A toy model of the solar wind dynamics around 67P/CG

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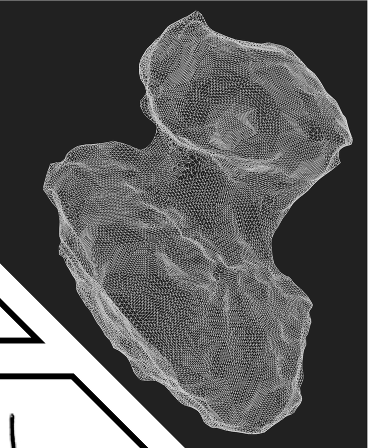
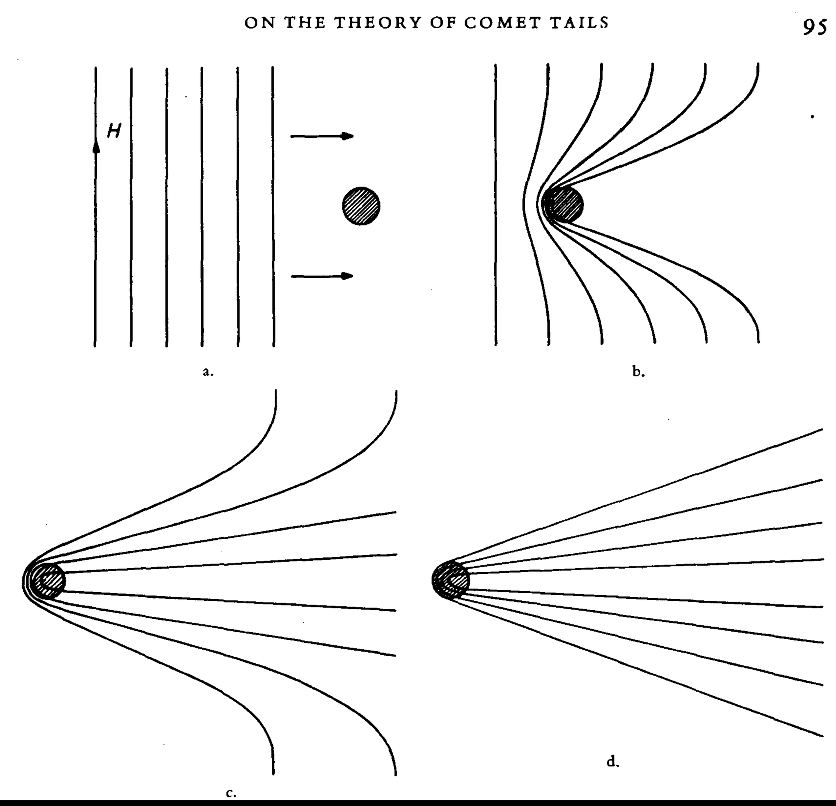


We propose a 2D toy model for the solar wind dynamics around a weak comet.

How much this dynamics can be simplified without losing the main structures seen either in observations or in elaborated hybrid model simulations?

