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Thermal Instability with Cosmic Ray Heating

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Observations have revealed clusters having high core densities; the cooling times of these clusters are much less than the Hubble time and should result in cooling flows, which were not seen. This means there is global heating supporting clusters from the cooling catastrophe. On the other hand, H-alpha observations have shown that despite being in global thermal equilibrium, cold gas do exist within clusters. Thus any heating mechanism proposed must not preclude the possibility of a local thermal instability. Cosmic ray heating has been proposed as a crucial candidate, and simulations including diffusive transport have demonstrated it can indeed support a globally stable atmosphere while allowing for local thermal instability. However, if cosmic ray transport were streaming dominated, we demonstrate that the bottleneck effect will redistribute the heating such that only the cold gas is heated. The hot gas will collapse from cooling, causing a cooling flow. This will have important implications to modeling cosmic ray transport in the ICM.

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