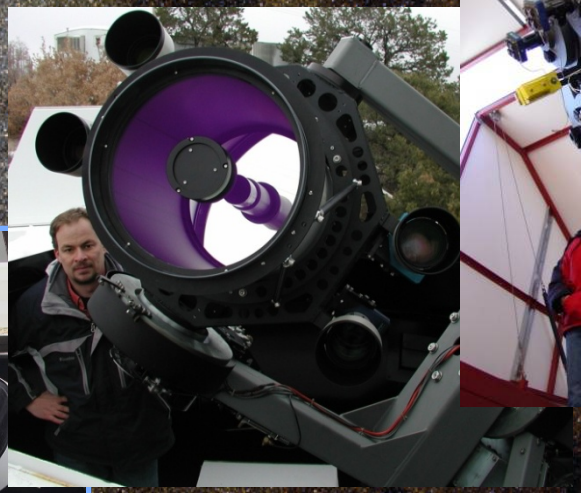
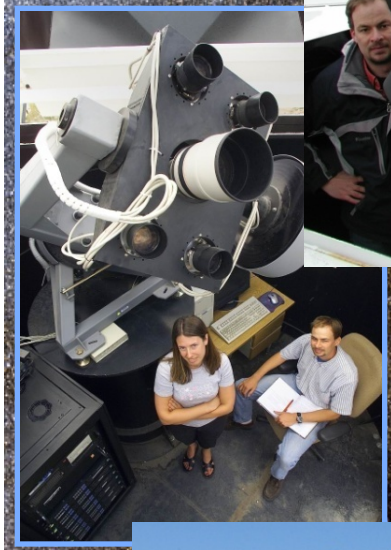
# The RAPTOR (*RAP*id *T*elescopes for *O*ptical *R*esponse) telescopes and GeV/TeV gamma-ray astronomy

