

Emission Lines From Tidally Disrupted White Dwarfs and Other Evolved Stars

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Tidal Disruption Events

- ❖ For stars initially on parabolic trajectories, half of the disrupted star is accreted, producing a bright UV / X-ray flare
e.g., Frank & Rees (1976), Lacy+ (1982), Ulmer (1999), Guillochon+ (2012), Komossa & Greiner (1999), Gezari+ (2006, 2008, 2009, 2012), Maksym+ (2010), and many others
- ❖ How do we identify TDEs?
- ❖ How can we determine
 - ❖ mass / spin of the BH?
 - ❖ properties of the disrupted star?



NASA / Goddard Space Flight Center / Swift

Emission Lines in the Debris

Emission lines are produced in the photoionized debris.

Bogdanovic+ (2004)

Strubbe & Quataert (2009)

Models:

- *Analytic prescriptions for dynamical evolution of the unbound debris

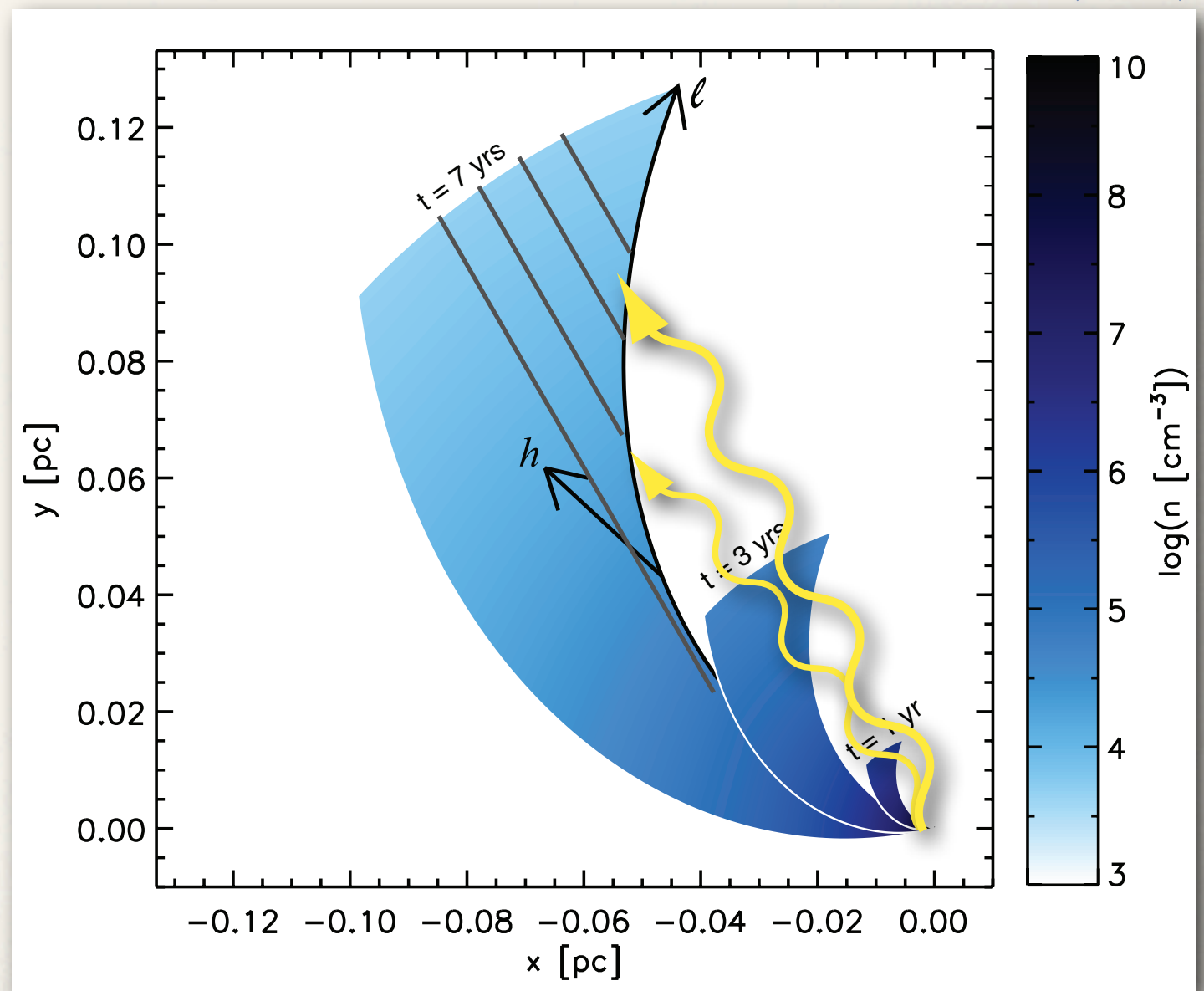
- * $\dot{M} \sim \dot{M}_{\text{fb}} \propto t^{-5/3}$

