Homepage : http://strings2013.sogang.ac.kr

Local Organizers

Chanju Kim (Ewha Women's Univerisy)
Wontae Kim (Sogang University, CQUeST)
Bum-Hoon Lee (Sogang University, CQUeST, Chair)
Ki-Myeong Lee (KIAS, CQUeST)
Soonkeon Nam (Kyung Hee University, CQUeST)
Chanyong Park (Sogang University, CQUeST)
Dongsu Bak (University of Seoul, CQUeST)
Jaemo Park (Postech,CQUeST)
Jeong-Hyuck Park (Sogang University, CQUeST)
Young Jai Park (Sogang University, CQUeST)
Soo Jong Rey (Seoul National University, CQUeST)
Chaiho Rim (Sogang University, CQUeST)
Sang-Jin Sin (Hanyang University, CQUeST)
Piljin Yi (KIAS, CQUeST)

KAVLI IPMU

Conference Summary

Hirosi Ooguri

Strings 2012 @ München, July 23 - 27, 2012

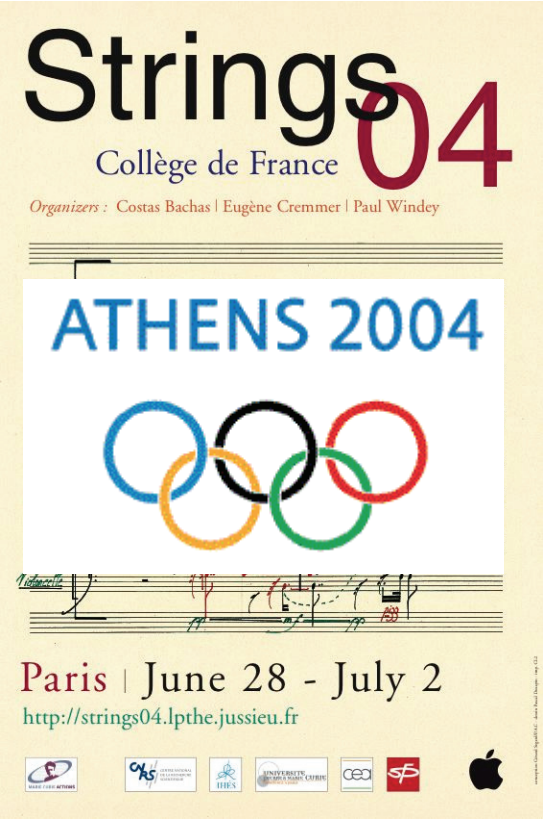
This is my third summary talk at Strings.

Strings 2004

Strings 2008

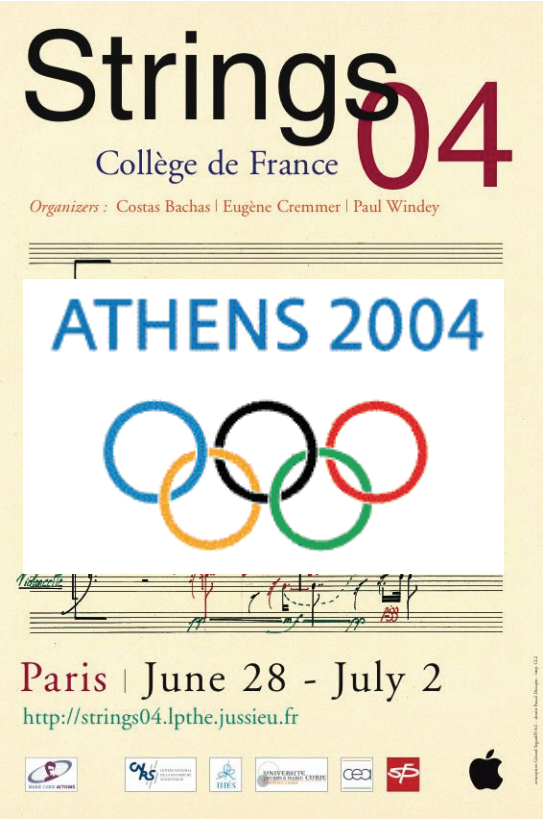
Strings 2012

This is my third summary talk at Strings.



Strings 2004 Strings 2008 Strings 2012

Let us compare the **three Strings** to see how much progress we have made.



