9.6 1/f noise

The universality of $1/f$ noise has fascinated many people. Following the citation trail forward for Press' article, on the NASA ADS database, shows that even within its purview there has been a lot published on the topic – and of course in the wider literature there is much, much more. Even amongst the citers of Press a pair of dominant themes are represented. One is the search for some generic microphysical mechanism for $1/f$ noise, involving some simple stochastic rules for state transitions. A paper in this genre is Davidsen & Schuster, *Phys Rev E*, **65**, 026120. The other theme is the emergence of $1/f$ noise from some kind of collective response of a system, for example the occurrence of avalanches in sandpile models. This leads to the field of self-organized criticality (probably connecting to astronomers' world via the related stochastic self-propagating star formation models). A starting point here is de los Rios & Zhang, *Phys. Rev. Lett.*, **82**, 472. Another line of thought alludes to connection between fractals and power-law spectra, and invokes the hierarchical nature of many real systems. In the case of music we can perhaps see, at least for classical music, how there might be some such structure in a piece.
Just what is the evidence for the presence of $1/f$ noise in music? The results of a quick survey of music and speech radio, based on 1-minute long recordings, are in Figure 1.

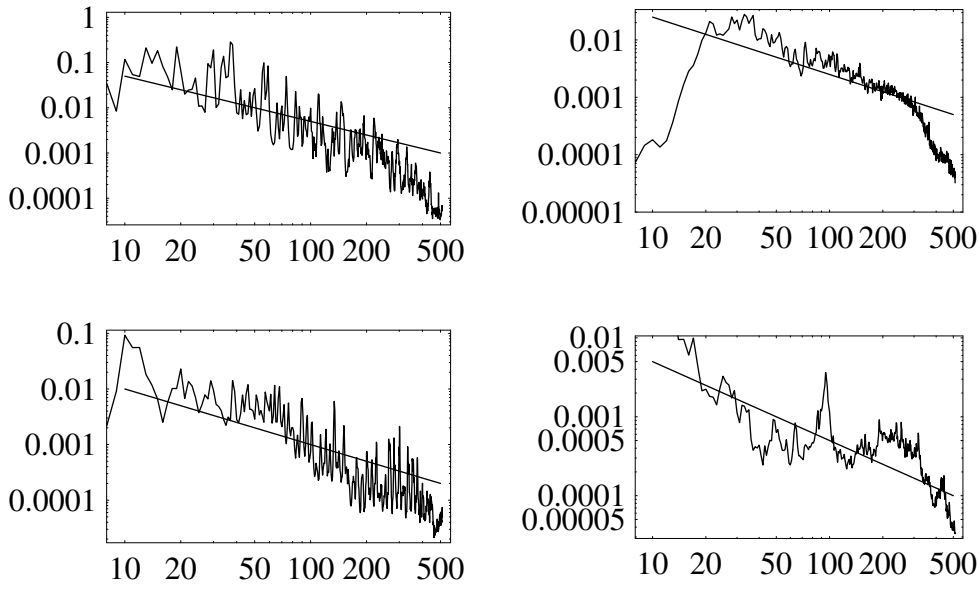

Figure 1: Power spectra of classical music (top left), lecture (top right), jazz (bottom left) and rock (bottom right), based on one-minute recordings. The solid line is a $1/f$ spectrum. The units of the axes are arbitrary.

There are some intriguing similarities and differences here; one might speculate that classical and jazz share structure, that rock is less organized (and shows its dominant beat

rather clearly!) and that speech comes in units on a couple of scales, which eliminates both long-range and short-range correlation.
However some caution is in order, because *amplitudes* convey only part of the story and it may not even be the significant part. If this is true then worrying about the universality of $1/f$ noise may be a bit of a distraction. To illustrate the point, suppose we take two images (Einstein, and the Mona Lisa) and then reconstruct the Einstein image with the correct phases but with the Mona Lisa's amplitudes; and the same in reverse for the Mona Lisa. The results are shown in Figure 2 and are quite instructive!
The same thing works in one dimension. Classical music can be recovered quite recognizably, using its phases and the amplitudes from the rock music. So while it may be true that the hierarchical structure of music and speech leads to a power-law spectrum, in fact this encodes rather little of their distinctive nature. So $1/f$ spectra may be universal because they express such a general feature that it is not actually very interesting.

Figure 2: Top, original images. Bottom left, Einstein phases and Mona Lisa amplitudes; bottom right, Einstein amplitudes and Mona Lisa phases.