Imaging the pre-PN/PN transition

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imaging the pre-PN/PN transition

Motivation:
a better understanding of the transition from the pre-PN to PN phase

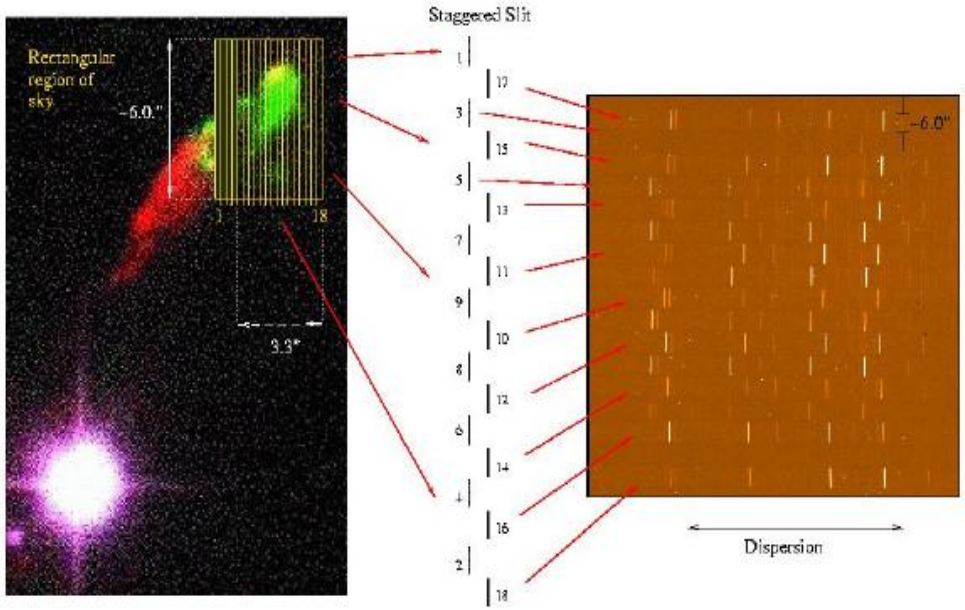
The developing ionization front will propagate into the envelope already shaped during the PPN phase and will determine the appearance of the emerging PN

There are not many resolved images of these “nascent” PNe

Approach:

- by observing IRAS sources with hot B-type post-AGB central stars which are on the point of ionizing their circumstellar envelopes
- K-band integral field spectroscopy of a sample of B-type hot post-AGB stars
- this spectral region includes many H_2 ro-vibrational lines, Brγ, He I etc..
- use with NIFS on Gemini North, AO correction, giving simultaneous spectroscopy with $\lambda/\Delta\lambda \sim 5000$ and imaging with ~ 0.15" angular resolution

