# Symbiotic Stars

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# Symbiotic stars [redacted]

Systems in which accretion from a red giant onto a compact star produces an observable signal at some wavelength.

Low mass: Donor mass ~2 $M_{sun}$

Wide: Separations of AU to tens of AU

Interacting: ~$10^{-10}$ to $10^{-8}$ $M_{sun}$/yr

In many cases, quasi-steady shell burning.

See also: Mikolajewska 2007 (Balt. Ast, 16, 1);
Mikolajewska 2012 (Balt. Ast., 21, 5);
Sokoloski et al. (2017, arXiv:1702.05898)

R. Hynes 2000

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this topic by Joanna M
(2007, 2012, 2014). I
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Joanna has been dilig
and also include my o
which has been more
wavelength observatio
through gamma-rays),
accretion and eruption

# Conundrums and open quest

CHECK: stability of RLOF from higher-mass RG to lower-mass WD

## ★ At what rate is mass transferred?

- Difficult to measure directly.
- ~$10^{-8}$ $M_{sun}$/yr, to maintain shell burning?

## ★ Mode of accretion: wind, RLOF, or in between?

- Ellipsoidal variations (e.g., Mikolajewska+ 2003)
- Roche lobe often under-filled (e.g., Boffin+ 2014)
- Difficult to constrain Mdot.

Influence of strong winds on $R_{RL}$?

## ★ Why is shell burning so pervasive?

- Range of Mdot required to maintain burning is narrow, but symbiotics are heterogeneous…

Selection effect?

## ★ Why do symbiotic giants have such strong winds?

- Red-giant rotation (e.g., Zamanov+ 2007)?
- Gravitational influence of companion (e.g., Tout & Eggleton 1988)?

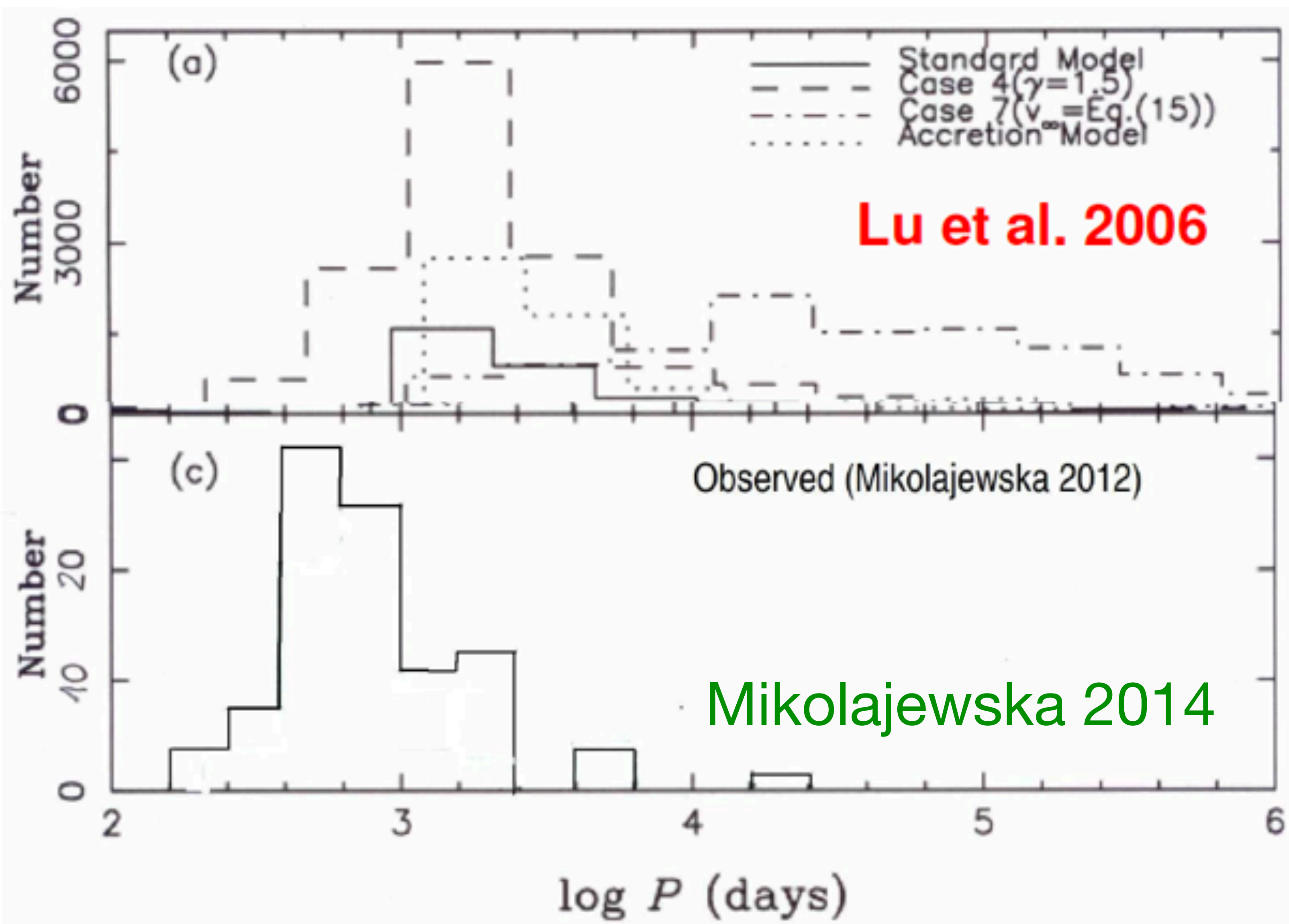
## ★ Why are the orbital periods so short?

## ★ Are symbiotic WDs high- or low-mass?

# Probing orbital evolution of wide binaries

Binaries either experience or avoid a common envelope
Symbiotic orbital periods appear short for CE-a

