e. The dot product of the normal vector with the magnetic fields gives the angles

$$\cos\theta_1 \;=\; \frac{\mathbf{B}_1\cdot\hat{\mathbf{n}}}{|\mathbf{B}_1|} \;=\; \frac{-1.73}{2.00} \;=\; -\,0.866 \quad , \qquad \theta_1 \;=\; 150.000^\circ$$

$$\cos\theta_2 \;=\; \frac{\mathbf{B}_2\cdot\hat{\mathbf{n}}}{|\mathbf{B}_2|} \;=\; \frac{-1.73}{3.42} \;=\; -\,0.507 \quad , \qquad \theta_2 \;=\; 120.438^\circ$$

f. From the expressions we find

$$M_{A2}^2 \;=\; \frac{n_1}{n_2}M_{A1}^2$$

and

$$(M_{A1}^2-1)\tan\theta_1 \;=\; (M_{A2}^2-1)\tan\theta_2 \;=\; \left(\frac{n_1}{n_2}M_{A1}^2-1\right)\tan\theta_2$$

Solving this gives

$$M_{A1} \;=\; \sqrt{\frac{\tan\theta_1-\tan\theta_2}{\tan\theta_1-(n_1/n_2)\tan\theta_2}}$$

$$M_{A1}=5.000 \quad , \qquad M_{A2}=3.024$$

g. We have several pieces of evidence that this is a **fast shock**. We could have noted early on that $|\mathbf{B}_2| > |\mathbf{B}_1|$. Later it was evident that $\mathbf{B}_2$ had deflected *away* from the shock normal (although it appears that $\theta_2 < \theta_1$ because the field is directed backwards). Finally, we wee that the Mach numbers are ordered

$$1 \;<\; M_{A2} \;<\; M_{A1} \quad , \tag{41}$$

which is a prerequisite for the *fast shock*.

h. The Alfvén Mach number refers to the normal component of the upstream velocity $v_{1,n}$ *in the reference frame of the shock*. If we denote the shock speed v_s the inflow speed is therefore

$$v'_{n,1} \;=\; v_{n,1}-v_s \;=\; -\,M_{A1}\,v_{A1,n} \quad , \tag{42}$$

since the inflow is always in the direction opposite $\hat{\mathbf{n}}$. The shock speed is therefore

$$v_s \;=\; v_{n,1} \;+\; M_{A1}\,v_{A1,n} \quad , \tag{43}$$

where $v_{1,n}$ is the component of the velocity, in the spacecrtaft frame,

$$v_{n,1} \;=\; \hat{\mathbf{n}}\cdot\mathbf{v}_1 \;=\; -\,2.10\times10^7\,\mathrm{cm/s} \;=\; -\,210\,\mathrm{km/s} \quad .$$

The normal component of the Alfvén velocity is

$$v_{An,1} \;=\; \frac{|\mathbf{B}_1\cdot\hat{\mathbf{n}}|}{\sqrt{4\pi n_1 m_p}} \;=\; \frac{1.73\times10^{-5}G}{9.44\times10^{-12}} \;=\; 1.83\times10^6\,\mathrm{cm/s} \;=\; 18.3\,\mathrm{km/s} \quad .$$

This gives the shock velocity in the reference frame of the spacecraft

$$v_s \;=\; (\,-210 \;+\; 5.00\times18.3\,)\,\mathrm{km/s} \;=\; -\,118\,\mathrm{km/s} \quad , \tag{44}$$

The shock propagates in the direction of the shock normal giving

$$\mathbf{v}_s \;=\; \hat{\mathbf{n}}\,v_s \;=\; (103,\,-32.2,\,-49.7)\,\mathrm{km/s} \quad . \tag{45}$$

The shock is therefore moving *outward* from the Sun, even though it is a *reverse shock*.