



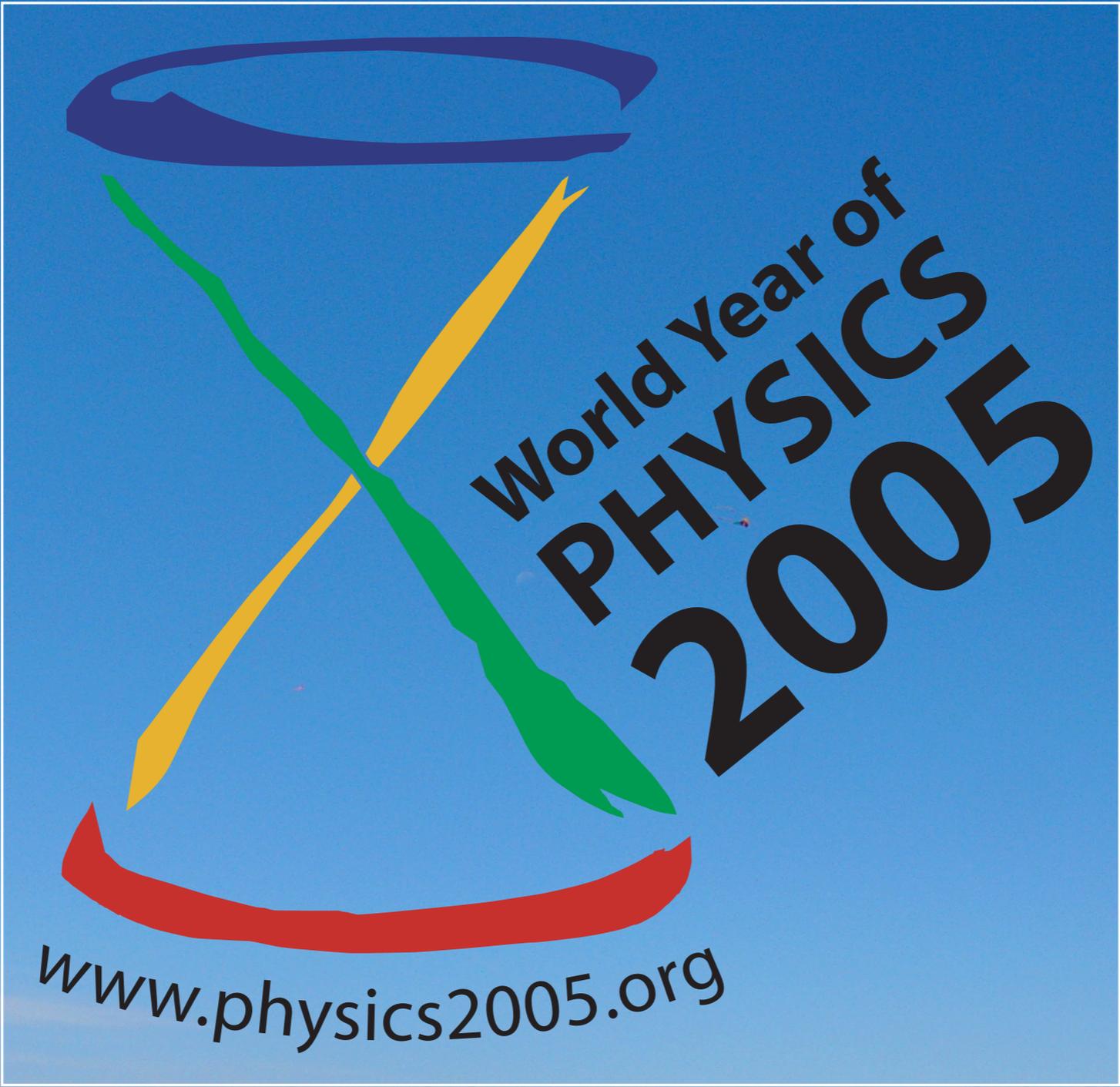
Physical Reflections on World Year of Physics, Near-Perfect Fluids, & Quantum Diaries

Peter Steinberg, Chemistry Department

BROOKHAVEN
NATIONAL LABORATORY

BNL CAC, November 10, 2005



The logo for the World Year of Physics 2005 is centered in the image. It features a stylized 'P' shape formed by four thick, curved lines: a purple line at the top, a red line at the bottom, a yellow line on the left, and a green line on the right. The text 'World Year of PHYSICS 2005' is written in a bold, black, sans-serif font, slanted upwards to the right, and positioned over the right side of the 'P'. Below the 'P' is the website address 'www.physics2005.org' in a smaller, black, sans-serif font.

World Year of
PHYSICS
2005

www.physics2005.org



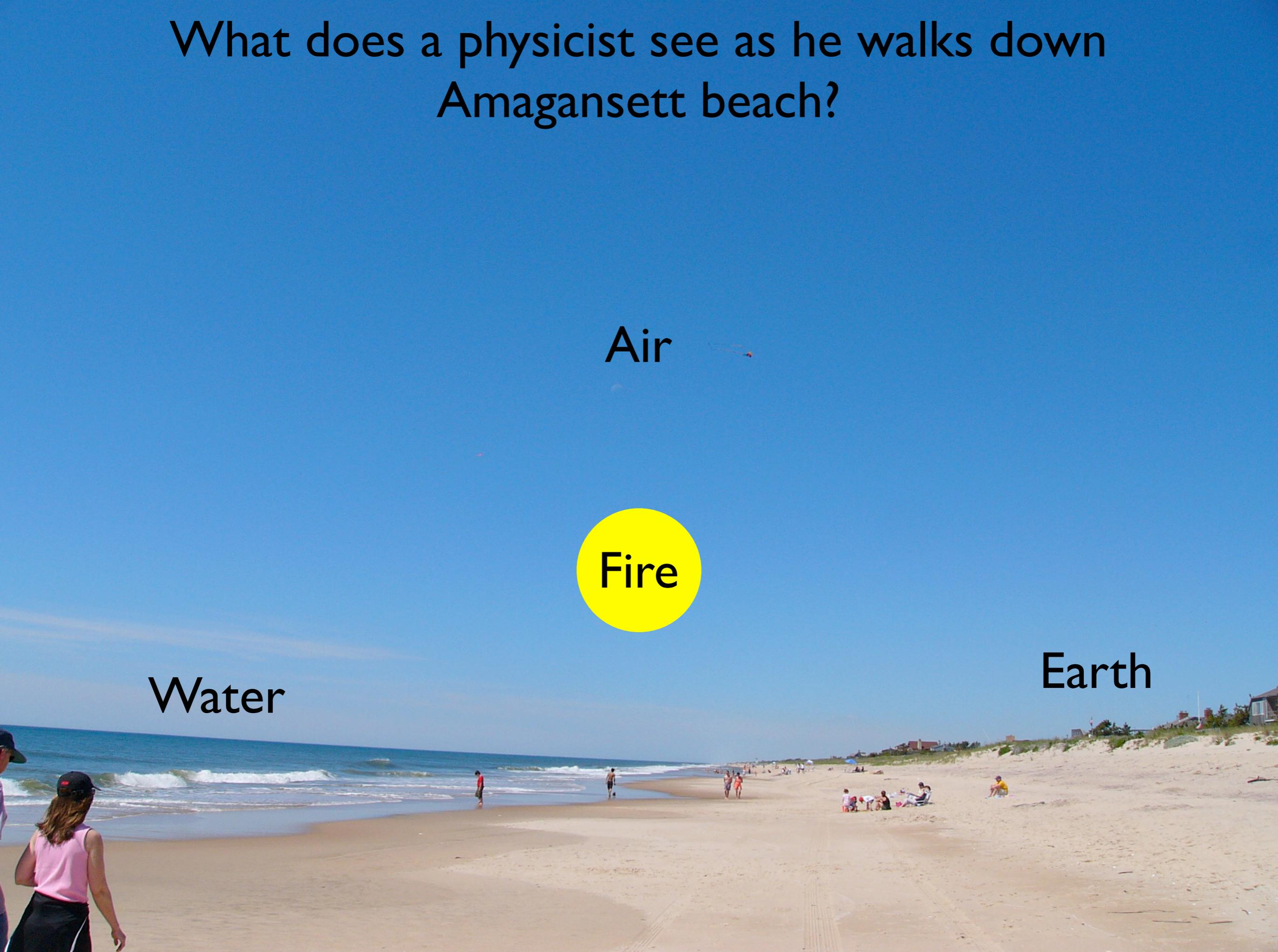
What does a physicist see as he walks down
Amagansett beach?

Air

Fire

Water

Earth



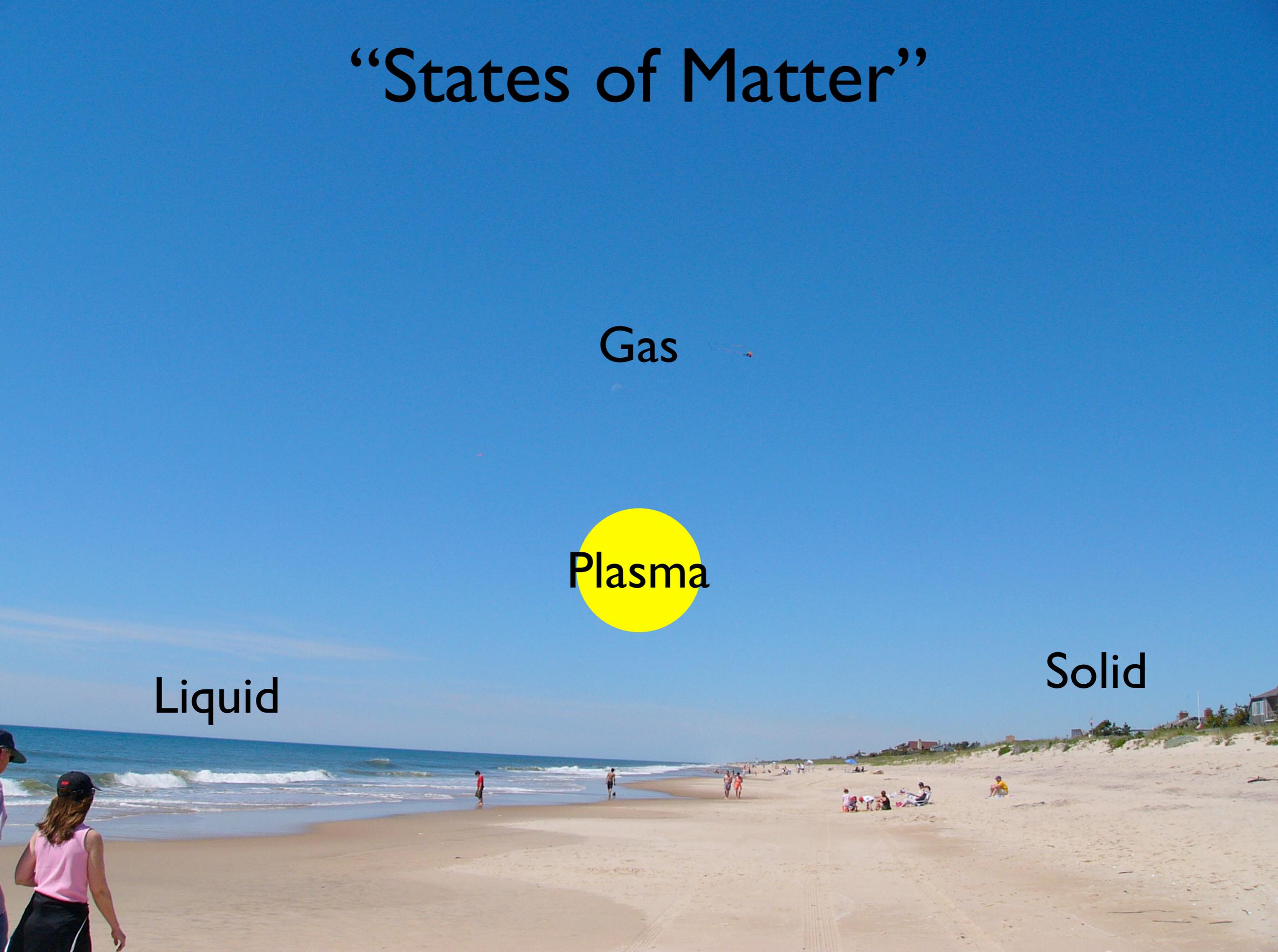
“States of Matter”