# RAPTOR, Thinking Telescopes



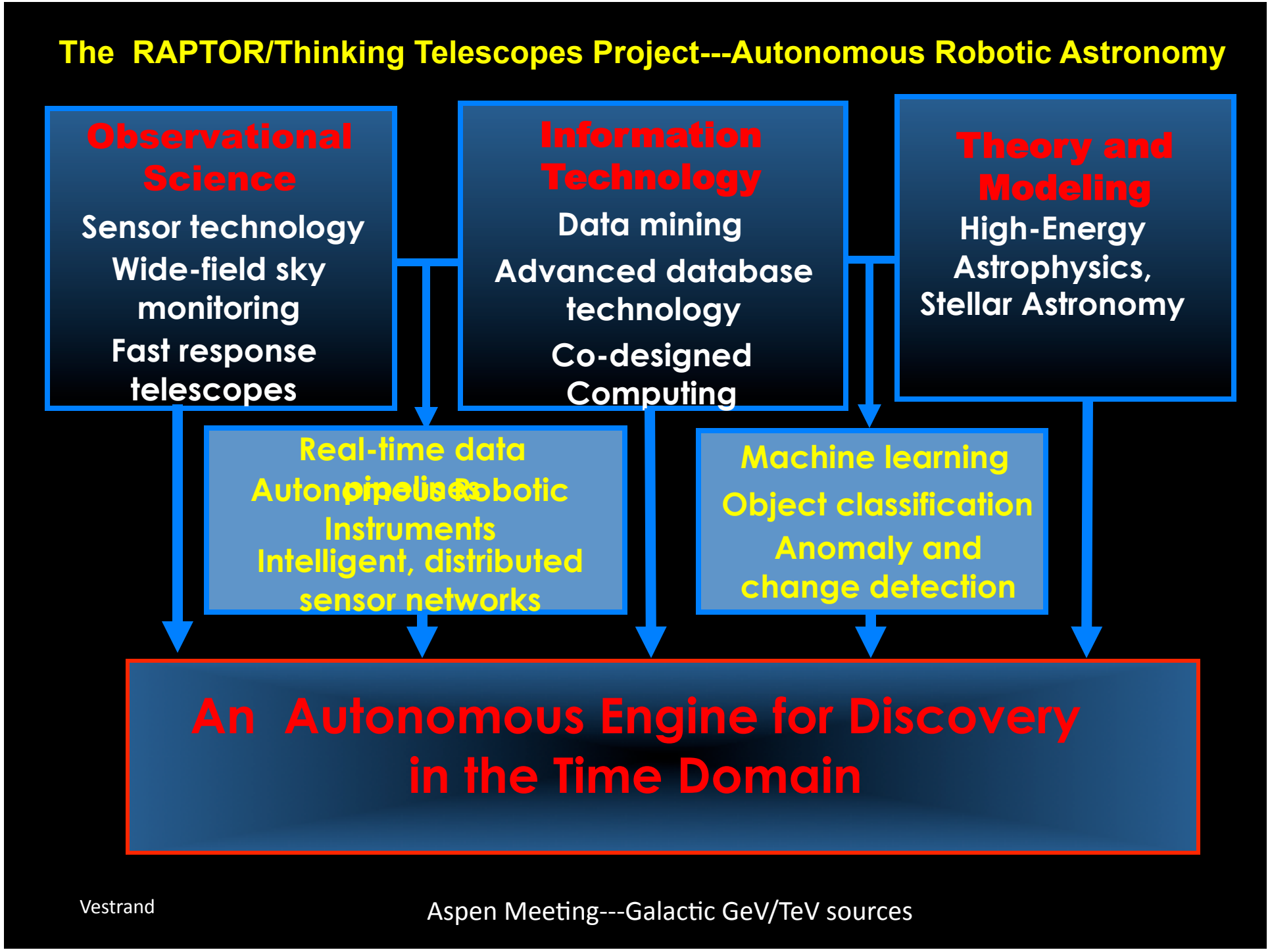


## Fast Response:

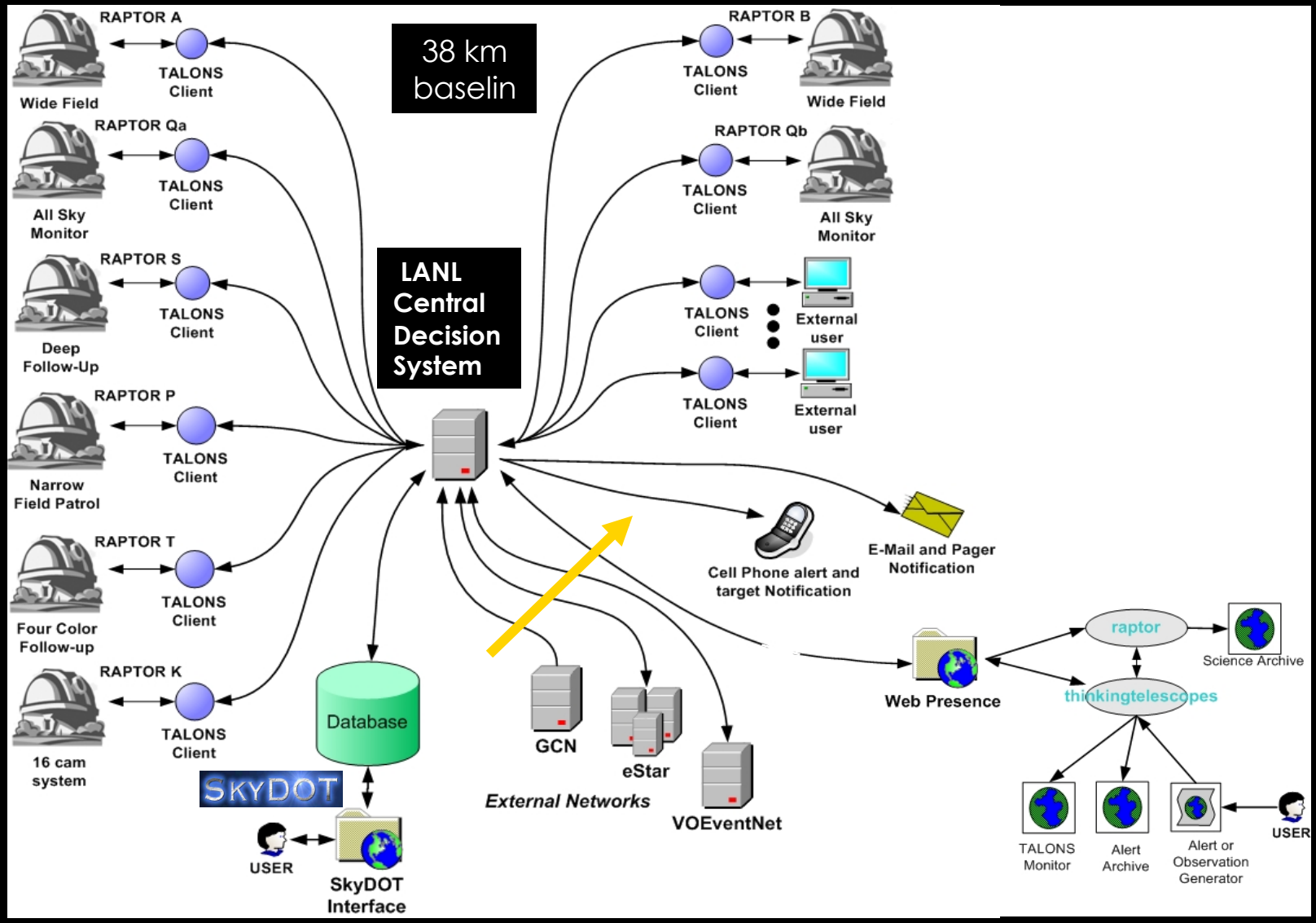
- Begin imaging anywhere in the sky in < 6s
- Seven 0.4m class telescopes
- T: True Simultaneous Multi-Color: Clear, V, R, I
- Z: Fast cadence: 7Hz

## Persistent Monitoring:

- Real-time transient detection
- Q: Full Sky to 10$^{th}$ Rmag in 20s
- K: 16$^{th}$ Rmag in 30s, Full Sky 7m


The RAPTOR/Thinking Telescopes Project---Autonomous Robotic Astronomy
Observational Science
Sensor technology
