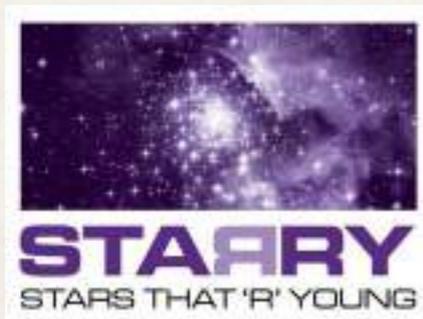


# Clustering properties of Herbig Ae/Be stars

***Alice Pérez Blanco***

*René Oudmaijer* (University of Leeds), Stuart Lumsden (University of Leeds)

Deborah Baines (QUASAR - ESAC) and Ricardo Pérez-Martinez (ISDEFE - ESAC).



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*This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA ITN-EID grant agreement No 676036.*

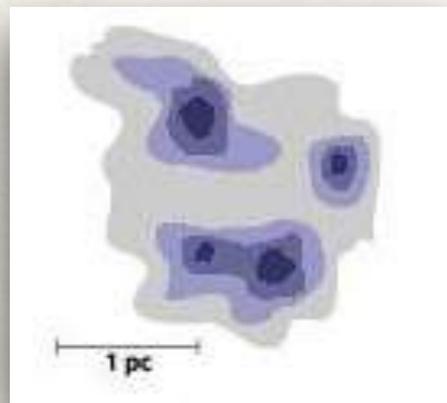
# Outline

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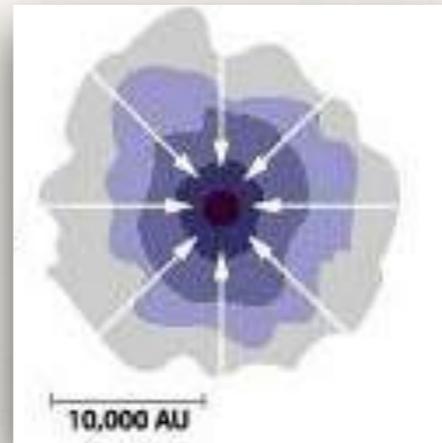
- ❖ Background.
- ❖ *ClustER* *detEction* *AL*gorithm (**CEREAL**).
- ❖ CEREAL vs Testi et al.
- ❖ Conclusions.

# Background: Star Formation

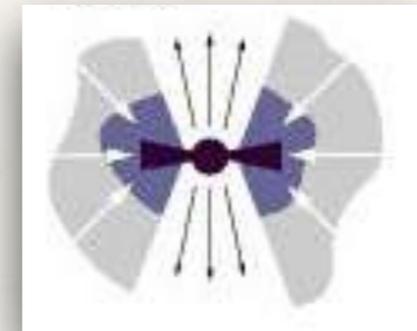
NASA/JPL-Caltech



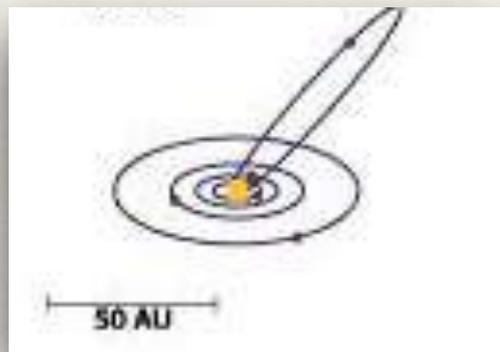
Dark cloud  
cores



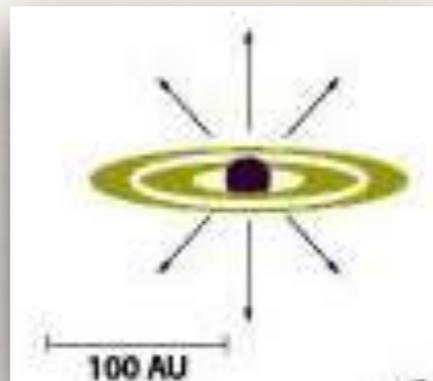
Gravitational  
collapse ( $t=0$ )



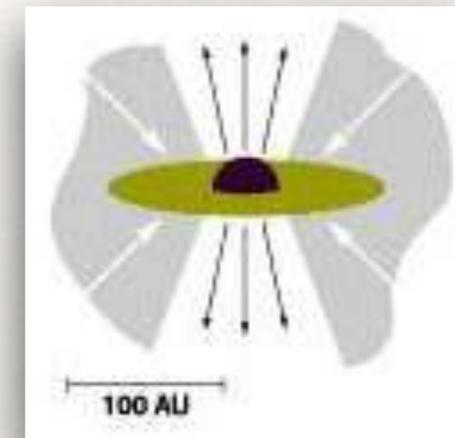
Protostars, disk, outflow  
( $t \sim 10^4 - 10^5$  year)



Main-sequence stars,  
Protoplanetary system  
( $t > 10^7$  year)



Pre-main-sequence stars,  
remnant disk  
( $t \sim 10^6 - 10^7$  year)

