
Young Stellar Associations

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-
1. History
 2. Identification method
 3. Currently known members
 4. Missing members
 5. Challenges toward a full census
 6. Future

Background

- Unbound star forming group will disperse over time.
- Δv of 1 km/sec $\rightarrow$ over 1 Myr $\rightarrow$ about 1 pc.
- About 10Myr old stellar group with an initial dispersion of about 3 km/sec $\rightarrow$ about 30pc in size!



Young Associations

Cluster

- gravitationally bound
- 1-2pc scale
- > 100 members
- overdensity of stars



Association

- gravitationally unbound
- > 10 pc scale
- 10-100 members
- no overdensity



Identification of moving groups and their

1. Proximity in space
2. Co-eval
3. Co-moving



History

- TW Hydrae Association (TWA)
 - An unusual grouping of IRAS sources around TW Hydrae was noticed by de la Reza et al. (1989) and Gregorio-Hetem et al. (1992)
 - Then, Kastner et al. (1997) noticed that these stars share similar X-ray and optical properties and form a physical association of about 20pc across.
 - Webb et al. (1999) found six more stars
 - Currently, about 30 known members

30	08131	-4432	CoD-44 4208	7
35	10001	-5857	WRA 488	8
45	(11058	-2946)	Cod-298887	7
47a	11068	-7717	Glass#I	9
47b	11068	-7717	Glass#I	9
50a	11080	-3715	Hen600	7
50b	11080	-3715	Hen600B	7
51	11091	-7716	Glass#Q	9
54	11195	-2430	HD98800	6
55	(11295	-3420)	Cod-337795	7
59	11472	-7934		9
62	12345	-6910		9
64	12535	-7623		9
65	12584	-7621	CM Cha	9
66	13185	-6922		9

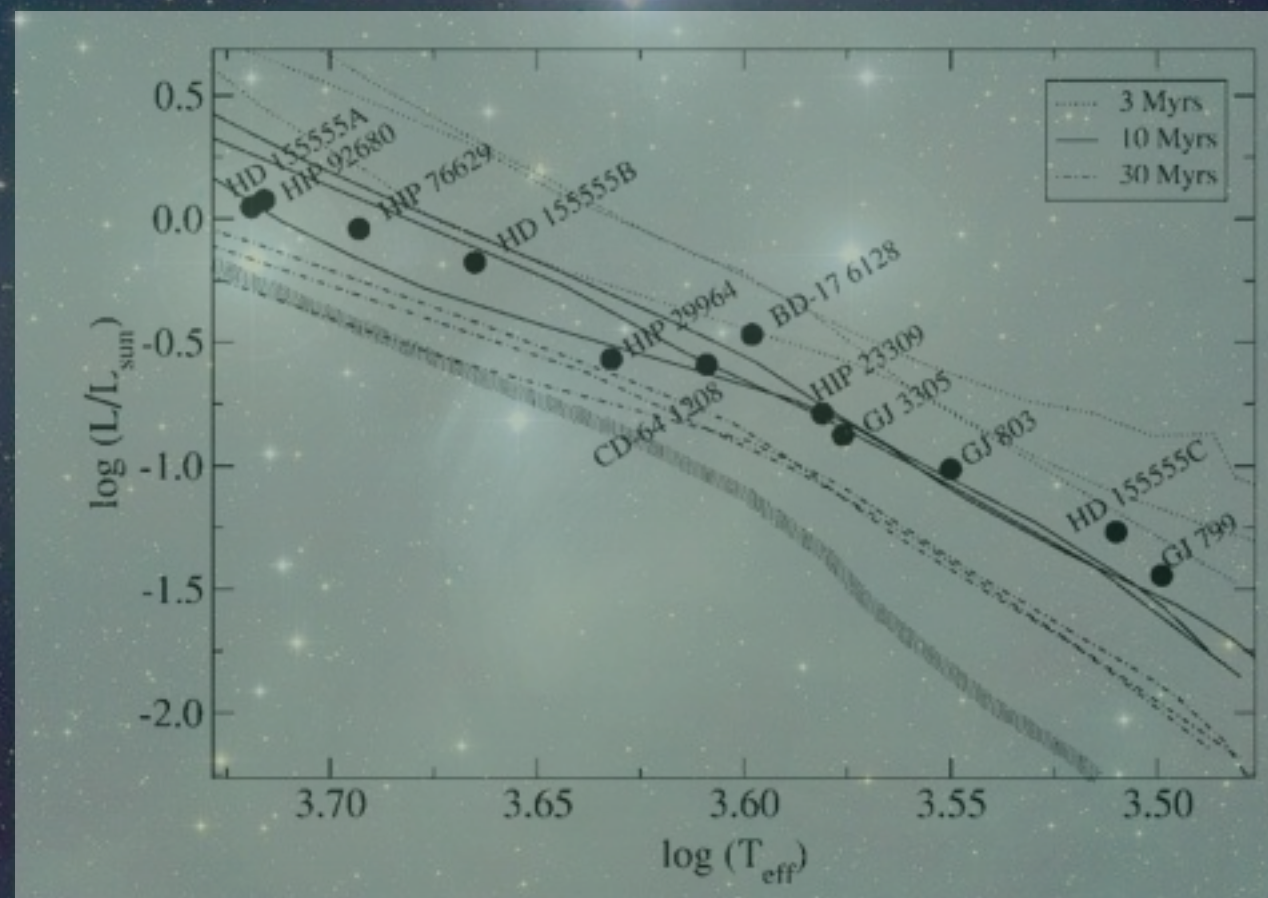
Gregorio-Hetem et al. (1992)

Star	ROSAT name	(a)
TW Hya	1RXP J110152-3442.2	
	1RXS J110152.0-344212	
CoD -29° 8887	1RXS J110913.5-300133	
Hen(3) 600	1RXP J111028-3731.8	
	1RXS J111028.9-373204	
HD 98800	1RXS J112205.4-244632	
CoD -33° 7795	1RXS J113155.7-343632	

Kastner et al. (1997)

History

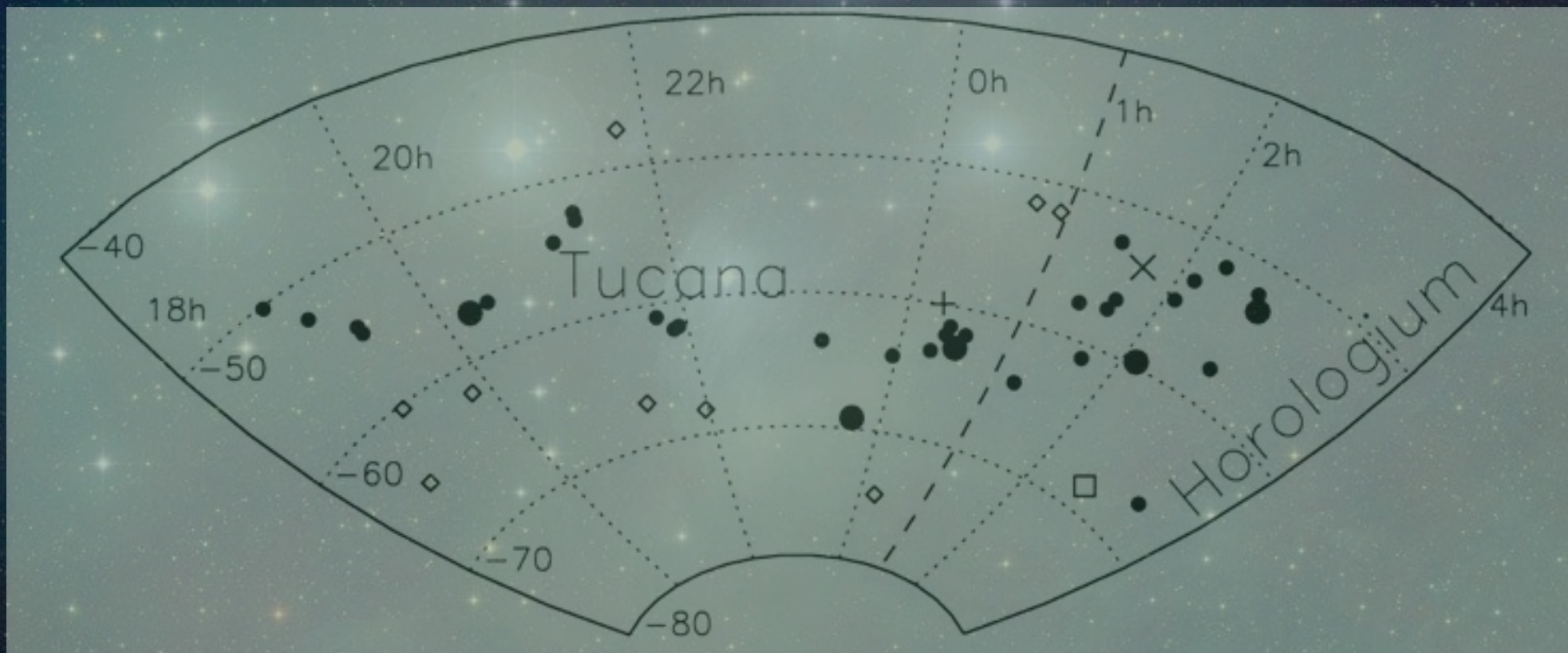
- β Pictoris moving group (BPMG)
 - Barrado y Navascues et al. (1999) discovered that β Pic shares the same Galactic motion with the group of AT Mic and AU Mic (Poveda et al. 1994)
 - Zuckerman et al. (2001) extended the membership list to a total of 17 star systems.
 - Song, Zuckerman, & Bessell (2003) added 10 more members



Zuckerman, Song, Bessell, & Webb (2001)

History

- Tucana + Horologium Association (TucHor)
 - Zuckerman & Webb (2000) discovered Tucana Association
 - Torres et al. (2000) discovered Horologium Association
 - Zuckerman, Song, & Webb (2001) noticed these two form a single group
 - Song, Zuckerman, & Bessell (2003) added 11 more members
 - ...



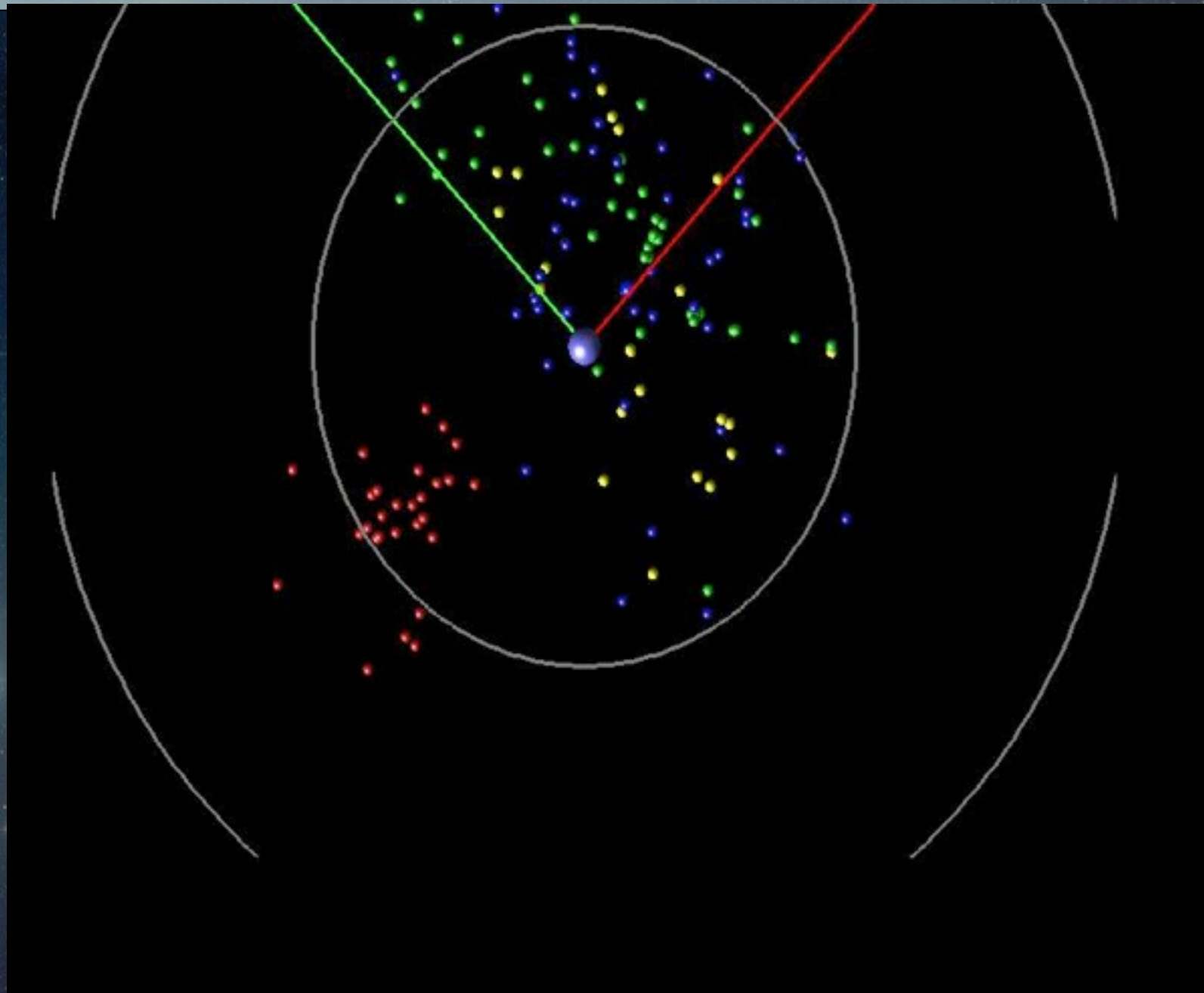
Zuckerman, Song, & Webb (2001)

History

- Columba, Carina, Argus, AB Doradus groups are identified subsequently.

