Gamma-ray Novae

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Pierre Jean (IRAP/Toulouse)

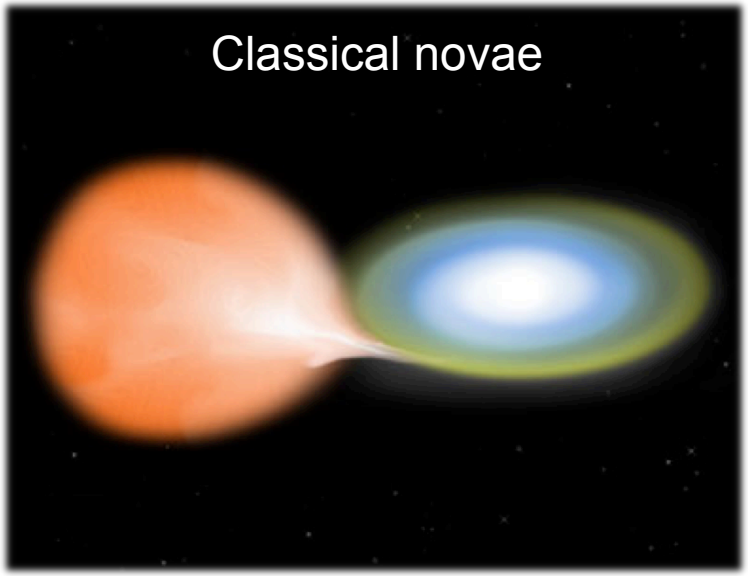
Thanks: Steve Shore (Pisa), Laura Chomiuk (MSU)

White Dwarfs in Close Binary Systems

Compact cataclysmic variable:

WD + Main Sequence

Roche lobe overflow



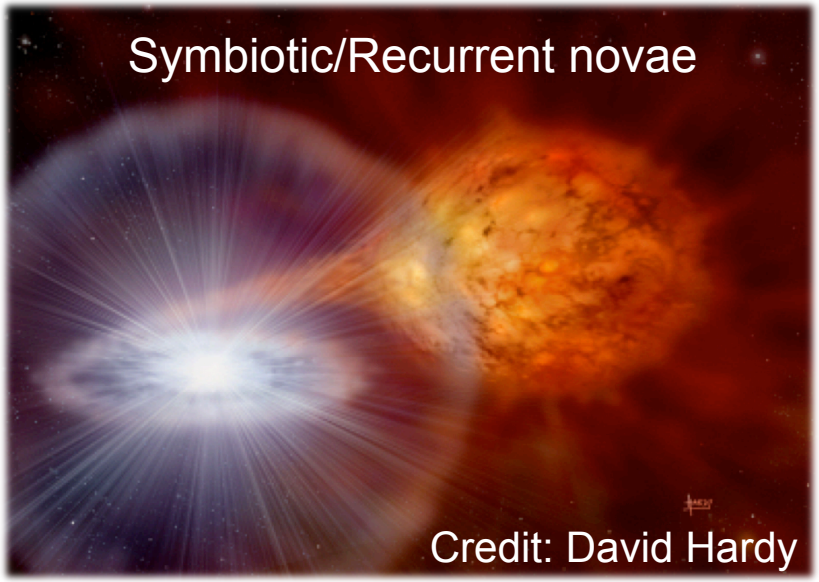
- a ~ 10^{11}cm ~ $R_\odot$
- P_{rec} >~ 10^4 yr; P_{orb}~ hr-day
- rate ~ 20 – 50 / yr in Galaxy

Hydrogen burning in degenerate conditions on top of the white dwarf

Symbiotic system:

Massive WD + Red Giant

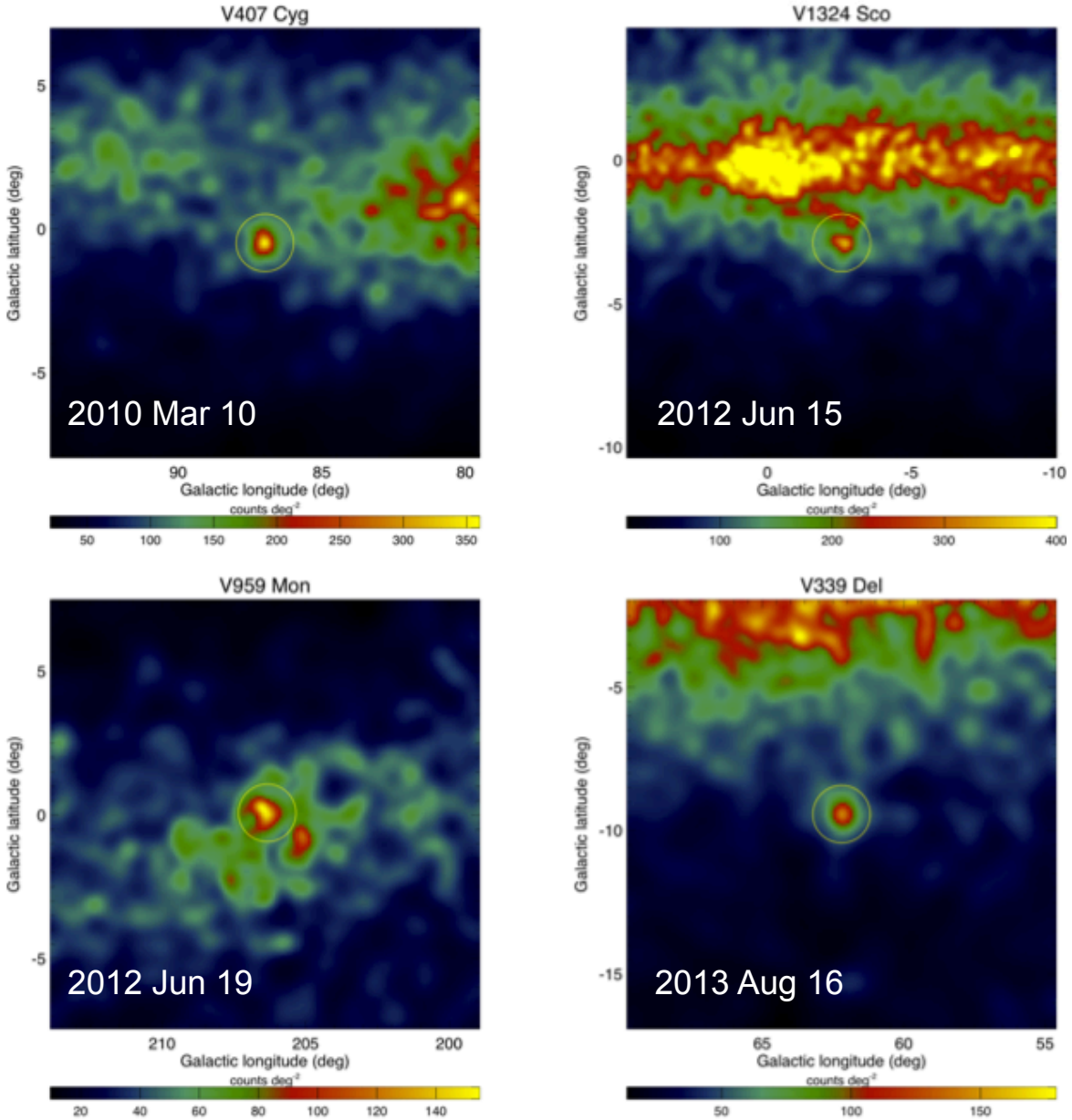
accretion from a red giant wind



- a ~ 100's $R_\odot$
- P_{rec} < 100 yrs; P_{orb}~ few years
- ~10 known

Adapted from M. Hernanz X-ray Universe 2011 talk

Fermi LAT >100 MeV Detections



E > 100 MeV counts maps

- V407 Cyg 2010
  Symbiotic
  D ~ 2.7 kpc

- V1324 Sco 2012
  CO nova
  D ~ 4.5 kpc

- V959 Mon 2012
  ONe nova
  D ~ 3.6 kpc

- V339 Del 2013
  CO nova
  D ~ 4.2 kpc

Ackermann et al. 2014
Science 345, 554

Similarity of LAT >100 MeV Lightcurves

- Duration ~ 17-27 days

- t_{rise} ~ t_{fall} ~ 2-7 days

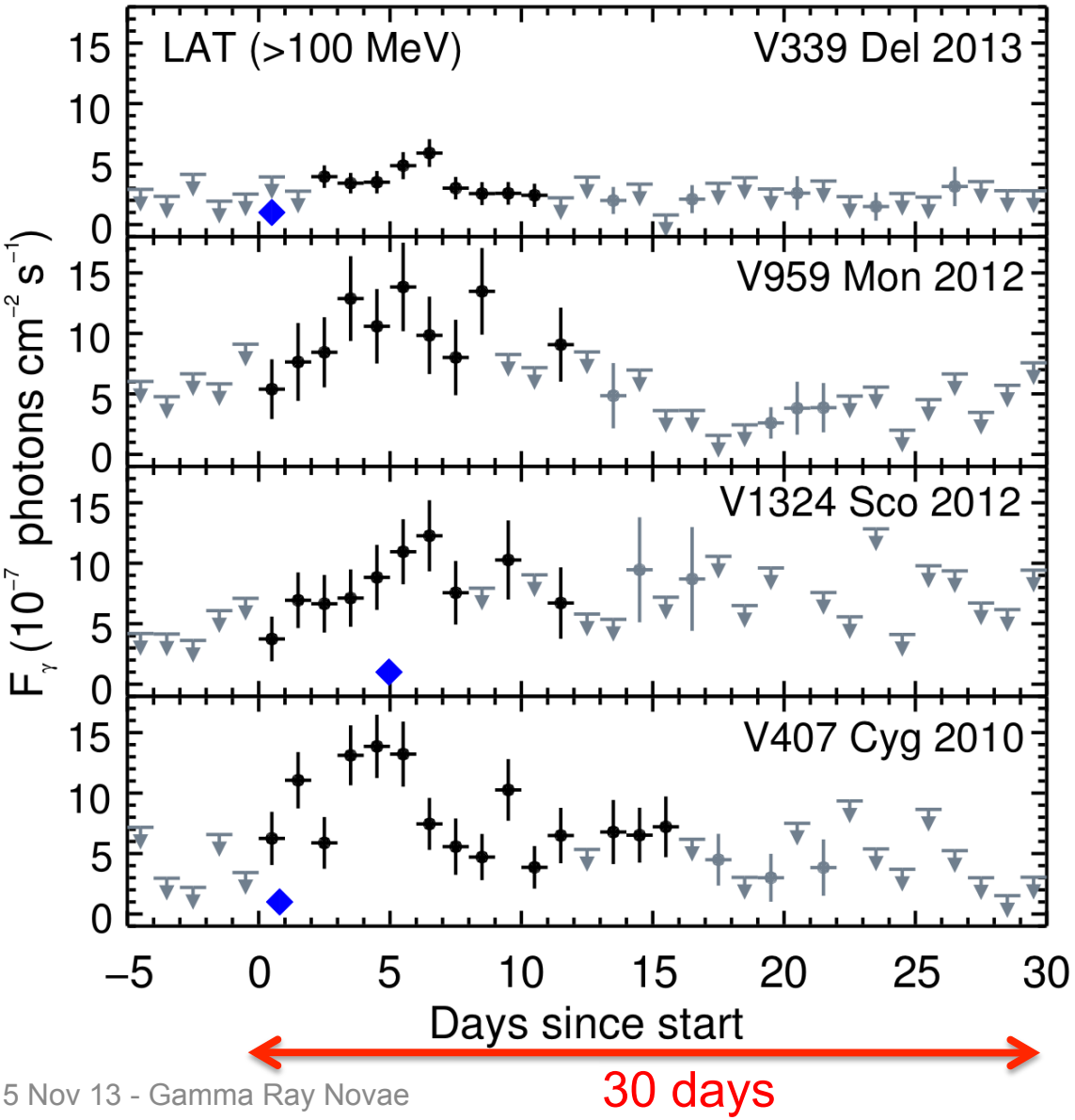
- Flux peaks ~10^{-6} ph/s/cm^2

-Total energy ~ 6-13 x 10^{41} erg

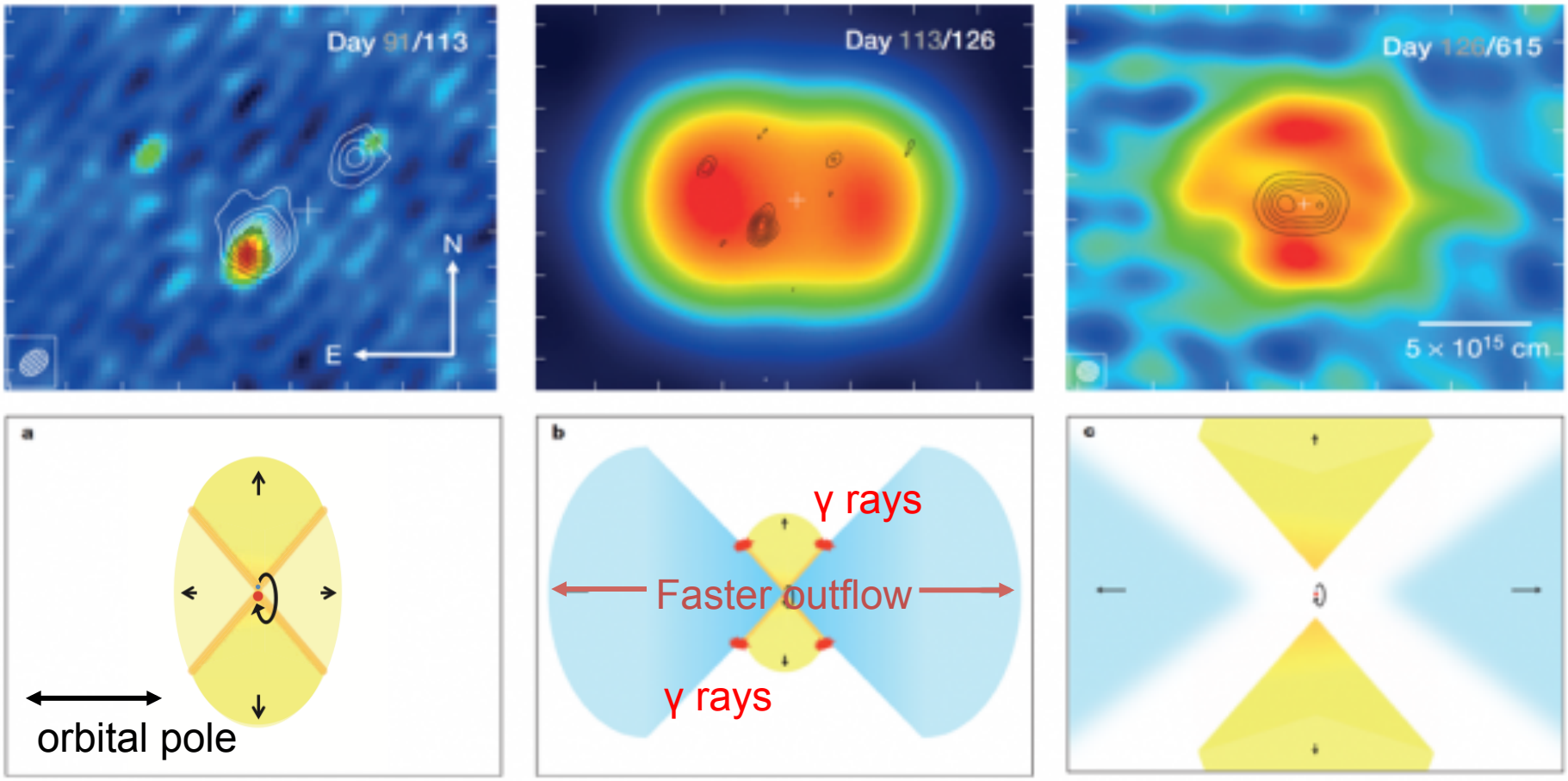
(Widening range >100 MeV properties with recent detections N Cen 2013, N Sgr 2015 No. 2)

- Origin and production site of >100 MeV emission is open problem – hadronic or leptonic fit LAT spectra

Ackermann et al. 2014
Science 345, 554



V959 Mon 2012 Radio Evolution: acceleration site?



