Massive stars affect strongly the interstellar medium through their intense stellar winds and their rich chemically processed material as they evolve. This interaction becomes substantial in short-lived transition phases of massive stars (e.g. B[e] Supergiants, Luminous Blue Variables, Yellow Hypergiants) in which mass-loss is more enhanced and usually eruptive. A complex environment, combining atomic, molecular and dust regions, is formed around these stars. In particular, the circumstellar environment of B[e] Supergiants is not well understood. To address that, we have initiated a campaign to investigate these environments for a sample of Galactic and Magellanic Cloud sources. Using high-resolution optical and near-infrared spectra (MPG-ESO/FEROS, GEMINI/Phoenix and VLT/CRiRES, respectively), we examine a set of emission features ([OI], [CaII], CO bands) to trace the physical conditions and kinematics in their formation regions. We find that the B[e] Supergiants are surrounded by a series of single and/or multiple equatorial rings, of different temperatures and densities, a phase for which the circumstellar material can be traced. In particular, CO forms very close to the star, while we notice also an alternate mixing of densities and temperatures (which give rise to the different emission features) along the equatorial plane.

Zickgraf et al. (1985) proposed a two-component model with a line-driven polar wind and a cooler, equatorial, outflowing disk (of lower velocity but of higher density). However, this outflow scenario seems outdated and recent high-resolution spectroscopy and interferometry has revealed detached dusty disks with Keplerian rotation (e.g. Liermann+ 2010, Millour+ 2011; Aret+ 2012; Cidale+ 2012; Wolfewright+ 2012b; Oksala+ 2013; Muratore+ 2015; Kraus+ 2016).

In NIR spectra we can detect CO bands in emission originating from the hot inner edge of the molecular disk which can be modeled as a narrow rotating ring of gas (Kraus+ 2000, Kraus+ 2009; Liermann+ 2010; Oksala+ 2013). Further support to this kinematical model comes from optical spectra where a set of lines displays broadened (and usually double-peaked) emission lines. The optically thin lines of [OI] λ5577, λ6300,6363 and [CaII] λ7291,7323 form under different temperatures and densities. In particular, [CaII] forms rather close to the star. [OI] λ5577 forms approximately at the same region with [CaII] lines or a little further, while the doublet [OI] λ5580,6363 originates from further out (Kraus+ 2010; Aret+ 2012, 2016). In lower temperatures (~5000 K) molecules of CO, TiO, and SiO can form, as well as dust further away. (Kraus+ 2010; Aret+ 2012, 2016). In lower temperatures (<5000 K) molecules of CO, TiO, and SiO can form, as well as dust further away. (Kraus+ 2010; Aret+ 2012, 2016).

For the kinematical model a rotational velocity (Vrot, de-projected, ~5.5-6.5 kms$^{-1}$) is used (see spectrum at lower left), (b) This velocity is not sufficient to fit the [Call] λ7292 line, (c) But if we use two rings (Vrot=30-40 kms$^{-1}$ and Vg=10-15 kms$^{-1}$, then their total sum matches the observed one. (d) The same approach leads us to two rings also for the [OI] λ6300 line at (Vrot=31±1 kms$^{-1}$ and Vg=10±1 kms$^{-1}$, Vrot=50±2 kms$^{-1}$ and Vg=2±1 kms$^{-1}$). Thus, both lines are forming in two separate regions with a typical ring-width of ~5 kms$^{-1}$ (see each Maravelias+ 2016).

In order to model the velocity field of the gas, we use two rings (~5.5-6.5 kms$^{-1}$) in between, (e) But if we use two rings (Vrot=30-40 kms$^{-1}$ and Vg=10-15 kms$^{-1}$, then their total sum matches the observed one. (f) The same approach leads us to two rings also for the [OI] λ6300 line at (Vrot=31±1 kms$^{-1}$ and Vg=10±1 kms$^{-1}$, Vrot=50±2 kms$^{-1}$ and Vg=2±1 kms$^{-1}$). Thus, both lines are forming in two separate regions with a typical ring-width of ~5 kms$^{-1}$ (see each Maravelias+ 2016).

