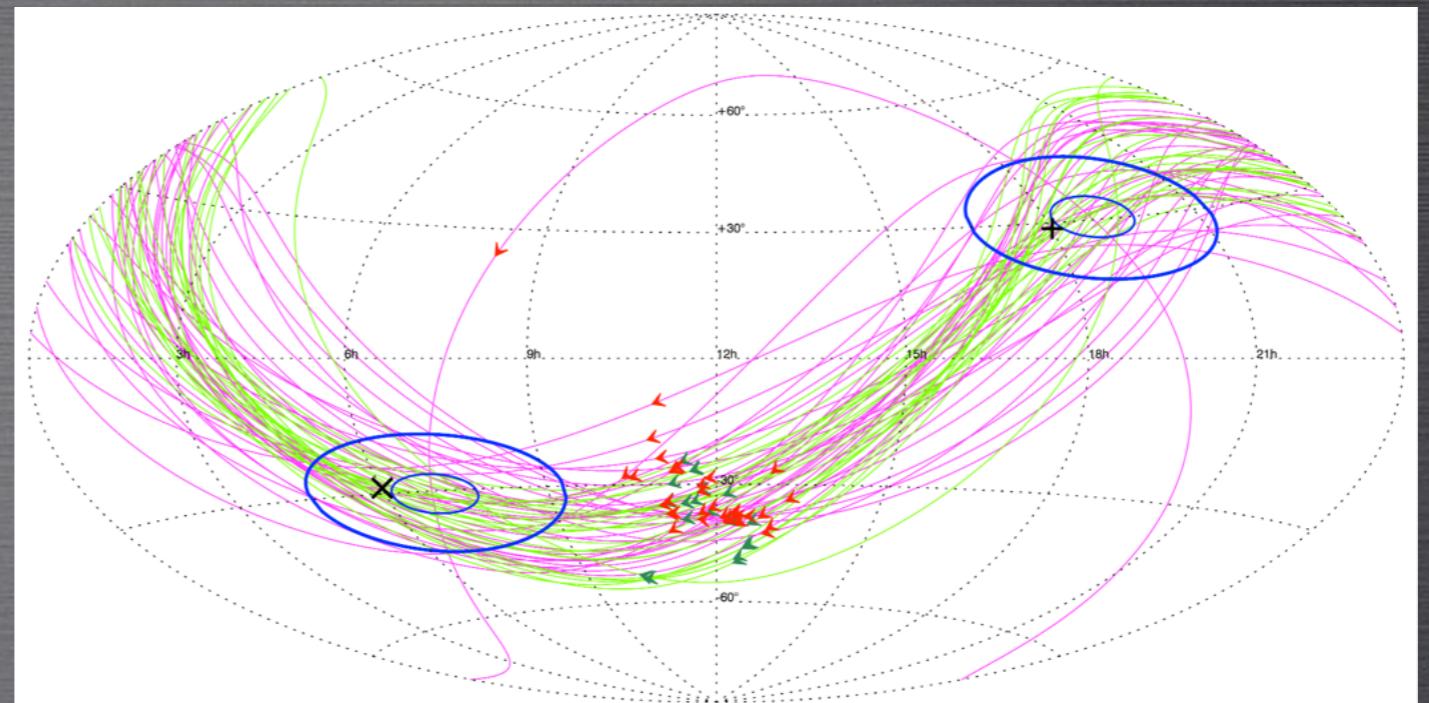




CREDIT ; JOURNEY TO THE STARS, AMNH



# BROWN DWARFS IN YOUNG MOVING GROUPS WITH THE BASS SURVEY

CARNEGIE INSTITUTE FOR SCIENCE, 2014

JONATHAN GAGNÉ, DAVID LAFRENIÈRE, RENÉ DOYON, JACKIE FAHERTY, LISON MALO,  
ÉTIENNE ARTIGAU, KELLE CRUZ, ADAM BURGASSER, MARIE-ÈVE NAUD, LOÏC ALBERT

