Gaia view of low-mass star formation

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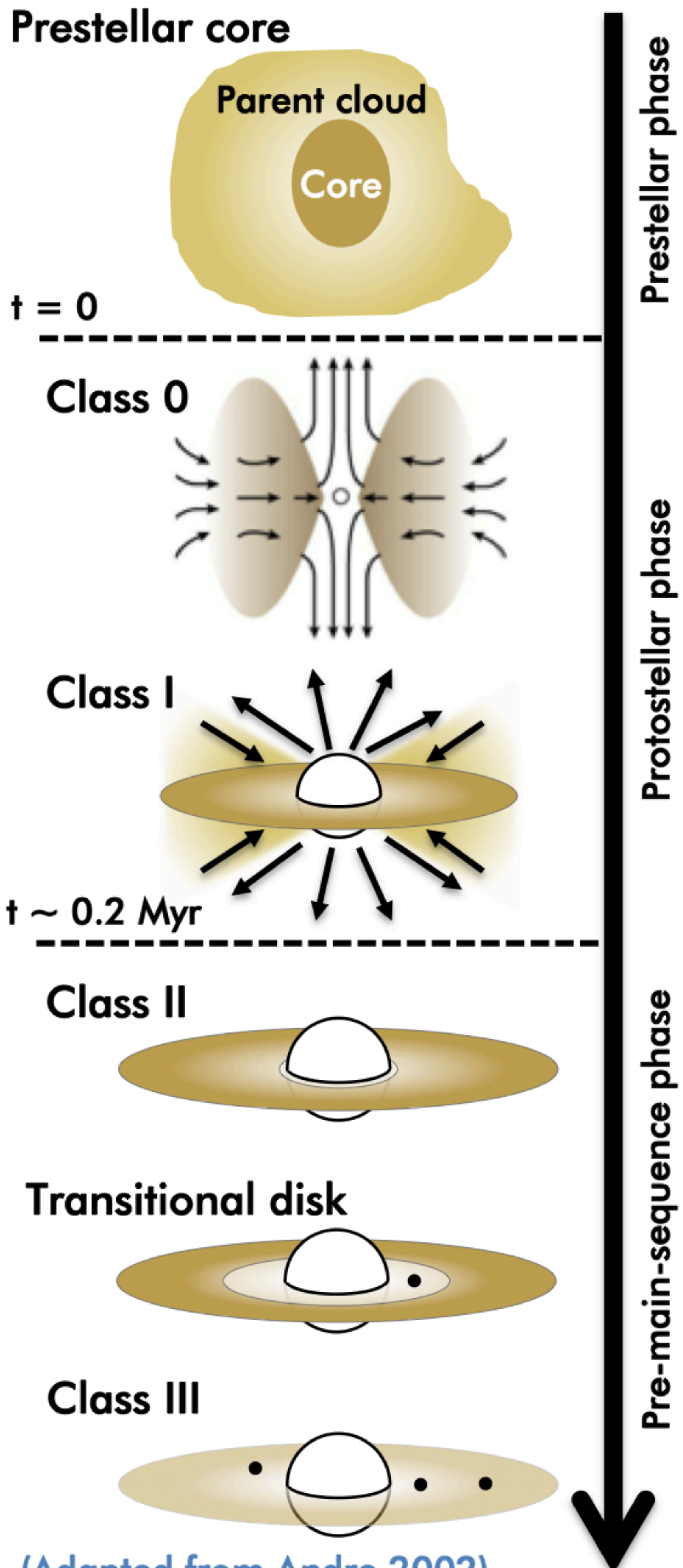
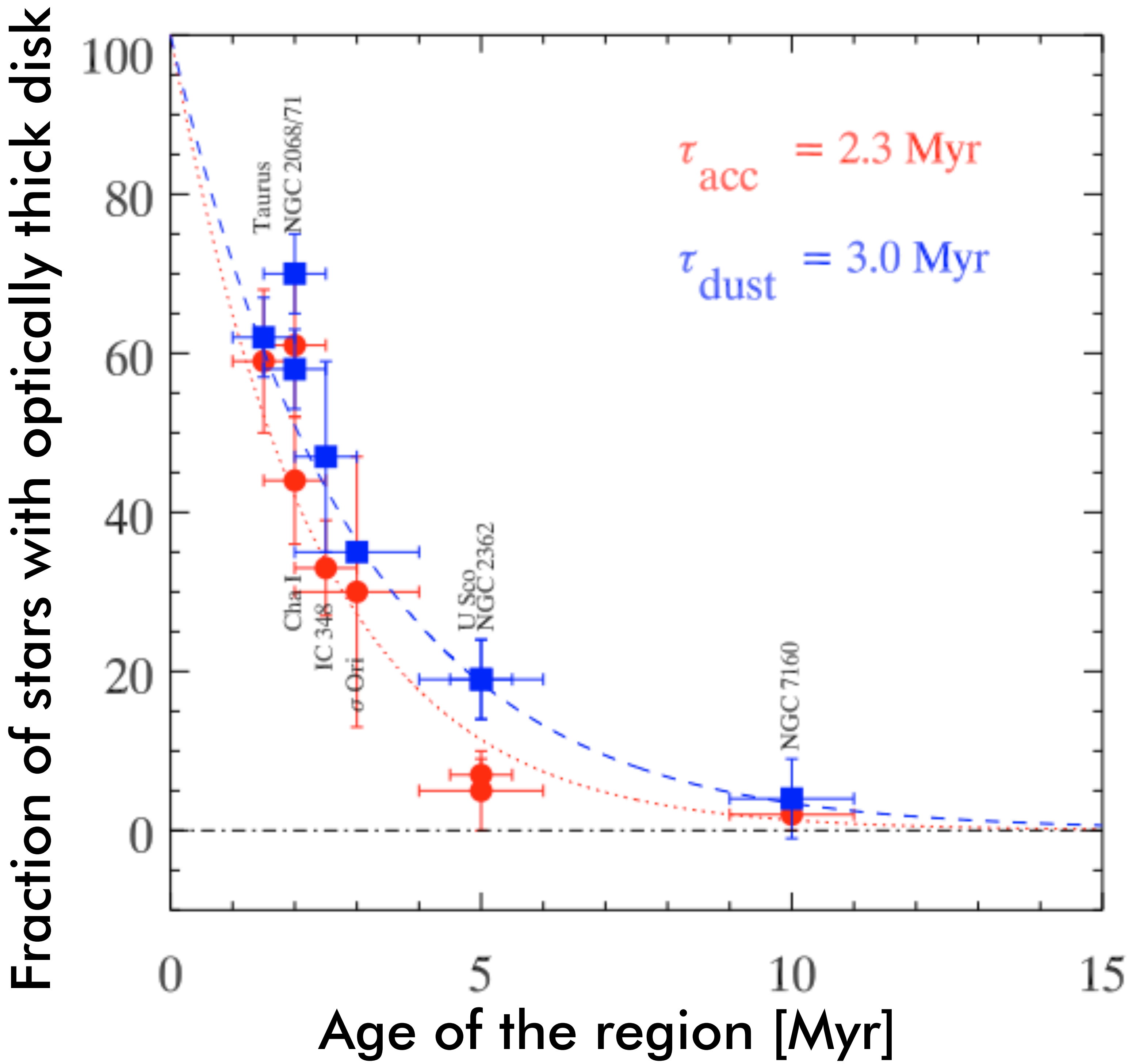
IAU Nice - 25.04.2017

The evolution of protoplanetary disks and their typical lifetime

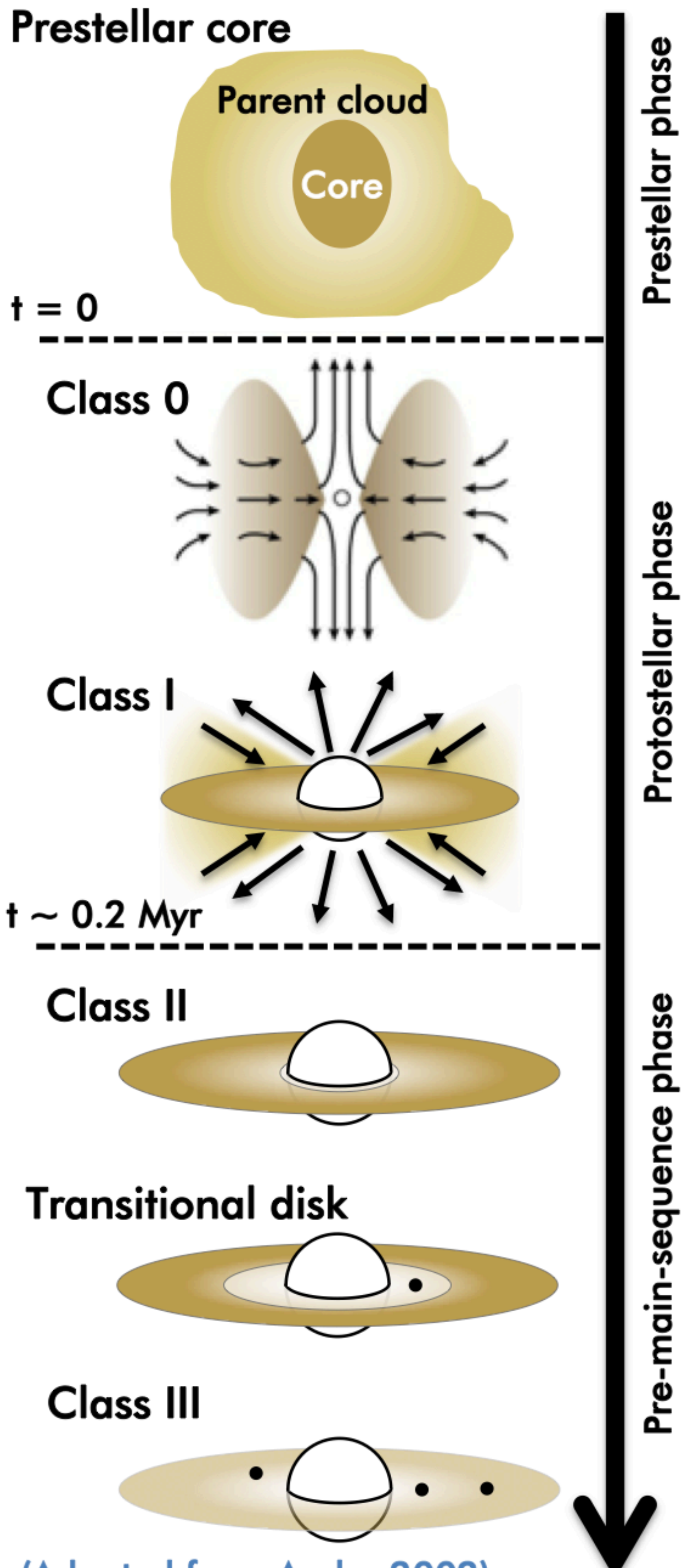


(Adapted from Andre 2002)



(Fedele et al. 2010, Haisch et al. 2001, Hernandez et al. 2007, Bell et al. 2013)

Planets form in EVOLVING protoplanetary disks



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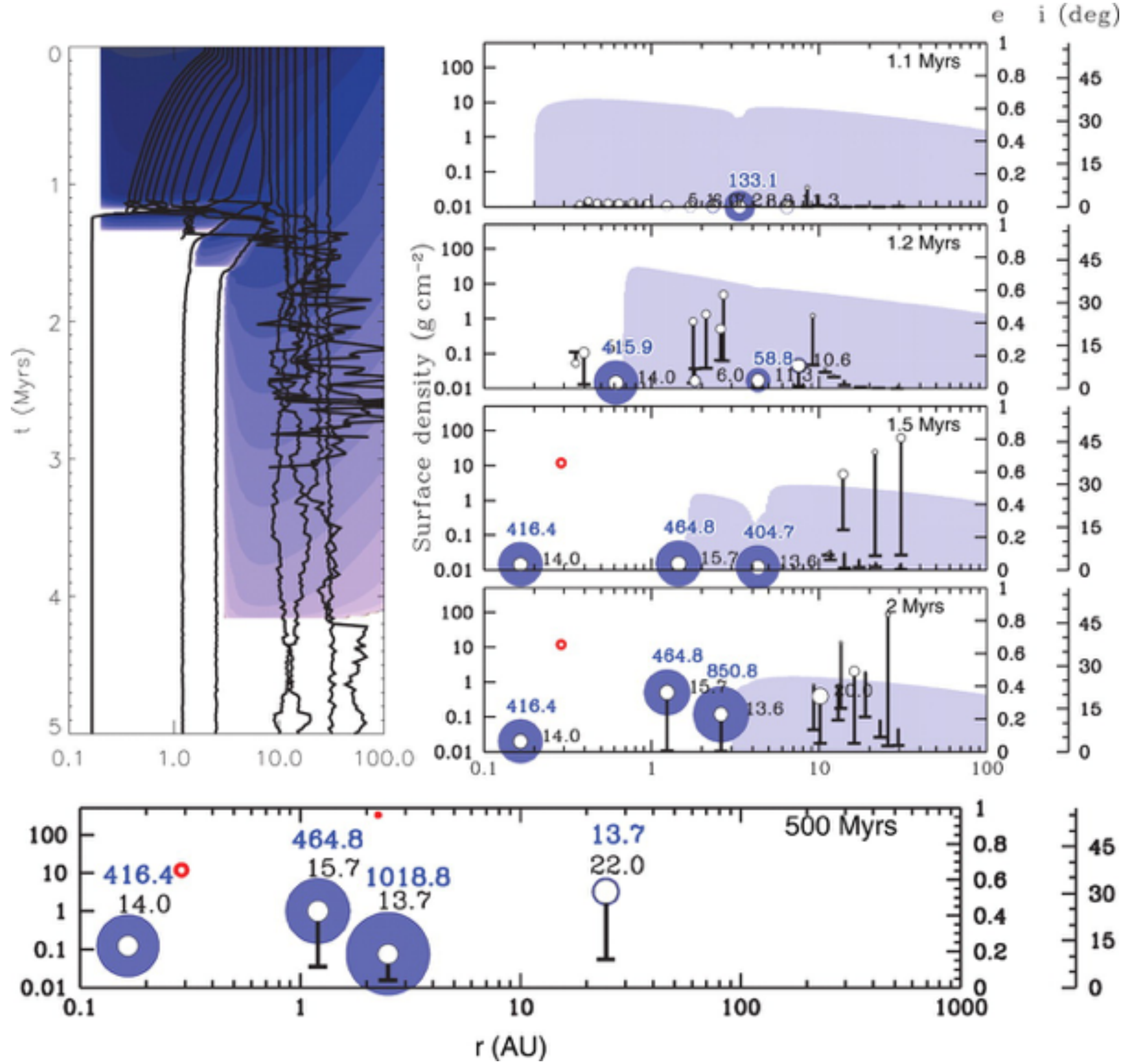
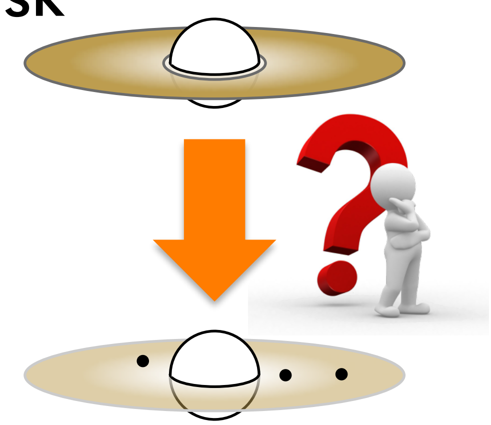


