The impact of stellar feedback in the Vela C molecular cloud

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Our Galactic Ecosystem: Opportunities and Diagnostics in the infrared and Beyond

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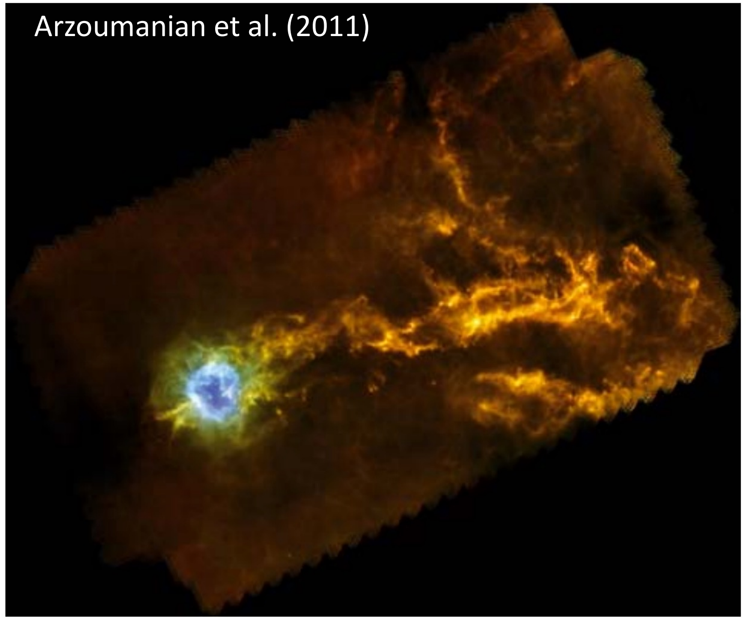
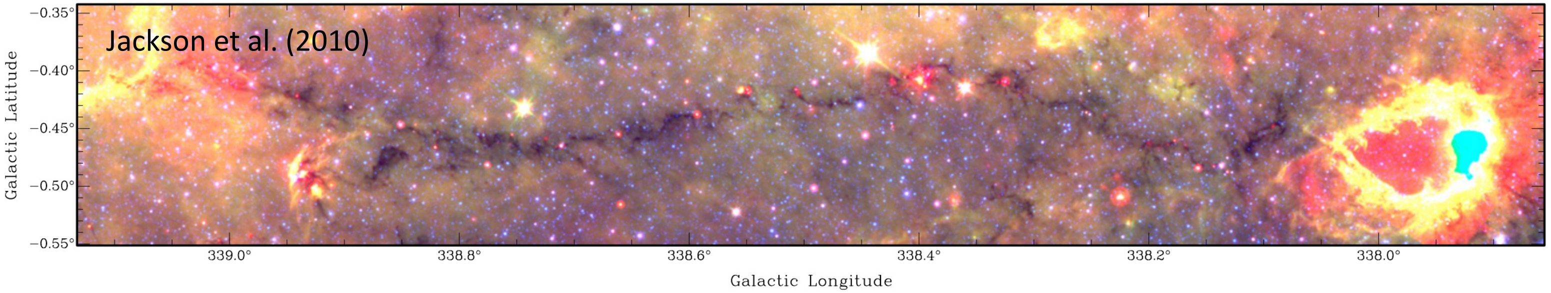
Feedback in molecular clouds

- ➢ Stars form in filamentary clouds (e.g. Churchwell et al. 2009; Jackson et al. 2010; André et al. 2010)

- ➢ Stellar feedback plays a central role in molecular cloud evolution
  - Regulates the star formation efficiency (SFE)?
  - Shapes the cloud morphology (e.g. Churchwell et. 2006)
  - Triggers new star formation?