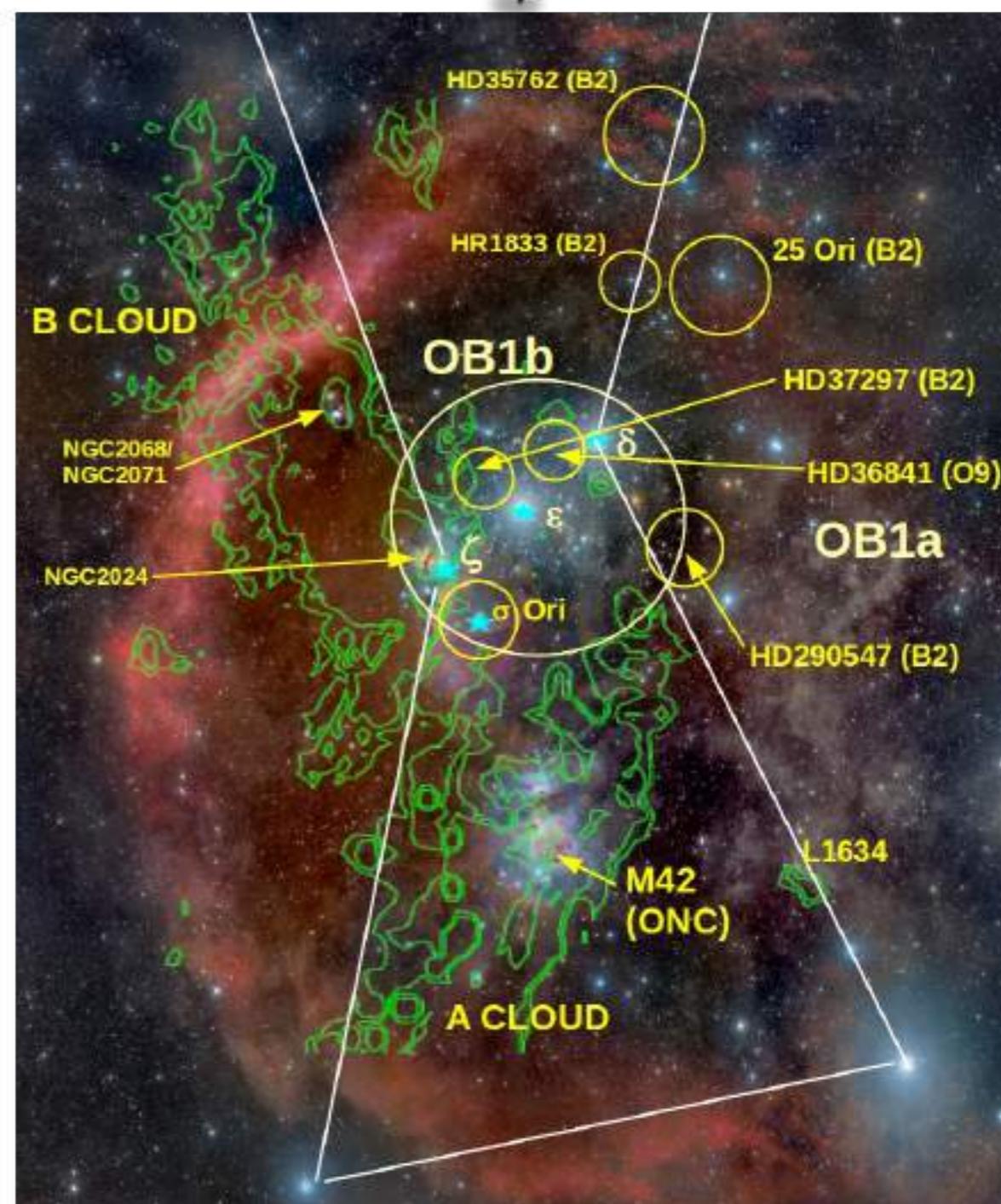


Disk, outflow  
( $t \sim 10^5 - 10^6$  year)

# Background: Star Formation

Briceño+2019

- ❖ **OB associations** are relatively large groups that share common movements (proper motion and radial velocity). Around the most massive stars there may be more compact groups (clusters).
- ❖ **Open clusters** ( $\leq 10$  Myrs) are groups of hundreds of stars, spatially conglomerated which share a common origin.

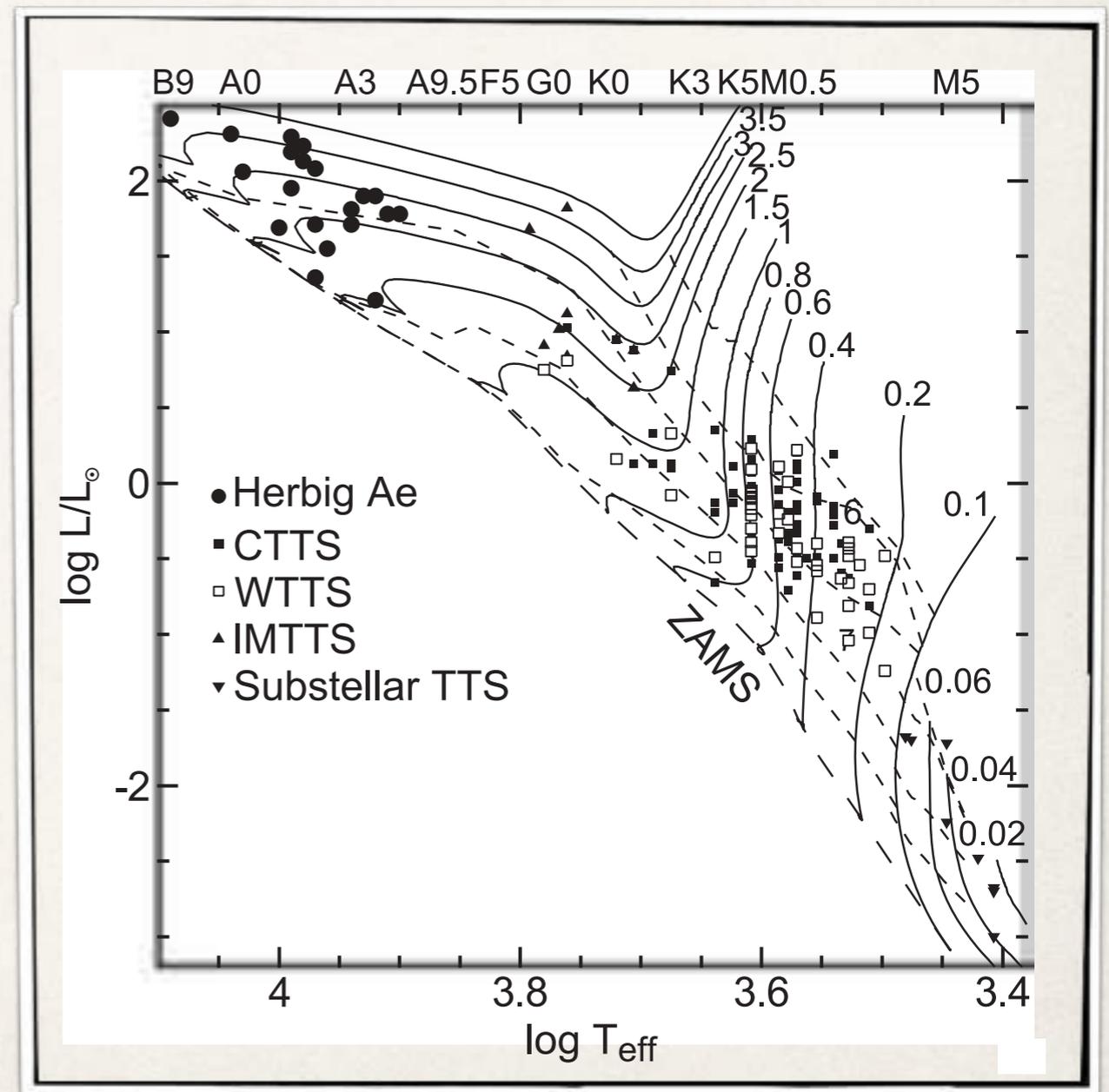


# Background: Young objects

Garcia, 2011; Herbig 60; Hernández+ 04

The newly formed stars follow a characteristic evolution path of the main pre-sequence stars.

