Mass flows in massive binaries: Clues from spectropolarimetry

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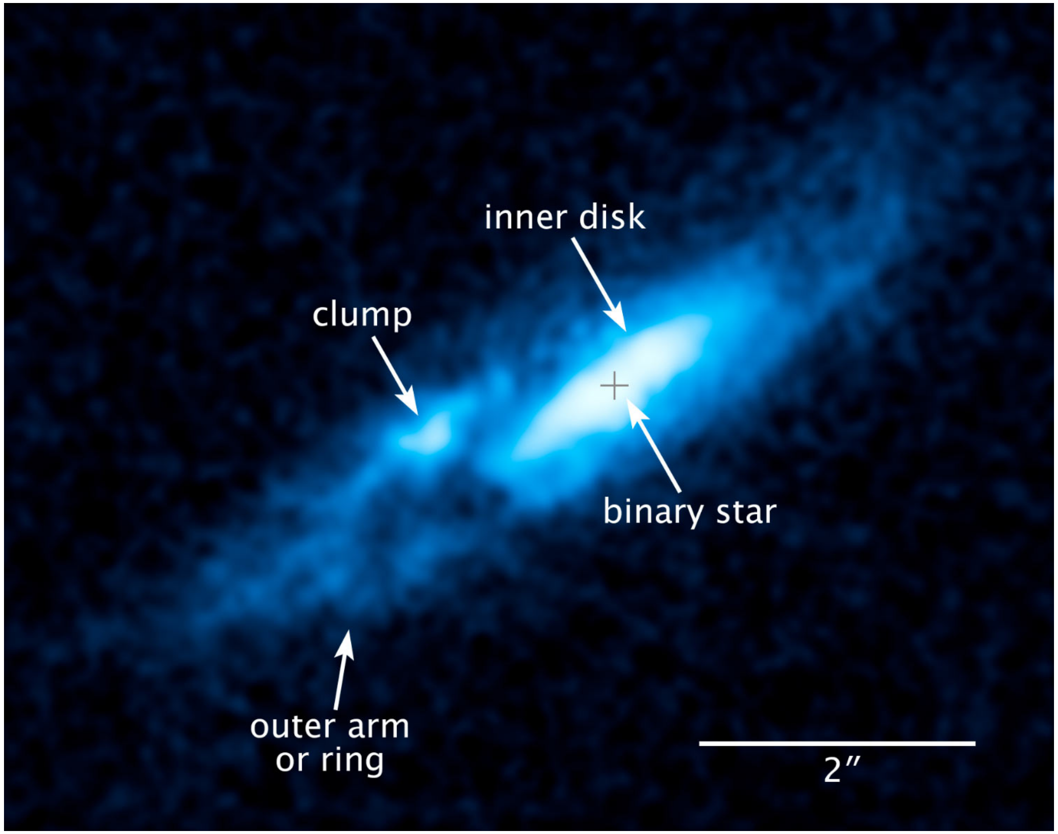
Jamie R. Lomax, U. Oklahoma



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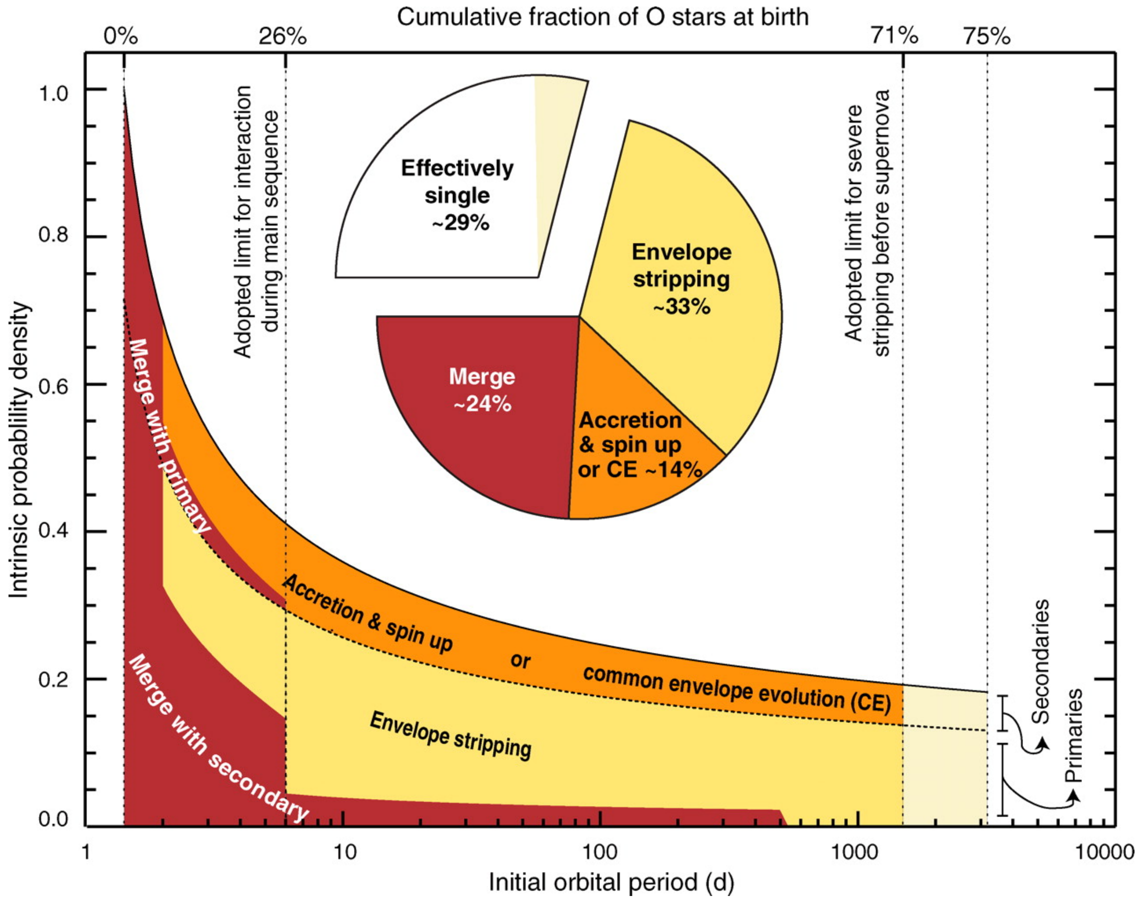
Mauerhan+ 2015

Why binaries?