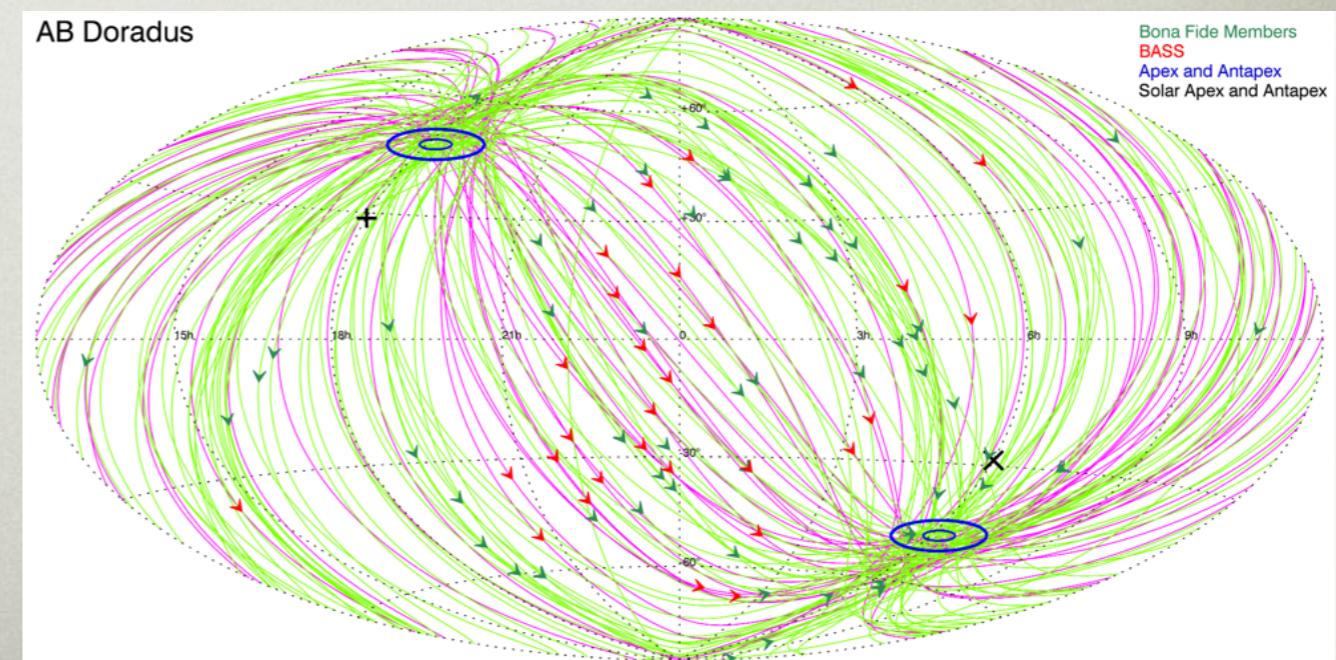
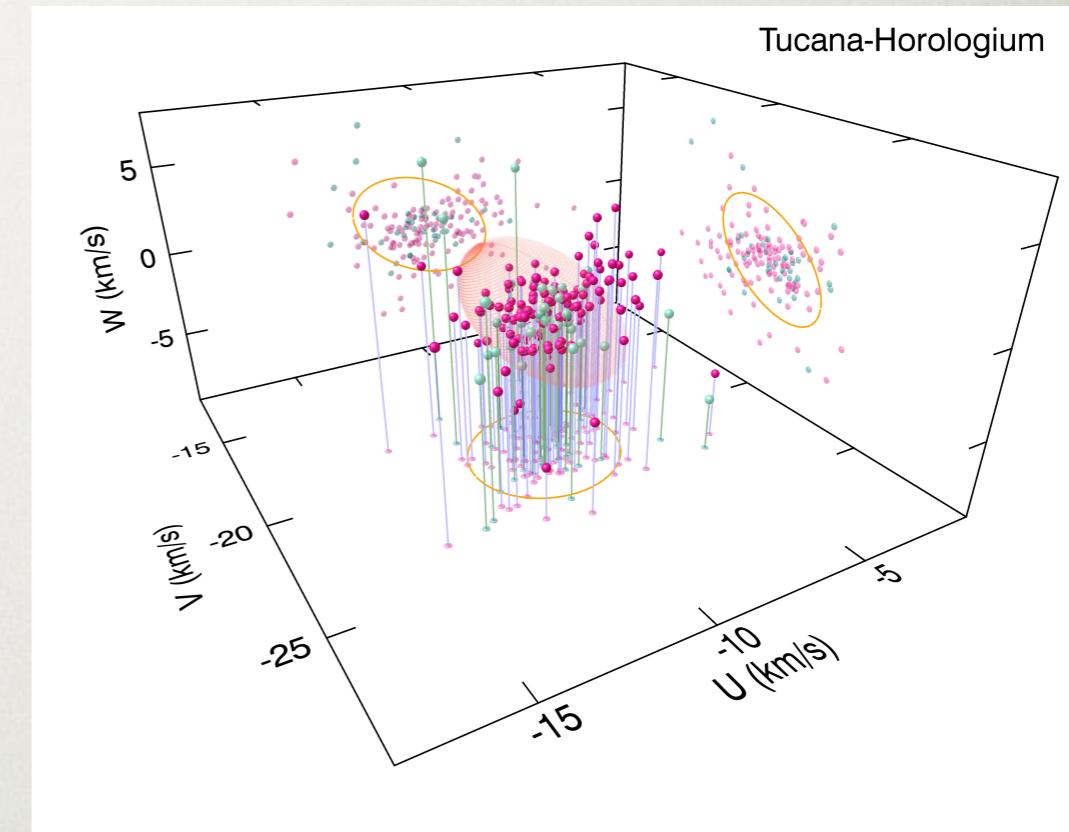


