Episodic SN Radio Light Curve Modulations from Luminous Blue Variable SN Progenitors

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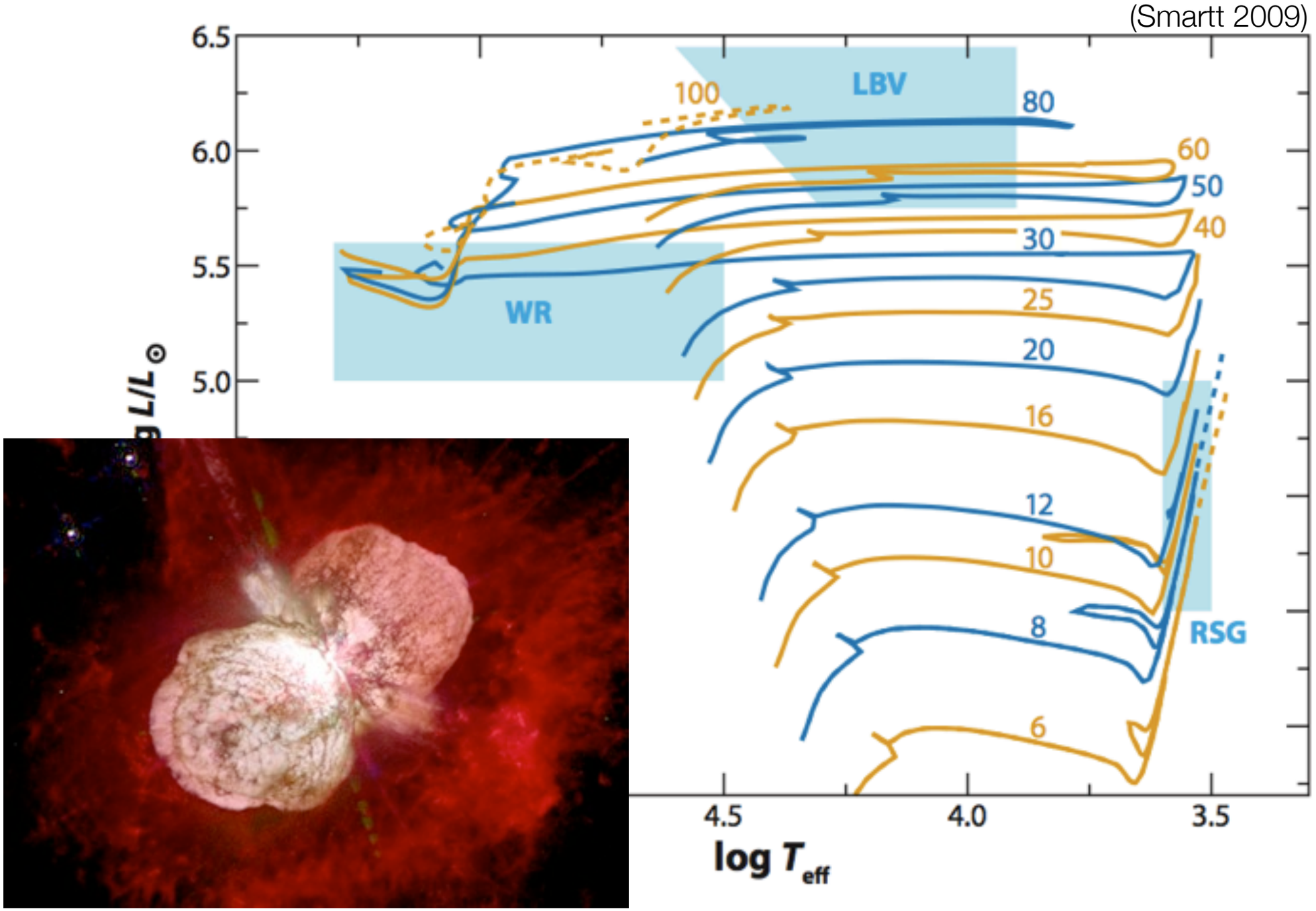
Luminous Blue Variables

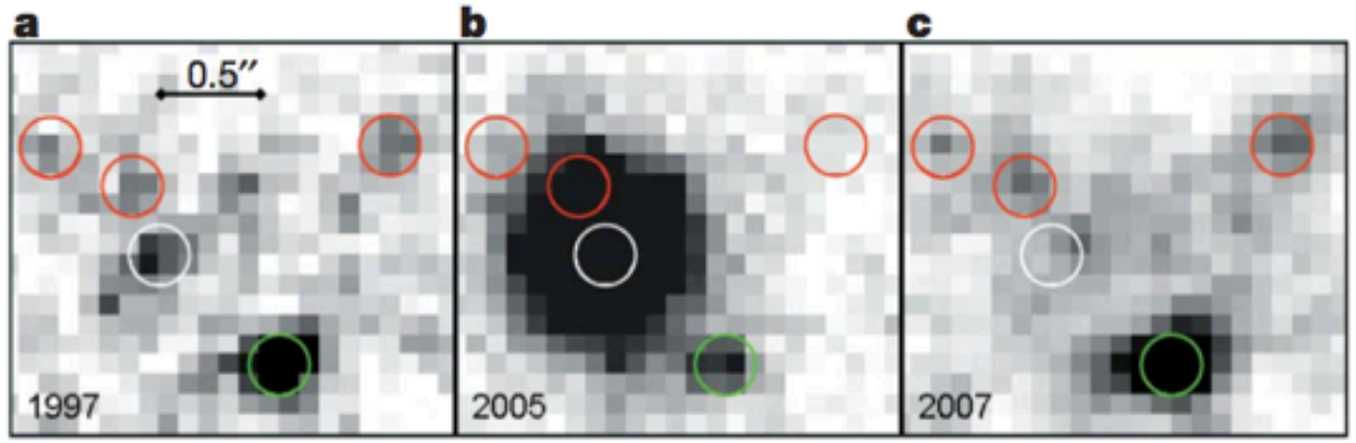
(Smartt 2009)



Luminous Blue Variables as SN Progenitors?

