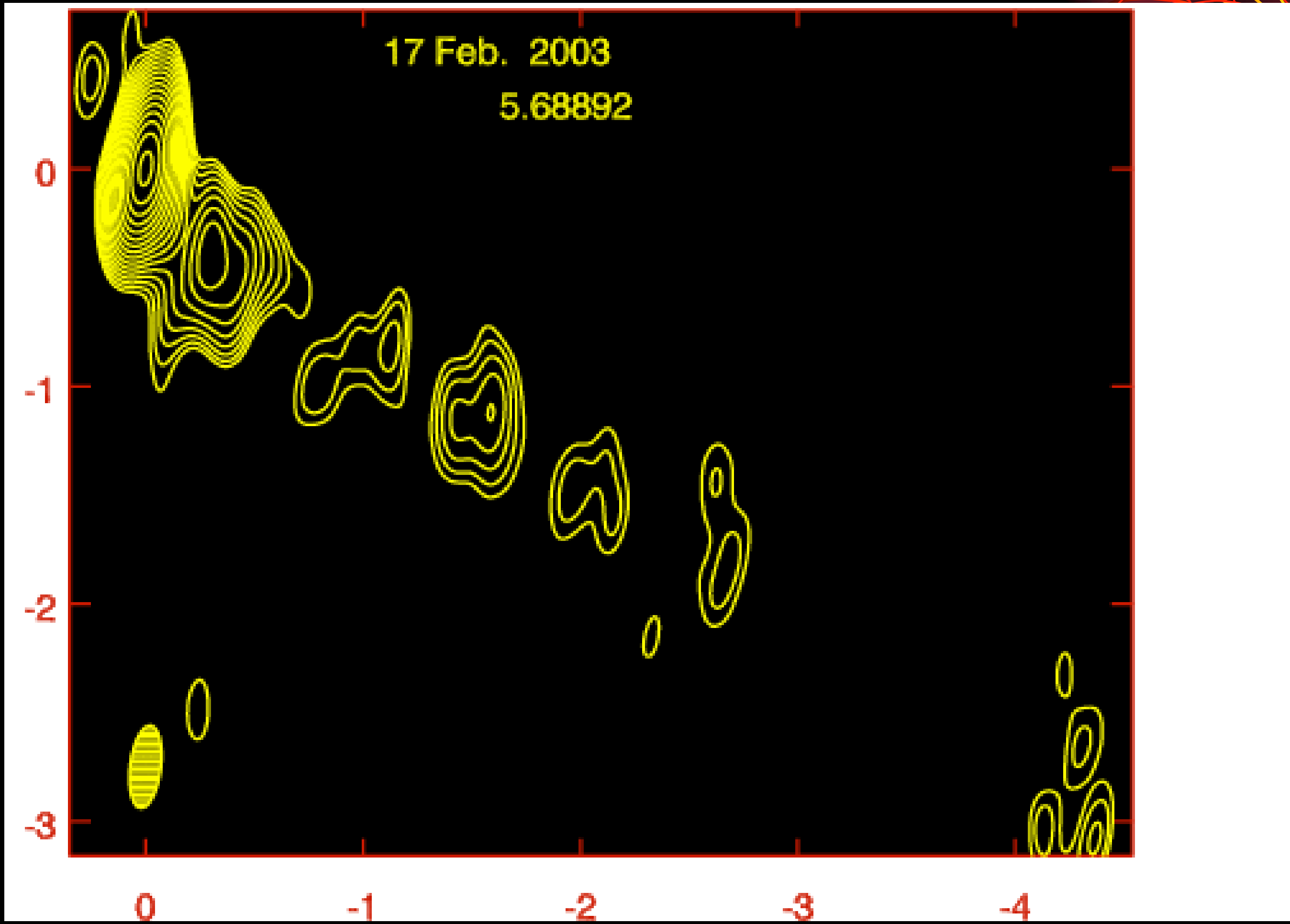
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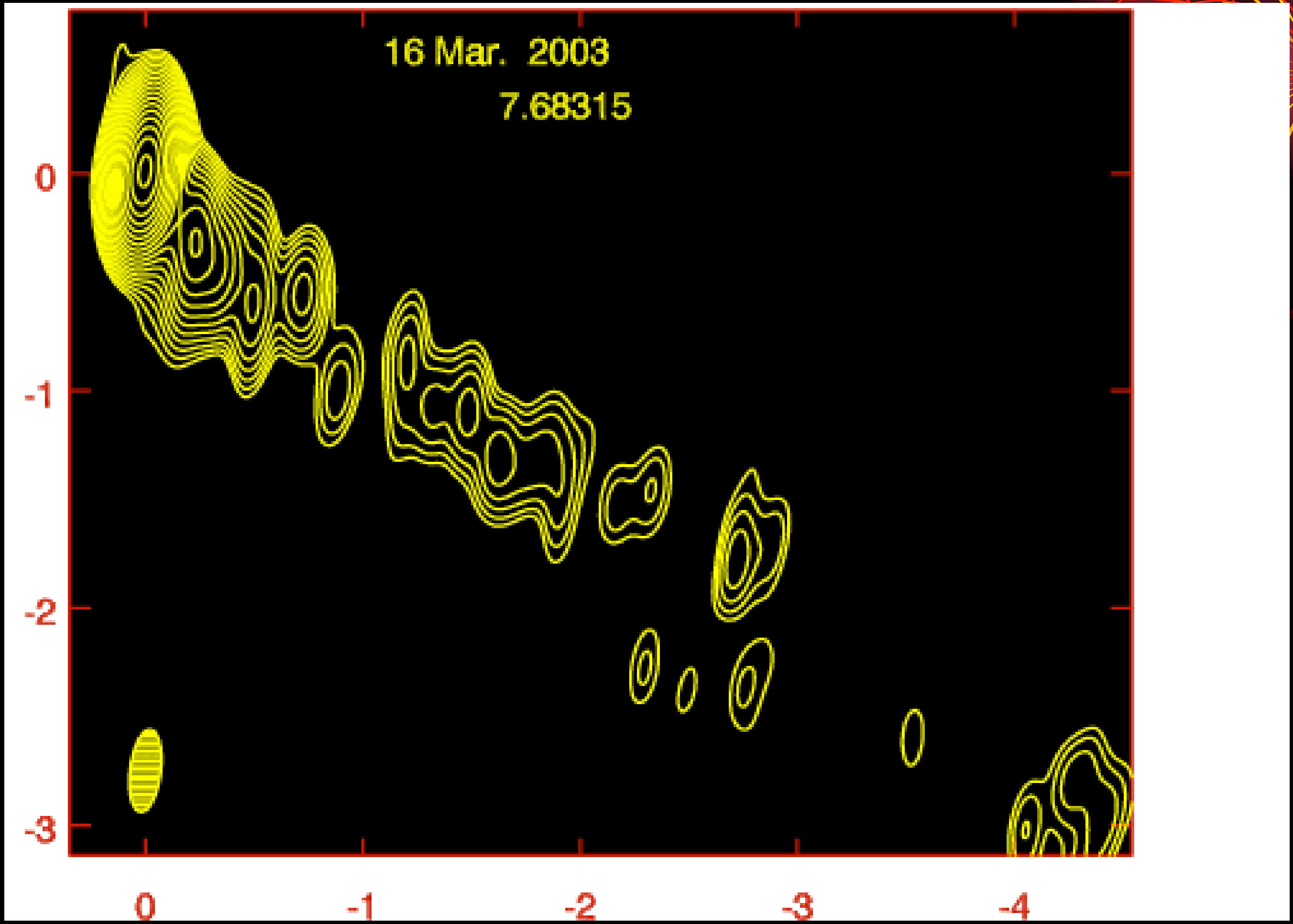
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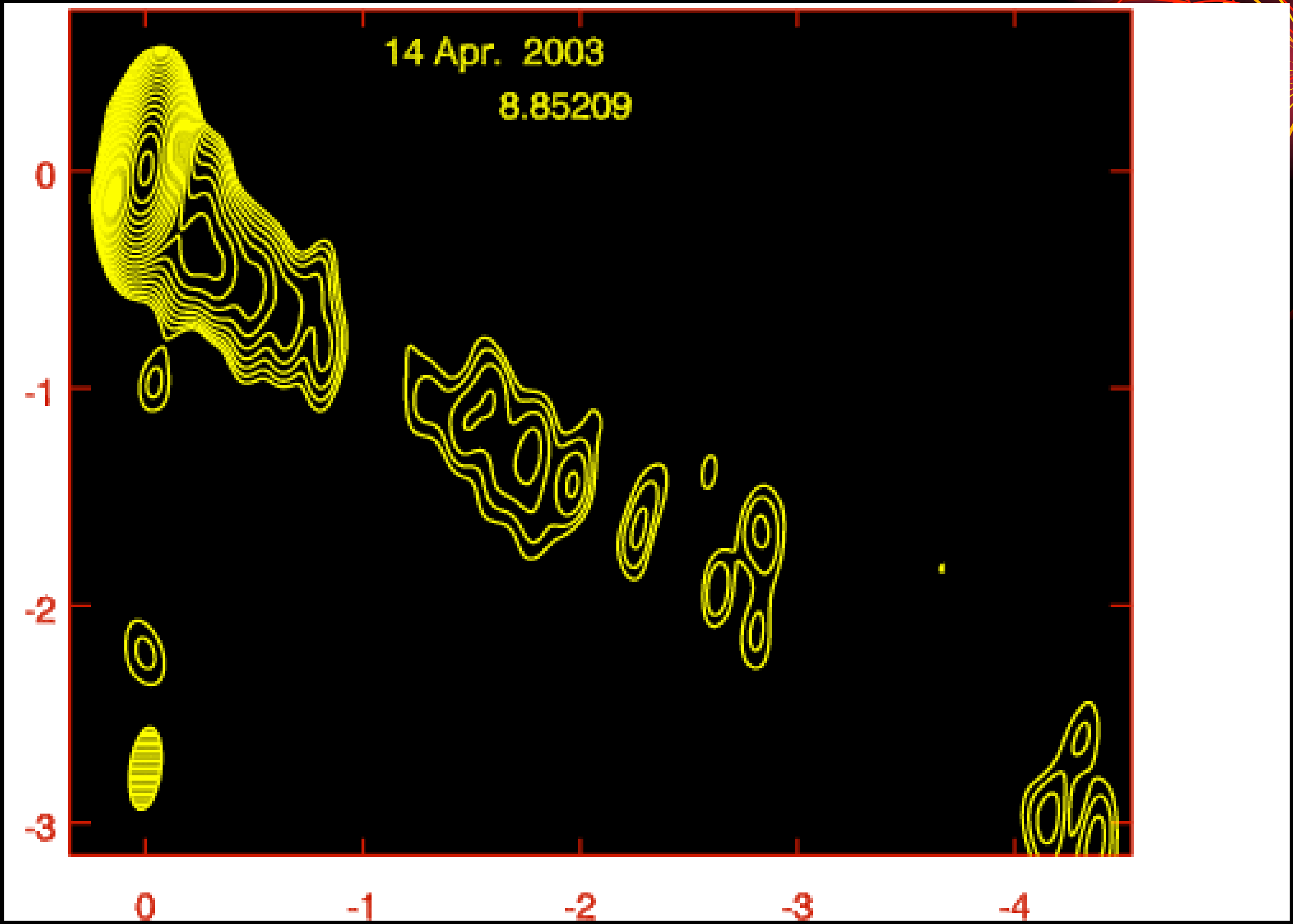