some

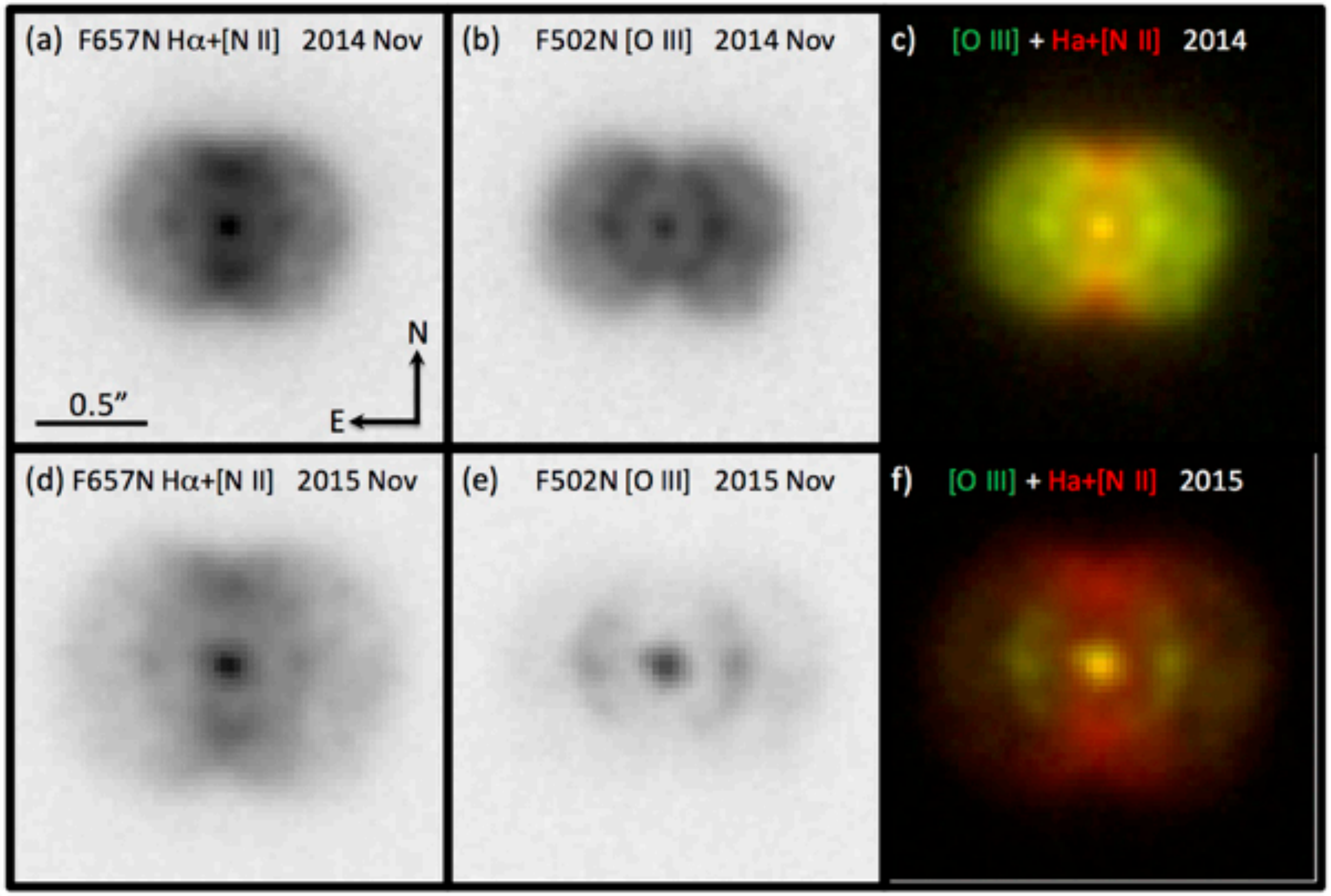



- Orbital periods shorter than expectations from population synthesis calculations.
- Separation of components often too small for AGB progenitor of current WD.

Proposed answer: angular momentum loss via the slow RG wind (Hachisu+ 1999; Jahanara+ 2005; Saladino talk)

# Role of novae in mass evoluti
# an accreting white dwarf

This question is important for
understanding the production of SNIa,
and even the basic question of whethe
accreting WDs increase or decrease in
mass.
I propose that the impact of the
companion depends on separations.

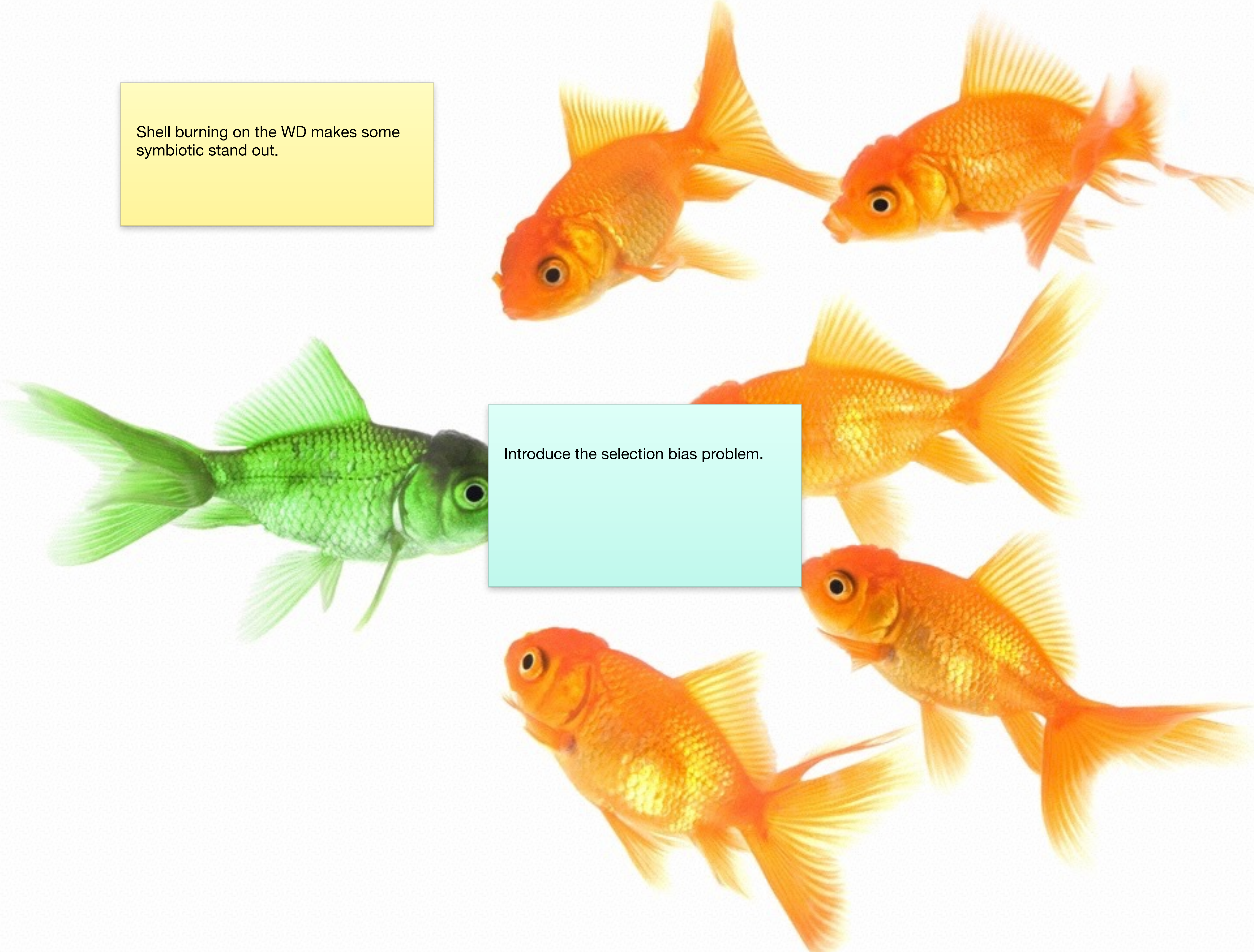



Sokoloski et al. (2017)

In classical novae, the close companion may help eject much of the envelope (e.g., Chomiuk et al. 2014, Nature).

Perhaps WDs in wide binaries can retain a higher fraction of accreted material than WDs in CVs.

Shell burning on the WD makes some symbiotic stand out.



Introduce the selection bias problem.

# Energetics of the Central Engine

Before we dive into any discussion of mass transfer in symbiotics, symbiotic outbursts, or an inferences from the known population, we need to clarify one feature of WD symbiotics that effects almost everything -- the presence or

