# The production of strong broad HeII emission after the tidal disruption of a main-sequence star by a supermassive black hole

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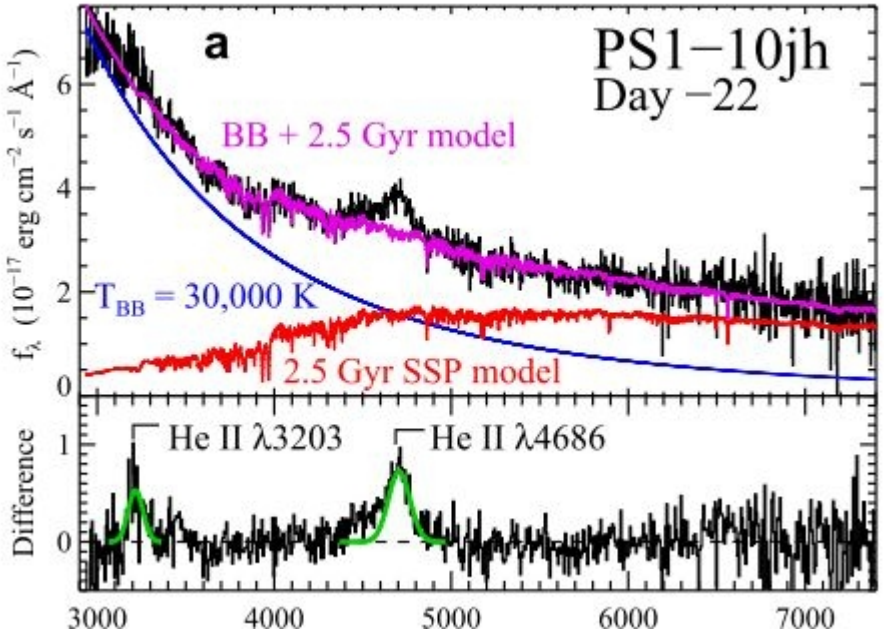
# OVERVIEW

- Stars can be tidally disrupted by supermassive black holes (Hills 1975: Rees 1988)
- Well studied optical spectrum of a tidal disrupted event (TDE) before maximum light was obtained for PS1-10jh by Gezari et al (2012)
- Contrary to was expected, the spectrum did not show strong broad Balmer emission lines, but strong broad HeII (λ4686 and λ3203) emision instead. This led Gezari et al. to propose that PS1-10jh was the disruption of an He core star.
- However, He core stars are extremely rare (Guillichon et al.2014)

# PS1-10jh pre-maximum spectrum




MMT spectrum fo Gezari et al. (2012) of PS1-10jh 22 days before maximum light. The top panel show the observed spectrum; the bottom shows spectrum after substraction of the host galaxy

