Models of Galaxy Clusters with Diffusive Heat Transport

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We present spherically-symmetric, steady-state models of galaxy clusters in which the hot gas maintains energy balance between radiative coolingand heat diffusion. We consider two diffusive transport processes: thermal conduction and turbulent mixing. In a conduction model, heat flux is proportional to temperature gradient multiplied by the electron conductivity that is assumed to be a fraction f of the Spitzer value.
In a turbulent mixing model, we adopt a mixing length prescription in which the heat flux is proportional to the local gradient of specific entropy, with a diffusion coefficient parameterized by a dimensionless constant $\alpha_{\rm mix}$. Models with either $f\sim0.3$ or $\alpha_{\rm mix}\sim0.01-0.03$ give reasonably good fits to the observed density and temperature distributions of typical cooling flow clusters, although the pure conduction model requires $f>1$ for some clusters with strong central activities. Both models are shown to be practically stable to thermal instability. Assuming that $\alpha_{\rm mix}$ is constant over a wide variety of clusters, the turbulent mixing model reproduces remarkably well the observed scalings of X-ray luminosity, gas fraction, and entropy with temperature. The break in the scaling relations at $kT\sim1-2$ keV is explained by the break in the cooling function at around this temperature, and the entropy floor observed in galaxy groups is reproduced naturally.
We conclude that turbulent mixing and perhaps thermal conduction as well should be taken seriously in the thermodynamical evolution of galaxy clusters.