Phinney (1989), Reese (1988)

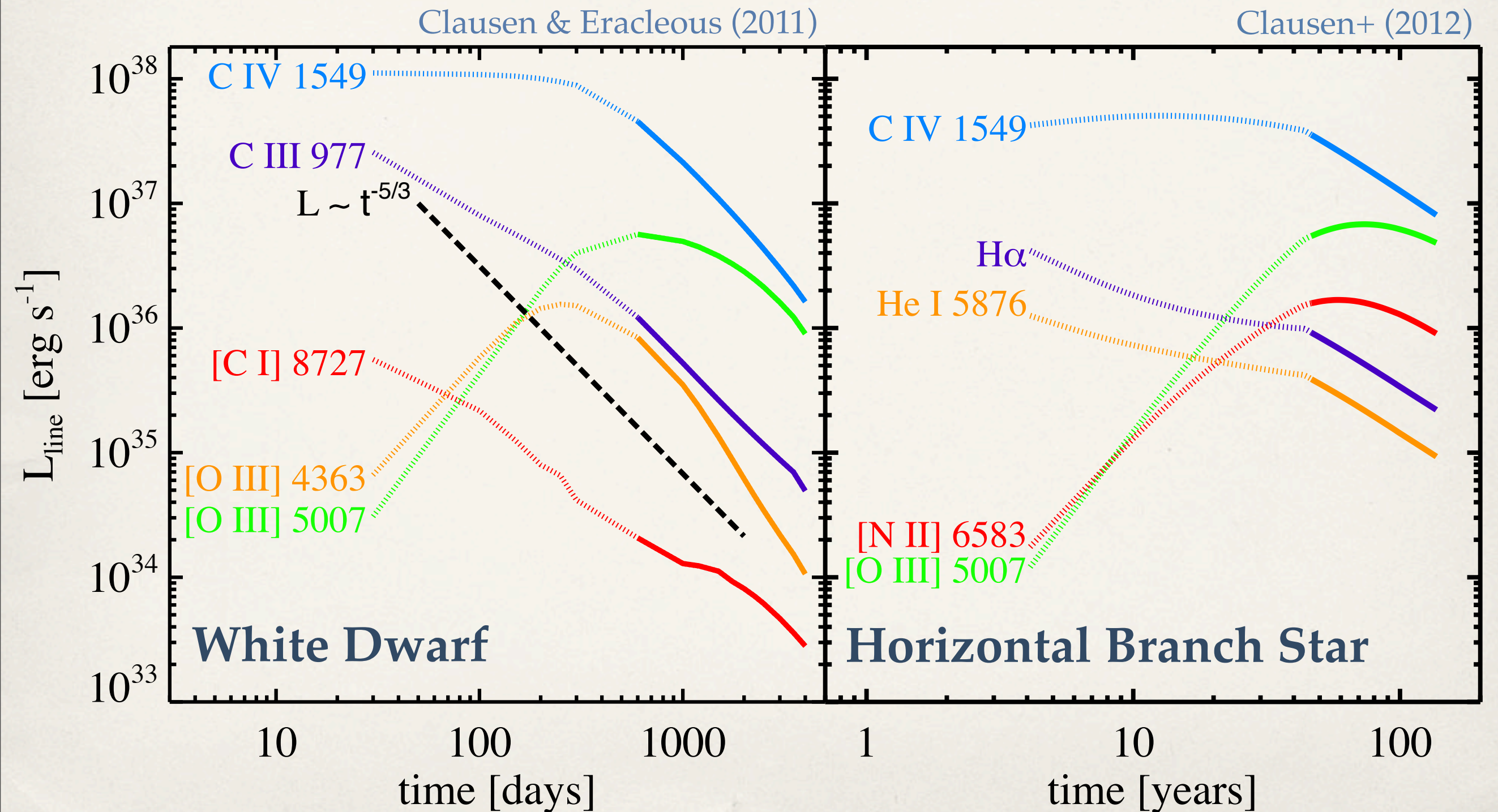
- **Cloudy* photoionization models

Ferland+ (1998)

Clausen & Eracleous (2011)

