The Signature of a Windy Radio Supernova Progenitor in a Binary System

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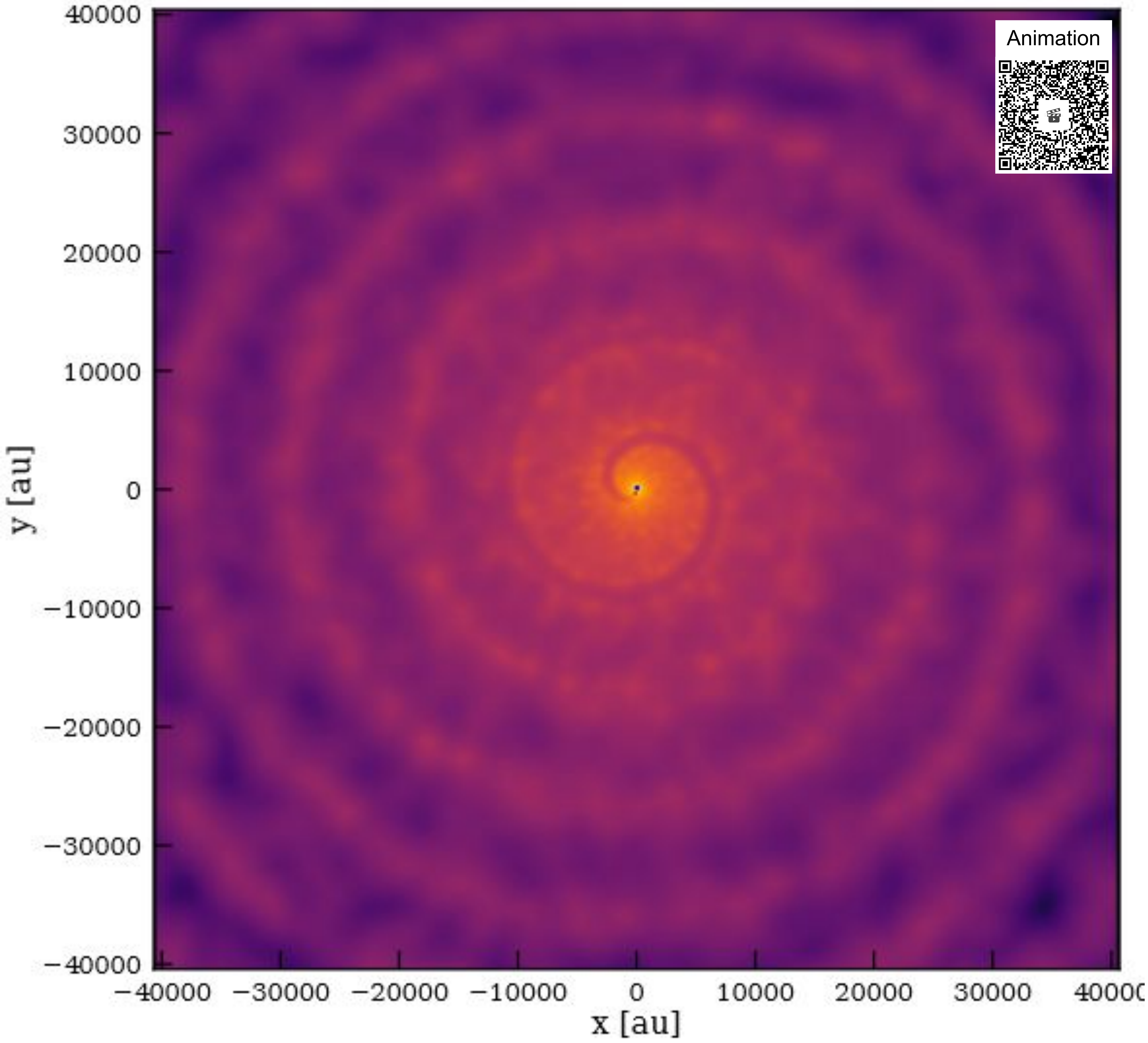
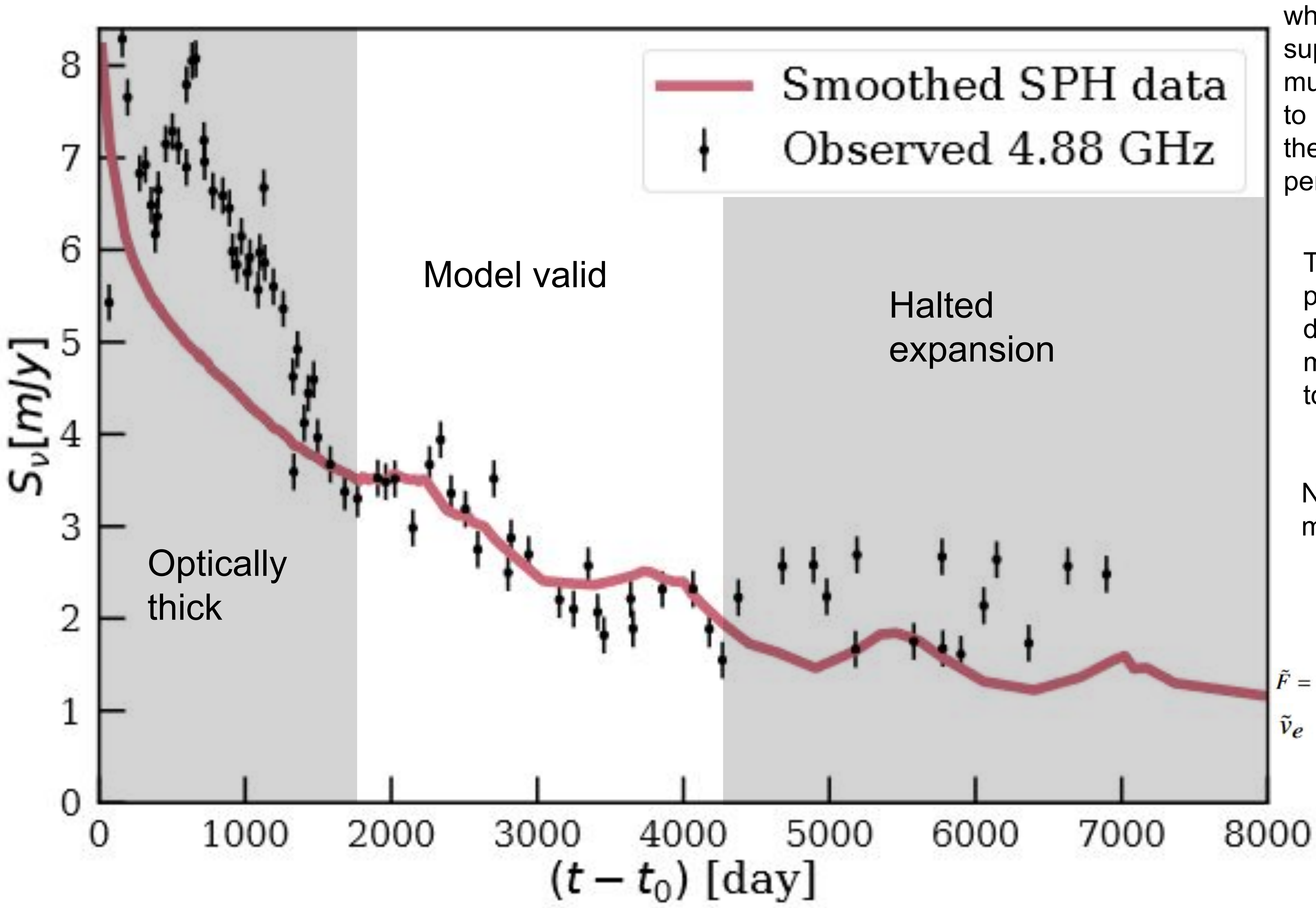