Currently known young (≤ 100 Myr) nearby stellar associations				
Name	Age (Myr)	UVW	Dist. (pc)	# of members
TWA	~8	-9, -18, -4	~50	~30
β Pic	12-20	-11, -16, -10	~40	~40
TucHorA	~30	-10, -21, -1	~50	~50
Columba	~30	-12, -21, -6	~60	~20
Carina	~30	-11, -22, -6	~70	~15
Argus	~50	-22, -12, -4	~40	~20
AB Dor	50-120	-7, -27, -14	~40	~50
...more...	10-200	varies	varies	100+

Distribution of young MG members



● β Pic group

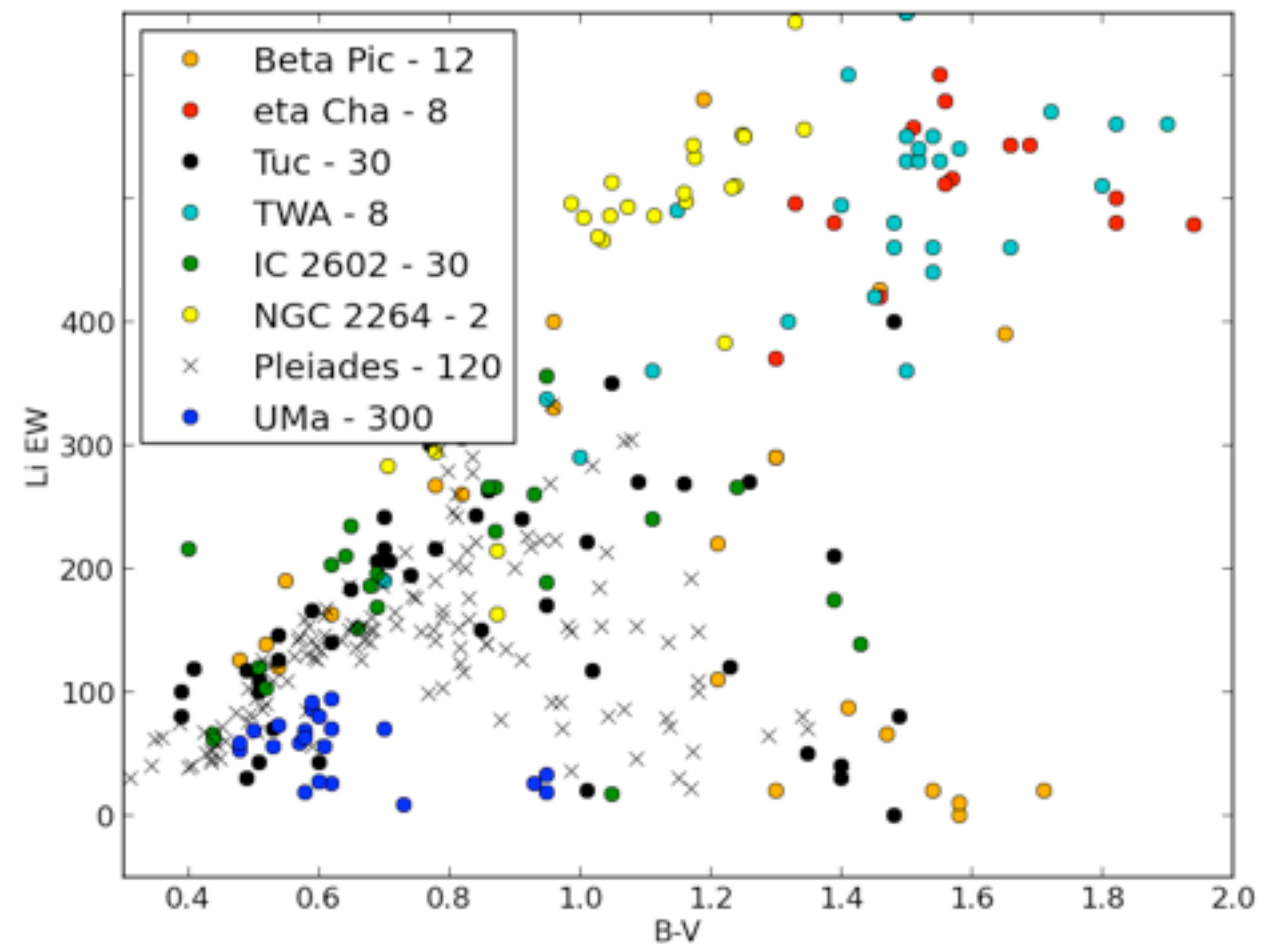
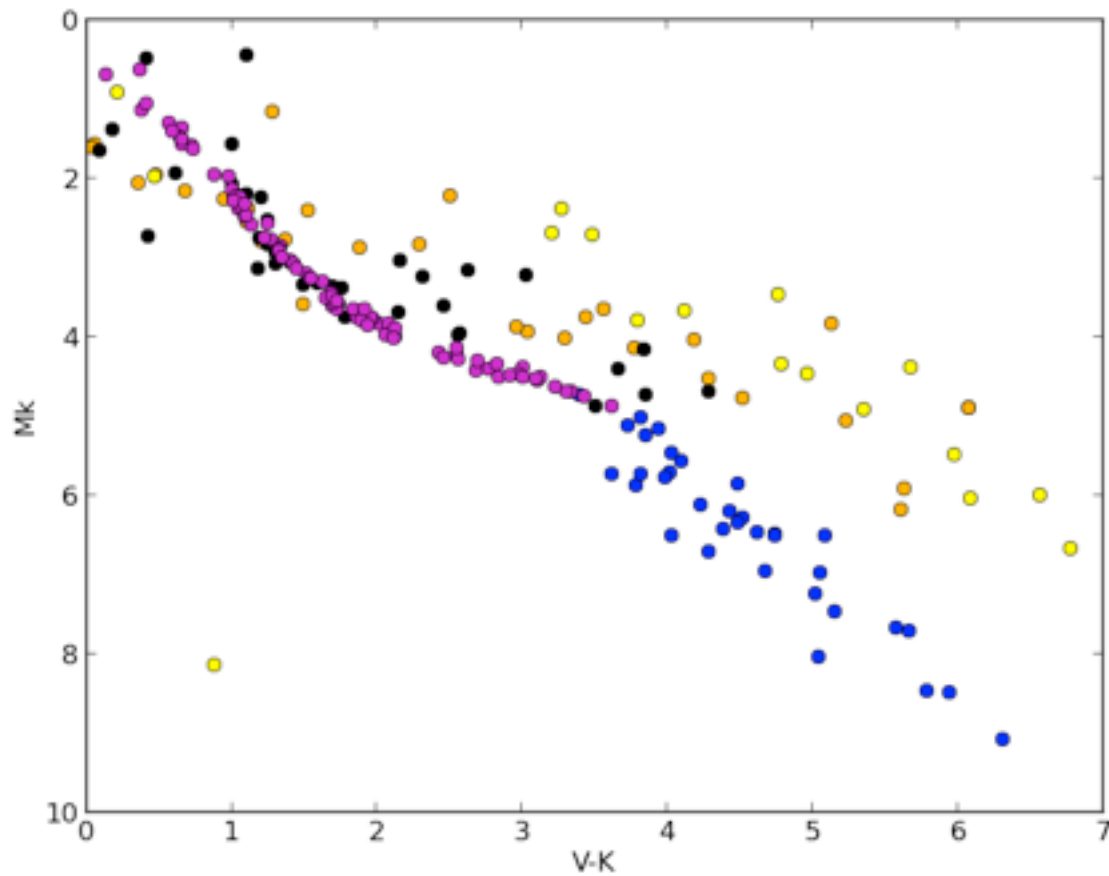
● TWA

○ 50 & 100 pc

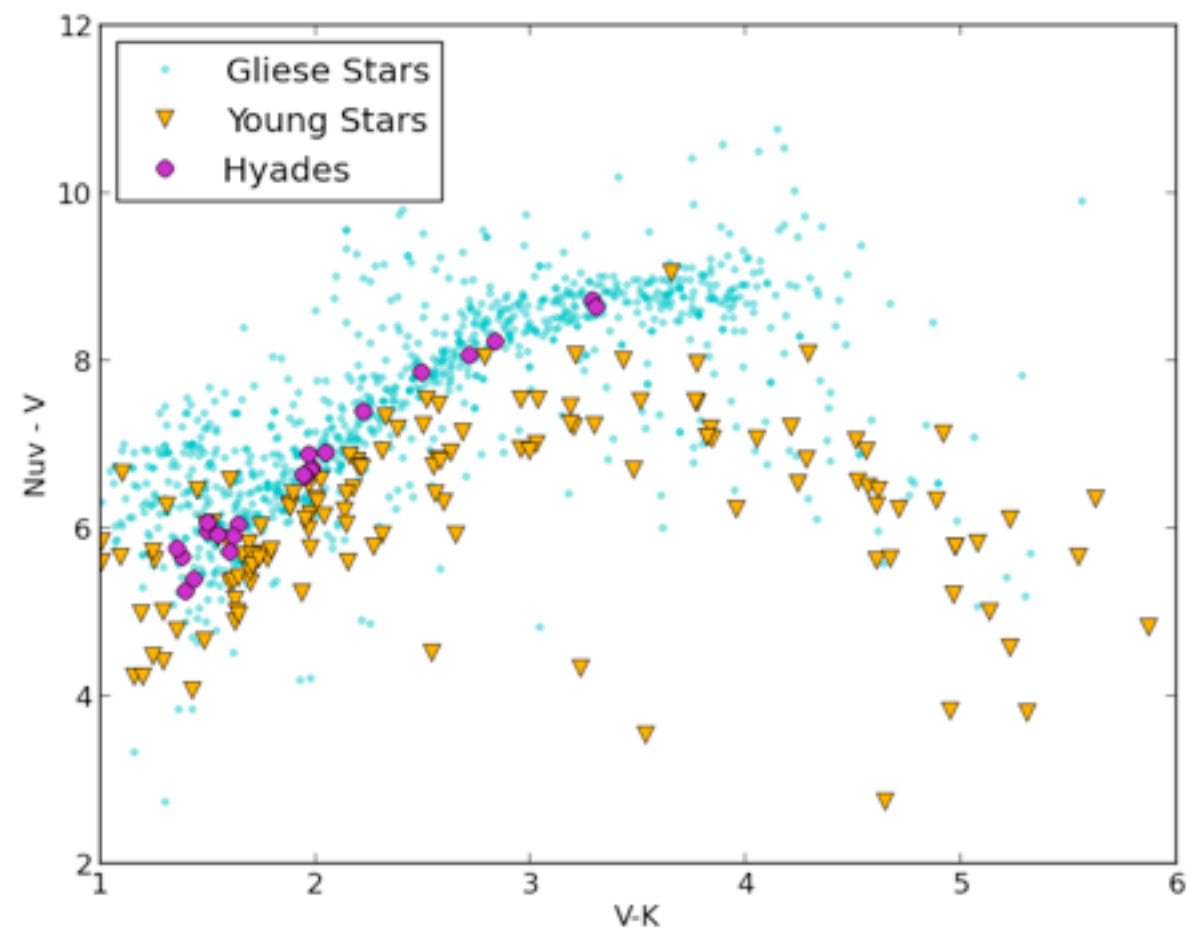
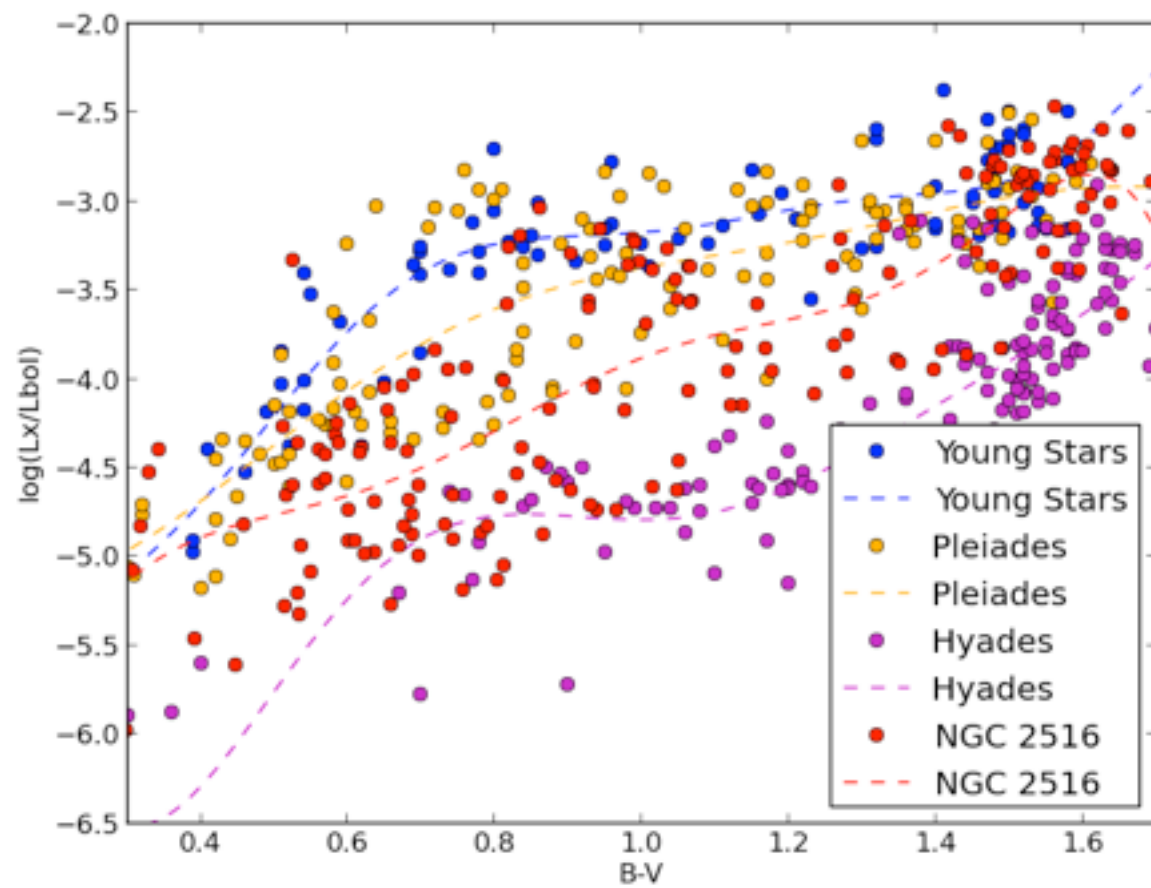
● Tucana/HorA

