Interstellar lines in the spectrum of Herbig Be star IL Cep

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Intro

Interstellar absorption lines:

Tool for probing interstellar matter on the line of sight.

- Atomic (*NaI, CaII, KI, CaI*...)
- Molecular (*CN, CH, CH^+, C_2*…)

→ Information about distribution, kinematics and physical properties of the clouds.

- Diffuse interstellar bands (DIBs) – *carriers still unknown*
  Long standing (since Heger,1922) mystery of astronomical spectroscopy!

Detection DIBs in different physical conditions (not only in quiscent IS medium) can be useful for carriers identification.

Circumstellar DIBs?

- IR excess stars (Snow&Wallerstein, 1972) — negative.
- Post-AGB stars (Luna et al., 2008) – negative.

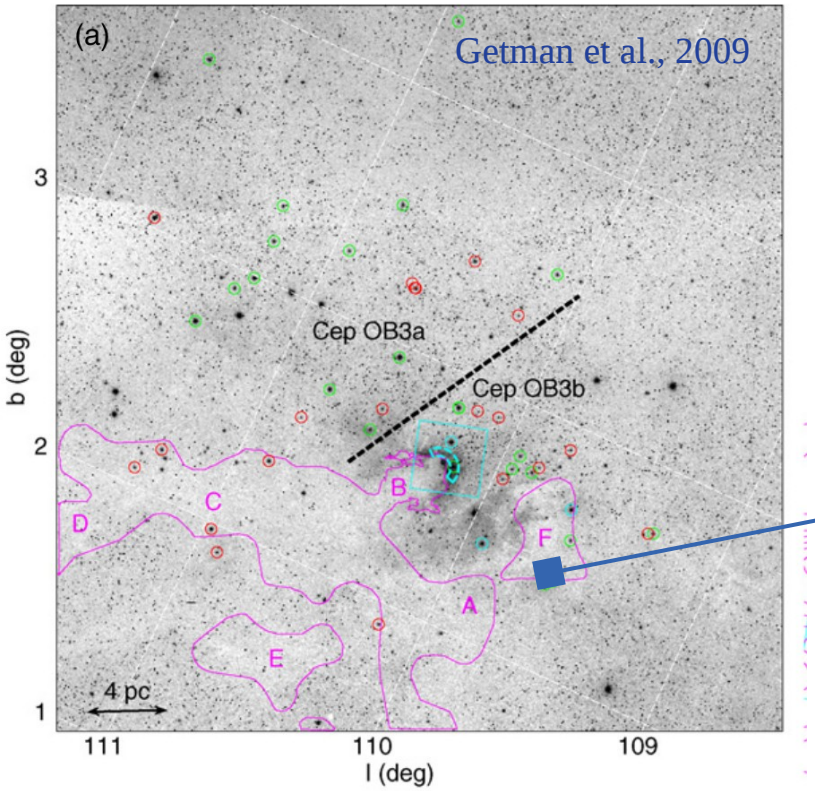
- Herbig Ae/Be stars. Promising class for DIBs studies: complex circumstellar (disks, envelopes) and interstellar (parental clouds) environment.

Tentative detections of DIBs variability:

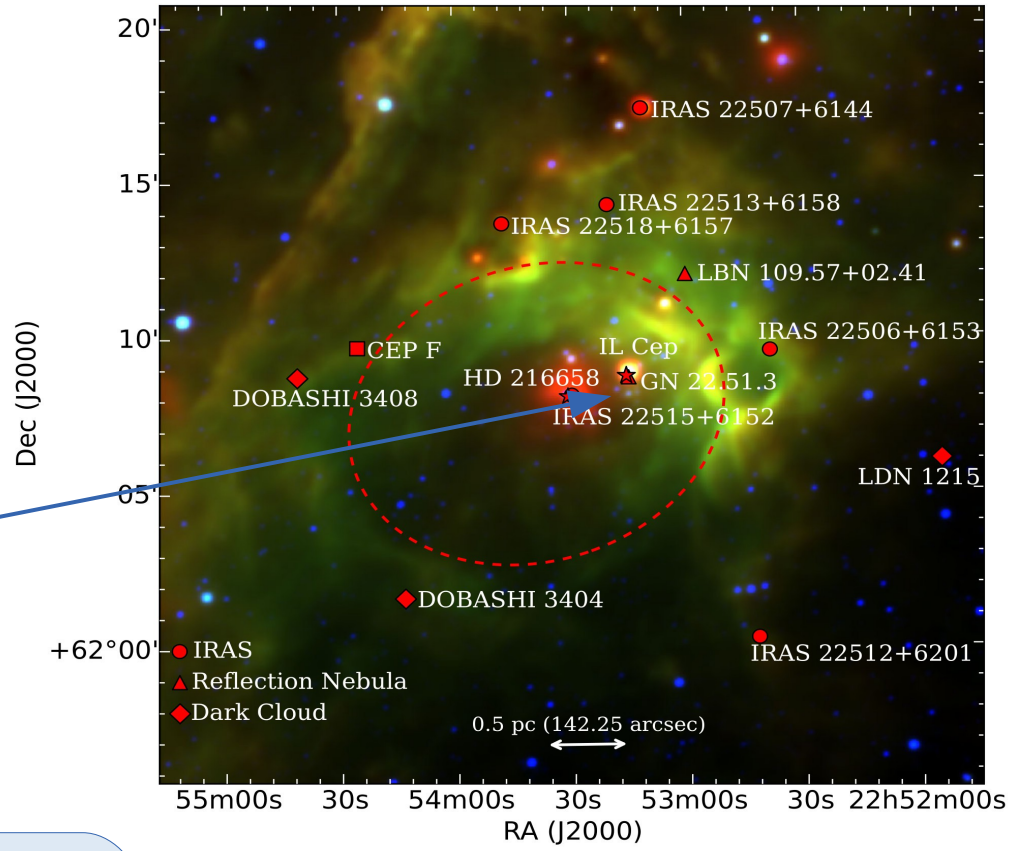
- RR Tau (Rodgers et al., 2002) – correlation EW(DIB 6283Å) with brightness
- IL Cep (Ismailov et al., 2013) – 15-20% variations of EW(DIBs 5780,5797Å)

Herbig Be star IL Cep

Member of Cep OB3b association (Blaauw, 1959)



WISE 3.4 – 12 – 22 μm



Zhang et al., 2016

IL Cep (sp. B3) and its neghbour HD216658 (sp. B0) locate inside cavity in the shocked molecular gas.

gaia

- IL Cep: ***D=808±18 pc*** (TGAS+DR2) ➡ secure distance
- HD216658: ***D=678±40*** pc ➡ foreground object