(Thommes et al. 2008)

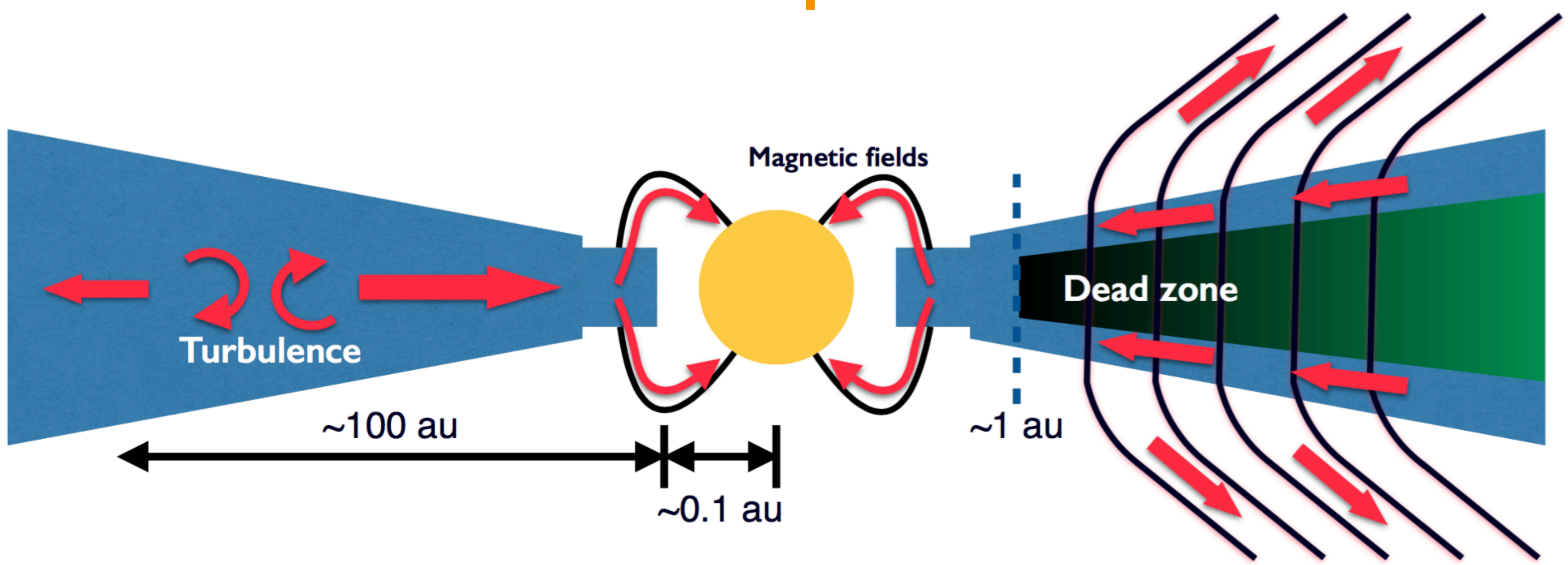
What is the driver of the evolution of protoplanetary disks?

Disk



Star & planets

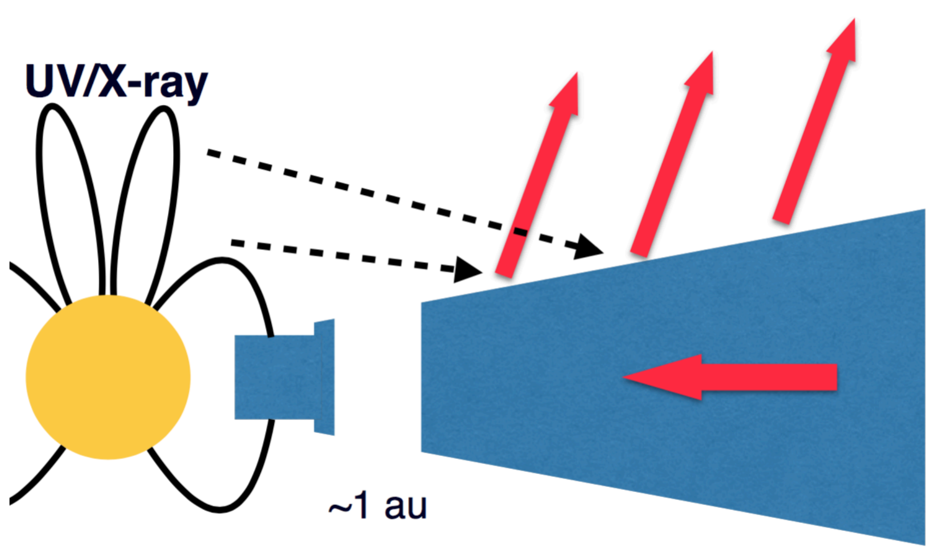
VISCOUS EVOLUTION | DISK WINDS



e.g., Lynden-Bell & Pringle 1974; Hartmann et al. 1998

e.g., Armitage et al. 2013, Bai et al. (2014, 2015, 2016), Gressel et al. 2015

INTERNAL PHOTOEVAPORATION

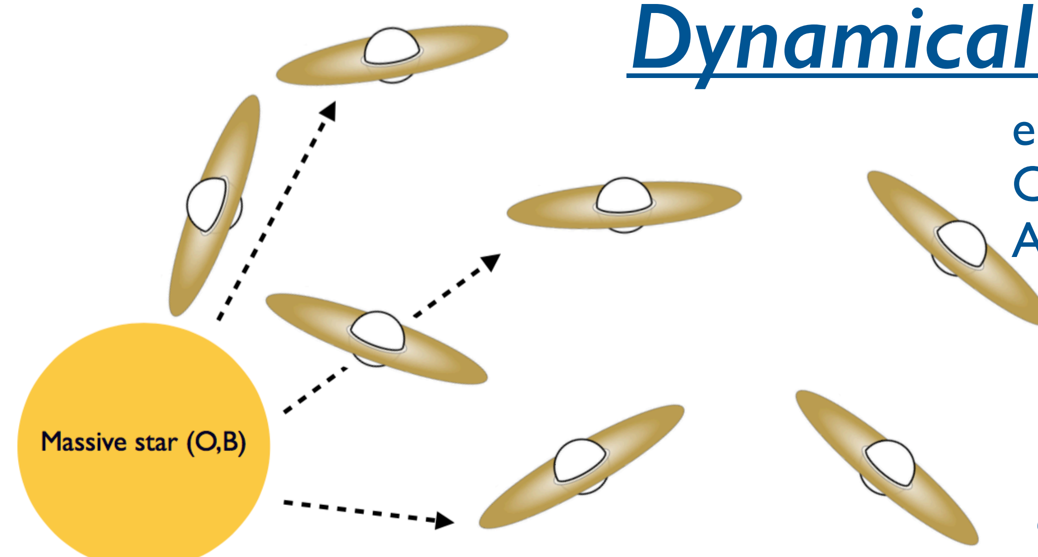


e.g., Alexander et al. 2014

EFFECTS OF ENVIRONMENT - STELLAR CLUSTERS

Dynamical interactions

e.g., Pfalzner et al., 2005; Clarke et al., 1993, 2008; Adams 2010



External photoevaporation

e.g., Clarke 2007, Anderson et al. (2013), Facchini et al. (2016)

1 Spectroscopy:

- Stellar properties
- Mass accretion rates
- Wind properties

2 mm-interferometry:

- Disk mass
- Disk morphology
- Surface density

3 IR-interferometry & spectroscopy:

- Inner disk morphology
- Inner disk composition

4 Astrometry:

- Distances
- Kinematic membership
- Dynamical properties

Credit:ESO/H.H. Heyer

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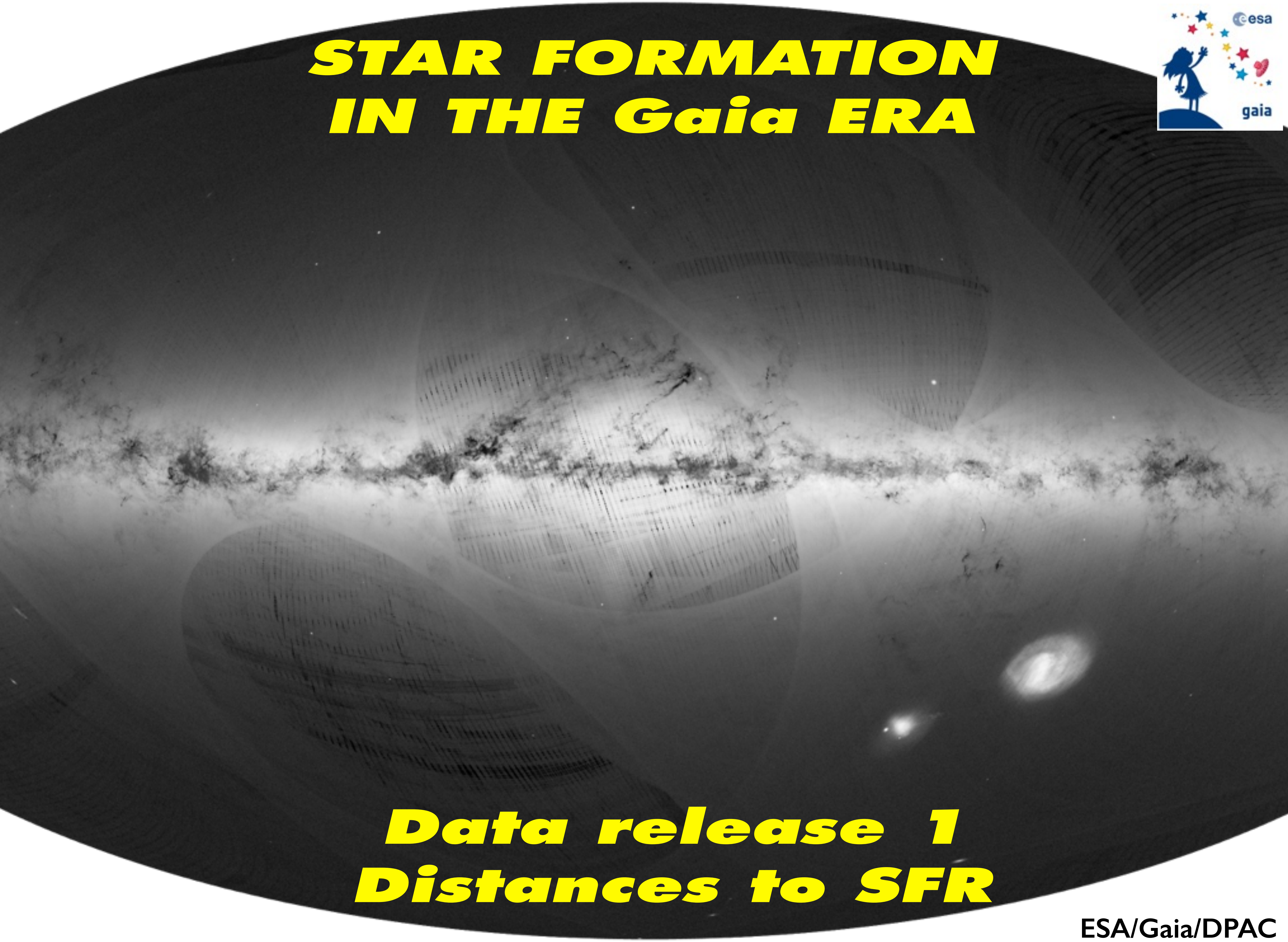
Credit:ESO/H.H. Heyer



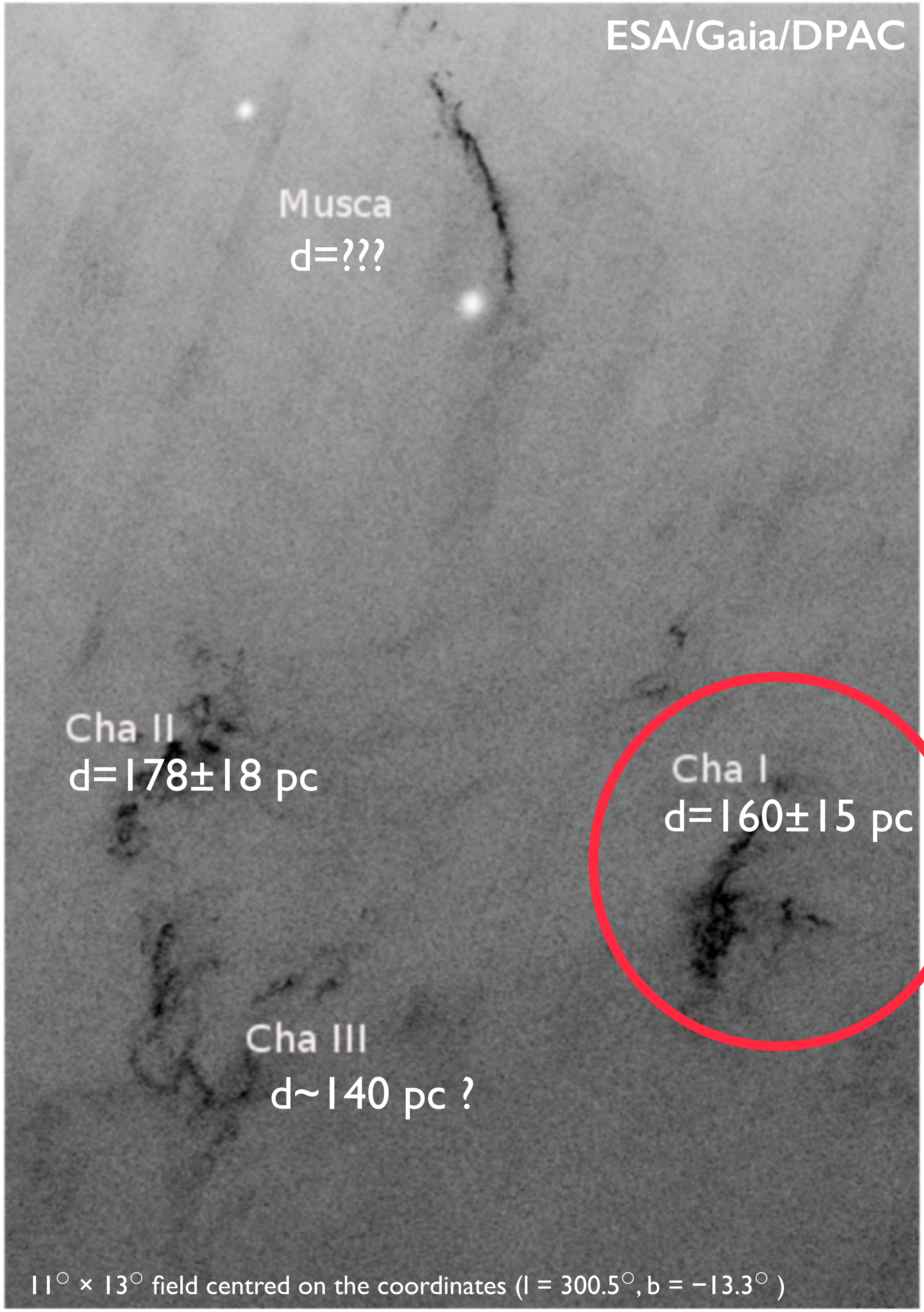
ESA/Gaia/DPAC

The Chamaeleon-Musca complex seen with Gaia DR1

One of the *closest* star forming complex with *hundreds* of young stellar objects, many surrounded by disks *(e.g., Luhman et al. 2004, 2008)* and still accreting *(e.g., Manara et al. 2016a,2017)*.