- Binaries are common! ~70–75% of all massive stars interact with companions sometime in their lives.



Sana+ 2012

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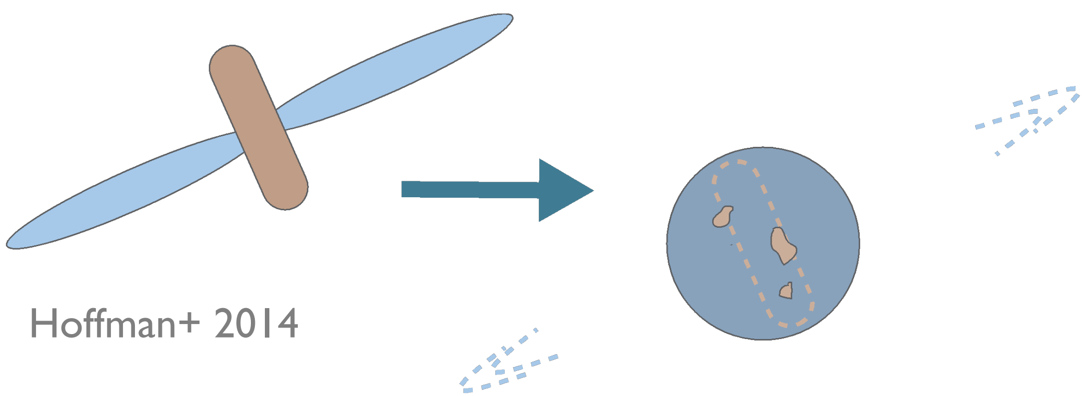
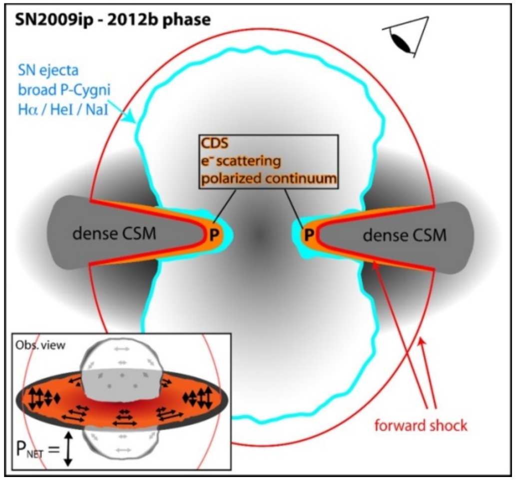


Hoffman+ 2014



Mauerhan+ 2014

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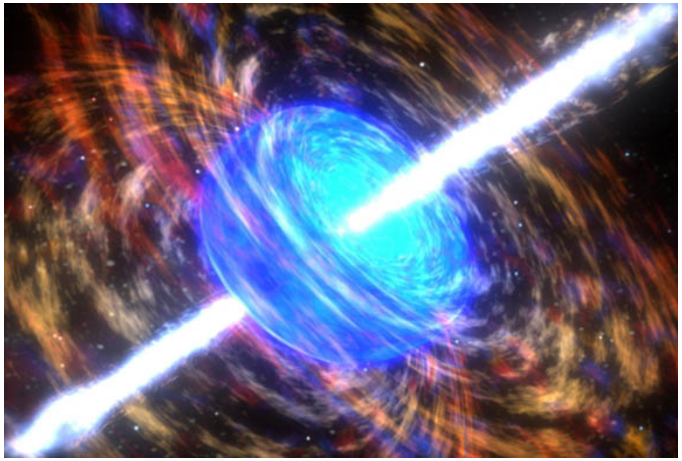
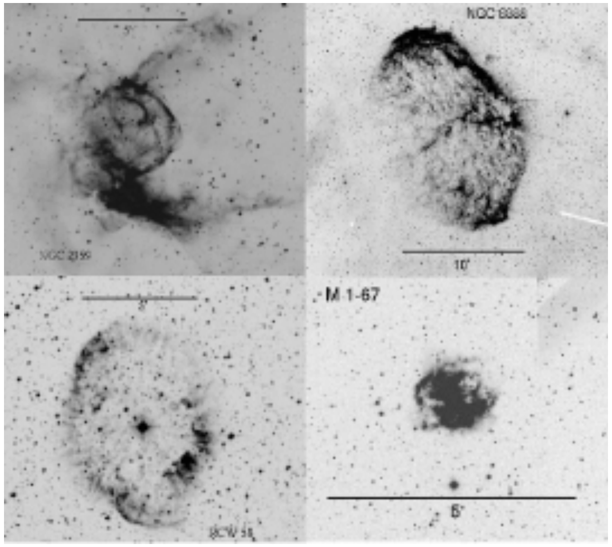
- Binary interactions shape stellar evolution through mass and angular momentum transfer.
- Supernovae are aspherical in a variety of ways that binaries can help explain (cf. Mohamed, Groh talks yesterday).
- GRBs require stripped H envelopes and rapidly rotating progenitors—binary interactions can produce both.



