Searching for Candidate Members of Star Moving Groups in the Kepler Field

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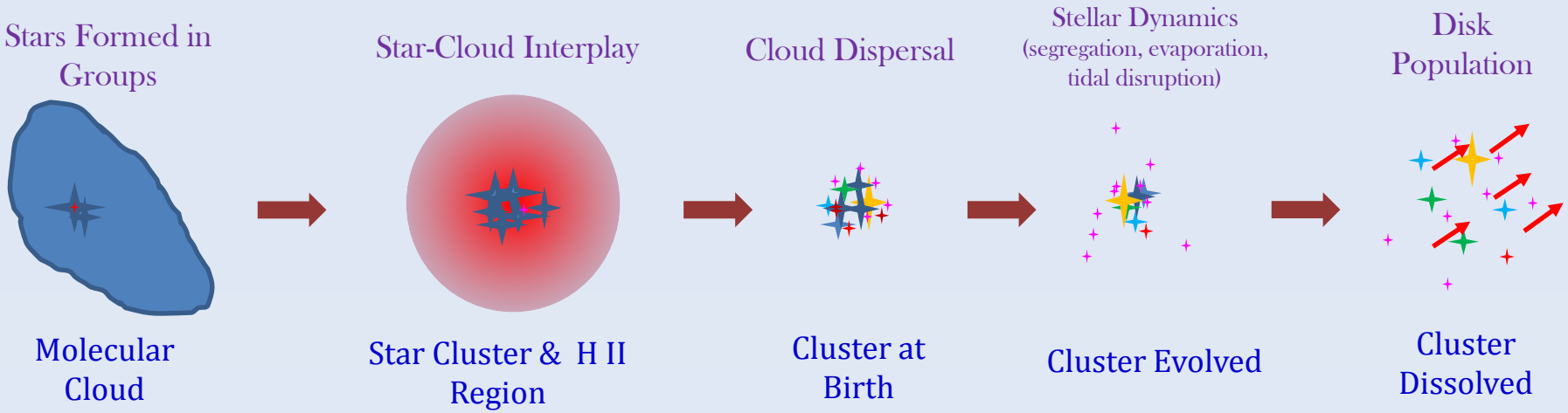
Acknowledgement:

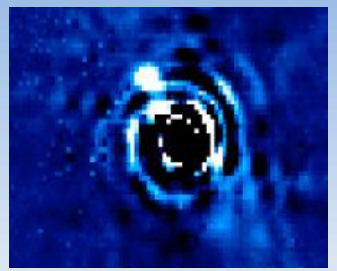
羅阿理, LAMOST group

What is a Moving Group?

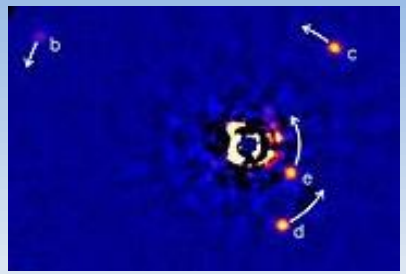
- Most, if not all, stars formed in a clustered environment
- Member star with the same birth place, age, and abundance
- **Same space motion**



Known Moving Groups



β *pic* in BPMG
Lagrange et al. 2009



HR 8799 in Columba
Marois et al. 2010

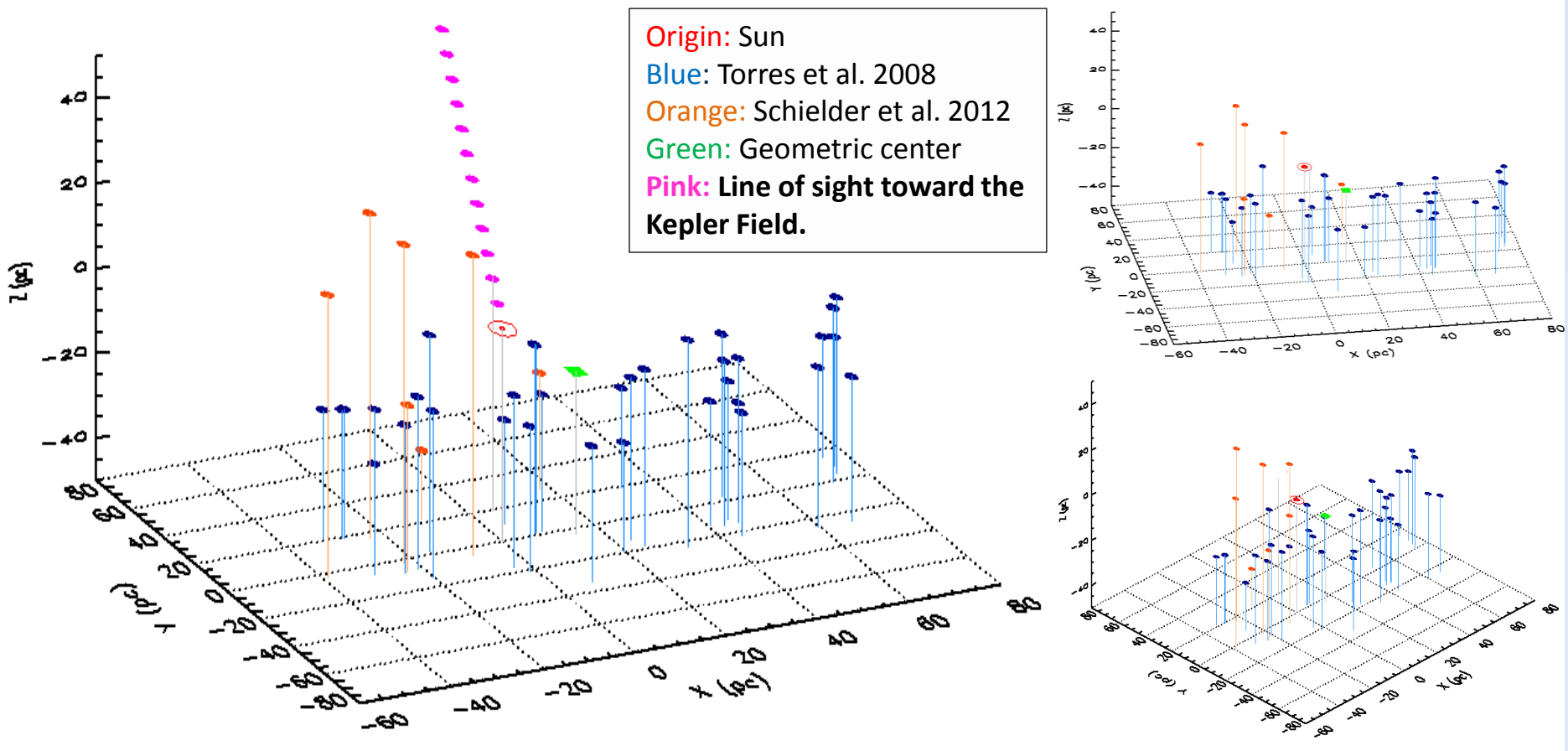
- 8 known MGs within 100 pc
- Age: 10 to 100 Myr (i.e., young)

➔ To study the survival of a star cluster

Known nearby moving groups, adapted from Torres et al. (2008)						
Name	D [pc]	Age [Myr]	U [kms^{-1}]	V [kms^{-1}]	W [kms^{-1}]	N
β Pictoris MG	31±21	21^{m}	-10.1±2.1	-15.9±0.8	-9.2±1.0	55^{s}
AB Doradus MG	34±26	70	-6.8±1.3	-27.2±1.2	-13.3±1.6	89
Tucana/Horologinm MG	48±7	30	-9.9±1.5	-20.9±0.8	-1.4±0.9	44
TW Hydrae MG	48±13	8	-10.5±0.9	-18.0±1.5	-4.9±0.9	31^{d}
Columba MG	82±30	30	-13.2±1.3	-21.8±0.8	-5.9±1.2	41
Carina MG	85±35	30	-10.2±0.4	-23.0±0.8	-4.4±1.5	23
Argus MG	106±51	40	-22.0±0.3	-14.4±1.3	-5.0±1.3	64
ϵ Cha MG	108±9	6	-11.0±1.2	-19.9±1.2	-10.4±1.6	24

