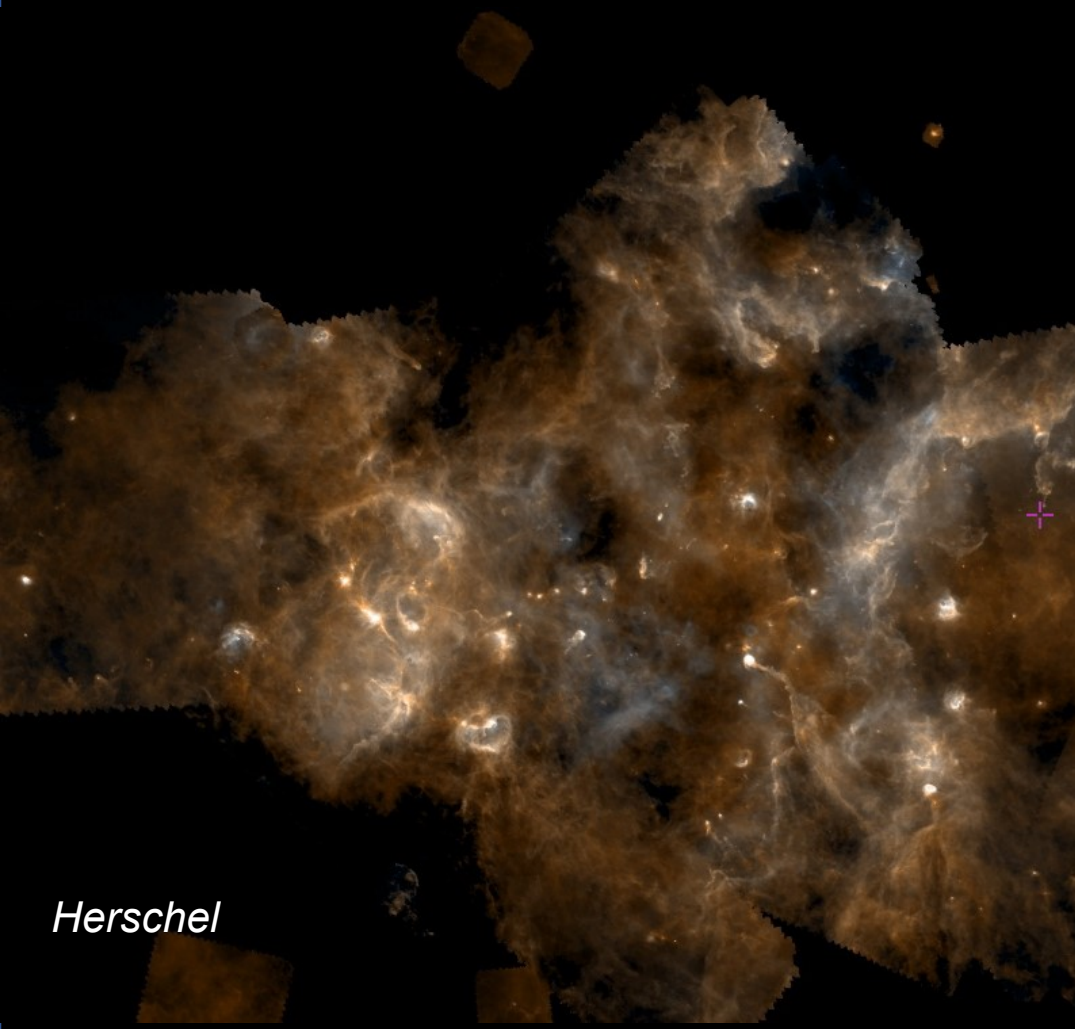

LACERTA. CYGNUS. LYRA. VULPECULA AND ANSER.
Pl.14.
Cygnus before yesterday
Fernando Comerón
CEPHEUS
DRACO
HERCULES
CERBERUS
SAGITTA
Grumium
Etanin
Rastaban
Azelfafage
Deneb
Sadr
Gienah
Albireo
Vega
Sidl Hall, sculp.t