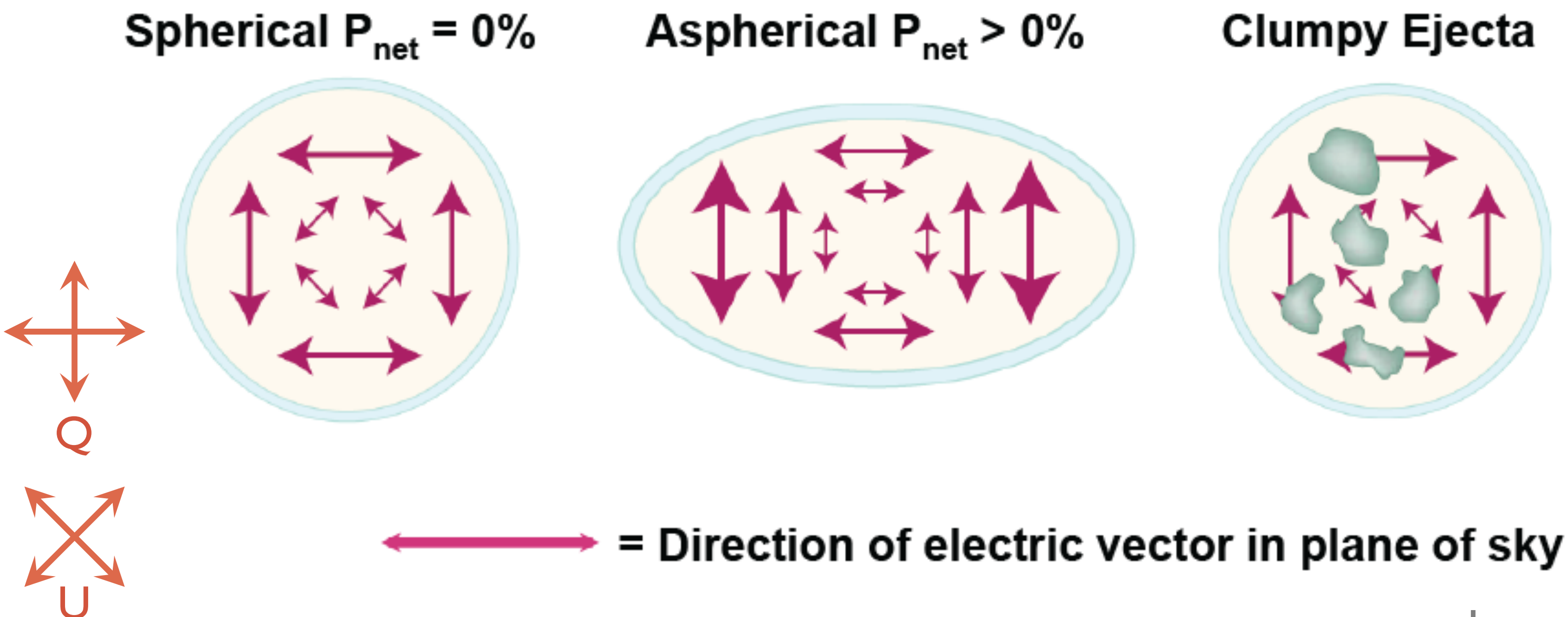
Current question: How can we look for links between binaries and SNe/GRBs?

- Vink et al. (2007) developed a way to use polarimetry to identify rapidly rotating WR stars that may be GRB progenitors: the "line effect method."
- Vink et al. (2011) and Gräfener et al. (2012) showed a correlation between the rapidly rotating WRs and the presence of ejecta nebulae.
- Exciting! But binarity complicates the line-effect diagnostic. We need to figure out how to get around this.



Gräfener+ 2012

Polarization (linear) in stellar winds/atmospheres



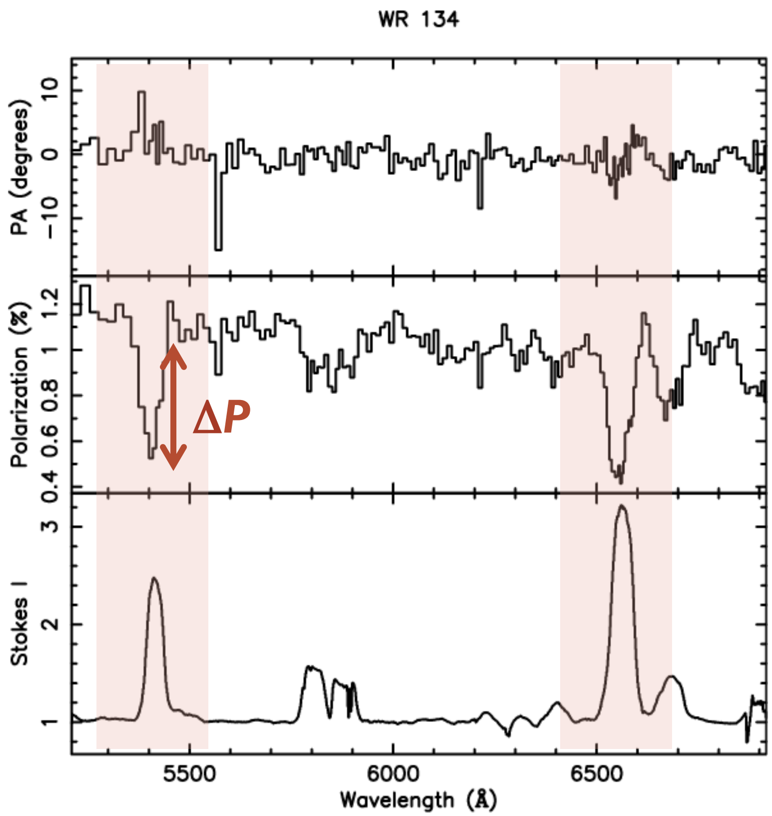
Leonard+ 2007

Hot stars, ionized winds ⇒ electron scattering is the dominant polarizing mechanism. (But dust is important in many cases!)

Note this picture assumes a central illumination source—line polarization is more complicated.

Line-effect method

- Continuum emission arises from the star, scatters & polarizes in aspherical inner wind.
- Line emission arises in winds, escapes with little scattering.
- Net effect: line depolarization (modulo interstellar polarization, or ISP).

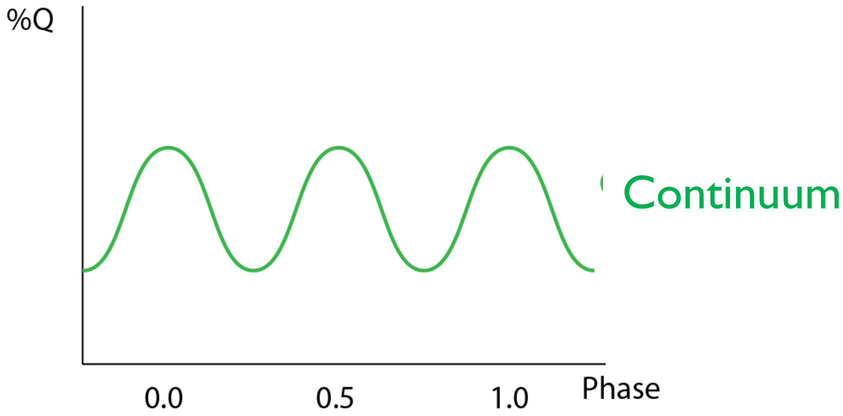


Vink+ 2011

Line-effect method in binaries

- Line effect can be variable due to binarity:
  - continuum polarization can change with orbital phase, causing ΔP to vary;
  - intra-binary scattering can cause intrinsic and variable line polarization.
- Statistical studies exclude (close) binaries for this reason. But we can extract information from these variations! Binary phase coverage is key.
- Following data are from the HPOL spectropolarimeter—low-res, but can extract *intrinsic* line polarization.