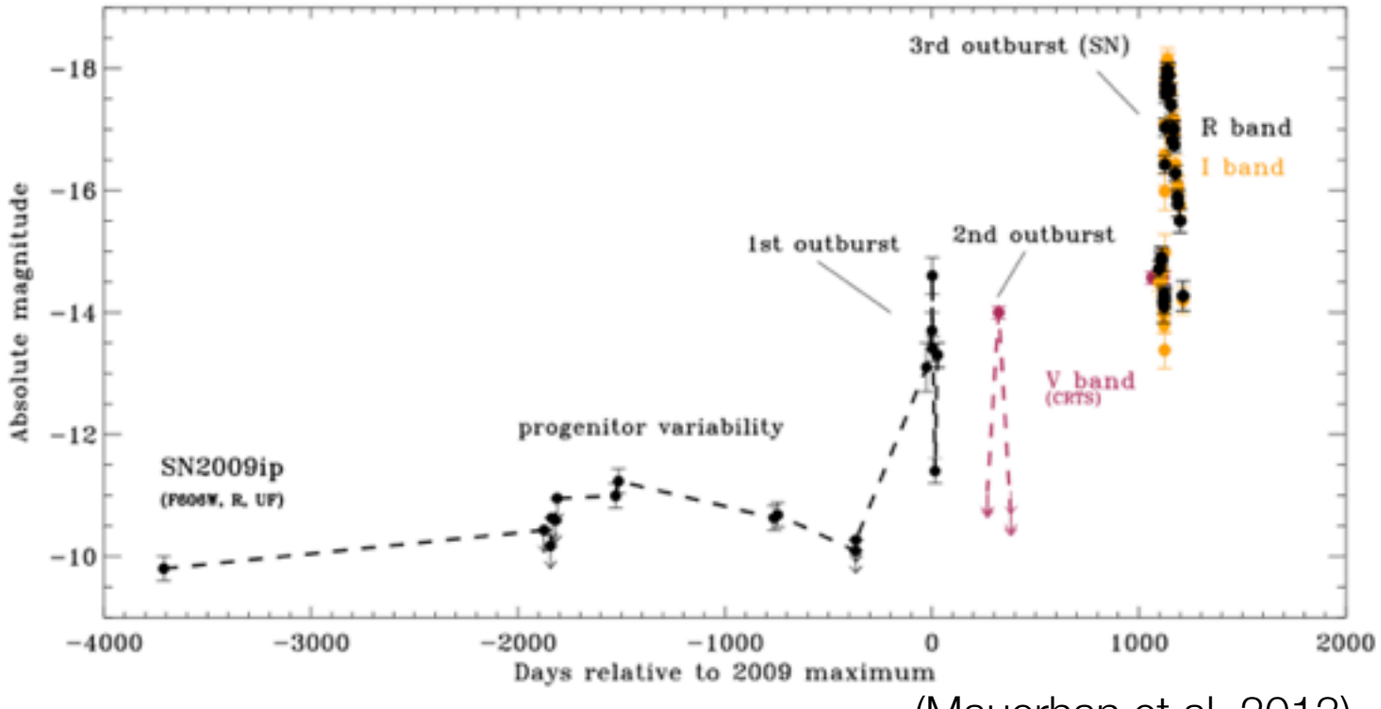
- Luminous Blue Variables detected in pre-explosion images (of SNe IIn)?
  - SN 2005gl

    $M_V \simeq -10$ mag



(Gal-Yam & Leonard 2009)

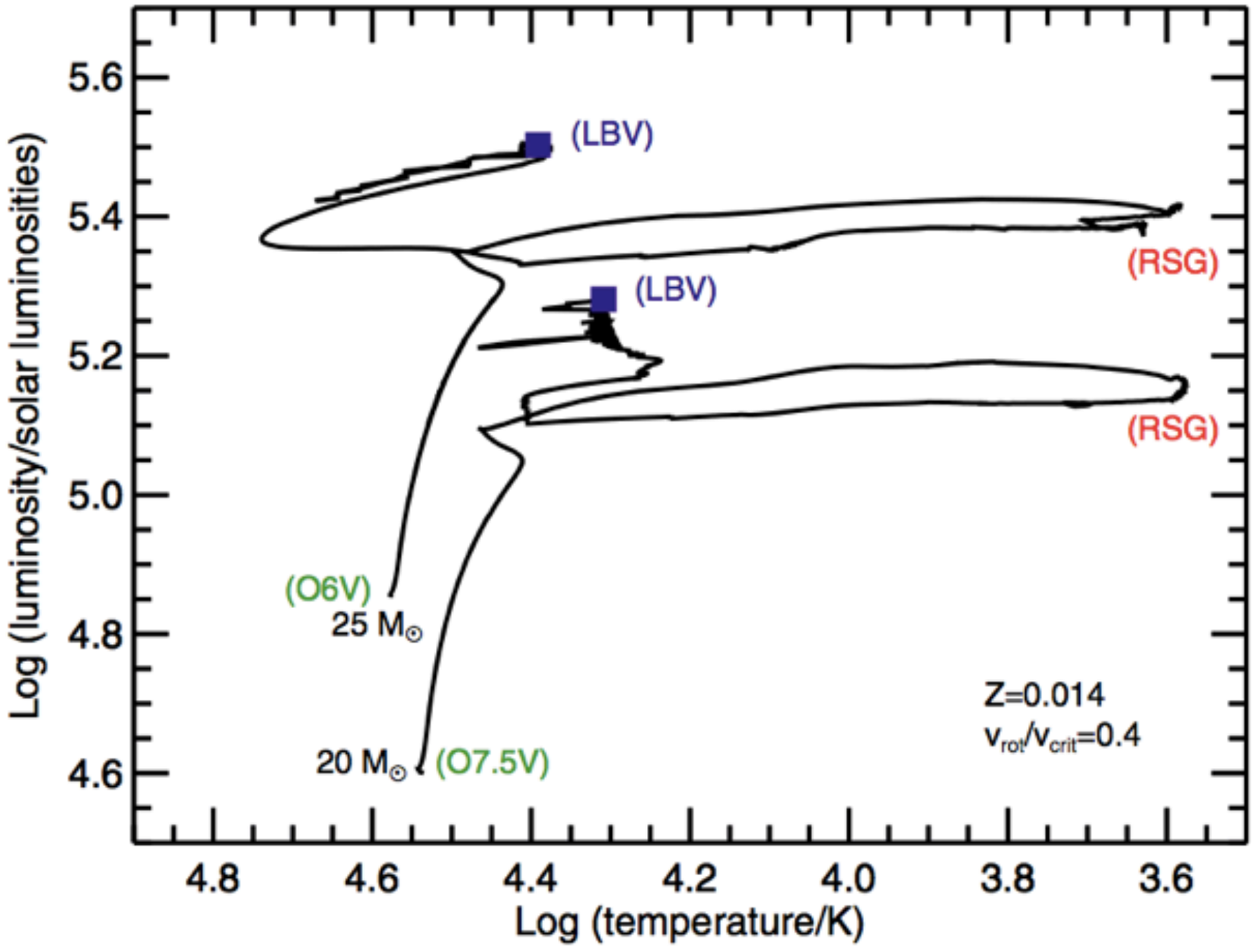
  - SN 2009ip



(Mauerhan et al. 2013)

