Summary of efforts to suppress resonant field error (Xerr)

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Goal: Design coils that do not produce islands and stochastic regions

- Coil design codes (NESCOIL, COILOPT, CUROPT etc.):

  1. Try to create B field parallel to a VMEC plasma surface (edge or inside)

  2. Resonant features (Xerr) of the normal component of B (Berr) may create islands

Idea: Calculate and suppress Xerr (edge or inside) to reduce islands due to coils

1. Minimize Xerr in NESCOIL svd-scan (along with Jmax, complexity, etc)

2. Target Xerr in GA or COILOPT or CUROPT for discrete coils

3. Simultaneously target Berr on outermost surface and Xerr on resonant surface

Summary of Nescoil-Xerr efforts completed so far

C10 Xerr targeting results (last year) (Talks valanju 1/19, 1/26, 2/4, and 3/4/99):

- Xerr-Nescoil-Svd was benchmarked. It takes ~same run-time as Berr target
- Targeting Xerr in NESCOIL reduced it by factors of 30 (Berr up by 20%)
- Dominant modes in Xerr were (7,1) and (6,1)
- Lower Xerr correlated with slightly better reconstructability. Xerr smaller by 3 and reconstruction “better” for mod2050.100.10 vs sad18ef.16/18 (same <M> VMEC)
- May be because Xerr was targeted only on plasma surface, not on resonant surface.
- Hence no PIES runs were made with Xerr-targeted coils. Effort was put on hold.
- Xerr-targeted coils got slightly more complex, but not a whole lot
- <M> VMEC not monotonic with number of coils cut from surface current. (Puzzle)

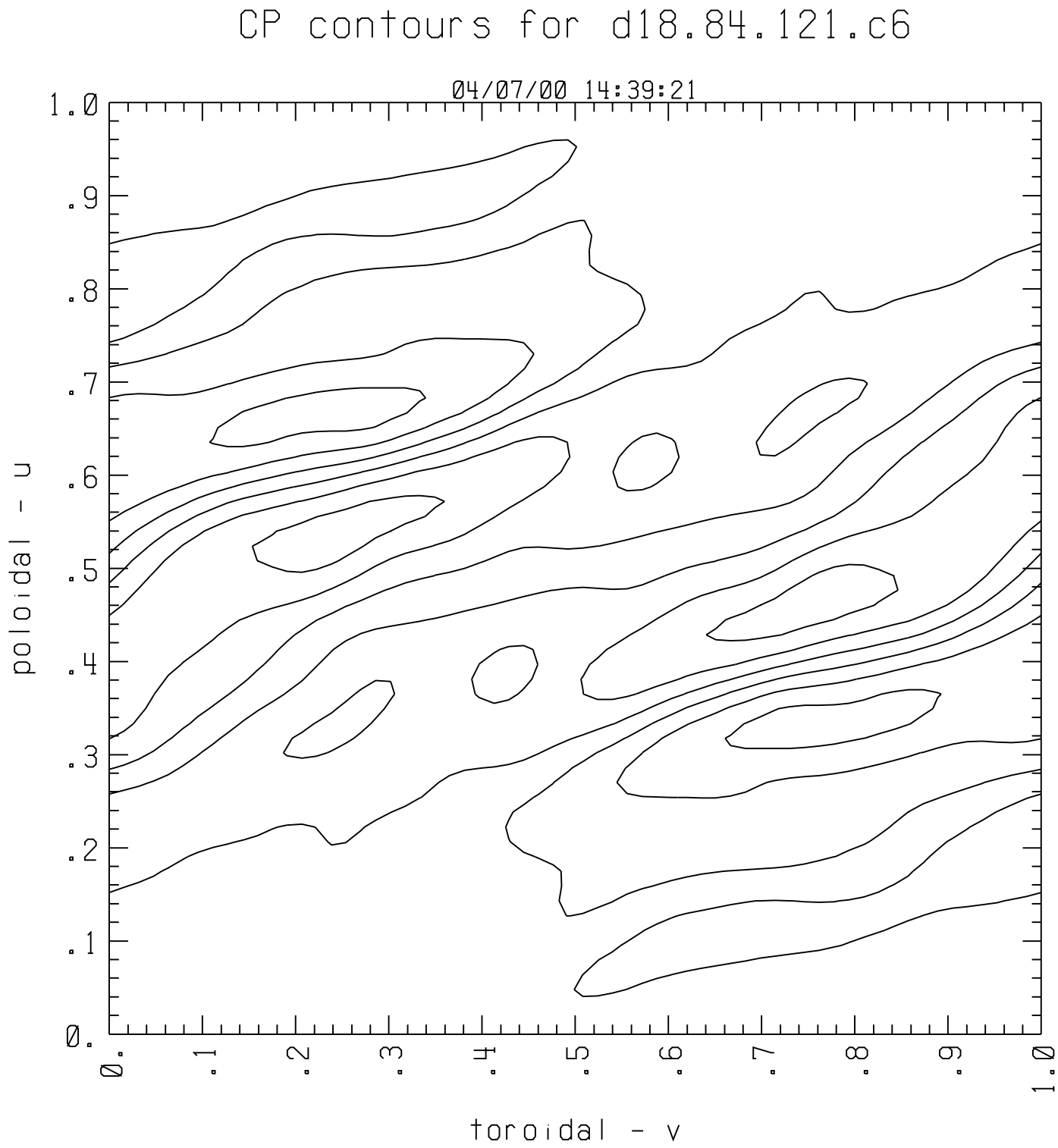
Summary of C82 Nescoil Xerr targeting results so far (recent work):

- Xerr does not go down as much as for C10 (only by 7 vs 30)
- Berr goes up more than for for c10 (by 80% rather than 20%)
- Minimum Jmax in SVD scan goes up by more than factor of 2 (c10 scan in progress)
- Complexity increases more than in c10 (visual comparisons of surface current plots)

VMEC reconstruction c82 m,nf=8,8. Case 82.121: Xerr, Case 84: Berr Targeted

#, Target	<Berr>	<Xerr>	Jmax	**Complexity**	**Max D cm**	**Ave D cm**
84: Berr	0.6003	0.1451	0.8316	3.119	1.64	0.32
82: Xerr	1.087	0.0201	1.632	4.046	3.46	0.31
Ratio > 1	1.811	7.219	1.962	1.297	2.11	0.97

