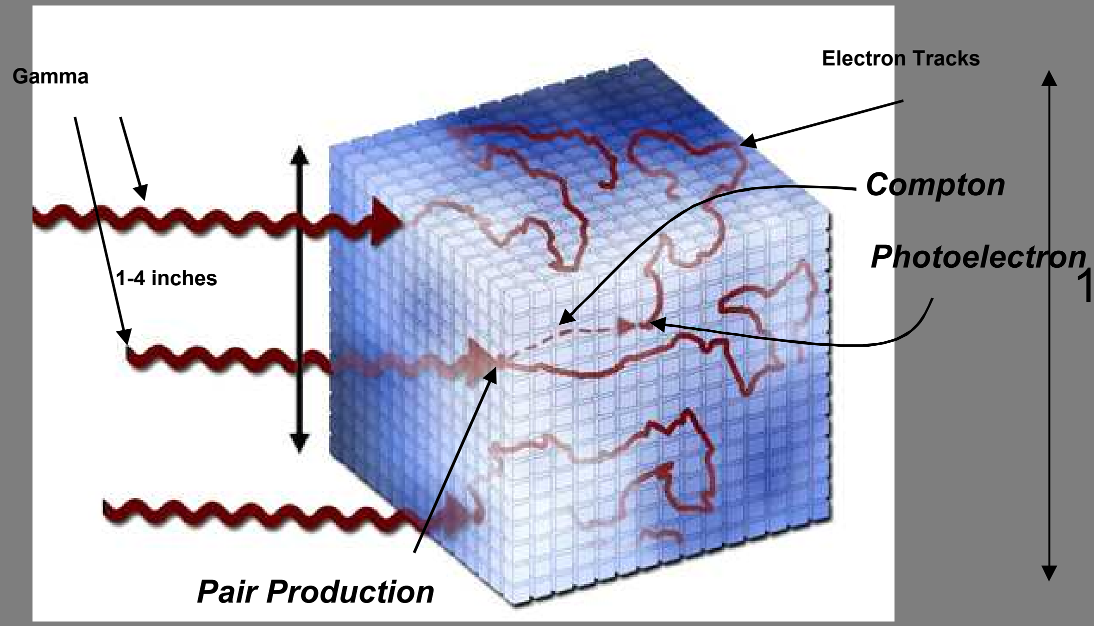
Improved Gamma Sensors –
Getting more info out of the radiation field

SAND2009-5015C

Orders of Magnitude Faster ID and location of material



$10^2 x 10^2 x 10^2$

DARPA Industry Day Sponsored by D. Shenoy, Santa Cruz, Ca, July 17, 2009

PI: Mark Derzon. SNL. Contributors: R. Anderson, G.Chandler, M, Cich, L. Claus, D. Derzon, M.S. Derzon, P. Galambos, M. Grohman, H. Hjalvarson, R. Jarecki, R. Kay, R. Kensek, T. Lemp, Shawn Martin, K. Ortiz, T. Parson, R. Renzi, K. Seager, S. Shinde, D. Trotter, 7/17/09

… specifically outlining the state of the art for the technology and metrics of a potential program

- Historical Analysis
- Competitive analysis?
- Gap Analysis?
- Impact analysis?
- Structure a BAA?

Problem
(gap analysis)
Proposed Solution
Benefit

State-of-Art

Phase Space

Limitations (efficiency, resolution, timing, cost

- Scintillators (NaI, plastic)
- Solid State (Ge, CdZnTe, etc.)
- Calorimeters (LANL/LLNL groups)

Volume, Z,
-.1% - 7% resolution
ns to 100-microsec
500$/unit to 50k$/unit
Cooled to room temp

