IGST 2014: Concluding Talk

$$... \to \text{IGST 2008} \to ... \to \text{IGST 2010} \to ... \to \text{IGST 2014} \to ...$$

Same general aims:

• understand quantum gauge theories at any coupling:
vacua, dimensions, correlators, amplitudes, hidden symmetries, ...

• understand quantum string theories in curved backgrounds
related to AdS/CFT, gauge/string duality

• develop new non-perturbative methods
uncover unifying relations between different subjects

Collection of subjects:

- integrable string sigma models and AdS/CFT

Gromov, Cavaglia, Banjok, Komatsu, Sfondrini, Vicedo, Frolov

- scattering amplitudes

Basso, Lipatov, Sever, Lukowski, Sprenger, Lipstein

- aspects of supersymmetric gauge theory

Pasquetti, Nekrasov, Rastelli, Yamazaki, Mitev, Bissi

- new methods and applications

Bazhanov, Dorigoni, Goncharov, Flauger

from Summary talk at IGST 2010:

Directions and Open Problems

• algebraic ideas should bring some fruit:
bridge the gap between SYM and SM (beyond Y/Yangian ? ....)

• reformulation of TBA? Analytic solution at strong coupling

• Pohlmeyer reduction – TBA for a Lorentz-invariant system ?
solution of generalized SG-type models

• integrability of string sigma-model: further implications
for WL's / amplitudes, correlation functions, ...

• generalizations: $AdS_n \times M^k$ models, (β-) deformations, ...

• less susy, non-critical strings, non-planar, ...

Some IGST 2014 observations:

- importance of deformation: gives new perspective or regularization
[Vicedo, Frolov, Nekrasov, Bazhanov, Lukowski, Pasquetti,...]

- new remarkable non-perturbative results
quantum spectral curve and null WL OPE bringing fruit
[Gromov, Basso, Sever, ...]

- new exact results from integrability/localization call for better understanding non-perturbative 4d/2d QFT and developing new tools
[Nekrasov, Bissi, Bazhanov, Dorigoni, ...]

- one should not not forget about physical applications
[Flauger, Lipatov, ...]

String sigma models

- which are physically interesting?
- which are integrable/solvable? perturb around integrable case?
- solvable examples with gauge-theory ("QCD string") connection?
- formal approach: start with simplest most symmetric cases

and consider integrable deformations [Vicedo, Frolov]

- deformations with hidden quantum group symmetry

e.g. $U_q(\mathfrak{psu}(2,2|4))$ – good motivation

- potentially important lessons:

do not trust too much point-particle /supergravity limit –
string sees hidden (super)symmetries, may avoid apparent singularities,

- role of other (non-local, non-abelian, duality) relations

place of Pohlmeyer reduction (generalized SG) theory in full picture?
use of complexification / double of $\mathfrak{psu}(2,2|4)$?

- quantum group symmetry on gauge theory side?

$AdS_2 \times S^2 \times T^6$ superstring: closely related supercoset

$$\frac{PSU(1,1|2)}{SO(1,1) \times SO(2)}$$

[Berkovits, Bershadsky, Hauer, Zhukov, Zwiebach 99]

[Sorokin, AT, Wulff, Zarembo 11]

embedding to IIB string: D3-D3-D3-D3 [Klebanov, AT 96]

$$ds^2 = -(1+\rho^2)dt^2 + \frac{d\rho^2}{1+\rho^2} + (1-r^2)d\varphi^2 + \frac{dr^2}{1-r^2} + dT^6$$

$$F_5 = \Omega_2(AdS_2) \wedge \Omega_3(T^6) \ + \ * \, , \qquad \Omega_3 = \mathrm{Re}(dz^1 \wedge dz^2 \wedge dz^3)$$

effective 4d theory:

$$L = e^{-2\Phi}\left[R + 4(\partial_m \Phi)^2\right] - \tfrac{1}{4} F_{mn} F^{mn} + \dots$$

Bertotti-Robinson: $AdS_2 \times S^2$ with $\Phi = 0$ and

$$F_2 = \sqrt{2}(d\rho \wedge dt + dr \wedge d\varphi)$$

Deformed $AdS_2 \times S^2$ metric

deformed supercoset action leads to 4d metric

$$ds_A^2 + ds_S^2 = \frac{1}{1-\kappa^2\rho^2}\big[-(1+\rho^2)dt^2 + \frac{d\rho^2}{1+\rho^2}\big]$$

$$+ \frac{1}{1+\kappa^2 r^2}\big[+(1-r^2)d\varphi^2 + \frac{dr^2}{1-r^2}\big]$$

• ds_S^2 = "sausage" model [Fateev, Onofri, Zamolodchikov 93]

deformation of S^2 stable under RG flow:

$ds^2 = f(y)(d\varphi^2 + dy^2), \quad \frac{\partial f}{\partial t} \sim R(f) \sim e^{-f}\partial_y^2 f$

$ds^2 = \frac{dy^2+d\varphi^2}{\cosh^2 y + \kappa^2 \sinh^2 y} = \frac{1}{1+\kappa^2 r^2}\big[(1-r^2)d\varphi^2 + \frac{dr^2}{1-r^2}\big]$

• curvature of deformed AdS_2 singular at $\rho \to \kappa^{-1}$

$R = 4(1+\kappa^2)\big[-\frac{1}{1-\kappa^2\rho^2} + \frac{1}{1+\kappa^2 r^2}\big]$

Full deformed background [Lunin, Roiban, AT]

$U(1) \times U(1)$ invariant background?

A non-trivial 4d solution of

$$\int d^4x\sqrt{G}\,[e^{-2\Phi}(R + 4\partial^m\Phi\partial_m\Phi) - \tfrac{1}{2}\partial^m C\partial_m C - \tfrac{1}{4}F^{mn}F_{mn}]$$

direct lift to 10d type IIB solution as $M^2_\kappa \times T^6$:

$F_1 = dC$ or F_3 and $F_2 = dC_1$ - reduction of F_5

$$e^\Phi = \left[(1-\kappa^2\rho^2)(1+\kappa^2 r^2)\right]^{-1/2} X^{1/2}(\rho,r)$$

$$C = 2a^{-1}\,X^{-1/2}(\rho,r)\left[\kappa\sqrt{1+\kappa^2 a^2}\,\rho\, r - \sqrt{1-a^2}\right]$$

$$C_1 = \sqrt{2}X^{-1/2}(\rho,r)\left[\sqrt{1+\kappa^2 a^2}\,(\rho\, dt + r\, d\varphi) + \kappa\sqrt{1-a^2}(r\, dt - \rho\, d\varphi)\right]$$

$$X = 1 + \kappa^2 a^2(r^2-\rho^2) - 2\kappa\sqrt{(1-a^2)(1+\kappa^2 a^2)}\, r\rho + \kappa^2\rho^2 r^2$$

solution for any κ and a

corresponds to supercoset for

$$a = a(\kappa) = \eta = \frac{1}{\sqrt{1+\kappa^2}+1}$$

$\star$ metric is direct product but RR fields + dilaton are not

$\star$ dilaton is also singular at $\rho \to \kappa^{-1}$: $\qquad e^{\Phi} \to \infty$

$\star$ $\sqrt{G}e^{-2\Phi}$ = regular:

singularity "resolved" by formal T-duality in t, cf.

$$dr^2 + r^2 d\phi^2 \,, \quad e^{\Phi} = 1 \qquad \leftrightarrow \qquad dr^2 + \frac{1}{r^2} d\widetilde{\phi}^2, \qquad e^{\tilde{\Phi}} = \frac{1}{r}$$

Solving integrable string sigma models

- symmetry-based l.c. gauge S-matrix approach for $AdS_3 \times S^3 \times T^6$

[Sfondrini]

importance of understanding massless modes – still at the beginning

[cf. flat space, Flauger; S^5: Basso]

comparison with perturbative string theory? requires resummation?

e.g. "dressed" propagator $\to e \sim 2h \sin \frac{p}{2h}$ dispersion relation

several yet undetermined phases – need alternative approach?

- quantum spectral curve approach [Gromov; Cavaglia]

classical action $\to$ Lax $\to$ spectral curve $\to$ quantum spectral curve

new version of integrability bootstrap – by-pass S-matrix

assumptions? 2d conformal invariance, quantum integrability, ...

extra conditions? normalizations / definitions of couplings?

how to determine $h(\lambda)$ "intrinsically"?

similar solution for other models $AdS_n \times S^n \times T^{10-2n}$?

3-point correlators at strong coupling: [Banjok, Komatsu]

• semiclassical limit:

HHL –use of formfactors

HHH – use of wave functions on classical one-cut solutions

• need understand string vertex operators

or is there an alternative formalism for correlators?

encode integrability data into string field theory?