● AB Dor group

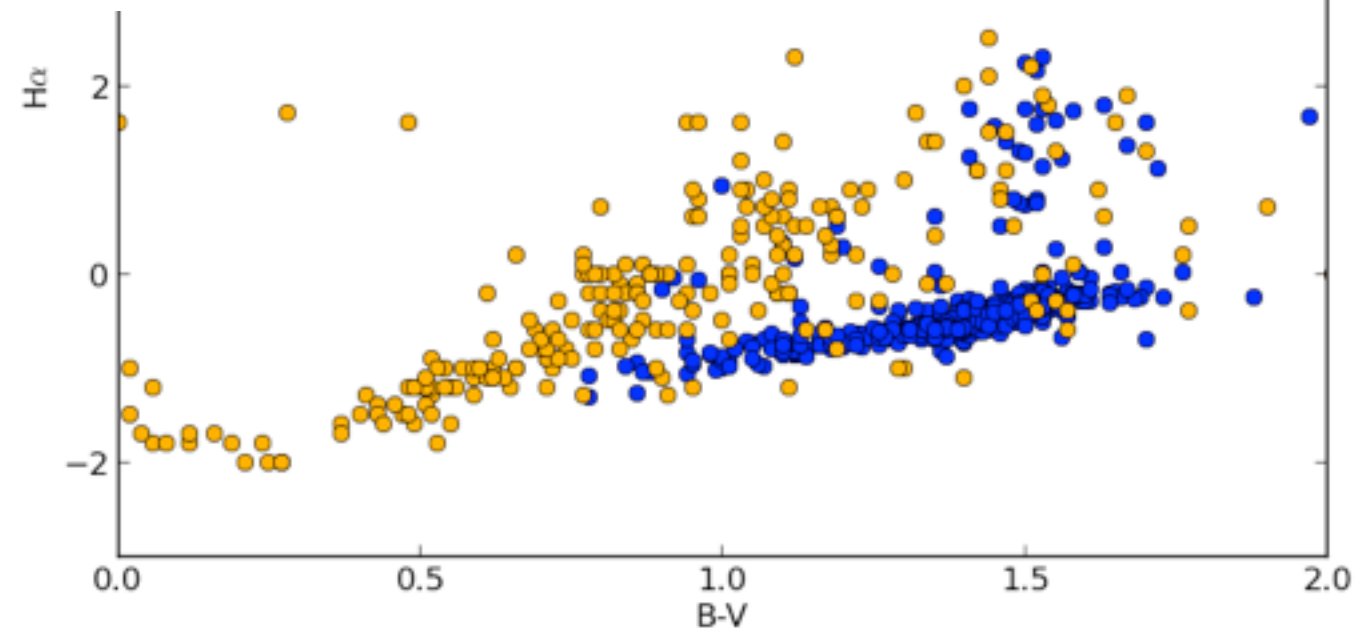
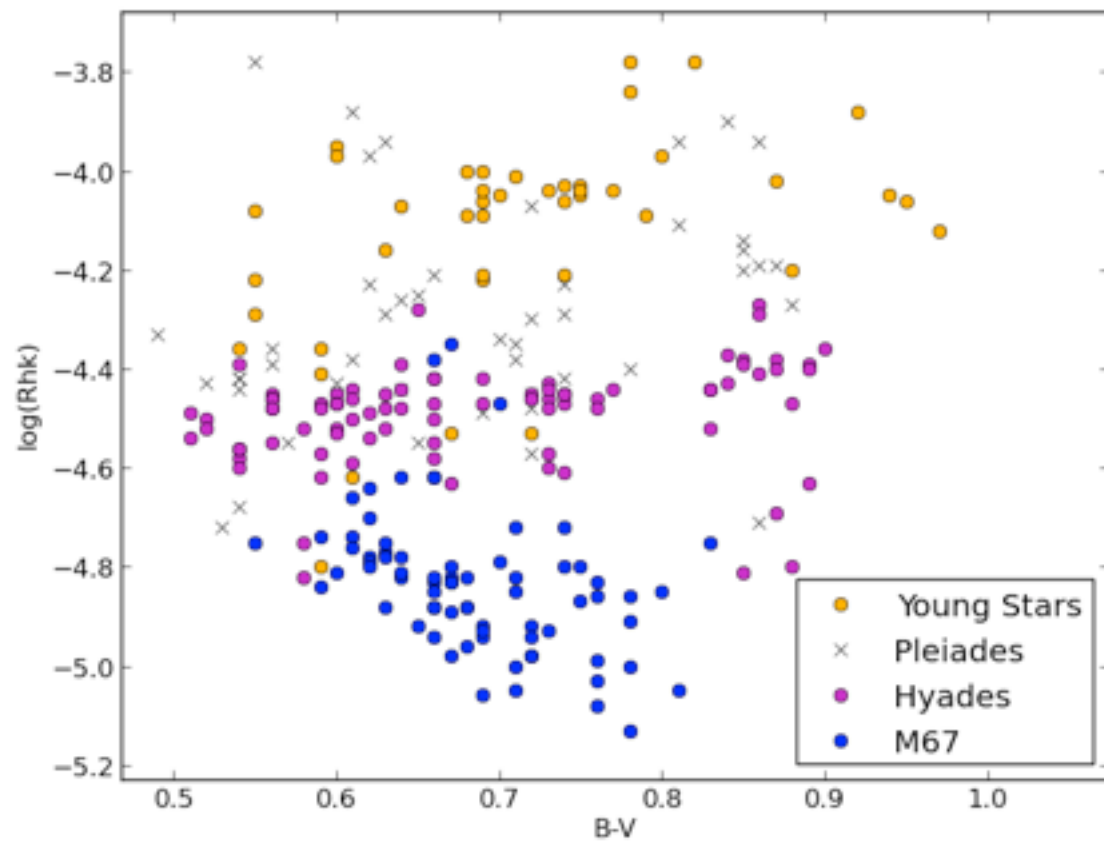
Distribution of members



Distribution of members

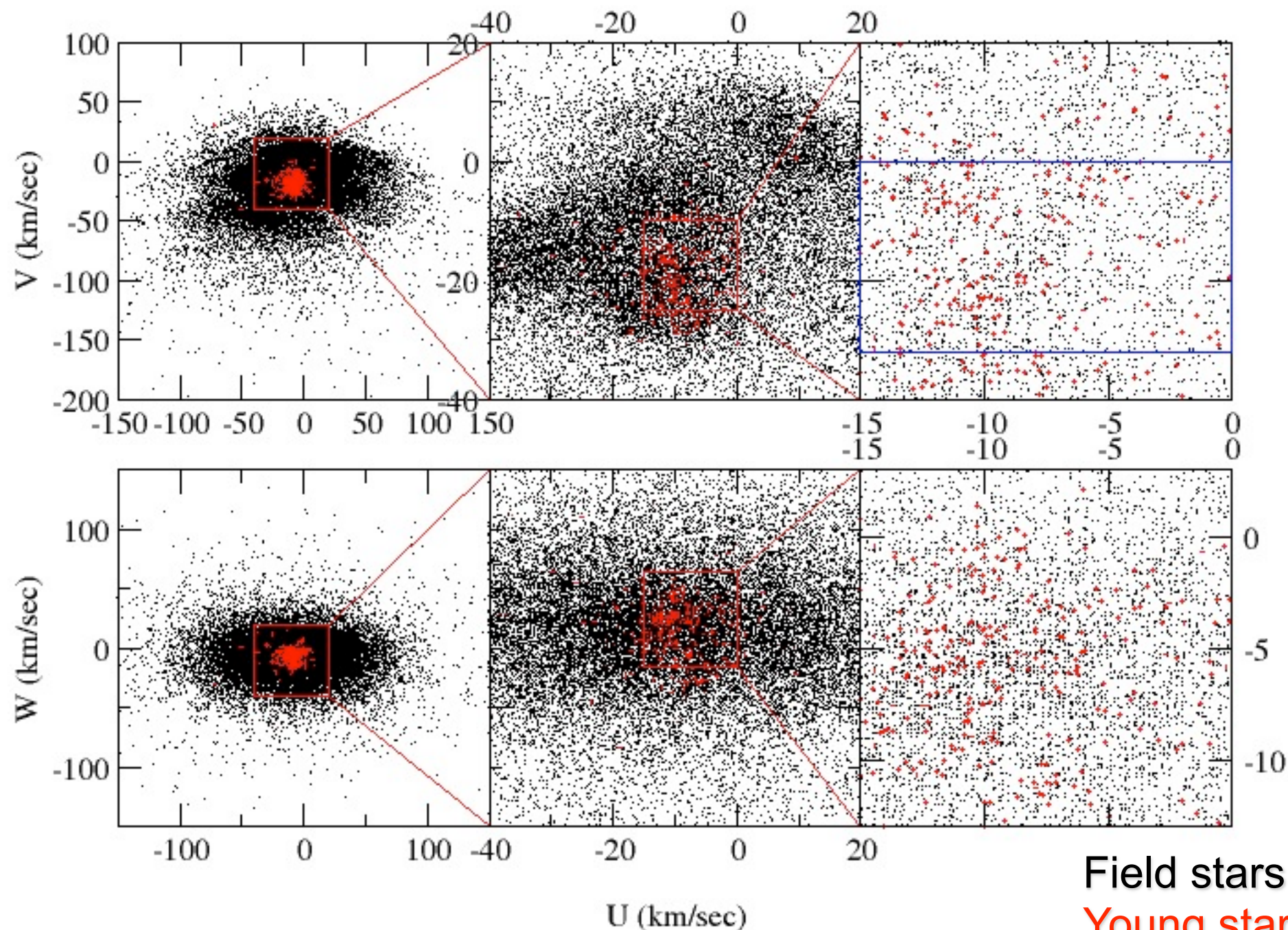


Distribution of members



Space Motions

Hipparcos Stars with measured RV from XHIP (N=32958)



Is the young stars' UVW box special?

Age-Dating Methods

Age (Myr)	Spectral Type				
	BA	F	G	K	M
10	A-ZAMS	A-ZAMS,Li	Li,X-ray	Li, CMD, Ha	Li, logg,CMD
50	A-ZAMS	Li,X-ray	Li,X-ray	Li, CMD, Ha	logg?, CMD
100	-	Li,X-ray	Li,X-ray	Li, X-ray	logg?,CMD
500	CMD	-	Li,Call HK	X-ray	-
>1000	CMD	CMD?	Call HK	X-ray?	-

- UVW, vsini, etc. can be used also, but not as decisive as the above methods.
- Of course, a companionship to a well age-dated star helps!

