The early phases of Star formation: from Filaments to Cores and Young Clusters

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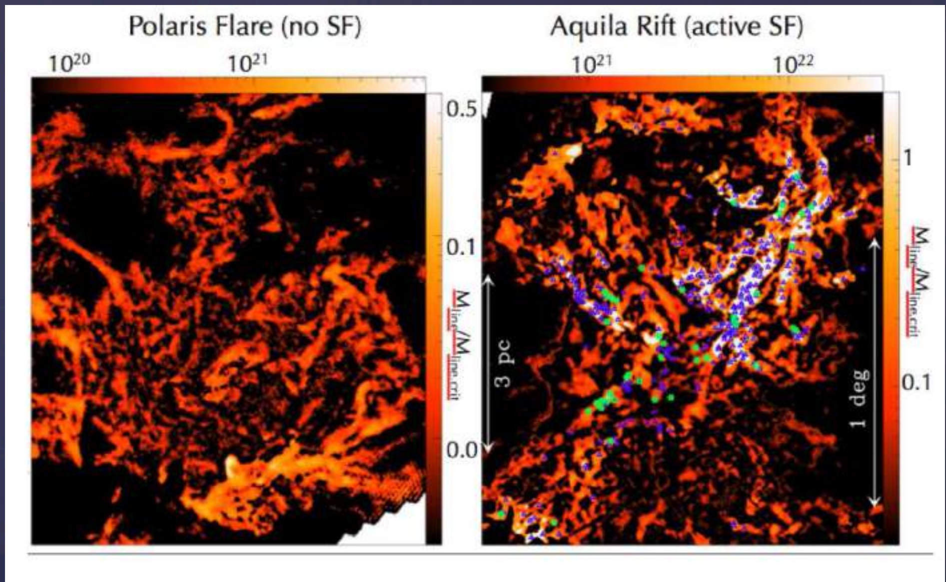
Outline

- filaments2core project
- Multiple population in Chamaeleon I
  - until April 2018
  - New Gaia DR2 observations
  - > New view of the populations on ChamaeleonI
- Results on another low mass star forming region
- Future …

Background … Filaments in the Herschel Era

(Roccatagaliata et al
et al. 2015)

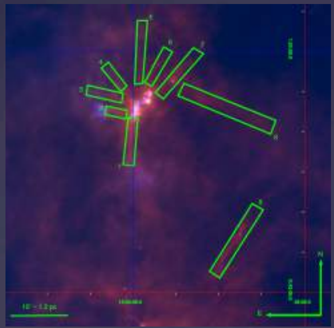
- Everywhere with and without on-going star formation



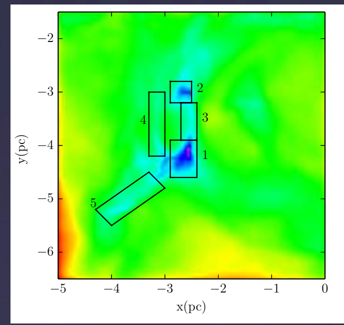
(e.g. *Ward-Thompson et al.* 2010)

(*Andre et al.*, 2010)

DR21 in
Cygnus X North
(*Hennemann et al.*, 2012)



filaments2core



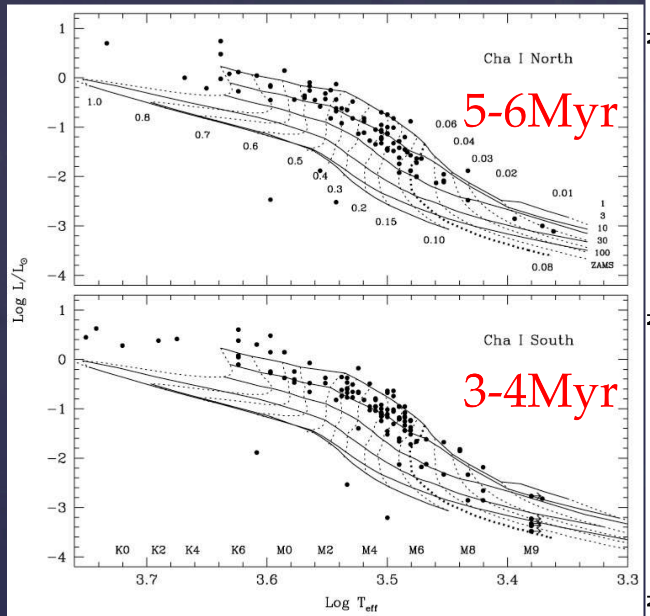
① How do filaments form stable?

② What is the connection between filaments and cores?
③ How do filaments evolve and form a young cluster?
④ What is the effect of feedback on filaments evolution?

Today: Filaments - Cores - Young Cluster
in the
post Herschel Era (public Archive!)
Large public survey in the submillimeter
in the Gaia Era !