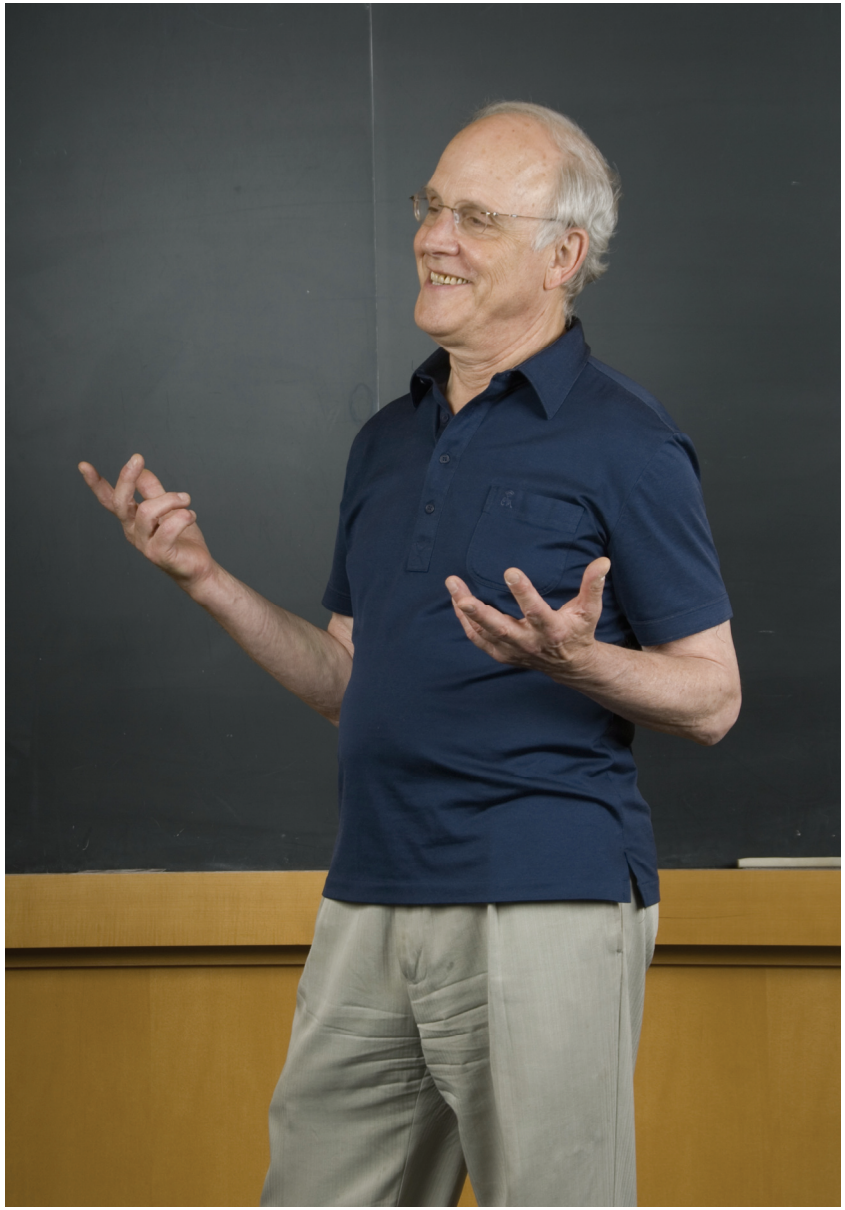
Strings 2004 Strings 2008 Strings 2012

First Observation

	4:30 PM - 5:00 PM Coffee -
5:00 PM	**5:00 PM** - 5:50 PM Ooguri - Conference Summary
	5:50 PM - 6:30 PM
6:00 PM	Gross - Outlook

4:45-5:15 Ooguri*Conferen* *Summary*
5:15-5:45 Gross*Outlook/V*

After the experience at Strings 2004, the strings oligarchy has decided that **I need adult supervision**.



"When I gave a summary talk, I made a mistake of summarizing a talk that was cancelled."

anonimous

Scientific Talks

Thanks to "Unofficial Mirror of Strings Slides"
maintained by Yuji Tachikawa:

http://member.ipmu.jp/yuji.tachikawa/stringsmirrors/

Review Talks

Karch: AdS/QCD, AdS/CMT

Yin: Higher Spin Holography

Carrasco: Perturbative Amplitudes

Uranga: String Phenomenology

Dimopoulos: LHC Physics

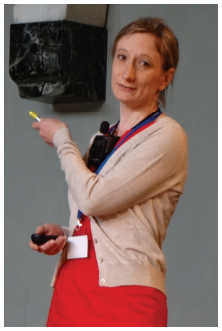
Kortner: LHC Experiment

Nicolai: Alternative Gravity

Vafa: Topological Strings

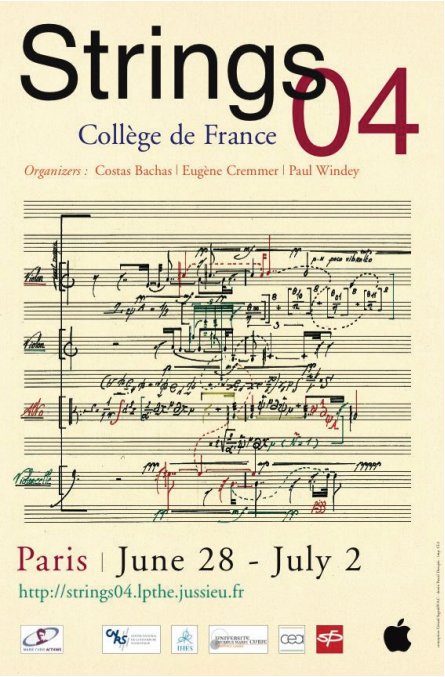




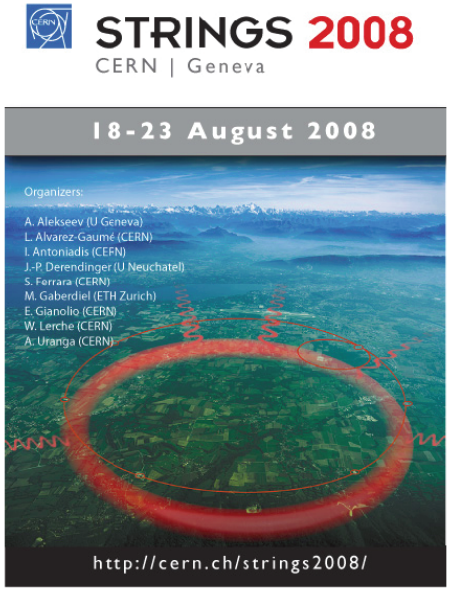



Applied AdS/CFT

string theory as a tool in theoretical physics



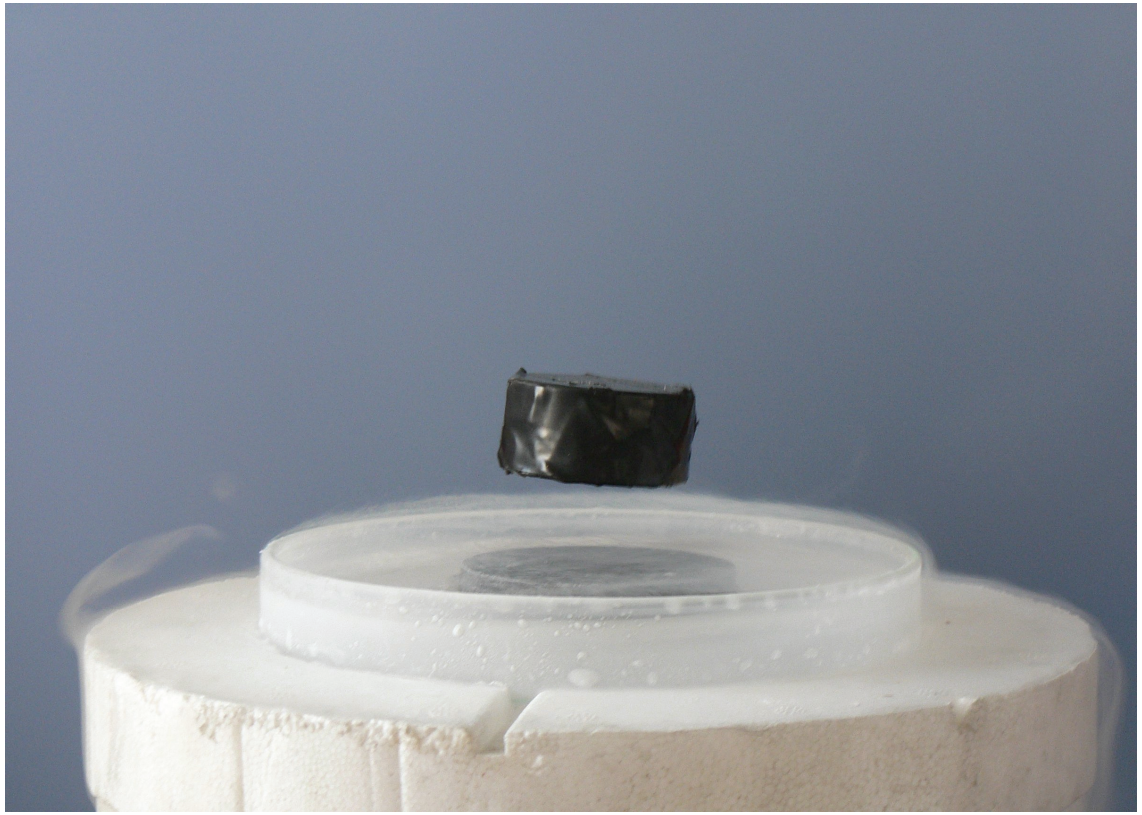
Aharony: deconfinement phase transition



Minwalla: fluid/gravity correspondence

Gubser, Starinets: quark gluon plasma

Focus was on AdS/QCD.



Kachru: Solutions in the Einstein-Maxwell-dilaton system with **dynamical critical exponent**, **hyperscaling violation**, and *L log L* behavior of the **entanglement entropy**.

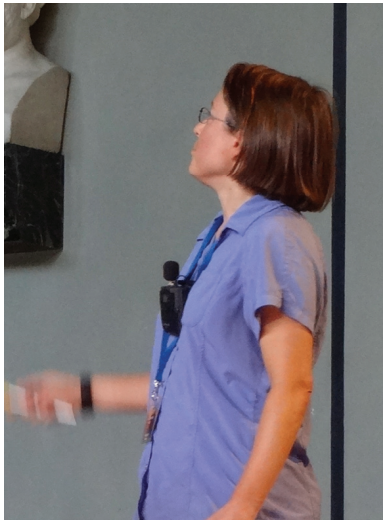
The solution I found with Nakamura and Park is analogous to **Bianchi VII**.

Iqbal: reproduced a bump in density correlation in momentum space, predicted by **Luttenger's theorem**, by **monopole-instantons** in AdS_3.

Horowitz: Adding lattice to holographic conductor

reproduces **Drude behavior** at **low** ω,
and agrees with **cuprates experiments**
at **intermediate** ω.

Siverstein: also considered position dependent perturbations and found novel fixed points and shifted unitarity bounds.