integral field spectroscopy – basic idea



instrument pipeline

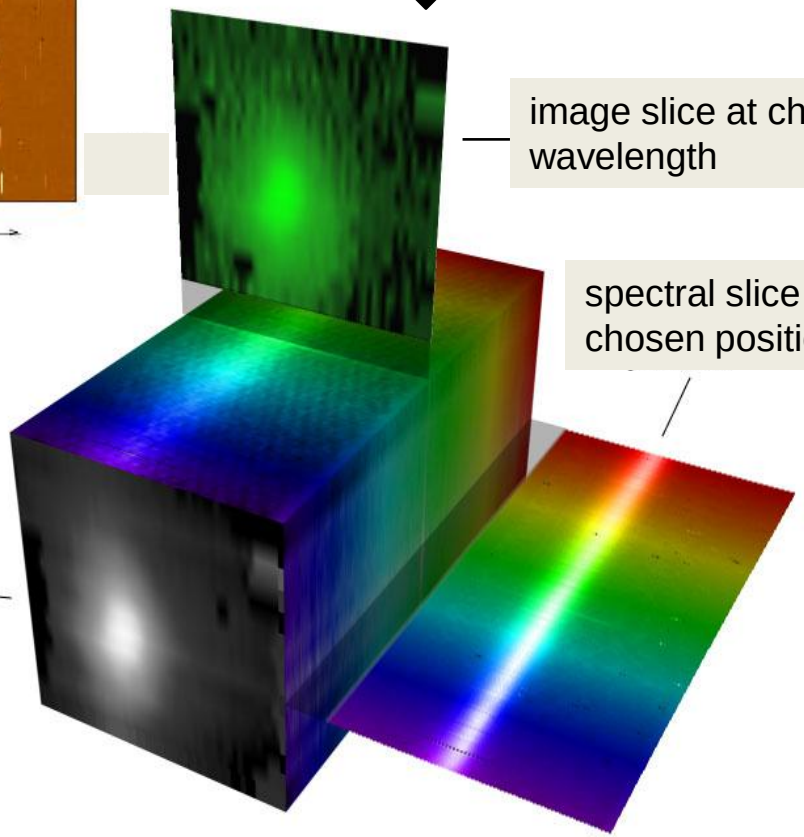


image slice at chosen wavelength

spectral slice through chosen position

post-AGB star
In combined light

a data cube is recorded as a single exposure on the detector

- same AO and atmospheric characteristics
- accurate continuum subtraction of extracted images