d: Ducourant et al. 2014, s: Schielder et al. 2012, m: Mamajek et al. 2014

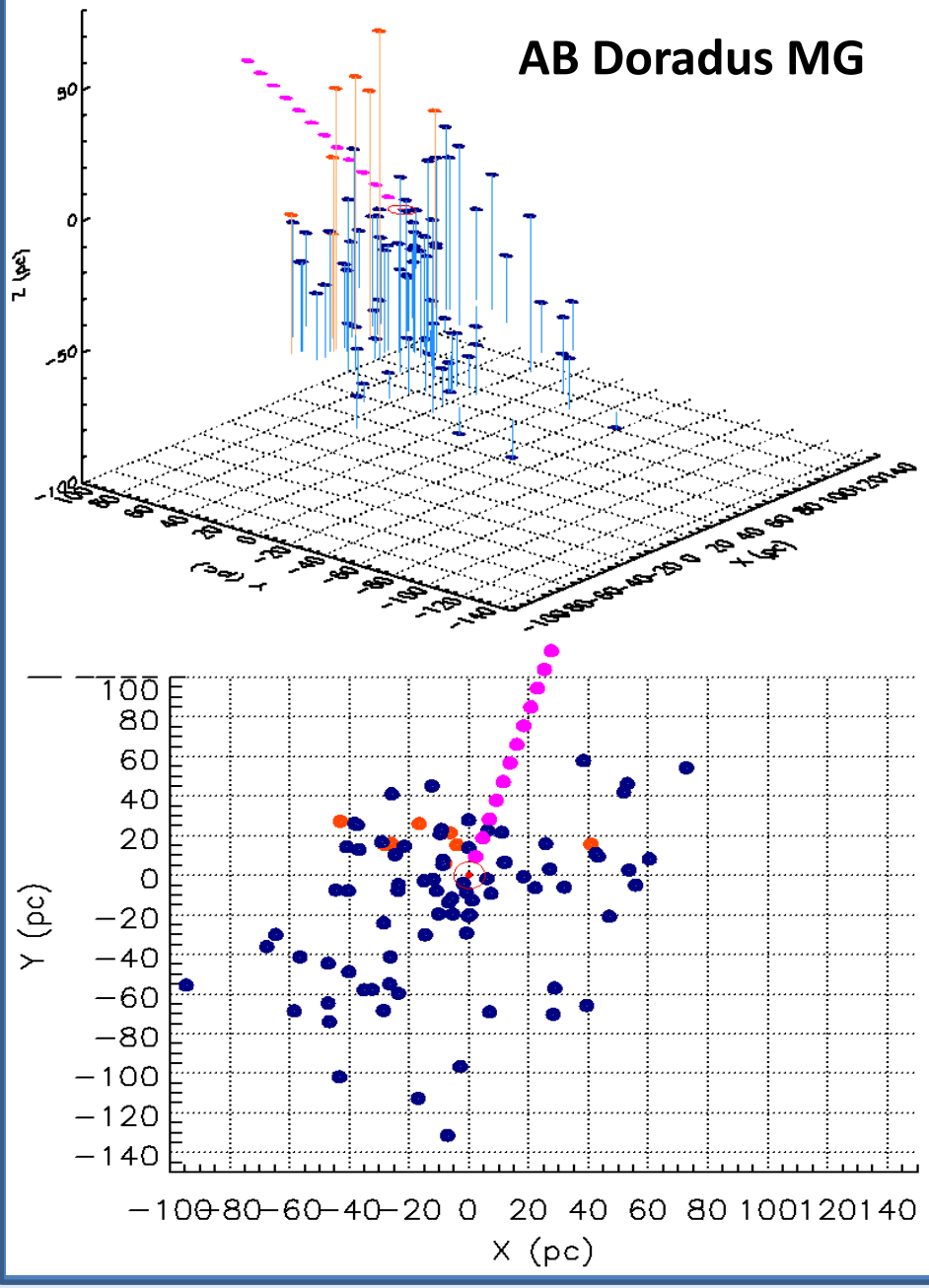
Locations of known members of BPMG



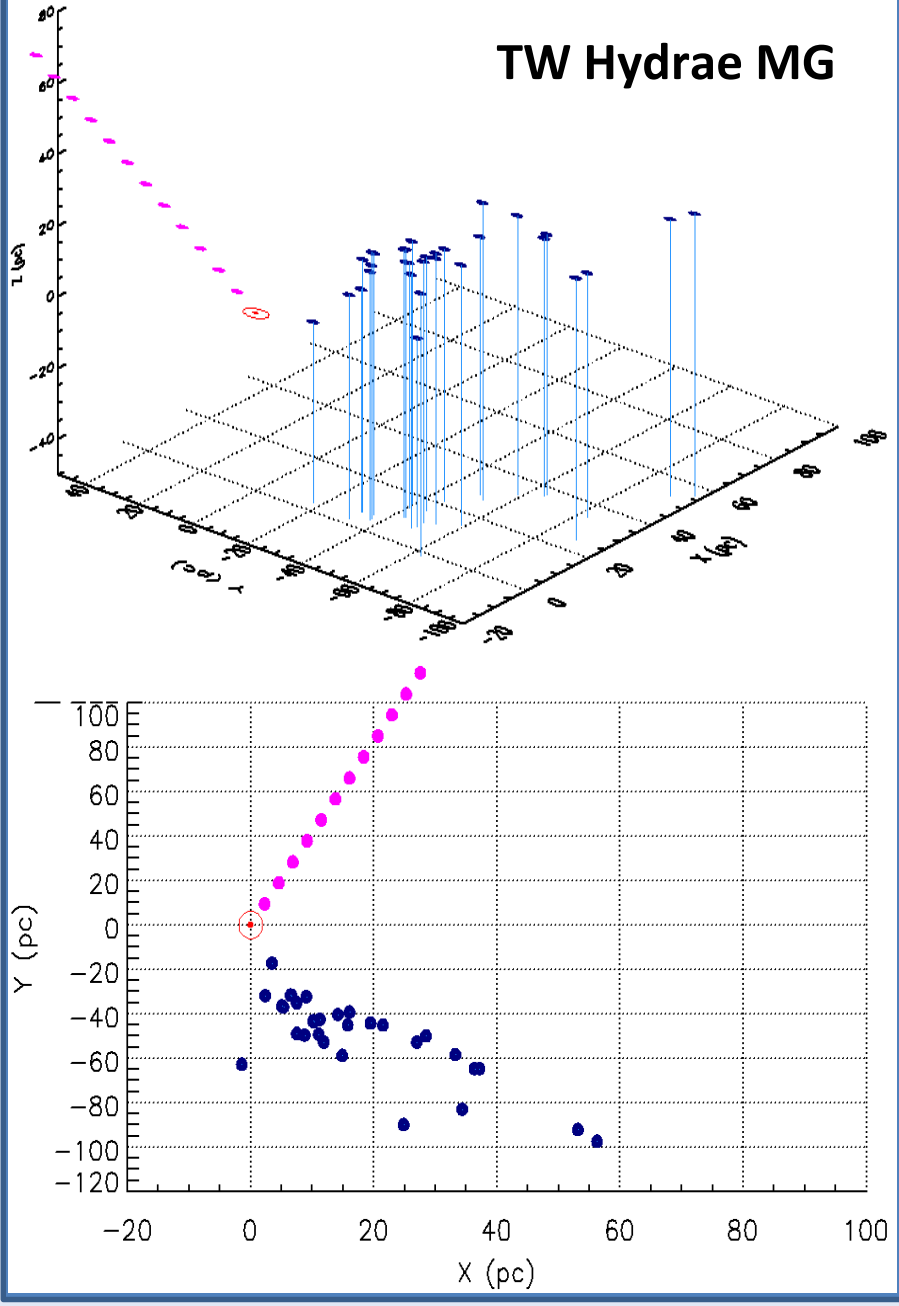
Locations of known members of BPMG with respect to the Sun in Galactic Coordinates

Origin: Sun, **Blue: Torres et al. 2008**, **Orange: Schielder et al. 2012**, **Pink: the Kepler Field**