Karch: reviewed progress of **AdS/QCD**,
as well as AdS/CMT:

Transport (viscosity, energy loss, thermalization)

Time scales for hydrolization
and thermalization differ by
infall time in the bulk geometry.

Integrability in AdS/CFT

toward a proof of the holography in string theory

Tseytlin: Semi-classical Strings in AdS

Beisert, Zarembo: N=4 SYM and spin model

⇒ 3-loop discrepancy

Staudacher: weak ⇔ strong extrapolation

Janik: resolution of disagreement in 4-loop anomalous dimensions

Alday, Berkovits, Sokatchev:

dual superconformal symmetry

Alday: **scattering amplitudes**

⇔ null **Wilson loops**

⇔ **correlation functions**

with null separations

It can be generalized with partial null limits.

Adventure in Perturbation

The S-matrix theory strikes back.

Dixon: iterative identifies in N=4 SYM

Witten: N=4 SYM and twistor-string theory

Dixon: factorization, spinor helicity basis

Cachazo: remarkable convergent behavior of N=8 supergravity

Stieberger: SUSY Ward-Takahashi id's.

Arkani-Hamed: on-shell planar diagrams are characterized by its **permutation structure**, which specifies cells in the **Grassmannian**.

Dual conformal invariance, Yangian symmetry, and motivic structure of amplitudes are made manifest.

Cachazo: presented a new formula for a complete tree-level S-matrix of **N=8 supergravity** combining Kawai-Lewellen-Tye formula and twistor in CP(3|8).

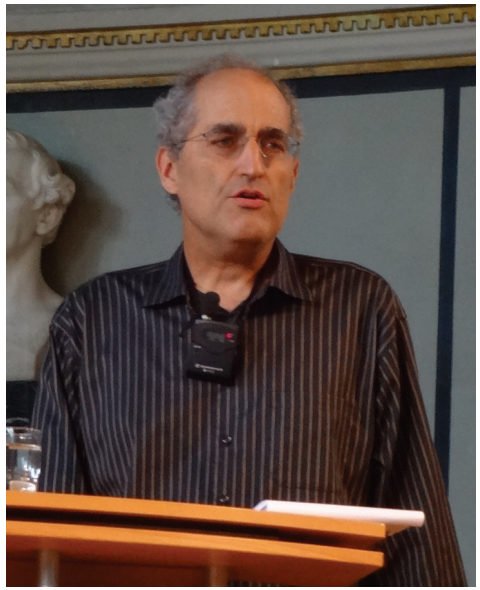
String Perturbation

important foundation of string theory

Berkovits: proof of finiteness in
the pure spinor formalism

no talk on this subject

Witten: settled lingering issues on **tadpole cancellation** and spacetime SUSY in superstring perturbation theory.



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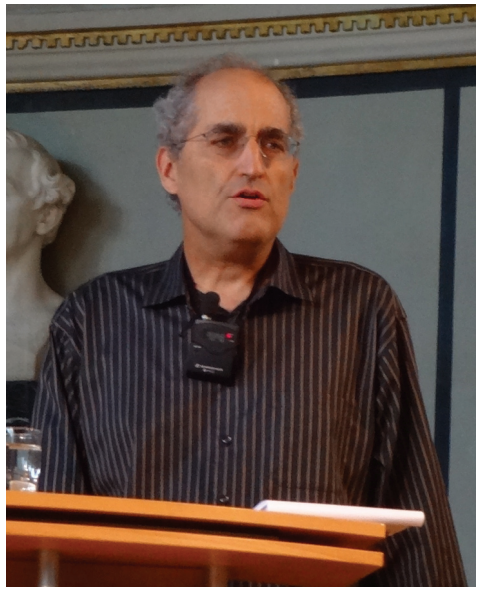
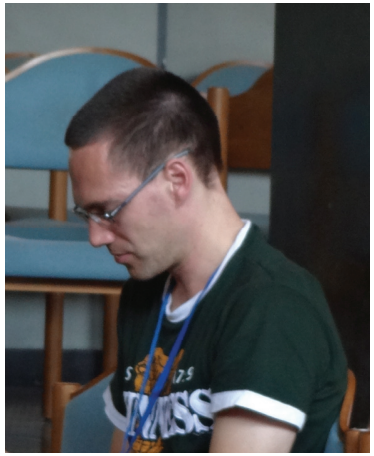


"If one asks precisely the questions whose answers one needs, these particular questions tend to have simple answers."

Schlotterer: derived interesting formulae for open superstring amplitudes at tree and one-loop, expressing them as sums of products of **YM parts & stringy parts**.



Higher Spin Theories

burst of activities

Vasiliev: introduced higher spin theories

Bianchi: higher spin symmetry

Gopakumar: AdS/free fields

no talk on this subject

Yin: The N=6 U(N) x U(M) ABJ model

⇔ IIA on AdS_4 x CP3

⇔ Vasiliev theory with U(M) Chan-Paton

IIA string as bound state of Vasiliev particles.

Gaberdiel: **W_N minimal model**

⇔ Vasiliev theory on AdS_3

Triality of W-algebra relates symmetries of minimal model and asymptotics of AdS_3.

Maldacena: **generalized Coleman-Mandula theorem**

to AdS_4:

Higher spin symmetry ⇒ free theory.

When the symmetry is slightly broken,
3-point functions are constrained.