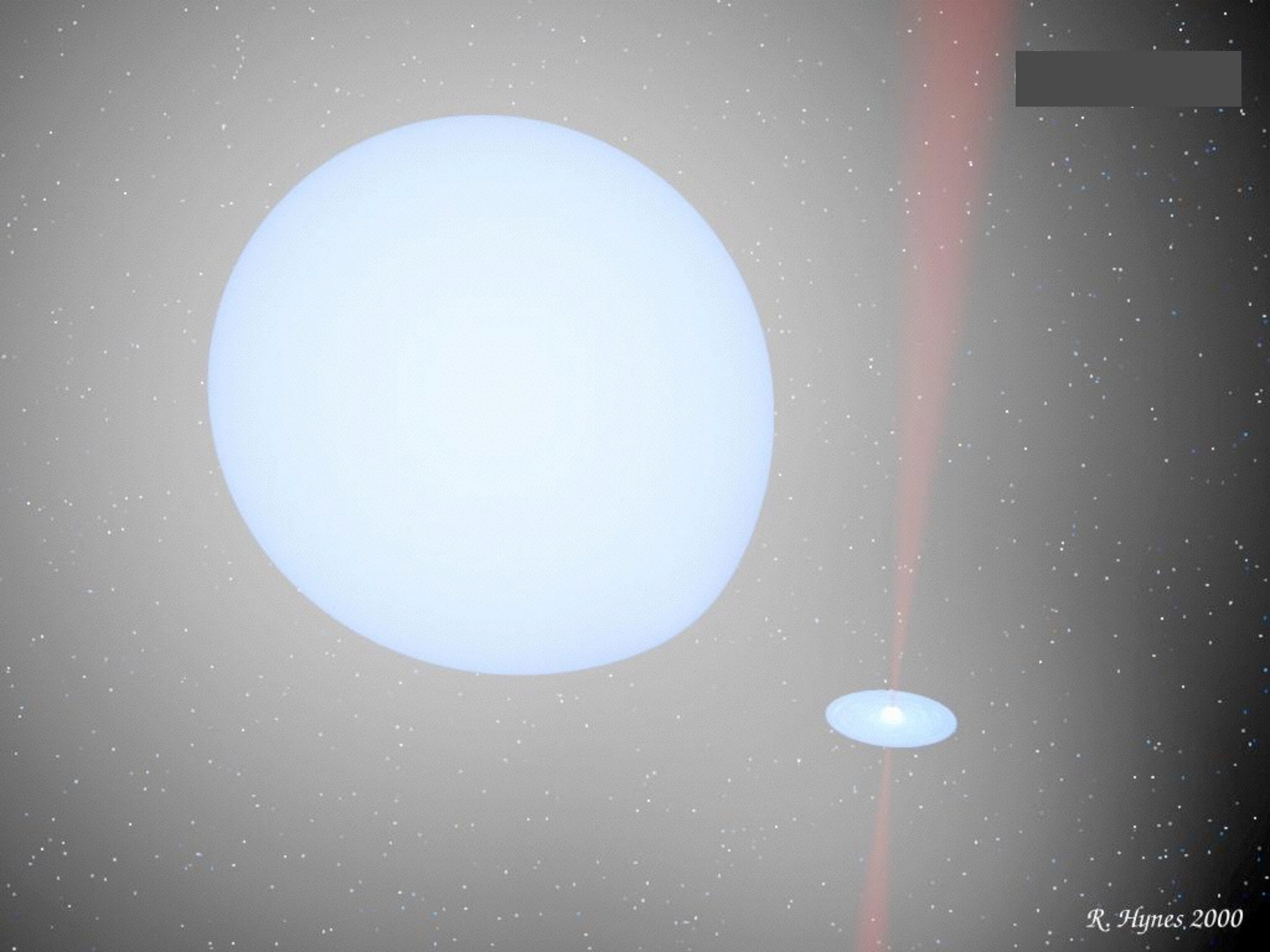
$$L_{burning} \sim 1000\, L_{\odot}$$

(e.g., Paczinski & Zytkow 1978)

$$L_{acc} = \frac{GM\dot{M}}{R}$$

$$\sim 10\, L_{\odot} \left(\frac{M}{0.6\, M_{\odot}}\right) \left(\frac{\dot{M}}{10^{-8}\ M_{\odot}\ \mathrm{yr}^{-1}}\right) \left(\frac{R}{10^{9}\ \mathrm{cm}}\right)^{-1}$$