Wide-field sky monitoring
Fast response telescopes
Information Technology
Data mining
Advanced database technology
Co-designed Computing
Theory and Modeling
High-Energy Astrophysics, Stellar Astronomy
Real-time data pipelines
Autonomous Robotic Instruments
Intelligent, distributed sensor networks
Machine learning
Object classification
Anomaly and change detection
An Autonomous Engine for Discovery in the Time Domain
Vestrand
Aspen Meeting---Galactic GeV/TeV sources

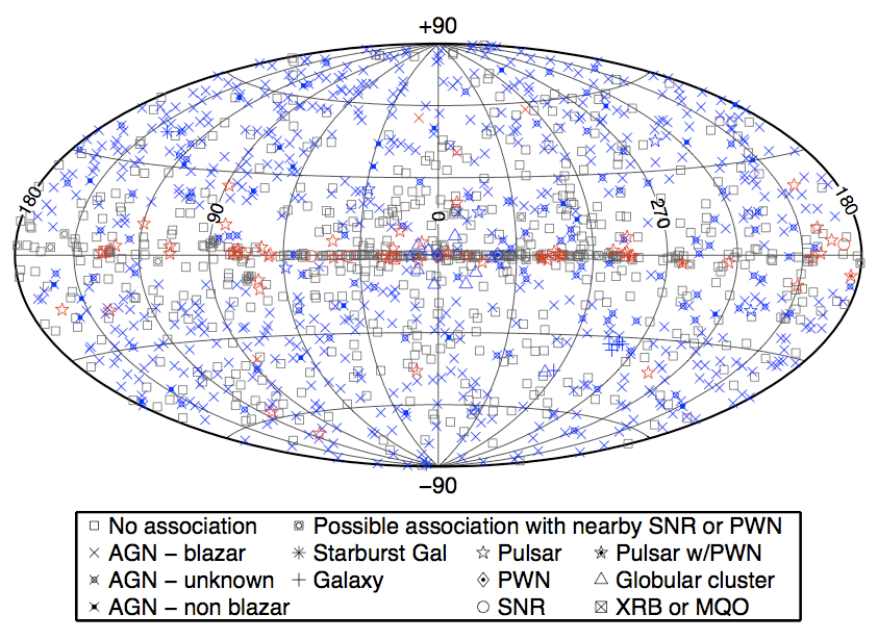
# Distributed "Thinking" Telescopes Network



