Fermi-LAT Discovery of Gamma-ray Emission Concurrent with the Nova in the Symbiotic Binary V407 Cyg

C.C. Teddy Cheung[1], A. Hill[2], P. Jean[3], S. Razzaque[4], K. Wood[5]

on behalf of the

Fermi-LAT Collaboration

[1]NRC resident at Naval Research Lab

[2]Université Joseph Fourier–Grenoble

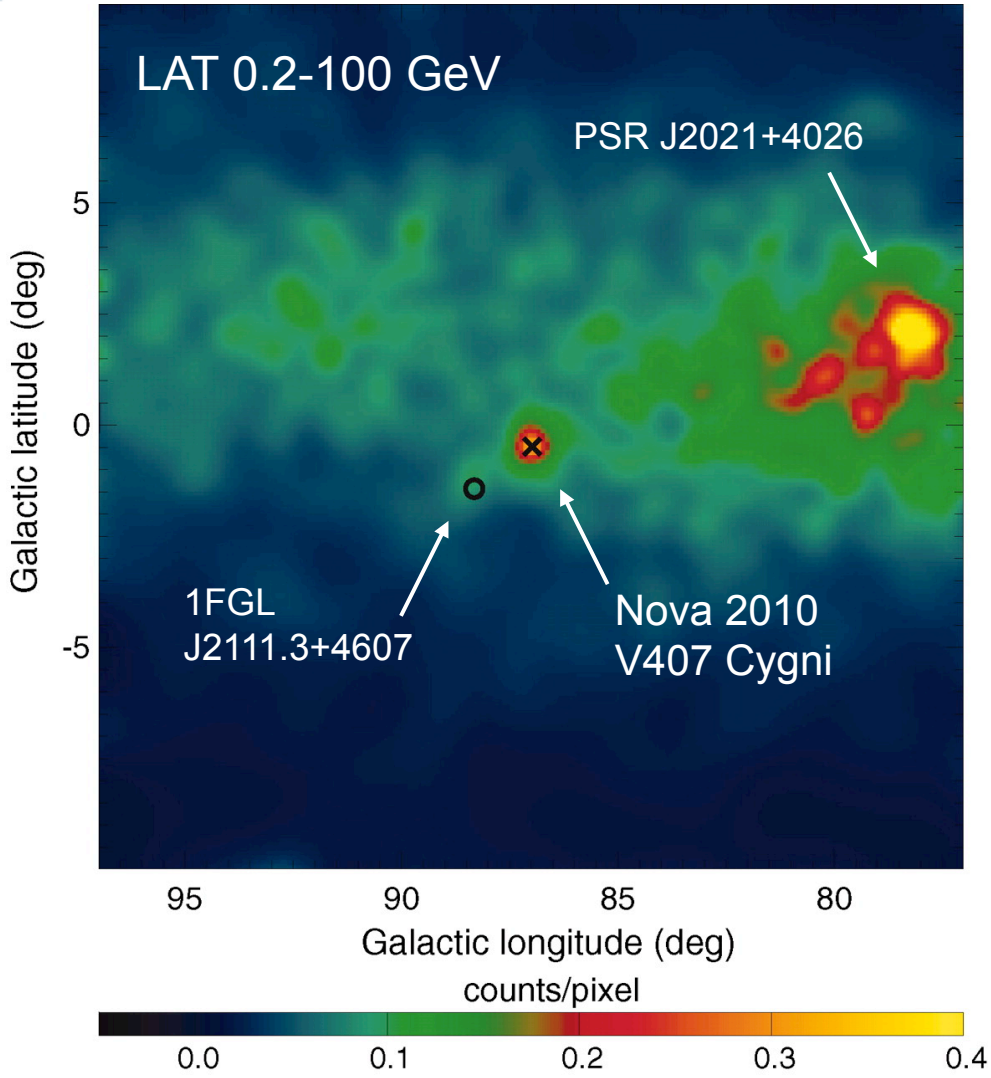
[3]CESR, Toulouse

[4]GMU resident at Naval Research Lab

[5]Naval Research Lab

Fermi Symposium – 2011 May

Fermi-LAT Discovery of a New Transient

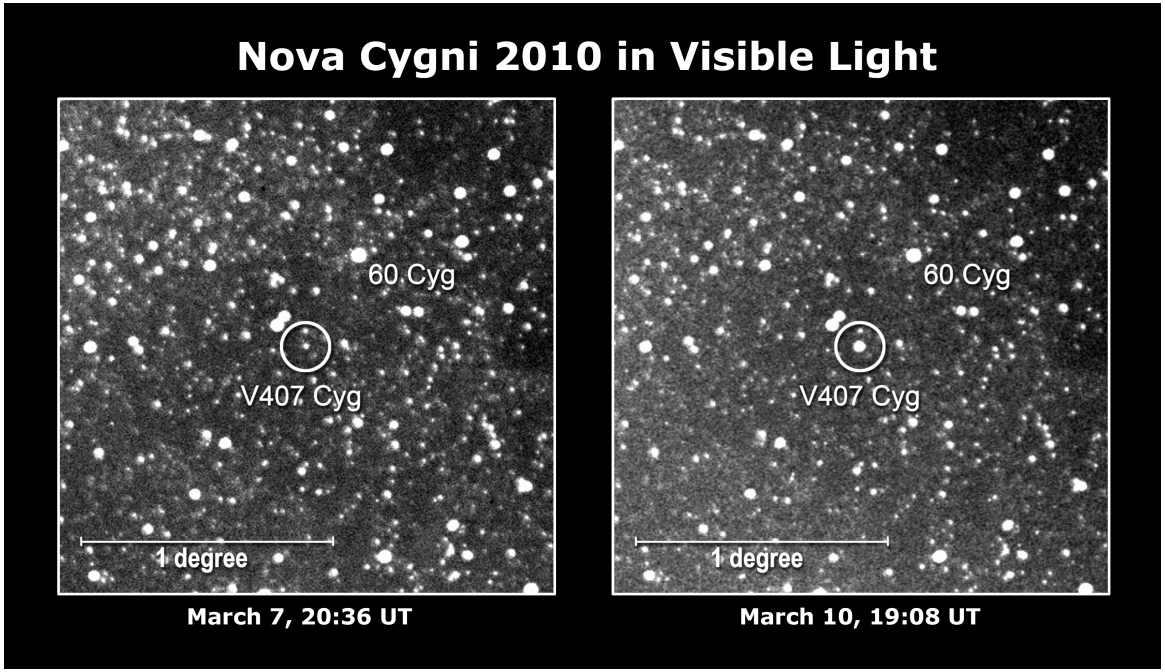