Gas

Plasma

Liquid

Solid



Underlying Dynamics

The universe, beyond the visible sky

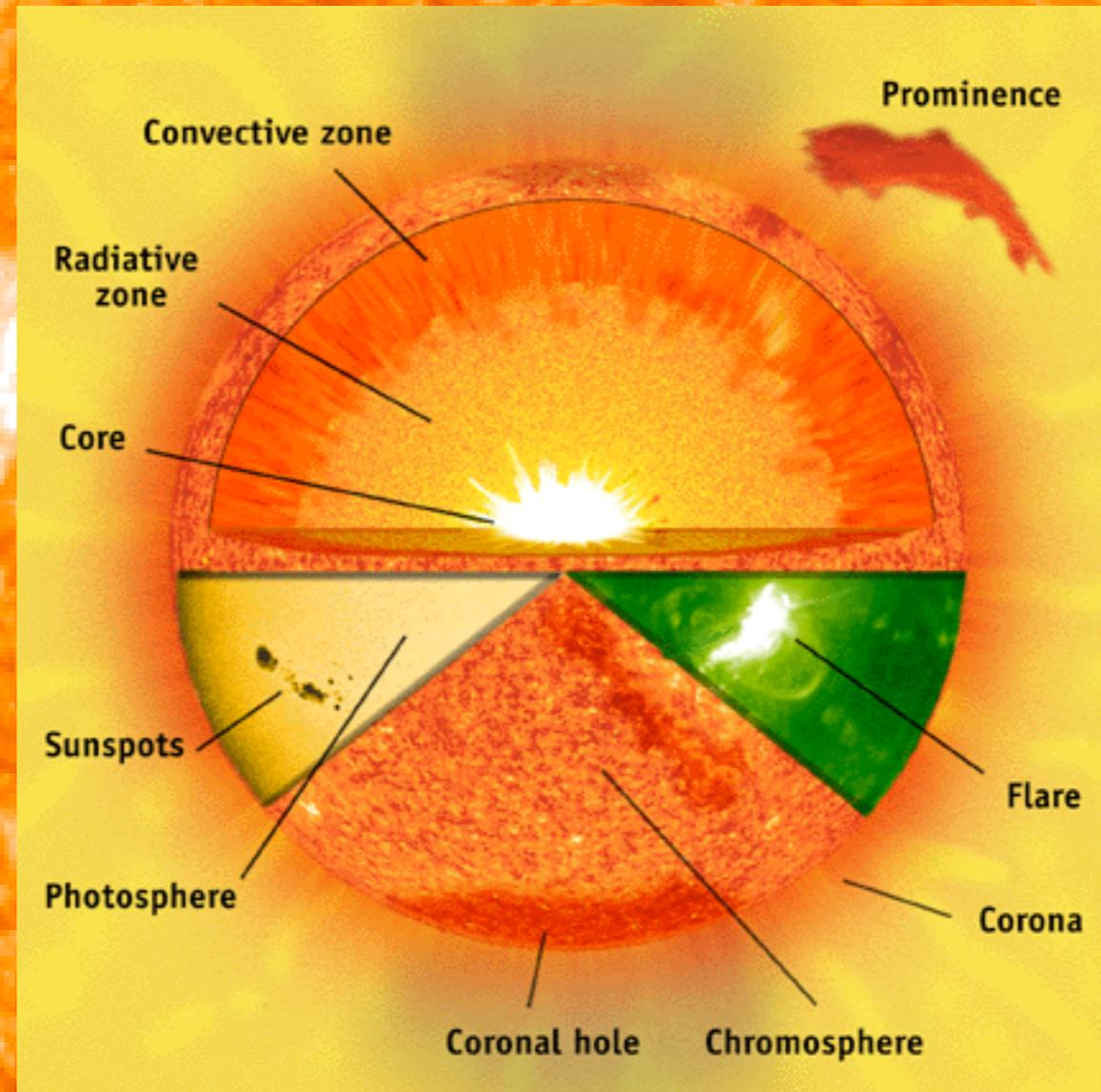
Light from the sun (scattering off of the atmosphere,
making the sky blue!)

Waves in water

Geological dynamics



“Temperature” of the Sun



Core of the sun is 13–25 million °K
Surface of the sun is 7000°K

Physics: It's all around you,
but is often hidden from view



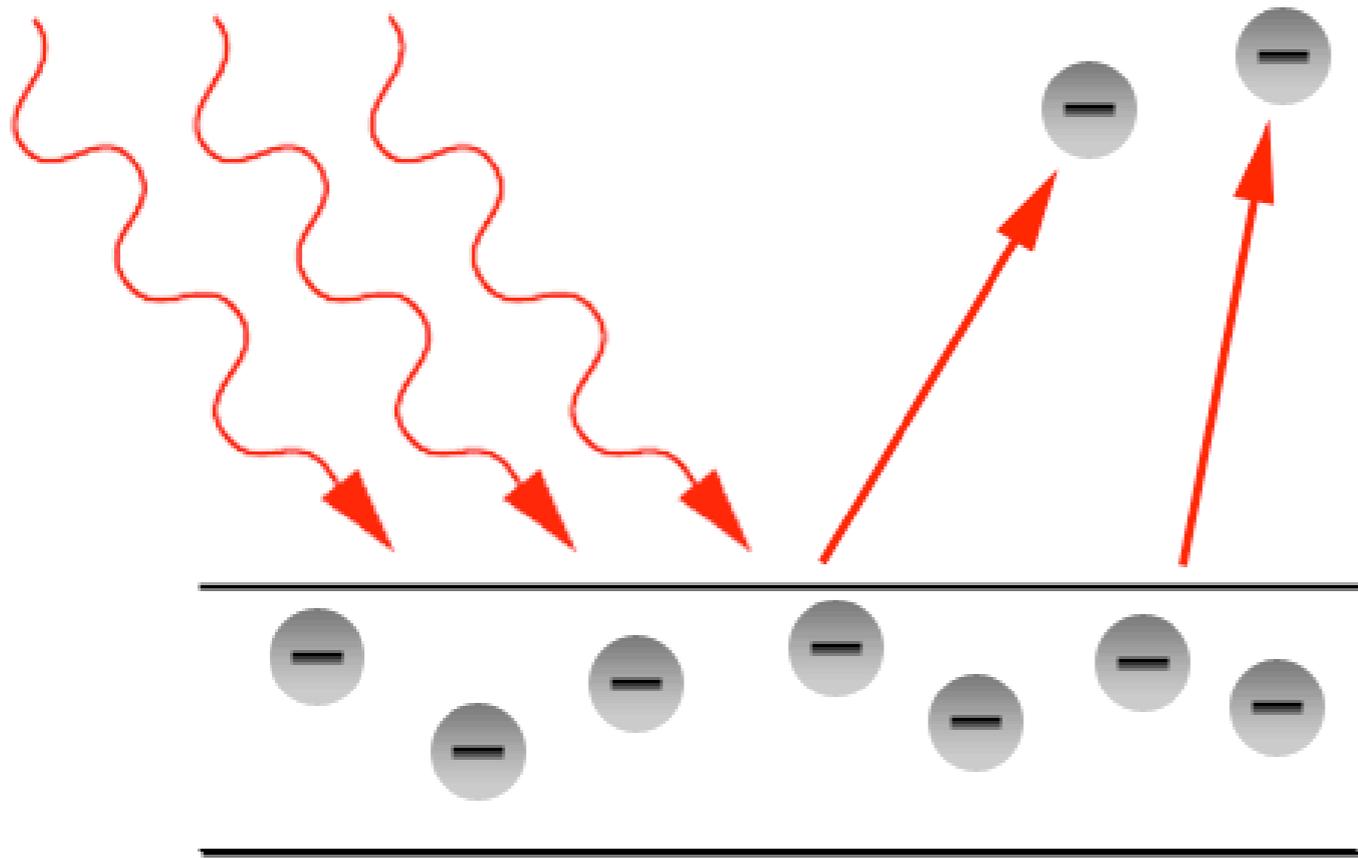
What difference can a year make?



In a single year,
1905,
Einstein published
four papers, three of
which could have
won a Nobel Prize
(and one did!)

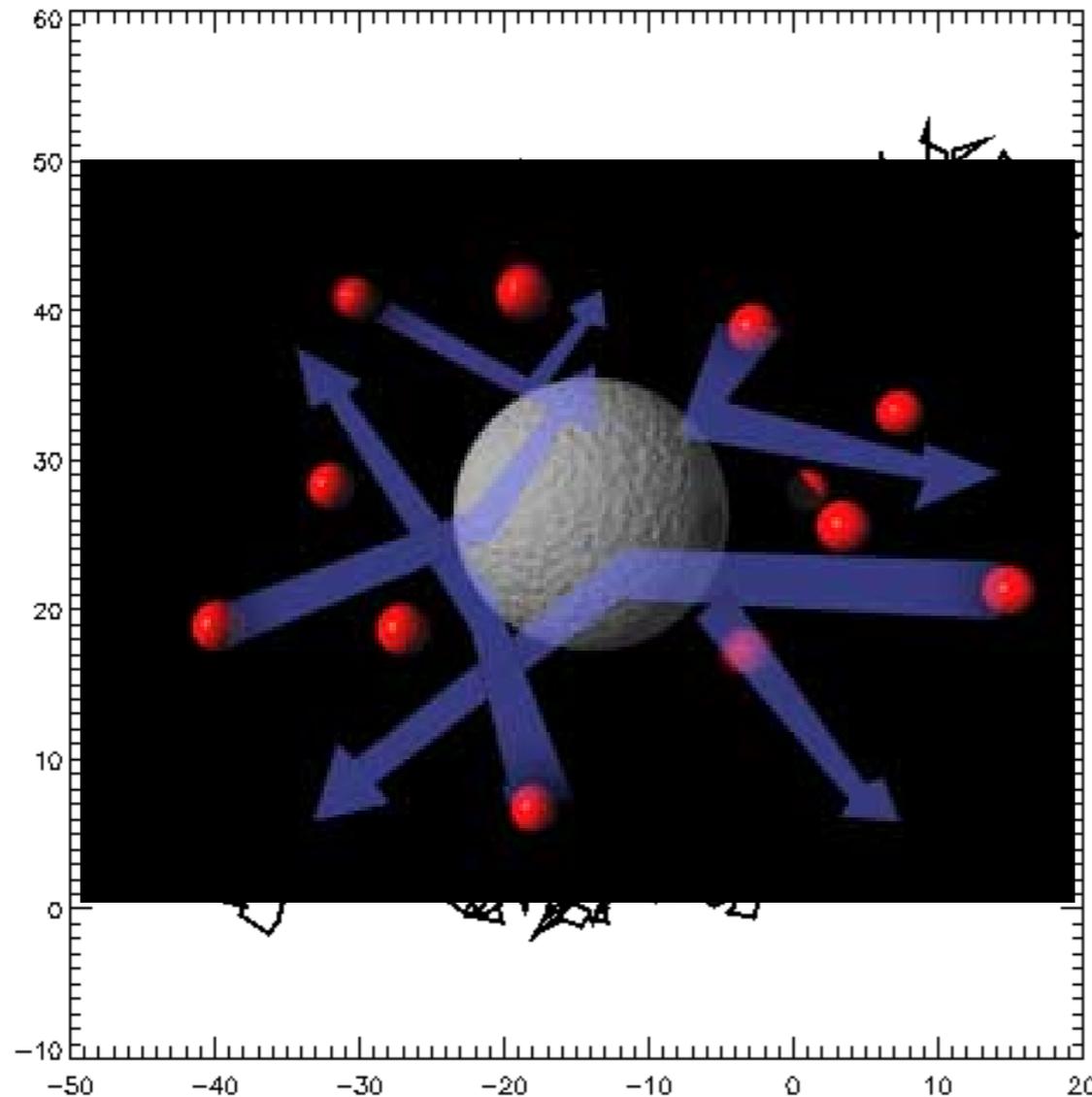


Rate of electron emission from a metal depends on a minimum frequency (energy) and not just on the intensity of the light



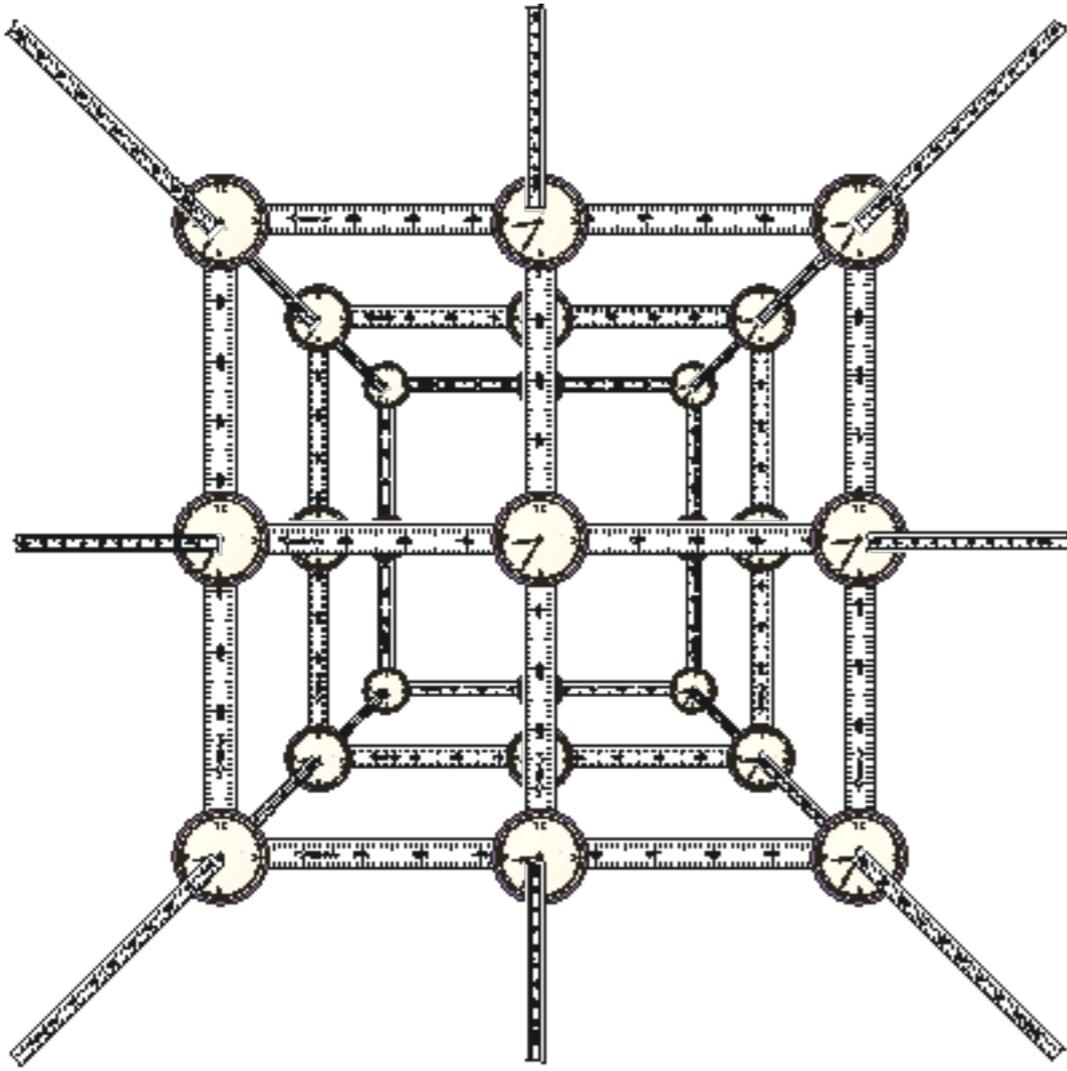
March 1905 - Einstein publishes paper on the “photoelectric effect”, determining that light has irreducible “particle” aspects.