Line-effect method in binaries



Polarization phase behavior constrains where lines arise and scatter.

Line-effect method in binaries

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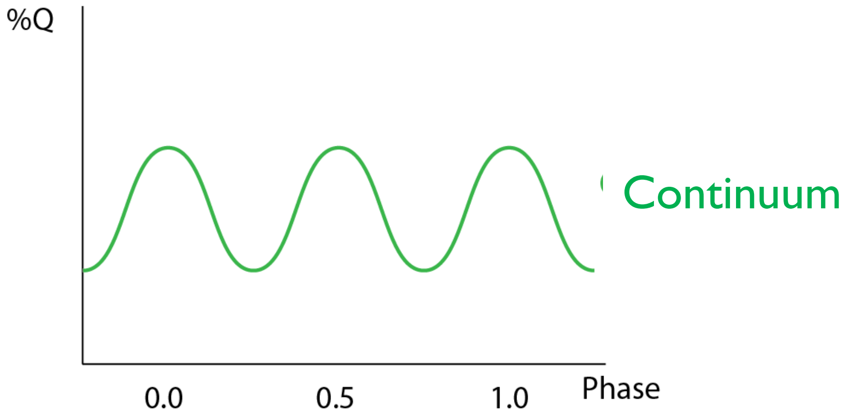

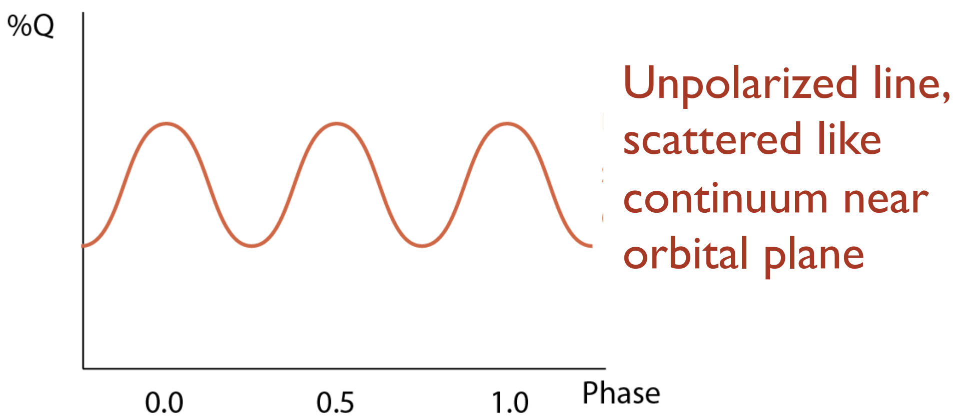

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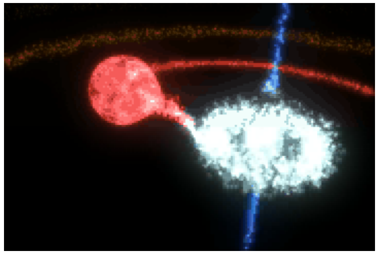
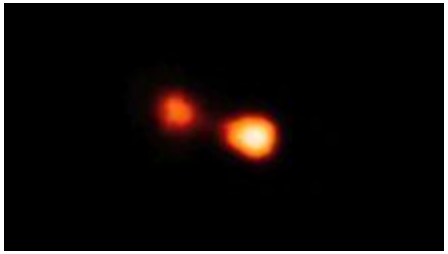
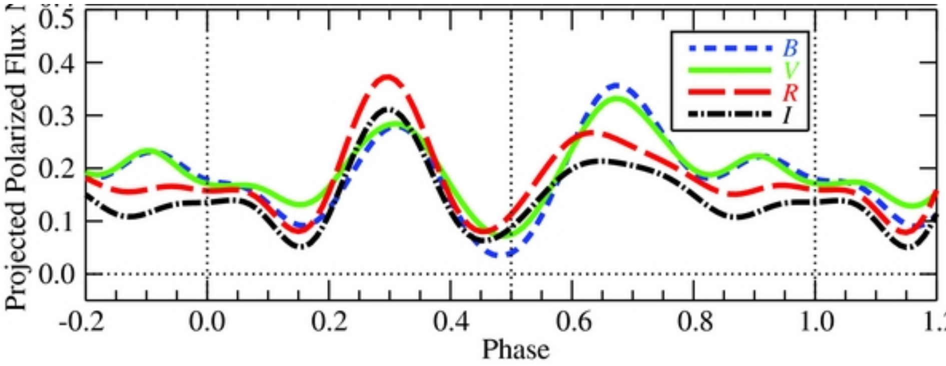
β Lyrae