The *distances* to the various clouds are still under debate.

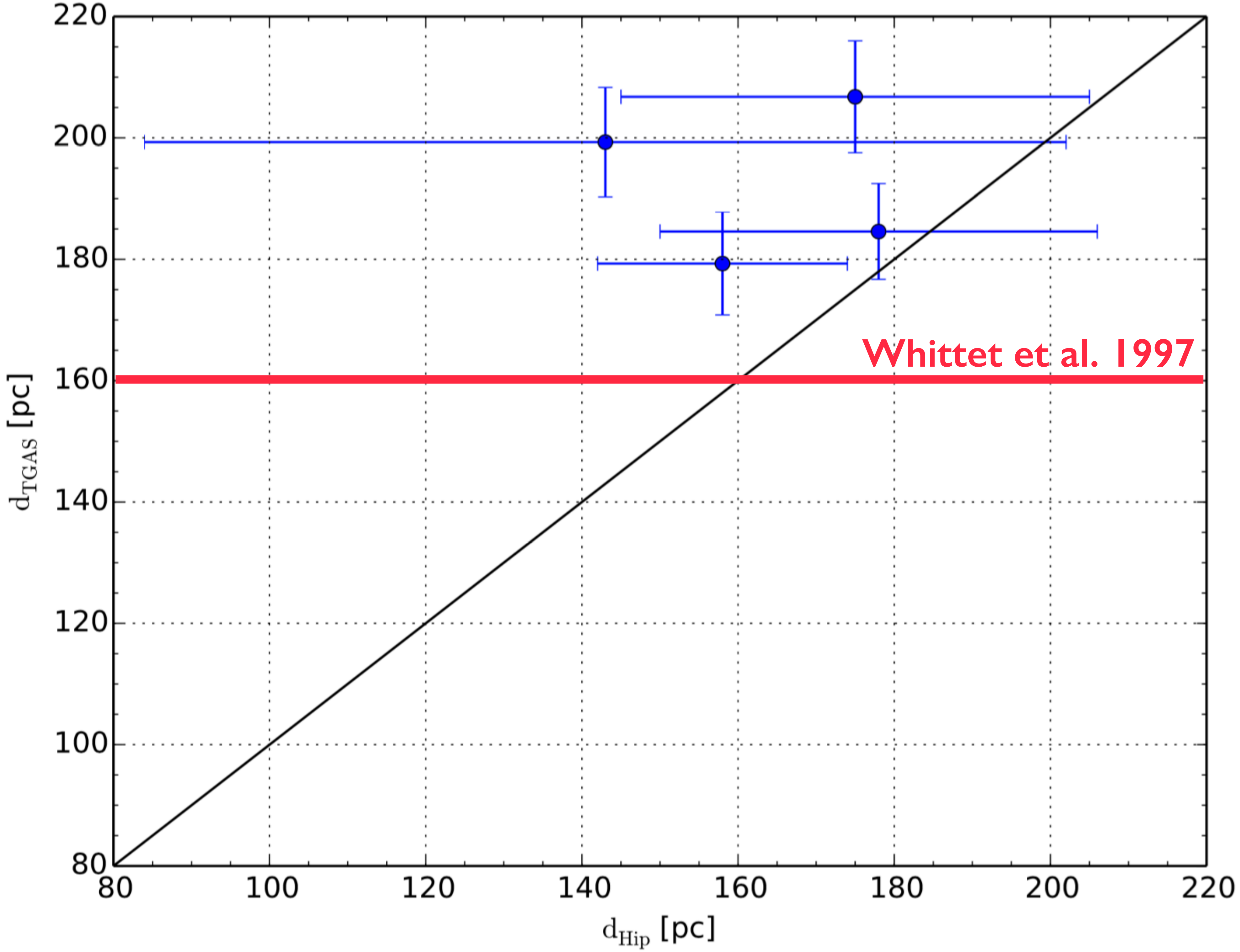
Only 8 known members of the Chamaeleon I cloud are included in the TGAS catalog, 4 in common with Hipparcos.



Voirin, Manara, Prusti, to be subm.

Distances from: Whittet et al. 1997, Franco et al. 1991, Luhman 2008

Chamaeleon I: TGAS vs Hipparcos distances

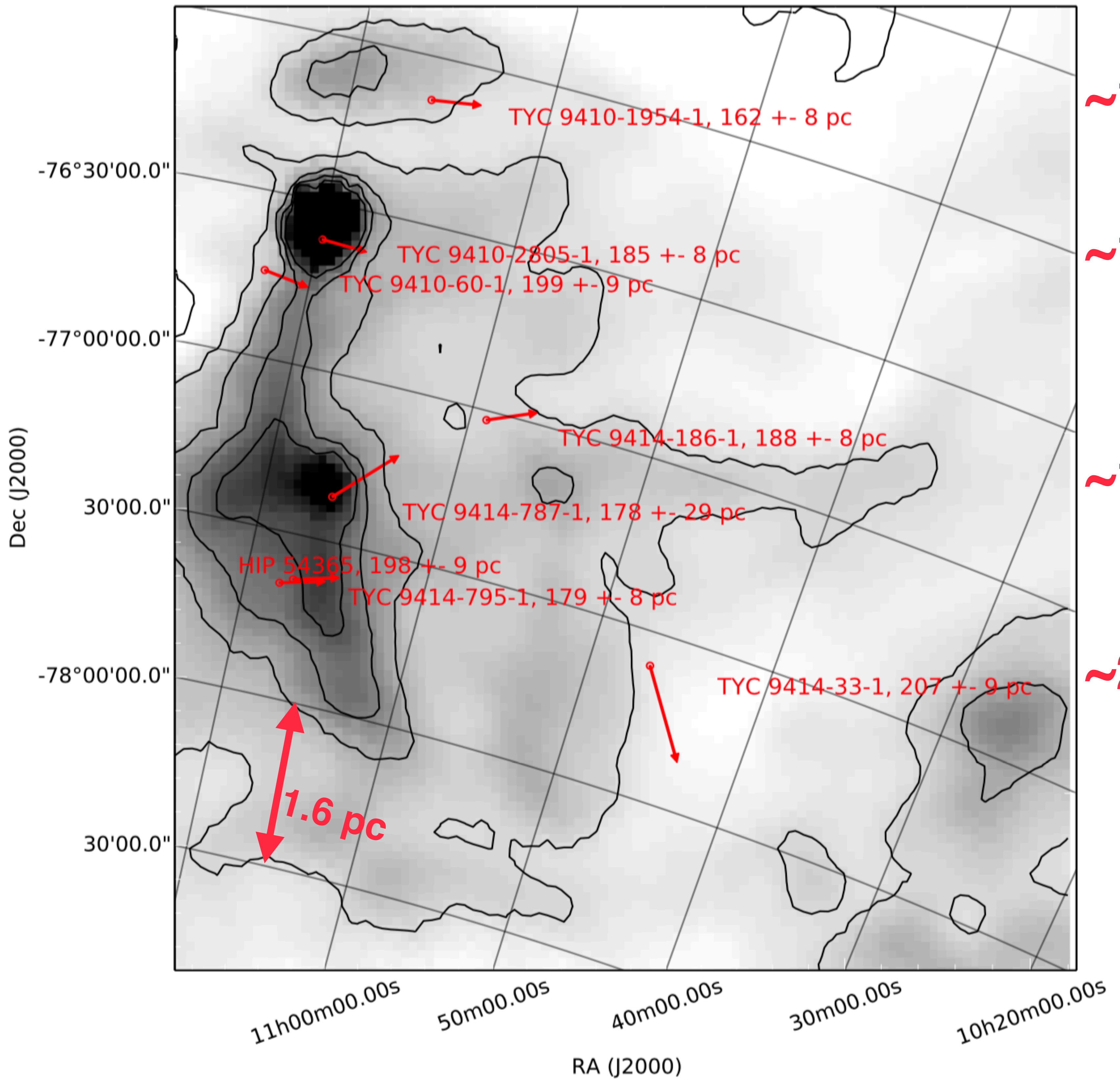


Voirin, Manara, Prusti, to be subm.

TGAS parallaxes suggest that Chamaeleon I is further away than assumed.

NB: all distances are from Astraatmadja & Bailer-Jones (2016), assuming an anisotropic prior

Chamaeleon I: TGAS distance using known members



~160 pc

~190 pc

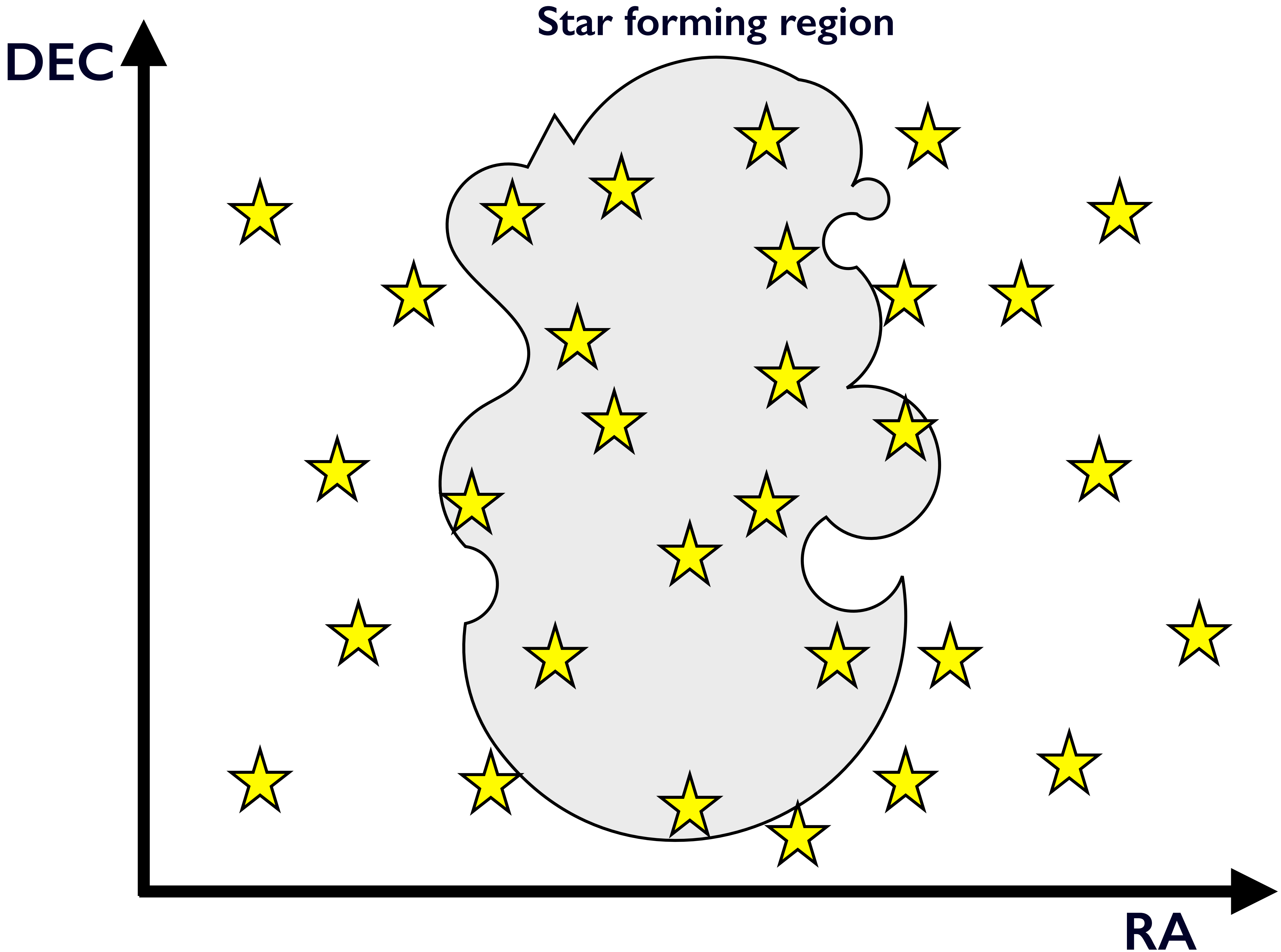
~180 pc

~200 pc

Voirin, Manara, Prusti, to be subm.