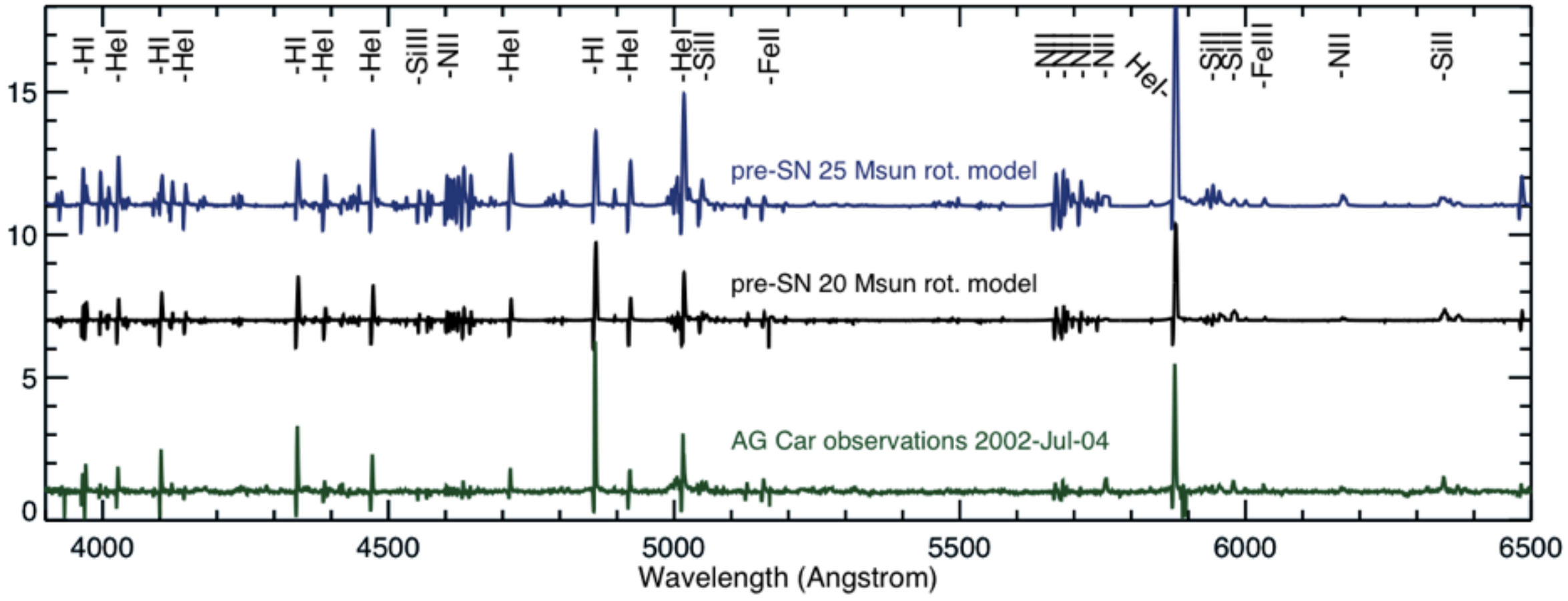
Theoretically Exploding Luminous Blue Variables

- Groh et al. (2013), Ekstrom et al. (2012)



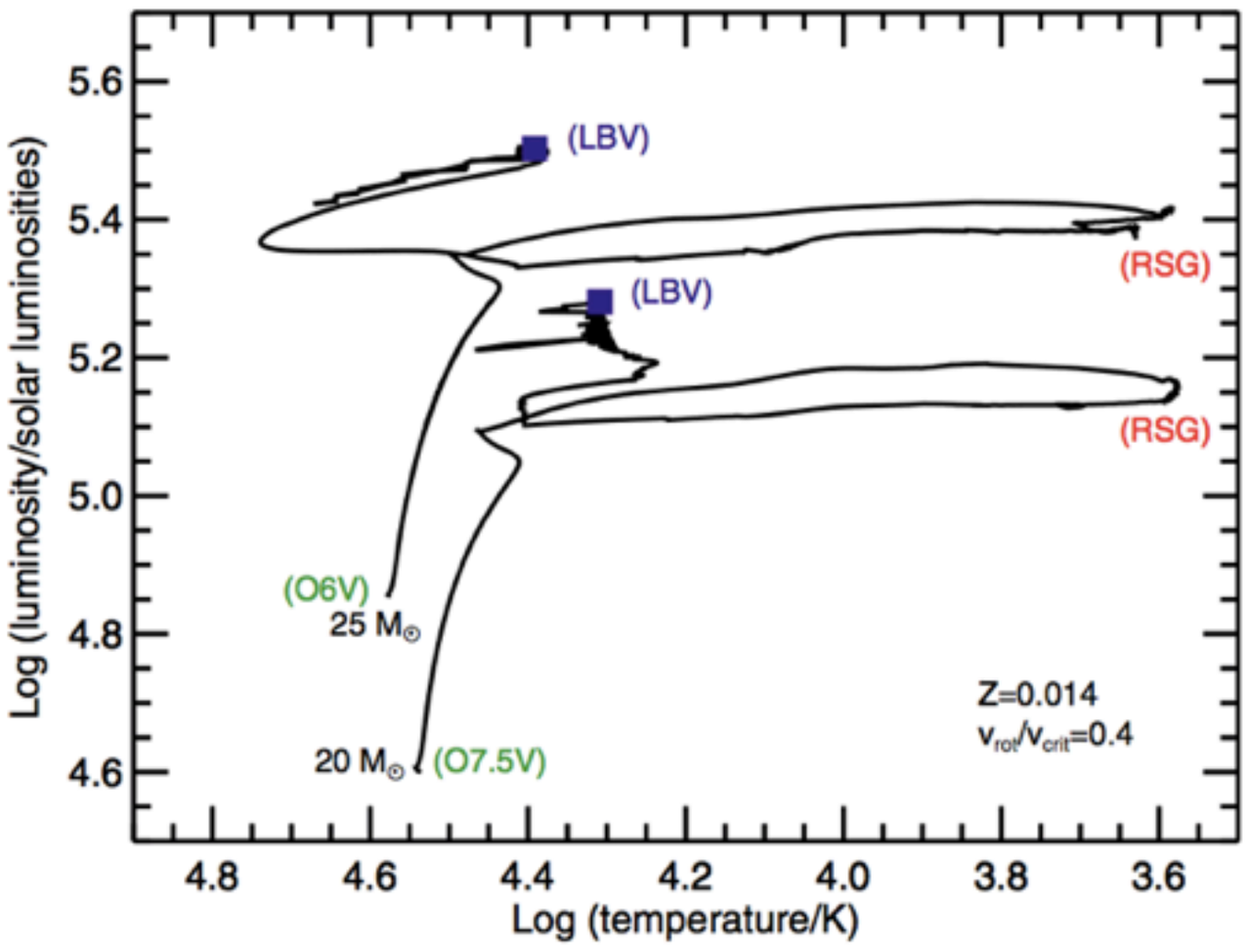
Theoretically Exploding Luminous Blue Variables

