

Fall 9-2014

# Dawn of Gravitational Wave Astronomy

Maria Babiuc-Hamilton

*Marshall University*, [babiuc@marshall.edu](mailto:babiuc@marshall.edu)

Follow this and additional works at: [http://mds.marshall.edu/physics\\_faculty](http://mds.marshall.edu/physics_faculty)



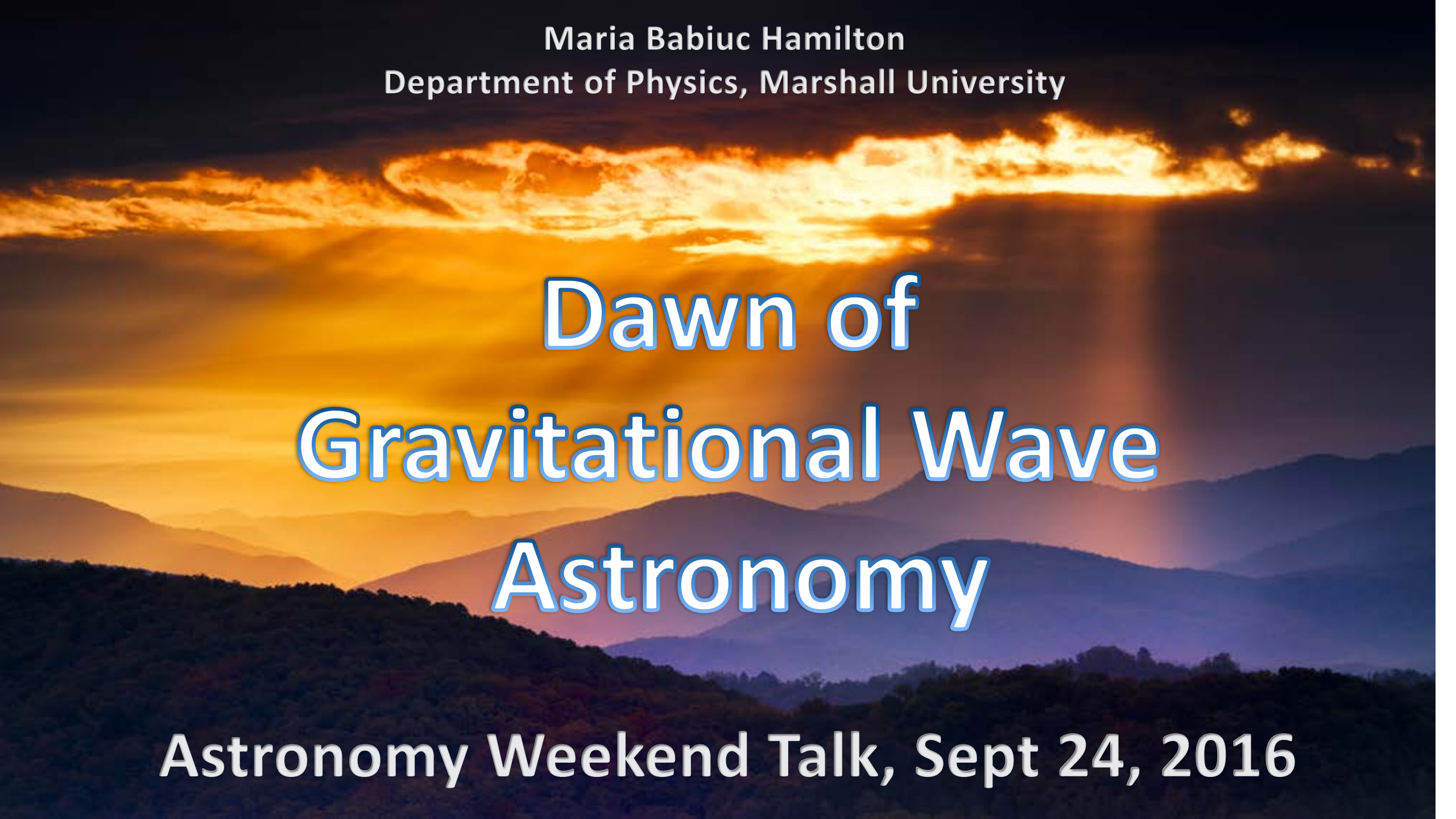
Part of the [Physics Commons](#)

---

## Recommended Citation

Hamilton, Maria B. (2014, September). Dawn of Gravitational Wave Astronomy. Slides presented at the Kanawha Valley Astronomical Society, Blackwater Falls State Park, WV.

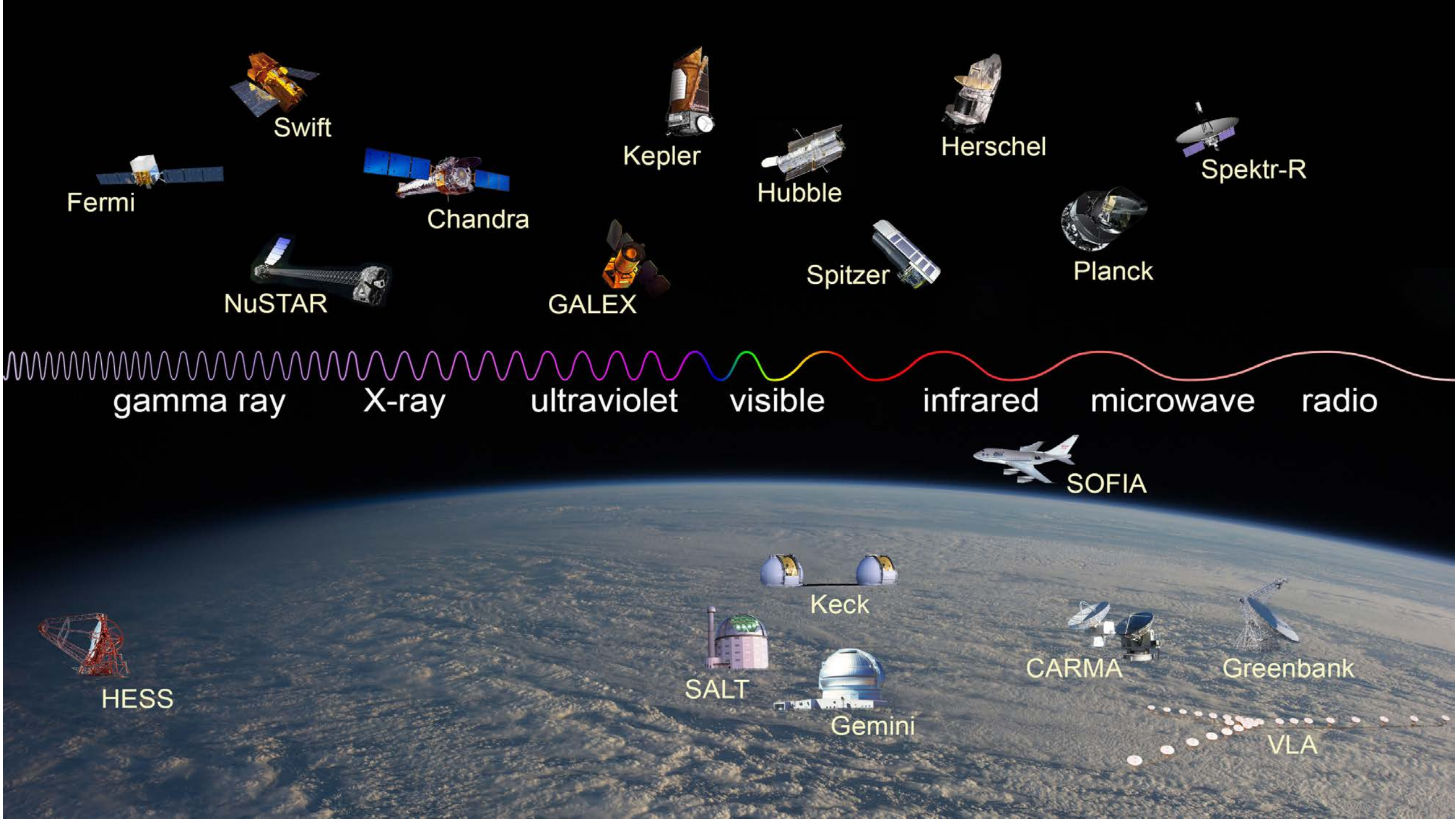
This Presentation is brought to you for free and open access by the Physics at Marshall Digital Scholar. It has been accepted for inclusion in Physics Faculty Research by an authorized administrator of Marshall Digital Scholar. For more information, please contact [zhangj@marshall.edu](mailto:zhangj@marshall.edu), [martj@marshall.edu](mailto:martj@marshall.edu).



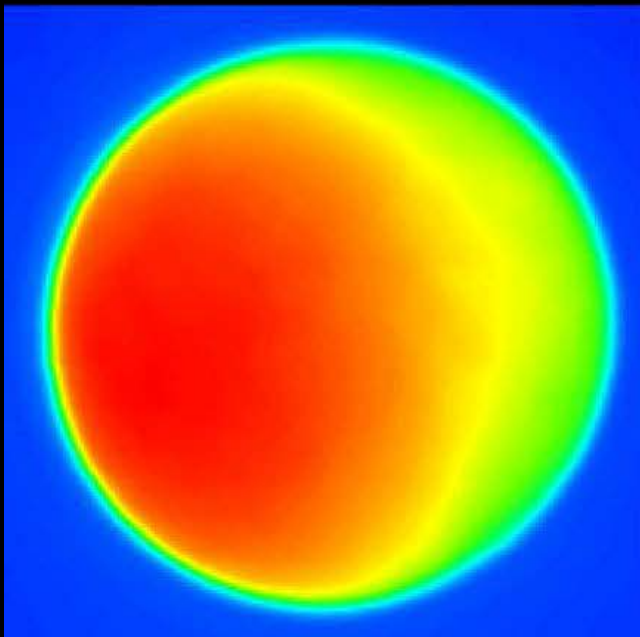
Maria Babiuc Hamilton  
Department of Physics, Marshall University

