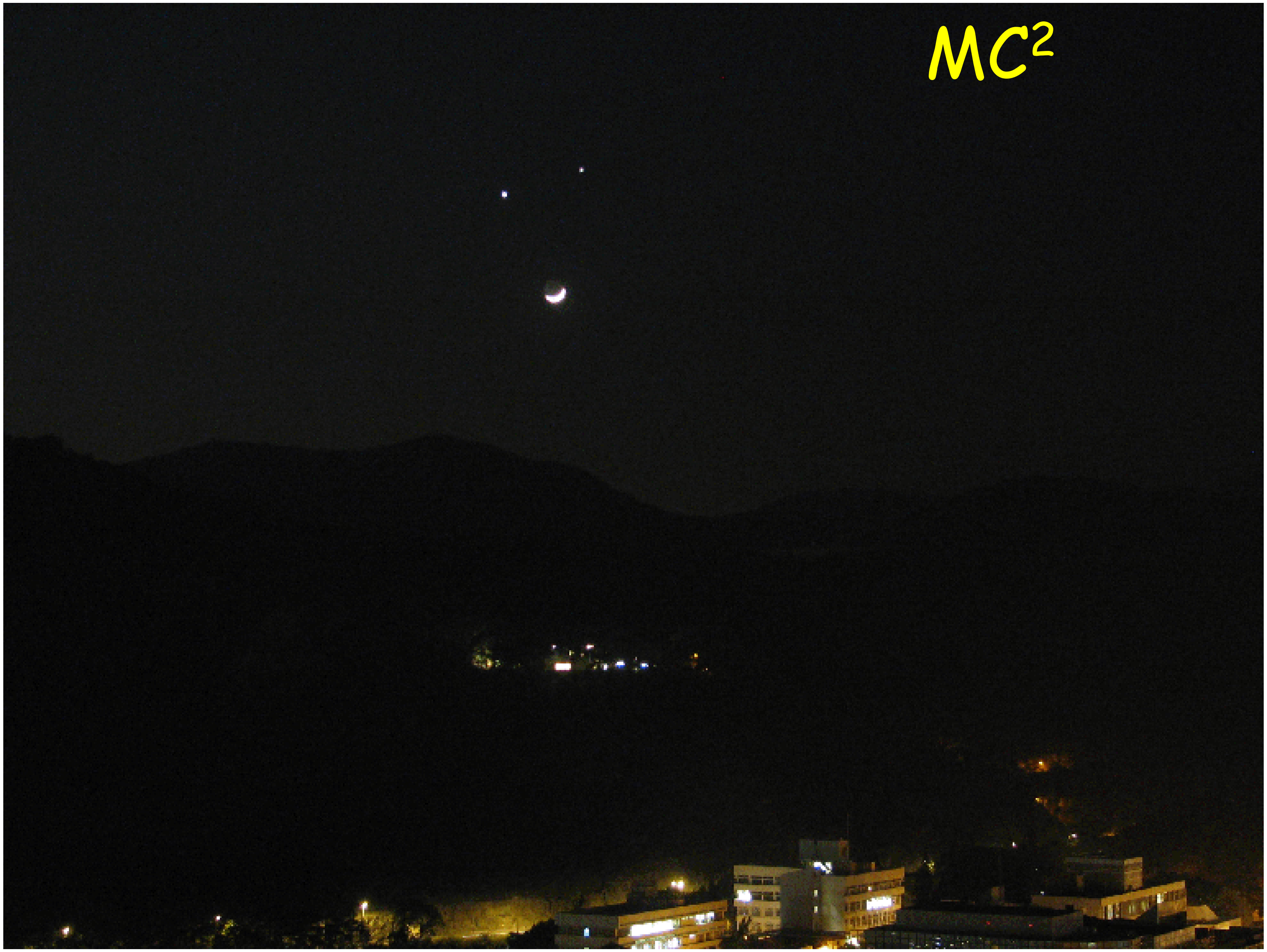
# Physics News 2008



Science Magazine Breakthrough of the Year 2008

http://www.sciencemag.org/btoy2008/

Nature Magazine Review of the Year 2008

http://www.nature.com/news/specials/2008/index.html

Nature Magazine News of the Year 2008

http://www.nature.com/news/2008/081217/full/456844a.html

**The Top 10 *Science*NOWs of 2008**

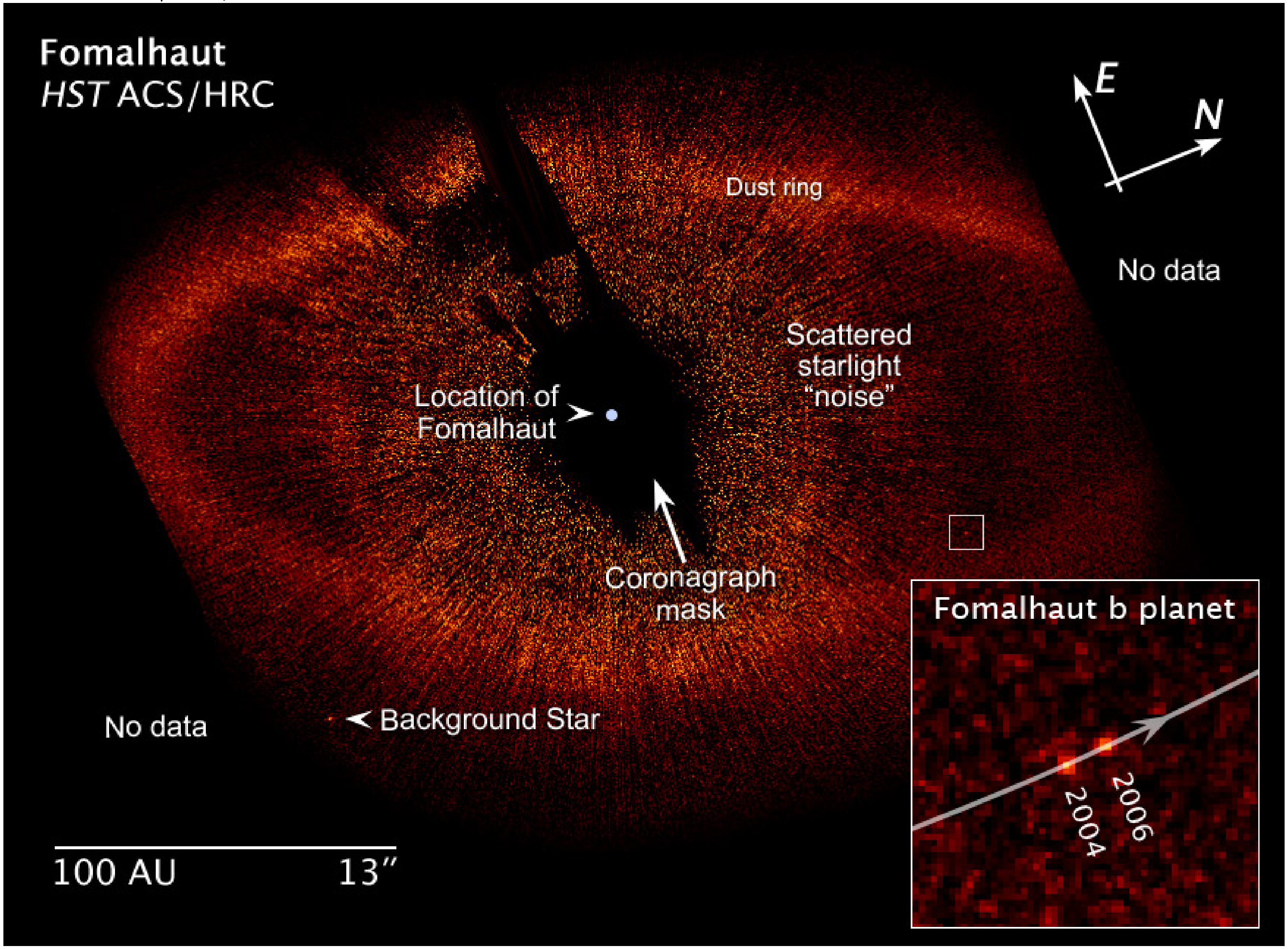
http://sciencenow.sciencemag.org/cgi/content/full/2008/1224/1