Important precursor to Quantum Theory



May 1905 - Einstein publishes paper on the “Brownian Motion”, explaining jagged paths of particles suspended in solution.

Helped us understand atomic nature of matter



June 1905 - Einstein publishes paper on the “Electrodynamics of Moving Bodies”, where he gives the formulae of the Theory of Special Relativity

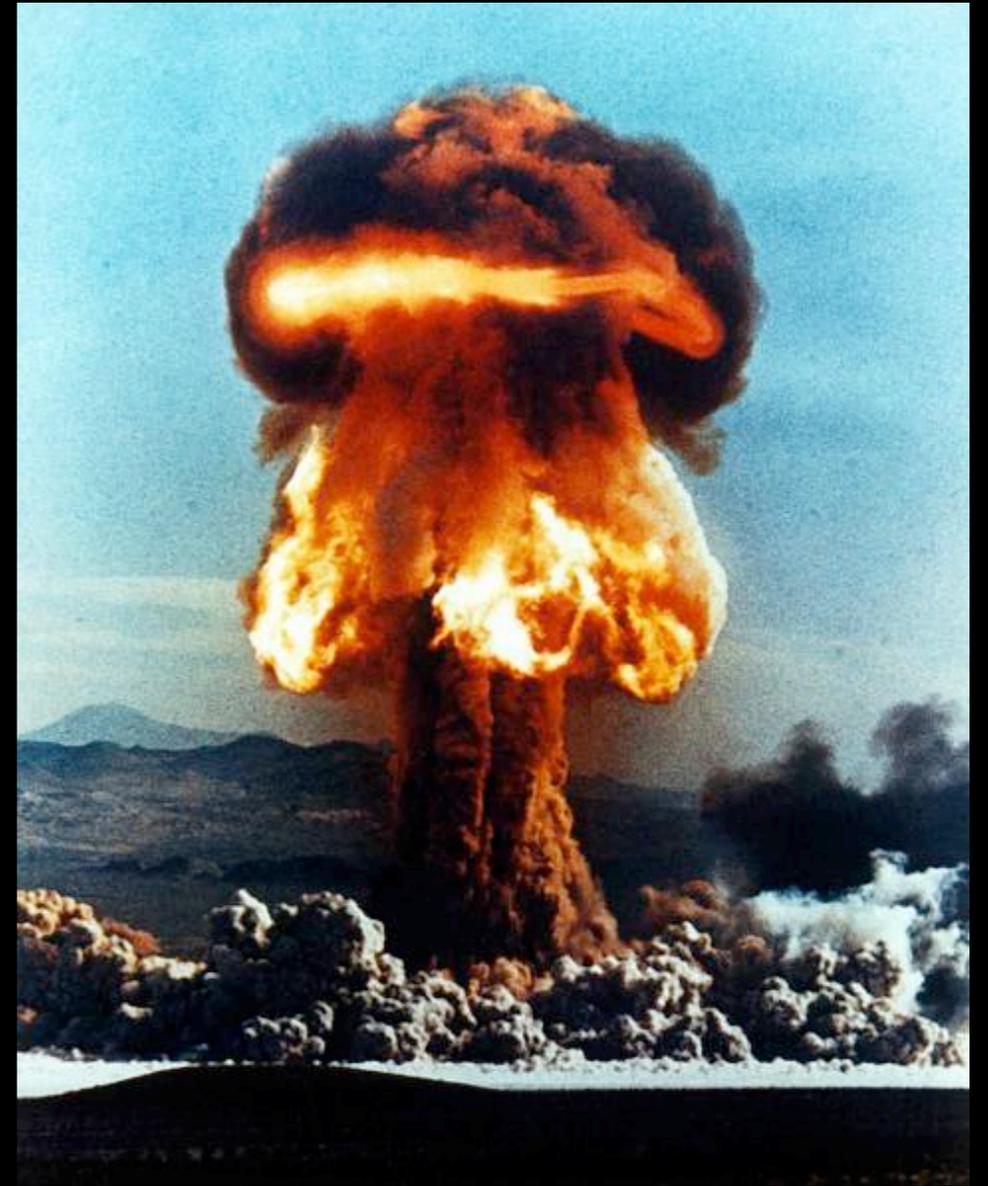
Completely upended classical view of space-time

$$E = mc^2$$



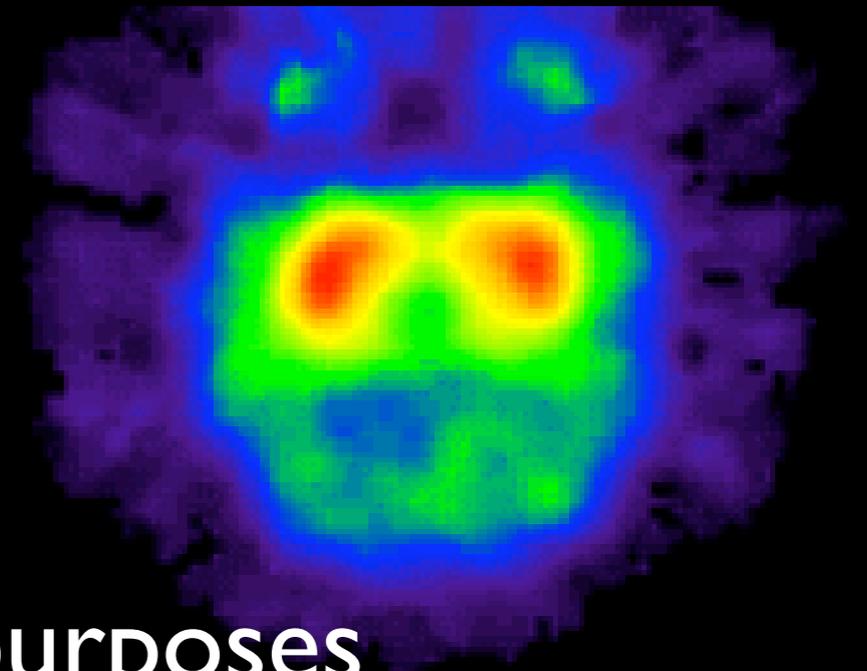
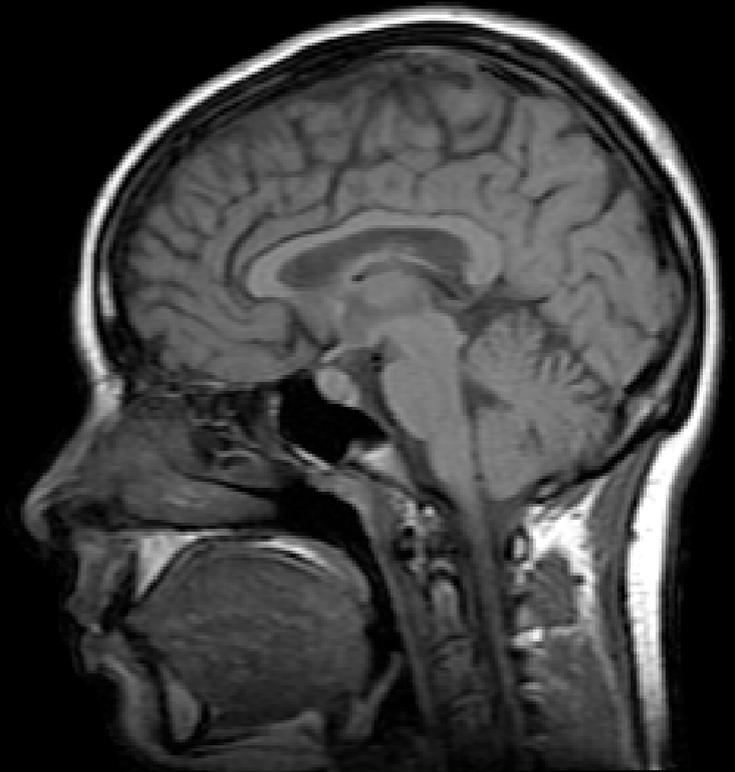
September 1905 - Einstein publishes paper, “Does the Inertia of a Body Depend on Its Energy Content?”, where he gives his most famous formula

$$E = mc^2$$



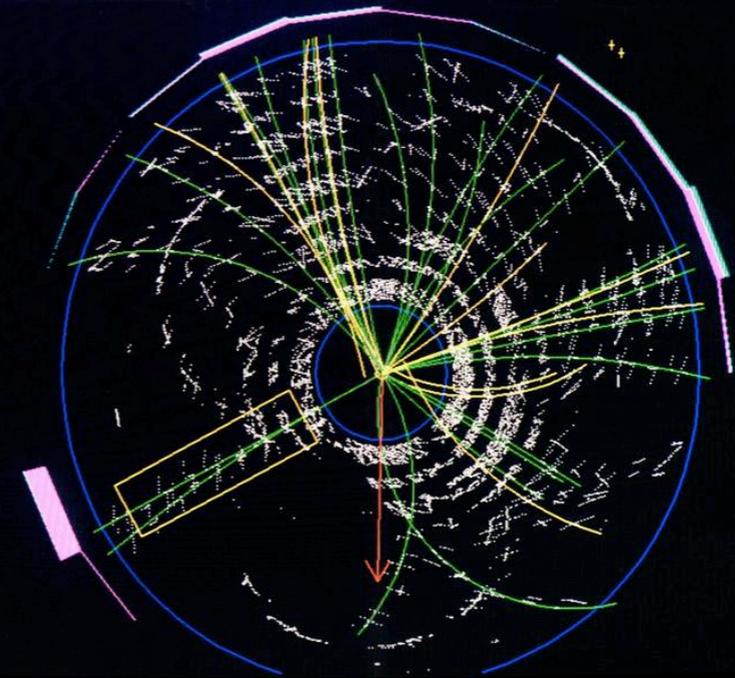
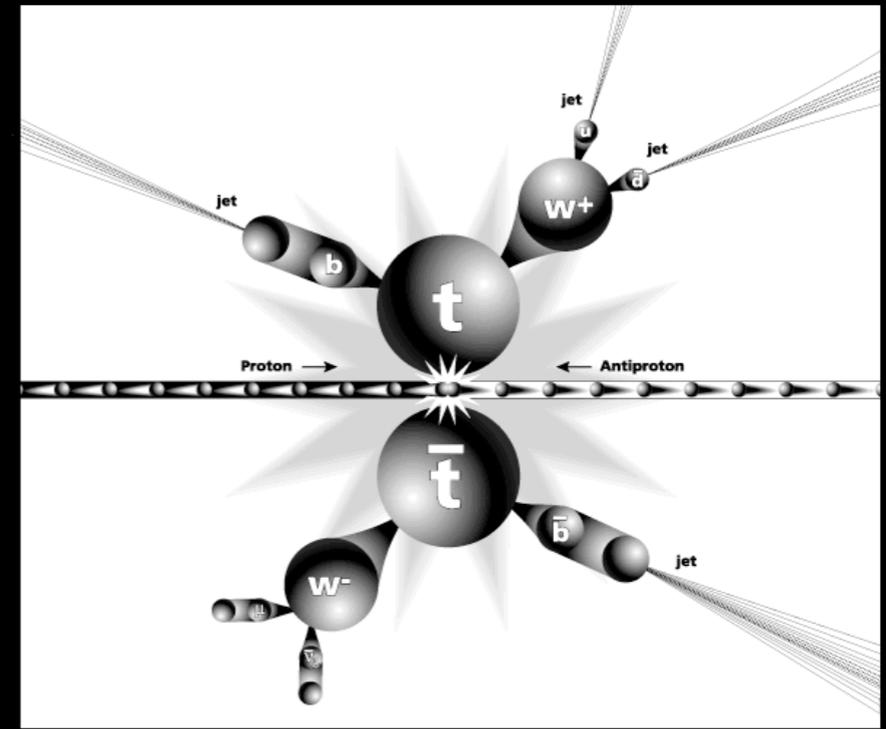
Of course, the conversion of mass to energy is the basis of the physics used to release energy from the nucleus, sometimes for destructive purposes...

$$E = mc^2$$

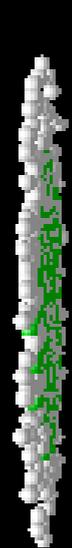


but also for constructive purposes
(e.g. medical imaging with PET & MRI)

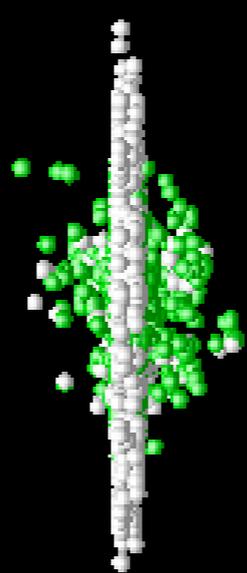
$$E = mc^2$$



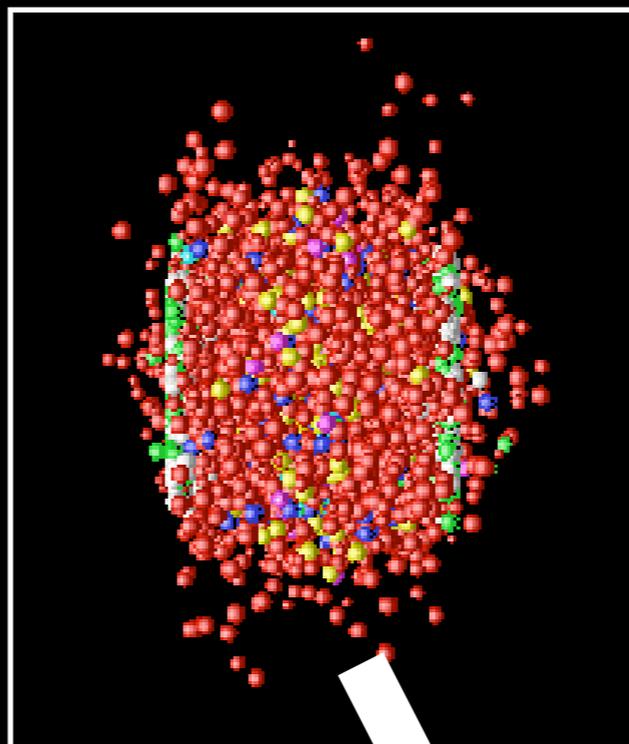
It is also the foundation of modern particle physics, colliding elementary particles at such high energies that new particles are created.