Cygnus hosts the nearest example of a Giant Molecular Cloud complex in our galactic neighbourhood



Herschel

- ~400 pc in extent
- ~1500 pc from the Sun
- Dominating structure of the local arm
- Several OB associations with hundreds of O stars
- Several 10^7 solar masses of molecular material
- Giant molecular clouds (Cygnus X)
- Active massive star forming sites (DR21)
- Supernova remnants
- Large-scale structures (Cygnus Superbubble)

A natural laboratory for studying recent and ongoing star formation at many scales

- O stars lifetimes up to 10 Myr
- Youngest population easily identifiable as long as it displays infrared excess

We can easily observe what is happening now and up to ~10 Myr into the past, but what happened before?

- Uppermost main sequence easily reachable, but down to ~B2; older stars lost in the confusion
- Extinction heavy toward most of the stellar population
- Presence of clusters older than 10 Myr shows that star formation has happened in the past, but they are poor probes (tracing local star formation, dispersion with time)

DSS-2

Red supergiants as probes of not-so-recent star formation

- Bright! Easy to see, especially in the infrared
- Descendants of stars with initiall mass 7-40 solar
- Beginning of red supergiant phase 10-50 Myr
- Duration of red supergiant phase 0.5-4 Myr
- Beginning, duration and luminosity of red supergiant phase mainly dependent on initial mass

However…

- Photometrically indistinguishable from other, far older bright cool stars (RGB, AGB…)
- Main, clearest spectral classification criteria in the blue (extinction…)

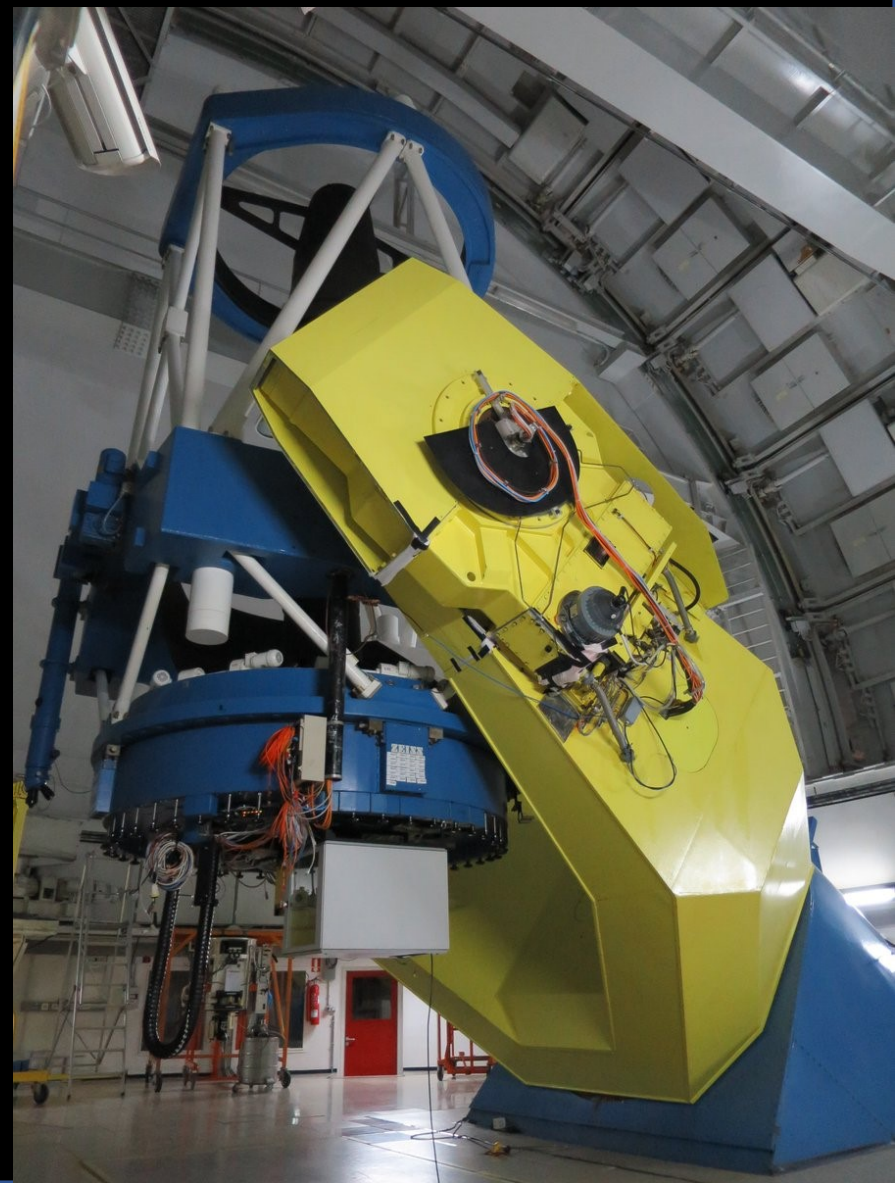
But sufficient, albeit subtle, gravity-sensitive features exist in the red too