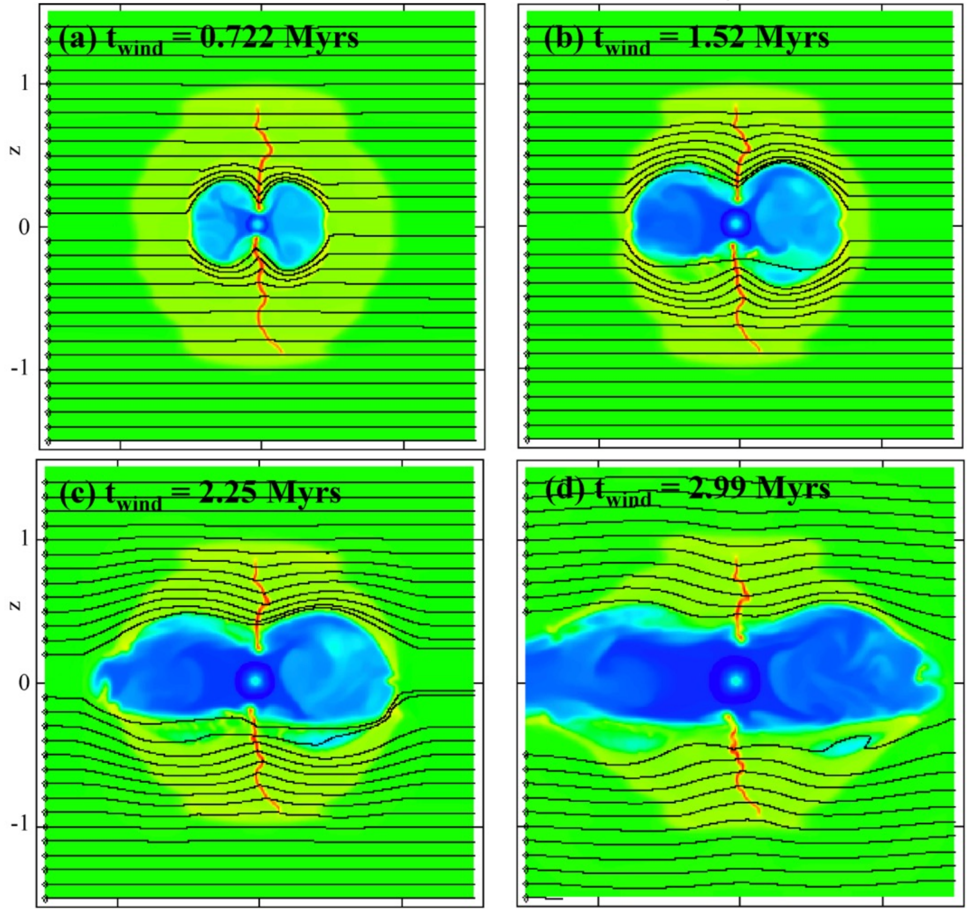
Bipolar HII regions

- Bipolar HII regions are rare (Samal et al. 2018)
  - < 10% (including correction for inclination)

- Limited amount of studies
  - Theoretical and observational

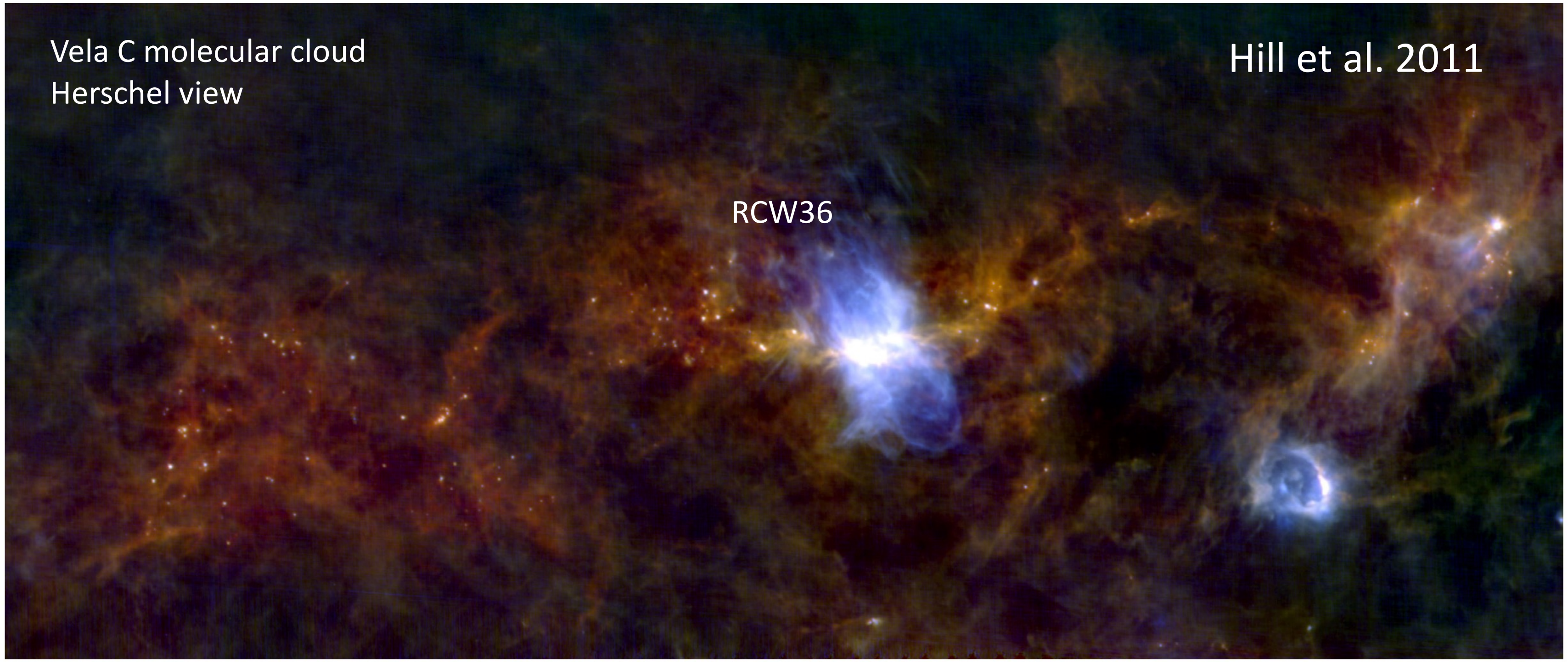
- Generally proposed to form from a sheet (e.g. Bodenheimer et al. 1979)
  - Simulations: bipolar morphology remains over time (e.g. Wareing et al. 2017)

Wareing et al. (2017)