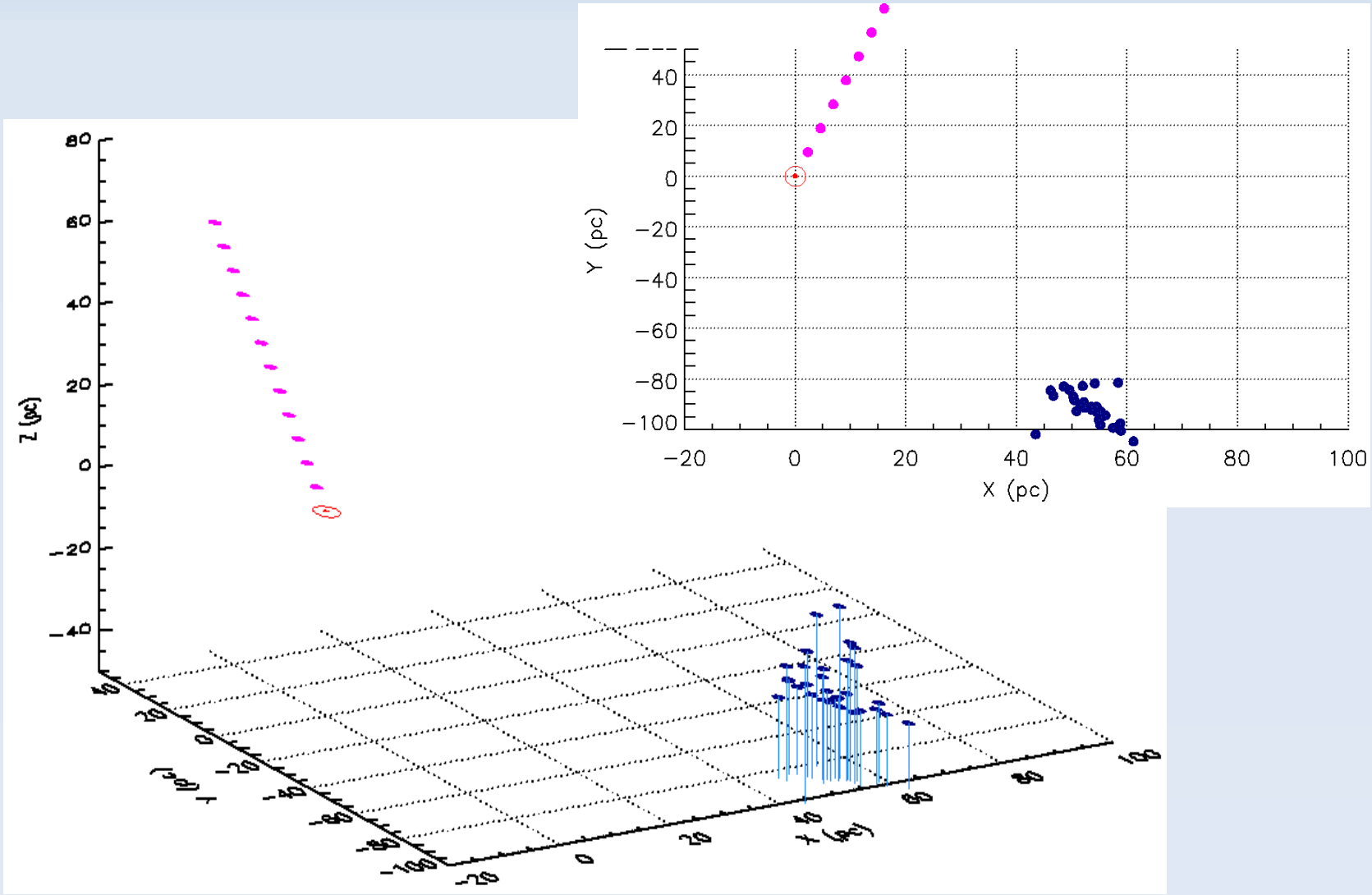
AB Doradus MG



TW Hydrae MG

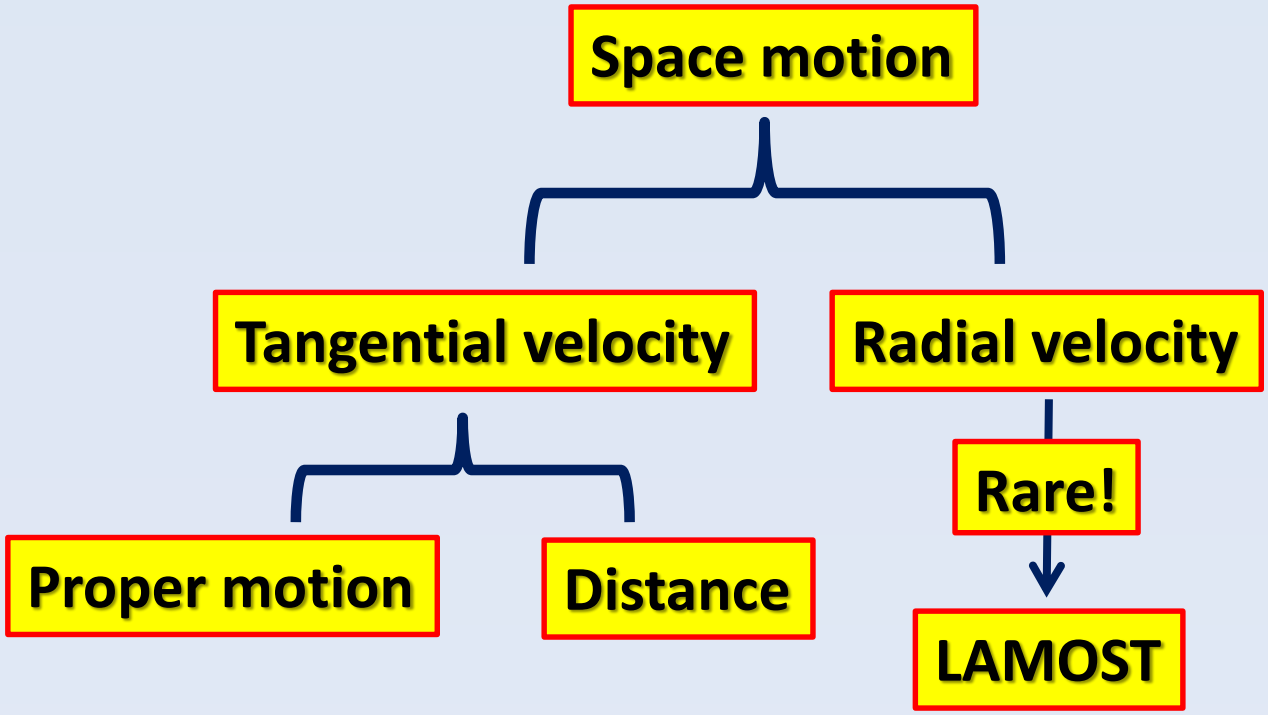


ε Cha MG serves as our false positive

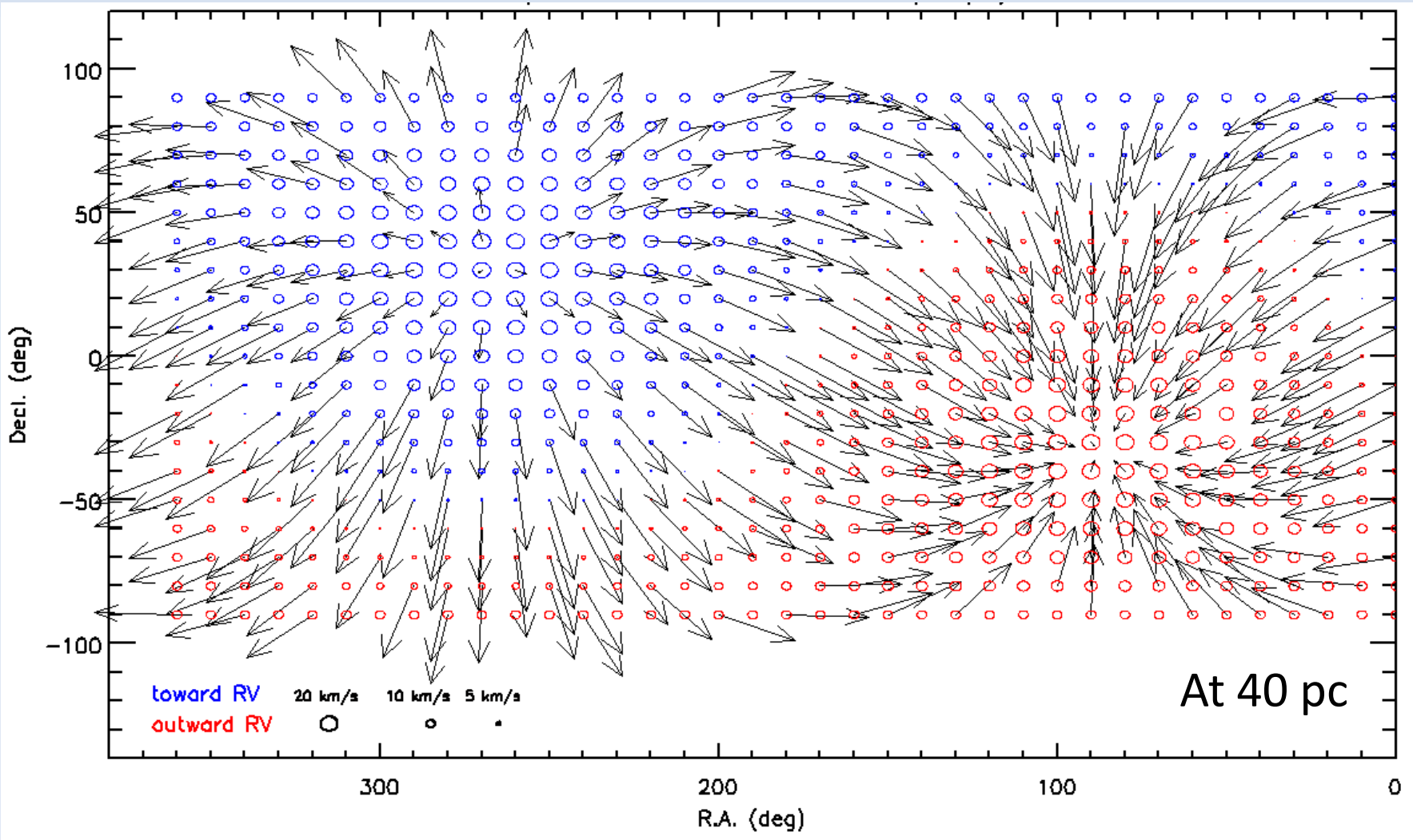


How to find more members of Moving Groups?