# Dawn of Gravitational Wave Astronomy

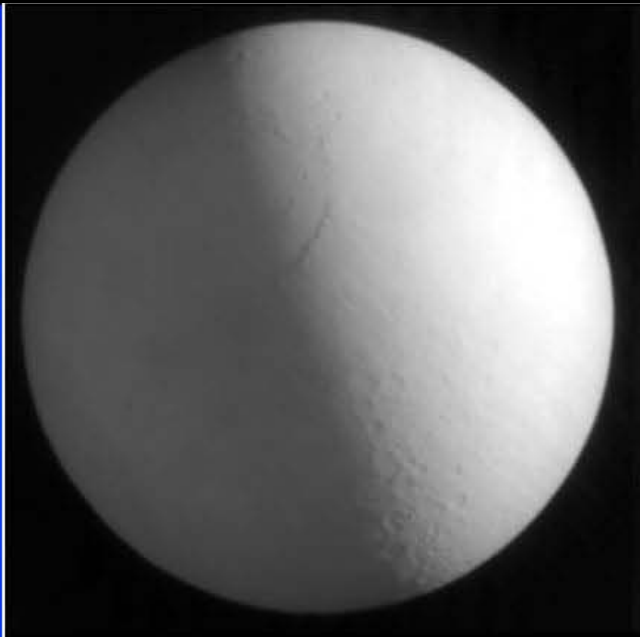
Astronomy Weekend Talk, Sept 24, 2016



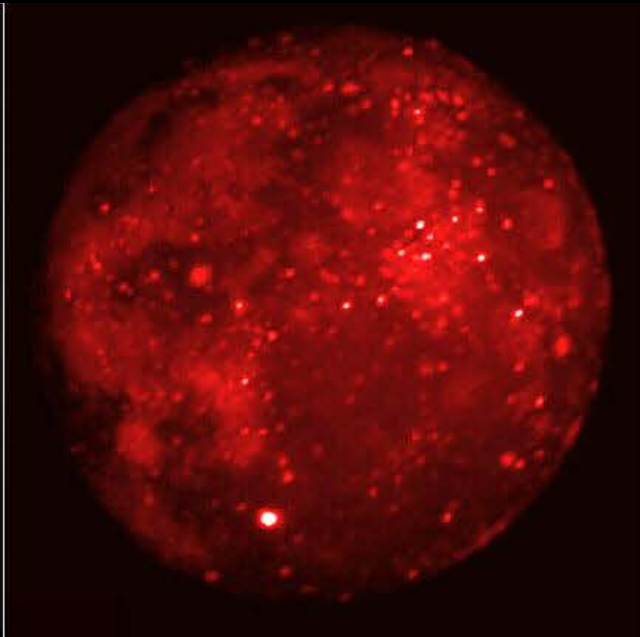
Radio Moon



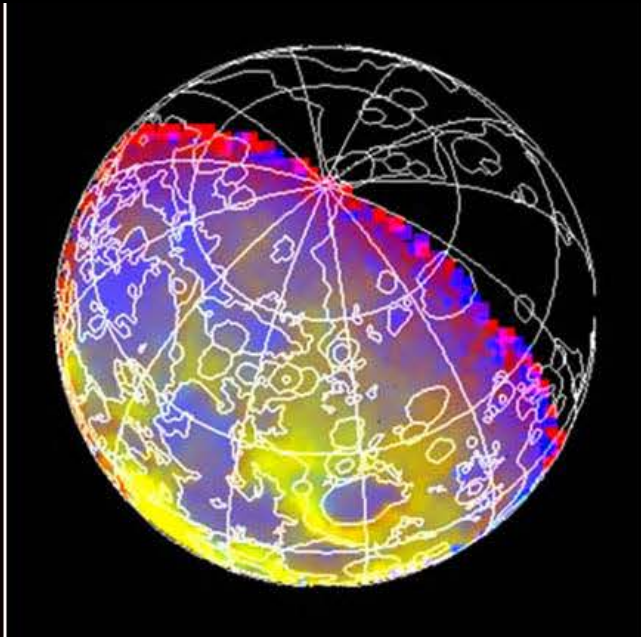
Submillimeter Moon



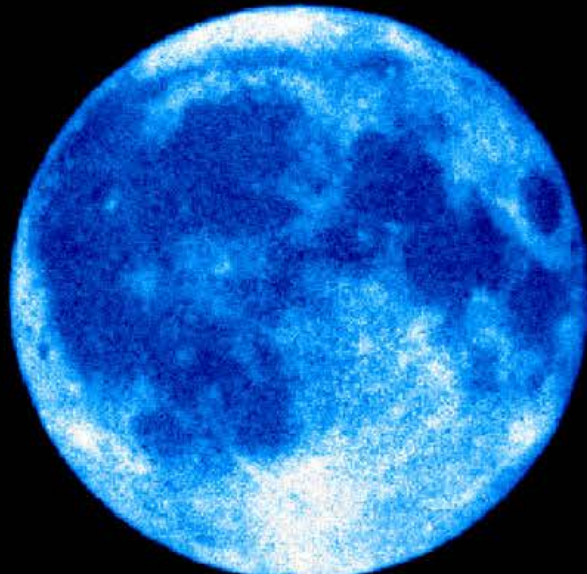
Mid-infrared Moon



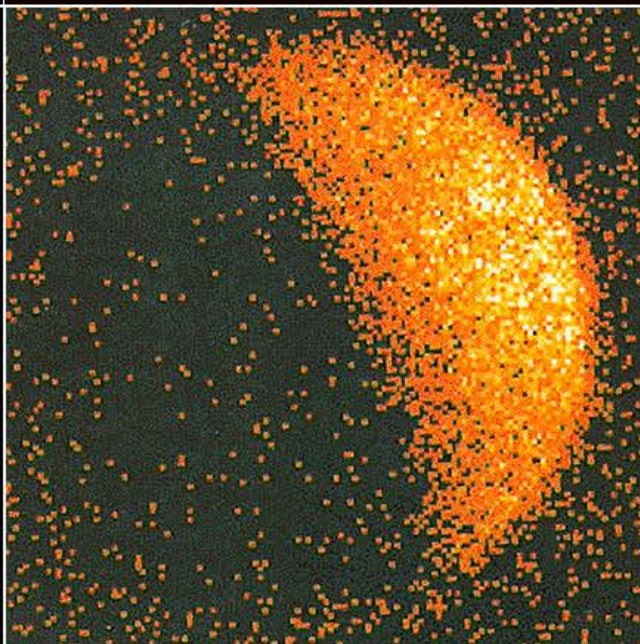
Near-infrared Moon



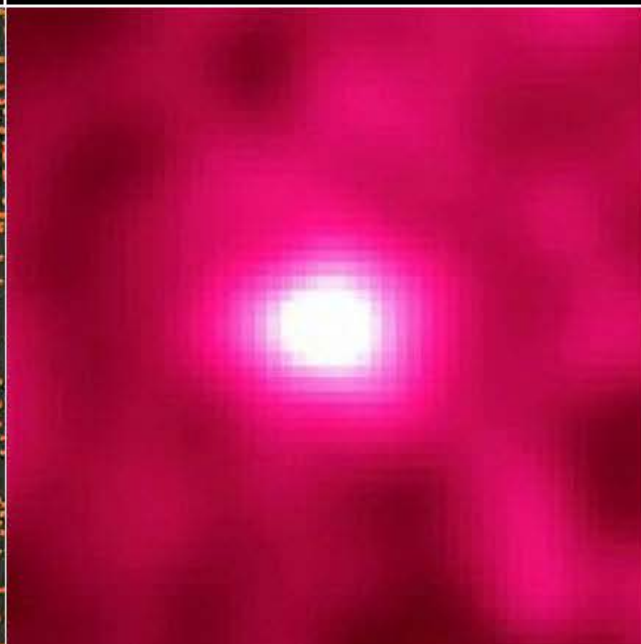
Visible light Moon



Ultraviolet Moon



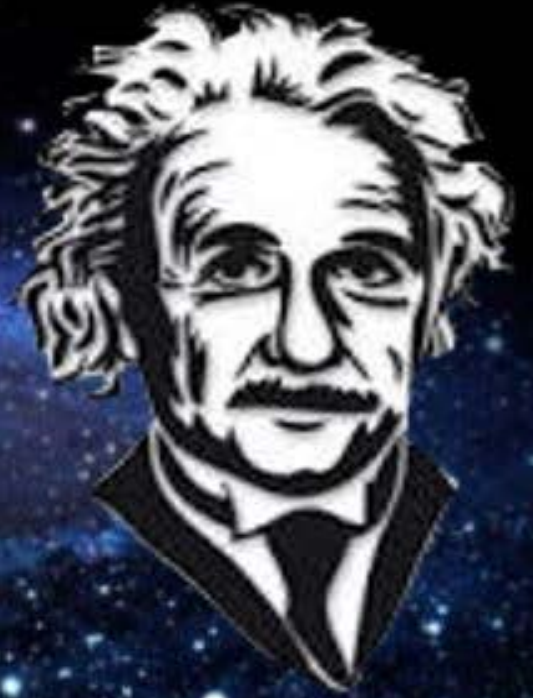
X-ray Moon



Gamma ray Moon

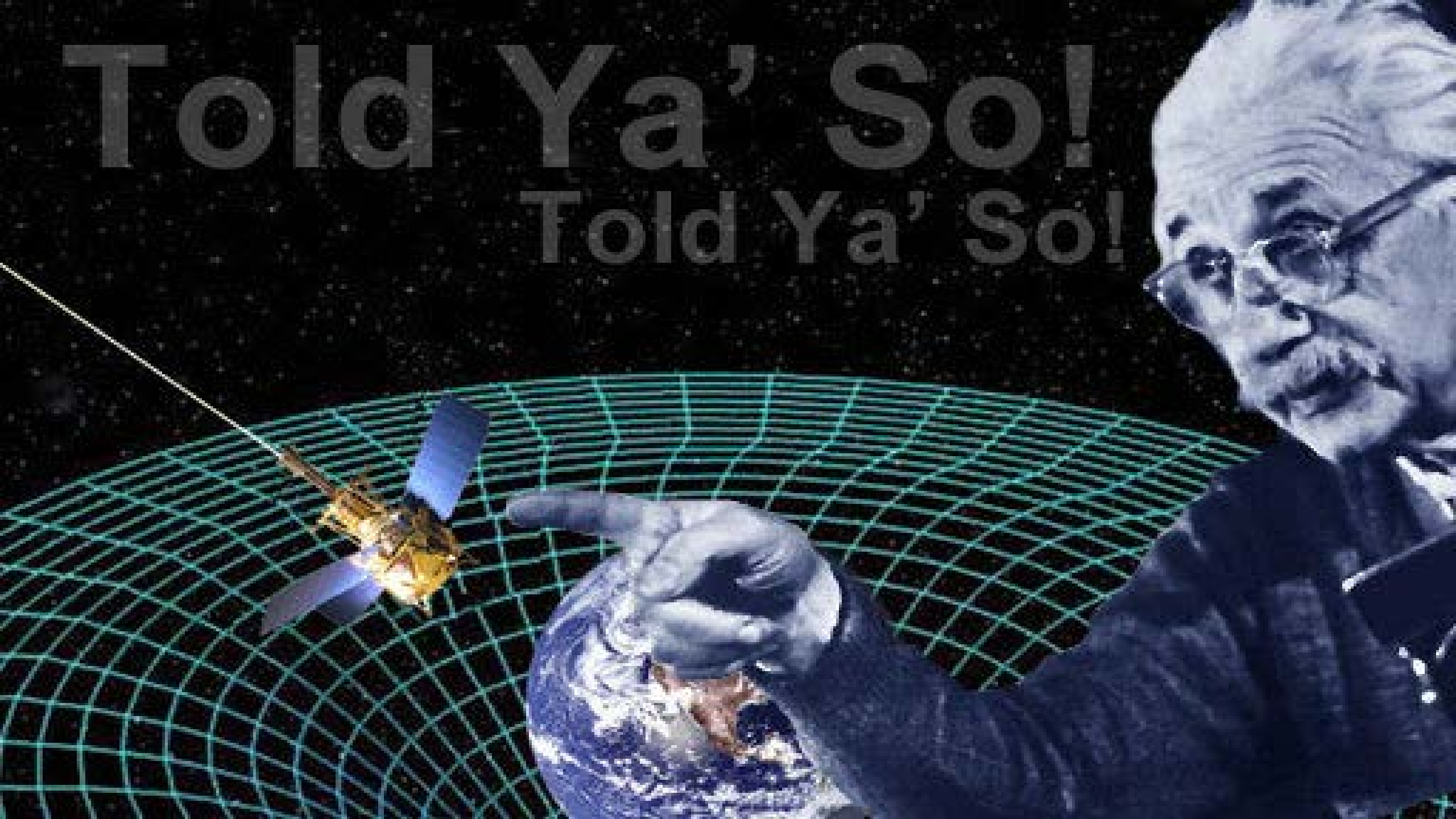


# Einstein's Revolutionary Equation



$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = (8\pi G/c^4) T_{\mu\nu}$$

Told Ya' So!  
Told Ya' So!



Herrn John T. Tate  
Editor The Physical Review  
University of Minnesota  
Minneapolis, Minn.

Sehr geehrter Herr:

Wir (Herr Rosen und ich) hatten Ihnen unser Manuskript zur Publikation gesandt und Sie nicht autorisiert, dasselbe Fachleuten zu zeigen, bevor es gedruckt ist. Auf die - übrigens irrthümlichen - Ausführungen Ihres anonymen Gewährmannes einzugehen sehe ich keine Veranlassung. Auf Grund des Vorkommnisses ziehe ich es vor, die Arbeit anderweitig zu publizieren.

Mit vorzüglicher Hochachtung

P.S. Herr Rosen, der nach Sowjet-Russland abgereist ist, hat mich autorisiert, ihn in dieser Sache zu vertreten.

[translation]