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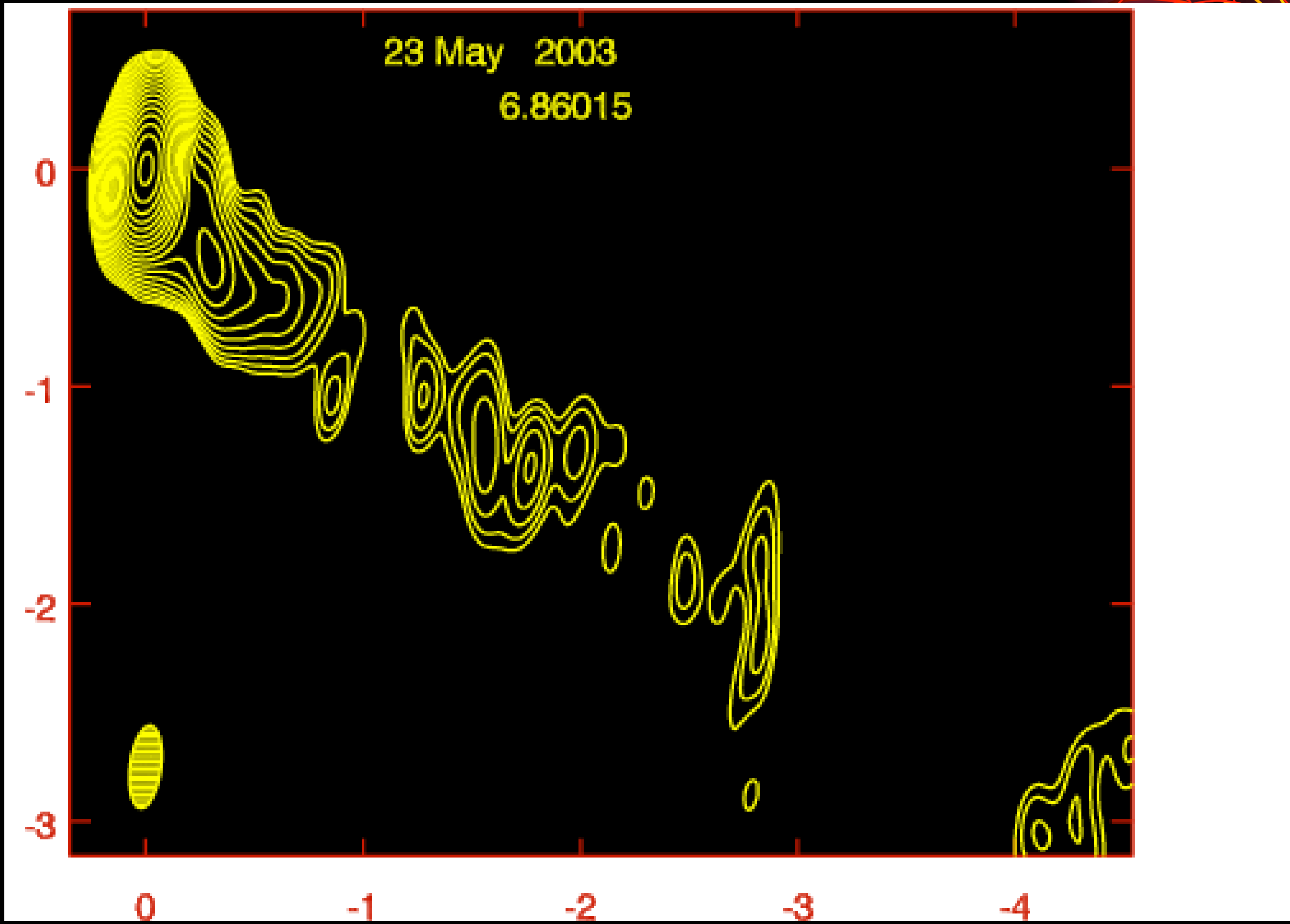
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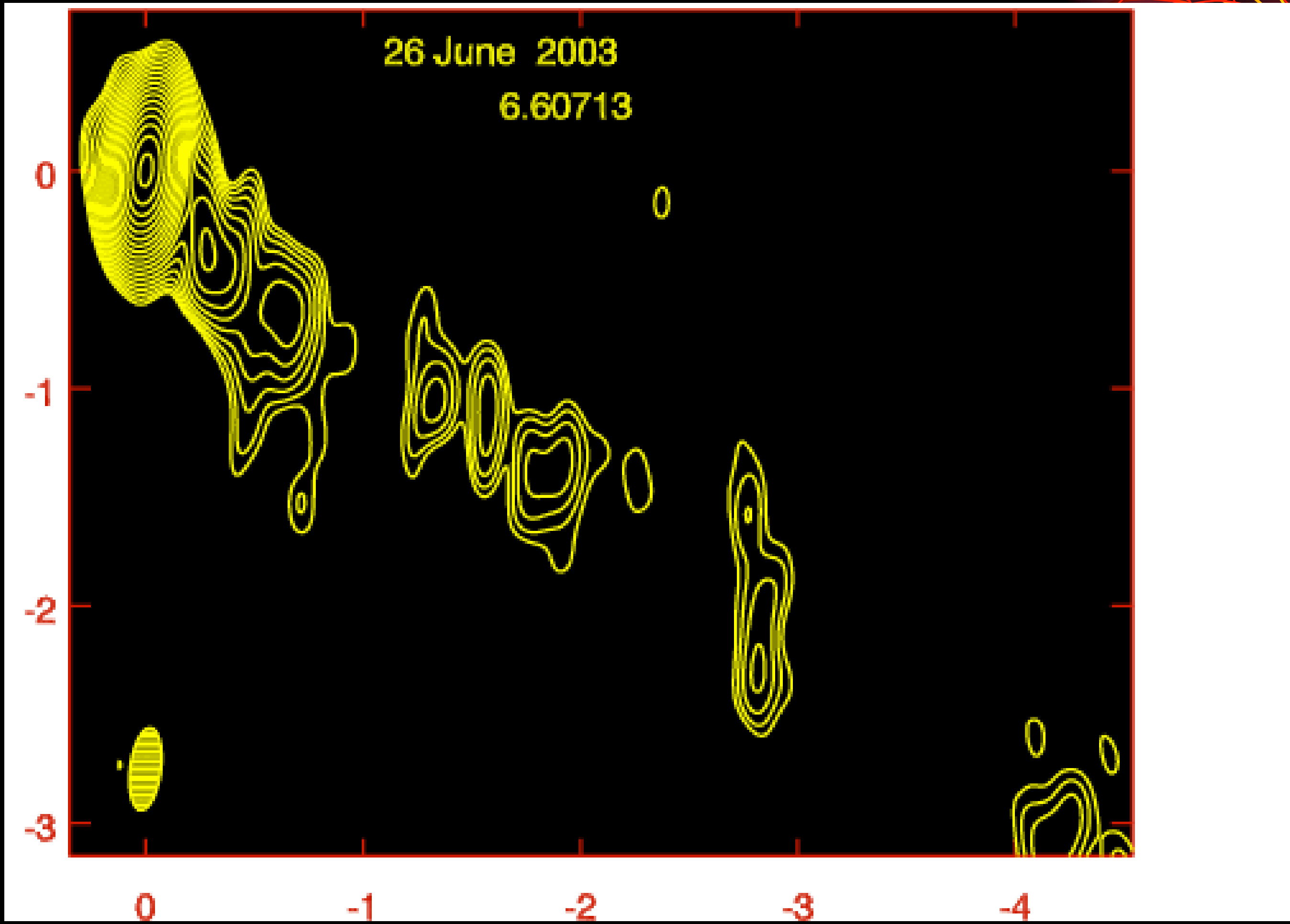
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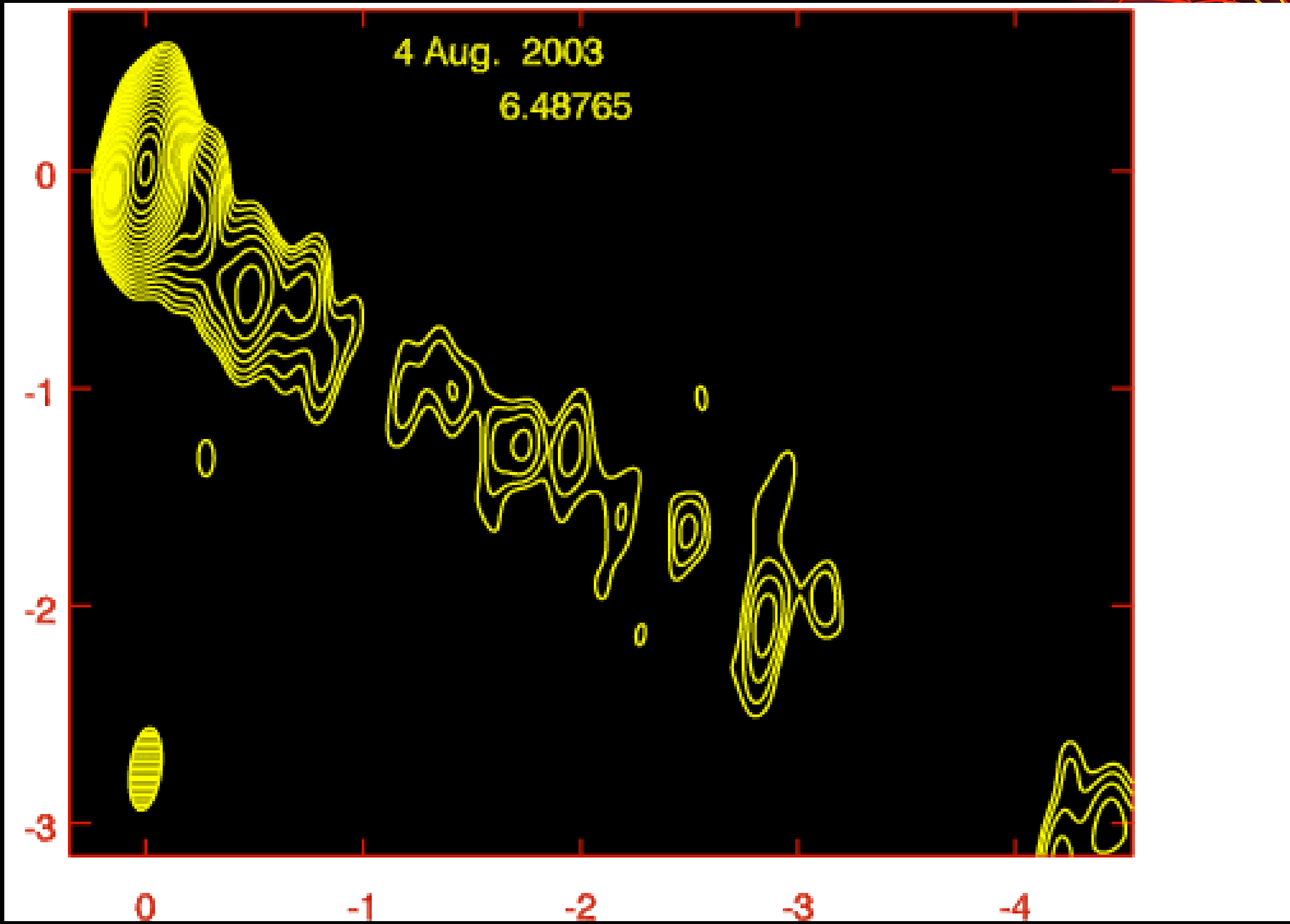