*Herbig Ae / Be stars*, type A and B stars with emission lines and masses between  $2M_{\odot} < M_* < 8M_{\odot}$ , associated with bright or dark nebulae.



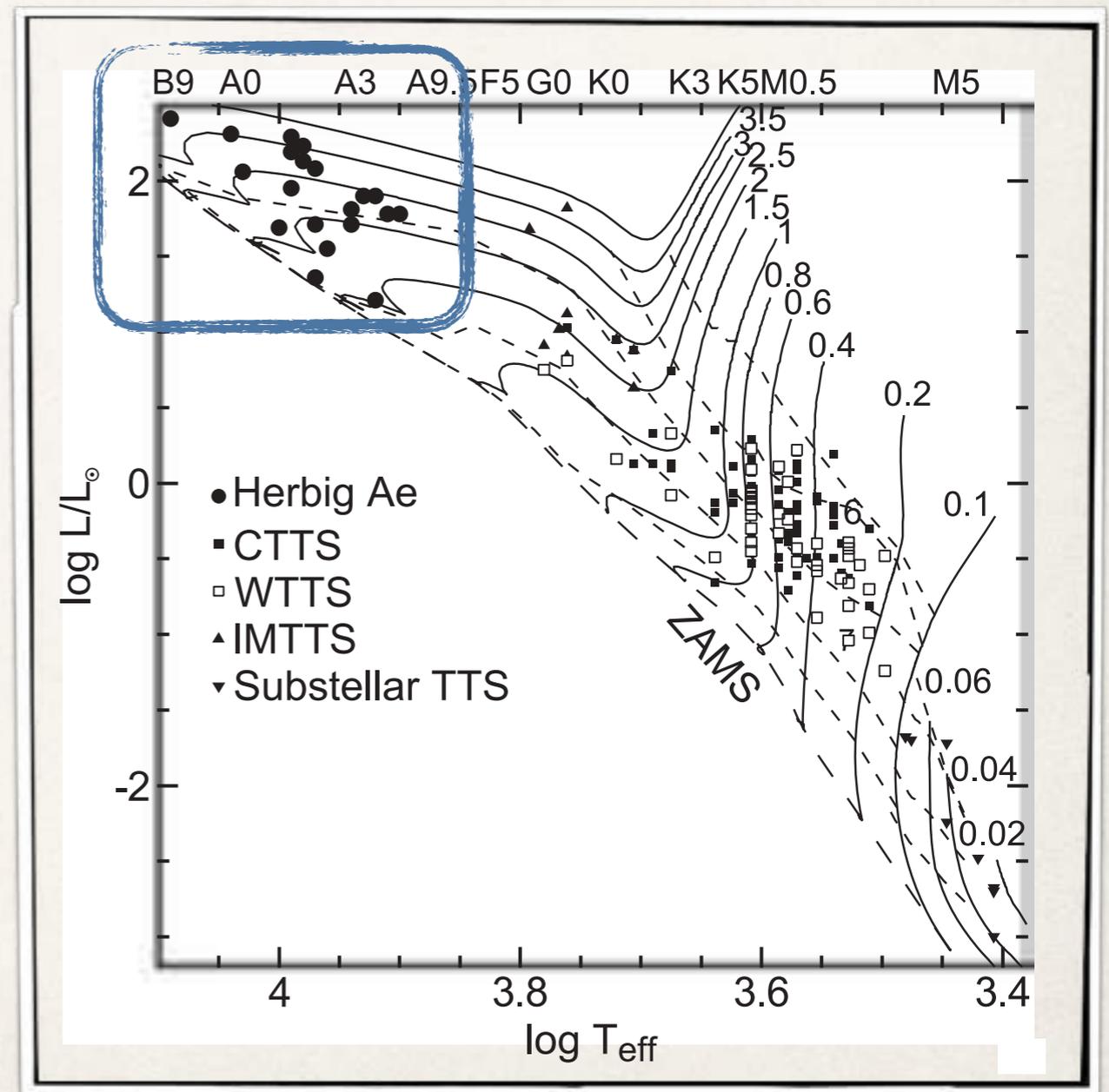
Location of the young stellar objects in the Hertzsprung-Russell diagram.