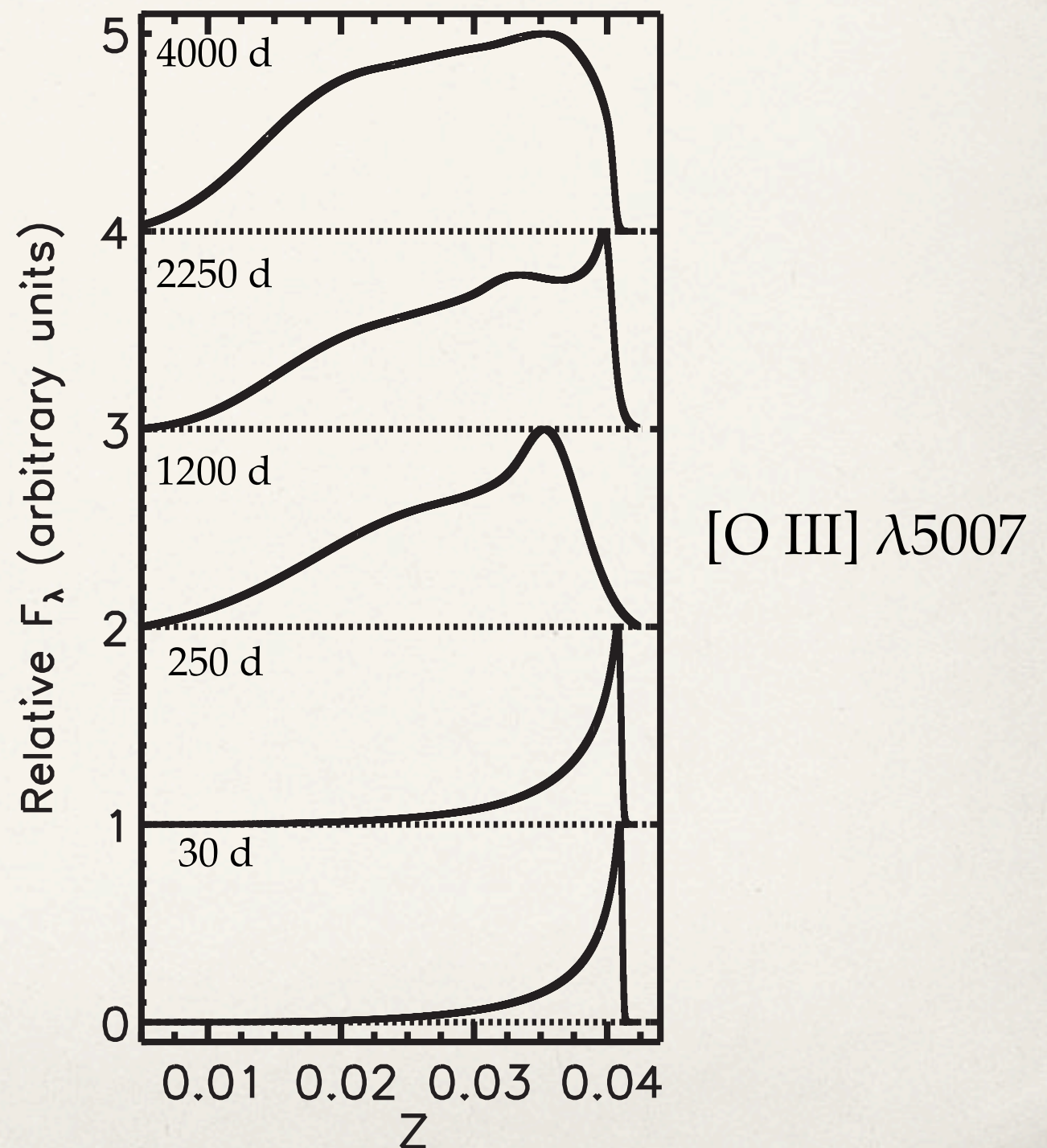


Emission Line Light Curves



Emission Line Profiles

- ❖ Significant changes in the line profile as the ionization state of the debris changes
- ❖ Asymmetric profiles
- ❖ Width and offset of the emission lines are dependent on the orientation of the observer
- ❖ Lines can be extremely broad with FWHM 2000-3000 km s⁻¹



Have we seen a WD TDE?

RZ 2109

- ❖ Globular cluster associated with NGC 4472

- ❖ Hosts a bright X-ray source that was the first firm BH candidate in a globular cluster

Maccarone+ (2007)