Symbiotic white dwarfs with quasi-steady shell burning are much more luminous than those without.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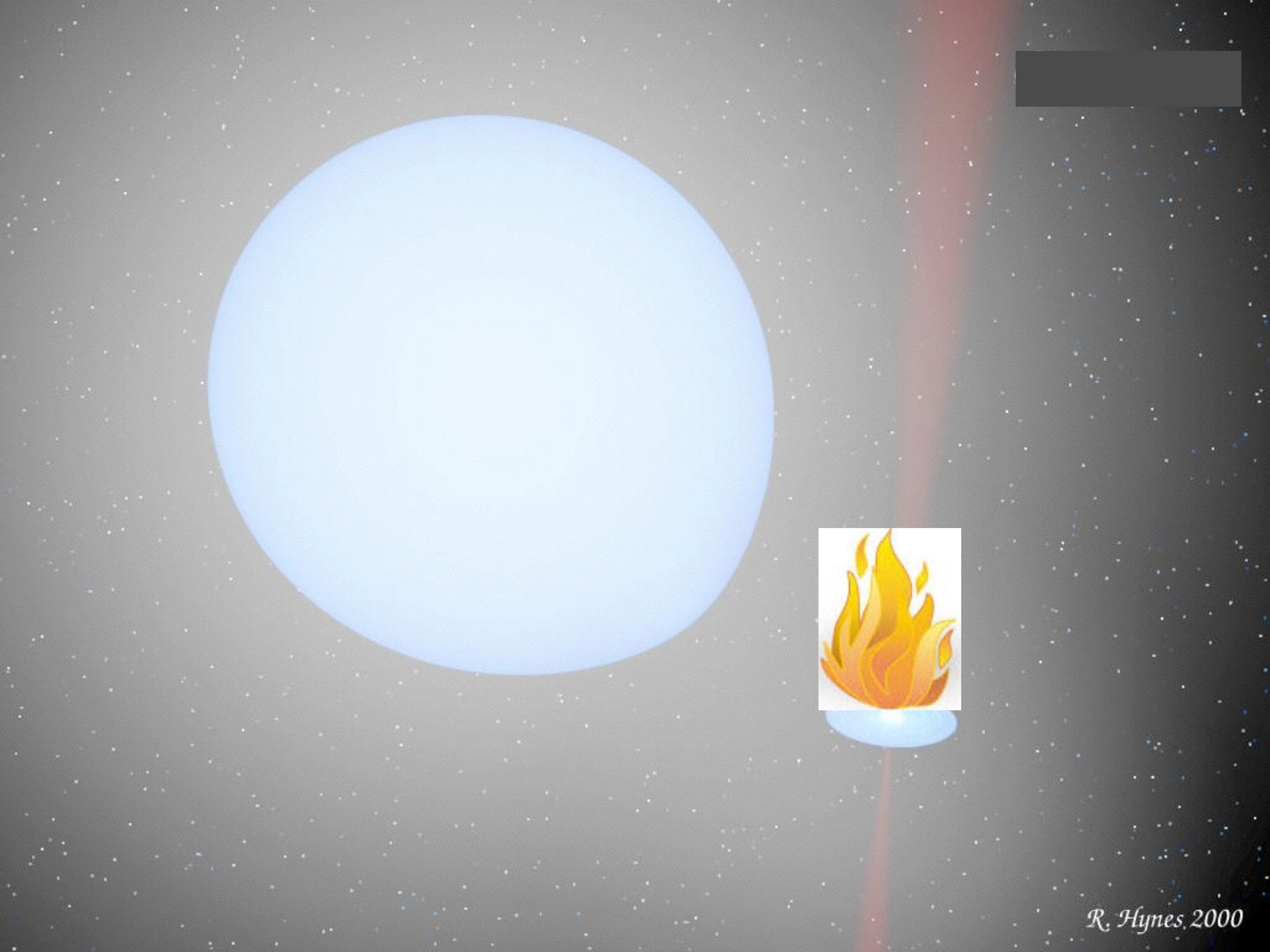
R. Hynes 2000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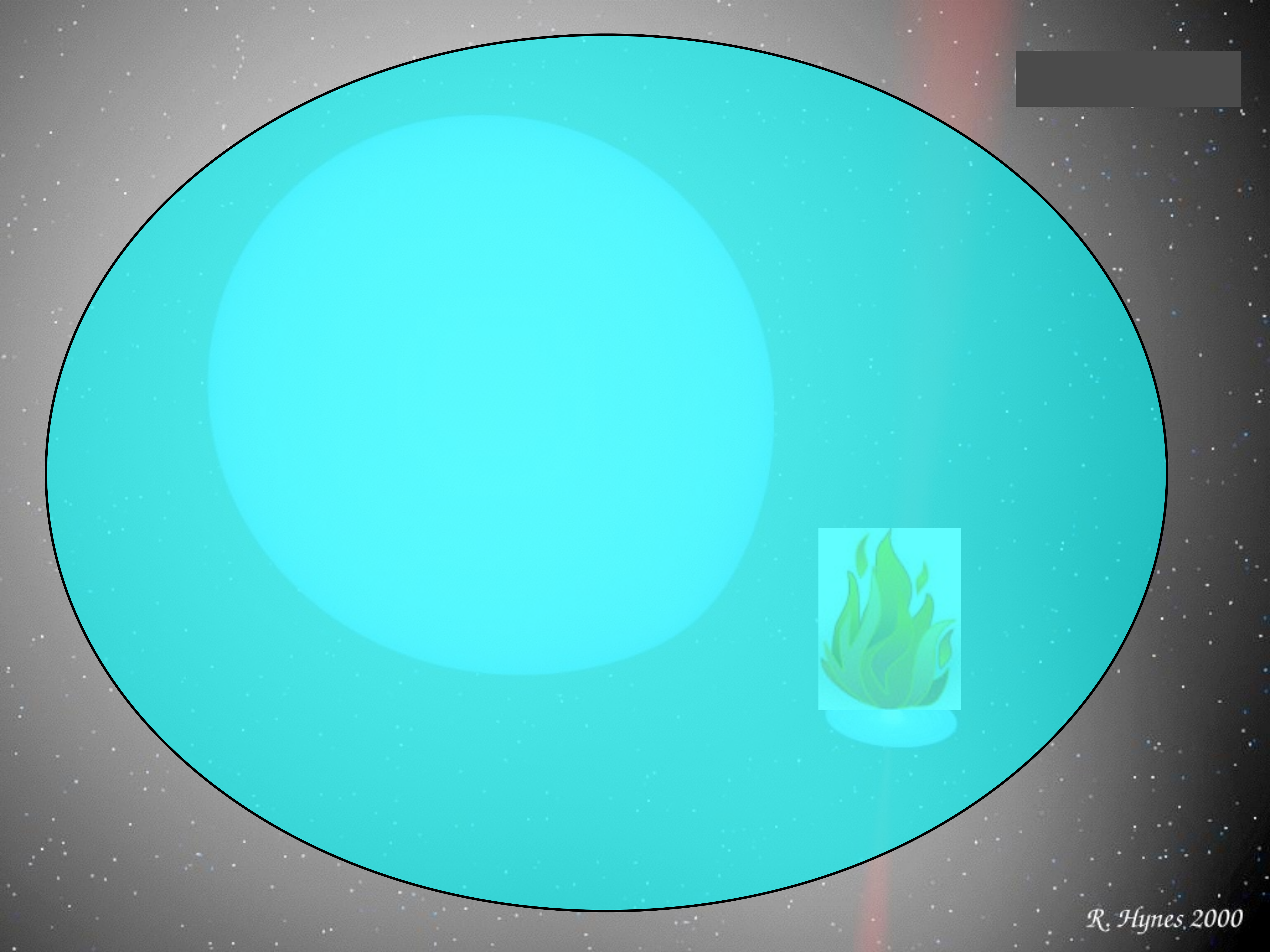
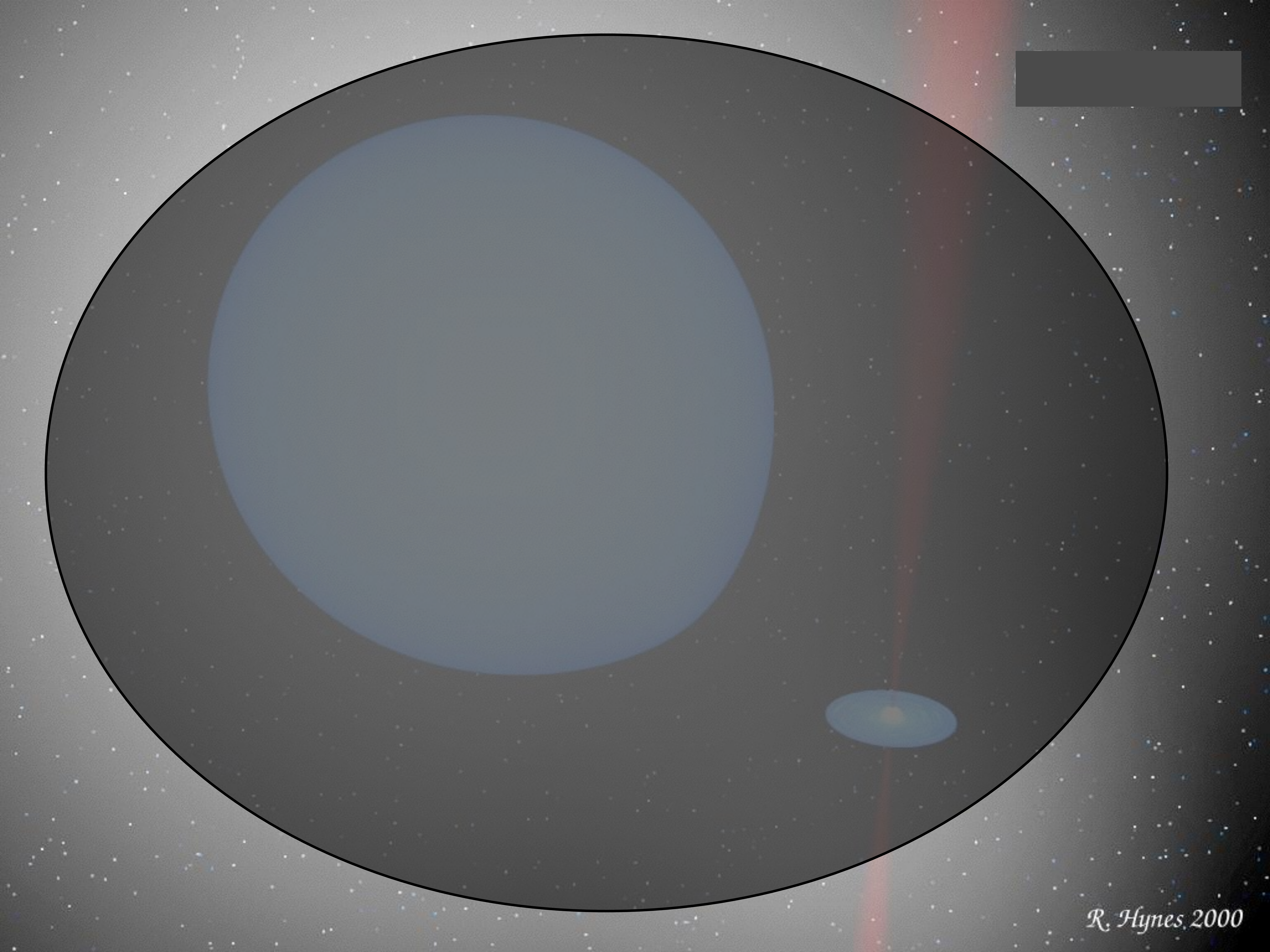
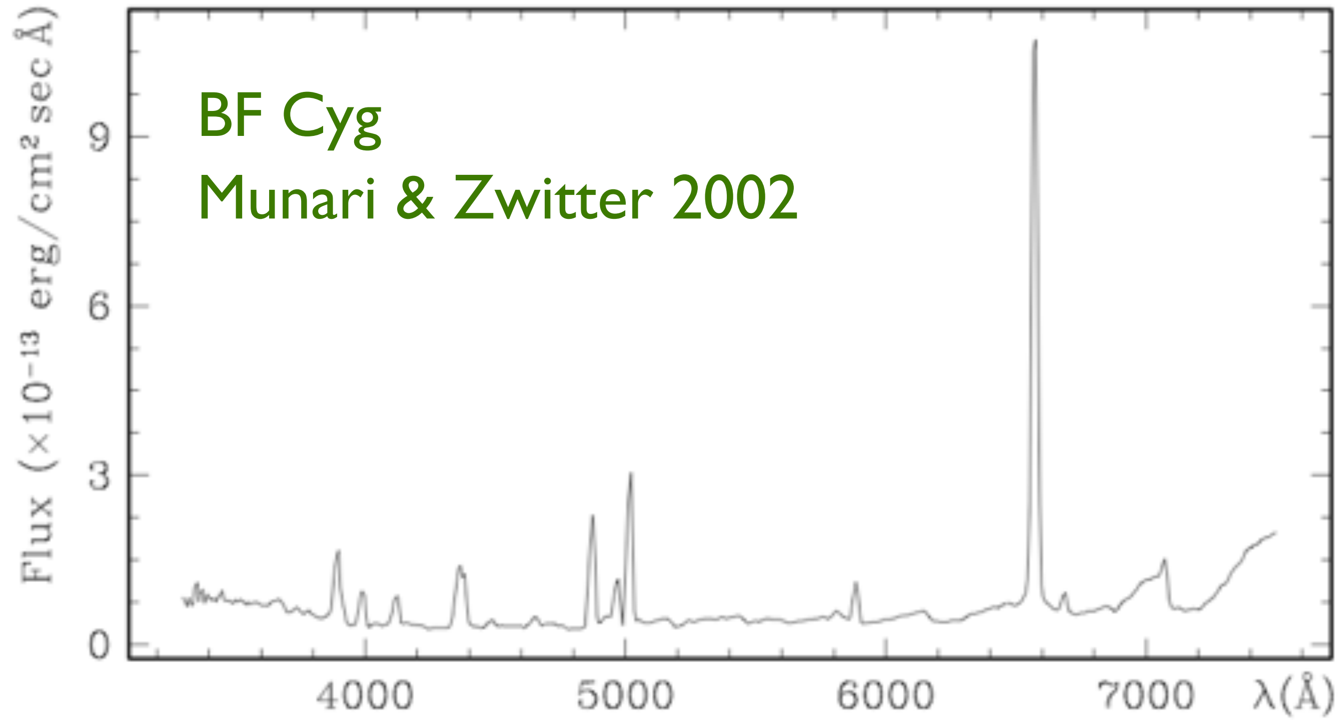
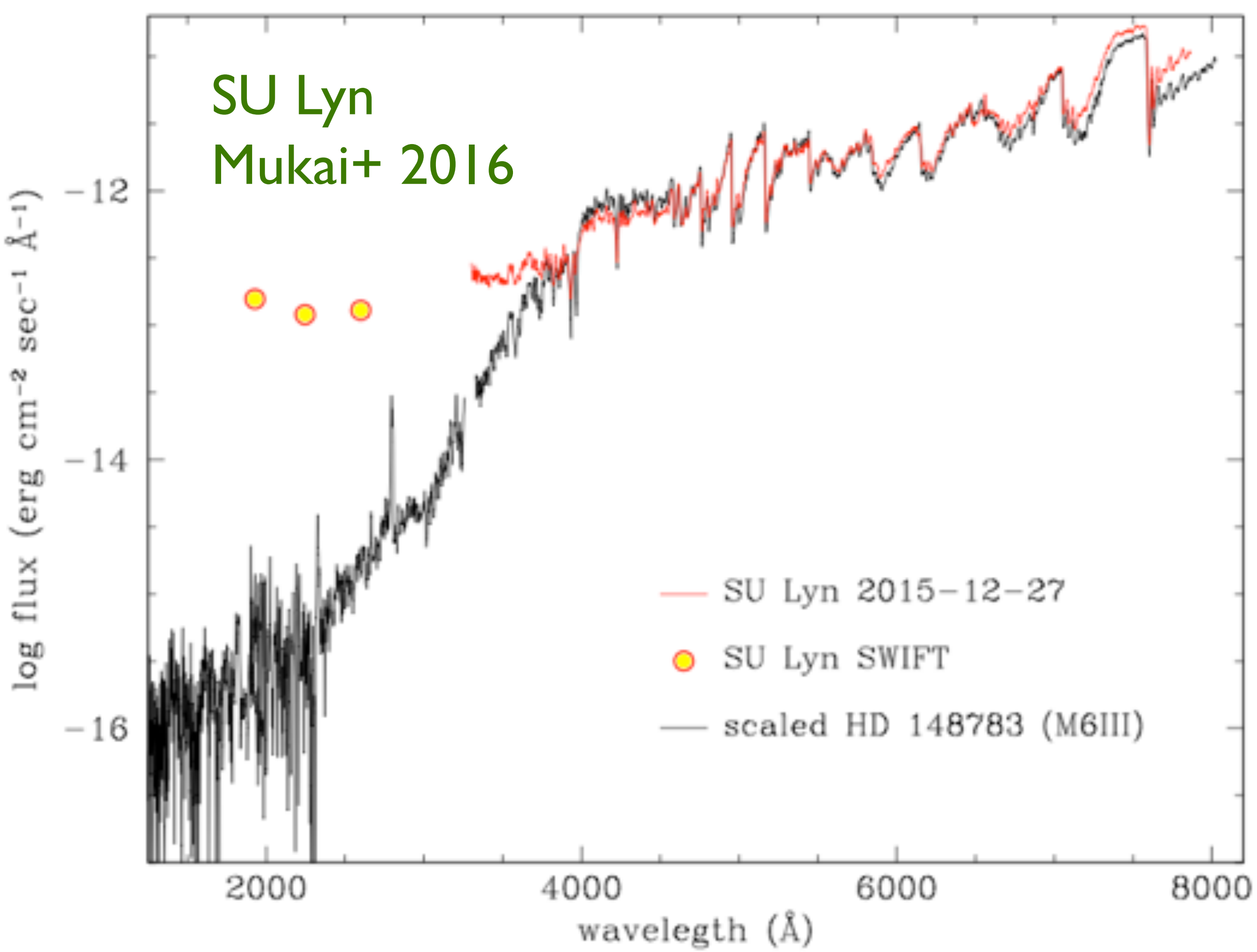