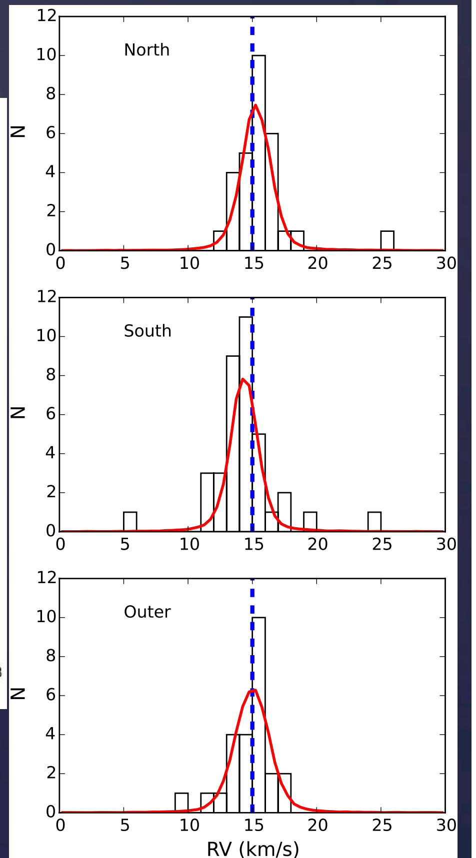
Chamaeleon I

different ages

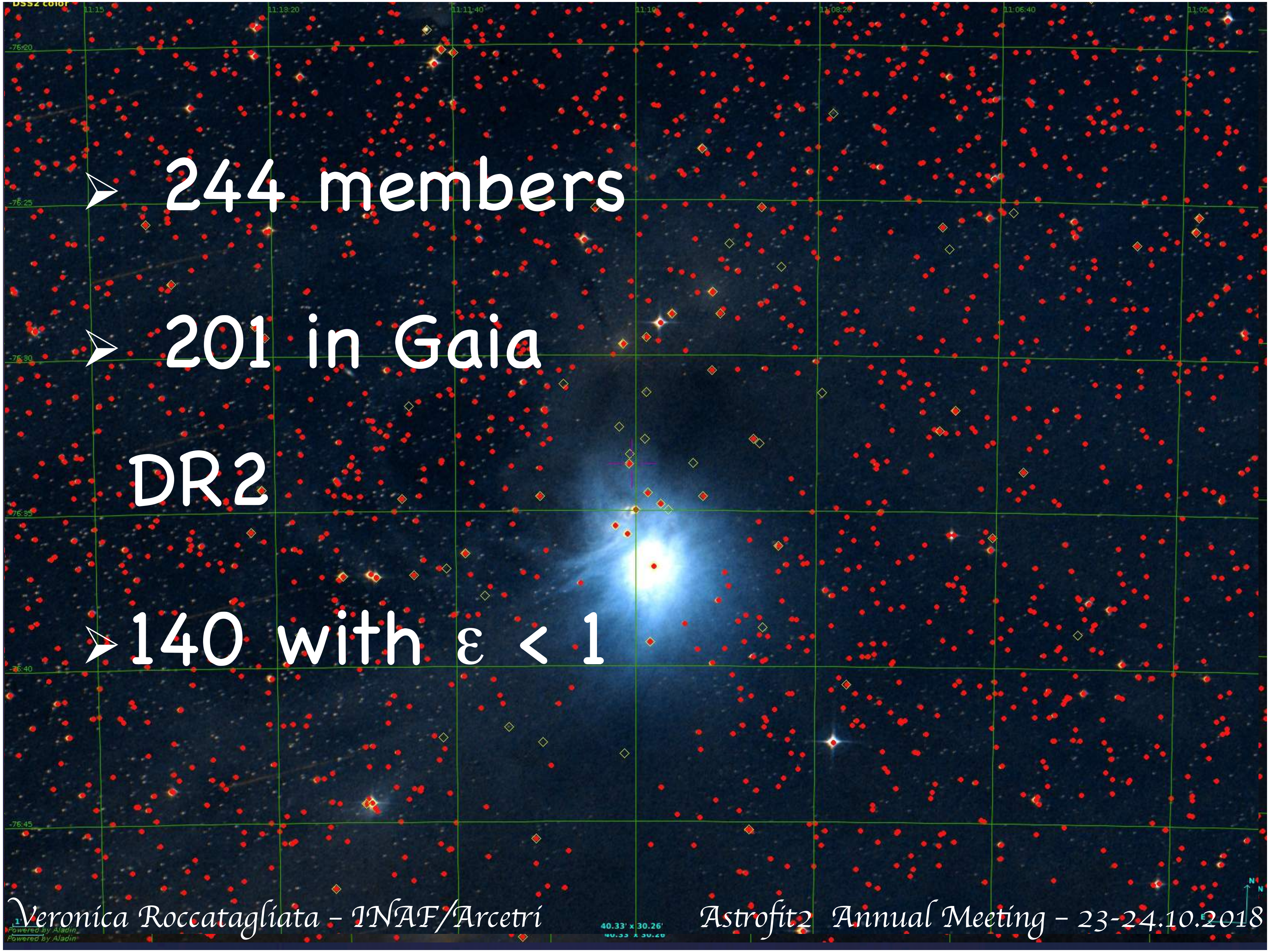


Luhman 2007

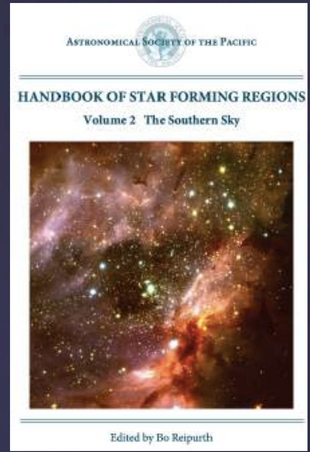
different RV

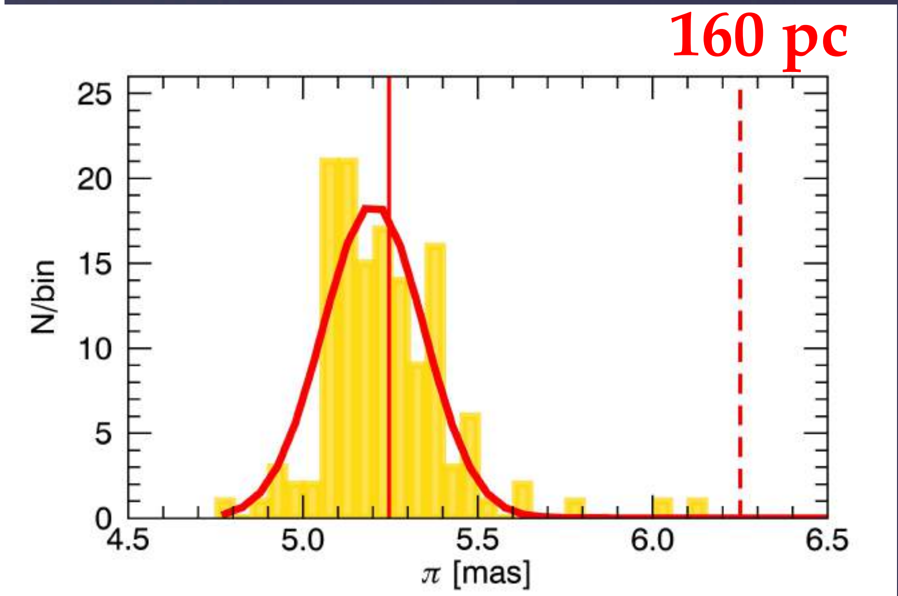


Sacco+ 2017


➢ 244 members
➢ 201 in Gaia DR2
➢140 with ε < 1
Veronica Roccatagliata - INAF/Arcetri
Astrofit2 Annual Meeting - 23-24.10.2018

1) New distance of ChaI!