Université  
de Montréal

# WHAT IS A MOVING GROUP ?

1/22

- A group of young coeval stars (typically  $< 200$  Myr)
- Born from the same molecular cloud
- Still share a similar galactic velocity
- Nearby = Spread-out on the sky
- Brown dwarf population is missing !



# WHAT IS BASS ?

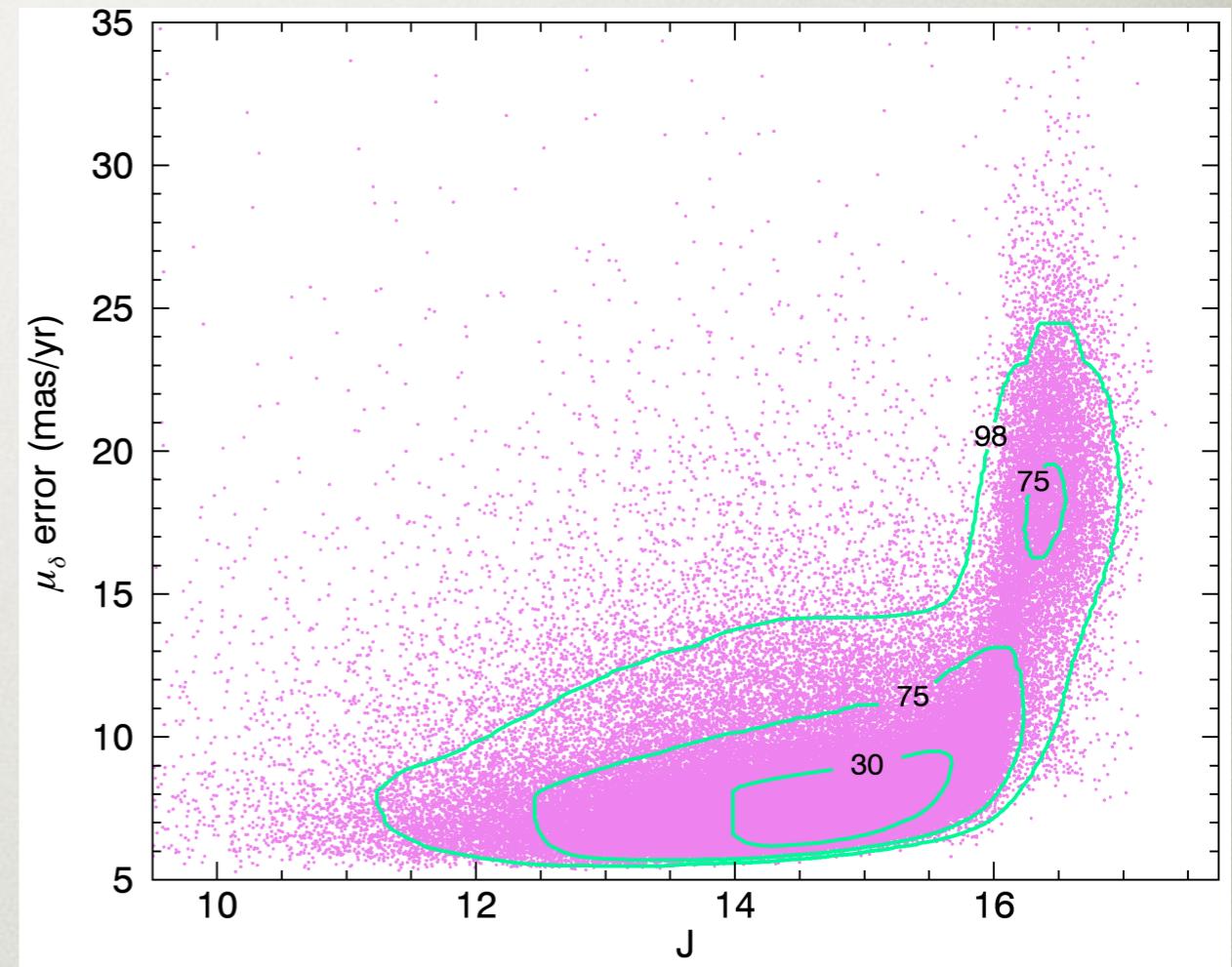
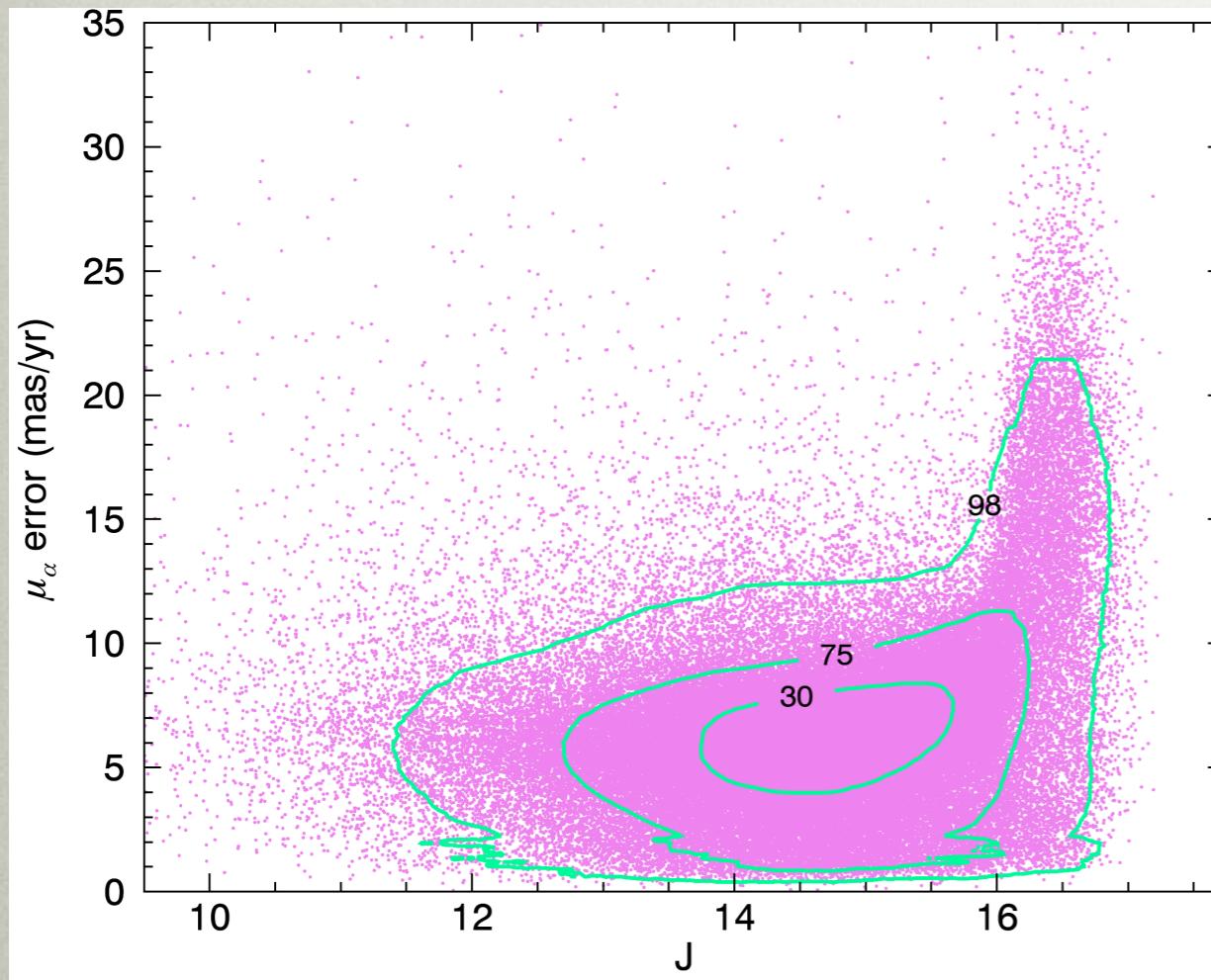
2/22