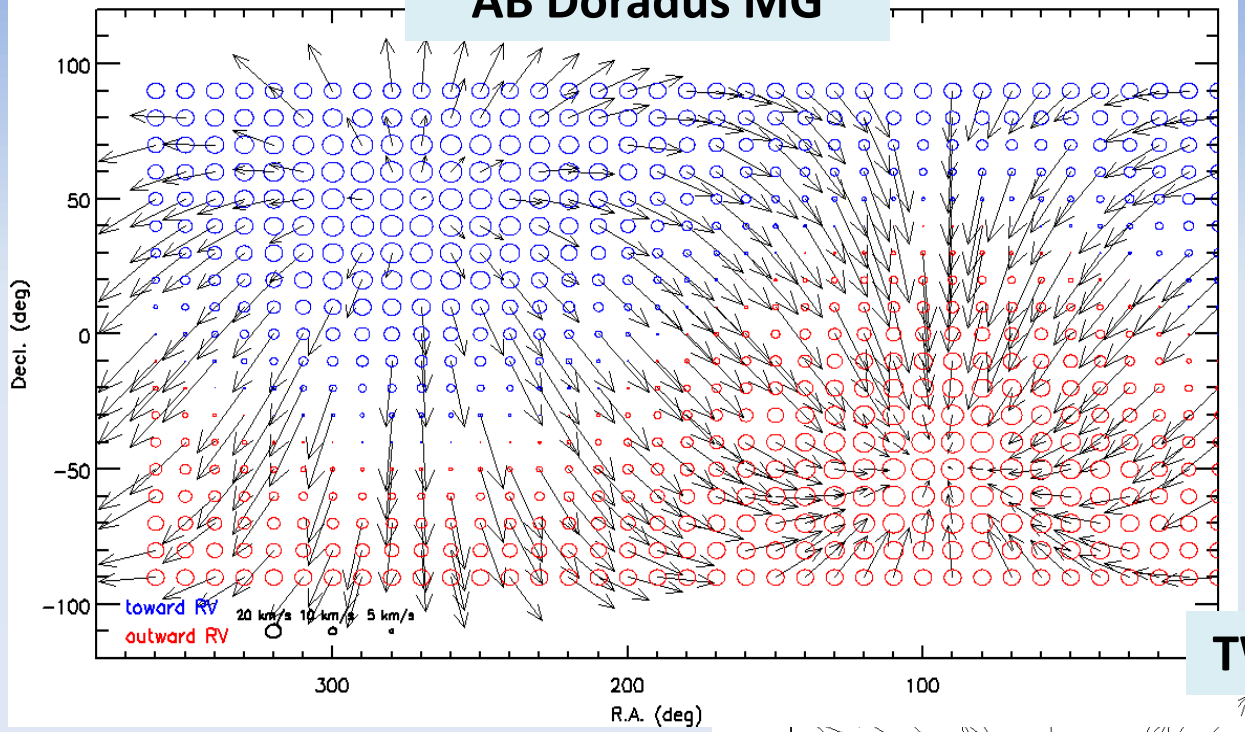
Name	U [kms^{-1}]	V [kms^{-1}]	W [kms^{-1}]	N
β Pic Moving Group	**-10.1±2.1**	**-15.9±0.8**	**-9.2±1.0**	**55[s]**
AB Dor Moving Group	-6.8±1.3	-27.2±1.2	-13.3±1.6	89
TW Hydrae Moving Group	-10.5±0.9	-18.0±1.5	-4.9±0.9	31[d]



