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Research Center for the Early Universe

Novae with super-Eddington luminosities

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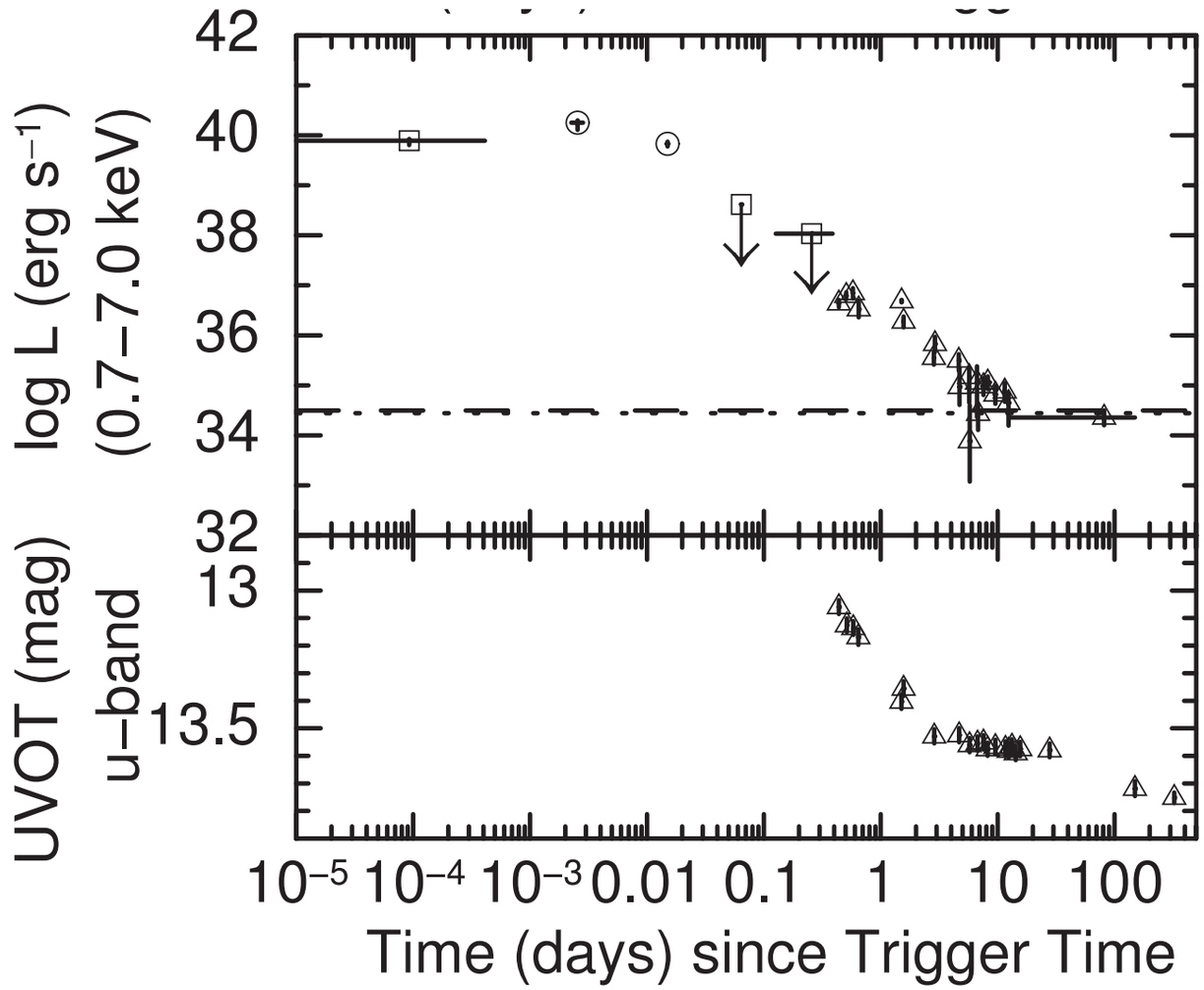
Based on Ohtani, Morii, TS 2014
and Wada, TS 2016