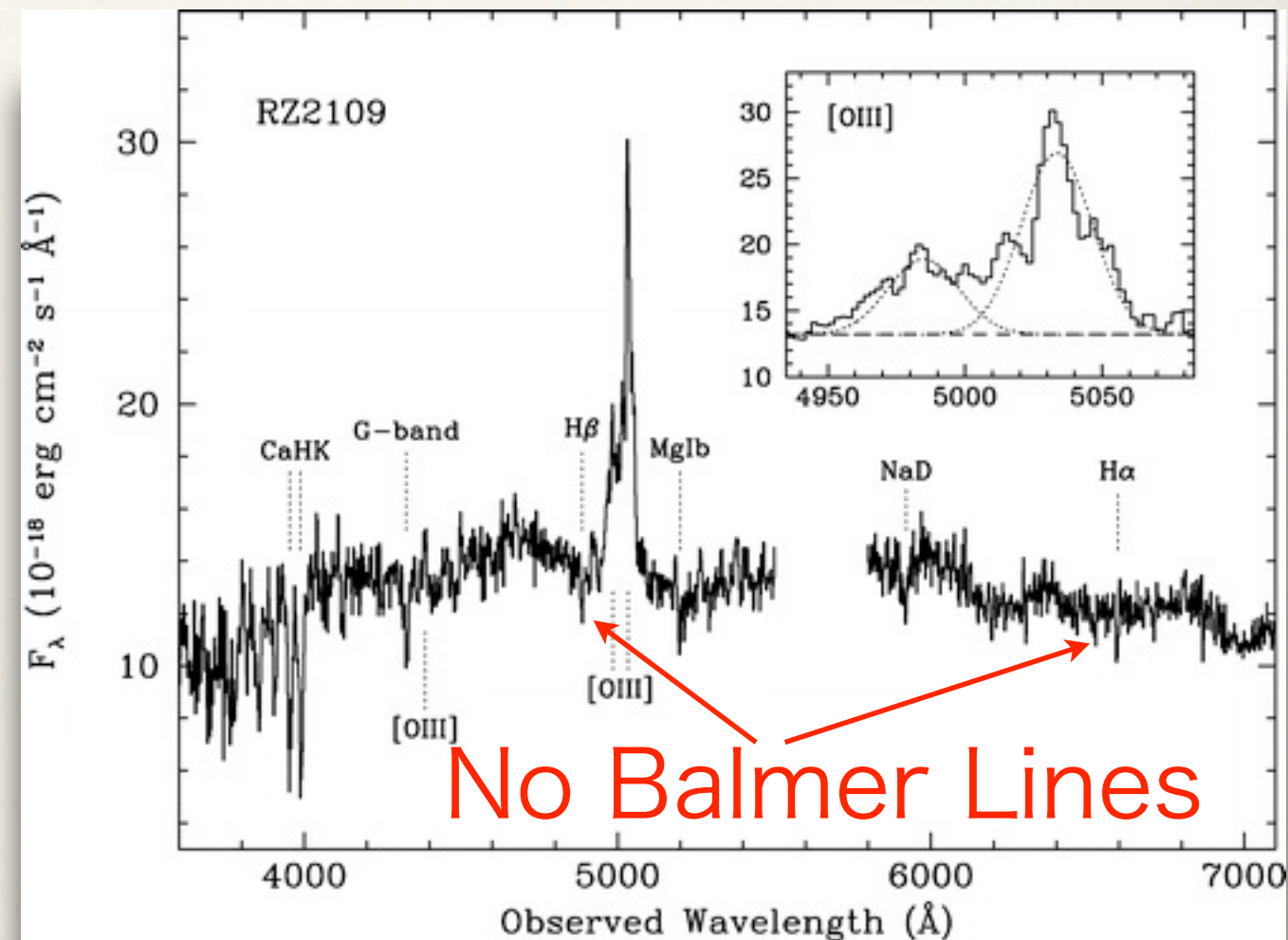
- ❖ Optical spectroscopy revealed:

- ▶ $L_{[\text{O III}]} = 1.4 \times 10^{37} \text{ erg s}^{-1}$

- ▶ Line width $\sim 2000 \text{ km s}^{-1}$

Zepf+ (2008)