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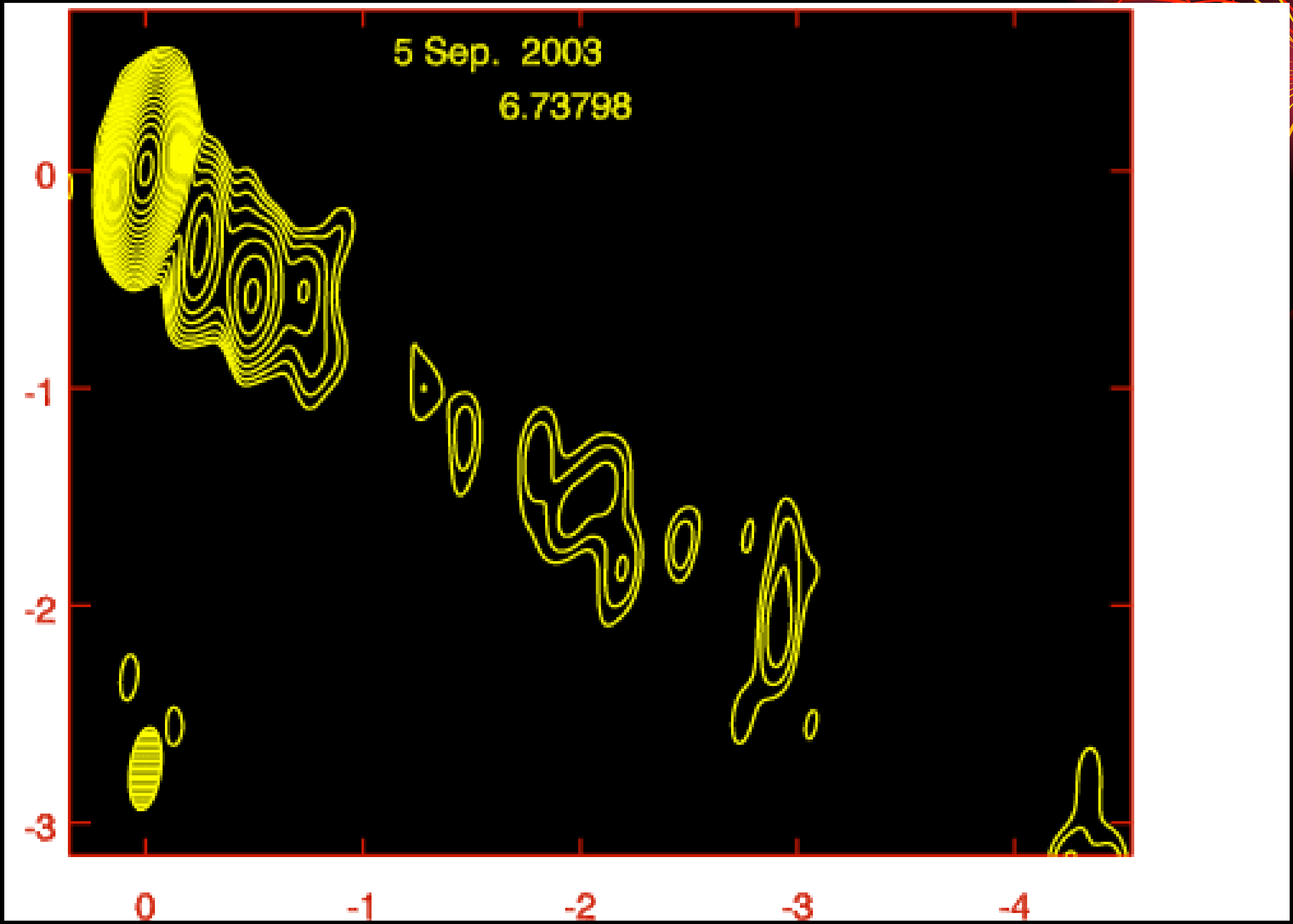
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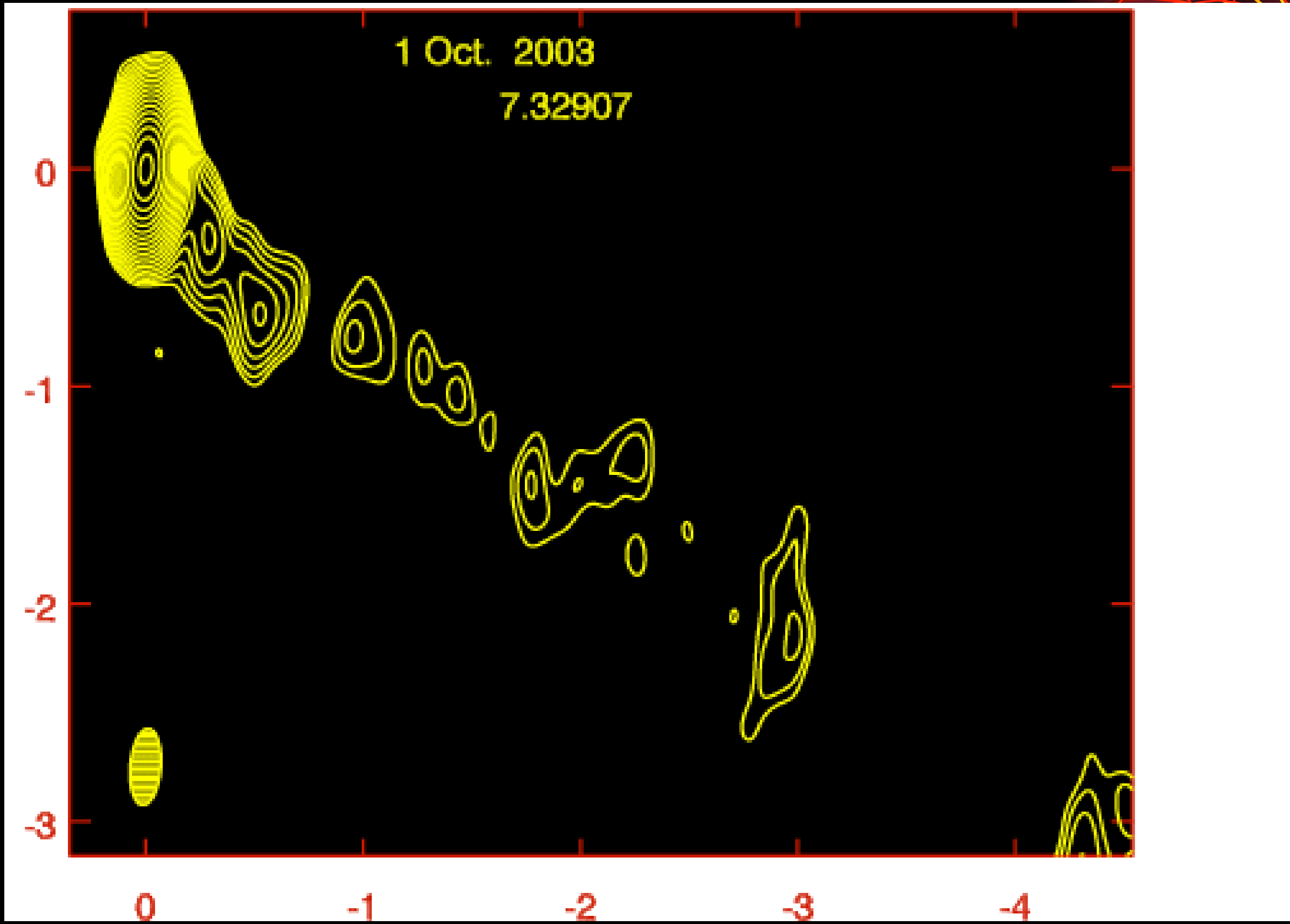
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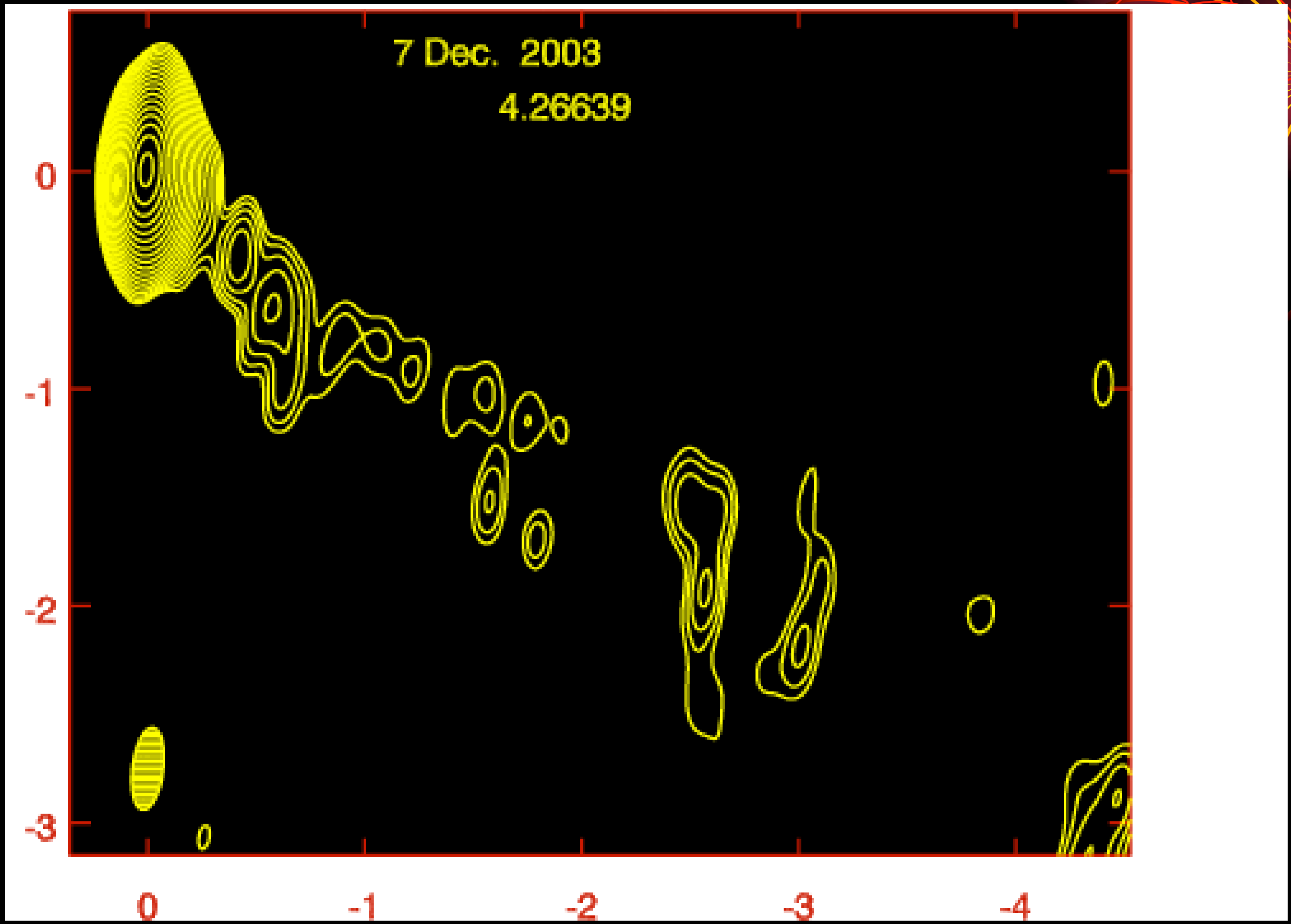