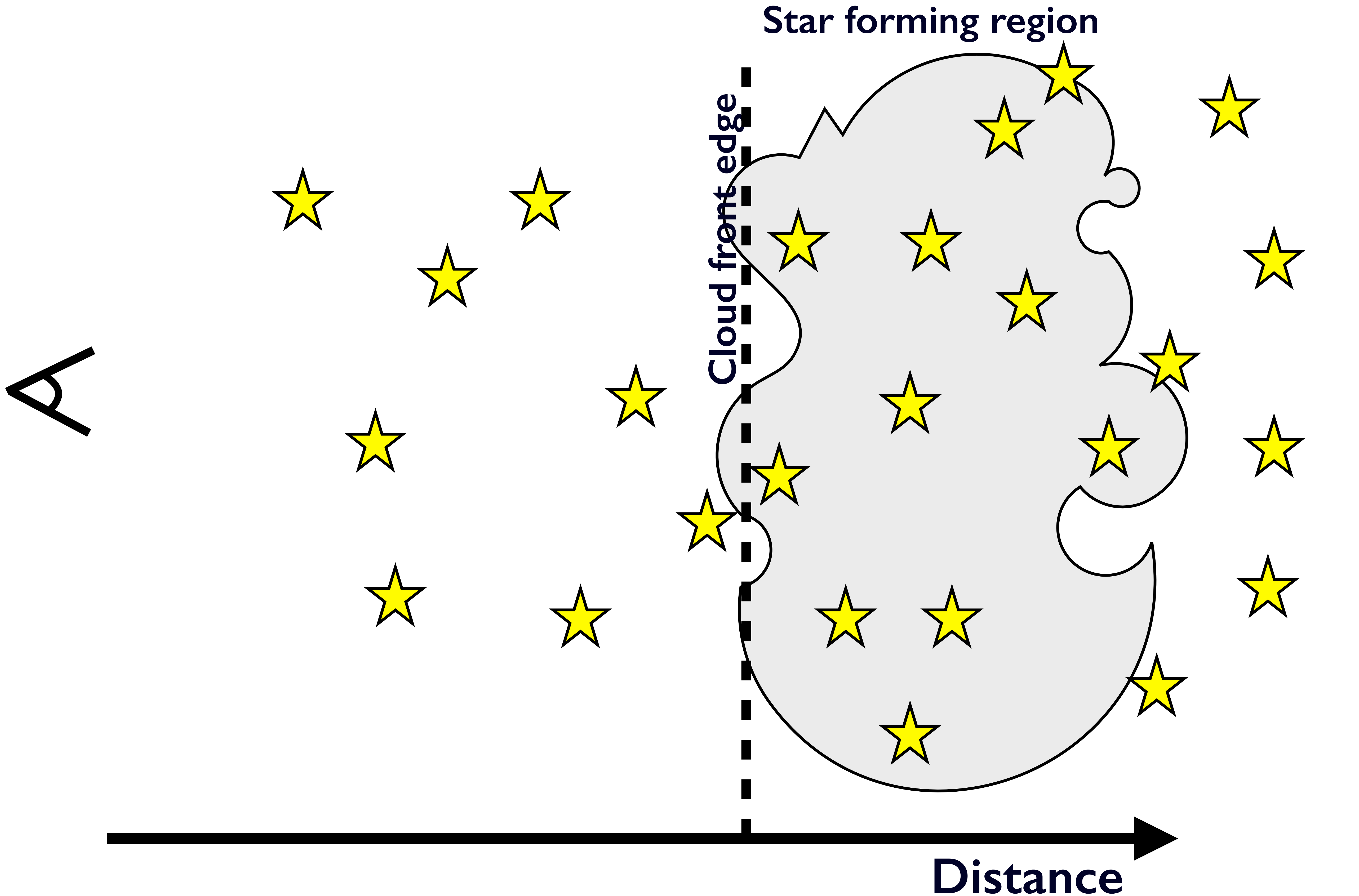
$$\text{distance}_{\text{Chamaeleon I, members}} = 189 \pm 9 \pm 10 \text{ [pc]}$$

TGAS distance using reddening turn-on



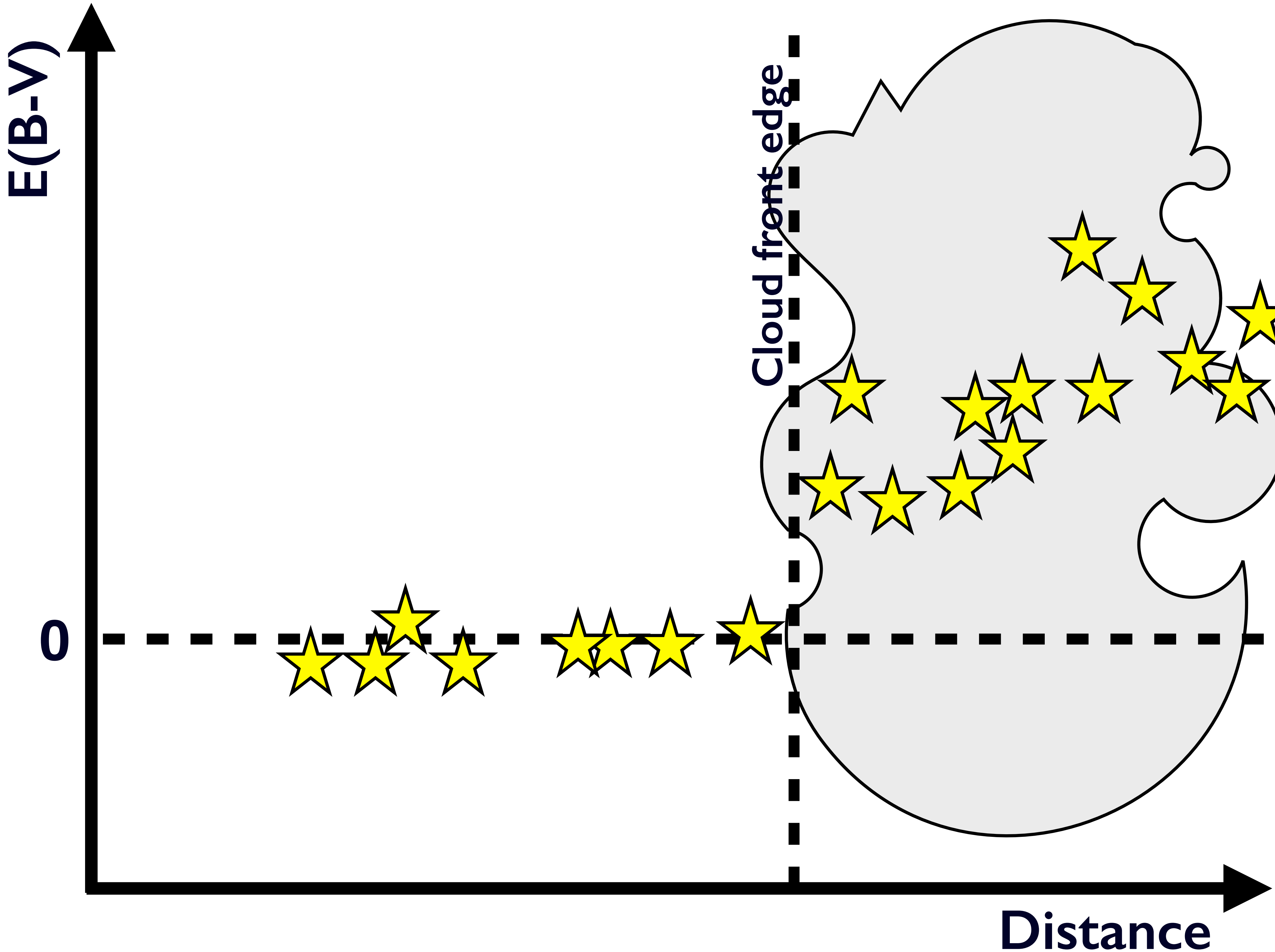
See Whittet et al. 1987, 1997

TGAS distance using reddening turn-on



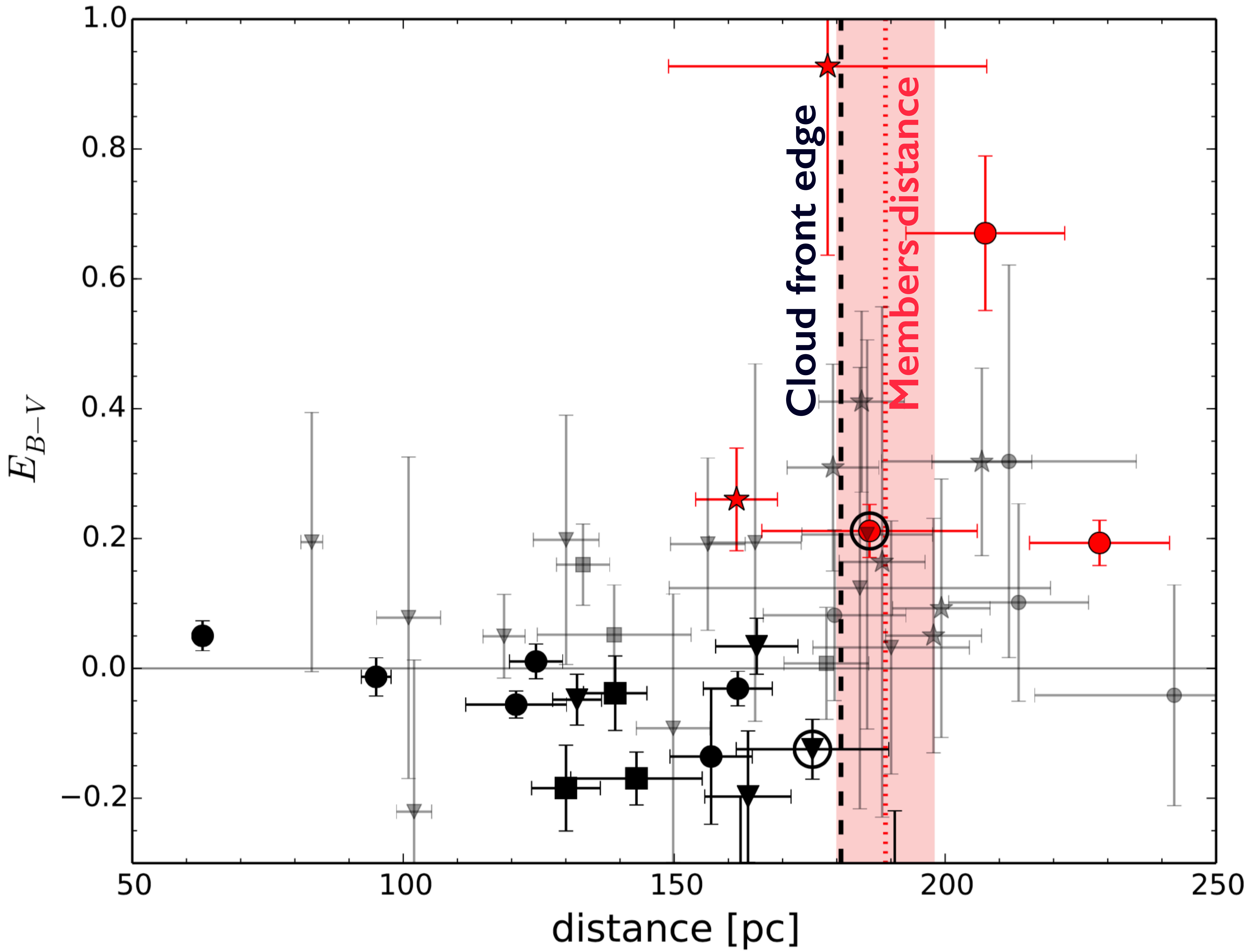
See Whittet et al. 1987, 1997

TGAS distance using reddening turn-on



See Whittet et al. 1987, 1997

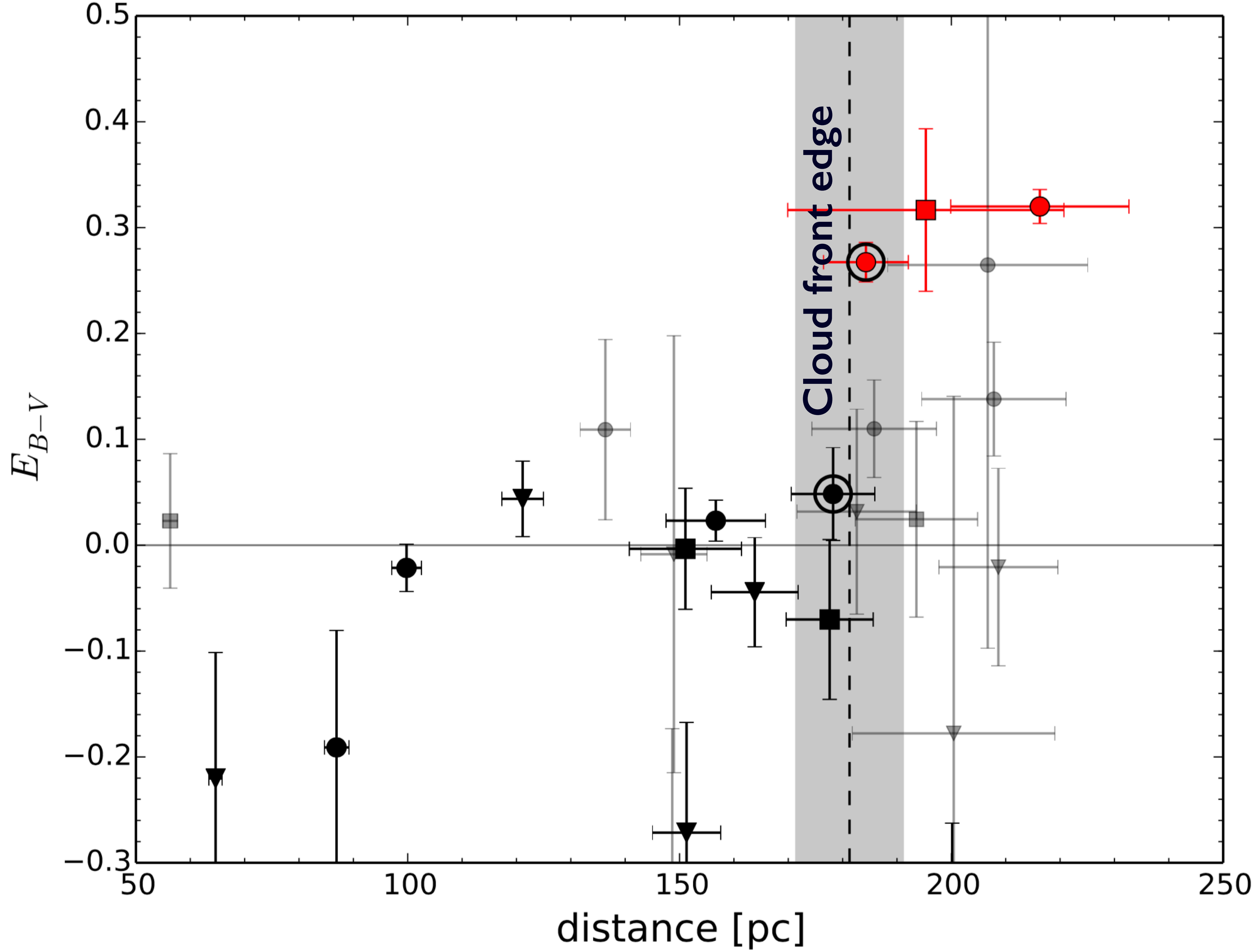
Chamaeleon I: TGAS distance using reddening turn-on



Voirin, Manara, Prusti, to be subm.