⇒ O(N) CS + N bosons/fermions

or

critial O(N) models
(Wilson-Fisher/Gross-Neveu)

String Model Building

String theory confronts the reality.

Landscape and **flux compactification** were leading ideas ... Douglas, Grana, Trivedi

soft ~~SUSY~~ terms: Ferrara, Louis, Luest, Uranga

Jones, Myers: cosmic strings

Vafa: (almost unique) local model of **F-theory**

Donagi: **heterotic** string $\Rightarrow$ SU(3)xSU(2)xU(1)

Ibanez, Weigand: MSSM landscape

H. Verlinde, Shih: gauge mediation

Cvetic: computed **instanton corrections** to the **F-theory** superpotential and found that E8 enhancement point is stabilized

⇒ favorable for top quark mass (E6)

⇒ CKM matrix (E7) ⇒ neutrino mixing (E8).

Anderson: used hermitian YM equations

(1) to **identify SM-like constructions**:

10^{12} bundles ⇒ 45 by phenom constraints.

(2) to **stabilize complex moduli** in the hidden sector (does not deform away from Kahler).

Nilles: pointed out that realistic **heterotic models** requires that Higgs and top multiplets are in bulk while the first two families tend to be localized.

He discussed remnants of N=4 SUSY in low energy.

Antoniadis: assessed string model building efforts in the last decade in the light of the LHC results.

"Our mistake is not that we take our theories too seriously, but that we do not take them seriously enough."

Stephen Weinberg

Quantum Gravity Phenomena

What can we learn from string theory?

Mathur: black hole microstates

Horava: Goedel universe at AGN

Shenker: singularities

Veneziano: trans-Planckian collision

Strominger: chiral CFT for extreme Kerr

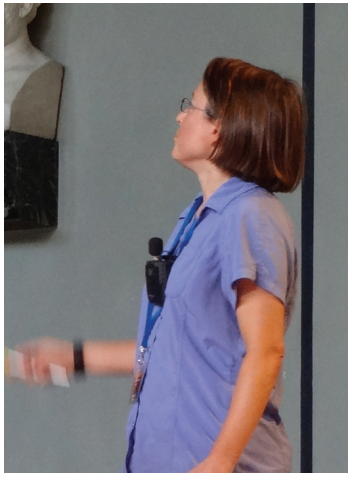
Hellerman: time-dependent solutions

Veneziano: in his opening remarks, updated progress on **trans-Planckian collisions**, including string-brane collisions.

Rabinovici: **Crunch in AdS cosmology** has two descriptions complementary to each other, one with crunch at finite time and and another with eternal evolution.

Strominger: used the **Vasiliev theory** to construct an example of the **dS/CFT duality**, pointed out exclusion principle and proposed physical observables for dS.

Silverstein: proposed the **dS/dS duality** and used it to interpret meta-stable vacua by **holographic renormalization group**.



Is gravity dynamical on both sides?

Castro: showed that sum over geometries for **pure gravity in AdS_3** works only when CFT duals are Ising or tri-critical Ising models.

Bousso: assured us that we do not have to die at a black hole event horizon to save the unitarity.

Freivogel: proposed a solution to the **measure problem** in the eternal inflation.

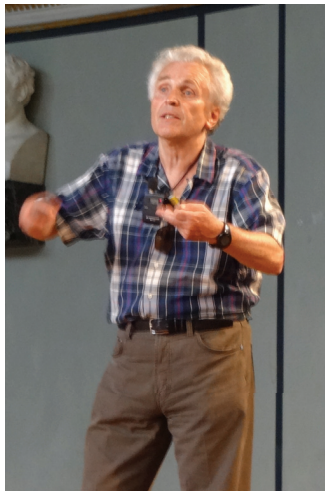
Bachas: tried to realize Karch-Randall **localization of gravity** by holographic dual of Gaiotto-Witten domain walls.

Kounnas: presented a new class of **bouncing universe** solutions in string theory.

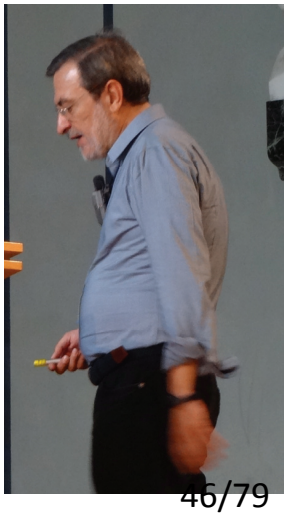
Zwiebach: described the **double field theory**
to make T-duality manifest and
to shed light on generalized geometry.

Heckman: introduced **non-commutative space with 4d Lorentz covariance** and
suggested that QFT on this space
is gravitational.

Polyakov: showed that de Sitter symmetry of the Bunch-Davis vacuum is broken by quantum effects, leading to **instability of the de Sitter space**.



Gomez: claimed that trans-Planckian scatterings in the Einstein gravity are dominated by **large number of weaking interacting quanta** and that condensate of such quanta leads to a black hole formation.



Nicolai: gave critical assessments of

Asymptotic Safety,
Loop Quantum Gravity,
and **Spin Forms**,

Nicolai: gave critical assessments of

Asymptotic Safety,
Loop Quantum Gravity,
and **Spin Forms**,

and exposed my secret past to the string community.