MAXI J0158−744

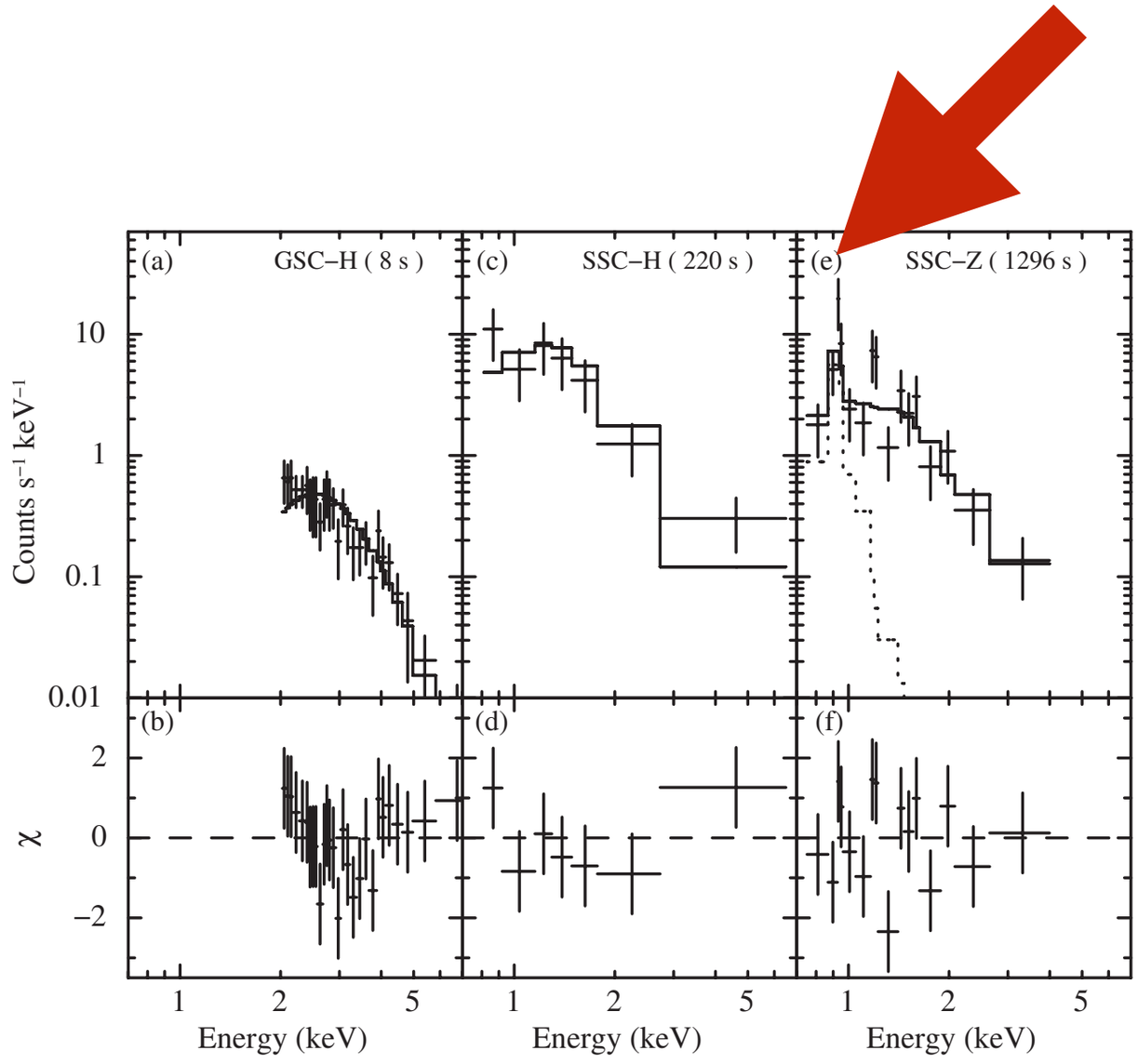
- A very luminous transient (Li+ 2012)
  - discovered on 2011 Nov. 11
  - in the direction of the SMC
  - X-ray luminous phase lasted for <11,000 s
  - companion star=Be star