VMEC reconstruction plots (with Nescoil surface current) (1+8 for each case):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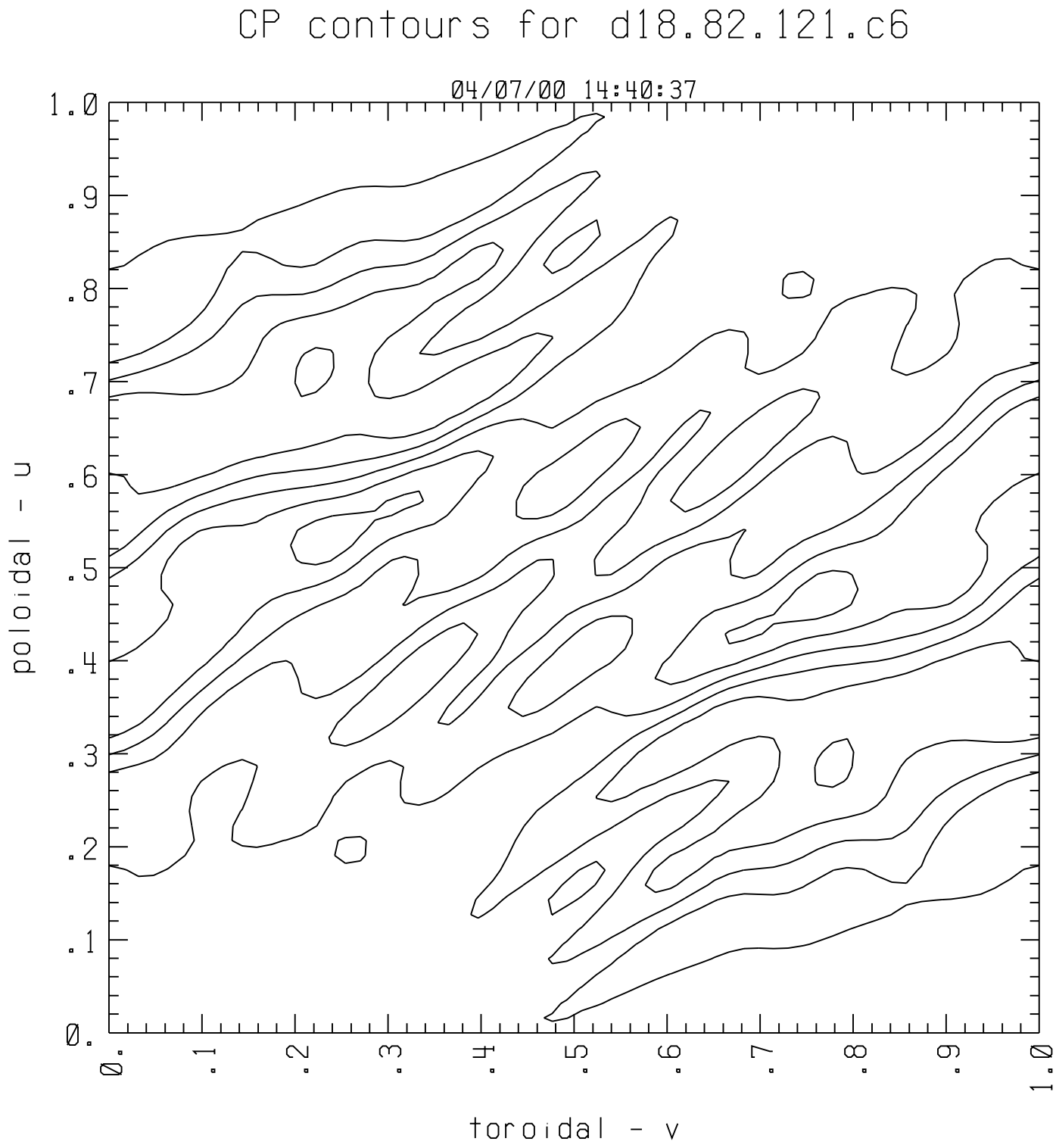
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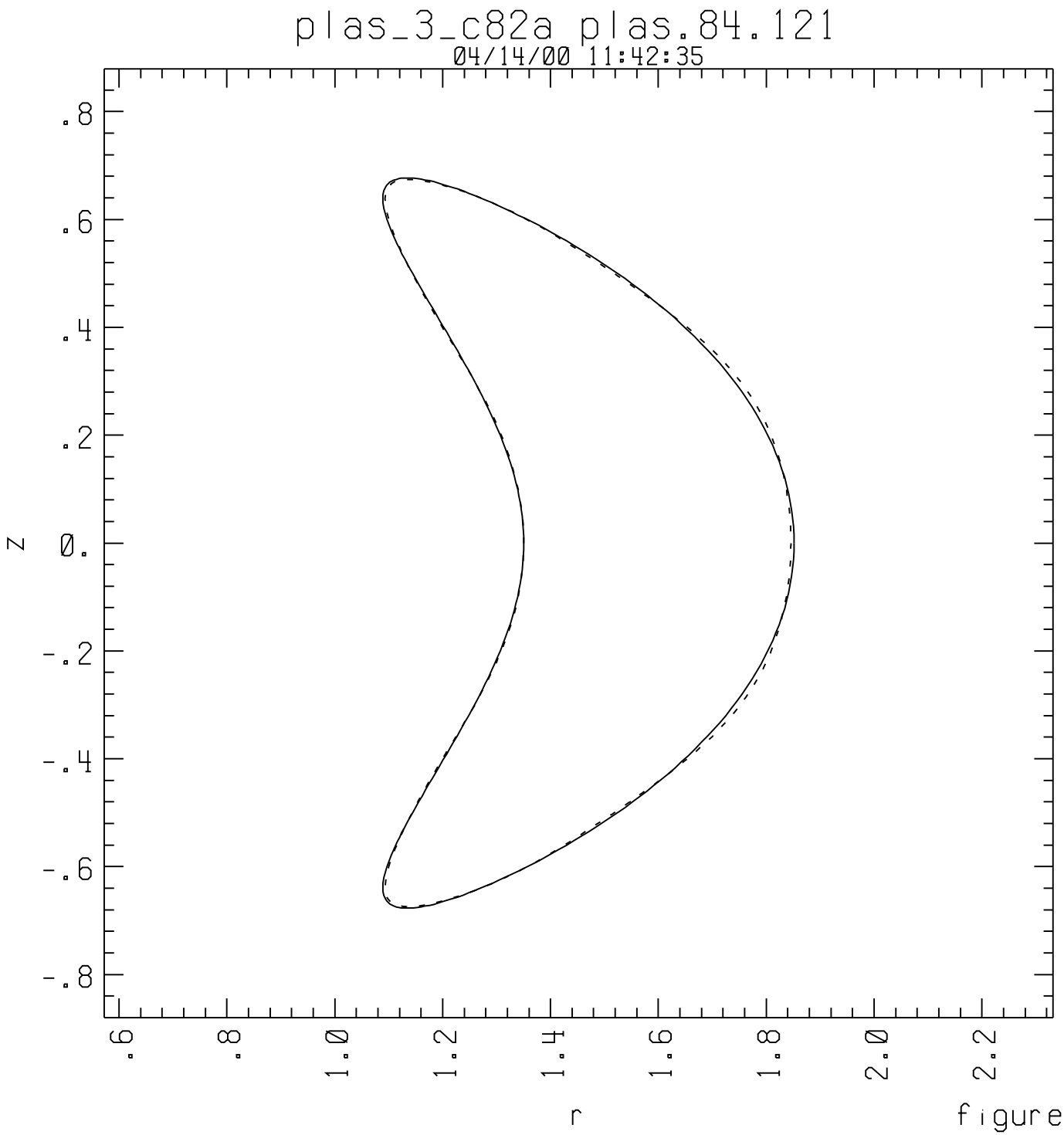