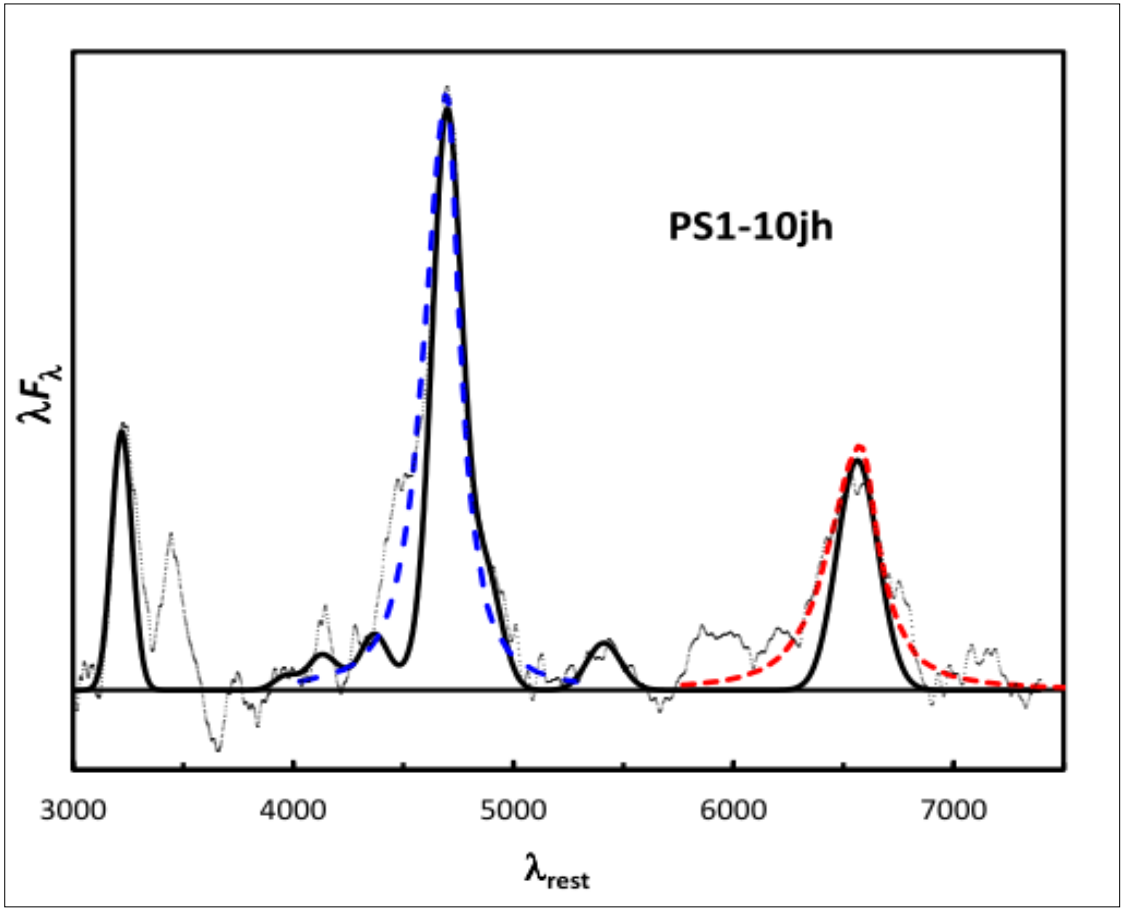
# Analisis of pre-maximum light spectrum

Thin line:
smoothed pre-maximum spectrum

Solid black curve:
synthetic HeII + Balmer line fit using a single gaussian fit

Blue dashed curve:
blueshifted AGN BLR profile from Gaskell&Goosmann (2013) with intensity and width scaled to HeII λ4686

Short-dashed red curve:
same profile shifted to the wavelength Hα




Gaskell & Rojas Lobos (2014) MNRSL438, L36-L40

# Intensities of He and H lines

- In addition to the broad HeII λ4686 and λ3203 lines previously identified by Gezari et al.(2012) we can see clearly a broad line at ~ λ6560
- This is not automatically Hα because alternate member of HeII Pickering series have similar wavelenghts to the HI Balmer lines, so some of the emission of 6560 is HeII
- From theoretical HeII line intensities we estimated that the Pickering line contributes 20% to the λ6560 blend