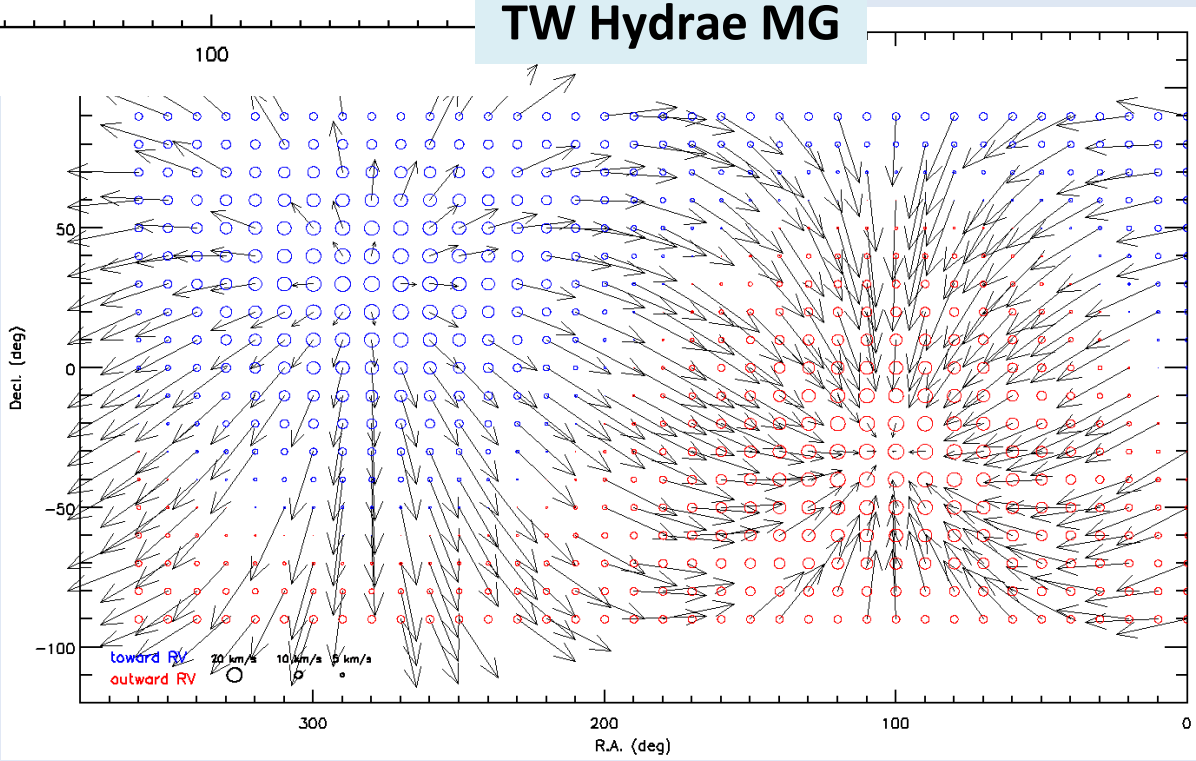
Expected Kinematics of BPMG members



AB Doradus MG



TW Hydrae MG

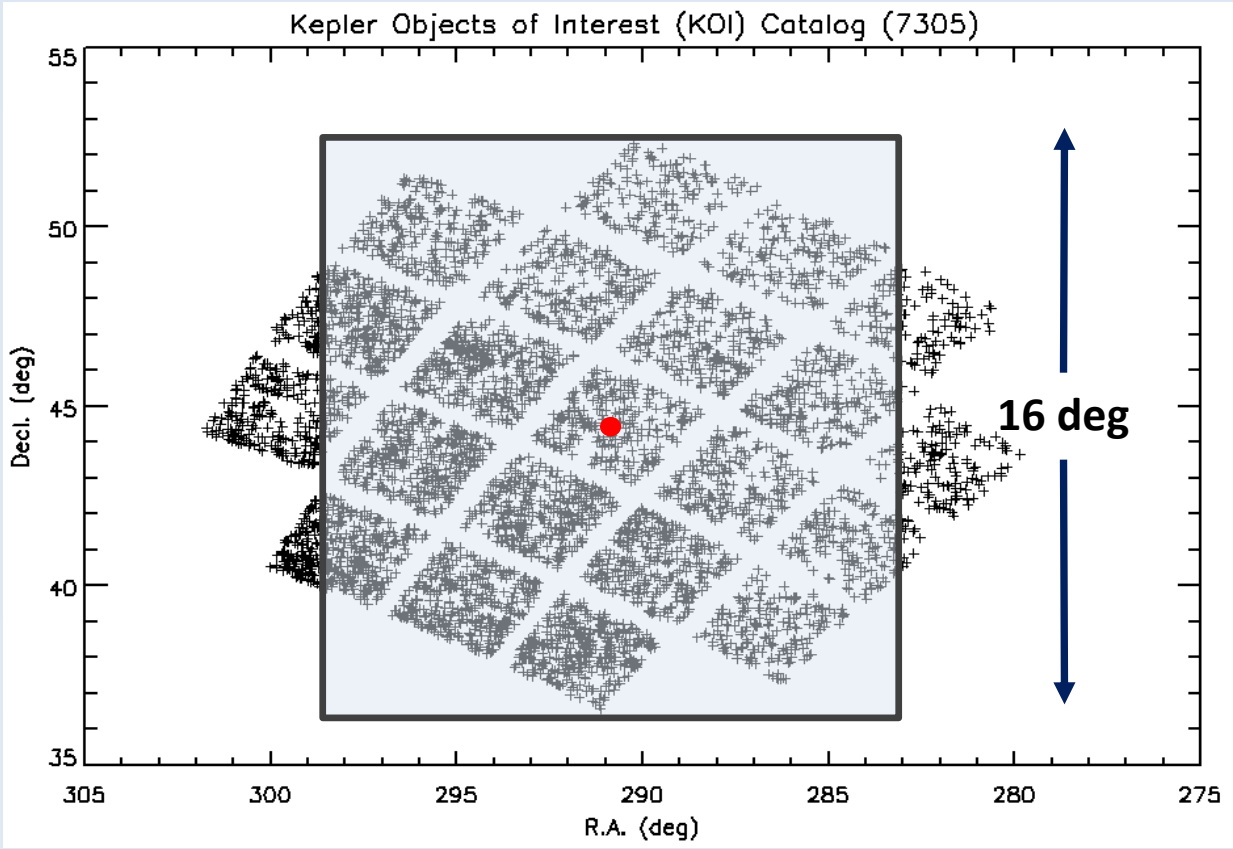


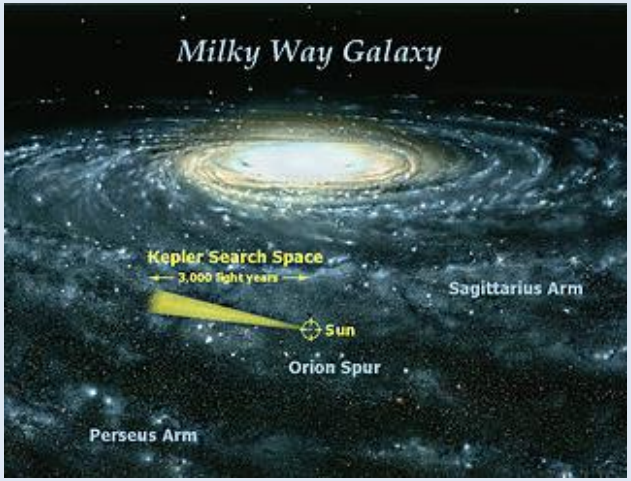
Searching for members in the *Kepler* Field

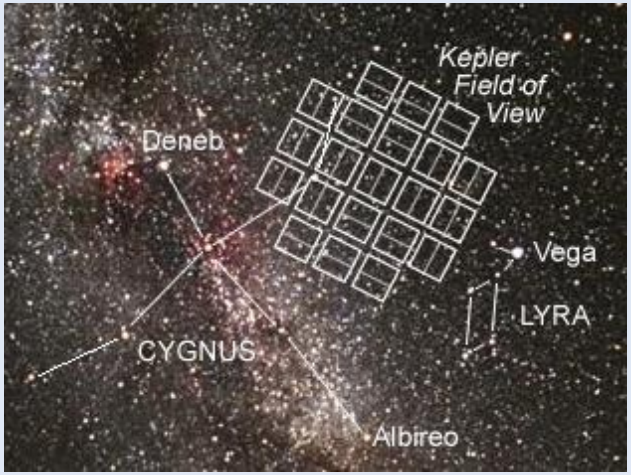
Center of the Kepler Field

R.A.: 19:22:40 (290.7 deg)

Decl.: 44:30:00 (44.5 deg)

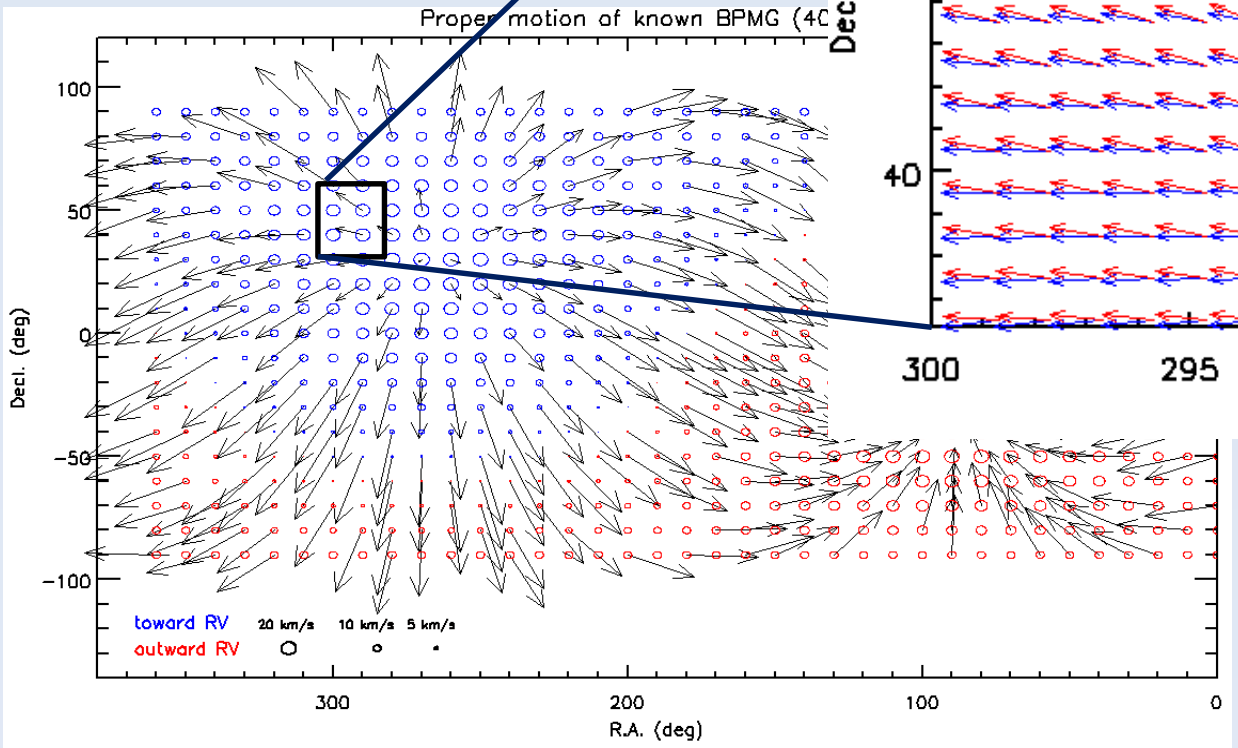


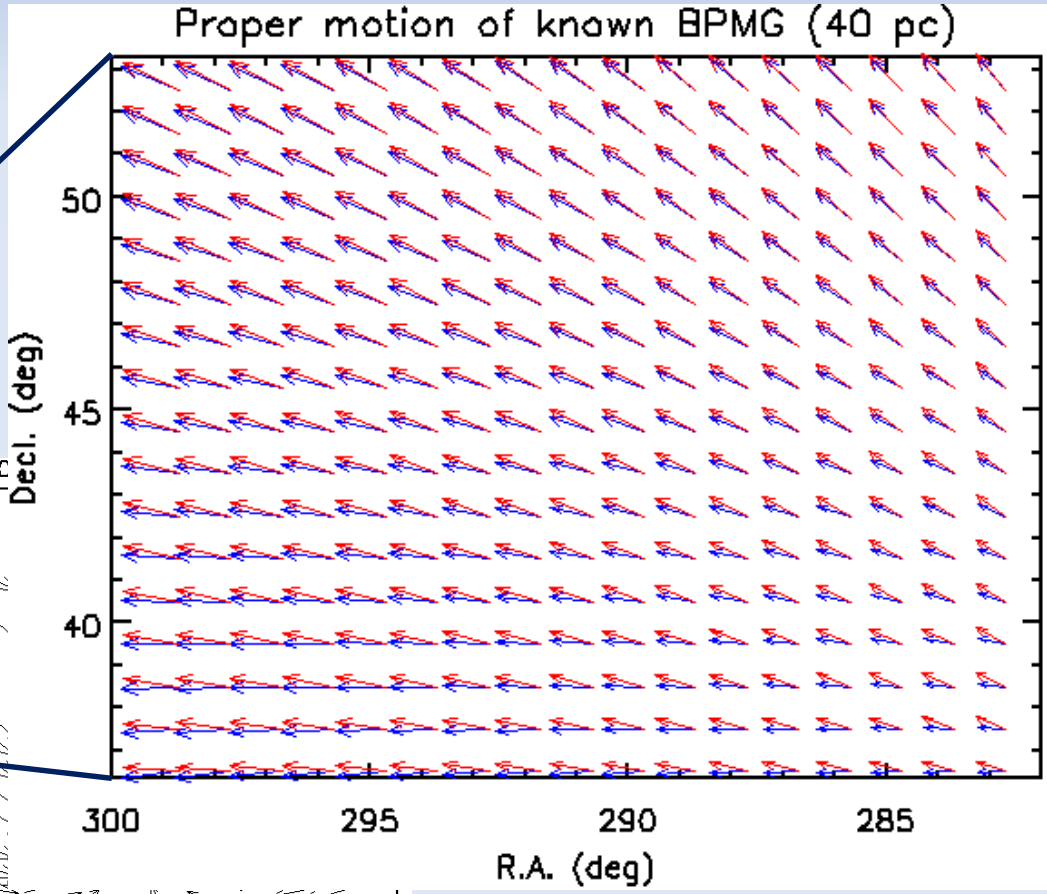




Expected kinematics of BPMG

mean PM at 40 pc:
pmRA: 36.25 (mas/yr)
pmDEC: 18.01 (mas/yr)
mean RV: -19.38 (km/s)