Median: 5.248 +/- 0.187 mas

Distance: 190.5 $^{+7.1}_{-3.5}$ pc

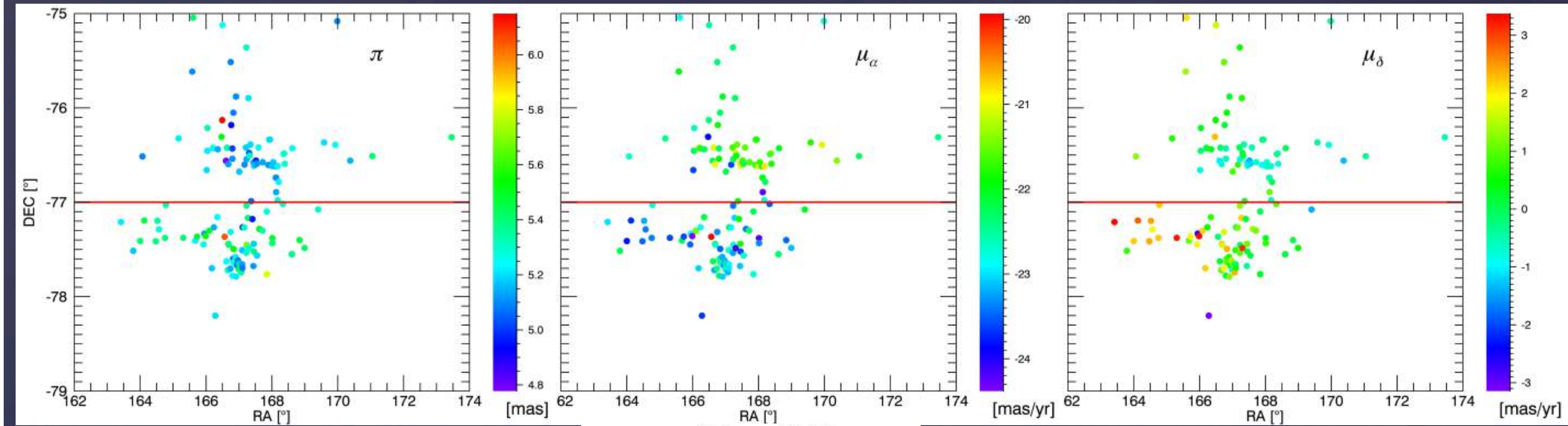
Chameleon 173

2. Distance

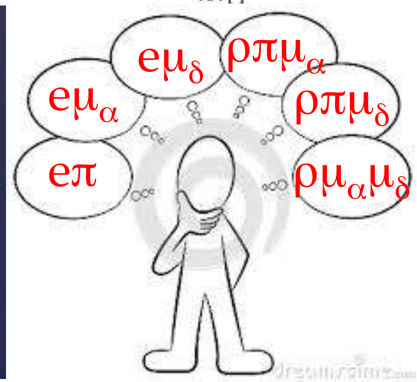
Published distance estimates for Cha I have ranged from 115 to 215 pc (Schwartz 1991). The newest measurements by Whittet et al. (1997), Bertout et al. (1999), and Wichmann et al. (1998) are revisited in this section. Whittet et al. (1987) measured a distance to Cha I by examining the distribution of extinction as a function of distance for stars projected against the cloud. That analysis was updated with newer photometry by Whittet et al. (1997), who derived lower and upper limits of 135 and 165 pc. Whittet et al. (1997) measured a second distance of 152±18 pc by assuming that HD 97300, which illuminates Ced 112, was on the zero age main sequence (ZAMS). They also considered the Hipparcos distances of 190±40 and 180±20 pc for HD 97300 and HD 97048 (Perryman et al. 1997). By combining these four distance constraints, Whittet et al. (1997) arrived at a final value of 160±15 pc. Although the strengths of the hydrogen lines in HD 97300 are consistent with those expected of a ZAMS star (Grasdalen et al. 1975), the distance based on the ZAMS assumption is not used in this review. Bertout et al. (1999) estimated the distance of Cha I using the Hipparcos measurements for young stars associated with the cloud. Among those stars, only HD 97300, HD 97048, and CR Cha have both definitive evidence of membership in the cloud and robust Hipparcos distances (i.e., empty H59 field in the Hipparcos catalog). The weighted average of the parallaxes for these three stars corresponds to 175^{+20}_{-16} pc. In comparison, Wichmann et al. (1998) used the Hipparcos data for CR Cha, HIP 54738, and T Cha to estimate the distance of Cha I. However, HIP 54738 probably should be omitted because its H59 field in the Hipparcos catalog indicates that it may be an astrometric binary and T Cha is not a member of Cha I. Therefore, 175^{+20}_{-16} pc appears to be the most appropriate measurement from Hipparcos for stars in the cloud. The combination of this distance and the constraint of 135-165 pc from the extinction analysis of Whittet et al. (1997) indicates a best estimate of 160-165 pc for Cha I.

Chamaeleon I on April 25 2018

"yes, we see the 2 sub-clusters also with Gaia!.."



BUT is it true?...



Multivariate Gaussian distribution

$$L_{N/S,i} = (2\pi)^{-3/2} |C_i|^{-1/2} \times \exp\left[-\frac{1}{2}(a_i - a_0)' C_i^{-1}(a_i - a_0)\right]$$

$$a_i - a_0 = \begin{bmatrix} \pi_i - \pi_0 \\ \mu_{\alpha,i} - \mu_{\alpha,0} \\ \mu_{\delta,i} - \mu_{\delta,0} \end{bmatrix}$$

Total likelihood of a double population

$$L_i = f_N L_{N,i} + (1 - f_N) L_{S,i}$$

fraction of stars that belong to the

N & S

$$C_i = \begin{bmatrix} C_{i,11} & C_{i,12} & C_{i,13} \\ C_{i,21} & C_{i,22} & C_{i,23} \\ C_{i,31} & C_{i,32} & C_{i,33} \end{bmatrix}$$

$$\begin{aligned} [C_i]_{11} &= \sigma^2_{\pi,i} + \sigma^2_{\pi,0} \\ [C_i]_{22} &= \sigma^2_{\mu_{\alpha,i}} + \sigma^2_{\mu_{\alpha,0}} \\ [C_i]_{33} &= \sigma^2_{\mu_{\delta,i}} + \sigma^2_{\mu_{\delta,0}} \\ [C_i]_{12} &= [C_i]_{21} = \sigma_{\pi,i} \cdot \sigma_{\mu_{\alpha,i}} \cdot \rho(\pi, \mu_\alpha) \\ [C_i]_{13} &= [C_i]_{31} = \sigma_{\pi,i} \cdot \sigma_{\mu_{\delta,i}} \cdot \rho(\pi, \mu_\delta) \\ [C_i]_{23} &= [C_i]_{32} = \sigma_{\mu_{\alpha,i}} \cdot \sigma_{\mu_{\delta,i}} \cdot \rho(\mu_\alpha, \mu_\delta) \end{aligned}$$

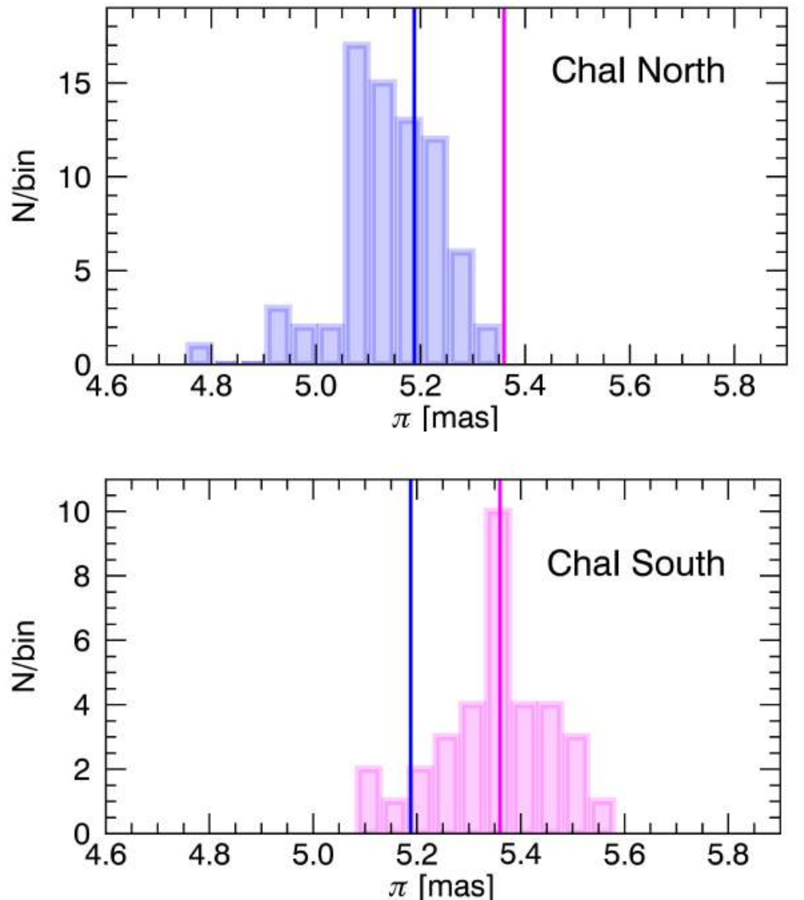
Probability of each star to belong to N or S sub-clusters

$$P_{N,i} = f_N \frac{L_{N,i}}{L_i} \qquad P_{S,i} = (1 - f_N) \frac{L_{S,i}}{L_i}$$

e.g. in Lindegren et al. (2000)