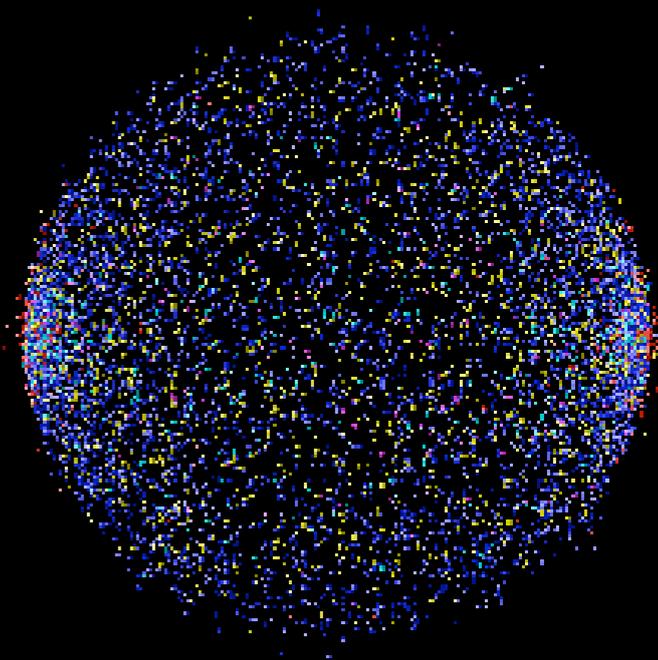
Colliding
Nuclei



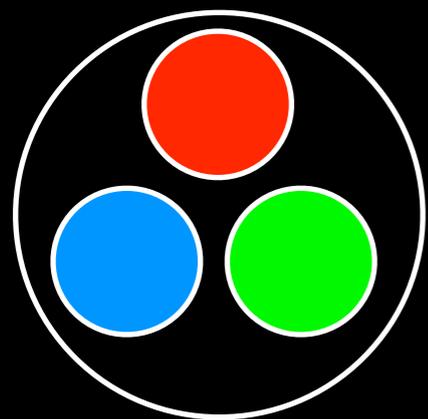
Bang!



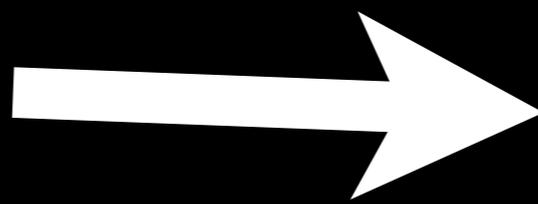
?



Final particles

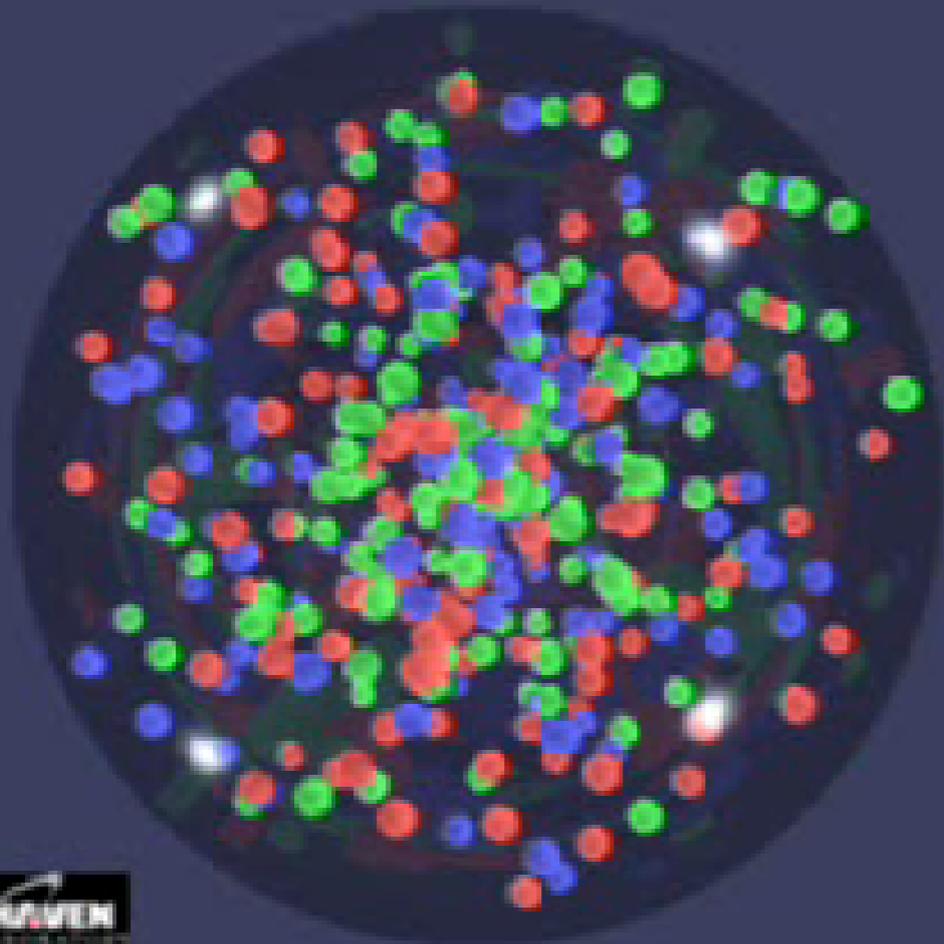


Protons &
Neutrons
"made" of
quarks held
together by
gluons

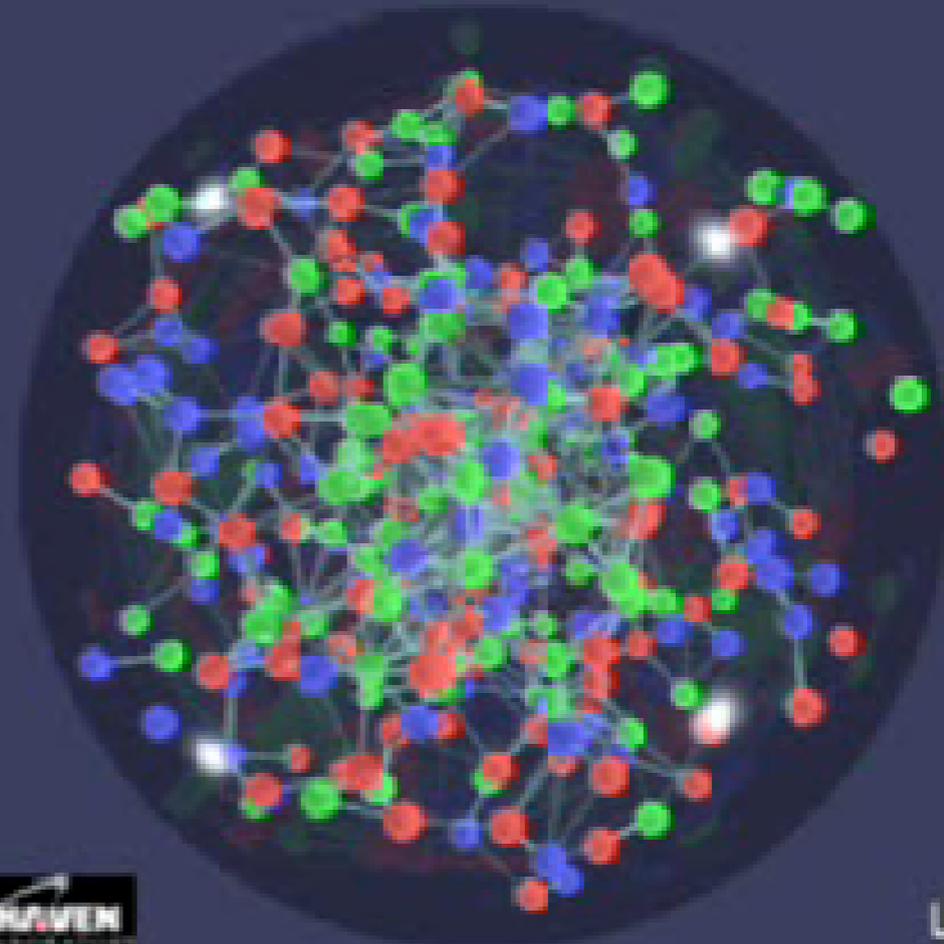


"Quark-Gluon
Plasma"
(QGP)?





Gas



Liquid

"Quark-Gluon
Gas"?

"Quark-Gluon
Liquid"?

RHIC @ BNL

(Relativistic Heavy Ion Collider)

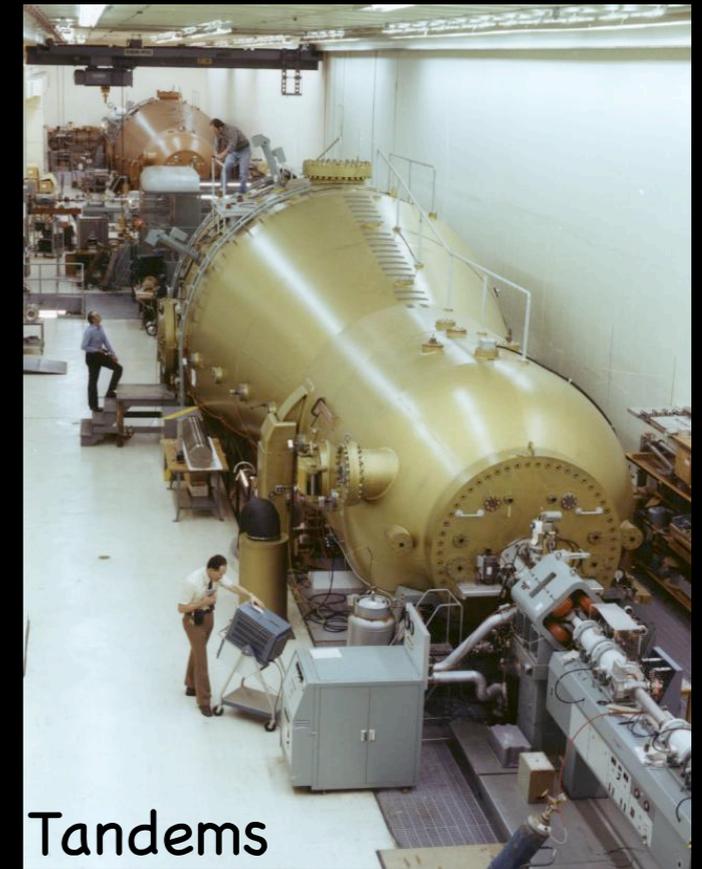


$E=mc^2$ is also the foundation of the physics we do here at
Brookhaven at the RHIC Collider..