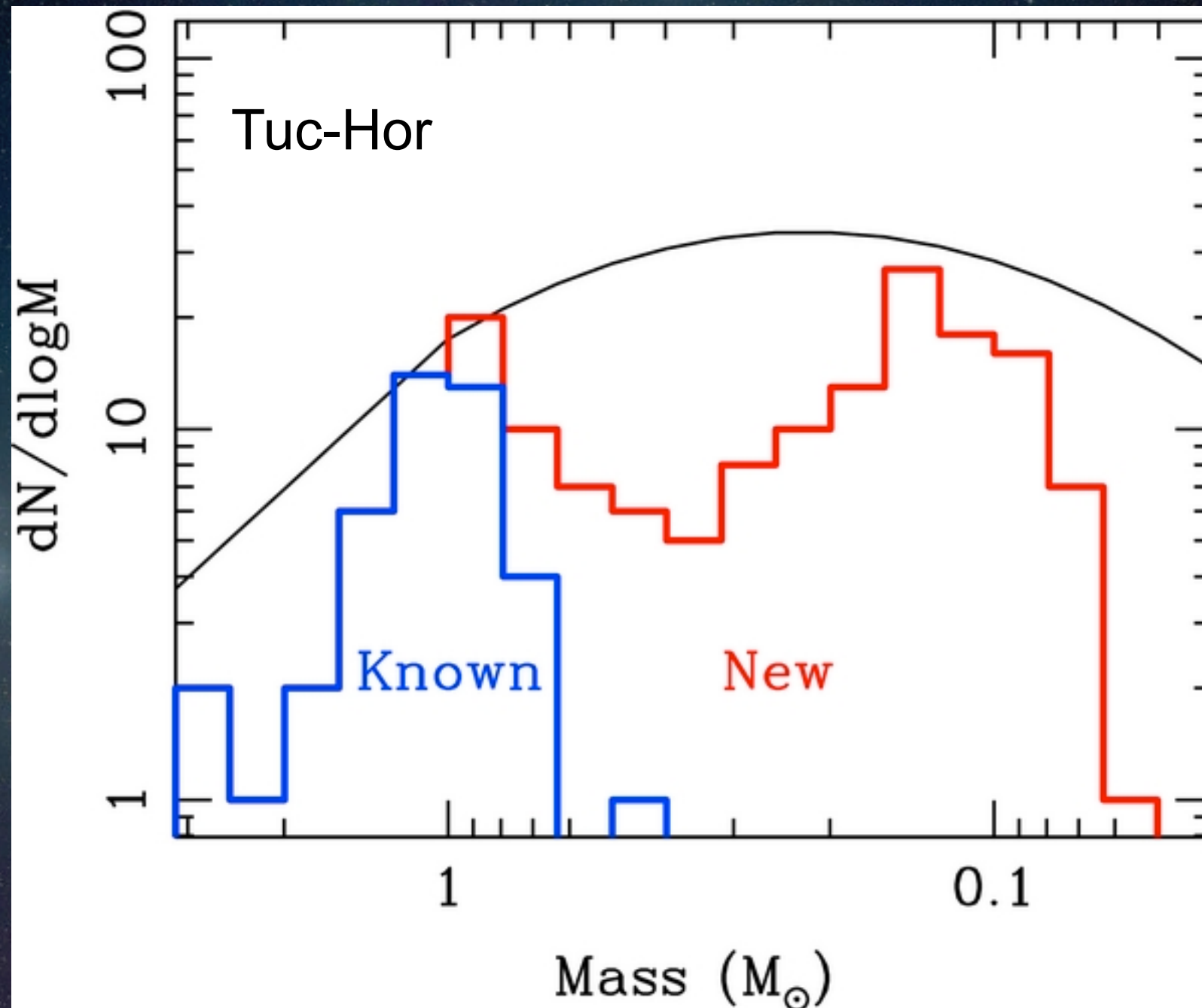
Well
constrained

Reasonably
constrained

Poorly or not
constrained

Distributions of members

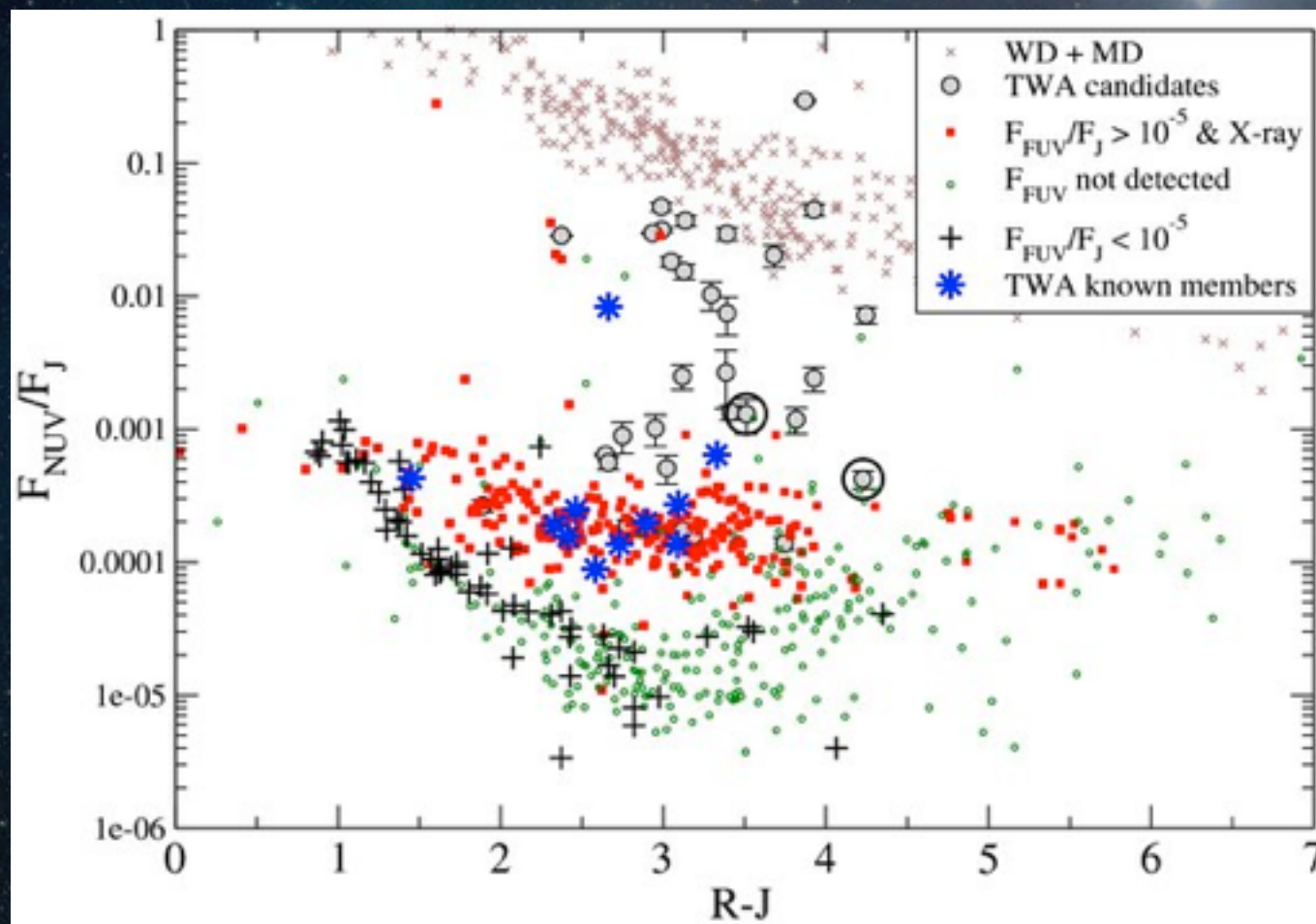
- Many missing low mass members compared to the field star MF.



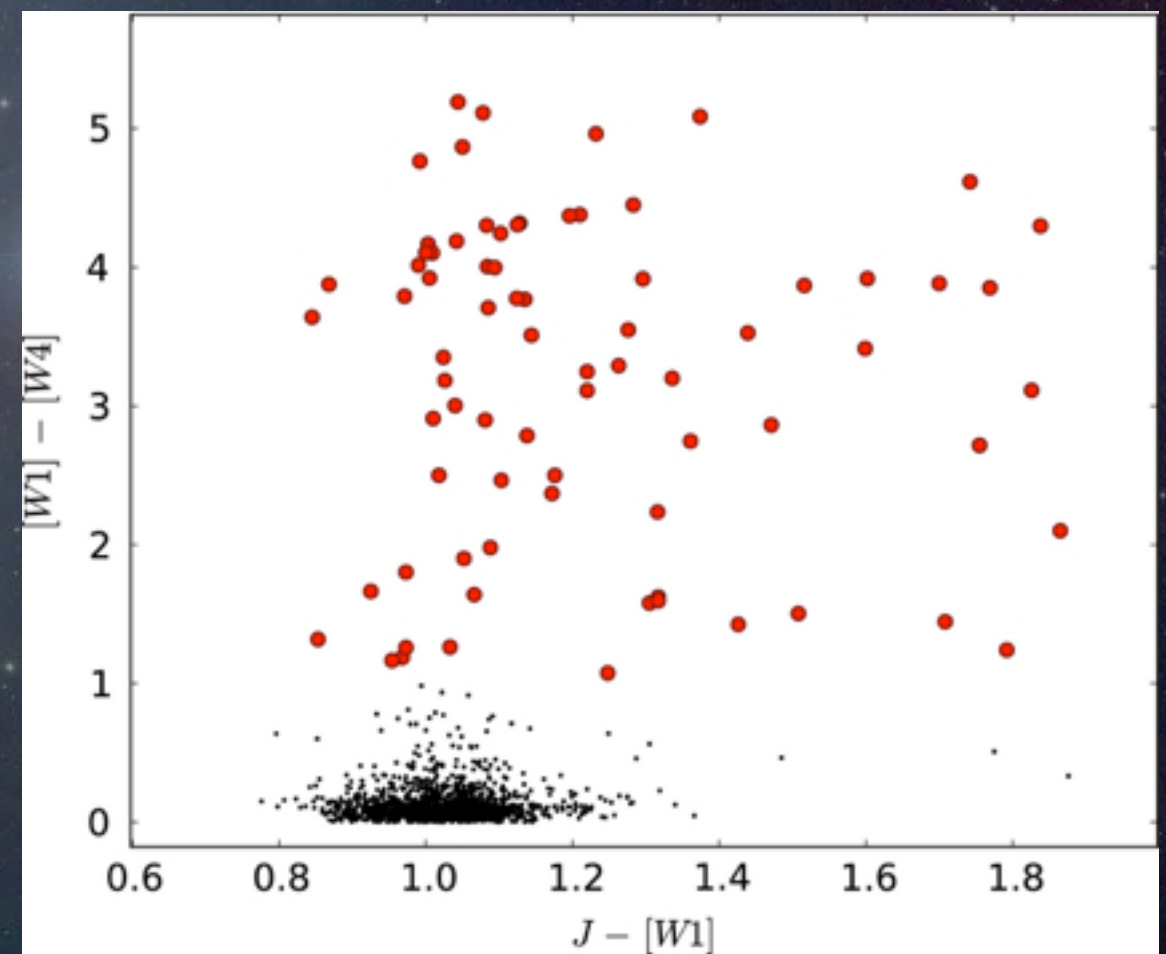
Kraus et al. (2014, AJ)

Identification of low mass members

- Previous candidate selections were limited by ROSAT
- Improved selections of M-type candidates using GALEX & WISE
- Main Difficulty → there is no good age-dating methods for pTTS (> 10Myr) M-type stars



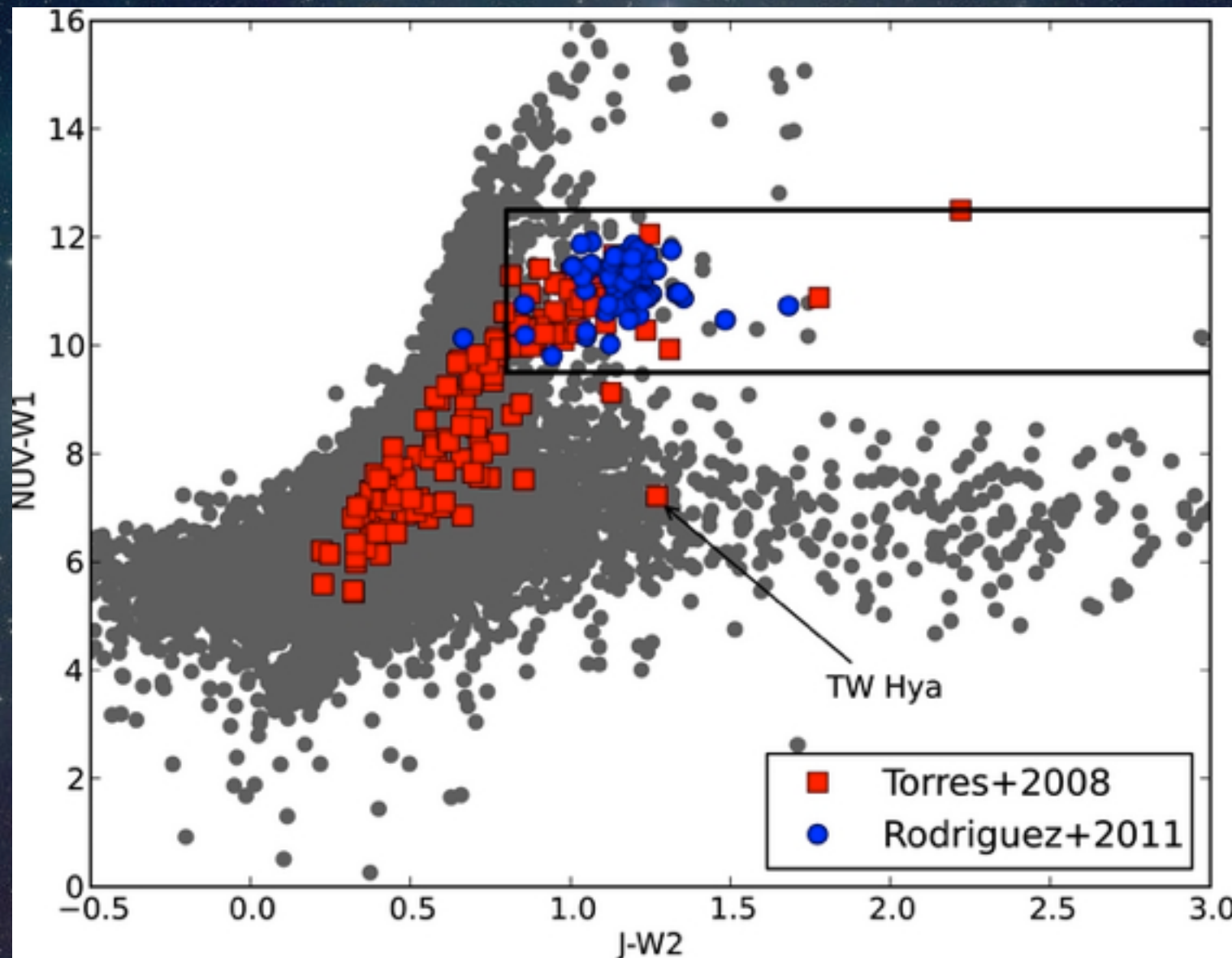
Shkolnik et al. (2011)