$\text{distance}_{\text{Chamaeleon I, reddening}} = 181 \pm 10 \pm 10$ [pc]

Chamaeleon II: TGAS distance using reddening turn-on

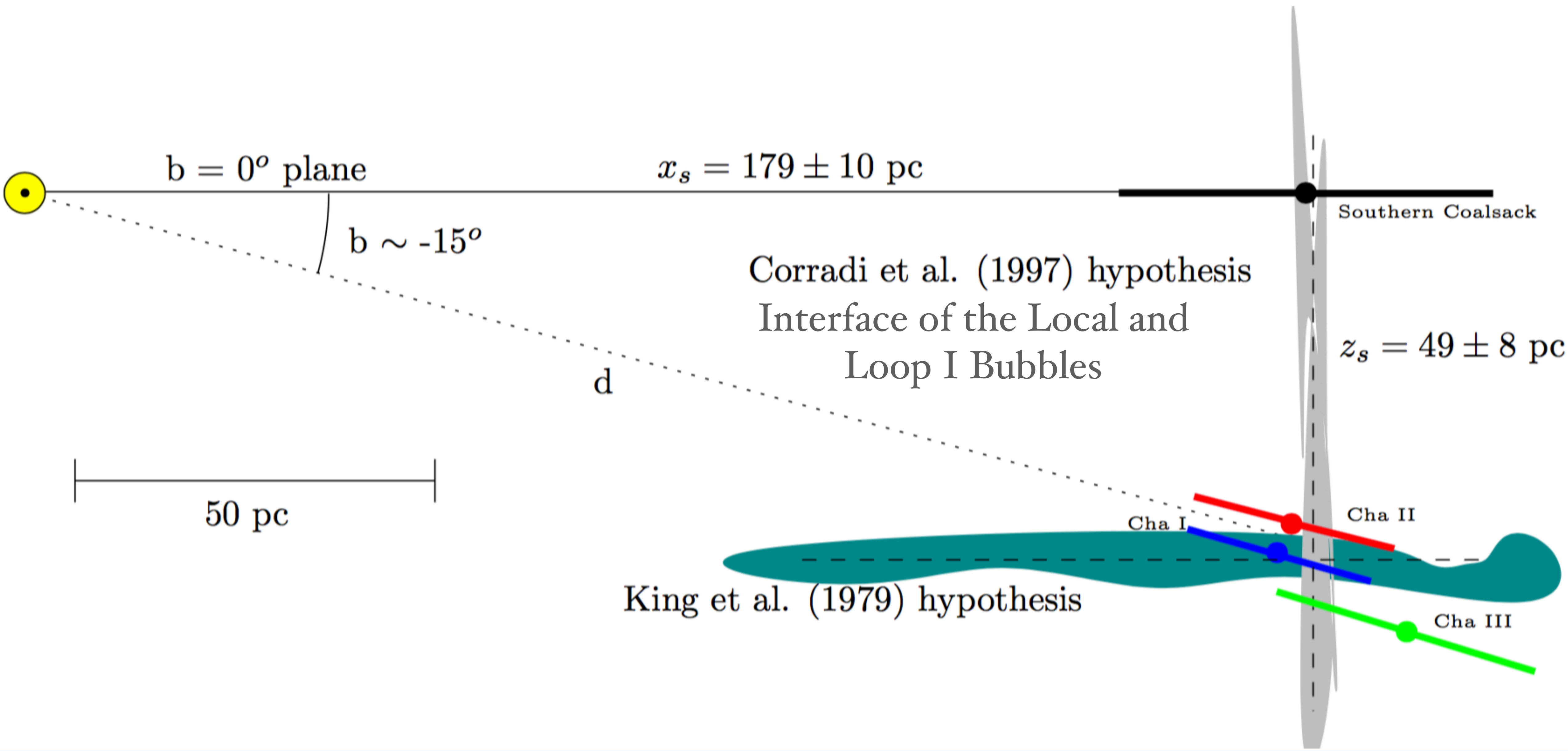


Voirin, Manara, Prusti, to be subm.

distance$_{\text{Chamaeleon II, reddening}}$ = 181± 10 ± 10 [pc]

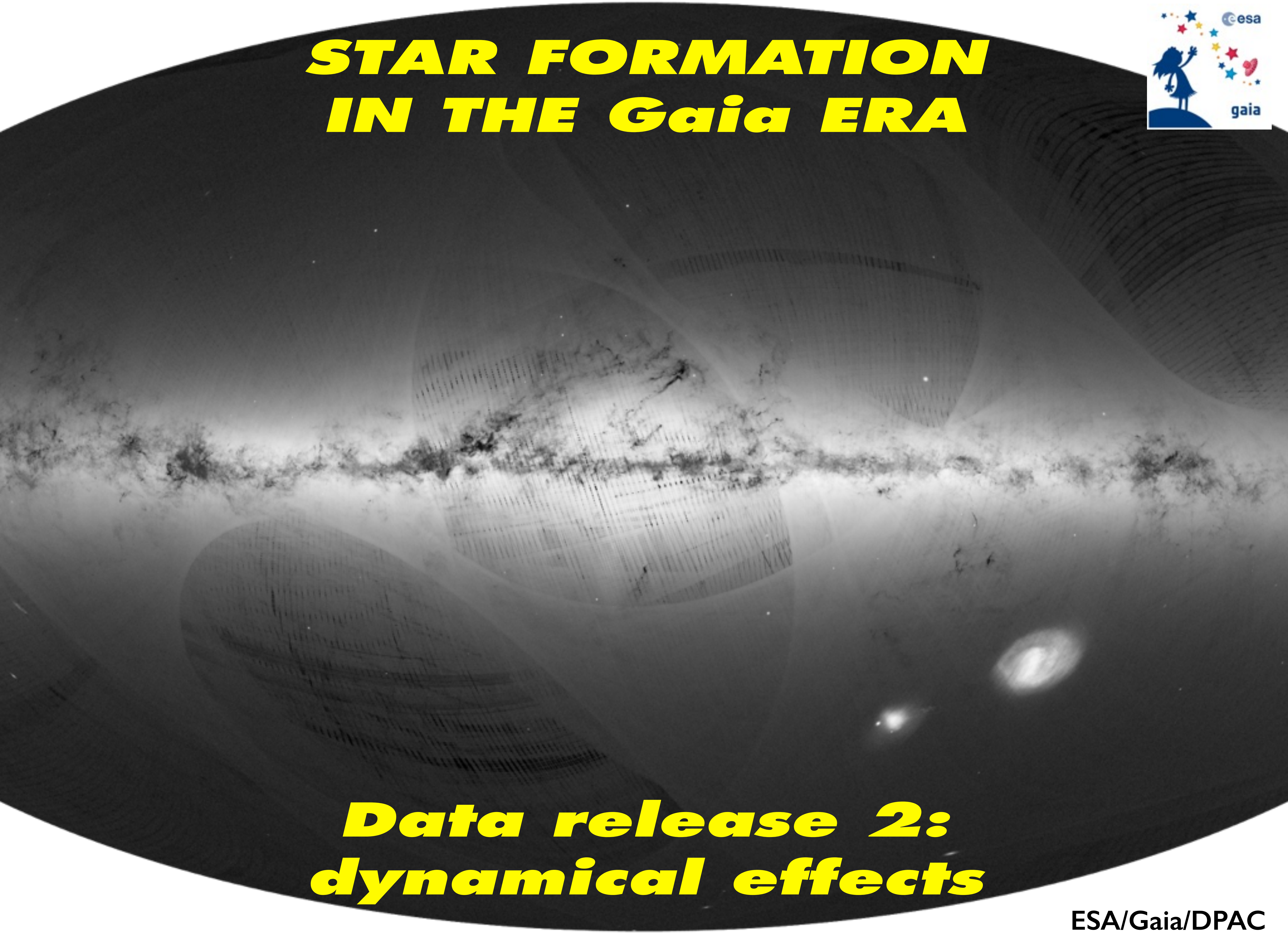
The Chamaeleon region seen with Gaia DR1

Name	Distance [pc]	Old Distance [pc]
Chamaeleon I	181 ± 10 ± 10	160±15
Chamaeleon II	181 ± 10 ± 10	178±18
Chamaeleon III	199 ± 15 ± 13	~140 ?
Musca	< 600	



Voirin, Manara, Prusti, to be subm.