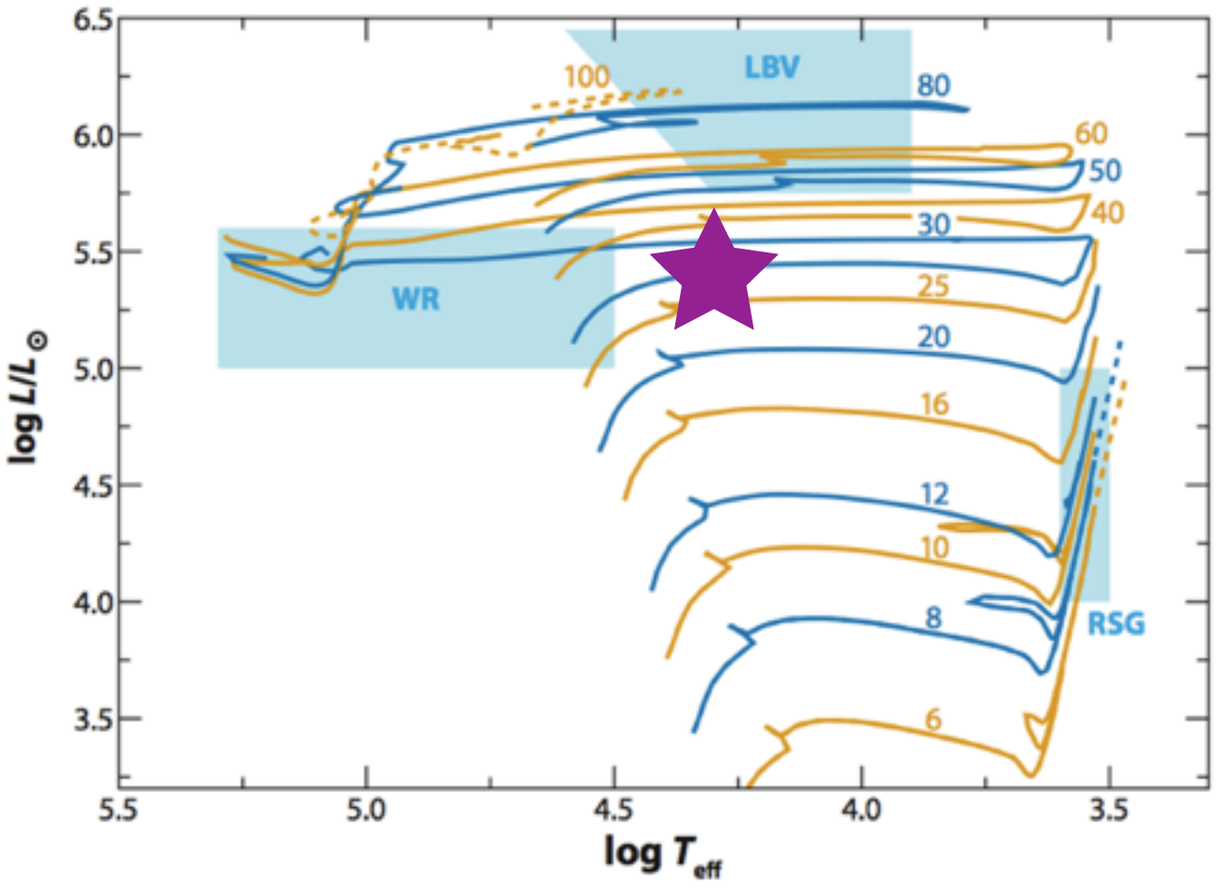
- Groh et al. (2013)
  - Low mass (20-25 Msun) rotating stars can be LBVs at pre-SN stage!



Theoretically Exploding Luminous Blue Variables

- **SN IIb** progenitor (Groh et al. 2013)



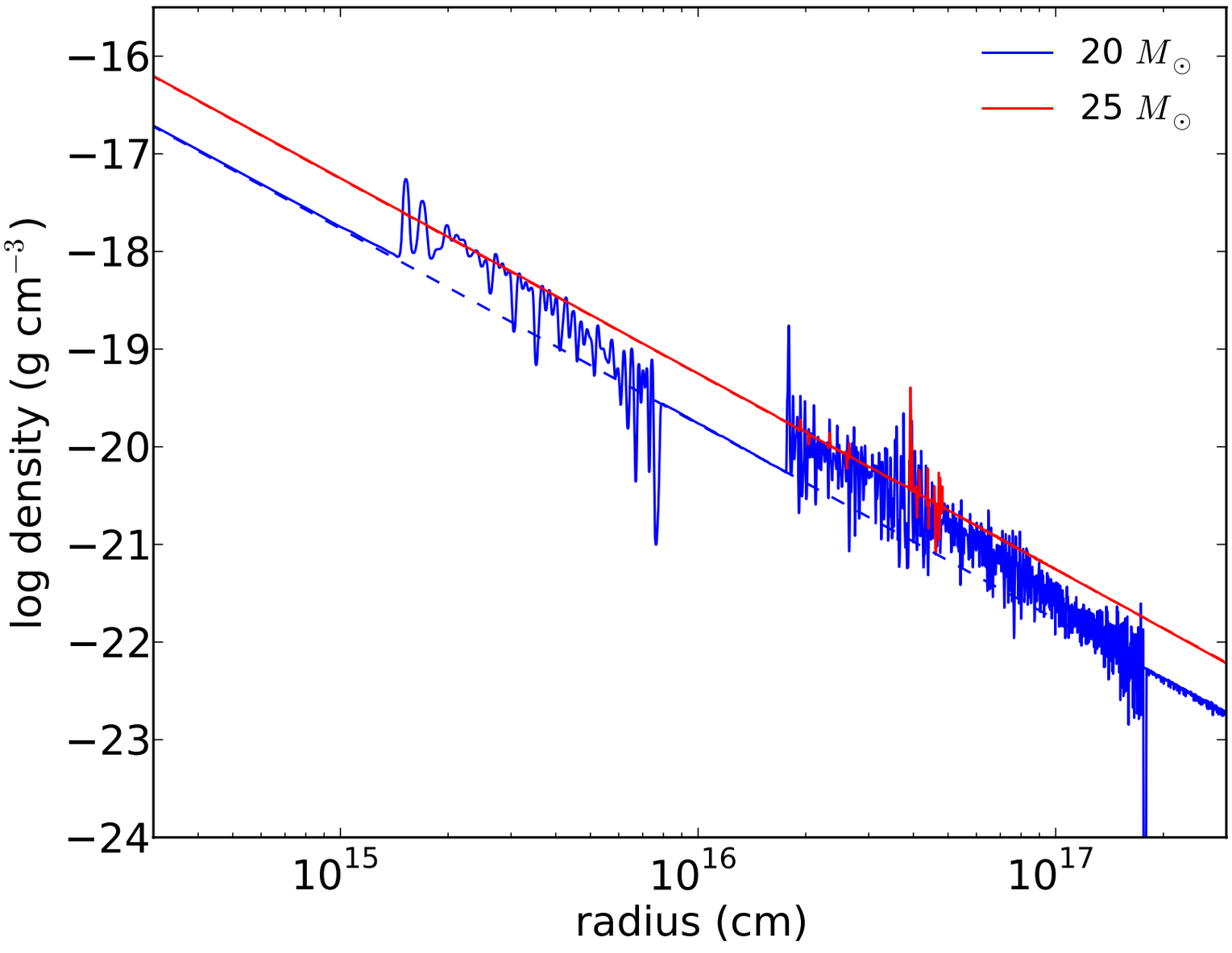


CSM Properties?