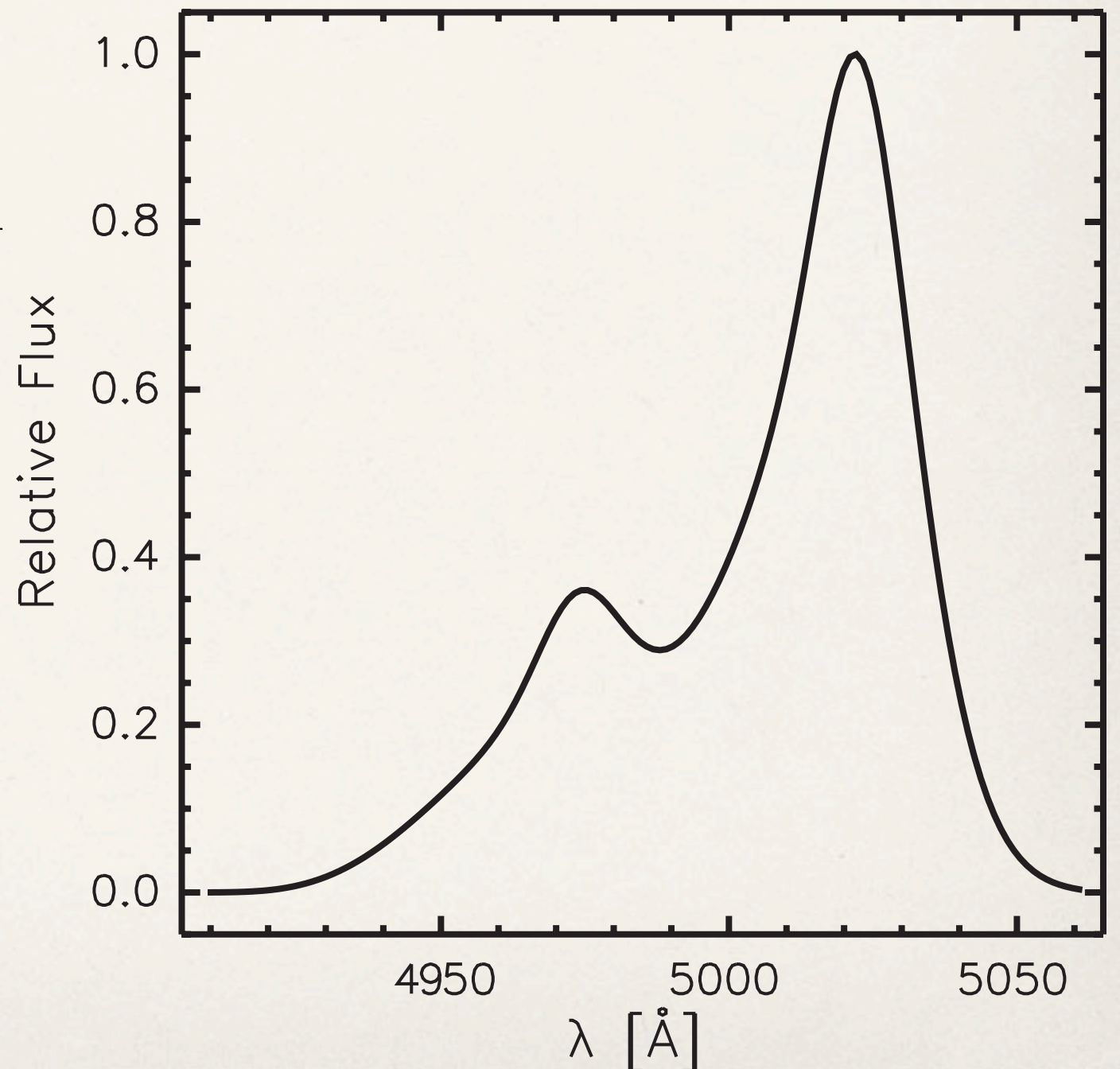
Zepf+ (2008)



Have we seen a WD TDE?

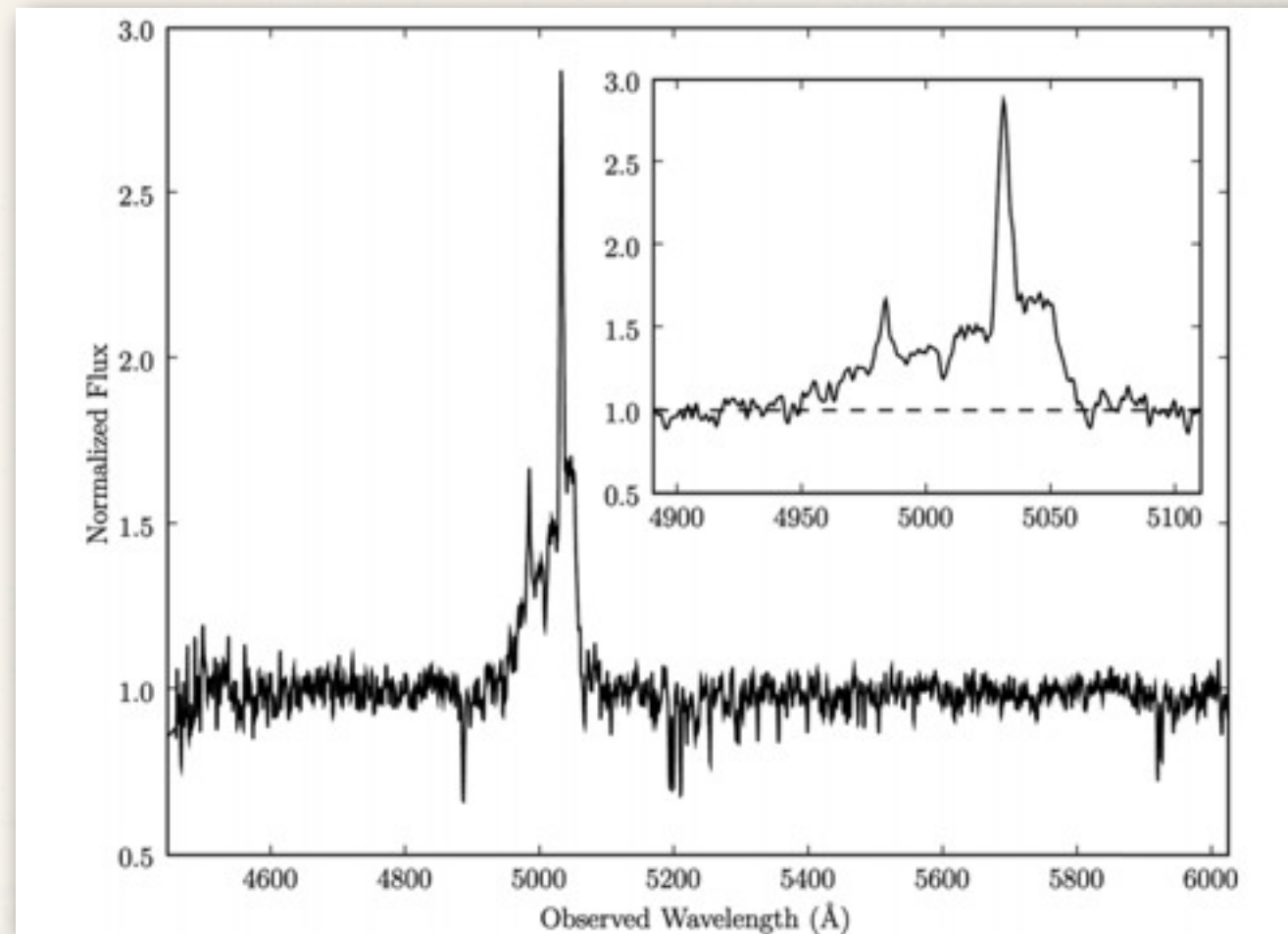
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But...

