BUBBLE GROWTH STUDIES FOR THE PICO EXPERIMENT

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DETECTING DARK MATTER WITH BUBBLES?

How Did Dark Matter Come To Be?

Galaxies Shouldn't Shine This Way

Light ≠ Mass

Zwicky 1930's[1]

$$2\langle T\rangle = -U$$ Virial theorem

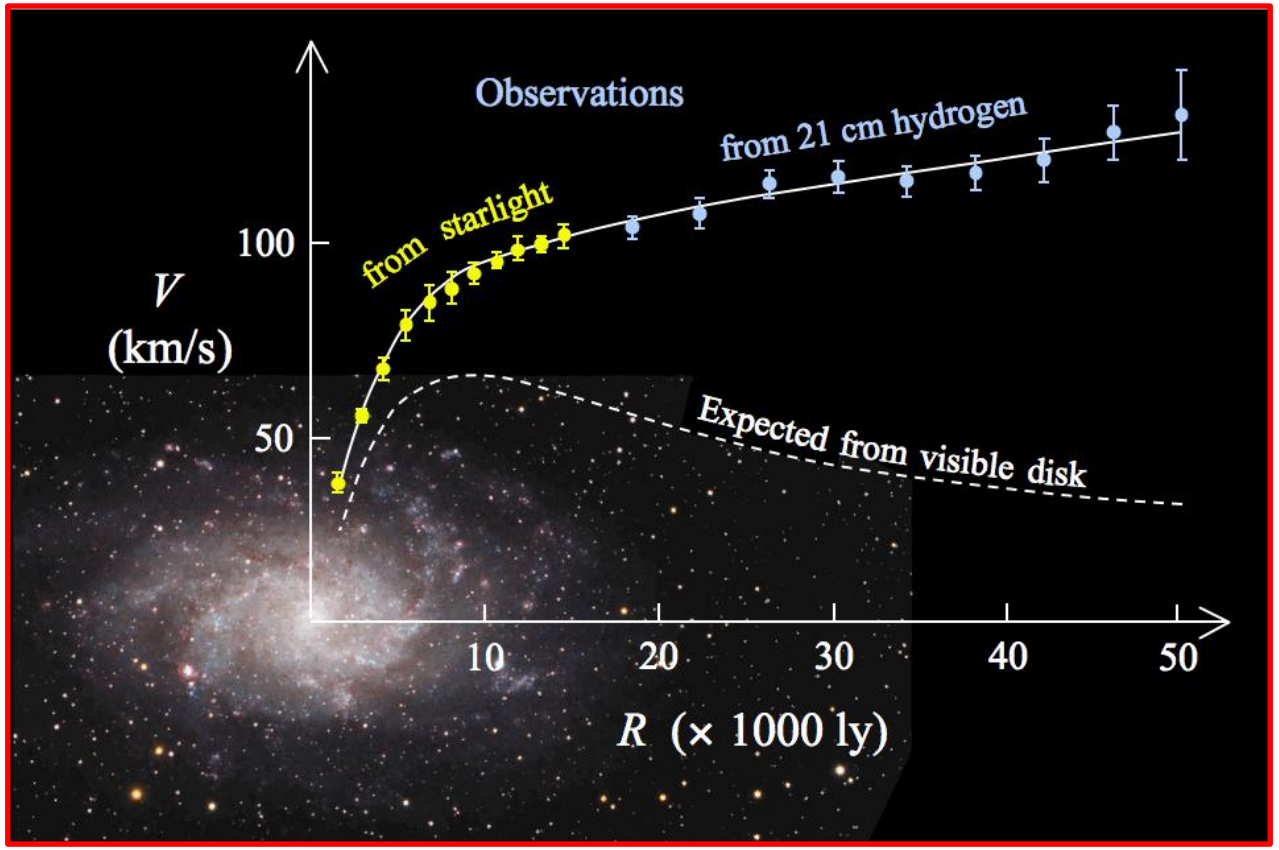
$$M = \frac{r\langle v^2\rangle}{G}$$ Mass of a cluster

$$L \approx M^{2.25}$$ Luminosity of a cluster

M was off by a factor of 400!

