Accretion in binary systems

Ilia Kosenkov, 2017-12-01 @ Tuorla

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  - Mass ejection in the form of stellar wind $\longrightarrow$ wind accretion
- Parameters of a binary can evolve with time (e.g. angular momentum loss)

Roche geometry

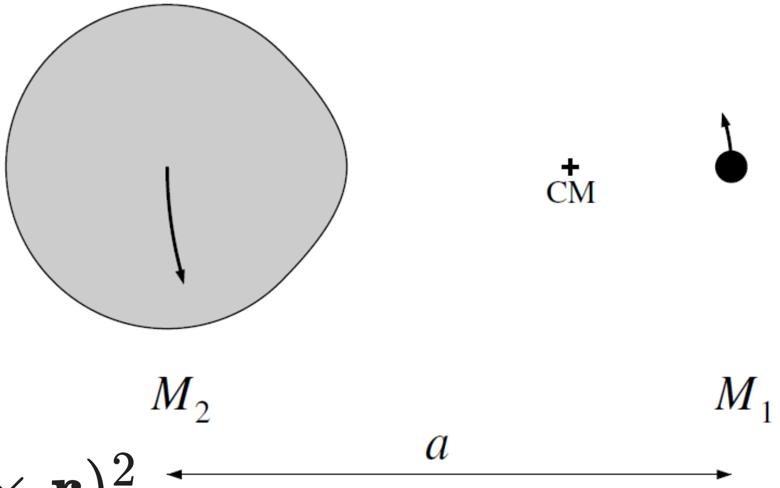
Kepler's law $4\pi^2 a^3 = GMP^2$

$q = \frac{M_2}{M_1}$ $m = \frac{M}{M_\odot}$, and

$|\omega| = \left[\frac{GM}{a^3}\right]^{\frac{1}{2}}$ $\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v} =$

$= -\nabla\Phi_{\mathrm{R}} - 2\omega\times\mathbf{v} - \frac{1}{\rho}\nabla P$

$\Phi_{\mathrm{R}}(r) = -\frac{GM_1}{|\mathbf{r}-\mathbf{r_1}|} - \frac{GM_2}{|\mathbf{r}-\mathbf{r_2}|} - \frac{1}{2}(\omega\times\mathbf{r})^2$



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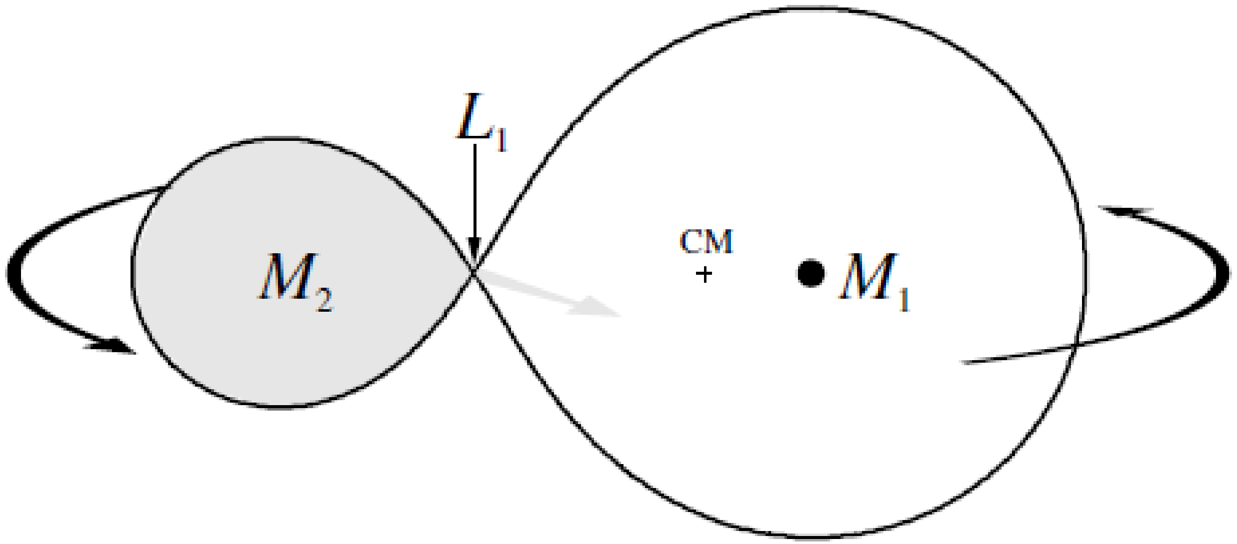

