A swarm of dusty objects in orbit around the central star of planetary nebula WeSb1

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Tatranska Lomnica, Sep 24, 2025

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Intro into PNe

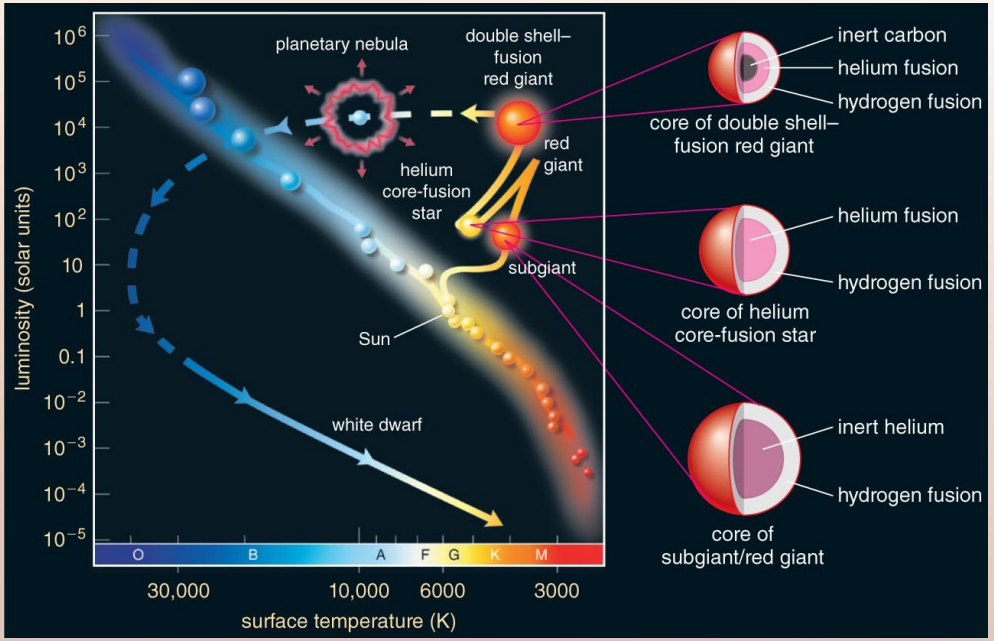
-PNe- a very rare (short-lived) stage of evolution of intermediate mass stars (0.8-8 Msol)

-AGB stars → strong mass loss → PN → WD

-lifetime only about 10^4 yr (only about 3000 of them in the Galaxy)

-strong emission lines, highly ionized mostly forbidden,[OIII]5007

-a misnomer - nothing to do with planets



© Cosmic Perspective Fig 17.8
https://jila.colorado.edu/~ajsh/courses/astr1200_18/starevol.html

Cat's eye nebula (Credit: NASA/HST)

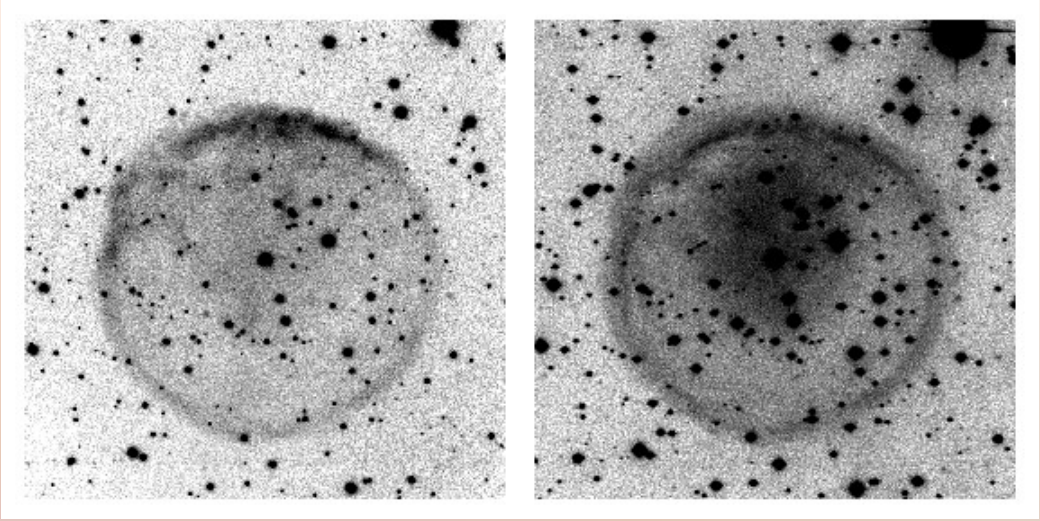
Context & motivation:
Exoplanets were detected around MS stars, giant stars as well as WD stars. However, we do not know what happens with exoplanets and smaller exobodies during AGB and PNe stages.