=>HeII λ4686/Hα ≈ 3.7 with an uncertity of 25%

# HeII emission light profile

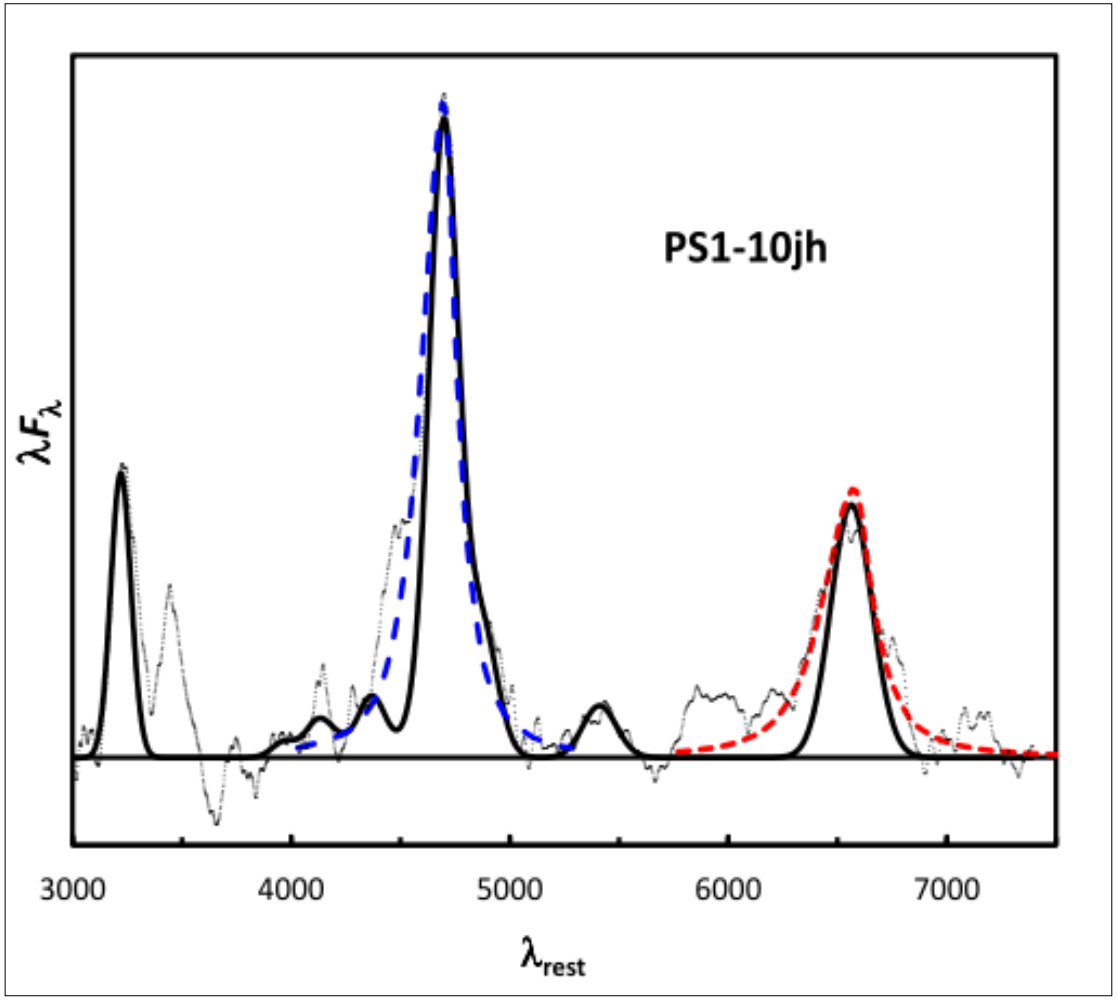
HeII λ4686 is more extended on the blue side than a simple Gausian.

However a blueward asymmetry of high-ionization lines is normal see in AGNs (Gaskell 1982)

Scattering off inflow material will naturally produced this (Gaskell 2009: Gaskell&Goosmann 2013)

The FWHM of this blueshifted profile is ≈ 11.000 km/s, similar to AGNs

We suggest that the HeII λ4686 profile of PS1-10jh, is also a blueshifted by the same mechanism as high-ionization BLR lines in AGNs.

