Getting started

The Legolas code can be found on GitHub, installation instructions are on the website. Make sure to look at the prerequisites for both Legolas and Pylbo first before running the code.

1 Equilibria

Below is a list of possible setups that can be implemented in the user submodule. We've added a reference figure together with the link to the original work so you can check your implementation and compare with known results.

1.1 Internal kink modes in force-free magnetic fields

This setup is taken from Goedbloed (2018) and corresponds to a cylindrical equilibrium with a force-free magnetic field of constant α and profiles given by

$$\begin{aligned} \rho(r) &= \rho_0\left(1-x^2\right) & \rho'(r) &= -\frac{2\rho_0}{a}x \\ v_z(r) &= v_{03}\left(1-x^2\right) & v_z'(r) &= -\frac{2v_{03}}{a}x \\ B_\theta(r) &= J_1(\alpha x) & B_\theta'(r) &= \frac{\alpha}{2a}\left[J_0(\alpha x)-J_2(\alpha x)\right] \\ B_z(r) &= J_0(\alpha x) & B_z'(r) &= -\frac{\alpha}{a}J_1(\alpha x) \\ T(r) &= \frac{p_0}{\rho(r)} & T'(r) &= \frac{2rp_0}{a^2\rho_0(1-x^2)^2} \end{aligned}$$

where $x = r/a$ and a denotes the outer wall of the cylinder.

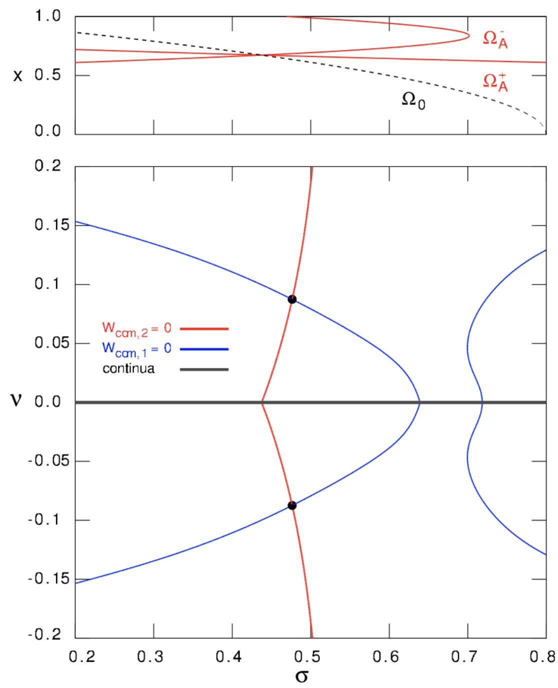

Figure 1: Values $\rho_0 = v_{03} = p_0 = a = m = 1$, $\alpha a = 5$, $k = 0.16\alpha$, incompressible.

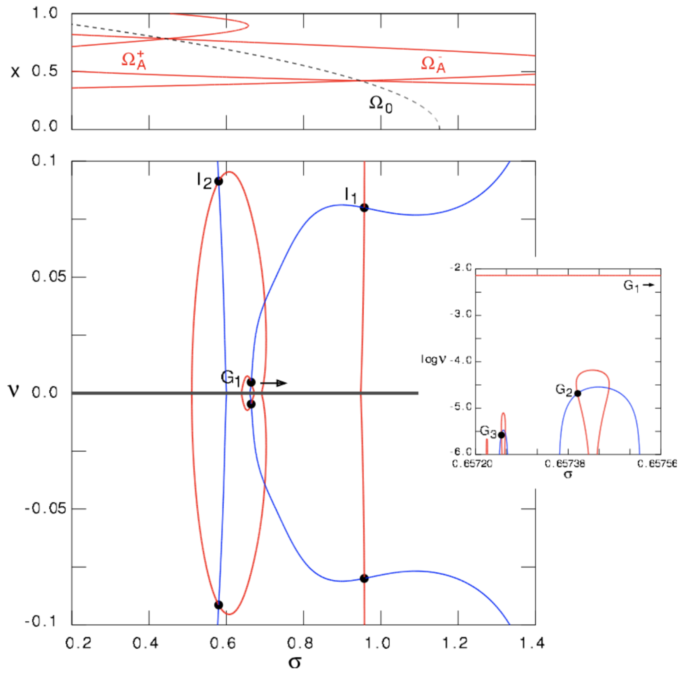

Figure 2: Values $\rho_0 = p_0 = a = m = 1$, $v_{03} = 0.8$, $\alpha a = 8$, $k = 0.16\alpha$, incompressible.

