Eta Carinae: The tamed shrew

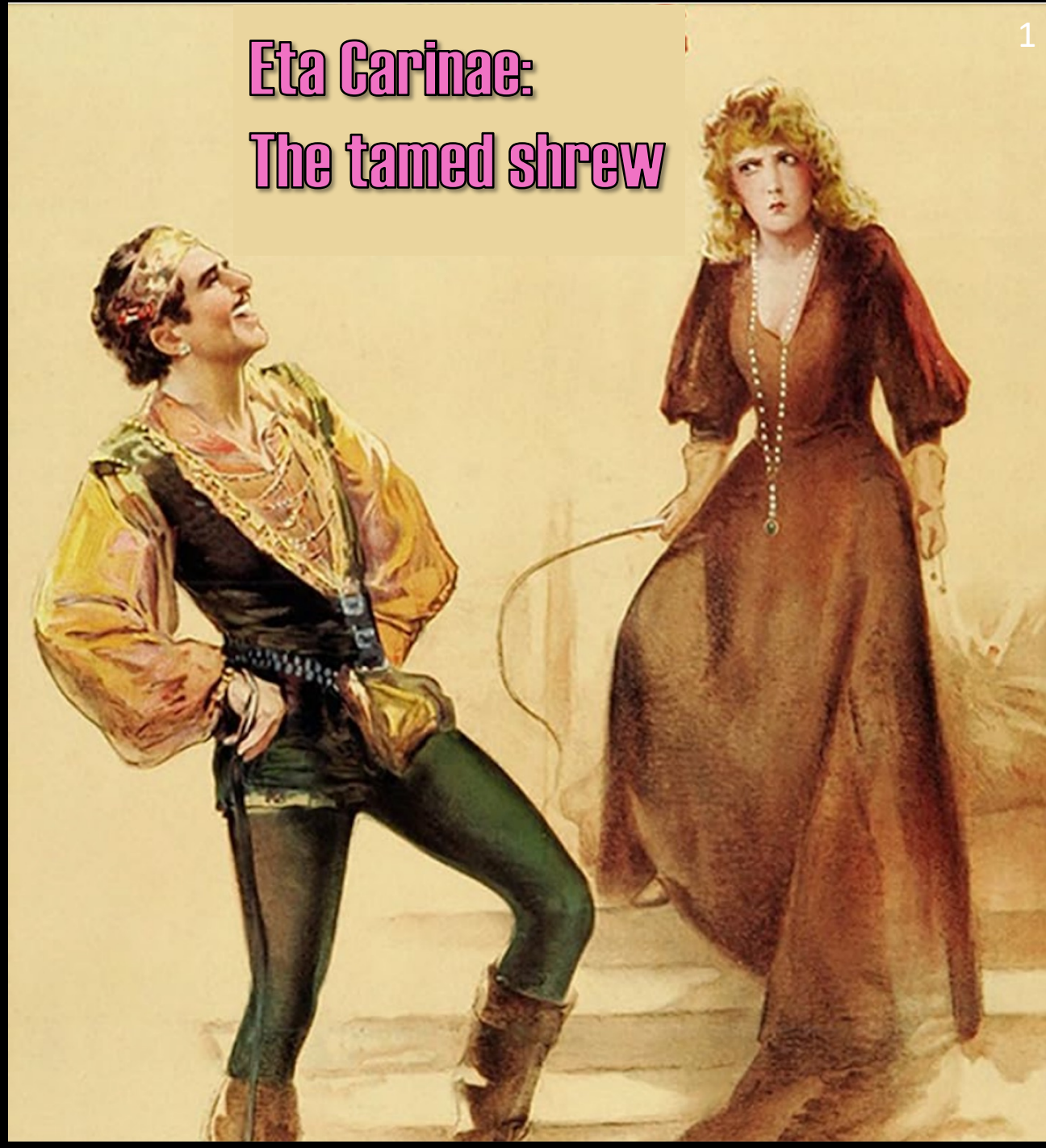
Augusto Damineli
+ large team

USP 90 ANOS 1934 2024

GMT+IAG

POEMS

ON/RJ – 24-28 June 2024



1rst act: OLD paradigm

- eta Car is an unstable LBV star, recovering from the 1847 Giant Eruption. Occasional shell ejections

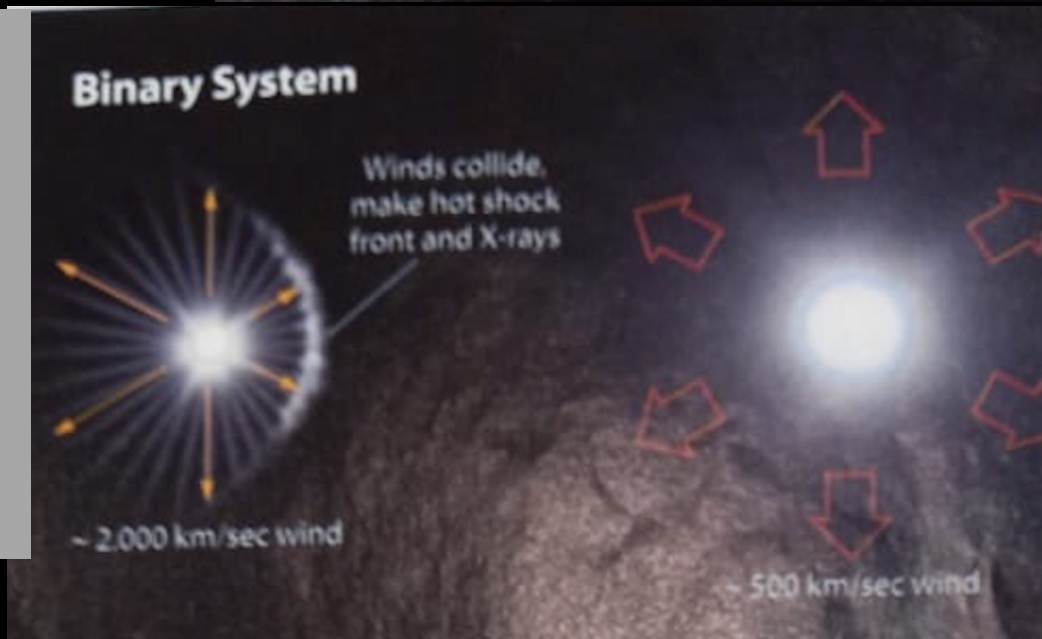
-Recent changes are due to a fast stellar evolution with decreasing $\dot{M}$ of the primary star

Kris Davidson
S&T 1998

2nd act: NEW paradigm

- Eta Car is an interacting massive binary with stable companions

-The changes since the 1900s are due to extinction decrease – dissipating occulter



Setting the stage: the main players

Little Homunculus (1890)

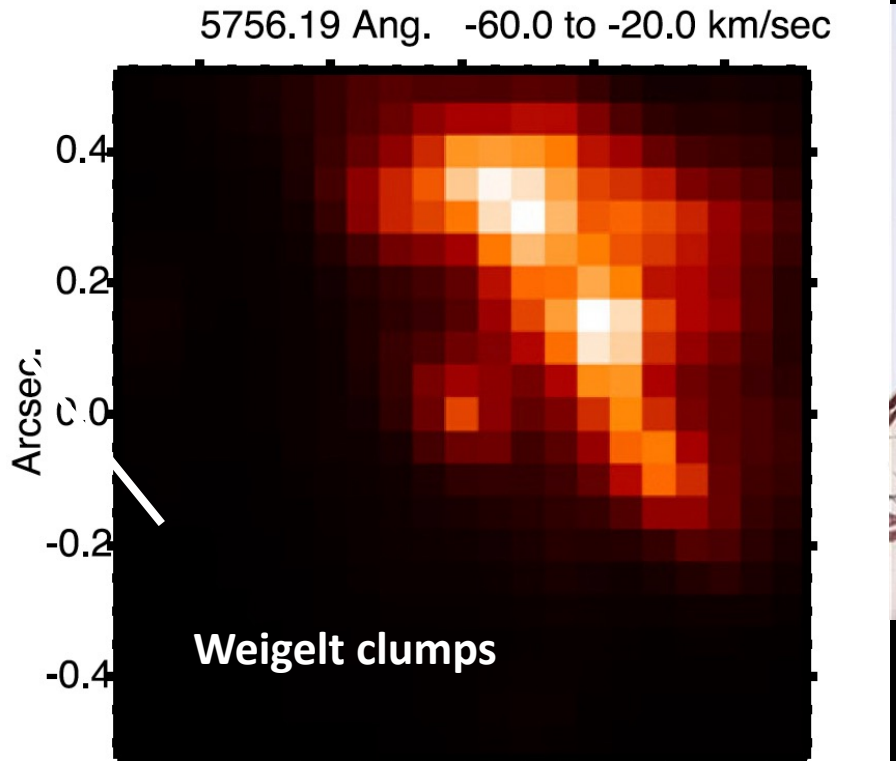
Homunculus (1847)

Older ejecta

massive binary
Powerhouse of
the system

45 00K

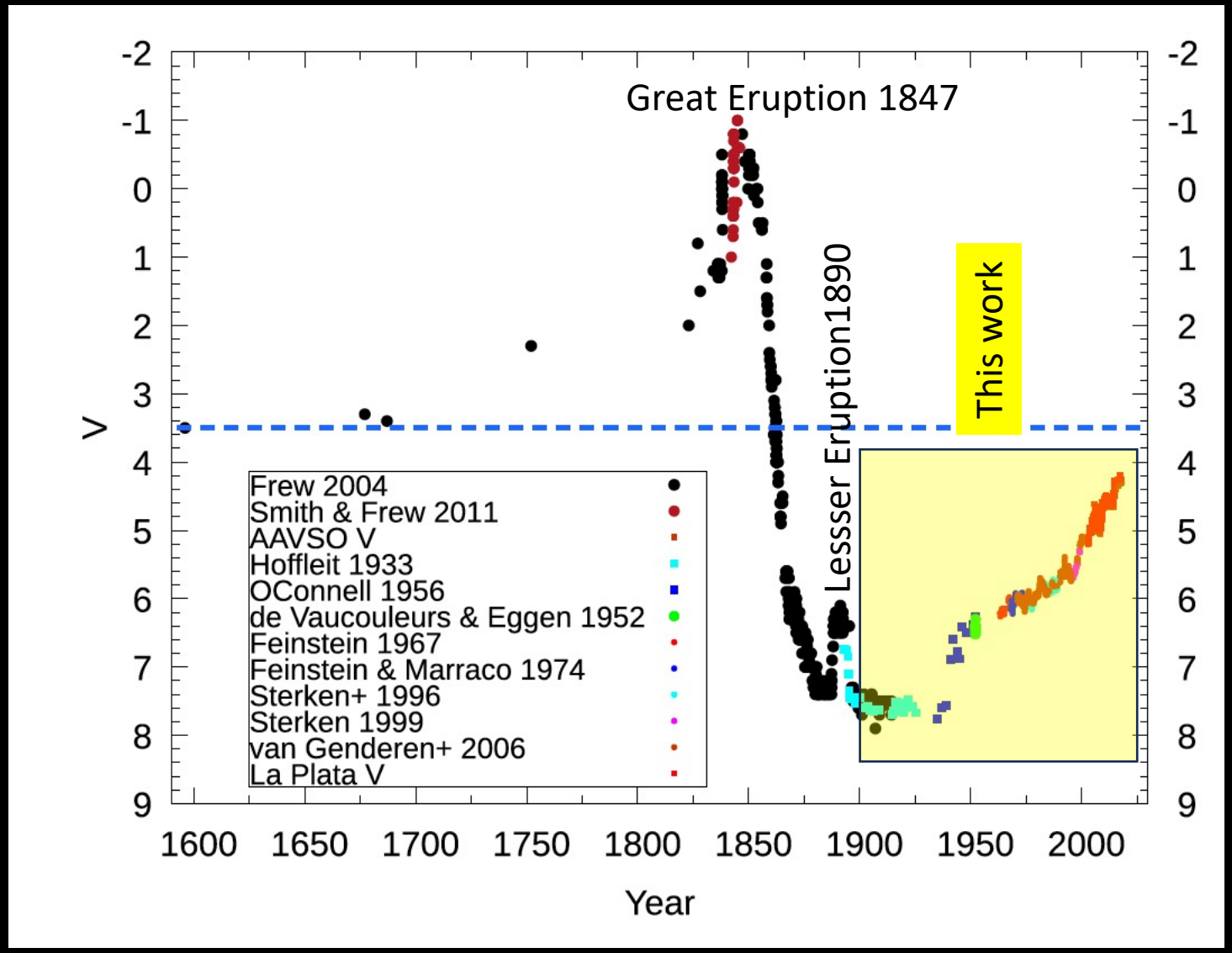
15 00K



dissipating occulter

Basis of the stellar instability scenario

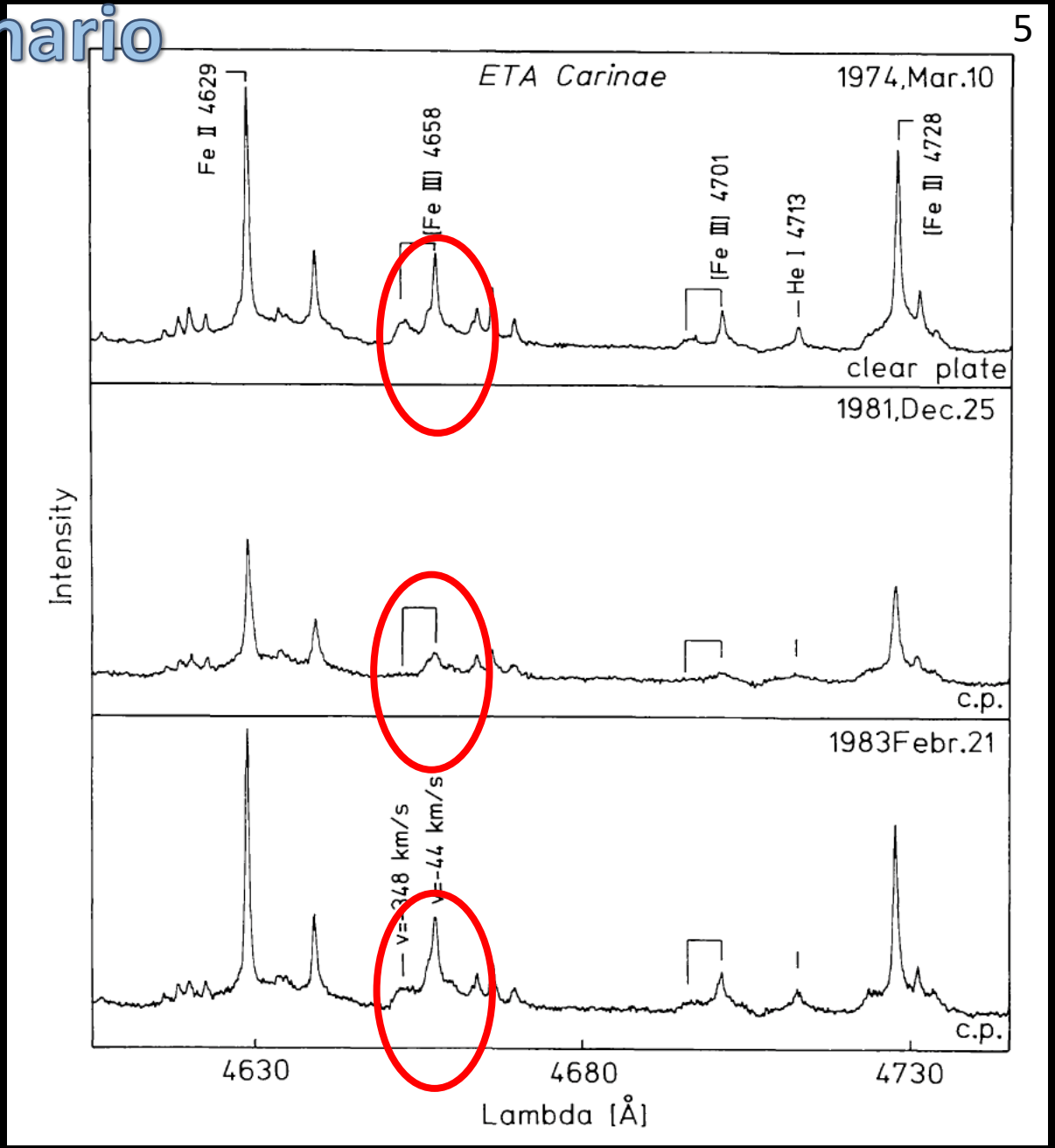
The ever-changing photometric light-curve of the whole object (core+nebula)