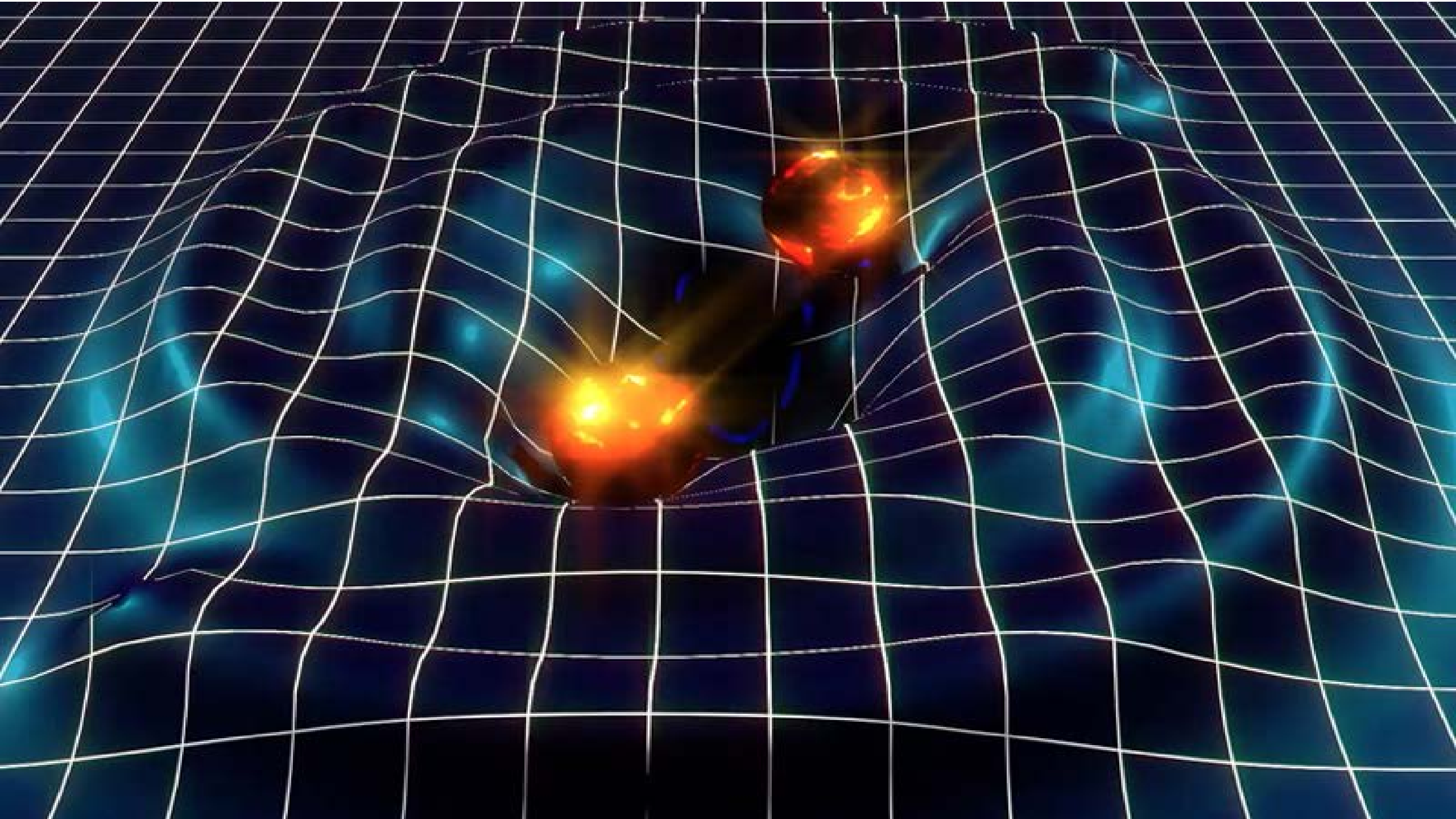
Dear Sir,

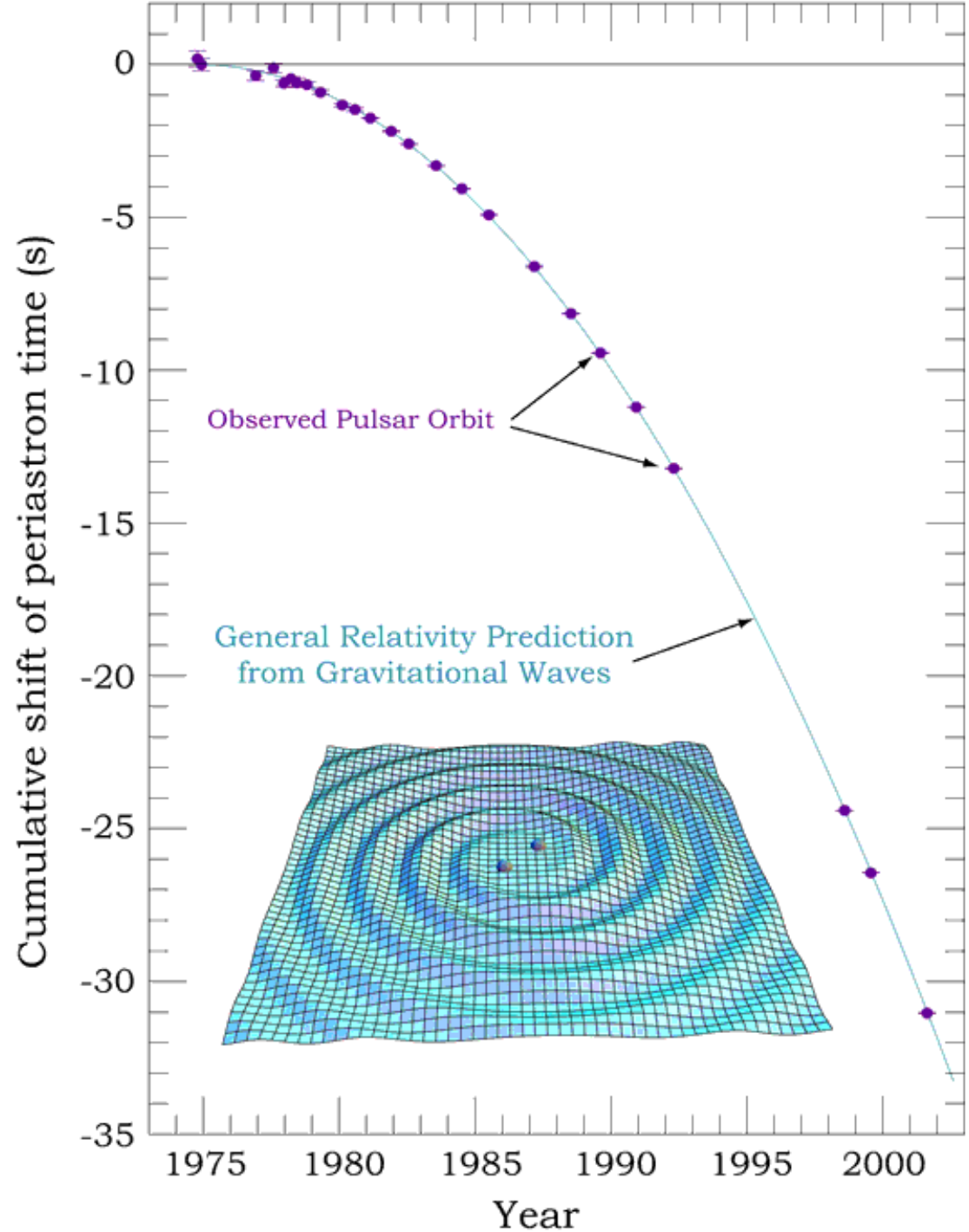
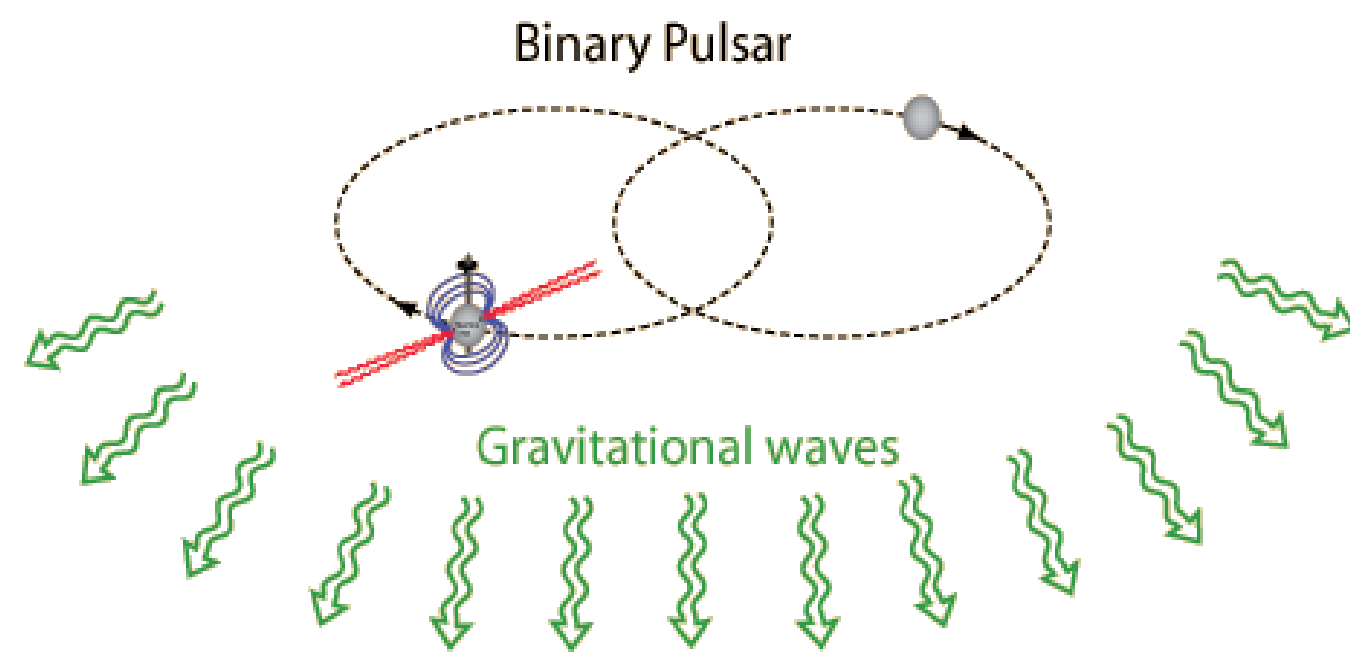
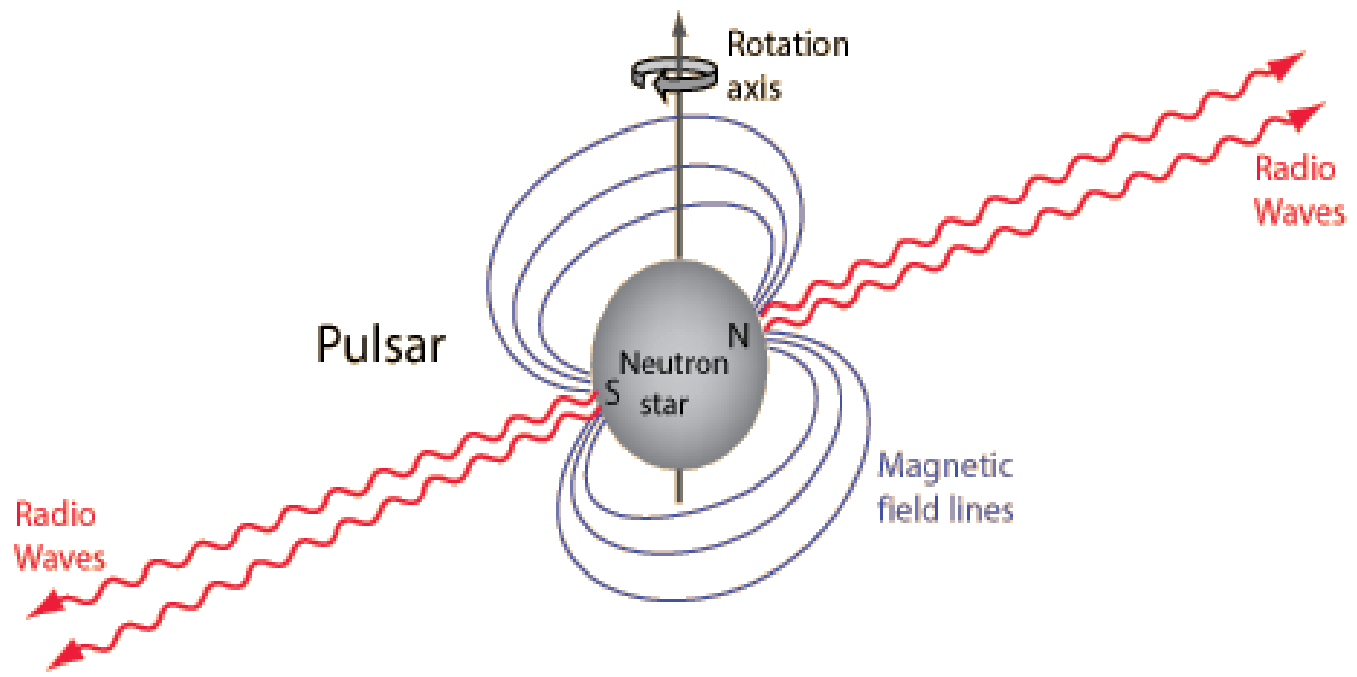
We (Mr. Rosen and I) had sent you our manuscript for publication and had not authorized you to show it to specialists before it is printed. I see no reason to address the— in any case erroneous— comments of your anonymous expert. On the basis of this incident I prefer to publish the paper elsewhere.

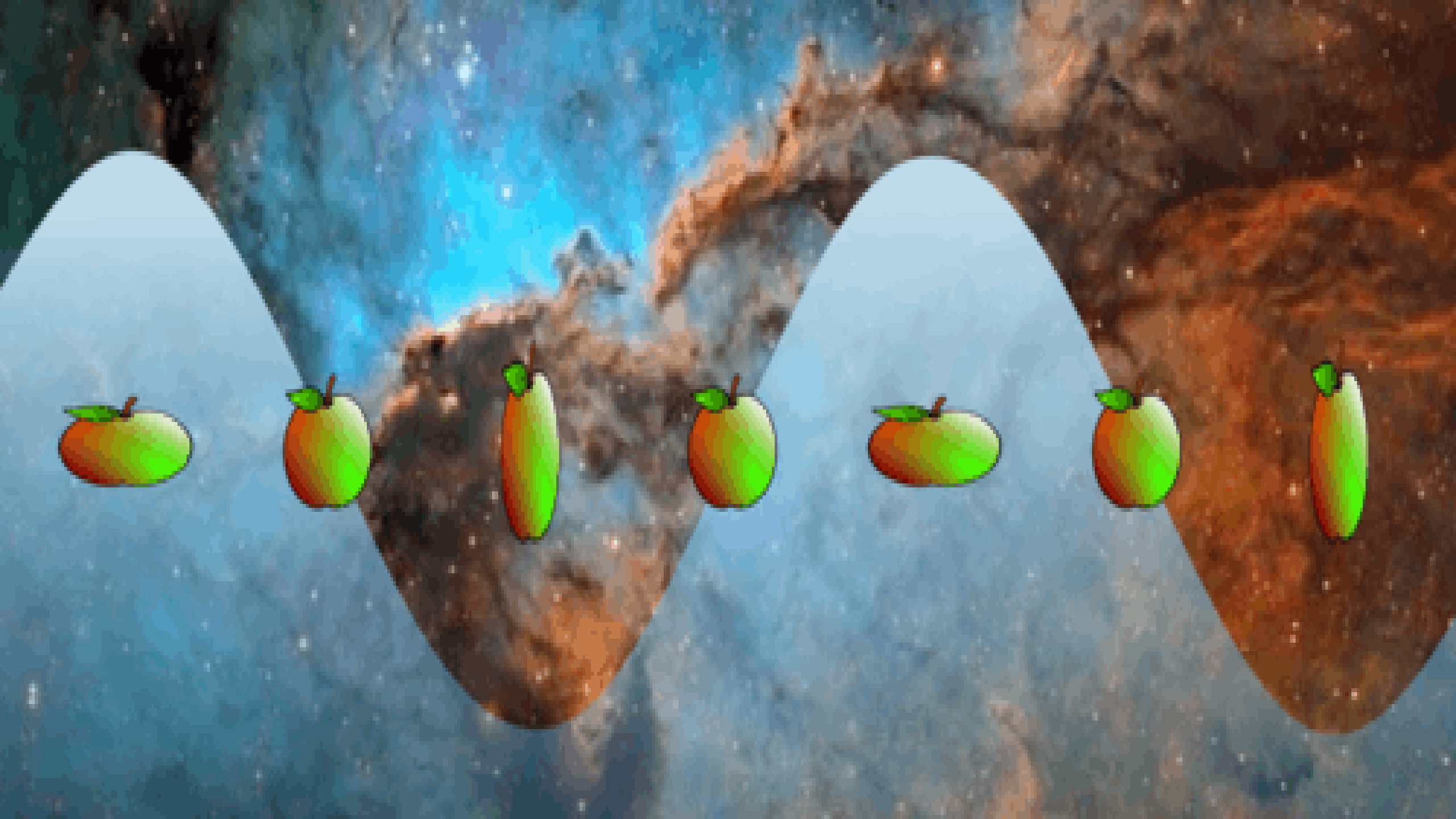
Respectfully,

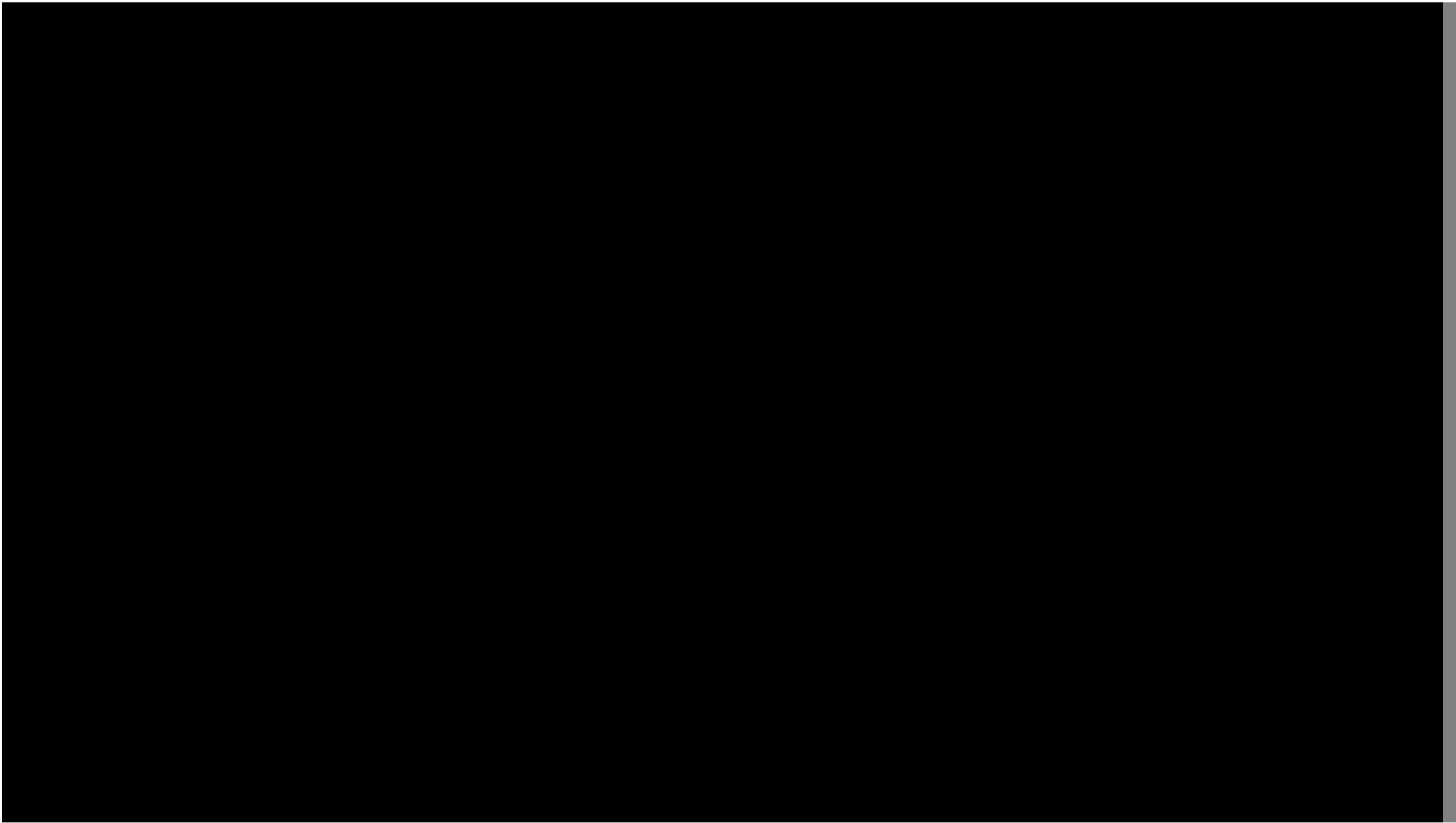
P.S. Mr. Rosen, who has left for the Soviet Union, has authorized me to represent him in this matter.