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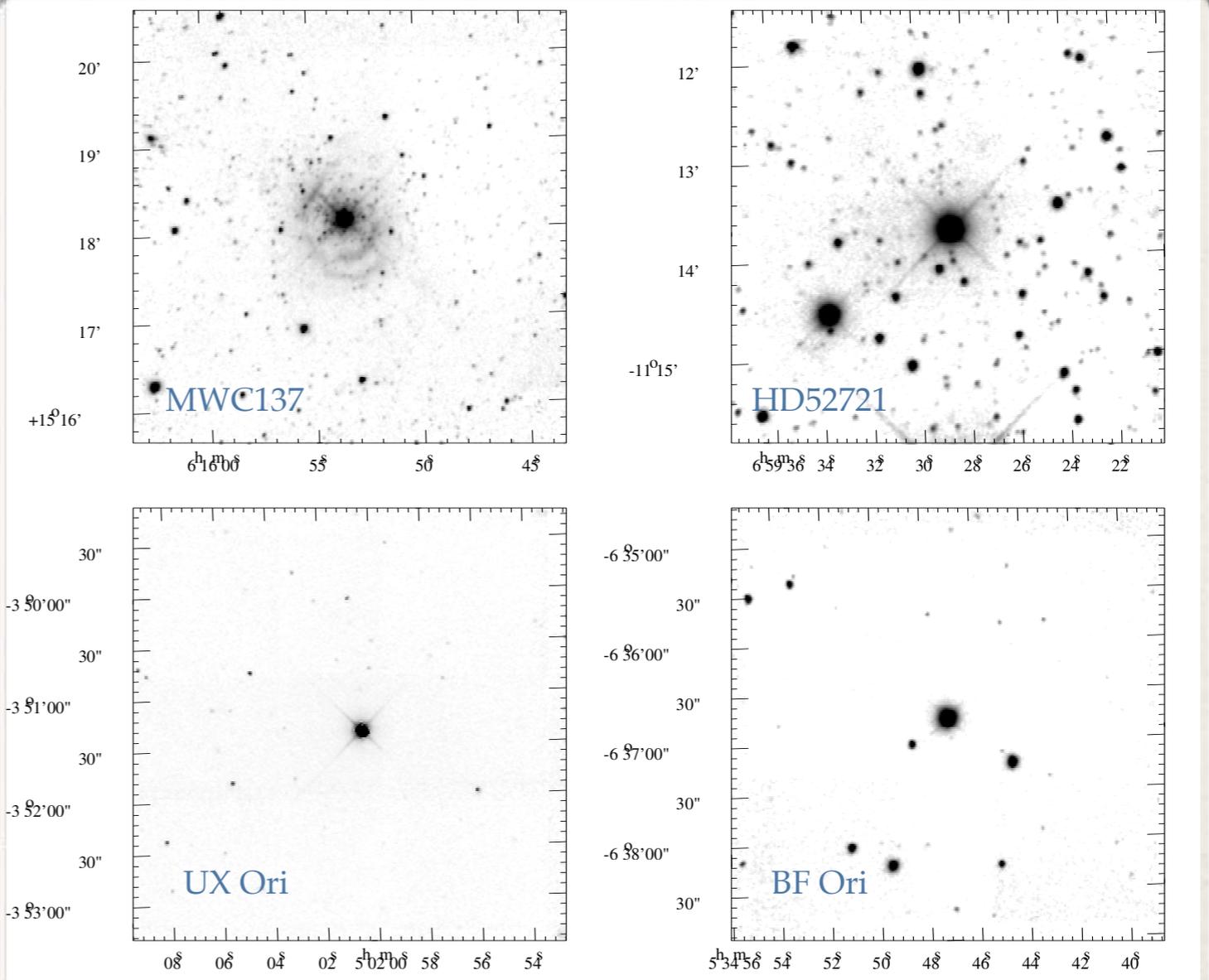


Location of the young stellar objects in the Hertzsprung-Russell diagram.

# Background: Occurrence of young stellar clusters around Herbig Ae/Be stars

*Lada +93; Hillenbrand + 95; Testi + 97*

- ❖ *Testi +99* analyzed the occurrence of young stellar clusters around Herbig Ae/Be stars from near-infrared images.
- ❖ Spectral type range O9 to A7.



K band images of four Herbig stars.

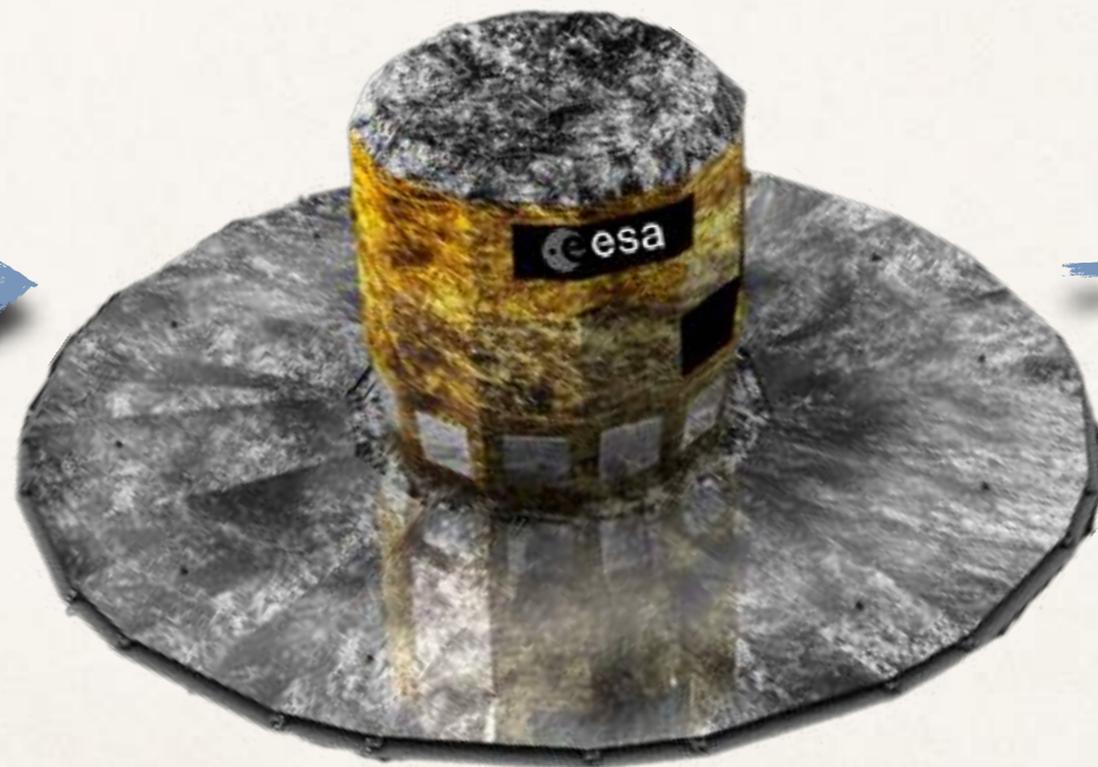
# Clust*ER* det*E*ction ALgorithm : CEREAL

*Gaia Collaboration+2018; Lindengren+18a; Vioque+18; Herbig 60; Thé+94; Che+16*

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Semi-automatic code to make selection using the astrometric parameters.