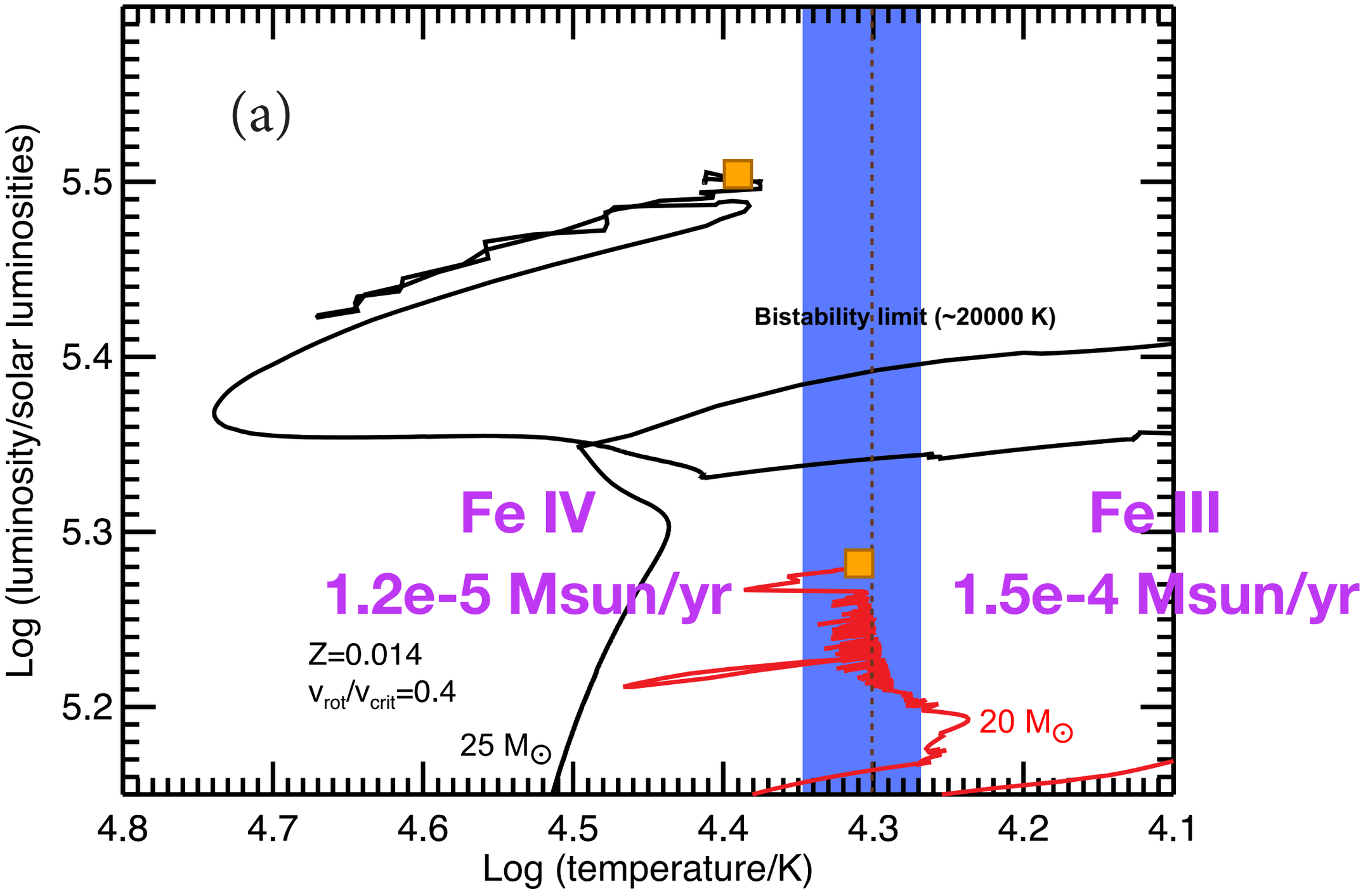
Are there any characteristic signatures?

Theoretically Exploding Luminous Blue Variables

- CSM density structures
  - ~ 1e-5 - 1e-4 Msun/yr (~ 300 km/s): density is too low to be SNe IIn..