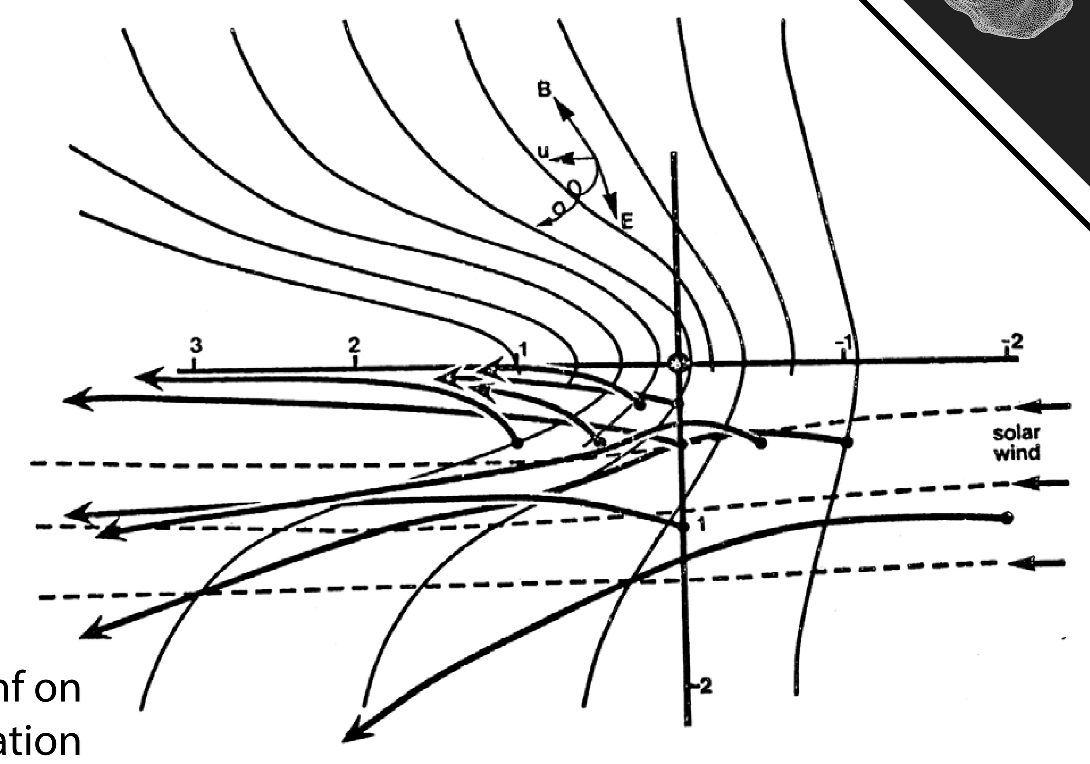
Can we get a tool, very cheap computationnaly wise, that can provide us with basic illustrations of the solar wind dynamics, for different levels of activity?