Basis of the stellar instability scenario

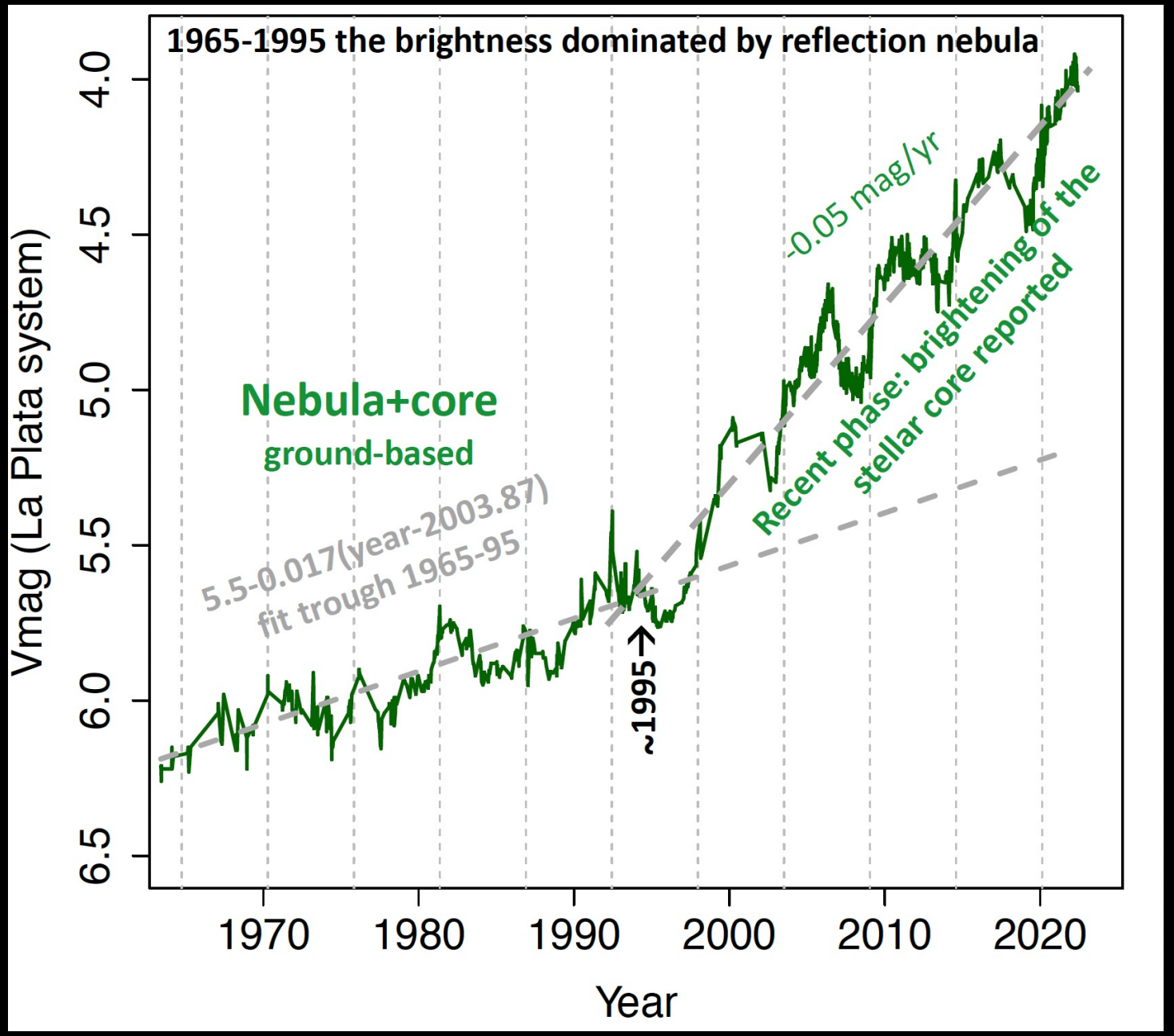
High excitation lines show transient low excitation events

Zanella et al. 1984



Basis of the stellar instability scenario

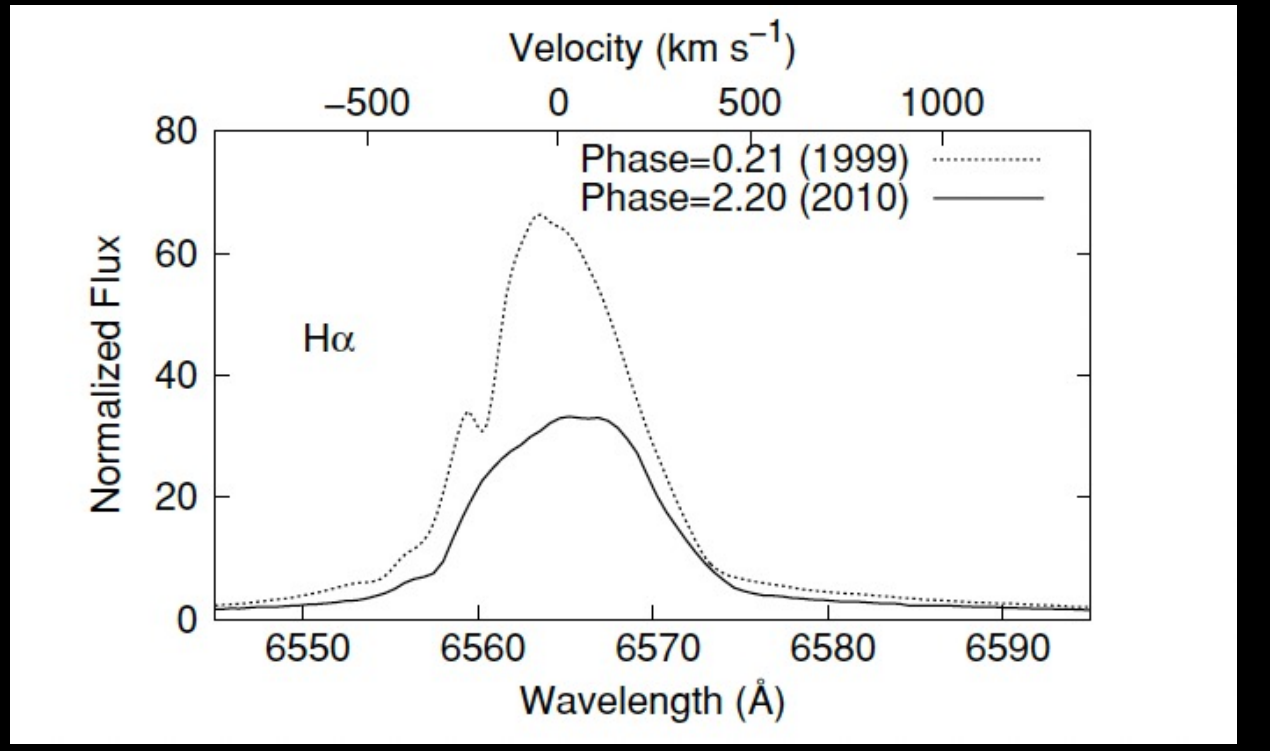
Unrestling brightness

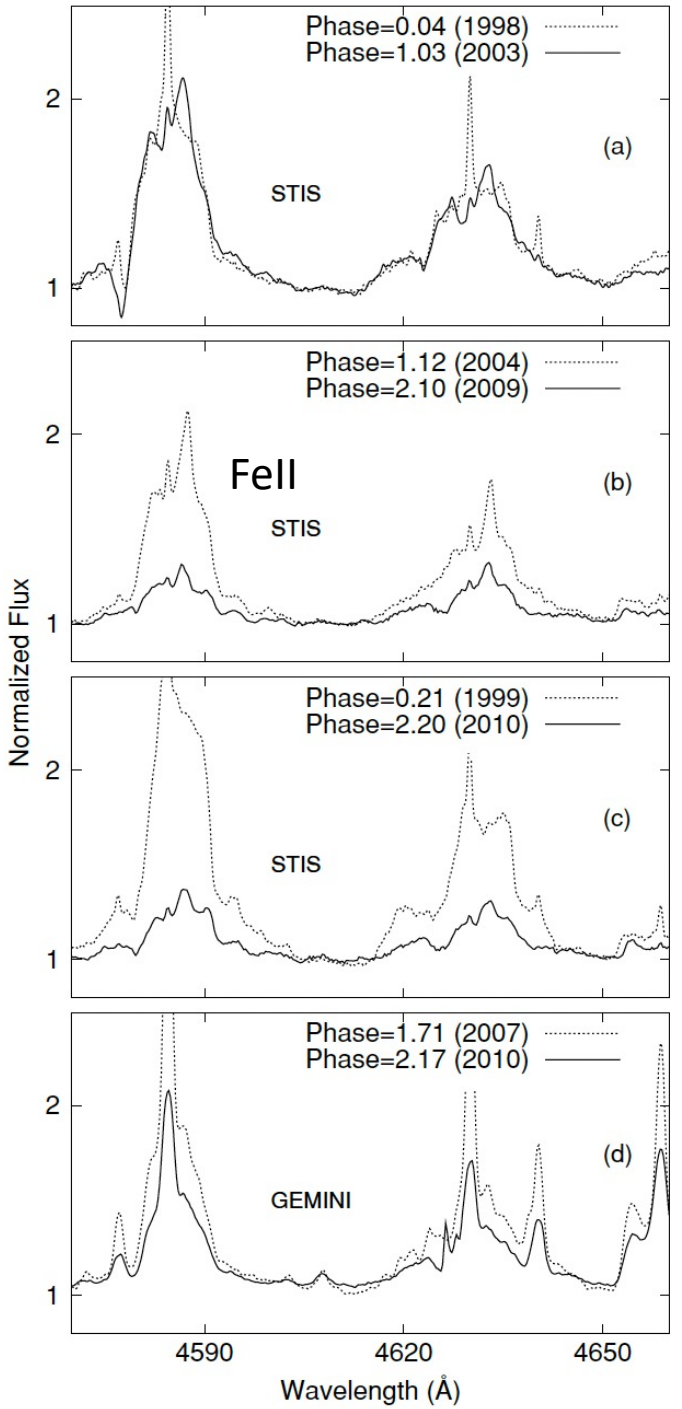


Basis of the stellar instability scenario

Large changes in the profile/intensity of the wind lines

Mehner et al 2010

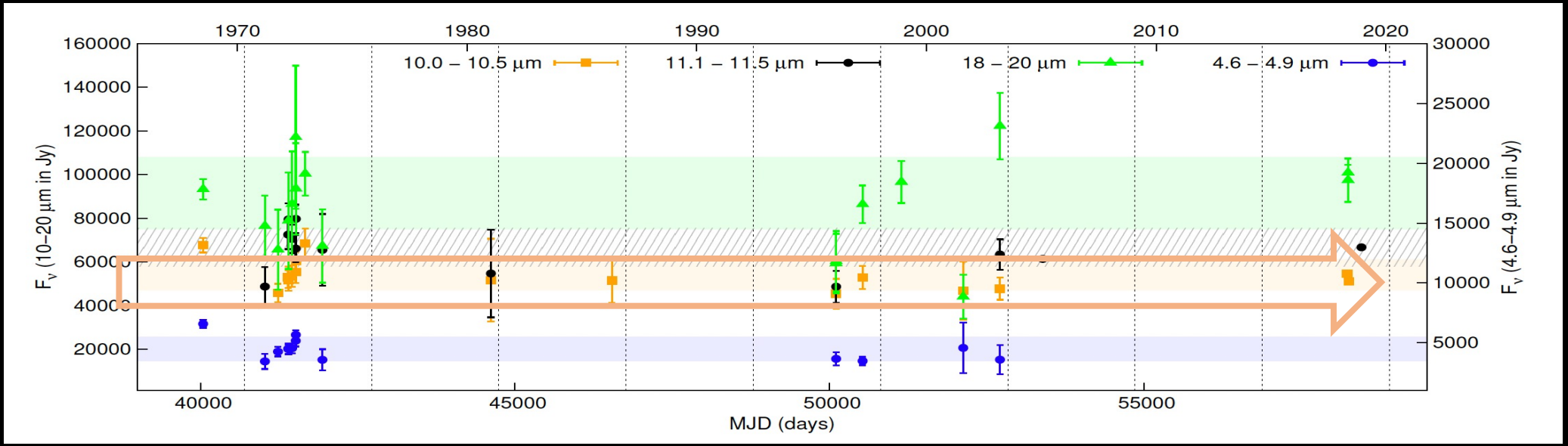




Cointractions between Intrinsic variability X observations

contradictions

The MI-IR brightness is constant (calorimetric re-emission of the dust in the nebula)