Image, https://ned.ipac.caltech.edu/level5/March02/Abell/Abell3_3.html

Stars Shouldn't Move This Way

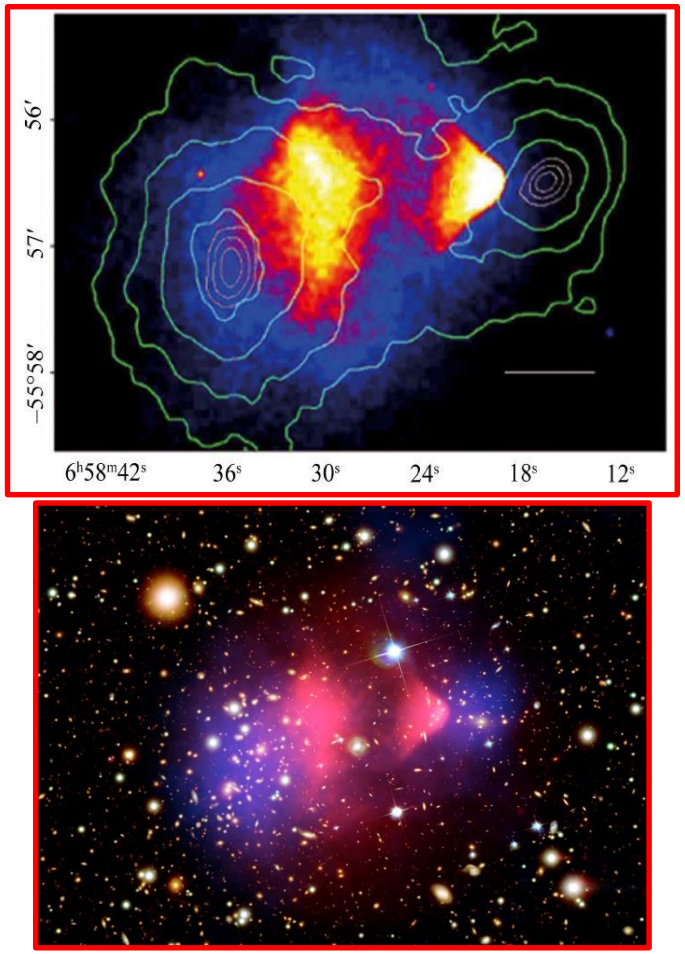


Vera Rubin 1970's[2]

Image, *Corbelli, E. & Salucci, P. (2000). "The extended rotation curve and the dark matter halo of M33". Monthly Notices of the Royal Astronomical Society. **311** (2): 441-447*

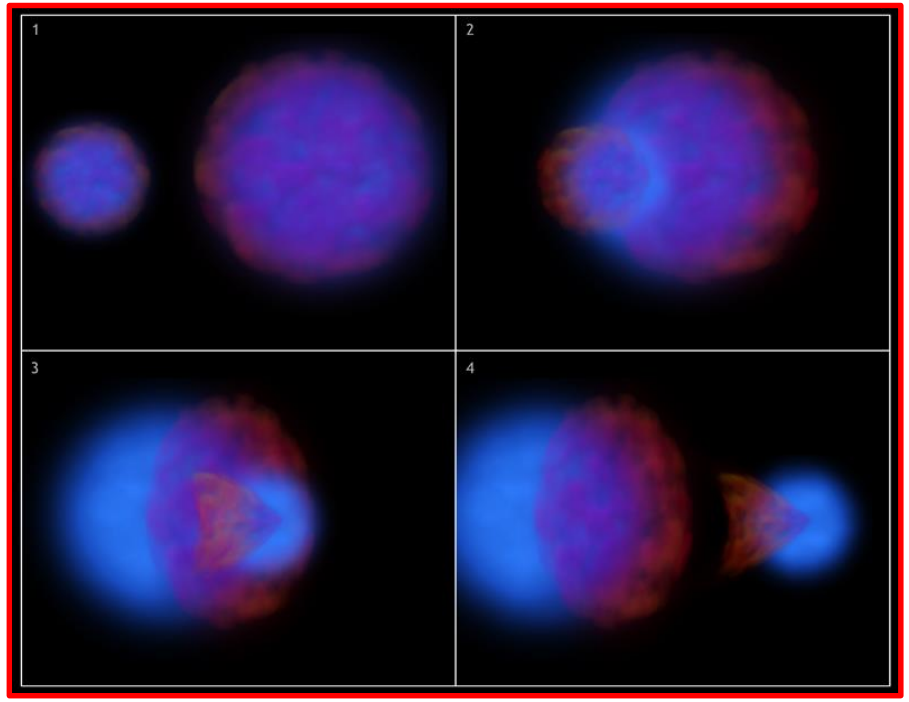
Galaxies Shouldn't Collide This Way

Bullet Cluster[3]