Intensity

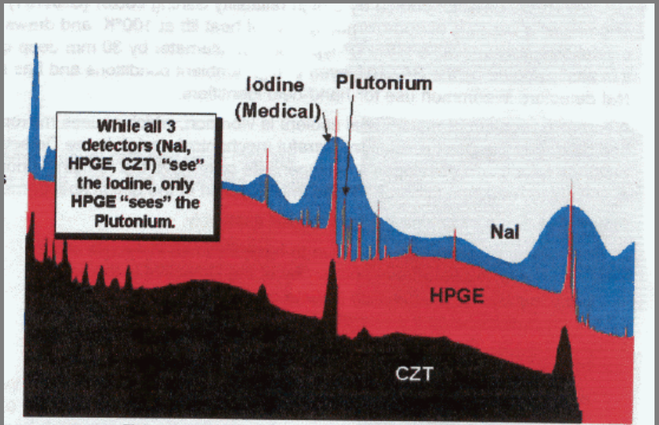
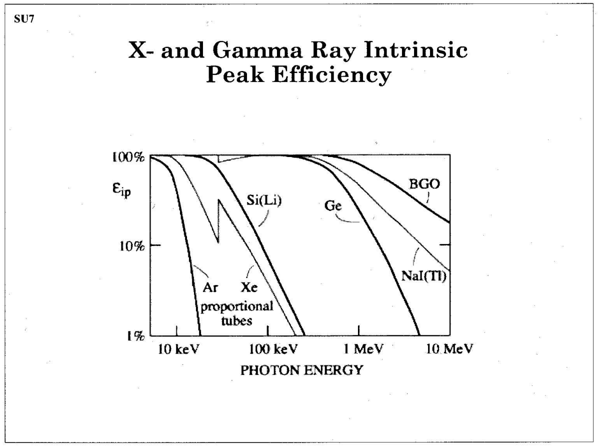
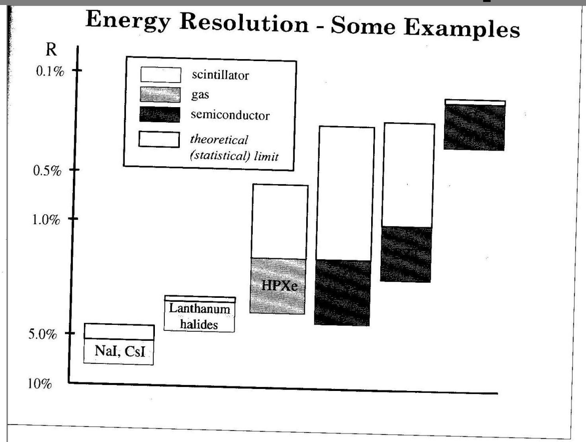


Figure 2. HPGe in comparison to NaI and CZT detectors.

Energy

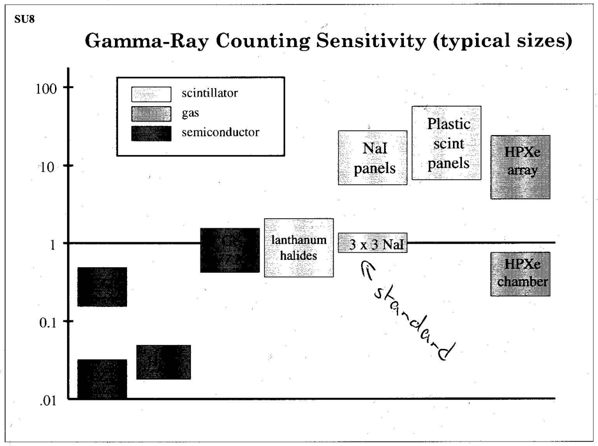
G. Knoll created some 'comparative' relationships