Morii+ 2013

MAXI J0158−744

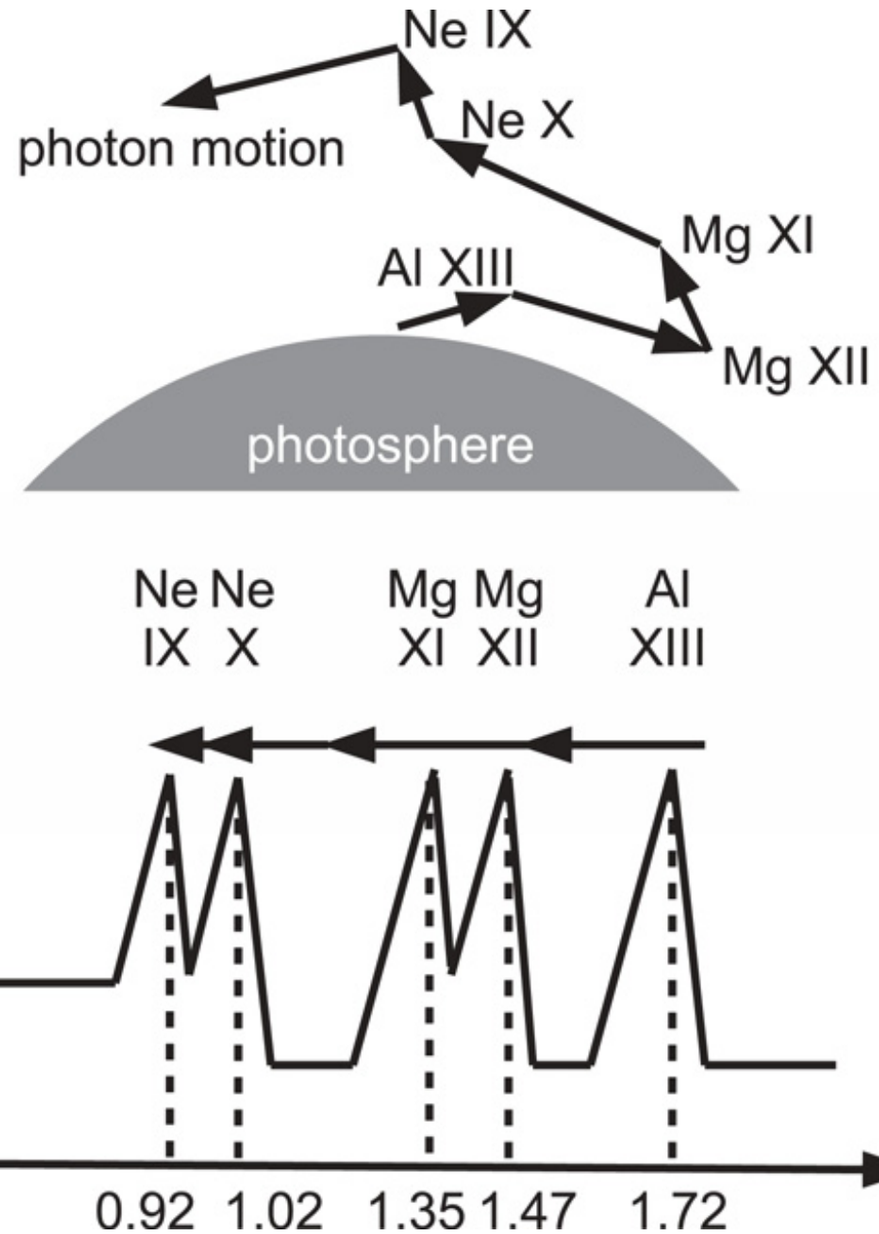
- Peculiar spectrum at t=1296 s
  - Prominent emission line at 0.92 keV due to He-like Ne ions (EW=0.32 keV+0.21-0.11)
- No other lines (e.g., due to H-like Ne ions)
- kT~0.33 keV black body