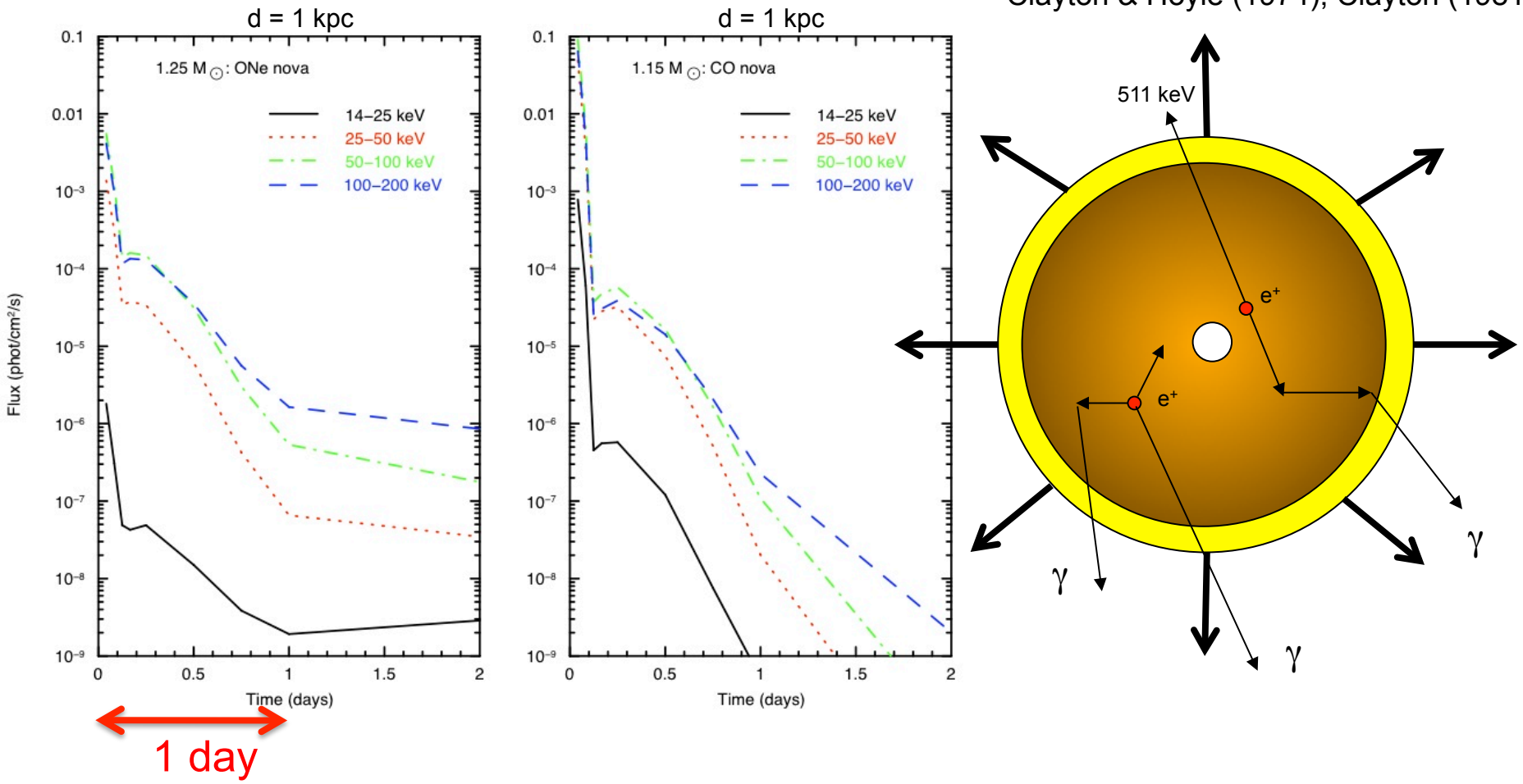
Chomiuk et al. 2014 Nature
See also Ribeiro et al. 2013, Shore et al. 2013, Linford et al. 2015
Recall Tuesday Plenary talks: Metzger, Linford

MeV Nuclear gamma-ray emissions

^{13}N & $^{18}F \rightarrow$ 511 keV + continuum (Compton diffusion & positronium)

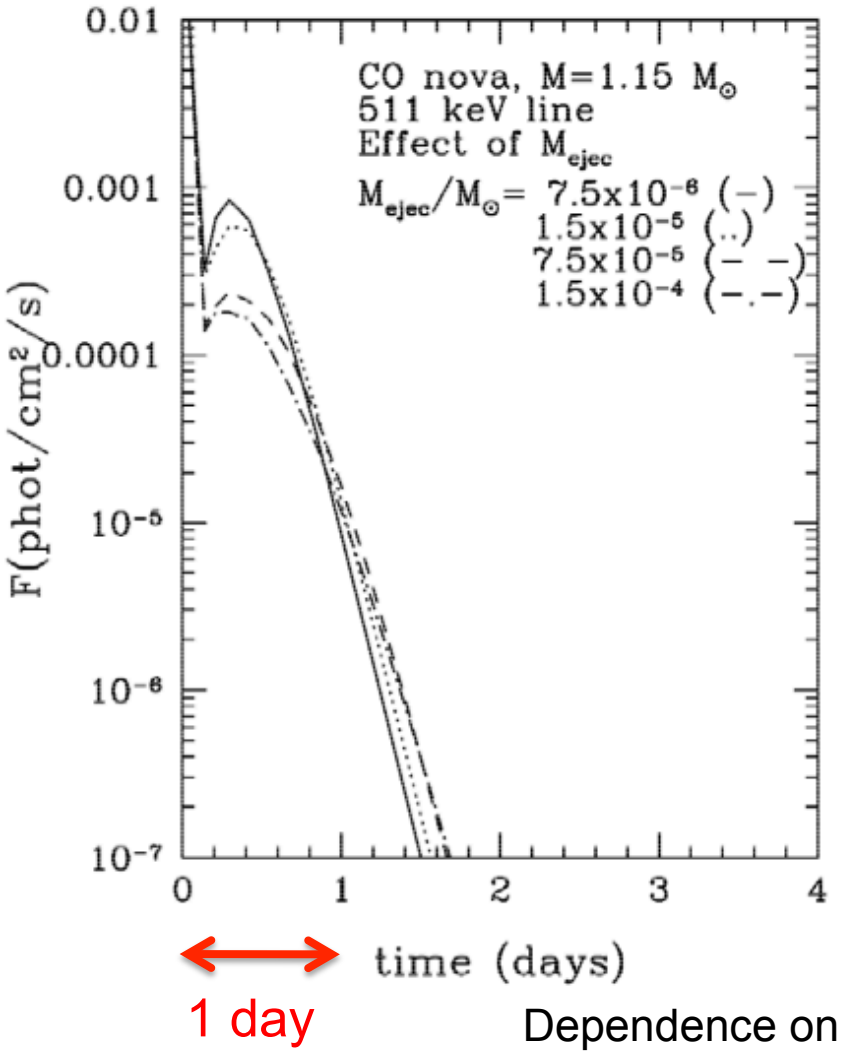
Gamma-ray lines: 478 keV from $^{7}Be \rightarrow {}^{7}Li$ & 1275 keV from $^{22}Na \rightarrow {}^{22}Ne$

Clayton & Hoyle (1974), Clayton (1981)