- New LAT source detected (6-8σ, >100 MeV) iniitally on March 13-14 (Cheung et al. 2010 Atel #2487)
- Best γ-ray position (r=3.7') consistent with binary V407 Cyg
- V407 Cyg nova detected on March 10, subsequent analysis found *first LAT detection same day*
  - *First γ−ray detection of a nova*
  - *White dwarf in binary system*

Abdo et al. 2010 Science, 329, 817 (arXiv:1008.3912)

V407 Cygni: a variable star

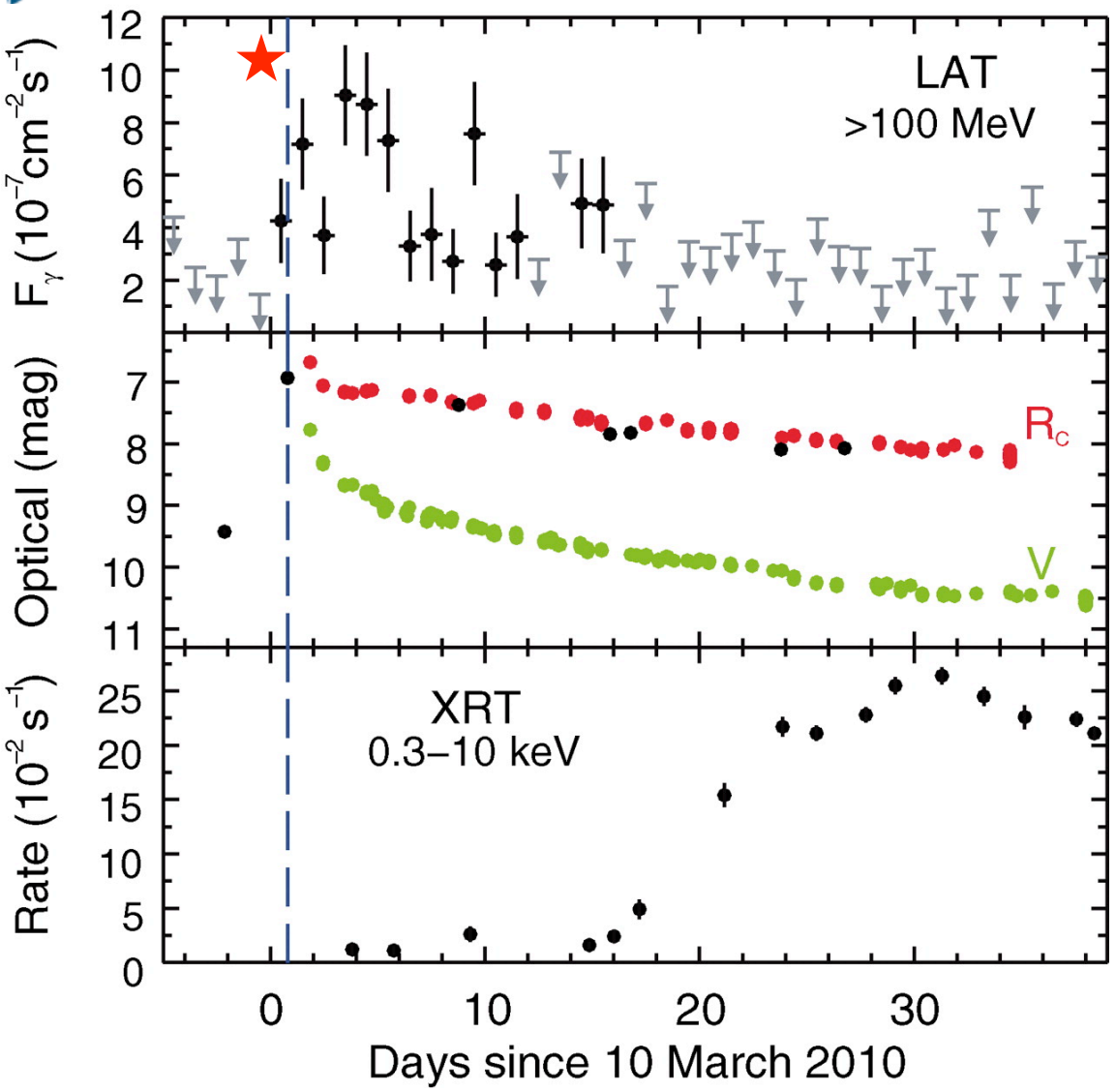
Symbiotic binary V407 Cyg: small white dwarf (WD) and large red giant (RG) orbiting each other closely.
Nova thermonuclear runaway on WD surface.