# Physics News 2008

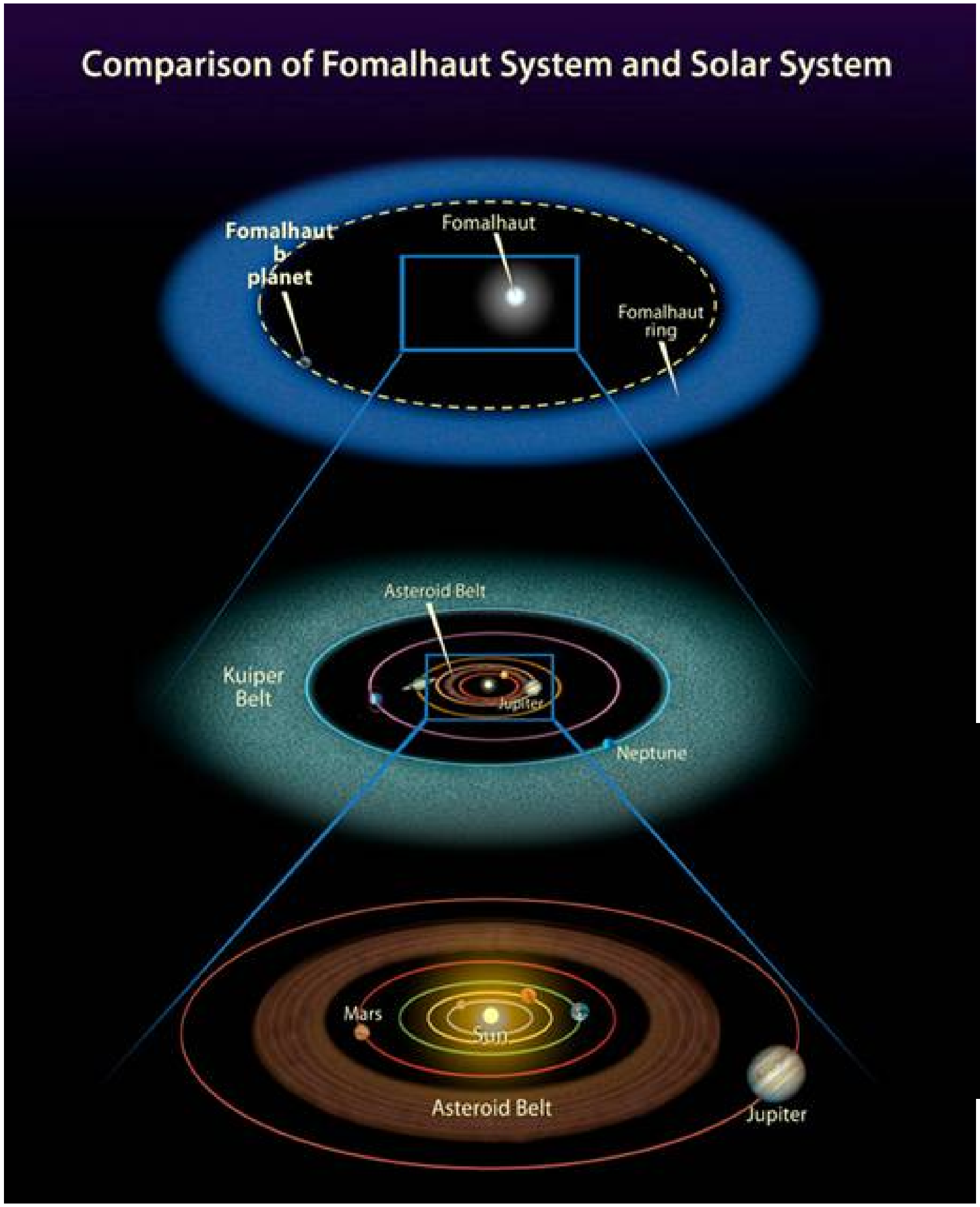
- Extrasolar planets: direct imaging, detection of organic molecules, water, $CO_2$
- Black holes: 'seeing' supermassive b.h., making b.h. in the lab: optical b.h., mini-b.h.
- New high $T_c$ superconductors
- Proton mass accurately 'predicted'
- Water (ice) found on Mars
- Long distance entanglement demonstrated
- Storing vacuum fluctuations
- Magnetic monopoles in spin ice
- CP violation in neutral B decays
- …

# Direct imaging of Fomalhaut b

北落師門: 南魚座主星




http://hubblesite.org/newscenter/archive/releases/star/2008/39/image/a/




First planet to be seen in visible light since Neptune (1846).

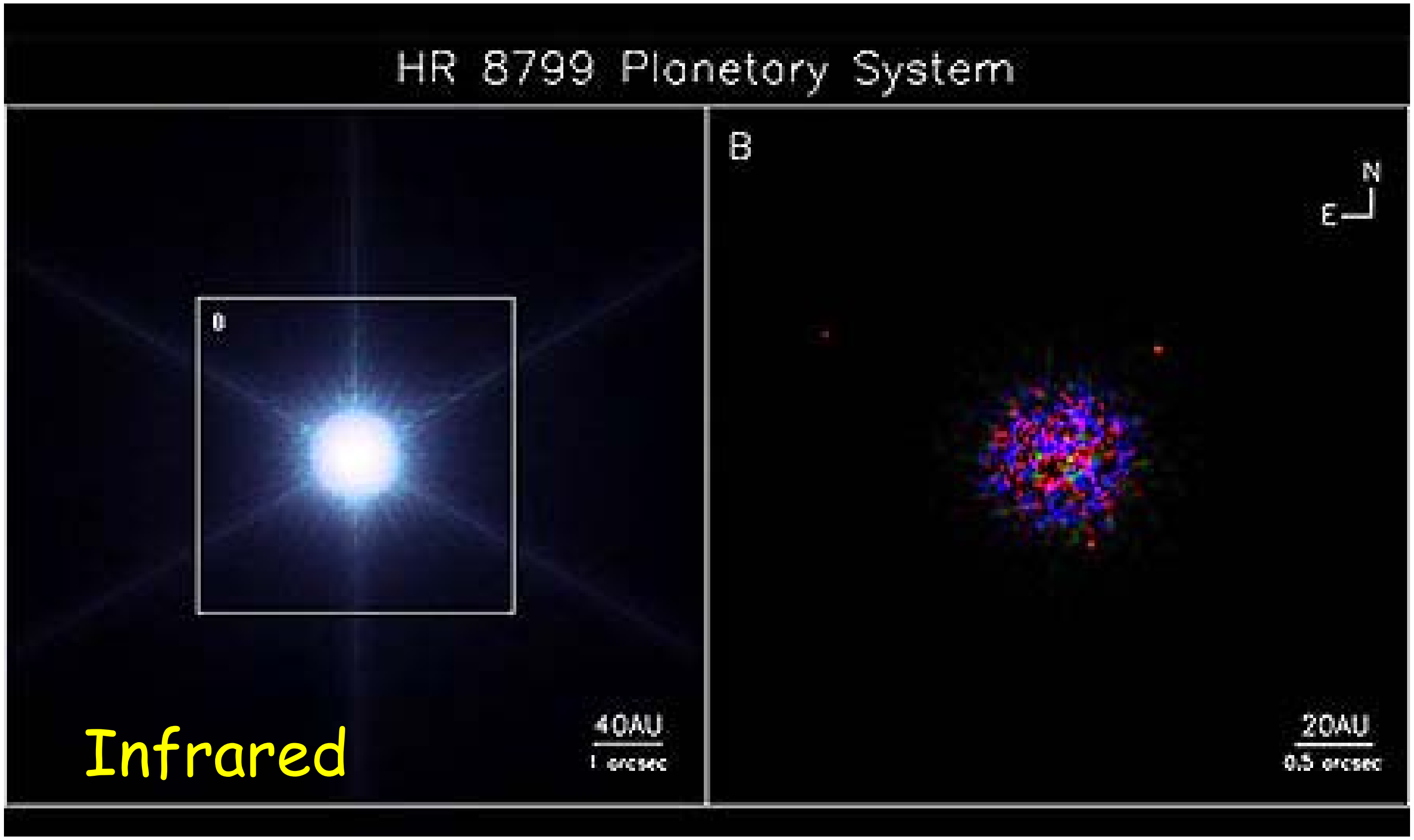
$r \sim 10^{10}$ miles

$T \sim 872$ yr

$d \sim 25$ l.y.

P. Kalas, J. Graham, E. Chiang, E. Kite (University of California, Berkeley), M. Clampin (NASA Goddard Space Flight Center), M. Fitzgerald (Lawrence Livermore National Laboratory), and K. Stapelfeldt and J. Krist (NASA Jet Propulsion Laboratory)

# Direct Imaging of 3 giant planets orbiting HR8799




*d* = 140 l.y.

*r* = 24, 37, 67 AU

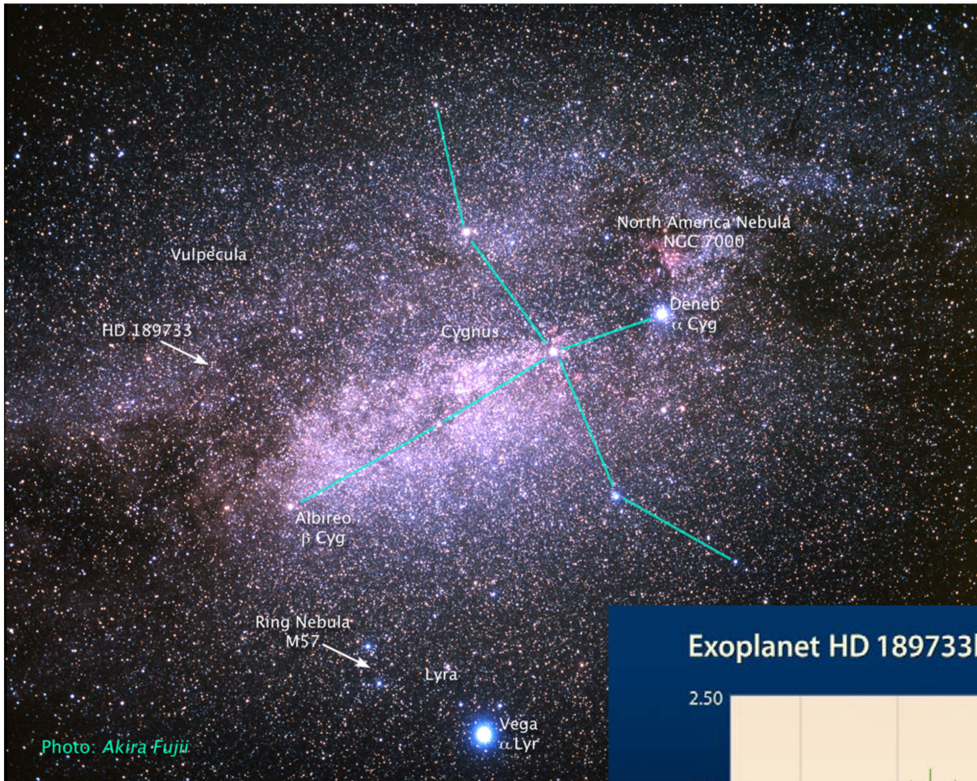
*M* = 10, 10, 7 $M_J$

*Science* 28 November 2008

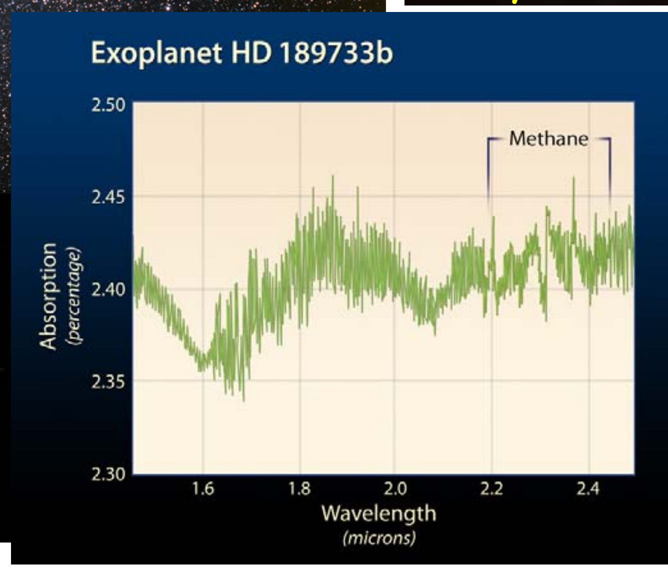
Christian Marois Bruce Macintosh, Travis Barman, B. Zuckerman, Inseok Song, Jennifer Patience, David Lafrenière, René Doyon