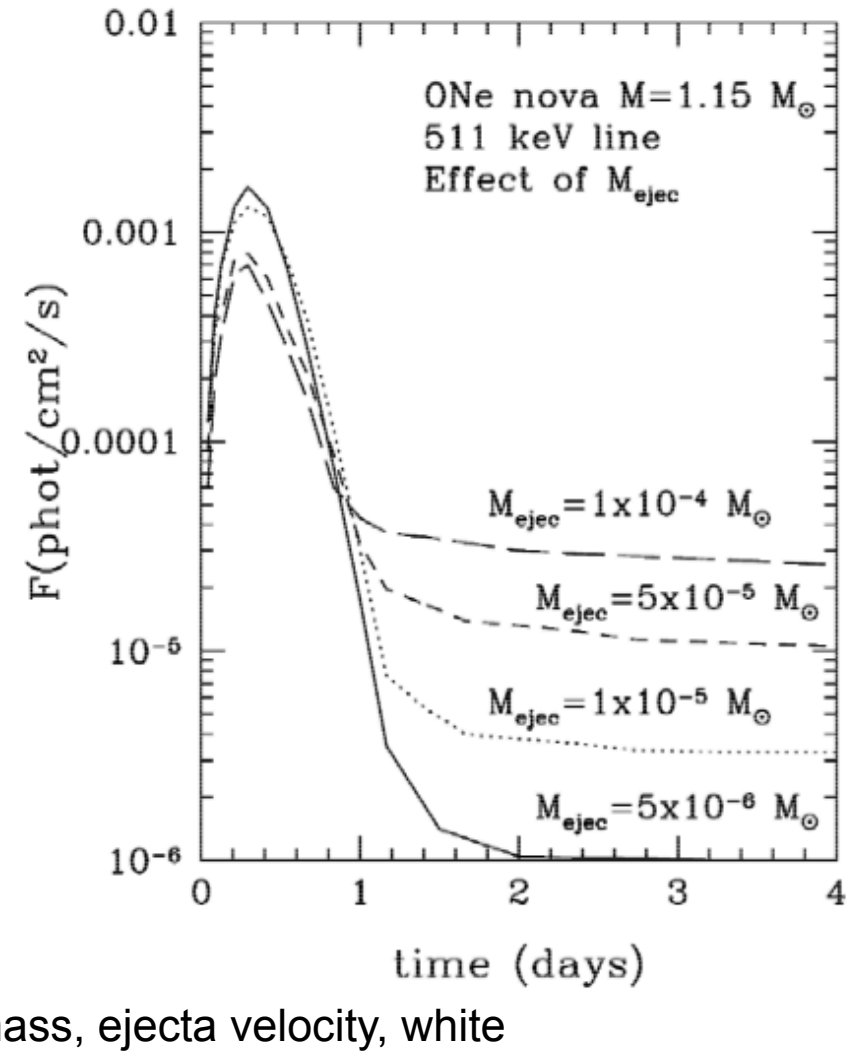


Senziani, Skinner, Jean & Hernanz (2008)

MeV Lightcurves: Ejecta Mass

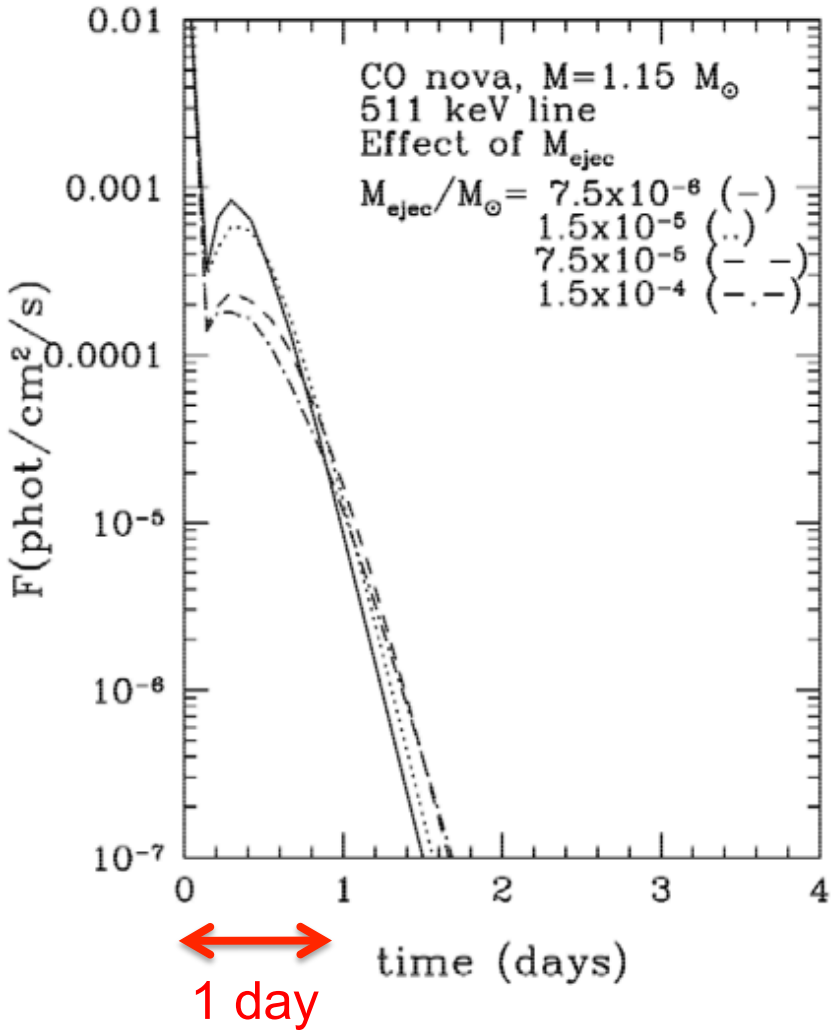


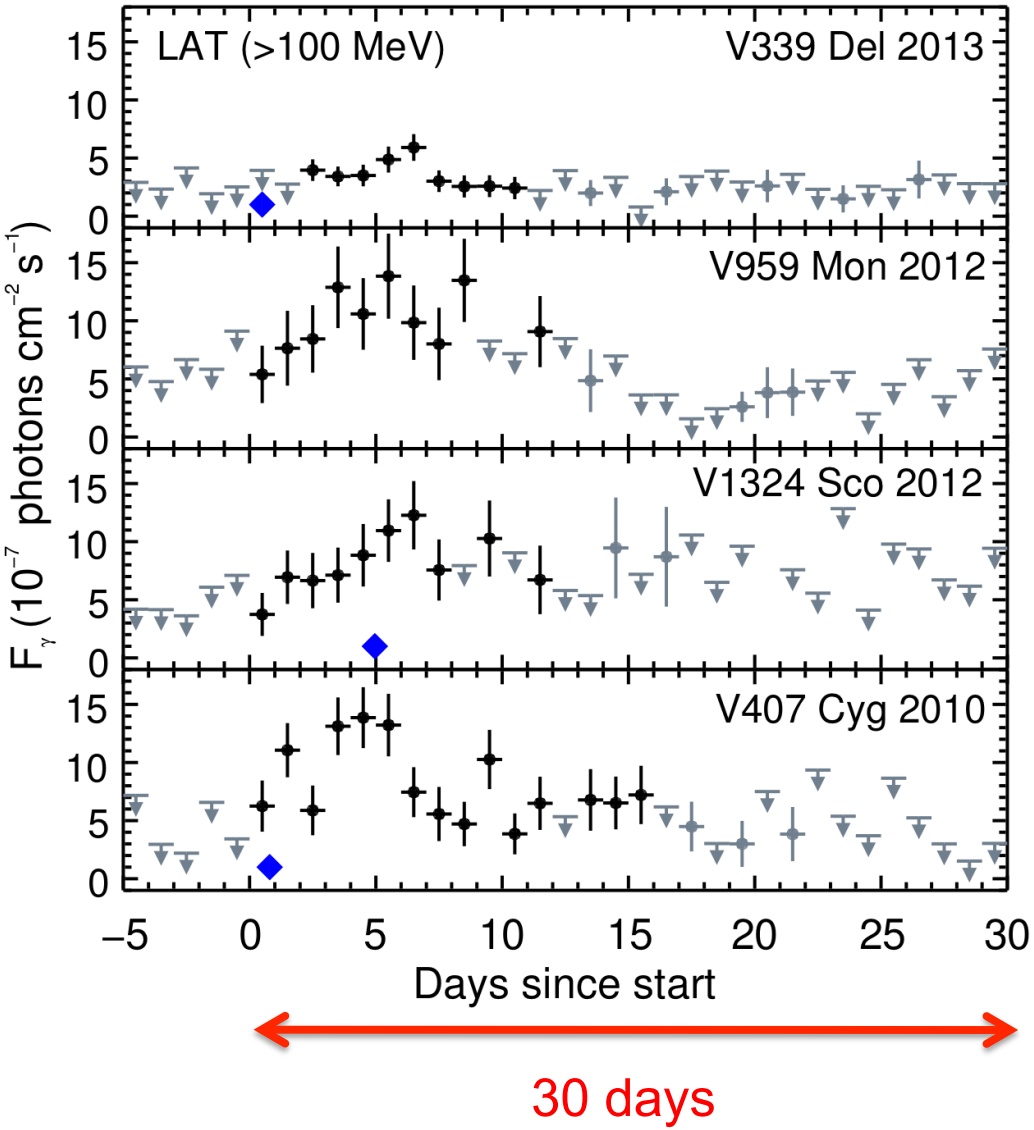
1 day



Dependence on ejecta mass, ejecta velocity, white dwarf mass (Hernanz et al. 2002)