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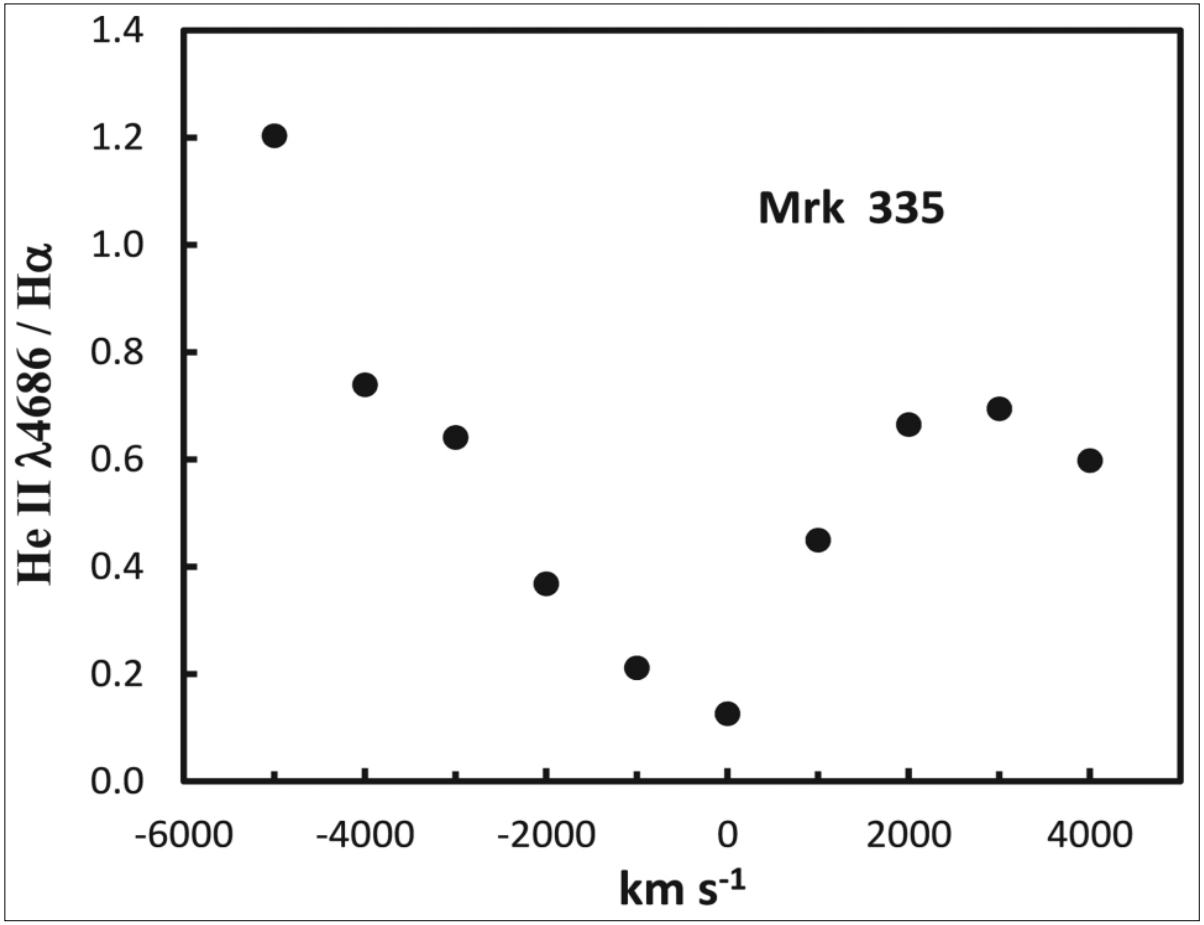
# The HeII λ4686/Hα ratio in normal AGN

- The high ionization lines are broader than the Balmer lines and low ionization lines

  =>The ratio are differente in the wings. E.g. the He I λ5876/Hβ ratio is three to five times higher in the wings (Shuder 1982, Crenshaw 1986)
- The HeII profiles in Osterbrock & Shuder (1982) are consistent with the increase in HeIIλ4686/Hα at high velocities
- This is clearly not a result of high He abundance