http://keckobservatory.org/article.php?id=231

# Extrasolar Planet HD 189733b: Discovery of Organic Molecules on an Exoplanet



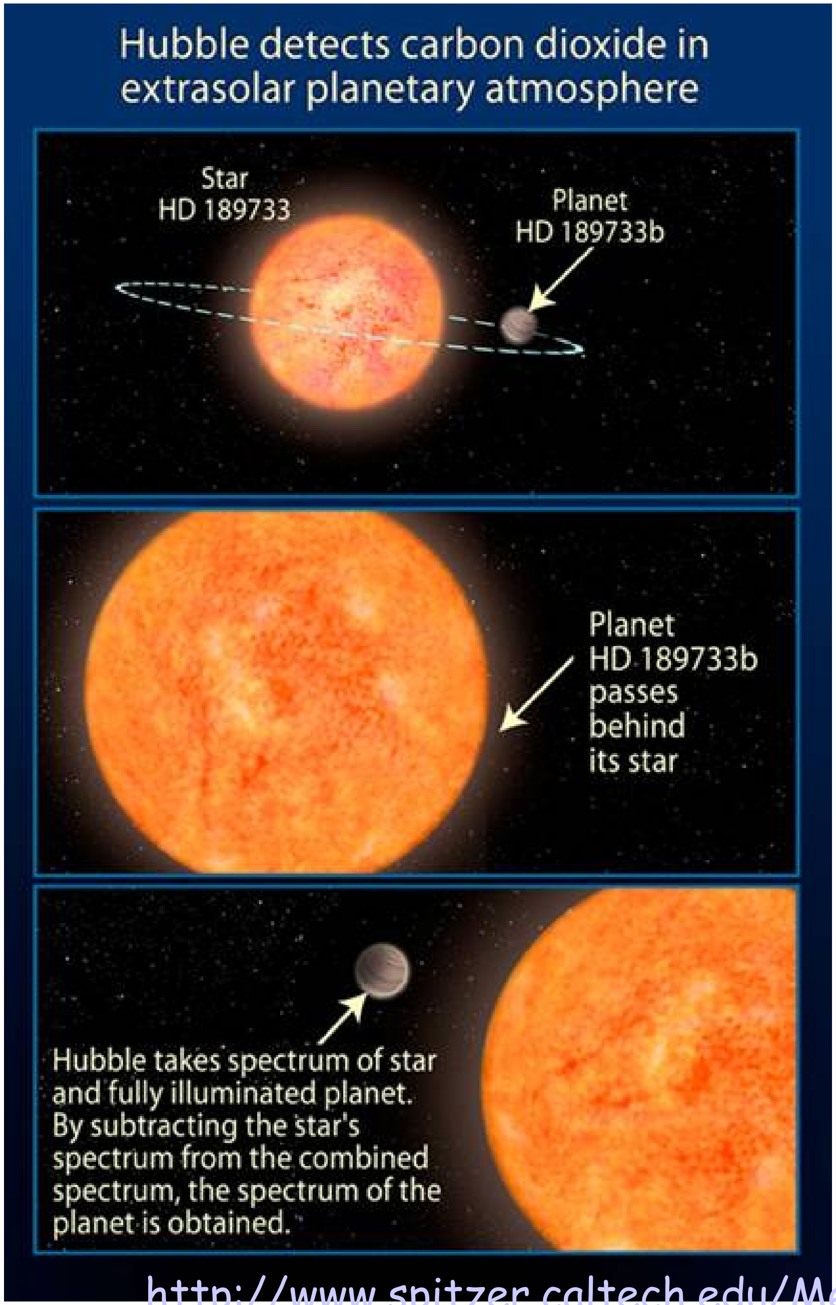




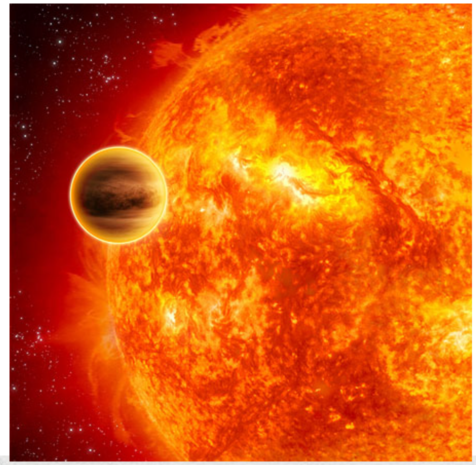

Used transit and IR spectroscopic method to detect methane and water on the planet

M. R. Swain et al., Nature, March 20, 2008.

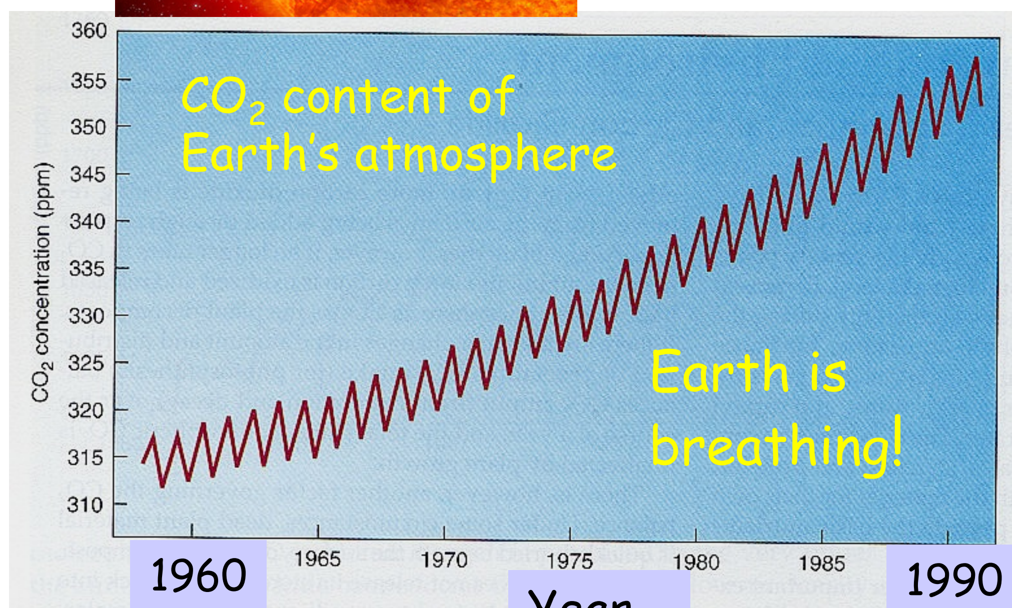
http://hubblesite.org/newscenter/archive/releases/star/2008/11/full/