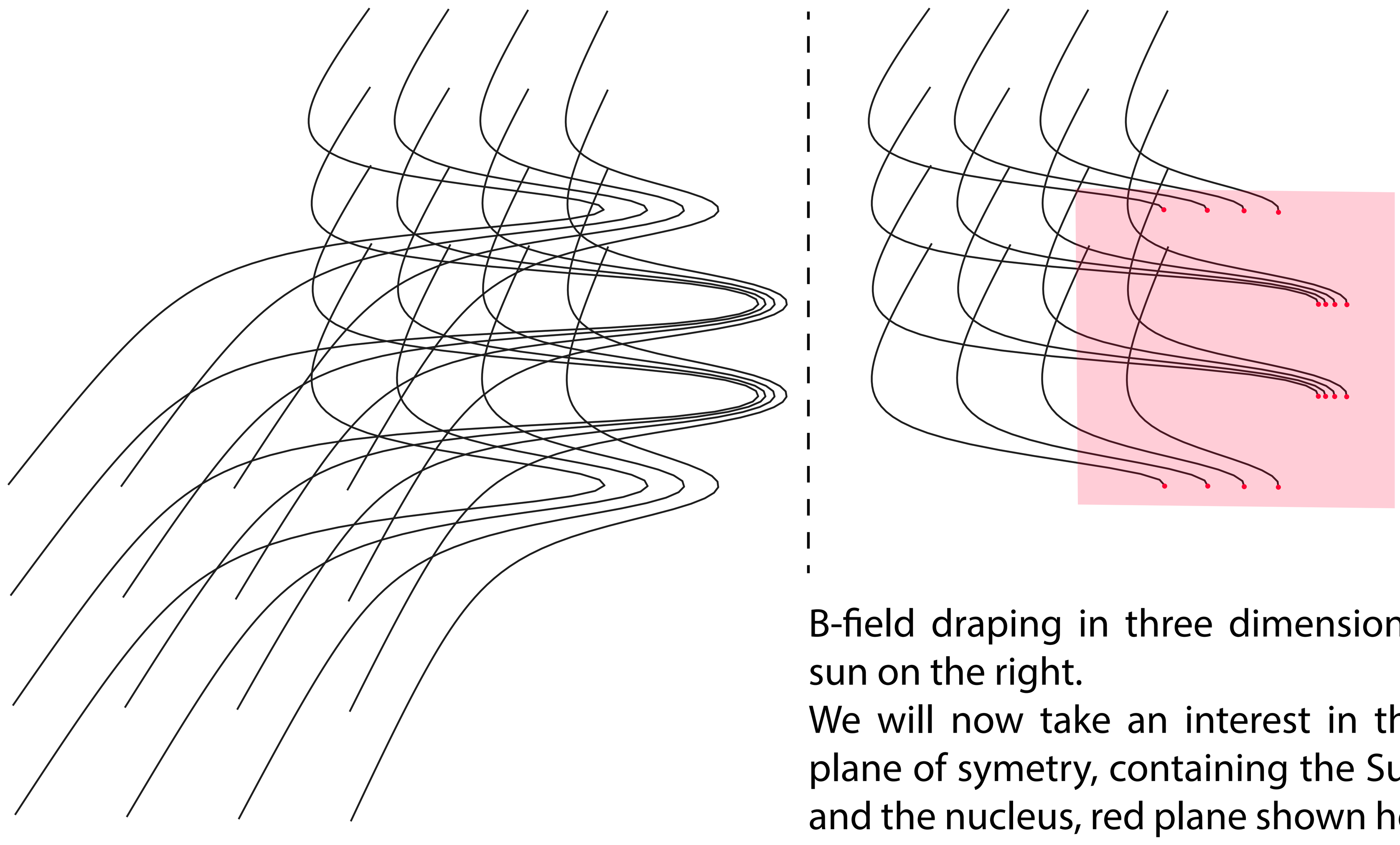
H. Alfvén, 1957, Tellus IX

In 1957, H. Alfvén introduced the concept of magnetic field draping at comets, as illustrated here on the left. This draping corresponds to an enhancement of the B-field amplitude within and close to the coma.

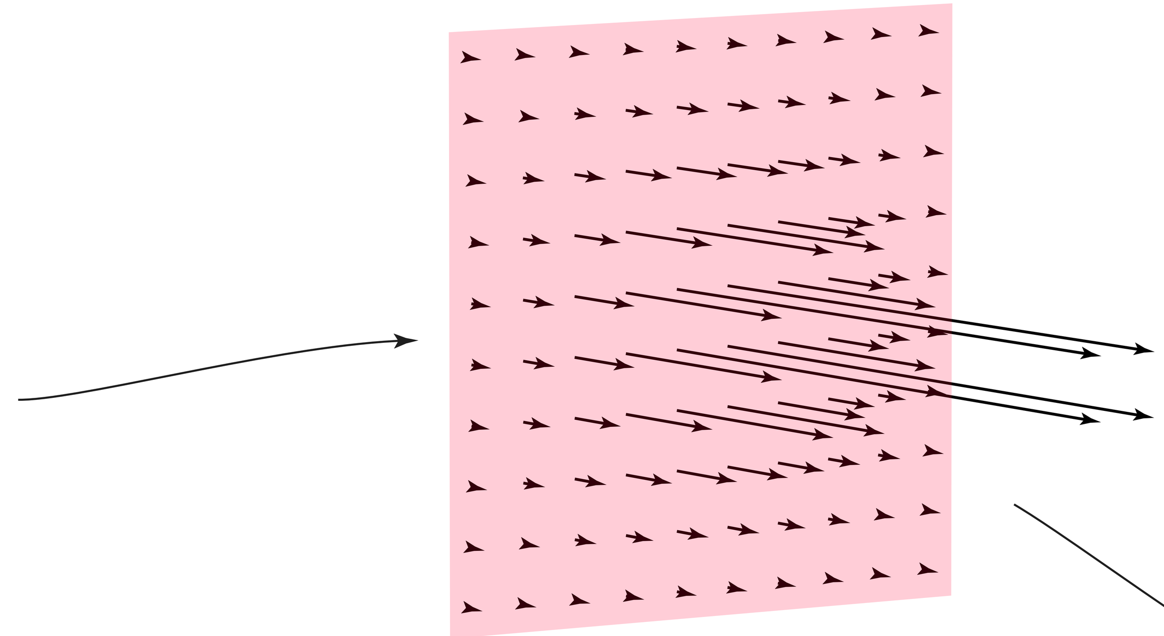
In 1982, M. Wallis proposed an analytical expression of this field draping, illustrated on the right.