Aim of the Project:
Planet formation or destruction is associated with dust clouds.
We searched for dust occultations in 2000 Pne.
We found 1 case: WeSb1

Imaging

WeSb1:
Weinberger & Sabbatin 1981

Properties:
G=14.77 mag
distance=3690+-330 pc,
spherical PN, diameter of about 3’



Halpha [OIII]

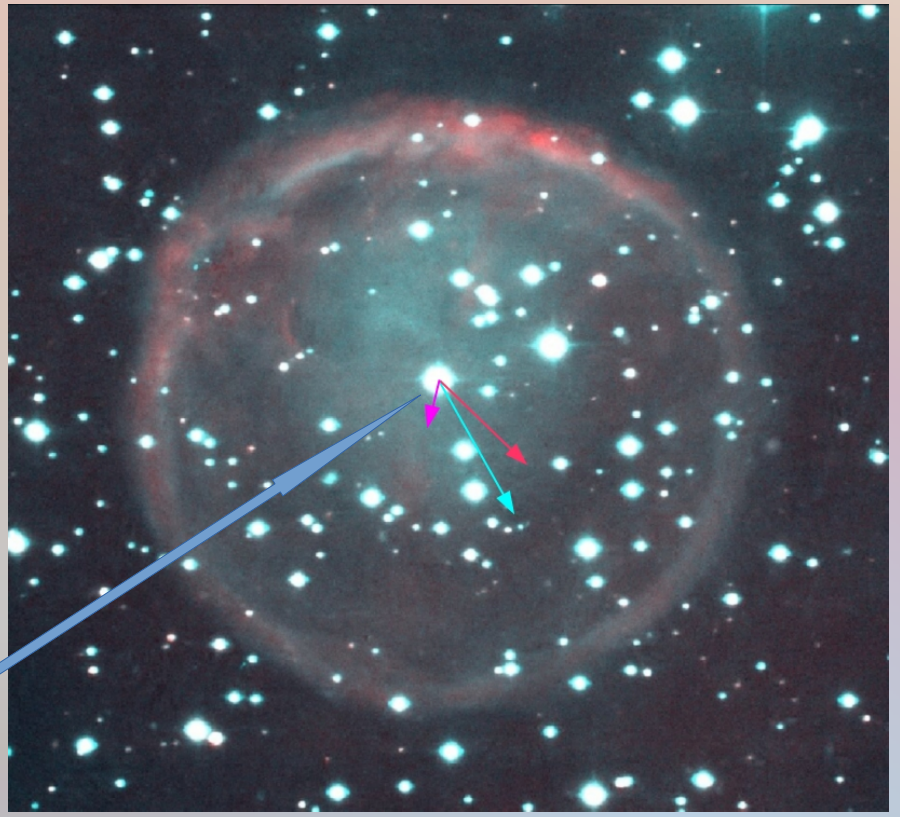
Observations:
2.56m Nordic optical telescope, ALFOCS,
Halpha filter, [OIII]5007 filter

2.54m Isaac Newton telescope, Wide Field Cam,
[OIII]5007 filter

Images: North is up, East is left, 4’x4’
Blue arrow -star, red arrow -ISM,
magenta arrow -star with respect to ISM