R. Hynes 2000


R. Hynes 2000

# Optical spectra of two types of symbiotics



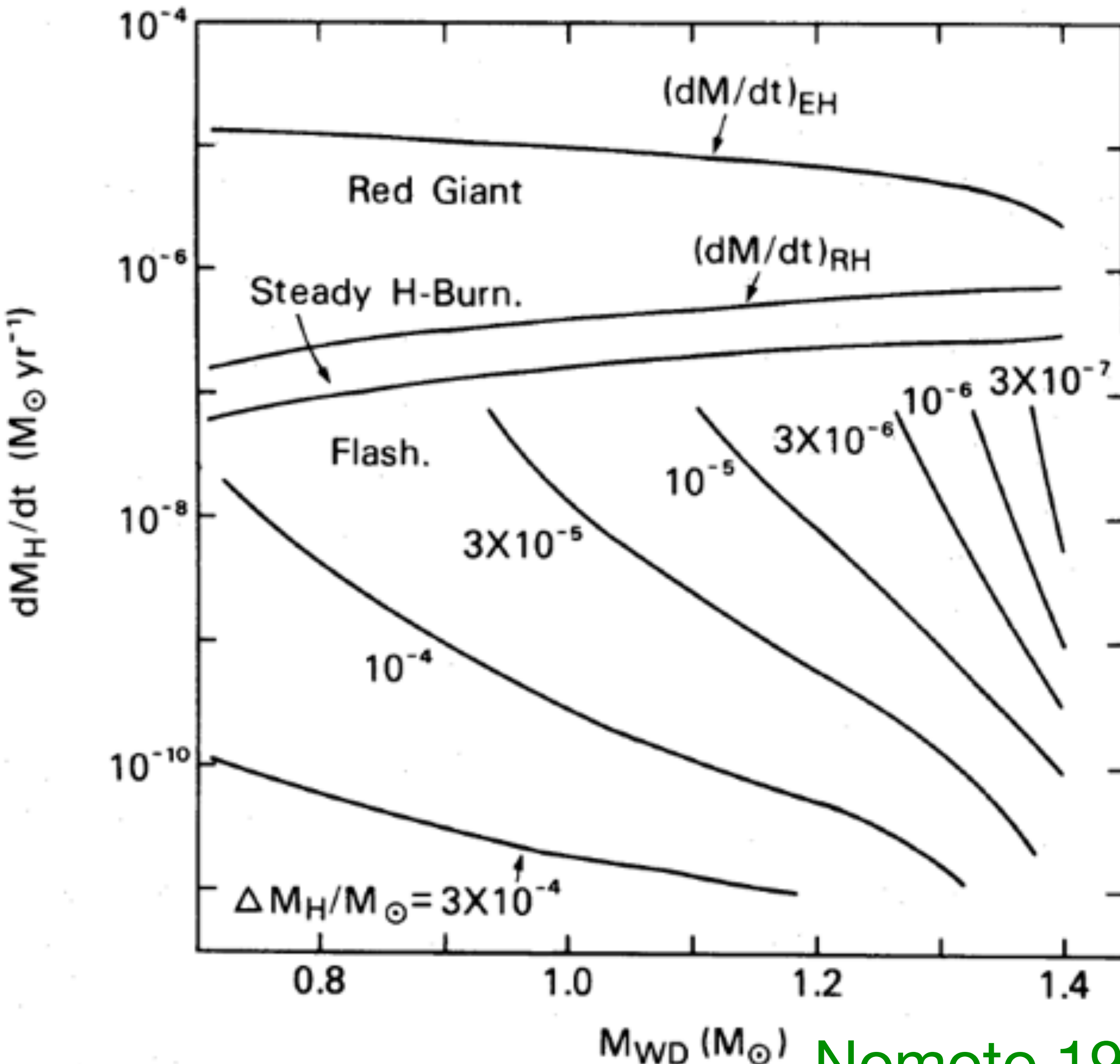

- Optical spectroscopic searches are likely to miss many or all non-burning symbiotics.
- Non-burning symbiotics may be common and have different properties than burning symbiotics.
- Other examples include symbiotic RNe.