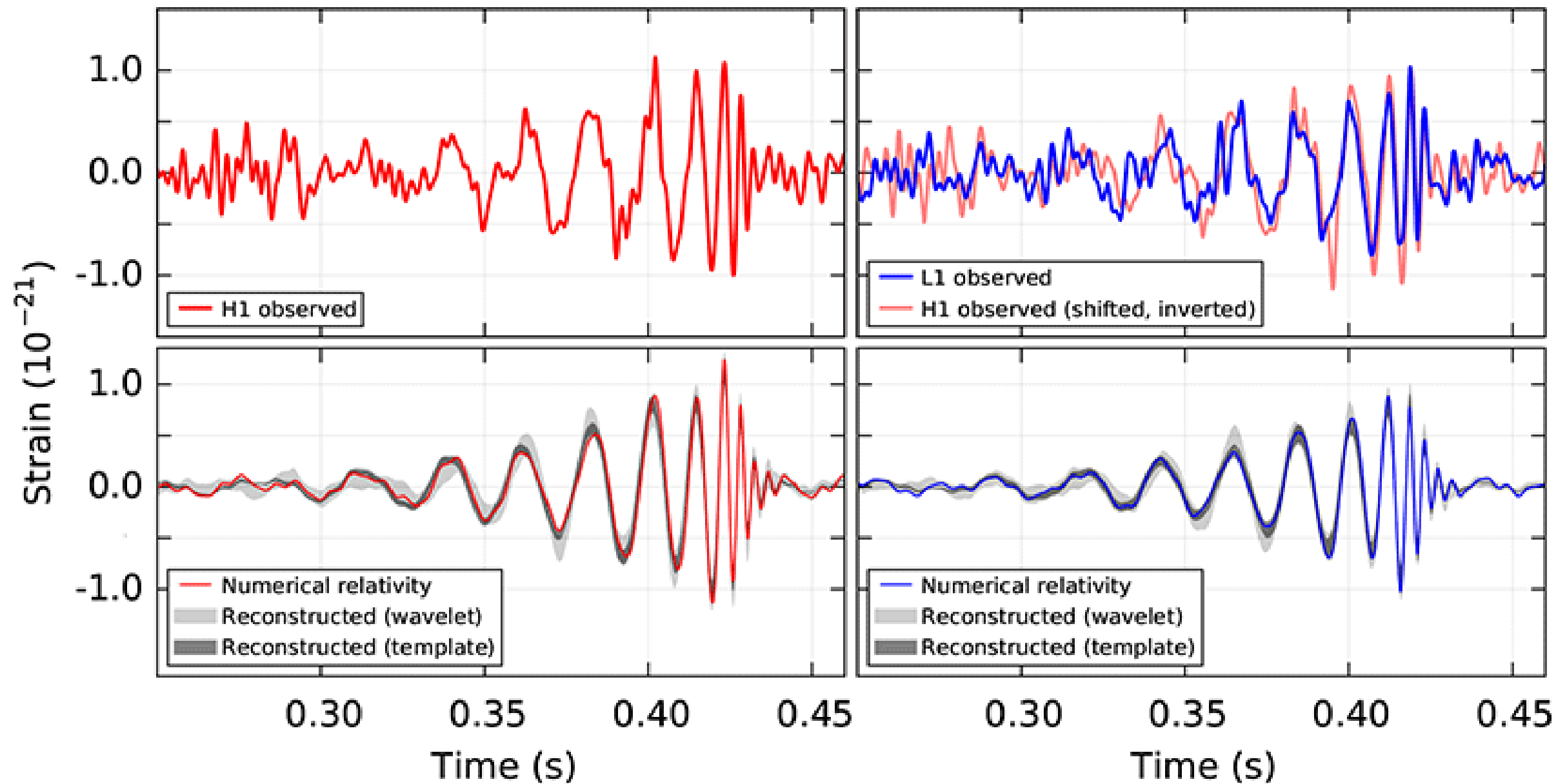




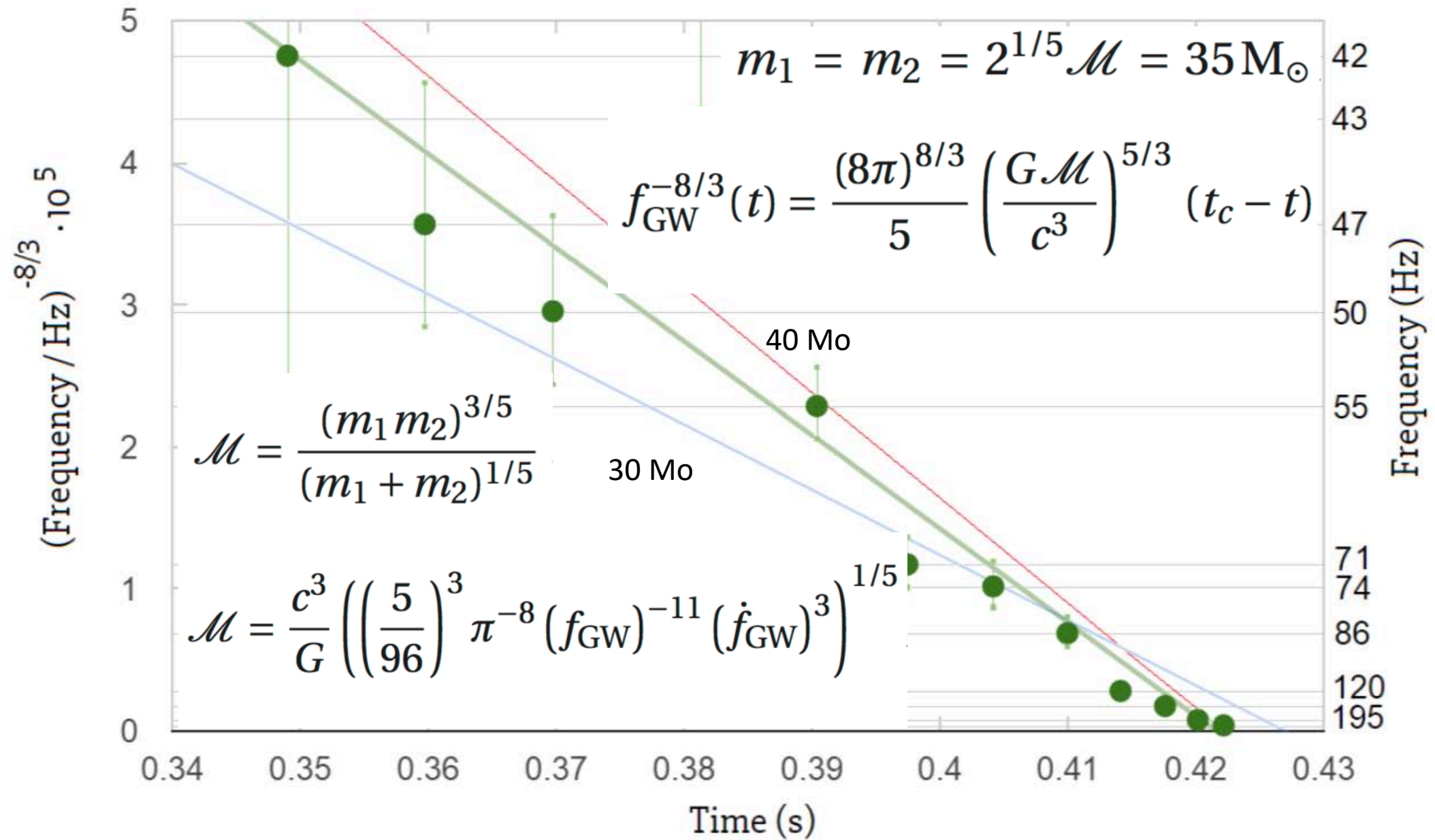


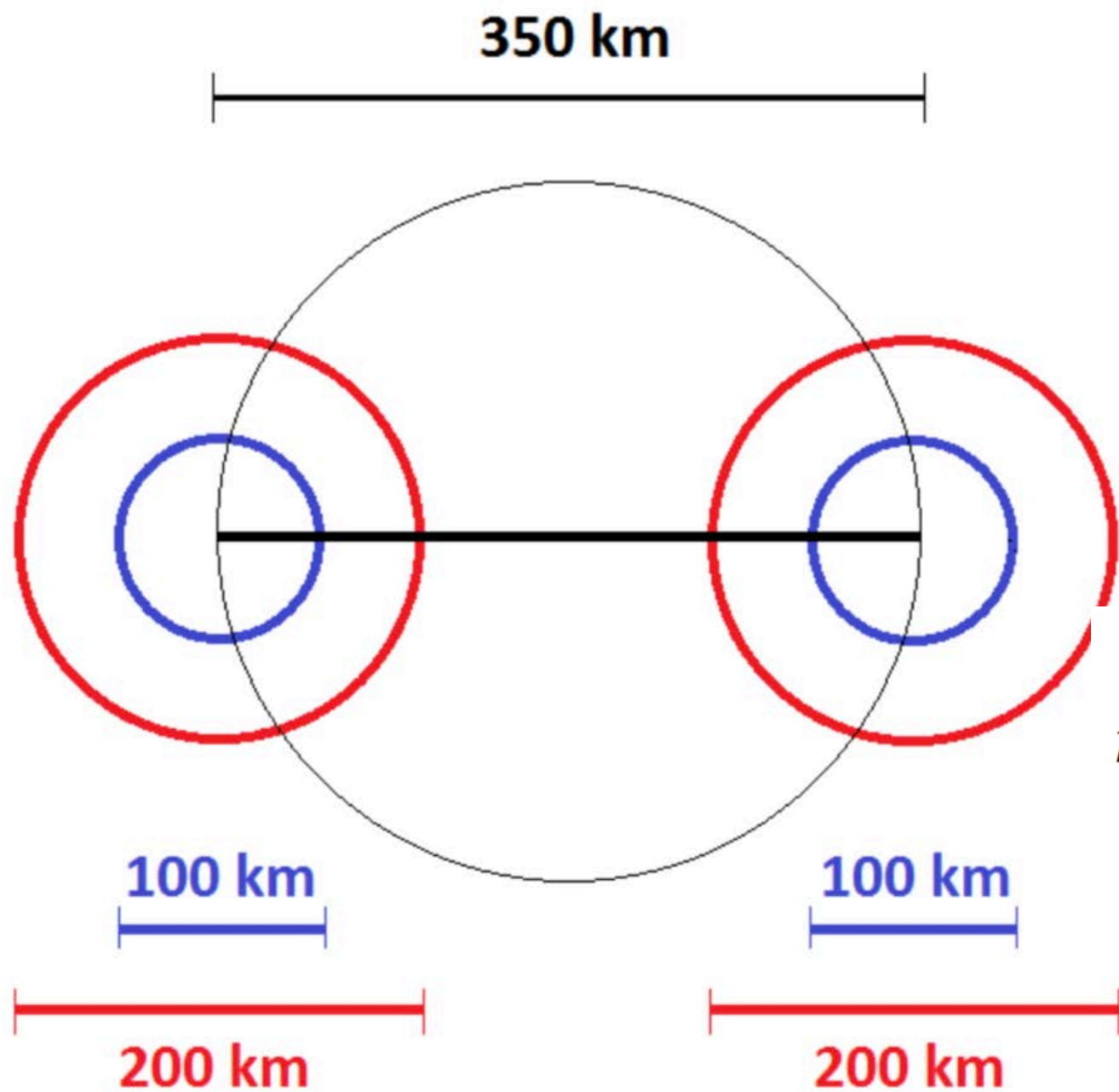
Hanford, Washington

Livingston, Louisiana



# Linear fit of $f_{\text{GW}}^{-8/3}(t)$ from combined H1, L1 strain





$$f_{\text{GW}}|_{\text{max}} \sim 150 \text{ Hz},$$

$$\omega_{\text{Kep}}|_{\text{max}} = \frac{2\pi f_{\text{GW}}|_{\text{max}}}{2} = 2\pi \times 75 \text{ Hz}.$$

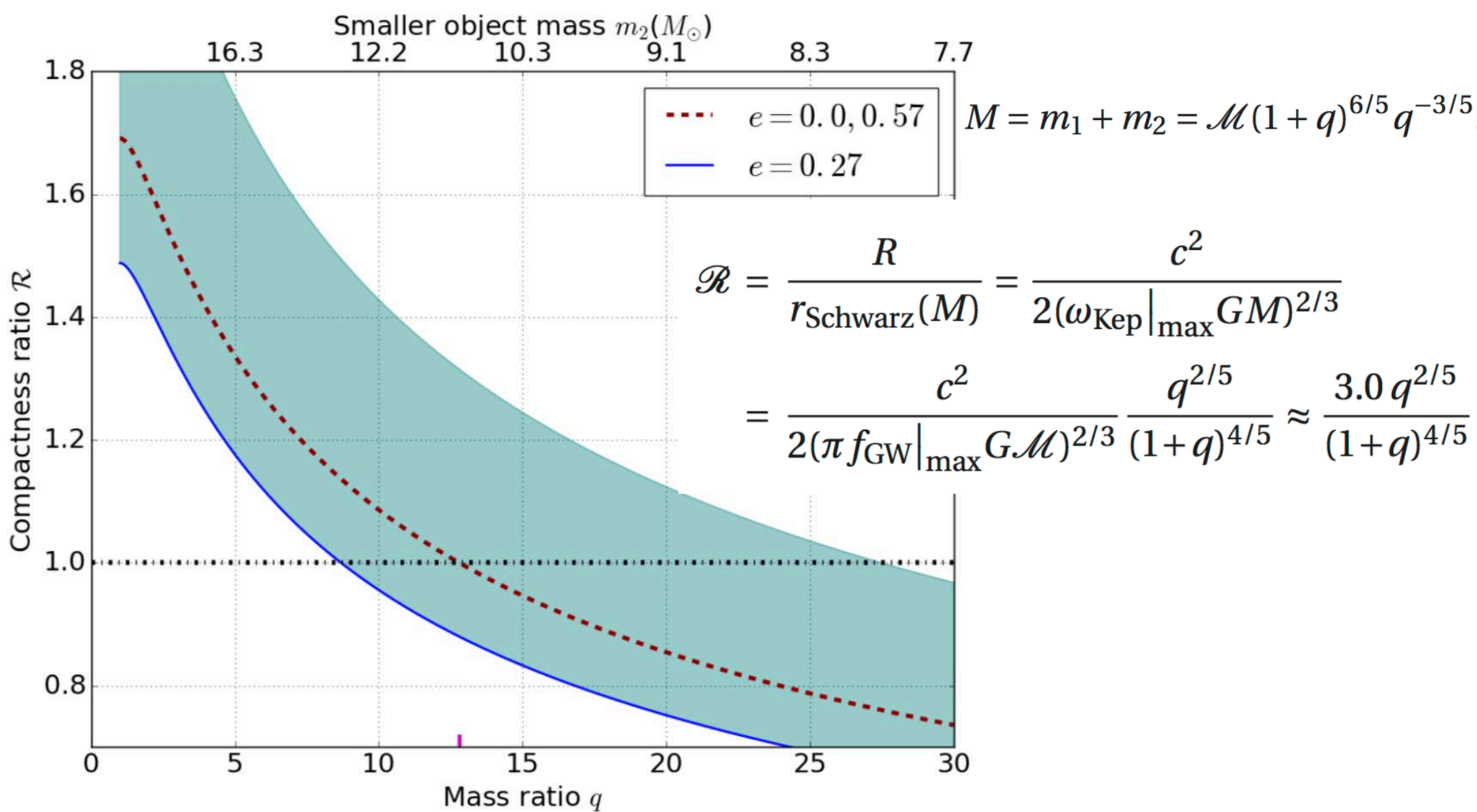
$$R = \left( \frac{GM}{\omega_{\text{Kep}}^2|_{\text{max}}} \right)^{1/3} = 350 \text{ km}.$$