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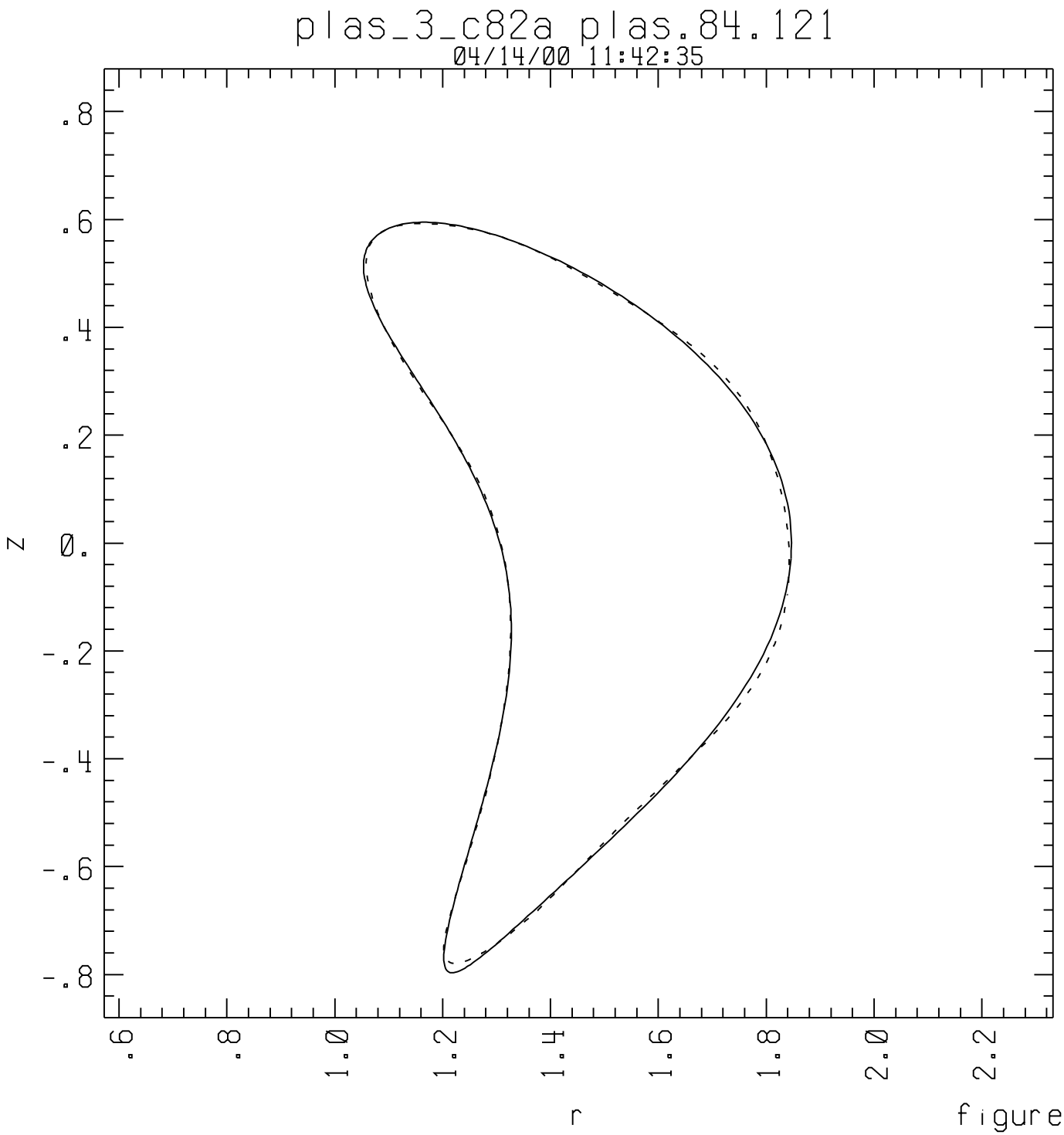
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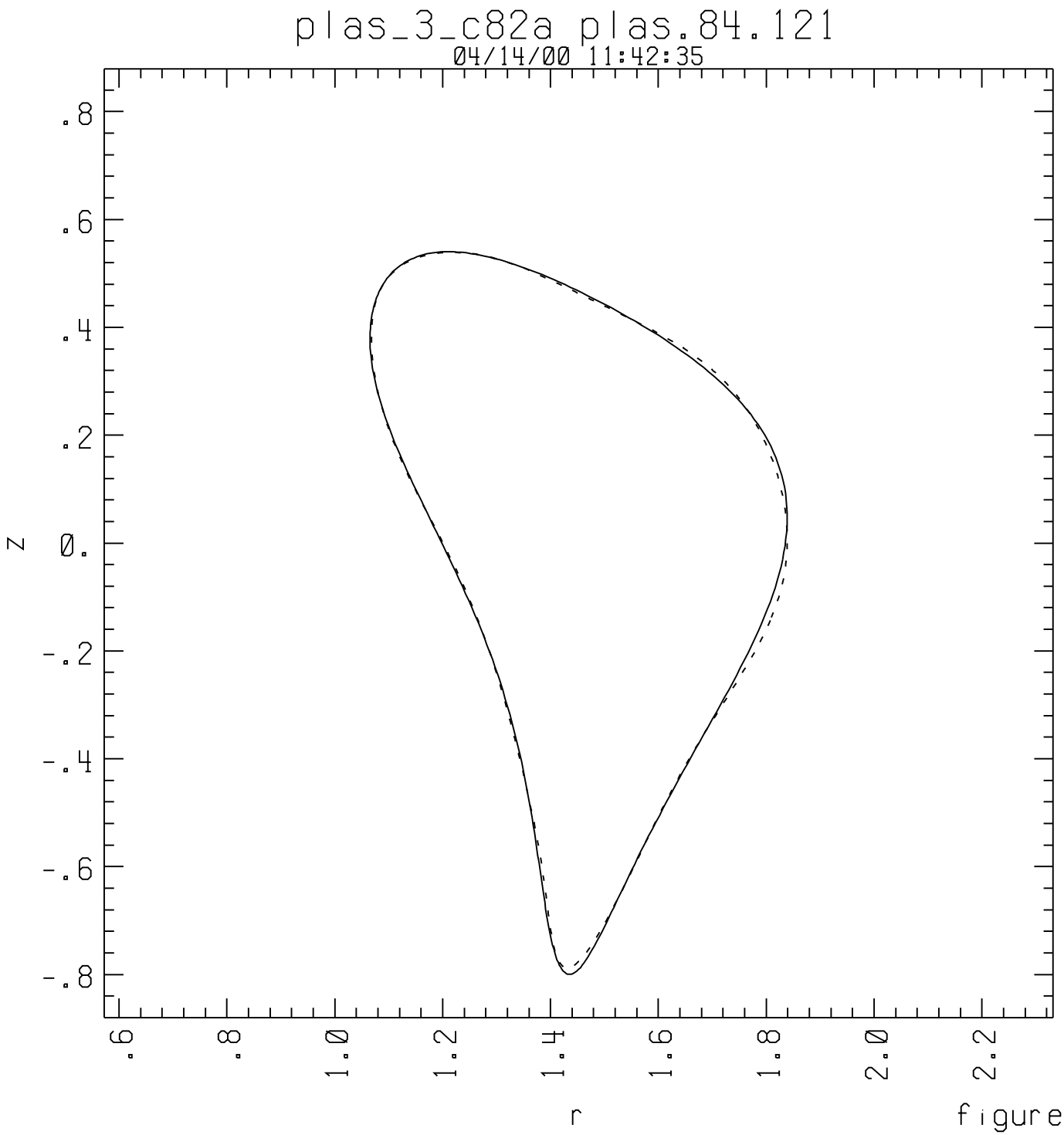
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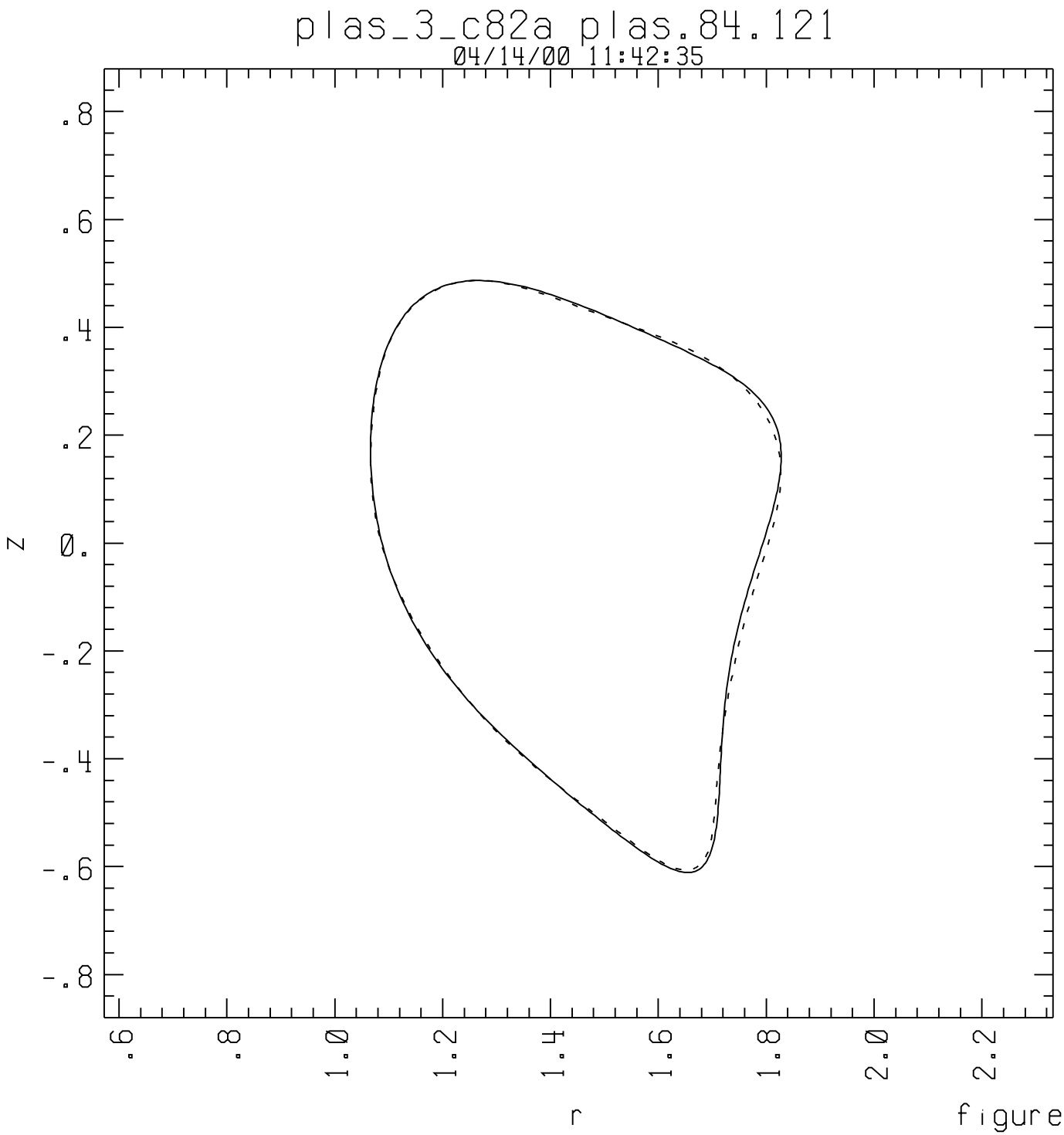