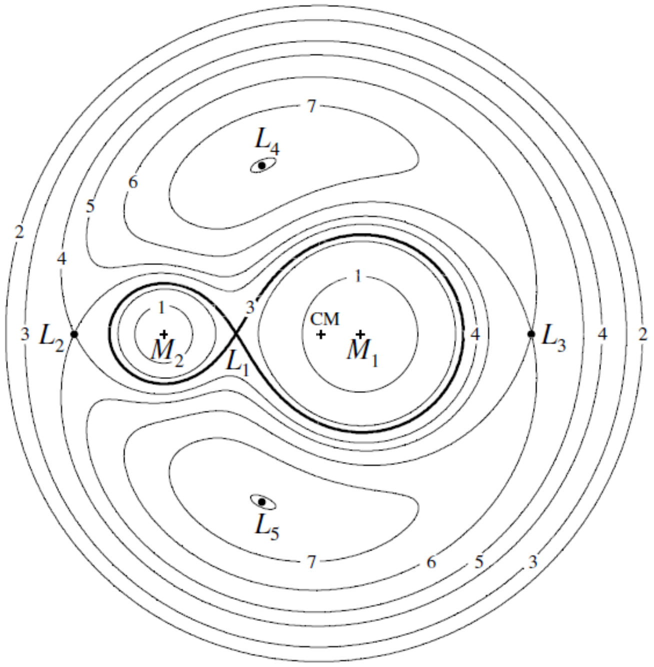

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And period-radius relation for a lower part main sequece star $R_2 \approx 7.9 \times 10^9 P_{\mathrm{hr}}\ \mathrm{cm}$

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and

$$\frac{\dot{R}_2}{R_2} = \frac{2\dot{J}}{J} + \frac{2(-\dot{M}_2)}{M_2}\left(\frac{5}{6} - \frac{M_2}{M_1}\right)$$

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$-\dot{M}_2(\mathbf{inst}) = \dot{M}_0 \,\mathbf{exp}\left[\frac{R_* - R_2}{H_*}\right] \approx \mathbf{10}^{-8} M_\odot \,\mathbf{yr}^{-1}$ for a lower main sequece stars

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$$v_\perp \approx b_1\omega \approx 100 m_1^{1/3}(1+q)^{1/3} P_{\rm day}^{-2/3}\ \mathbf{km\ s^{-1}}$$

$v_\parallel \lesssim c_{\rm s} \approx \mathbf{10\ km\ s^{-1}}$ for a $\mathbf{10^5\ K}$ envelope temperature

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$$L_{\rm disc} = \frac{GM_1\dot{M}}{2R_*} = \frac{1}{2}L_{\rm acc}$$

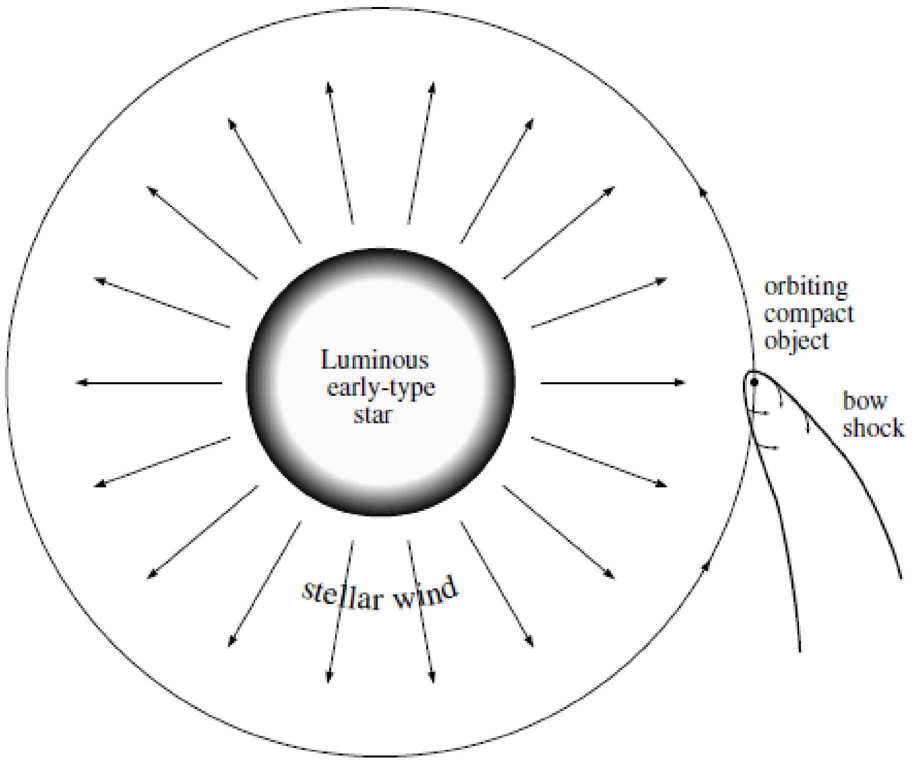
Accretion in close binaries: other possiblities

$$v_{\rm w} \approx \left(\frac{2GM_{\rm E}}{R_{\rm E}}\right)^{1/2}$$

For a $\mathbf{10^{-5}}\ M_\odot\ \mathbf{yr^{-1}}$ mass loss rate
$v_{\rm w} \approx \mathbf{few} \times \mathbf{10^3\ km\ s^{-1}}$