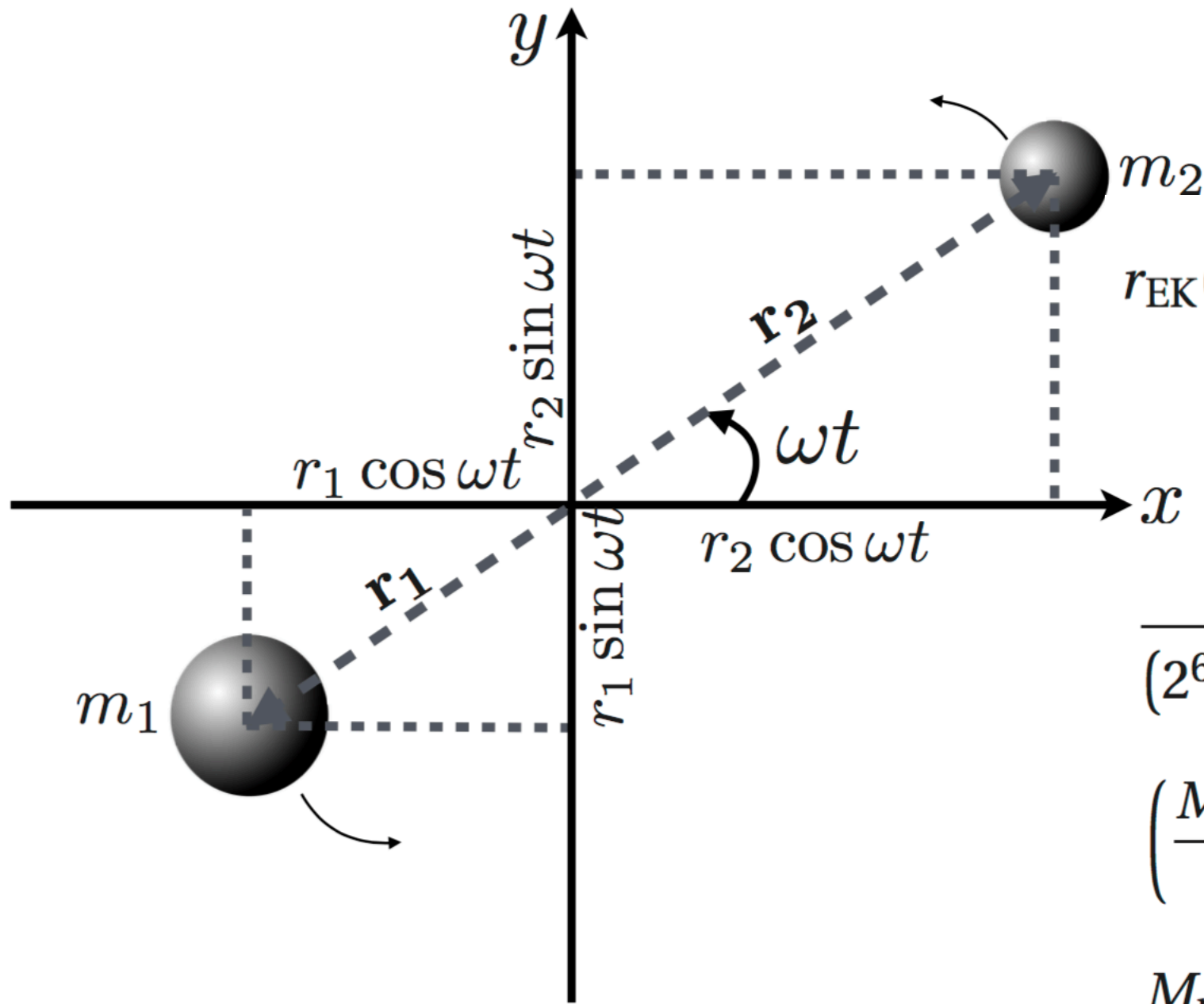
$$r_{\text{Schwarz}}(m) = \frac{2Gm}{c^2} = 2.95 \left( \frac{m}{M_{\odot}} \right) \text{ km},$$

$$\bar{M} = m_1 + m_2 = 70 M_{\odot}$$

$$\mathcal{R} = 350 \text{ km} / 206 \text{ km} \sim 1.7.$$







$$\chi = \frac{c}{G} \frac{S}{m^2}$$

$$r_{\text{EK}}(m_1) + r_{\text{EK}}(m_2) = \frac{1}{2} r_{\text{Schwarz}}(M)$$

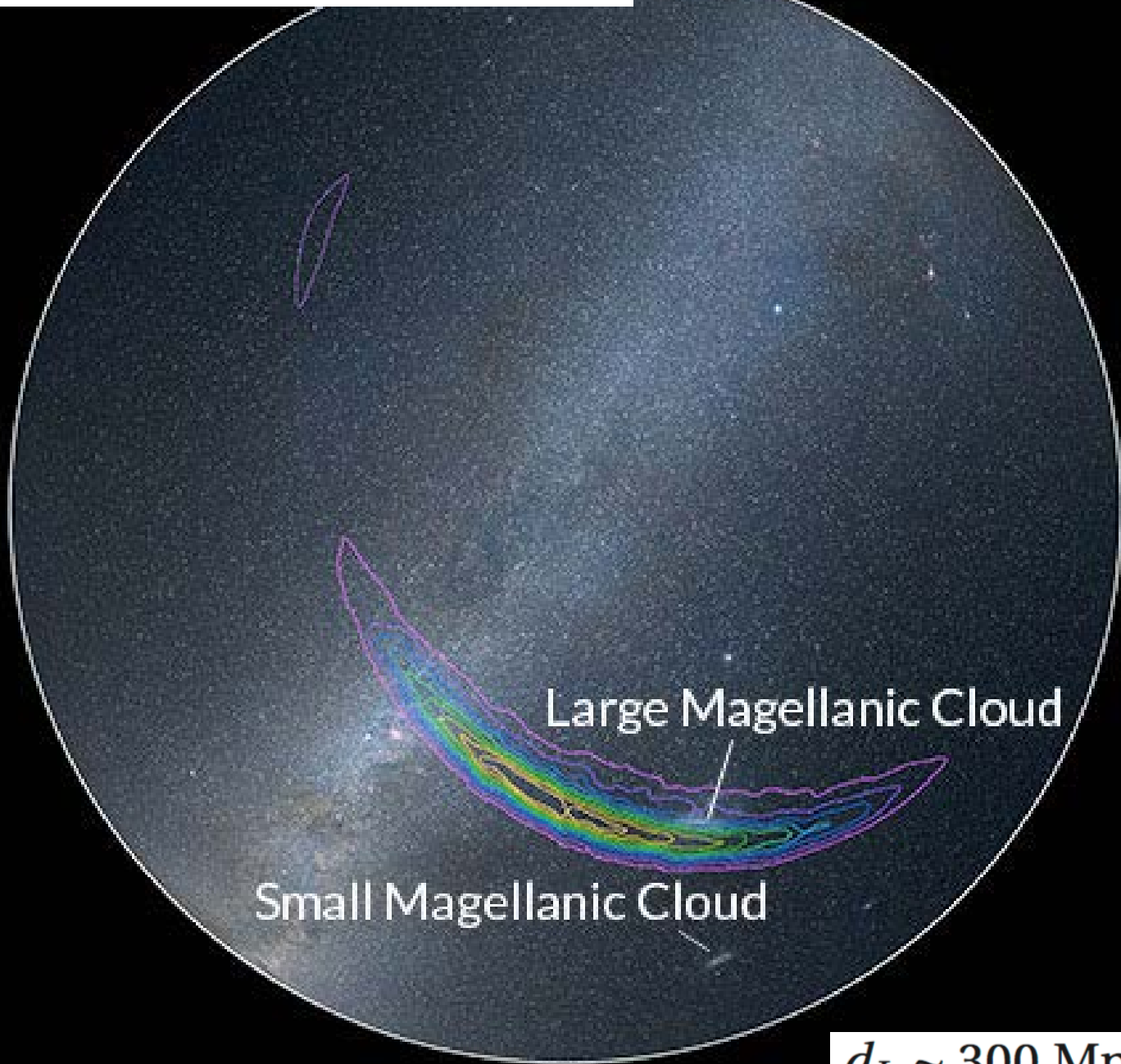
$$\mathcal{R} = \frac{r_{\text{sep}}(M)}{r_{\text{EK}}(M)} \leq \frac{c^2}{(2^{6/5} \pi G \mathcal{M} f_{\text{GW}}|_{\text{max}})^{2/3}} \simeq 3.4$$

$$\left( \frac{M_{\text{max}}}{\mathcal{M}} \right) \simeq 3.4^{3/2} \times 2^{6/5} \simeq 14.4$$

$$M_{\text{max}} \simeq 432 M_{\odot} \text{ (and } q \simeq 83)$$

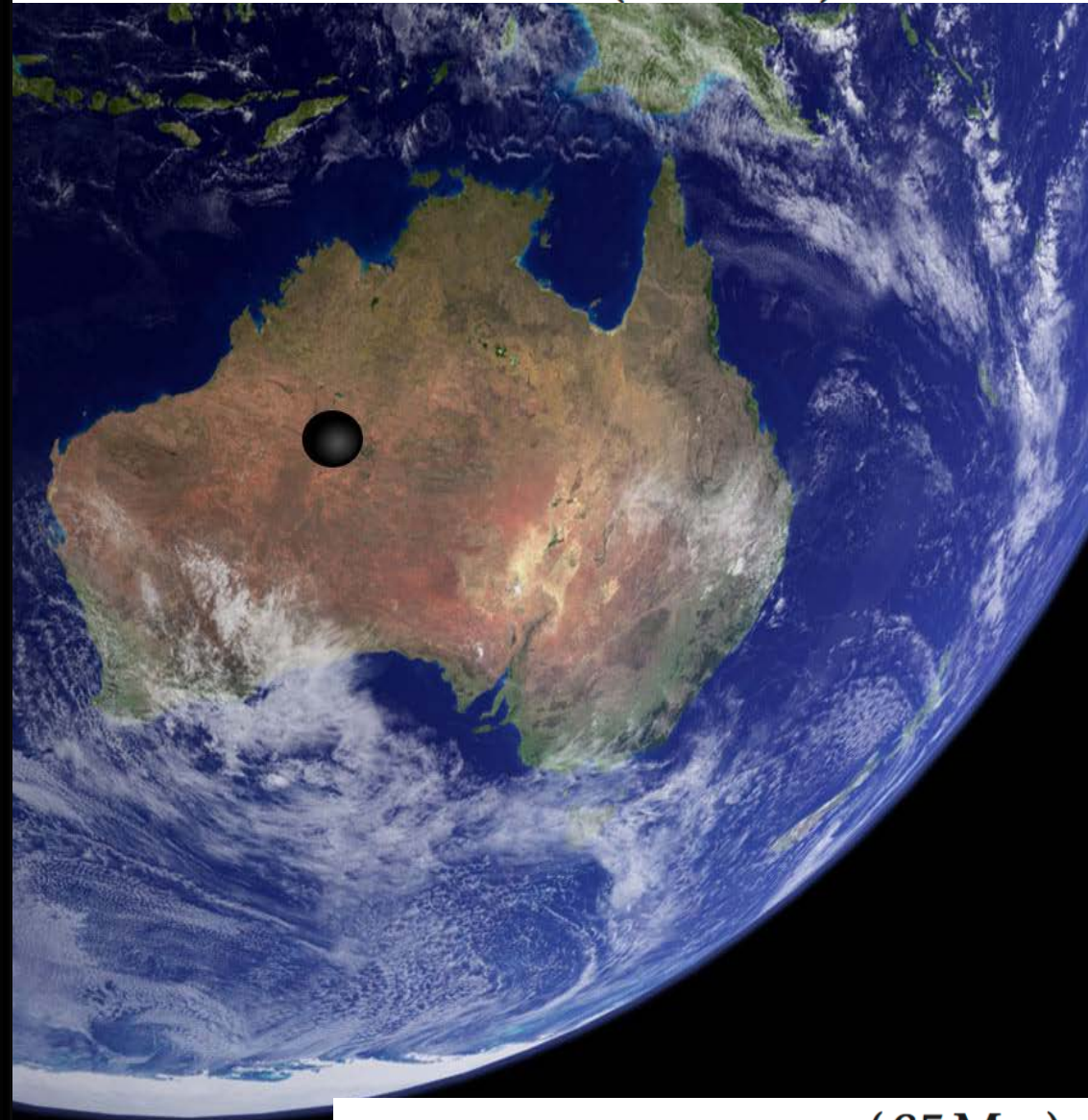


$$d_L \leq 10^{21} \times 100 \text{ km} \sim 3 \text{ Gpc}$$



$$d_L \sim 300 \text{ Mpc}$$

$$E_{\text{GW}} = E_{\text{orb}}^i - E_{\text{orb}}^f = 0 - \left( -\frac{GM\mu}{2R} \right) \sim 3M_{\odot} c^2$$