1.2 RTI in rotating theta-pinches

This setup is taken from Goedbloed (2018) and corresponds to Rayleigh-Taylor instabilities in rotating theta-pinches. Introducing the following quantities

$$x = \frac{r}{a} \qquad f_x = \alpha^2 \left(x^2 - r_0^2\right) \qquad f_x' = \frac{2\alpha^2 x}{a}$$

where a denotes the cylinder wall and $r_0 = 0$ in this case. The equilibrium is then given by

$$\begin{aligned}
\rho(r) &= \frac{\rho_0}{\cosh^2(f_x)} & \rho'(r) &= \frac{-2\rho_0 f_x' \tanh(f_x)}{\cosh^2(f_x)} \\
v_\theta(r) &= \Omega r & v_\theta'(r) &= \Omega \\
B_z(r) &= B_\infty \left[\delta + (1-\delta)\tanh(f_x)\right] & B_z'(r) &= \frac{B_\infty \,(1-\delta)\, f_x'}{\cosh^2(f_x)} \\
T(r) &= \frac{p_0}{\rho_0}
\end{aligned}$$

where

$$p_0 = \frac{1}{2}(1-\delta)^2, \qquad B_\infty = a\sqrt{\rho_0}, \qquad \Omega = \alpha\sqrt{2\delta(1-\delta)}$$

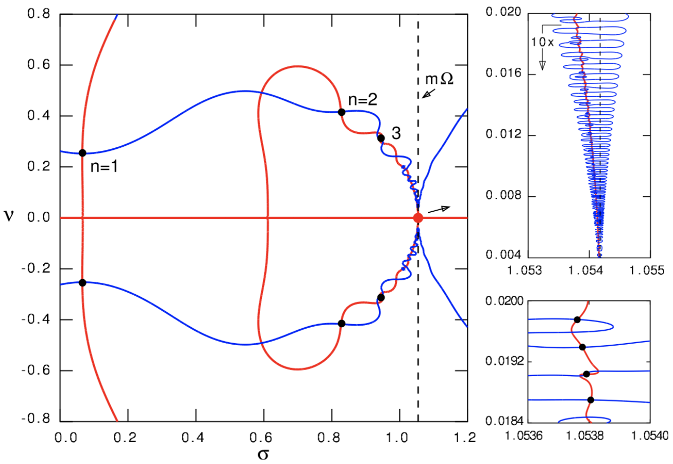

Figure 3: Values $\rho_0 = a = m = 1$, $\alpha = 2$, $\delta = 1/6$, $k = 0$ (hydrodynamics), incompressible.

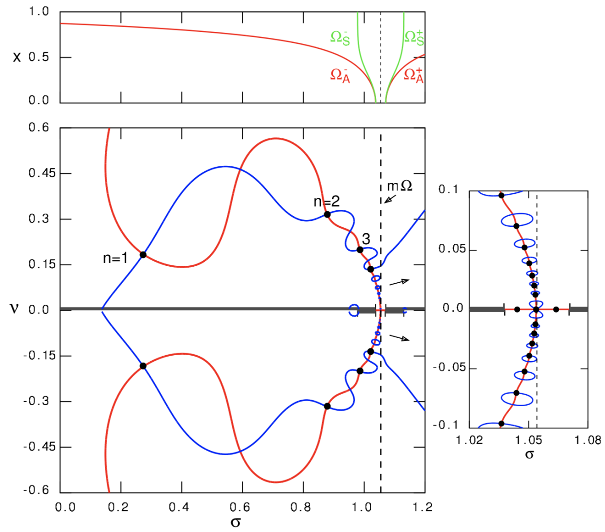

Figure 4: Values $\rho_0 = a = m = 1$, $\alpha = 2$, $\delta = 1/6$, $k = 0.1$ (magnetohydrodynamics), incompressible.