Searching for members in the *Kepler* Field with the *UCAC4* proper motions

The fourth U.S. Naval Observatory CCD Astrograph Catalog (UCAC4)

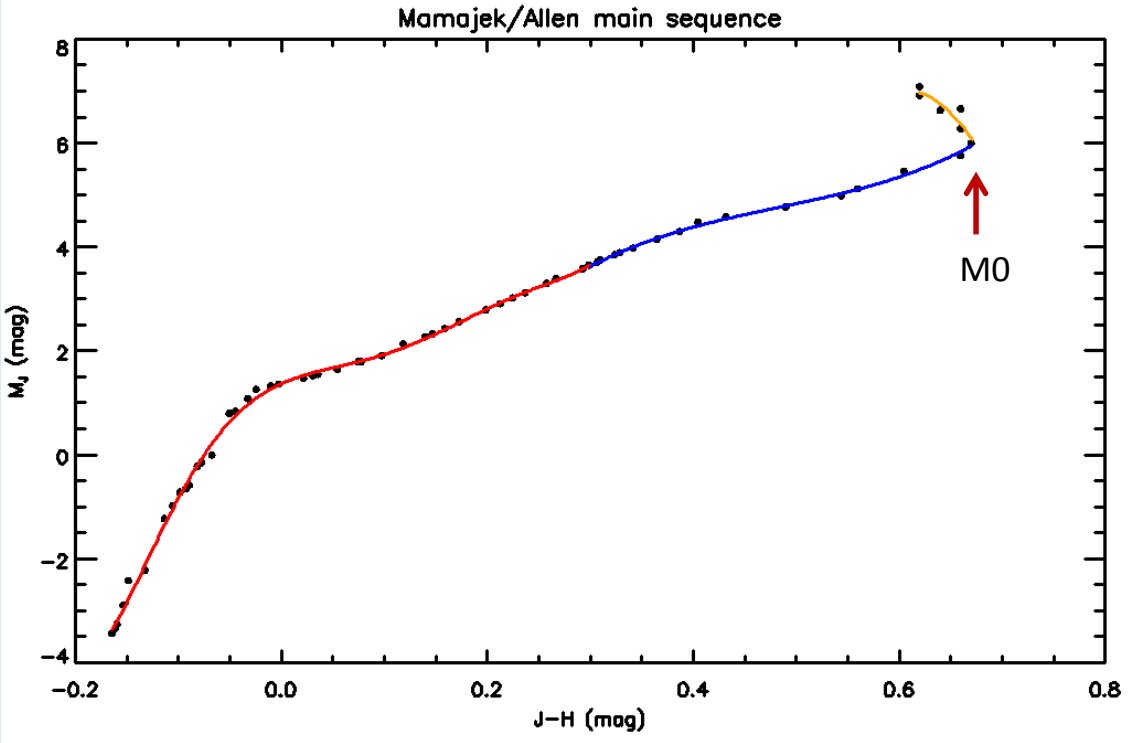
A compiled, all-sky star catalog covering mainly the 8 to 16 mag range in a single bandpass (579-642 nm) between V and R.

1. UCAC4 contains over 113 million objects; over 105 million of them with proper motions.
2. Bright stars are supplemented with *Hipparcos/ Tycho-2* stars.
3. Positional errors is 15 to 20 mas for stars in the 10 to 14 mag.
4. The distribution of UCAC4 proper motion error peaks at 4 mas/yr.

References:
The Fourth US Naval Observatory CCD Astrograph Catalog (UCAC4), N. Zacharias et al. 2012
http://dc.zah.uni-heidelberg.de/ucac4/q/s/info

Computing photometric distance

- The color-magnitude relation for O9~M5 main sequence stars
- $m - M = 5 \log d_{\mathrm{pc}} - 5$ (ignore the extinction)



Color (2MASS J-H)

↓

Absolute magnitude J

↕

Apparent magnitude J

↓

Photometric distance

Dist. Criteria for different MGs

References:

Allen's Astrophysical Quantities

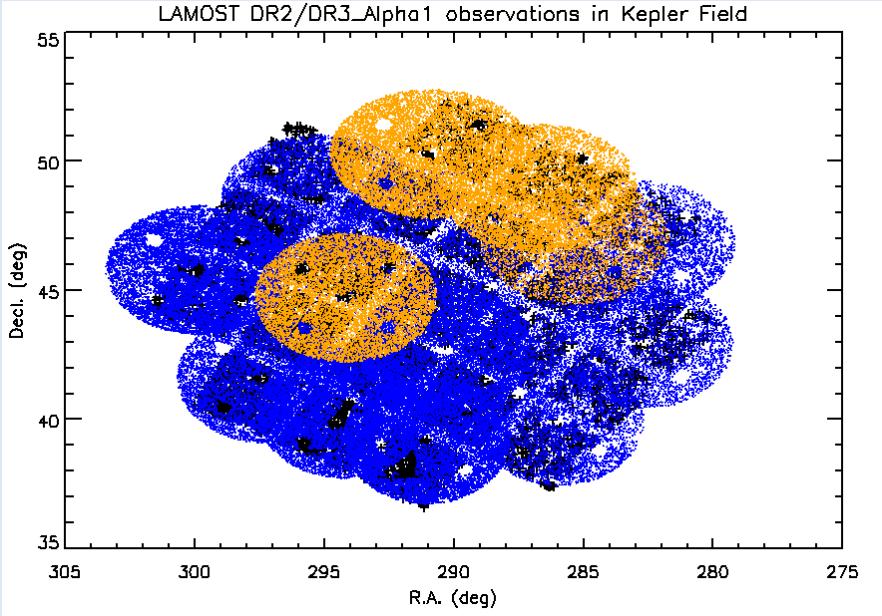
Eric Mamajek (University of Rochester): http://www.pas.rochester.edu/~emamajek/EEM_dwarf_UBVIJHK_colors_Teff.txt# # Version 2015.07.03

LAMOST (郭守敬望遠鏡)

Large Sky Area Multi-Object Fiber Spectroscopic Telescope

The large focal surface can collects large-number objects' light with 4000 fibers, and transfers into the spectrographs and record on the CCD detectors, respectively and simultaneously.

