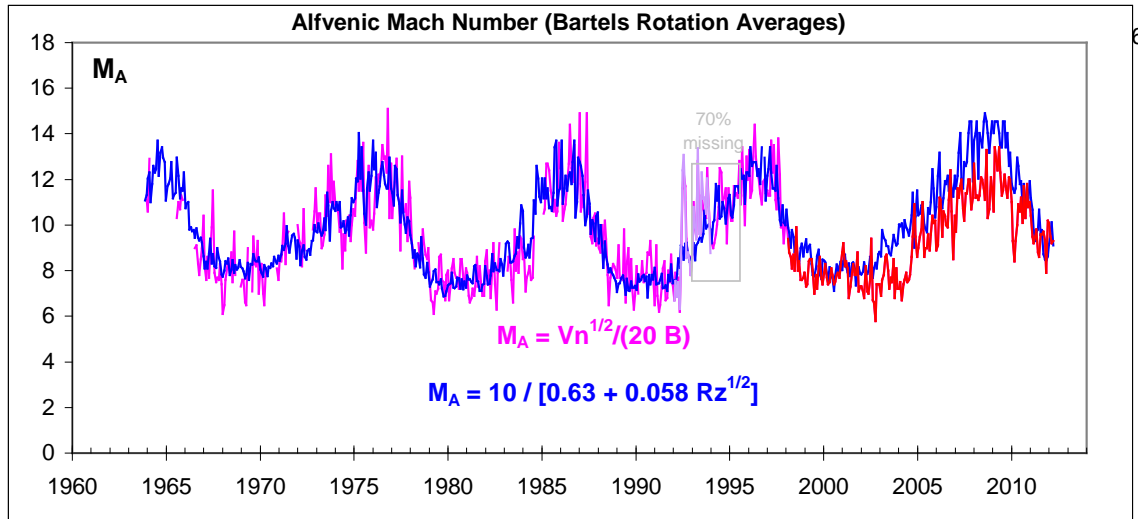


Alfvenic Mach number variation

Here is an interesting plot:

<http://www.leif.org/research/Alfvenic-Mach-Number.png>



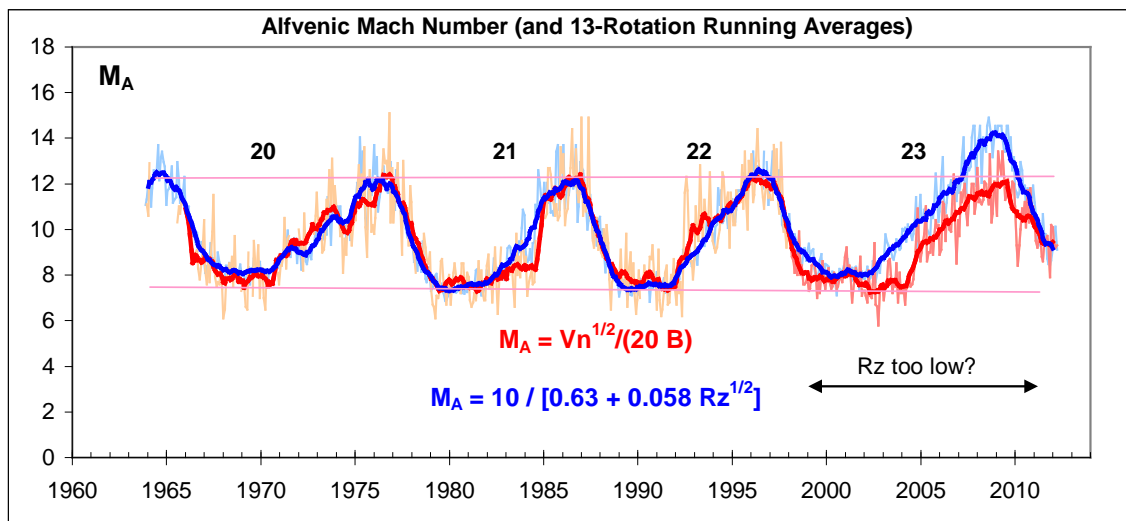
Just as for sound waves in air, there is a concept of 'supersonic' flow [an airplane going at Mach 2, for instance] in the solar wind as well. The speed with which hydrodynamic waves can propagate is called the Alfven speed [after Hannes Alfven who first figured this out]. In the solar wind this speed is about 40 km/s. Since the solar wind is moving at 400 km/s which is 10 times the Alfven speed we can say that its Alfvenic Mach number M_A is $400/40 = 10$. With the units commonly used in solar wind studies, M_A can be computed from $M_A = V * \text{sqrt}(n) / (20 * B)$, with speed V in km/sec, n density in protons per cubic centimeter, and magnetic B in nanoTesla, and is shown in the Figure as the pink (and red) curve. As these parameters vary over time and with the solar cycle, the Alfvenic Mach number, M_A , will also vary as shown in the Figure. You can see a clear solar cycle variation, with M_A being lowest at solar maximum and largest at solar minimum. One can formalize this relationship as shown by the blue formula: $M_A = 10 / [0.673 + 0.0538 \text{sqrt}(Rz)]$, where Rz is the [Zurich or International] Sunspot Number. This relationship is derived from a least squares fit of the data before 2002. The fit during 1993-1994 is less good because of large data gaps [70% of the data missing - due to no satellite being in the solar wind at most of that time interval]. Using the relationship one can with good approximation *calculate* the Alfvenic Mach Number from the Sunspot number. We do that now for the whole period up to the present, the blue curve continuing and one would expect the observations to 'cling' to the blue curve just as the pink curve did. This is clearly not the case, the observation since 2002 being plotted in red and clearly falling below the expected values.