M. Wallis, 1982, Proc. Int. Conf on Cometary Exploration



B-field draping in three dimensions, sun on the right.
We will now take an interest in the plane of symetry, containing the Sun and the nucleus, red plane shown hereabove.



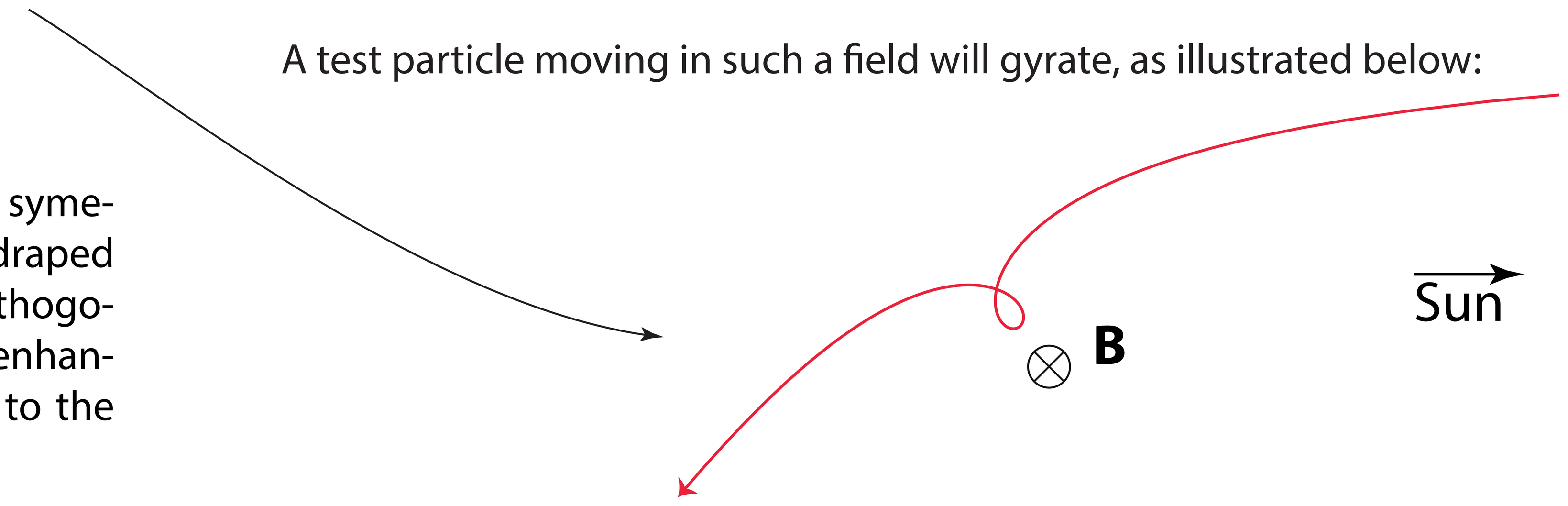
In this plane, because of the symetry assumed for an ideal draped field, the field vectors are orthogonal to the plane, with a local enhancement of the strength due to the B-field pile-up.