Null Wilson loops / amplitudes [Basso, Sever, Sprenger]

great progress but

go beyond OPE / special limits ?

what is quantum integrable system behind TBA for WL area?

precise mathematical formulation of

“excitations of GKP string” or “flux tube” ?

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King's College London

Imperial College London

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- organizers:
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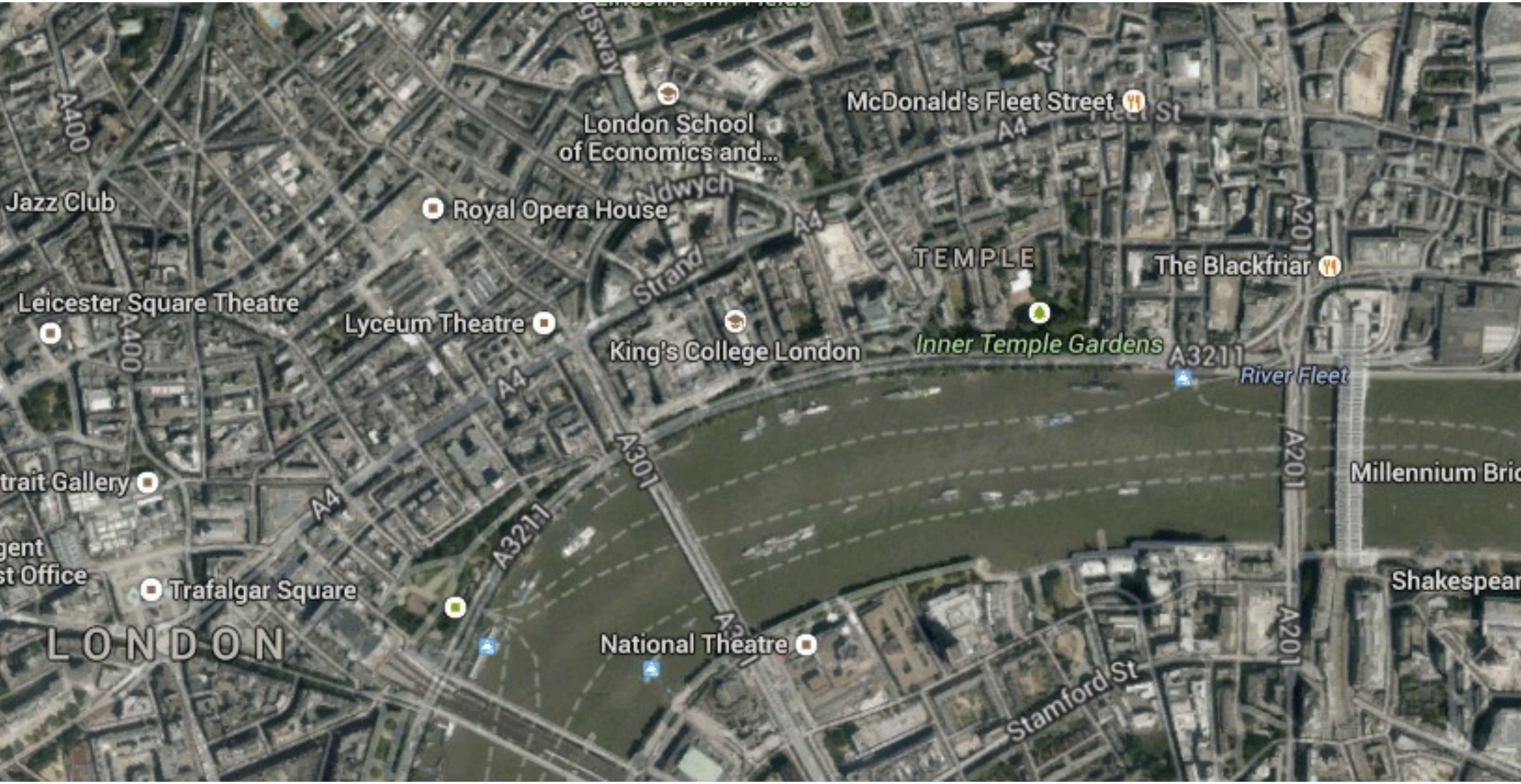
- http: //strongcoupling.org/igst



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