# Detection of $CO_2$ in exoplanet HD189733b



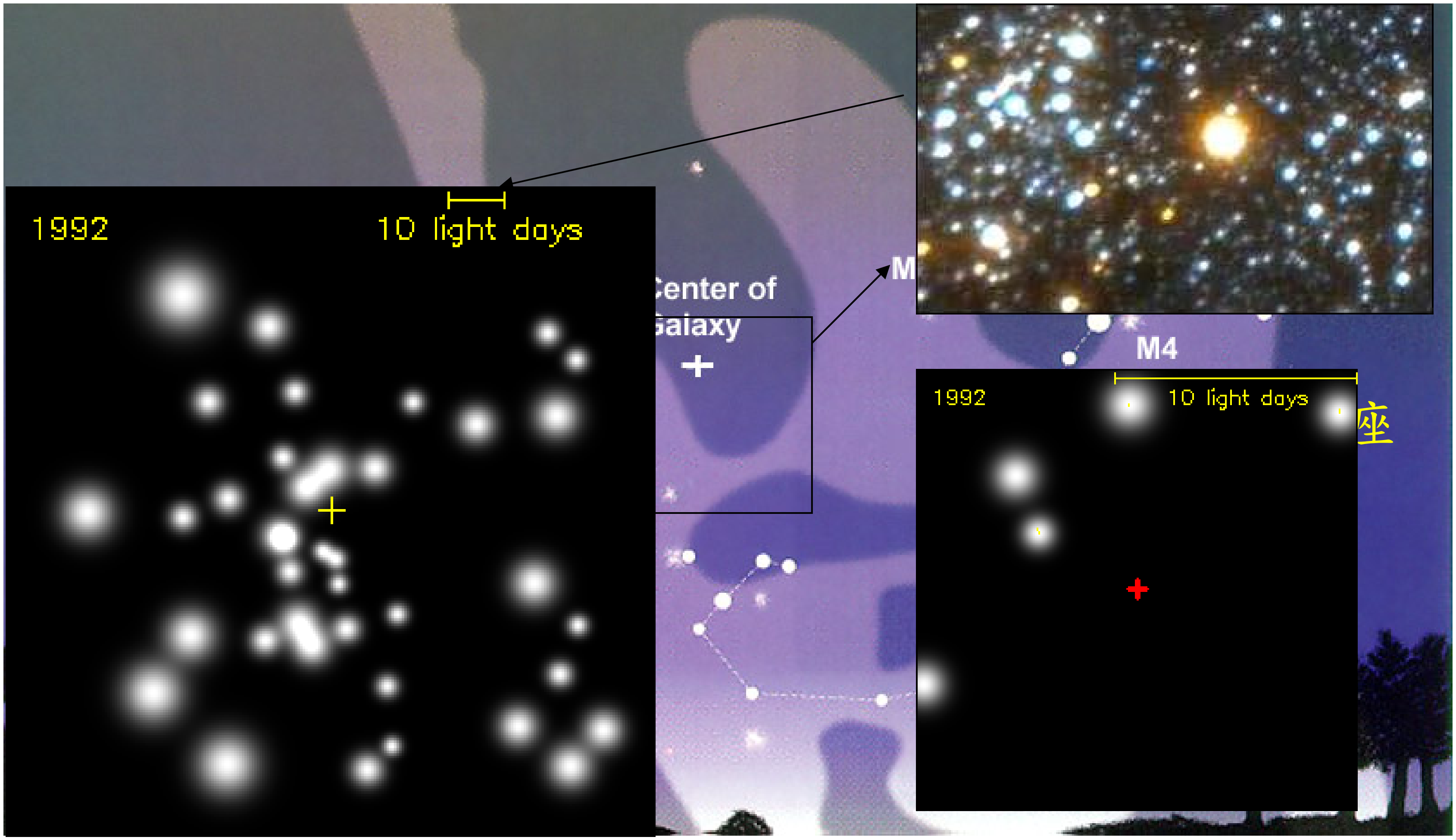
water was found in the same planet in 2007




http://www.spitzer.caltech.edu/Media/releases/ssc2007-12/index.shtml

http://hubblesite.org/newscenter/archive/releases/star/2008/41/

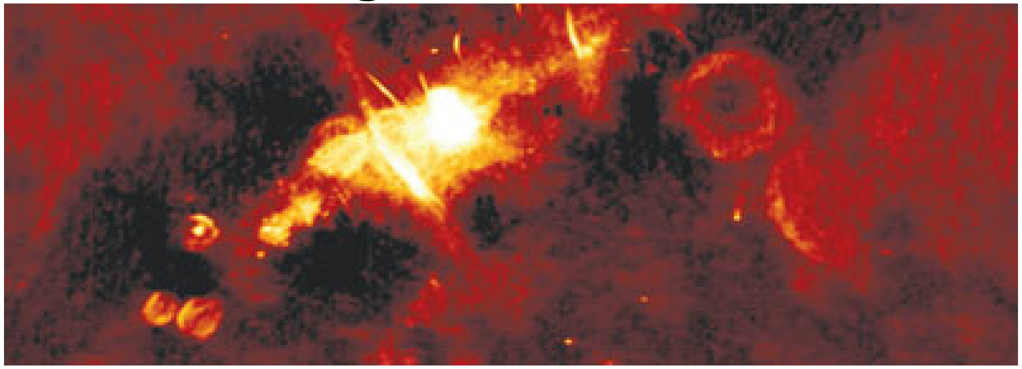
# Center of Milky Way: Sgr A*




Black Hole mass > 4 million solar masses at the center of Milky Way (Sgr A*).

http://www.mpe.mpg.de/www_ir/GC/

Sgr A*



VLBI array at 1.3mm: baseline ~ Arizona to Hawaii

→Sgr A*: structure size < $37\times10^{-6}$" ~ 4 x $R_S$

$R_S$ = Schwarzchild Radius ~ 0.1 AU

1" ~ 10m over 2000 km (HK-Beijing)

Ruled out all non-bh models!

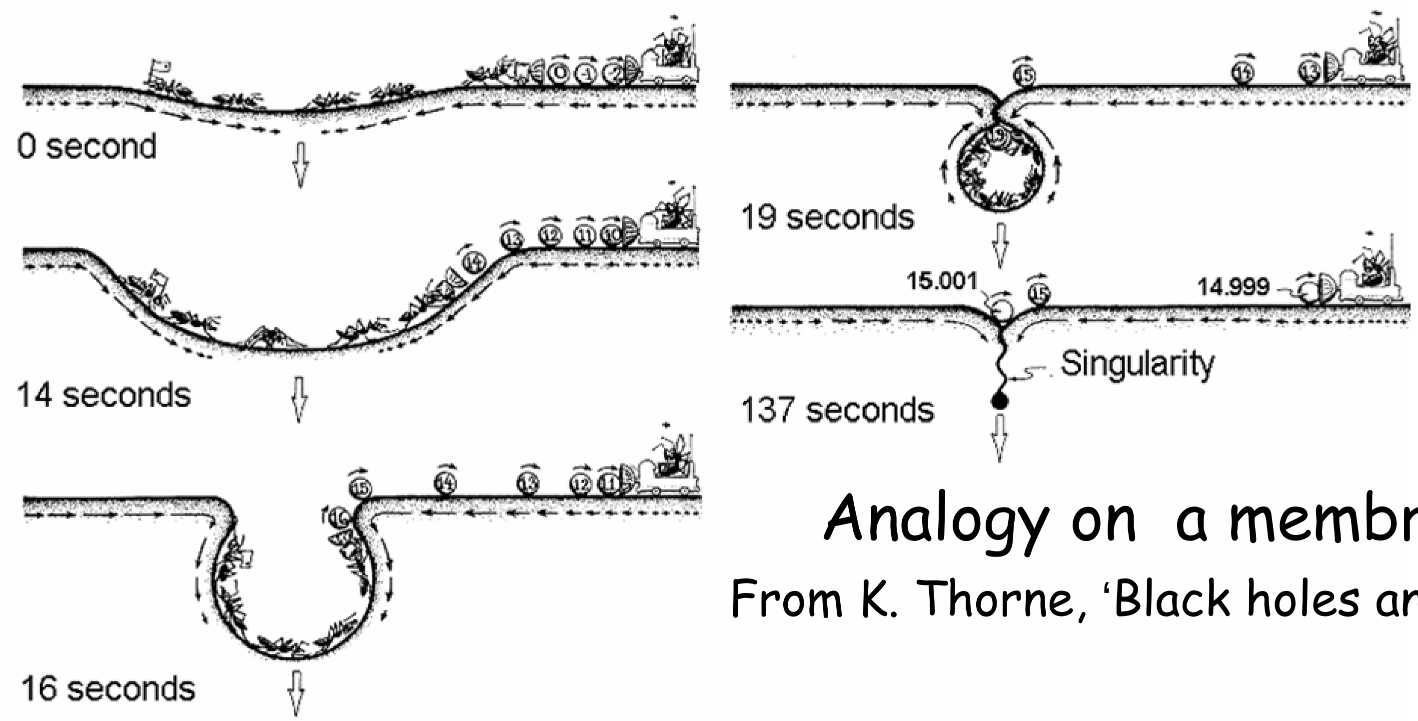
Event Horizon scale observation becoming realistic!

S. S. Doeleman et al., *Nature* **455**, 78-80 (4 September 2008).

http://www.nature.com/nature/journal/v455/n7209/full/nature07245.html

# Artificial black holes

Blackhole: infinite time dilation at the horizon




Analogy on a membrane

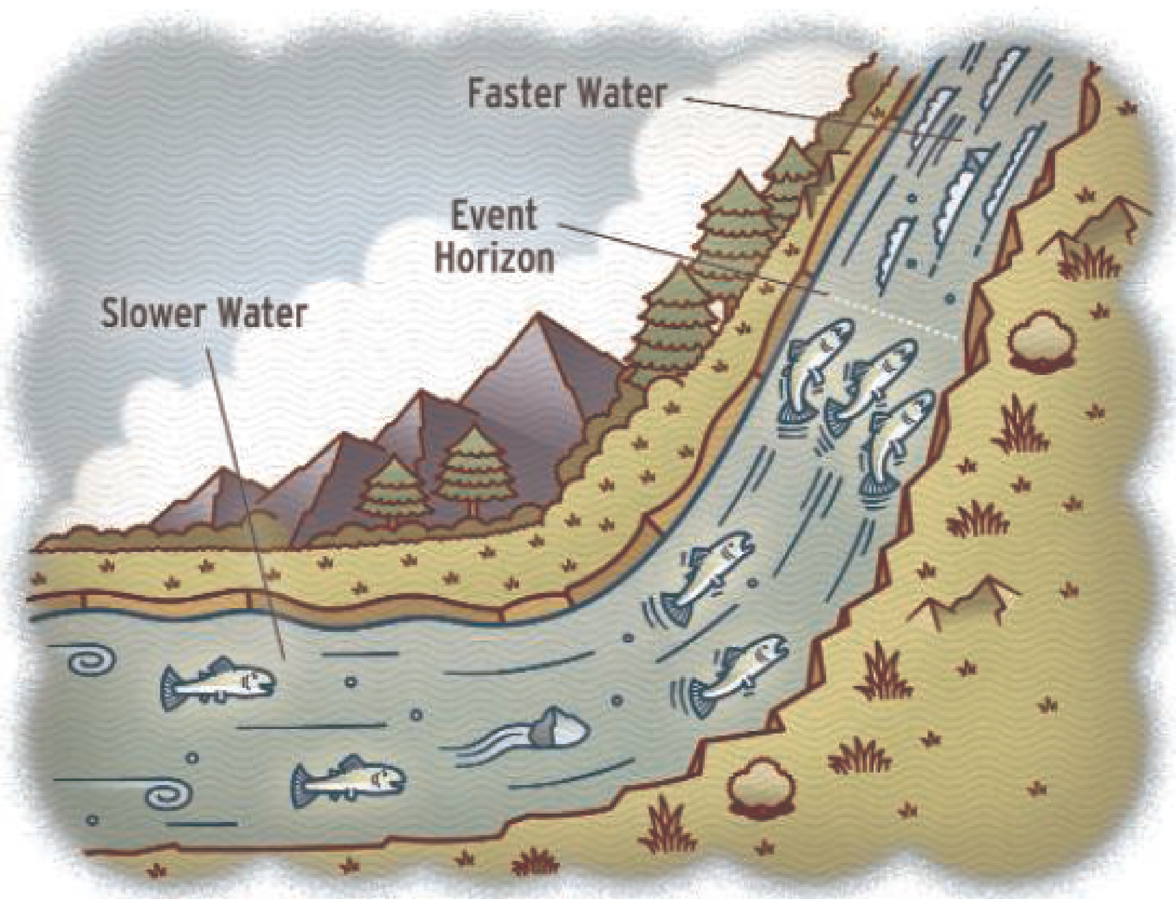
From K. Thorne, 'Black holes and time warp'

