On the influence of galactic magnetic fields on the shape of circumstellar bubbles

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Wind-blown bubbles around massive stars

- Massive stars create large ($>>10$ pc) bubbles, through their stellar wind
  - Numerical models, including stellar evolution (e.g. Garcia-Segura et al. 1996a,b; Freyer et al. ´03, ´06; Dwarkadas ´05, ´07; Eldridge et al. ´06; van Marle et al. ´05, ´07, ´08; Toala & Arthur ´11)
  - Results can be used as a fingerprint of stellar evolution
  - These models tend to take the interstellar medium as a passive background

- The interstellar medium contains magnetic fields (Rand & Kulkarni 1989; Ohno & Shibata 1993; Beck ´09; Shabala et al. ´10)
  - Galactic disk: 5-10 $\mu$G
  - Galactic bulge: 10-50 $\mu$G
  - Inside molecular clouds: 100+ $\mu$G

- Even weak interstellar magnetic fields can limit the expansion of superbubbles (Tomisaka 1990, 1992; Ferriere et al. 1991)

- How does this influence the shape of circumstellar shells?
Wind driven bubble expanding in a non-magnetic ISM

- 40 M\(_\odot\) star
  - MS (10\(^{-6}\) M\(_\odot\)/yr, 2000 km/s)
  - RSG (10\(^{-4}\) M\(_\odot\)/yr, 10 km/s)
  - WR (10\(^{-5}\) M\(_\odot\)/yr, 2000 km/s)
- Spherical bubble with thin, unstable shell
- Multiple shells resulting from evolutionary changes in the wind
Wind-driven expansion with $B_{\text{ISM}} = 20 \, \mu G$

- Elongated bubble
  - Expansion perpendicular to the field stops completely!
- No visible outer shell
  - Slight compression of field lines
- RSG and WR shells constricted by the bubble into jet-like shapes
Supernova expansion with $B_{\text{ISM}} = 20 \, \mu G$

- Bubble remains elongated
- **Supernova remnant** follows the shape of the bubble
The mystery of the α-Orionis bowshock

- **Red supergiant** interacts with ISM: \( v_w < v_\star \)
- **Bowshock** should be unstable. (e.g. Dgani et al. 1996; Brighenti & d’Ercole 1995; van Marle et al. 2011)
- **But it isn’t!**
  - Too young? (Mohamed et al. 2012; Mackey et al. 2012)
  - Warm ISM? (Decin et al. 2012)
  - Magnetic field?

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The model:

- $\dot{M} = 3.0 \times 10^{-6} \, M_\odot/\text{yr}$
- $V_\infty = 15 \, \text{km/s}$
- $V_\star = 28.3 \, \text{km/s}$
- $\rho_{\text{ISM}} = 2 \, \#/\text{cm}^3$

ISM B-field near $\alpha$-Orionis
- 1.4 - 5 $\mu$G (Frick et al. 2001, Heerikhuisen & Pogorelov 2011, Opher et al. 2009)
- Assume 3 $\mu$G, parallel with stellar motion (to preserve 2D symmetry)

(Ueta et al. 2008, Decin et al. 2012)
α-Orionis in an interstellar magnetic field

\[ B = 3 \, \mu G \]

\[ B = 0 \]
Conclusions:

- **Galactic magnetic fields** can influence the shape of **circumstellar bubbles**
- This can indirectly change the shape of temporary **circumstellar shells and supernova remnants**
  - Asphericity of shells may be unrelated to stellar parameters
- The lack of large scale instabilities in the bowshock of **α-Orionis** can be explained as the result of the **local interstellar magnetic field**.
What comes next?

- Low mass stars in interstellar magnetic fields: AGB → Post-AGB (Planetary nebulae)
- Structured magnetic fields (3D)
- Bowshocks encountering non-parallel magnetic fields (3D)
- Stars in clusters (3D)