Morii+ 2013

Line blanketing in accelerating nova wind

- In expanding matter with dv/dr>0
  - photons emitted by an ion are red-shifted in the rest frames of the other ions
  - photons degrade their energies by subsequent scattering



Model of accelerating wind

- Steady states

$$v\frac{dv}{dr} = \frac{\kappa L}{4\pi r^2 c}\left(1 - \frac{L_{\rm Edd}}{L}\right)$$

$$L_{\rm Edd} = 4\pi c G M_{\rm WD}/\kappa$$

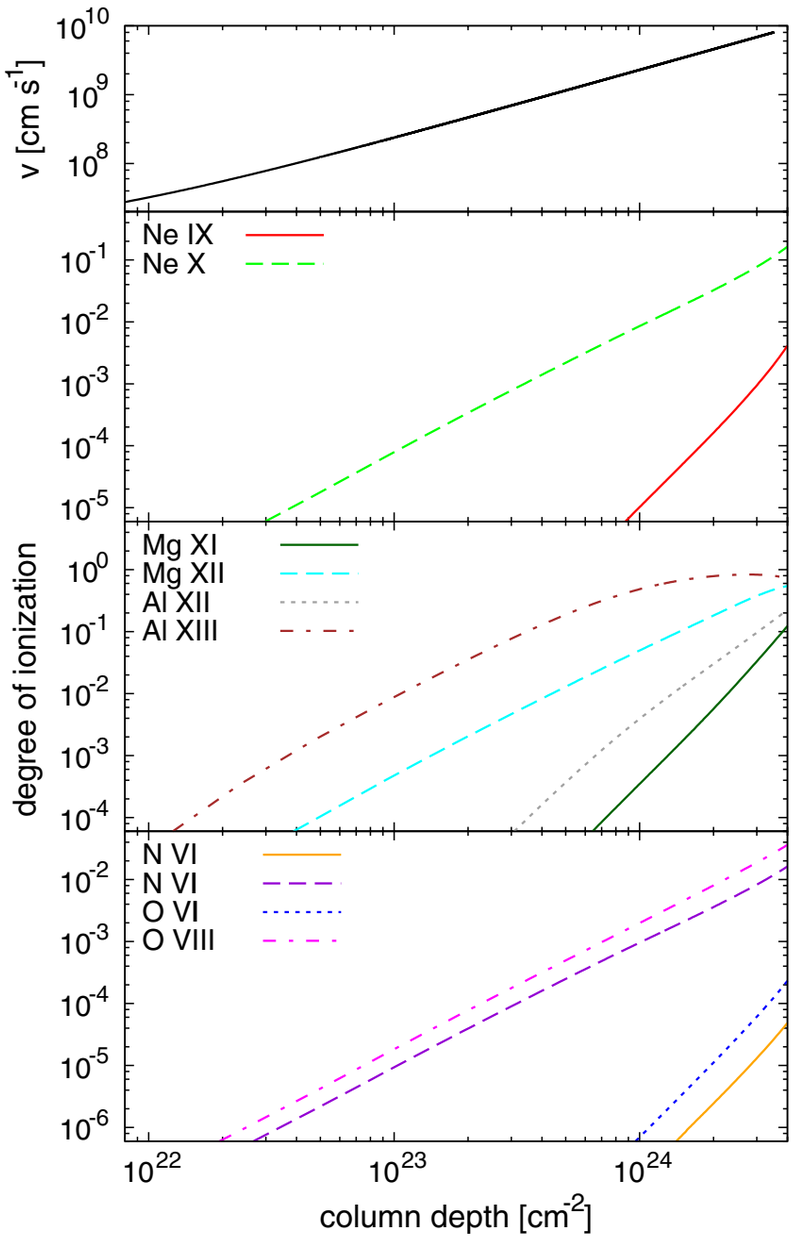
  - constant L(=8x10^{39} erg/s)