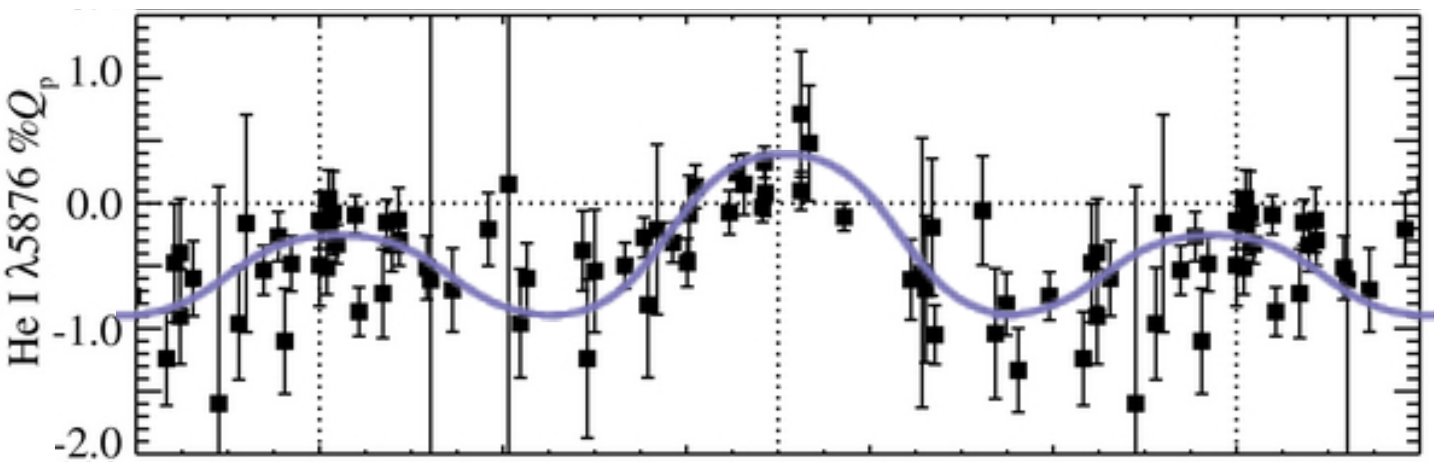
McCarty, CCSSC



Zhao+ 2008



Lomax+ 2012



Lomax+ 2012

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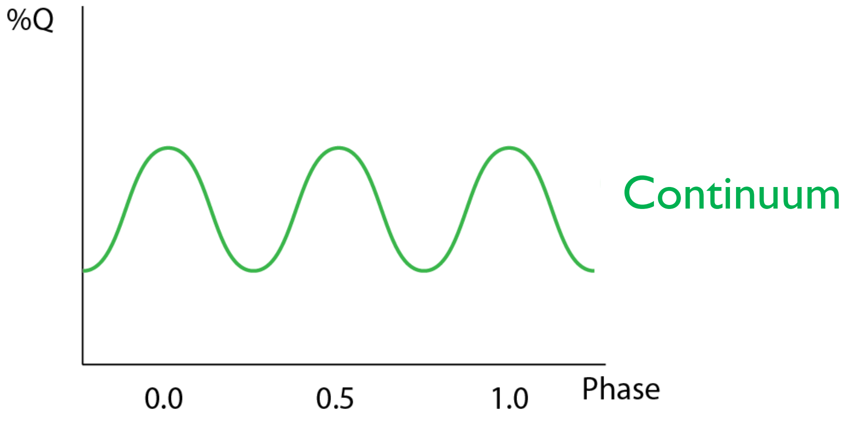
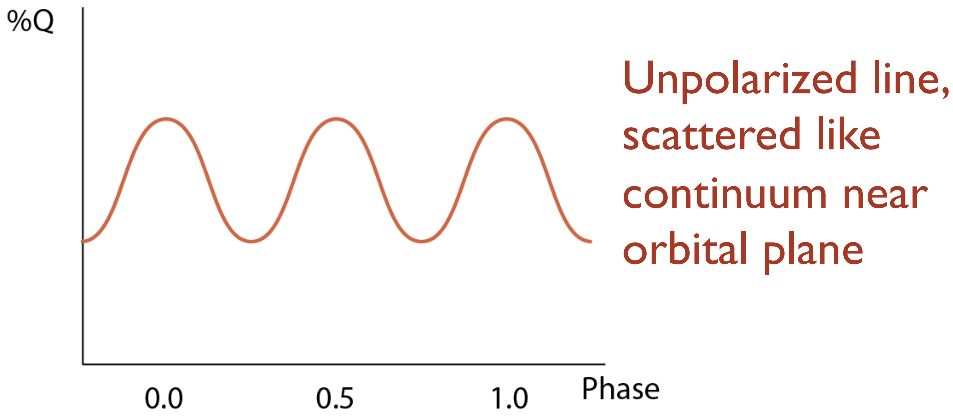
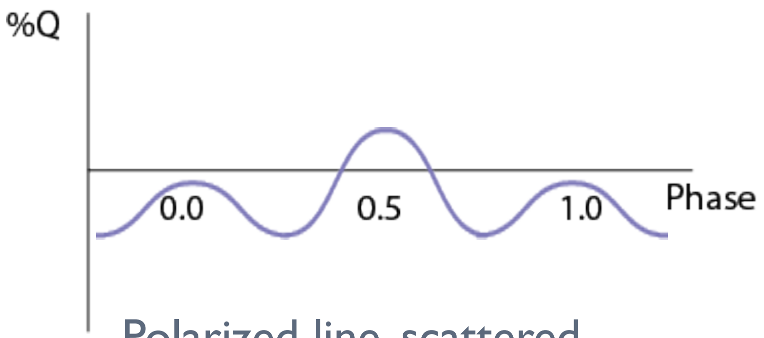




Polarization phase behavior constrains where lines arise and scatter.



Polarized line, scattered differently from continuum near orbital plane (e.g.)

Line-effect method in binaries

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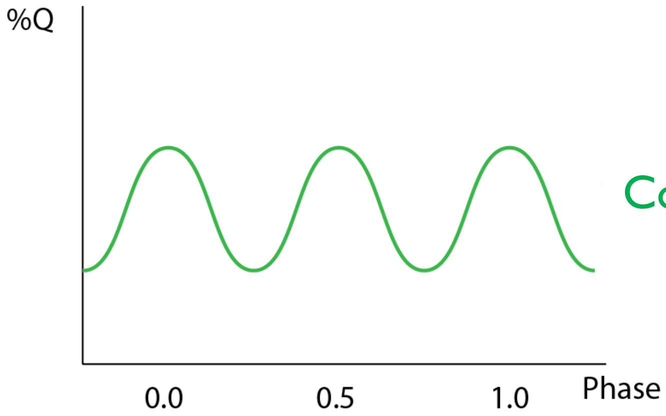
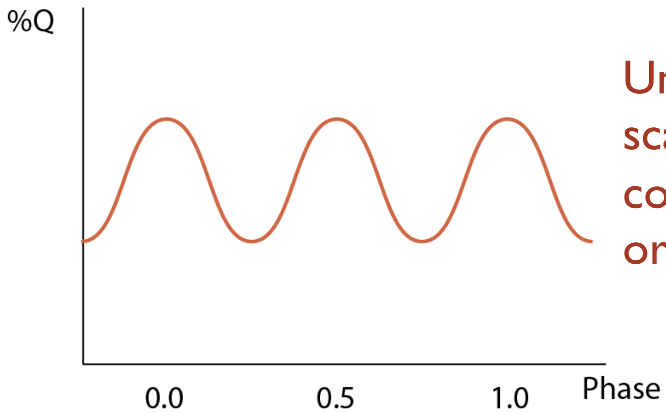
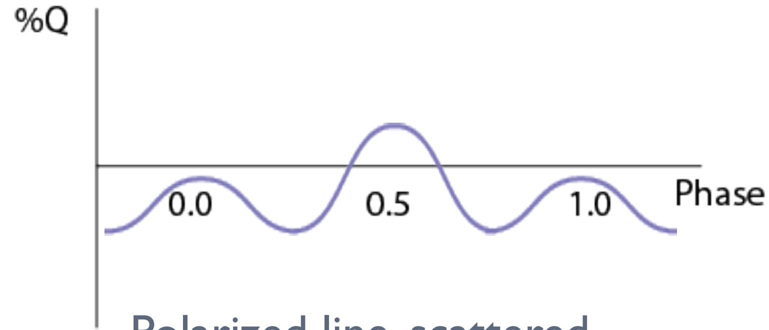