Massive stars, the progenitors of type II supernovae, emit copious amounts of wind. When the star explodes, the ejecta collide with this wind, producing a shock wave and non thermal radio emission. If the progenitor is in a binary, then the orbital motion induces spiral density ripples in the wind. The top figure shows a simulated density map from a face on view of a wind from a binary consisting of a 20 solar mass progenitor (blue dot) and a 6 solar mass companion (red dot), moving on circular orbits with semi major axis of 400 au.

When the shock wave sweeps through the density troughs and crests, the intensity of the radio signal will also oscillate. We propose that this is the origin of the variability seen in the 20 year radio follow up of SN1979C (lower figure). For this particular supernova the properties of the progenitor are well constrained. The mass of the progenitor is roughly 20 solar masses, the mass loss rate is about 1e-4 solar mass per year and the wind velocity is about 20 km/s. Can we then use the radio signal to find the properties of the binary before the explosion? This will be explained in the next section.



We can think about these wind ripples like grooves on a vinyl record. The process of "recording" the wind ripples proceeds at the wind velocity, while "playing" proceeds at the supernova ejecta velocity, which is much higher (10,000 km/s compared to 20 km/s). The orbital period is therefore shorter than the orbital period by the velocity ratio

$$P_{obs} \approx P_{orb} \frac{v_w}{v_e}$$

The relative flux difference is proportional to the relative density difference. Due to conservation of mass, the density ratio is proportional to orbital to wind velocity ratio

$$\frac{\delta f}{f} \approx \frac{v_M}{v_w}$$

Now we can solve for the semi major axis and companion mass

$$m \approx 6\tilde{F}\tilde{M}^{2/3}\tilde{P}_{obs}^{1/3}\tilde{v}_w^{2/3}\tilde{v}_e^{1/3}\, M_\odot,$$

$$a \approx 430\tilde{P}_{obs}^{2/3}\tilde{v}_e^{-2/3}\tilde{v}_w^{2/3}\tilde{M}^{1/3}\text{au},$$

$\tilde{F} = 10 \cdot \delta f/f$ $\quad \tilde{M} = M/20M_\odot$ $\quad \tilde{v}_w \approx v_w/20\,\text{km/s}$. $\tilde{v}_e \approx v_e/10^4\,\text{km/s}$ $\quad \tilde{P}_{obs} = P_{obs}/4\,\text{year}$,

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