OPENING REMARKS

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String theory returns to Italy

Veneziano

Ademollo, Amati, Caneschi, Del Guidice, Di Vecchia, Ferrara, Fubini, Gliozzi, Rebbi, Sciuto, Virasoro, ... many more

In Rome 41 years old still seems very young!

OPENING QUESTIONS

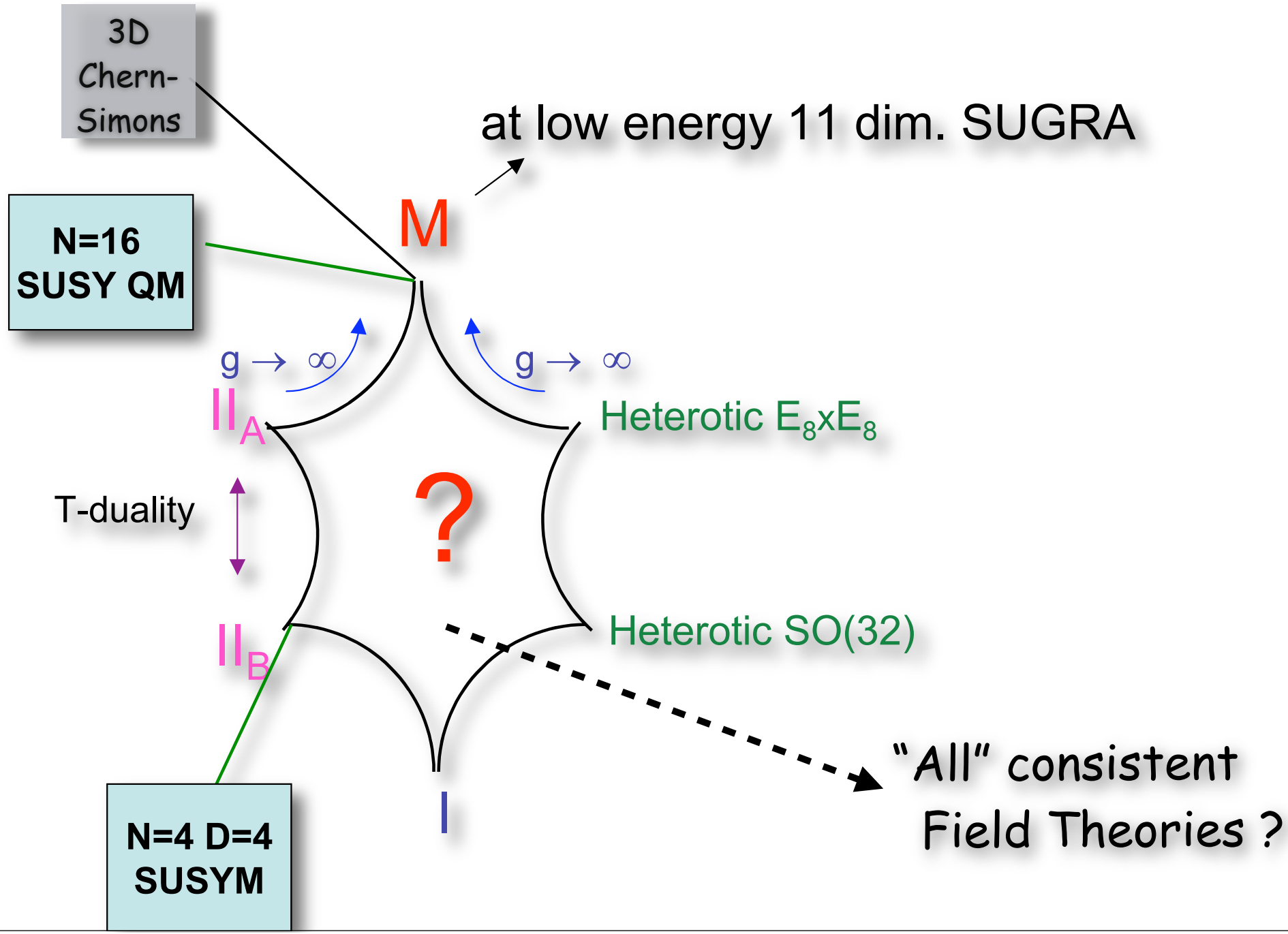
ITP WORKSHOP----1985

It is quite appropriate to open this workshop on string theory with a list of questions. In the flurry of excitement generated by recent developments some people have wondered whether we might be witnessing the beginning of the end of physics. For the first time we have a theory which appears, in principle to be capable of answering all the traditional questions of elementary particle physics. Preliminary investigation of the phenomenology of the $E_8 \times E_8$ heterotic string is quite encouraging. However the game is far from being over, quite the opposite is the case.