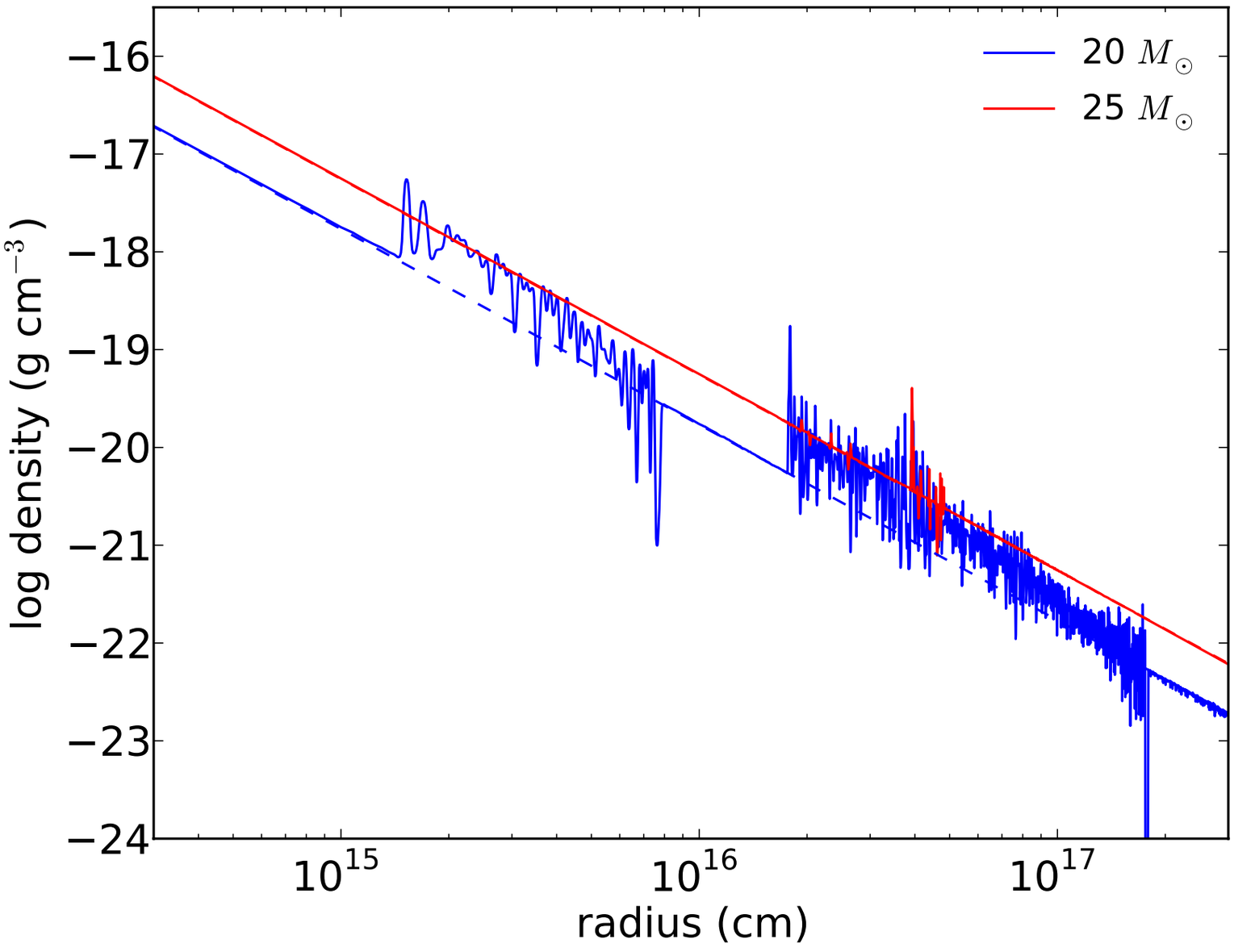


Rotating 20 Msun Pre-SN Model at Bistability Limit



Exploding Luminous Blue Variables

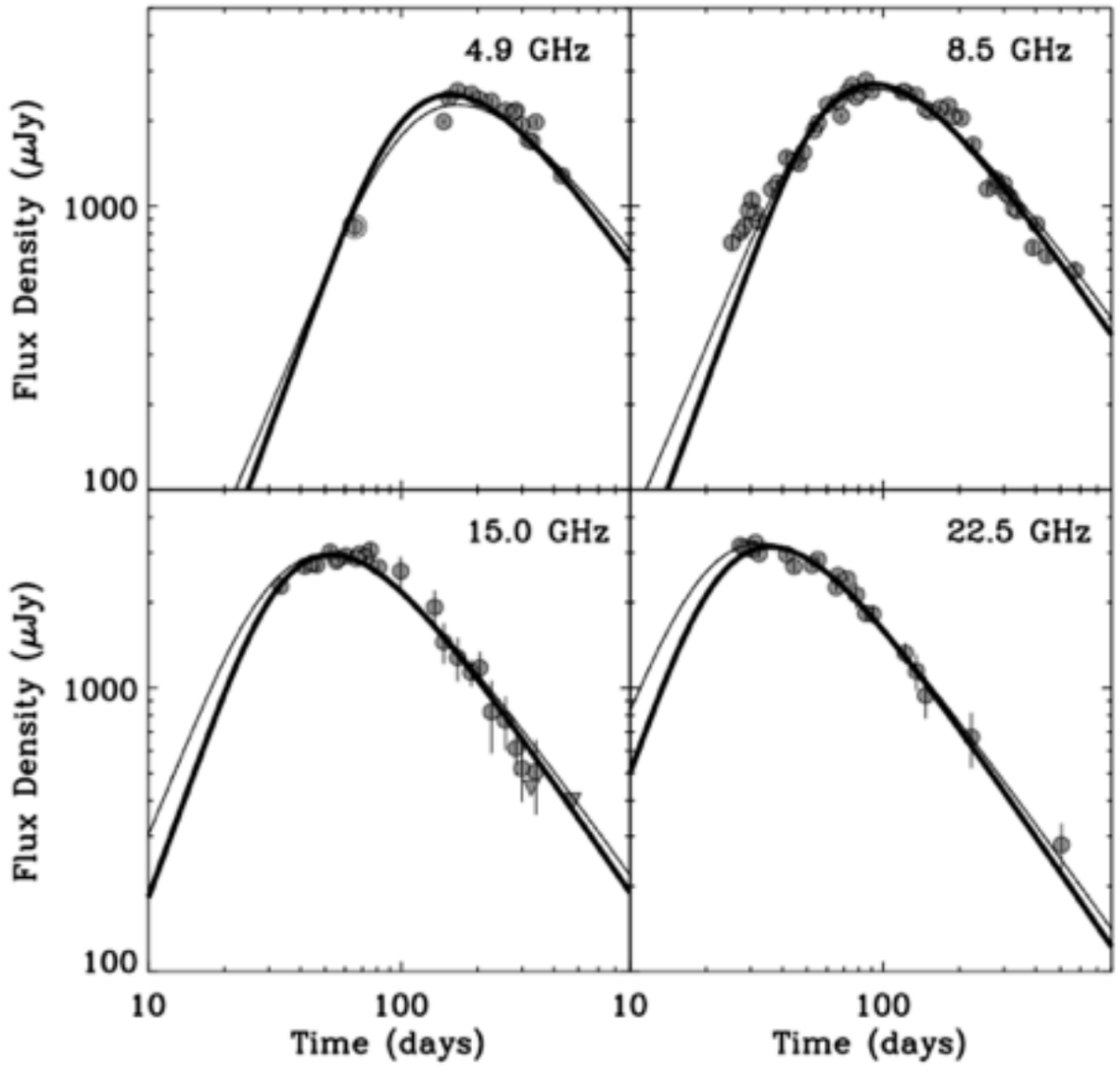
- CSM density structure
  - mass-loss variations at ~175-20 years and ~10-1 years before explosion



Theoretically Exploding Luminous Blue Variables

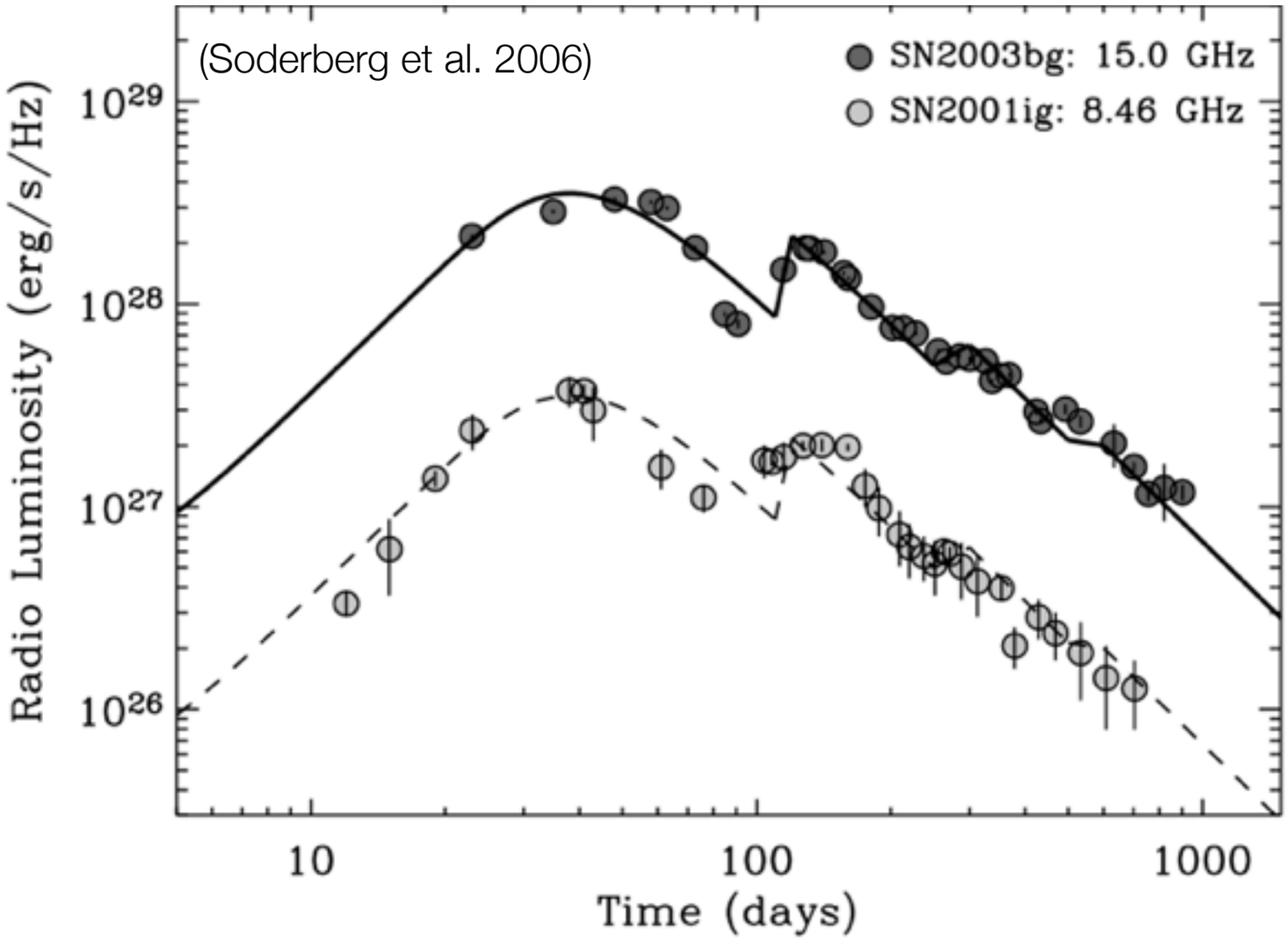
- SN radio LCs
  - synchrotron emission from accelerated electrons at forward shock
  - CSM properties are imprinted in radio LCs

(Soderberg et al. 2005)