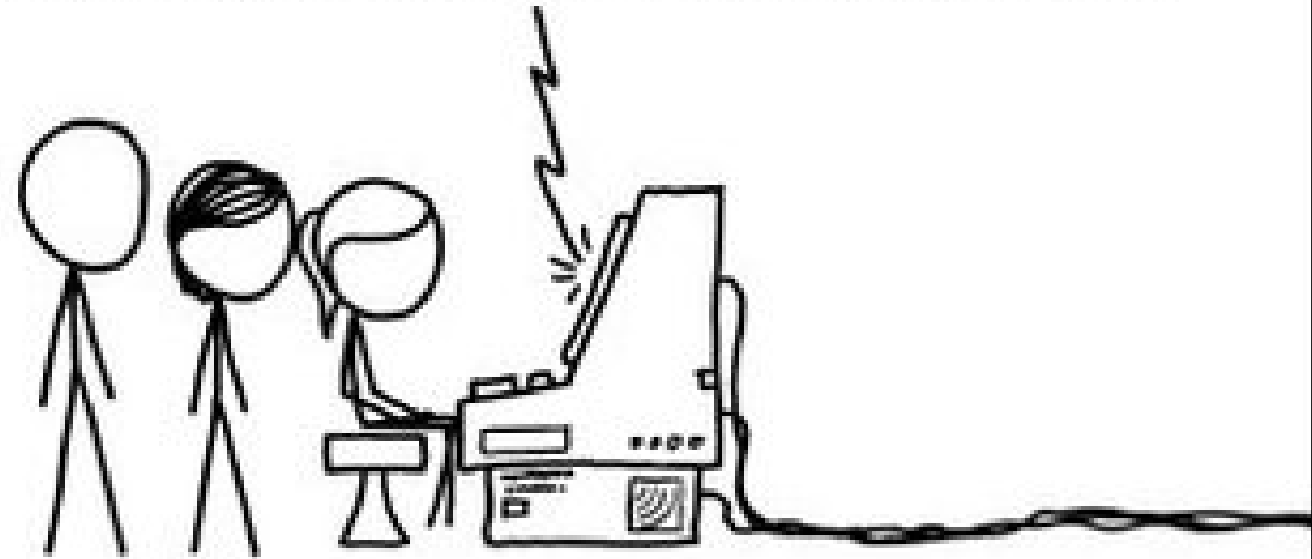


$$f_{\text{GW}| \text{ringdown}} \approx 260 \text{ Hz} \left( \frac{65 M_{\odot}}{M} \right)$$

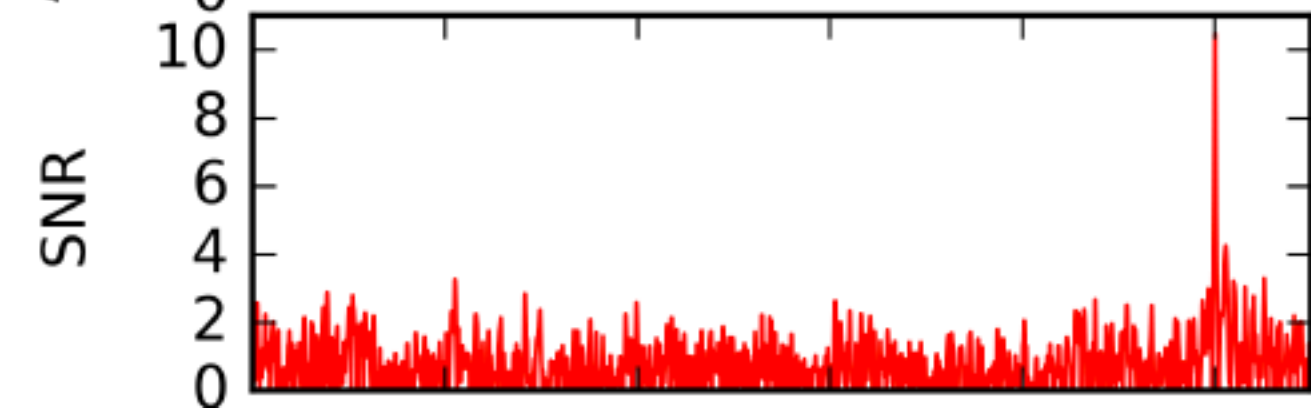
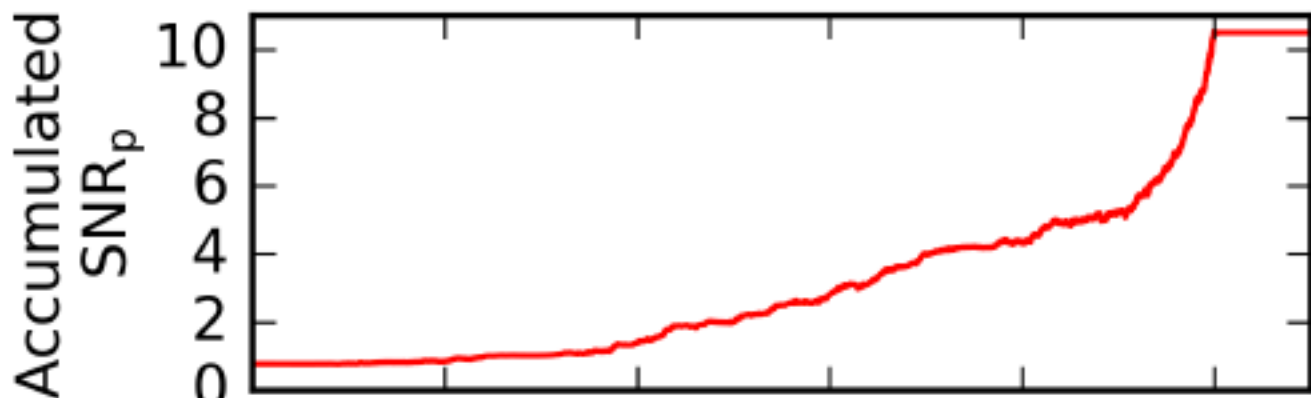
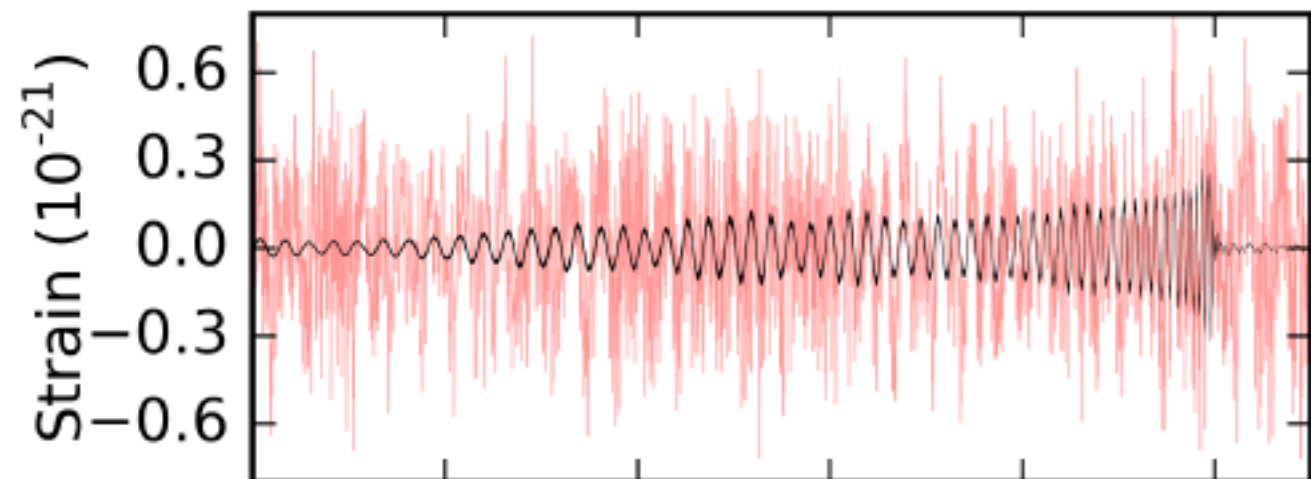
THE GRAVITATIONAL WAVE  
DETECTOR WORKS! FOR THE  
FIRST TIME, WE CAN LISTEN  
IN ON THE SIGNALS CARRIED  
BY RIPPLES IN THE FABRIC  
OF SPACE ITSELF!



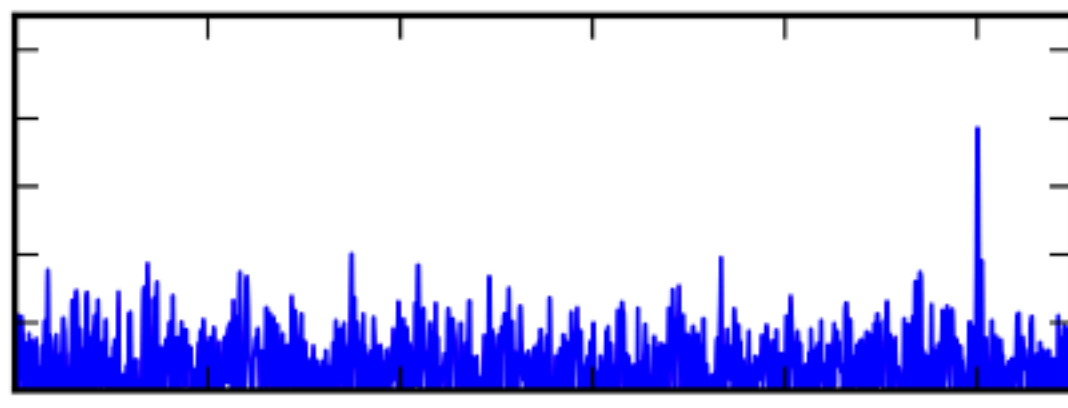
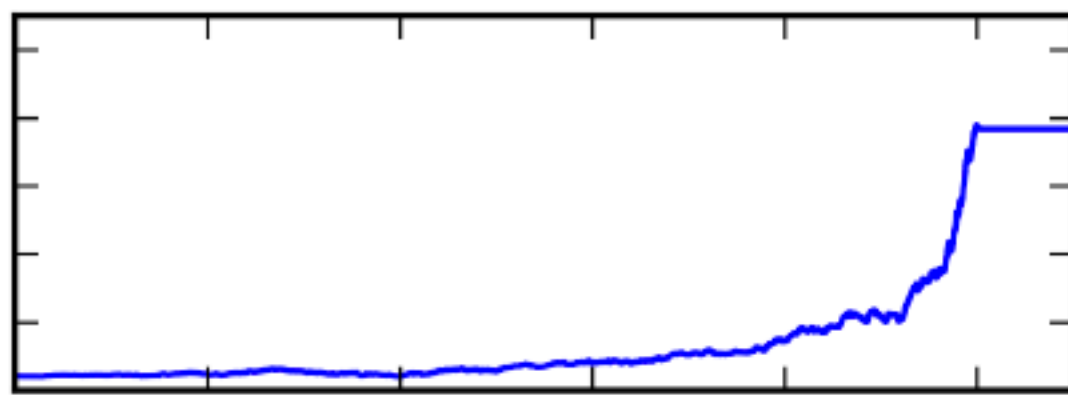
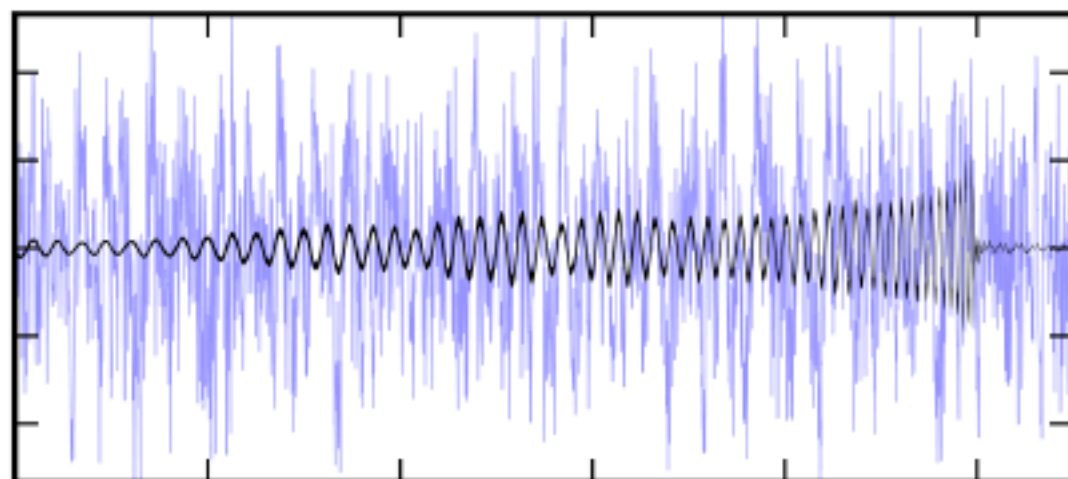
EVENT: BLACK HOLE MERGER IN CARINA (30  $M_{\odot}$ , 30  $M_{\odot}$ )  
EVENT: ZORLAX THE MIGHTY WOULD LIKE TO CONNECT ON LINKEDIN  
EVENT: BLACK HOLE MERGER IN ORION (20  $M_{\odot}$ , 50  $M_{\odot}$ )  
EVENT: MORTGAGE OFFER FROM TRIANGULUM GALAXY  
EVENT: ZORLAX THE MIGHTY WOULD LIKE TO CONNECT ON LINKEDIN  
EVENT: MEET LONELY SINGLES IN THE LOCAL GROUP TONIGHT!