A search for red supergiants in Cygnus to reconstruct its star forming history

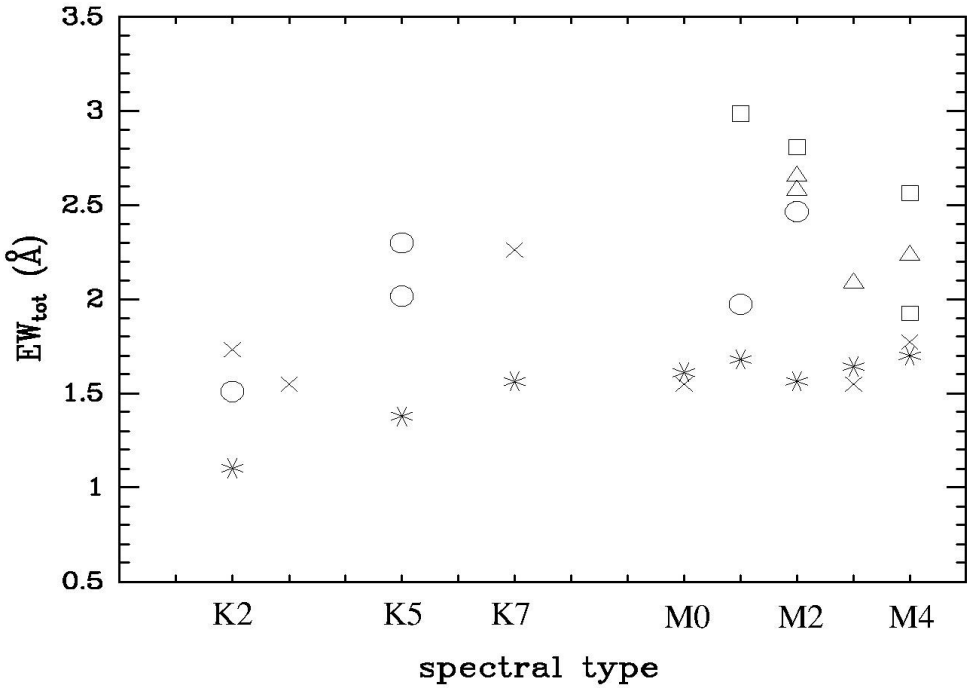
- 71 < l < 85, -2 < b < +4
- Ks < 4.0 (sufficient for Cygnus)
- J-Ks > 1.1 (may be mimicked by extinction though)
- Q > 0.1 (reddening-free index separating red from blue photospheres)