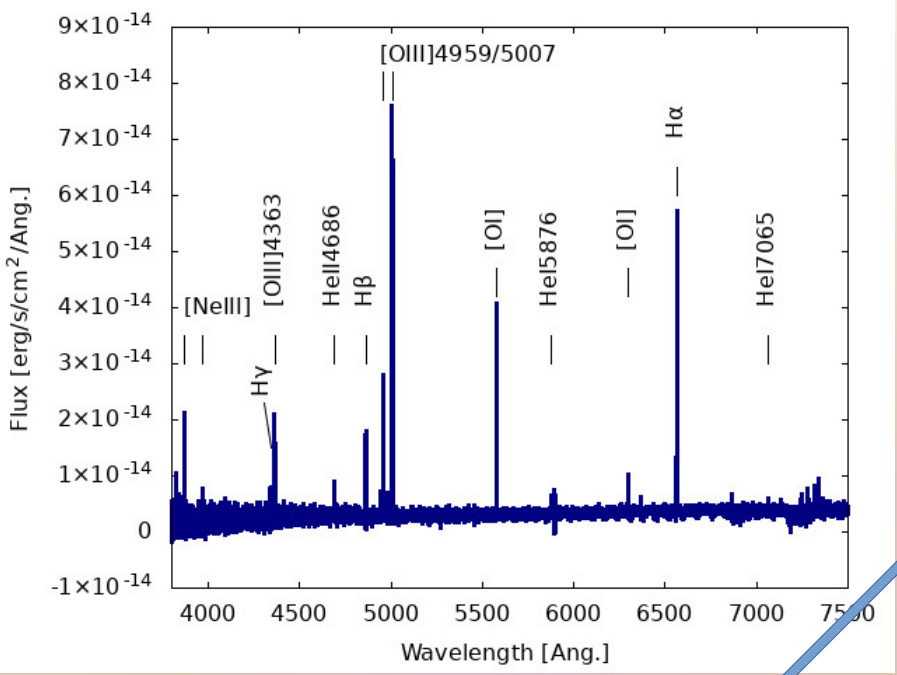
PN radius=1.6pc (5.4lyr)
PN kinematical age=80kyr
One of the largest and oldest PNe.

Central star



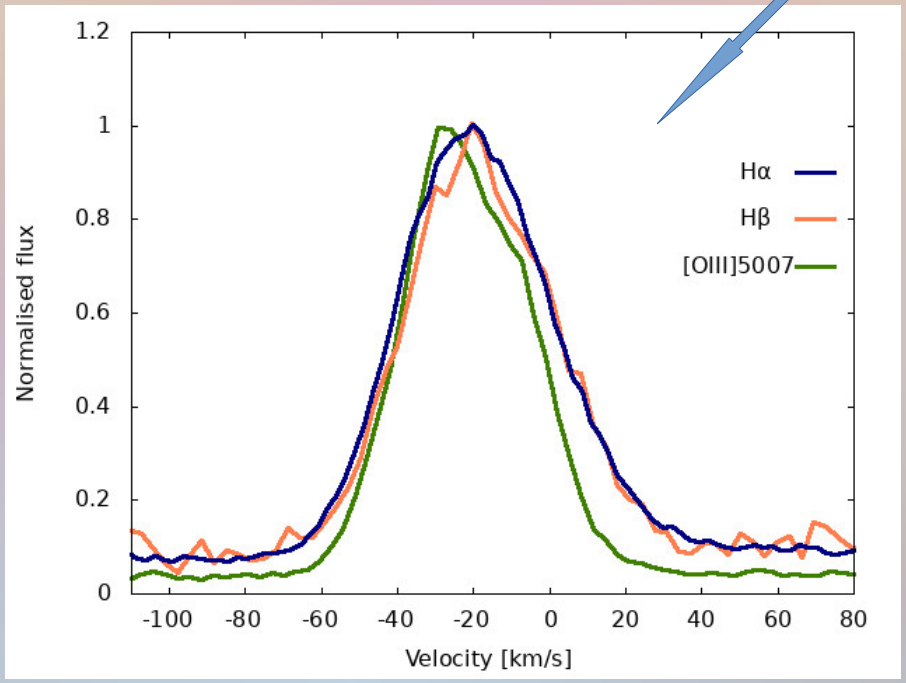
Halpha (red) [OIII] (green+blue)