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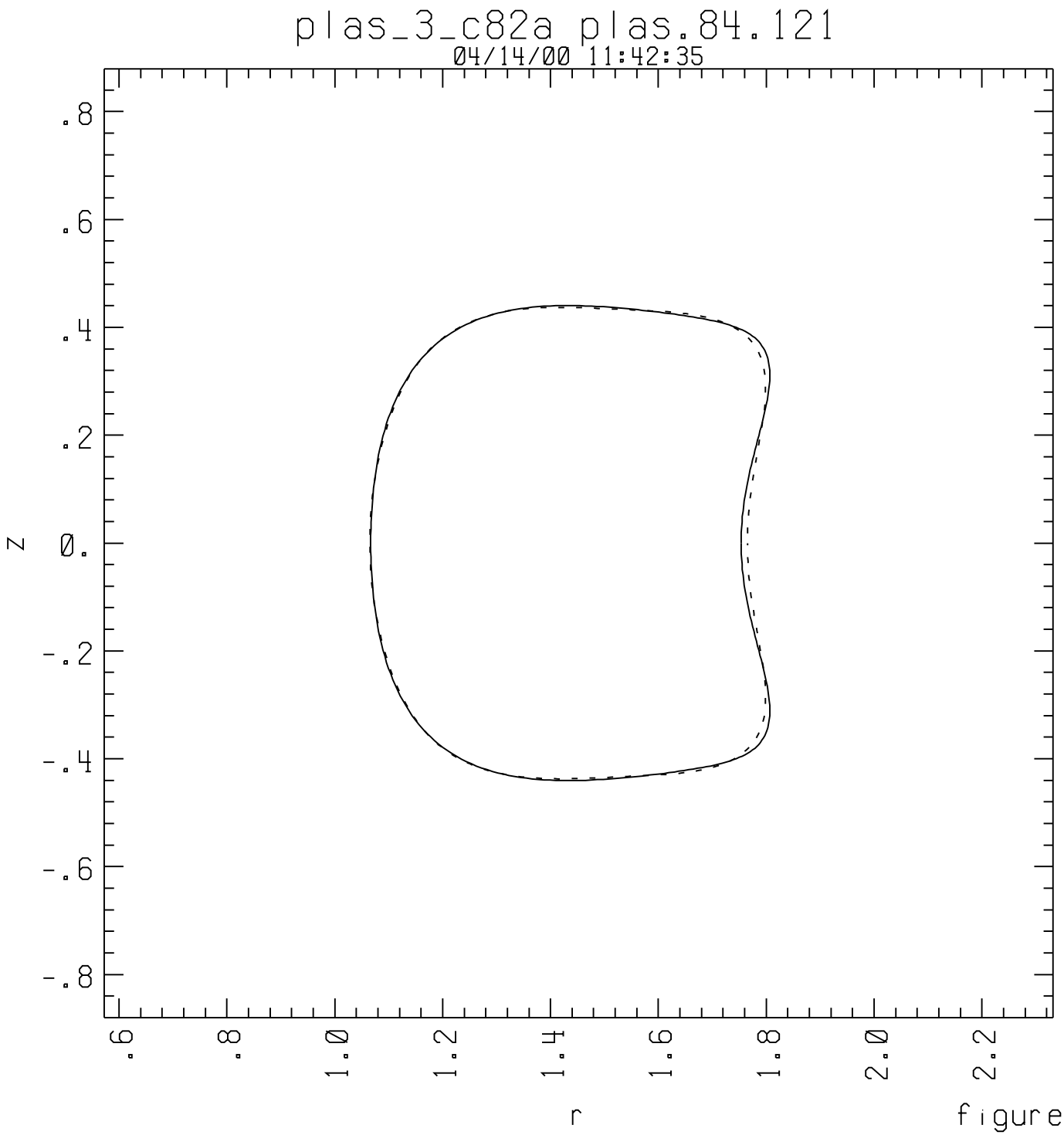
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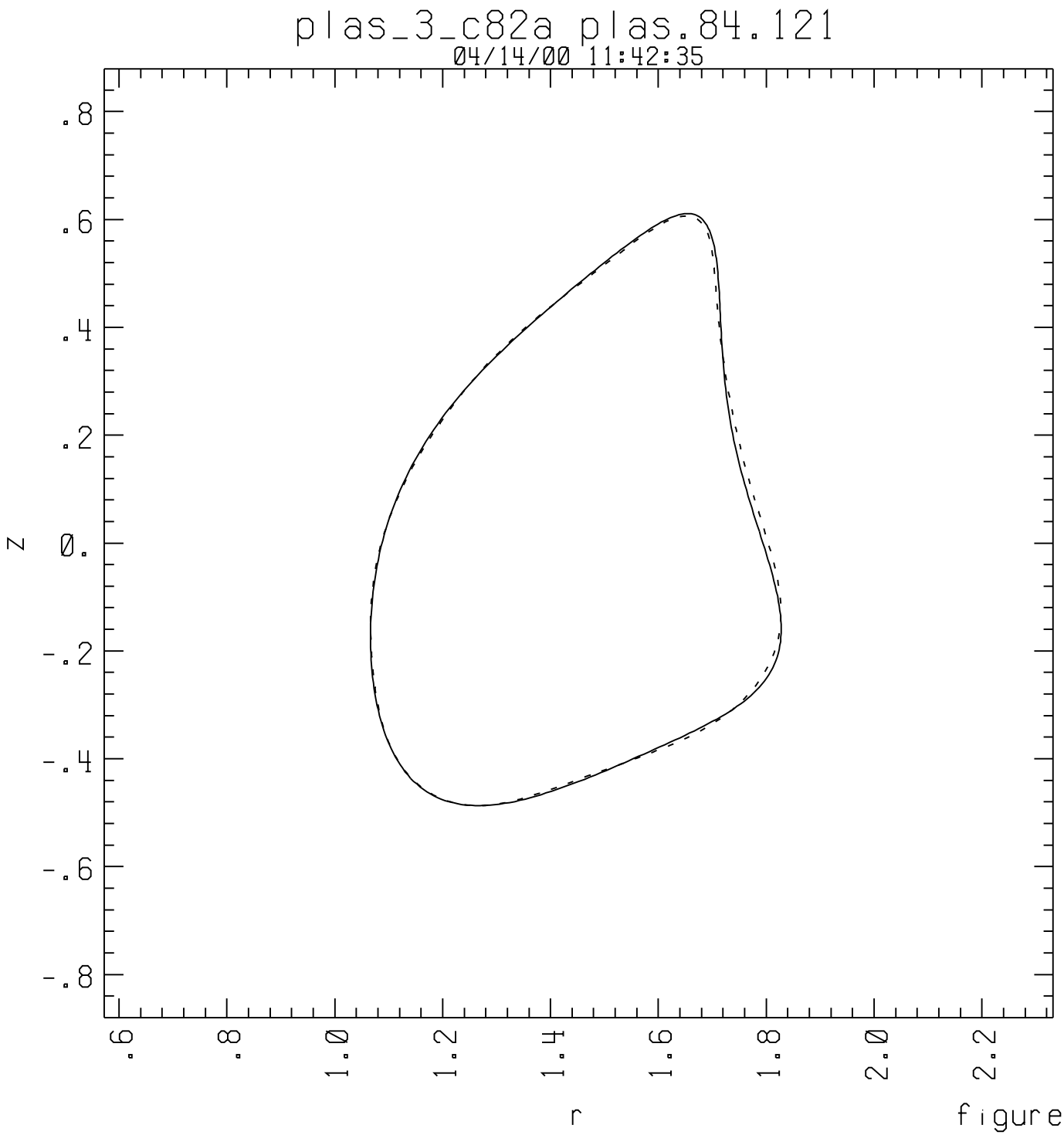
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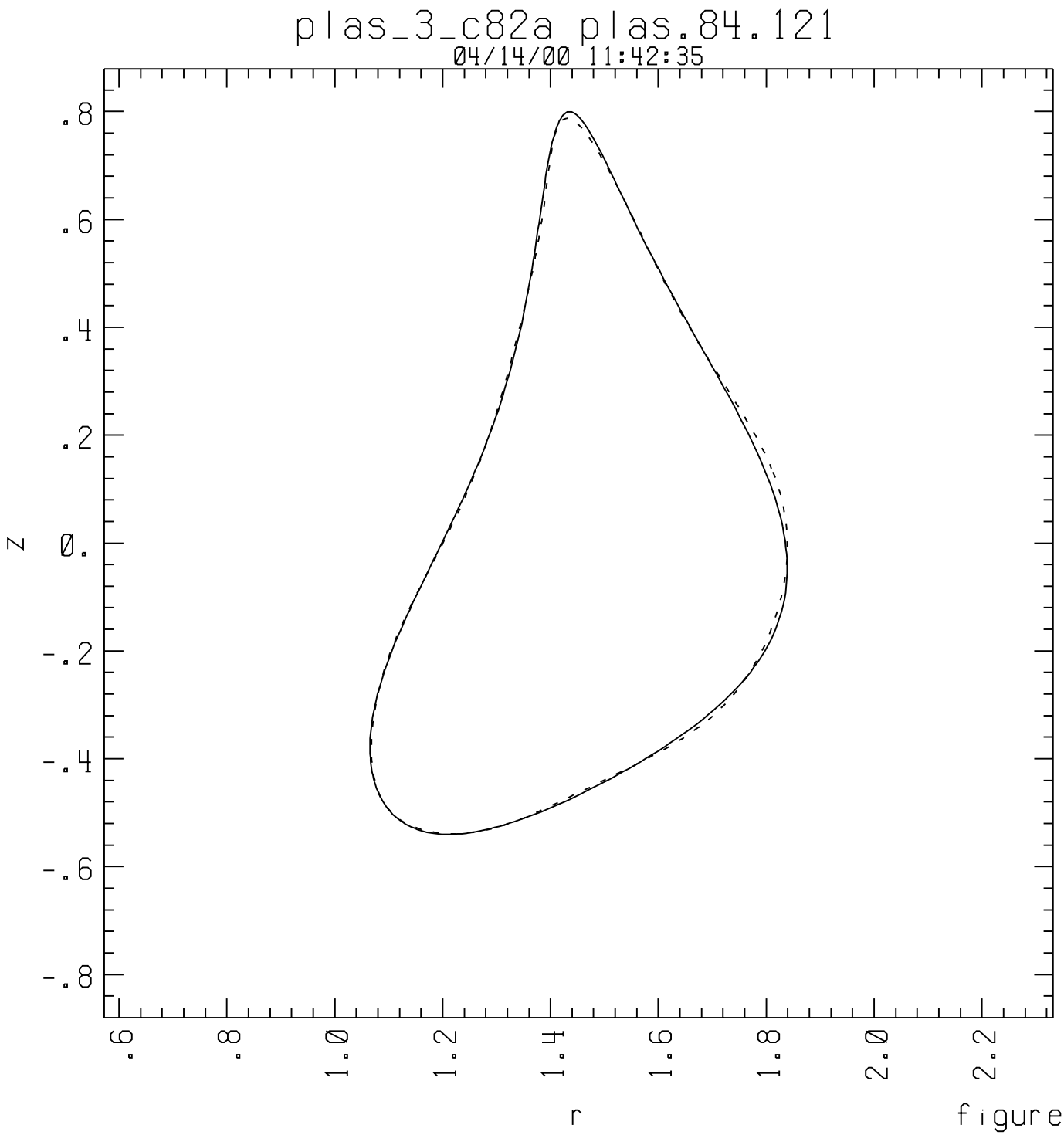
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