Variability can come from:
- Mira-type pulsations of red giant (IR/optical)
- accretion disk around the white dwarf (UV)
- the binary motion

Nova discovery by Nishiyama & Kabashima IAUC 2199 (2010); H. Maehara (Kyoto)

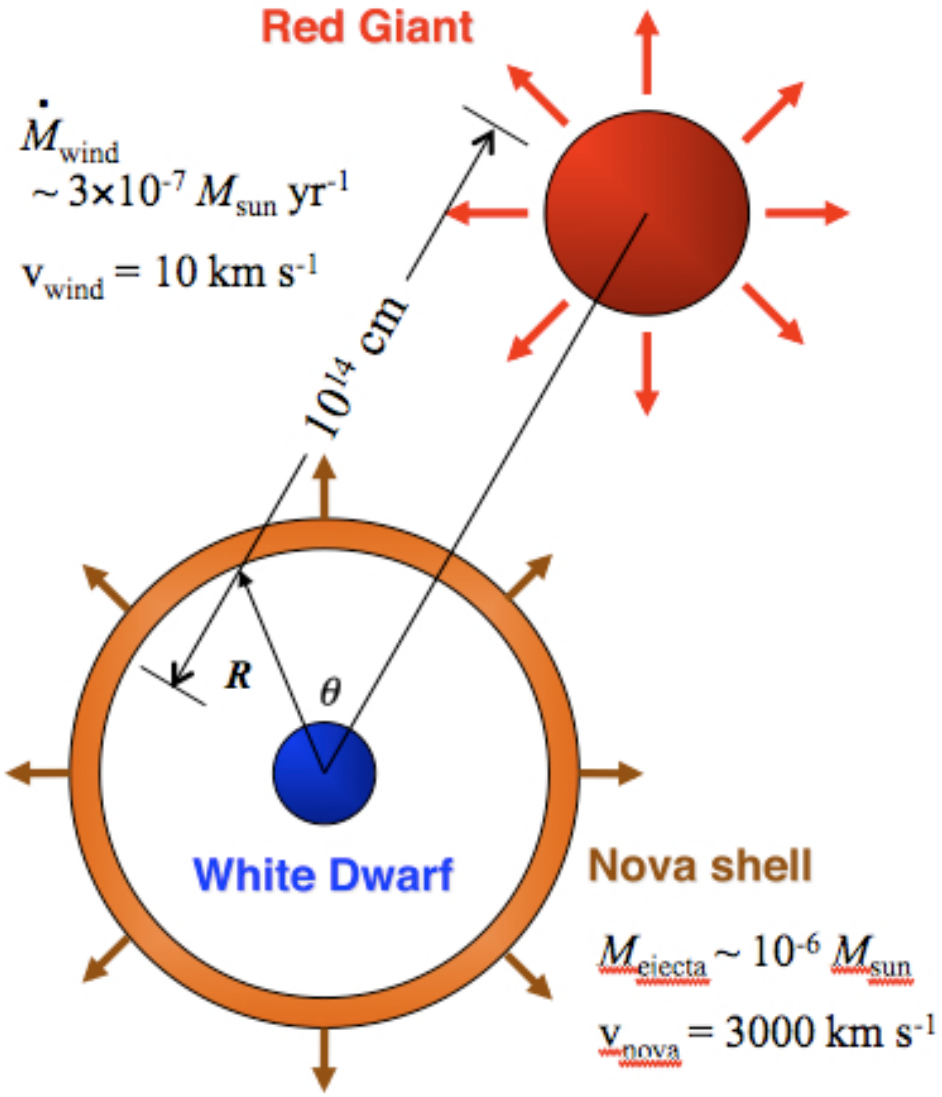
Gamma-ray, Optical, X-ray Lightcurves



- Optical emission peaks first after substantial rise
- First γ-ray detection day of nova optical discovery
  - peak 3-4 days later
  - duration ~15 days
- X-rays peak at ~30 days; substantial rise after γ-rays below detectability

Multi-wavelength emission broadly understood from system geometry

V407 Cyg Binary System



- Evolved Red Giant (M6 III) with Mira-like pulsations (745 day period)