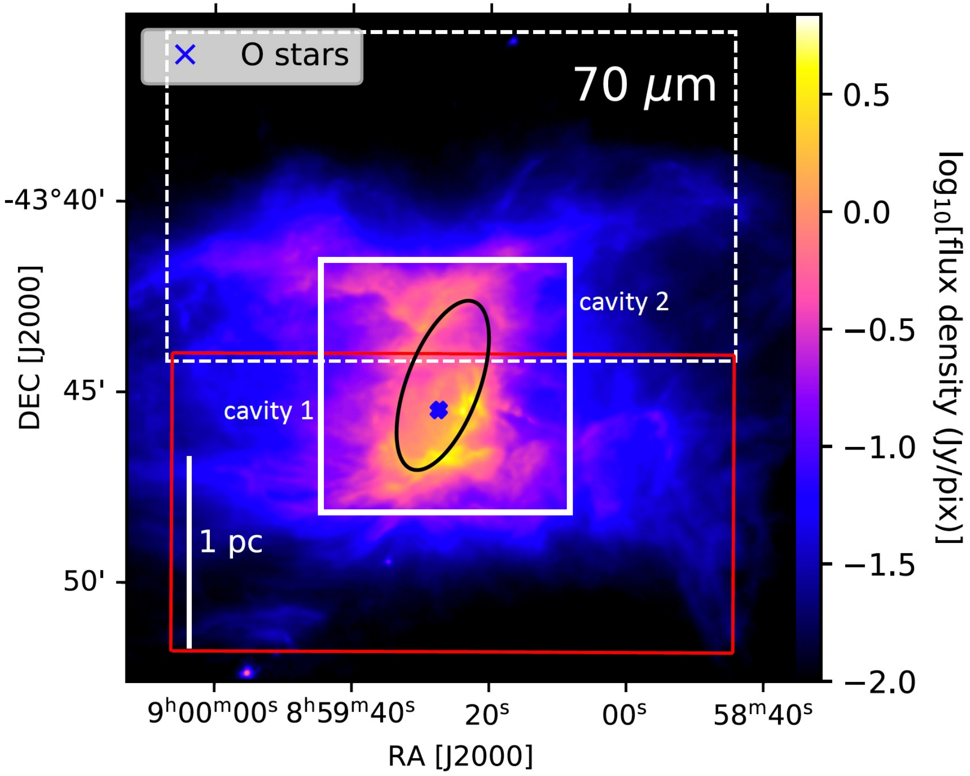
RCW 36 in the Vela C molecular cloud

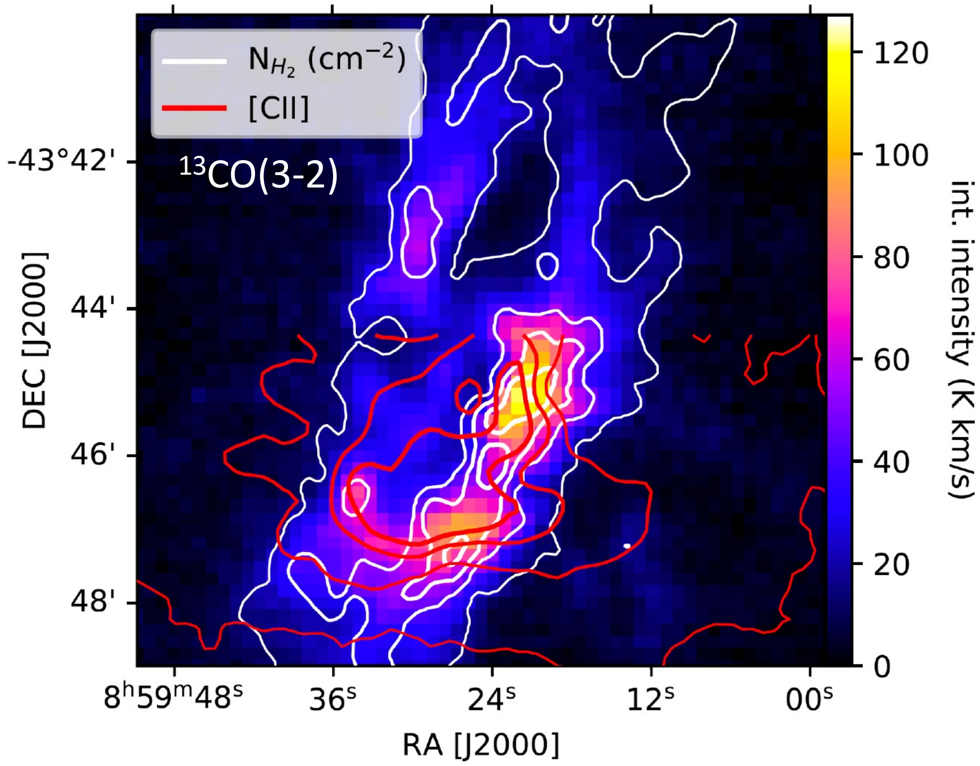
- ➢ RCW 36: a bipolar HII region
  - 1 Myr old OB cluster (Ellerbroek et al. 2013)
  - Bipolar cavities centred on a dense molecular ring (Minier et al. 2013)



RCW 36 with FEEDBACK

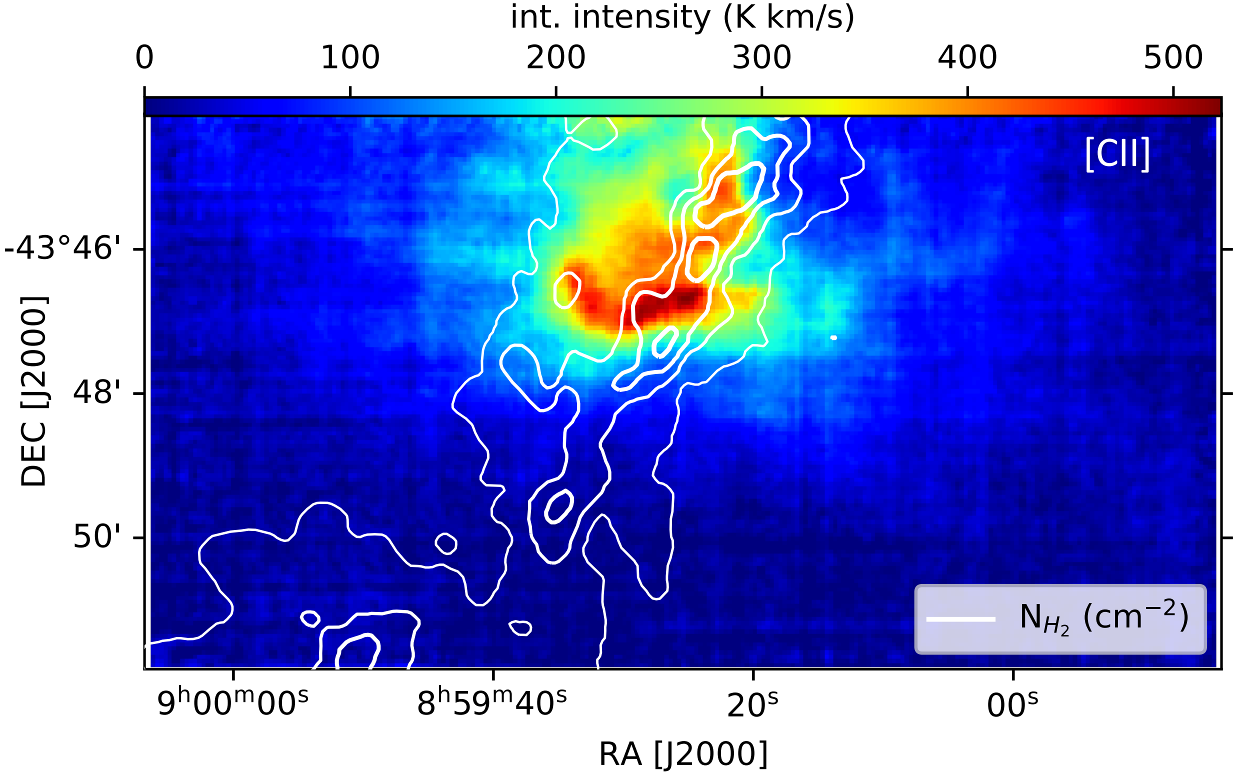
- [CII] & [OI] from upGREAT on SOFIA (Schneider et al. 2020)
  - Complemented with $^{12}CO(3\text{-}2)$ & $^{13}CO(3\text{-}2)$ from APEX