Schneider et al. (2013)

Notable New Surveys

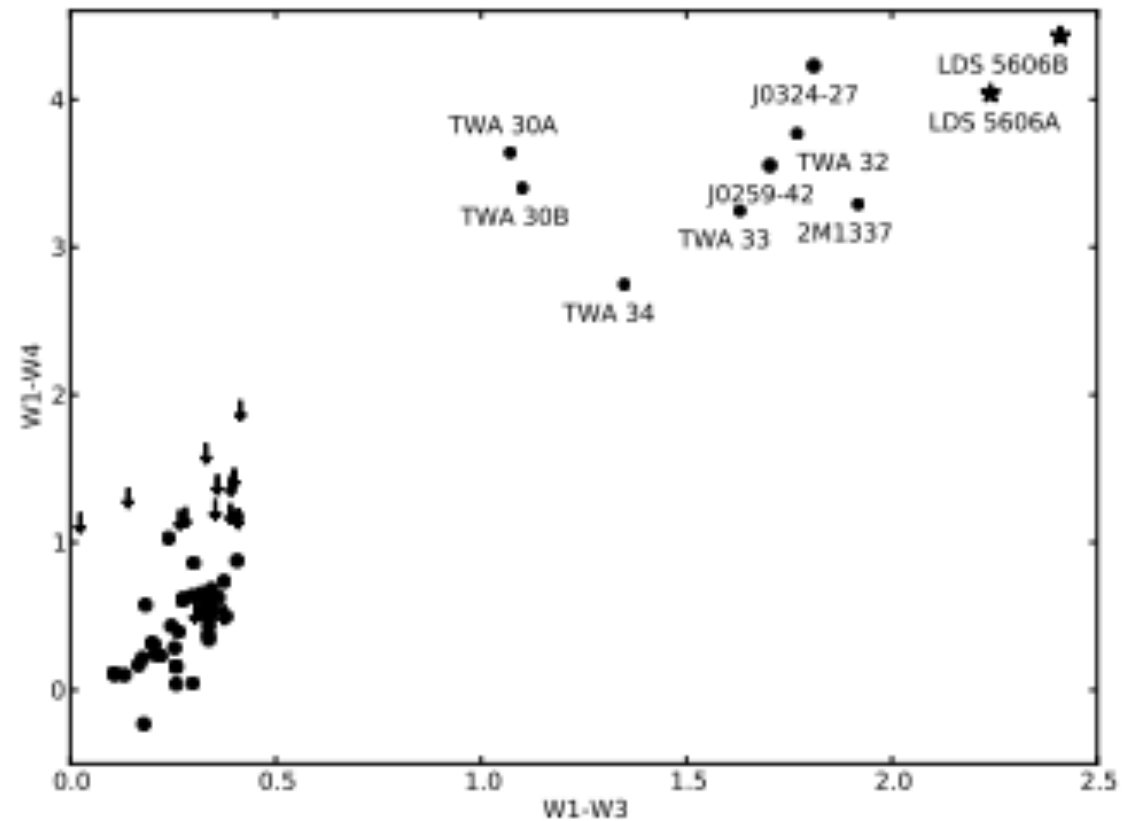
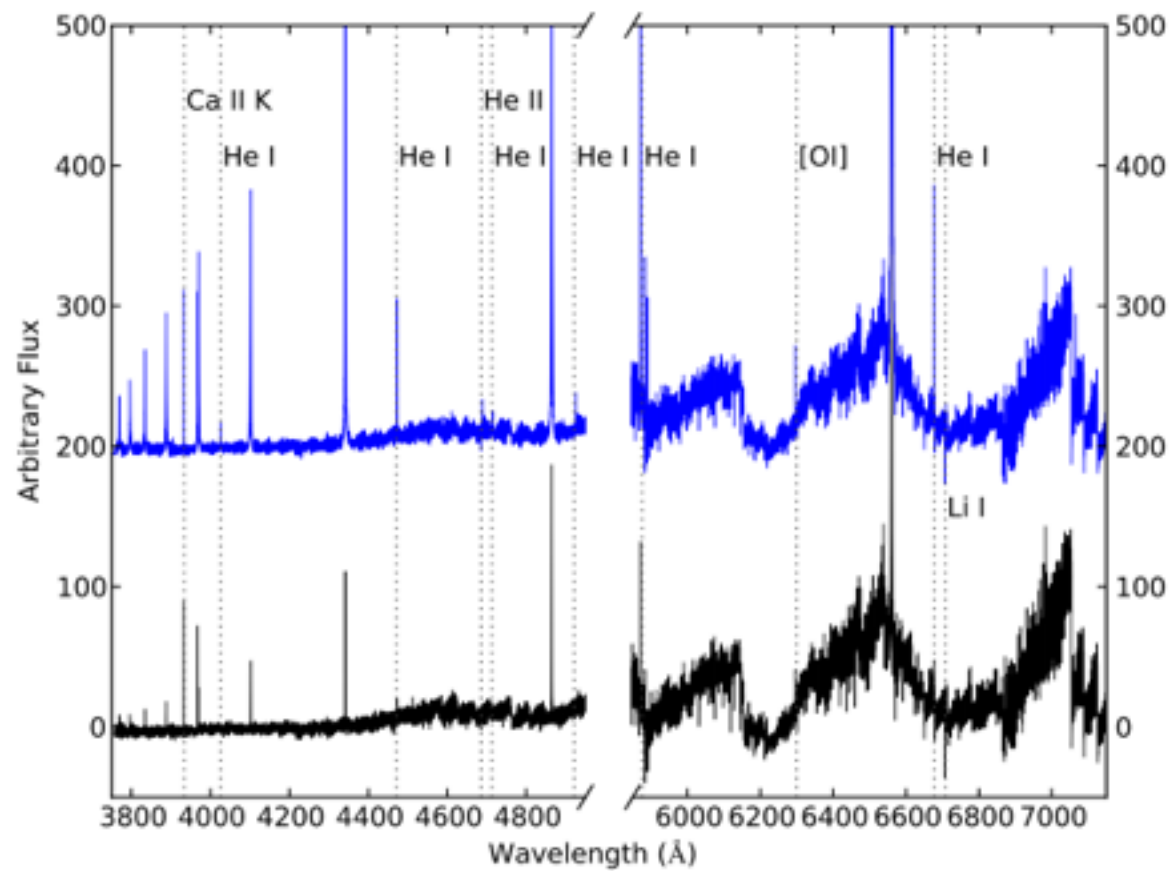
- Malo et al. (2013) : BANYAN
- Kraus et al. (2014) : SEDistance
- Rodrigues et al. (2013-) : GALNYSS



Rodrigues et al. (2013)

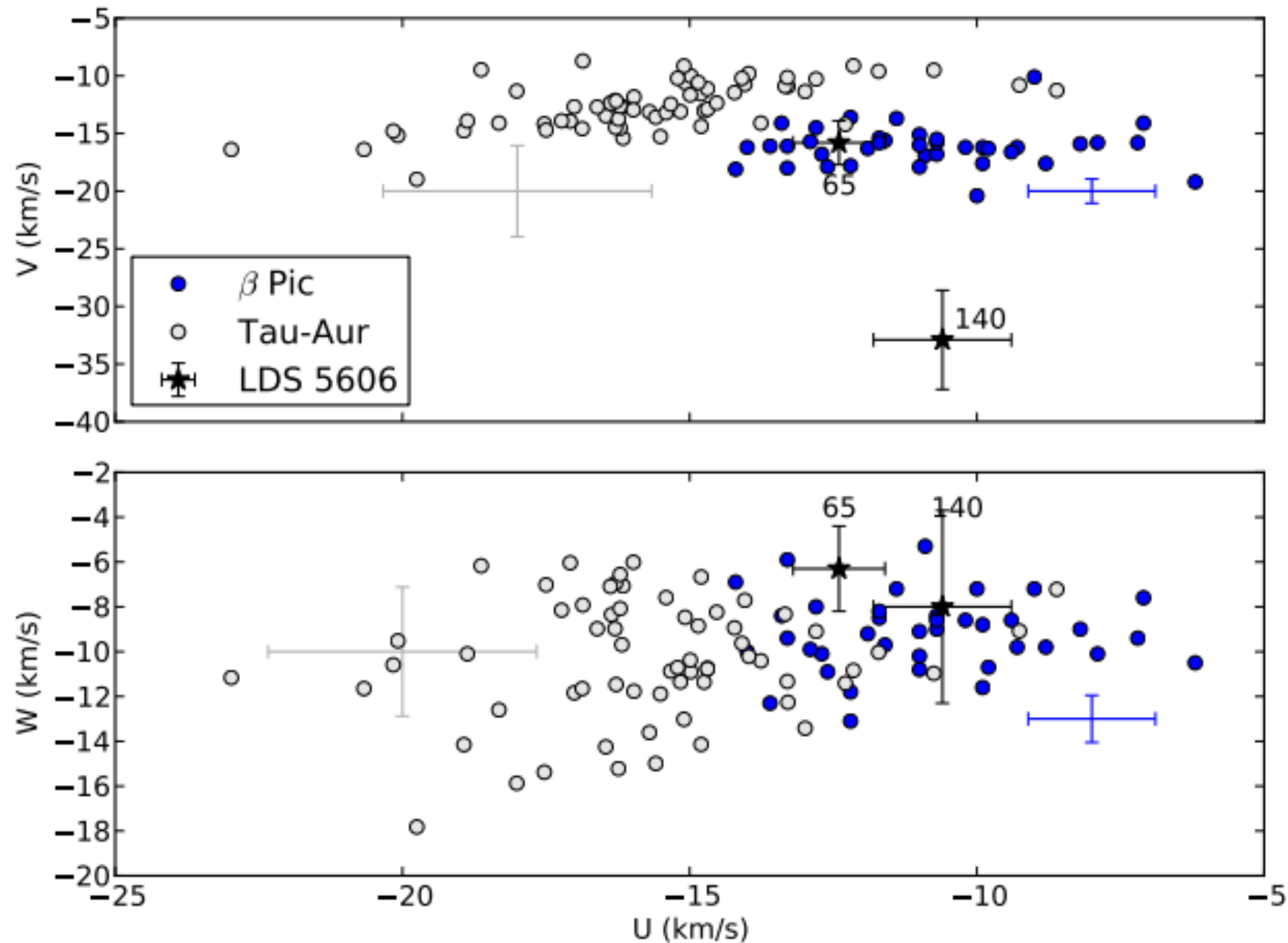
GALNYSS

- LDB 5606 A & B



GALNYSS

- LDB 5606 A & B $\rightarrow$ age + motion $\rightarrow$ new BPMG member



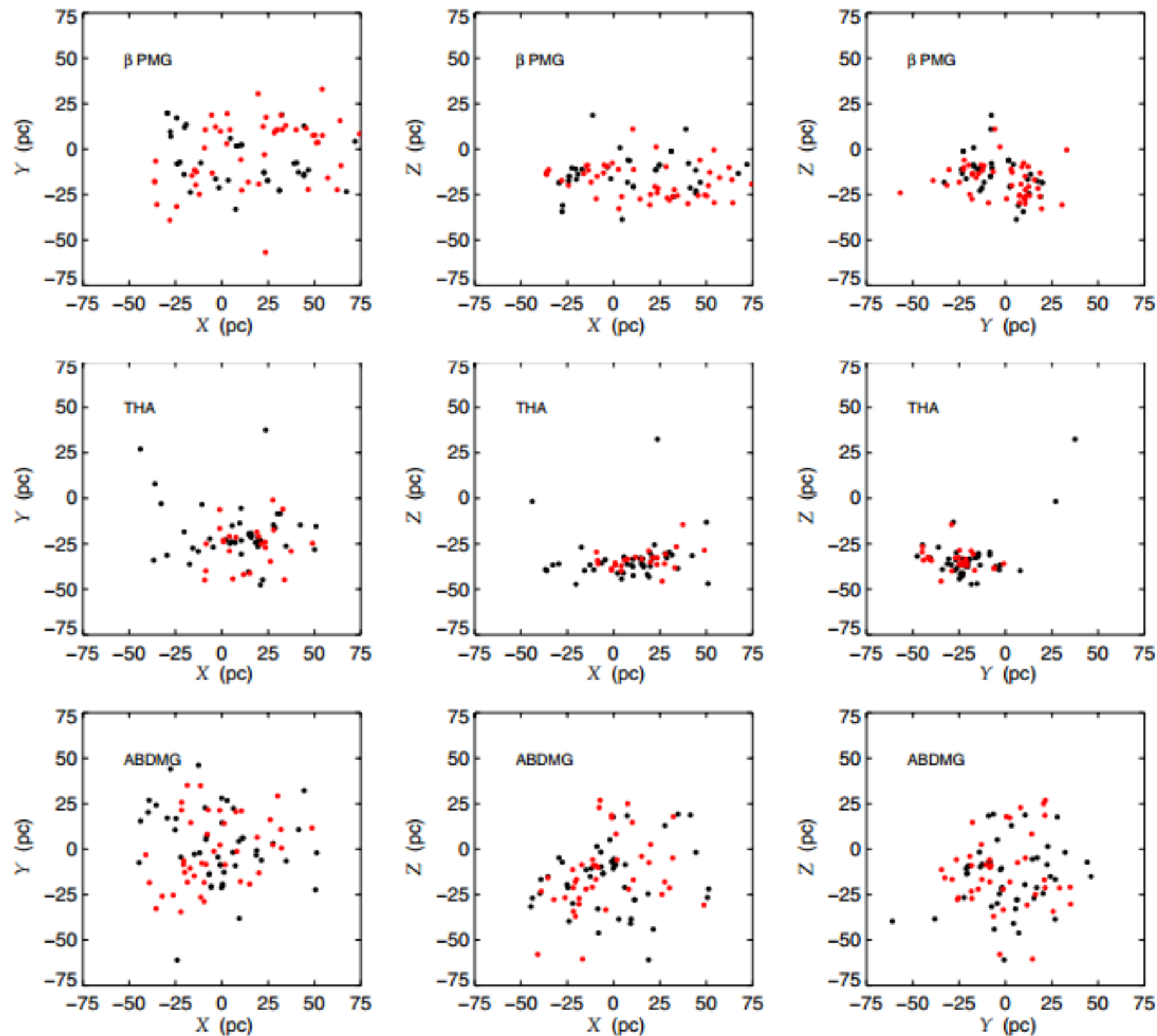
BANYAN

- Malo et al. (2013) : Bayesian approach with known distributions of groups as prior information.