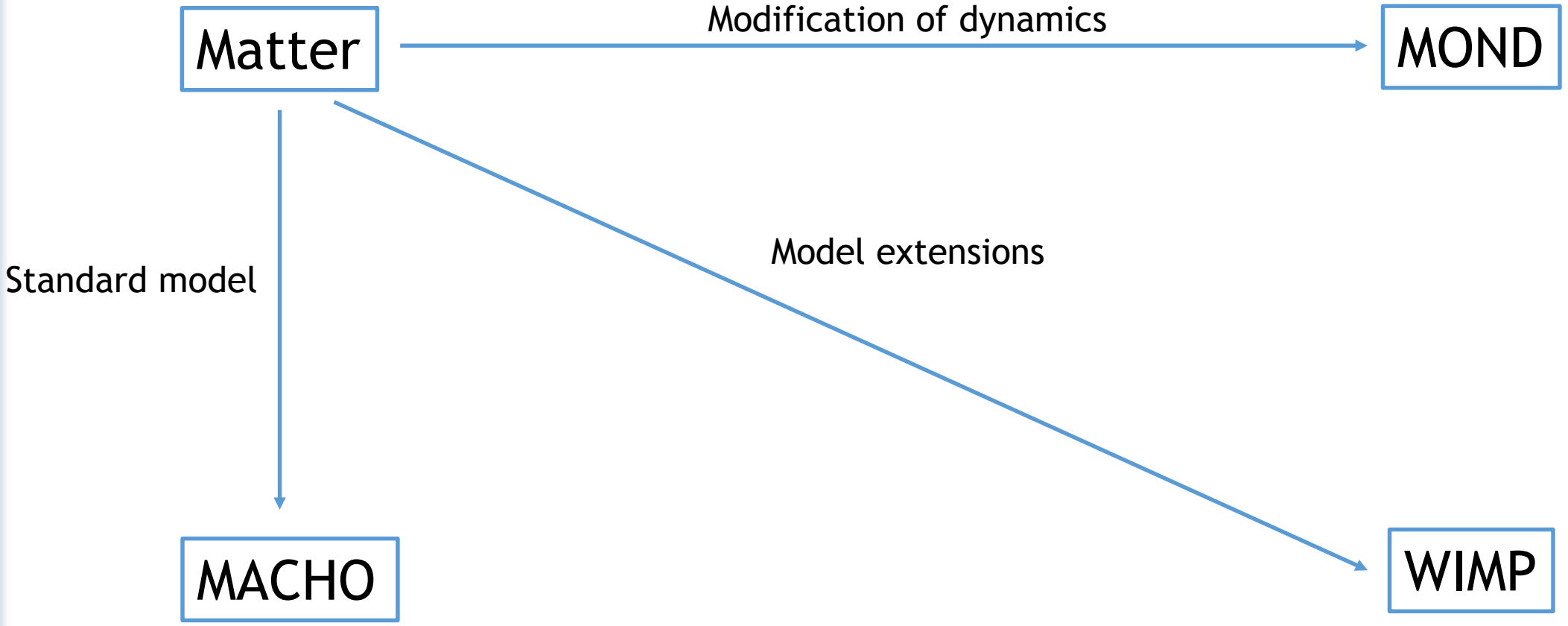
Equivalent to

Bullet Cluster Collision Simulation[4]