- ❖ X-ray source detected with ROSAT in 1994
[Colbert & Ptak \(2002\)](#)
 - ▶ [O III] line observed at least 14 years after the TDE, models predict 2 years
- ❖ X-ray source was not detected in *Chandra* or *Swift* observations in 2008 and 2010
[Maccarone+ \(2010\)](#)
- ❖ [O III] emission has a half-light radius of 3-7 pc
[Peacock+ \(2012\)](#)
 - ▶ See Peacock+ poster 113.03

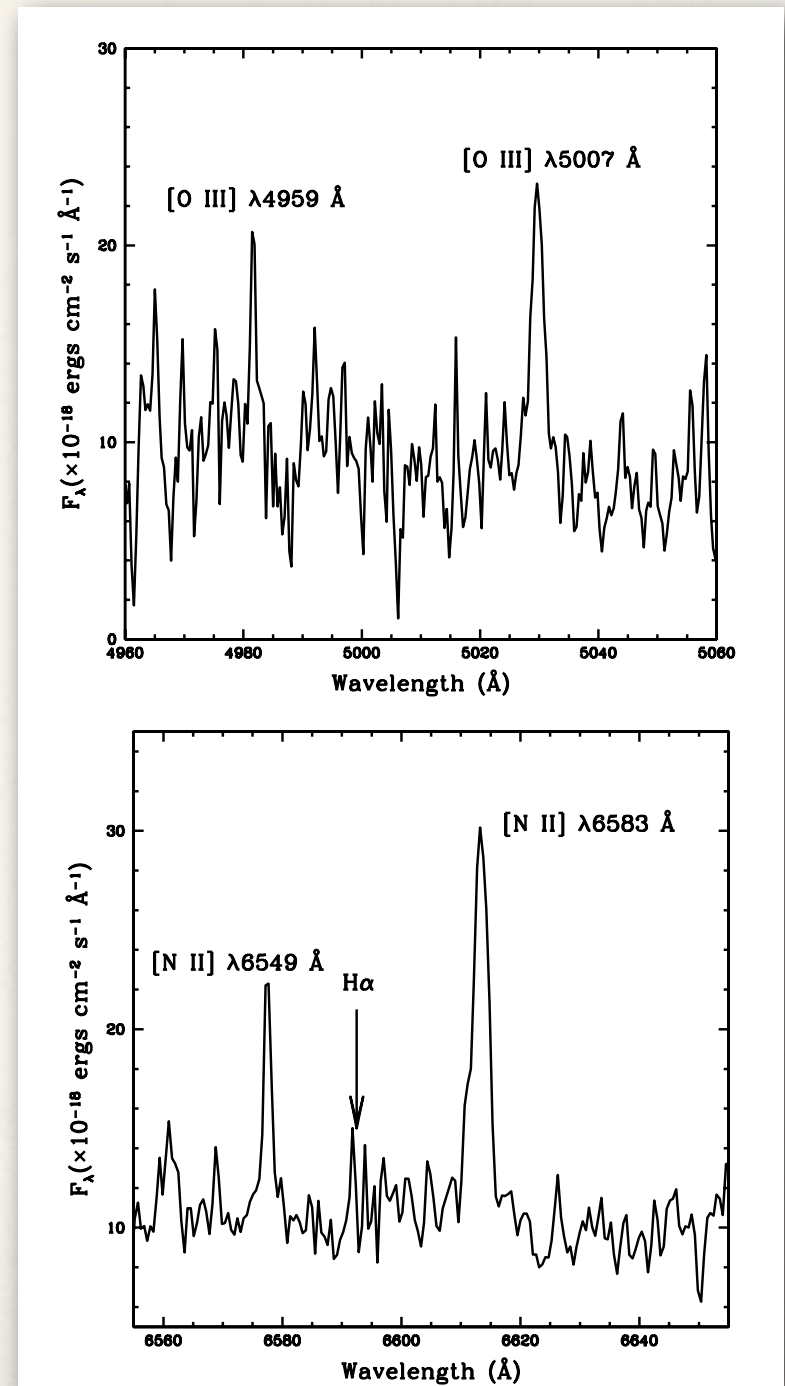


[Steele+ \(2011\)](#)

Horizontal Branch Star TDE?