STAR FORMATION IN THE Gaia ERA

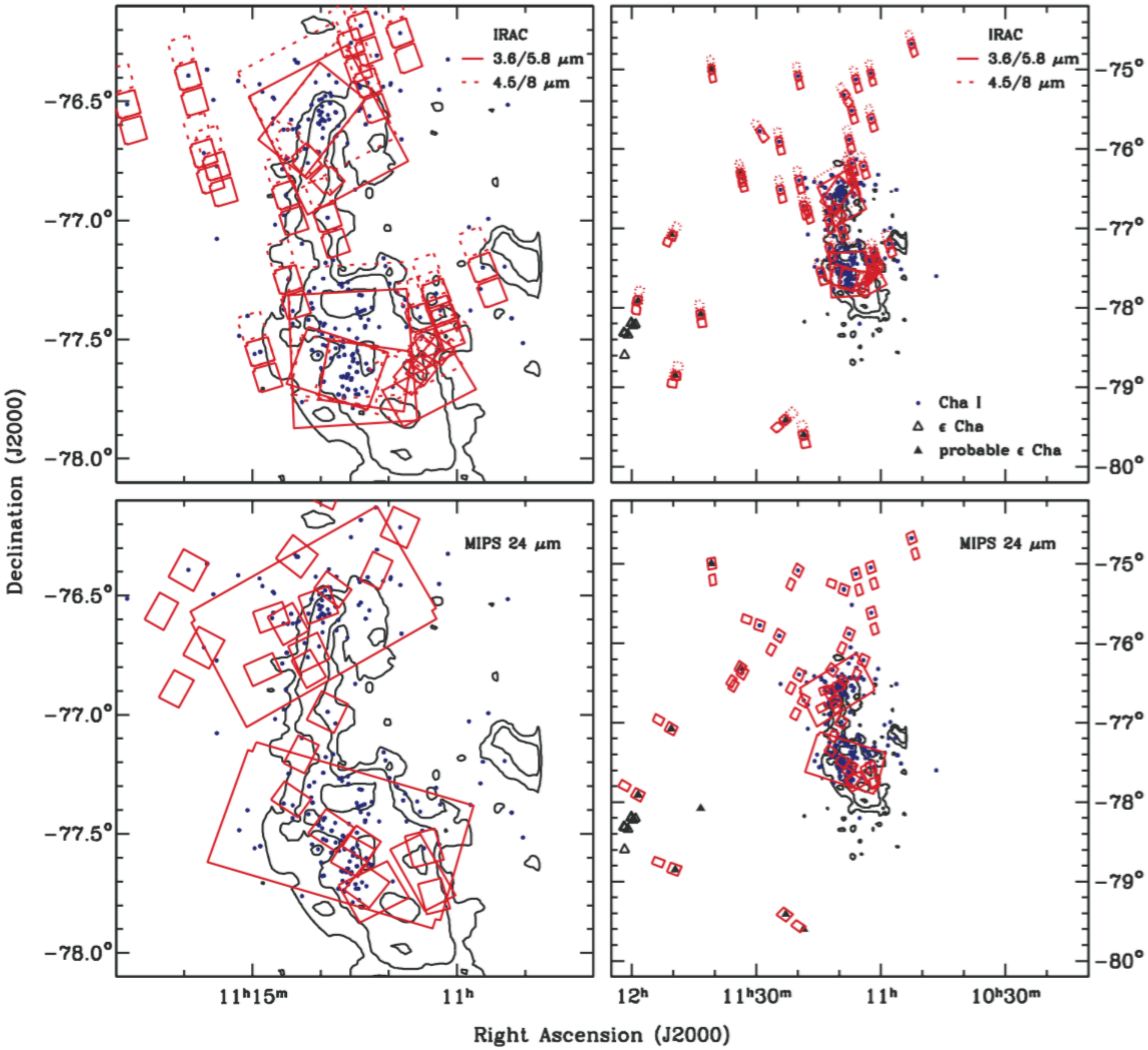


Data release 2: dynamical effects

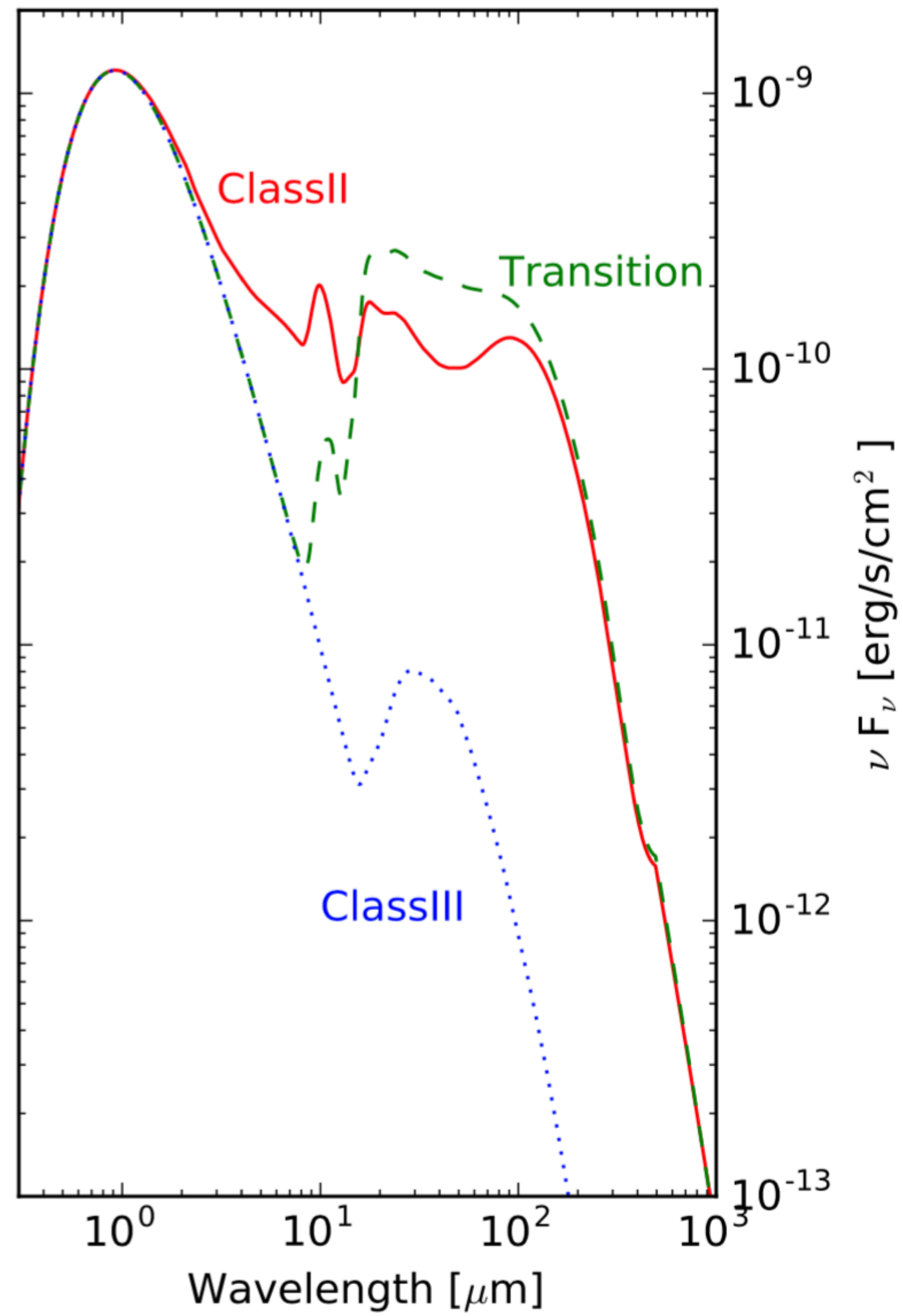
ESA/Gaia/DPAC

Detection of young stellar objects from IR-excess

1. Limited coverage of IR surveys
2. Low sensitivity to small IR-excess (e.g., diskless stars)

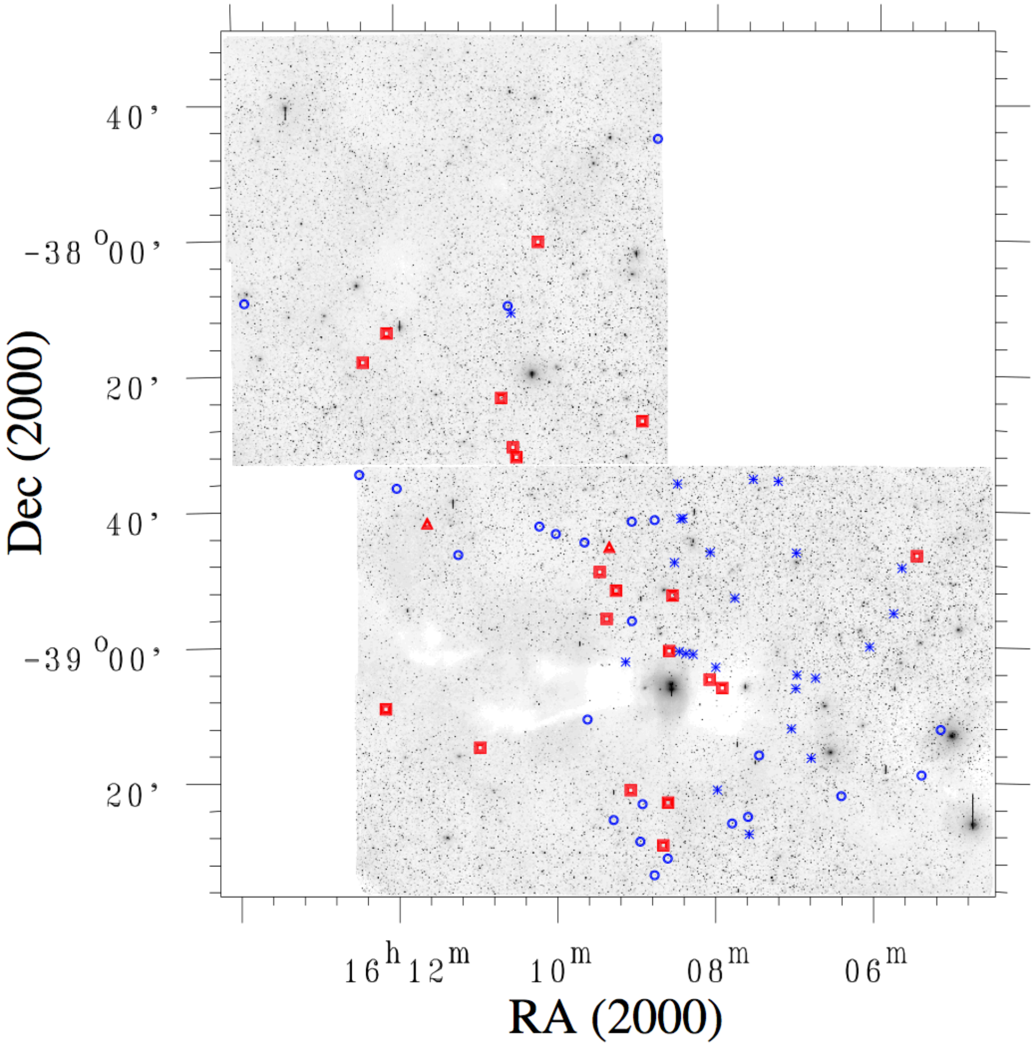


Chamaeleon I, Luhman et al. 2008

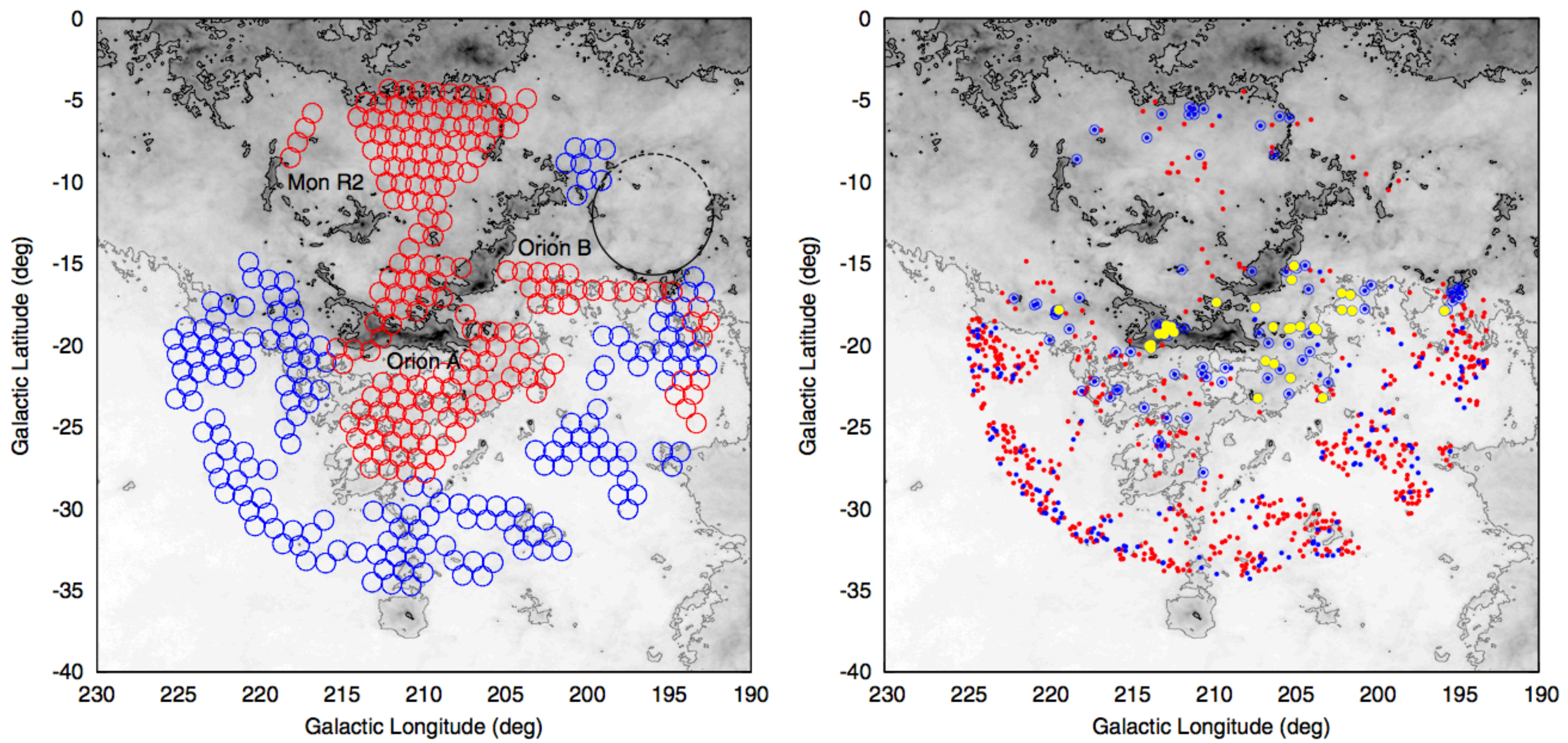


Ercolano & Pascucci 2017

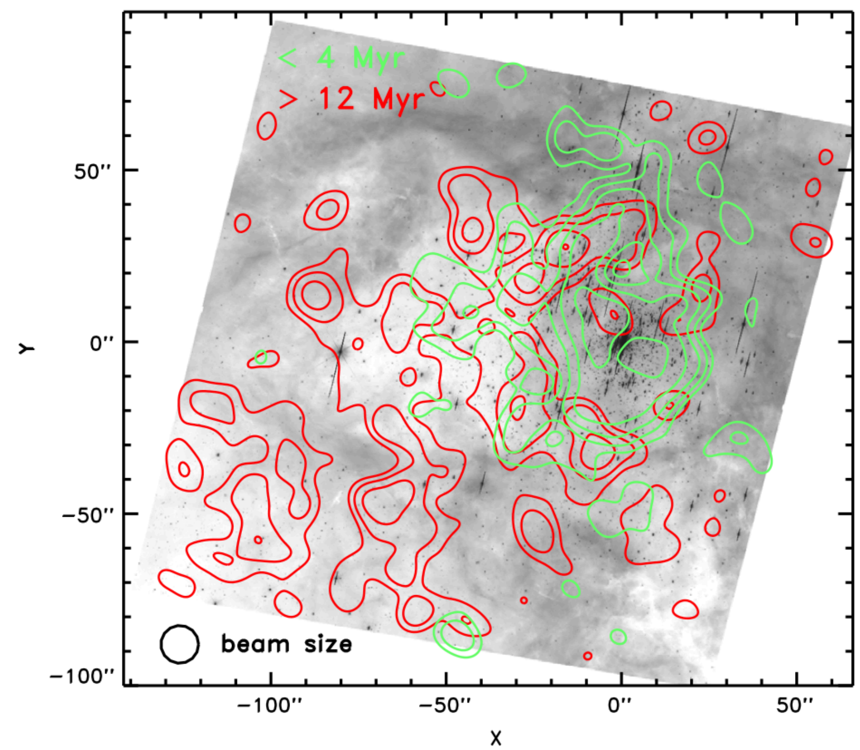
Sparse populations in young regions



Lupus, Comeron et al. 2013



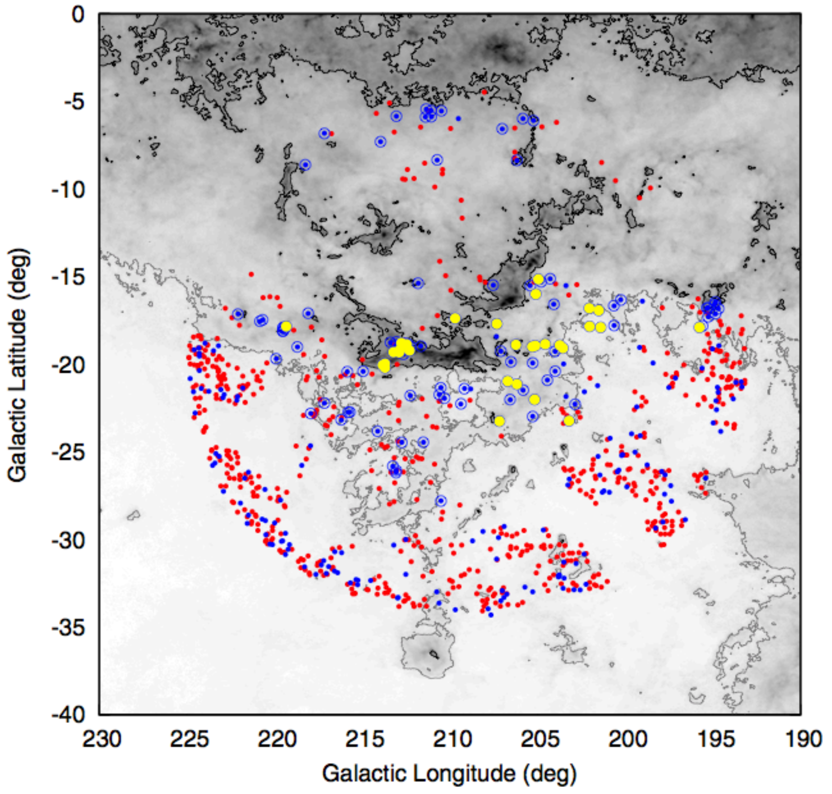
Orion, Sanchez et al. 2014



30 Dor, De Marchi et al. 2011

See also:
Taurus, Gomez de Castro et al. 2015
Vela OB2, Sacco et al. 2015

Sparse populations in young regions



ORIGIN:

- different star formation sites
- dynamical interactions

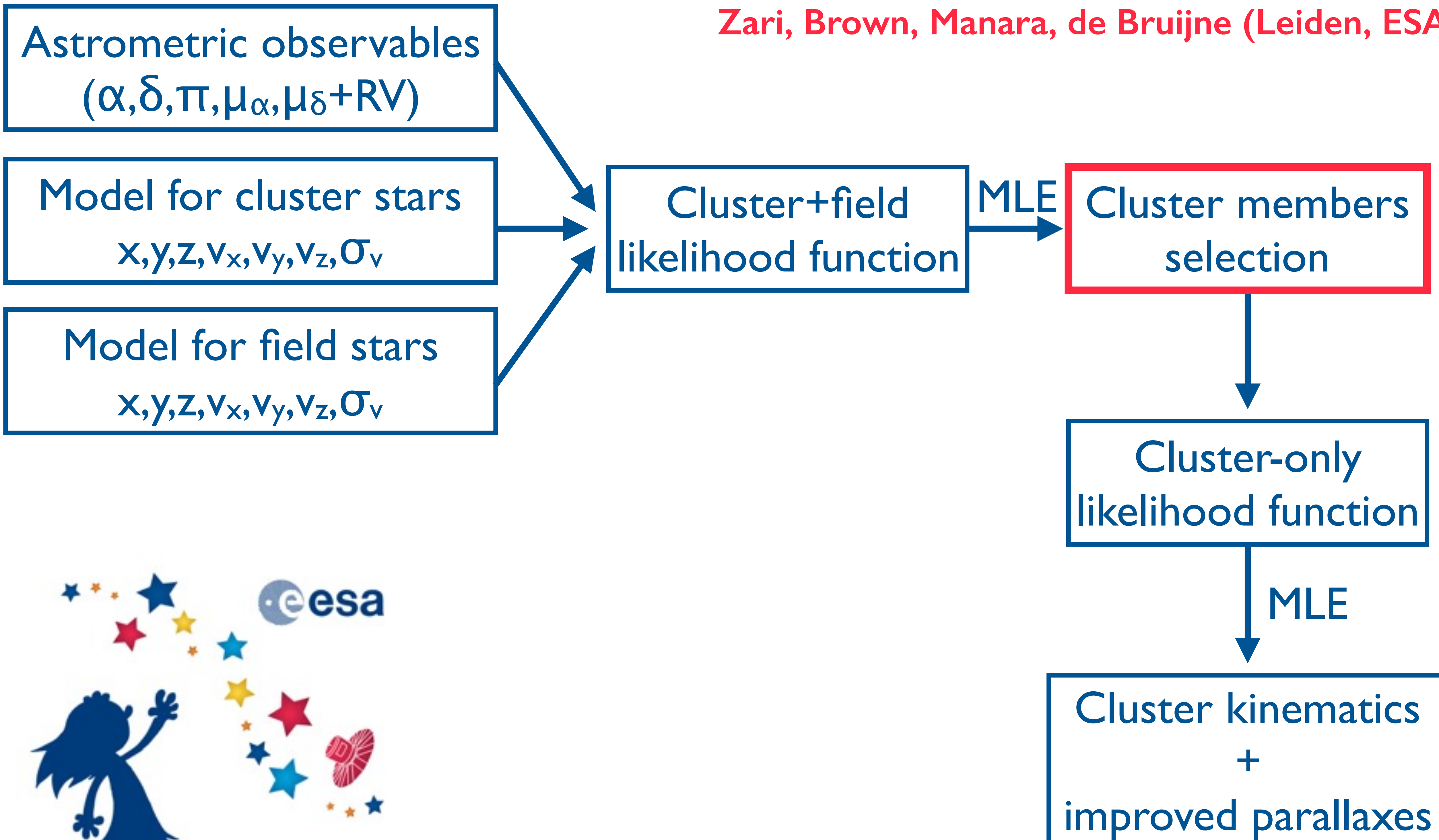
EFFECTS:

- are we missing many young stars? (e.g., Pfalzner et al. 2015)
- wrong disk lifetime estimates? (e.g., Armitage & Clarke 1997)
- can we use this population to study dynamical evolution? (e.g., Allison et al. 2012)

HOW CAN WE FIND THIS SPARSE POPULATION?