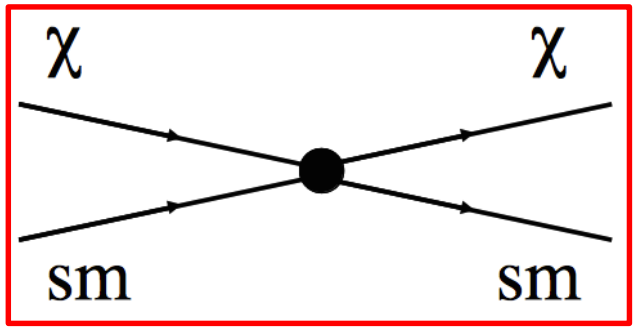
Detection Philosophy

How Do We Decide What's This Missing Thing

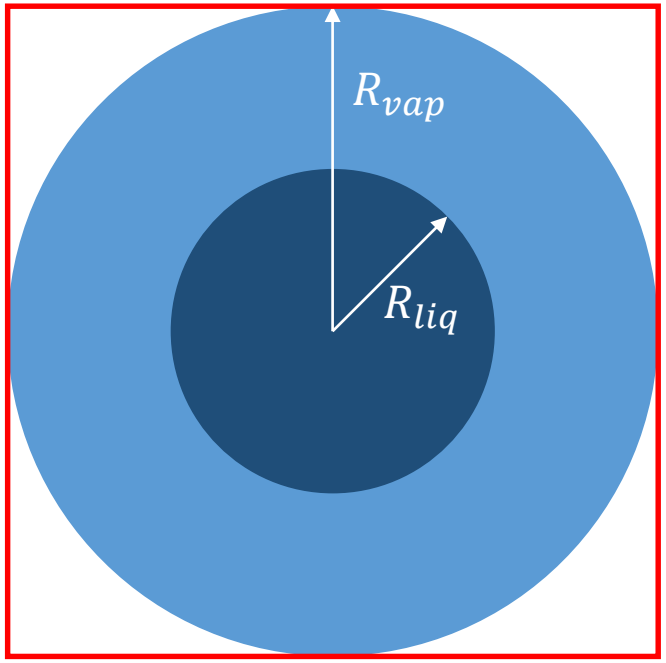


The PICO Detection Principle

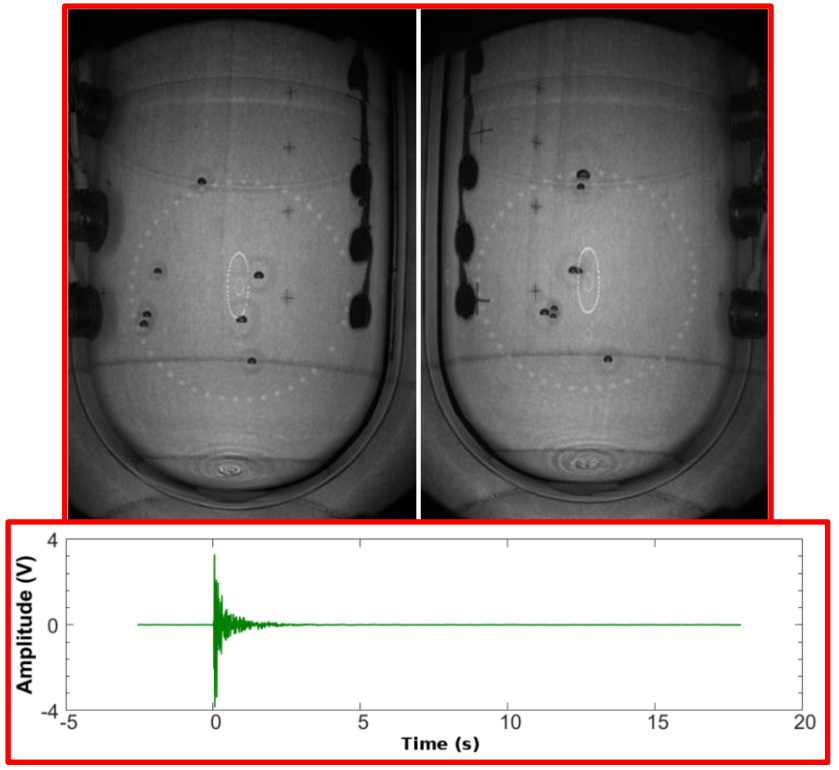
WIMP Interaction



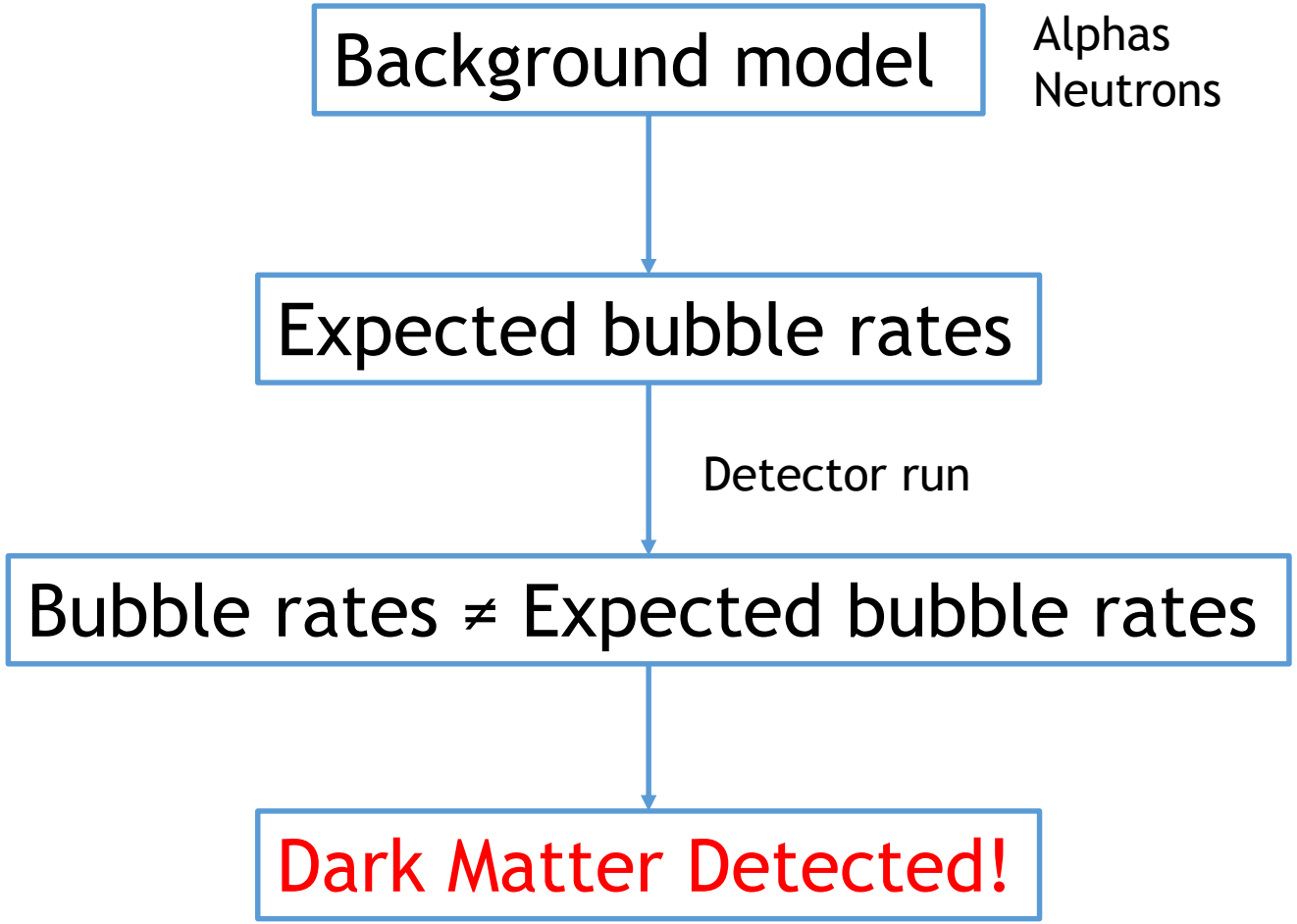
Phase Transition



Acoustic Signal

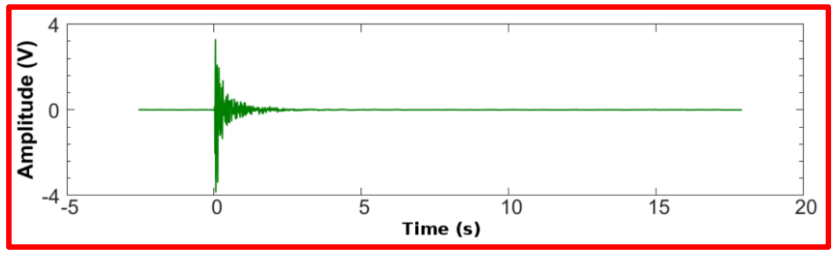


The PICO Detection Principle



Background Discrimination: AP