Hanford



Livingston





The Gravitational Wave Spectrum

Sources



Big Bang

Supermassive Black Hole Binary Merger

Compact Binary Inspiral & Merger

Extreme Mass-Ratio Inspirals

Pulsars, Supernovae

age of the universe

Wave Period

hours

seconds

milliseconds

$10^{-16}$

$10^{-14}$

$10^{-12}$

$10^{-10}$

$10^{-8}$

$10^{-6}$

$10^{-4}$

$10^{-2}$

1

$10^2$

Wave Frequency

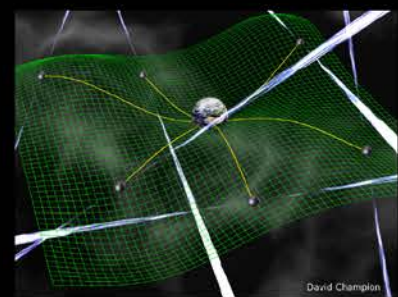
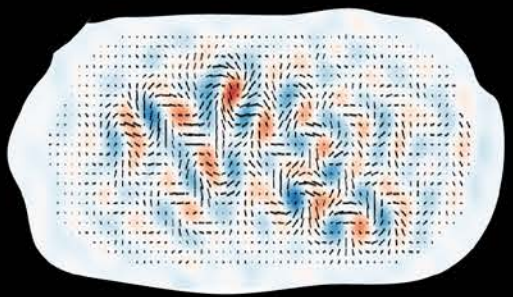
CMB Polarization