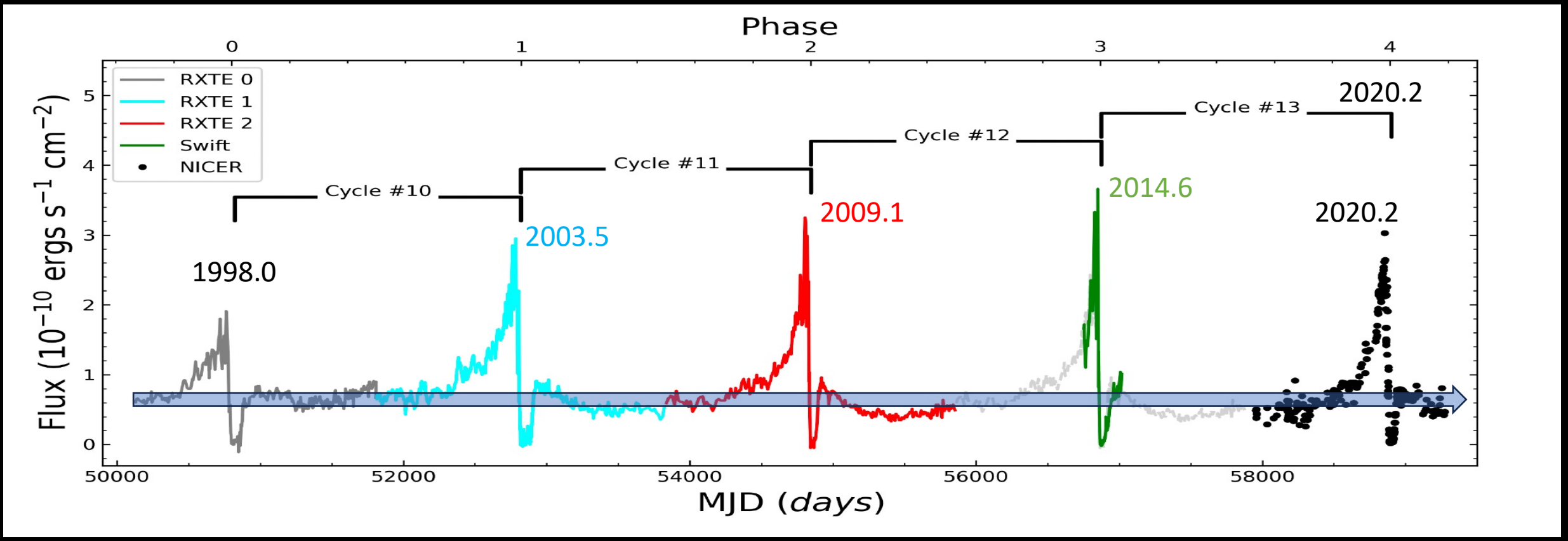


Mehner et al. 2019

MID-IR brightness
tracks the central star luminosity
low ampl. variations?

contradictionss

The X-rays light-curve (wind-wind collision) is constant, indicating a stable wind of the secondary star



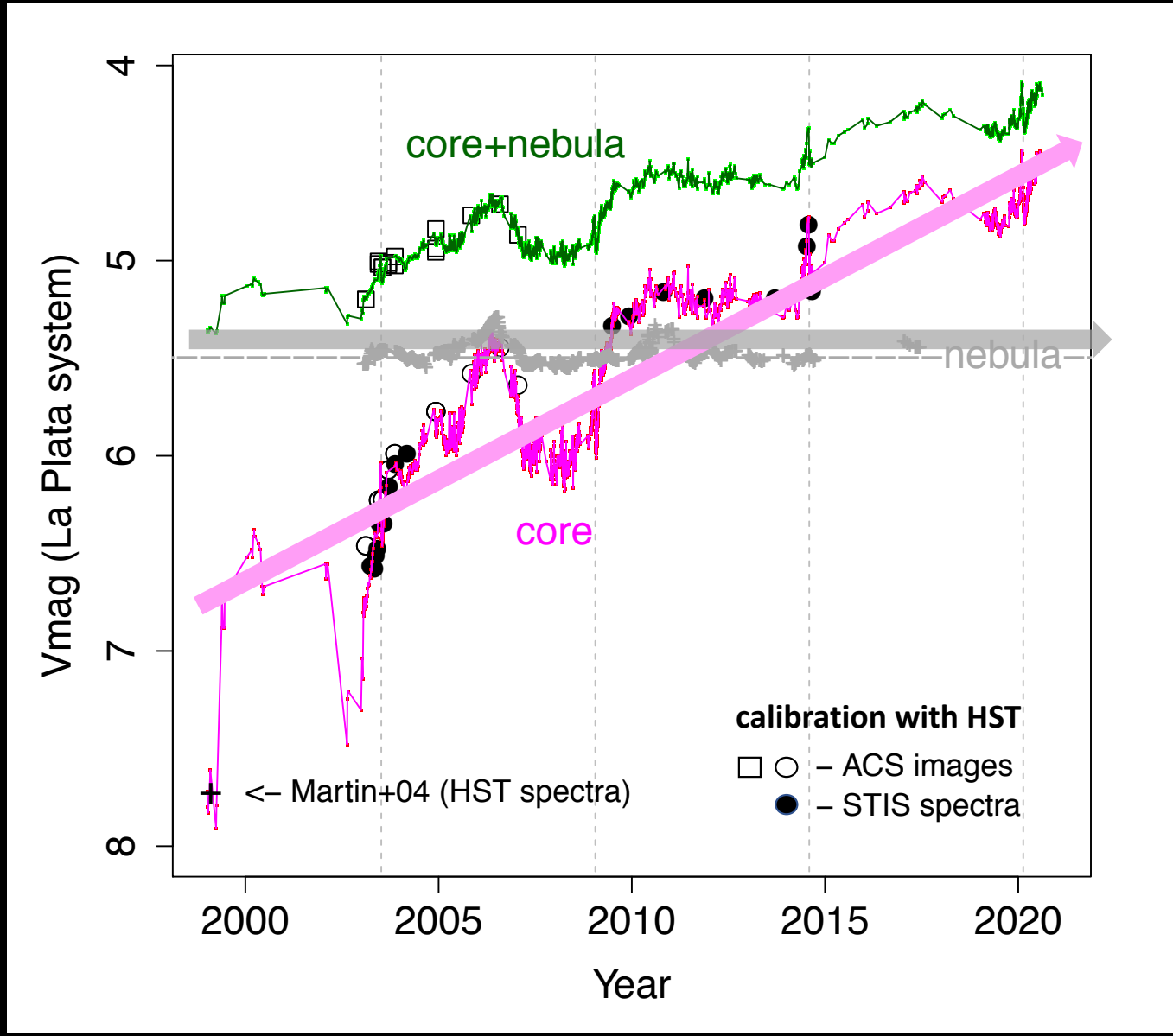
Espinoza-Galeas+2022

Contradictions

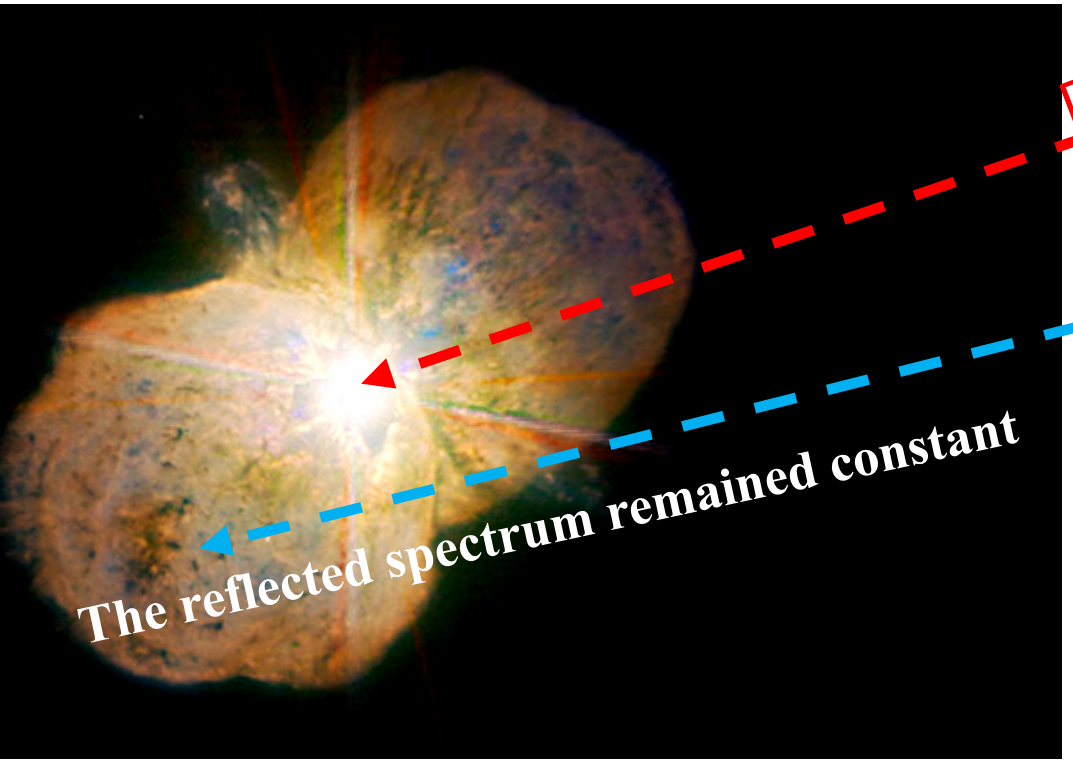
In 2000-20s the stellar core brightned by 10X, what is not allowed for a star close to the Eddington limit

The reflecting nebula remained constant (contrary to 1940) .

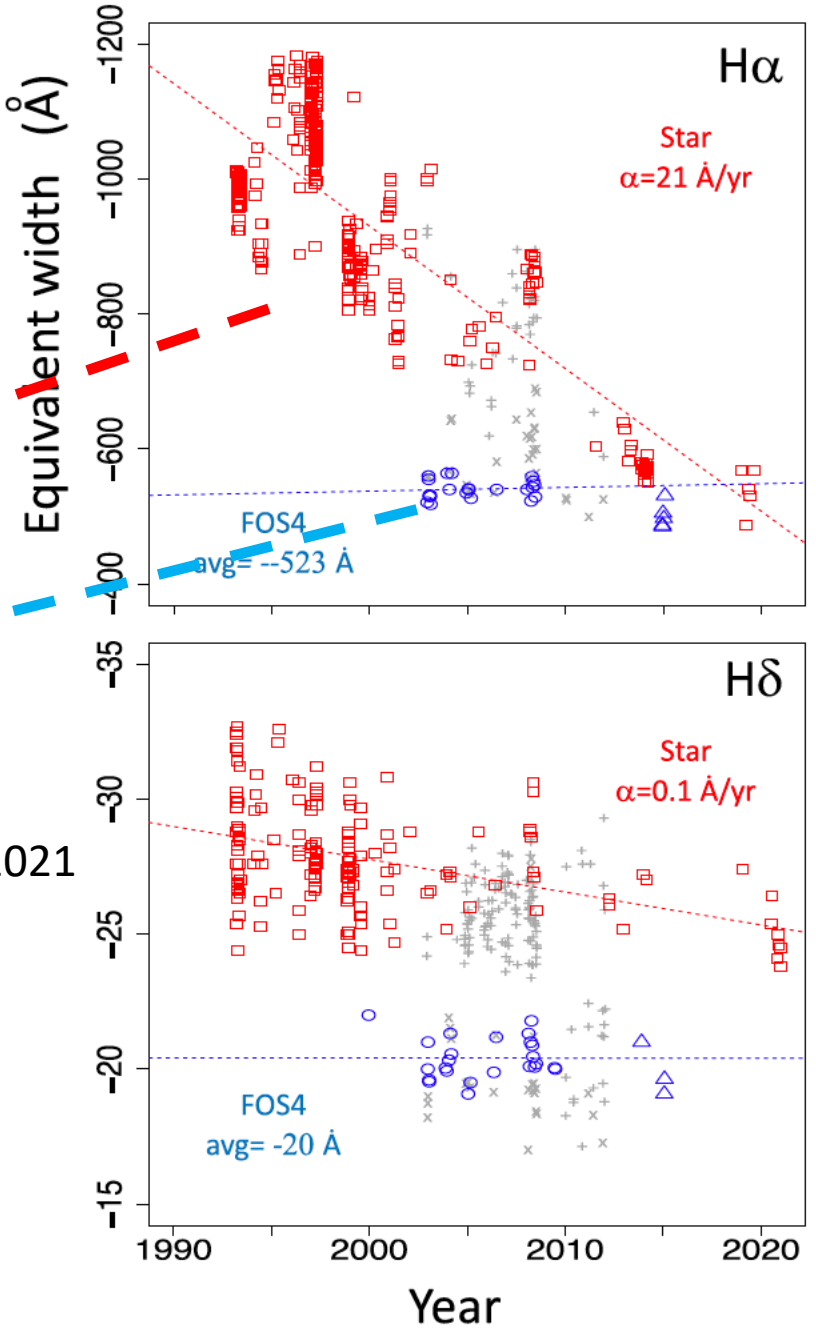
How does it reflect the central core?
The extinction decreased for us,
but have not changed for the Homunculus.
Coronagraphic occulter



The direct spectrum is converging to the reflected one as the occulter dissipates because we see more stellar continuum.