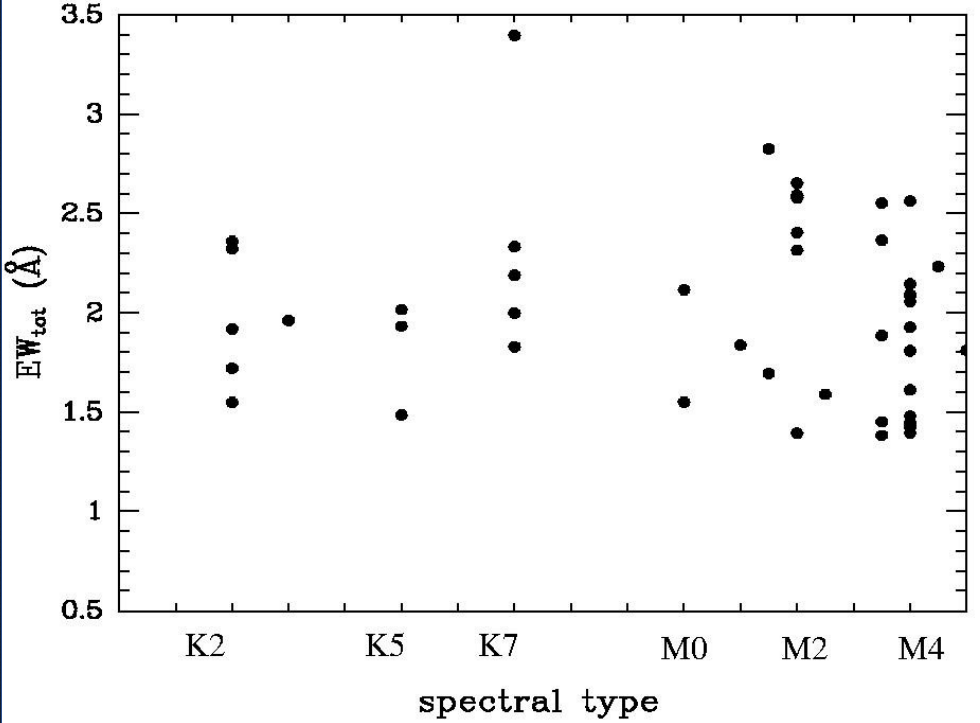
91 objects selected in this way, but sample expected to be severely contaminated

- Red spectroscopy (CaI triplet region) using 2.2m telescope on Calar Alto



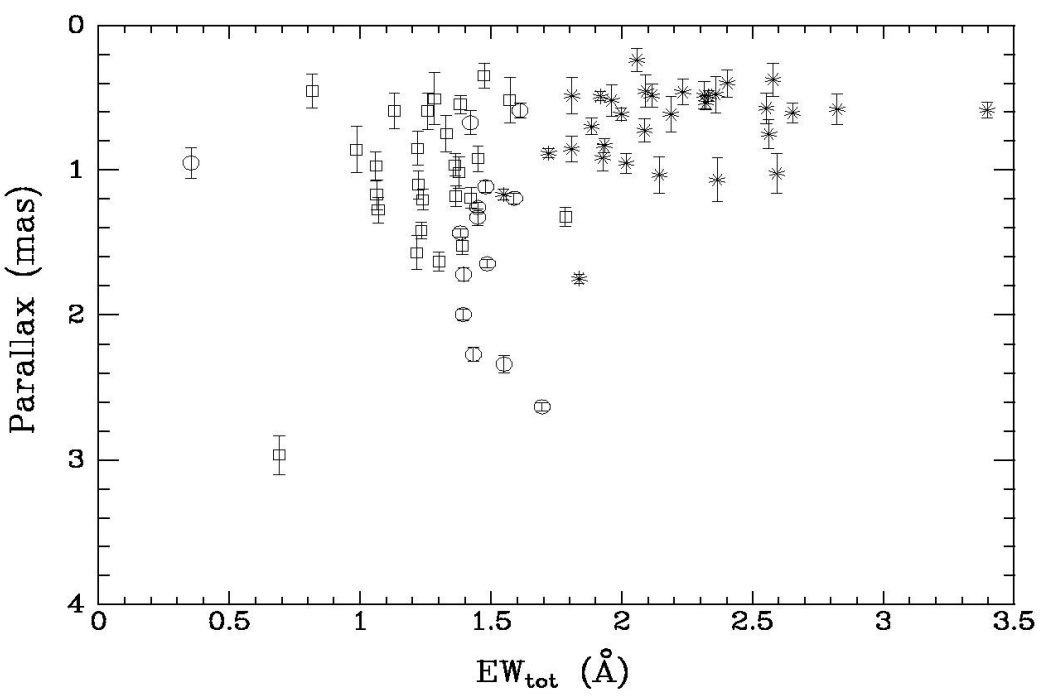
- Gravity-sensitive luminosity class criterion verified on a sample of standard stars
- Cygnus sample contains good supergiant candidates