Maximum likelihood kinematic membership

Zari, Brown, Manara, de Bruijne (Leiden, ESA)



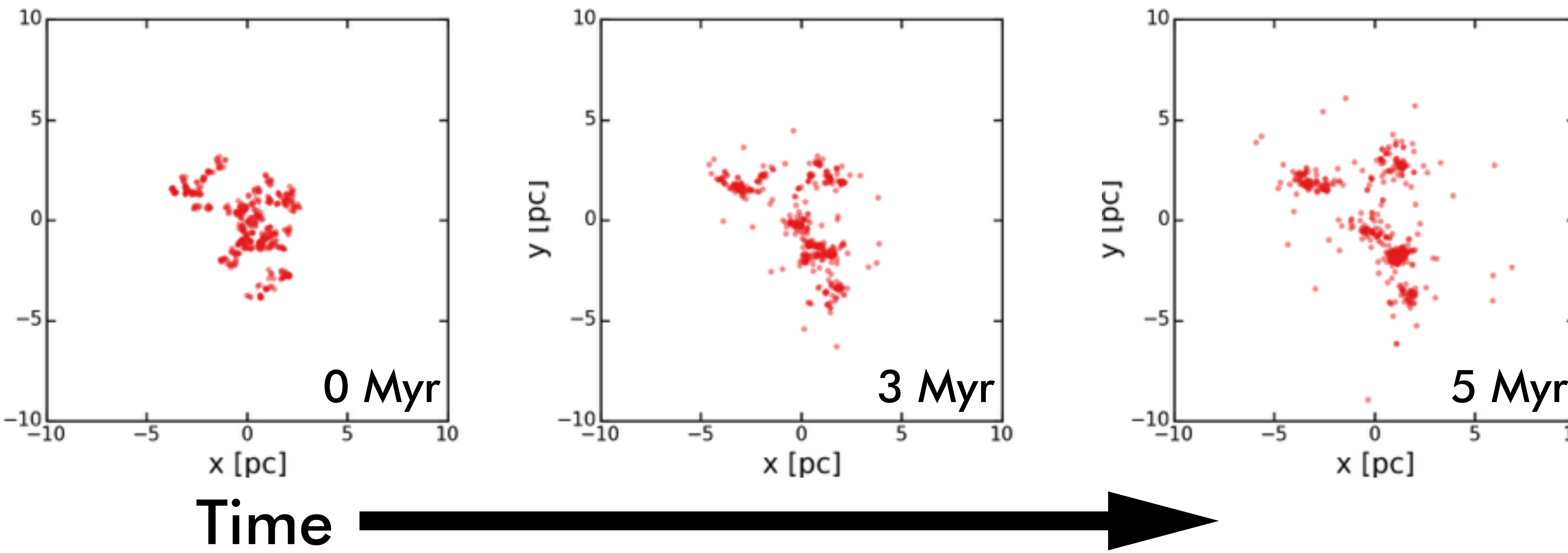
See an application in poster D6 by Difeng Guo

Detailed description of the method: Lindegren et al. (2000), de Bruijne (1999)

Gaia as a tool to detect sparse populations

Chamaeleon I-like cluster

($N_\star=400$, $t_{sim}=5$ Myr, $R=2$ pc, $\alpha_{vir}=0.4$, $f_{bin}=0.2$, $D=1.6$)



Zari, Manara, Brown, de Bruijne, Jilkova

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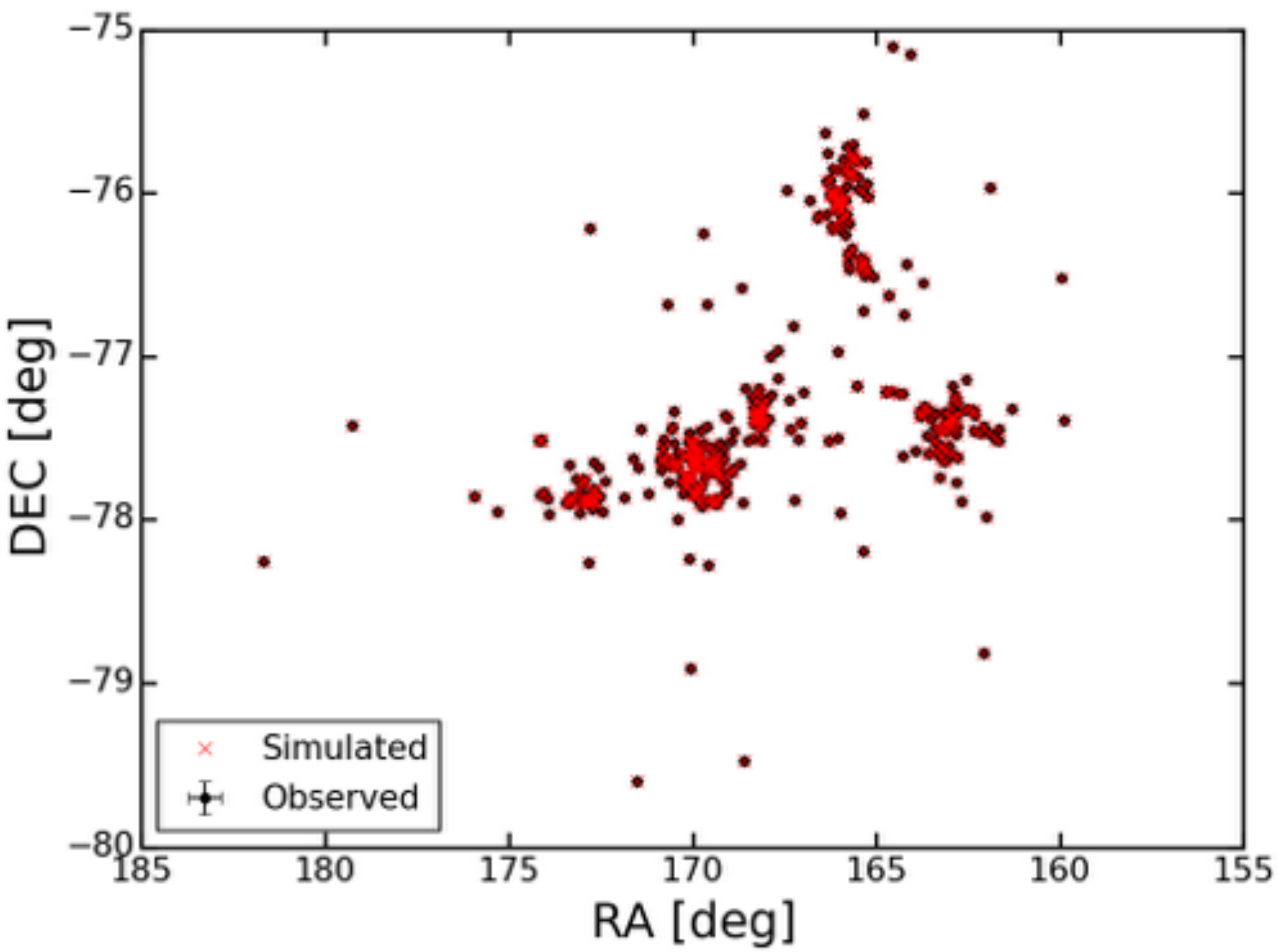
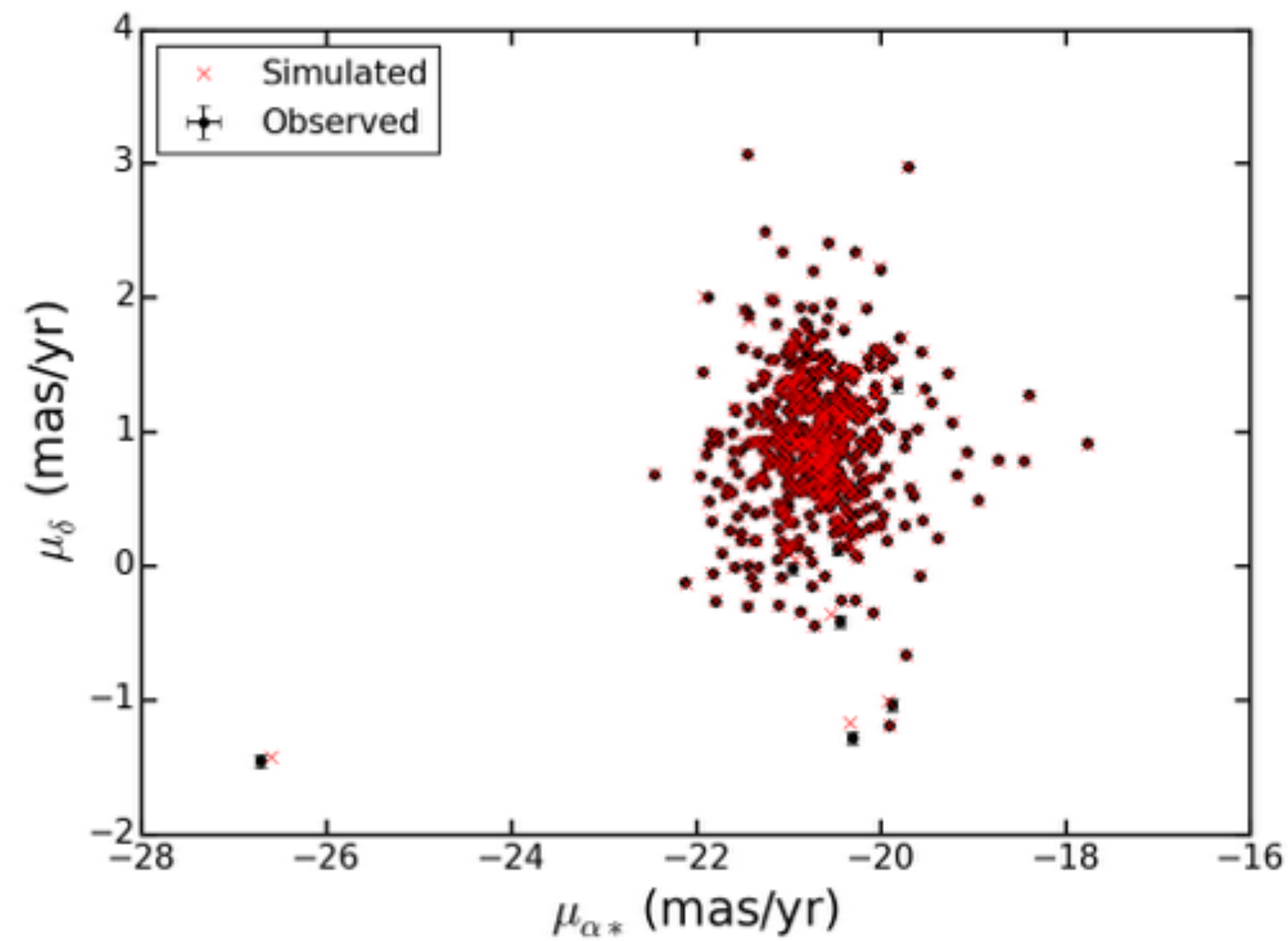
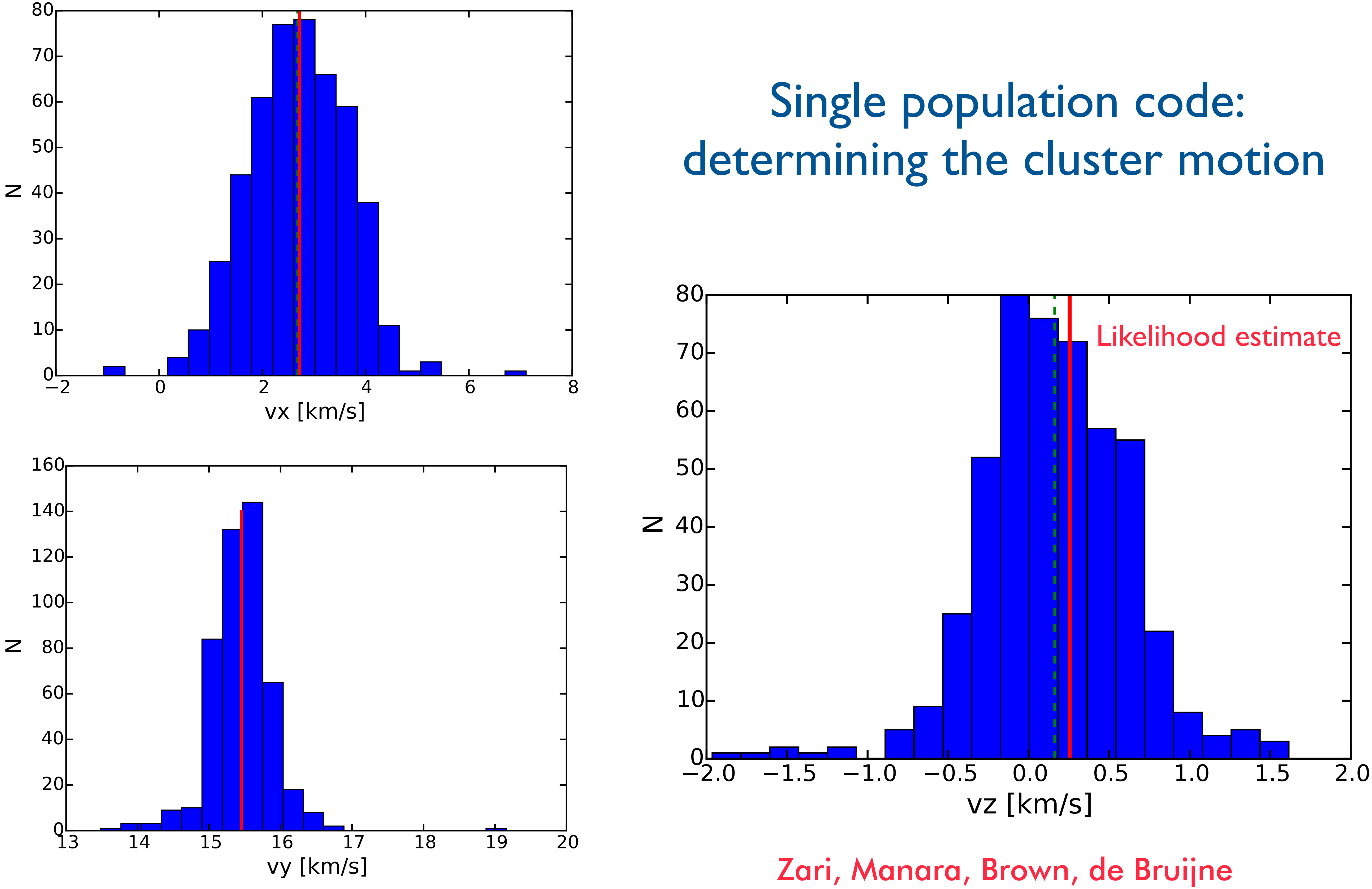
Simulate observation with Gaia (G, V-I, α, δ, π, μ_α, μ_δ)