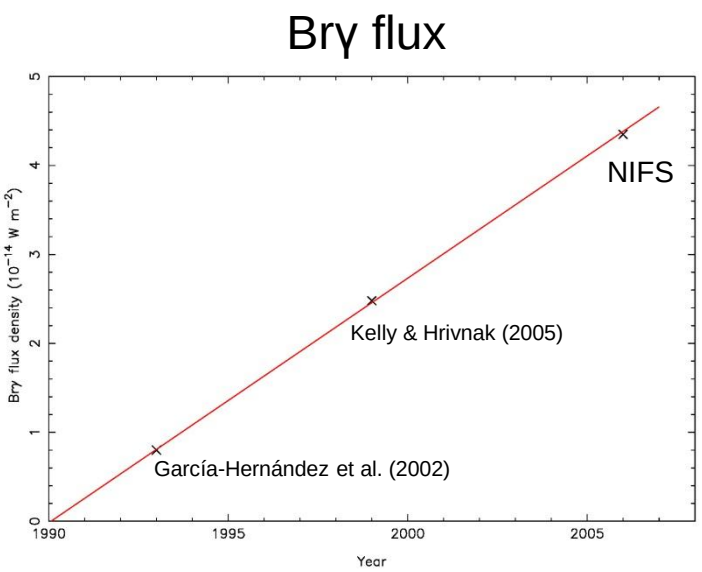
diagram adapted from UKIRT web pages

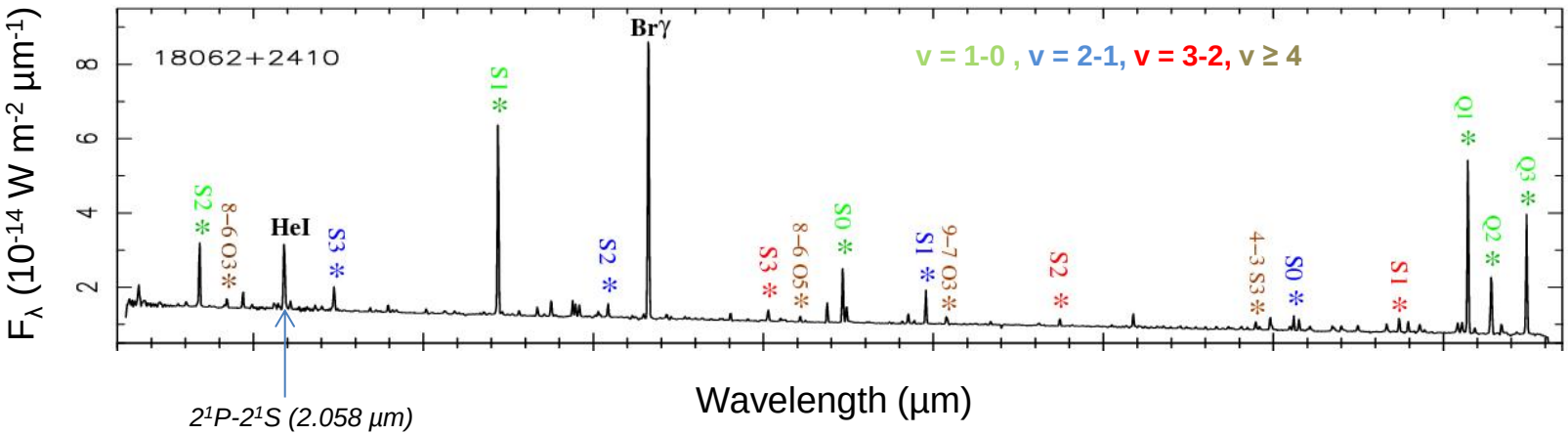
IRAS 18062+2410

= SAO 85766 = HD 341617 : l = 51 b = +20

- A5 in HDE catalogue (1940), B1 I in 1993 with low excitation nebula (Parthasarathy et al. 2000) => >200 K /yr
- T_{eff} = 20750 K, log *g* = 2.35 (non-LTE atmosphere fit; Ryans et al. 2003) => high-mass core (0.846 $M_{\odot}$ post-AGB track)?
- Brγ flux has increased ~linearly in recent years

- The 8.4 GHz flux density has increased linearly from 1.5 mJy in 2001 to 2.7 mJy in 2009 (Cerrigone et al. 2011)
- ionization front propagating at 120 km/s





IRAS 18062+2410

the nebula morphology can be seen in the H_2 lines:

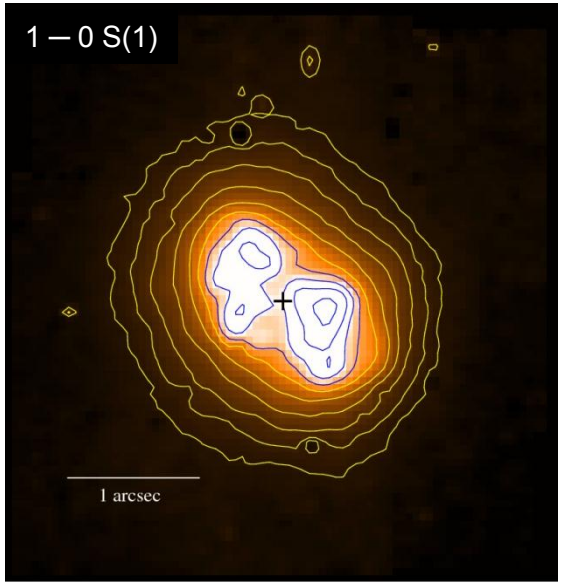
- an elongated structure with emission peaks on either side of the star
- peaks offset by ± 0.25" (2.2 x 10^{16} cm at 6 kpc)
- higher vibrational lines hint at a perpendicular bipolar structure
- the central peaks are seen in high-*v* lines such as 8 – 6 O(3) so H_2 must be (at least partially) UV-excited in this region

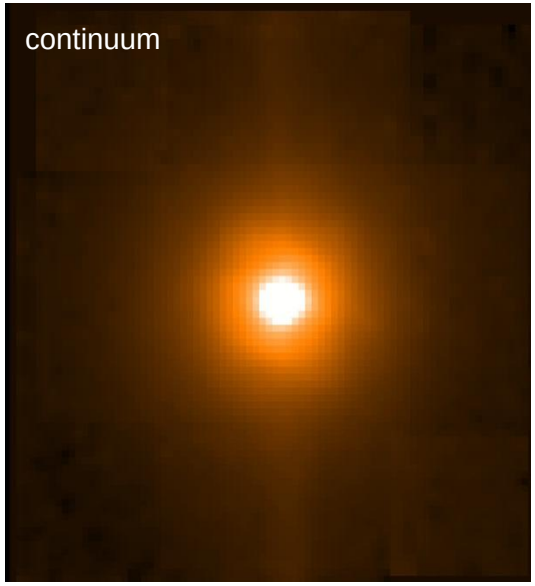
the Brγ and He I emission is not spatially resolved