Lightcurves: MeV➔ ➔GeV



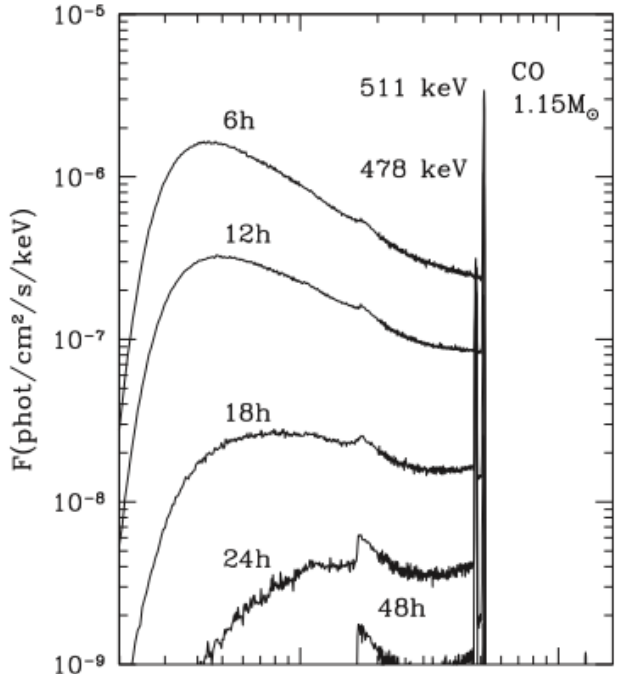


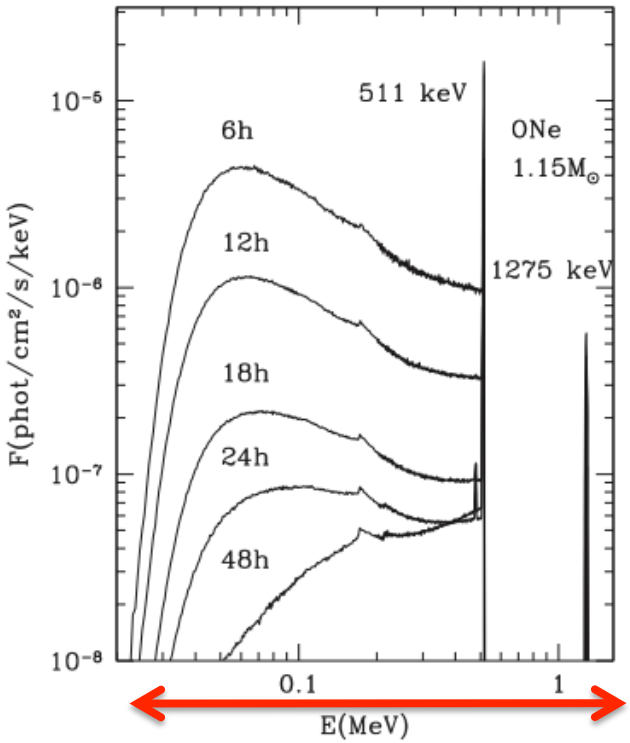
Spectra MeV➔ ➔GeV

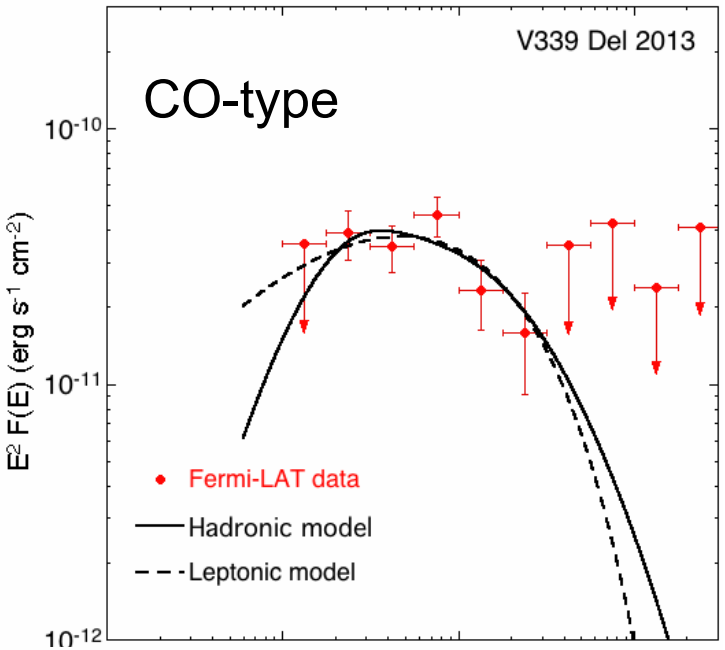
CO-type
478 keV

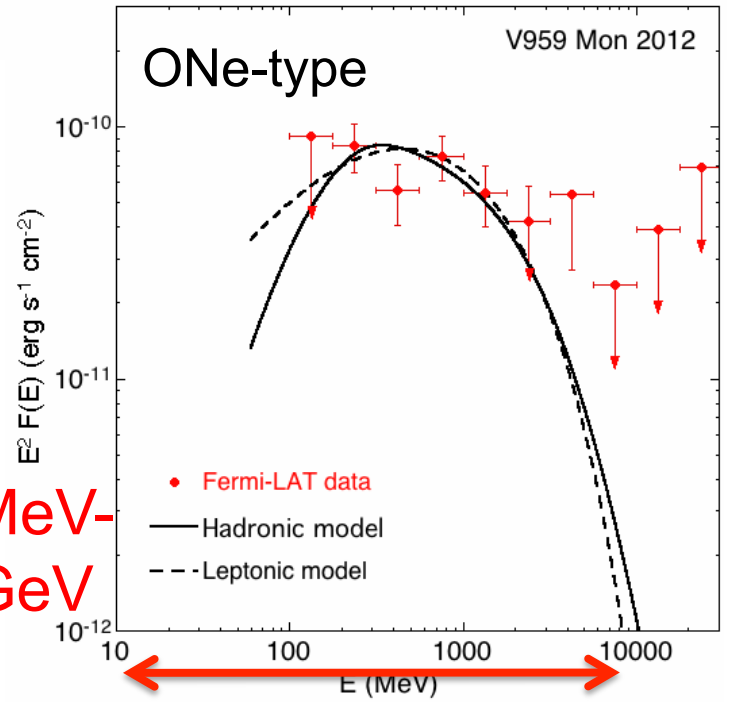
Hernanz 2014

ONe-type
1275 keV





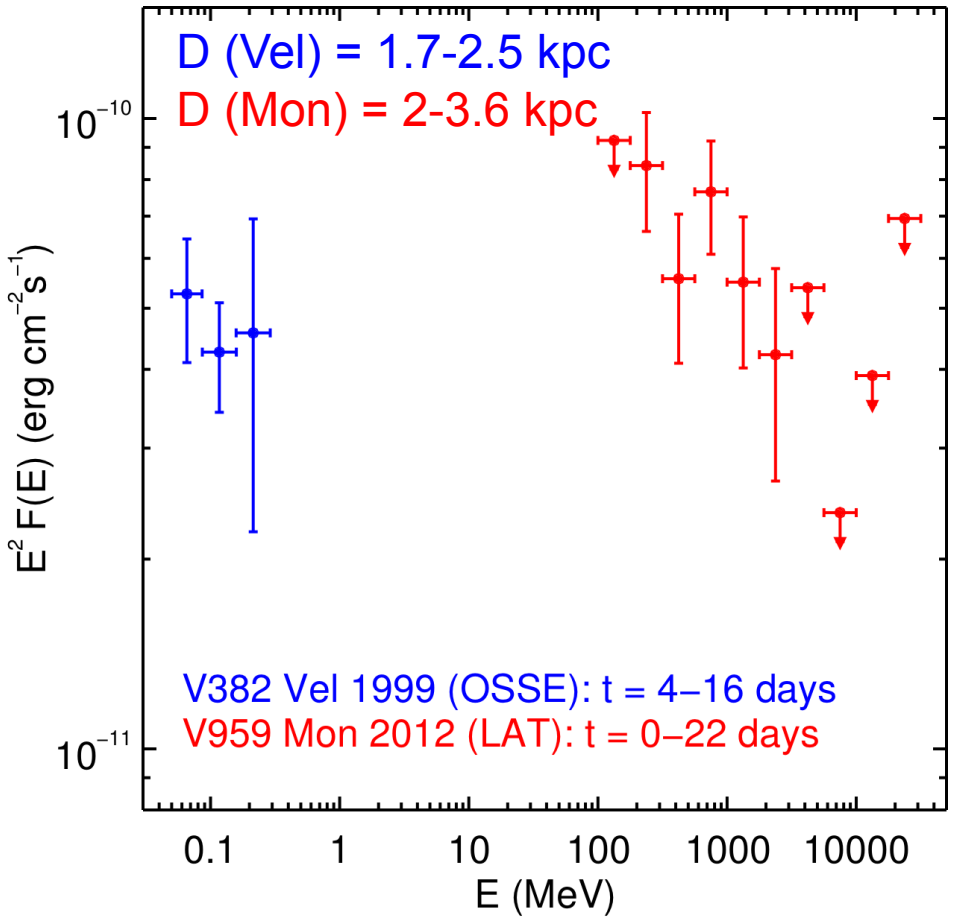




~0.02-2 MeV

10 MeV-
10 GeV

MeV➔⬅GeV Novae



V382 Vel: Leising et al. 1999, 5th Compton symp.
V959 Mon: Ackermann et al. 2014 Sci. 345, 554

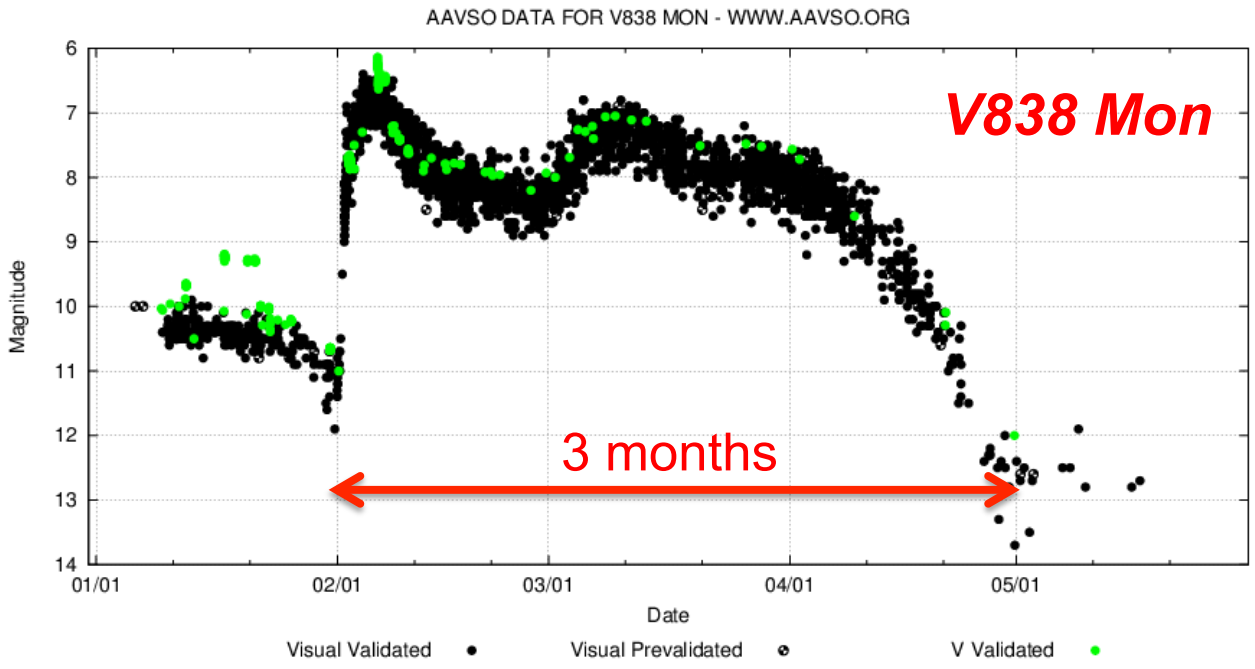
- Revisited *Compton (1991-99)* novae observations in light of *Fermi* discoveries
- V382 Vel 1999 peaked at 2.5 mag; Compton/OSSE detected at 7σ over 12-days starting 4 days after optical peak (non-detection in next 14-day)