Targets



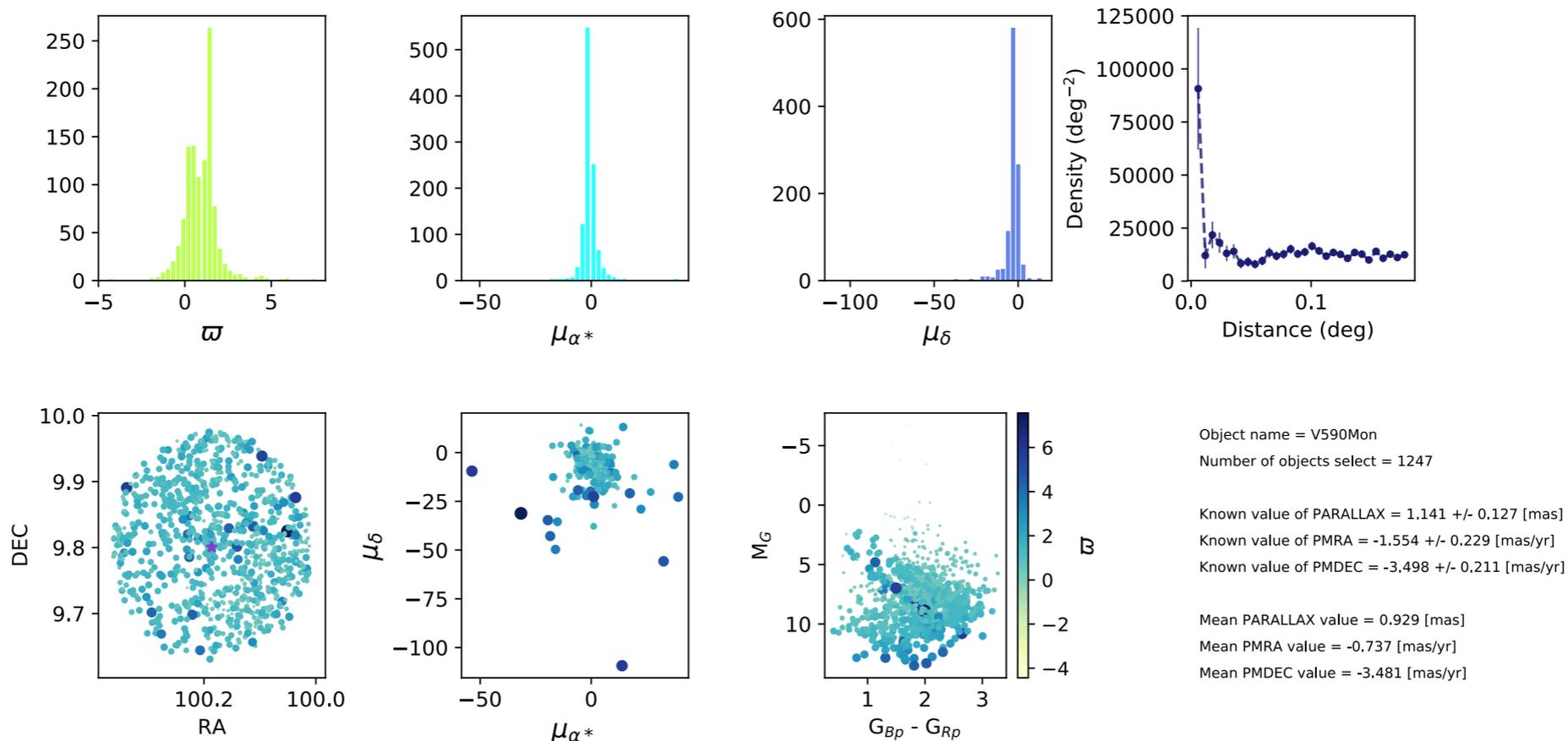
CEREAL

We compiled *270 stars* from the known Herbig Ae/Be star candidates

# V590 Mon (LkHA 25)

Monoceros Constellation

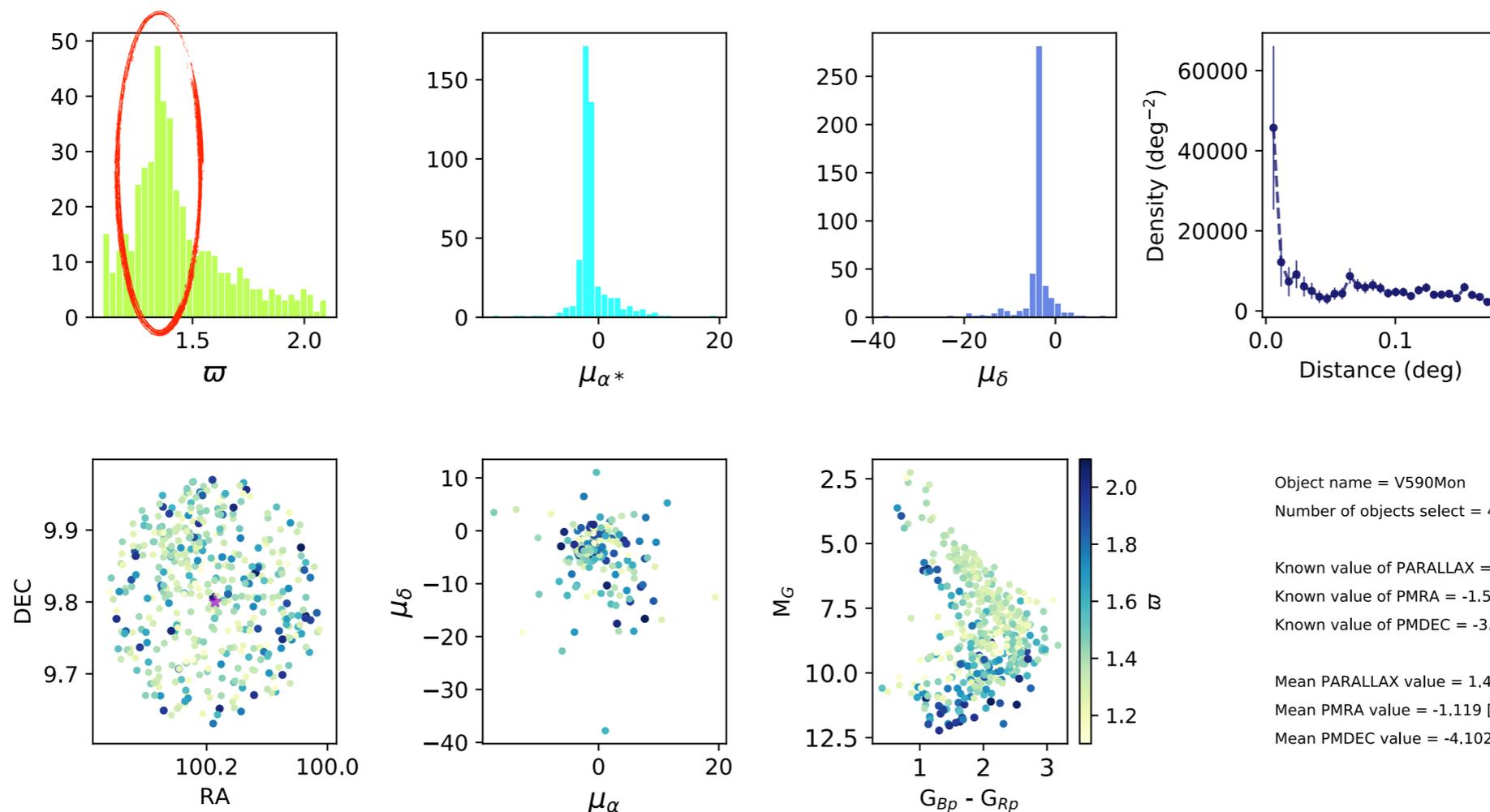
<b>Located</b>	NGC 2264	<b>PMRA</b>	$-1.55 \pm 0.22$ mas/yr	<b>SPT</b>	B7
<b>Parallax</b>	$1.14 \pm 0.12$ mas	<b>PMDEC</b>	$-3.49 \pm 0.21$ mas/yr	<b>G</b>	12.74 mag