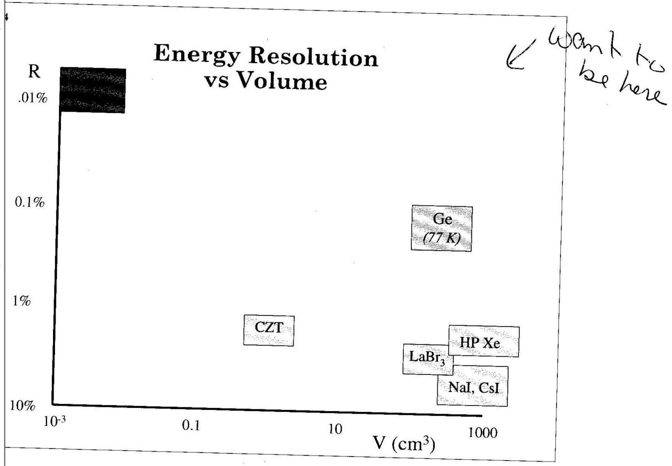


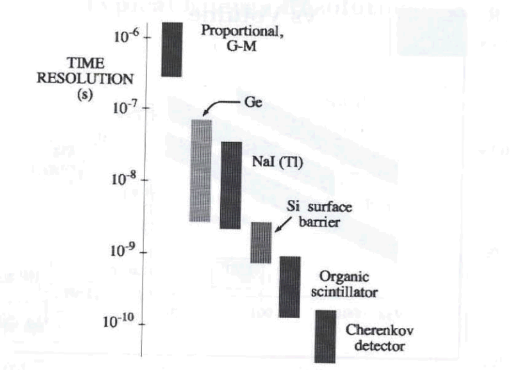


Timing Characteristics

- Charge collection time in detector sets lower limit on pulse rise time
- Preamplifier and capacitive loading of detector may slow the observed rise time from fast detectors
- Variations in pulse shape may lead to additional timing uncertainties
- Timing jitter due to discreteness of charge carriers is minimized in detectors with large number of carriers







Gaps: too inefficient <u>or</u> poor resolution <u>or</u> to small <u>or</u> slow, <u>or</u> expensive, <u>or</u> to hard to use

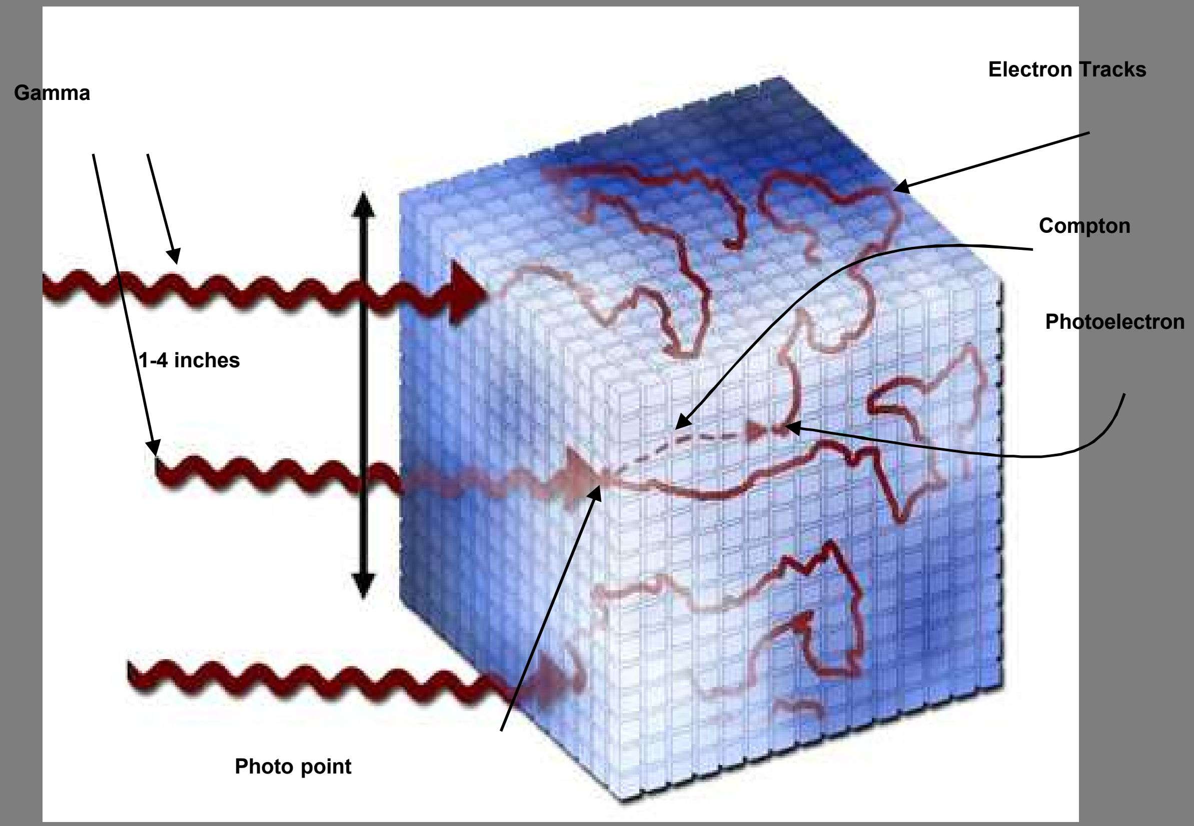
Community Direction

- Better Materials
- Improved anode/cathode design
- New Designs –GEMs, vertex, Silicon drift, Calorimeters, pixel detectors (e.g. Zhong He, et al, at Michigan), straw tubes