# Potential *Fermi* Science Areas

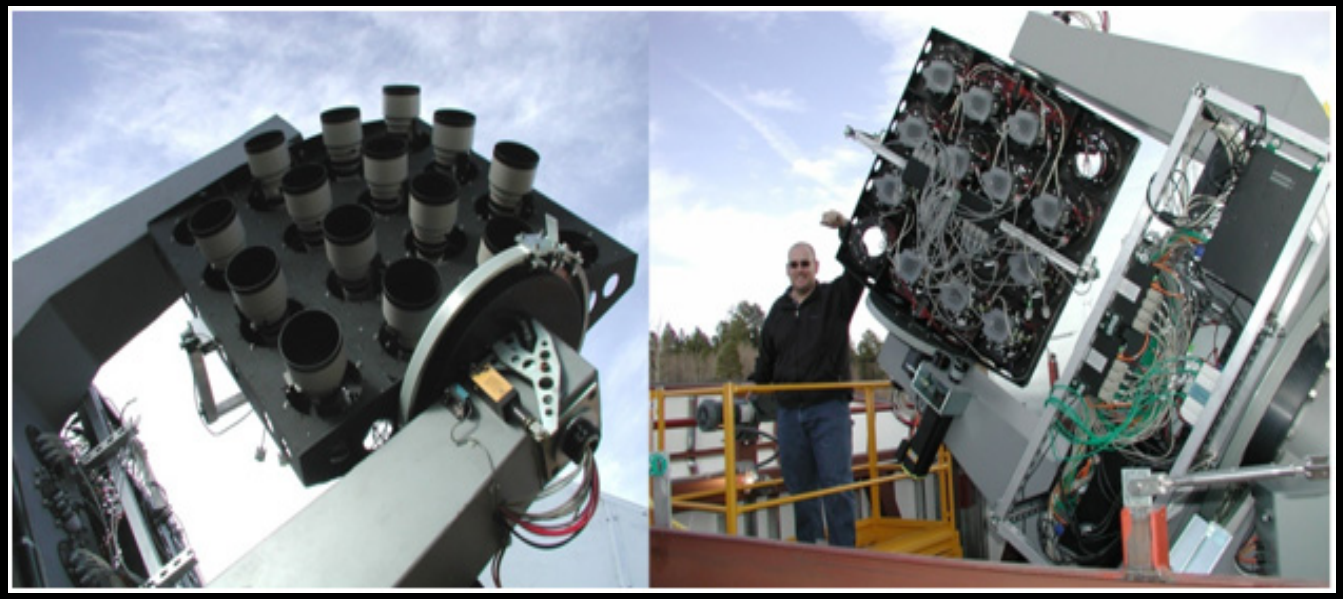
- Revealing the identities of unidentified Fermi GeV gamma-ray sources
- GeV emitting Blazars
- GeV emitting explosions in Galactic Sources
- GeV emitting Gamma-ray Bursts (GRBs)