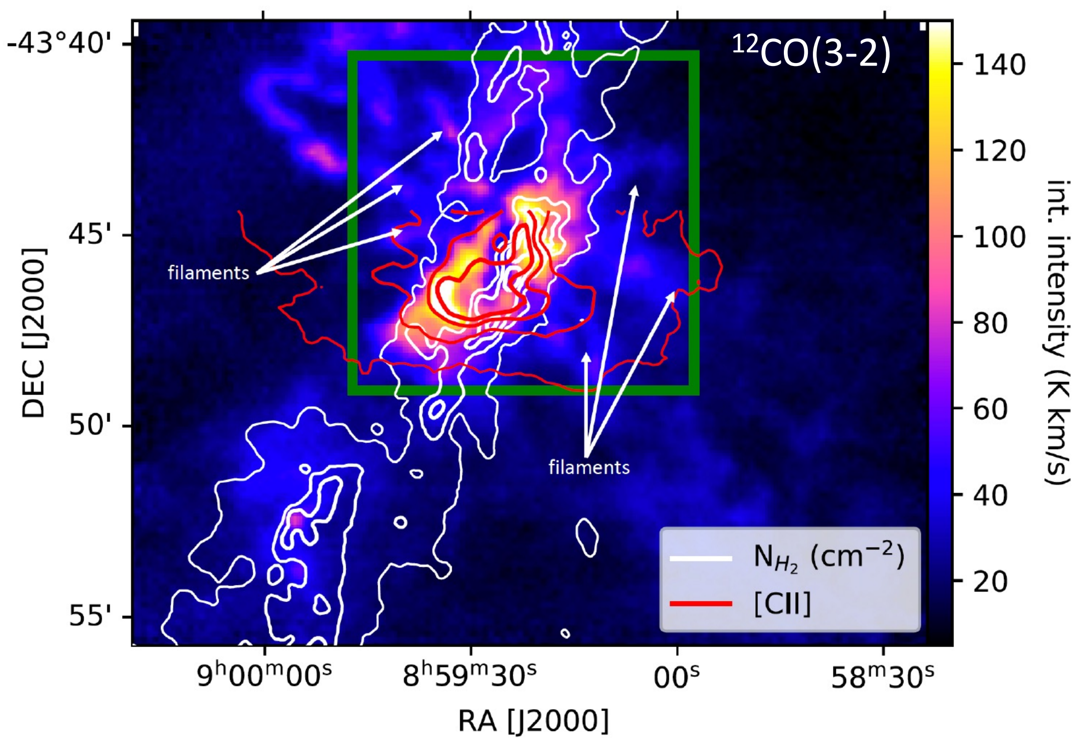




RCW 36 with FEEDBACK

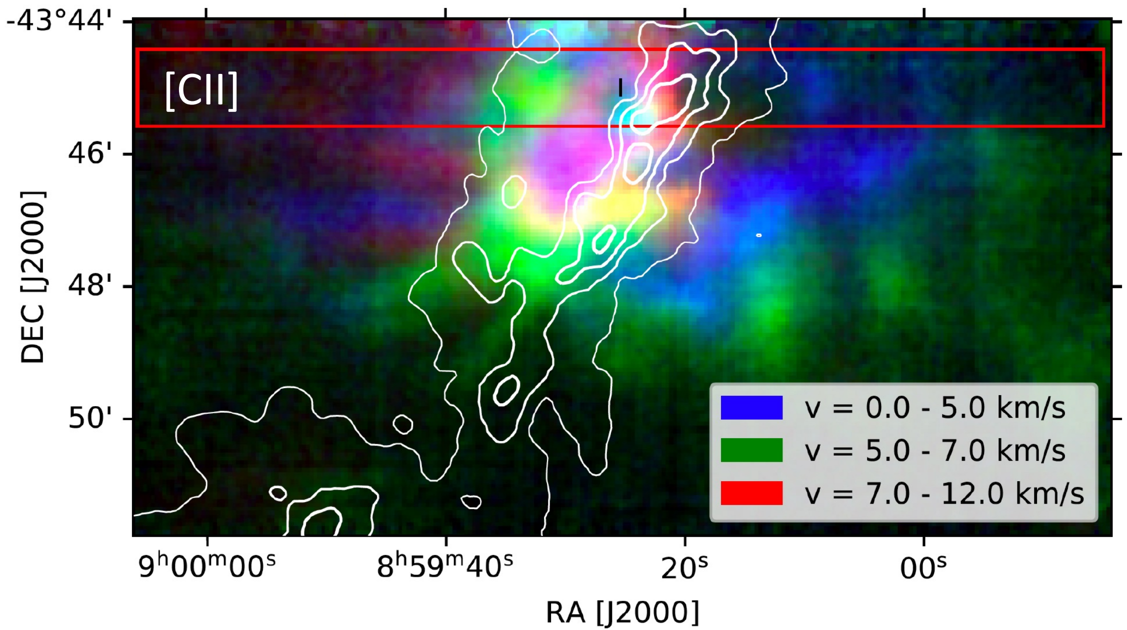
- ➢Bright [CII] emission goes through the molecular ring
- ➢Several curved molecular filaments being swept away?