1.3 Magneto-rotational instabilities in accretion disks

This setup is taken from Goedbloed (2018) and models magneto-rotational instabilities in accretion disks. Legolas can model an accretion disk by assuming a cylindrical geometry and letting the grid start from a non-zero value, that is, $r \in [r_0, R]$. In what follows the parameter δ denotes R/r_0. The equilibrium is given by

$$\begin{aligned} \rho(r) &= r^{-3/2} & \rho'(r) &= -\frac{3}{2}r^{-5/2} \\ p(r) &= p_1 r^{-5/2} & p'(r) &= -\frac{5}{2}p_1 r^{-7/2} \\ v_\theta(r) &= \Omega_1 r^{-1/2} & v_\theta'(r) &= -\frac{1}{2}\Omega_1 r^{-3/2} \\ B_\theta(r) &= B_{\theta 1} r^{-5/4} & B_\theta'(r) &= -\frac{5}{4}B_{\theta 1} r^{-9/4} \\ B_z(r) &= B_{z1} r^{-5/4} & B_z'(r) &= -\frac{5}{4}B_{z1} r^{-9/4} \\ g(r) &= \frac{1}{r^2} \end{aligned}$$

where

$$p_1 = \epsilon^2, \qquad B_{z1} = \sqrt{\frac{2p_1}{\beta(1+\mu_1^2)}}, \qquad B_{\theta 1} = \mu_1 B_{z1}, \qquad v_{\theta 1} = \sqrt{1 - \frac{5}{2}p_1 - \frac{1}{4}B_{\theta 1}^2 - \frac{5}{4}B_{z1}^2}$$

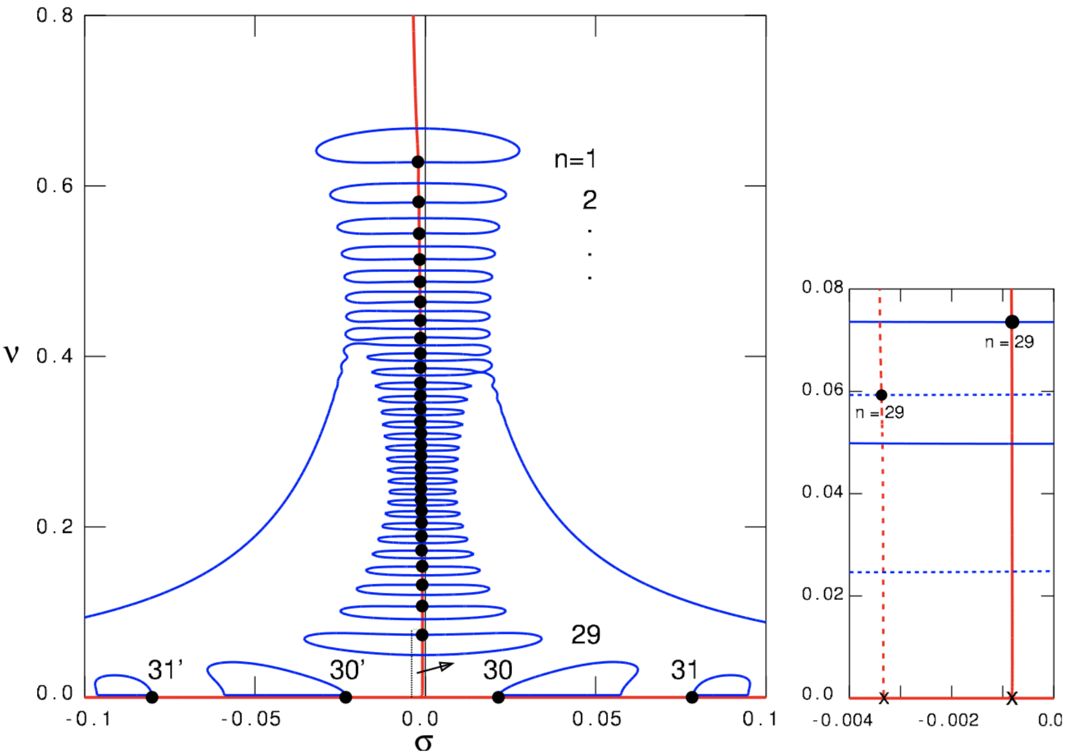

Figure 5: Values $m = 0$, $k = 70$, $\beta = 100$, $\mu_1 = 1$, $\epsilon = 0.1$ and $\delta = 2$.