Zari, Manara, Brown, de Bruijne, Jilkova

Gaia and young clusters: kinematical modelling

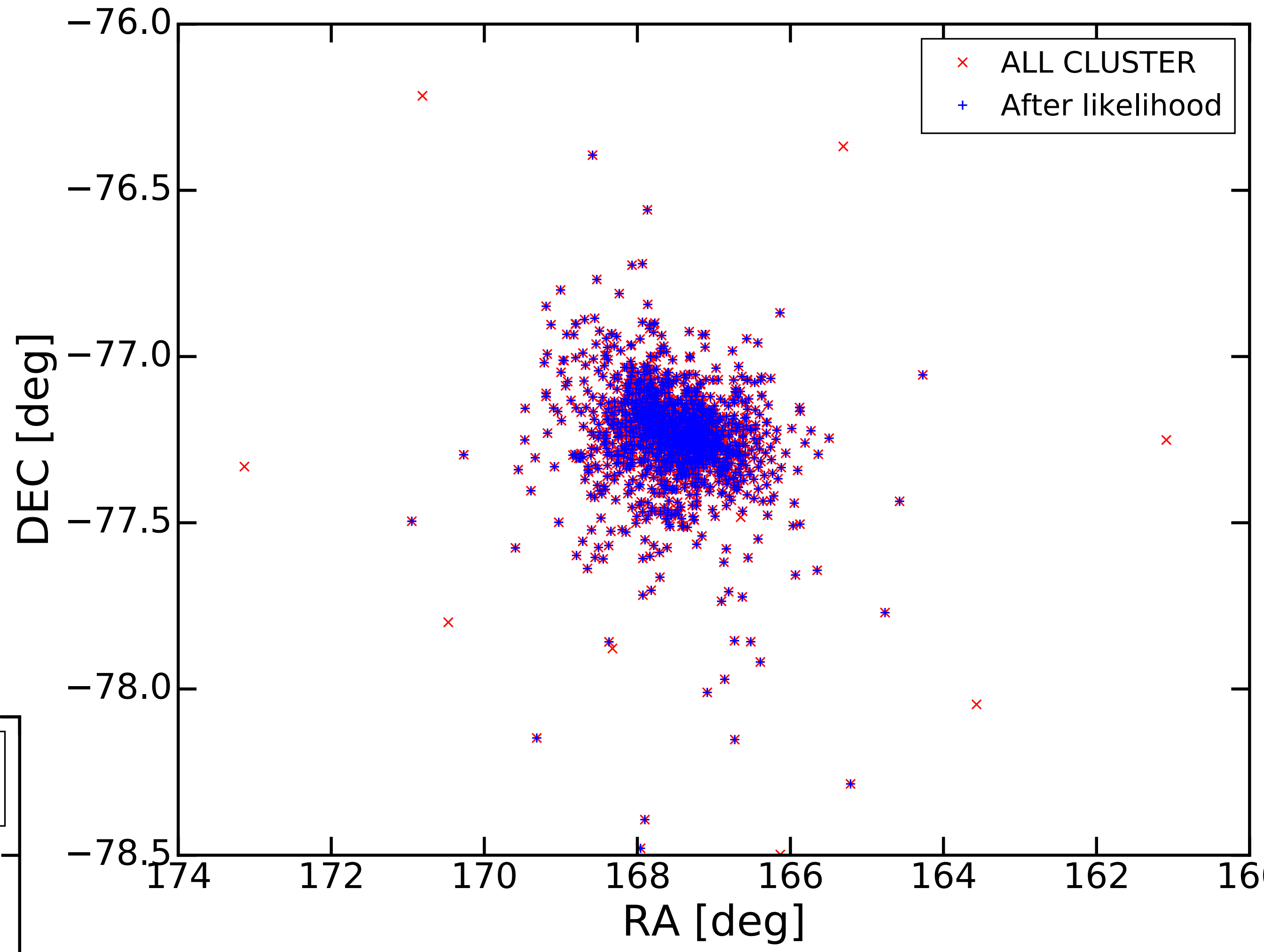


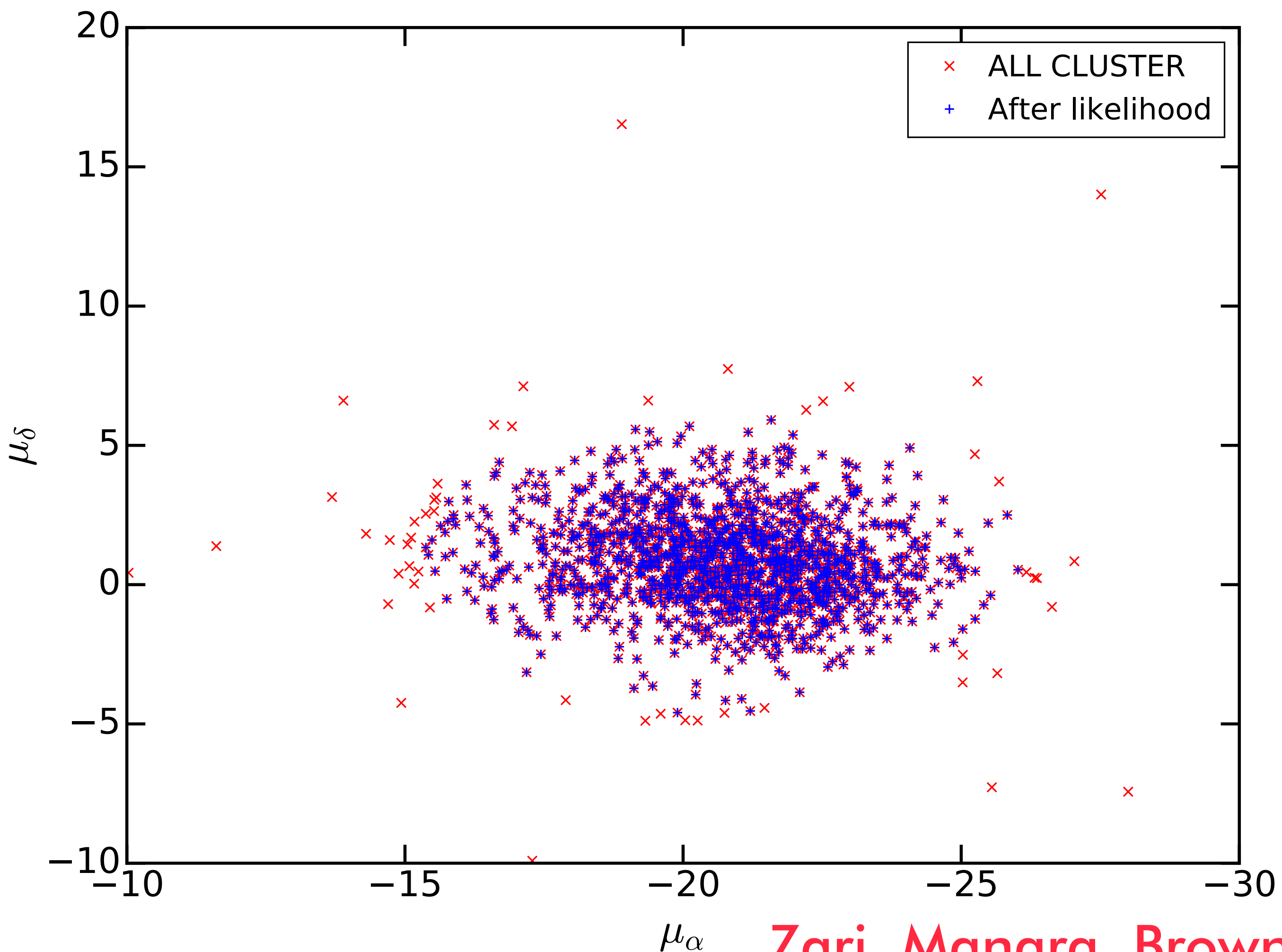
Single population code: determining the cluster motion

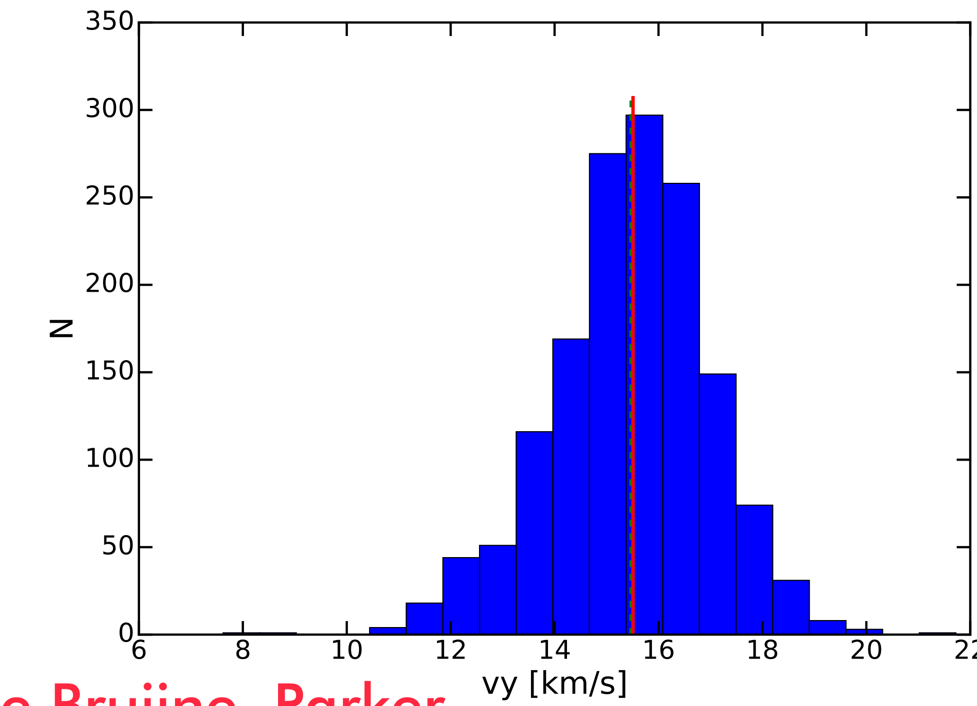
Zari, Manara, Brown, de Bruijne

Gaia and young clusters: kinematical modelling

Sub-virial model of a star forming region
(Parker et al. 2014)

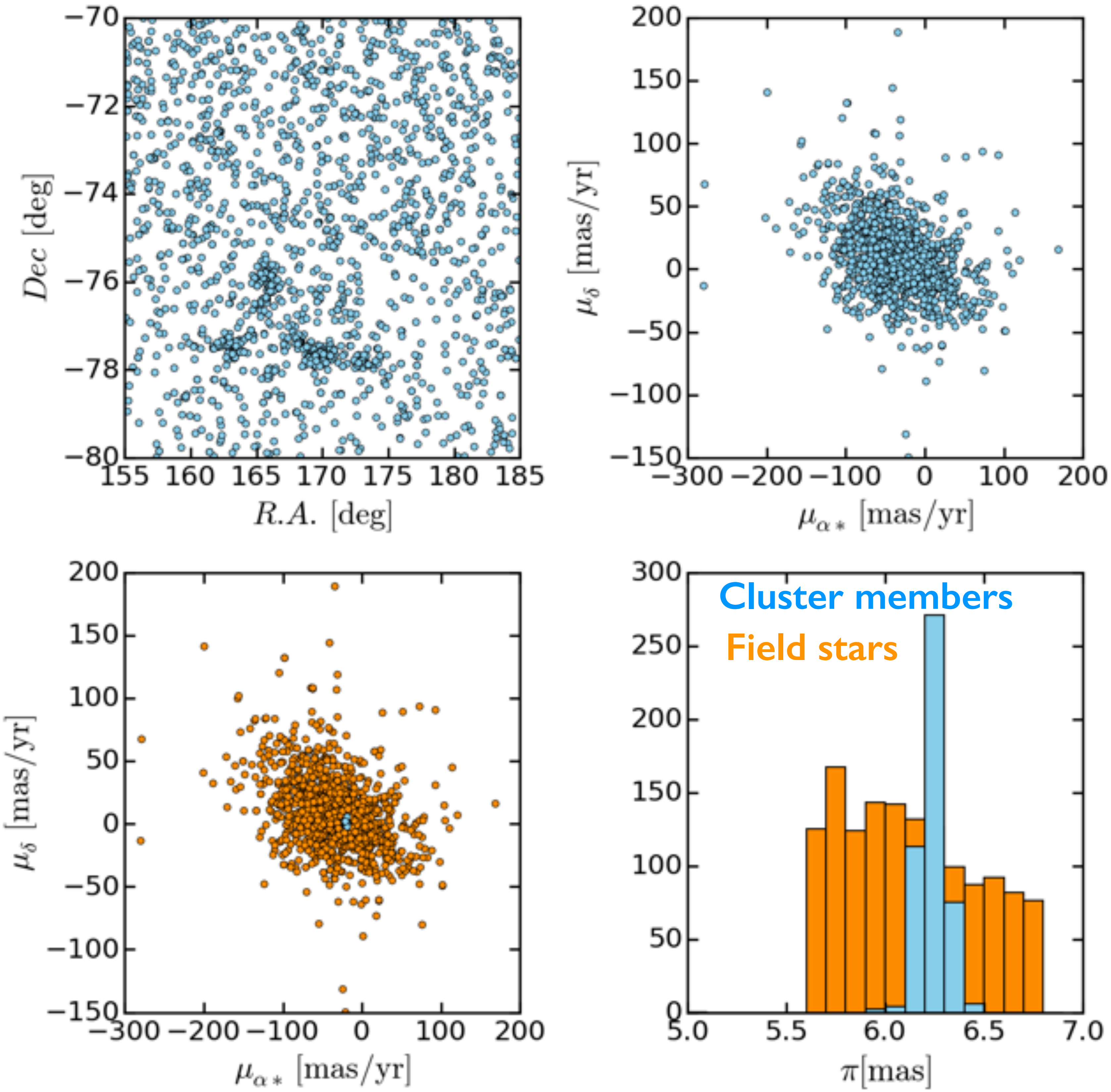






Zari, Manara, Brown, de Bruijne, Parker

Cluster+field code: assigning membership to cluster stars



Zari, Brown, Manara, de Bruijne

>95% of cluster members recovered, <5% false positive

TAKE HOME

1

Gaia DR1:
Refined distance and 3D structure of the Chamaeleon region

2

Gaia DR2:
Kinematic-based membership in nearby young stellar clusters to test disk evolution

Carlo Felice Manara (ESA/ESTEC)