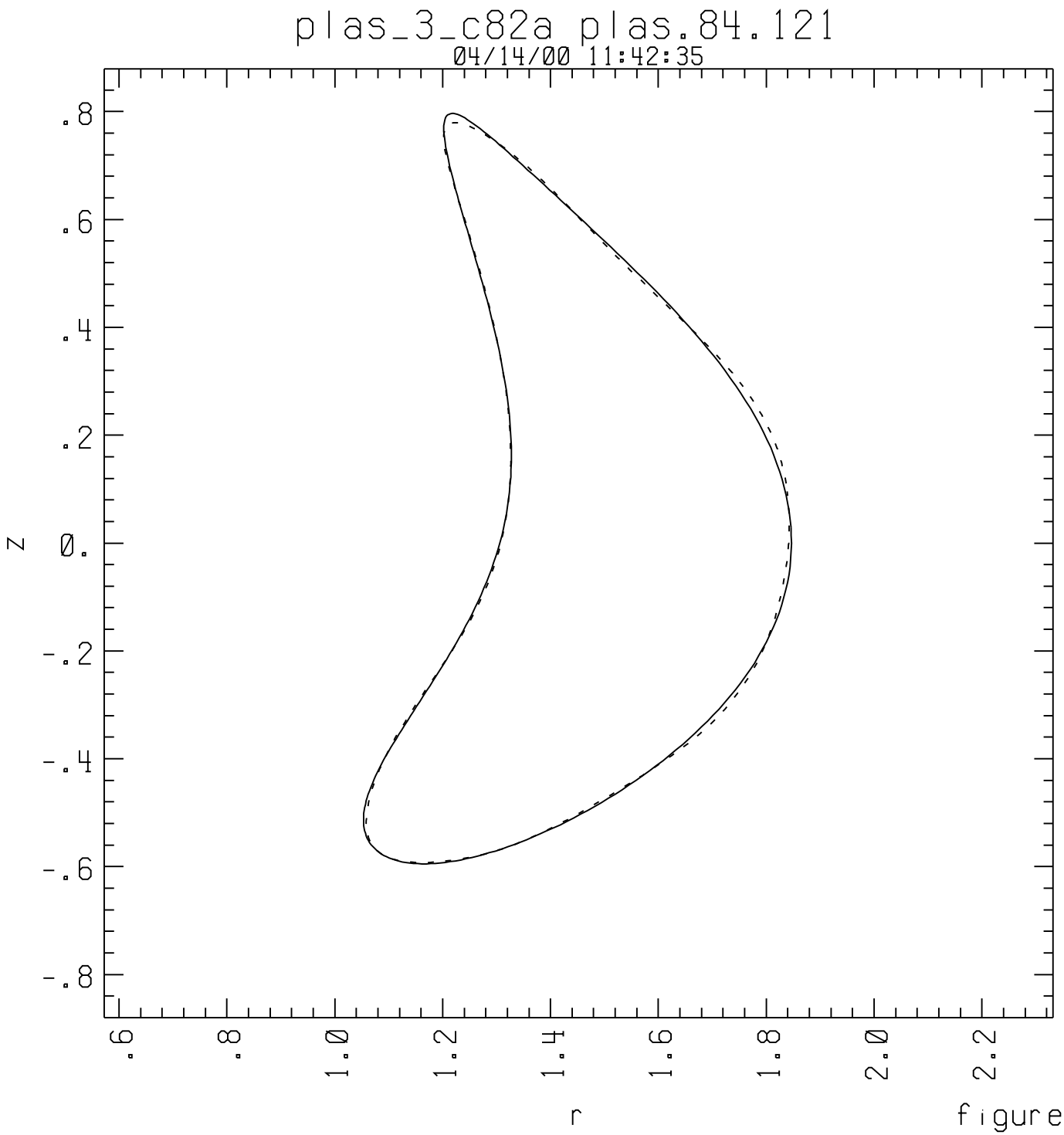
figure 7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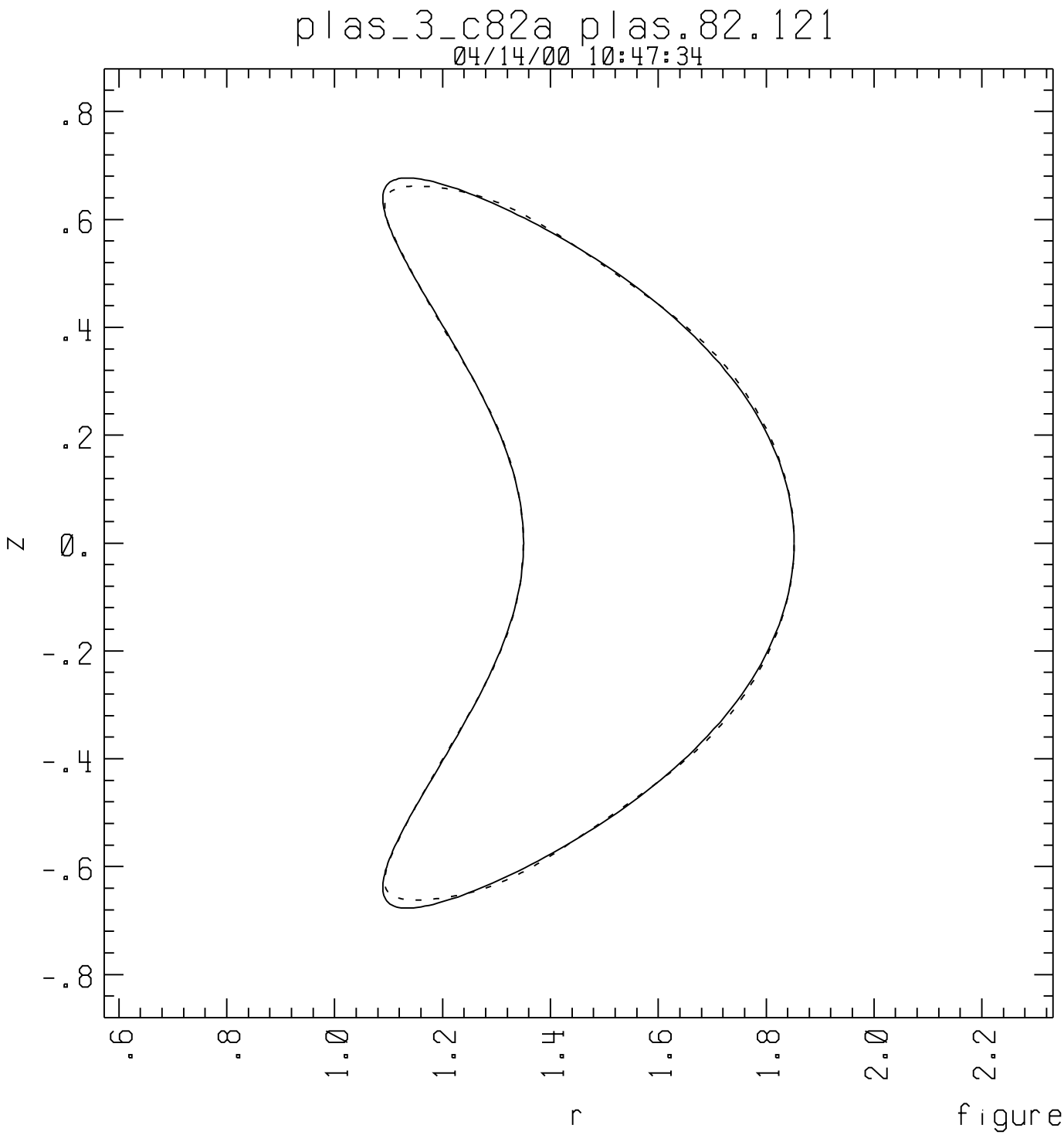
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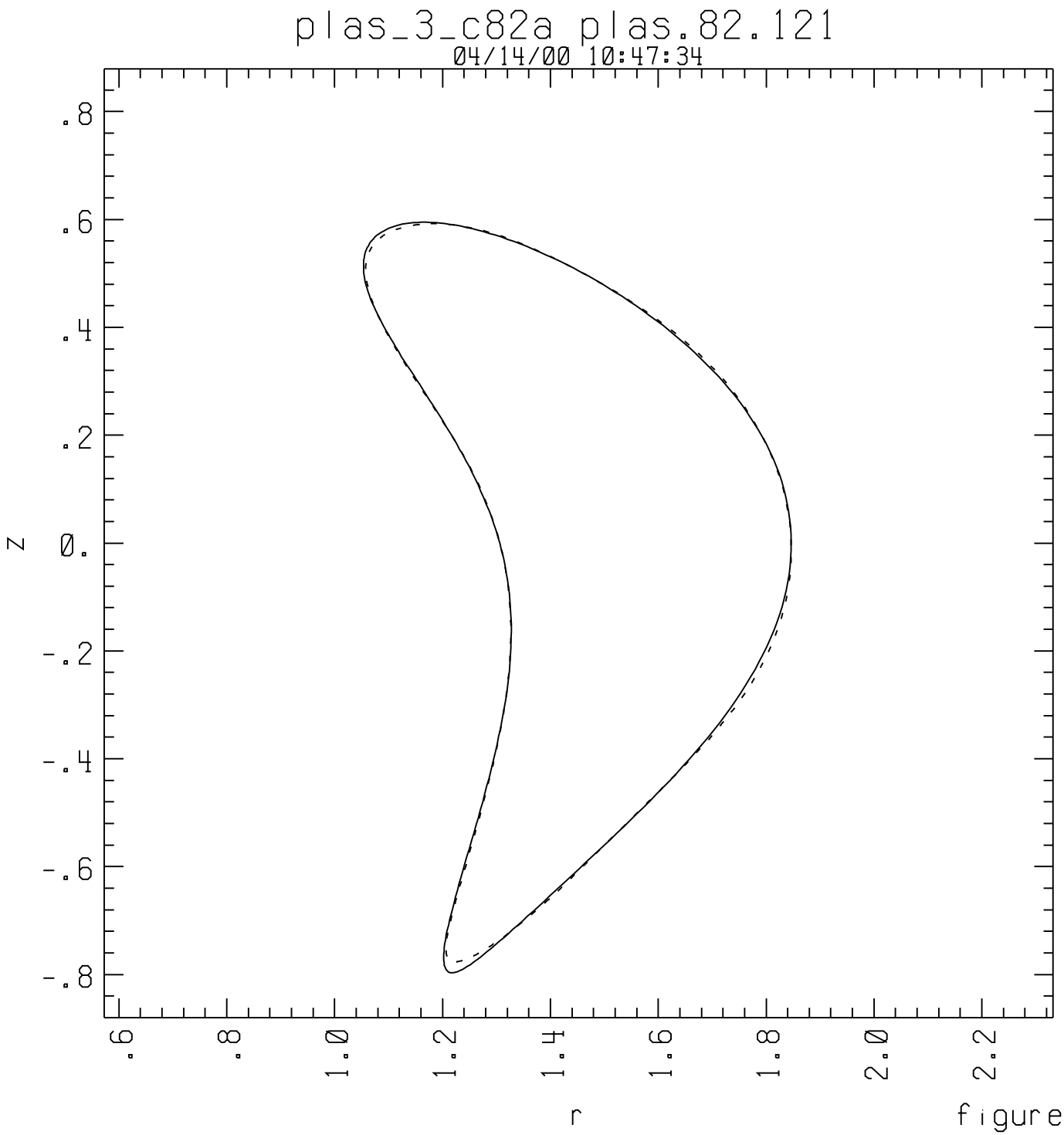
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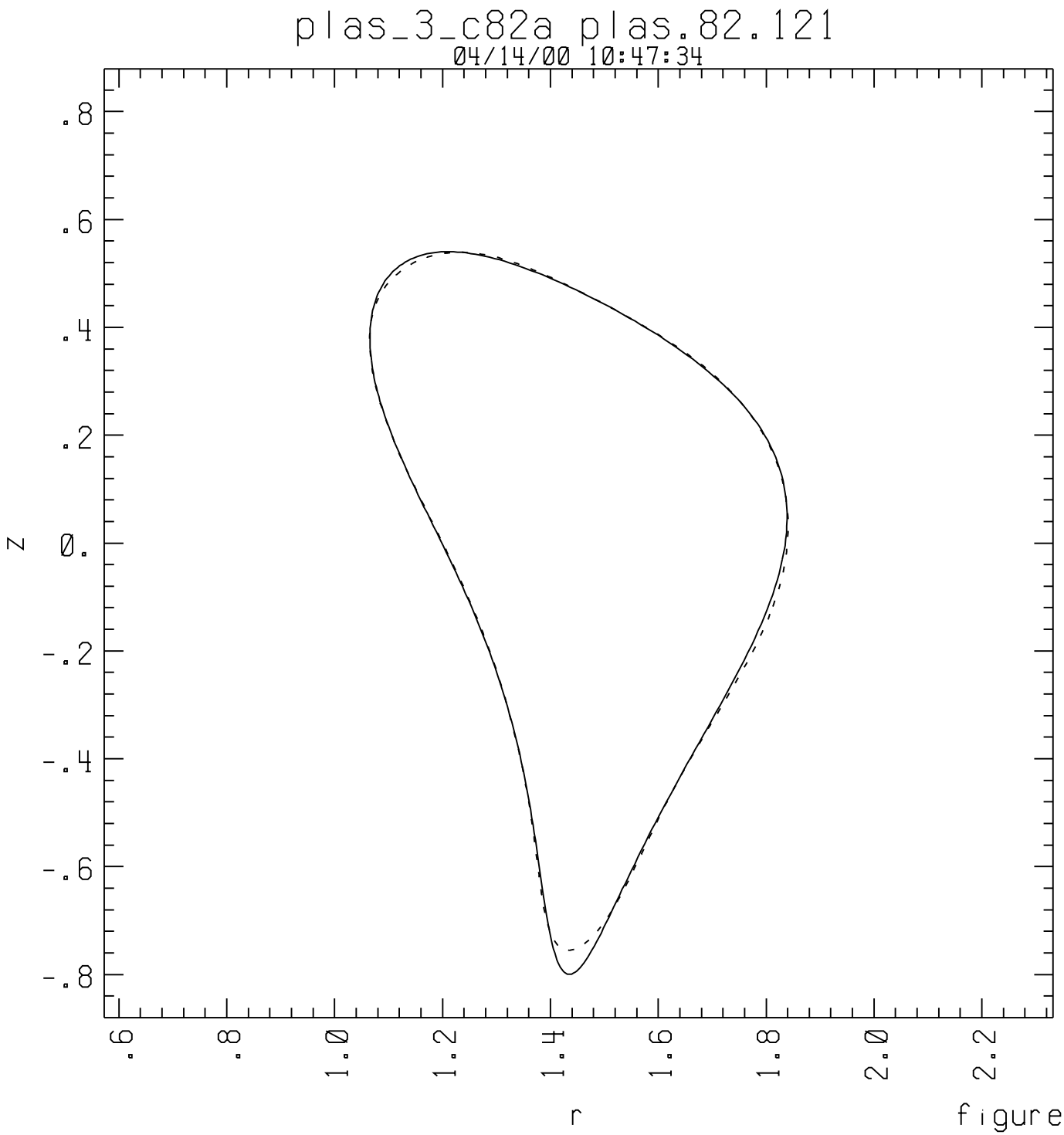