# V590 Mon (LkHA 25)

Monoceros Constellation

Located	NGC 2264	PMRA	$-1.55 \pm 0.22$ mas/yr	SPT	B7
Parallax	$1.14 \pm 0.12$ mas	PMDEC	$-3.49 \pm 0.21$ mas/yr	G	12.74 mag



Object name = V590Mon  
 Number of objects select = 451

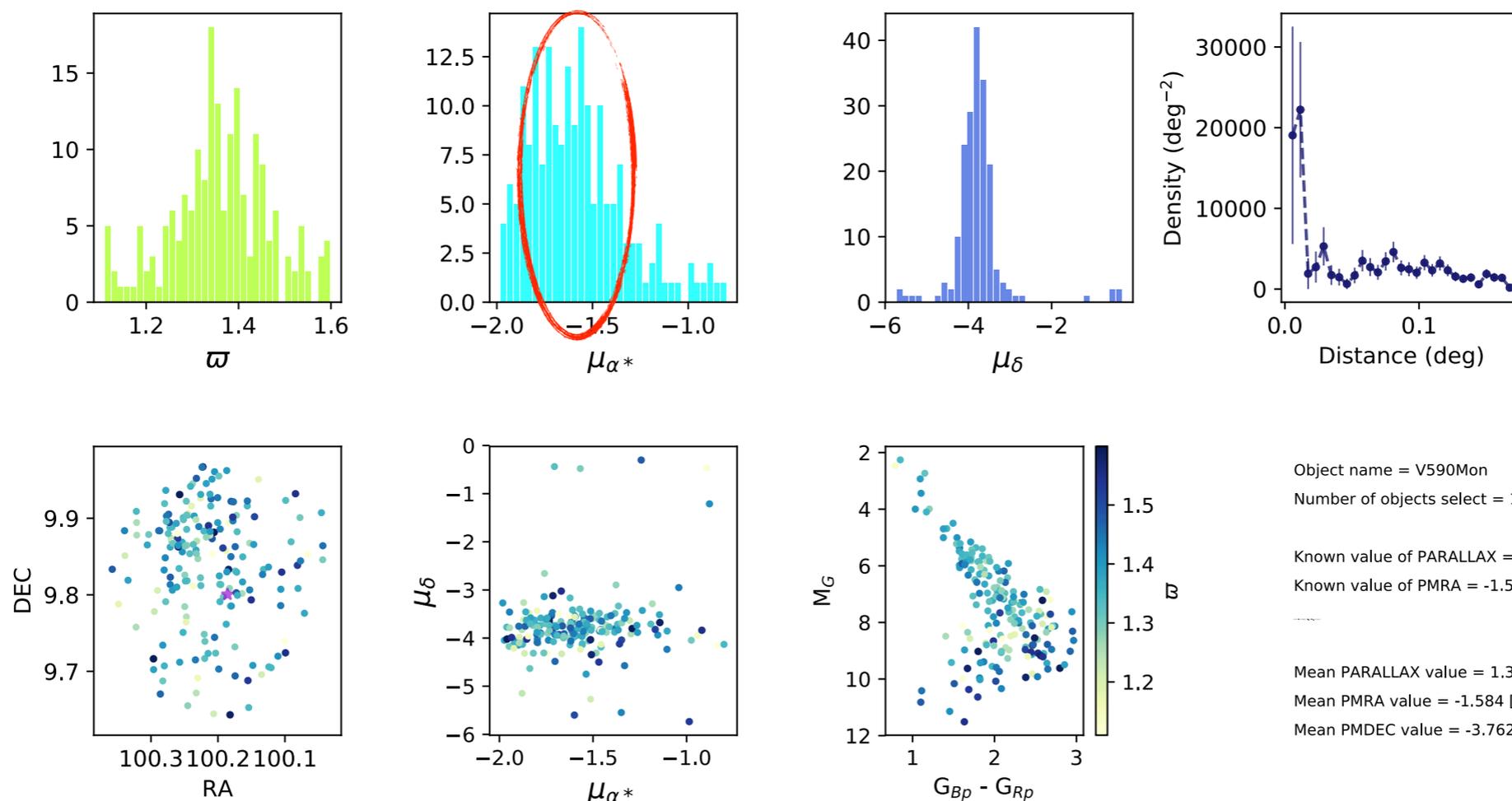
Known value of PARALLAX =  $1.141 \pm 0.127$  [mas]  
 Known value of PMRA =  $-1.554 \pm 0.229$  [mas/yr]  
 Known value of PMDEC =  $-3.498 \pm 0.211$  [mas/yr]

Mean PARALLAX value = 1.437 [mas]  
 Mean PMRA value = -1.119 [mas/yr]  
 Mean PMDEC value = -4.102 [mas/yr]

# V590 Mon (LkHA 25)

Monoceros Constellation

Located	NGC 2264	PMRA	$-1.55 \pm 0.22$ mas/yr	SPT	B7
Parallax	$1.14 \pm 0.12$ mas	PMDEC	$-3.49 \pm 0.21$ mas/yr	G	12.74 mag