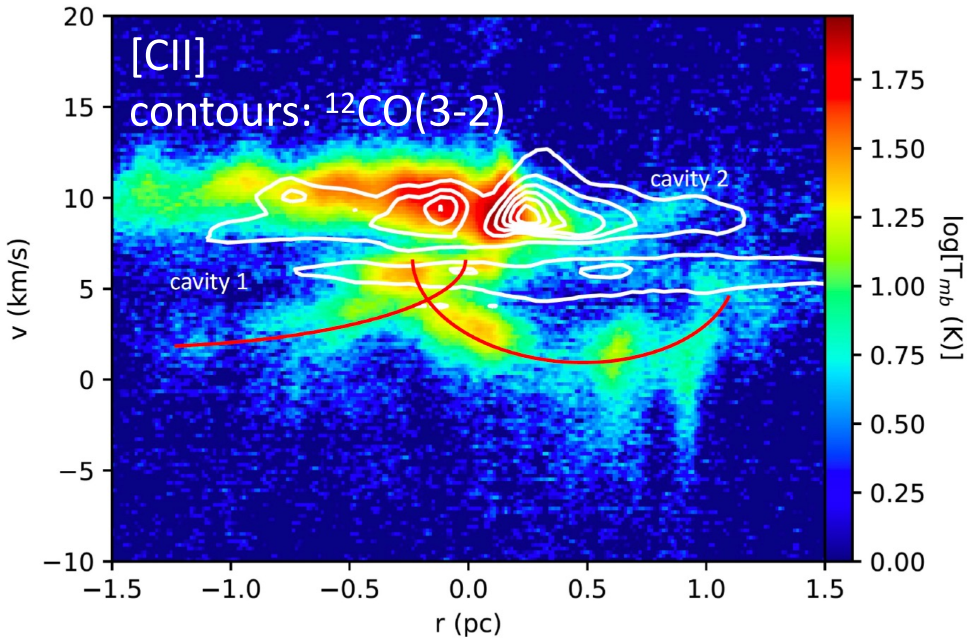




Expansion of RCW 36 unveiled with [CII]

- Expanding molecular ring
  - 1-2 km s^{-1} => t_{exp}= 0.5-1 Myr (see also Minier et al. 2013)
- Blueshifted expanding shells in the cavities
  - 5 km s^{-1} => t_{exp} = 0.2 Myr



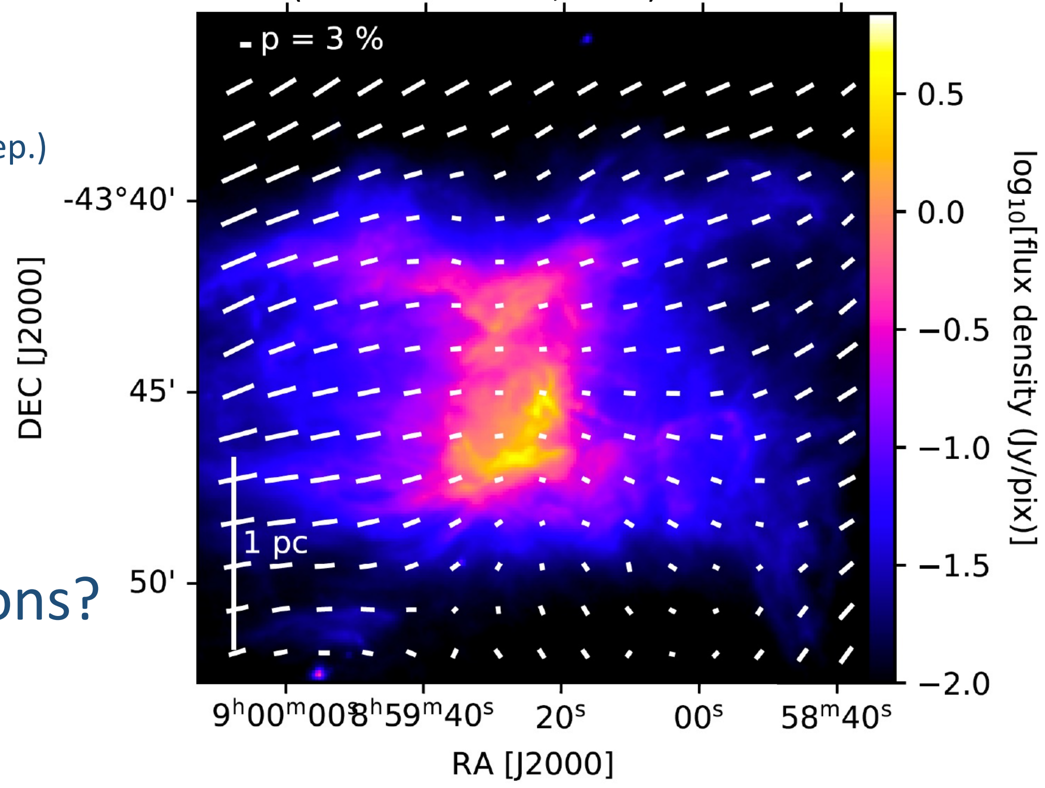


The evolution of a bipolar HII region

- In Vela C:
  - Perpendicular to the ridge(/edge-on sheet?)
  - Aligned with the magnetic field (see also Bij et al. in prep.)