- SiO maser emission, D-type symbiotic (wind-accreting); anomalous Li abundance
- Probable distance ~2.7 kpc
- Fast rise and decline of nova indicate massive WD (>1 M_{sun})

- RG wind & nova shell velocities inferred from optical spectroscopy
- Orbital period uncertain; binary separation from ~4 day γ-ray peak

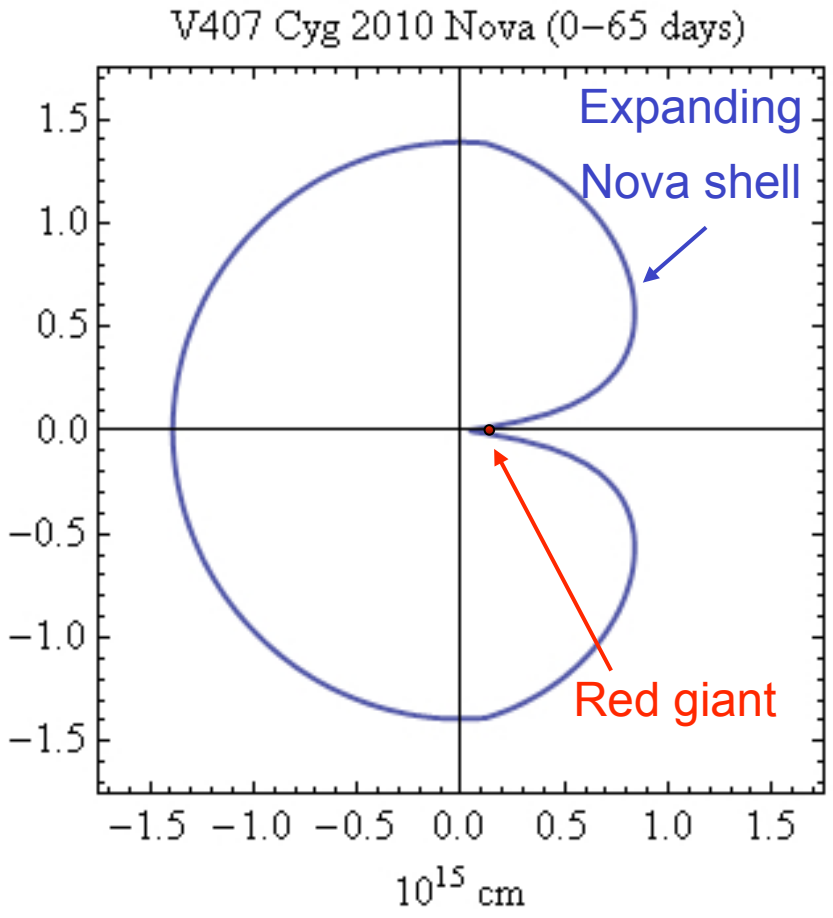
Nova Expansion & γ-ray / x-ray Evolution

- Nova shell initially freely expands into asymmetric dense medium

- Shell toward RG slows down quickly, Sedov condition reached in few days
  - Gamma rays peak early when efficiency for pion and inverse-Compton processes is favorable