Group Field Theory

[Boulatov(1992); Ooguri(1992); DePietri,Freidel,Krasnov,Perez,Reisenberger,Rovelli(1999)]

Aim: reproduce *spin foam amplitudes via Feynman graphs* of an abstractly defined (space-time-less!) field theory defined on a

New Insights in QFT

Exact results have unexpected applications.

Intriligator: proposed the *a*-theorem

Klebanov: warped deformed conifold

Eguchi, Rastelli, Seiberg: Liouville theory

Lambert, Maldacena, Mukhi:
M2 brane *mini*-revolution

Moore: BSP wall-crossing and *tt** equations

Gaiotto: S-duality and boundary conditions
in N=4 SYM

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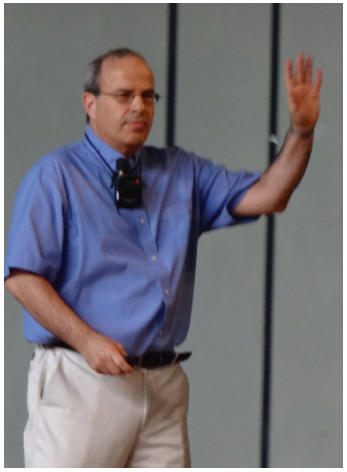
Gaiotto: S-duality and boundary conditions
in N=4 SYM

Komargodski: **proved the *a*-theorem.**

He also discussed interesting constraints on operator dimensions in CFT.

Seiberg: pointed out that 3d N=2 theory can have **anomalies in compact R-symmetry**, with CS terms with factional coefficients.



This clarified **F-maximization** and led to new **tests of dualities**.

Dimofte: Class R includes M5 on 3-mfd's.

6=3+3 version of AGT:

3d class R theory ⇔ 3d CS

Yamazaki: showed

index(**4d N=1 quiver theory**)
= Z(**2d integrable spin system**)

and that it leads to 6=3+3
by dimensional reduction and oxidation.

Gaiotto: introduced **RG domain walls**,

relating operators in UV and IR CFT's,
and showed how they work in
2d minimal models.

Rastelli: computed superconformal index
for all generalized quiver theories
of type A for generic three fugacities,
with or without surface defects.

Topological Strings

24th anniversary edition

Strominger, Vafa: OSV conjecture

Dijkgraaf, Nekrasov: topological M theory

Marino: remodeling the B model

Walcher: BCOV holomorphic anomalies for open strings

Pioline: BPS black holes and topological strings

Aganagic: pointed out that **mirror** of the resolved conifold **is not unique**.

A distinct mirror for each knot or link in S3, leading to a new way to think about knot invariants.

Thriving collaborations between physicists and mathematicians.

Science Lives : oral history project by the Simons Foundation

December 2011

Interviewer:

"Are there new fields in mathematics in which you would like to work?"

Science Lives : oral history project by the Simons Foundation

December 2011

Interviewer:

"Are there new fields in mathematics in which you would like to work?"

Hirzeburch:

"I would not mind becoming an expert on string theory."

Overall Impression

Science has universal value.

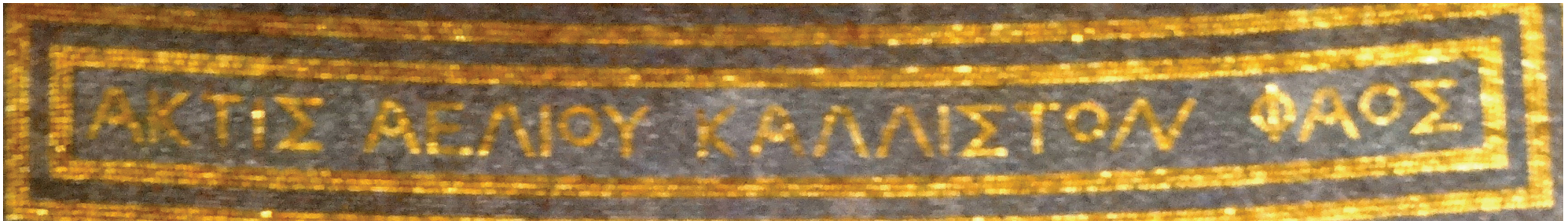
One way to evaluate a particular field is to see **how much it is influencing progress in other fields**.

String Theory ⇒ CMP, QCD, Math

In addition to the breadth of impacts, the **depth and richness** of the field are also remarkable.

Holography ⋯ higher spin, integrability, etc.

Amplitudes ⋯ supermoduli, twistor, etc.



Golden Age of Exact Results in SUSY QFT

Significant progress has been made in understanding how to derive the Standard Model of Particle Physics from Superstring Theory.

We should take our theory seriously.

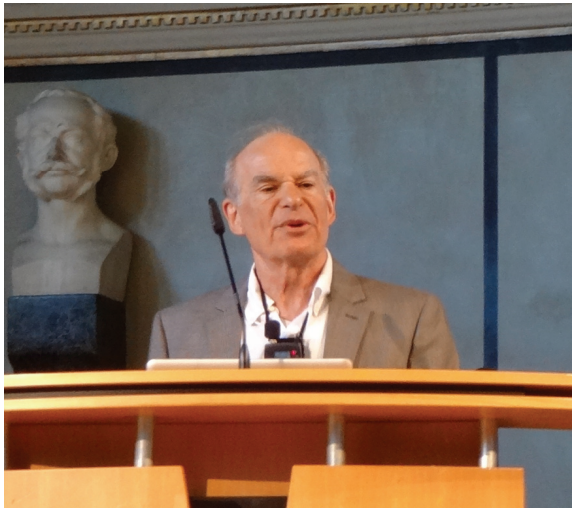
More talks with finite α'.

