My “Track”

Results

Dark Matter Evidence

Idea

Model

Future
How Much Evidence do we Need?

Light ≠ Mass

Zwicky 1930’s

Rubin 1970’s

\[ V_{\text{rot}} \propto \frac{1}{\sqrt{r}} \]

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

C. Amole et al. Dark Matter Search Results from PICO-60 C$_2$F$_6$ Bubble Chamber, Phys. Rev. lett. 118, June 2017
How does this...
How does this Become

C. Amole et al. Dark Matter Search Results from PICO-60 C$_2$F$_6$ Bubble Chamber, Phys. Rev. lett. 118, June 2017
Storytelling

• A disturbance is a small perturbation of the equilibrium condition to start the bubble growth.
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• Separation between disturbances
• ≈11 orders of magnitude of difference for the interface velocity

A disturbance is a small perturbation of the equilibrium condition to start the bubble growth.

Separation between disturbances

$\approx 11$ orders of magnitude of difference

Slight side-track... There seems to be information contained in the bubble growth.

A disturbance is a small perturbation of the equilibrium condition to start the bubble growth.

Separation between disturbances

≈11 orders of magnitude of difference

What about C$_3$F$_8$???
The Model

Detector:

1. Temperature
2. Pressure

1. Energy threshold
2. Equilibrium bubble radius
The Model

SUPERHEAT

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The Model

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P \rightarrow \text{Boiling Temperature } (T_b) \rightarrow T-T_b = \text{Superheat}
The Model

Superheat

Detector:

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P → Boiling Temperature \( (T_b) \) → \( T - T_b = \text{Superheat} \)
The Model

Detector: 1. Temperature 2. Pressure

THRESHOLD

1. Min. energy to form a bubble
2. Equilibrium bubble radius
The Model

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Region in which the energy needs to be deposited

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THRESHOLD
**The Model**

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Region in which minimum energy needs to be deposited

Alpha track

Neutron interaction

Carbon or Fluorine track
The Model

Detector:

Superheat
1. Temperature
2. Pressure

Region
1. Min. energy to form a bubble
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**Threshold Energy**

**Excess Energy**

Region in which minimum energy needs to be deposited

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1. Temperature
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Superheat

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2. Equilibrium bubble radius

Threshold Energy
Excess Energy
Region in which minimum energy needs to be deposited

The excess energy can be converted into the temperature disturbance!
Bubble Growth in $\text{C}_3\text{F}_8$, Interface Velocity

- There is still a 10 order magnitude separation

1.75 keV
High Superheat: 88 K  1/10 atm.
Low Superheat: 22 K  ~5 atm.

- Alpha Temp. dist.: $10^{-1}$ K
- Neutron Temp. dist.: $10^{-12}$ K
Bubble Growth in C₃F₈, Interface Velocity

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• There is a difference in rise time

Alpha Temp. dist.: 10⁻¹ K
Neutron Temp. dist.: 10⁻¹² K
Bubble Growth in C$_3$F$_8$, Interface Velocity

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- There is still a 10 order magnitude separation
- There is a difference in rise time
- There is a difference in the decay

Alpha Temp. dist.: 10^{-1} K
Neutron Temp. dist.: 10^{-12} K
Bubble Growth in C\textsubscript{3}F\textsubscript{8}, Interface Velocity

There seems to be a possibility to distinguish

But extremely hard

1.75 keV
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Low Superheat: 22 K ~5 atm.

Alpha Temp. dist.: 10\textsuperscript{-1} K
Neutron Temp. dist.: 10\textsuperscript{-12} K
Bubble Growth in C$_3$F$_8$, Acoustic Intensity

- Pressure waves propagate through the medium
- Energy is transmitted to the materials and can be measured
- The amount of energy traversing a unit surface per unit time in a fluid is the Acoustic Intensity

\[ I = P \times \nu \]

P is the hydrodynamic pressure
\( \nu \) is the velocity field

For an incompressible fluid the velocity is given by

\[ \nu = \left( \frac{R}{r} \right)^2 \dot{R} \]

R is the interface position (bubble wall)
r is the radial position
\( \dot{R} \) is the interface velocity
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Bubble Growth in $\text{C}_3\text{F}_8$, Acoustic Intensity

- Complete loss of separation

1.75 keV
- High Superheat: 88 K 1/10 atm.
- Low Superheat: 22 K ~5 atm.

Neutron T dist.: $10^{-12}$ K
Alpha T dist.: $10^{-1}$ K

Condition | Disturbance
--- | ---
Low superheat | $10E-1$ K
Low superheat | $10E-12$ K
THERE IS STILL HOPE
Future Work

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• 1-D and incompressibility might be too stringent of a simplification
• 3-D and fluid compressibility would naturally have acoustic waves
• There might work-arounds with two cameras to see a separation