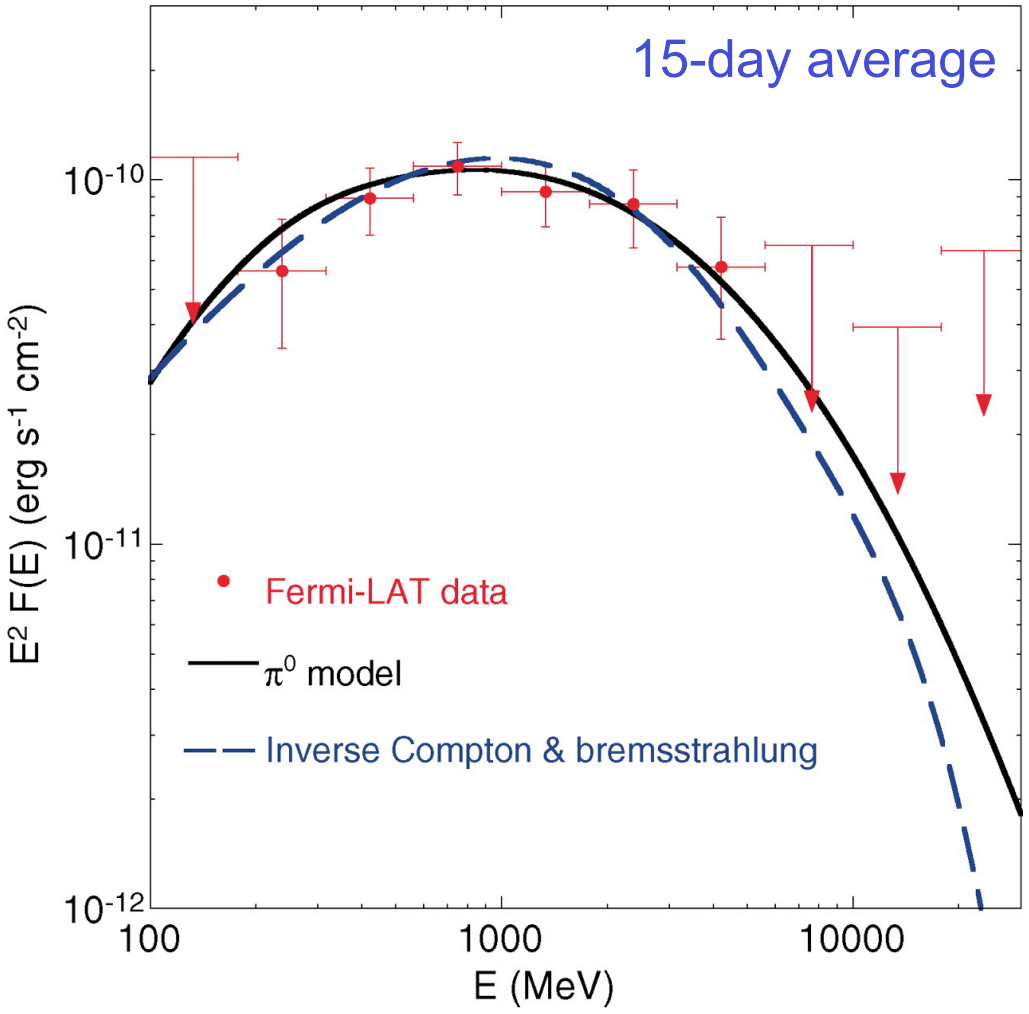
- Shell decelerates slowly away from RG
  - X-rays peak later, flux increasing with volume of shock-heated gas
  - Radio emissions also peak later (ATel #2506, 2511, 2514, 2529, 2536, 2741, 2905)

(White dwarf at center)



Credit: S. Razzaque

γ-ray Spectrum and Energetics



- ***pion:*** accelerated p's collide with ambient material producing π^0 with prompt decay
- ***inverse Compton:*** accelerated electrons up-scattering infrared photons from the red giant
- Kinetic energy of shell: ~10^{44} erg
- Total energy in γ-rays: ~4×10^{41} erg
- Total energy of protons (electrons) gone into producing γ-rays ~9% (~0.4%) of kinetic energy

Nova V407 Cygni Summary

- V407 Cyg first γ-ray nova (white dwarf in binary system)
- Fermi acceleration in nova shell; interaction with massive red giant wind plays important role
- Shell evolution recapitulates SNR evolution in miniature, and scaled down in timescale
- Gamma-ray novae could affect Galactic cosmic ray content in their vicinity
- Gamma-ray nova V407 Cyg 2010 not necessarily unique; symbiotic binaries relatively common, novae are numerous