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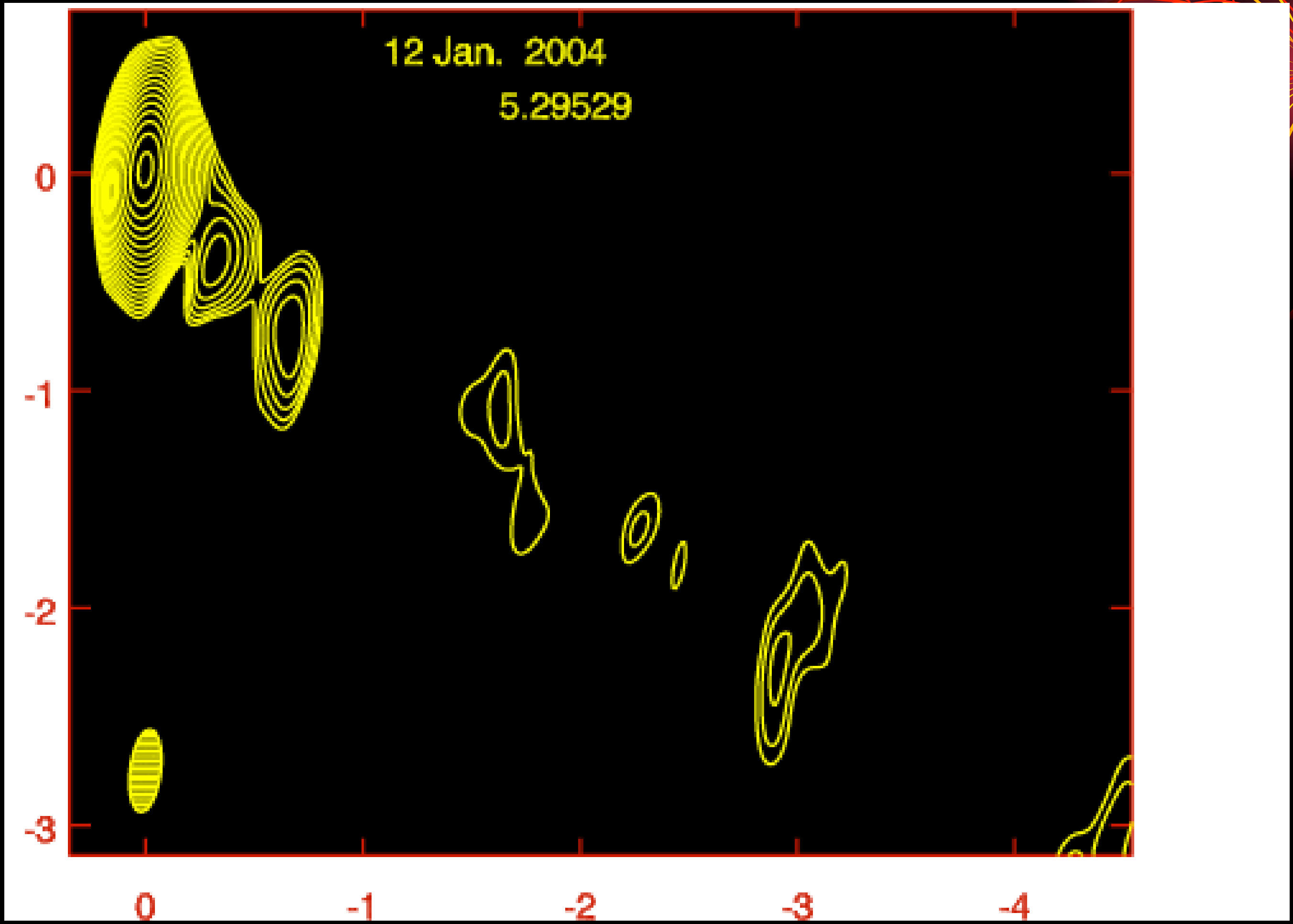
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-2
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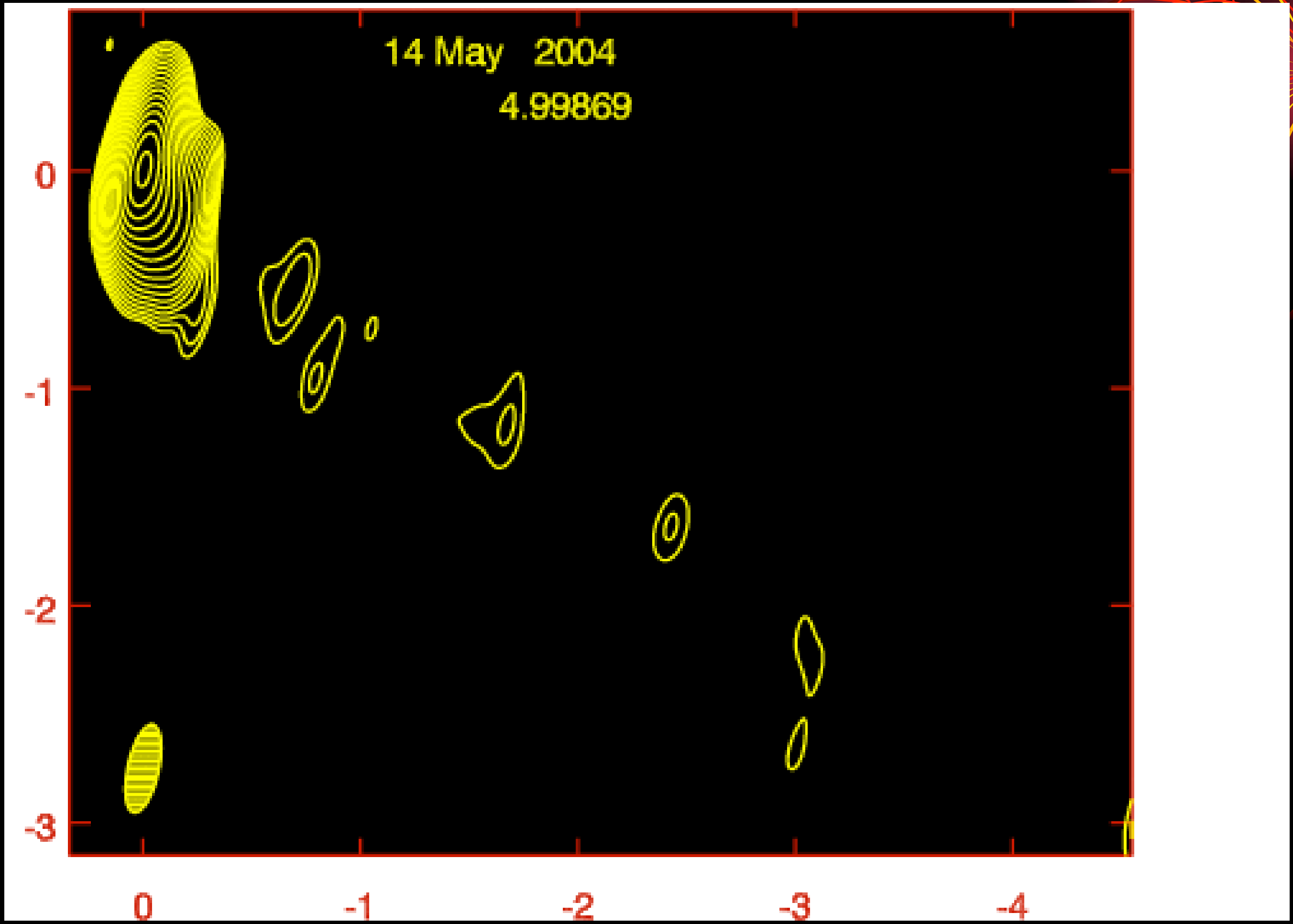