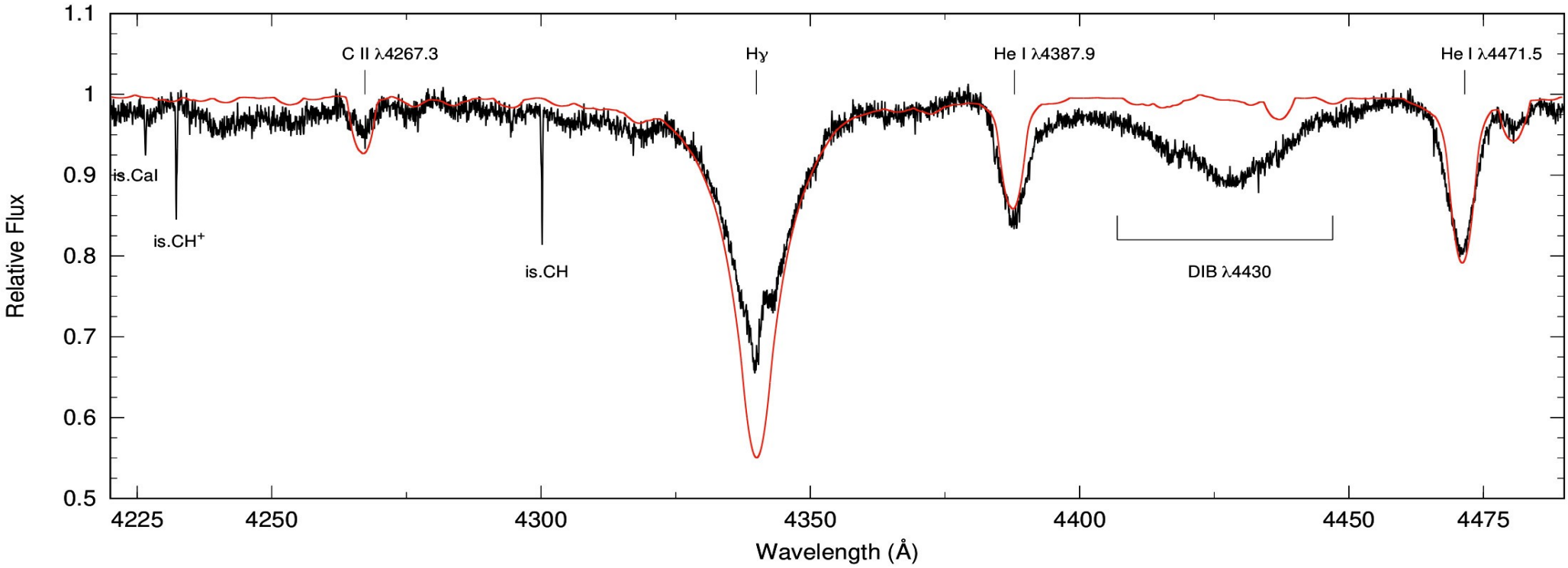
Line of sight to IL Cep crosses the gas outlined the cavity and the CS environment of the star.

IL Cep optical spectroscopy

Observations:

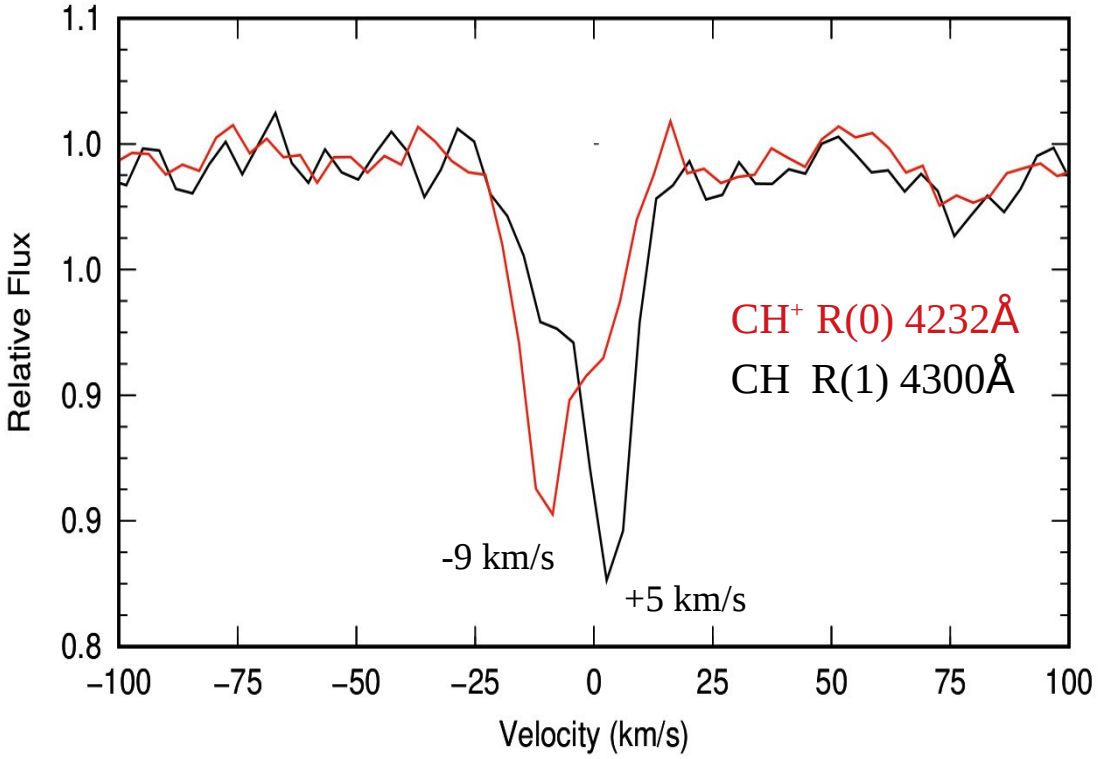
- **Terskol observatory**. 3 spectra 2015 (averaged), *R*=40000 (7.5 km/s)
- **Thai National Observatory.** 2 spectra 2015 + HD216658. *R*=18000 (17 km/s)
- **ELODIE archive.** 3 spectra: 1994, 1995, 1997. *R*=42000 (7.2 km/s)