Horizon: wave (light) speed = 'stretching speed' of time

Idea: 1. slow down speed of light

2. strengthen gravity

# Analog Horizon



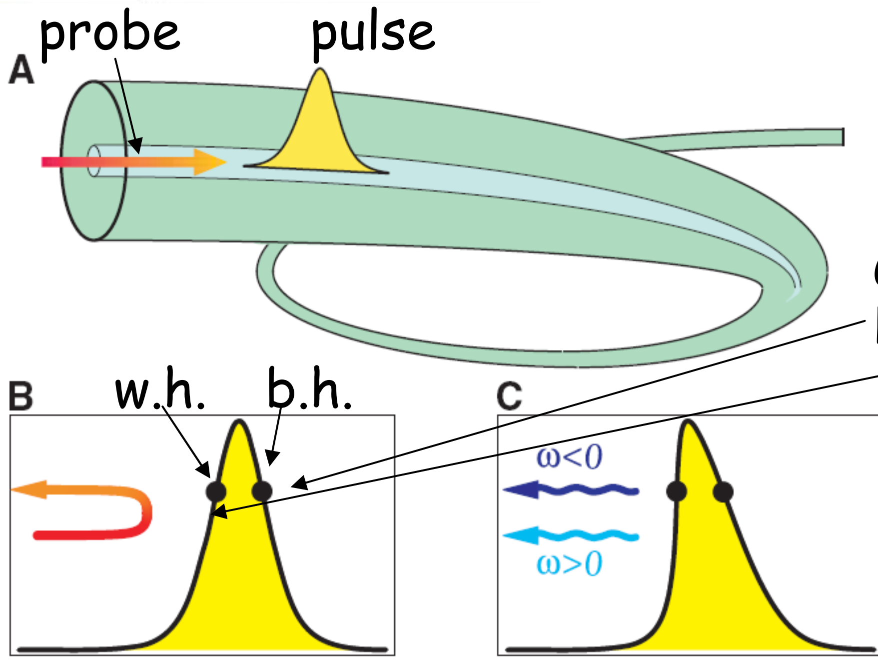

**No go.** Current can stop fish moving upstream and mimic an event horizon. A pulse in an optical fiber captures the physics, too.

# Optical blackholes

make use of non-linear optics → slow down speed of light in a medium; simulated white hole horizon, can get $T \sim 1000$ K

Nonlinear optical effect: speed of light slower around a pulse

Kerr effect: $n = n_0 + \delta n, \quad \delta n \propto I(z,t)$




Group velocity of probe light = speed of pulse

**Fig. 1.** Fiber-optical horizons. (**A**) A light pulse in a fiber slows down infrared probe light, attempting to overtake it. The diagrams below are in the co-moving frame of the pulse. (**B**) Classical horizons. The probe is slowed down by the pulse until its group velocity matches the pulse speed at the points indicated by black dots, establishing a white-hole horizon at the back and a black-hole horizon at the front of the pulse. The probe light is blue-shifted at the white hole until the optical dispersion releases it from the horizon. (**C**) Quantum pairs. Even if no probe light is incident, the horizon emits photon pairs corresponding to waves of positive frequencies from the outside of the horizon paired with waves at negative frequencies from beyond the horizon. An optical shock has steepened the pulse edge, increasing the luminosity of the white hole.

T. G. Philbin et al., Science **319**, 1367 (2008).

# Mini-black holes?

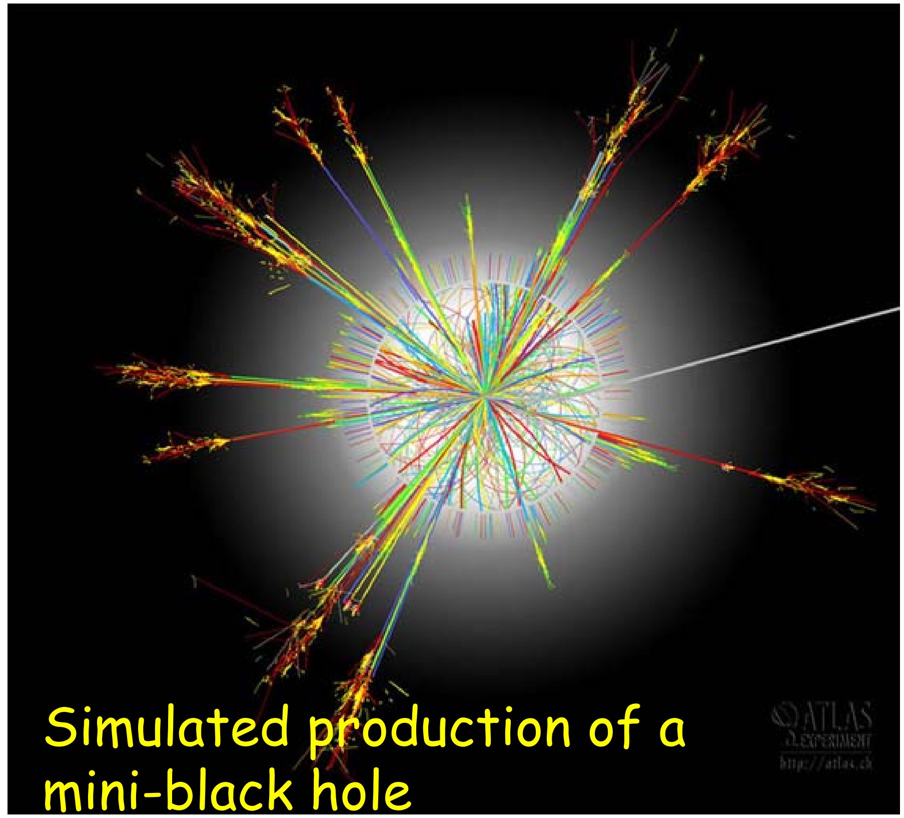
If G is much larger in small length scales → mini-black holes

ADD Model:

- large extra dimensions (a ~mm)

- strong/weak/EM forces confined to ordinary 3 spatial dimensions

- gravity can propagate to other dimensions! →G so small at large scales



Simulated production of a mini-black hole

→ when r ~ a, G become very strong ($\sim 1/r^{n-1}$, n >>3)

N. Arkani-Hamed et al. (1998). "The Hierarchy problem and new dimensions at a millimeter". *Phys. Lett. B* **436**: 263–272.

# Looking for Extra Dimensions in LHC

If *a* is ~ mm, can reach quantum gravity scale with *E* ~ TeV.

Gravity strong → much easier to produce blackholes!

Dimopoulos + Landsberg (2001): If LHC reaches quantum gravity scale, can produce 1 mini blackhole every second ($R \sim 10^{-19}$ m)!

$T \sim 10^{11}$ eV($\sim 10^{15}$ K), evaporates via Hawking radiation in $10^{-26}$s!

