

# Particle physics with intense lasers

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Review: Fedotov et al, Phys.Rept. 1010 (2023) 1 [arXiv:2203.00019]

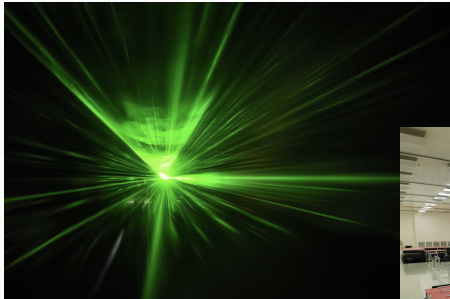
# What do I do?

- Fancy words: quantum field theory in extreme conditions.
- Less fancy words:
- Instead of colliding particles in accelerators  
(and seeing what falls out. . . )
- Collide particles with intense lasers  
(and see what falls out).

# Sources of strong fields: intense lasers

Modern laser pulses: huge number of photons, delivered to micron spot-size in femto-seconds.

High intensity / flux



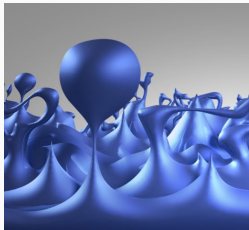
Getty Images / The Independent



ELI NP. [www.science.org](http://www.science.org)

# Exciting the quantum vacuum

- **Classical** vacuum = empty. **Quantum** vacuum... different.
- “Full of virtual electron-positron pairs”
- Intense laser **excites** vacuum.
- **Quantum vacuum phenomena**

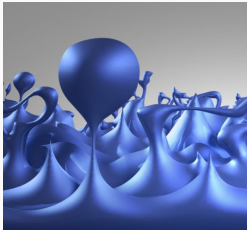


NASA/CXC/M.WEISS

- Light by light scattering
- Schwinger pair creation
- Vacuum birefringence

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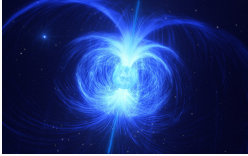
NASA/CXC/M.WEISS



→ Light

→ Schwin... ion

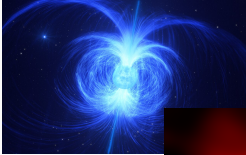
## Other sources of strong fields



Strong magnetic fields: **magnetar environments**

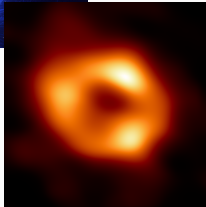
ESO/L. Calçada.

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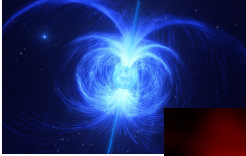
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Strong **gravity** near massive bodies

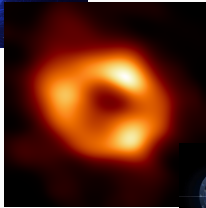
EHT Collaboration

# Other sources of strong fields



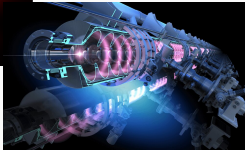
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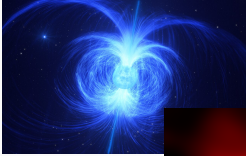


Dense bunches

→ **strong Coulomb**

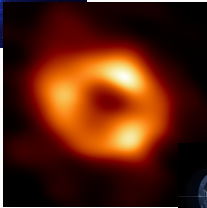
ILC international dev. team.

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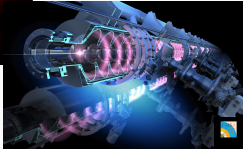
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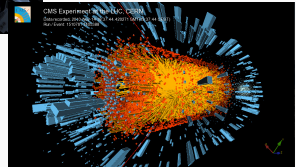
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ILC international dev. team.

**Heavy ion collisions**

CMS/CERN



# Summary

- Intense laser light probes **fundamental quantum physics**.

## Strong field physics:

- **QED** – quantum vacuum effects Fedotov et al, Phys.Rept. 1010 (2023)
- **Gravity** – black hole physics with R. Aoude, W. Lindved, D.O'Connell, K. Rajeev
- **Amplitudes program** – new formulations of QFT with T. Adamo, SoM
- **Quantum computing** P. Draper, L. Hidalgo, A. Ilderton PRD 113 (2026) 056010
- **BSM searches** Bai et al, PRD 106 (2022) 115034