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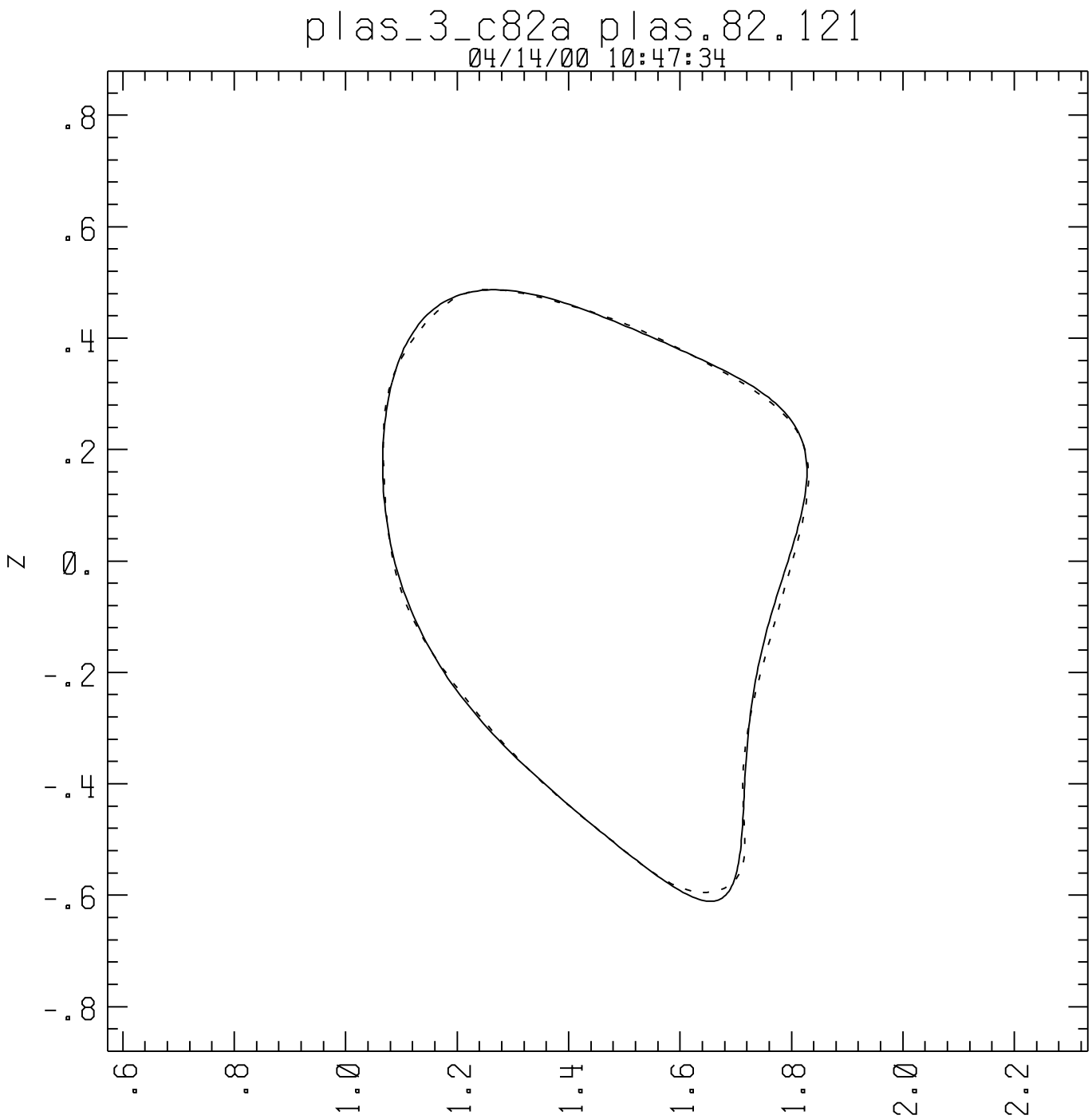
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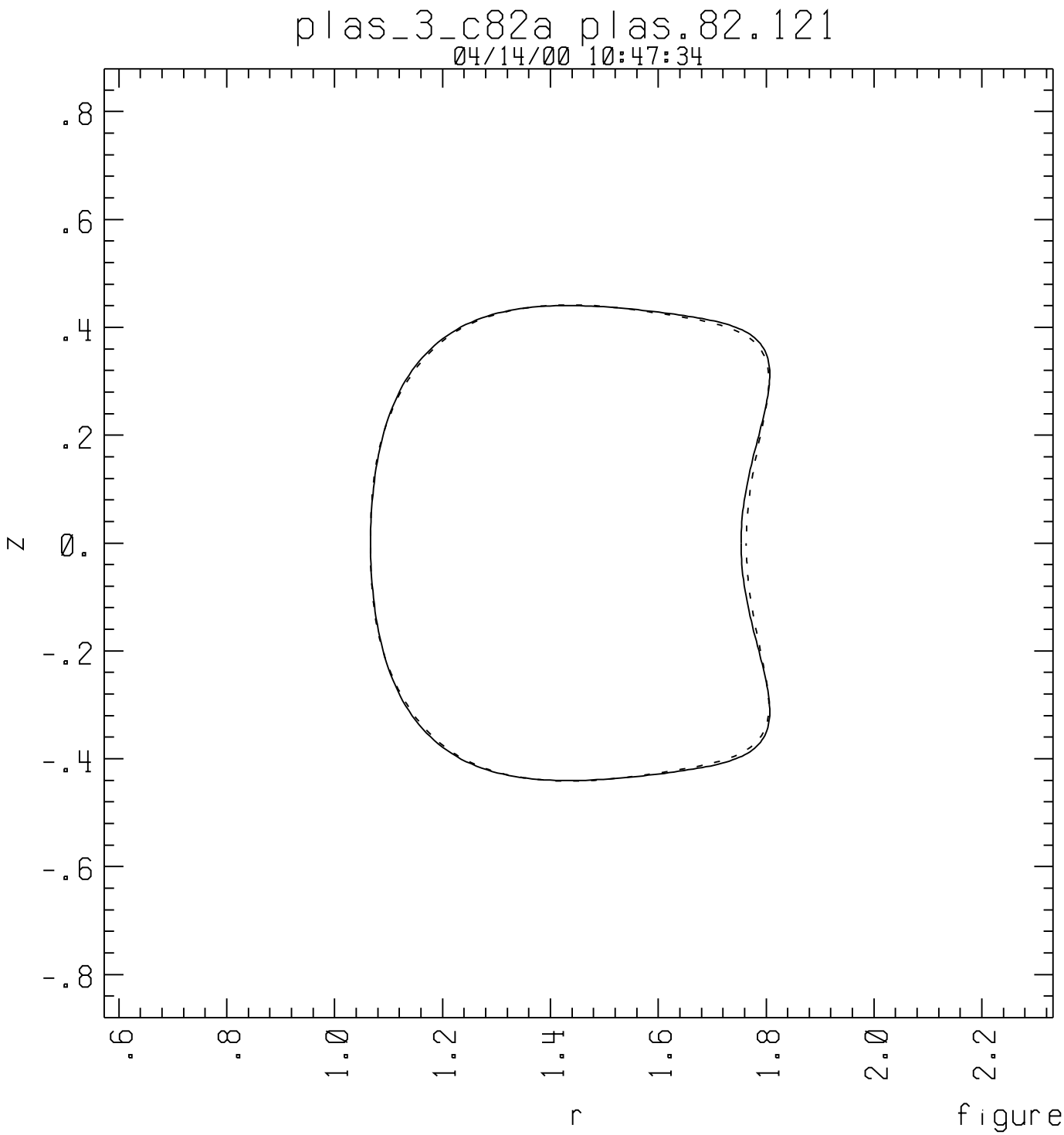
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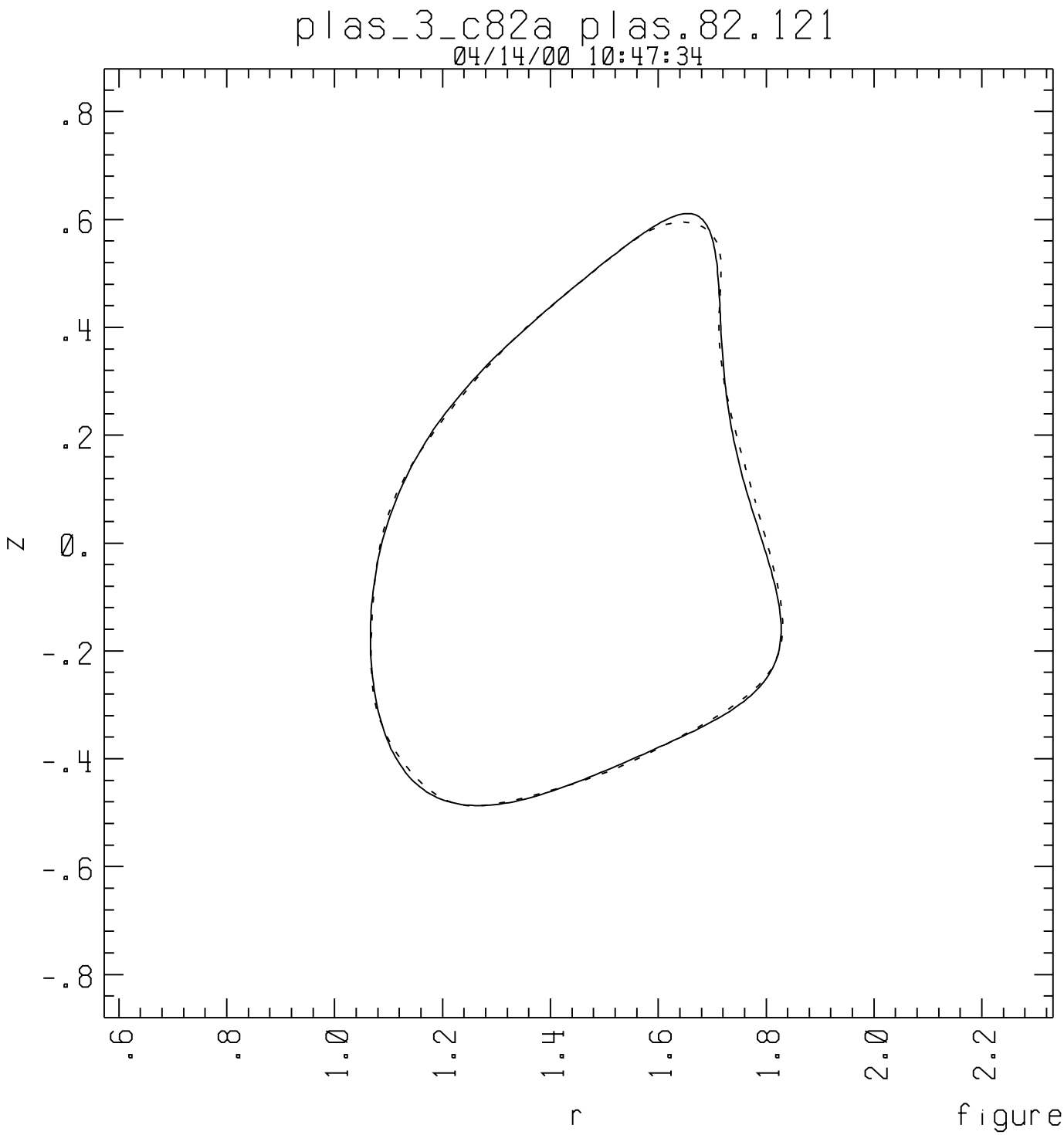