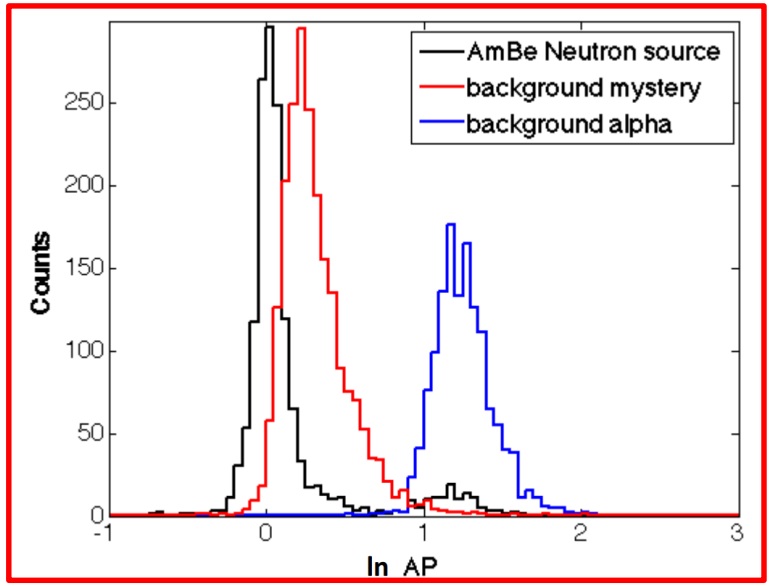
Acoustic signal



AP Calculation Tool

Output value

Histogram of values



Neutrons and alphas are different!

What Am I Doing?

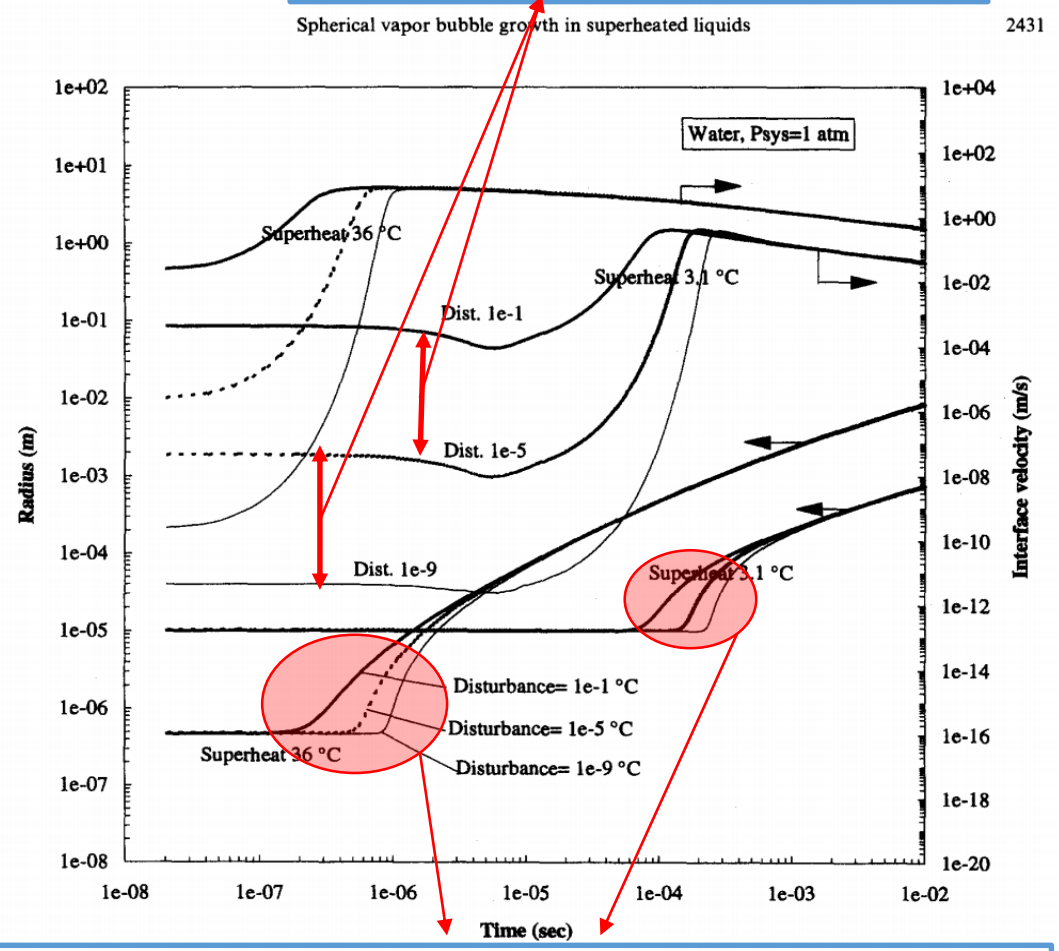
Bubble Growth

DISCRIMINATION TOOL

Governing Equations

$$R\frac{d^2R}{dt^2}+\frac{3}{2}\left(\frac{dR}{dt}\right)^2=\frac{P'(T)-P_\infty(T)}{\rho''}-\frac{2\sigma(\mathrm{T})}{\rho''R}-\frac{4\mu}{\rho''R}\frac{dR}{dt}$$