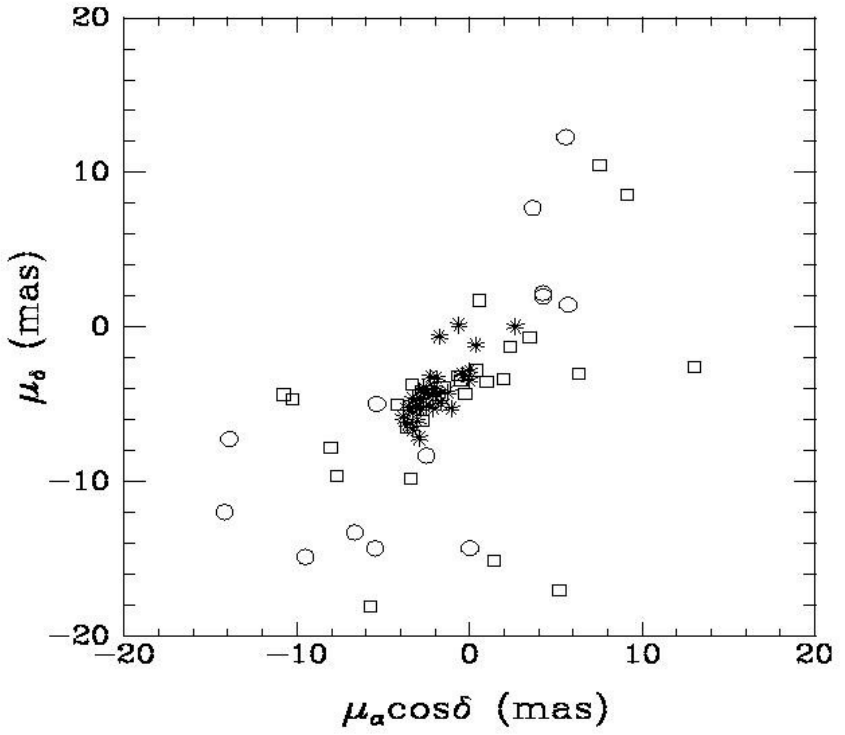




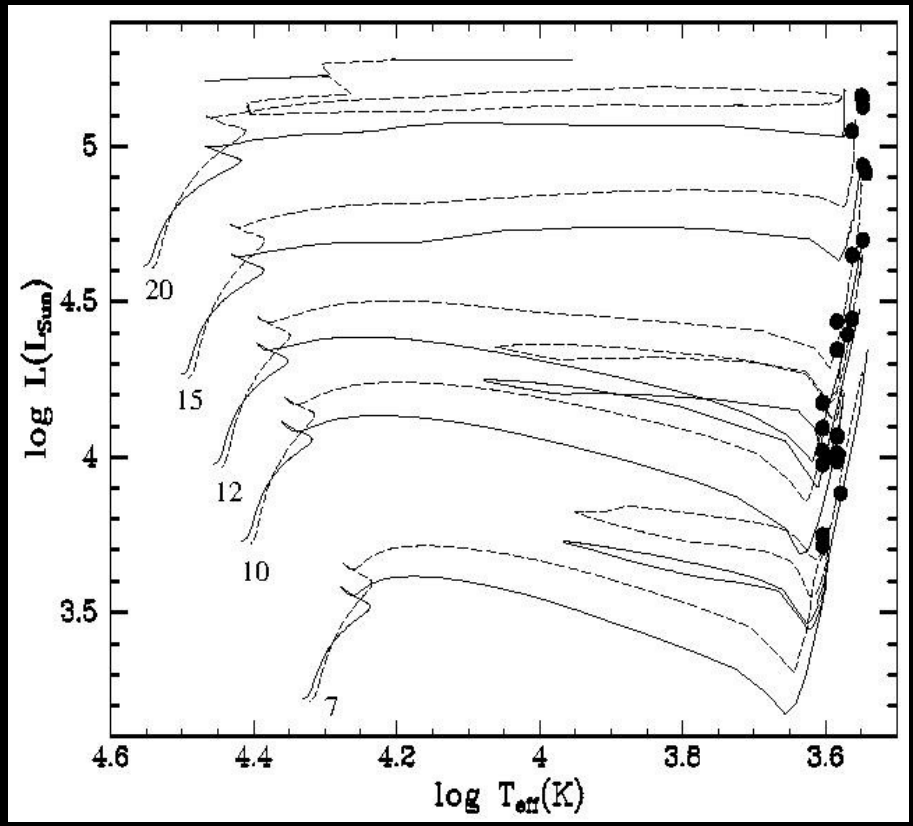
- Spectroscopically-selected supergiants have systematically smaller parallaxes
- Most concentrate in a small range of parallaxes (distance ~1650 pc)
- Spectroscopically-selected supergiants are a cold population
- Some background (Perseus arm) supergiants selected, identified by large negative radial velocities