Distances of the N & S sub-clusters

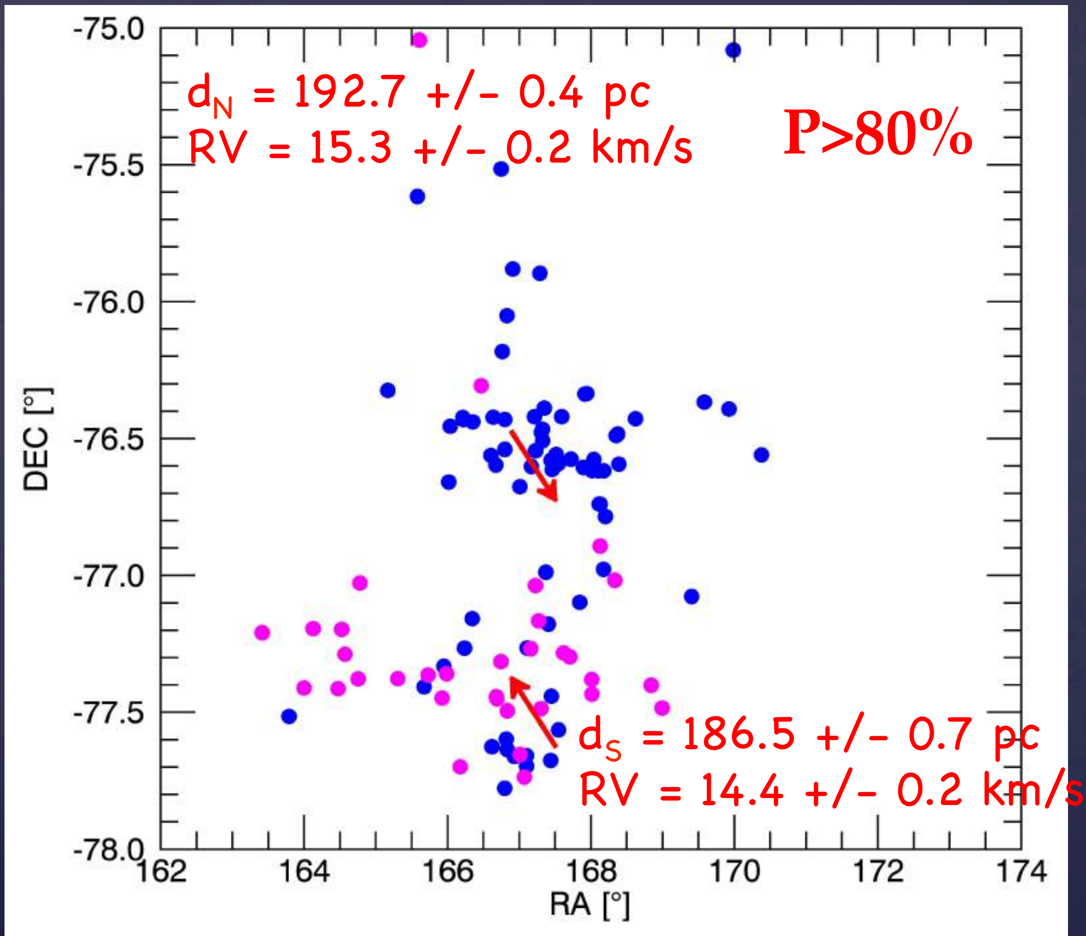
	π	$\sigma_{\pi,0}$	μ_α	$\sigma_{\mu_\alpha,0}$	μ_δ	$\sigma_{\mu_\delta,0}$
Cha I North	5.188±0.012	0.060±0.011	-22.069±0.101	0.738±0.063	-0.050±0.115	0.873±0.079
Cha I South	5.363±0.021	0.085±0.017	-23.127±0.114	0.571±0.072	1.593±0.238	1.126±0.159



d_N = 192.7 +/- 0.4 pc

d_S = 186.5 +/- 0.7 pc

Spatial distribution of 2 populations



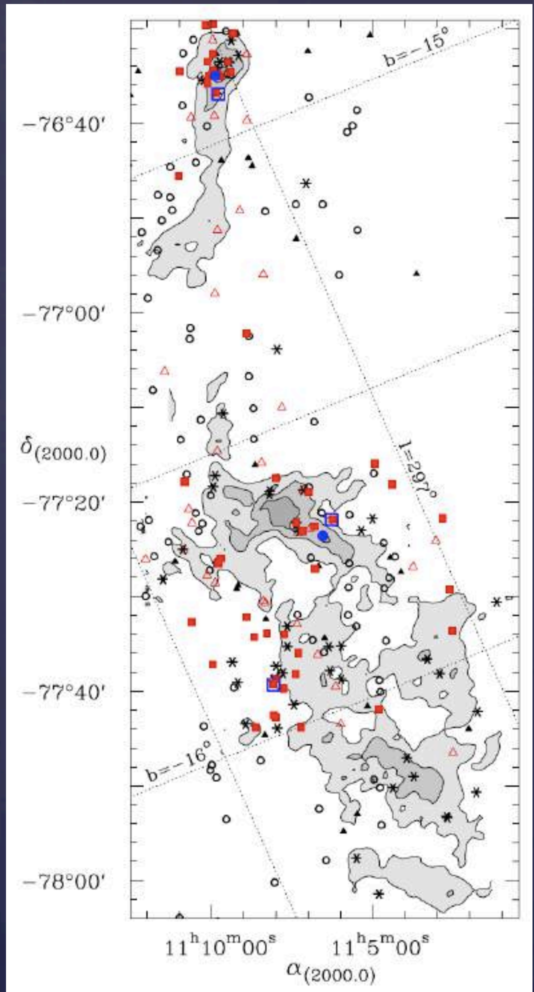
- N: extends down to the S
- S: compact

- Distance + RV ->
  2 clusters are moving away each other

  Arrows: pm respect to a reference system centered on the cluster

- The 2 clusters are not merging & have a non-zero angular momentum
  + RV from Sacco+ 2017
  -> hint of rotation