  - the photospheric radius=2,300 km ($kT_{\rm eff}$=0.33 keV)

- The optical depth of the wind above the photosphere=2/3→mass loss rate~1.4x10^{-6} Msun/yr

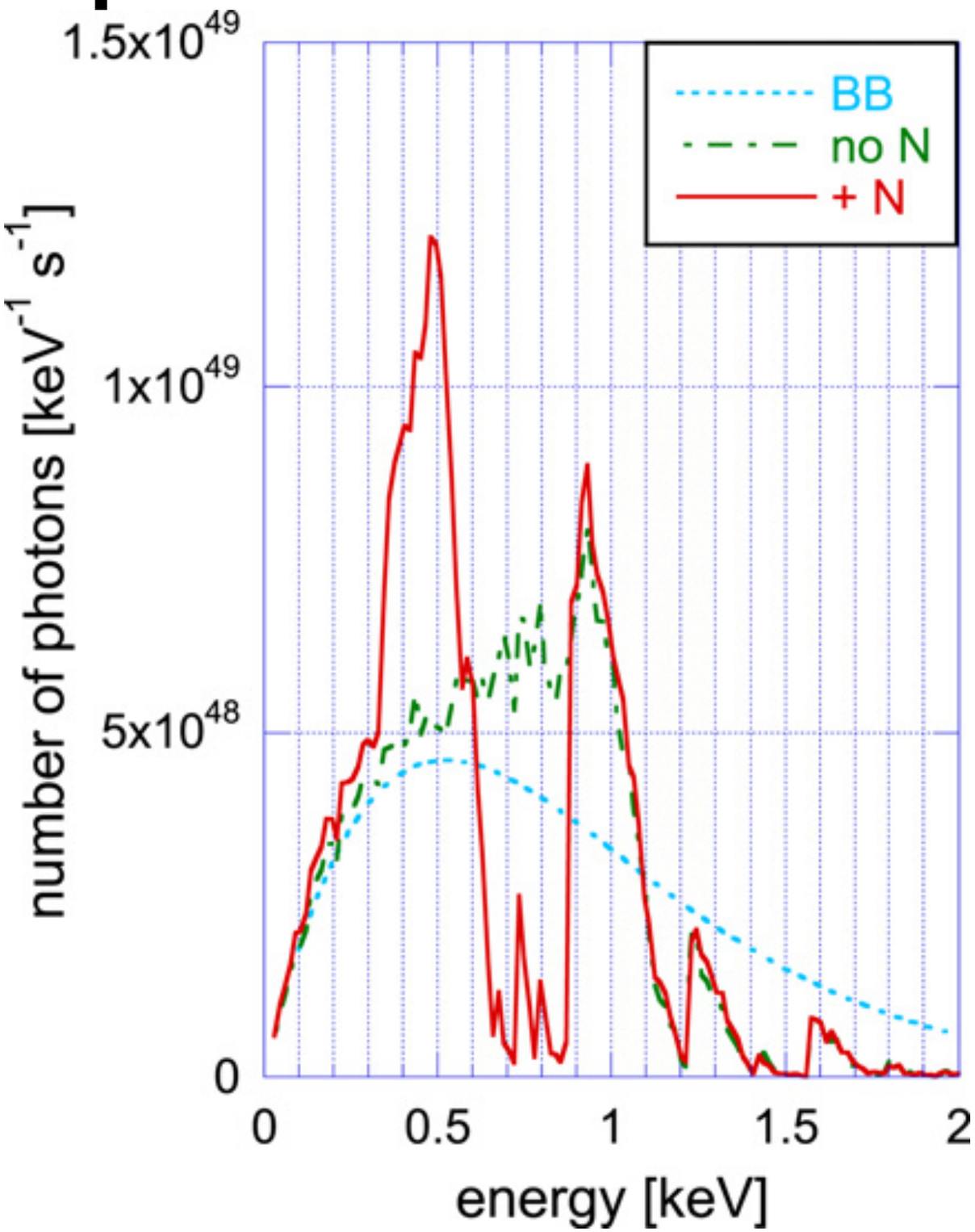
  - cf. ~10^{-4} Msun/yr for Novae

- Photo-ionizing plasma (XSTAR)



Model spectra

- Radiative transfer of photons emitted from the photosphere
  - Monte Carlo method
- Emission line at 0.92 keV
  - wiped by Oxygen
  - $X_O < 5 \times 10^{-9}$ is needed
  - CNO cycle converts Oxygen to Nitrogen
  - Nitrogen sharpens the shape of the line
  - To obtain EW~0.3 keV, X(Ne)>0.001



Conditions to reproduce the observations

- Low mass loss rate
- Enhanced Ne abundance (a factor of >5) indicating ONe White dwarf