- Short expansion timescale in the cavities
  - Suggests a relatively short bipolar lifetime
  - Disagrees with simulations?
  - Underestimate abundance of bipolar HII regions?

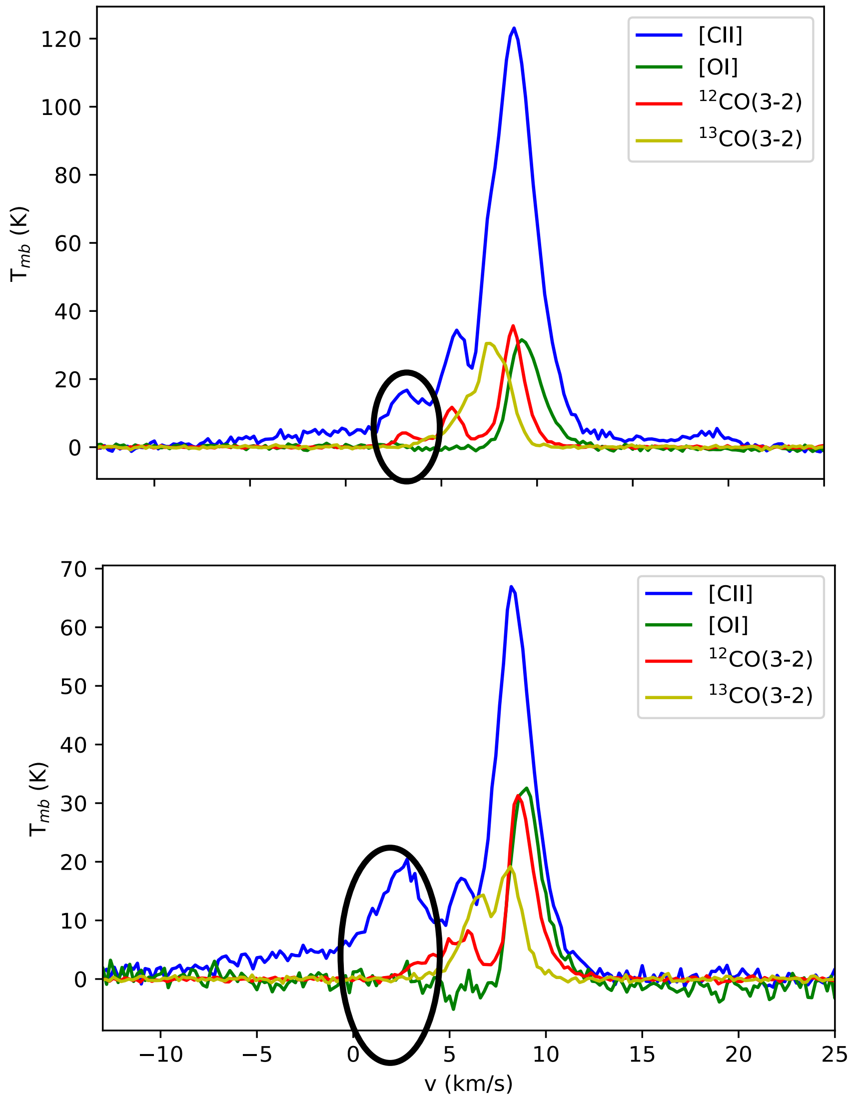
70 μm + BLASTPol magnetic field (Fissel et al. 2016; 2019)



The [CII] high-velocity wings in RCW 36

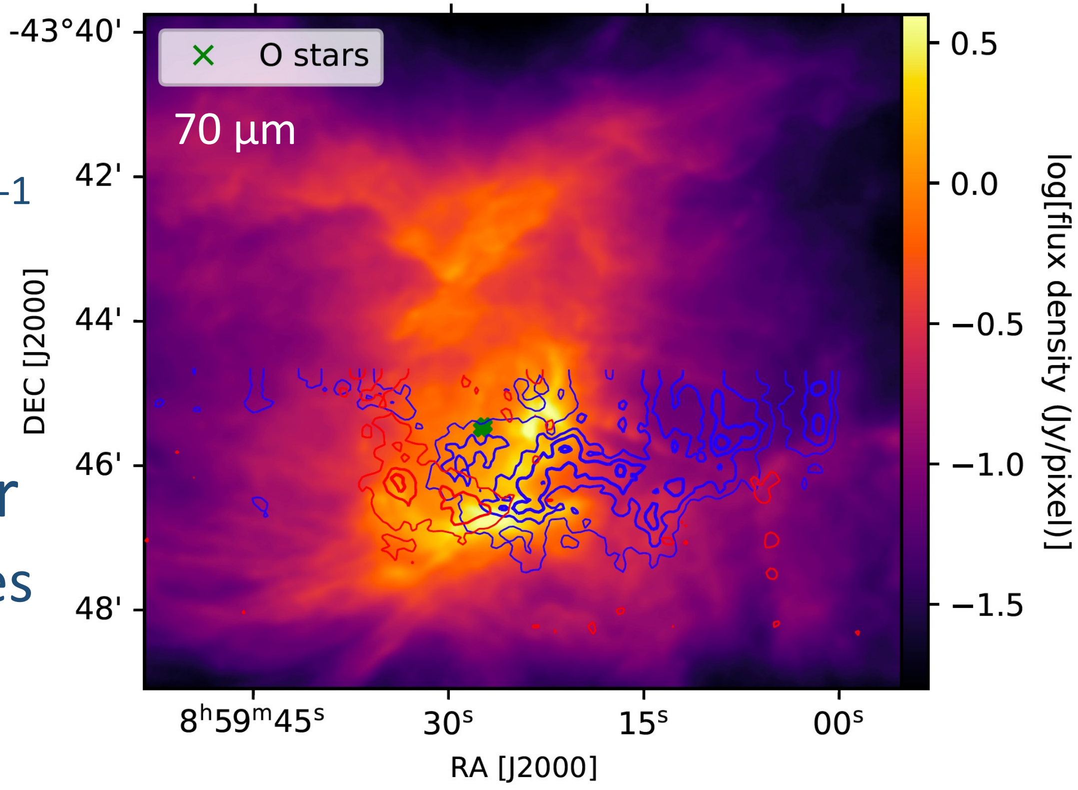
- Multiple velocity components in [CII]
  - V_{lsr} = 5-12 km s^{-1}: Emission from the ring
  - V_{lsr} = 0-5 km s^{-1}: Blueshifted expanding shell