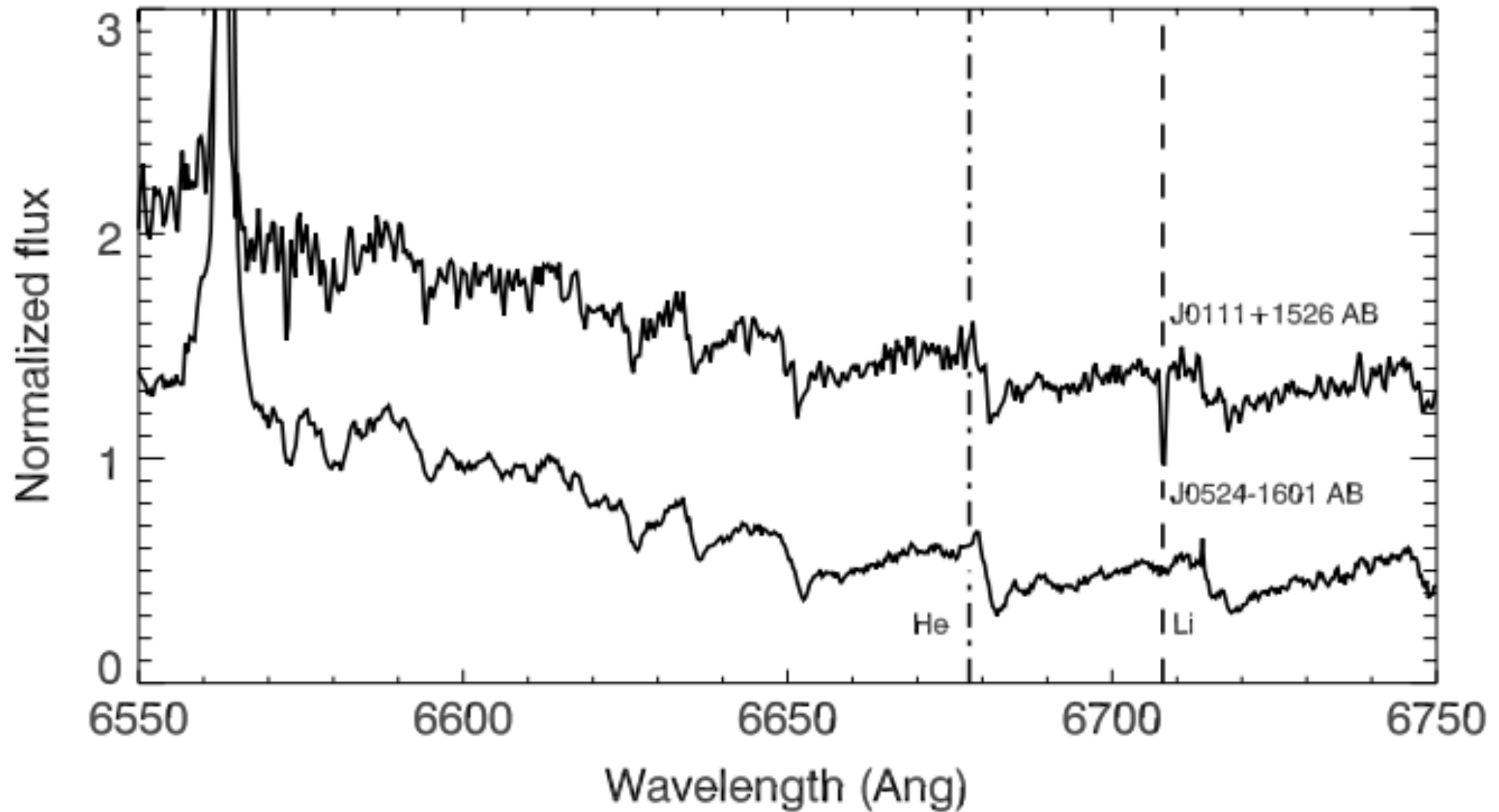
$$P_{member} = \sum_{dist, group}^{dist, group} P_{CMD} \times P_{XYZ} \times P_{UVW}$$

$$P_{xxx}(H_d^g | \theta) = \frac{P(\theta | H_d^g) \times P(H_d^g)}{Normalization}$$

Applied the selection method to 758 X-ray bright stars and spectroscopic follow-up observations.



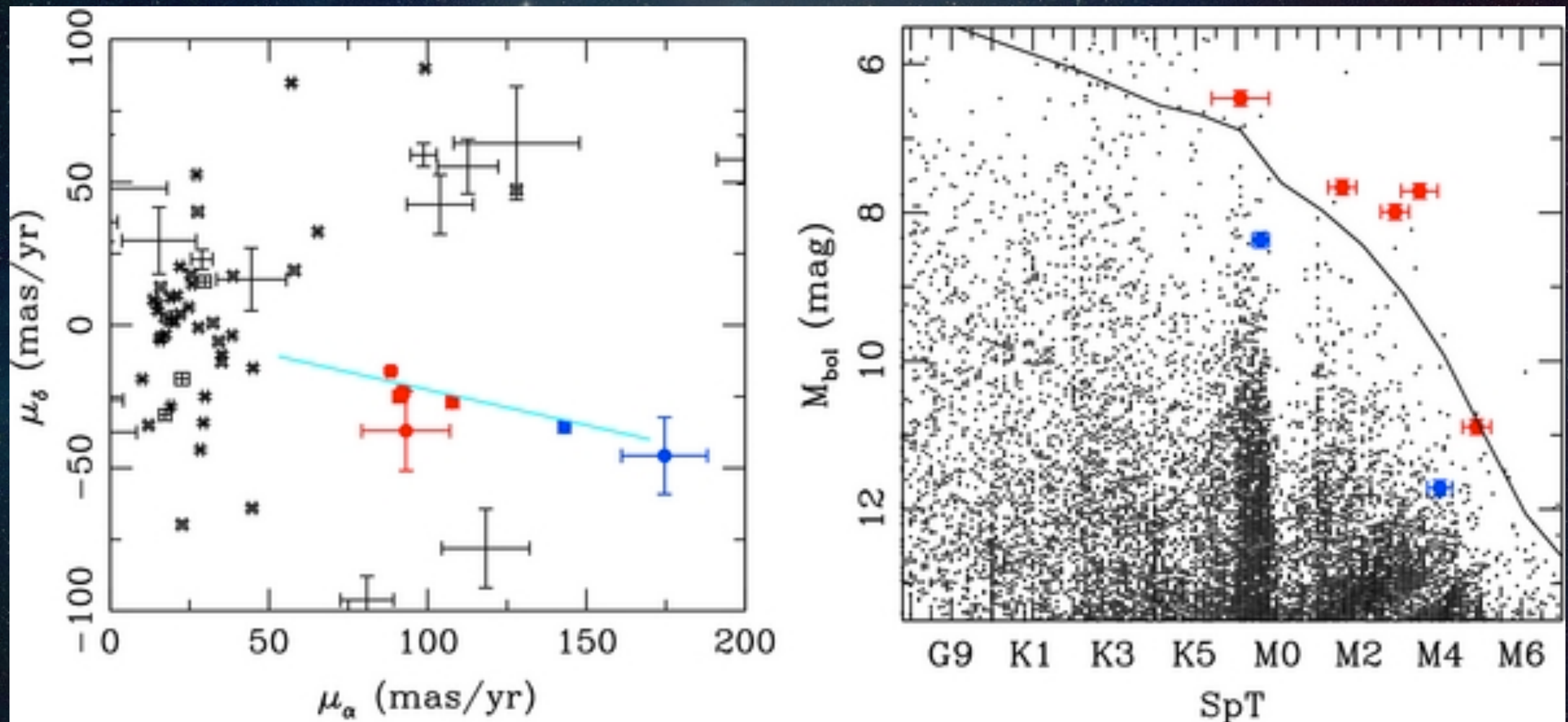
Some Li-confirmation



A lot of BANYAN candidate members need to be age-dated. However, most of new members being very late-type stars whose age-dating is very difficult.

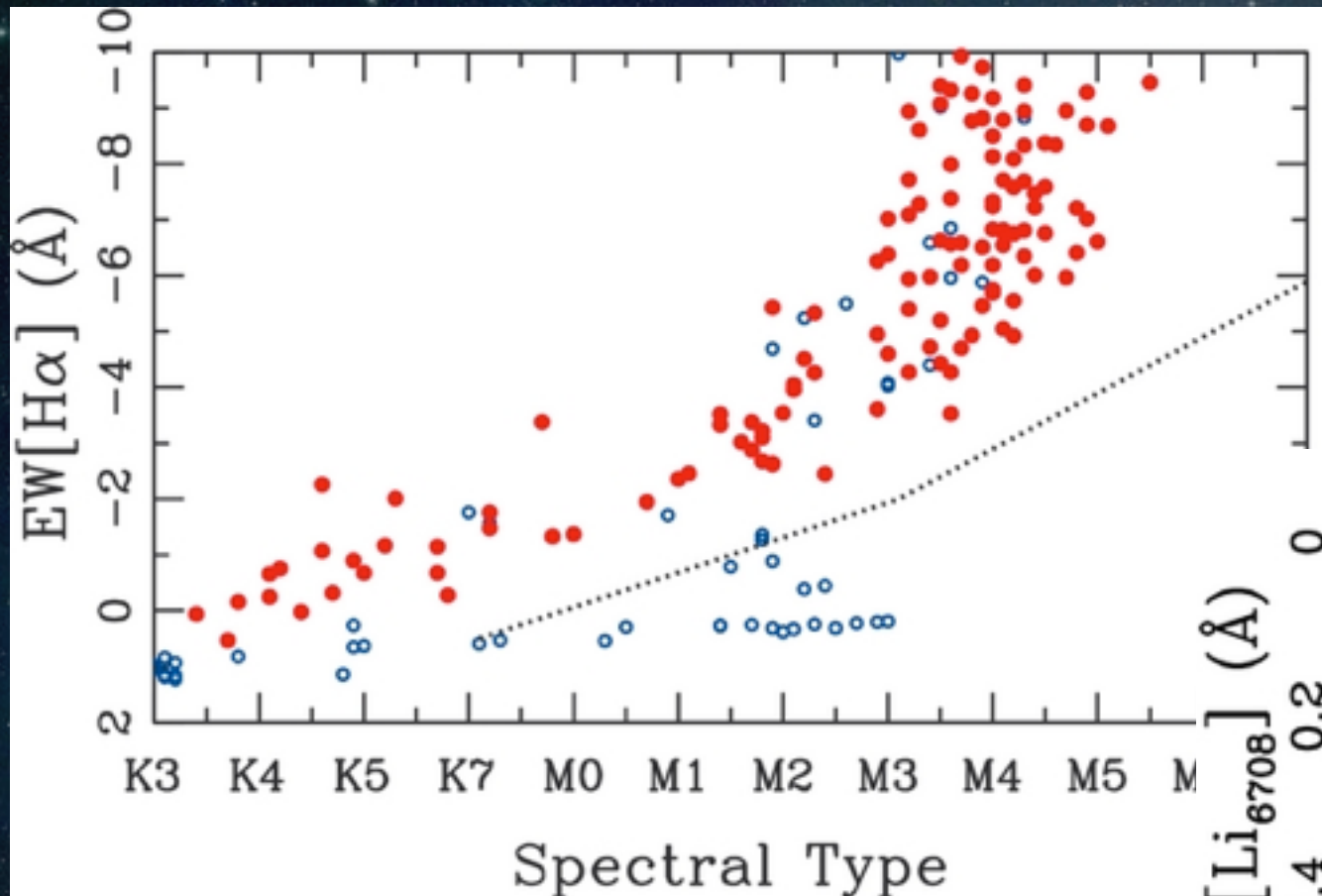
SED Distances

- Kraus et al. (2014) : Fitting 16 photometric points simultaneously with an assumed evolutionary stage (e.g., assumed radius) → good estimates on distances → selection based on overluminosity.