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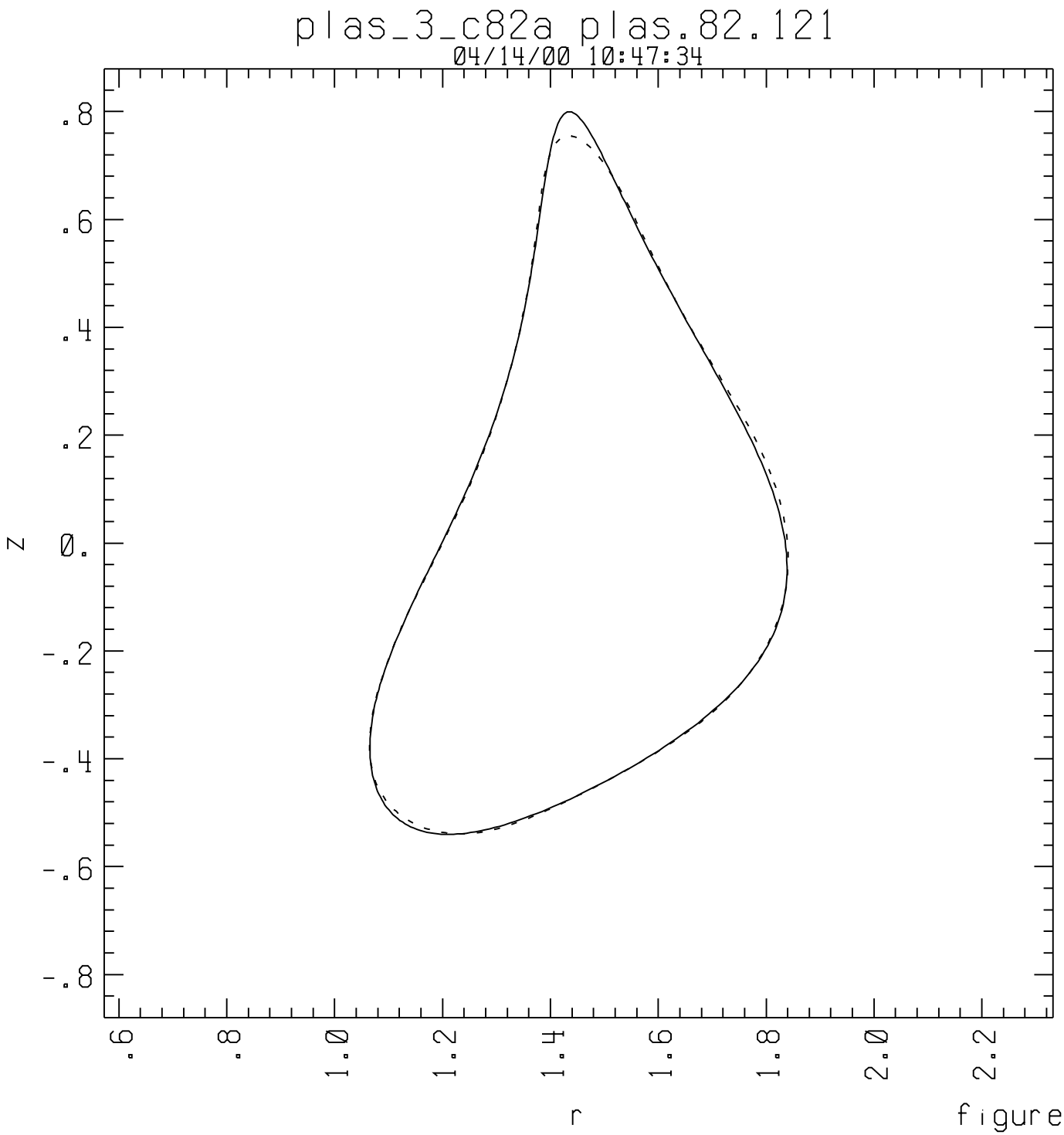
figure 6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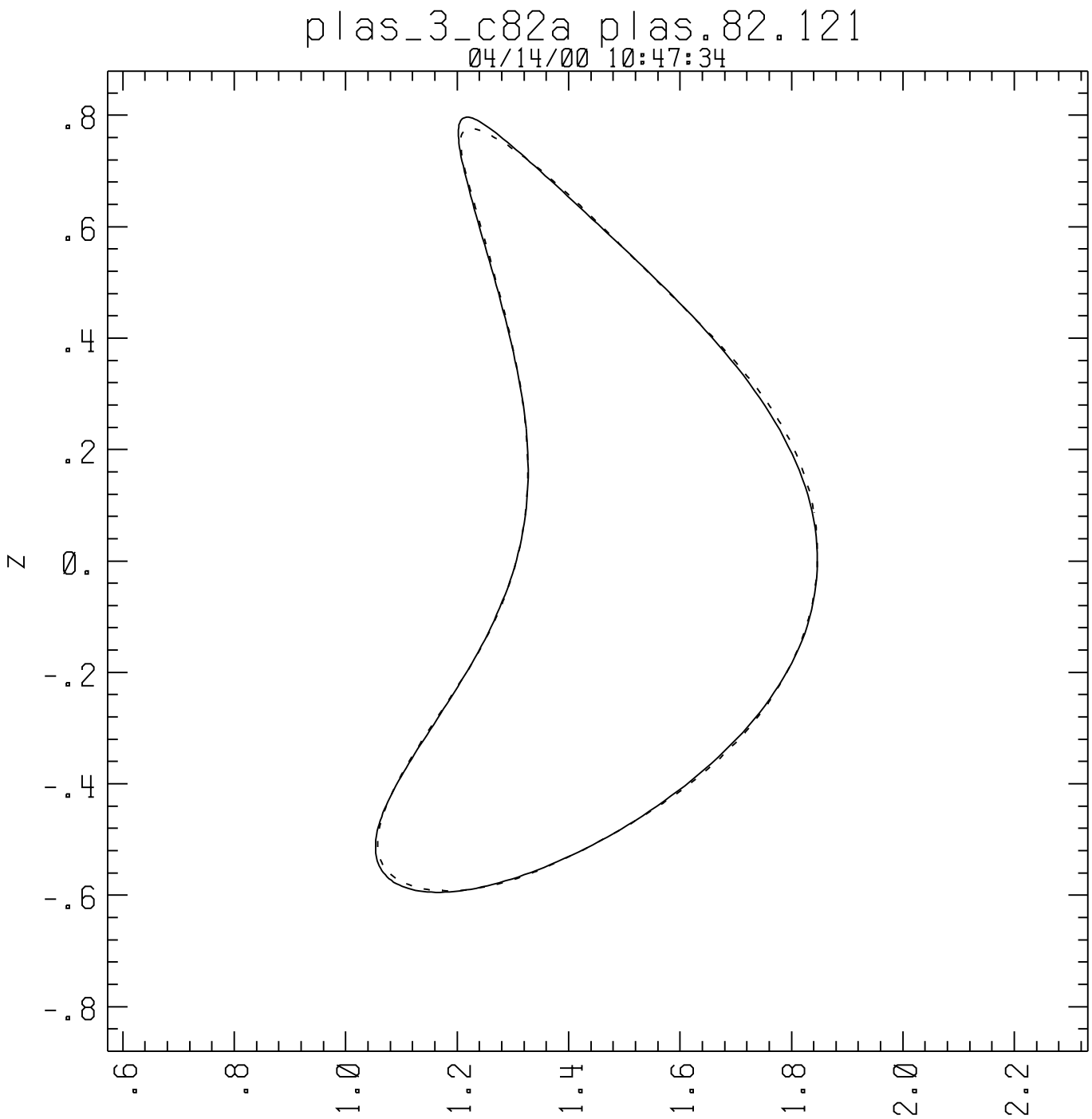
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figure 8

