DAMOP14-2014-000040
Abstract for an Invited Paper
for the DAMOP14 Meeting of
the American Physical Society

## Transverse Spin Diffusion

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Transverse spin diffusion is a relatively new transport coefficient and a review of its history and physical basis will be presented. In NMR spin diffusion is often measured by spin echo techniques, which involve spin currents perpendicular to the direction of the magnetization, in contrast with the usual longitudinal case where the current is parallel to the magnetization. The first indication that this involved new physics was the Leggett-Rice effect (1970) in which spin waves, new spin-echo behavior, and an altered spin diffusion coefficient were predicted in liquid $^3$He. This effect gave the possibility of the first measurement of $F_1^a$, the parameter of the Landau Fermi-liquid theory mean-field responsible for the effect. In 1982 Lhuillier and Laloe found a transport equation very similar to the Leggett equation, but valid for highly-polarized dilute Boltzmann Bose and Fermi gases, and describing the "identical spin rotation effect" (ISRE), the analog of a Landau mean field. Coincidentally Bashkin and Meyerovich had also given equivalent descriptions of transport in polarized Boltzmann gases. That a mean-field effect could exists in dilute Boltzmann gases was theoretically surprising, but was confirmed experimentally. At low polarization the basic transverse diffusion constant $D_\perp$ coincides with the longitudinal value $D_\parallel$; however Meyerovich first pointed out that they could differ in highly polarized degenerate gases. Indeed detailed calculations (Jeon and Mullin) showed that, while $D_\parallel$ is proportional to $T^{-2}$, $D_\perp$ approaches a constant (depending on polarization) at low $T$. Considerable controversy existed until experimental verification was achieved in 2004. The importance of ISRE again arose in 2008 as the basis of "anomalous spin-state segregation" in Duke and JILA experiments. More recently application of the ideas of transverse spin diffusion to strongly interacting Fermi gases has resulted in the observation of the diffusion constants at the quantum limit where $D \sim \hbar/m$.