General Trend

- More information from the radiation field

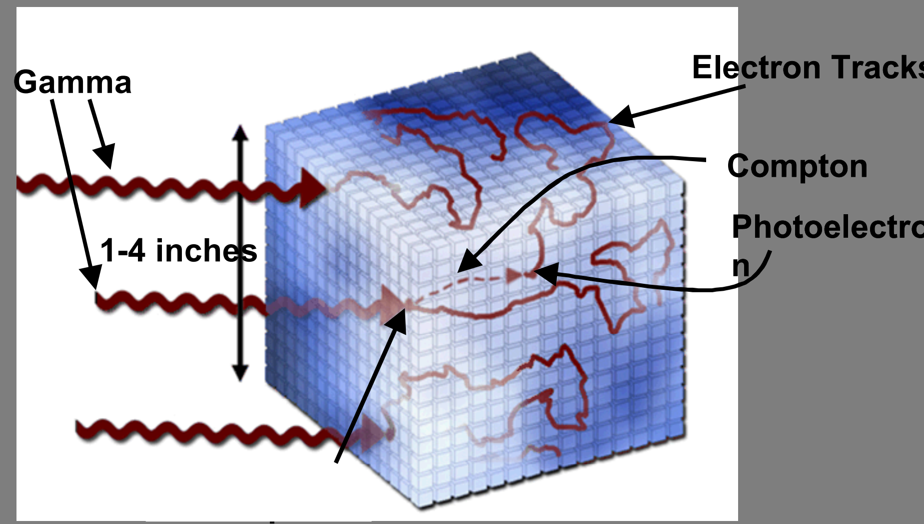
The gap analysis – High Z and high resolution and large total volume and easy to use

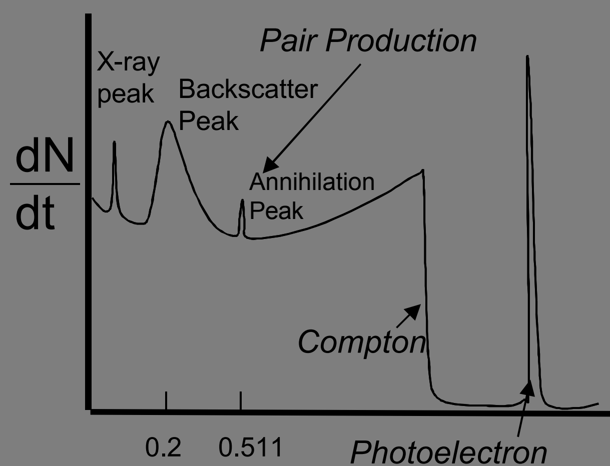


leads to this proposed solution – massively pixellated and macroscale integrated 3D systems

Gather more info from the incident radiation field? Improved Identification/understanding of a Source