IS spectrum: *CaII*, *CaI*, *NaI*, *KI*, CH^+, CH lines + up to 30 most prominent DIBs were identified

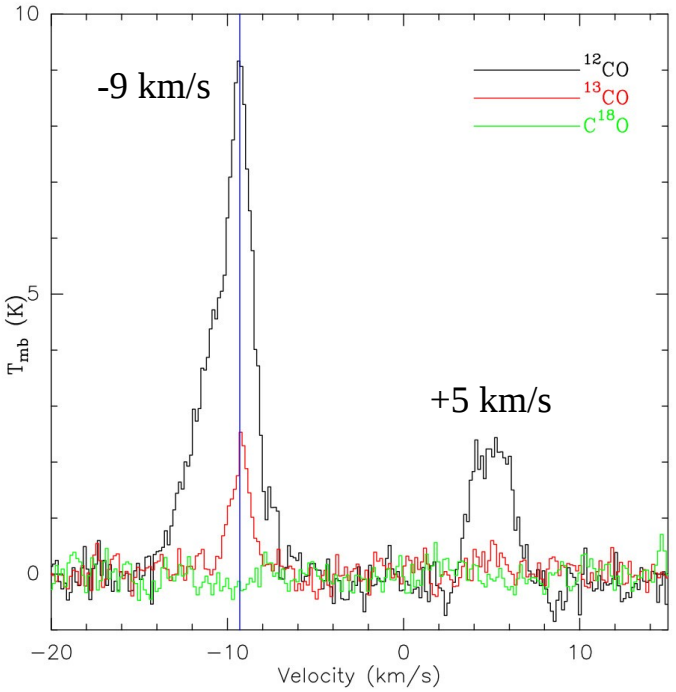


CH and CH^+ molecular lines

Optical data



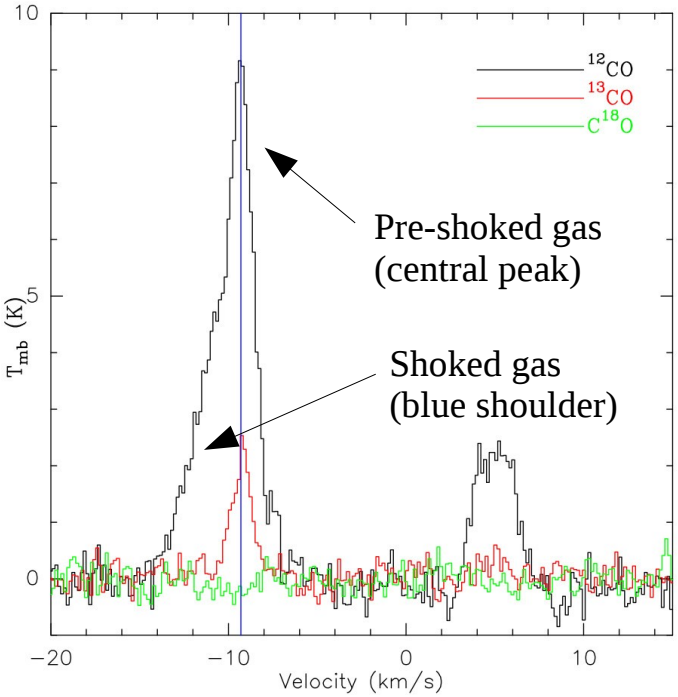
^{12}CO radio emission



Zhang et al., 2016

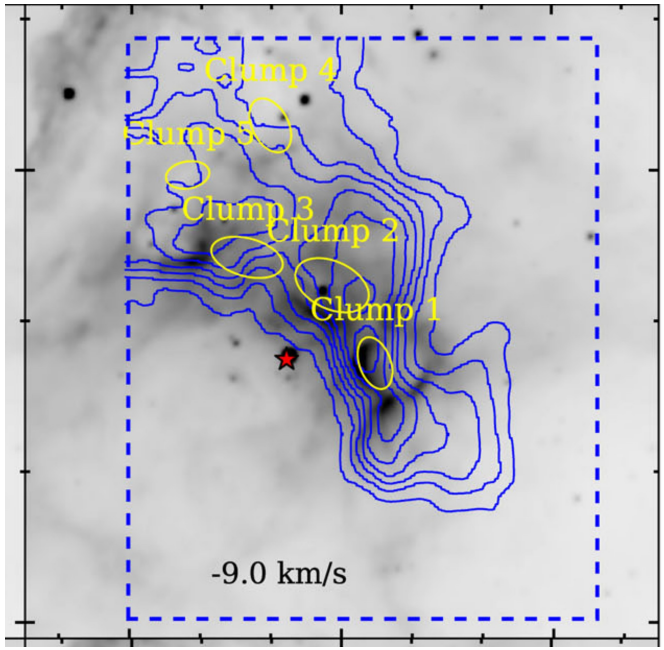
Optical CH+ and CH profiles show two components at -9 km/s and +5 km/s (LSR) in agreement with radio mapping of IL Cep vicinity by Zhang et al., 2016.

CH and CH^+ molecular lines



Average spectrum

Foreground (to IL Cep) molecular clumps at -9 km/s trace the rim of the cavity.