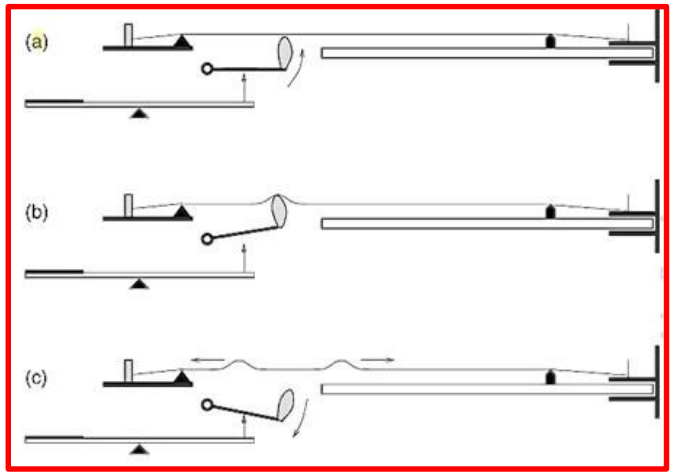
$$\frac{\partial T}{\partial t}+\frac{R^2}{r^2}\frac{dR}{dt}\nabla_s T=\alpha\nabla_s^2 T$$



IMPORTANT PART OF BUBBLE GROWTH

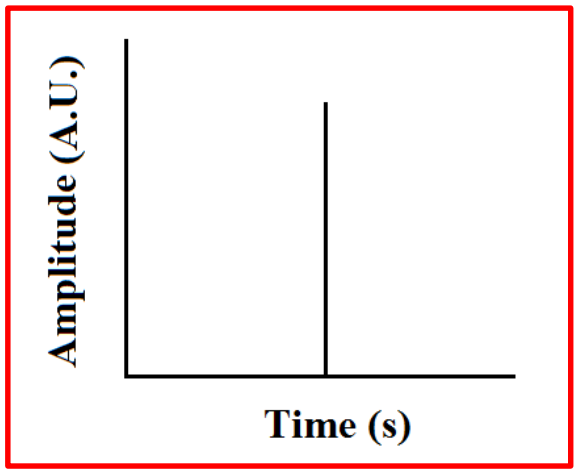
Image, H. S. Lee and H. Merte, "Spherical vapour bubble growth in uniformly superheated liquids", *Int. J. Heat Mass Transfer Vol. 39 No. 12, 2427-2447 (1996)*

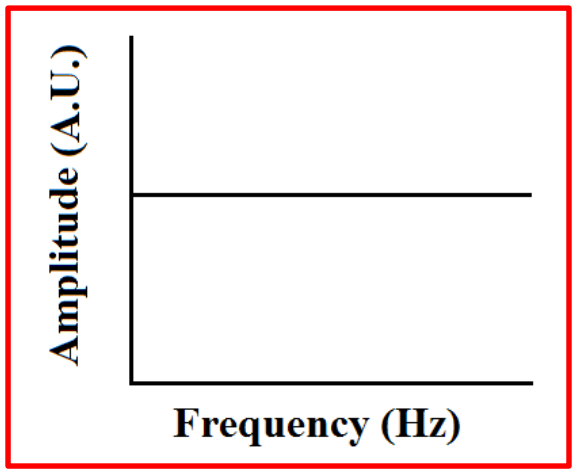
How do You Make an Acoustic Signal?



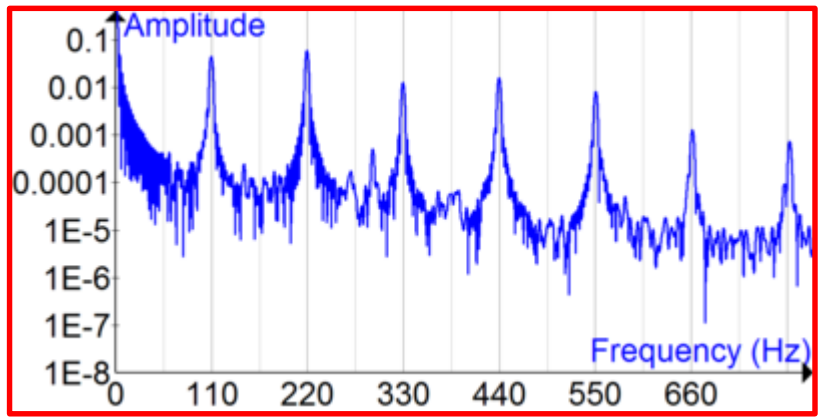
Sound you can hear!