- 3D Microsystem
- Physics





Gamma Interactions

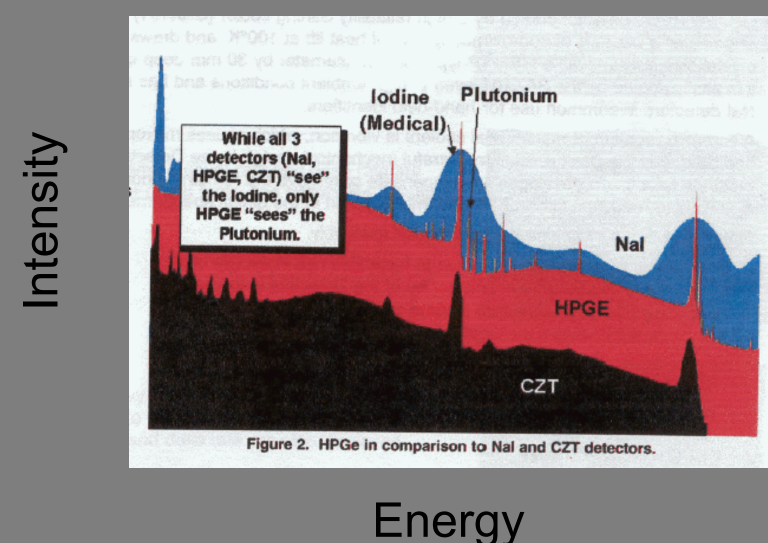
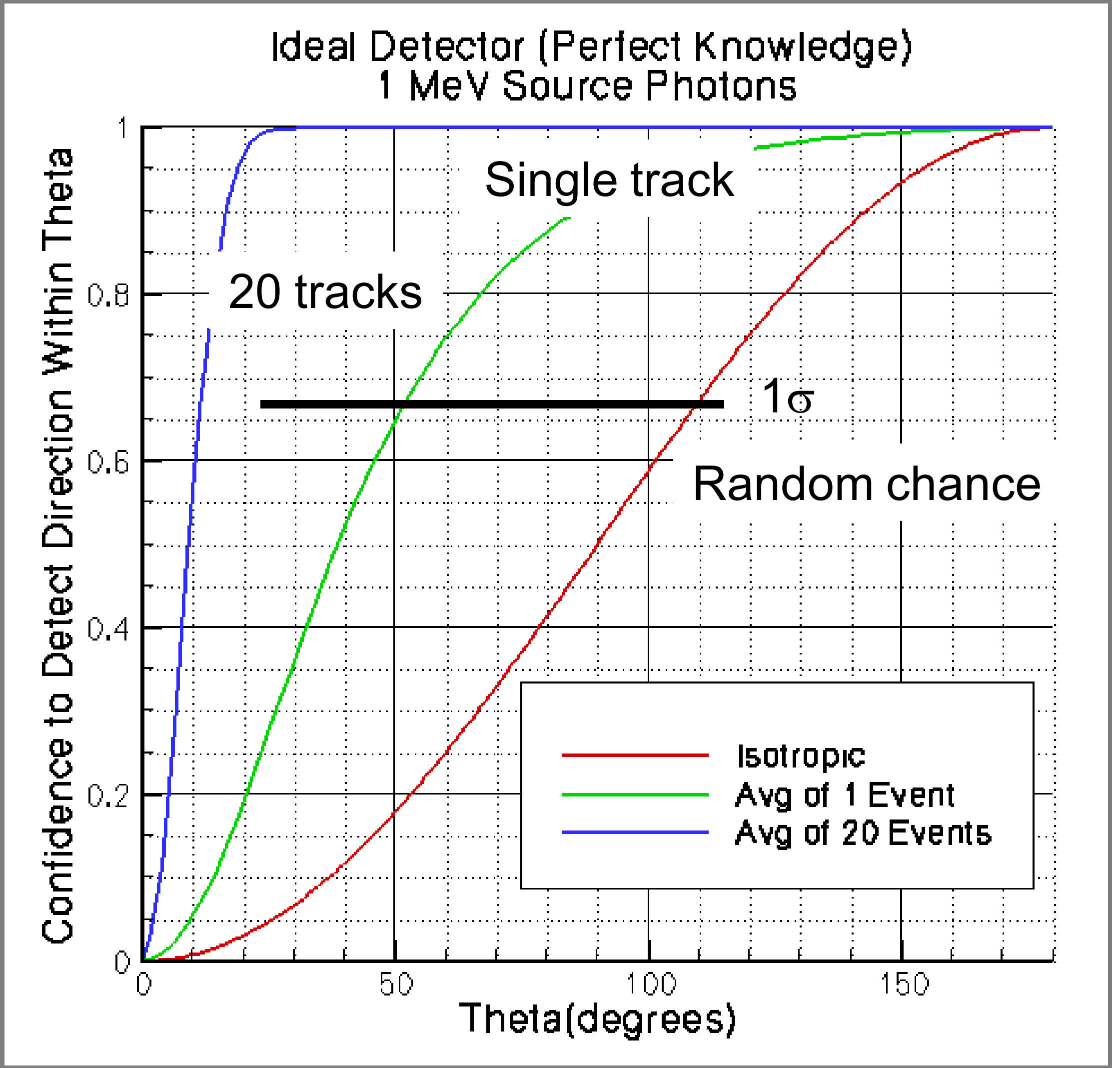


Figure 2. HPGe in comparison to NaI and CZT detectors.

Why? Potentially orders of magnitude improvement over existing methods in *finding a source*

ITS Model



These lines are the Integrals of the confidence density function in theta.

They represent the probability that the real source is within theta of the inferred direction.