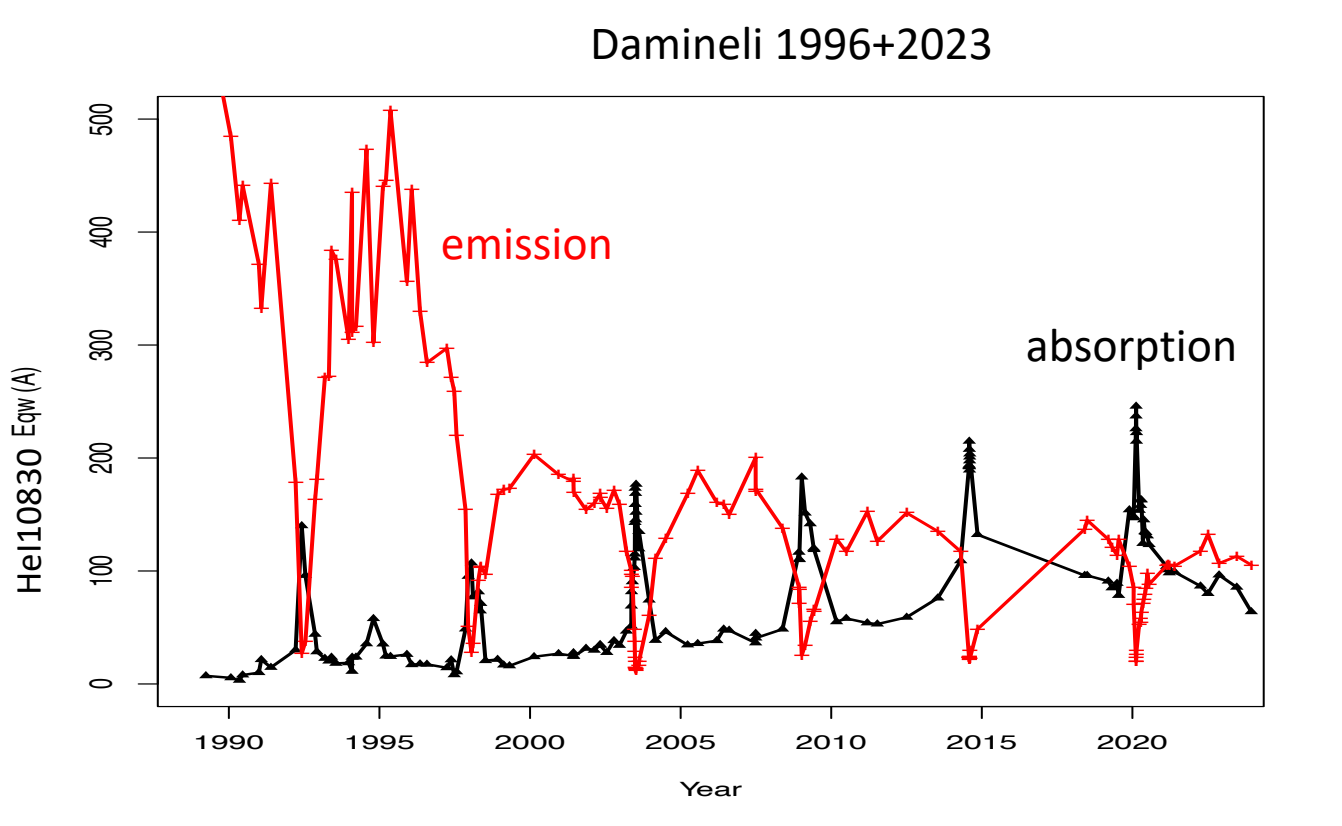
Damineli et al. 2021

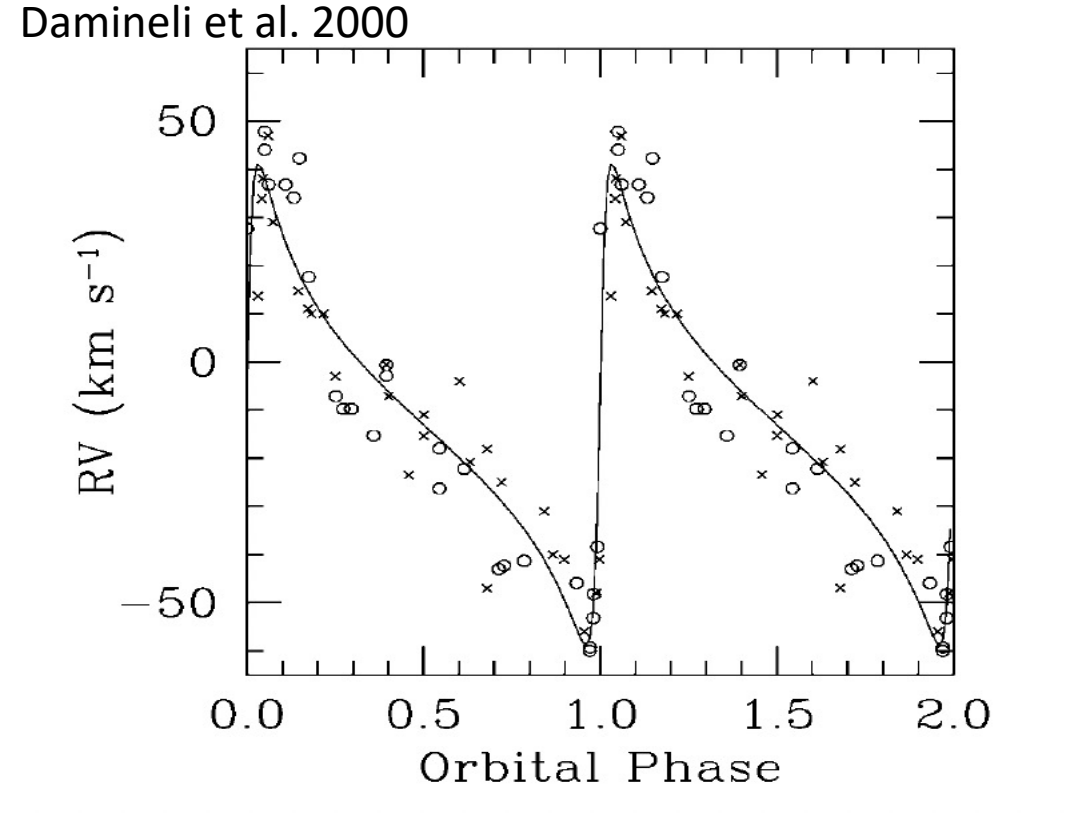


Binarity of the central star is a key ingredient to monitor the long-term evolution (same orbital phases)

The short-lived low excitation events were found to have strict periodicity P=5.534 yr

They correspond to periastron passsages in a very eccentic binary. (ec=0.9)

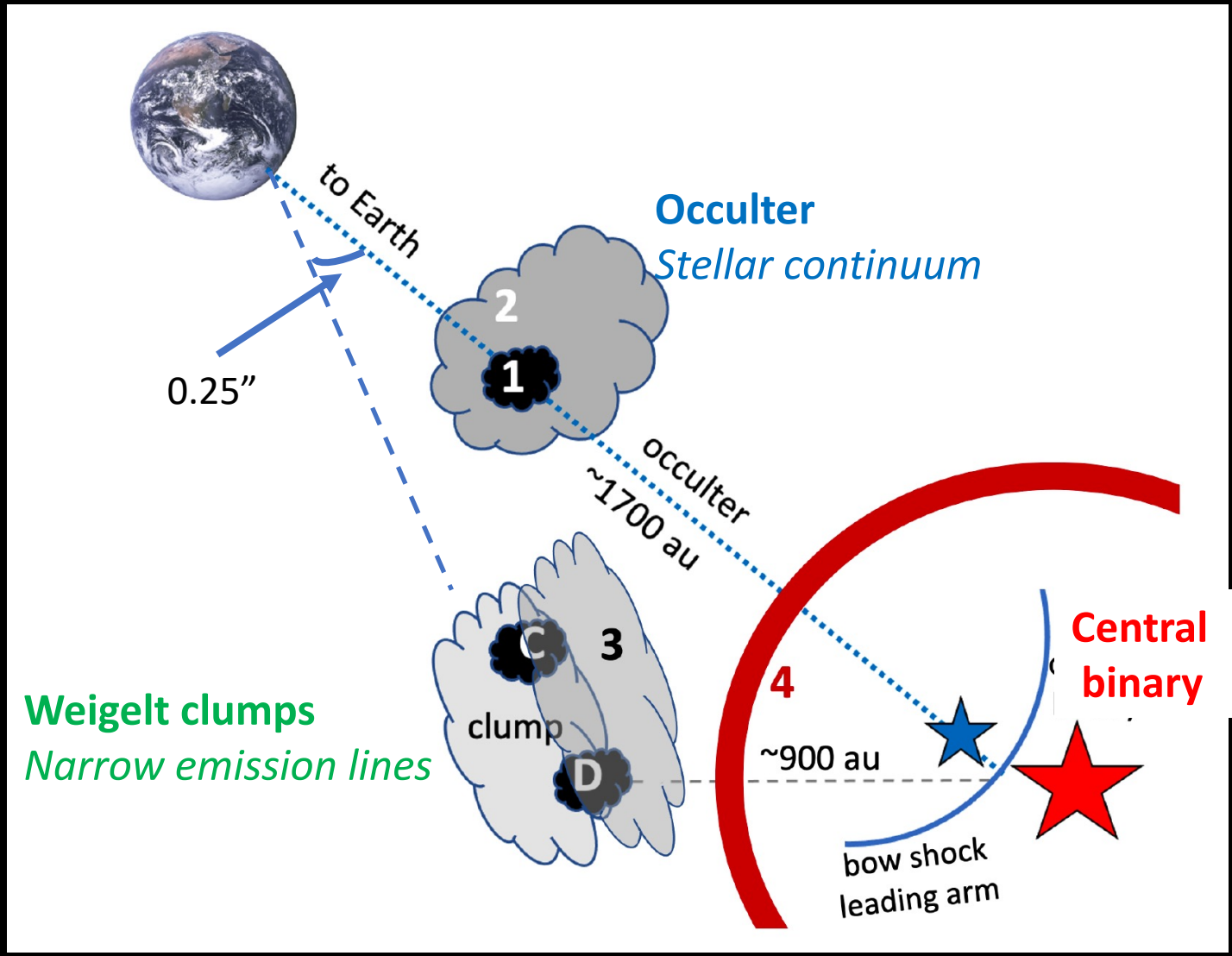




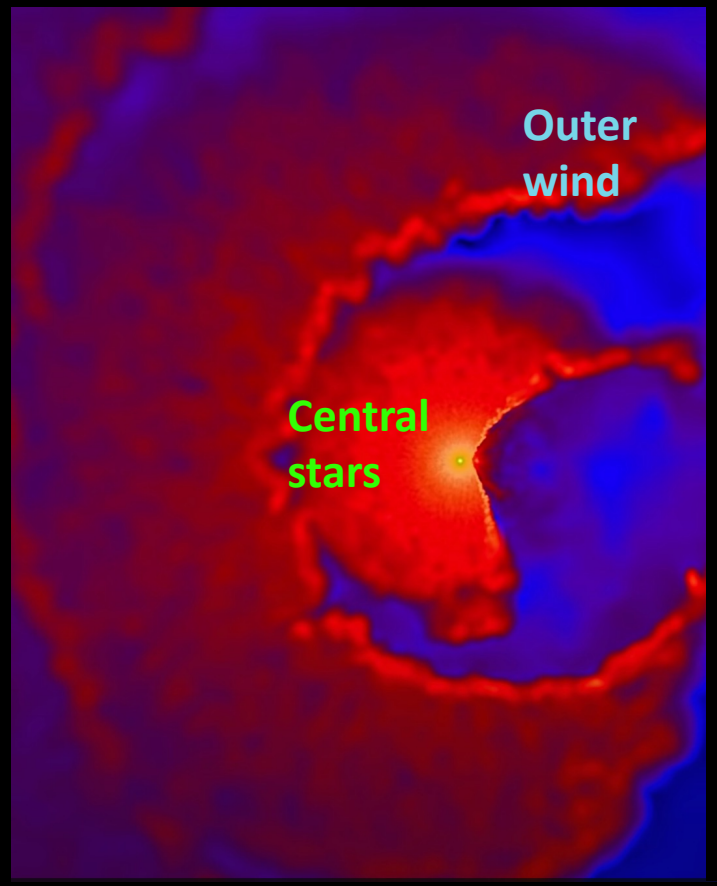
- ***The star is constant!***
- ***The extinction is decreasing (only) to our L.O.S.***
- ***There must be a (coronagraphic)*** **occulter** ***to our L.O.S.***
- ***The*** **occulter** ***is dissipating (its extinction is decreasing)***

All the the relevant spectroscopic changes occur close to our line-of-sight (except that in 1940)