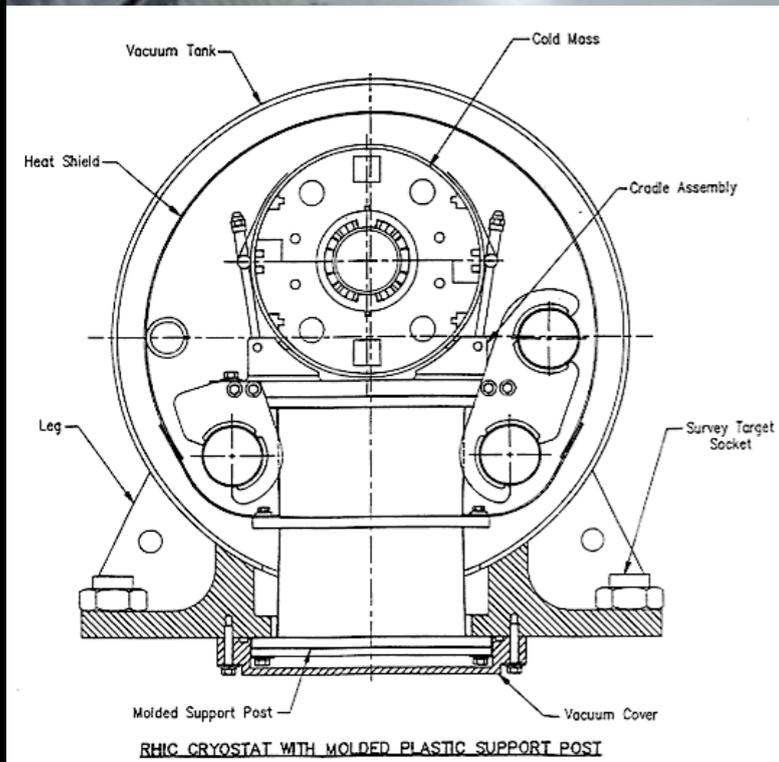
RHIC @ BNL



RHIC @ BNL



Tandems



Collaboration w/
Northrop Grumman

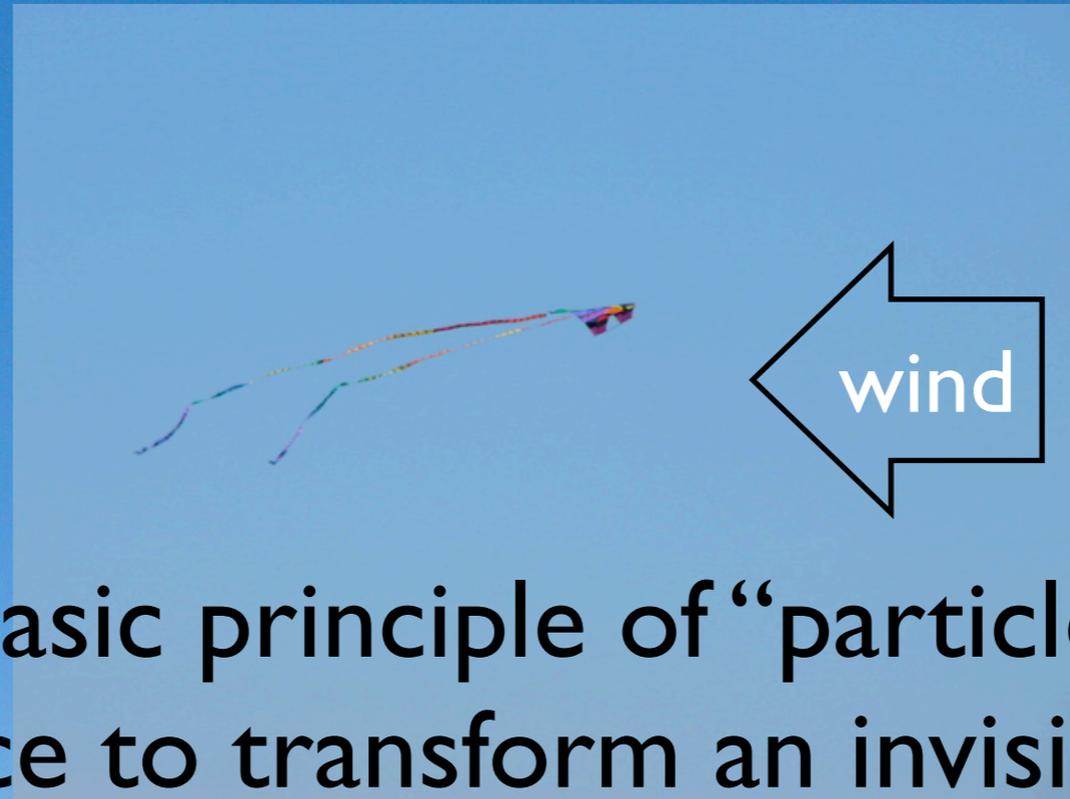
Superconducting
Magnets (@ 4°K)



RF Cavities

Question: The air is transparent. How do we “see” it?

Answer: We can see it push things around, like kites...



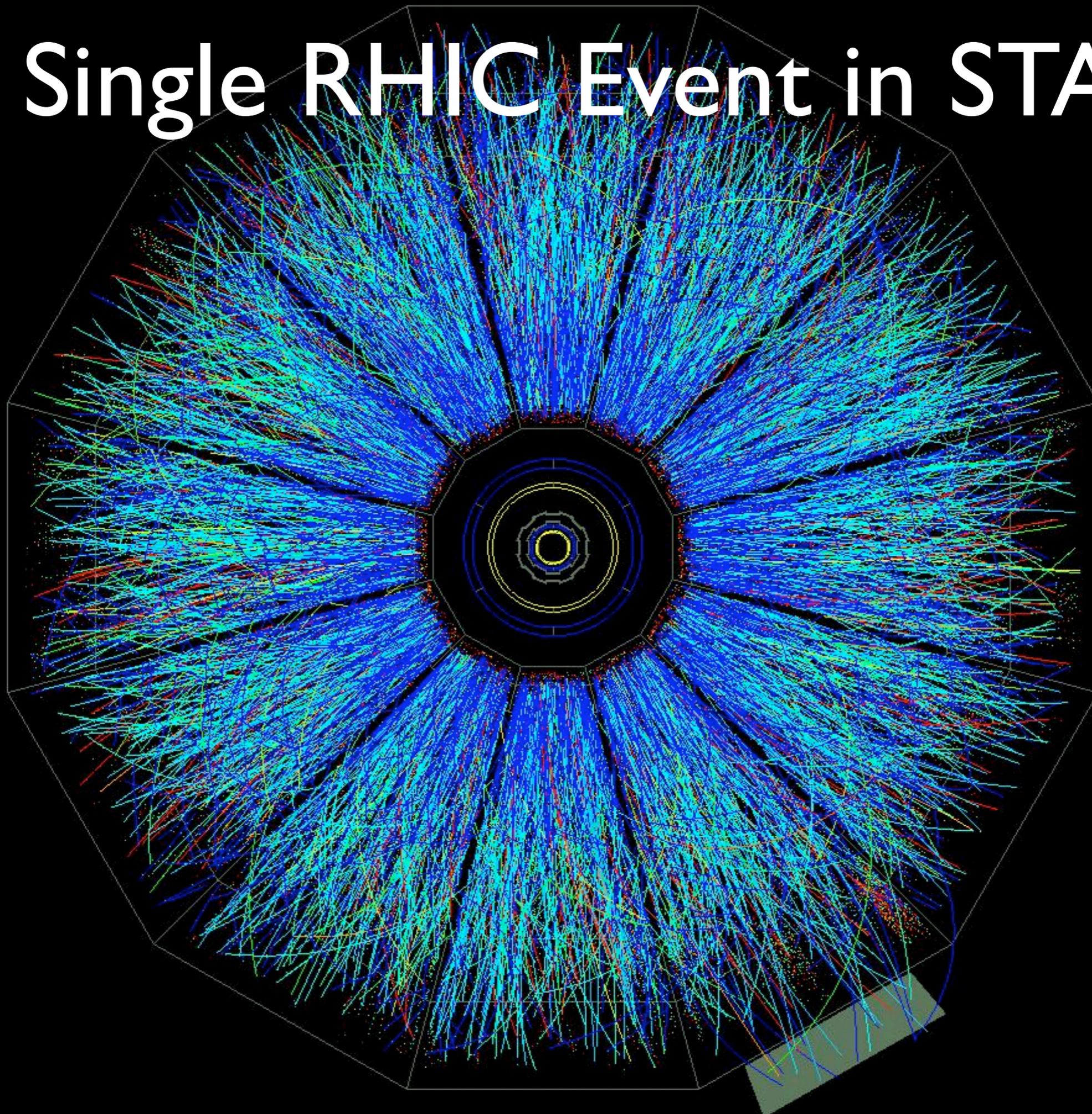
This is the basic principle of “particle detection”,
use a device to transform an invisible particle
into something we can see (& record!)



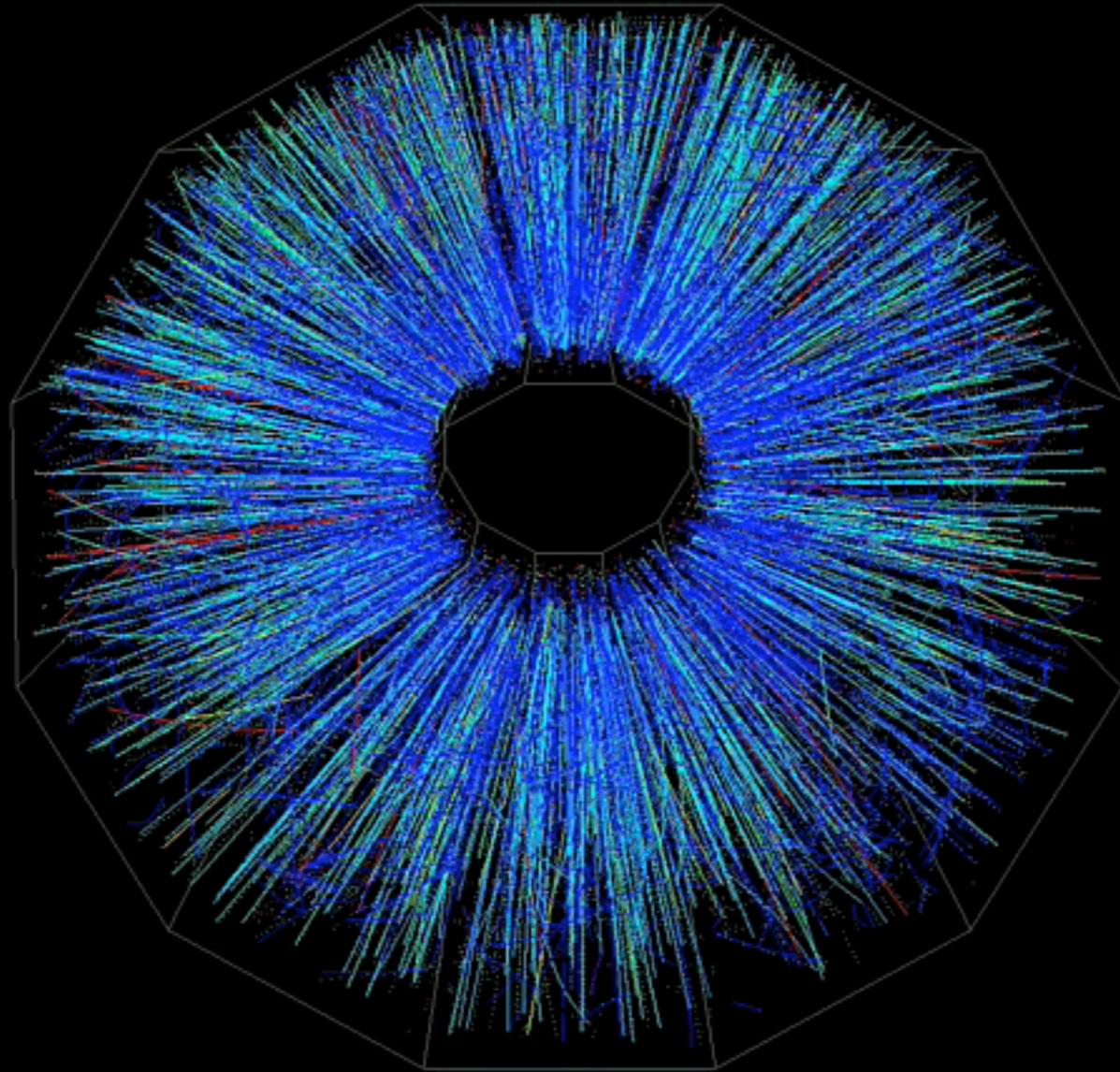
The STAR Detector



A Single RHIC Event in STAR



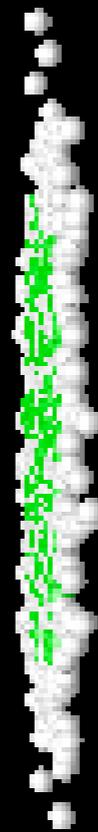
A Single RHIC Event



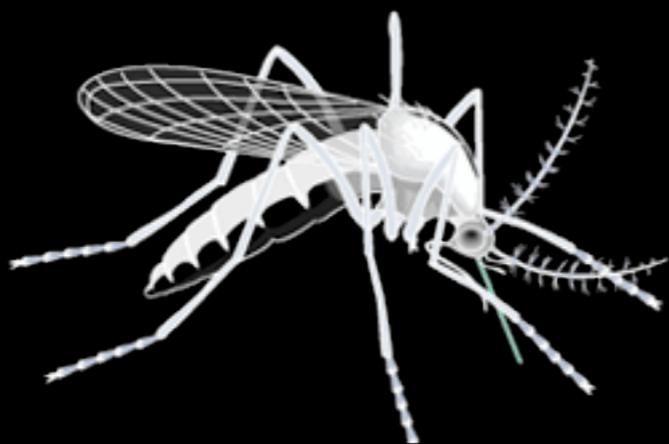
STAR: A giant 3D camera...