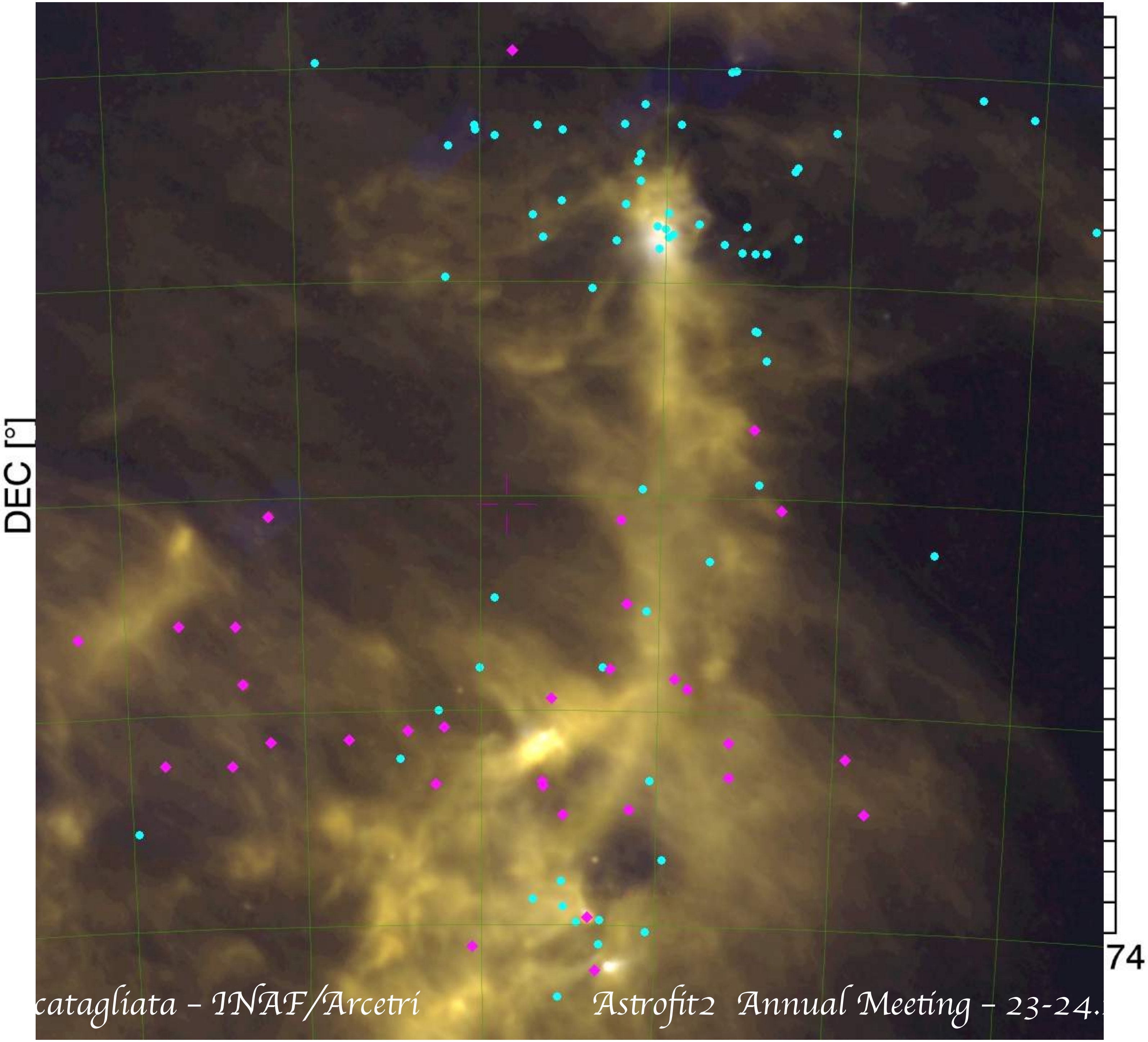
Why this spatial distribution?



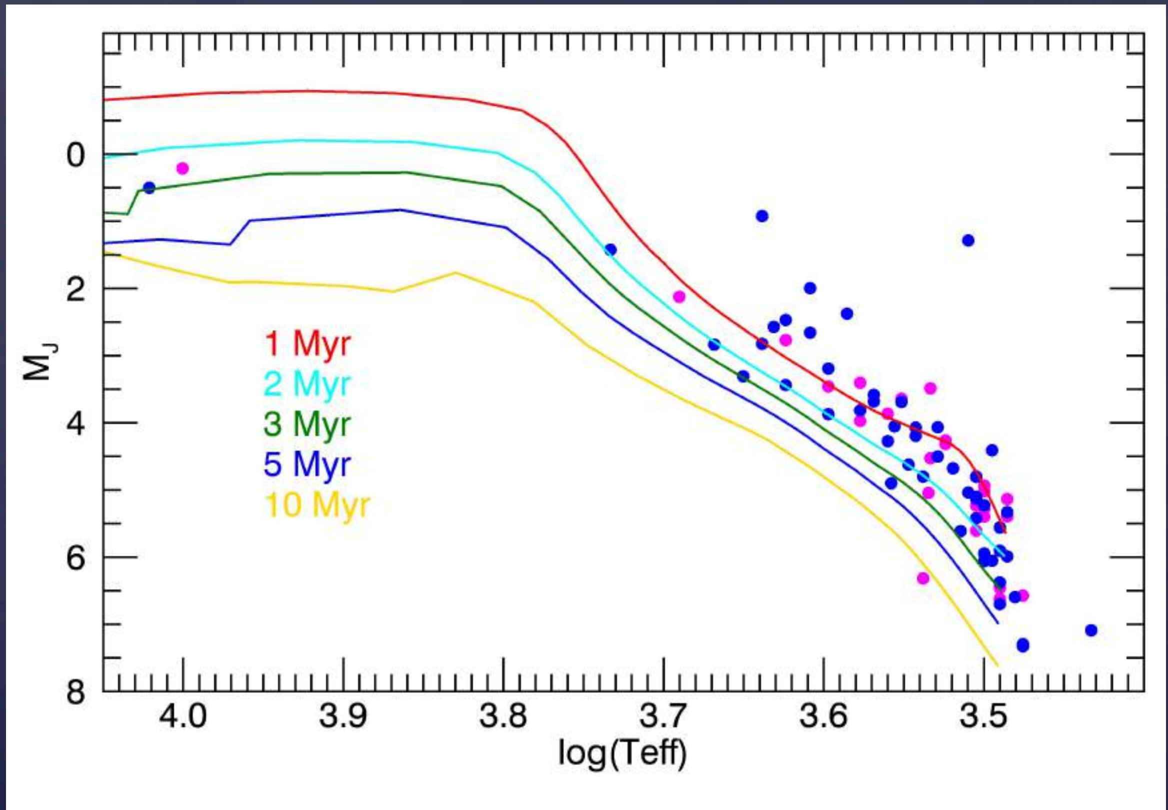
$C^{18}O$ maps from SEST

spatial distribution of the 2 populations can be influenced by the interaction with the filament!

Haikala et al. 2005


DEC [°]
74

What is the age & is there a difference in age between N and S ?



