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Coherent structures in wave turbulent transport - graph-theoretical approach

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Wave turbulence theory starts with the Euler equations for water with free surface in gravity field and falls into two parts - statistical (SWT) and discrete (DWT), describing wave systems with continuous and discrete vector space correspondingly. It means that SWT studies real solutions of the resonance conditions while DWT regards only their integer solutions. Statistical approach yields wave kinetic equation for wave spectra while discrete dynamics is presented by a few independent clusters of resonantly interacting waves, with no energy flow among the clusters. General opinion that discrete effects are only important for small wave vectors was broken quite recently when it was shown (2005) in the numerical simulations (capillary and surface water waves) that both regimes - statistical and discrete - co-exist all over the wave spectra, with majoring role of discrete interactions in the energy transport. Moreover, it was established in laboratory experiments (2006) that discrete effects are major and SWT predictions are never achieved while with increasing wave intensity the nonlinearity becomes strong before the system loses sensitivity to the vector space discreteness.

Theory of laminated wave turbulence (2006) allows to study the problems of statistical and discrete WT in the frame of one model, as two co-existing layers of turbulence. Having the understanding of the major role of discrete layer, one is naturally led to study the structure of the wave clusters providing the energy transport at this layer. We use graph-theoretical approach to 1) point out primary graphs; 2) present any cluster as a planar graph constructed of primary graphs; 3) write out the corresponding system of ODEs on the slowly changing amplitudes of the waves belonging to the cluster, 4) determine all isomorphic cluster graphs. In this way the study of turbulent transport covered by nonlinear PDE can be reduced to the study of a few special systems of ODEs accordingly to the form of corresponding cluster graphs. Primary/cluster graphs may coincide for different NPDEs which makes our approach quite general.