2. HOW MANY STRING THEORIES ARE THERE?

Do there exist more consistent string theories than the known five – the two forms of the closed superstring, the SO(32) open superstring and the two forms of the heterotic string? Do there exist fewer, in the sense that some of the above might be different manifestations (different vacua?) of the same theory? Are some of the known theories actually inconsistent?

A Vast Landscape of Formulations



3. STRING TECHNOLOGY? ✓

This is not a question but a program of development. Much work remains to be done in developing the calculational techniques of string theory, including control of multiloop perturbation theory and the construction of manifestly supersymmetric and covariant methods of calculation.

Enormous progress in developing calculational techniques in string theory, and in gauge theory.

4. WHAT IS THE NATURE OF STRING PERTURBATION THEORY?

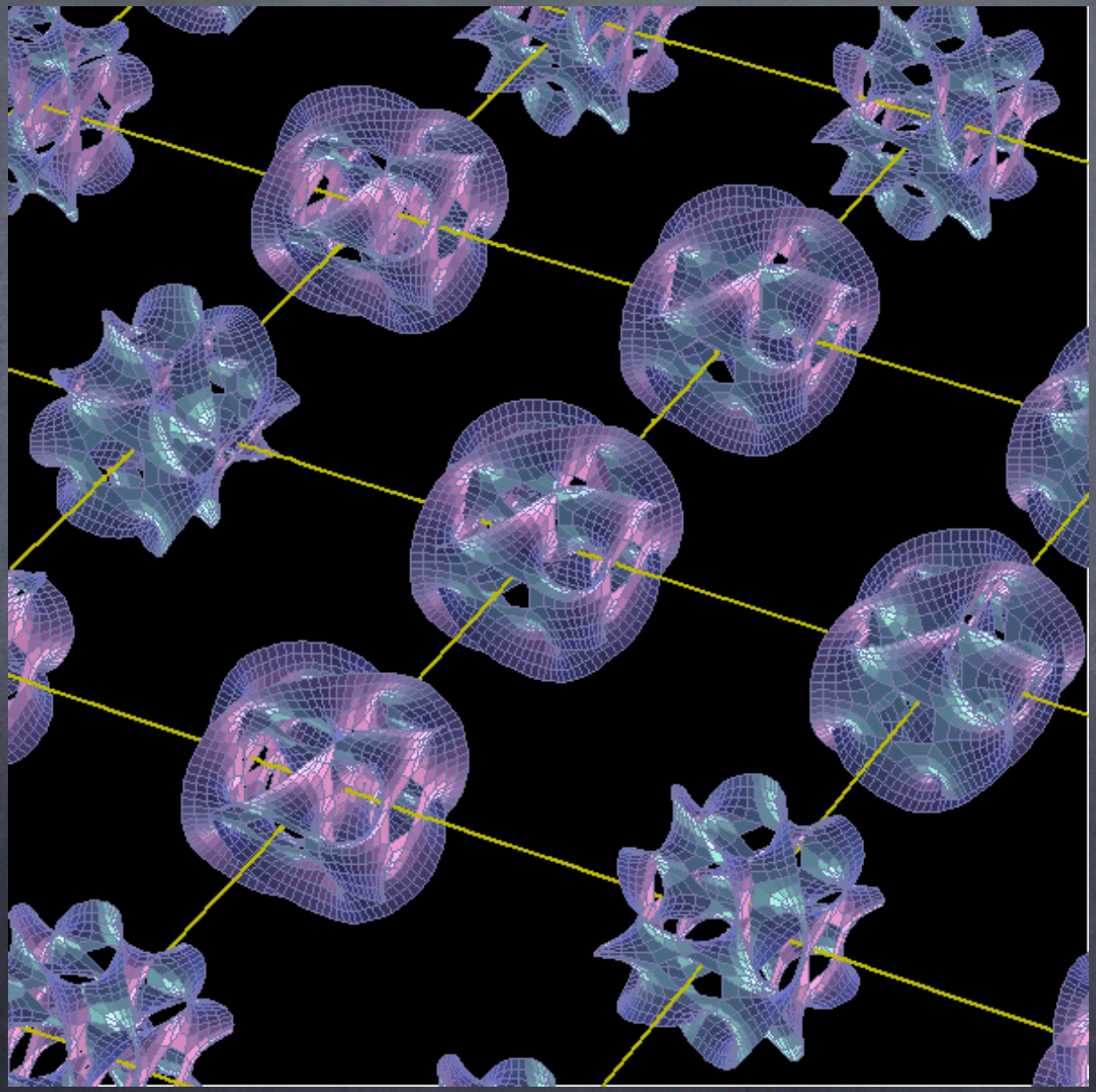
Our present understanding of string theory has been restricted to perturbative treatments. Does this perturbation theory converge? Most likely it does not. ✓ In that case when does it give a reliable asympototic expansion of physical quantities? How can one go beyond perturbation theory and what is the nature of nonperturbative string dynamics? ✓ This question is particularly difficult since we currently lack a useful nonperturbative formulation of the theory.