- High velocities up to ~a few x10,000 km/s
- Acceleration outside of the photosphere
    - Previous nova wind models show acceleration only in the photosphere (Optically thick wind model, e.g., by Kato & Hachisu 1994)
- Mass of the WD close to the Chandrasekhar limit

Remaining problems

- The origin of high luminosities
  - CNO cycle on the surface of a WD?
  - Construction of new nova wind models including optically thin region
- Ignition mechanism
  - A small amount of the involved mass ~10^{-8} Msun
  - Dynamical?
    - Is Be star companion a key? Circumstellar disk

Novae with super-Eddington Luminosities?

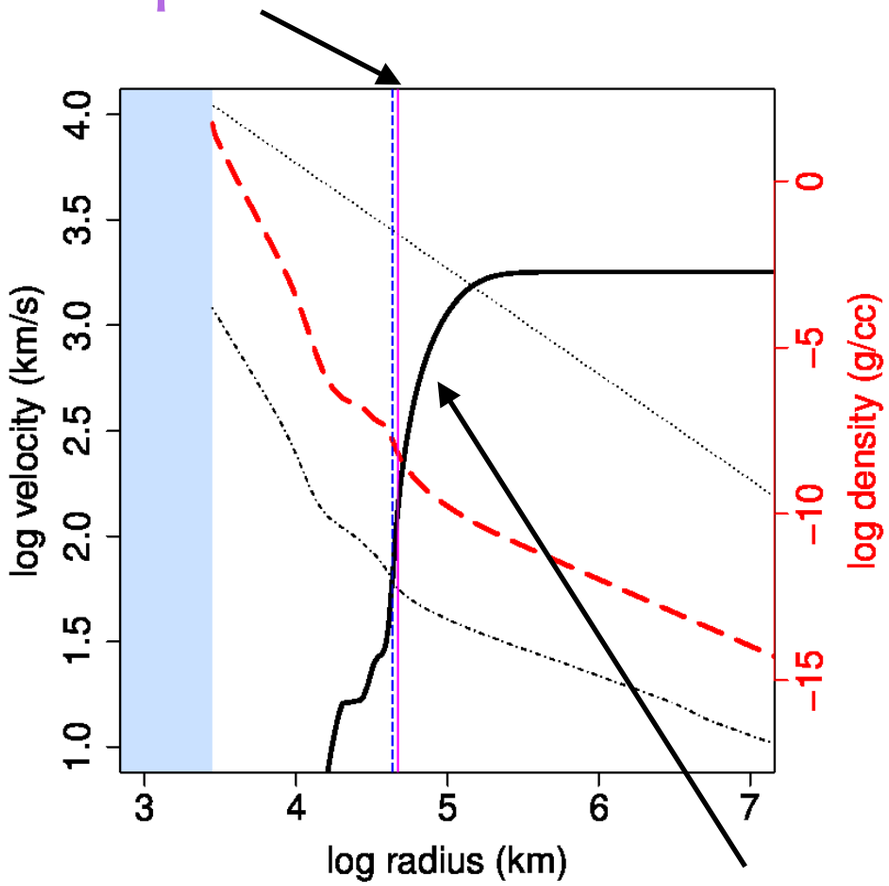
- Higher luminosity requires sonic point closer to the photosphere