1.4 RTI in magnetised plasmas

This setup is taken from Goedbloed, Keppens, and Poedts (2019) and corresponds to pure Rayleigh-Taylor instabilities in a Cartesian slab with a unidirectional magnetic field and linear velocity profile. The equilibrium for $0 \leq x \leq 1$ is given by

$$
\begin{aligned}
\rho(x) &= \rho_0(1-\delta x) & g(x) &= g_0 \\
p(x) &= p_0 - g_0\left(x - \frac{1}{2}\delta x^2\right) & \rho'(x) &= -\rho_0\delta \\
& & p'(x) &= -g_0(1-\delta x) \\
v_y(x) &= \xi(x)\sin\theta & v_y'(x) &= \xi'(x)\sin\theta \\
v_z(x) &= \xi(x)\cos\theta & v_z'(x) &= \xi'(x)\cos\theta \\
B_y(x) &= \sin\phi(x) & B_y'(x) &= \alpha\cos\phi(x) \\
B_z(x) &= \cos\phi(x) & B_z'(x) &= -\alpha\sin\phi(x)
\end{aligned} \tag{1}
$$

with

$$
\xi(x) = v_0 + v_1\left(x-\frac{1}{2}\right) + v_2\sin\left[\tau\left(x-\frac{1}{2}\right)\right], \qquad \xi'(x) = v_1 + v_2\tau\cos\left[\tau\left(x-\frac{1}{2}\right)\right],
$$