# The HeII λ4686/Hα ratio in normal AGN




He II λ4686/Hα as a function of velocity for BLR of Mrk 335

(Gaskell & Rojas Lobos 2014: data from Shuder & Osterbrock 1982)

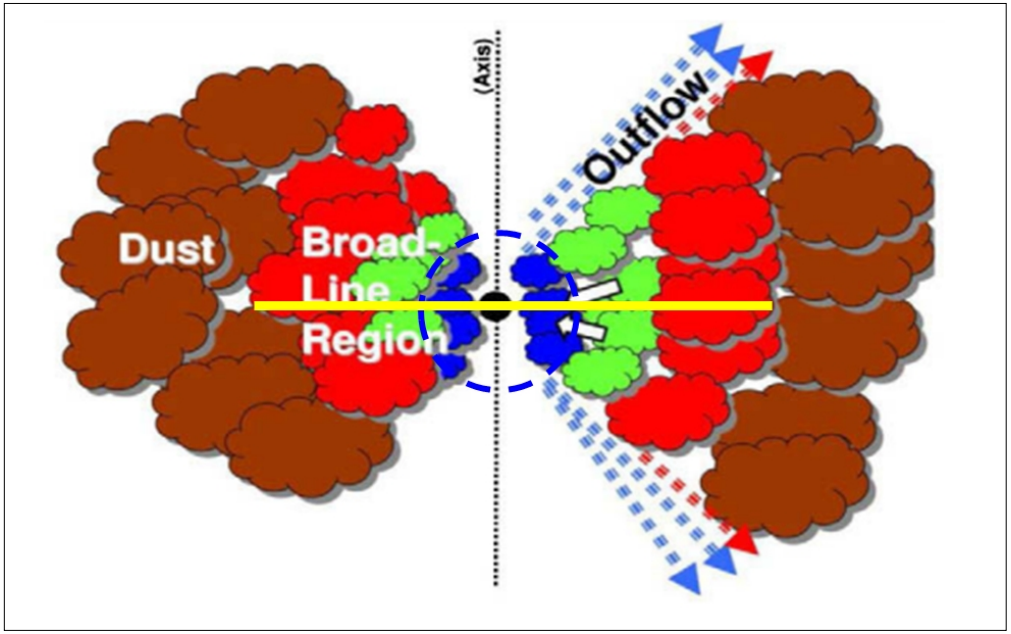
# Earliest time optical spectra of II-P supernova

- By definition, type II SN show strongh H emission
- At earliest time(before maximum light), strongest feature is broad emission around λ4600. Initially more prominent than Hα (Lewis et al. 1994, Leonard et al. 2002, Quimby et al. 2007)
- Quimby et al. (2007) demonstrated that λ4600 feature is a blueshifted HeIIλ4686
- High HeII λ4686/Hα ratio, similar to that observed in PS1-10jh.However, after maximum light the IIP Sne show normal H emission (suggests thes H is not depleted).

# Modelling HeII λ4686 emission

- GKN model (Gaskell, Kimek, & Nazarova 2007)
  - BLR is flattened (just above the accretion disc) and is self shielding