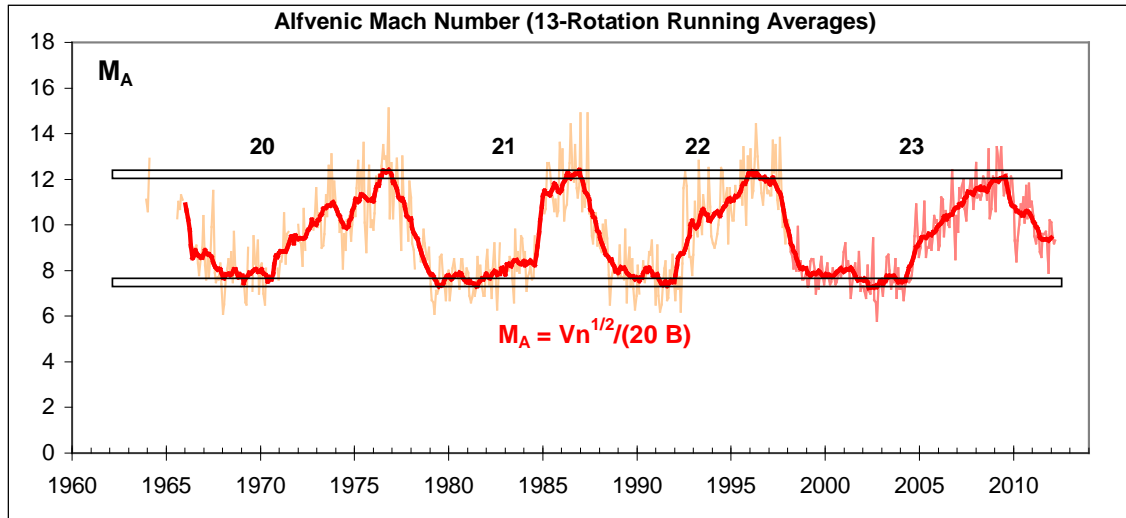
Several hypotheses can now be made:

- 1) the relationship somehow changed. This is unlikely as those things are fundamental plasma properties that eventually are derived from solar magnetism.
- 2) since the observed values are too low, it could be that the magnetic field, B , is too high for some reason as it occurs in the denominator. The excellent agreement between B measured by spacecraft and that derived from geomagnetic activity argues against B being wrong.
- 3) the solar wind speed V could be too low. The excellent agreement between V measured by spacecraft and that derived from geomagnetic activity argues against V being wrong.
- 4) the density, n , could be too low
- 5) since the expected M_A [blue line] depends on the sunspot number in the denominator, it will appear too large [hence the red curve too low] if the sunspot number is wrong [too low] from 2002 onwards
- 6) something completely different or multiple errors just conspiring to fool us

My assessment is that either (4) or (5) or both are the culprits. The good news is that we are beginning to understand the physics of all this to the point where we can *demand* that everything **must** fit, so such discrepancies become important clues rather than just annoying noise.

There is a version with smoothed data:





There is a clear solar cycle variation of the Mach number, but it is remarkable that the amplitude of the variation is the same in every cycle, *independent* of the amplitude of the sunspot number cycle. It is also clear that at the time of writing [end of June 2012] we are not yet at solar maximum, where the Mach number reaches its minimum value.