Object name = V590Mon  
 Number of objects select = 188

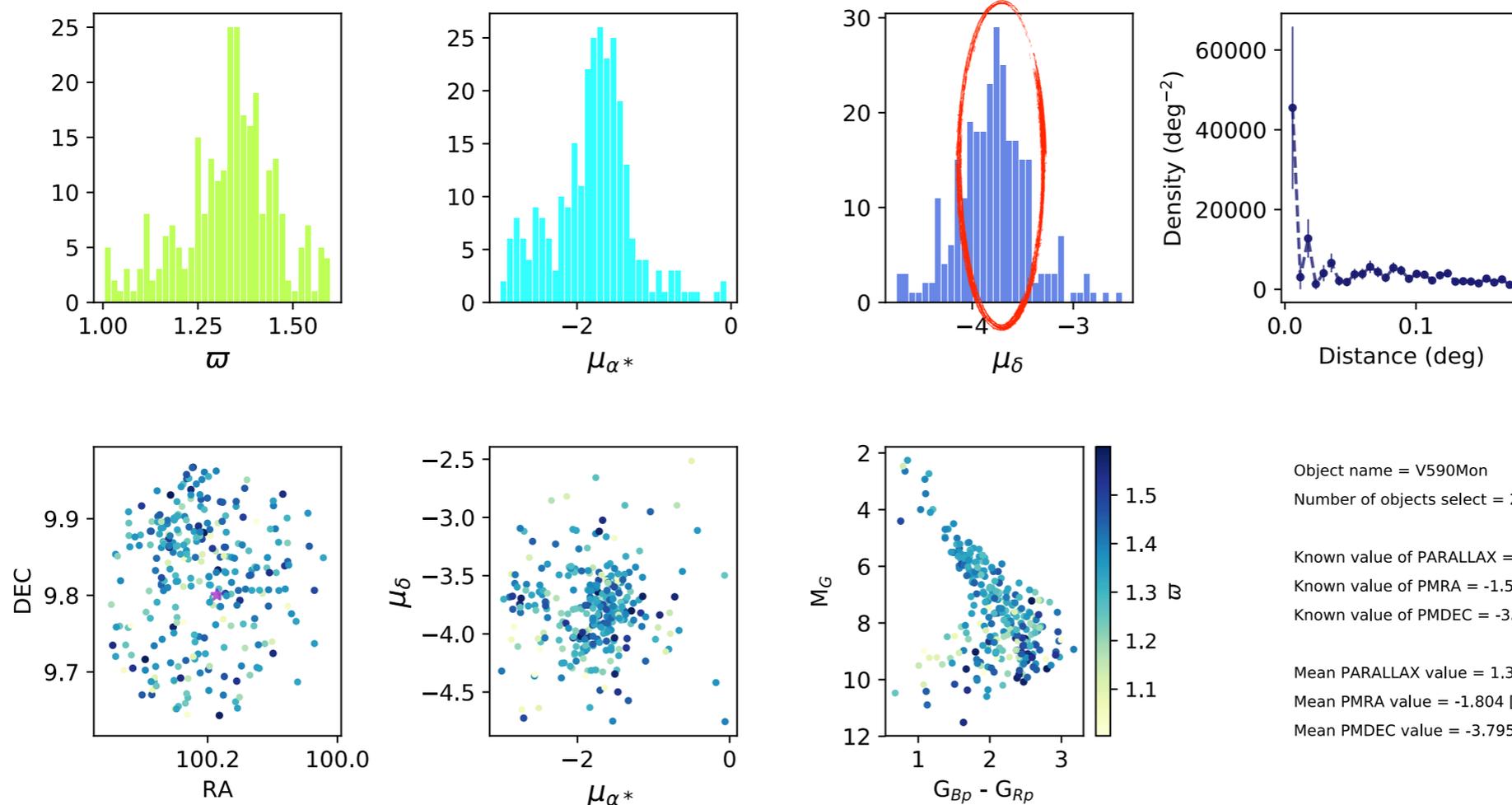
Known value of PARALLAX =  $1.141 \pm 0.127$  [mas]  
 Known value of PMRA =  $-1.554 \pm 0.229$  [mas/yr]

Mean PARALLAX value = 1.361 [mas]  
 Mean PMRA value = -1.584 [mas/yr]  
 Mean PMDEC value = -3.762 [mas/yr]

# V590 Mon (LkHA 25)

Monoceros Constellation

Located	NGC 2264	PMRA	$-1.55 \pm 0.22$ mas/yr	SPT	B7
Parallax	$1.14 \pm 0.12$ mas	PMDEC	$-3.49 \pm 0.21$ mas/yr	G	12.74 mag