Fourier Transform



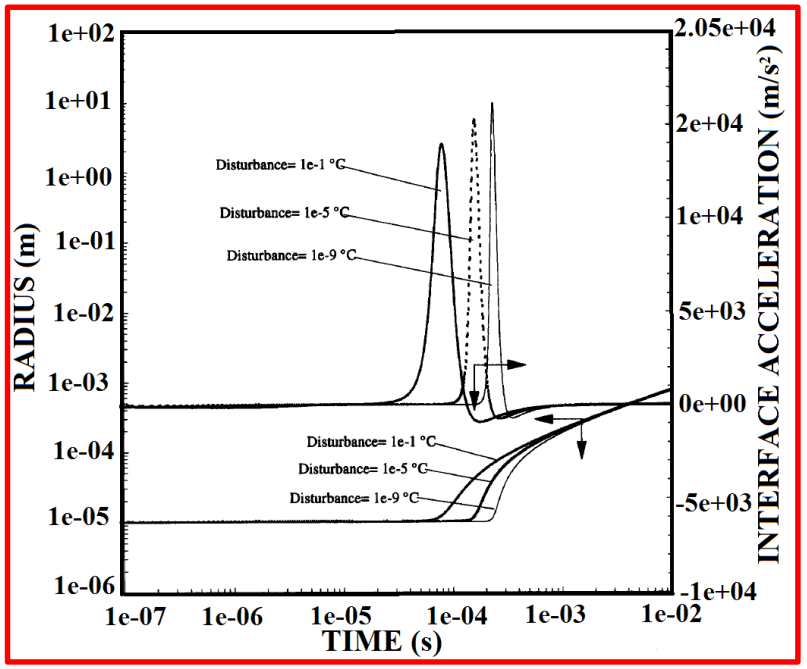


A string frequency response



Acceleration Curves' Analysis

Acceleration —Is equal to→ Force ←Is equivalent to→ Striking a piano string



Fourier Transform of acceleration curves →

Key signatures in frequency

↓

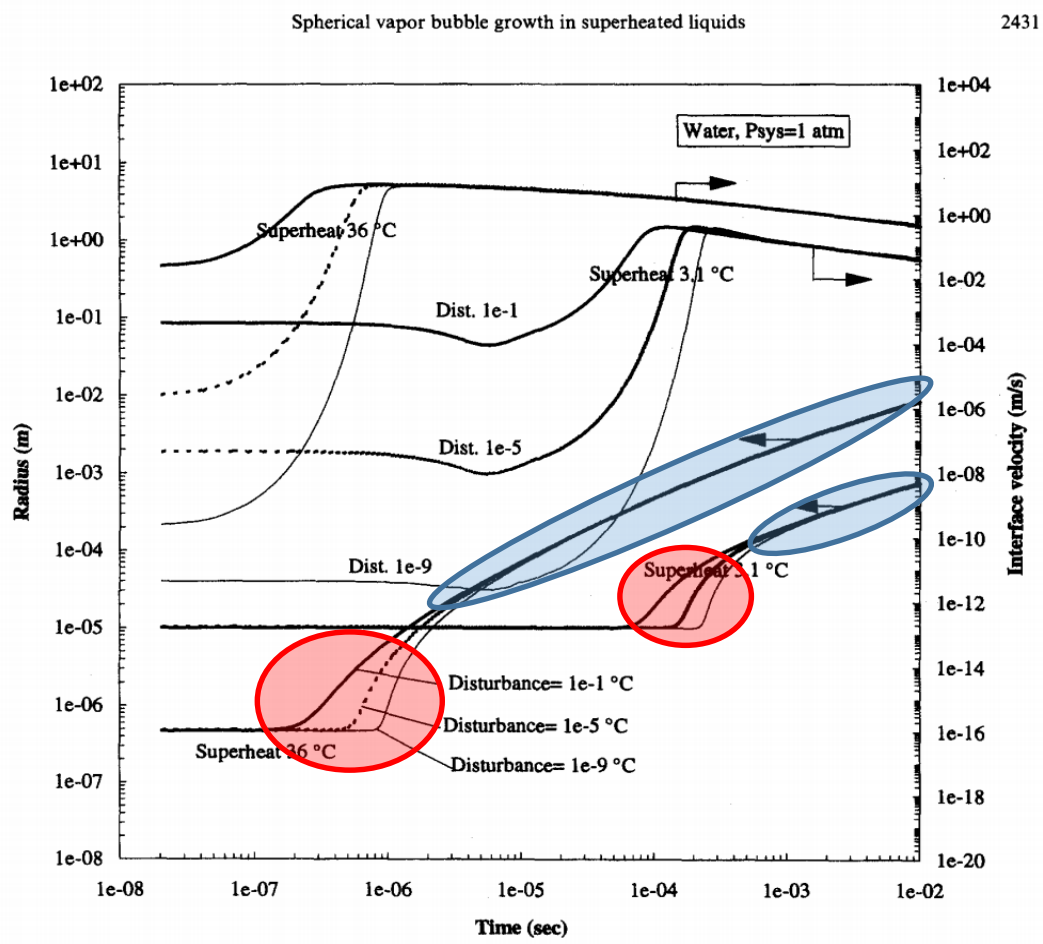
Improved AP

Image, H. S. Lee and H. Merte, "Spherical vapour bubble growth in uniformly superheated liquids", *Int. J. Heat Mass Transfer Vol. 39 No. 12, 2427-2447 (1996)*

Optical Discrimination

Blue: curves are degenerate

Red: curves are non-degenerate!