- ✓ No age difference
- ✓ all < 5 My
- ✓ most of them < 3 Myr

Chamaeleon I … Near Future

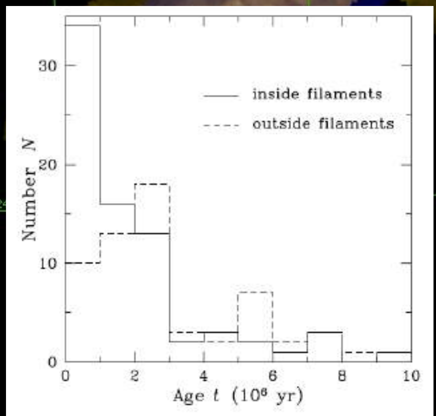
- complete census of the 2 populations
- update the RV measurements of the two populations
- investigate relation between stellar population, cores and main filament !

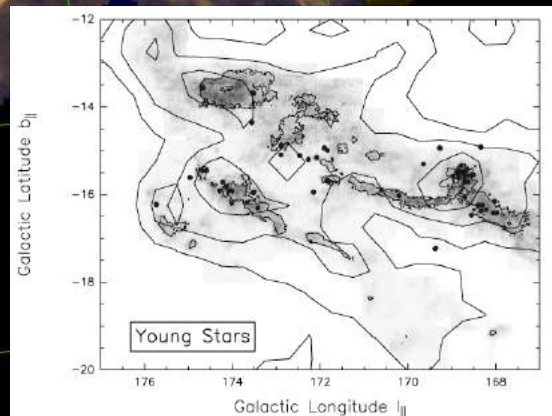
Another fundamental region with a prominent filament and a young cluster … Taurus-Auriga !!!

The Astrophysical Journal, 581:1194–1203, 2002 December 20

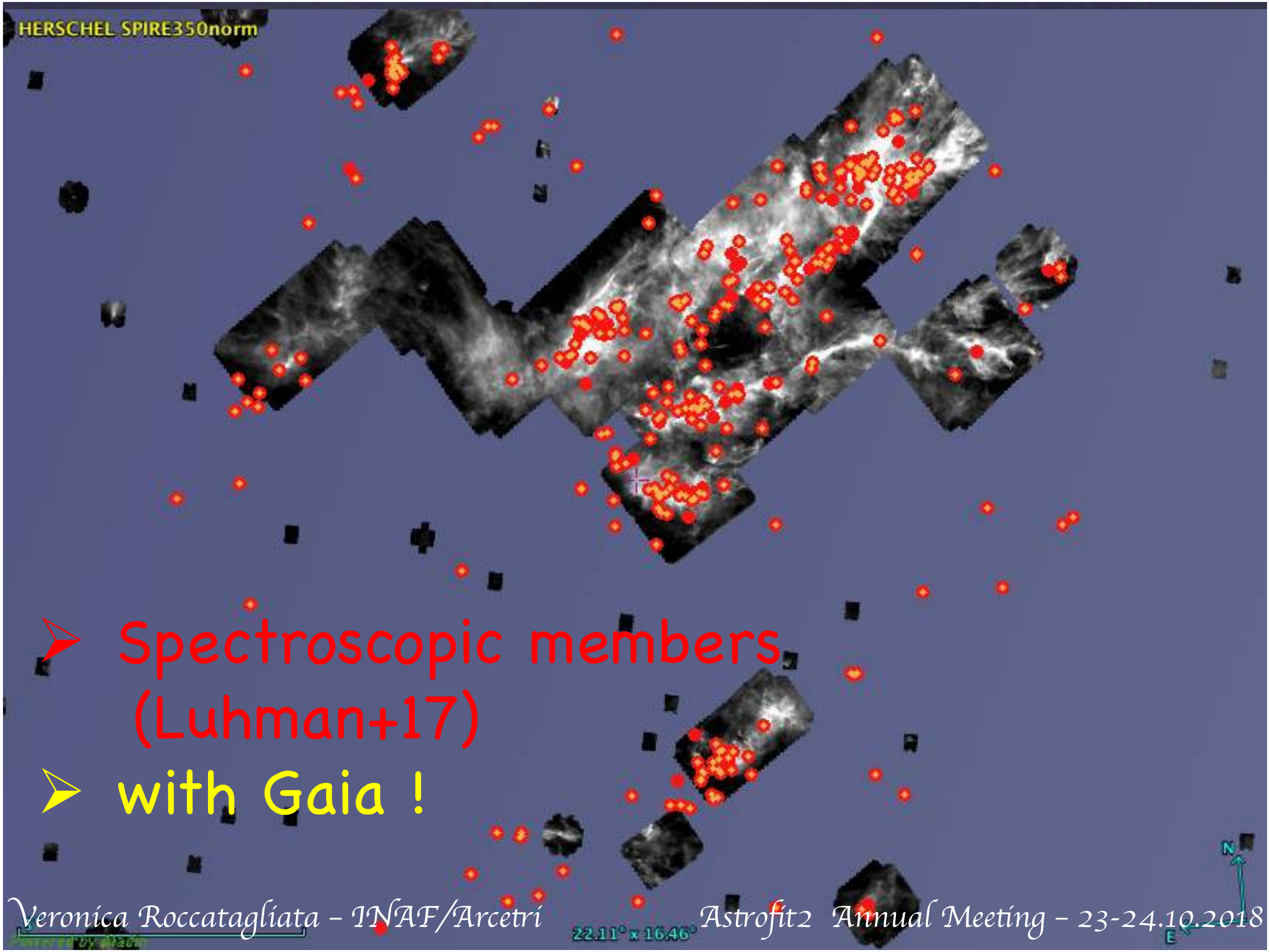
STAR FORMATION IN SPACE AND TIME: TAURUS-AURIGA

Francesco Palla[1] and Steven W. Stahler[2]
Received 2002 April 10; accepted 2002 August 21



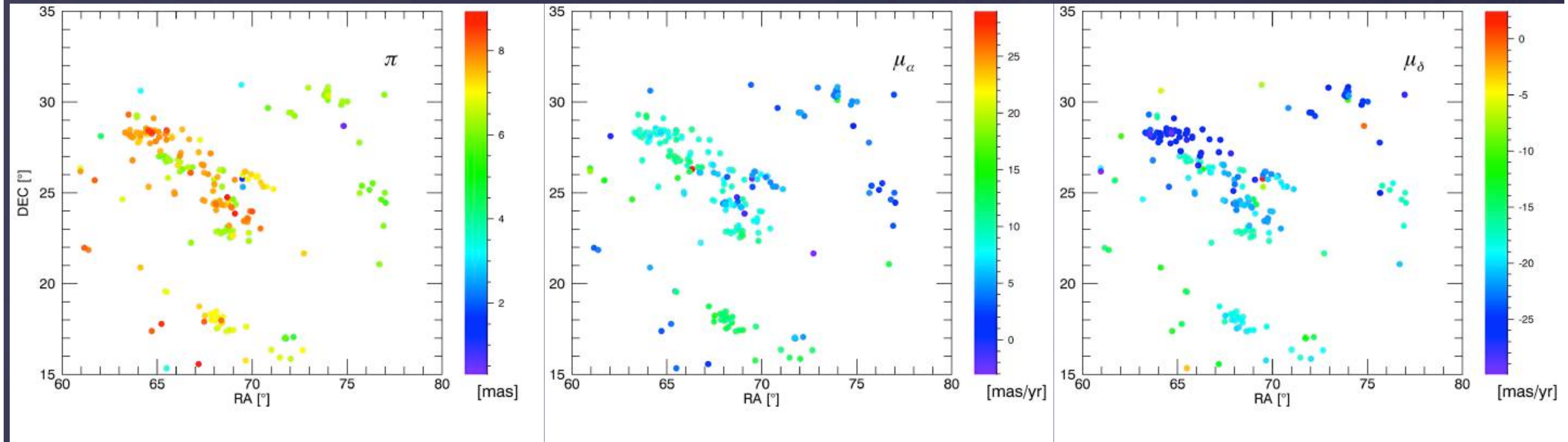


Herschel all public PACS and SPIRE @70 μm (blue), 350 μm (green) and 500 μm (red)