# Quasi-Steady shell burning

Residual burning from a prior nova persists for longest on low-mass WDs (e.g., Henze + 2014)

High Mdot. Accretion rate needed to maintain shell burning is lower (easier to achieve) for lower-mass WDs.

A combination of both?



Nomoto 1982

Whatever the cause of shell burning, it preferentially occurs on WDs with low mass and/or high Mdot.

So/to address these important questions,

We would like to know the distribution of WD masses, accretion rates, and orbital periods (among other quantities).

To use symbiotics to constrain all this interesting physics, we first have to find them. find

# Galactic population very poorly known

➡ About 300 individual systems identified, mostly through optical spectroscopic searches (e.g., Allen 1984, Belczynski+ 2000; Corradi+ 2008, 2010, 2012, Miszalski+ 2013, Miszalski & Mikolajewska 2014).

Estimates of the total Galactic population:

3000 (Allen 1984)

30,000 (Kenyon+ 1993)

400,000 (Munari & Renzini 1992; Magrini+ 1992)

Plus: massive selection effects!

# Symbiotics in M31 and M33

Distances to Galactic symbiotics often poorly known, so Mikolajewska+ (2014, 2015, 2017) extended the search for symbiotics to the Local Group.

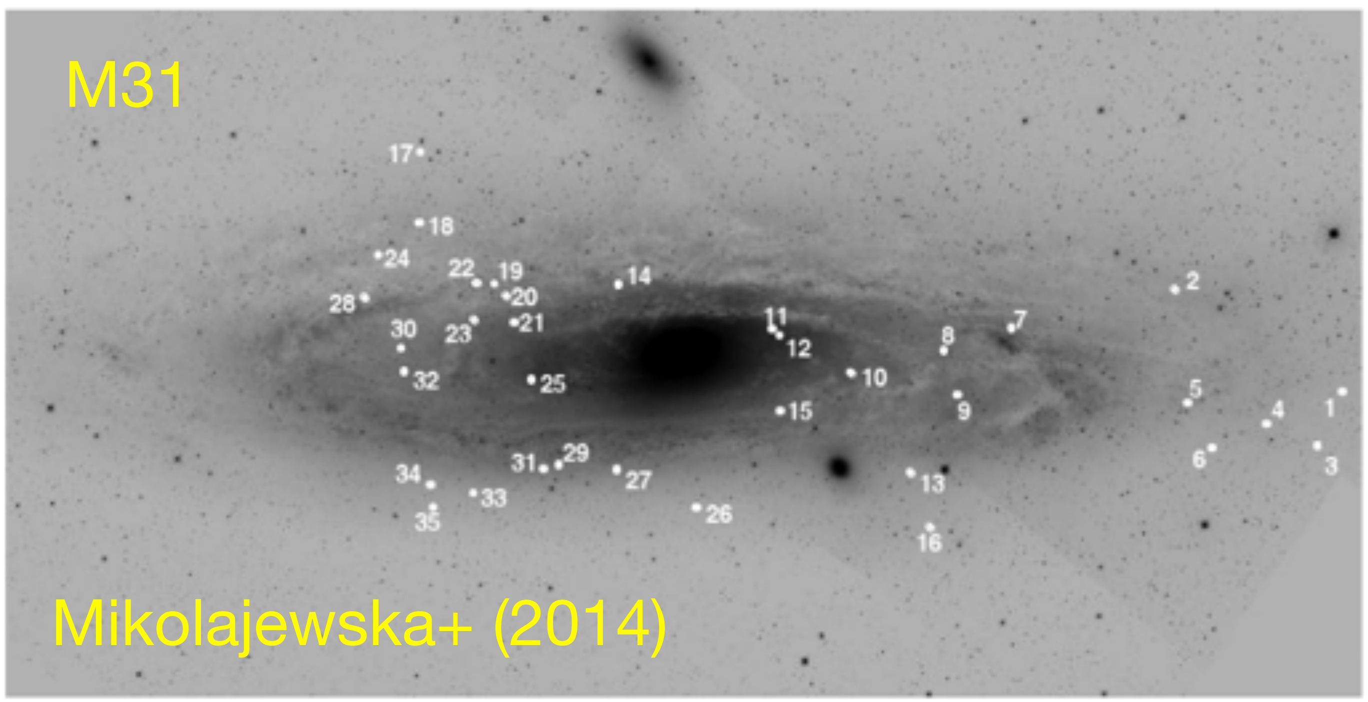
M31: 31 new and 4 possible symbiotics found (Mikolajewska+ (2014).

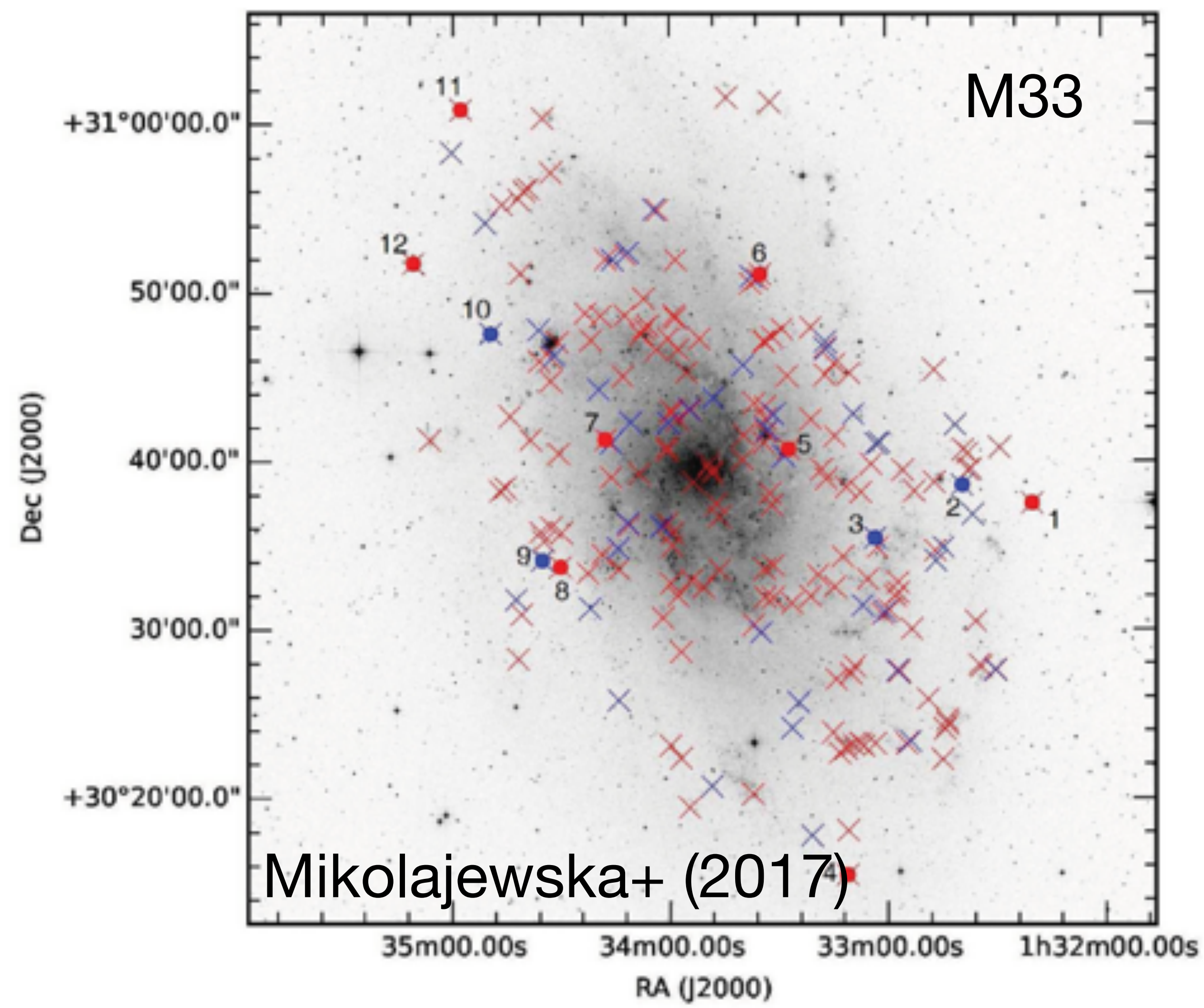
M33: 12 new symbiotics, with a high number ratio of C- to M-giants (Mikolajewska+ 2017

Authors ascribed high number ratio of C to M giants to the low metalicity of M33.