Damineli et al. 2024



Impact of the dissipating occulter on the observed spectrum

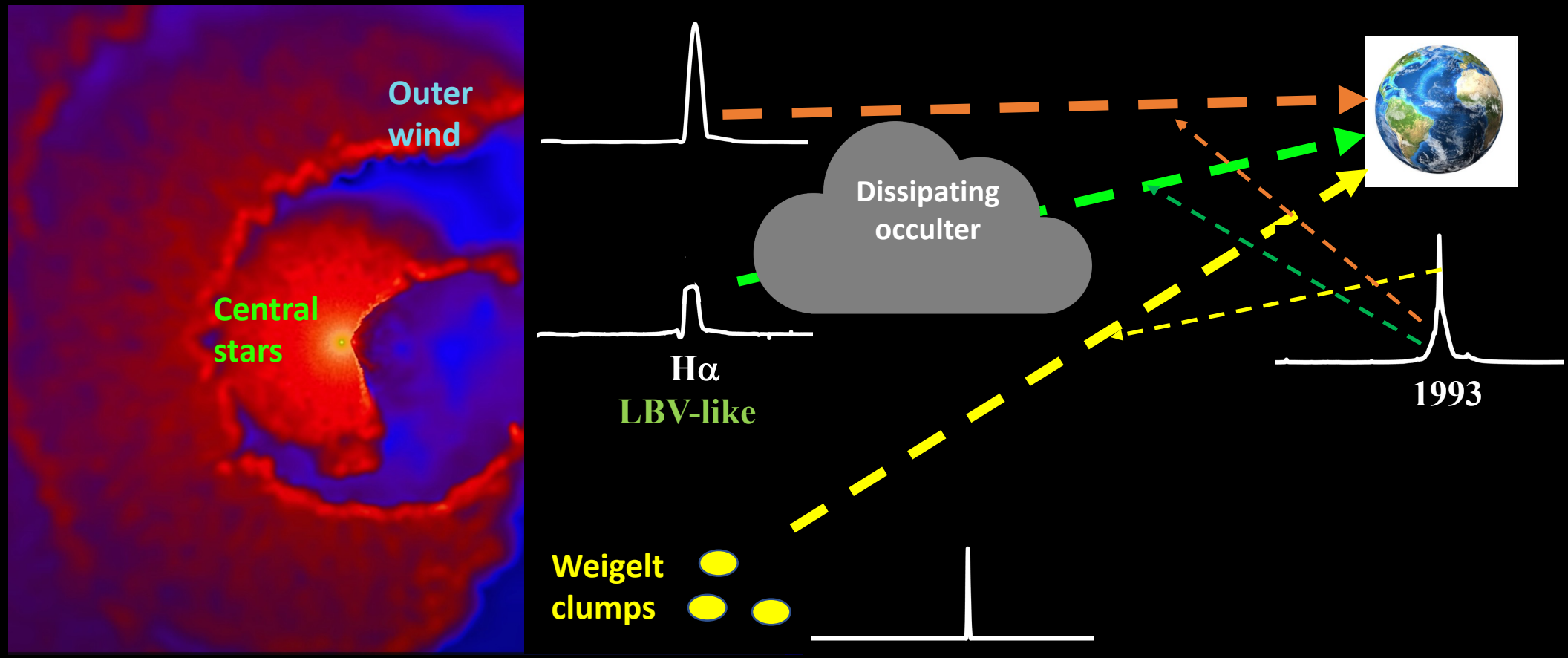


Hα

LBV-like

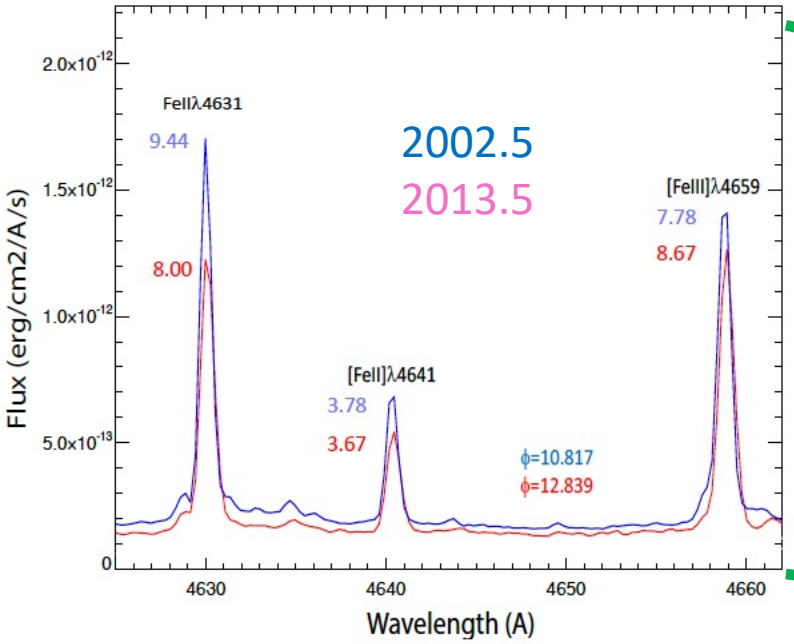
Weigelt
clumps

Impact of the dissipating occulter on the observed spectrum



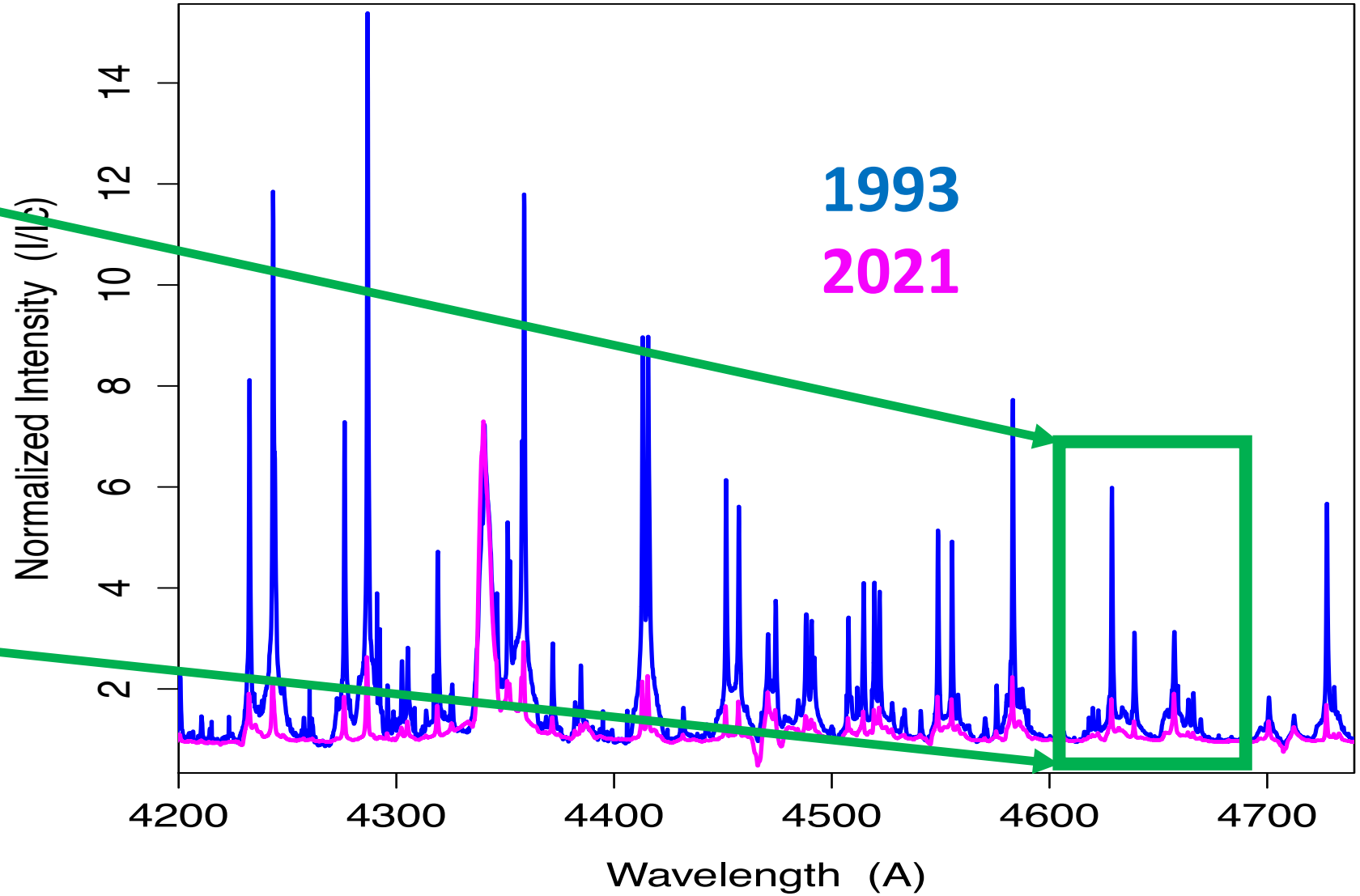
NEBULAR EMISSION LINES: Weigelt clumps

HST/STIS
Constant flux



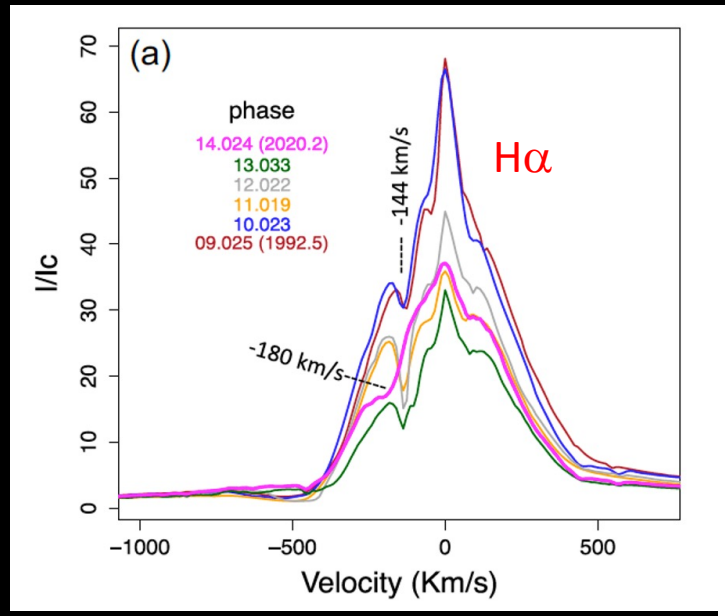
Damineli et al. 2023

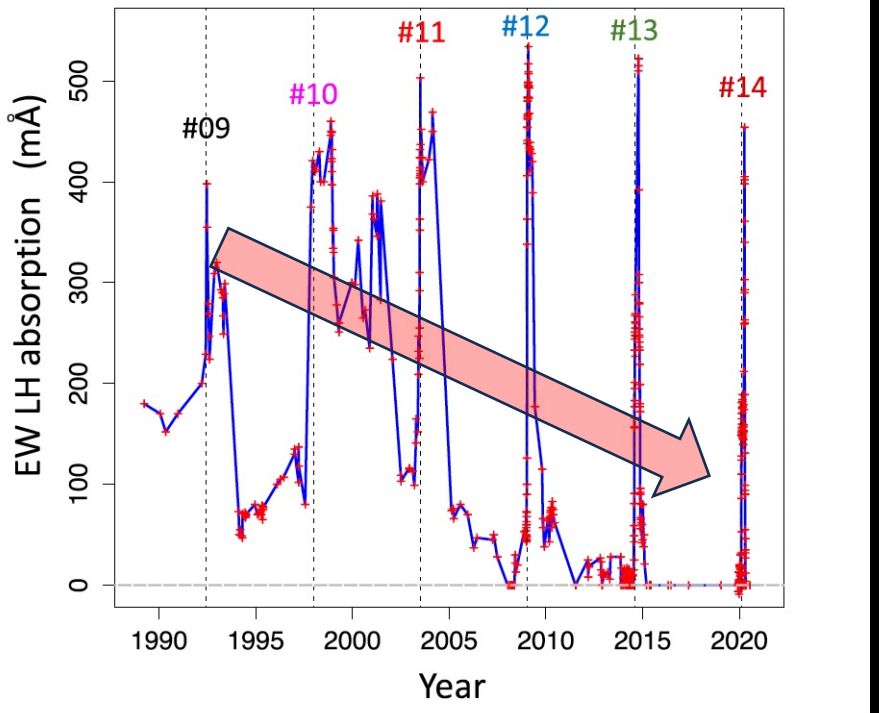
From the ground



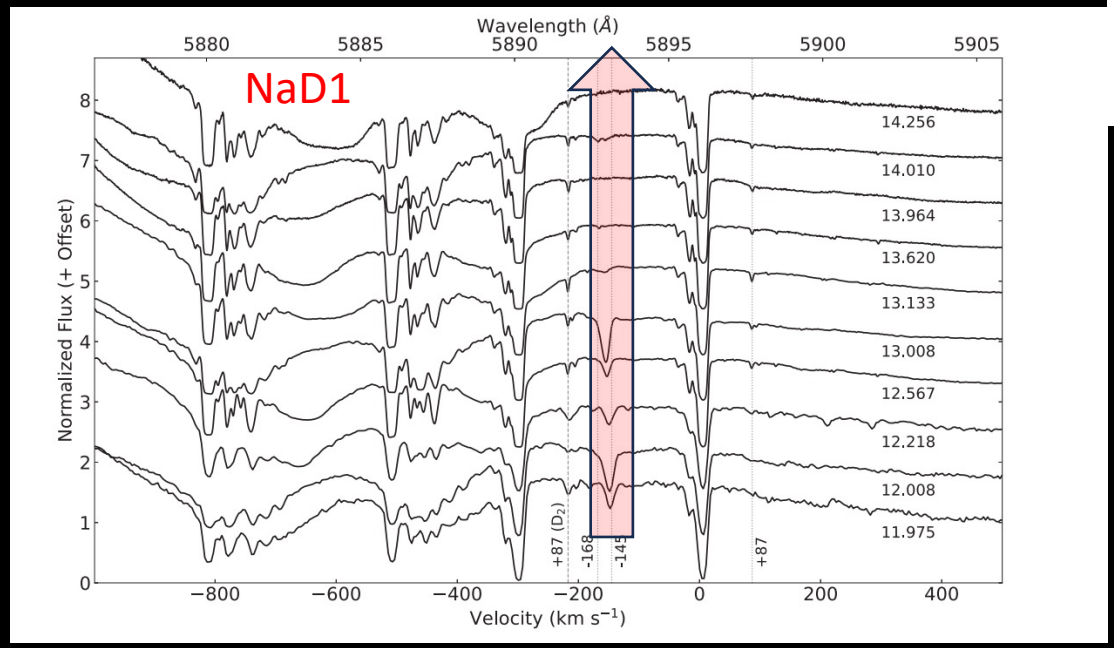
NEBULAR ABSORTPION LINES: a) Little Homunculus (UV ionization)

Damineli et al. 2021





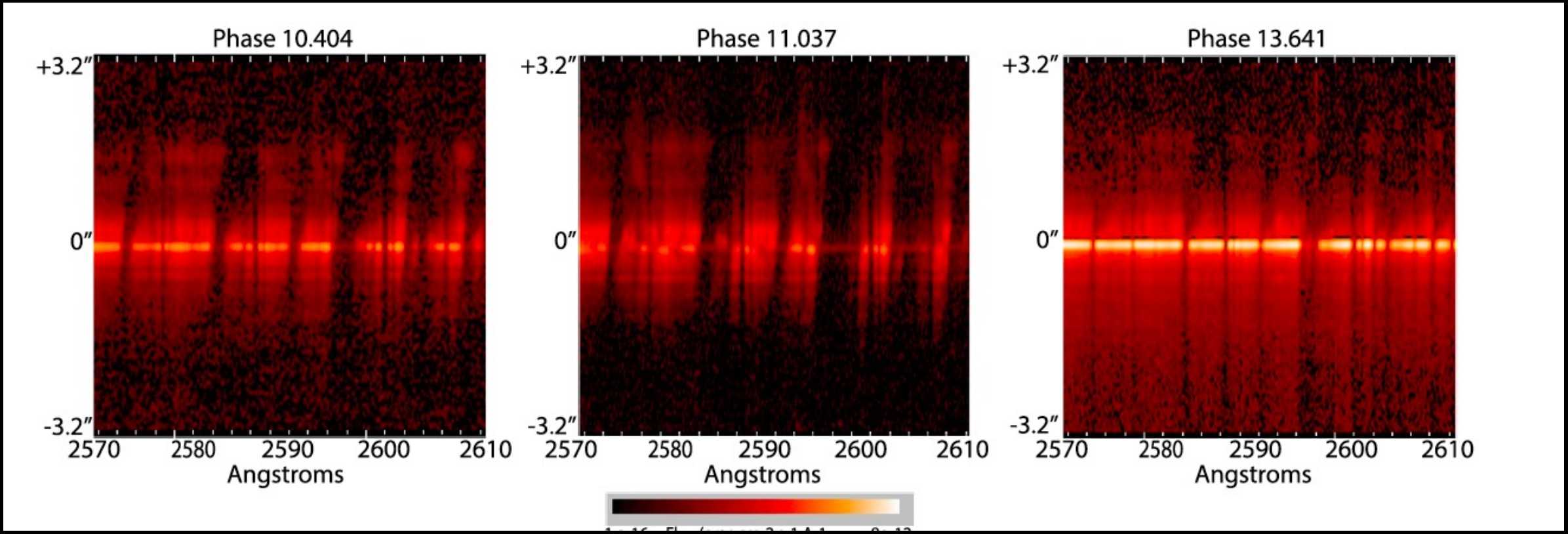
Pickett et al. 2022



NEBULAR ABSORTPION LINES: a) Homunculus (UV ionization)