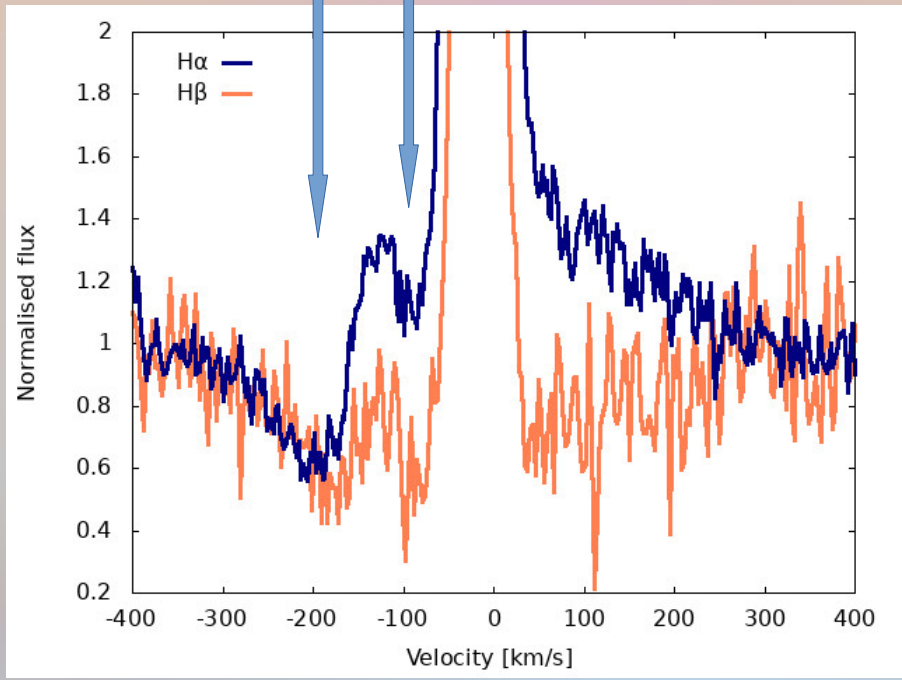
Spectroscopy



2.56m NOT telescope, FIES instrument, fiber diameter 2.5", R=25000, S/N=15, 370-900 nm
HI, HeI-II, [NII], [OIII], [NeIII]-41eV, [ArIII]

Spectrum of the star confirmed that this is central star. Emission lines are narrow and originate from **a compact unresolved nebula around the star** (not from the PN).
Hydrogen lines show P Cyg profiles → two expanding shells?





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SED

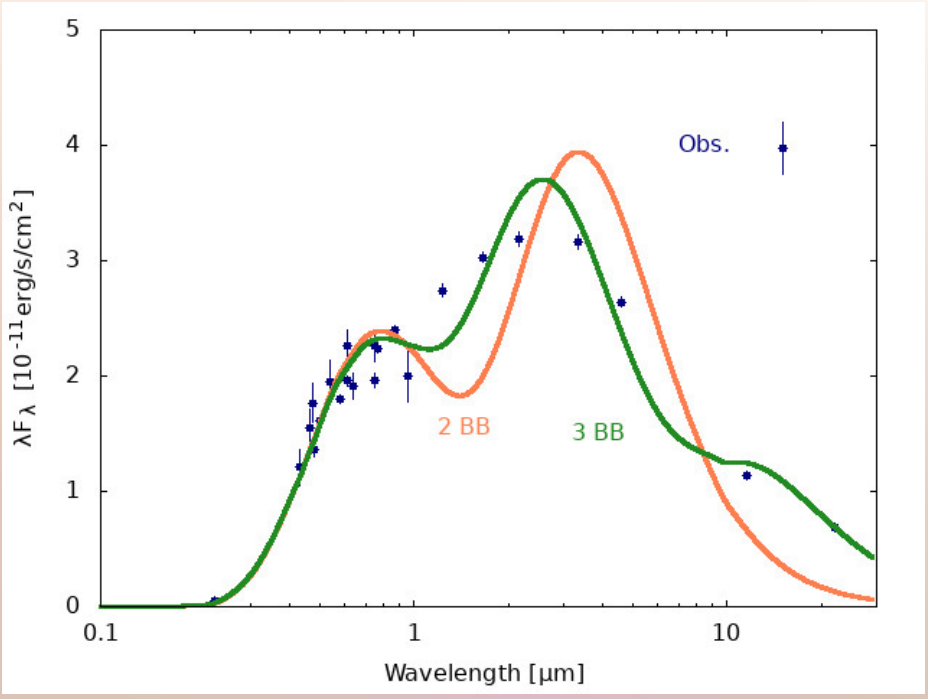
Infrared excess
A(V)=0.8mag, E(B-V)=0.255mag
Extinction curve Gordon et al. (2023)