More talks with finite α'.

I hope it is going to be the case
in applications of the AdS/CFT also.

Schwarz: Three Lessons

(1) Be willing to modify your goals.
(2) Take coincidences seriously.
(3) Explore generalizations.



Strings Demgraphics

Are we getting younger?

My years after Ph.D. :

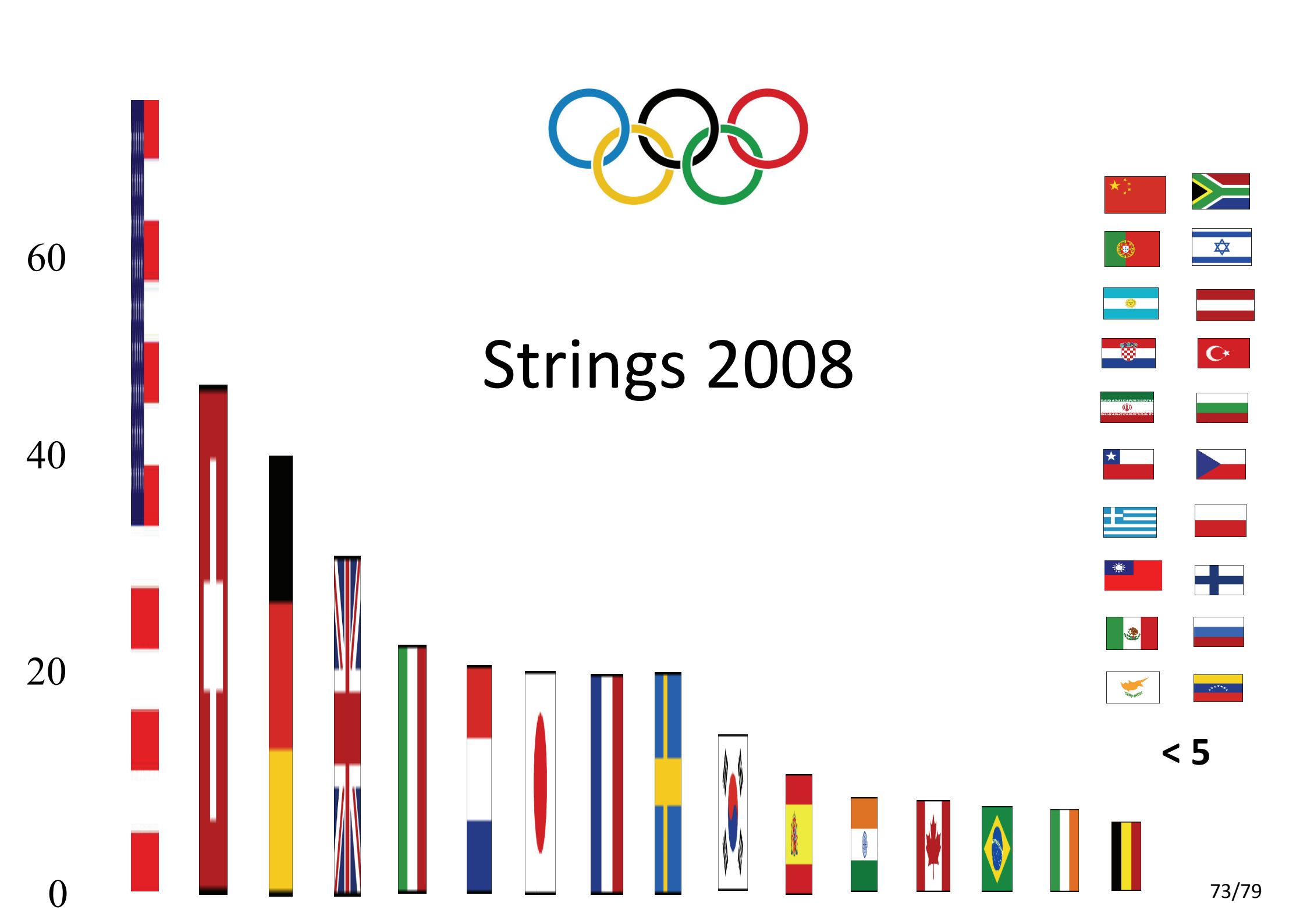
Strings 2004: top 58 percentile

Strings 2008: top 48 percentile

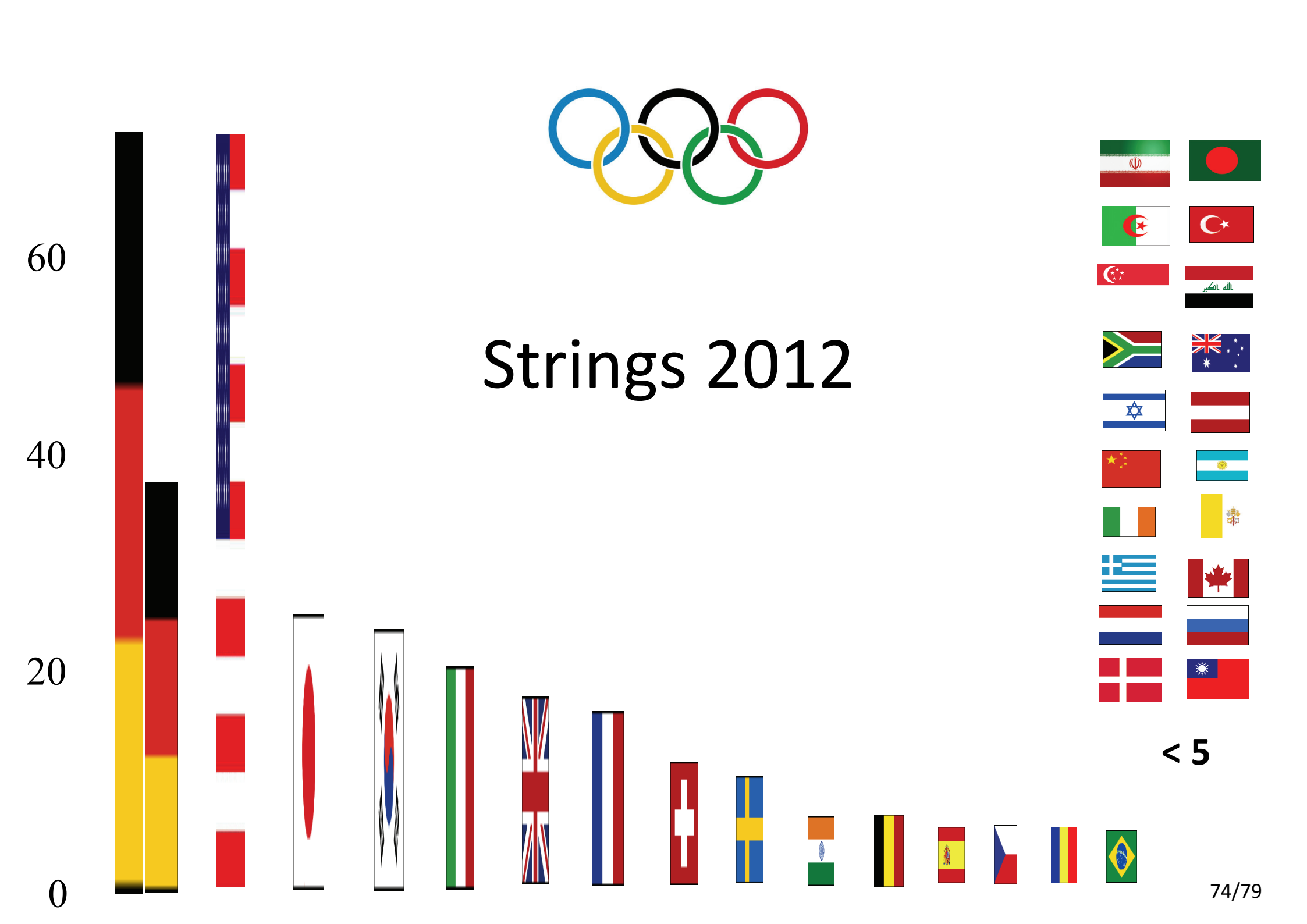
Strings 2012: top 40 percentile