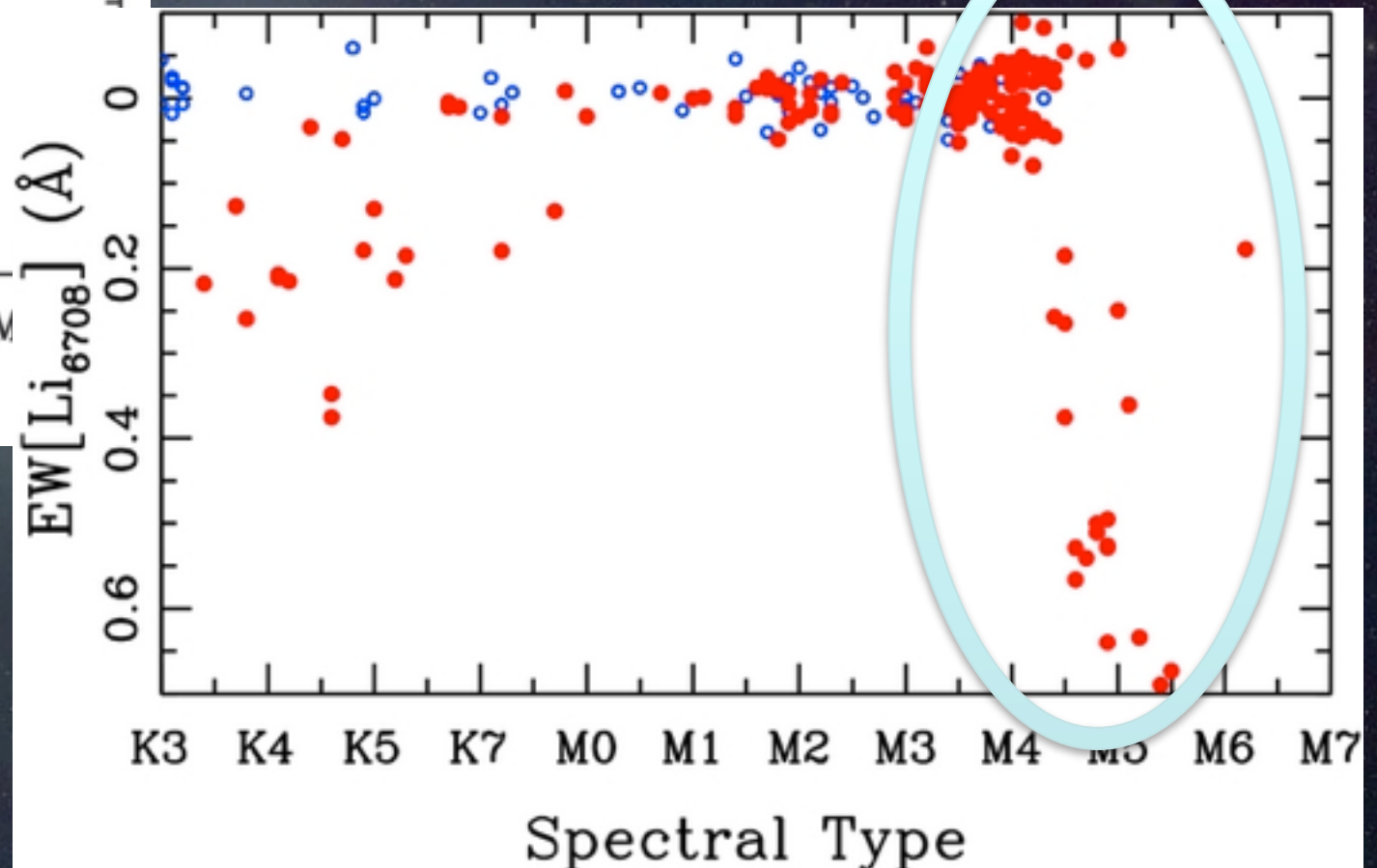


Kraus et al. (2014)

- Over the TucHor region, from 120,000,000 input sources, 497 candidate low mass members were selected (kinematics + overluminosity) → spectroscopic follow-up



Many young stars were confirmed



Kraus et al. (2014)

- However, even after a dedicated spectroscopic follow-up, it is difficult to assess the membership unambiguously (e.g., too many stars are claimed to be candidate members based only on RV and/or H α data)

Table 2. Spectroscopic Results and Membership Assessments

Name	V_{rad}	ΔV_{rad}	$v \sin(i)$	SpT	EW[H α]	EW[Li $_{6708}$]	Assessments	
	(km s $^{-1}$)	(km s $^{-1}$)	(km s $^{-1}$)		($\text{\AA}$)	(m $\text{\AA}$)	RV, H α , Li	Final
AF Hor	12.6 ± 0.7	0.30	6.6 ± 0.8	M2.1	-3.96	14.8	Y,?,?	Y - RV
CD-35 1167	13.2 ± 0.3	-0.33	4.6 ± 1.2	K4.7	-0.32	48.4	Y,?,?	Y - RV
J04213904-7233562	15.6 ± 0.4	0.75	5.6 ± 0.4	M2.1	-4.05	11.2	Y,?,?	Y - RV
J04240094-5512223	19.0 ± 0.7	2.12	6.9 ± 0.9	M2.0	-3.54	21.2	Y,?,?	Y - RV
J04274963-3327010	18.8 ± 1.4	1.25	15.8 ± 1.3	M4.0	-7.33	-23.3	Y,?,?	Y - RV
J04334610-4511249	21.0 ± 0.3	3.10	4.6 ± 0.2	M1.8	-1.36	-9.2	N,N,?	N - H α
J04365738-1613065	16.6 ± 1.9	-0.05	27.5 ± 1.3	M3.3	-7.28	3.4	Y,?,?	Y - RV
J04435860-3643188	19.4 ± 0.5	0.98	8.5 ± 0.6	M3.6	-7.99	-3.3	Y,?,?	Y - RV
J04440099-6624036	16.0 ± 0.5	-0.26	5.6 ± 0.4	M0.0	-1.37	21.6	Y,?,?	Y - RV
J04440824-4406473	24.6 ± 0.5	6.23	5.2 ± 0.5	M0.9	-1.71	14.6	N,?,?	N? - RV

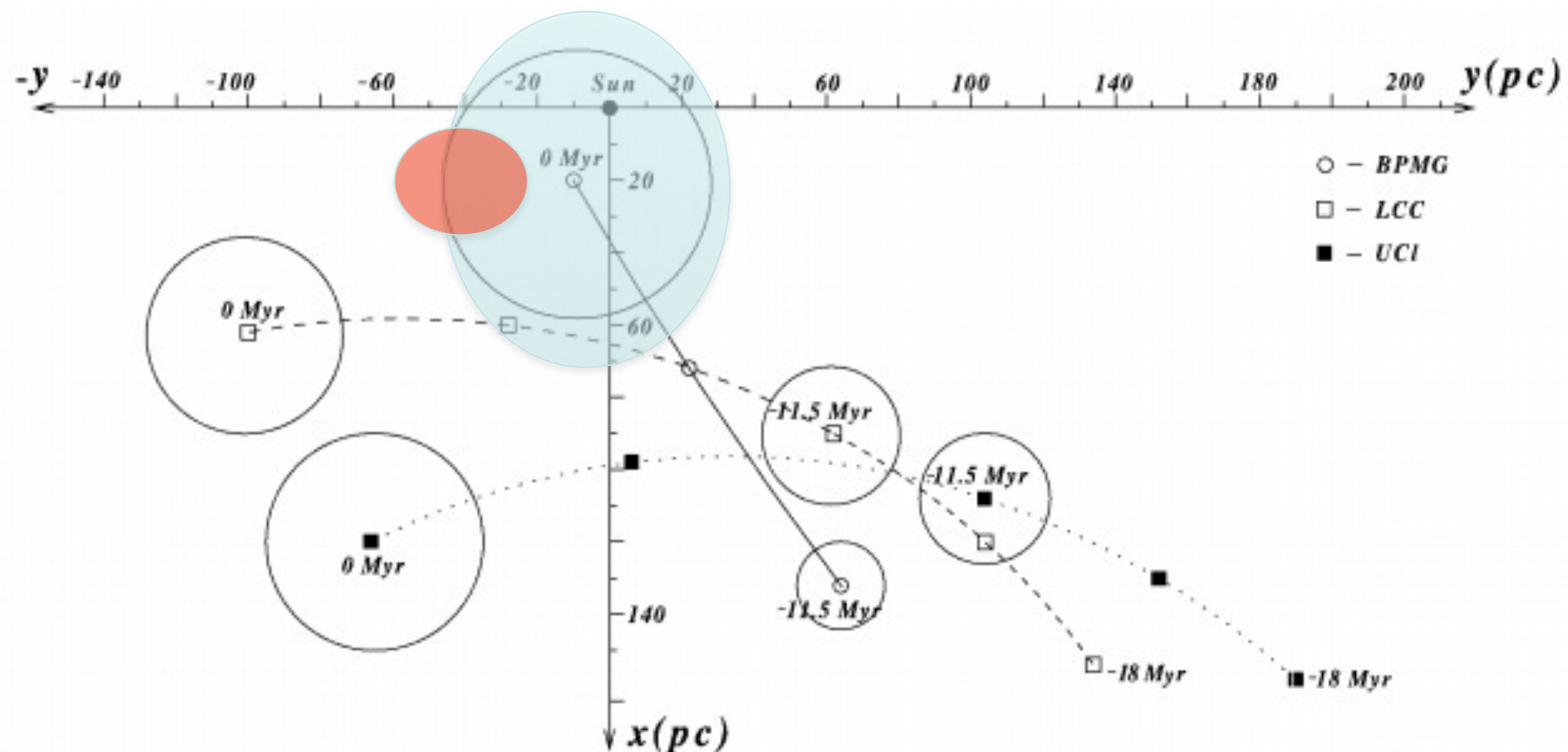
Adding dubious young stars

- Adding dubious kinematic members with a marginal hint of youth → causing the size of BPMG to be ~ 100 pc
- A ~ 100 pc size for BPMG (even larger than LCC or UCL). Is it OK?

No. 2, 2002

ORTEGA ET AL.

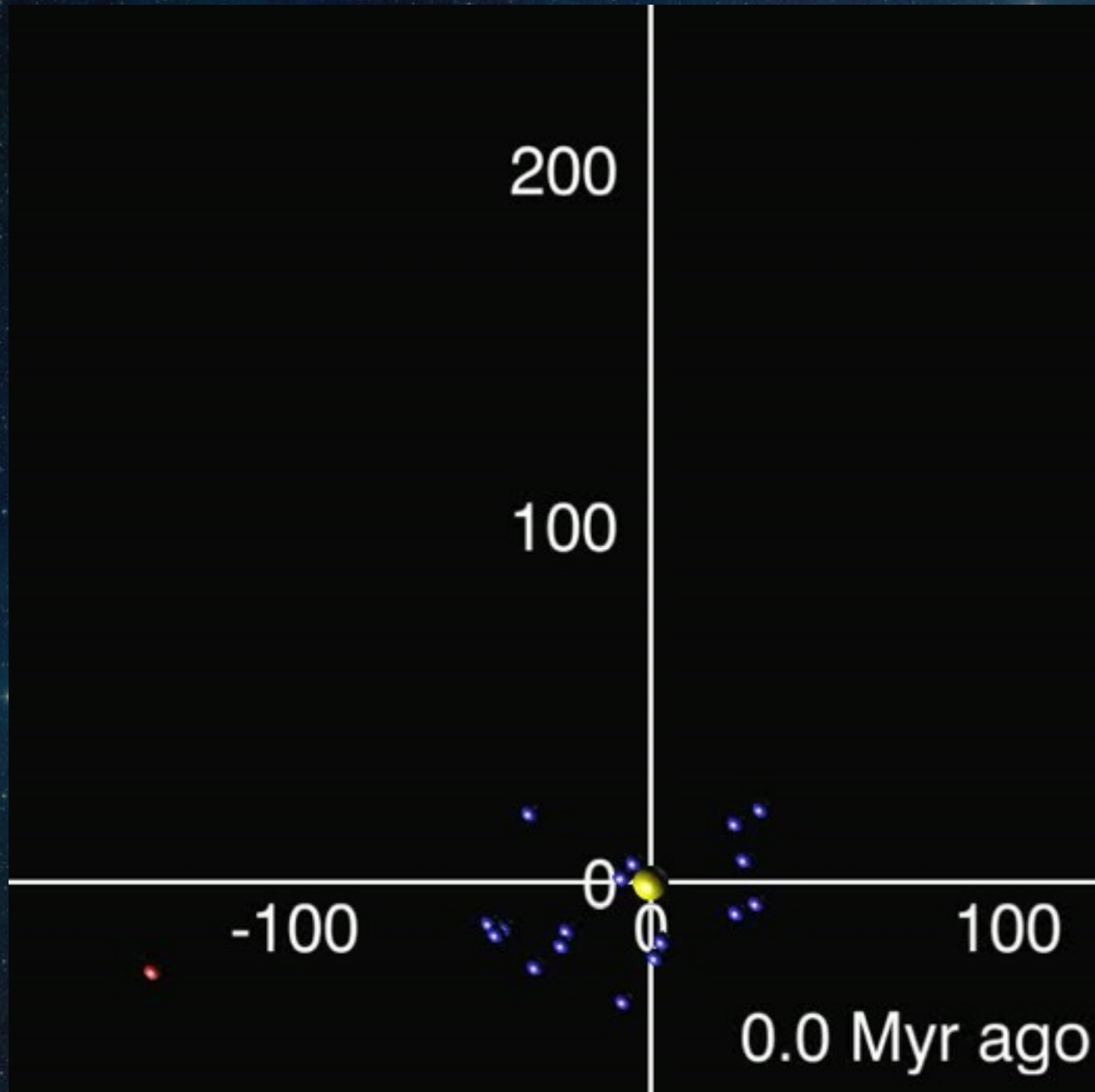
L77



Confirmation Criteria

- When do we accept a candidate as a confirmed member?
 - Is RV consistent to be a member enough?
 - Yes → with an unambiguous youth indicator
 - No → without an unambiguous youth indicator
 - Is unambiguous youth indicator enough?
 - Yes → with matching kinematics
 - Maybe → with matching partial kinematics
 - No → otherwise
- What about criteria for bona-fide members?
 - Are clear youth + good UVW enough?
 - Maybe
 - Convergence on back-traced position with youth + UVW!