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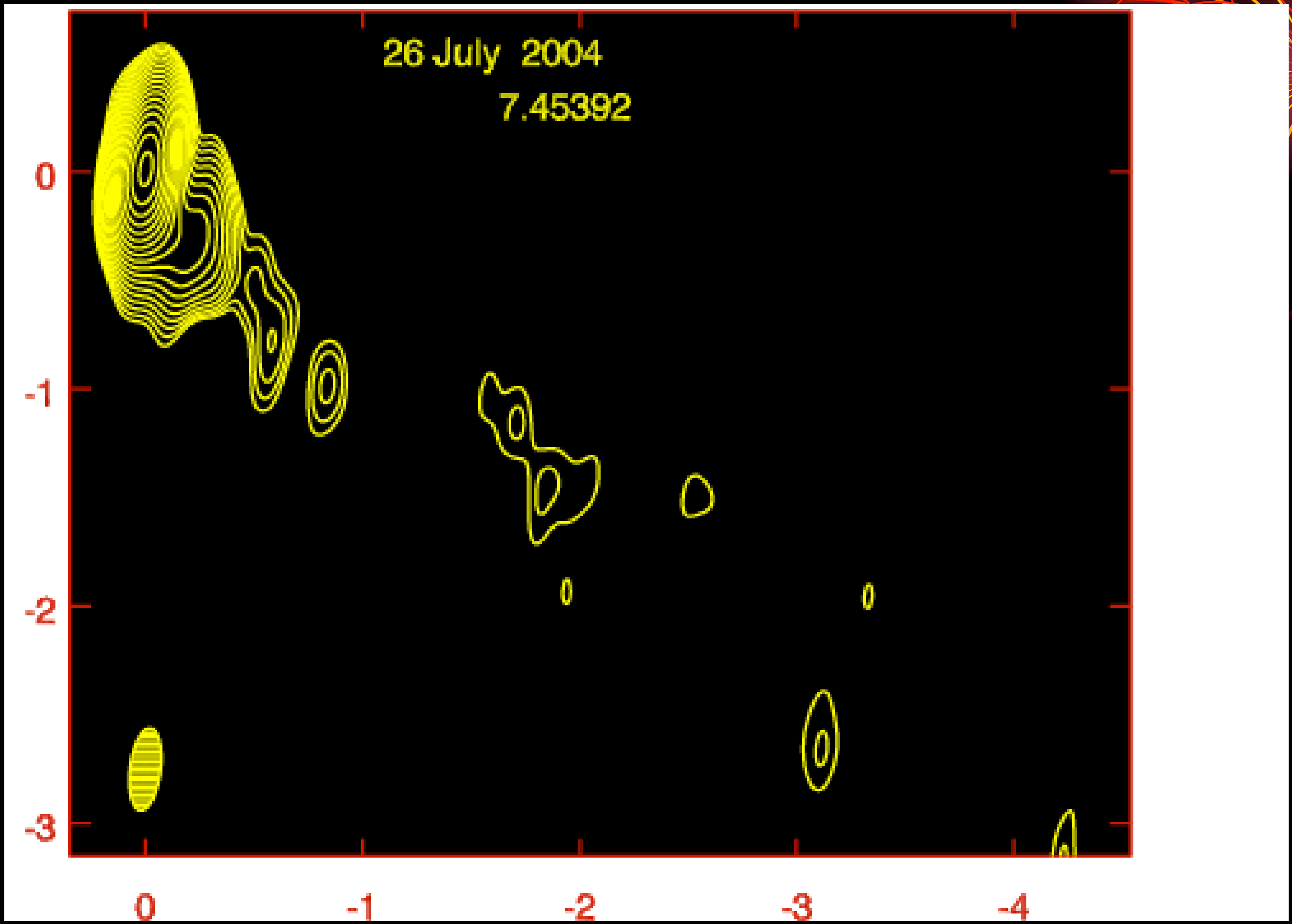
26 July 2004
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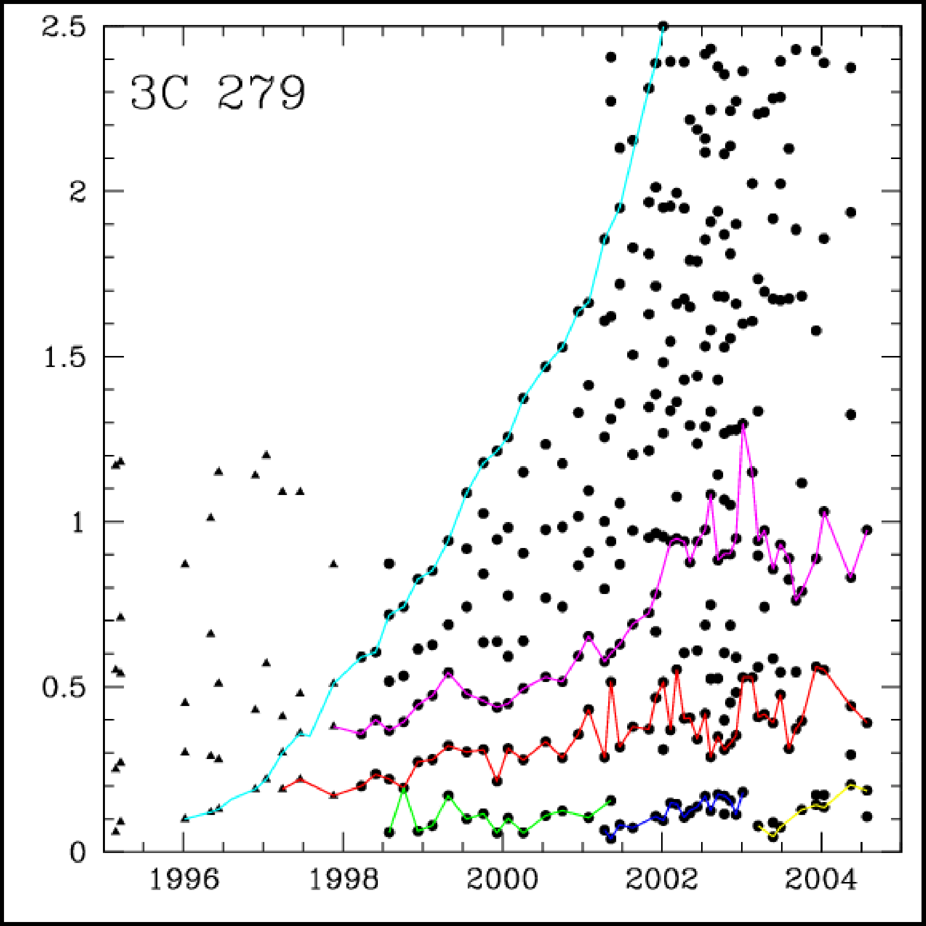
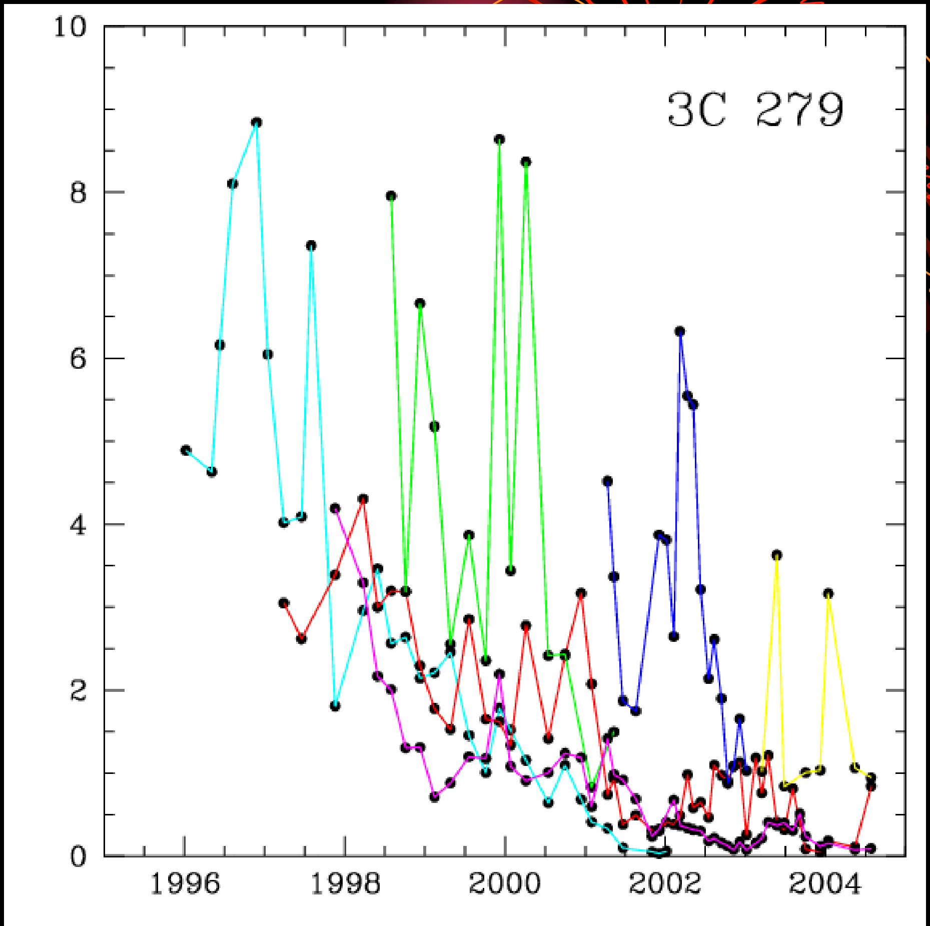
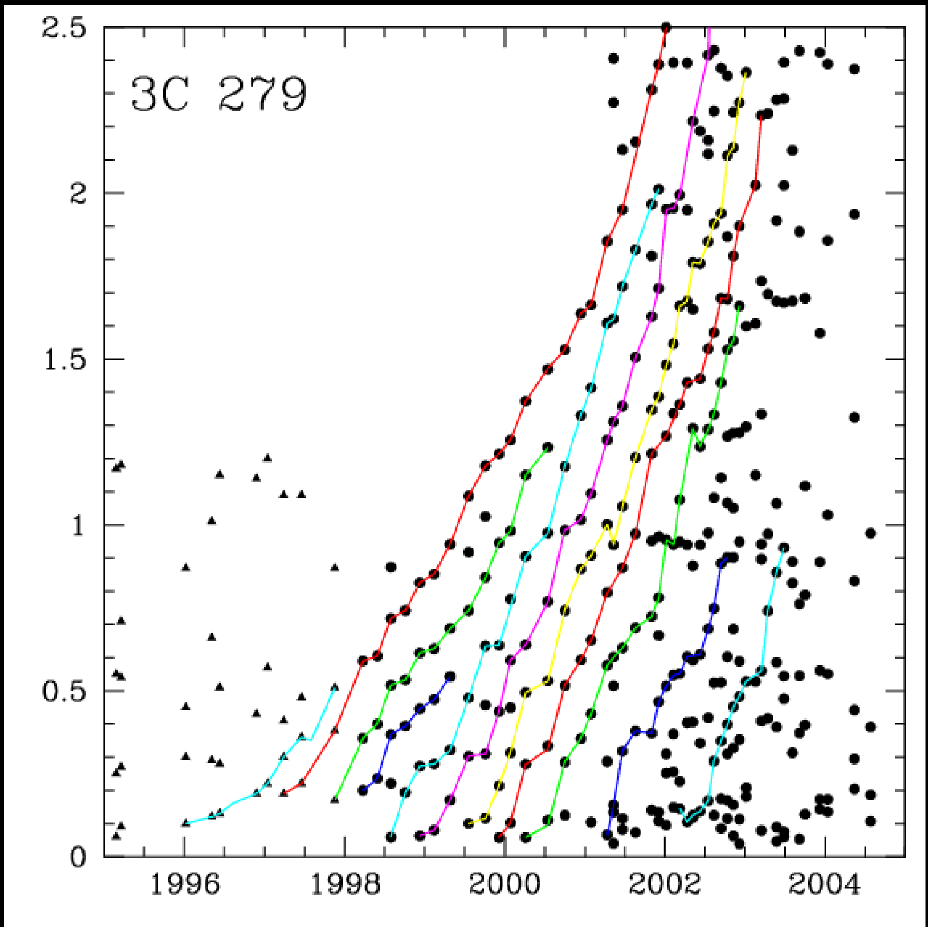