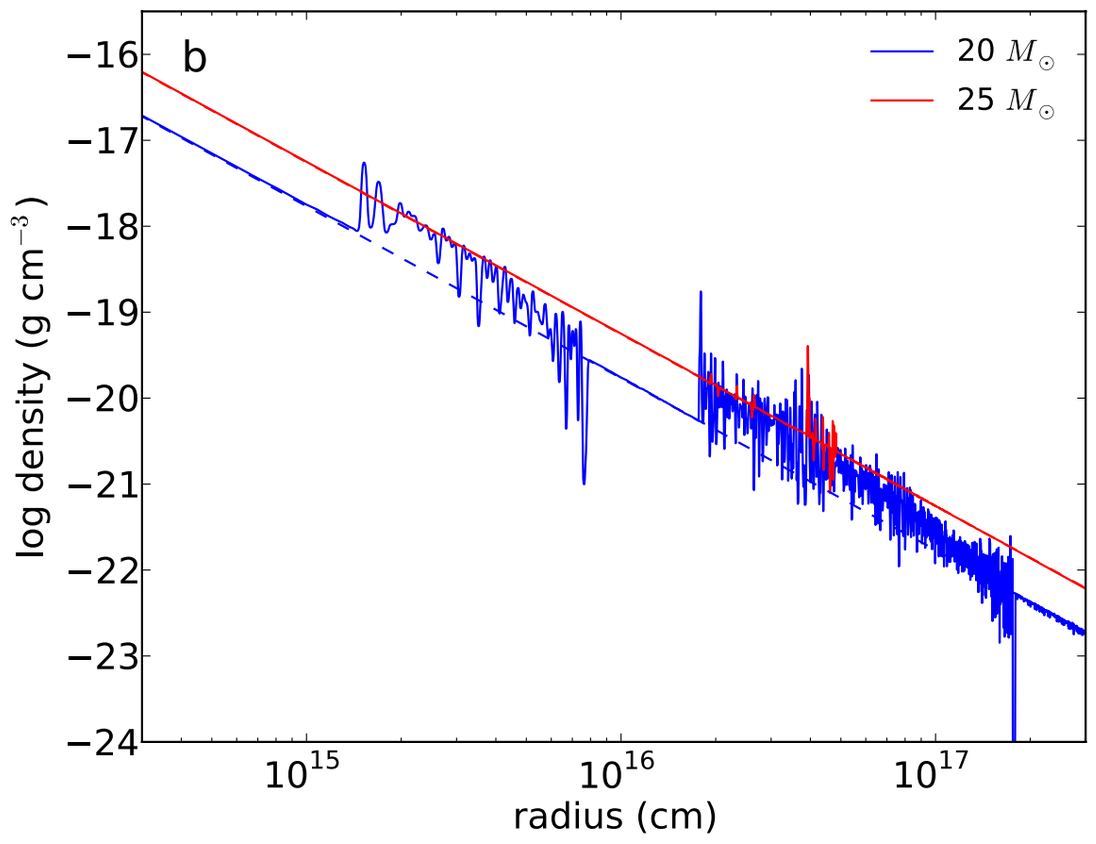
Exploding Luminous Blue Variables

- Episodic radio LC variabilities
  - Observed in some SNe IIb, GRB-SN Ic
  - Kotak & Vink (2006) discussed a possible connection to LBVs



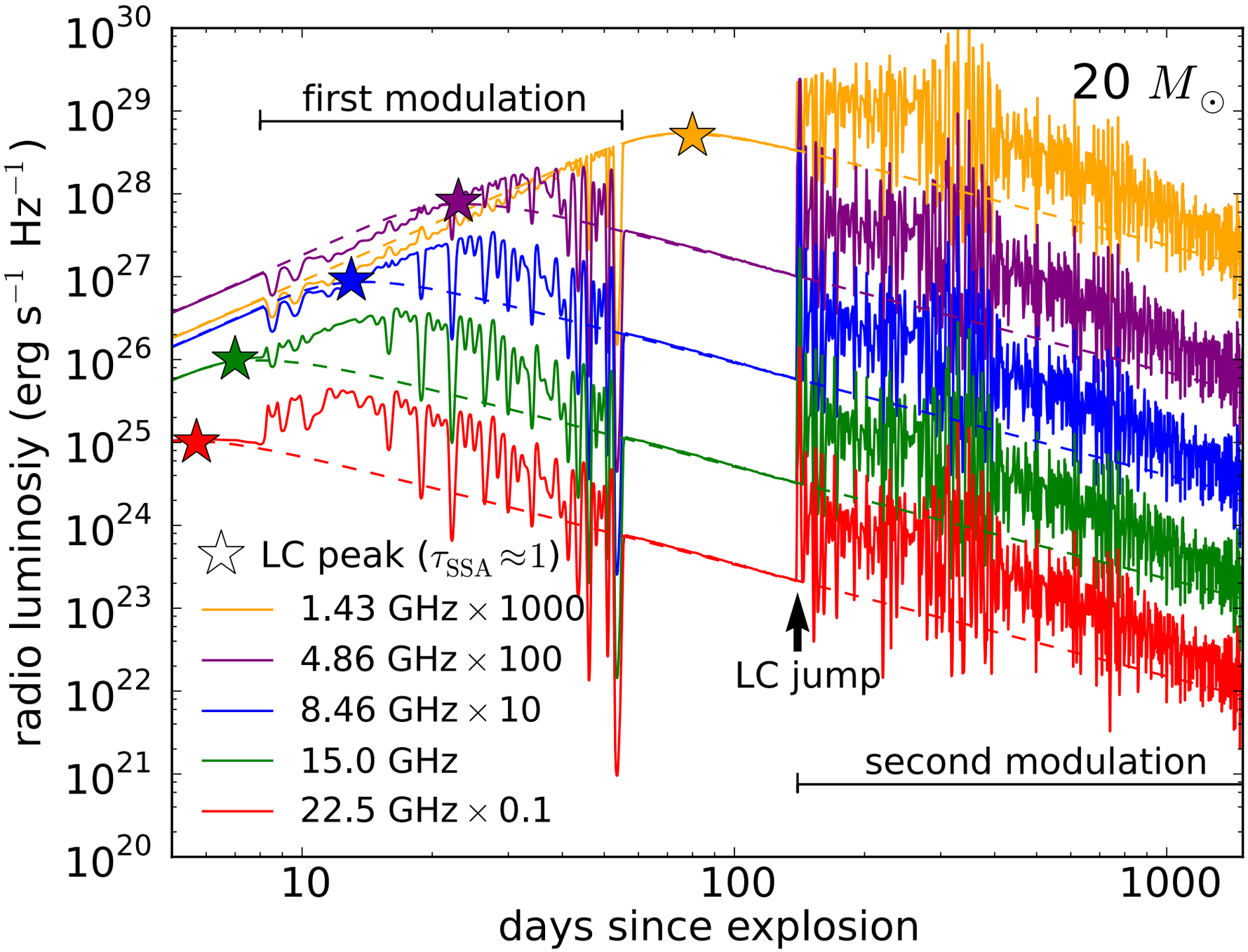
SN Radio LC Modeling

- Synchrotron emission + synchrotron self-absorption
  - Fransson & Bjornsson (1998), Chevalier (1998), etc.
  - with standard parameters: p = 3 ($\frac{dn_{\rm re}}{d\gamma} \propto \gamma^{-p}$), ε_B ~ 0.1, ε_e ~ 0.1
- 20 Msun pre-SN model
  - 7.1 Msun (Mej = 5.7 Msun), 35 Rsun
  - Self-similar solution of Chevalier (1982)