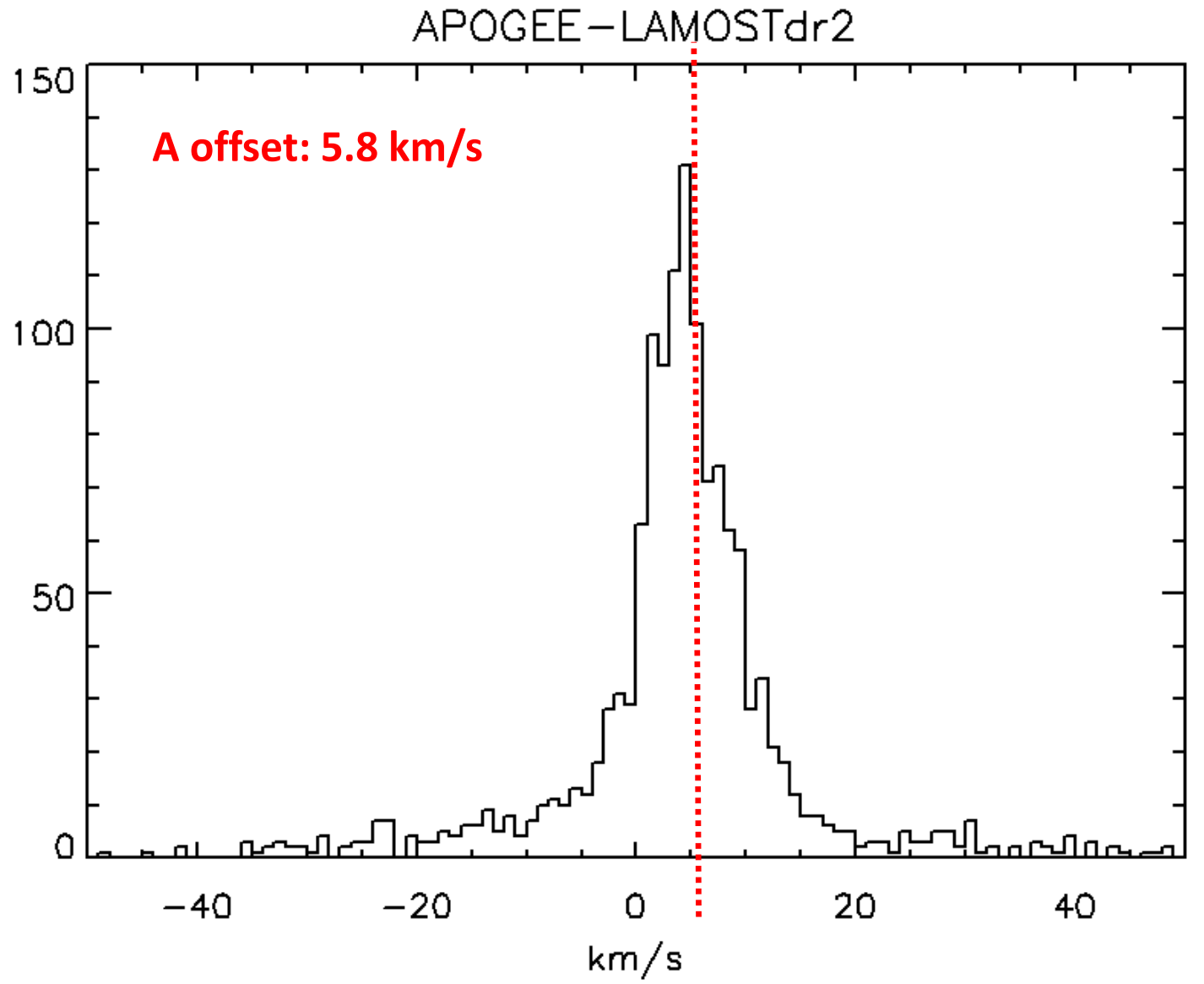
Clear aperture: 4m
Field of view: 5°
Focal plane: f 1.75m
Focal length: 20m
Spectral ranges: 370-900nm
Spectral resolution power: R= 1800
Spectral resolution: 1/0.25nm
Observable sky: -10° to +90° Declination



DR2 (blue): 67,241 RVs from 2012 to 2014
DR3 (orange): 31,395 RVs from Sep.2014 to May 2015

References:
http://www.lamost.org/public/instrument?locale=en

LAMOSTdr2 vs. SDSS-III APOGEE Radial Velocities



About 1 million UCAC4 sources (JHK AAA) in Kepler Field			
BPMG	**AB Dor MG**	**TWH MG**	**ε Cha MG (false positive)**
PM+dist. selection			
Dist. $<$ 80 pc $450 <$ pmRA $\times$ dist < 3010 $-39 <$ pmDEC $\times$ dist < 2057	**Dist. $<$ 120 pc** $279 <$ pmRA $\times$ dist < 2810 $-1756 <$ pmDEC $\times$ dist < 233	**Dist. $<$ 80 pc** $-28 <$ pmRA $\times$ dist < 1565 $354 <$ pmDEC $\times$ dist < 2293	**80 pc < Dist. $<$ 140 pc** $403 <$ pmRA $\times$ dist < 2845 $100 <$ pmDEC $\times$ dist < 1722
survivors: 603 $(0.08\ pc^{-3})$ **(10 X-Ray sources, 7B+3F)**	**survivors: 3425** $(0.15\ pc^{-3})$ **(12 X-Ray sources, 5B+7F)**	**survivors: 952** $(0.12\ pc^{-3})$ **(7 X-Ray sources 6B+1F)**	**survivors: 1443** $(0.05\ pc^{-3})$

About 1 million UCAC4 sources (JHK AAA) in Kepler Field

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(LAMOST dr2/dr3)			
Match: #119	**Match: #617**	**Match: #205**	**Match: #279**
RVs selection			
-26.6 < RVs < -12.1 (km/s)	**-37.8 < RVs < -22.6 (km/s)**	**−28.1 < RVs < -12.8 (km/s)**	**-31.5 < RVs < -16.4 (km/s)**

About 1 million UCAC4 sources (JHK AAA) in Kepler Field

BPMG	AB Dor MG	TWH MG	ϵ Cha MG (false positive)
PM+dist. selection			
survivors: 603 ($0.08\ pc^{-3}$) **(10 X-Ray sources)**	**survivors: 3425** ($0.15\ pc^{-3}$) **(12 X-Ray sources)**	**survivors: 952** ($0.12\ pc^{-3}$) **(7 X-Ray sources)**	**survivors: 1443** ($0.05\ pc^{-3}$)
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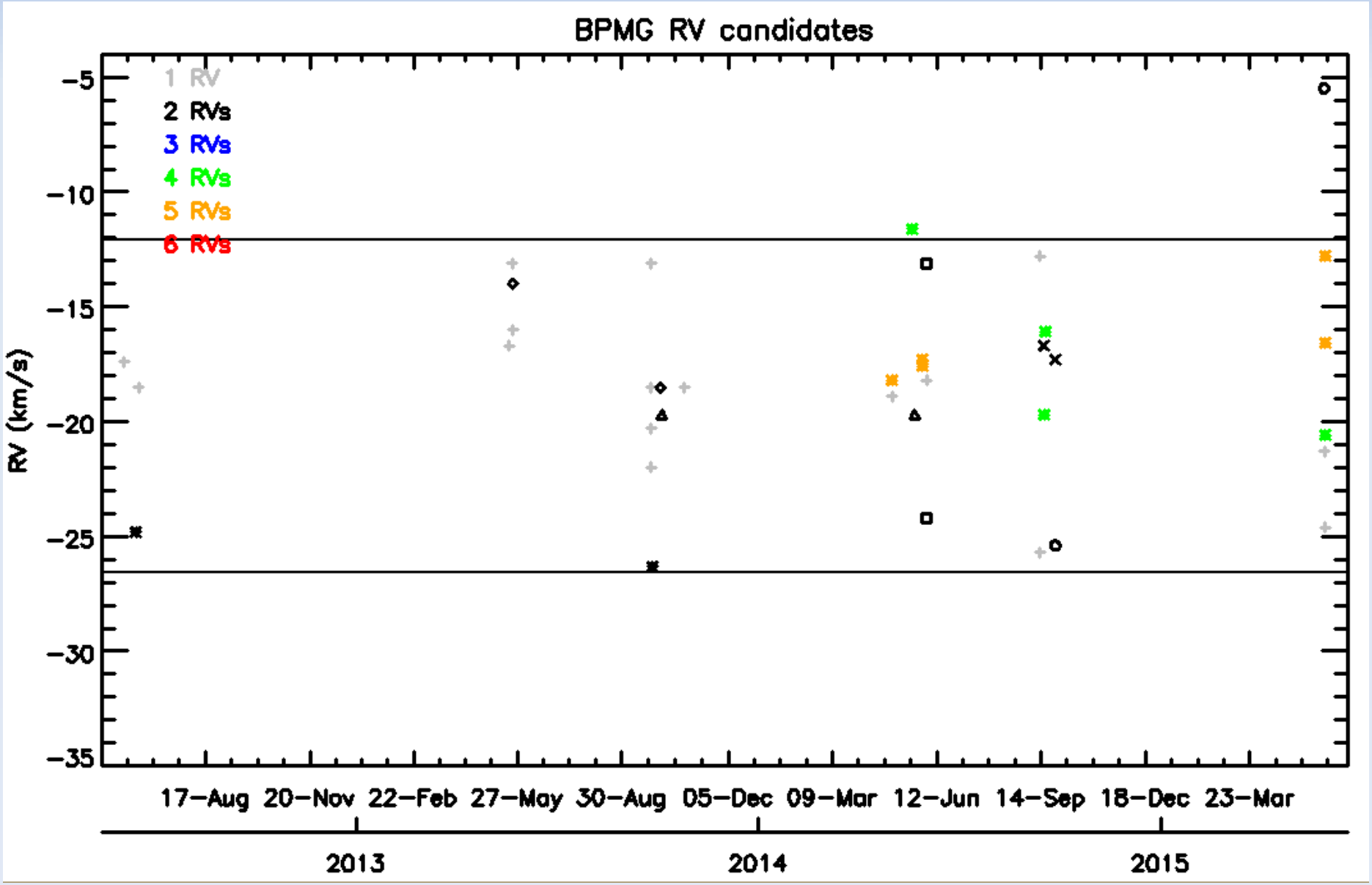
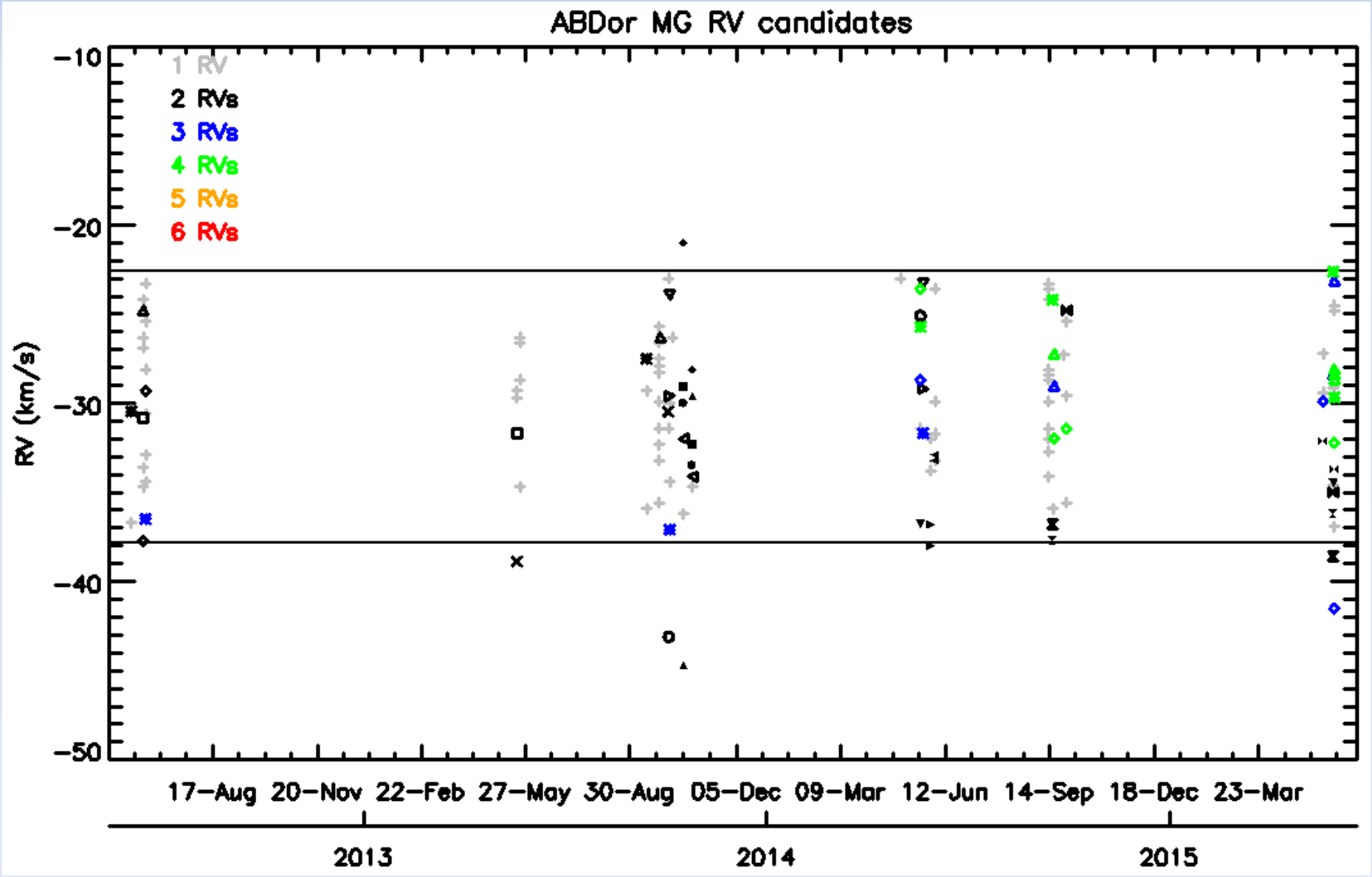
Match: #119	**Match: #617**	**Match: #205**	**Match: #279**
RVs selection			
-26.6 < RVs < -12.1 (km/s)	**-37.8 < RVs < -22.6 (km/s)**	**−28.1 < RVs < -12.8 (km/s)**	**-31.5 < RVs < -16.4 (km/s)**
Survivors: 24 **(No X-ray source)** (2.99e-3 pc^{-3})	**Survivors: 98** **(No X-ray source)** (4.30e-3 pc^{-3})	**Survivors: 34** **(No X-ray source)** (4.24e-3 pc^{-3})	**Survivors: 68** (2.12e-3 pc^{-3})
kinematic candidates			