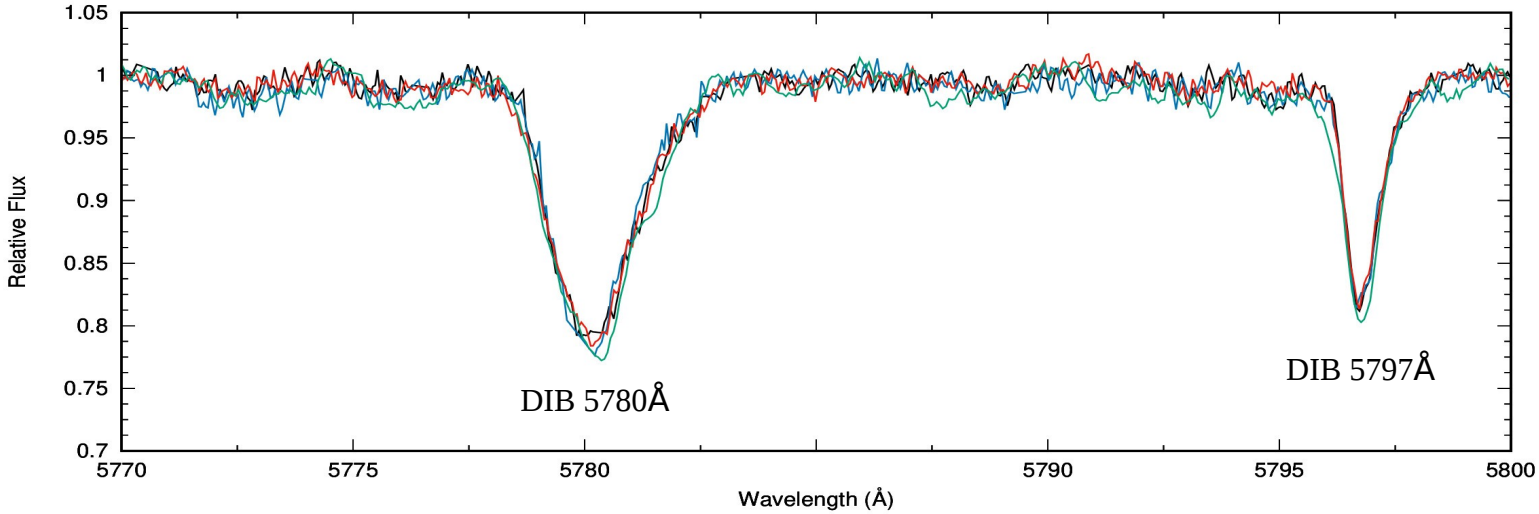
Channel map

Column densities:

Cloud	-9 km/s	+5 km/s
N(CH)x10^{13}	1.9	3.2
N(CH^+)x10^{13}	3.1	1.5

Main absorption at -9 km/s is due to unstable CH^+ ion and forms in the thin transition layer in front of unshocked molecular gas. «+5» km/s — quiscent foreground cloud with dominated neutral CH absorption.

DIBs



Profiles and EWs were stable in 4 spectra from 1994 to 2015!

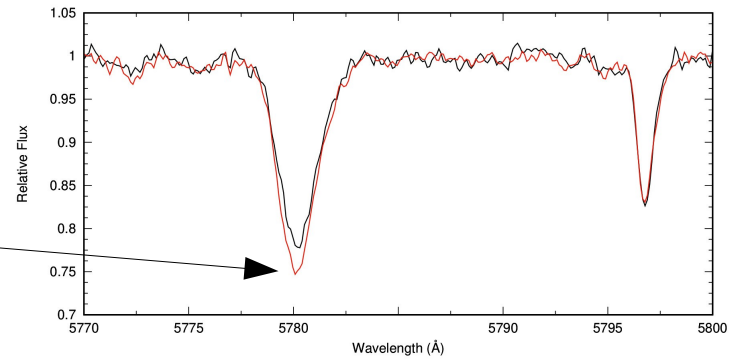
But... Hope dies last – insufficient temporal resolution?

Where DIBs observed in IL Cep spectrum are formed?

✗? Circumstellar origin

No variability.

Same DIBs spectrum in HD216658.



✔Interstellar origin: RV_{LSR}(DIBs) ≈ -8.6-11 km/s indicate their formation in the foreground cloud at -9 km/s, which outlined the cavity.

Summary

- According to GAIA distance HD 216658 is the foreground object and most probable source created the cavity in surrounding gas. IL Cep is observed trough the gas outlined this cavity.

- The profiles of molecular CH and CH+ lines in IL Cep spectrum show double structure in agreement with CO radio observations and indicate the presence of two clouds with inverse $N(CH^+)/N(CH)$ ratios on the line of sight.

- Our spectroscopic material does not support previously reported DIBs variability in IL Cep spectrum. But question on CS DIBs is still open.

- Most plausible formation site of DIBs observed in IL Cep spectrum is the foreground pre-shocked part of the cloud outlined the cavity, while CH^+ absorption associated with this cloud forms in the transitional layer of heated gas.

Thank you!