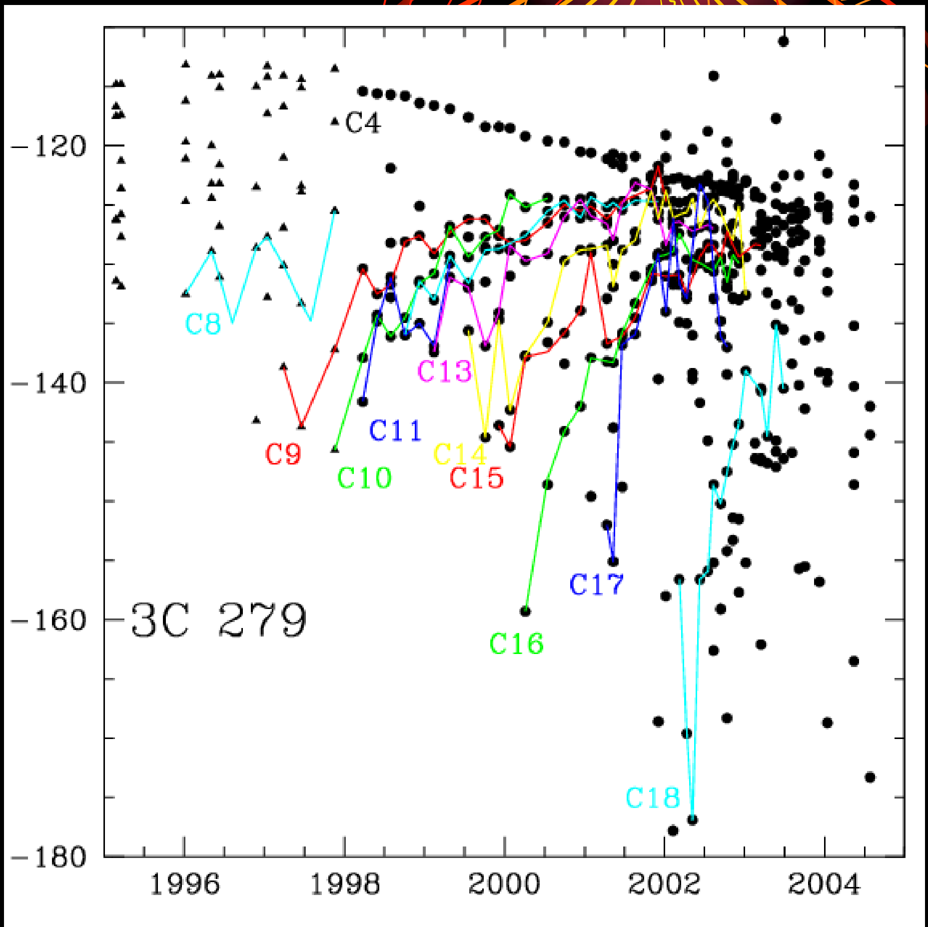


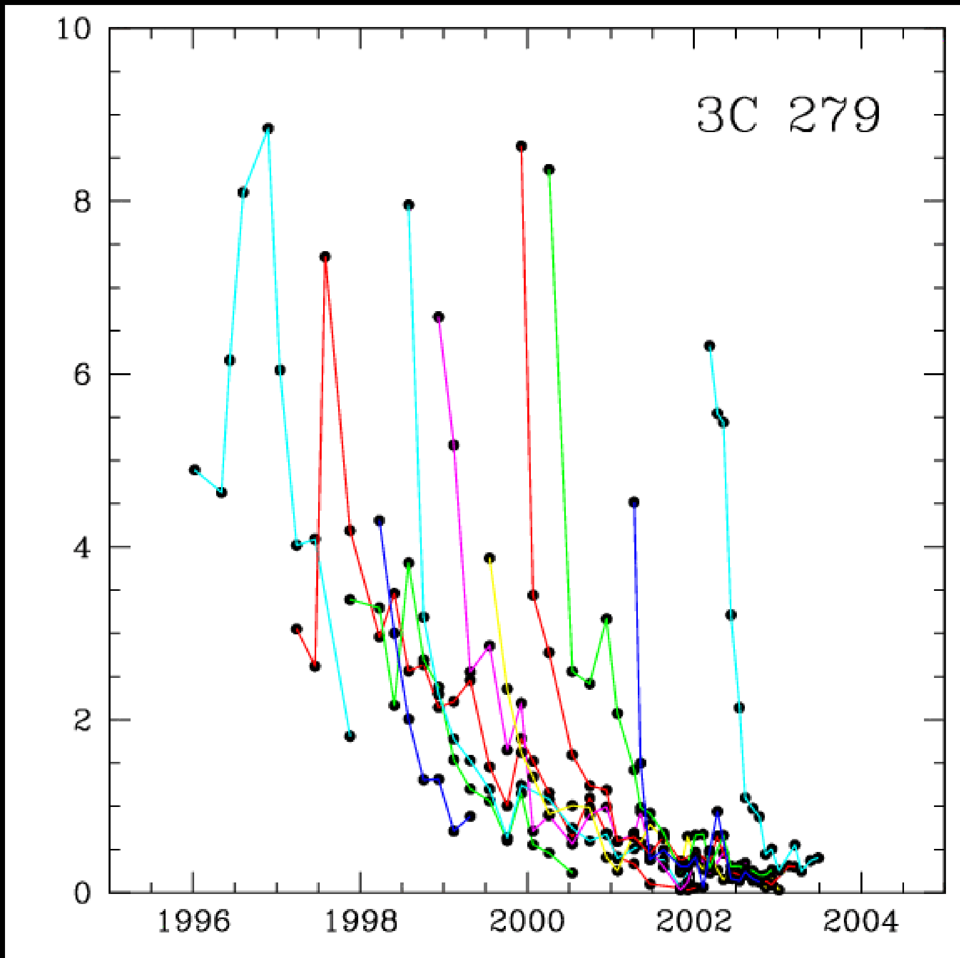
Ω_M=0.3 Ω_Λ=0.7
H_0=70 km $s^{-1}Mpc^{-1}$

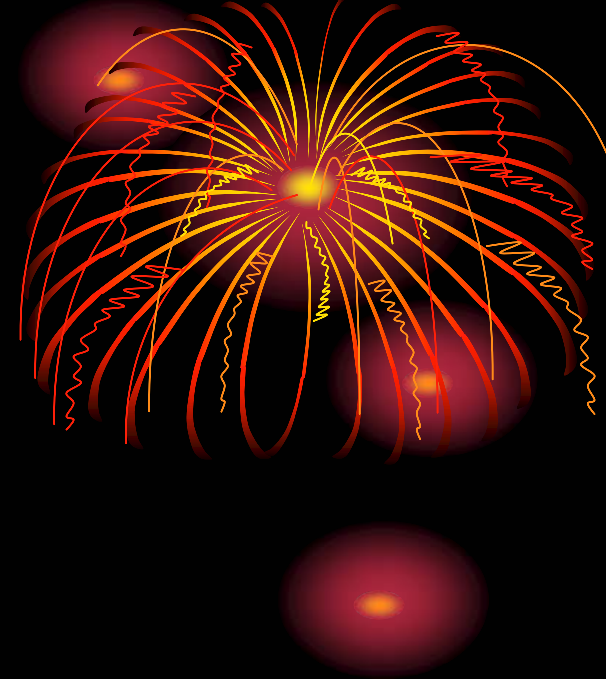
Apparent Speed
C8: β_{app}= 5.5c → 13c
t1: β_{app}= (1.13±0.12)c
t2: β_{app}= (3.65±0.14)c
Agudo et al. 2001

