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Subject: filaments!
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hi Alan & Mark --

(I'm sending a copy of this, as well, to Mark; hoping he has a standard email address.)

So, you want to know about filaments, do you? Well, I've been trying to think of references to start you off -- this is hardly a well-developed area, altho' it touches on some very detailed MHD/plasma areas. So here goes.

First, a caveat: I don't find Parker's big book much help to learn from. He does have a lot of information in there, true; but his ratio of words to useful facts is so large, I have rarely gotten much from him.

In general -- as we were speaking about, I think there are three areas which may be, or have been suggested as, the origin of the filaments.

1. Synchrotron cooling instability. This was discussed at some length in Hines etal (1989; and the reference to the original work by Eilek & Caroff, ~ 1979, should be in there). The only other discussion that I'm aware of is in a series of papers by the Argentinians -- Opher, dal Pino & others. They argue for *bright* filaments, & they & I went around & around over their first paper (I was the referee) -- they didn't seem to have thought about the cooling effects on the luminosity, to start -- they then did work out some time evolution models, which found, as I recall, some luminosity enhancement at the start of the collapse, then eventual darkening. After the referee battle, I didn;t have the strength to read the rest of the series -- but they are all in MN over the past few years. You can see my prejudices here; I still don't think this is the right answer.

References: Hines etal; Opher/dal Pino papers in MN.

2. Strong MHD turbulence. "Strong" means transonic, in order to get the (delta B) / B enhancement up to useful levels, to boost the emissivity by the factor-of-a-few-or-more that one sees. This means it has to be driven -- which is probably not much of a problem, there is lots of directed kinetic energy about. However I don't know how to go very much further in quantifying this one. As I mentioned, along with Judy Karpen & Russ Dahlburg at NRL I started to use their commpressible MHD code to track synchrotron enhancements in driven transonic MHD turb; I have a few results sitting on my floor, somewhere, but none of us have followed up on this as yet. If you want starter references here, I'd have to give you a few Phys. Fluids references, & dig out the plots from the stack on the floor -- let me know if you want to do that. And, note, these simulations won't address synchrotron aging, spectral index, or things like that; they will address the B-field enhancement & the gas-B field mixing.

references: ask me for specific Phys. Fluids papers if you want.

3. Resistive instabilities & reconnection. These all start as what I call surface instabilities -- needing a current sheet, which might well

occur at an interface (between the lobe & the ambient medium? at the edge of a jet?). The current sheet is unstable to filamentation -- bunching together of the current into flux ropes/filaments. Its also unstable to interchange mode, if there's a local acceleration -- I sort of picture the surface rippling, & developing "wiggles" which may become flux ropes. Now, these are "resistive", because the plasma must have a finite diffusivity (resistivity^{-1}); this allows the plasma to cross the field lines, thereby bunching the field lines together. This goes on a fairly slow timescale -- the one I referenced in Hines etal. (My emendation to that paper, thinking about it again currently, is that I may have taken the length scale too long -- if some dynamical process thinned out the current sheet, it might have gone faster than I estimated there).

Now, the contentious part. I gave you Zun-Hui Zhao's preprint, in which he suggested that fast reconnection can be the answer. Since I saw you, I read Fang Zhou's MS thesis, also addressing M87, & Fang used Zun-Hui's idea to explain the M87 filaments. So, that got me thinking, & I've gone back into the literature a bit. The problem is, I do not believe that fast reconnection leads to filaments -- I see no evidence for it in the literature I've found. It seems to lead simply to energy release & mass outflow. Situations which develop "magnetic islands", aka flux ropes or filaments, that I've found all go on the slower, tearing time scale. For the purpose of Fang's thesis, I'm going to suggest that he say "Zhao suggests this model, but the case isn't closed yet". . . which both gets Fang through, since this is a small part of his work, and is an attempt to be polite to someone else in the building. But on longer timescales, I have severe doubts about this; & will talk to Jun-Hui some more. I still think the tearing timescale (or the interchange timescale, as the case may be) is the right one.

references: harder here. I'd start with textbooks: ch. 7. of Priest, Solar Magnetohydrodynamics (Reidel, 1982); ch. 10 of Bateman, MHD Instabilities (MIT Press, 1978; a plasma-machine book); and ch. 15 of Parker, Cosmical Magnetic Fields, esp. sec. 15.8. Also a couple of recent reviews in conference proceedings: Priest, in Magnetic Reconnection in Space Plasmas (Geophysical Monograph 30, AGU, 1984; Ed. E. Hones; in the AOC library if you can't get it); and Biskamp in Magnetic Fields and Extragalactic Objects (Cargese workshop, 1987; ed. E. Asseo & D. Gresillon, Editions de Physique, French). Past this, its Phys. FLuids again, if you want more.

That's it for now -- I hope its a useful start. Since most of the material is really in the plasma literature, it takes some digging, & I can't promise that I haven't missed one really wonderful review . . .

cheers for now,

Jean