# Unidentified Fermi Sources



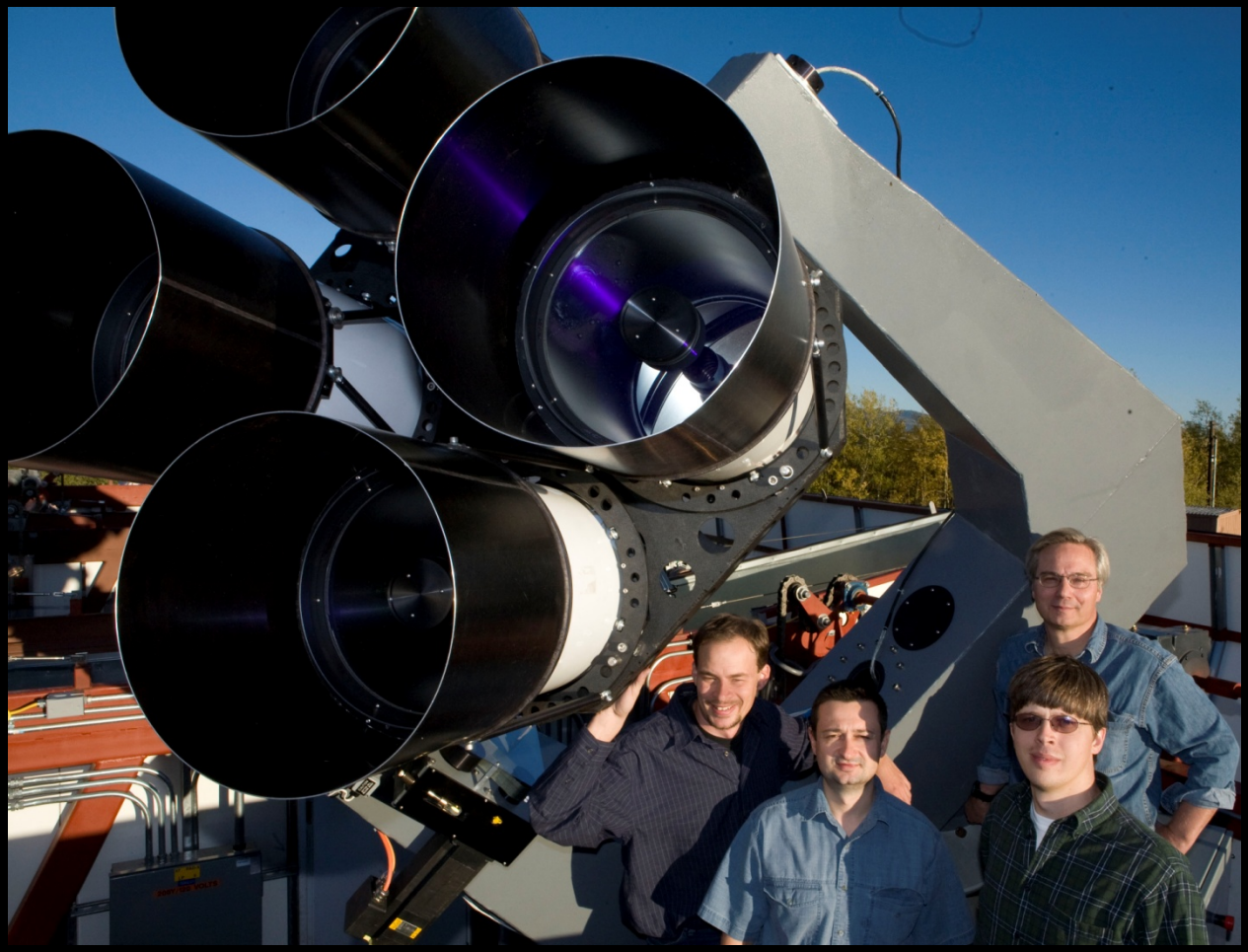

- More than 1000 new sources have been discovered, most (~600) are unidentified.
- Gold standard for identification is finding of optical counterpart through correlated variability
- Most localized to ~1 degree. Each has many possible counterparts even at depth of 16$^{th}$ magnitude
- In survey mode, Fermi scans the sky in 180 minutes.
- Challenge for optical systems --- scan the sky at a similar cadence.