http://cosmiclog.msnbc.msn.com/archive/2008/03/27/823924.aspx

http://cerncourier.com/cws/article/cern/29199

http://www.aip.org/pnu/2008/split/871-1.html

# Cosmic Rays

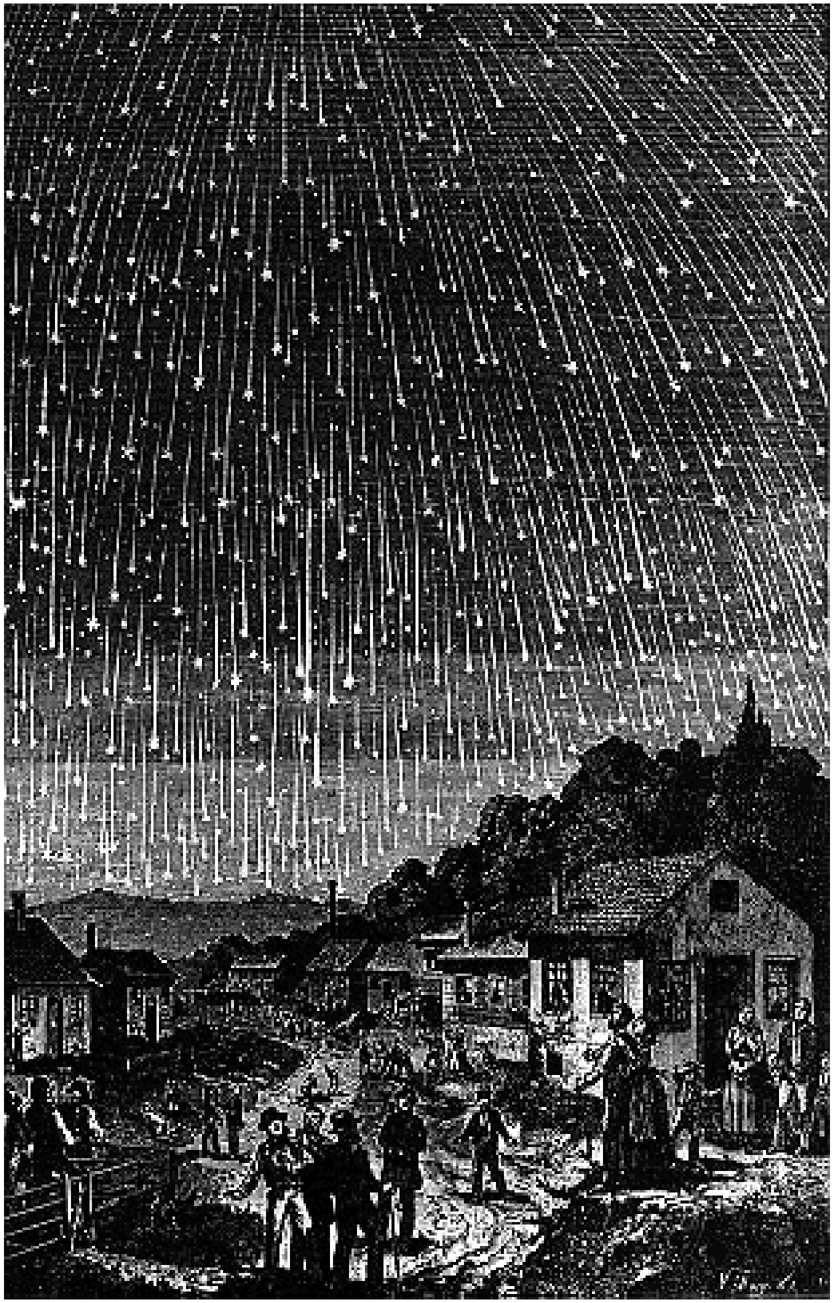
- subatomic particles: Protons, electrons, atomic nuclei, photons...

- E can be $>10^{20}$ eV >> LHC energy

World record: $3x10^{20}$ eV

Mini-blackholes?

http://www.newscientist.com/article.ns?id=dn4446



更吹落，黑洞如雨

Quantum Entanglement of photons retained over long distance: action > 10,000 times faster than speed of light


http://sciencenow.sciencemag.org/cgi/content/full/2008/813/3

# Storing and retrieving vacuum fluctuations

J. Appel et al., PRL **100**, 093602 (2008).
K. Honda et al., PRL 2009.

Normal light wave

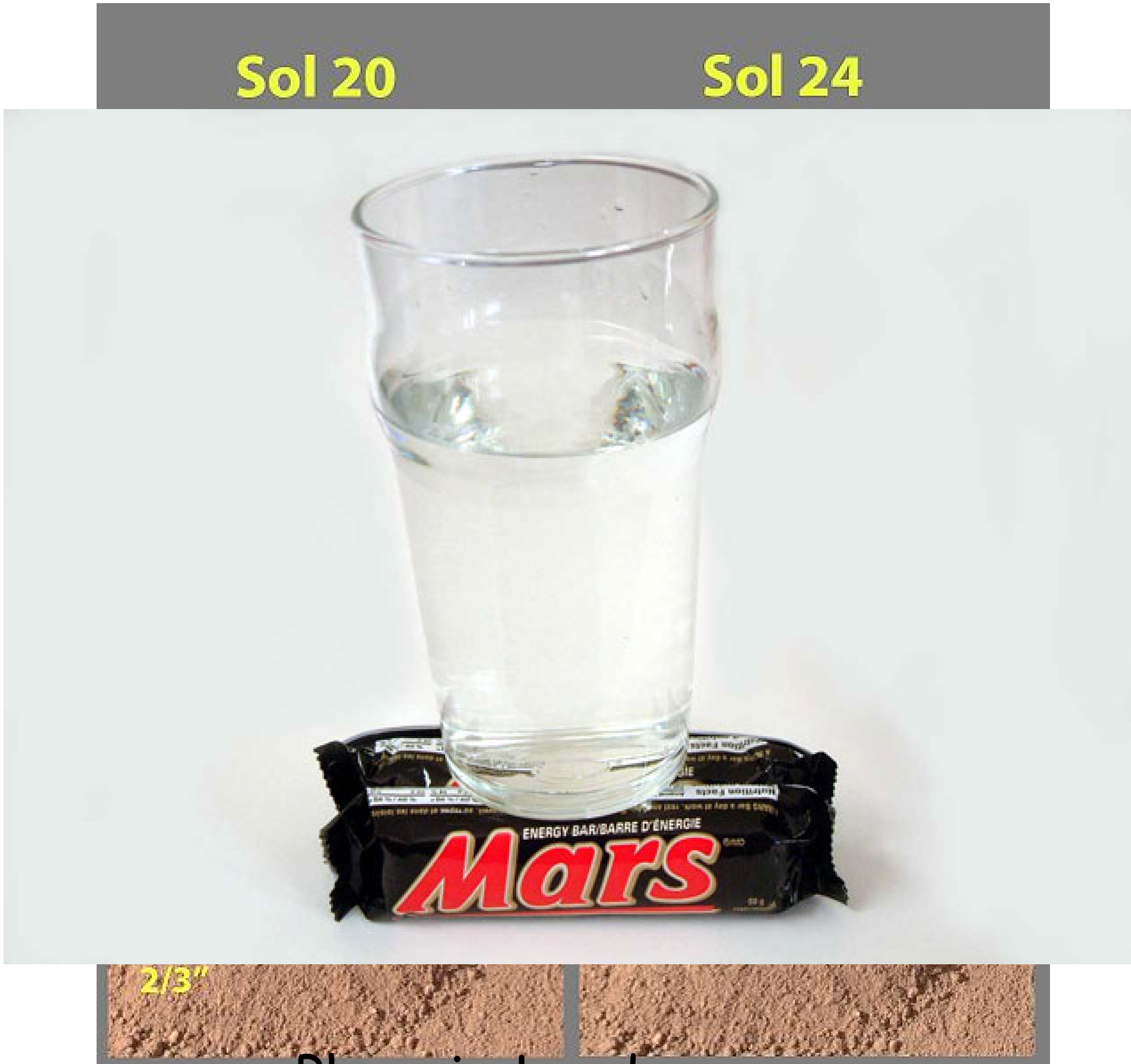
Phase-squeezed: more uncertainties for some phases

Light amplitude → 0: only phase-squeezed vacuum remains

Stored in Rubidium atoms for 3 μs

http://sciencenow.sciencemag.org/cgi/content/full/2008/229/1

# Water found on Mars

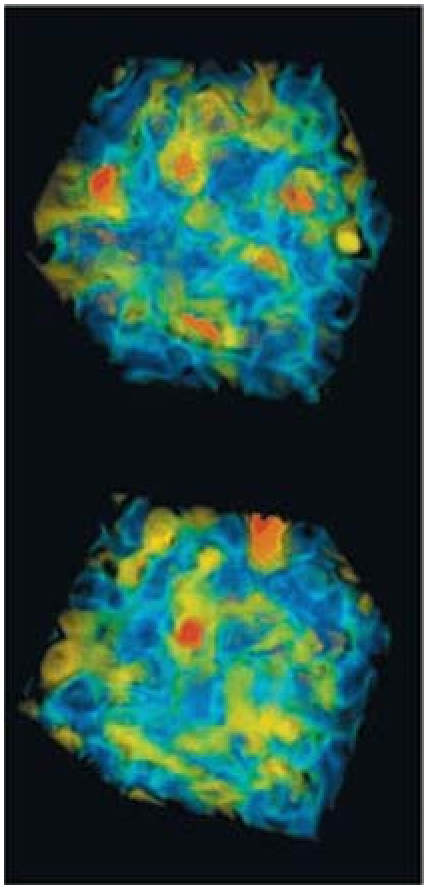



Phoenix Lander

http://phoenix.lpl.arizona.edu/

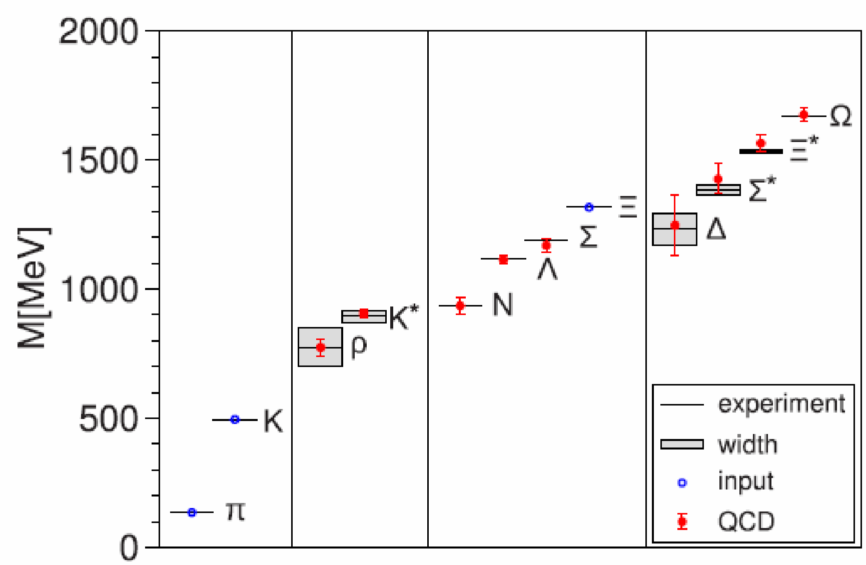
# Accurate calculation of light hadron masses using lattice QCD

Durr et al., Science **322**, 1224 (2008).