3 or 2 rings: CO+SiO form a common region, circumbinary structure (binary within CO ring) 3 or 2 rings: CO+SiO form a common region, circumbinary structure (binary within CO ring)

3 rings or possible only one with coexisting gas – note the presence of [OI]5577 line

7 rings – possible disk, complex structure with alternate regions of atomic/molecular gas 2 rings with only [OI] further out, a circumbinary structure (binary within CO ring)

4 rings of [OI], [Call] only at the outermost ring + CO (binary ?) 4 rings, with [OI]5577+ [Call] rings and CO+ [OI]8300 in between, only [OI]8300 further out (see more in 16)

3 rings, CO closer to star, [OI] is probably circumbinary (B[e] to A separation ~13AU)

Common picture? Each system displays a unique environment, but all show a sequence of rings. Common formation mechanism? Either mass loss triggered by non-radial pulsations and/or other instabilities, or even due to the presence of objects that can clear their paths and stabilize these rings.

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**Abstract**

Massive stars affect strongly the interstellar medium through their intense stellar winds and their rich chemically processed material as they evolve. This interaction becomes substantial in short-lived transition phases of massive stars (e.g. B[e] Supergiants, Luminous Blue Variables, Yellow Hypergiants) in which mass-loss is more enhanced and usually eruptive. A complex environment, combining atomic, molecular and dust regions, is formed around these stars. In particular, the circumstellar environment of B[e] Supergiants is not well understood. To address that, we have initiated a campaign to investigate these environments for a sample of Galactic and Magellanic Cloud sources. Using high-resolution optical and near-infrared spectra (MPG-ESO/FEROS, GEMINI/Phoenix and VLT/CRiRES, respectively), we examine a set of emission features ([OI], [CaII], CO bands) to trace the physical conditions and kinematics in their formation regions. We find that the B[e] Supergiants are surrounded by a series of single and/or multiple equatorial rings, of different temperatures and densities, a phase for which the circumstellar material can be traced. In particular, CO forms very close to the star, while we notice also an alternate mixing of densities and temperatures (which give rise to the different emission features) along the equatorial plane.

**Introduction**

Zickgraf et al. (1985) proposed a two-component model with a line-driven polar wind and a cooler, equatorial, outflowing disk (of lower velocity but of higher density). However, this outflow scenario seems outdated and recent high-resolution spectroscopy and interferometry has revealed detached dusty disks with Keplerian rotation (e.g. Liermann+ 2010, Millour+ 2011; Aret+ 2012; Cidale+ 2012; Wolfewright+ 2012b; Oksala+ 2013; Muratore+ 2015; Kraus+ 2016). In NIR spectra we can detect CO bands in emission originating from the hot inner edge of the molecular disk which can be modeled as a narrow rotating ring of gas (Kraus+ 2000, Kraus+ 2009; Liermann+ 2010; Oksala+ 2013). Further support to this kinematical model comes from optical spectra where a set of lines displays broadened (and usually double-peaked) emission lines. The optically thin lines of [OI] λ5577, λ6300,6363 and [CaII] λ7291,7323 form under different temperatures and densities. In particular, [CaII] forms rather close to the star. [OI] λ5577 forms approximately at the same region with [CaII] lines or a little further, while the doublet [OI] λ5580,6363 originates from further out (Kraus+ 2010; Aret+ 2012, 2016). In lower temperatures (~5000 K) molecules of CO, TiO, and SiO can form, as well as dust further away. Combining the kinematical information from all these tracers allows us to probe the structure of the disk.

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**Conclusions**

A common picture? Each system displays a unique environment, but all show a sequence of rings. Common formation mechanism? Either mass loss triggered by non-radial pulsations and/or other instabilities, or even due to the presence of objects that can clear their paths and stabilize these rings.