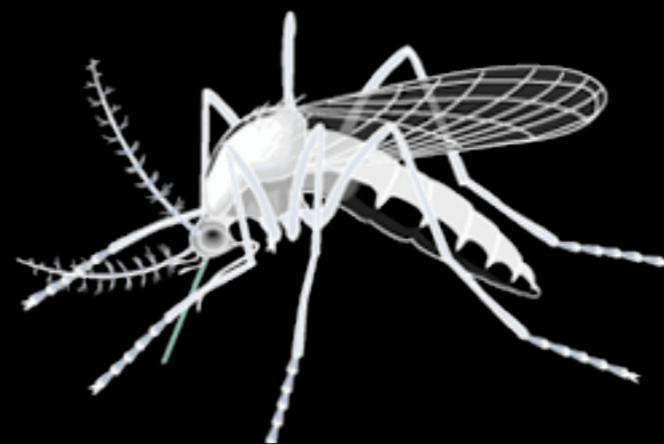
How much
energy
in each
collision?



$$1.6 \times 10^{-19} \frac{J}{eV} \times 197 \times 200 GeV \sim 6 \mu J$$



Consider
two mosquitos
colliding...



$$2 \times \frac{1}{2} mv^2 = (1g) \times (10cm/s)^2 = 10 \mu J$$

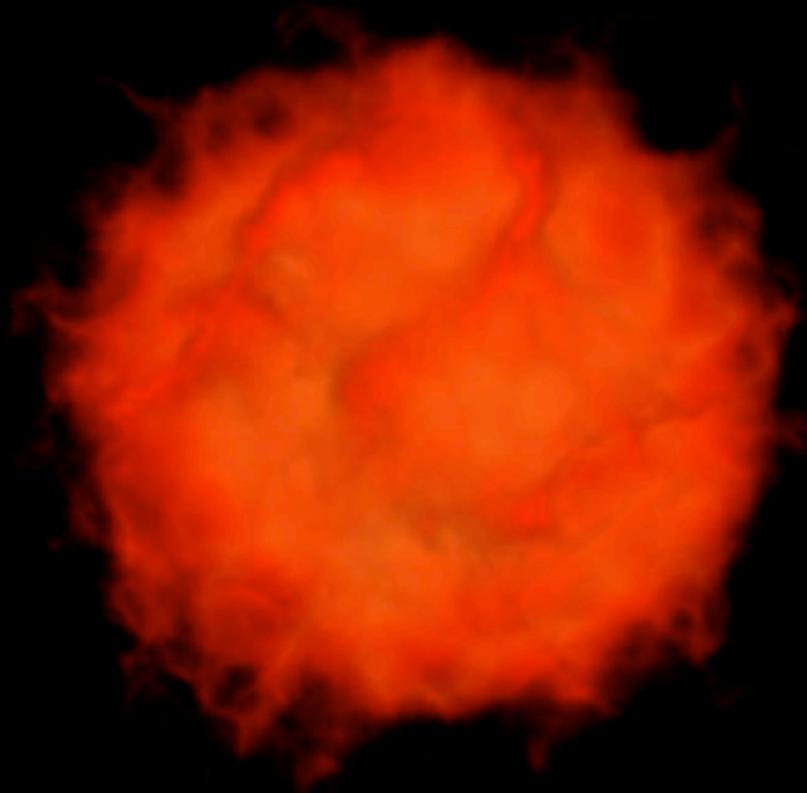
“Temperature” of the QGP

$\sim 4 \times 10^{12}$ degrees F

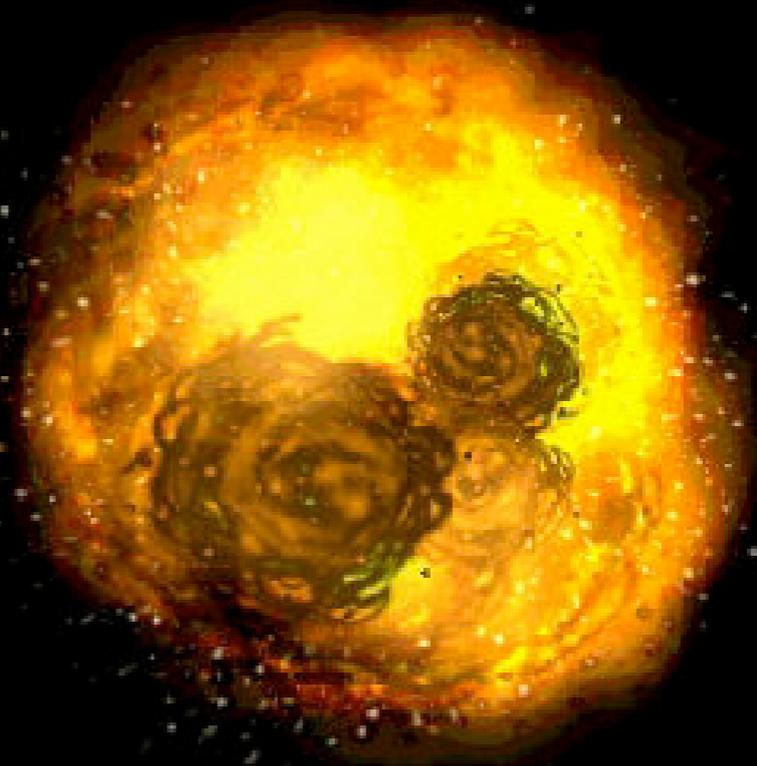
This is, in some sense, the “surface temperature” of a RHIC collision, when it “freezes” into particles

The “core” must have been much hotter!

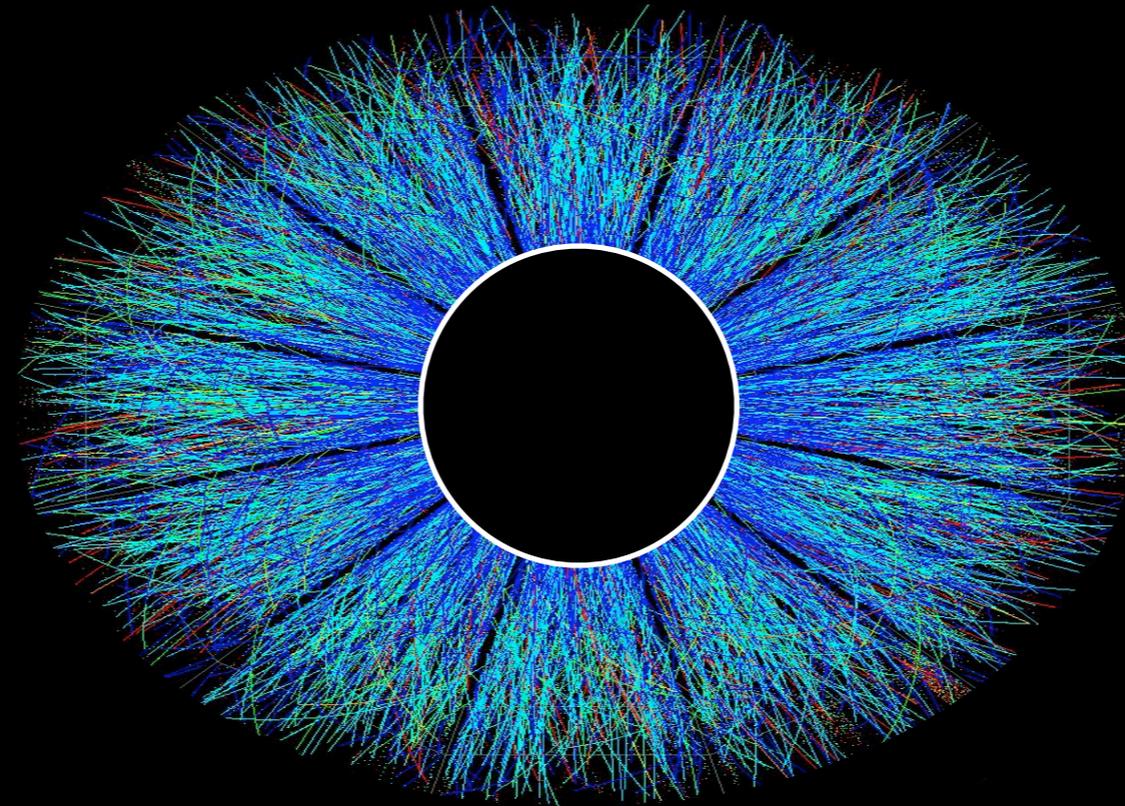
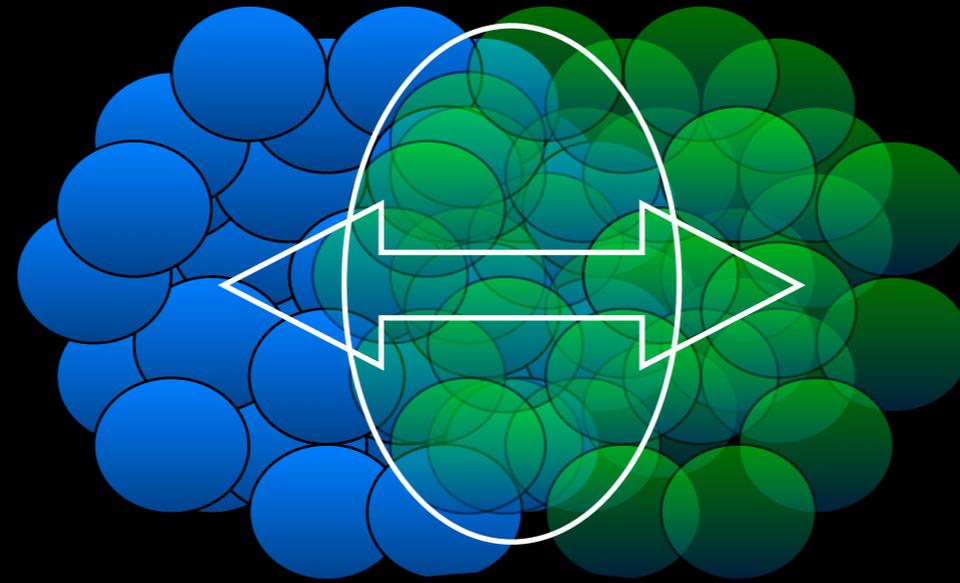
Is QGP a gas or a liquid?



Is the QGP just
a “fireball”, just radiating
into free space?



Or is the QGP
more fluid?
(Does it flow?)



Even at these high energies,
RHIC “flows” like a fluid



Honey



Water



Superfluid He³

A perfect fluid is one where there is no resistance to the liquid flowing.

We say that a perfect fluid then has zero “viscosity”, the feature of “sticky” liquids like honey.

Black Holes at RHIC?

BBC NEWS UK EDITION

Last Updated: Thursday, 17 March, 2005, 11:30 GMT

[E-mail this to a friend](#)

[Printable version](#)

Lab fireball 'may be black hole'

A fireball created in a US particle accelerator has the characteristics of a black hole, a physicist has said.

It was generated at the Relativistic Heavy Ion Collider (RHIC) in New York, US, which smashes beams of gold nuclei together at near light speeds.

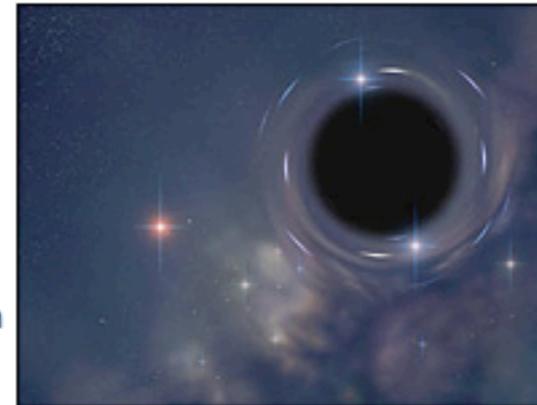
Horatiu Nastase says his calculations show that the core of the fireball has a striking similarity to a black hole.

His work has been published on the pre-print website arxiv.org and is reported in New Scientist magazine.

When the gold nuclei smash into each other they are broken down into particles called quarks and gluons.

These form a ball of plasma about 300 times hotter than the surface of the Sun. This fireball, which lasts just 10 million, billion, billionths of a second, can be detected because it absorbs jets of particles produced by the beam collisions.