- OSSE spectrum of V382 Vel 1999 compared to LAT for Nova Mon 2012, both oxygen-neon novae

Novae Classes and Diversity

- Classical Novae:
  - Carbon-Oxygen Novae: Majority
  - Oxygen-Neon (ONe) Novae: ~15-25% - *uniform class* (comparison V959 Mon 2012 with V382 Vel, V1974 Cyg, and others; Shore et al. 2013)
- Recurrent Symbiotic Novae: < few %
- Connection to SN type-1a (?)

Novae Classes and **Diversity**

- What was Nova Sco 2012
  - not a ‘nova’?
  - Diversity of stellar explosions


AAVSO DATA FOR V838 MON - WWW.AAVSO.ORG
V838 Mon
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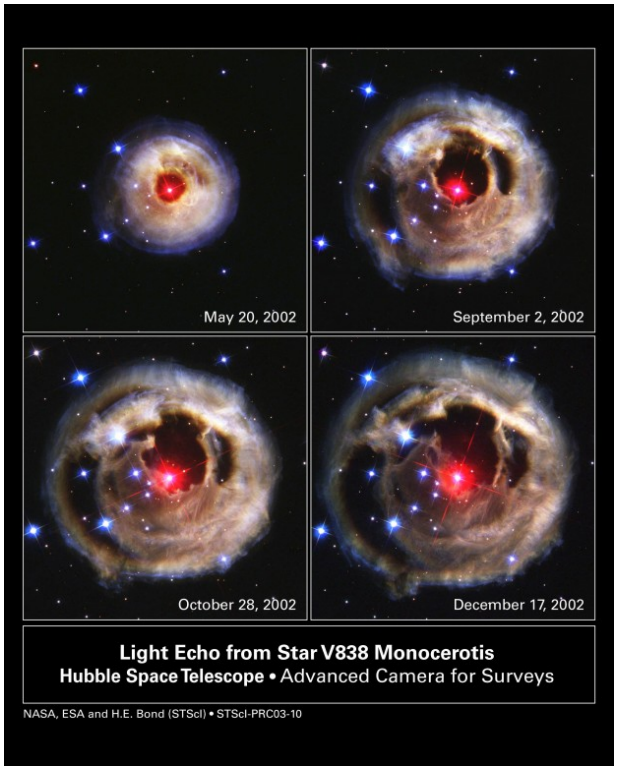
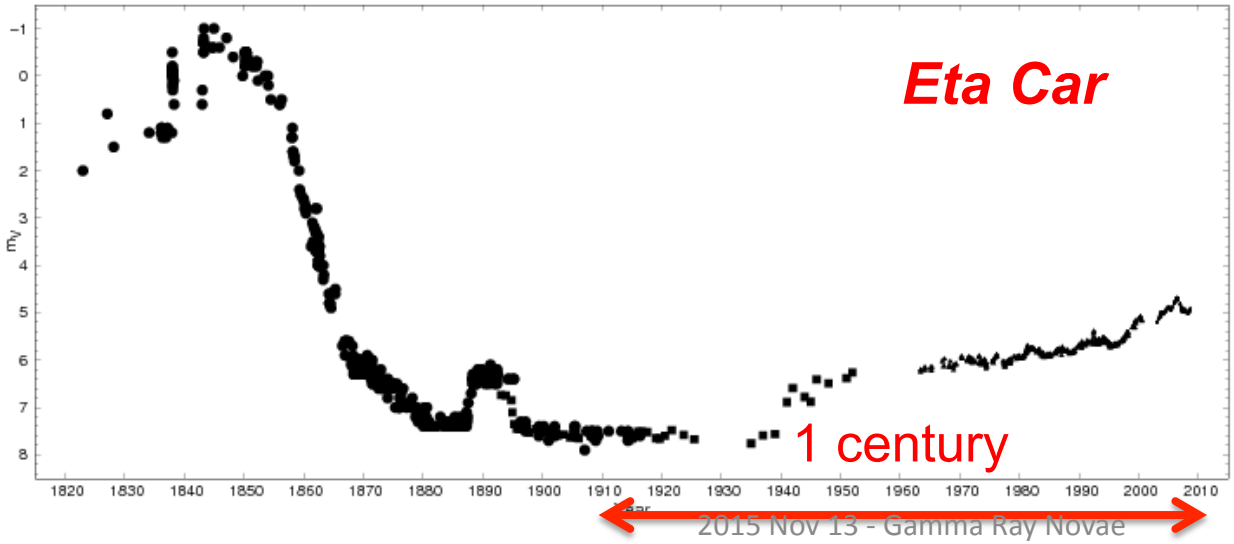

