mSUGRA celebrates its 20th year

The invention of minimal supergravity grand unification - mSUGRA - had a profound influence on the phenomenology of supersymmetry, and now mSUGRA is a leading candidate for yielding new physics beyond the Standard Model. A current assessment of mSUGRA in the search for unification and supersymmetry was the focus of the SUGRA20 conference held on 17-20 March at Northeastern University in Boston, where mSUGRA first evolved 20 years ago.

Participants

In supersymmetry, each particle has a superpartner - a sparticle - with a spin that differs by half a unit. The particles and sparticles should have the same mass, for example the mass of a quark should be equal to that of its superpartner, the squark, but this is contrary to observation. A mechanism for breaking supersymmetry is therefore crucial if theories that include supersymmetry are to confront experiment.

Models based on so-called global supersymmetry or rigid supersymmetry lead to a pattern of sparticle masses tha are also in contradiction with experiment - for example, a squark mass may lie below the quark mass. They also yield a cosmological constant that is in gross violation of observation. However, both these obstacles are removed in supergravity grand unification and its minimal version, mSUGRA, which was first formulated by Ali Chamseddine, Richard Arnowitt and Pran Nath at Northeastern University in 1982 (Chamseddine *et al.* 1982).

The framework of supergravity grand unification is the so-called applied supergravity, where matter (quarks, leptons and Higgs particles) is coupled with supergravity and the potential of the theory is not positive definite. The breaking of supersymmetry in mSUGRA takes place through a "super Higgs" effect where the massless gravitino, which is the spin 3/2 partner of the graviton, becomes massive by "eating" the spin 1/2 component of a chiral super Higgs multiplet. This is a phenomenon akin to the Higgs_Kibble mechanism through which the W boson gains mass by absorbing the charged component of a Higgs doublet in the Glashow-Salam-Weinberg model.

mSUGRA has an ingenious mechanism to protect the electroweak scale from "pollution" by the high-energy scales of the Planck mass M_{Planck} (2.4 x 10^{18} GeV) and the grand unification mass M_{GUT} (2 x 10^{16} GeV). In mSUGRA, supersymmetry breaking occurs in the hidden sector and is communicated by gravitational interactions to the physical sector, where physical fields such as leptons, quarks, Higgs and their superpartners reside (see figure 1). Since the vacuum energy of the theory is not positive definite, it is possible to fine-tune the vacuum energy to zero (or nearly zero) after the spontaneous breaking of supersymmetry, and so avoid any contradiction with experiment. Further, as a consequence of the communication between the hidden and physical sectors, soft breaking terms arise in the physical sector. These give masses to sparticles and generate non-vanishing trilinear couplings among scalar fields. Thus, for example, the squarks and selectons gain masses of the size of the electroweak scale and fall within reach of colliders such as the Tevatron at Fermilab and the Large Hadron Collider (LHC) at CERN.

A remarkable aspect of the hidden-sector/physical-sector mechanism is that the mass generation in the physical sector does not involve terms of the size of M_{Planck} - which is fortunate given the large size of M_{Planck}. A similar result was found by Riccardo Barbieri of Pisa, Sergio Ferrara of CERN and Carlos Savoy of Saclay, who also achieved soft breaking through the hidden-sector mechanism (Barbieri *et al.* 1982). Equally remarkable is the result found by Chamseddine, Arnowitt and Nath that the grand unification scale M_{GUT} cancels in the computation of soft parameters (Chamseddine *et al.* 1982, Nath *et al.* 1983). The soft parameters are thus shielded effectively from the high-energy scales of M_{Planck} and M_{GUT}. There are many later analyses where grand unification within supergravity has been discussed in further detail (Hall *et al.* 1983, Nilles 1984). In mSUGRA, universality of the soft parameters leads to a suppression of the flavour-changing neutral currents that is compatible with experiment. Furthermore, the mSUGRA model can be easily generalized to include non-universalities in certain sectors of the theory, maintaining consistency with experiment.

mSUGRA provides a dynamical explanation of the electroweak symmetry breaking that splits the weak nuclear force from electromagnetism and gives mass to the W and Z bosons. In the Standard Model this is done by giving a negative squared mass to the Higgs field, which can be considered contrived. In mSUGRA the breaking of supersymmetry naturally triggers the breaking of electroweak symmetry and leads to predictions of masses of sparticles lying in the 100 GeV-TeV energy range.

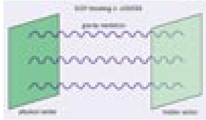

Figure 1

The SUGRA20 conference opened with talks that looked at the current and future prospects for experimental tests of mSUGRA. Xerxes Tata of Hawaii discussed the constraints on the sparticle masses from various experiments including the recent Brookhaven experiment on g_{μ}-2. Speakers in several other talks pointed out that the most direct test of mSUGRA and other competing models will come in accelerator experiments at Run II of the Tevatron, at the LHC and at the Next Linear Collider (NLC). Such tests for the Tevatron were outlined by Michael Schmitt of Northwestern, while Frank Paige from Brookhaven National Laboratory and Stephno Villa of California, Irvine, discussed the possibilities for the ATLAS and CMS detectors at the LHC. Richard Arnowitt from Texas A&M discussed similar tests for the NLC.

mSUGRA also possesses the remarkable feature that it provides a natural candidate - the so-called neutralino - fo cold dark matter in the universe. The talks by Howard Baer of Florida and Keith Olive of Minnesota revealed that the predictions of cold dark matter in mSUGRA and its extensions are consistent with the most recent data from the satellite experiment, the Wilkinson Microwave Anisotropy Probe. David Cline from UCLA later outlined future dark-matter experiments (GENIUS, ZEPLIN) to test mSUGRA and other competing models.

There were also talks in several areas complementary to the main theme of the conference. Mary K Gaillard of Berkeley discussed the connection of SUGRA models to strings, while the idea of conformal quiver gauge theories with a novel type of grand unification at about 4 TeV was explained by Paul Frampton of North Carolina. Other more theoretical ideas included talks on strong gravity by Ali Chamseddine from Beirut, on M theory by Michael Duff of Michigan, and on non-commutative geometry by Bruno Zumino from Berkeley.

Northeastern University, as a key player in the birth of mSUGRA 20 years ago, provided an ideal location for SUGRA20. While mSUGRA remains only a model, more than 100 participants at the conference expressed optimism that future experimental data may convert it from a theoretical model to an established theory.

Further reading

R Barbieri, S Ferrara and C A Savoy 1982 *Phys. Lett.* **B119** 343.
A H Chamseddine, R Arnowitt and P Nath 1982 *Phys. Rev. Lett.* **49** 970.
L Hall, J Lykken and S Weinberg 1983 *Phys. Rev.* **D27** 2359.
P Nath, R Arnowitt and A H Chamseddine 1983 *Nucl. Phys.* **B227** 121.
P Nath, R Arnowitt and A H Chamseddine 1984 Applied N=1 Supergravity Trieste lecture series, vol. I (World Scientific).
H P Nilles 1984 Supersymmetry, Supergravity and Particle Physics *Phys. Rep.* **110** 1.
The programme of the SUGRA20 conference can be found at http://www.sugra20.neu.edu.

About the author

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