Gamma

Key Technical Challenges

- **Material Science**
  - Grow/Deposit/fabricate detector material
  - High Z≥Ge
  - >80% charge collection
  - >95% yield over 3cmx3cm square; target 6” wafer
  - Incorporate discrete electrodes (electronic interface)
  - Material Alternatives:
    - CZT
    - GaAs
    - Germanium
    - TlBr
    - Si
  - Depletion Depth>200µm@room temp

  200µm min., 600µm target

- **Packaging**
  - 64-296 layers
  - 3cm x 3 cm-> 6” diameter
  - Interconnects
  - Flatness
  - Thermal Expansion
  - Inactive volume

Electronics

Data rate
Track Processing
Scaling (voxel count, rate, etc.)
In-situ signal processing
Architecture

Algorithm Development

Tracking
Unfolding the track back to source (inverse problem)
Background Projection
Thresholding
Compton Coincidence Indentification

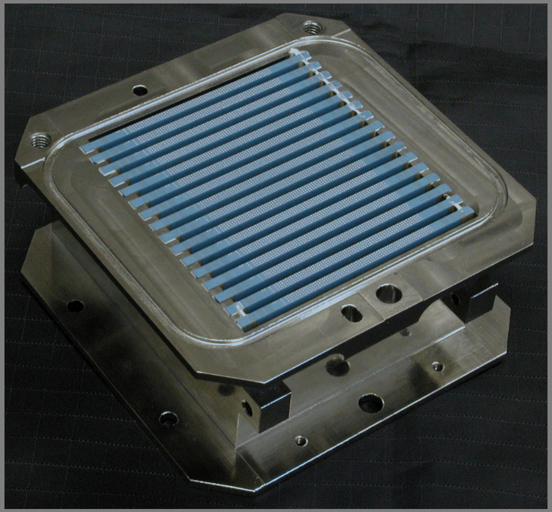
System Scaling Studies

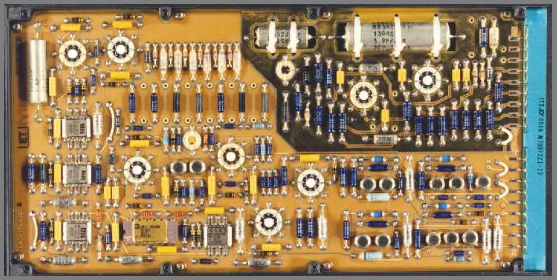
System Perf. Modeling
System Optimization

Lots of work (though not considered tech challenge): *Integration*

Microsystems Technology can meet these Needs

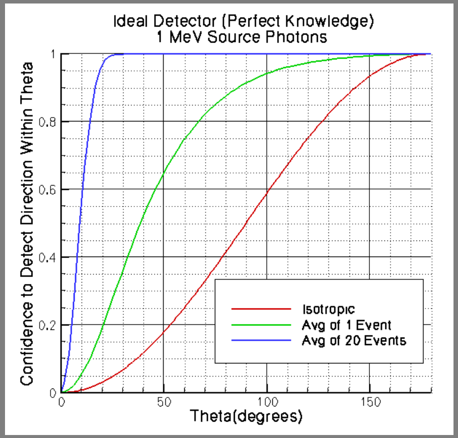
We believe it is possible but will be Very Difficult.





The 5 cubic inch assembly (bottom) replaced 4096 PWBs resulting in a 2000X reduction in weight & volume and a 1000X reduction in power for this mission.

Images and analysis supplied by C. Sumpter, SNL, Organization 1700.



We believe we can create the team ...

Typical Scientist or Engineers Dilemma

MIssion	Time To find	Time to identify	Size	Power	Cost	Confidence
	Efficiency	Resolution	Data Rate	Volume	Temp	Size
SNM						
Active Detection						
Counterproliferation/non-pro						
Nuclear Power						
Nuke Forensics						
Astrophysics						
High Energy Physics						

User ≠ Engineer

User Benefits and Needs

Discussing the ‘more info’ leads into a limitations and a gap analysis discussion

- Time-to-detect/identify
- Spectral Resolution (expected to be equivalent to todays HPGe materials)
- Cost/Performance
- Ergonomic
  - Smaller footprint (no cryogenics, no aperture, less volume)
  - Lower power requirements
- Confidence
- Background Subtraction
- Sensitivity
- Aperture-less