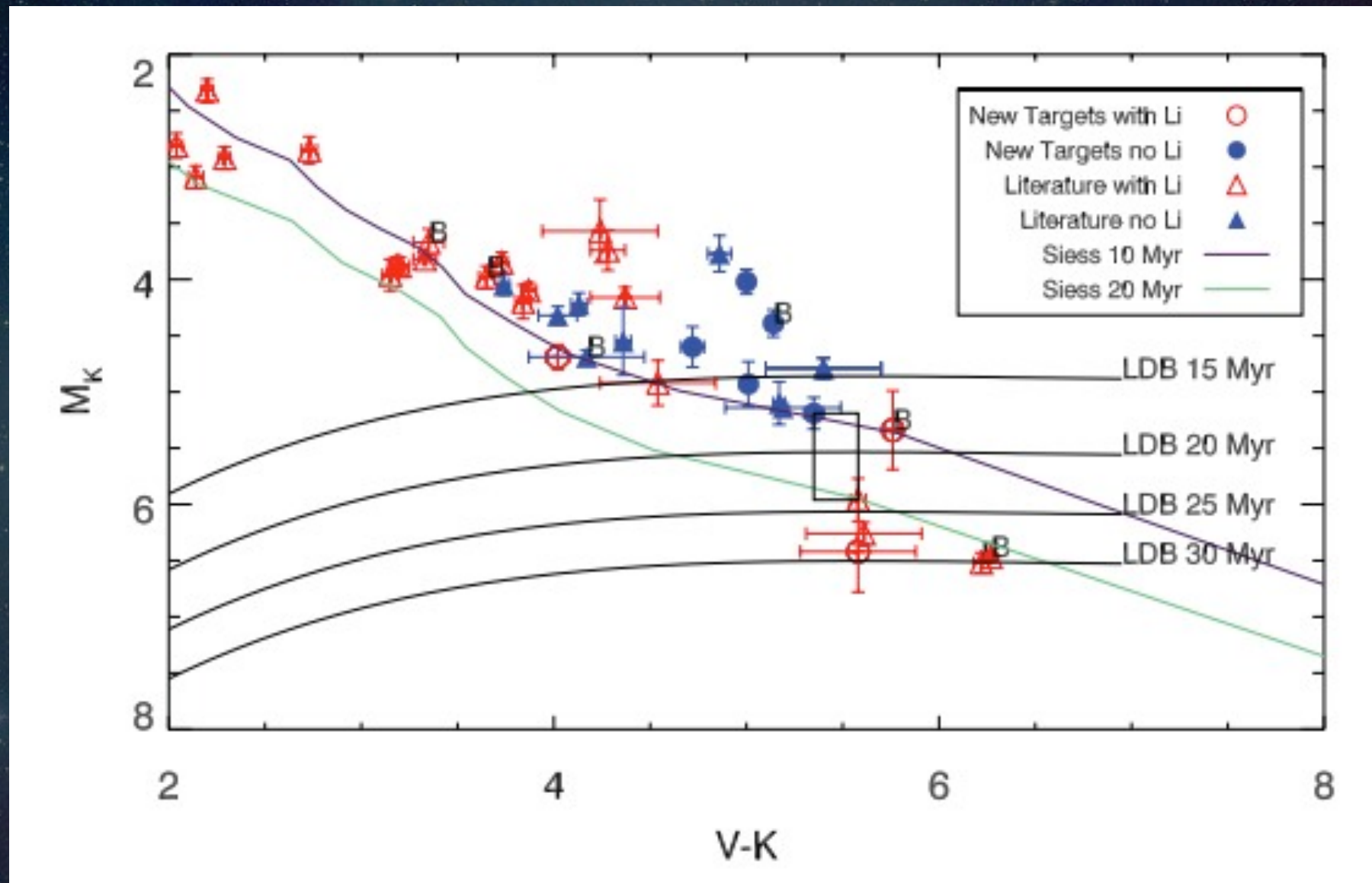
Traceback with an outlier rejection



- Traceback positions can be quite uncertain because of large input uncertainties!
- As an ensemble, a group can show a generally decreasing volume → outlier rejection is necessary → A good example is Doucourant et al. (2014)
- A formal calculation can be done using a minimal enclosed ellipsoid with outlier rejections or Bayesian inference.

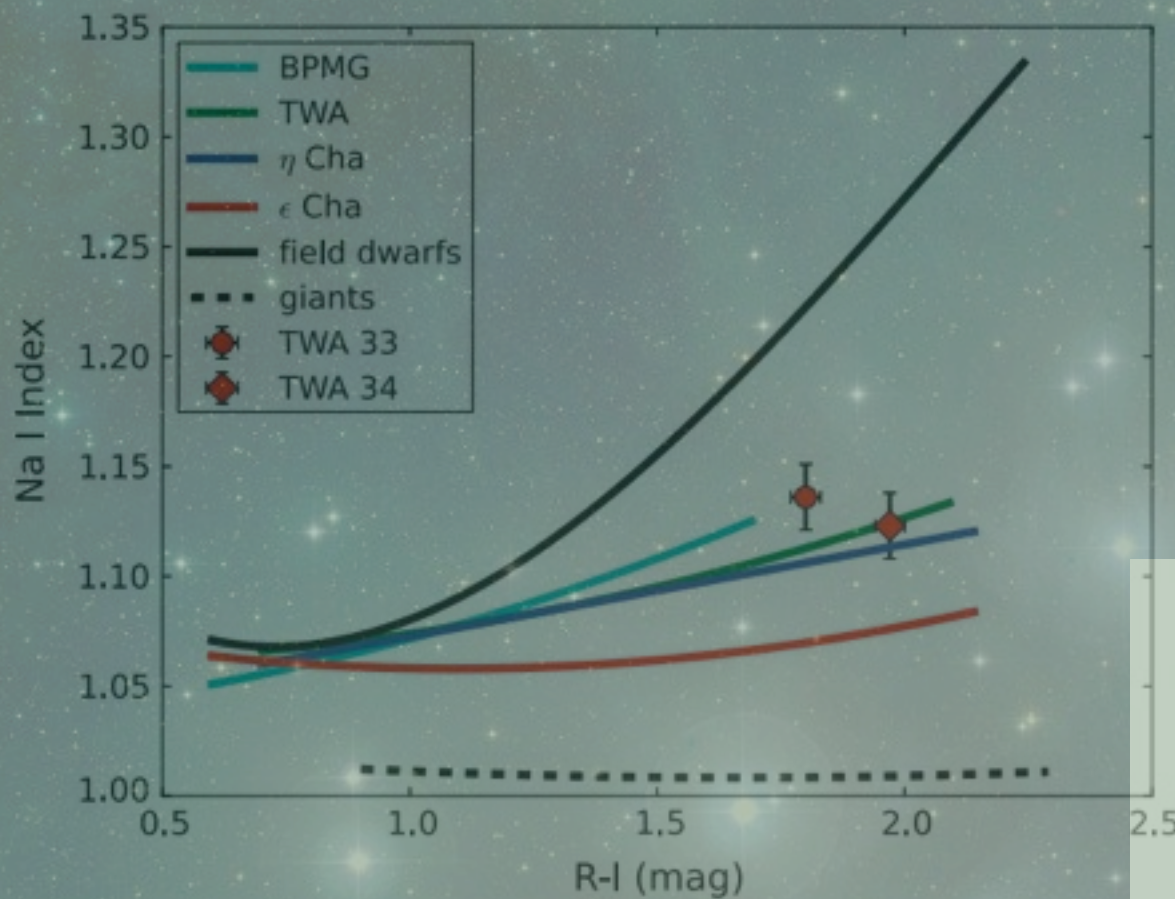
Ages of Moving Groups

- The quality of moving group age estimates are dependent on the list of bona-fide members used in the analysis



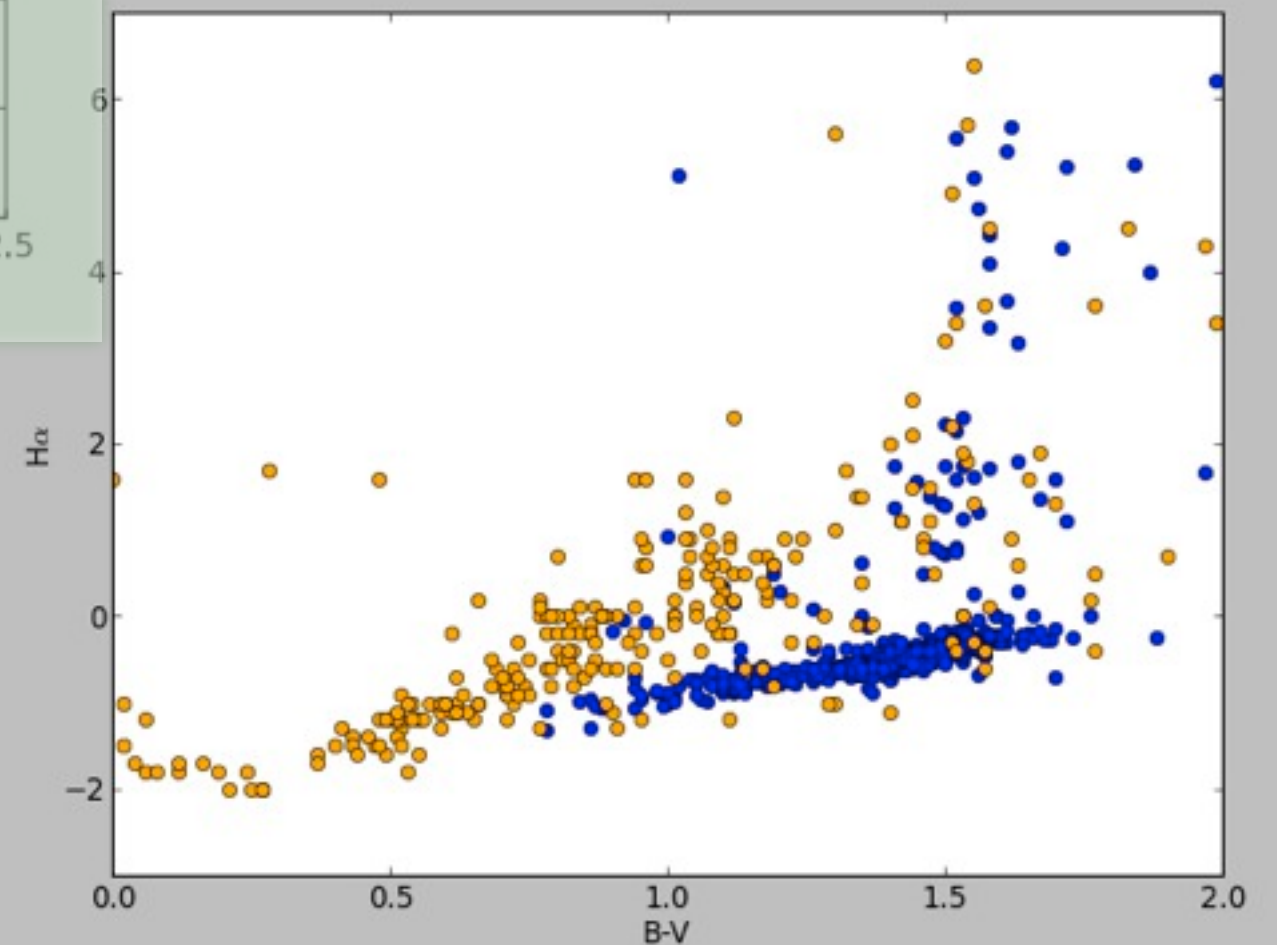
Binks & Jefferies (2014). More on later...
Are these BPMG members all real?

Needs for improved age indicators



← We are in a dire need of better calibrated surface gravity index as a function of ages. Add Pleiades and Hyades brown dwarf measurements!!

→ H α feature strengths can be useful after a careful calibration.



Future

- GAIA
 - launched on 2013 Dec 19
 - 10^9 stars observed
 - for brighter stars, distance measured at the 0.001% precision
 - will complete the survey of low mass members down to ~ 15 mag (much less ambiguity for age-dating)
- Better age-scale for M-type and L-type dwarfs?