

# BELYI STUFF

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## I. BIELLIPTIC BELYI

Combining my recent interests of Belyi maps and glueing curves along their 2-torsion, I decided to look at which genus 2 Belyi maps we've computed so far are defined on bielliptic curves, i.e., genus 2 hyperelliptic curves  $X$  with distinct morphisms  $\psi_1 : X \rightarrow E_1$  and  $\psi_2 : X \rightarrow E_2$  where  $E_1$  and  $E_2$  are elliptic curves. You can easily spot at least some of these from their equations: when  $y^2 = f(x)$  and  $f$  contains only even powers of  $x$ . Let's see why in an example: consider

$$X : y^2 = x^6 + 4x^4 + 6x^2 + 3,$$

the curve from 6T6-6\_6\_3.3-a. Replacing  $x^2$  by  $x$ , we obtain the elliptic curve

$$E_1 : y^2 = x^3 + 4x^2 + 6x + 3.$$

Homogenizing the equation defining  $X$  (gradedly, of course), we have

$$y^2 = x^6 + 4x^4z^2 + 6x^2z^4 + 3z^6$$

and dehomogenizing by setting  $x = 1$ , we have

$$y^2 = 1 + 4z^2 + 6z^4 + 3z^6$$

find the second elliptic curve

$$E_2 : y^2 = 1 + 4z + 6z^2 + 3z^3.$$

So we get the maps

$$\begin{aligned} X &\rightarrow E_1 \\ (x, y) &\mapsto (x^2, y) \end{aligned}$$

and

$$\begin{aligned} X &\rightarrow E_2 \\ (z, y) &\mapsto (z^2, y). \end{aligned}$$

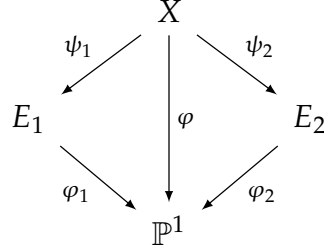
on the open subsets where these equations hold. (I could work out the maps on the homogenized version, but I'm too lazy.)

Anyway, here's a list of all the genus 2 bielliptic Belyi maps I've found so far.

- <https://beta.lmfdb.org/Belyi/5T4/5/5/5/a>
- <https://beta.lmfdb.org/Belyi/6T1/6/6/3.3/a>
- <https://beta.lmfdb.org/Belyi/6T5/6/6/3.3/a>
- <https://beta.lmfdb.org/Belyi/6T6/6/6/3.3/a>

- <https://beta.lmfdb.org/Belyi/7T7/7/4.3/4.3/b>

I was hoping to find an example where we have computed a Belyi map on the genus 2 curve and both elliptic curves. Maybe we could find a commutative diagram?



I came close, but no cigar so far. Here's the near-example. The map 6T6-6\_6\_3.3-a (<https://beta.lmfdb.org/Belyi/6T6/6/6/3.3/a>) is defined on the curve 1728.b.442368.1 (<https://beta.lmfdb.org/Genus2Curve/Q/1728/b/442368/1>). It is a 2-glueing of the elliptic curves 36.a4 (<https://beta.lmfdb.org/EllipticCurve/Q/36/a/4>) and 48.a5 (<https://beta.lmfdb.org/EllipticCurve/Q/48/a/5>). The curve 36.a4 has minimal Weierstrass model

$$E_1 : y^2 = x^3 + 1$$

and we've computed a couple Belyi maps on  $E_1$ , namely the Euclidean map 3T1-3\_3\_3-a (<https://beta.lmfdb.org/Belyi/3T1/3/3/3/a>) and the hyperbolic map 9T20-9\_2.2.2.1.1.1\_6.3-a (<https://beta.lmfdb.org/Belyi/9T20/9/2.2.2.1.1.1/6.3/a>). But despite some near misses, we haven't gotten to a Belyi map on 48.a5. However, while searching for Belyi maps of conductor 48, I did make an interesting observation.

## II. CURVE WITH MANY MAPS

I noticed that the elliptic curve with label 48.a6

$$E : y^2 = x^3 + 47/768x + 2359/55296$$

admits a bunch of Belyi maps of low degree. First we have one of my favorites, the genus 1 hyperbolic triple of minimal degree 4T5-4\_4\_3.1-a (<https://beta.lmfdb.org/Belyi/4T5/4/4/3.1/a>). Today I noticed there are a bunch of degree 8 maps defined on the isomorphic curve

$$E' : y^2 = x^3 + 47/12288x + 2359/3538944$$

(this equation just differs by a factor of 2), namely 8T46-8\_8\_3.1.1.1.1.1-a (<https://beta.lmfdb.org/Belyi/8T46/8/8/3.1.1.1.1.1/a>), 8T47-8\_2.2.2.2.4.3.1-a (<https://beta.lmfdb.org/Belyi/8T47/8/2.2.2.2.4.3.1/a>), and 8T47-8\_6.2.4.1.1.1.1-a (<https://beta.lmfdb.org/Belyi/8T47/8/6.2.4.1.1.1.1/a>). Even curiously, all 3 have nearly the same equation! I wonder if there's some explanation for this. Maybe they arise from composing the degree 4 map with a degree 2 map, or maybe from taking a fiber product?

### III. DIFFERENT FIELDS OF DEFINITION FOR CURVE AND MAP

When I was first computing genus 1 Belyi maps, I ran into a problem. I thought that the Belyi map  $\varphi : X \rightarrow \mathbb{P}^1$  with label 5T3-5\_4.1\_4.1-a was defined over  $\mathbb{Q}$ , as the curve  $X$  was. But it turned out that  $\varphi$  is only defined over  $\mathbb{Q}(i)$ : see <https://beta.lmfdb.org/Belyi/5T3/5/4.1/4.1/a>. I saw another instance of this today: <https://beta.lmfdb.org/Belyi/7T7/7/4.3/4.3/c>.