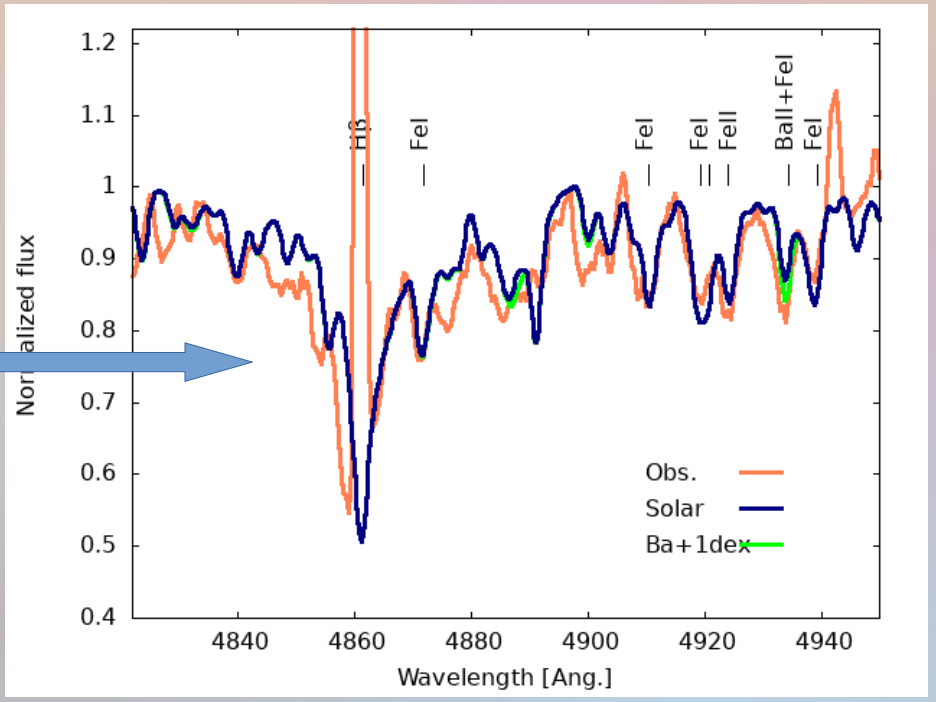
3 BB fit :