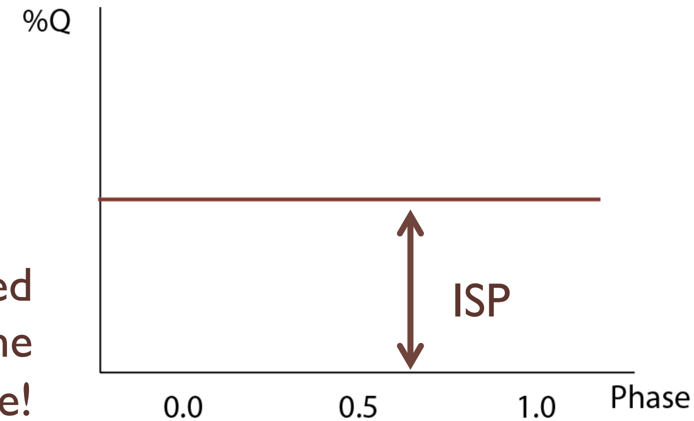
Continuum



Unpolarized line, scattered like continuum near orbital plane



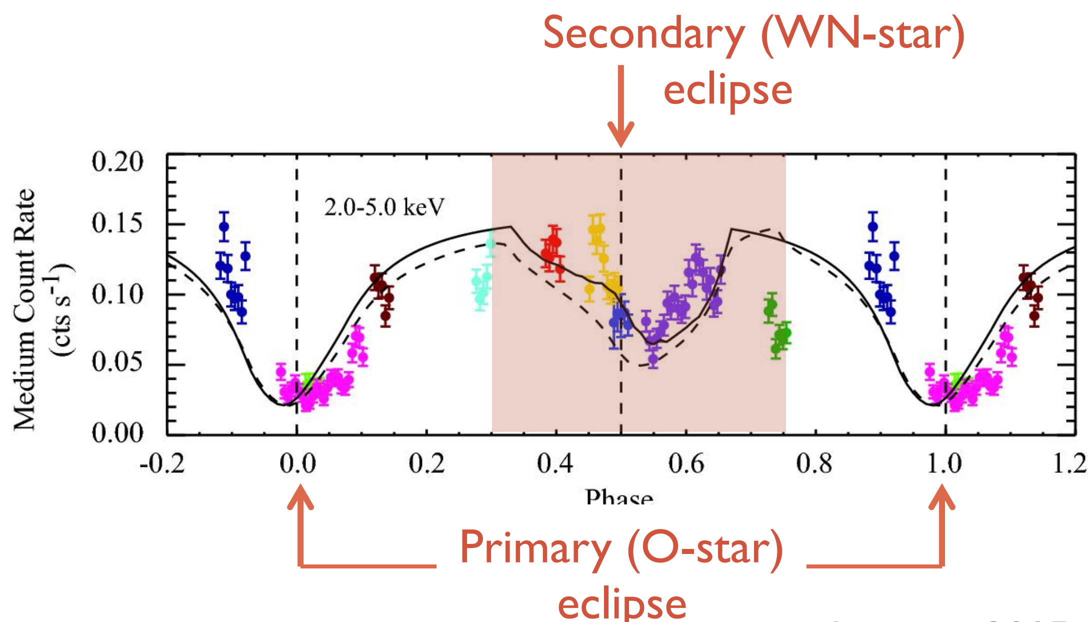
Polarized line, scattered differently from continuum near orbital plane (e.g.)



Unpolarized line, scattered far from orbital plane —line effect here!

Test case: V444 Cygni (WR 139)

- Eclipsing (i = 78°) WN5+O6 with a circular orbit and small orbital separation ~$36R_{\odot}$.
- Colliding-wind system; bright & variable X-rays arise from collision region.
- X-ray spectral fits find 2 temps and weaker absorption at phases 0.3–0.75 (O star wind is less dense).