- Spectra also have line wings (~ 15 km s^{-1})
  - Only detected in [CII]
  - Blue- and redshifted



Expansion and dispersion of RCW 36

- Map of the [CII] high-velocity wings
  - Bipolar outflow originating in the ring
  - Brightest towards the cavity walls
  - Associated mass ejection rate: ~10^{-3} M_{sun} yr^{-1}



- Can disperse the central ridge in 1-2 Myr
  - Halt local star formation on short time scales

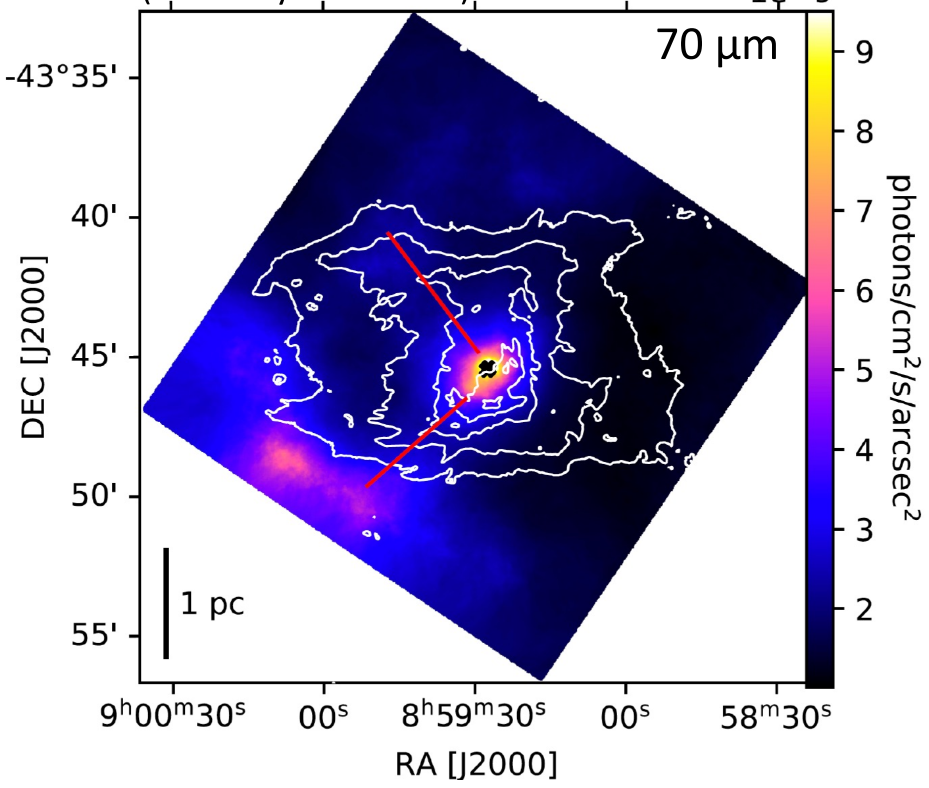
Chandra observations of RCW 36

- X-ray emission from hot plasma created by stellar winds
  - Bright at the center
  - Weak, but detected, in the cavities
  - Bright outside the cavity walls

- Fitting the X-ray spectra (using XSPEC; Arnaud 1996)
  - Hot plasma is leaking from the region