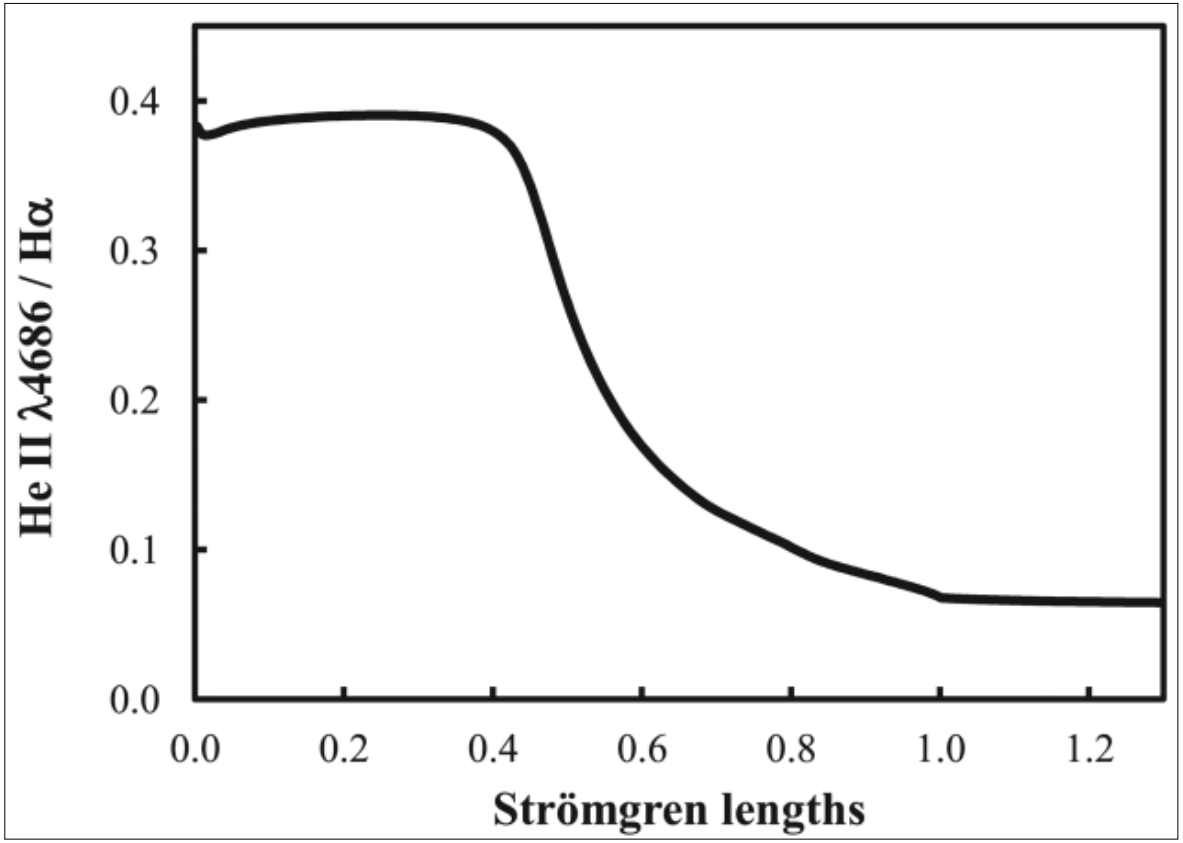
    => high degree of radial ionization stratificaction
  - The ensembled of self-shielded BLR clouds is treated like as an expanded single cloud. (Gaskell 2009)



# Modelling HeII λ4686 emission

- We use version 13.1 of the photoionization code CLOUDY (Ferland et al.,1998, 2013) to calculate theorical HeII 4686/Hα ratio for GKN model
- For ionizing continuum we adopted the standard AGN continuum of Mathews&Ferland (1987)
- Ran constant-density models. (insuficient time to achieve pressure equilibrium in the stellar debris before the first spectrum of 22d. before maximum)
- Ran models with a ionization parameter, U, in the range $-2 < \log U < 2$ and solar abundance.