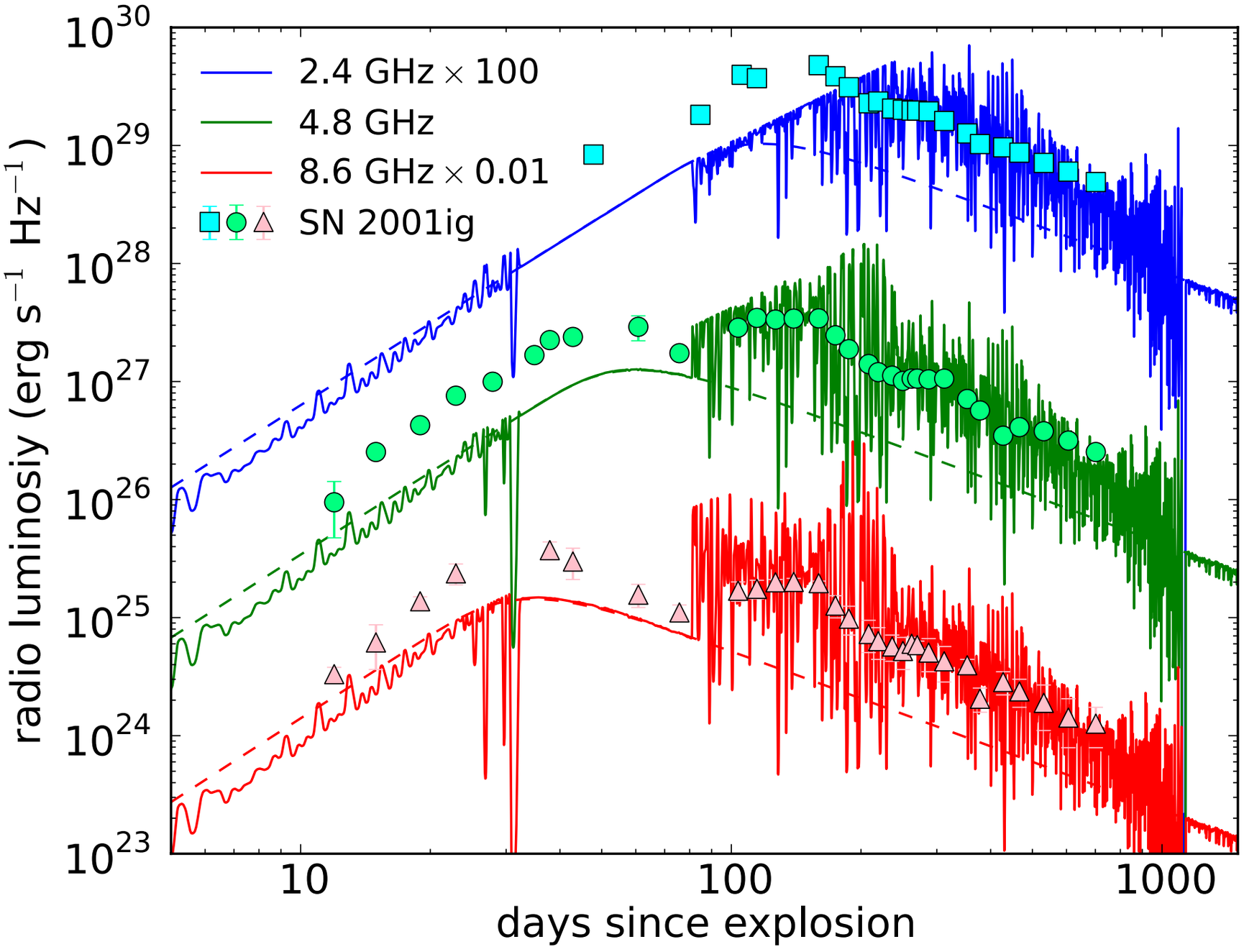
Radio LC from the Rotating 20 Msun Model

- Eej = 1e51 erg



Comparison to SN IIb 2001ig (Ryder et al. 2004)

- Eej = 4e51 erg, CSM density x 3

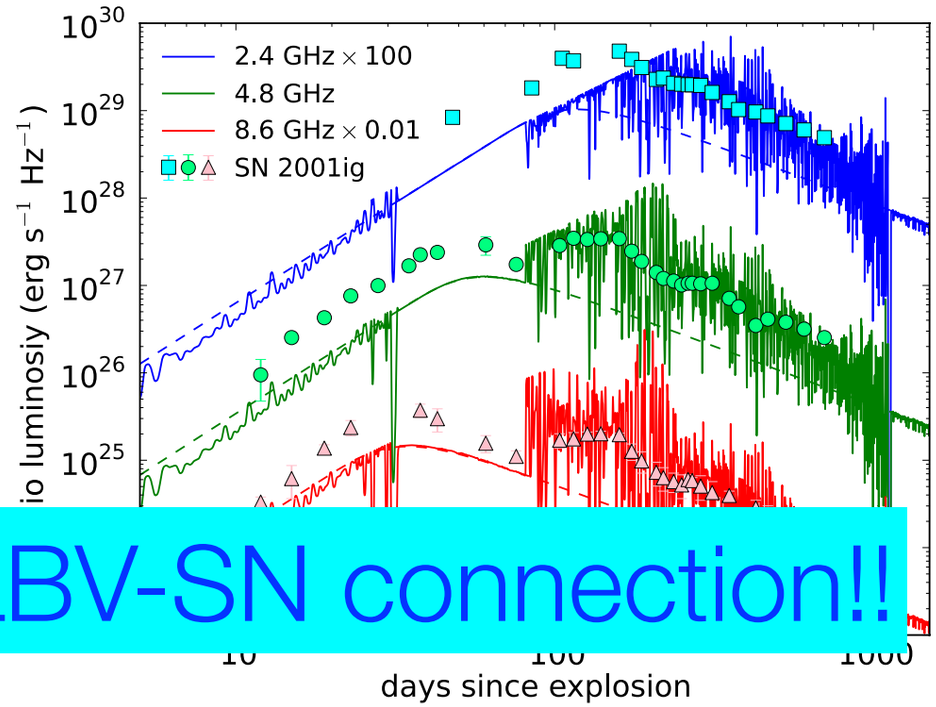


LBVs as Common SN Progenitors?

- SNe with radio ‘bumps’ from LBV progenitors
  - observation
    - relation to LBVs suggested by Kotak & Vink (2006)
  - theory
    - 20 Msun rotating LBV SN progenitor from Geneva
      - SN IIb progenitor (from surface composition)
      - shows a radio bump, consistent with some SNe IIb (e.g. SN 2001ig)
- LBVs are related to not only SNe IIn but also some SNe IIb and maybe others
  - other SNe radio bumps include..
    - broad-line SN Ic 1998bw (Kulkarni et al. 1998)
    - SN IIL 1979C (Weiler et al. 1992)

Summary

- Low mass rotating stars can be LBVs
  - They can be LBVs at the time of their explosion!
- Their mass-loss rates is not enough to be SNe IIn
  - Luminosity is too low to be the observed SN IIn progenitor (e.g. SN 2005gl)
- They can explain radio LC variations in some SNe IIb (e.g. SN 2001ig)
  - LBVs as progenitors of other SN types
    - a part of SNe IIb is from LBVs?
  - LBVs may be common SN progenitors



First theoretically established LBV-SN connection!!