X-ray emission between 0.5 and 7 keV

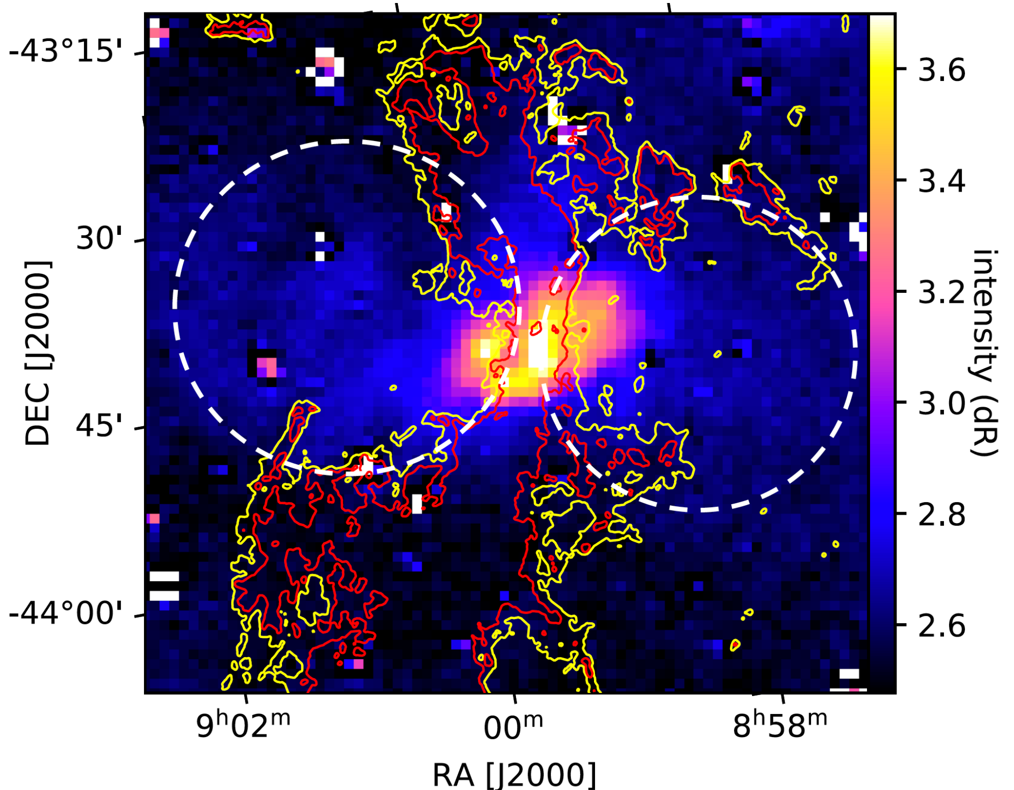
(Townsley et al. 2014)

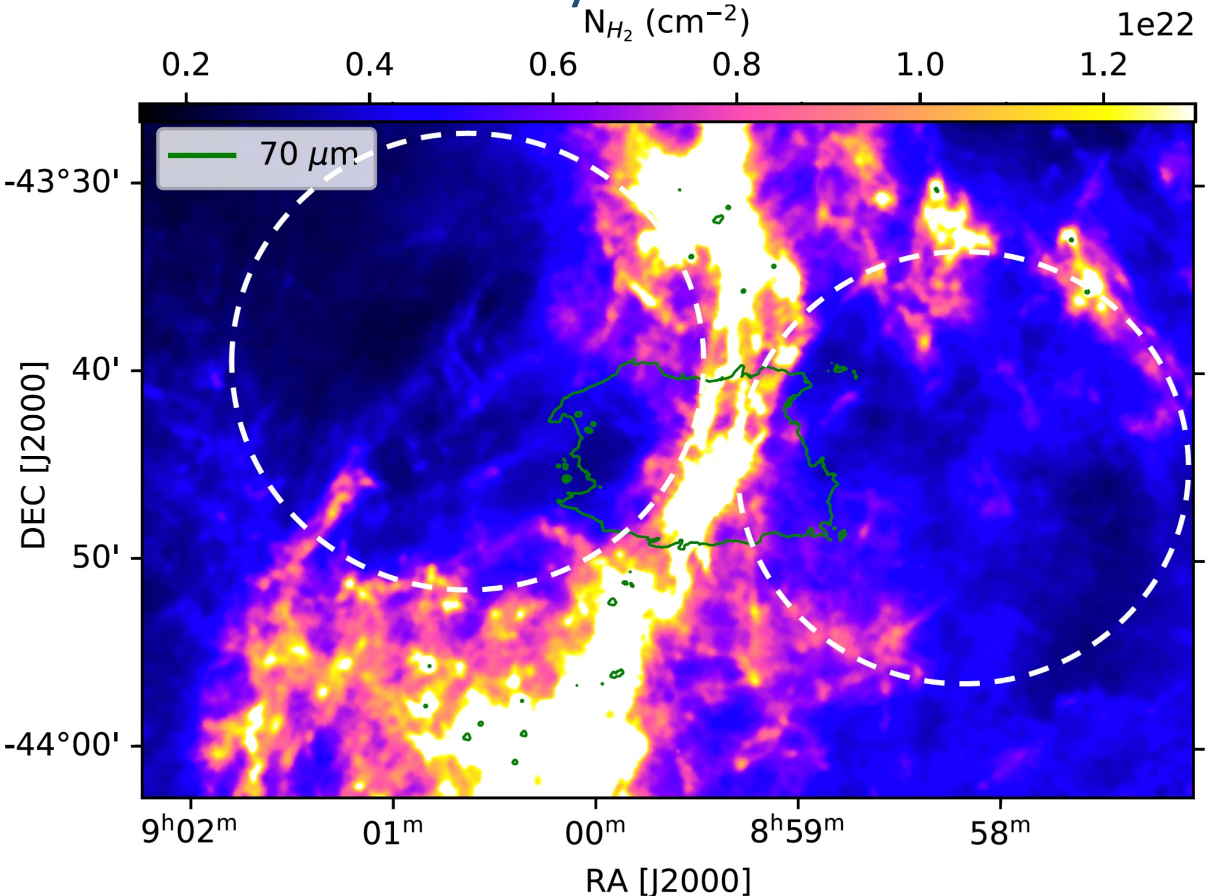


Large-scale clearing around RCW 36?

- Larger cavities around RCW36
  - Leaking stellar winds and ionizing radiation in a filamentary cloud

Hα emission + column density contours





Conclusion

- ➢Highly non-uniform expansion in a filamentary cloud
  - The bipolar morphology might be a short evolutionary stage
- ➢The origin of bipolar HII regions
  - Expansion in sheet?
  - Expansion favored along the magnetic field?
- ➢High-velocity outflow: rapid dispersion of the ridge
  - Could limit star formation in the dense ring
- ➢Leakage appears to clear low-density ambient gas of the cloud