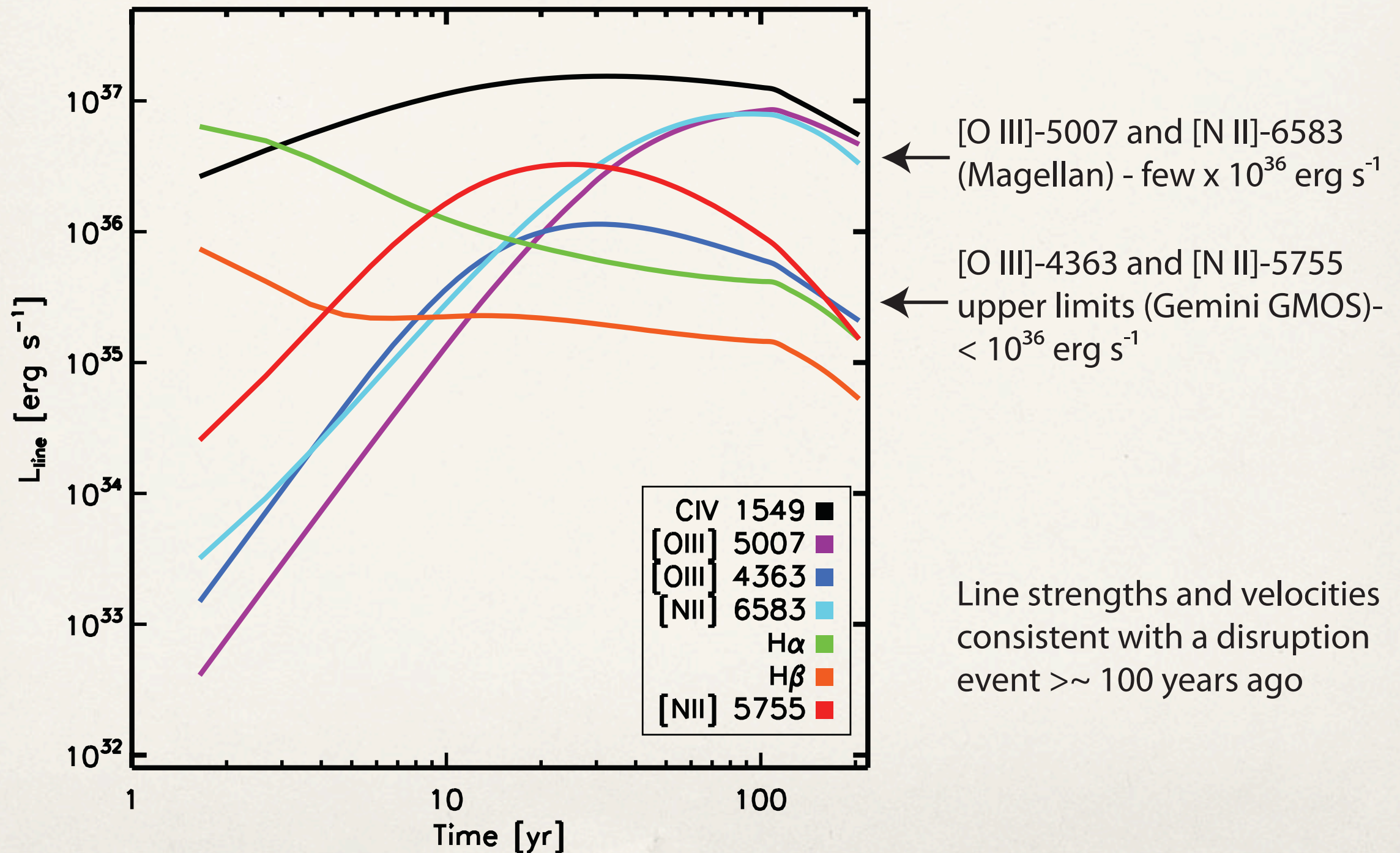
NGC 1399 globular cluster:

- ❖ Hosts an X-ray source with $L_x = 2 \times 10^{39} \text{ erg s}^{-1}$
- ❖ Optical spectroscopy revealed:
 - ▶ $L_{[\text{O III}]} = \text{few} \times 10^{36} \text{ erg s}^{-1}$
 - ▶ $L_{[\text{N II}]} = \text{few} \times 10^{36} \text{ erg s}^{-1}$
 - ▶ No Balmer lines
Irwin+ (2010)



Irwin+ (2010)

Horizontal Branch Star TDE?