Gull et al. 2023

> 800 lines H_2



The coronagraph has an extended halo ±3”

WIND LINES: MODELS

CMFGEN CODE

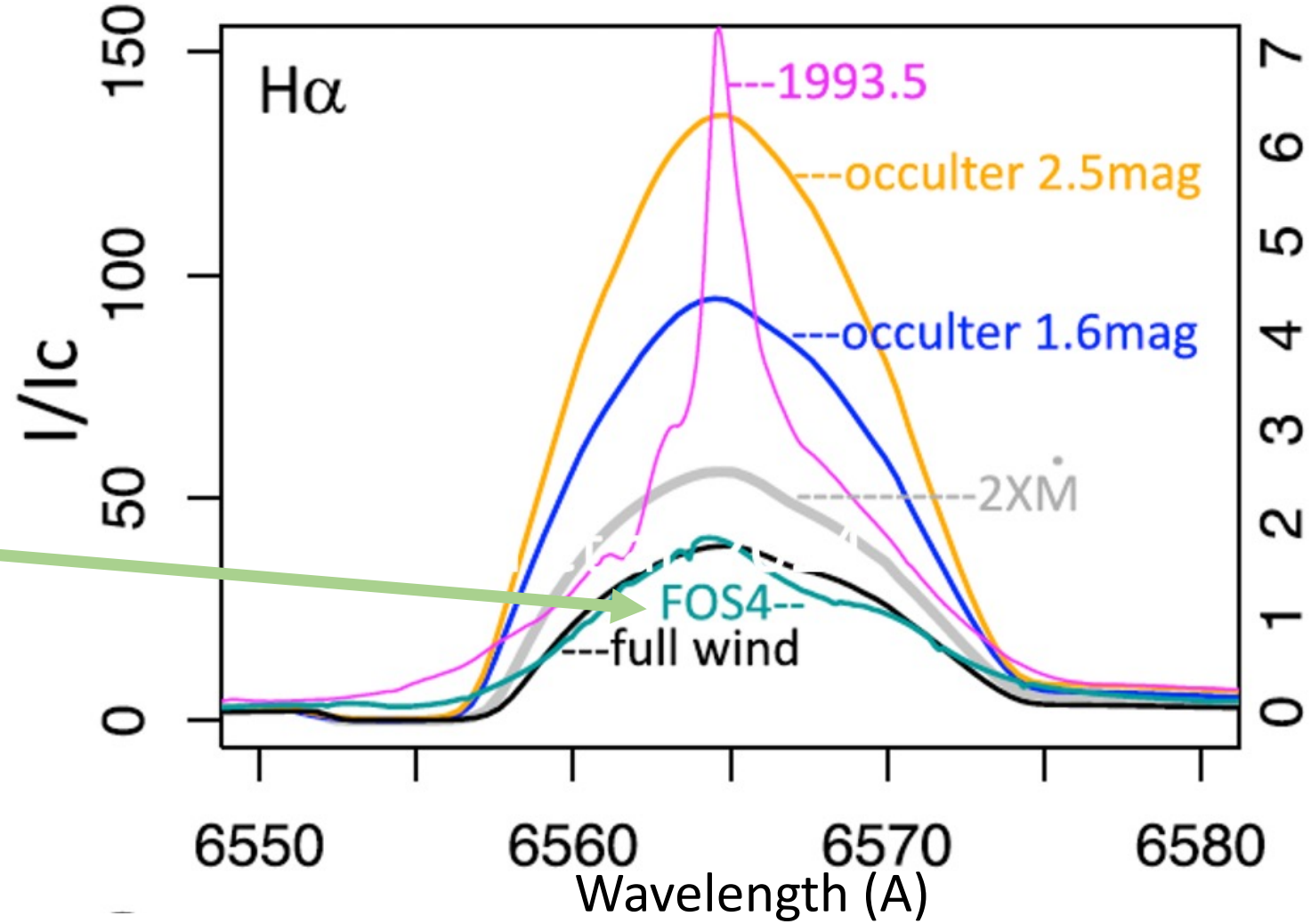
Occulter extinction decrease: 1.6 and 2.5 mag since 1993

$\dot{M}$ decreased? by 2X since 1993

Fit to the reflected spectrum at FOS4 = full wind

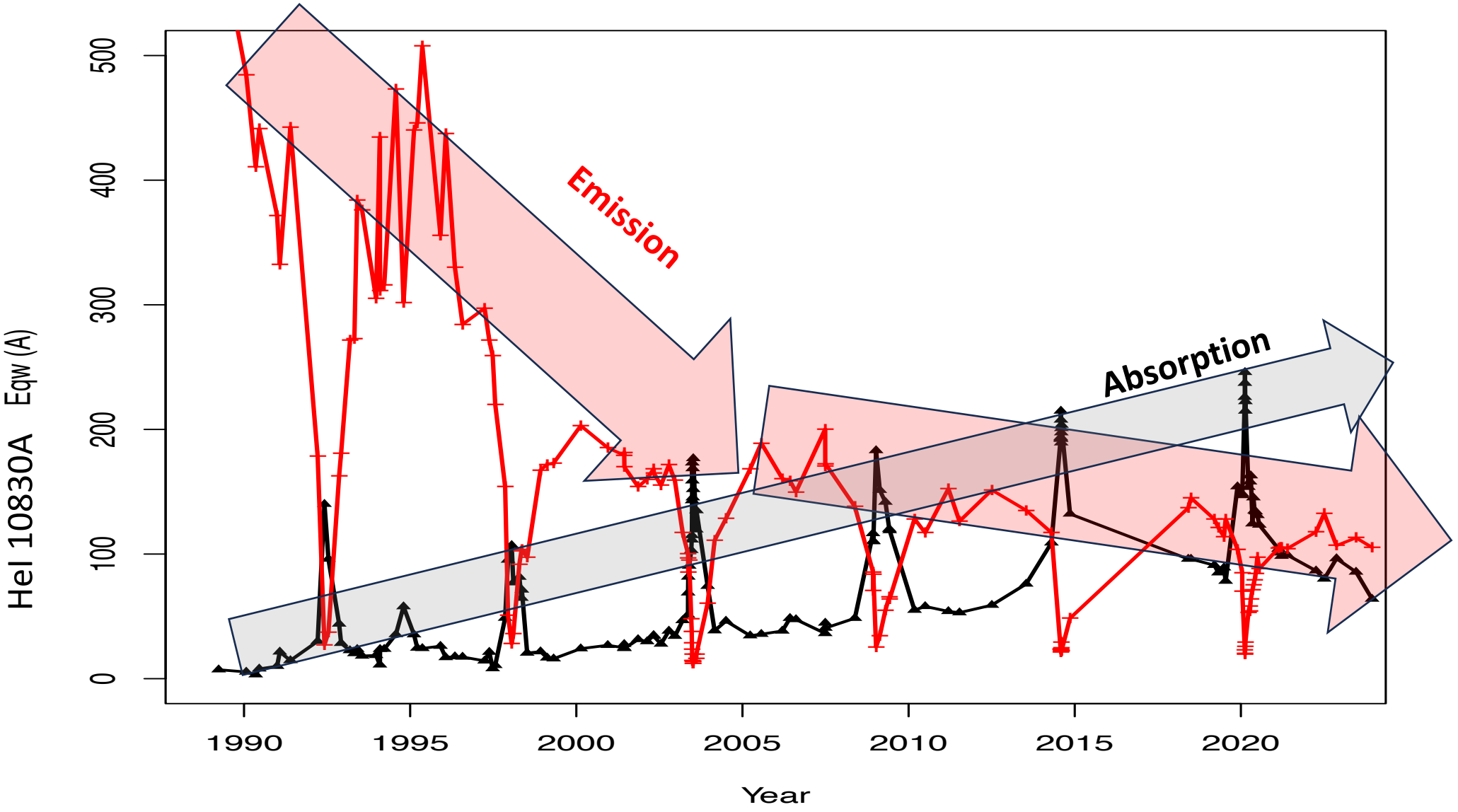
$R_* = 240\,R_\odot$;
$\dot{M} = 3.9 \times 10^{-4}\,M_\odot\,\mathrm{yr}^{-1}$;
$L = 4 \times 10^6\,L_\odot$; and
$N(\mathrm{H})/N(\mathrm{He}) = 10.$

Damineli et al. 2023



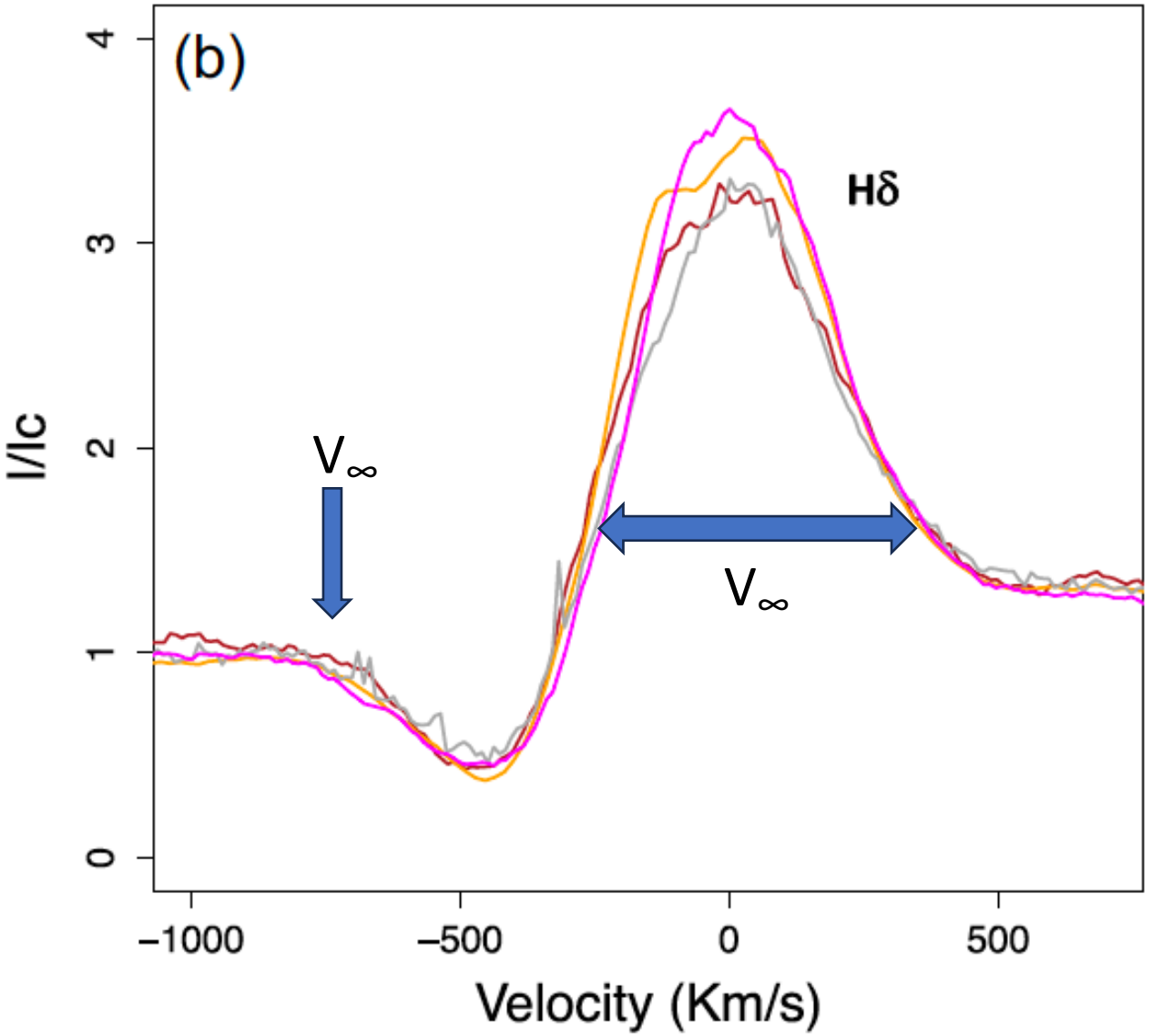
WIND LINES: a) absorption strength. (KILLING FOR DECREASING $\dot{M}$)

Damineli et al. 2023



WIND LINES: a) absorption & emission width (BIG PROBLEM FOR **DECREASING $\dot{M}$**)