# Full Sky Persistent Monitoring
# RAPTOR-K



- Scans the full sky at site in 10 minutes
- Sensitivity of R~16$^{th}$ magnitude in 30s
- 16 telescope array
- $10^3$ deg-sq FOV

# Persistent monitoring of localized (<0.5 deg) sources
# RAPTOR-T



- Each site monitors about 100 sources of interest twice per night .
- Simultaneous cVRI Imaging, $C_R$=19.9 in 90-sec.
- RAPTOR-T North (built and operating since 2008)
- RAPTOR-T South (built)
- (Also monochrome monitoring with RAPTOR-S and two RAPTOR-W telescopes)

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# How do you establish the existence of new classes of transients?

- Seen simultaneously by multiple instruments in the same wavelength/energy band.
- Or, in a single instrument, see enough of them to exclude instrumental or man-made effects.
- Seen simultaneously in different energy band with a both having a distinct (and uncommon) temporal signature.

# Are there Explosive, >100 MeV gamma-ray emitting, galactic sources? (not counting the Sun)

## EGRET Detection of Cen X-3 outburst

Vestrand, Sreekumar and Mori (ApJ, **483**, L49 (1997))

- Found as part of an EGRET GI program to survey suspected TeV emitting x-ray binary systems
- Detected an outburst of >100 MeV with a flux of $9 \times 10^{-7}$ photons $cm^{-2}$ $s^{-1}$ (~5σ significance) during a two week interval in October 1994.
- Cen X-3 is a disk-fed pulsar in orbit around an O-type supergiant companion ---2.09 day orbit period, 4.8 second spin period
- Detected during an interval of rapid x-ray pulsar spin-down

# Cen X-3 Outburst

- $L\gamma \approx 5 \times 10^{36}$ ergs/sec-----$L_x \approx 10^{38}$ ergs/sec
- Spectrum– power law with index 1.8+/-0.4

Was it a background Blazar? Maybe but…

- Six Parkes sources within the 95% contour, using the standard gamma/radio flux ratios for EGRET blazars one predicts a 5 Ghz flux of ~4500 mJy---- all potential candidates have fluxes less than 70 mJy. (But maybe it is an outlier…)

# Evidence for gamma-ray modulation at drifting x-ray spin period

- No sign of 2.09 day orbital modulation
- No sign of nominal (steady) 4.8 second orbital modulation
- But pulsar was undergoing an interval of rapid spin-down during the EGRET observations. When the gamma ray arrival times were folded with the simultaneous BATSE measurements of the drifting x-ray spin period, we found modulation at the 3.5-sigma significance level for the EGRET detected gamma-rays.
- We did the timing analysis at four other positions in the field as controls, those locations showed no modulation.

# Are there new classes of Galactic GeV /TeV transients?

## GeV emission from Recurrent Nova?

- Nova, detected in the optical at 8th mag on March 10, 2010--V407 Cygni
- White dwarf accreting from Red giant star wind, material accretes and triggers thermonuclear explosion
- In ATEL #2487 Cheung et al. report the emergence of Fermi J2102+4542 on March 12 and associate it with the V407 Cygni
- Did a strong shock in the wind generate GeV emitting particles?
- Suggests that bright optical outbursts could signal the pending onset of gamma-ray outbursts. (as it sometimes does for x-ray outbursts)

# Conclusion

- Time domain astronomy employing advances in robotic instrumentation, real-time knowledge extraction, and global networking of heterogeneous observing platforms is fundamentally changing the way we search and interrogate astrophysical transients.
- Autonomous, Robotic, Optical instruments like RAPTOR have the potential to make important contributions to the study of explosive GeV/TeV transients. I would be very interested in talking about potential collaborations.