24 bona fide red supergiant candidates left

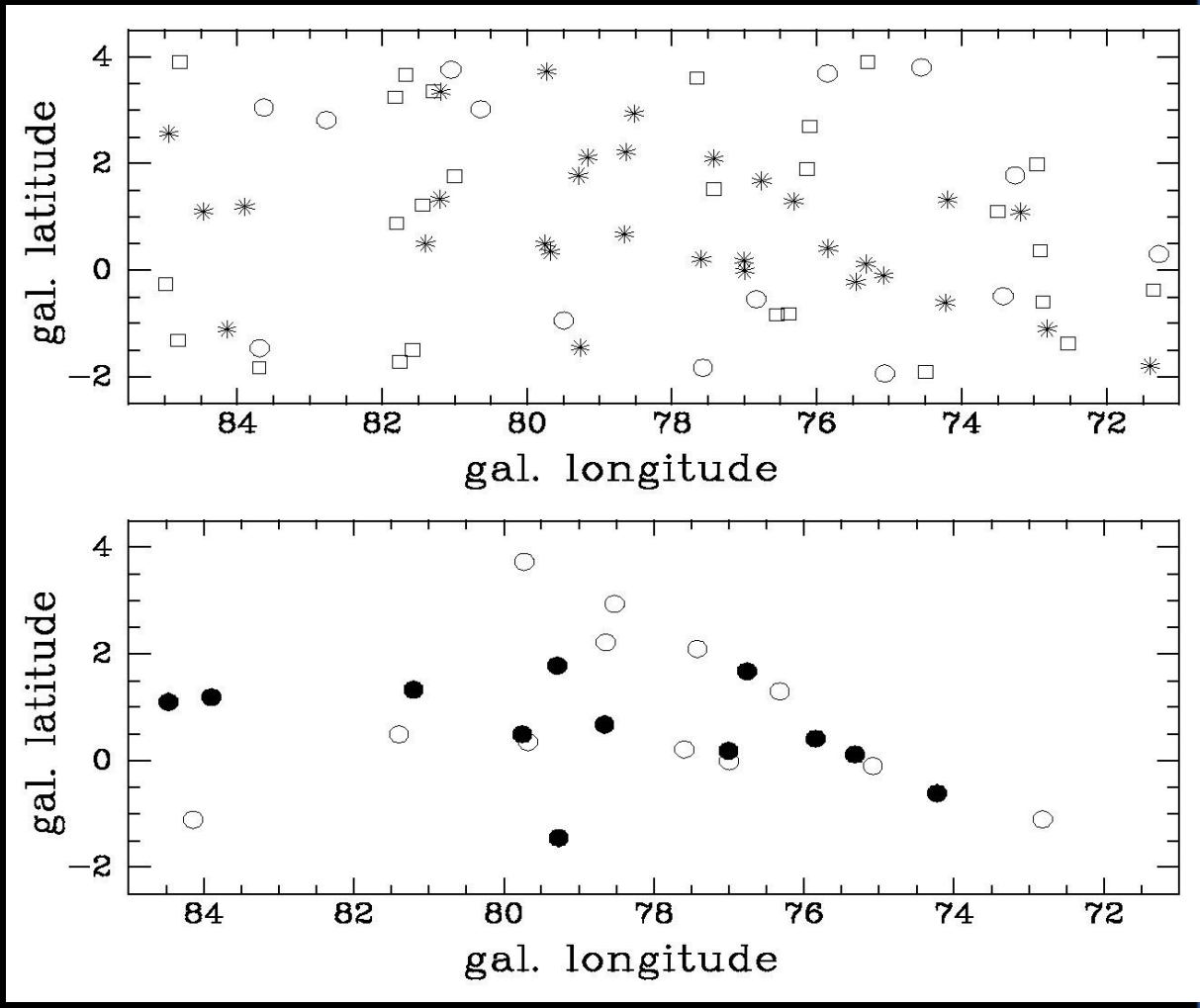




- Assuming common distance, log Teff – log L relation appears where expected from evolutionary tracks
- Sample of supergiants cover the *mass* range 8-20 M_{sun}
- Sample of supergiants cover the *age* range 10-50 Myr



- No spatial clustering (expected from velocity dispersion at birth)
- No obvious age sequence (no progression of star formation across the giant molecular cloud complex)



Deriving the star formation history from the mass distribution of red supergiants

$$N_{RSG}(M > M_{min}) = A \int_{t=-\infty}^{0} dt \int_{M=M_{min}}^{\infty} \Psi(t) V_{RSG}(M,t) \xi(M) dM$$

