섭동의 한계를 넘어서
(Beyond Perturbation theory)

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Perturbation theory is an approximation method to solve dynamical equations in physics. As physical systems get more and more complicated, even with infinite degrees of freedom, the per- turbation theory has been a universally powerful theoretical tool. In a simple term, it is a series expansion of a small parameter in a similar way as an elementary mathematical approximation $\sin(x) \approx x$ when x is small.

Amazing successes of the 20th century physics can be attributed to the perturbation theory. In fact, it has been applied to all the four fundamental forces in nature including the strong force since its strength gets weak when quarks are very close. Therefore, it may seem that the perturbation theory is enough to understand most of physical phenomena. Quite on the contrary. Thanks to amazing advances of both experiments technologies and theoretical methods, a lot of "non-perturbative" physics are being discovered. One of the most important challenges in physics is to establish a new paradigm for this.

I will explain the integrability, which appears when a quantum system has infinite numbers of conserved charges, can do it by taking two examples. The first example is an excellent experiment with a cobalt compound which is a magnetic spin system described by Ising model with an external magnetic field. It realizes a huge E_8 group symmetry predicted by Zamolodchikov from the integra- bility. The other example is gauge/string duality between certain string theories moving in some 10 dimensional curved space and some gauge theories in 4 dimensions. Since this duality relates strongly coupling gauge theories to weakly interacting string theories and vice versa, non-perturbative un- derstanding of the gauge theories are essential. Again, it turns out that the integrability plays an essential role.