Abstract Submitted
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Asymmetric, Mirror-Symmetric and Helical Traveling Waves in Pipe Flow[1] CHRIS PRINGLE, RICH KERSWELL, University of Bristol — New families of three-dimensional nonlinear travelling waves are discovered in pipe flow. In contrast to known waves (Faisst & Eckhardt *Phys. Rev. Lett.* **91**, 224502 (2003), Wedin & Kerswell, *J. Fluid Mech.* **508**, 333 (2004)), they possess no discrete rotational symmetry and exist at significantly lower Reynolds numbers (Re). First to appear is a mirror-symmetric travelling wave which is born in a saddle node bifurcation at $Re = 773$ (the next lowest being the three-fold symmetric wave at $Re = 1251$). As Re increases, 'asymmetric' modes arise through a symmetry-breaking bifurcation. These look to be a minimal coherent unit consisting of one slow streak sandwiched between two fast streaks located preferentially to one side of the pipe. These travelling waves have higher upper branches and lower lower branches than any previously found, with the asymmetric branch being closest of all to the laminar state. Helical and non-helical rotating waves are also found emphasizing the richness of phase space even at these very low Reynolds numbers. The helical asymmetric wave is the first know travelling wave to possess no symmetries of any kind. The gap in Re from when the laminar state ceases to be a global attractor to turbulent transition is then even larger than previously thought.

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