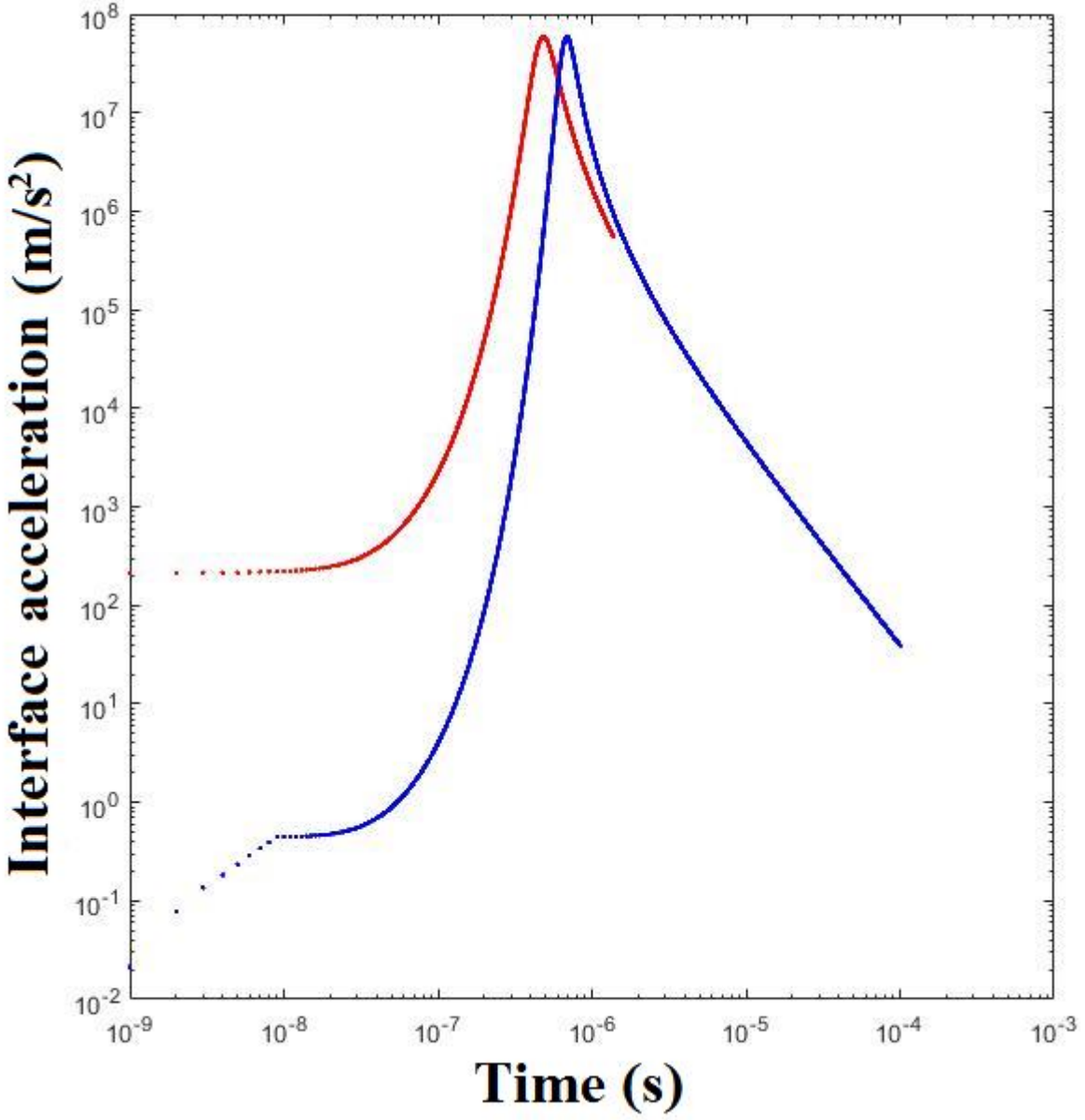


Image, H. S. Lee and H. Merte, "Spherical vapour bubble growth in uniformly superheated liquids", *Int. J. Heat Mass Transfer Vol. 39 No. 12, 2427-2447 (1996)*

THANKS!

References/Acknoledgements:
1. https://ned.ipac.caltech.edu/level5/March02/Abell/Abell3_3.html
2. *Corbelli, E. & Salucci, P. (2000). "The extended rotation curve and the dark matter halo of M33". Monthly Notices of the Royal Astronomical Society. **311** (2): 441–447*
3.1 (Top) Deep Chandra image of the Bullet cluster. Shown in green are mass contours from weak lensing - reconstruction. From Clowe et al. 2006.
3.2 (Bot) X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.
4. NASA/CXC/M. Weiss
5. H. S. Lee and H. Merte, “Spherical vapour bubble growth in uniformly superheated liquids”, *Int. J. Heat Mass Transfer Vol. 39 No. 12, 2427-2447 (1996)*

Interface Acceleration Curves for Different Initial Conditions



In red: temperature disturbance of 10^{-5}°C
In blue: temperature disturbance of 10^{-9}°C

36°C Superheated water at 1 atmosphere