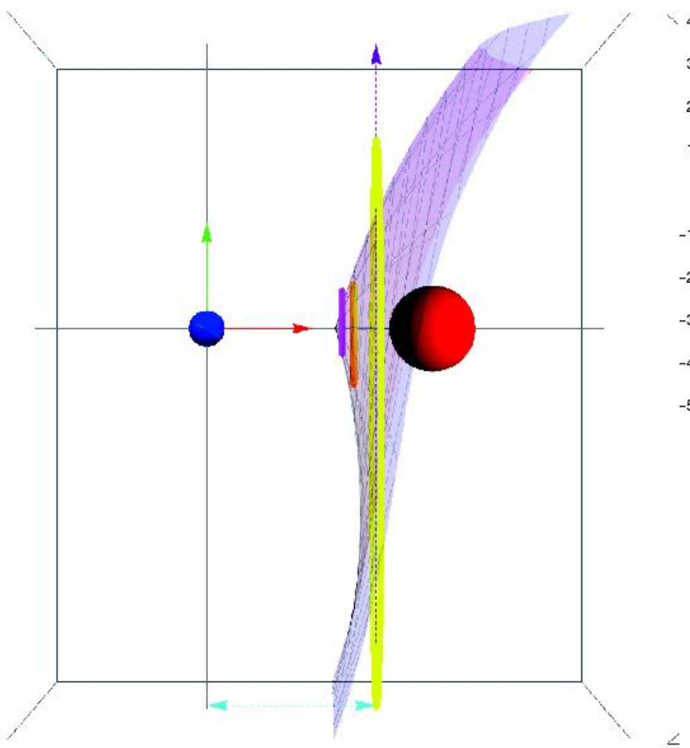


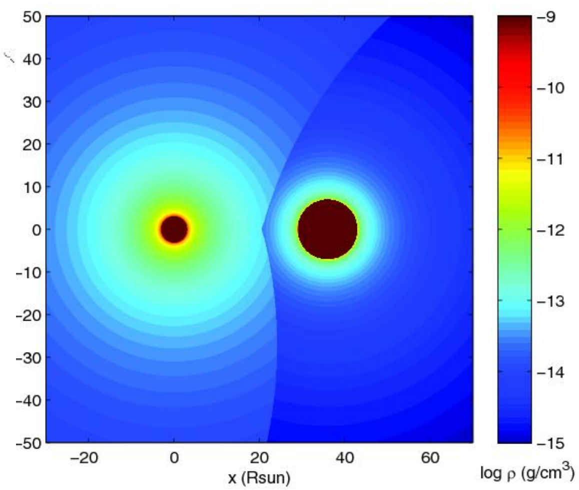
Lomax+ 2015

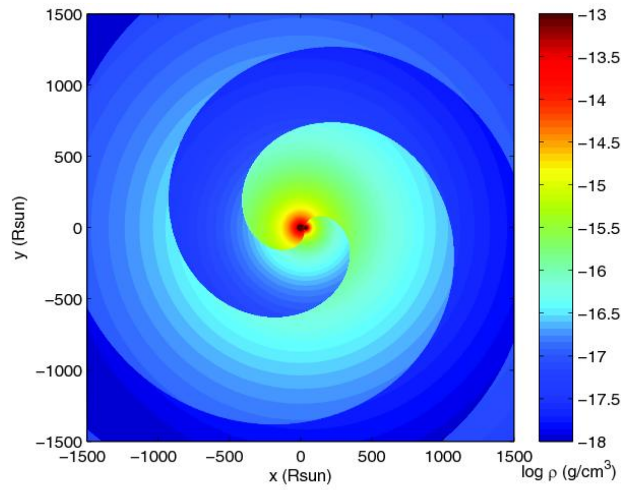
- Large phase range suggests very wide shock cone.

Test case: V444 Cygni (WR 139)

- X-ray light-curve modeling by C. Russell confirms large opening angle = signature of radiative braking/inhibition within the system.







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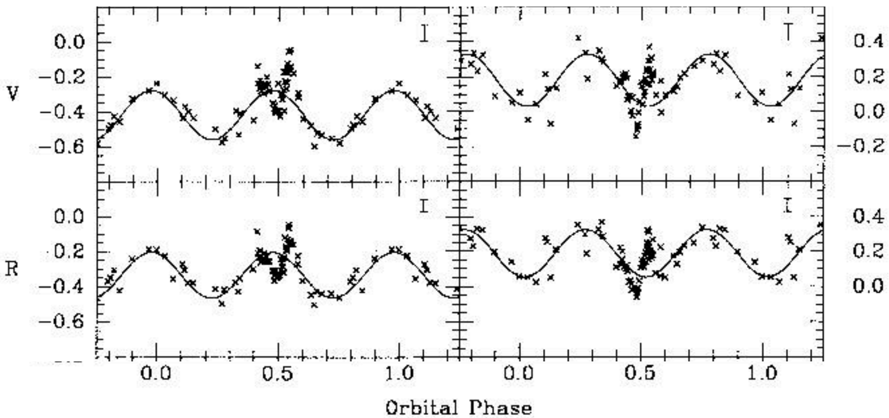
Test case: V444 Cygni (WR 139)

Continuum %Q and %U

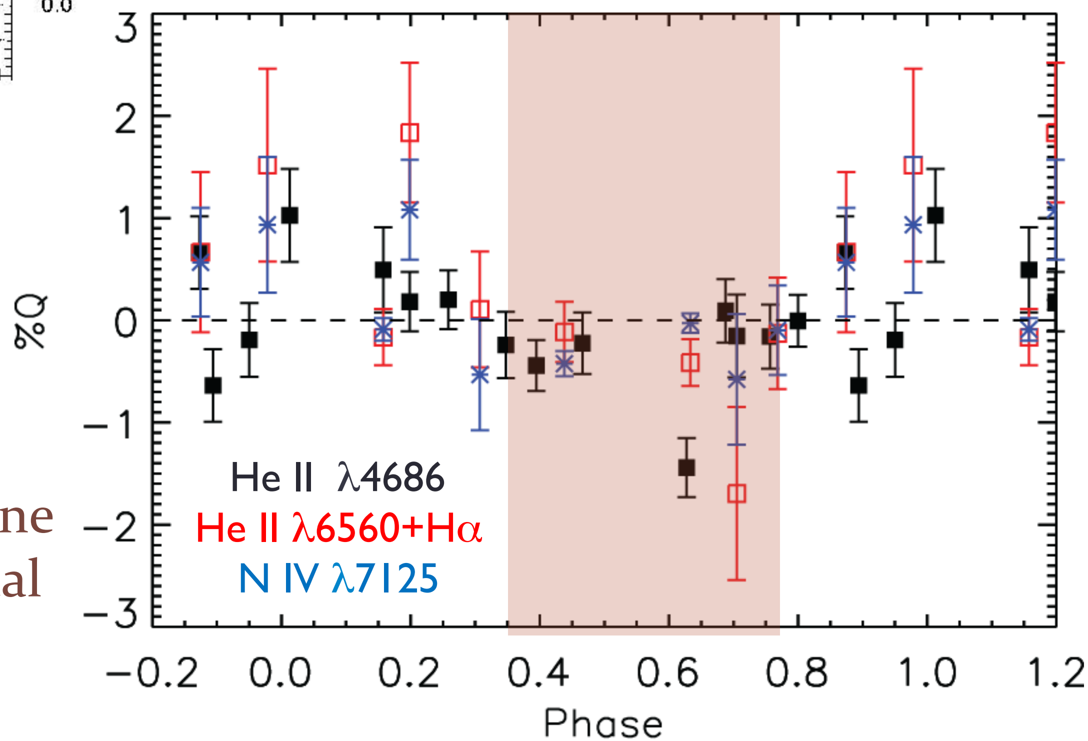


St-Louis+ 1993

B, *V*-band continuum polarization is double-peaked and dominated by light from the WN star.