$$
\phi(x) = \phi_0 + \alpha\left(x - \frac{1}{2}\right)
$$

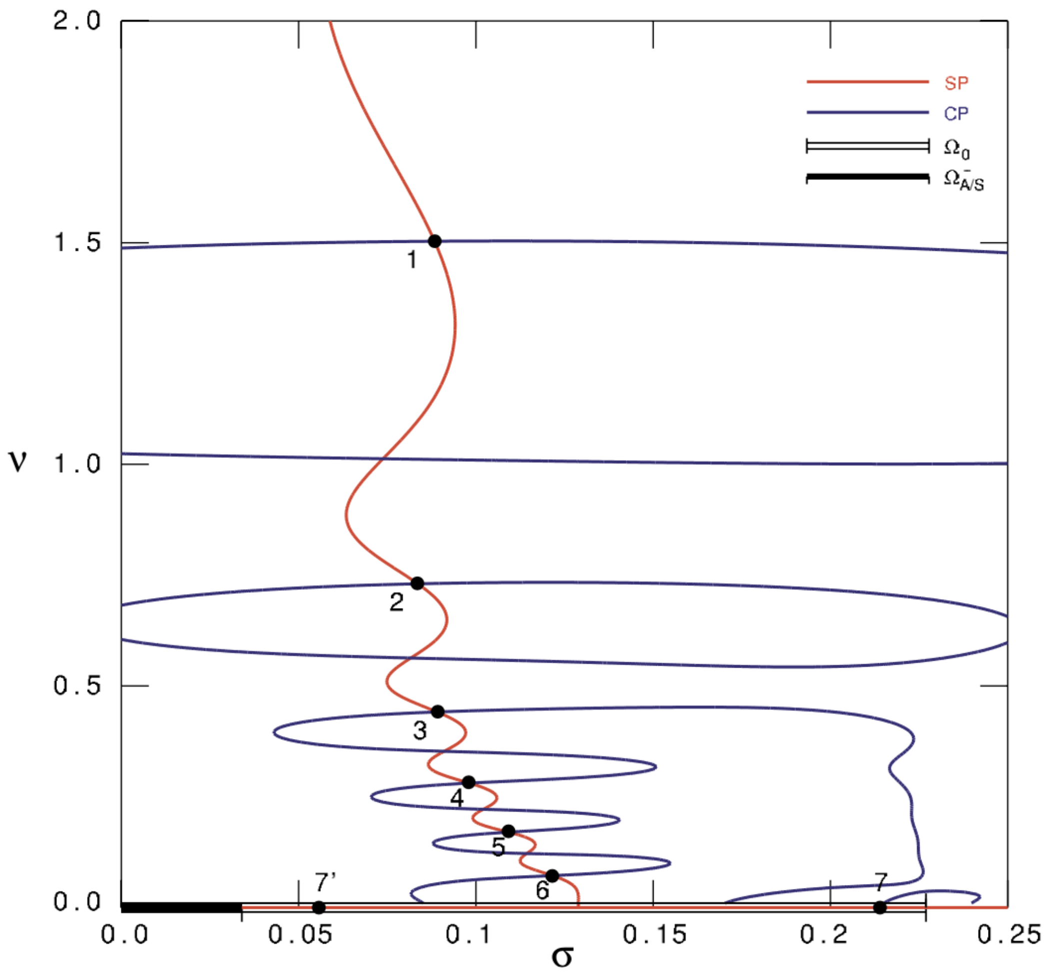

Figure 6: Values $k_y = 0$, $k_z = 1$, $\delta = -5$, $g_0 = 15$, $\rho_0 = 1$, $p_0 = 10^3$, $\phi_0 = -0.35\pi$, $\alpha = 0$, $\theta = 0.35\pi$, $v_0 = 0.2$, $v_1 = 0.6$, $v_2 = 0$, $\tau = 0$.

1.5 KHI in hydrodynamics

This setup uses the same equilibrium prescription as (1) but with different parameters, which corresponds to Kelvin-Helmholtz instabilities of a stationary fluid with a sinusoidal velocity profile.

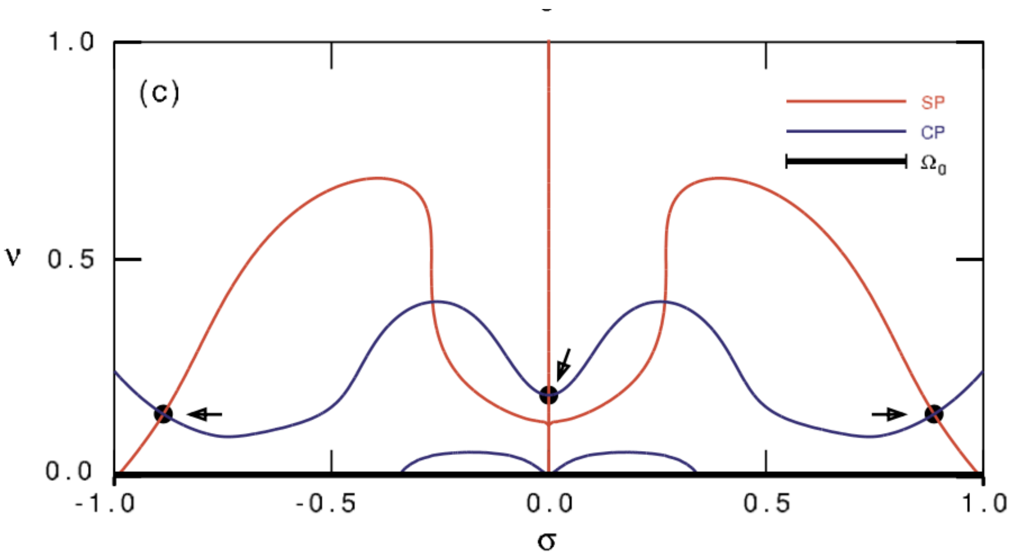

Figure 7: Values $k_y = 0$, $k_z = 1$, $\delta = 0$, $g_0 = 0$, $\rho_0 = 1$, $p_0 = 10^3$, $\phi_0 = 0$, $\alpha = 0$, $\theta = 0$, $v_0 = v_1 = 0$, $v_2 = 1$, $\tau = 11$.

References

Goedbloed, H., Keppens, R., Poedts, S.: 2019, *Magnetohydrodynamics of Laboratory and Astrophysical Plasmas*, Cambridge University Press, Cambridge, UK. DOI.

Goedbloed, J.P.: 2018, The Spectral Web of stationary plasma equilibria. II. Internal modes. *Physics of Plasmas* **25**, 032110. DOI. ADS.