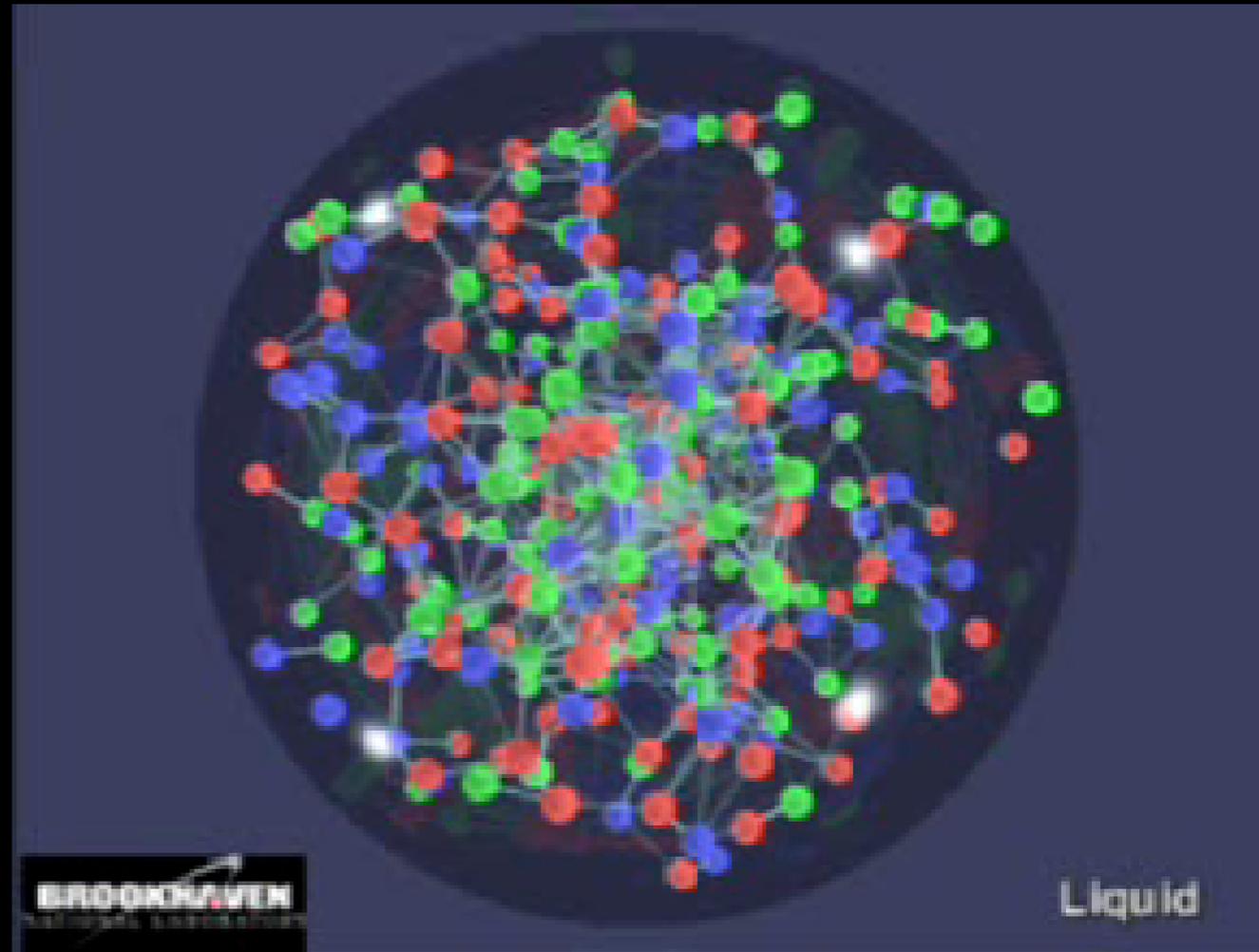
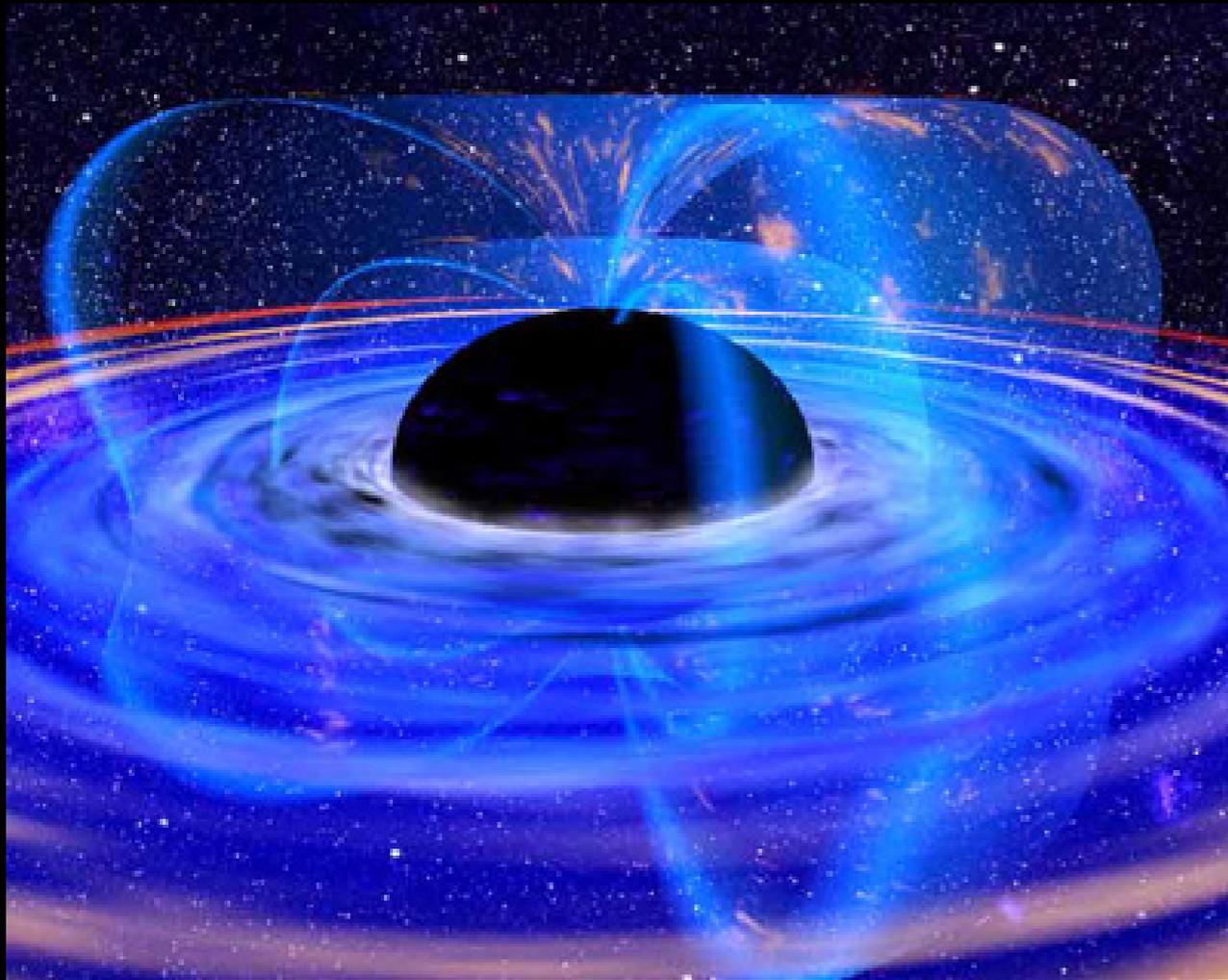
But Nastase, of Brown University in Providence, Rhode Island, says there is something unusual about it.



Creating the conditions for the formation of black holes is one of the aims of particle physics

sorry, no...

A Mathematical Connection



10-dimensional
Black Hole
(not a "real"
black hole...)



"Quark-Gluon
Liquid"?

Viscosity in Strongly Interacting Quantum Field Theories from Black Hole Physics

P. K. Kovtun,¹ D. T. Son,² and A. O. Starinets³

¹*Kavli Institute for Theoretical Physics, University of California, Santa Barbara, California 93106, USA*

²*Institute for Nuclear Theory, University of Washington, Seattle, Washington 98195-1550, USA*

³*Perimeter Institute for Theoretical Physics, Waterloo, Ontario N2L 2Y5, Canada*

(Received 20 December 2004; published 22 March 2005)

The ratio of shear viscosity to volume density of entropy can be used to characterize how close a given fluid is to being perfect. Using string theory methods, we show that this ratio is equal to a universal value of $\hbar/4\pi k_B$ for a large class of strongly interacting quantum field theories whose dual description involves black holes in anti-de Sitter space. We provide evidence that this value may serve as a lower bound for a wide class of systems, thus suggesting that black hole horizons are dual to the most ideal fluids.

DOI: 10.1103/PhysRevLett.94.111601

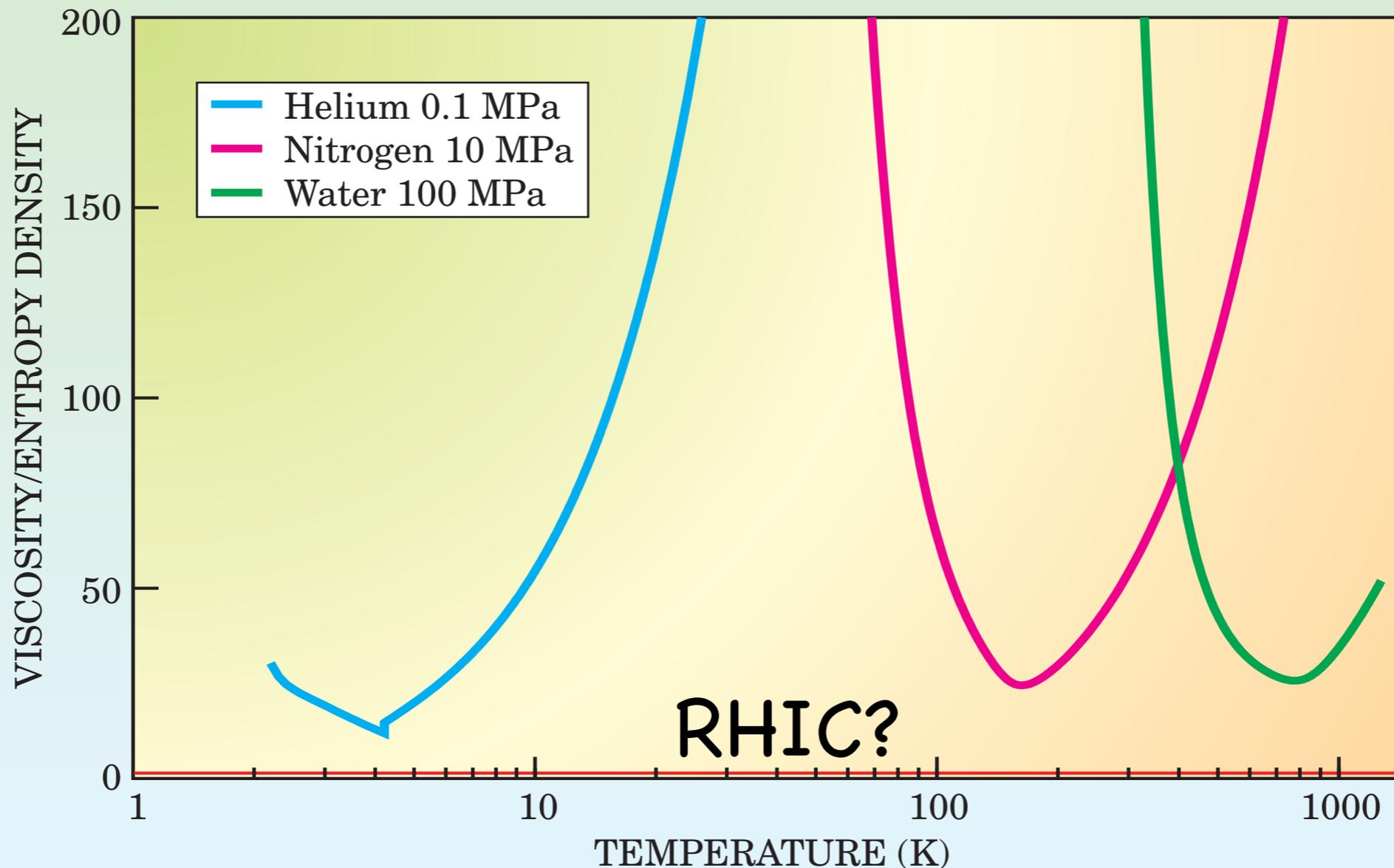
PACS numbers: 11.10.Wx, 04.70.Dy, 11.25.Tq, 47.75.+f

Details aside, this paper makes a calculation about RHC physics using a 10 dimensional black hole and gets a meaningful result about its viscosity...

Lower Viscosity Bound

Physics Today, May 2005

P. K. Kovtun, D. T. Son, A. O. Starinets, *Phys. Rev. Lett.* **94**, 111601 (2005).



A perfect liquid is impossible - but is RHIC the most perfect?

The Big Bang

1 thousand million years

300 thousand years

3 minutes

1 second

10^{-10} seconds

10^{-34} seconds

10^{-43} seconds

10^{32} degrees

10^{27} degrees

10^{15} degrees

10^{10} degrees

10^9 degrees

6000 degrees

18 degrees

3 degrees K

-  radiation
-  particles
- W^+ } heavy particles carrying the weak force
- W^- }
- Z }
-  quark
-  anti-quark
- e^- electron
- e^+ positron (anti-electron)
-  proton
-  neutron
-  meson
- H hydrogen
- D deuterium
- He helium
- Li lithium

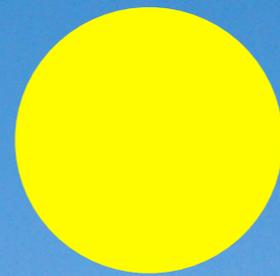


MS/1000/1989

So what have we found at RHIC?

We thought it would be a gas of quarks & gluons,
or more like a plasma

But it turns out to
have fluid-like
properties





What a difference a year can make!

What difference can a year make?



We don't get many chances to think
about what we do.

Nor do we get many chances to try and describe
what we do for a wider audience.

InterAction collaboration, a consortium of the
public affairs departments of physics labs worldwide,
decided that they could reveal the creative energy
of physicists from all over the world by using
the power and immediacy of the internet.

“web log” → “blog”



QUANTUM DIARIES

journal diario 전표 tagebuch ジャーナル diary dagboek 學報 diário

Follow physicists from around the world as they live the World Year of Physics.