T1[K]	R1	T2[K]	R2	T3[K]	R3[Rsol]
5890	4.1	1360	74	280	910

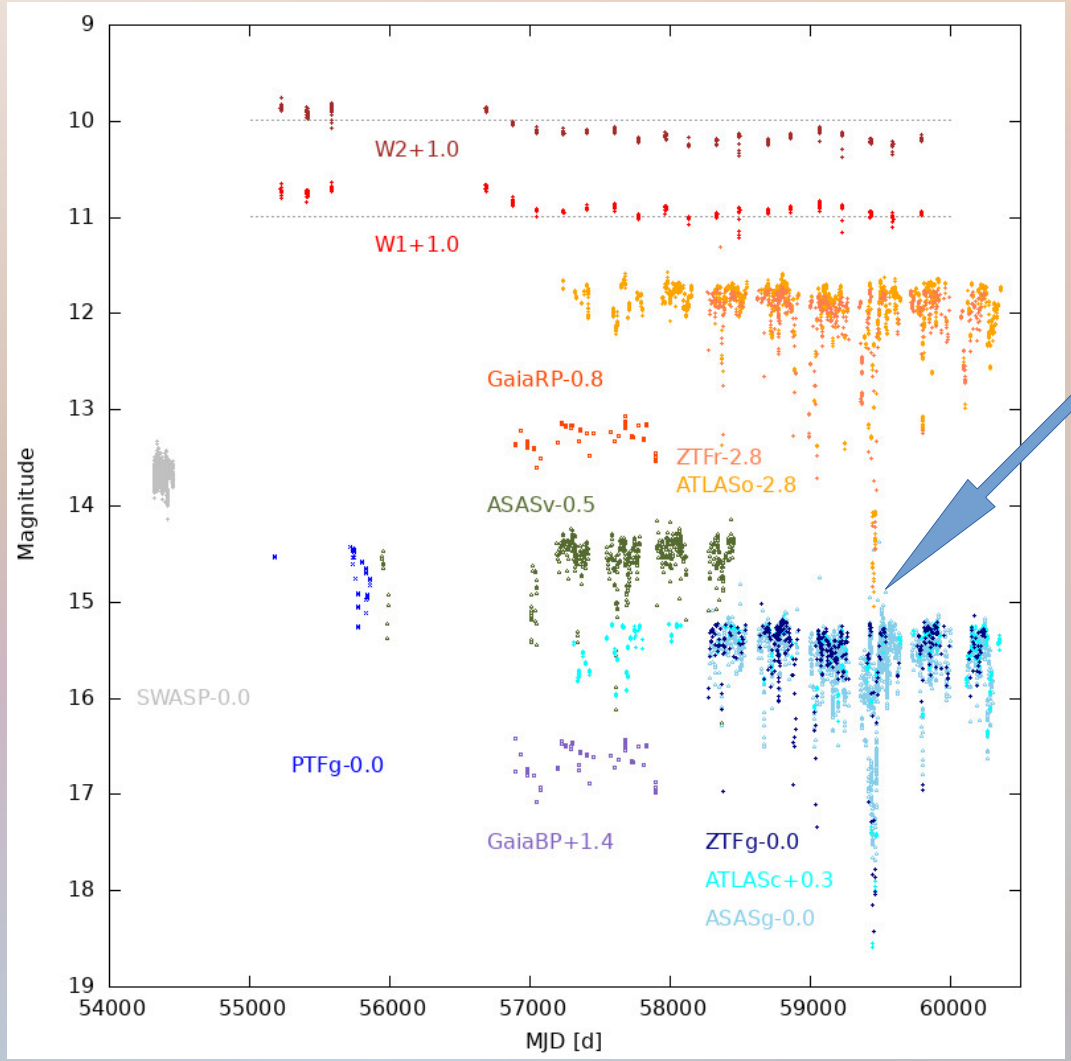
2nd +3rd BB=IR excess=dust
True Central star of PN (CSPN) is not seen in SED:
T<150kK from HeII/Hβ
T>130kK from [OIII]/HeII

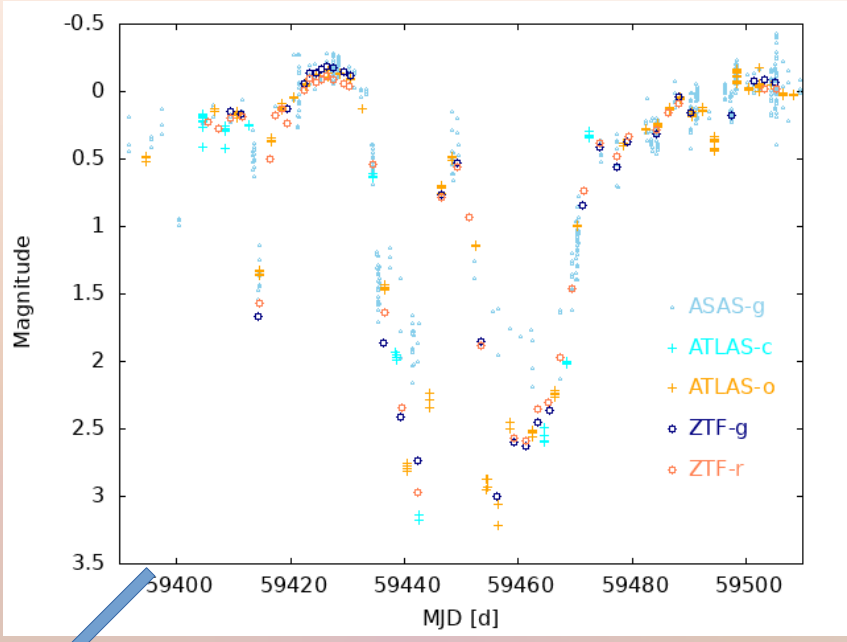
1st BB=Optical source is an F/G subgiant star. Confirmed=detection of absorption lines. Hence CSPN is likely a binary star.
(A chance alignment of CSPN and F subgiant is unlikely.)