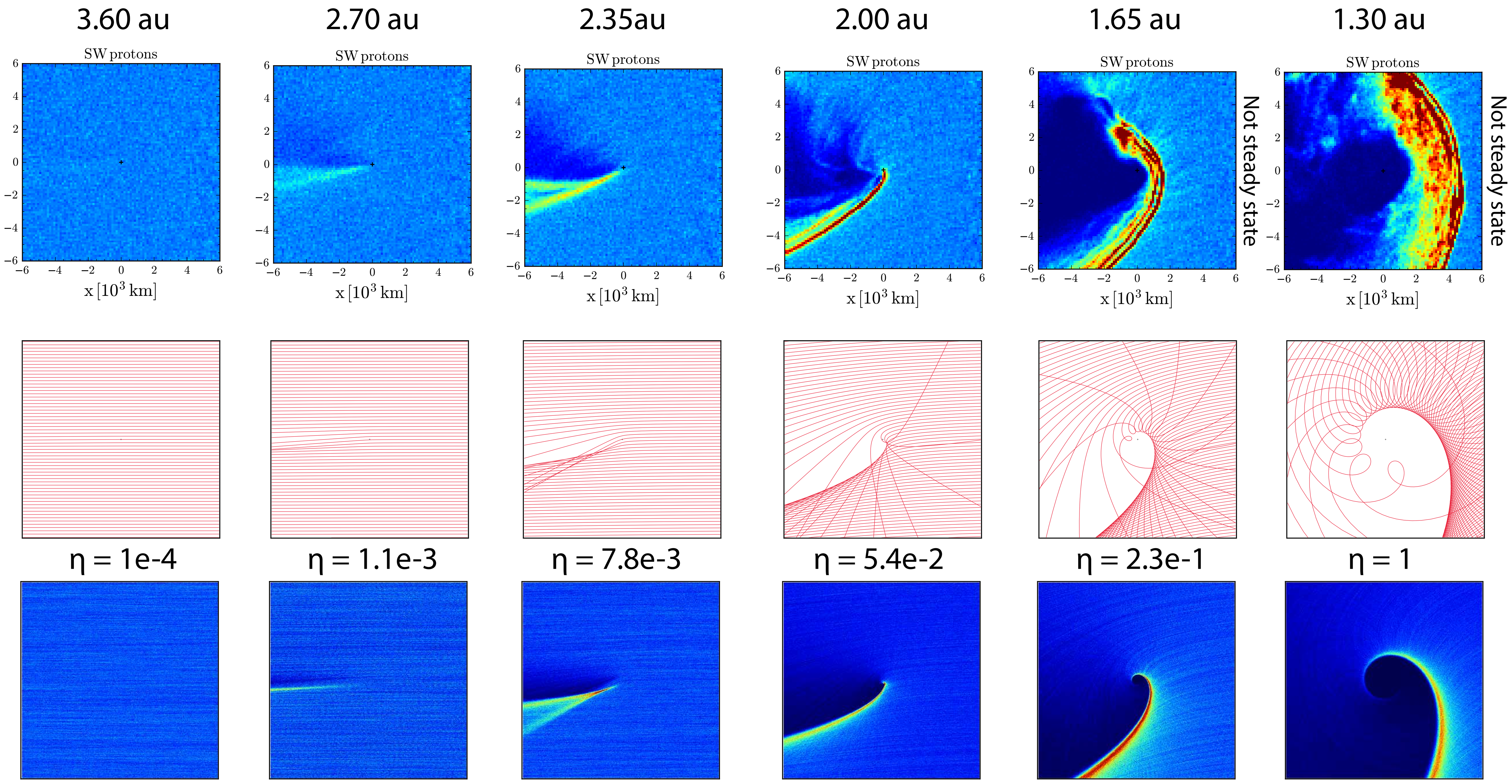
Based on this basic picture here on the left: we launch test particles from upstream in this 2D plane, in a magnetic field orthogonal to the plane and with an amplitude function of the distance to the center (nucleus). The amplitude follows:

$$|\mathbf{B}| = \eta/r^2, \quad \eta \in \mathbb{R}$$

This is a purely arbitrary choice, a first attempt! It can be also interpreted with a very simplistic consideration: the denser the ionised coma is, the more momentum is taken from the solar wind, *i.e.* the more it is deflected.