- Extension of optically thick wind models (Wada & TS 2016)
  - including the optically thin region
    - relax the diffusion approximation in the flux calculation
    - M1-closure algorithm to calculate the flux in the optically thin region

High luminosity models

- A sequence of steady state models for each WD mass
- We obtain models
  - in which matter is accelerated outside of the photosphere
  - slightly brighter than previous models
- But
  - not so high velocities
  - not so luminous
- as MAXI J0158-744

photosphere and sonic point



acceleration

above the photosp

Wada & TS 2016

High luminosity models

highest luminosities attained by previous models

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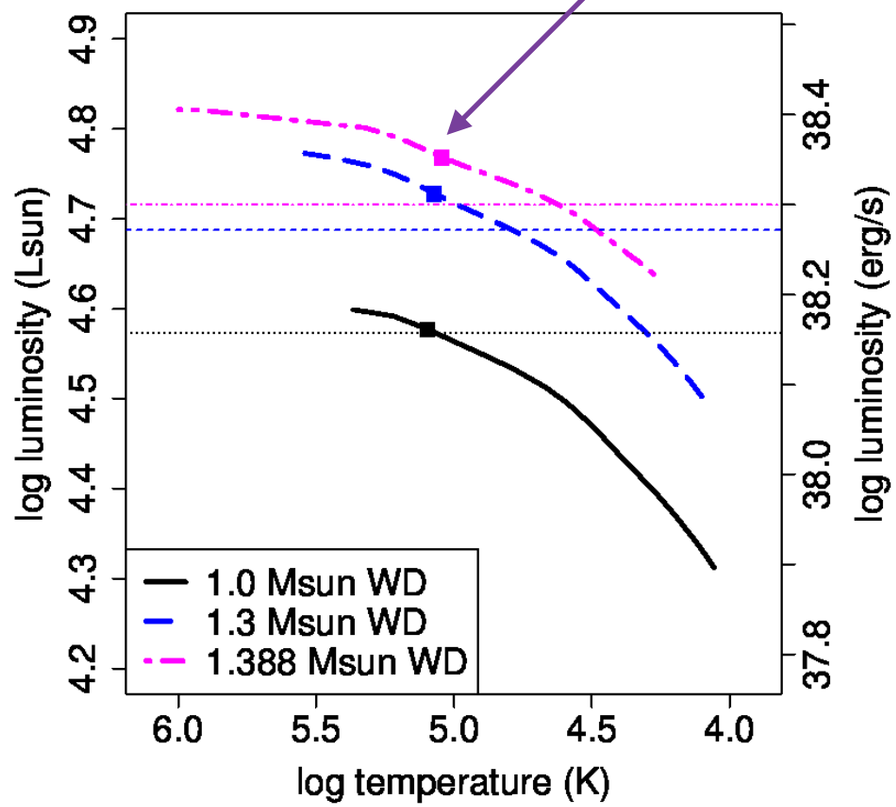

Wada & TS 2016

Future prospects

- Neutron star instead of White dwarf?
  - Be star companion indicates massive progenitor?
  - High velocity
  - Small photosphere
- Not in steady state?