Polarization in 3 emission lines:

- unlike that of the continuum
- distinct difference between phases "in and out" of shock cone
- all similar if rotated to individual average angles
- similar behavior to SN "cavity" simulations.



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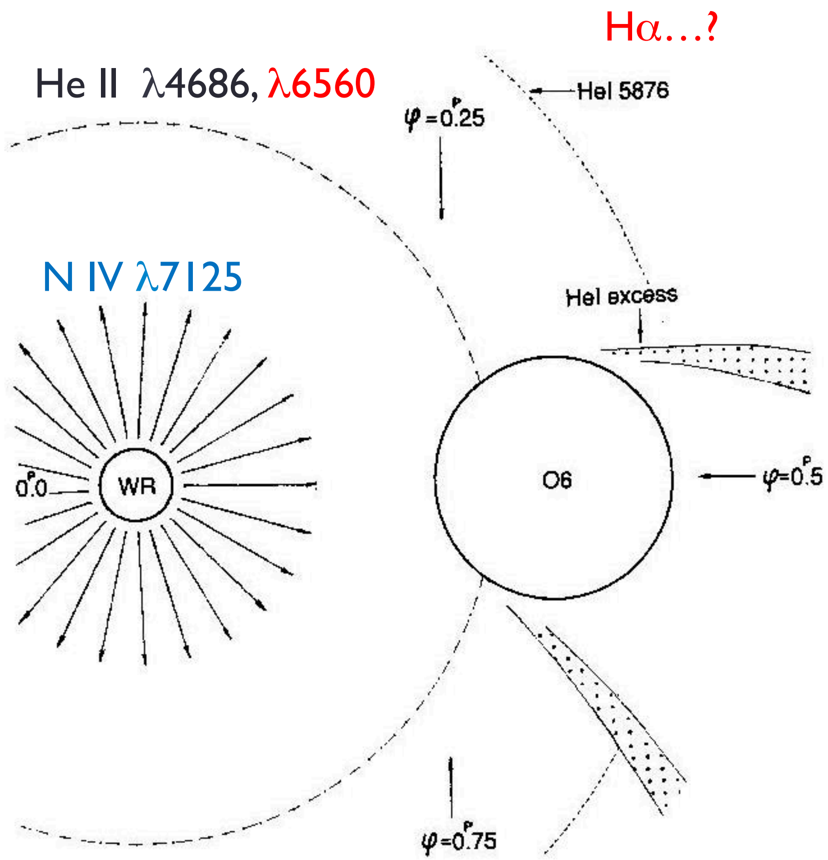

Marchenko+ 1997

No "far-scattering" lines yet detected, though Hα contribution to blend *could* be unpolarized!

Future work:

- more polarimetric data on V444 Cyg (new HPOL @Ritter, SPOL @UA telescopes)
- MCRT polarimetric modeling to clarify emission, scattering regions and proposed shock structure **(see Manisha Shrestha's poster)**
- line polarization observations of other WR binary stars, further testing binary line effect method.

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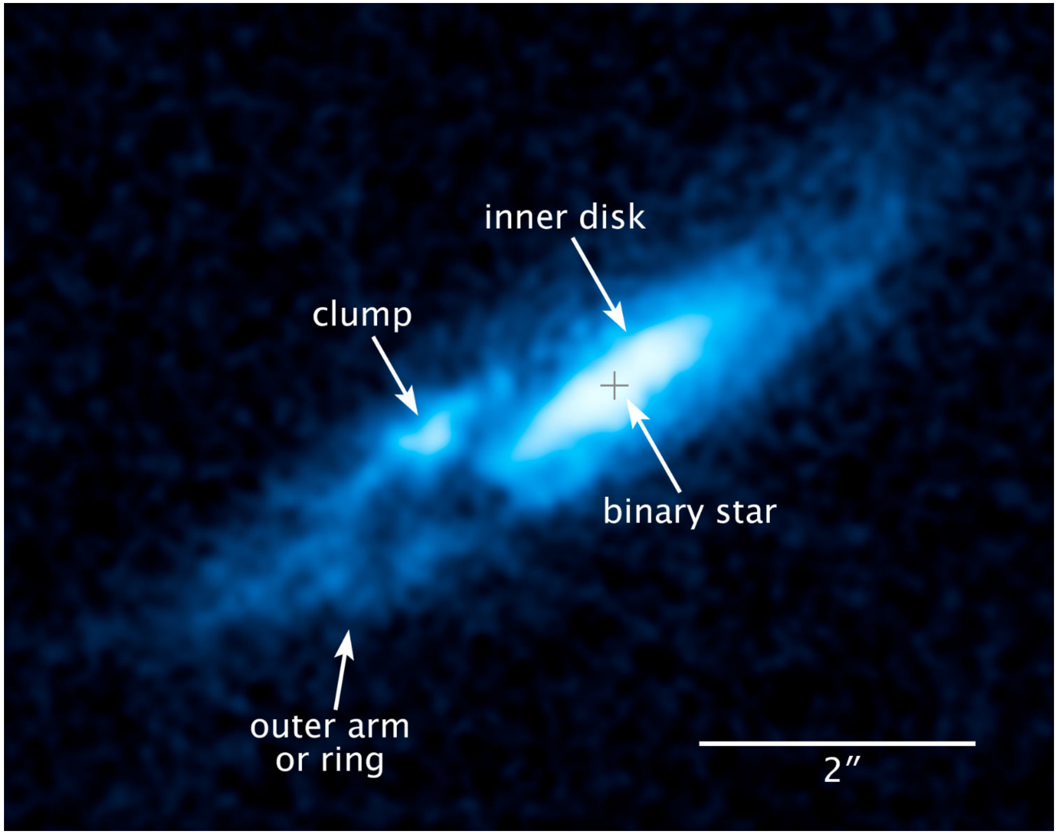

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