May 20, 2002
September 2, 2002
October 28, 2002
December 17, 2002
Light Echo from Star V838 Monocerotis
Hubble Space Telescope • Advanced Camera for Surveys
NASA, ESA and H.E. Bond (STScI) • STScI-PRC03-10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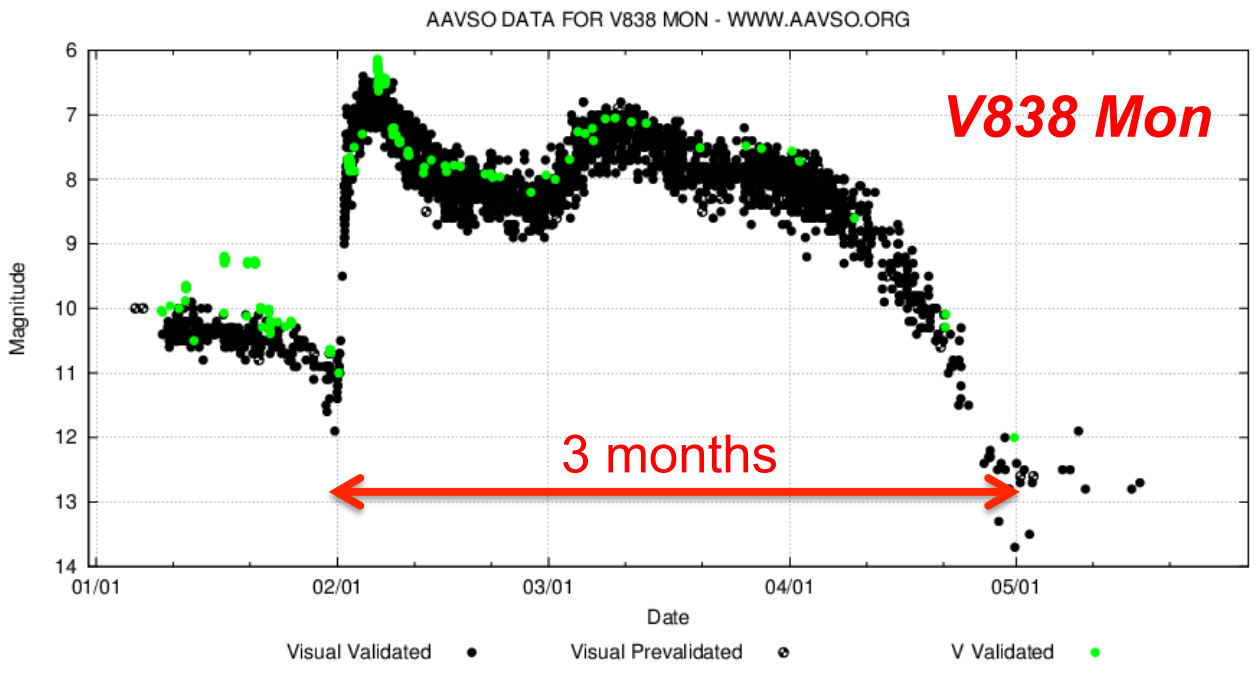
AAVSO DATA FOR V838 MON - WWW.AAVSO.ORG
V838 Mon
3 months
Magnitude
Date
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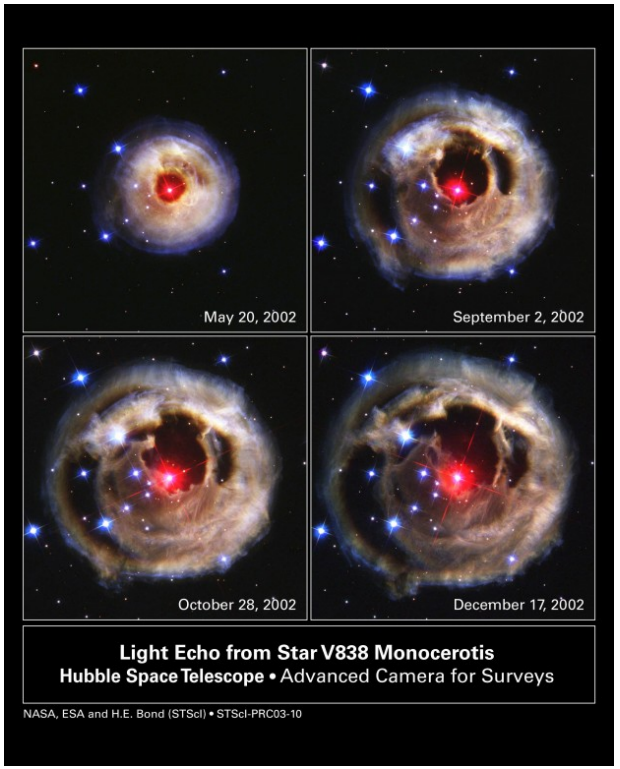
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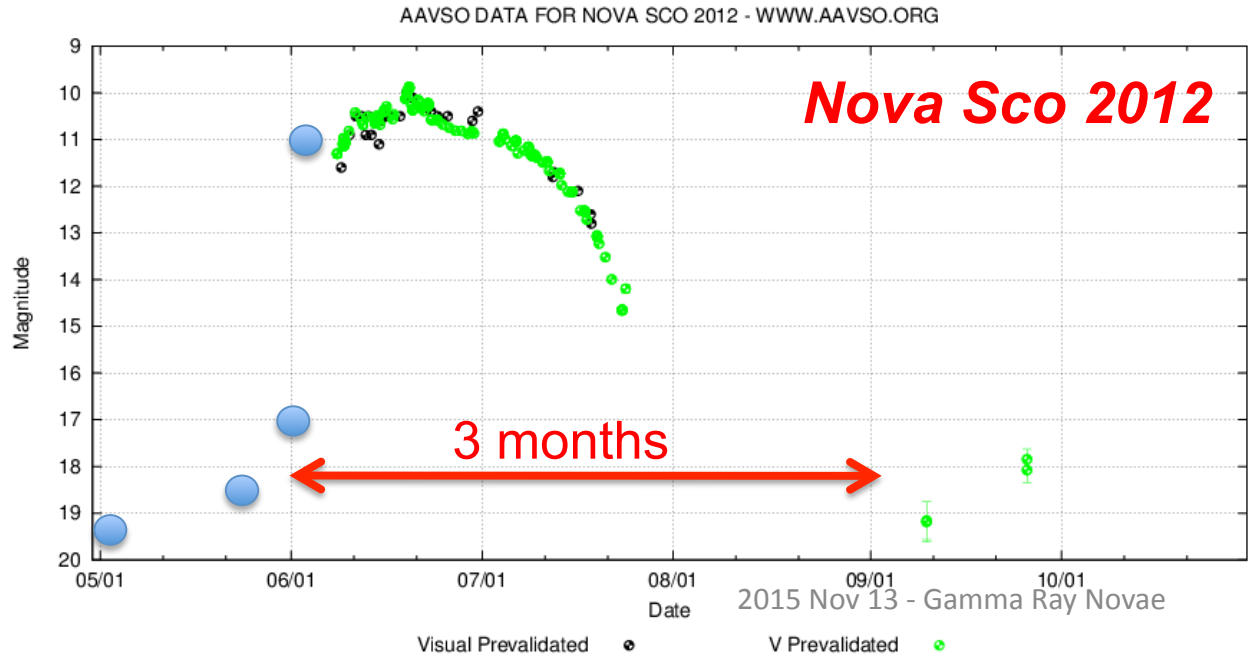
AAVSO DATA FOR NOVA SCO 2012 - WWW.AAVSO.ORG
Nova Sco 2012
3 months
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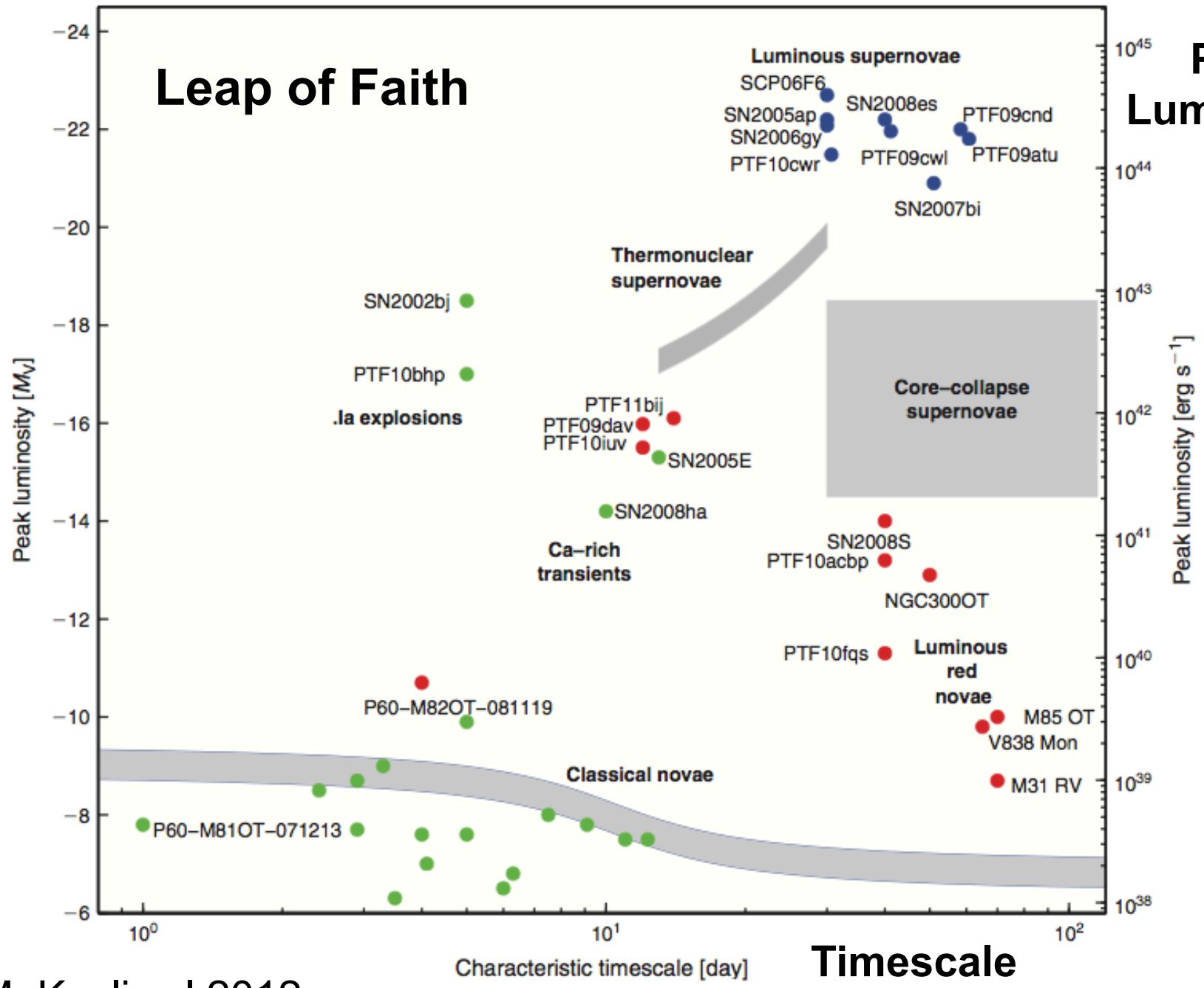