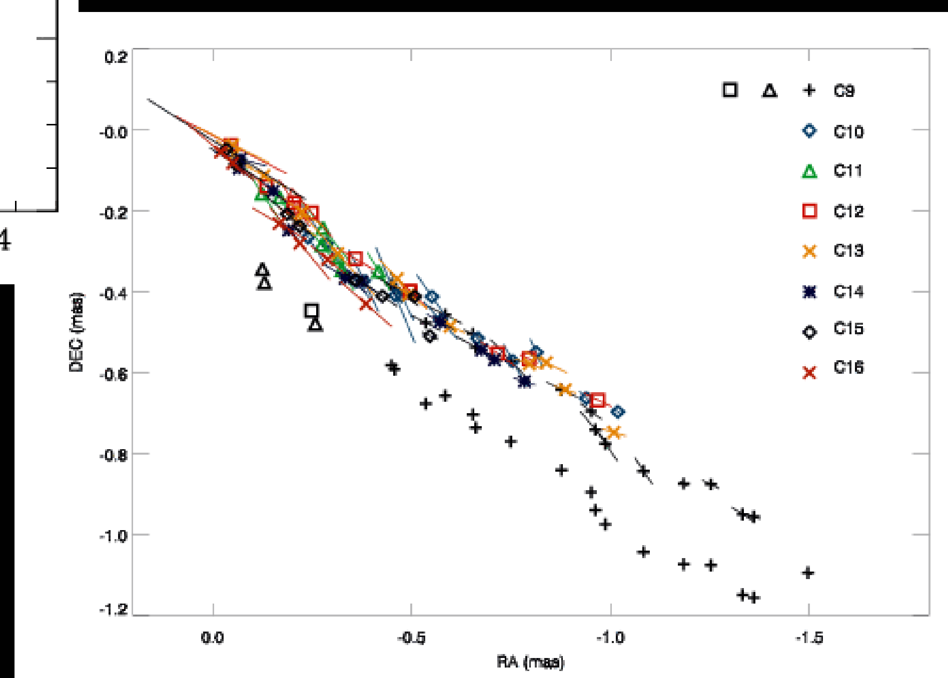
Apparent Speed
C9: β_{app}= (0.35±0.50)c
C10: β_{app}= (2.1±0.6)c
C11 β_{app}= (3.8±0.8)
Unwin et al. 1979:
β_{app}= (2.2±0.4)c

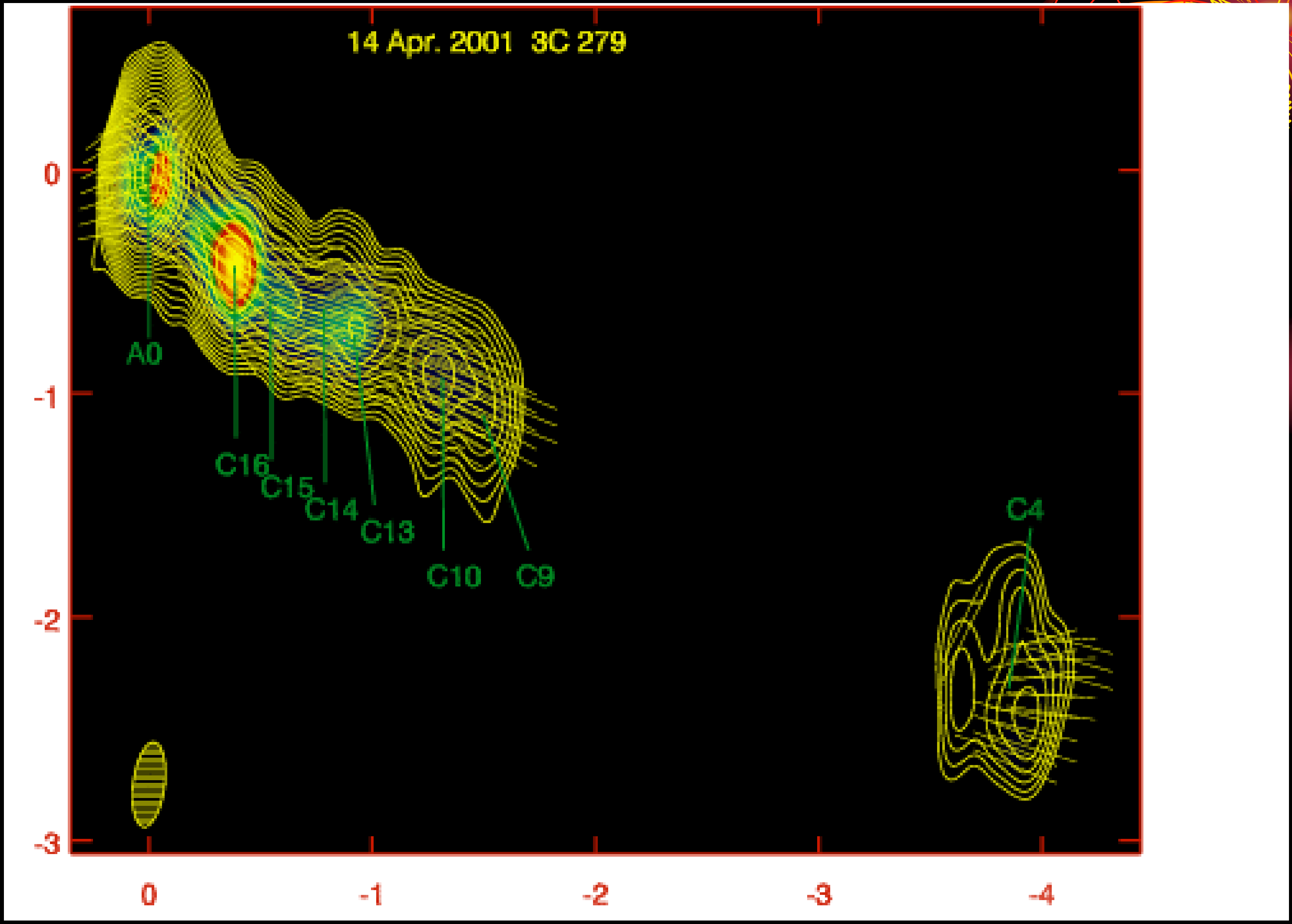

3C 279
2.5
2
1.5
1
0.5
0
1996
1998
2000
2002
2004


3C 279
−120
−140
−160
−180
1996
1998
2000
2002
2004
C4
C8
C9
C10
C11
C13
C14
C15
C16
C17
C18


3C 279
0
2
4
6
8
10
1996
1998
2000
2002
2004




C9
C10
C11
C12
C13
C14
C15
C16
DEC (mas)
RA (mas)
0.2
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
0.0
-0.5
-1.0
-1.5