# Modelling HeII λ4686 emission

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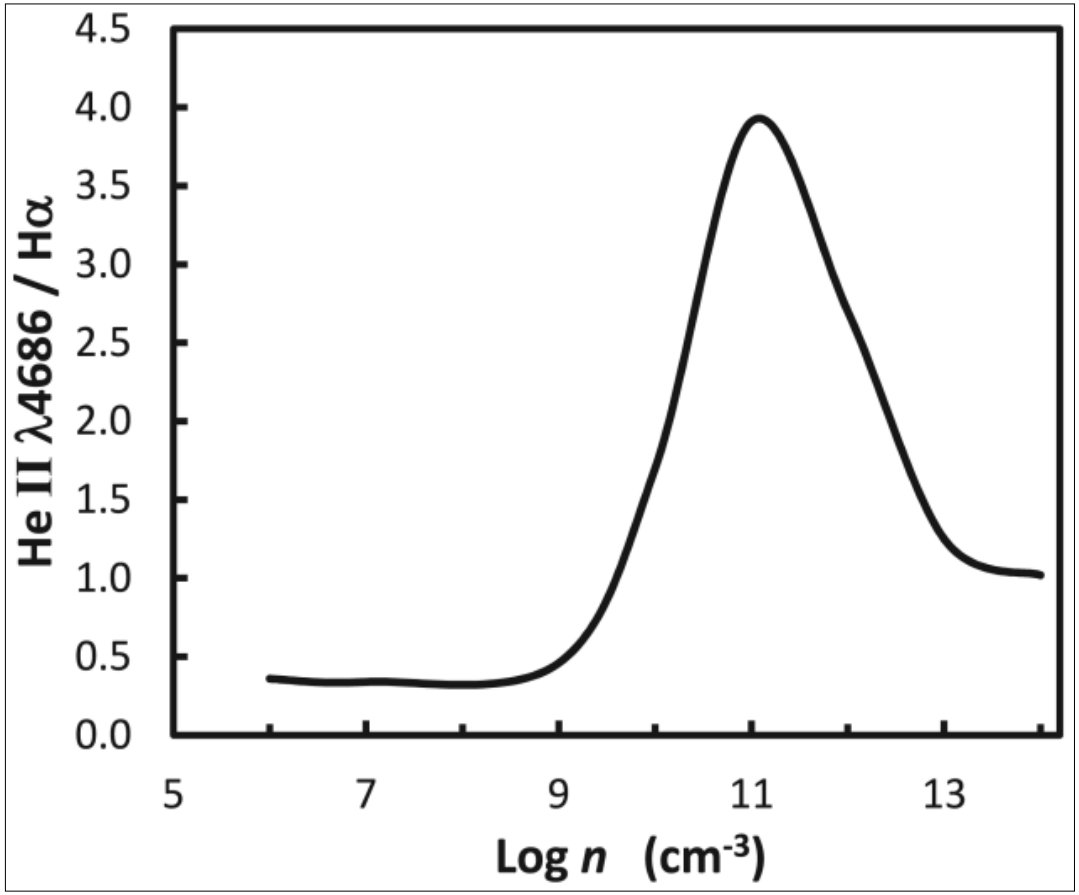
Cumulative ratio of He II λ4686/Hα as a function of the size of a matter-bounded cloud. Given in hydrogen Strömgren length (for the low-density limit $n_H < 10^8$ cm$^{-3}$) when cloud ionized by Mathews & Ferland AGN continuum.

# Modelling HeII λ4686 emission




Gaskell & Rojas Lobos (2014)

Maximum ratio of HeII λ4686/Hα for matter-bounded clouds as function of density, $n_H$. The peak arises because Hα is thermalized at a lower column density than HeII λ4686

# Conclusion

- **We have derived the HeII(λ4686)/Hα ratio from the pre-maximum light spectra of the candidate PS1-10jh**
- **The candidate PS1-10jh and HeII(λ4686) spectra profile is similar to a blueshifted high-ionized BLR lines in normal AGNs**
- **Both the inner, high velocity BLR normal AGNs, and the ejecta of type II-P SN right after shock breakout also show high HeII(λ4686)/Hα ratio.**
- **The HeII/Hα ratio can be reproduced with photoionization models with solar abundance so long as n $10^{11}$ $cm^{-3}$.**
- **This provides strong support that the star disrupted in PS1-10jh was a common main sequence star rather than a very rare helium core star.**
- **The HeIIλ4686 emission in PS1-10jh is very similar to the emission from BLRs of normal AGNs.**
- **The emision after a TDE is a temporary version of the emission in normal AGNs.**