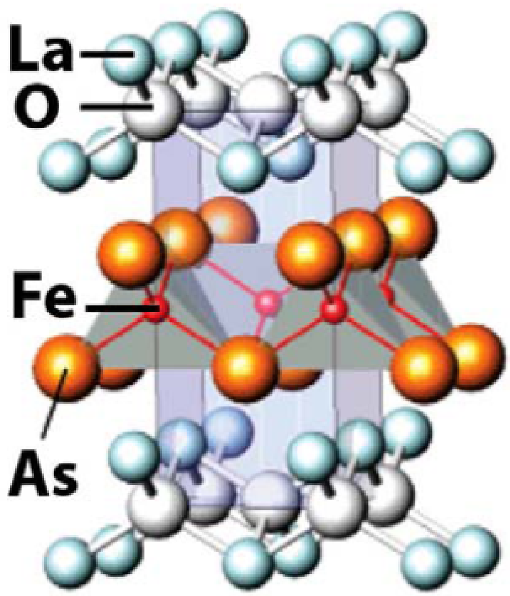
| $X$ | Experimental (*28*) | $M_X$ ($\Xi$ set) | $M_X$ ($\Omega$ set) |
|---|---|---|---|
| $\rho$ | 0.775 | 0.775 (29) (13) | 0.778 (30) (33) |
| $K^*$ | 0.894 | 0.906 (14) (4) | 0.907 (15) (8) |
| $N$ | 0.939 | 0.936 (25) (22) | 0.953 (29) (19) |
| $\Lambda$ | 1.116 | 1.114 (15) (5) | 1.103 (23) (10) |
| $\Sigma$ | 1.191 | 1.169 (18) (15) | 1.157 (25) (15) |
| $\Xi$ | 1.318 | 1.318 | 1.317 (16) (13) |
| $\Delta$ | 1.232 | 1.248 (97) (61) | 1.234 (82) (81) |
| $\Sigma^*$ | 1.385 | 1.427 (46) (35) | 1.404 (38) (27) |
| $\Xi^*$ | 1.533 | 1.565 (26) (15) | 1.561 (15) (15) |
| $\Omega$ | 1.672 | 1.676 (20) (15) | 1.672 |

**Fig. 3.** The light hadron spectrum of QCD. Horizontal lines and bands are the experimental values with their decay widths. Our results are shown by solid circles. Vertical error bars represent our combined statistical (SEM) and systematic error estimates. $\pi$, $K$, and $\Xi$ have no error bars, because they are used to set the light quark mass, the strange quark mass and the overall scale, respectively.



# New High-Temperature Superconductors

LaFeAsO(1-x)Fx




**Between the sheets.**
In new superconductors, electrons flow through layers of iron and arsenic interspersed among layers of other atoms.

CREDIT: KAMIHARA *ET AL.*, JACS, 130 (2/23/08)

A new family of superconductors:
Iron and Arsenic based compounds

02/08: H. Hosono: $T_c$ = 26K for $LaO_{1-x}F_xFeAs$

03/08: X. H. Chen: $T_c$ = 43K for $SmO_{1-x}F_xFeAs$

03/08: Z. X. Zhao: Tc = 52K for $PrO_{1-x}F_xFeAs$

04/08: Z. X. Zhao: Tc = 55K for $PrO_{1-x}F_xFeAs$ under pressure

# News to be expected in 2009

- IYA 2009
- NIF starting https://lasers.llnl.gov/
- LHC start again

# International Year of Astronomy

**nature** International weekly journal of science

WEB FOCUS

## Year of Astronomy

**In this focus**

[Current Research]

[Link]

To mark in 2009 the International Year of Astronomy and 400 years since Galileo made his first telescope observations, *Nature* has commissioned a series of special articles and reviews. From telescopes to planets, stars, galaxies and cosmology, plus commentary on the state of the field from top experts, we hope they will make you look at the universe with new eyes.

Image: Hubble Space Telescope/Christian Darkin

## Current Research

Editorial

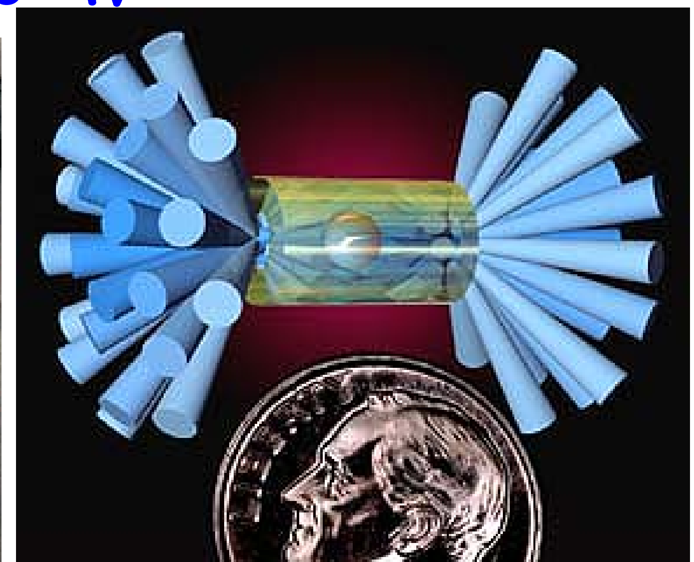
**Starry messages**

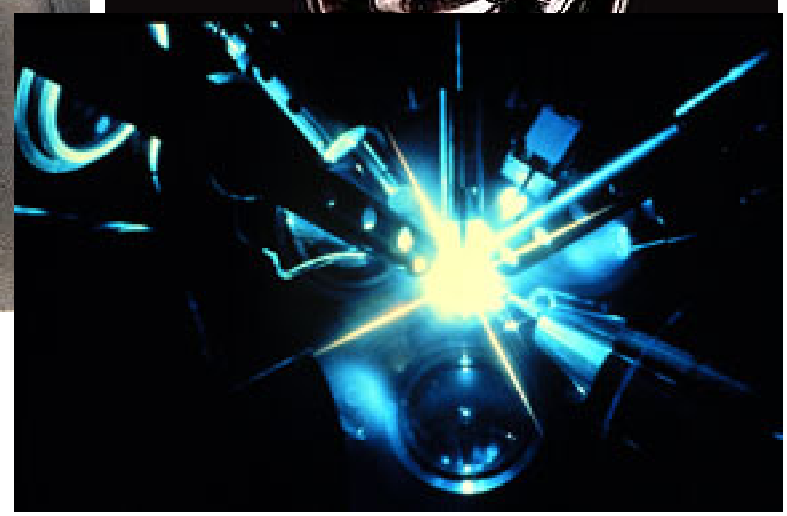
*Nature* 457, 7 (1 January 2009) doi:10.1038/457007a

http://www.nature.com/nature/focus/yearofastronomy/#curr

# Laser fusion

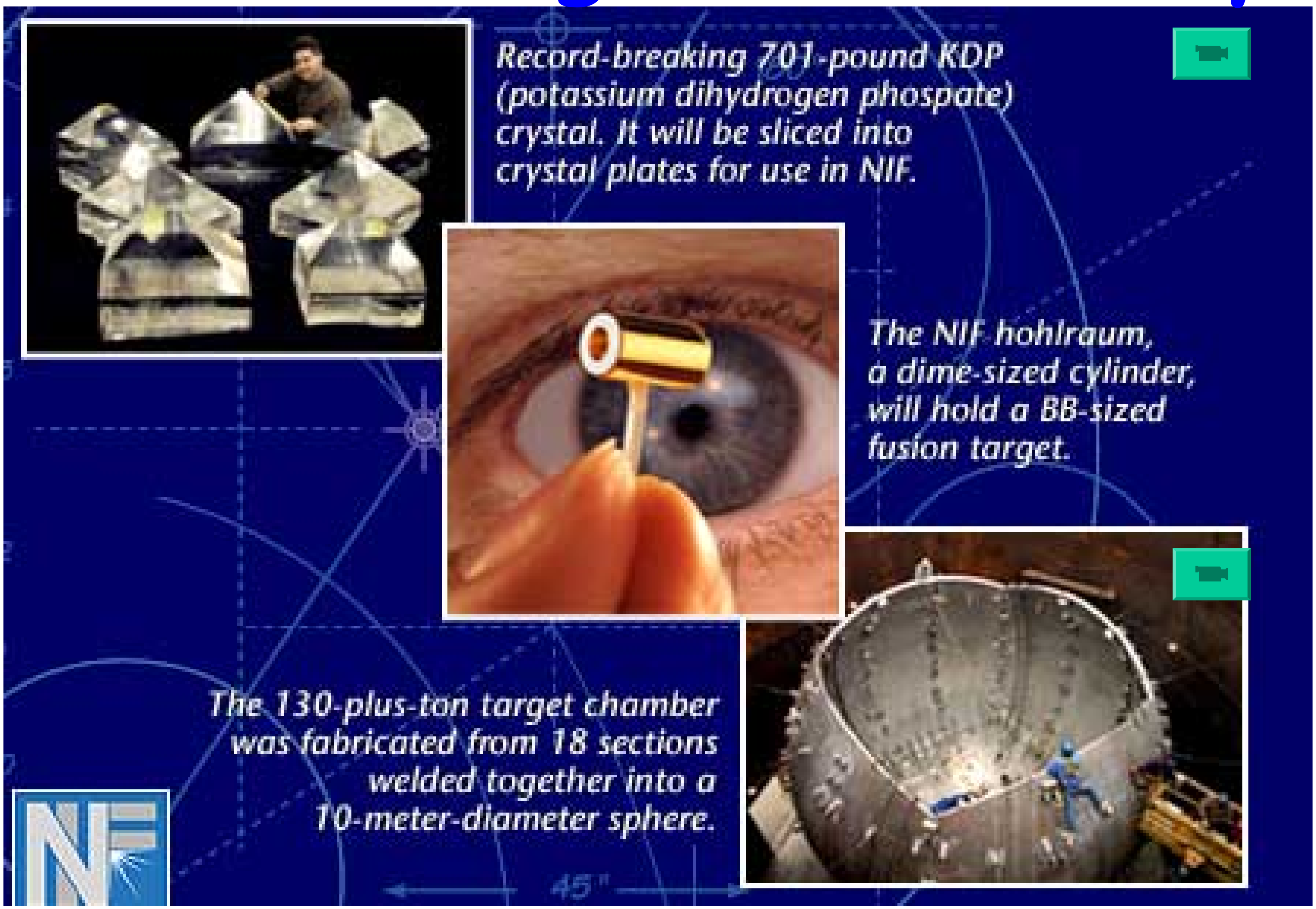
- 2007: 96high power lasers reaching 2MJ
- 2009: 192 lasers, 4MJ, 10ns, $4\times10^{14}$W