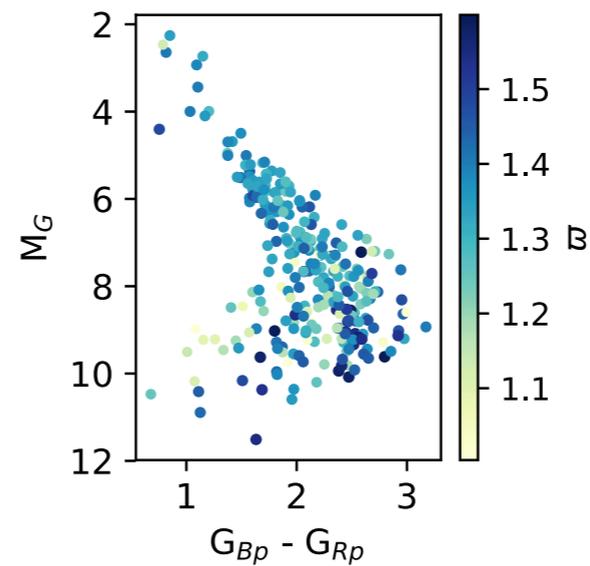
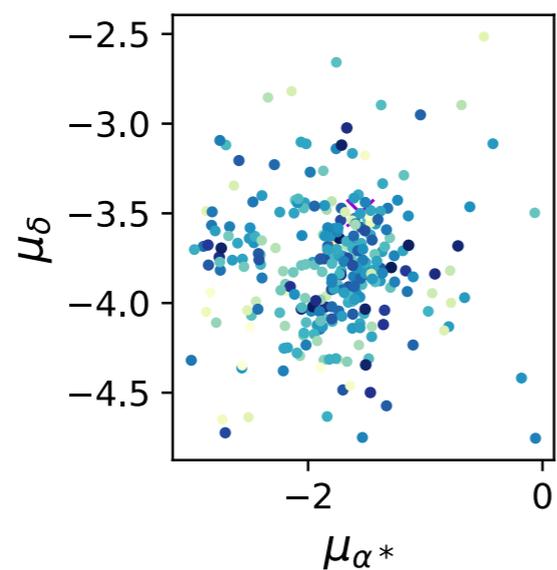
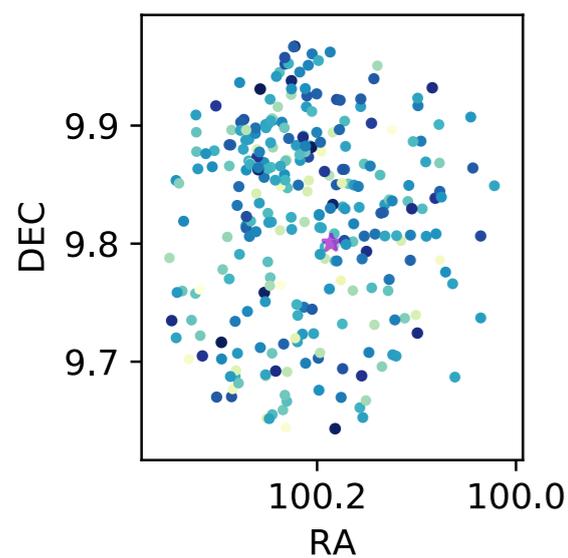
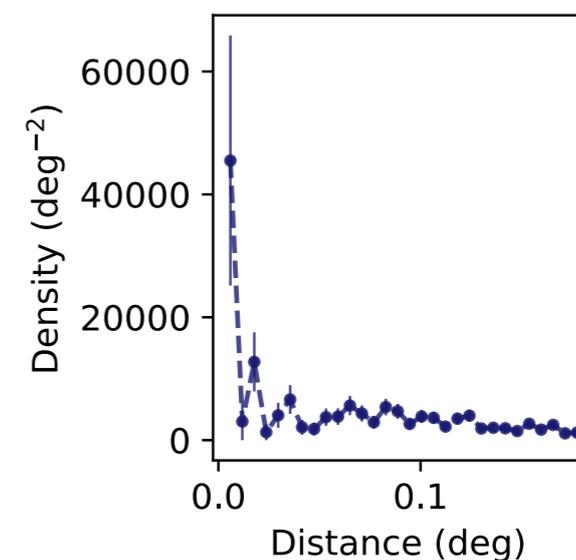
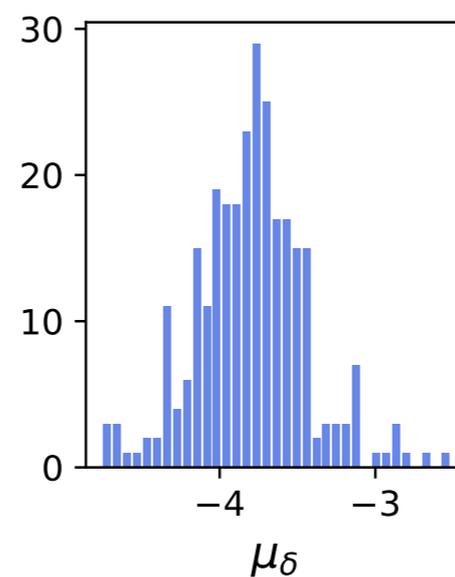
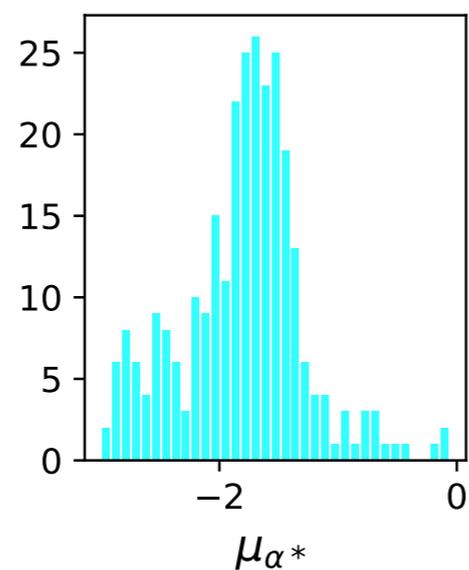
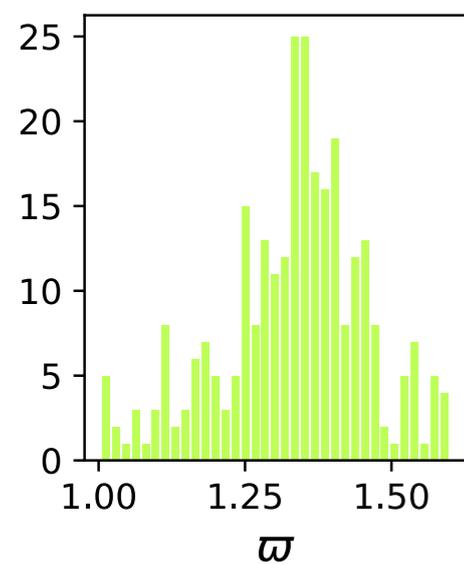
Object name = V590Mon  
 Number of objects select = 281

Known value of PARALLAX =  $1.141 \pm 0.127$  [mas]  
 Known value of PMRA =  $-1.554 \pm 0.229$  [mas/yr]  
 Known value of PMDEC =  $-3.498 \pm 0.211$  [mas/yr]

Mean PARALLAX value = 1.333 [mas]  
 Mean PMRA value = -1.804 [mas/yr]  
 Mean PMDEC value = -3.795 [mas/yr]

# V590 Mon (LkHA 25)

Monoceros Constellation



Object name = V590Mon  
Final number of objects select = 281  
Known value of PARALLAX =  $1.141 \pm 0.127$  [mas]  
Known value of PMRA =  $-1.554 \pm 0.229$  [mas/yr]  
Known value of PMDEC =  $-3.498 \pm 0.211$  [mas/yr]

PARALLAX value =  $1.352 \pm 0.004$  [mas]  
PMRA value =  $-1.798 \pm 0.007$  [mas/yr]  
PMDEC value =  $-3.731 \pm 0.006$  [mas/yr]



# Conclusion...

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- ❖ CEREAL has classified  $\sim 70$  stars to be in a cluster.
- ❖ *As preliminary result: B stars are more likely to be in clusters than A stars.* (Testi+99)

# Conclusion... Future work

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- ❖ CEREAL has classified ~ 70 stars to be in a cluster.
- ❖ *As preliminary result: B stars are more likely to be in clusters than A stars. (Testi+99)*
- ❖ Clustering properties for those Herbig Ae / Be stars.
- ❖ Clustering algorithms comparison (*Cánovas+19*).

# Conclusion... Future work

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*Thank you!*