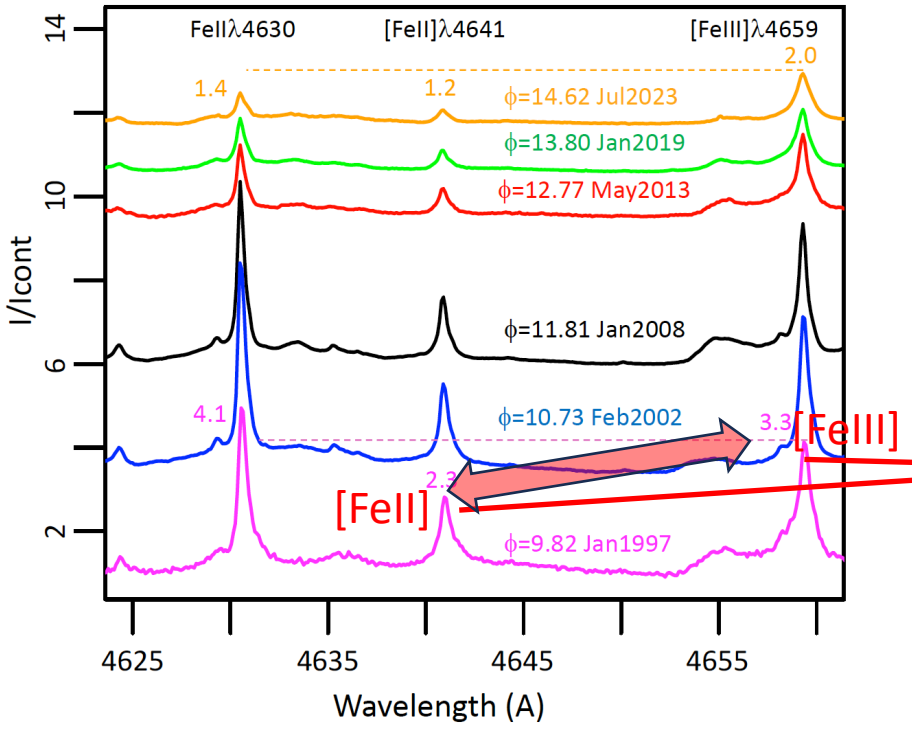
CONSTANT $V_{terminal}$

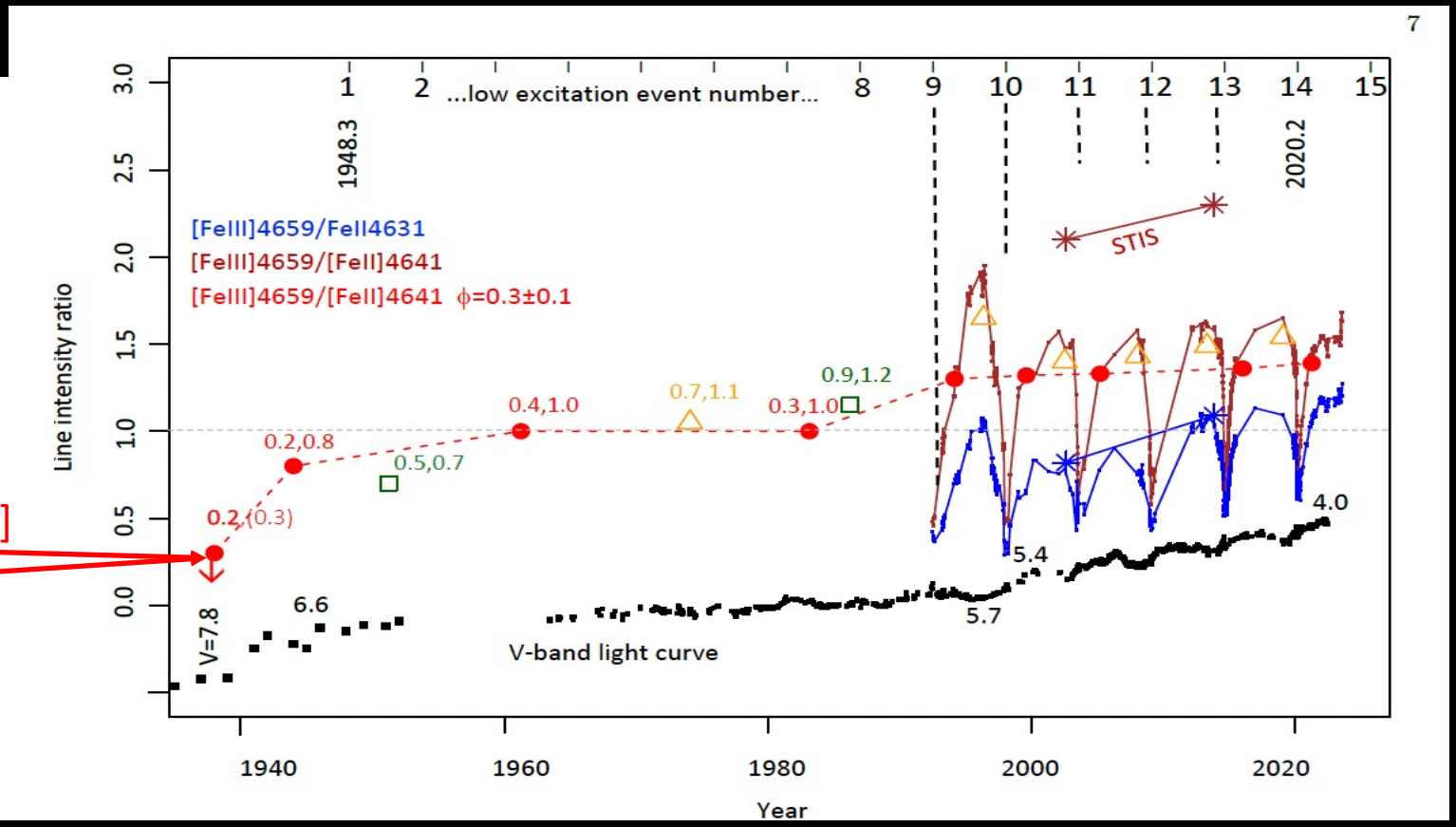


The ratio [FeIII]/[FeII] monitor the excitation at the Weigelt clumps

The excitation jumped in 1940 and 1980: dust cleaning close to the binary

Damineli et al. 2024

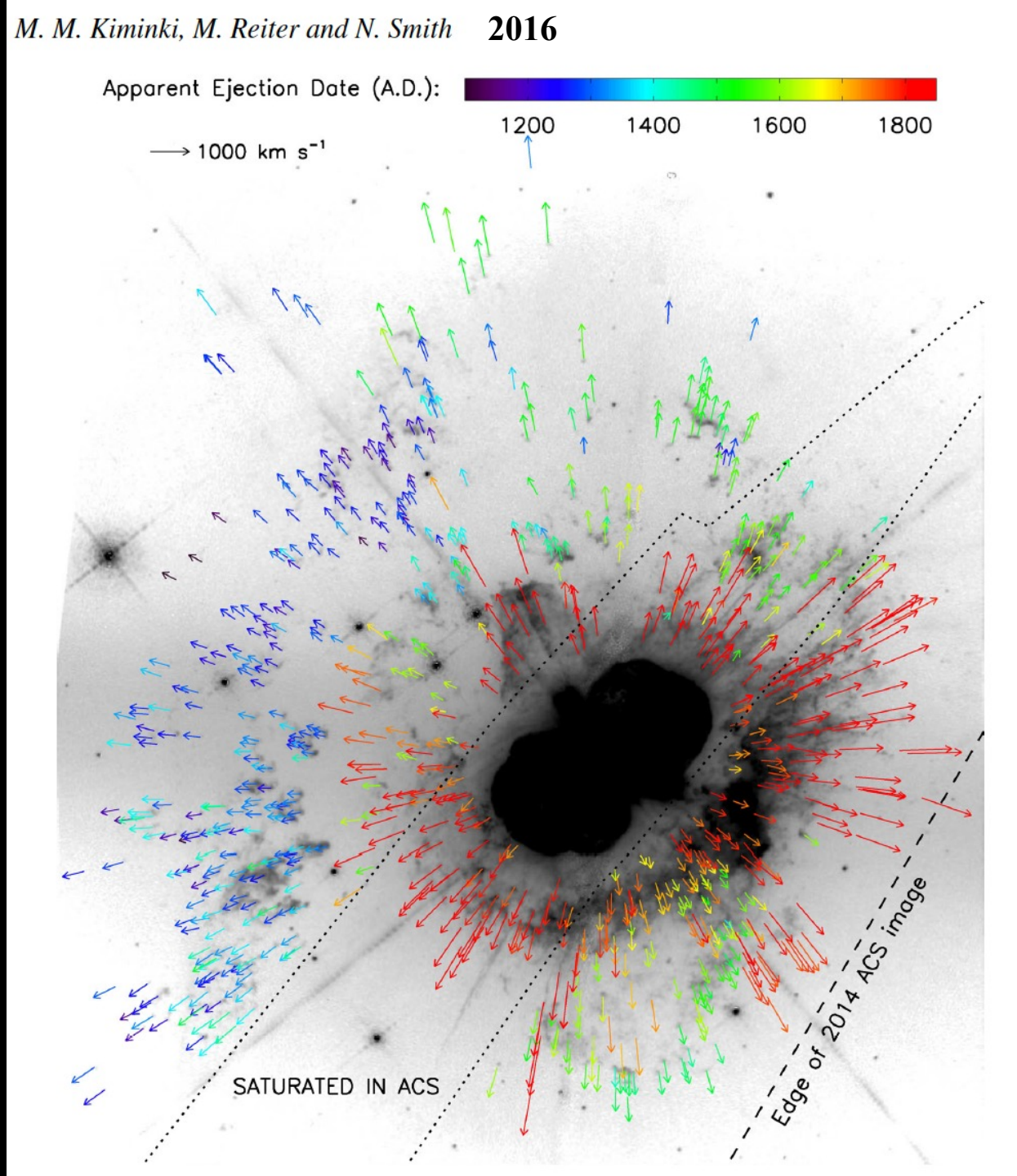




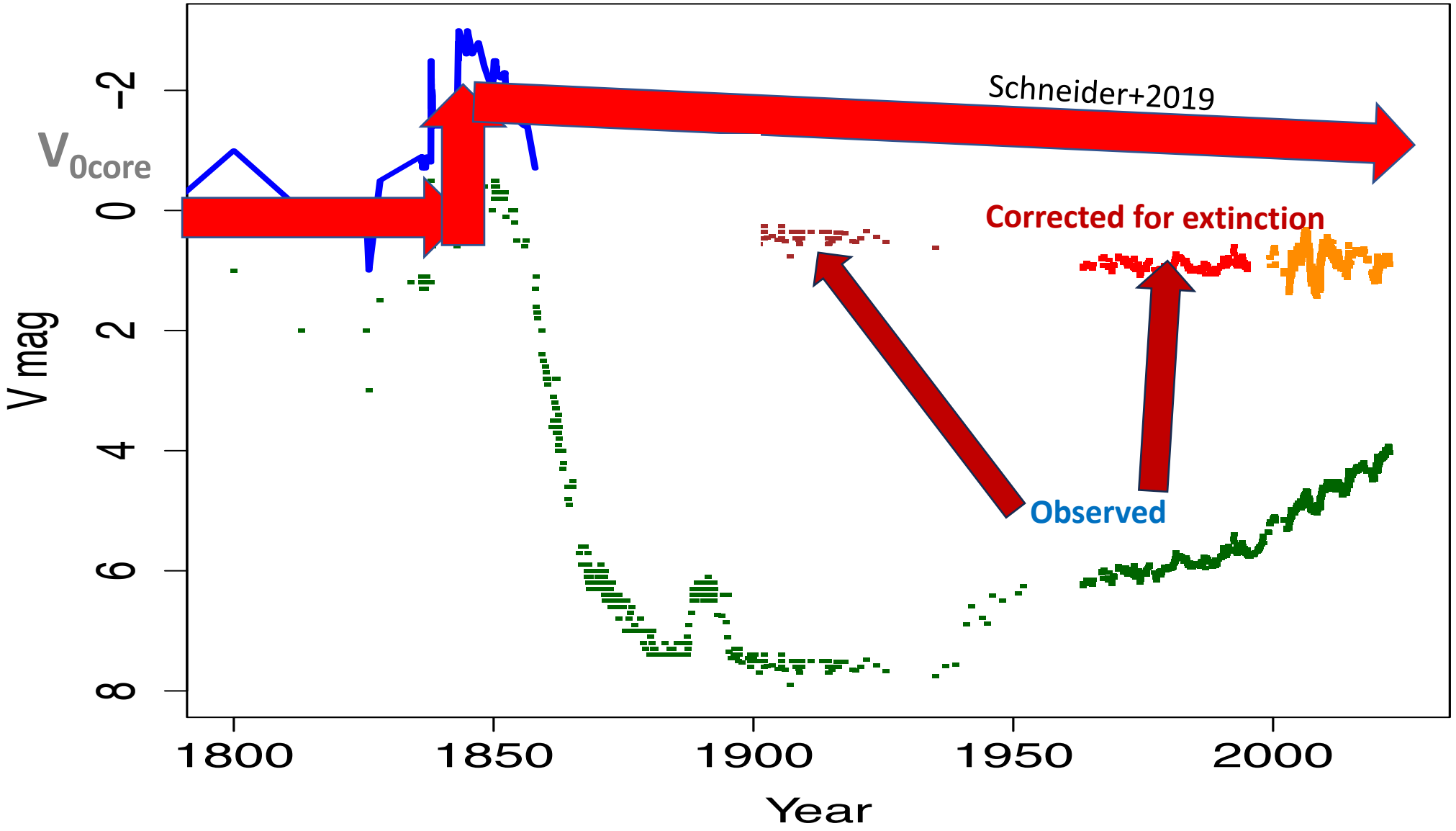
Is eta Carinae a dormant LBV? - Like PCygni

1- A turbulent past before the GE1847

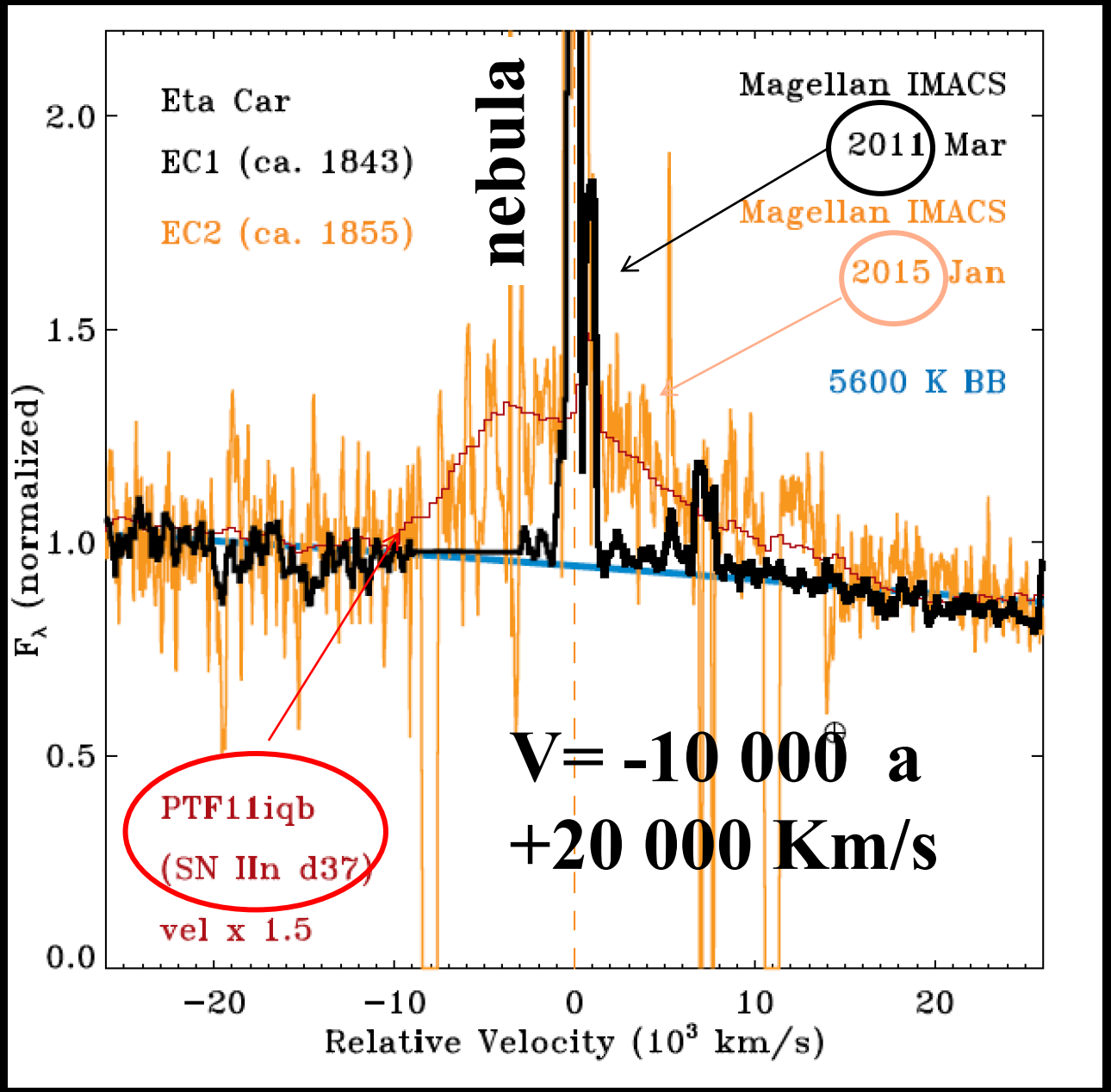
2- But the GE was not a typical LBV eruption