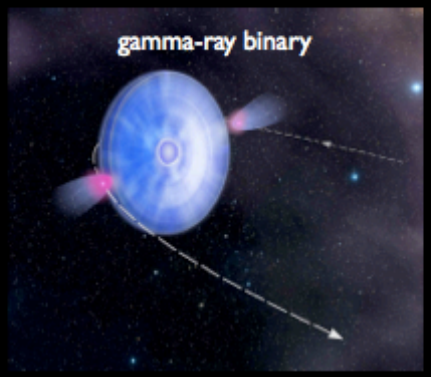
M. Kasliwal 2012

Binaries > 100 MeV

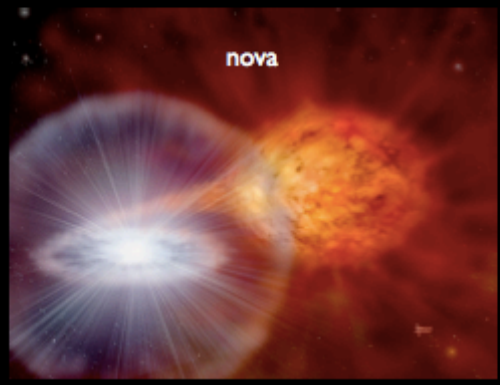
High-E particle-particle & particle-photon interactions

Many types detected in past years by Fermi, AGILE, VERITAS, HESS, MAGIC

BH/NS jet-disk

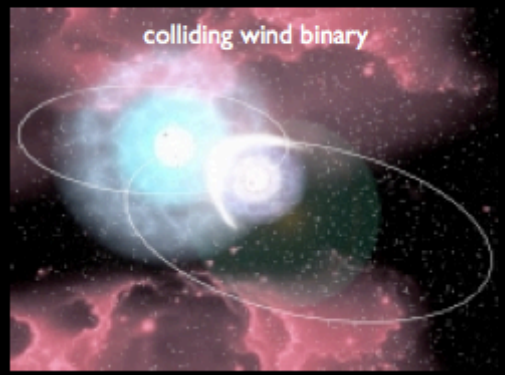


NS wind / disk



Mass ejection from WD / companion

Mass loss from LBV (massive star)



NS wind ablating companion

see Dubus, 2013, Astron. Astrophys. Rev., 21, 64

MeV-GeV Novae: Key Points

- Despite limited angular resolution, novae can be identified as transient sources of MeV line emission with continuum down to ~30 keV, followed by >10 MeV γ's
- Fast response times for nuclear decay emission
- keV-MeV to >GeV, and lower-frequency coverage key to particle acceleration (INTEGRAL, Astro-H)
- Appeal to broader community (understanding stellar endpoints)
- Recurrent T CrB (2026?), d~0.8 kpc could be remarkably bright MeV-GeV-TeV γ-ray source, and a transient higher-energy neutrino signal expected in the hadronic scenario