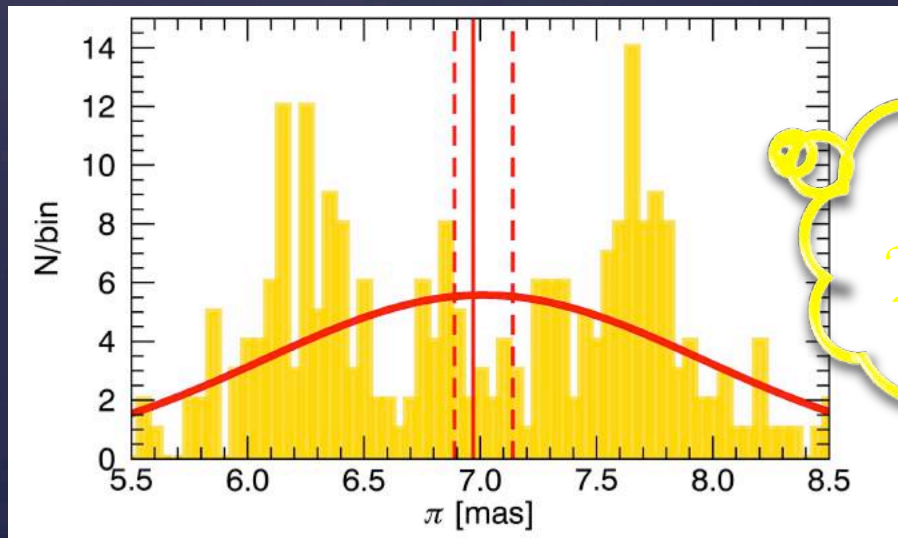
- Spectroscopic members (Luhman+17)
- with Gaia !

Gaia data of Taurus - Auriga



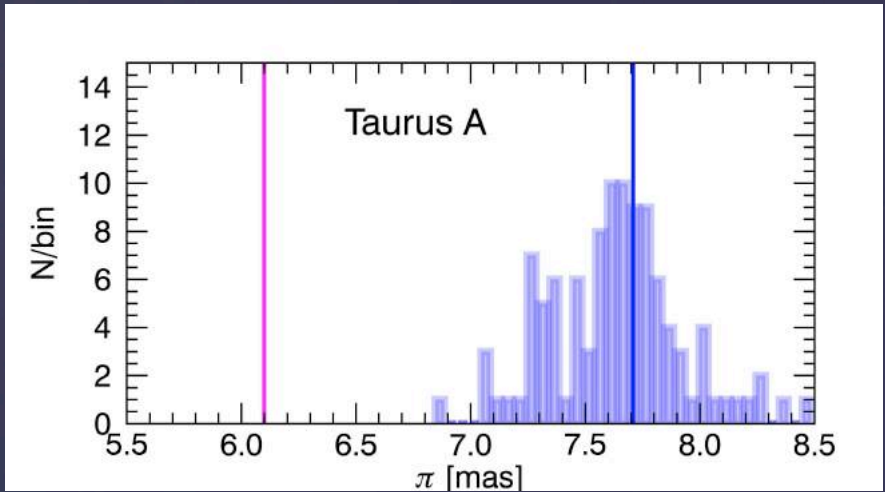
Mean (3s clipping):
7.01 +/- 0.06 mas

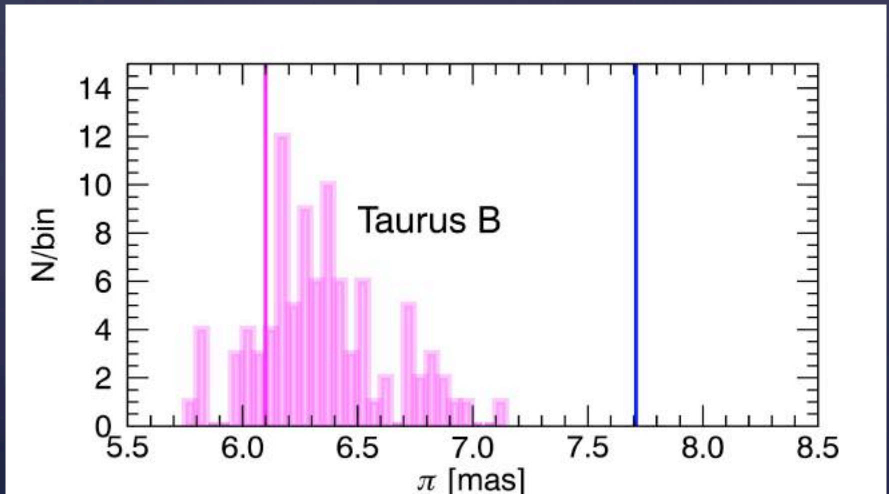
Distance:
142.6 +/- 1.2 pc



Double population?

	π	$\sigma_{\pi,0}$	μ_α	$\sigma_{\mu_\alpha,0}$	μ_δ	$\sigma_{\mu_{\delta,0}}$
Taurus A	7.697 ± 0.014	0.100 ± 0.007	7.671 ± 0.170	2.000 ± 0.078	-22.512 ± 0.168	2.000 ± 0.060
Taurus B	6.326 ± 0.014	0.100 ± 0.003	8.421 ± 0.166	2.000 ± 0.058	-18.768 ± 0.162	2.000 ± 0.055