Long term variability

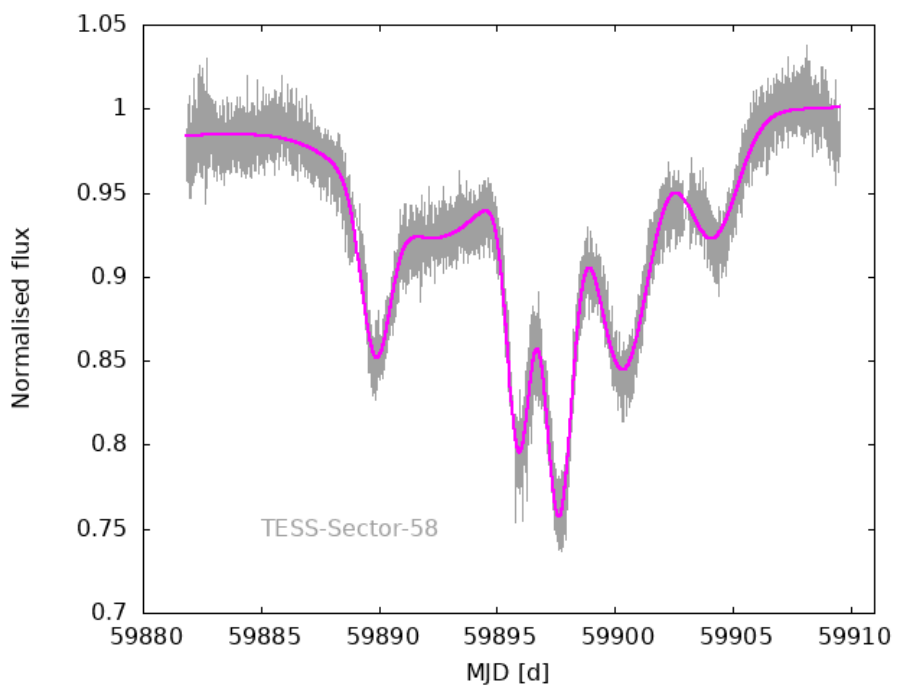




WISE/NEOVISE: W1, W2 (3.4, 4.6 mic), 13 yr
ASAS-SN: V, g (24x14cm telescopes), 11yr
ZTF: r, g (Palomar 48”), 5yr
Gaia DR3: G,BP,RP, 3yr
Palomar transient factory (PTF): g, 2yr
SuperWASP-North,
ATLAS: c,o, 9 yr

Many dips seen in the optical → something is eclipsing/orbiting F subgiant or both stars. Eclipses are deep and numerous → many large bodies >4 Rsol → dust clouds.

Short term variability



TESS light curve -transits of >5 clouds in a chain.

Analogy with String of the Pearls?
Shoemaker-Levy 9 disintegrated into 21 pieces after crossing the Roche limit of Jupiter and subsequently collided with Jupiter in 1994.
Credit: NASA-HST.

A likely interpretation (not the only possibility)

Nature of the clouds?
Dust eclipses are grey → dust particles are larger than 0.1mic → debris of collisions or disintegration rather than a dust condensation.
Eclipses are clustered → numerous smaller bodies embedded in dust and having a common progenitor, similar to Boyajian's star (Neslusan & Budaj 2017) or 'string of the pearls'.

Where do the bodies come from? A possible hypothesis:
-AGB star + F subgiant
-AGB star lost significant amount of its mass → shrinking of its Roche lobe + engulfment of inner planets and destabilization of outer planets → some planets wander into Roche lobe of the companion + are focused into the orbital plane → collisions: mutual and/or with native population of bodies around the companion.

It means that planetary systems are present and undergo a violent evolution during the PN stage.

Independent discovery with similar conclusions:
Bhattacharjee et al. 2025, PASP 137, 024201

Thank you!

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