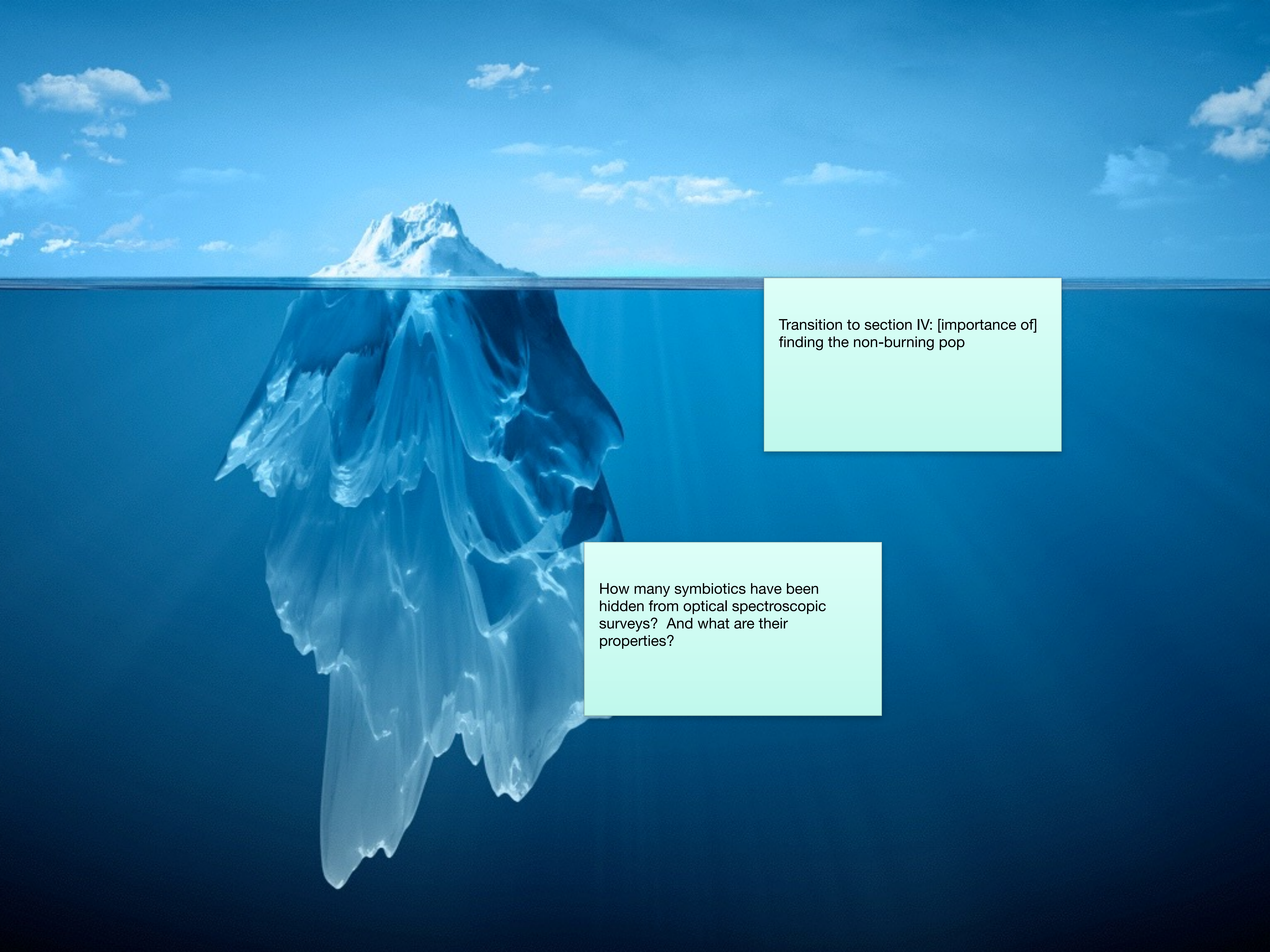
# Implications: M31 and M33

Symbiotics not associated with spiral arms, nucleus, or star clusters — consistent with a broad range of progenitor ages (Mikolajewska+ 2017).




Selection effects: only sensitive to hottest and most luminous symbiotic WDs (Mikolajewska+ 2014).

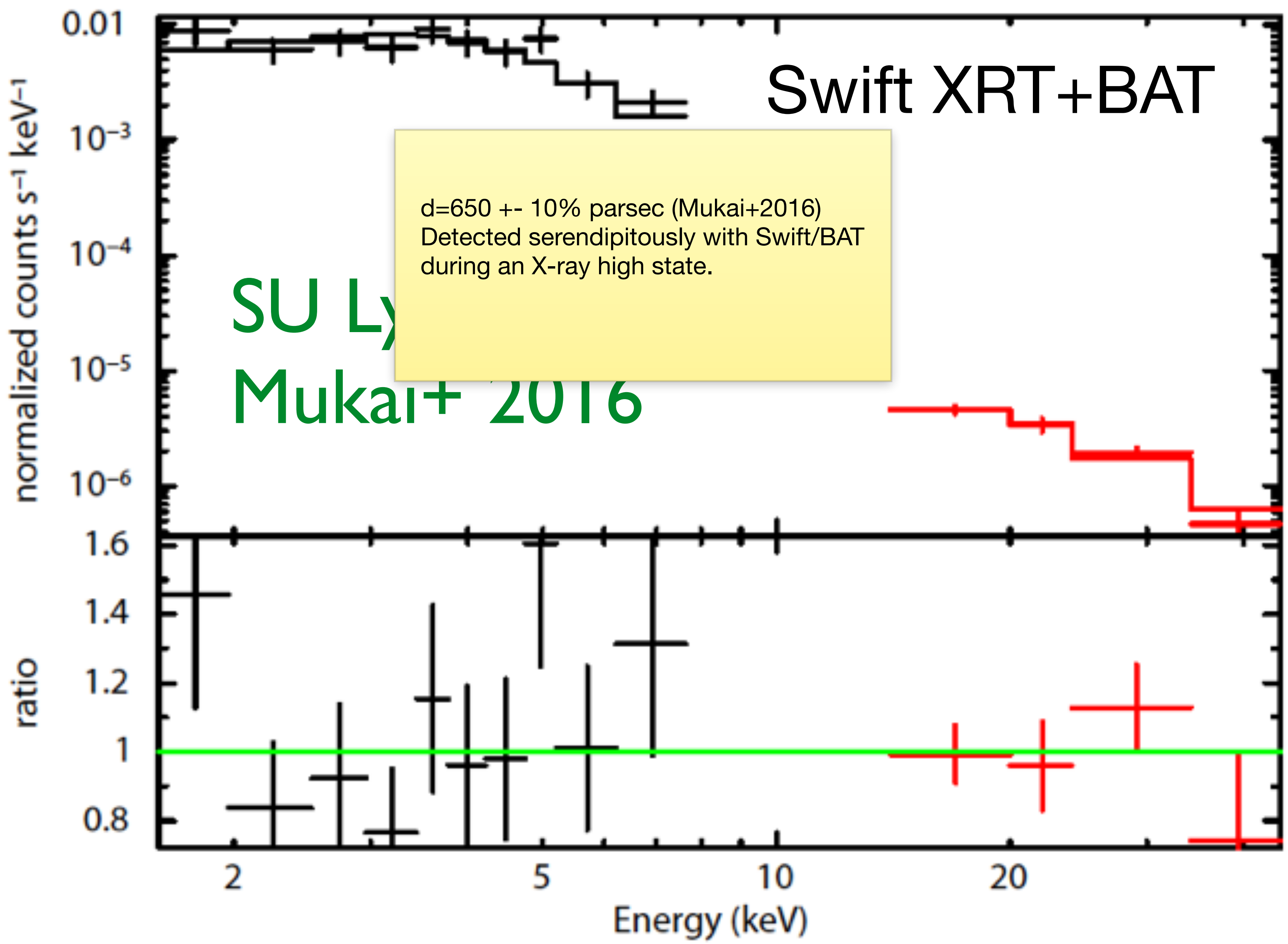


Transition to section IV: [importance of] finding the non-burning pop

How many symbiotics have been hidden from optical spectroscopic surveys? And what are their properties?