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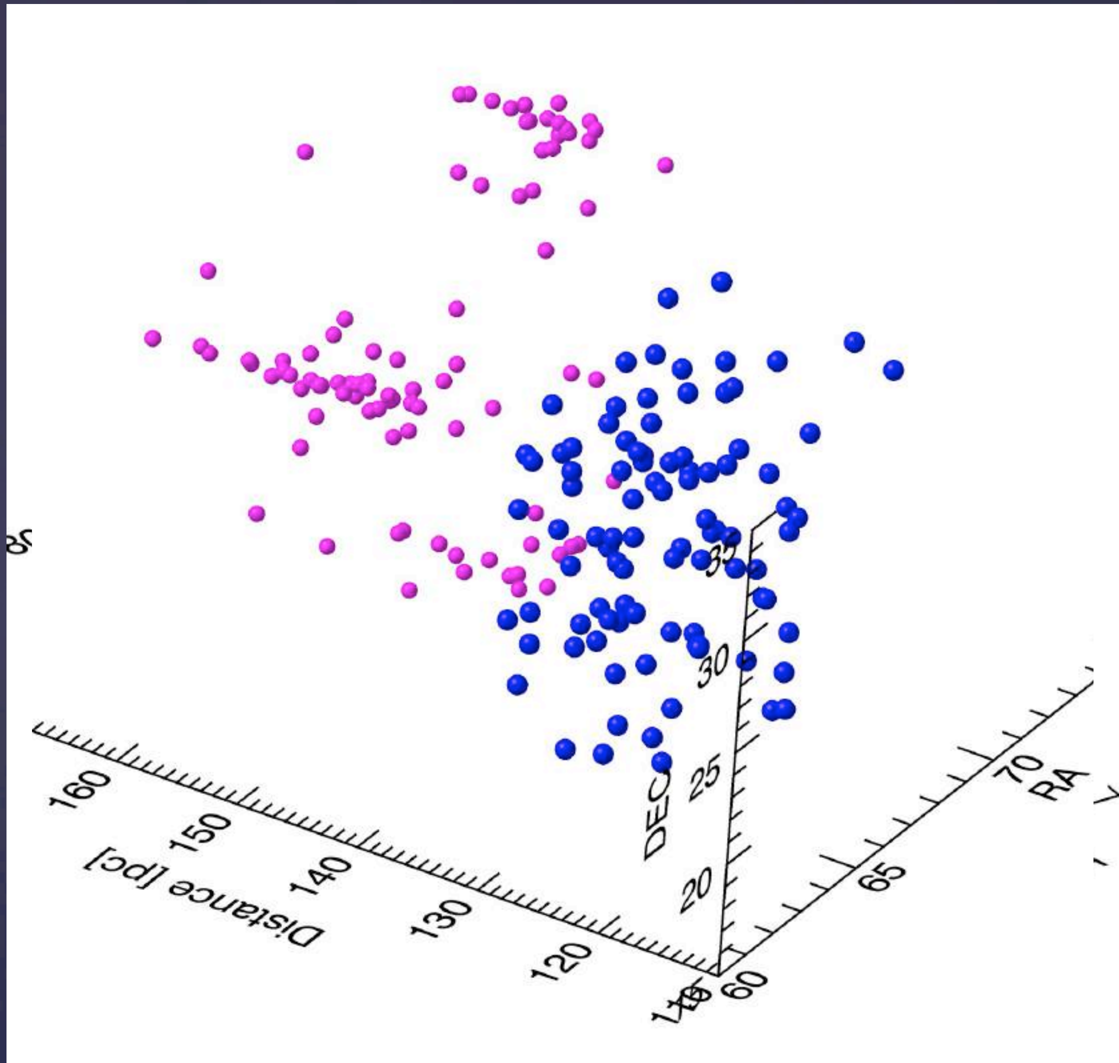
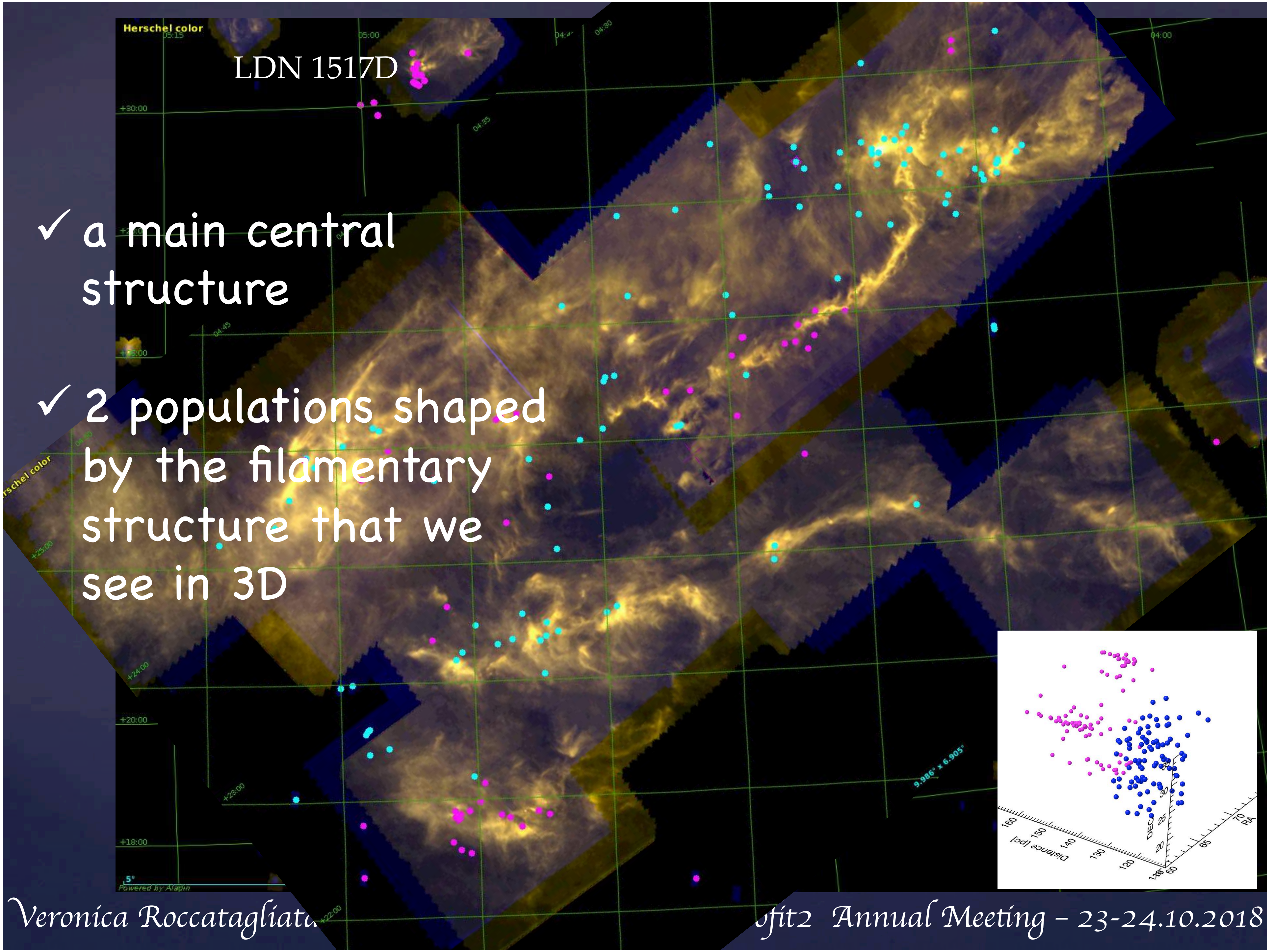


Distance [pc]
160
150
140
130
120
DEC
20
25
30
35
RA
60
65
70



- ✓ a main central structure
- ✓ 2 populations shaped by the filamentary structure that we see in 3D

Since June 2018…

- ✓ Talk at the coolstars20 in Boston
- ✓ Roccatagliata et al. 2018 A&A 617, 4
- ✓ MEDIA INAF ``Diaspora stellare nel Camaleonte e nelle Vele"
- ✓ Proceeding coolstars20
- ✓ paper on Taurus to be submitted in November

December 1st:


Thanks for your attention!