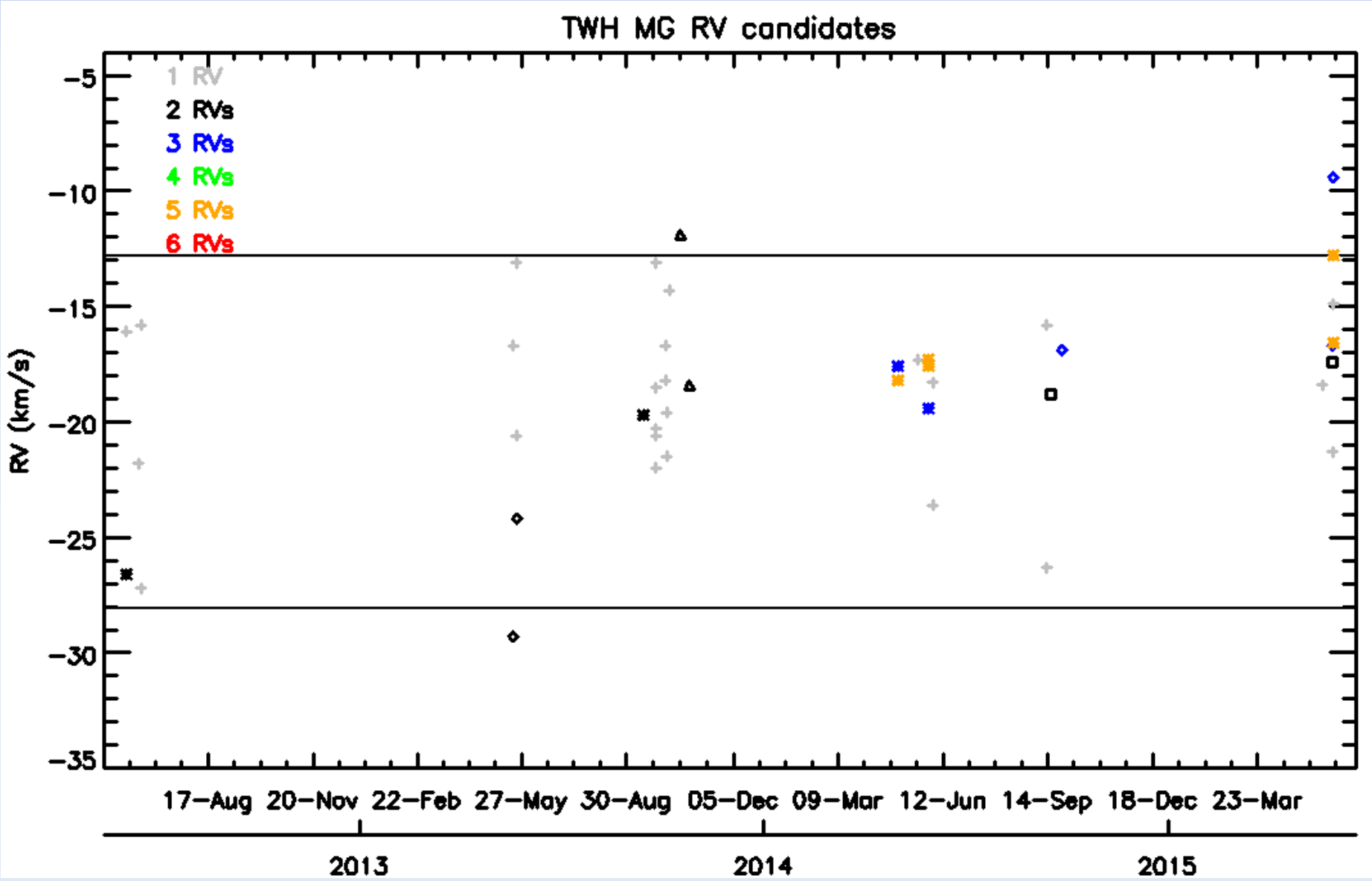
24 Kinematic members of BPMG:
1 RV: #16, 2 RVs: #6, 4 RVs: #1, 5RVs: #1



98 Kinematic members of AB Dor MG:
1 RV: #72, 2 RVs: #20, 3 RVs: #3, 4RVs: #3



34 Kinematic members of TWH MG:
1 RV: #27, 2 RVs: #4, 3 RVs: #2, 5RVs: #1



Conclusions

- **We have developed the pipeline to identify member candidates of MGs.**

  (PM + dist + RV/LAMOST dr2/dr3)

- **Analysis of the MGs (BP/ABDor/TWH)**
  - about 160 probable kinematic candidates (41 of them with multiple LAMOST RVs)
  - about 30 X-Ray sources without RVs (They are likely young or active dwarfs).
- **Spectroscopic confirmation**
  - Radial velocities at different epochs, e.g., spectroscopy by

    2.4 m in June 2016
  - Indicators of stellar youth, e.g., Li absorption