* not counting opening remarks and non-strings talks

Where are we from?



Strings 2008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40
20
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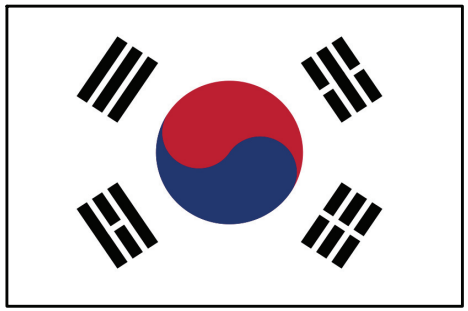
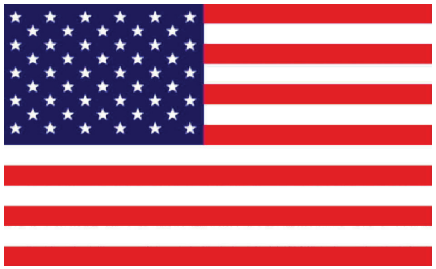
Strings 2012
< 5

Strings 2013, Seoul

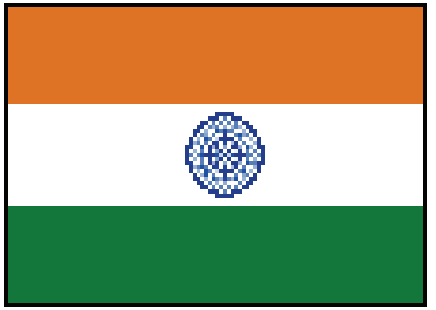
Strings 2013



Strings 2014



Strings 2015



Wir hatten
eine
wunderbare
Zeit
in München.

Thank you,
Dieter & Friends!

Auf Wiedersehen im nächsten Jahr in Seoul !