Conclusions from VMEC reconstruction for c82 Xerr Nescoil surface current:

- Both Xerr and Berr targeted cases show similar average VMEC reconstruction
- Xerr target reconstruction has more surface displacement near corners and so bigger max displacement (by factor of 2)
- Results shed no light on effect of Xerr targeting on islands
- Need full PIES fixed boundary reconstruction to see Xerr-Berr differences

Possible next steps in c82 Xerr reduction efforts (will they be useful?):

- Cut 6,8,…,20 coils and check Xerr vs number of coils to find optimum
- VMEC reconstruction at optimum number of coils (min Xerr)
- If Xerr targeting shows improvements, then do PIES reconstruction (2 weeks)

Summary of PIES and CUROPT Efforts completed so far

Objective: suppress islands produced by a given coil set

Method: Vary the coil currents while simultaneously targeting both B•n on the plasma surface and calculated island width on resonant surface inside plasma.

Results obtained so far:

1. First we demonstrated that methods used to target island size do correlate with reduction in islands observed with PIES
2. Good progress was made for full beta, full current and vacuum “snapshots
3. We have fairly good confidence that the coils can be cut and optimized to preserve the good physics of the fixed boundary equilibrium (good kink and vertical stability and good surfaces in the largest bore).

4. Trim coils can reduce islands, but carry currents of the order of the other saddle coils!

5. Reason for large trim currents: island poloidal mode # is large (10) - high mode fields fall off rapidly away from “trim” coils

6. This may imply that we must optimize the original equilibrium (and its coils) to not have islands and not need trim-coils (to lowest order)

7. Bore was be grown to an adequate size by adjusting poloidal field coils.

8. No progress was made for the full current, zero beta equilibrium (no runs).

9. This snapshot presents the potentially most challenging problems.

We need to discuss which (if any) are the most promising Xerr reduction efforts (NESCOIL, PIES, COILOPT, and CUROPT) we should undertake soon.

Appendix 1: Method of Xerr post-processor calculation from Berr:

Solve $(B \cdot \quad)X = (B^{\theta}\partial_{\theta} + B^{\varphi}\partial_{\varphi})\, X(\theta,\varphi) = B \quad | \quad \rho|$ for given Berr on plasma surface

Use $\lambda(\theta,\varphi)$ to transform from Nescoil to VMEC coordinates

$u = \theta + \lambda(\theta,\varphi)$, and $v = \varphi$

Solve $(\iota\partial_u + \partial_v)x(u,v) = b(u,v) \equiv \left[\frac{B \quad \sqrt{g} \quad \rho}{\Phi'(1+\lambda_{\theta})}\right]$ for Xerr in fourier space to get

$$x(m,n) = -\frac{b(m,n)}{m \cdot \iota + n}, \text{ with}$$

$$b(m,n) = \frac{1}{4\pi^2}\iint du\,dv \sin(mu + nv)\, b(u,v)$$

$$= \frac{1}{4\pi^2}\iint \frac{dA}{\Phi'} \sin\left(m[\theta + \lambda] + n\phi\right) B \quad (\theta,\phi)$$

Inverse fourier transform Xmn to get Xerr.

Appendix 2: Method of Xerr Targeting within Nescoil:

Use linearity of Berr to Xerr transformation to get

modified Xerr-Nescoil Green functions g and h from original G and H

$$g_{mn,m'n'} = \frac{1}{4\pi^2(m\iota + n)} \iint \frac{dA}{\Phi'} \sin\left(m\left[\theta + \lambda(\theta,\varphi)\right] + n\varphi\right) G_{m'n'}(\theta,\varphi)$$

$$h_{mn} = \frac{1}{4\pi^2(m\iota + n)} \iint \frac{dA}{\Phi'} \sin\left(m\left[\theta + \lambda(\theta,\varphi)\right] + n\varphi\right) H(\theta,\varphi)$$

Use Nescoil solver (using SVD) to get Xerr-optimized current potential

$$x_{m,n} = h_{m,n} + \sum g_{mn,m'n'} \Phi_{m',n'} => 0$$

All Nescoil solver enhancements (SVD scan, Jmax target) can also be used here.