The wind sweeps at angle
$\beta \approx \mathbf{tan}^{-1}(v_{\rm n}/v_{\rm w})$

and relative speed $v_{\rm rel} \approx (v_{\rm n}^2 + w_{\rm w}^2)^{1/2}$



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Fraction of mass captured by accretor is

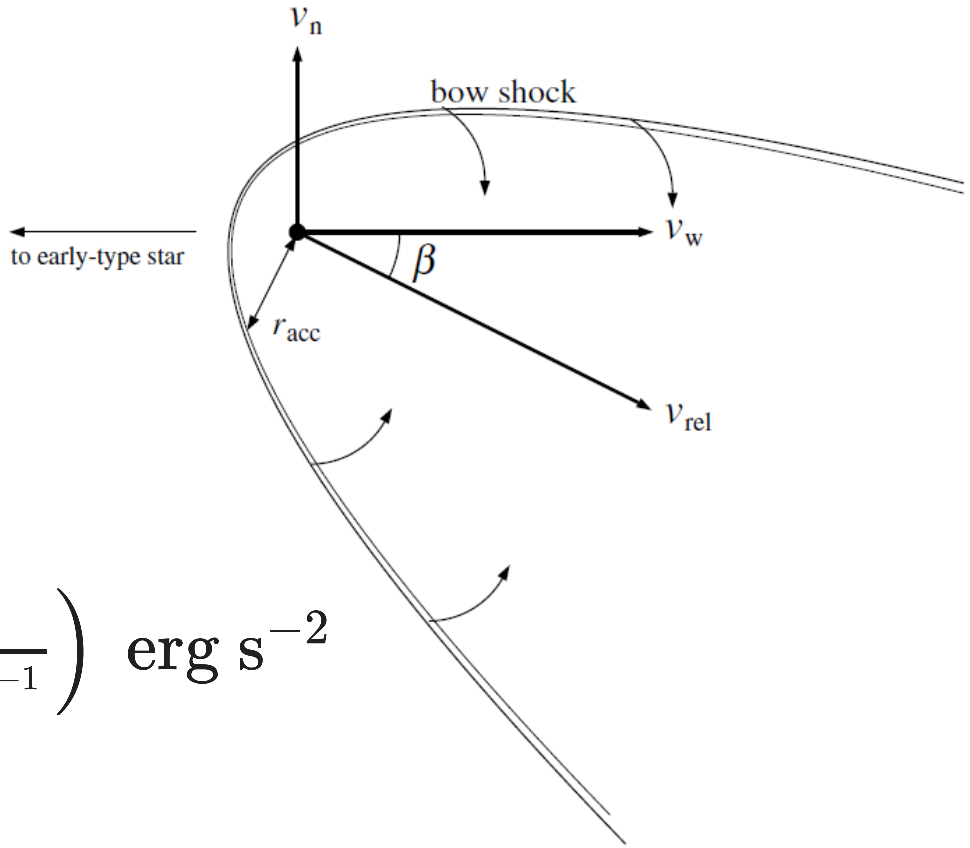
$$\frac{\dot{M}}{-\dot{M}_{\rm w}} \approx \frac{1}{4}\left(\frac{M_{\rm n}}{M_{\rm E}}\right)^2\left(\frac{R_{\rm E}}{a}\right)^2$$

in a cylindrical region of $r \approx 2GM_{\rm n}/v_{\rm rel}^2$

which gives luminosity of the order of

$$L_{\rm acc} \approx 10^{37}\left(\frac{\dot{M}}{-10^{-4}\dot{M}_{\rm w}}\right)\left(\frac{-\dot{M}_{\rm w}}{10^{-5}M_{\odot}\ {\rm yr}^{-1}}\right)\ {\rm erg\ s}^{-2}$$

which is mainly emitted in X-rays



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The circularization radius is $\frac{R_{\rm circ}}{a} = \frac{M_{\rm n}^3(M_{\rm n}+M_{\rm E})}{16\lambda^4(a)M_{\rm E}^4}\left(\frac{R_{\rm E}}{a}\right)^4$ with $\lambda(r) \approx \frac{v_{\rm w}^2}{v_{\rm esc}^2} \approx 1$

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The unceraintty in λ makes it hard to estimate whether the circulaization radius is large enough for a disk to form.

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- Asynchronous rotation of the donor or eccentric orbits - irregular accretion. Short-lived phenomena as tidal forces tend to circularize everything
- Irradiation by the luminocity resulting from accretion can further boost the process and make it self-sustainable. Can possibly stimulate wind loss.
- In supersoft binaries (accretor is WD) accretion process can be boosted by a factor of ~40 by steady nuclear burning at the surface.

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Thank you!