Horizontal Branch Star TDE?

BH mass:

$30 M_{\odot}$

$50 M_{\odot}$

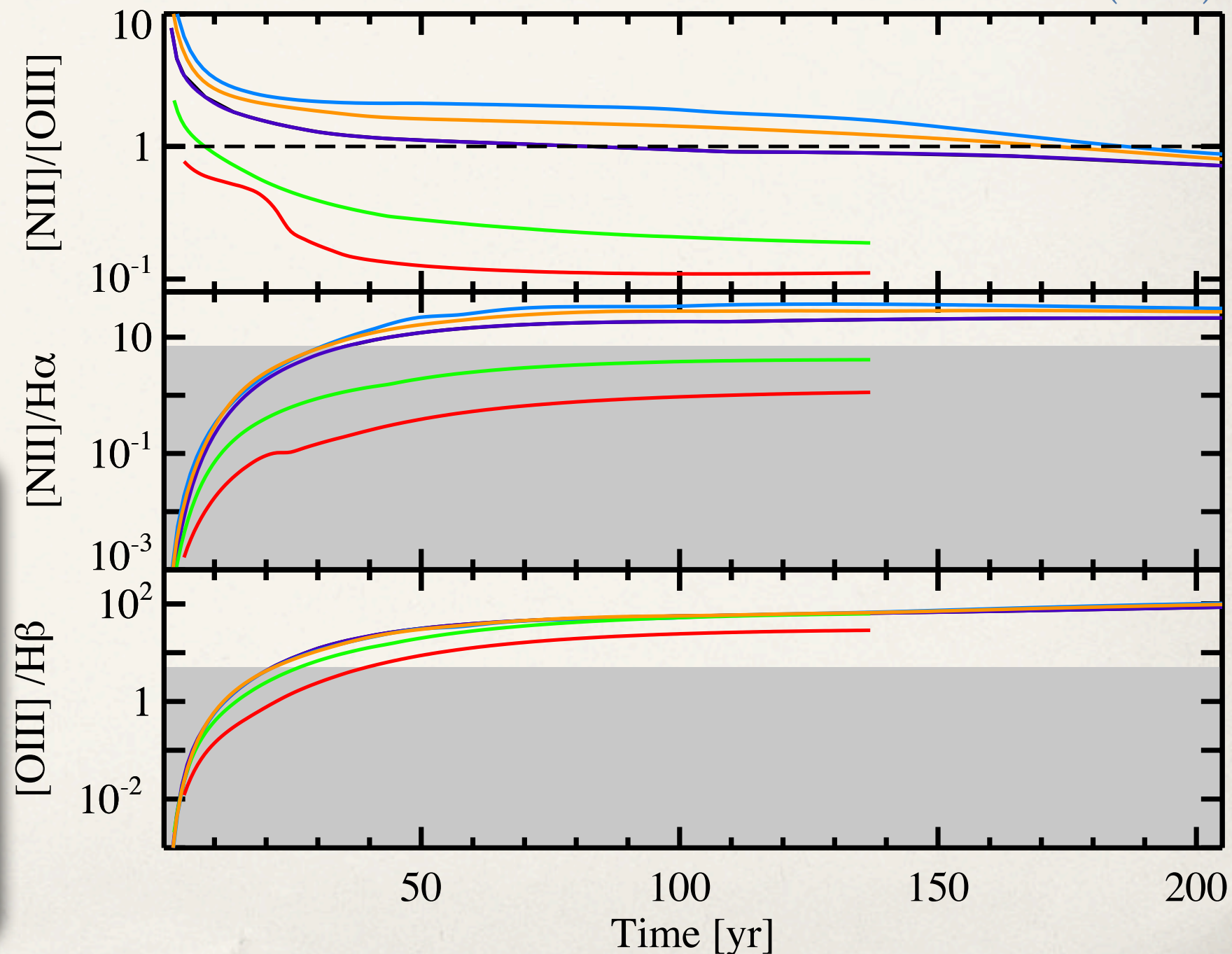
$10^2 M_{\odot}$

$10^3 M_{\odot}$

$10^4 M_{\odot}$

Within the tidal
disruption scenario,
producing the observed
[N II]/O [III] and
[N II]/H α ratios
requires $M_{\text{BH}} < 1000 M_{\odot}$

Clausen+ (2012)



Summary

White Dwarfs

Broad, asymmetric C IV 1549 and [O III] 5007 emission lines can indicate WD tidal disruption if:

- Lines coincide with a UV / X-ray flare at the center of a globular cluster or galaxy
- There are not hydrogen lines in the spectrum

Horizontal Branch

The X-ray luminosity and emission line spectrum observed in a GC associated with NGC 1399 are consistent the mild tidal disruption of a horizontal branch star by a $50 - 200 M_{\odot}$ black hole.

- Hypothesis can be tested with UV spectroscopy