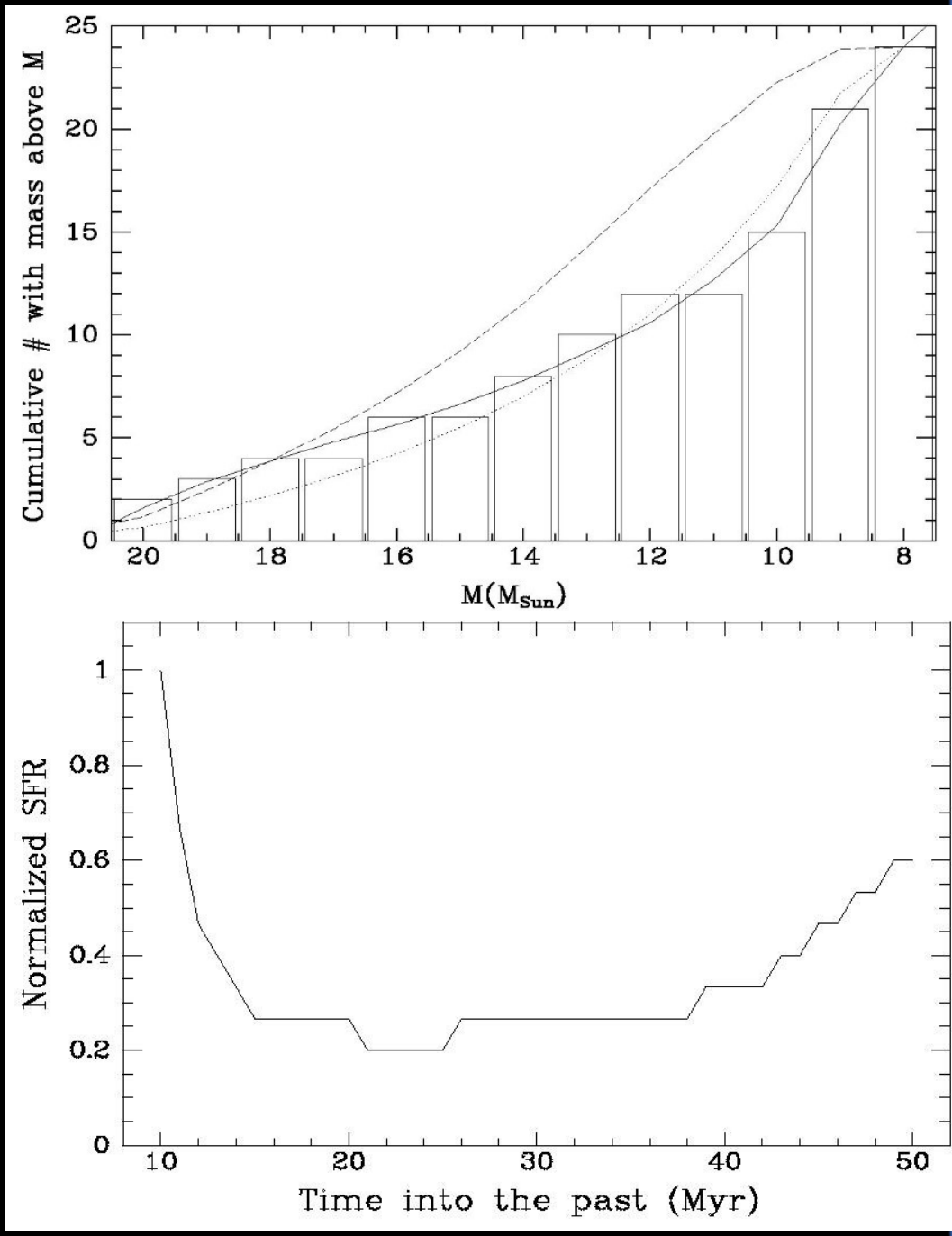
Where

- $\Psi(t)$ is the star formation rate at time t
- $V_{RSG}(M,t) = 1$ if a star of initial mass M born at time t is undergoing the red supergiant phase at present $(t = 0)$, $V_{RSG}(M,t) = 0$ otherwise
- $\xi(M)$ is the initial mass function (assumed Salpeter)
- $N_{RSG}(M > M_{min})$ is the cumulative number of red giants above mass M_{min}

Inverting the equation yields the star formation rate $\Psi(t)$

The mass distribution of Cygnus red supergiants is reproduced through a star formation history implying

- Recent (~12 Myr) burst of star formation
- Low-level but non-zero sustained star formation rate over previous ~25 Myr
- Higher star formation rate in the distant past (> 40 Myr)! Passage through a spiral arm?



Conclusions

- Red supergiants are probes of the past history of star formation over the *entire* lifetime of a giant molecular cloud
- The presence of red supergiants in Cygnus implies a massive star formation history previous to the present generation of O stars
- The Cygnus giant molecular cloud complex has undergone a low-level, but sustained star formation activity between ~12 and ~40 Myr ago
- The star formation rate in the Cygnus giant molecular cloud complex was high ~50 Myr ago, then declined until ~40 Myr ago

The Cygnus giant molecular complex was sculpted for at least 50 Myr before reaching its recent level of star forming activity. This may be true for other large complexes too. Look for the supergiants!