5. STRING PHENOMENOLOGY?

Here there are many questions that can all be summarized by asking whether one can construct totally realistic four-dimensional model which is consistent with string theory and agrees with observation?

Great progress, but still not constructed.

Growing list of models



6. WHAT IS THE NATURE OF HIGH ENERGY PHYSICS?

By this I mean what does physics look like at energies well above the Planck scale. This is a question that is addressable for the first time and may be of more than academic interest for cosmology. In analogy with past theories one might expect physics in this domain to look entirely different. Does the string undergo a phase transition at high temperatures or densities to a new phase, as perhaps indicated by the existence of a limiting temperature? Can one avoid in string theory the ubiquitous singularities that plague general relativity?

Black Holes YES Cosmological NO

7. WHAT PICKS THE CORRECT VACUUM?

This is one of the great mysteries of the theory which appears, at least when treated perturbatively, to possess an enormous number of acceptable (stable) vacuum states. Why, for example, don't we live in ten dimensions? Does the theory possess a unique vacuum, in which case all dimensionless physical parameters would be calculable or is the vacuum truly degenerate, in which case we would have free parameters? How does the value of the dilaton field get fixed, thereby giving the dilaton a mass? ✓ Does the vanishing of the cosmological constant survive the mechanism that lifts the vacuum degeneracy?

The crucial issue is still unresolved.

$$\Lambda$$

THE ANTHROPIC PRINCIPLE

8. IS THERE A MEASURABLE, QUALITATIVE, DISTINCTIVE PREDICTION OF STRING THEORY?

String theories can, in principle, make many "postdictions" (such as the calculation of the mass ratios of quarks and leptons, Higgs masses and couplings, gauge couplings, etc.). They can also make many new predictions (such as the masses of the supersymmetric partners of the observed particles, new gauge interactions, etc.) These would be sufficient to establish the validity of the theory, however in each case one can imagine (although with some difficulty) conventional field theories coming up with similar pre or post dictions. It would be nice to predict a phenomenon, which would be accessible at observable energies and is uniquely characteristic of string theory.

New patterns of SUSY breaking

New Scenarios:

Large Extra Dimensions

Cosmic Strings

But accessible signatures seem to be unlikely.

1. WHAT IS STRING THEORY?

This is a strange question since we clearly know what string theory is to the extent that we can construct the theory and calculate some of its properties. However our construction of the theory has proceeded in an *ad hoc* fashion, often producing, for apparently mysterious reasons, structures that appear miraculous. It is evident that we are far from fully understanding the deep symmetries and physical principles that must underlie these theories. It is hoped that the recent efforts to construct covariant second quantized string field theories will shed light on this crucial question.

What is the fundamental formulation of string theory?

Quantum Space of all 2-d field theories

Second Quantized Functionals of loops (SFT)

M-theory . . .

Is string theory a framework, not a theory?
What is missing?

How many more string revolutions are required?

NEW QUESTIONS

9. WHAT IS SPACETIME MADE OF?

~~Smooth Manifold~~

~~Fixed Number of Dimensions~~

~~Topology~~

Is all of spacetime emergent?

Can we imagine physics with more than one dimension of time?

What are the rules of physics without spacetime?

10. WHAT ARE THE RULES OF QUANTUM COSMOLOGY?

THE END

BOUNDARY

THE UNIVERSE

=

SPACETIME HISTORY

THE BEGINNING

WHAT ARE THE RULES ?

11. WHAT WILL WE LEARN FROM THE LHC ?

BUONA CONFERENCIA