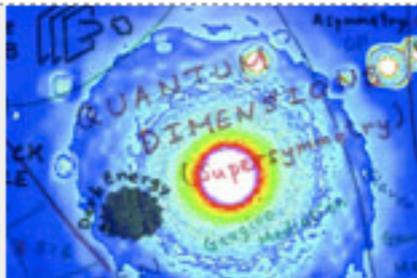


- LATEST POSTS
- THIS WEEK
- THE PHYSICISTS
- AROUND THE WORLD
- WORLD YEAR OF PHYSICS
- ABOUT QUANTUM DIARIES
- BUZZ
- SUBSCRIBE
- FIND A BLOG



Maaïke Limper
NIKHEF
Netherlands
Lang: Dutch

In Maaïke's dagelijks leven wordt de internationale sfeer van het werken in de wereld van de hoge energie fysica nogmaals benadrukt. Samen met een Italiaanse en een Franse promotiestudente woont ze in een huis op een steenworp afstand van het NIKHEF.

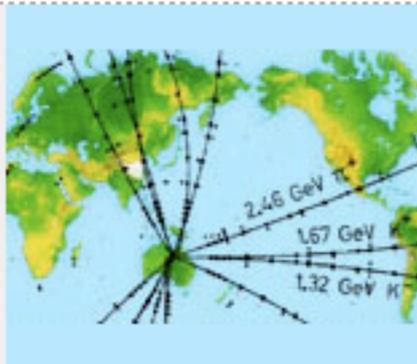


New

A night to be proud
Rob Gardner **photographs** the Chicago skyline—lit up with White Sox pride. (posted 10/27)

Saturday at the park
Maaïke Limper helps **host** a public open house at the Amsterdam Science Park. "When I start talking about science I always forget to breathe," she writes. (posted 10/26)

Why blog?
Peter Steinberg **discovers** that not all bloggers have motivations as pure as the Quantum Diarists'. (posted 10/26)



Zhi-Zhong Xing

October 26, 2005

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Jochen Weller

October 27, 2005

So for a change I post a question here:
Who can provide me with the most simple explanation: Why is $E=mc^2$?
Read more...

Follow physicists from around the world as they live the World Year of Physics.

33 Physicists, 16 Nations

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The Physicists



[Peter Steinberg](#)
Brookhaven, USA,
Lang: English
[BLOG](#)
[VIDEO](#)




[Tommaso Dorigo](#)
Fermilab, USA
Lang: English
[BLOG](#)
[VIDEO](#)




[Sophie Trincz-Duvoid](#)
IN2P3, France
Lang: French
[BLOG](#)




[Ursula Bässler](#)
IN2P3,
France
Lang: English
[BLOG](#)
[VIDEO](#)




[Shohei Nishida](#)
KEK,
Japan
Lang: Japanese
[BLOG](#)
[VIDEO](#)




[Jose Ucariz](#)
IN2P3,
France
Lang: Spanish
[BLOG](#)




[Frank Linde](#)
NIKHEF,
Netherlands
Lang: Dutch
[BLOG](#)
[VIDEO](#)




[Jochen Weller](#)
Fermilab,
USA
Lang: English
[BLOG](#)
[VIDEO](#)




[Maaike Limper](#)
NIKHEF,
Netherlands
Lang: Dutch
[BLOG](#)




[Nick Brook](#)
CERN,
Switzerland
Lang: English
[BLOG](#)




[Makoto Fujiwara](#)
TRIUMF, Canada
Lang: English
[BLOG](#)



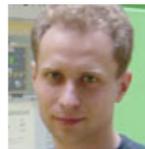

[John Ellis](#)
CERN,
Switzerland
Lang: English
[BLOG](#)
[VIDEO](#)




[Debbie Harris](#)
Fermilab,
USA
Lang: English
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[VIDEO](#)




[Frederic Deliot](#)
CEA/DAPNIA
France
Lang: French
[BLOG](#)

[Andrey Tamonov](#)
JINR Dubna,
Russia
Lang: Russian
[BLOG](#)




[Karsten Buesser](#)
DESY, Germany
Lang: English , German
[BLOG](#)




[David Waller](#)
Sudbury Neutrino
Obsv, Canada
Lang: English
[BLOG](#)




[Zhi-Zhong Xing](#)
IHEP
Lang: Chinese
[BLOG](#)




[Gordon Watts](#)
Fermilab,
USA
Lang: English
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[Caoliann O'Connell](#)
SLAC, USA
Lang: English
[BLOG](#)




[Alex Koutsman](#)
NIKHEF,
Netherlands
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[BLOG](#)




[Marcello Pavan](#)
TRIUMF
Lang: English
[BLOG](#)




[Sandra Leone](#)
INFN
Lang: Italian
[BLOG](#)




[Alessandro Cardini](#)
INFN
Lang: Italian
[BLOG](#)




[Karsten Heeger](#)
Berkeley,
USA
Lang: English
[BLOG](#)
[VIDEO](#)




[Stephon Alexander](#)
SLAC, USA
Lang: English
[BLOG](#)




[Bryan Dahmes](#)
SLAC,
USA
Lang: English
[BLOG](#)




[Rosa Alba](#)
INFN
Lang: Italian
[BLOG](#)




[Julio Rodriguez Martino](#)
Pierre Auger
Observatory
Lang: Spanish
[BLOG](#)




[Claire Gray](#)
Wits University/
Jefferson Lab
Lang: English
[BLOG](#)



One World Year of Physics!



[Sarah Phillips](#)
Jefferson Lab
Lang: English
[BLOG](#)




[Anuj Purwar](#)
Los Alamos
Lang: English
[BLOG](#)




[Rob Gardner](#)
Univ. of Chicago
Lang: English
[BLOG](#)





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SHOHEI NISHIDA

KEK



QUANTUM DIARIES

Quantum Diaries Home

最近の投稿

Belle in trouble

先週あたりから

KEK一般公開

Belle in maintainance

つくばエクスプレス (つづき)

つくばエクスプレス

I'm off now

Upsilon(5S)

New Belle Results (cont'd)

New Belle Results

アーカイブ

Overheard at the

ARCHIVES

October 2005

[« 先週あたりから](#) | [メイン](#)**10月 28, 2005**

Belle in trouble

Though Belle started operation in September, it's not working now. Last week, some problems happened in the Silicon detector, which is in the innermost part of the Belle detector.

We decided to open the detector to check what was happening, and found that some connectors were burnt. Maybe some deterioration due to radiation?

We need a few more days to fix the problem.

10月 28, 2005 at 09:59 午前 | [Permalink](#)

コメント

コメントを投稿

October 2005

Okay, a couple more. One from Grant park, the other from the Shedd

ARCHIVES

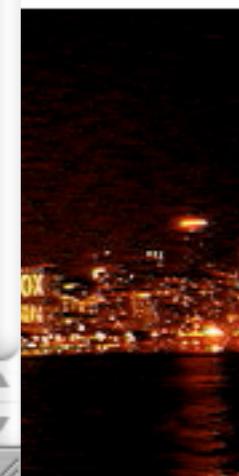
June 2005

May 2005

Trini Steff: How yuh mean? Dey get meh main man Mike Kelsey at de control room an ting.

SLAC Steff: What about that cute experimentalist, Caolionn?

oved so I
sn't alone
n - last night
it was lined
unning vista



QUANTUM DIARIES

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Follow physicists from around the world as they live the World Year of Physics.

PETER STEINBERG

Brookhaven



QUANTUM DIARIES

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[Quantum Diaries Home](#)

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[Do You Love Your Job Yet?](#)

[A View of the Horizon](#)

[Do You Know The Way...](#)

[The iPod and Einstein](#)

[Ghost in the Machine](#)

[Einstein off-Broadway, Elephants under Bridges and Endless Biking](#)

[Forgive Me \(and Einstein's Gift III\)](#)

ARCHIVES

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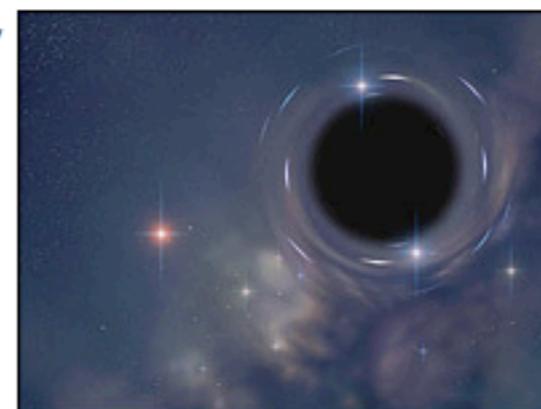
[September 2005](#)

[August 2005](#)

March 17, 2005

Public Service Announcement: Black Holes @ RHIC

Why didn't I see this coming? As early QD readers may remember from my [post](#) on the QD launch date (Jan 13), I was very enthusiastic about a paper by Horatieu Nastase which made an intriguing claim that RHIC collisions produce "Dual Black Holes", and calculated some properties of various collisions (both of two protons and two nuclei) based on this claim. Unfortunately, some reporters have gotten to Horatieu and it seems to have created a press firestorm overseas.



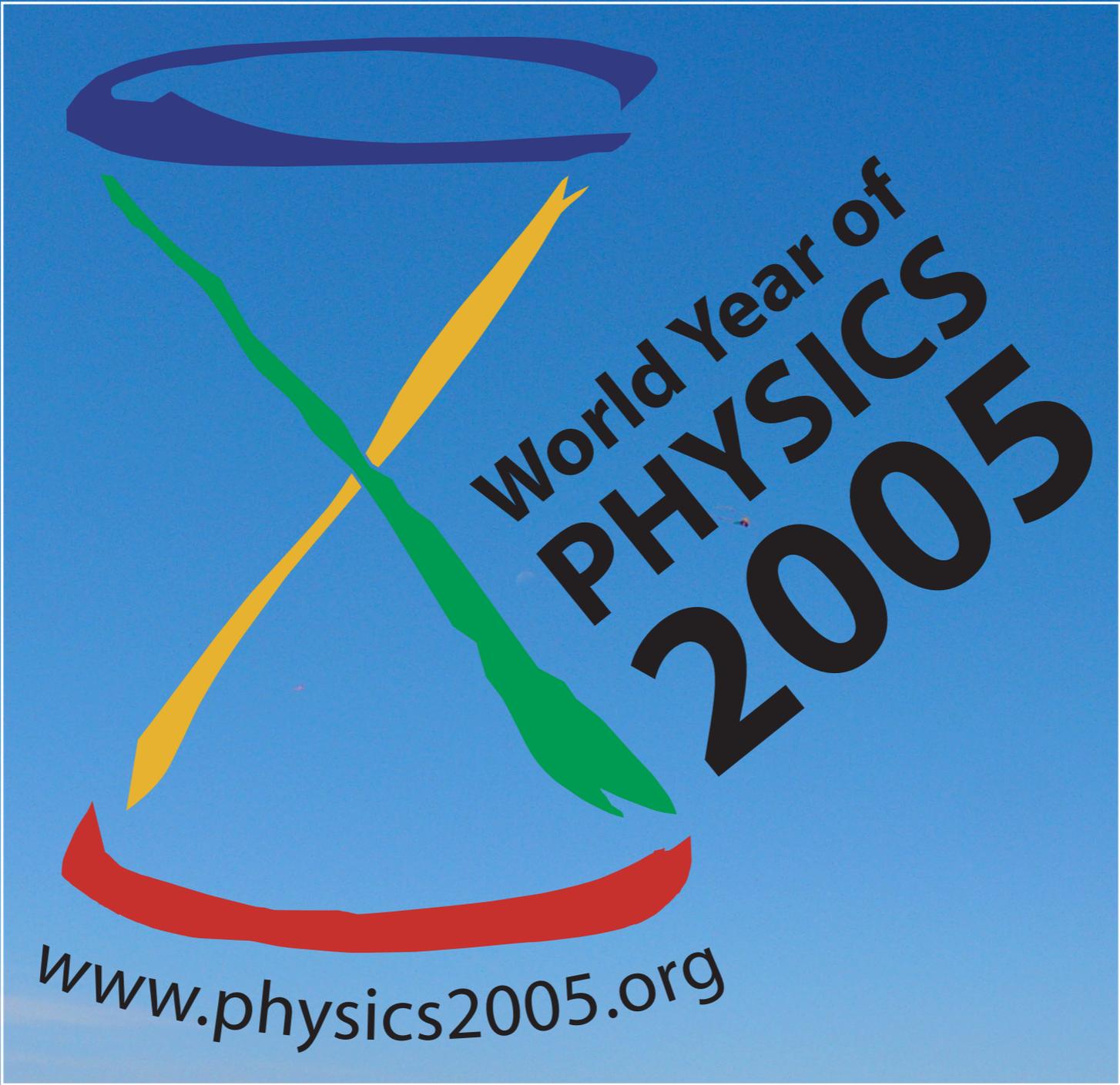
I stumbled on this the usual way, via [slashdot.org](#). This piece led straightaway to a [story](#) at the BBC website (from which I stole this image). And a quick scan of [Google news](#) led to [several more](#) articles, and I don't think we've heard the last of this: it's a science fiction dream-come-true, and a doomsayer's worst nightmare (and dream-come-true in some sense...)

Unfortunately, all of this is overstated. At RHIC we don't make a

These blogs are now a time capsule: who knows what
one of us might have come up with
on a sunny day on the beach in 2005?

and there are still two months to go!...



The logo for the World Year of Physics 2005 is centered in the image. It features a stylized 'P' shape formed by four thick, curved lines: a purple line at the top, a red line at the bottom, a yellow line on the left, and a green line on the right. The text 'World Year of PHYSICS 2005' is written in a bold, black, sans-serif font, slanted upwards to the right, and positioned over the right side of the 'P' shape. Below the 'P' shape, the website address 'www.physics2005.org' is written in a smaller, black, sans-serif font.

World Year of
PHYSICS
2005

www.physics2005.org





BNL has been taking an active role in the World Year of Physics 2005, with lectures and events all year...