# Non-burning symbiotics have X-ray boundary layers

To introduce you to non-burning symbiotics, let's start with X-rays.



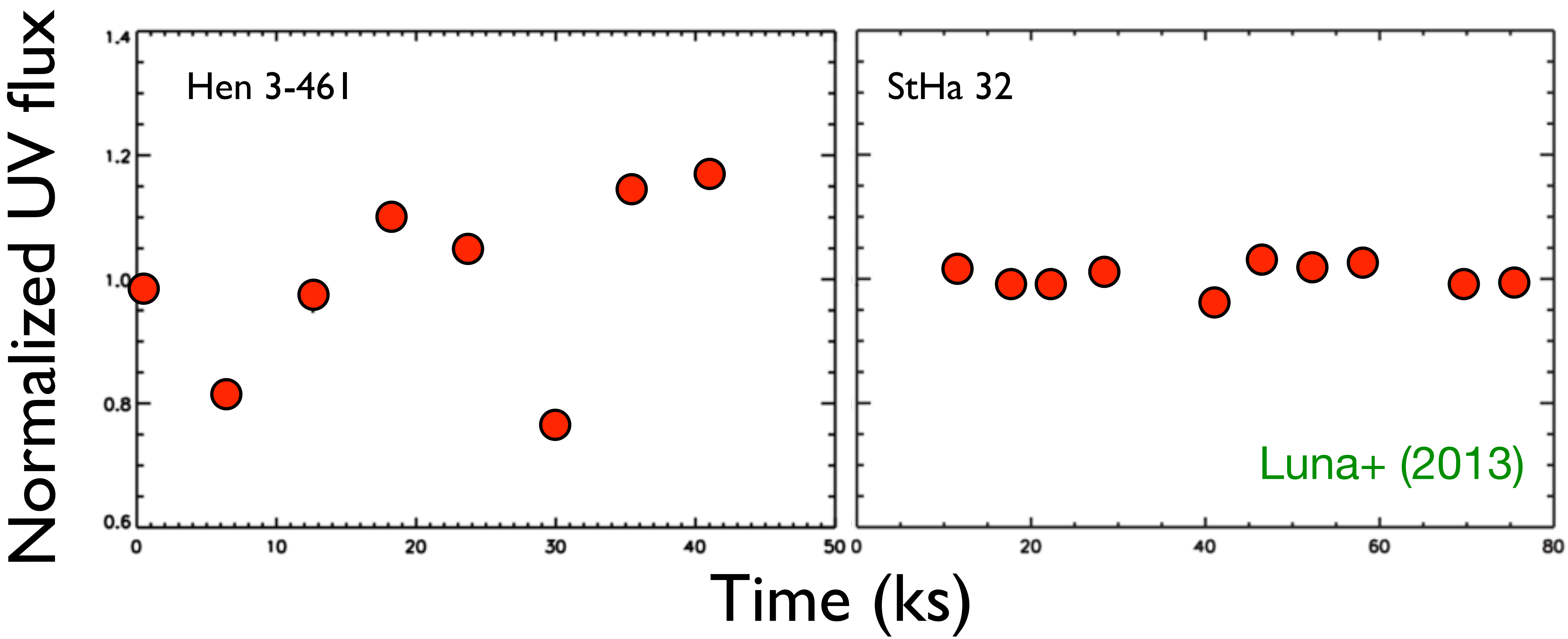

d=650 +- 10% parsec (Mukai+2016)
Detected serendipitously with Swift/BAT during an X-ray high state.

- $F_X \rightarrow$ Mdot.
- $T_X \rightarrow M_{WD}$.
- X-rays from $>10^{-9}$ $M_{sun}$/yr accreting onto a 1 $M_{sun}$ white dwarf.
- Boundary layer likely Compton cooled in burning symbiotics

$$T_{ps} = \frac{3}{16}\frac{\mu m_p}{k_B}v_s^2 = 4 \times 10^7 \left(\frac{v_s}{1700\ \mathrm{km\ s^{-1}}}\right)^2 \frac{\mu}{0.6}\ \mathrm{K}$$

# Ionized nebulae are small

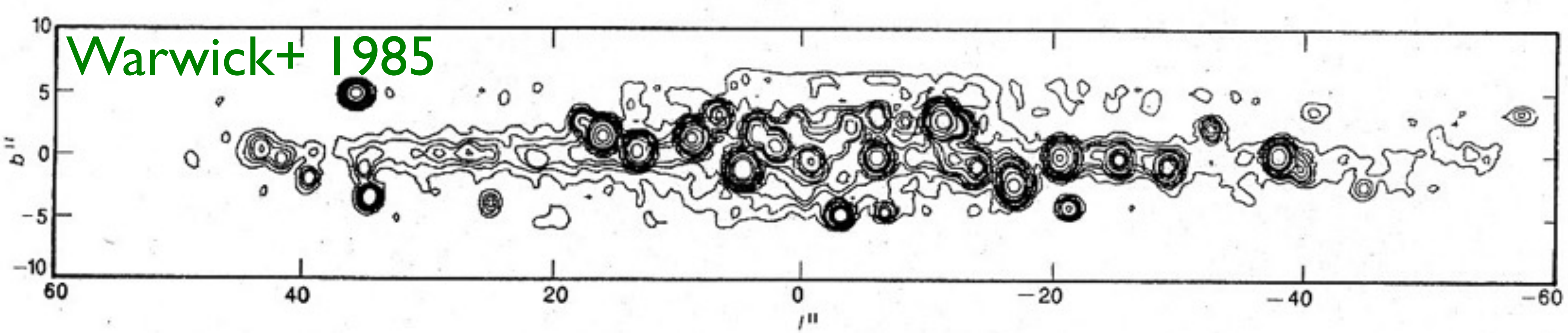
- Low radio flux (Weston 2017, PhD)
- Large-amplitude UV disk flickering is not swamped by nebular emission.



# What fraction of symbiotics are non-burning?

➡ Based on space density of nearby, serendipitous discoveries, Mukai+ (2016) estimated that there could be as many non-burning as burning symbiotics.

Additional support: Galactic ridge X-ray emission




NIR spectroscopy of 65 point sources revealed 3 classes. One is WD + RG binaries (Morihana+ 16).

# Non-burning symbiotics could change our understanding of interaction in wide binaries

★ $M_{WD}$: connects to accretion history, rate, efficiency and mode; and the MS mass of the current WD.

From traditionally selected symbiotics (excluding RNe):

$<M_{WD}>$ ~ 0.6 Msun, with distribution peaking below 0.6 Msun (Mikolajewska 2003)

Non-burning symbiotics:

$<M_{WD}>$ >0.8 Msun (Sokoloski+ in prep)

★ Full symbiotic population: numbers and properties.

★ Direct view of emission from large, often jet-producing, WD disks.

➡ Plans: Seek red giants with UV excess or variability (A. Lucy, PhD)

# Conclusions

- Symbiotics probe physical processes that are crucial for understanding how interaction in wide binaries impact stellar evolution.
- Targets with strong optical emission lines preferentially contain WDs with shell burning on the WD and are unlikely to represent the full population.
- Symbiotics in nearby galaxies provide comparison samples, constrain ages, and alleviate the problem of poor distances, but worsen selection effects.
- Non-burning symbiotics give a more direct view of mass transfer and may force a revision of estimates of the number of symbiotics in the Galaxy and their parameters.

➡Those odd-ball, hard X-ray symbiotics might actually represent the bulk of the iceberg.