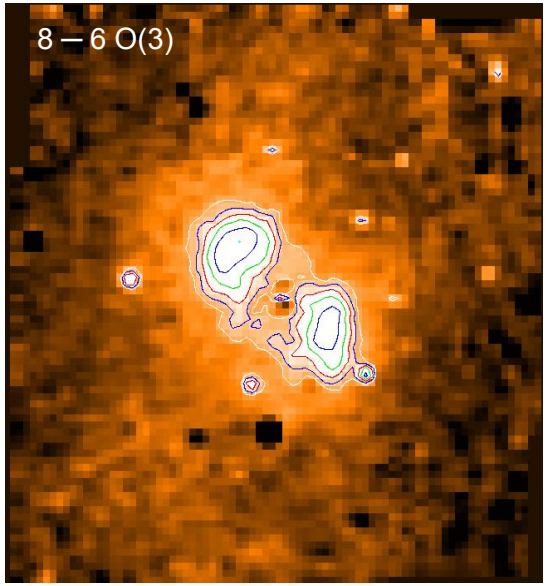
- consistent with an ionized region currently $r \leq 0.1''$

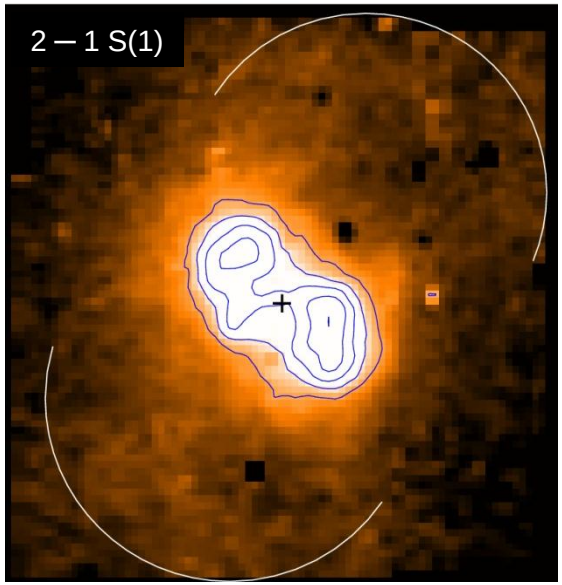
we do not see any extended emission in the continuum image

- where has all the dust gone?









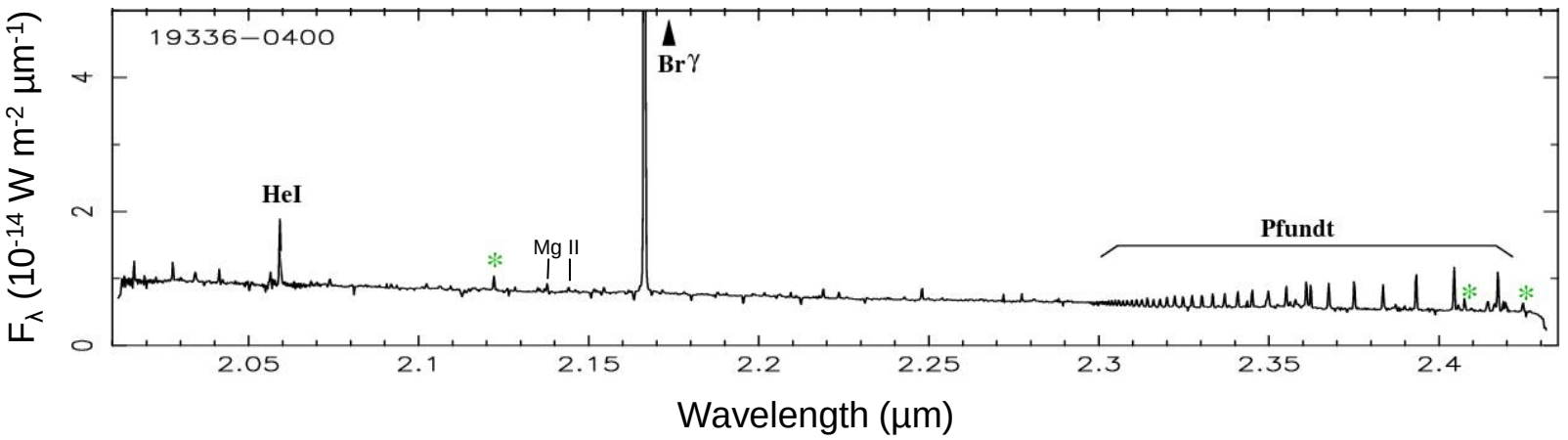
IRAS 19336-0400

= SS 441 : l = 35, b = -12

- B1 I , nebular emission lines typical of low-excitation PN
- flat 1.4–8.4 GHz spectrum, extended emission in 8.4 GHz imaging
- mixed chemistry with PAH and silicate features

this is the only object in our sample of early B stars where there is no clear detection of structure in H_2 emission