Constancy after 1900: just 50 years after the GE1847
In line with the model of a binary merger in a triple star system



GE1847=> not a SN impostor => true explosion



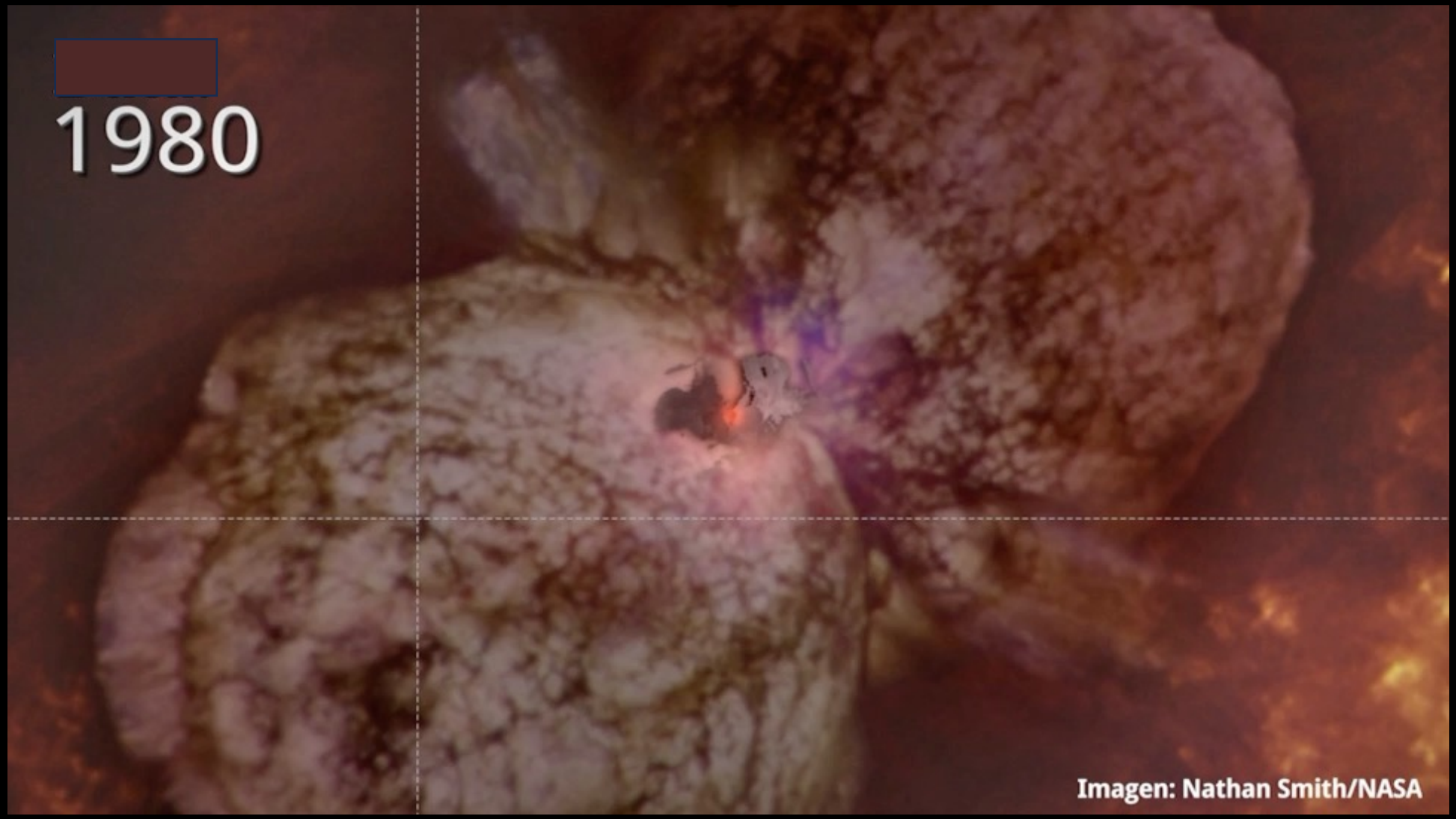
1- speed og the light-echoes

Smith et al. 2018

2-Ejected mass (central) ~45$M_\odot$

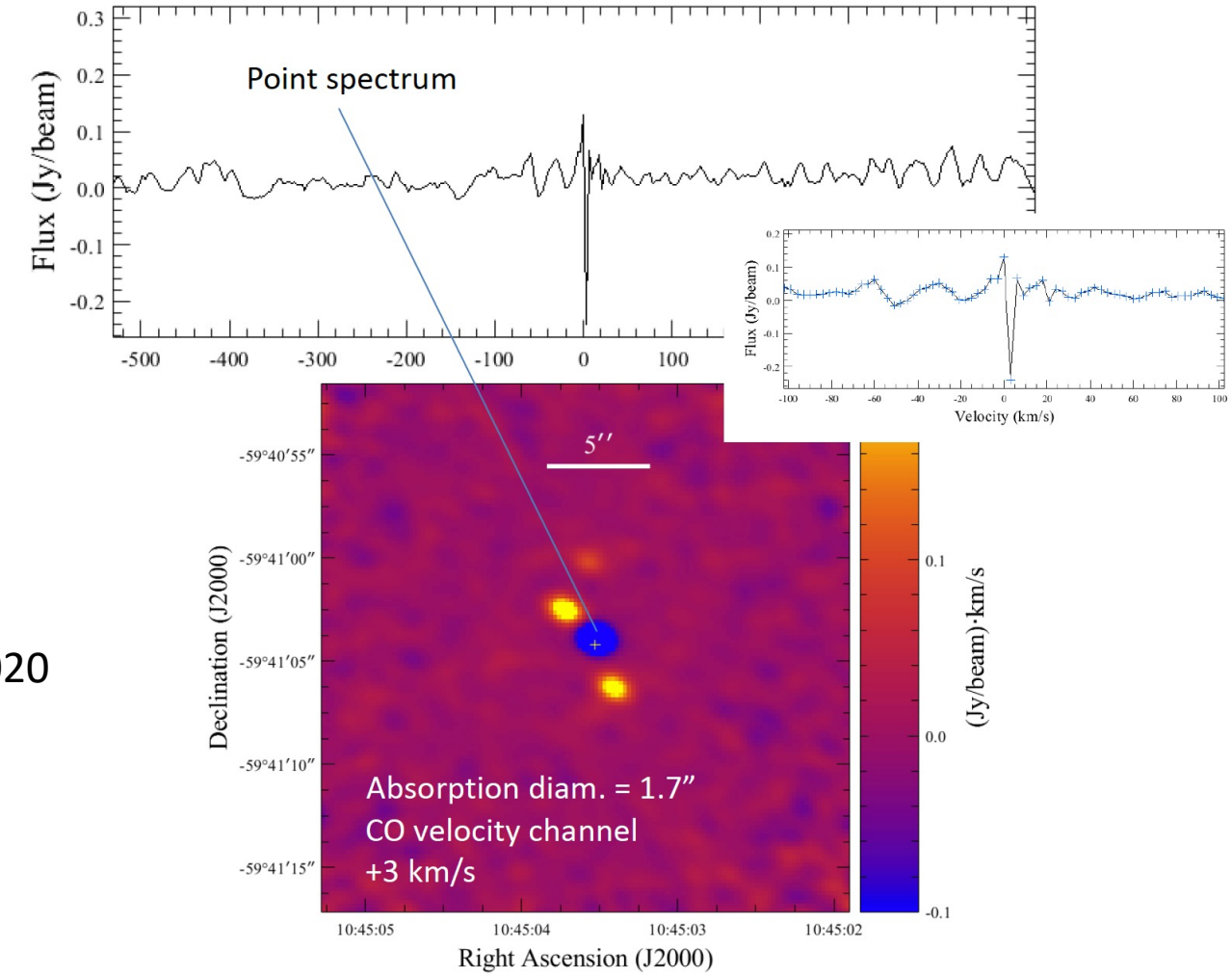
Morris et al. 2017

When will we see the companion stars dancing naked?



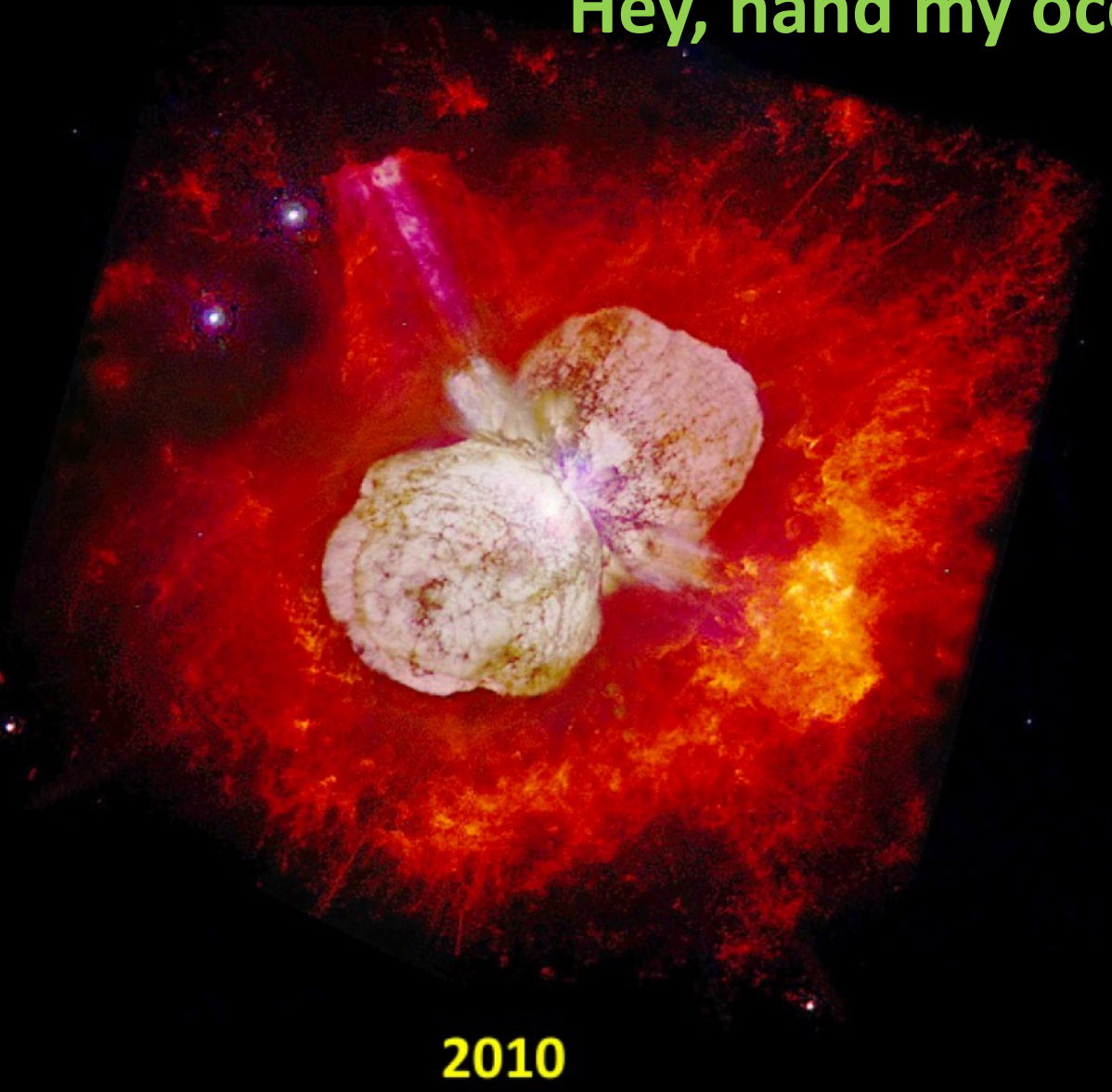
Did we already revealled the dissipating occulter?

Morris et al. 2020



When the occulter dissipates, the nebula will get less charming.

Hey, hand my occulter back !



Summary- eta Carinae: the tamed shrew

A paradifm shift

1- Eta Carinae earned a fame of an unpredictable star from its Giant Eruption in 1847. This scenario continued, based on its photometric and spectroscopic variations.

2- This paradigm changed in the XXIst century based on a number of new data

a) The recognition that a number of fluctuations have stricty periodicity (P=5.534y) an fit to an eccentric (e=0.9) binary system

b) The binary companions have a strong interaction due to wind-wind collision, which are enhanced around periastron

c) Once the periodic changes are discounted, we see a long-term evolution which has many apparent contradictions with the brightness constancy of the reflection nebula, which remains constant.

Such a contradiction are explained by the existence of an intervening nebula in our line-of-sight which has coronagraphi properties. It is in a process of dissipation, but only structures close to our L.O.S. shows long-term variations. The mechanism is regulated by amount of stellar continuum blocked by the occulter to our direction.

A short list of the contradictions:

- - The X-ray and NIR light-curves remained constant thorough the last 30-50 years while the core brightness increased by 10
- - The Weigelt clumps - which reflect the central system without off the occulter's intervention - remained at constant brightness and degree of excitation over the past 20 years .
- -The EW of the wind lines remained constant when measured in the reflection nebula. In direct light to the central system, the lower Balmer lines are decreasing, but the upper members of the series remained constant. This is due to the fact that the lower Balmer members are emitted also at larger radii and so, with different contrast with the central star.
- - The terminal speed of the wind lines remained constant, so, no intrinsic changes in the primary star.

Once the decrease in the extinction to the central star is discounted, the central star have been constant since the 1900s.