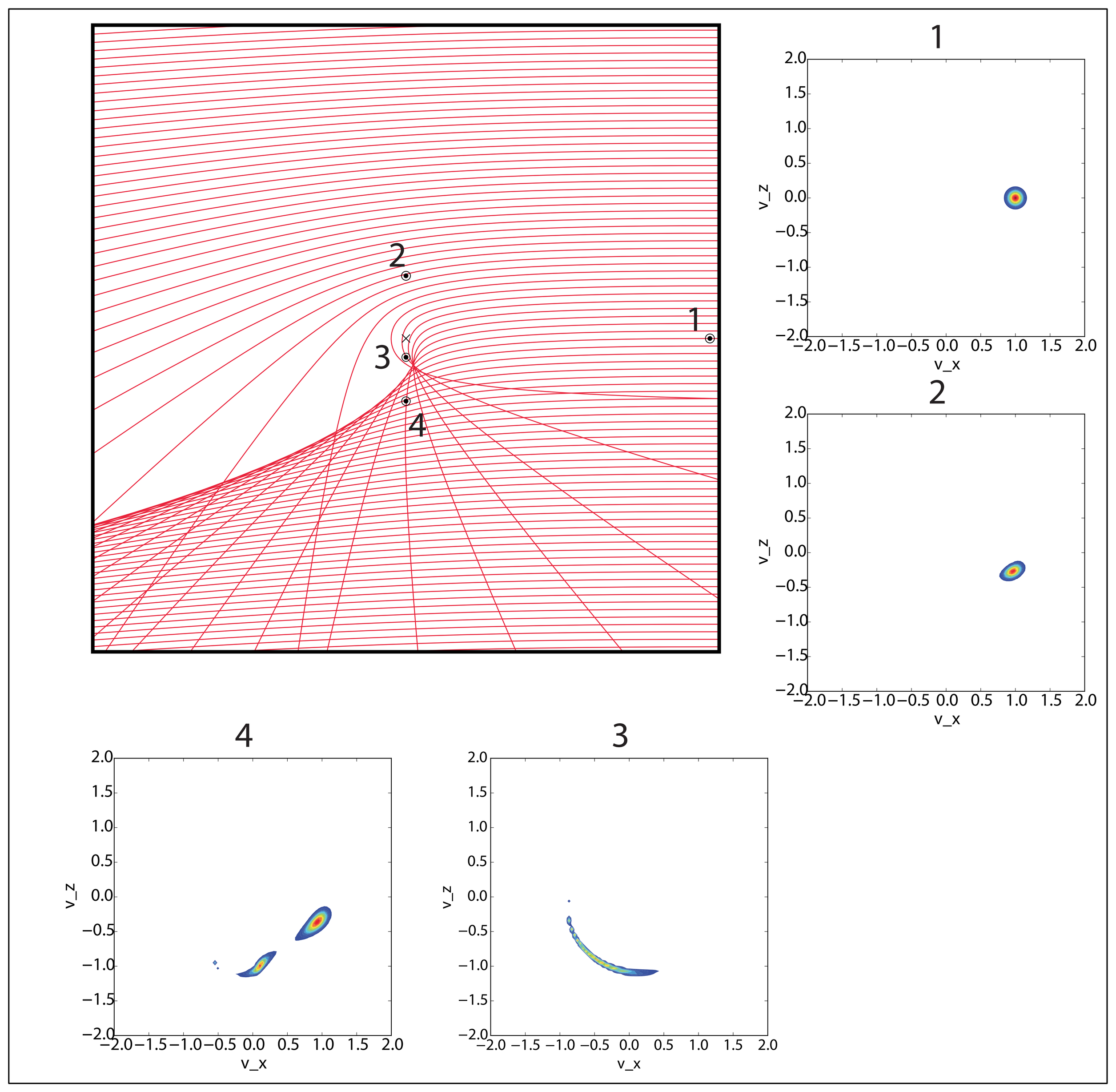
A test particle moving in such a field will gyrate, as illustrated below:





Above: The first row presents solar wind density in the same (x,z) plane, Sun on the right, from hybrid model simulations for 67P/CG. The heliocentric distance is decreasing towards the right.
The second row presents test particle trajectories based on the toymodel, with an increasing value of η with decreasing heliocentric distance.
The last row presents the same test particle runs, now as density maps. The value of η is visually fitted to the hybrid results.

If the choice of such a simplistic and unphysical magnetic field is to a very large extent arbitrary, the comparison with an elaborated model is surprising. For large to medium heliocentric distances, we get very similar density structures. Closer to the Sun however, the simplistic model breaks down. The effects induced from the cometary ion dynamics are significantly adding up below ~2 au, which cannot be reproduced by such a simple model.



Above: velocity distributions from the toy model. Already at low/-medium activity, distributions can get significantly distorded, which has to be taken into account when analysing data.

Future work:

- Add physics!
- Extend to 3D
- Further comparison between observations, hybrid model, and toy model.