- the K-band spectrum is dominated by Brγ emission, with He I seen at 2.058 μm and a strong H Pfundt series
- there are weak features at the positions of the 1–0 S(1) and Q-branch lines, but the emission appears constant across the 3x3" NIFS field



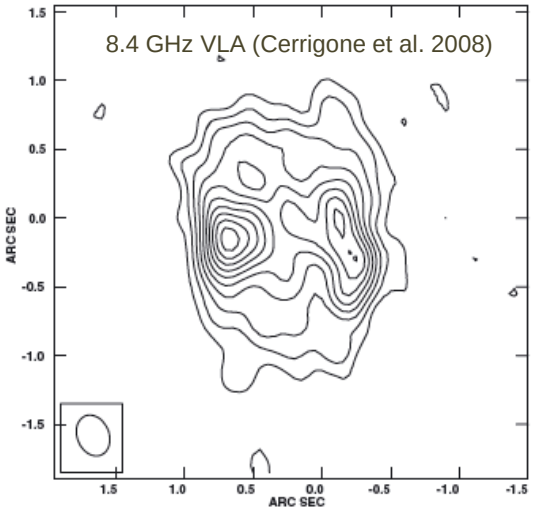
IRAS 19336-0400

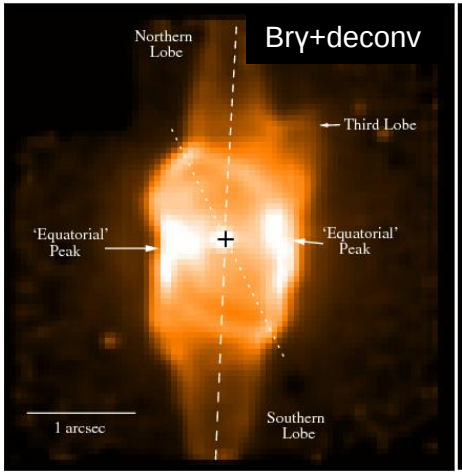
the deconvolved Brγ image shows detailed structure, consistent with the radio image

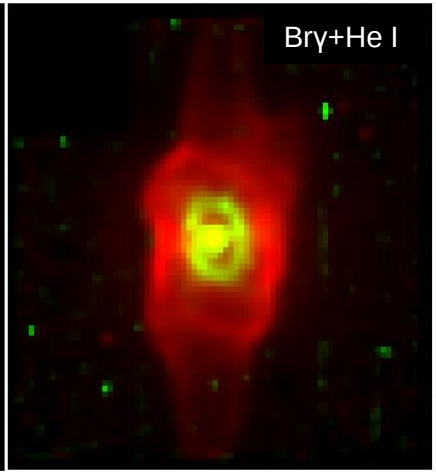
- north/south limb-brightened lobes, extending off the field
- Inner “rim structure with bright spots
- a possible third lobe – multiple axes?
- “equatorial” peaks, also seen at 8.4 GHz

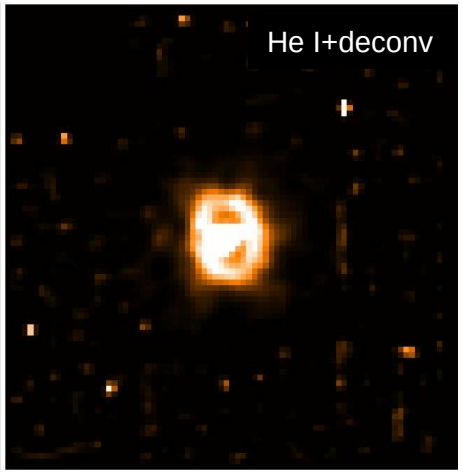
we also see a ring in the deconvolved He I image, which sits inside the Brγ structure

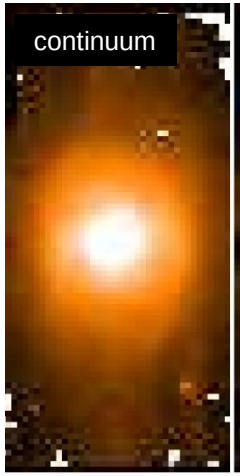
the continuum image is dominated by the bright star but traces similar structures to those seen in the emission line image