Radio Pulsar Timing Arrays

Space-based interferometers

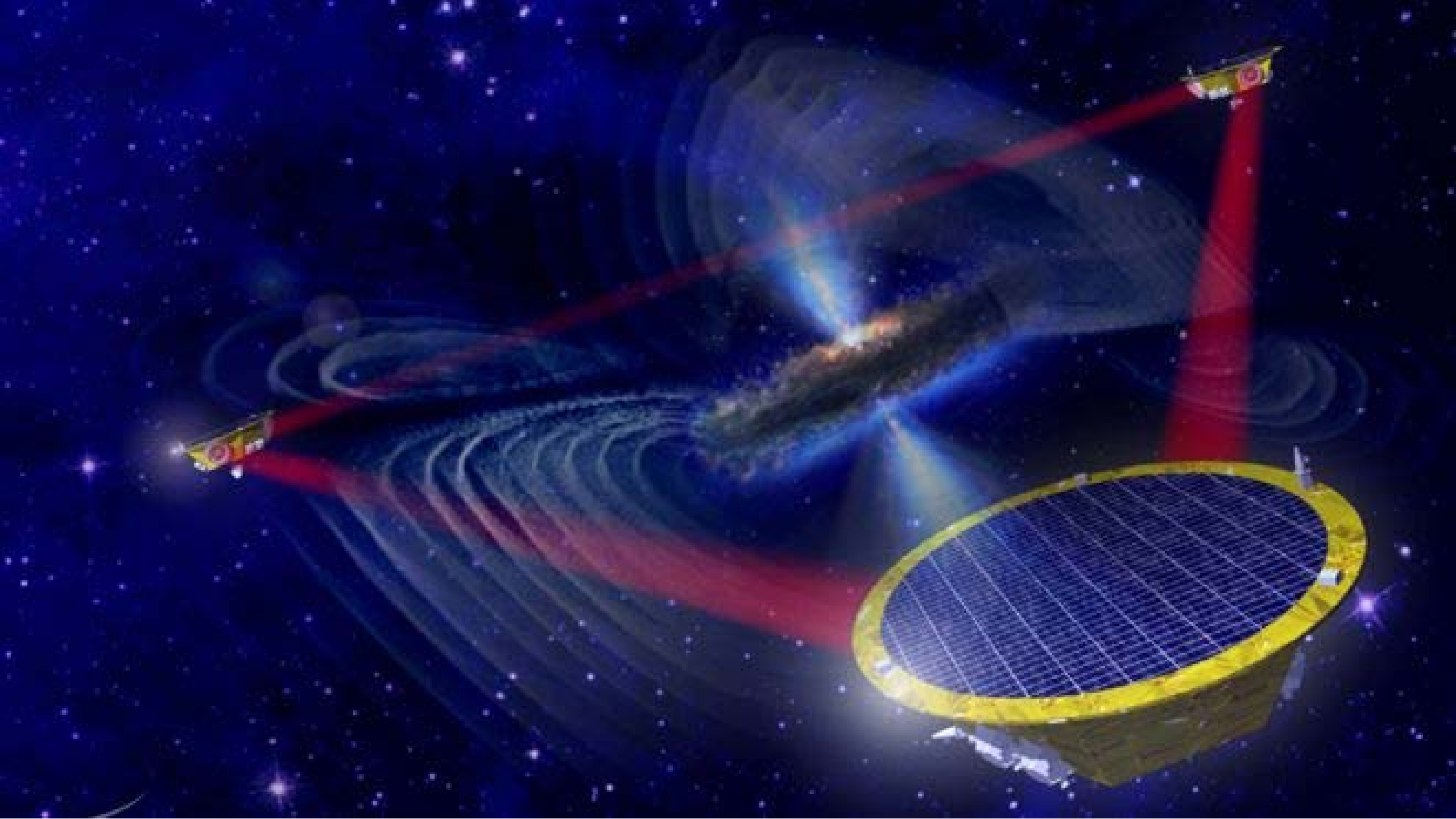
Terrestrial interferometers

Detectors

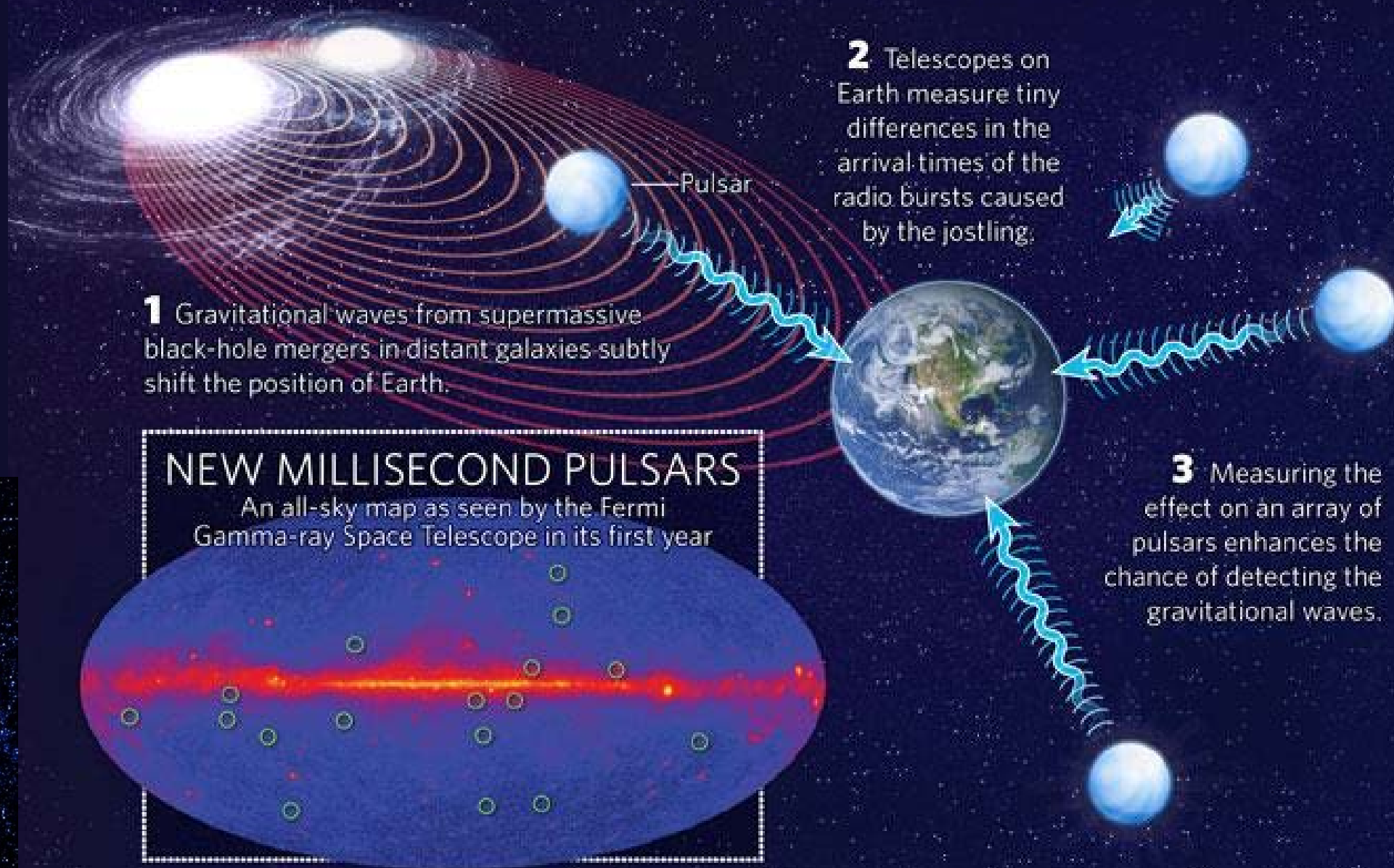


David Champion



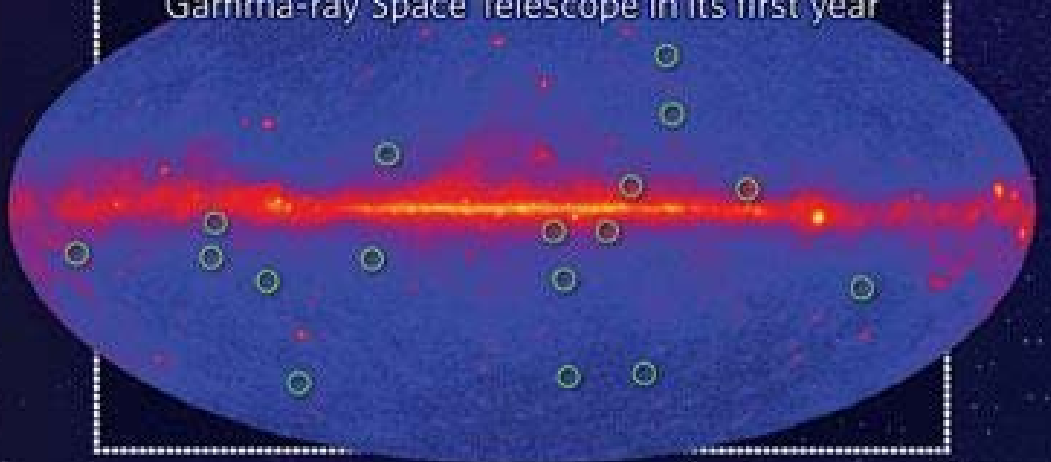


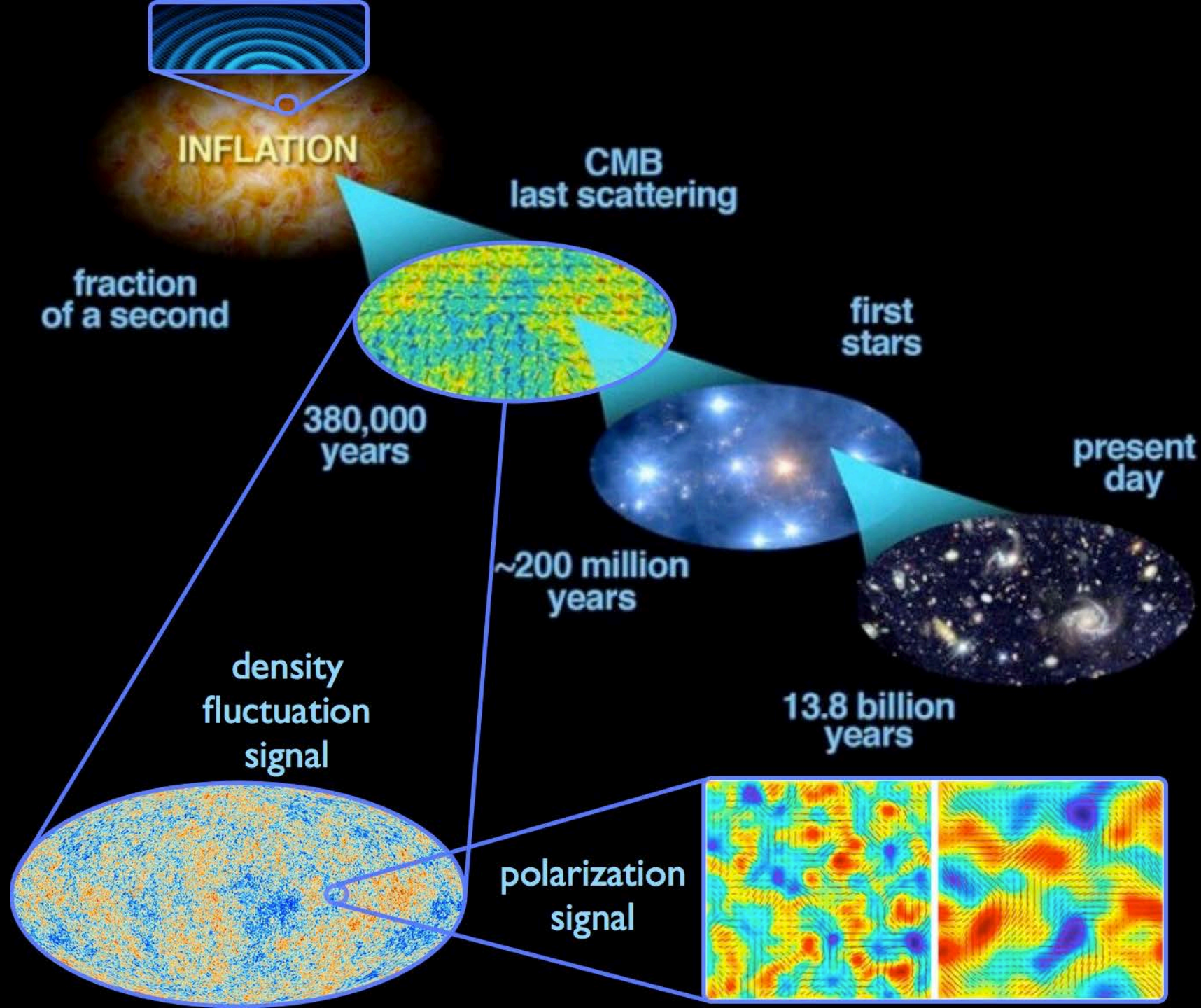
# HUNTING GRAVITATIONAL WAVES USING PULSARS

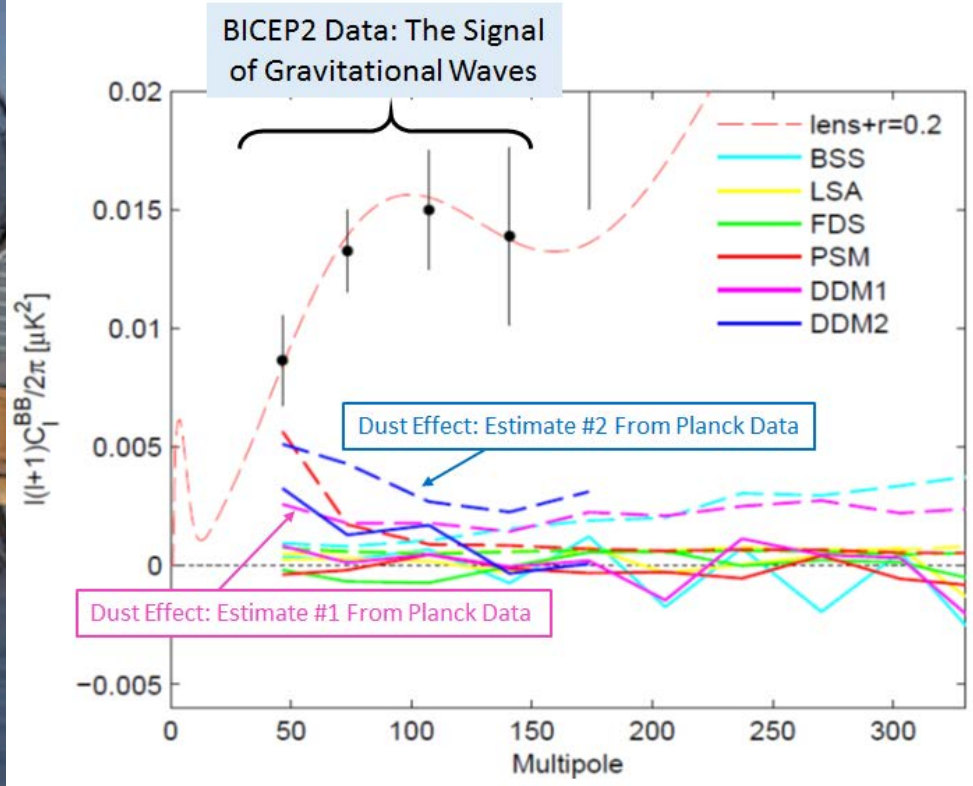
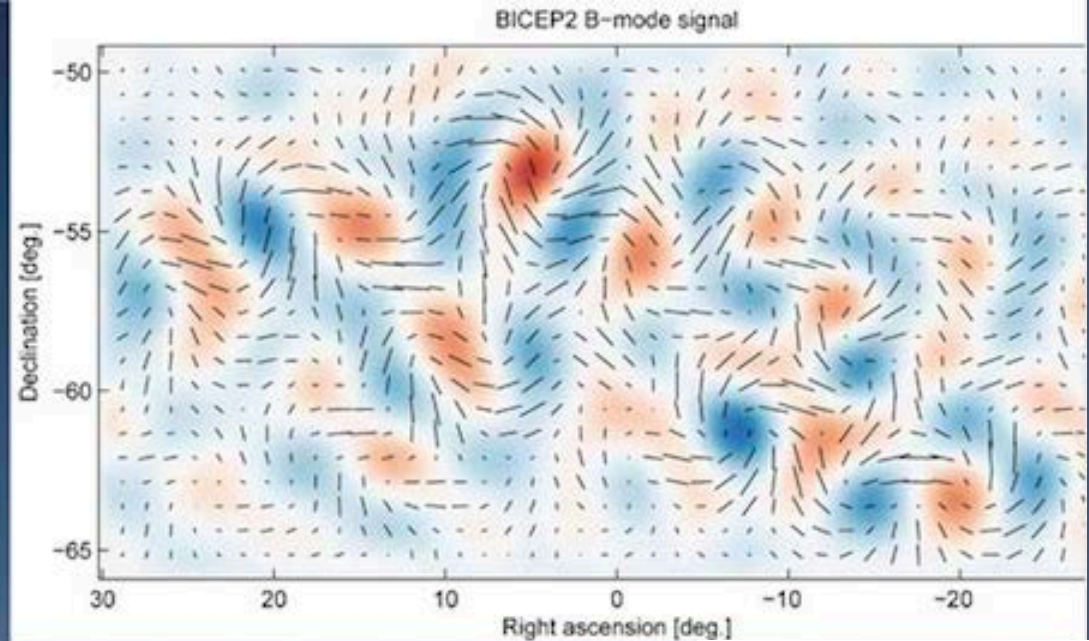
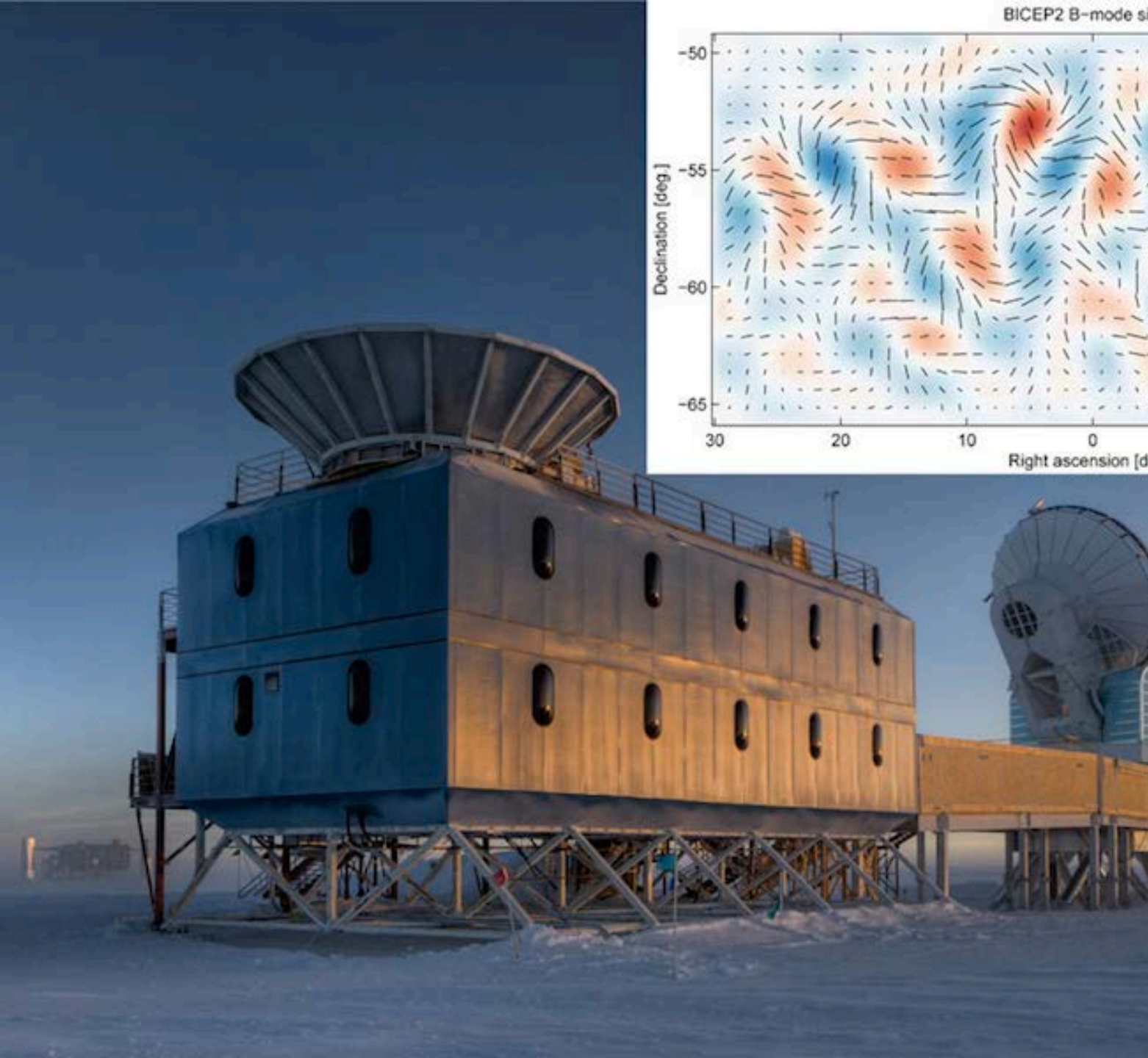


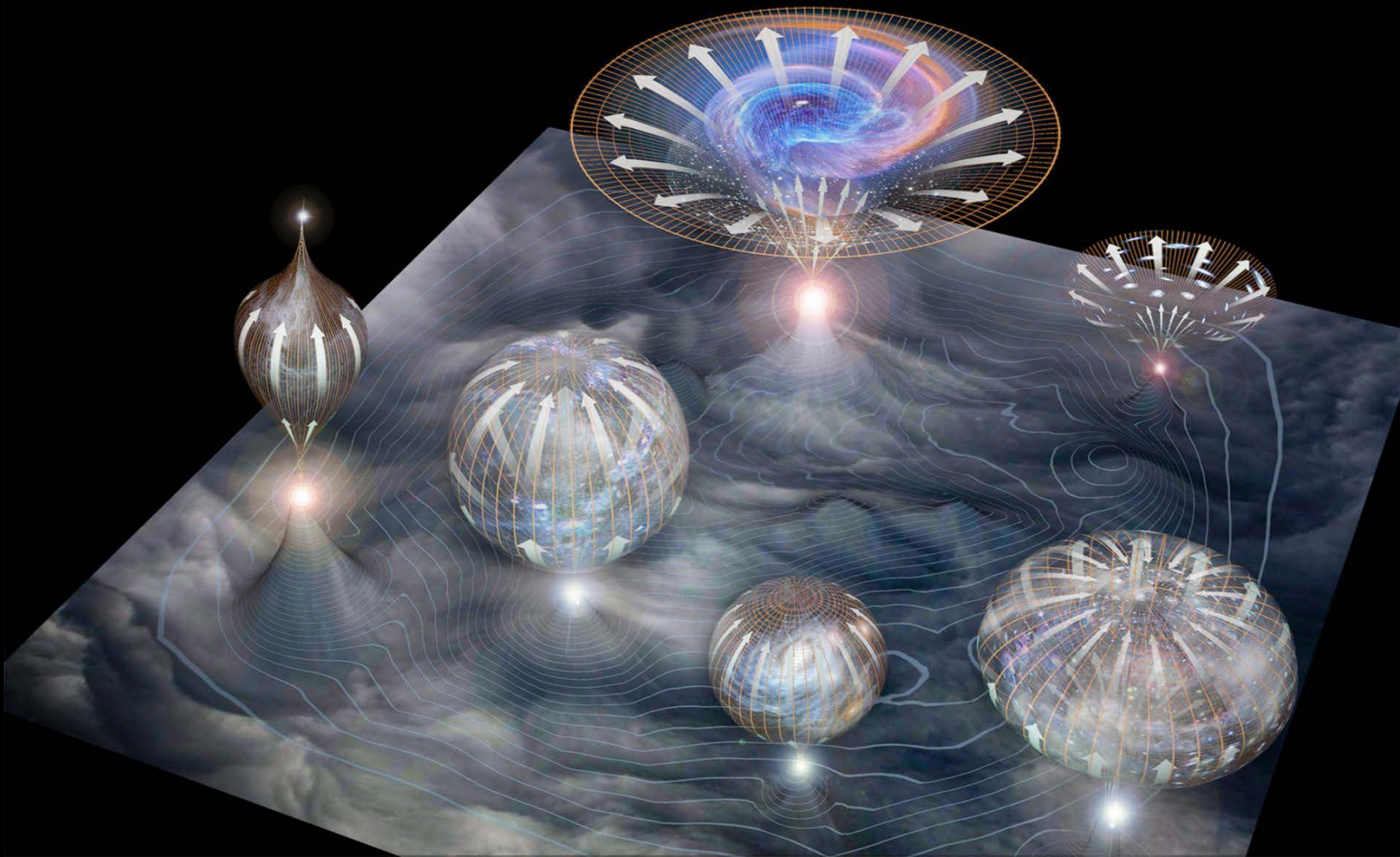
## NEW MILLISECOND PULSARS

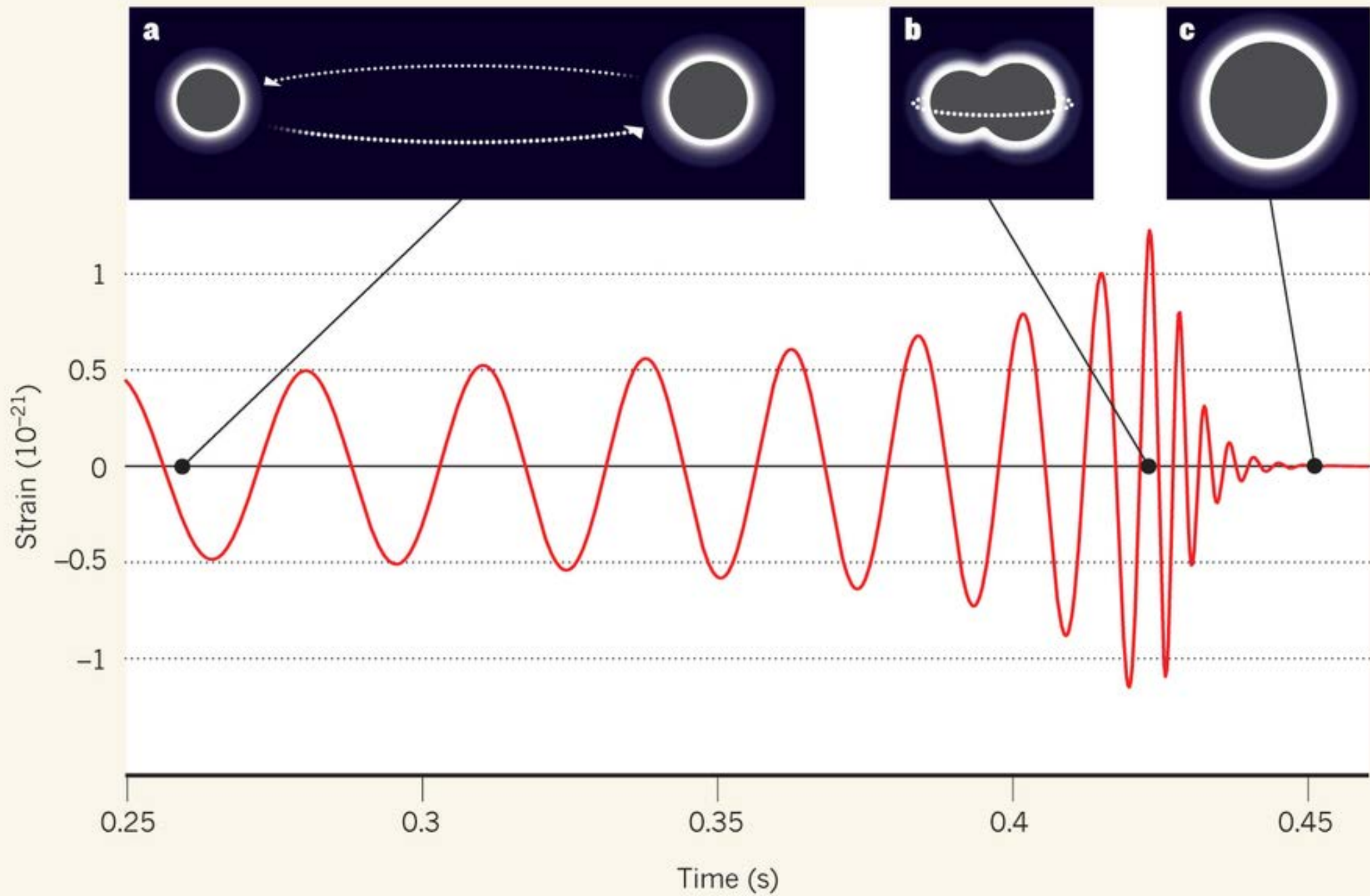
An all-sky map as seen by the Fermi Gamma-ray Space Telescope in its first year











# Top 10 supercomputers

Petaflop/s on the Linpack benchmark