14 Apr. 2001 3C 279
A0
C16
C15
C14
C13
C10
C9
C4
0
-1
-2
-3
0
-1
-2
-3
-4

Apparent Speed

C8: $\beta_{app}=(5.9\pm0.4)c$
$T_0=1995.74\pm0.03$

Wehrle et al. 2001

Jorstad et al. 2001

C9: $\beta_{app}=(12.8\pm0.3)c$
$T_0=1996.87\pm0.22$

C10: $\beta_{app}=(11.1\pm0.6)c$
$T_0=1997.20\pm0.23$

C11: $\beta_{app}=(10.1\pm1.9)c$
$T_0=1997.58\pm0.11$

C12: $\beta_{app}=(14.8\pm1.2)c$
$T_0=1998.46\pm0.05$

C13: $\beta_{app}=(14.9\pm1.2)c$
$T_0=1998.92\pm0.03$

C14: $\beta_{app}=(18.2\pm1.0)c$
$T_0=1999.50\pm0.10$

C15: $\beta_{app}=(17.2\pm0.9)c$
$T_0=1999.84\pm0.09$

C16: $\beta_{app}=(15.7\pm1.0\ )c$
$T_0=2000.22\pm0.17$

C17: $\beta_{app}=(15.2\pm1.0)c$
$T_0=2001.00\pm0.11$

C18: $\beta_{app}=(17.4\pm1.7)c$
$T_0=2002.13\pm0.13$

Projected Position Angle

C8: $\Theta=(-131\pm2)^{o}$

C9: $\Theta=(-136\pm4)^{o}$

C10: $\Theta=(-137\pm5)^{o}$

C11: $\Theta=(-135\pm4)^{o}$

C12: $\Theta=(-131\pm3)^{o}$

C13: $\Theta=(-132\pm4)^{o}$

C14: $\Theta=(-138\pm4)^{o}$

C15: $\Theta=(-139\pm4)^{o}$

C16: $\Theta=(-143\pm5)^{o}$

C17: $\Theta=(-137\pm7)^{o}$

C18: $\Theta=(-153\pm9)^{o}$

$\Delta t_{var} = \delta t / Lg(S_{max}/S_{min})$

Burbidge, Jones, & O'Dell 1974

$\beta_{app} = \beta \sin\Phi / (1 - \beta \cos\Phi)$

$D = 1/[\Gamma(1 - \beta \cos\Phi)]$

$D = Rs / [c\, \Delta t_{var}(1+z)]$

$R = 3.1 Gpc$

$z = 0.538$

$s = 1.6a$

$a = FWHM$

Doppler Factor

C8: $D=48$

C9: $D=35$

C10: $D=22$

C11: $D=21$

C12: $D=20$

C13: $D=18$

C14: $D=18$

C15: $D=19$

C16: $D=21$

C17: $D=37$

C18: $D=42$

Lorentz Factor

C8: $\Gamma=24$

C9: $\Gamma=20$

C10: $\Gamma=14$

C11: $\Gamma=13$

C12: $\Gamma=15$

C13: $\Gamma=15$

C14: $\Gamma=15$

C15: $\Gamma=18$

C16: $\Gamma=19$

C17: $\Gamma=22$

C18: $\Gamma=25$

Viewing Angle $(^{o})$

C8: $\Phi=0.3$

C9: $\Phi=1.1$

C10: $\Phi=2.1$

C11: $\Phi=2.2$

C12: $\Phi=2.8$

C13: $\Phi=3.2$

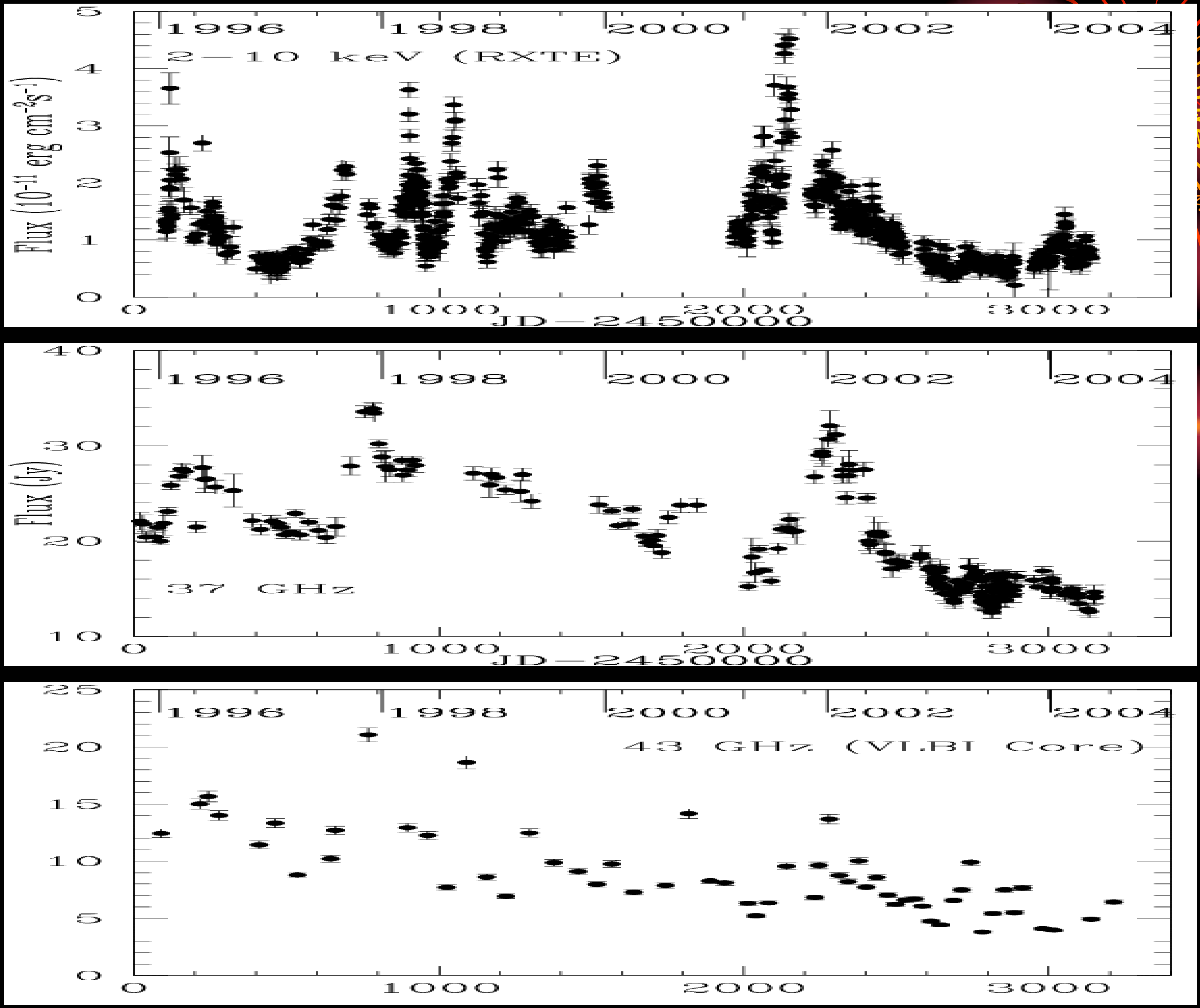
C14: $\Phi=3.2$

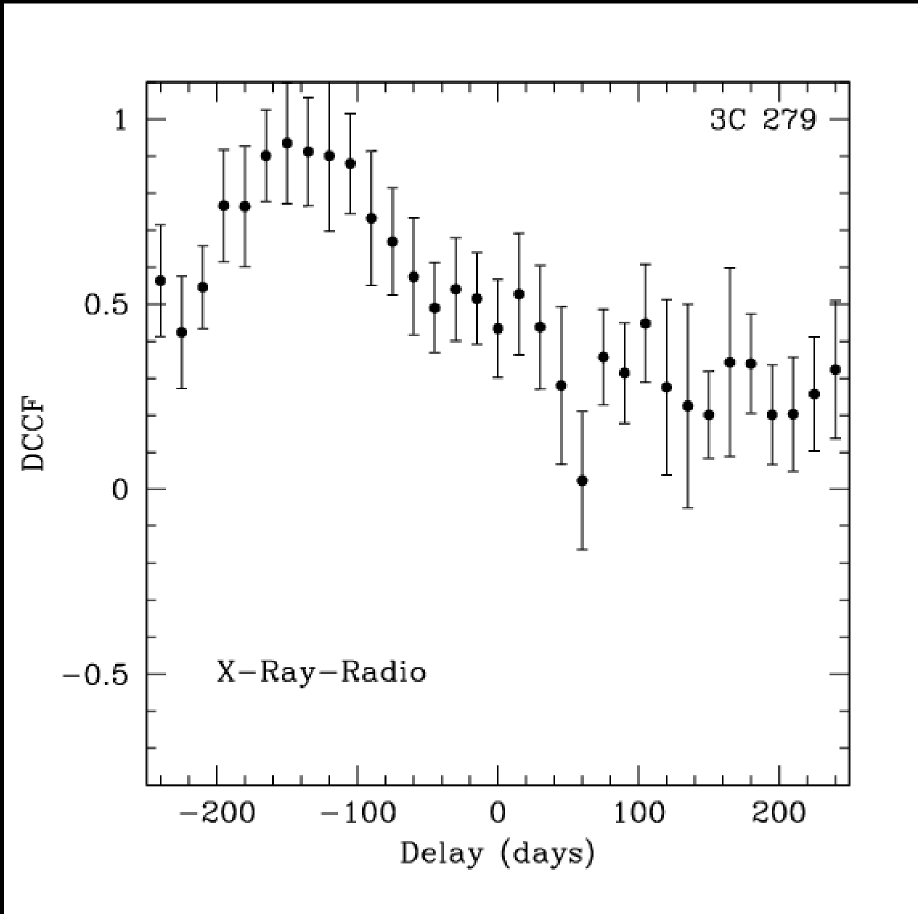
C15: $\Phi=3.1$

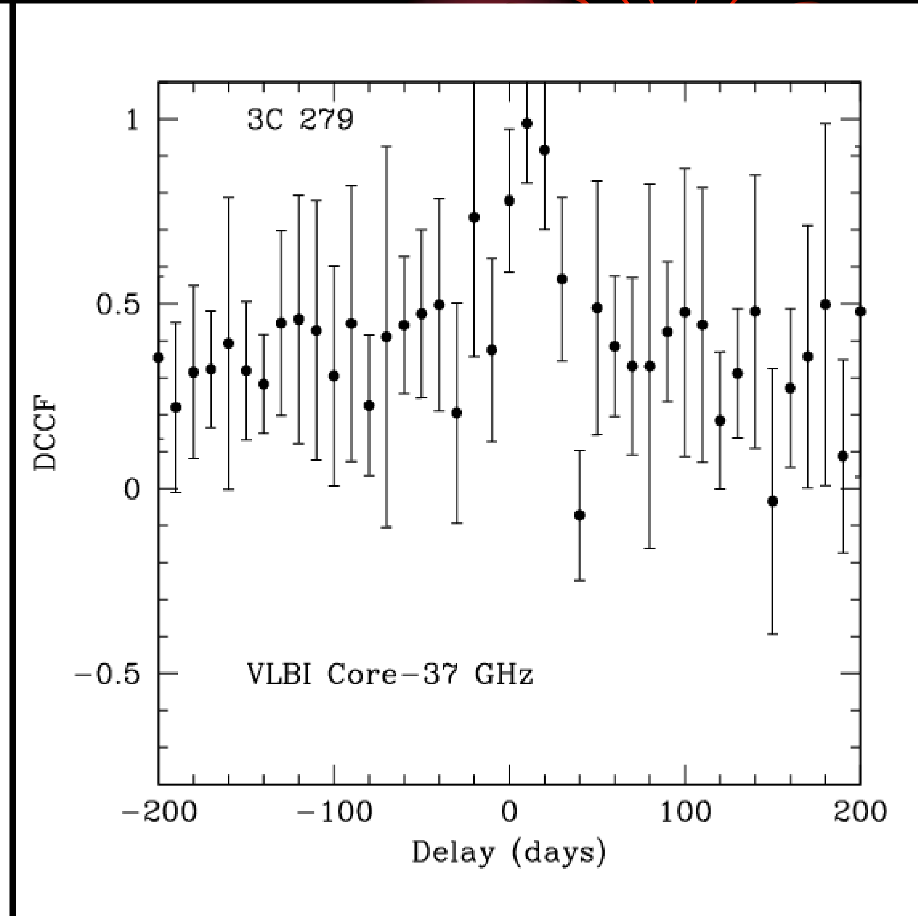
C16 $\Phi=2.6$

C17: $\Phi=1.1$

C18: $\Phi=1.0$


1996
1998
2000
2002
2004
2 – 10 keV (RXTE)
Flux (10^{-11} erg cm^{-2}s^{-1})
JD – 2450000
37 GHz
Flux (Jy)
43 GHz (VLBI Core)





Δt = (130±40) days $\rightarrow$Dist~40 pc deprojected, or ~0.016 mas projected
$Size_{core}$~0.03-0.05 mas $\rightarrow$ 5-10pc

Conclusions

1. We have detected an increase in the apparent speed inside of 2 mas from the VLBI core from 6c to 18c.
2. The apparent acceleration is accompanied by a change in the projected position angle of the jet ``nozzle" from -120º to -160º .
3. We explain these effects as the result of a change in the jet nozzle direction from 0.3º to 3.2º relative to the line of sight while the Lorentz factor of the jet flow experiences modest variations, Γ=20$\pm$5.
5. The total intensity light curve at 37 GHz varies simultaneously with the VLBI core light curve at 43~GHz. The X-ray variations lead the radio variations at 37~GHz by 130$\pm$40 days. This implies that the X-ray emission region is 0.016 mas upstream of the VLBI radio core observed at 43 GHz and may coincide with the "true" core of the jet.
6. Highly relativistic perturbations create stationary features behind the main disturbance with average lifetime ~0.5 yr.