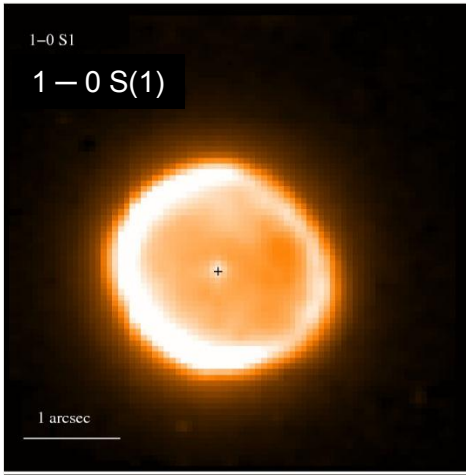
IRAS 19200+3457

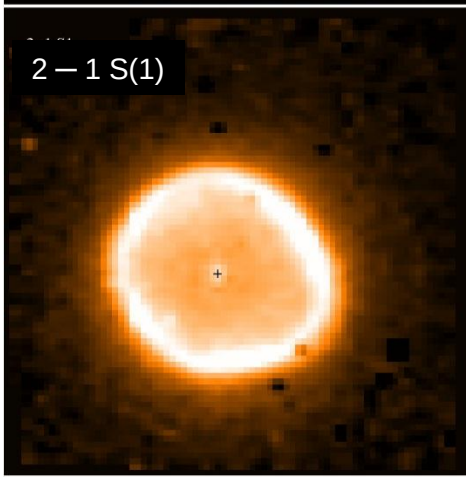
= StHA 161 variable Balmer lines, irregular brightness changes

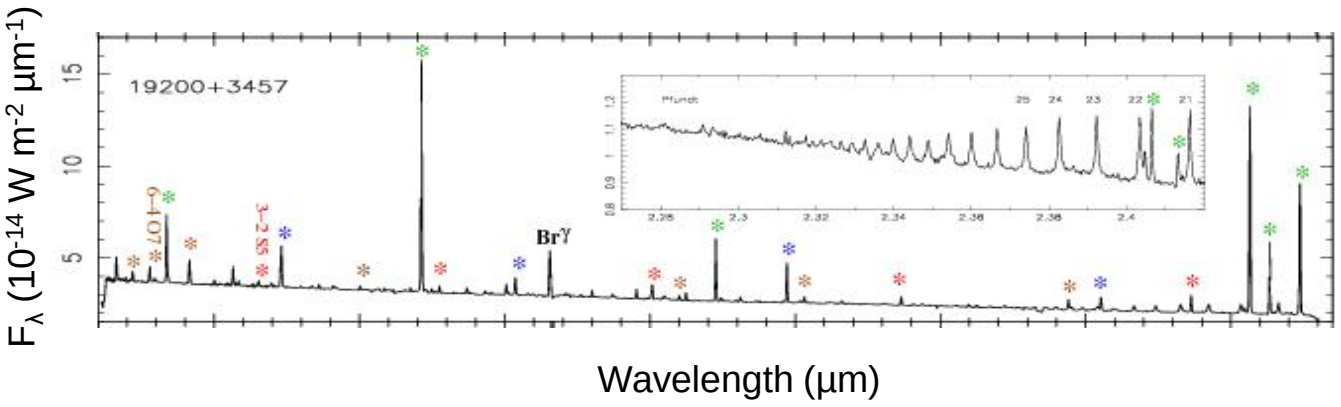
- B type spectrum
- double-peaked SED, carbon-rich? 30 μm feature

- the spectrum shows Brγ and Mg II lines, Pfundt series
- no He I feature at 2.058 μm
- strong H_2 lines

- the H_2 emission forms a (slightly distorted) ring with radius ~1"
- atomic lines unresolved







…some questions

These objects are not obvious in dust-scattered light in the IR
Where has the dust gone (e.g. in IRAS 18062+2410)?

What are the progenitors of these objects – in the PPN phase?
Did they evolve from optically thin (SOLE-type) PPN?

Did these PPN have H_2 emission? Probably not

So optically thick PPN with shock-excited H_2 (fast winds)
evolve into something else – like AFGL 618?