http://www.llnl.gov/nif/

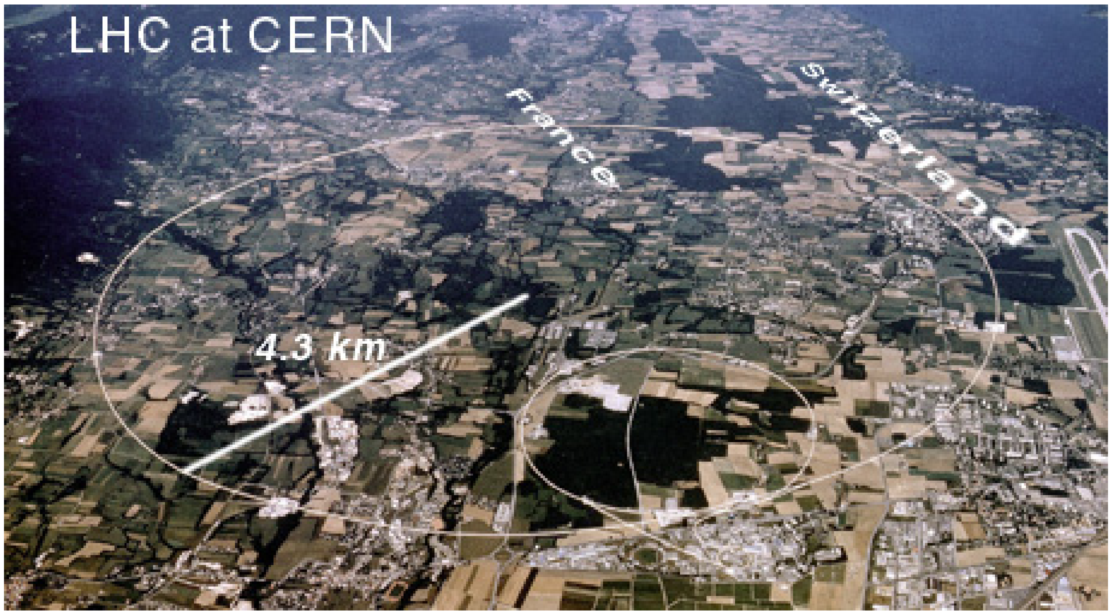
# National Ignition Facility




http://www.llnl.gov/nif/project/movies/ucrl_video_225695.mov

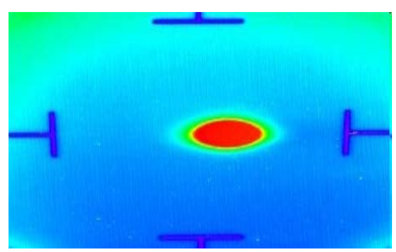
# Large Hadron Collider

末日實驗? http://news.bbc.co.uk/2/hi/south_asia/7609631.stm




CERN: largest lab in fundamental physics in the world

Protons at $v$ = 99.999999% $c$ (7 TeV)
beam: 2808 bunches x $1.15\times10^{11}$ protons
(mmxcm) E = 362 MJ
~ a train at 150 km/h
melts 500kg of Cu



LHC: 8.75 billion US$

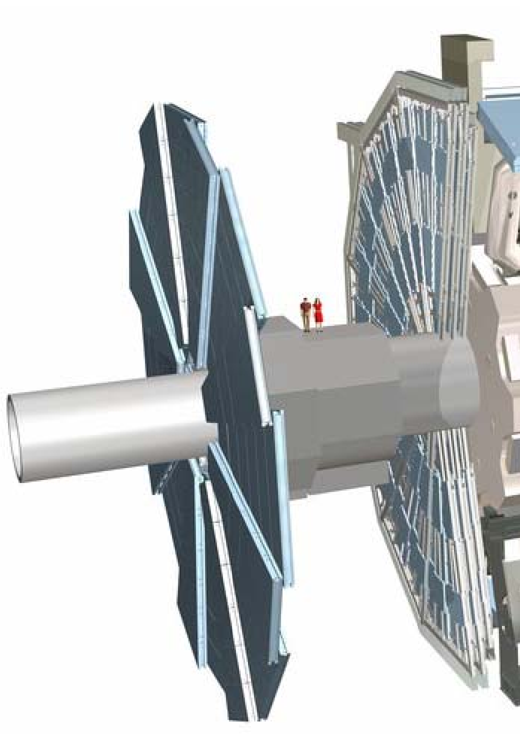
http://lhc-machine-outreach.web.cern.ch/lhc-machine-outreach/

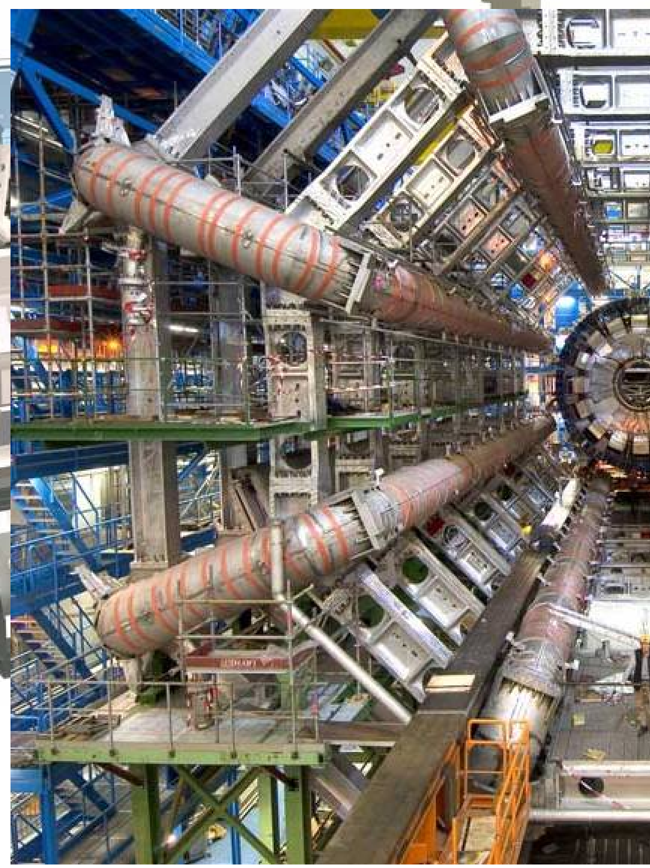
# ATLAS Collaboration

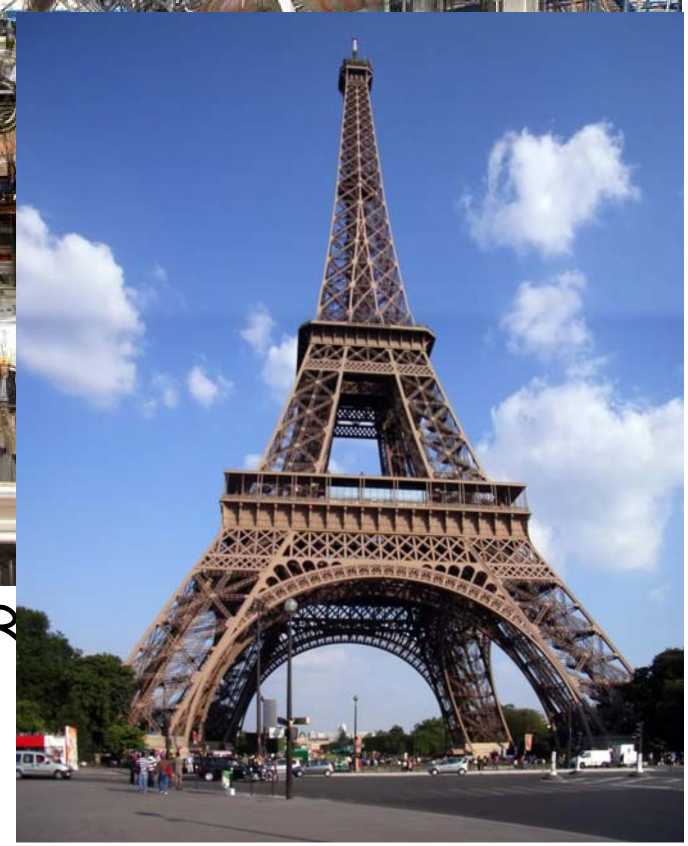
2,500 physicists, 37 countries, 169 universities


張承亮, CUHK BSc '01, MPhil '03, PhD U. of Toronto

# ATLAS detector







45m x22m

Weight ~ Eiffel Tower

Data per s = 100,000 CDs R

# LHC

- 7 TeV +7 TeV hadron collisions to search for:
- Higgs particles – origin of masses of elementary particles
- Supersymmetric particles – unification of fermions and bosons
- Quark-gluon plasma – quark deconfinement
- Mini-black holes – extra dimensions
- …

# Happy New Year!