- BASS = Banyan All-Sky Survey
- Cross-Match of the whole  
*AllWISE + 2MASS*
- 100,000 potential > M5 dwarfs  
with PMs
- BANYAN II tool to identify  
candidate members of MGs
- 230 **new** high priority candidates
- 250 new low priority candidates



# THE BASS SAMPLE

3/22



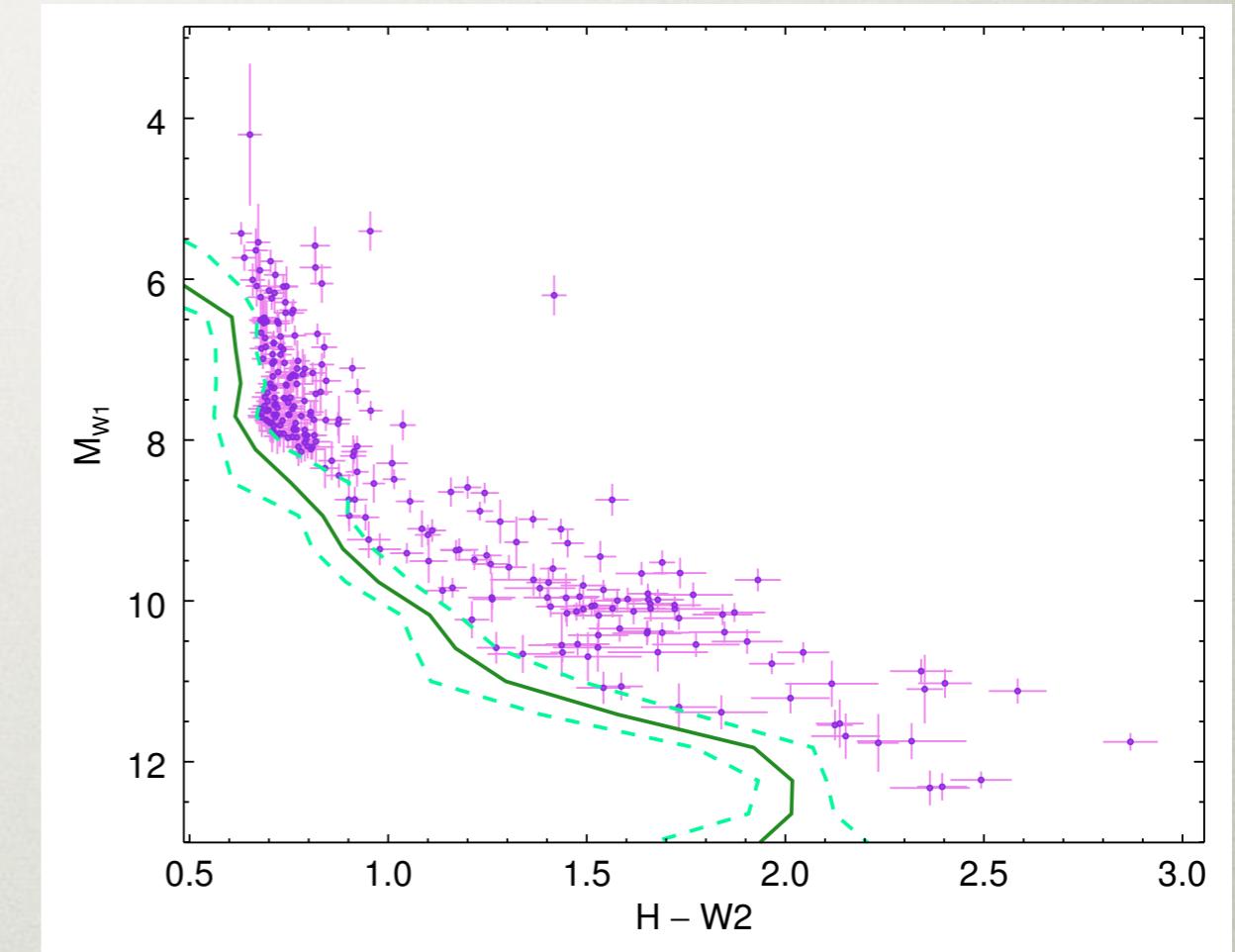
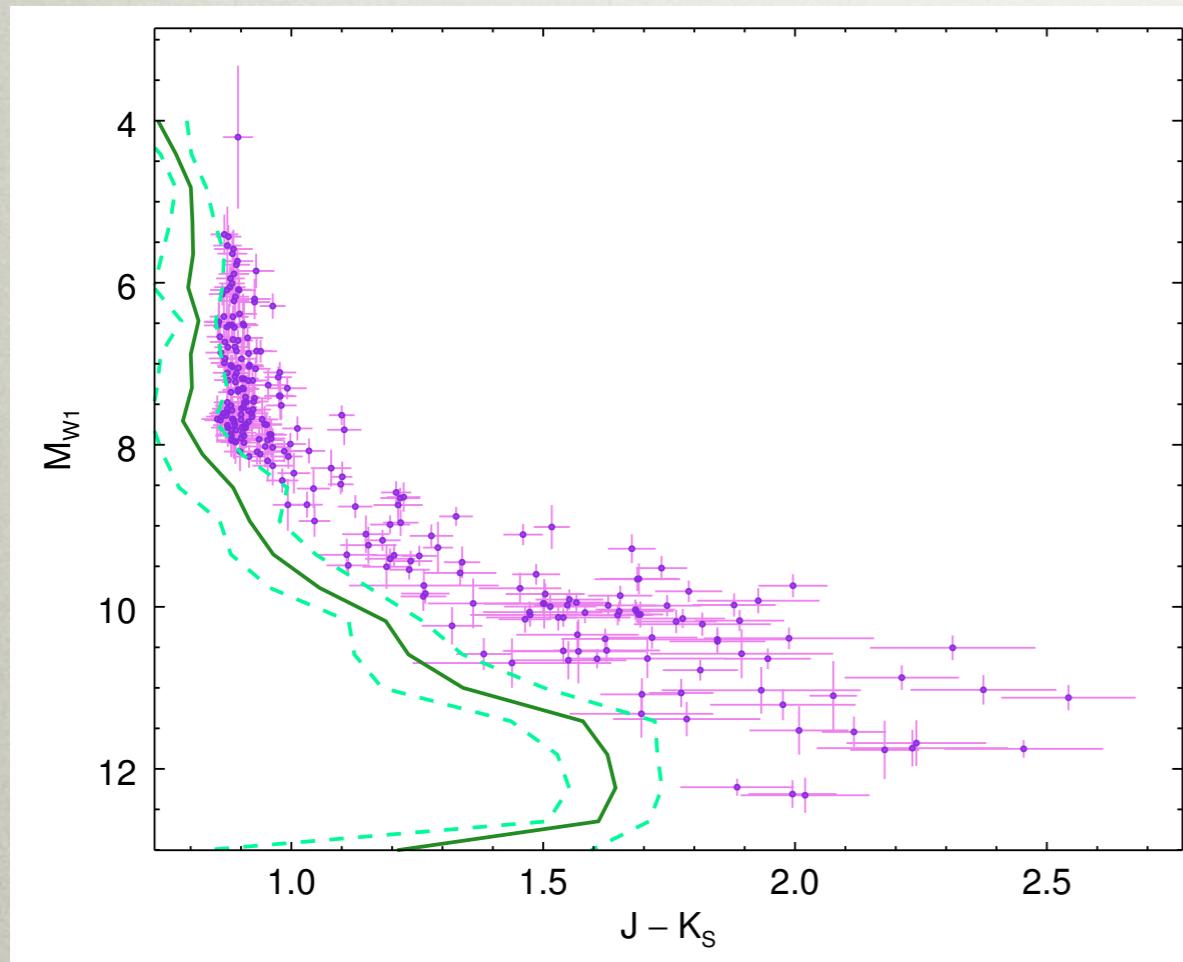
Gagné 2014d (Accepted ApJ)  
arXiv 1410.4864

THE 2MASS / ALLWISE CROSS-MATCH YIELDS PRETTY GOOD  
PM MEASUREMENTS !

TYPICAL PRECISION IS  $\pm 10 - 15$  MAS/YR

# THE BASS SAMPLE

4/22

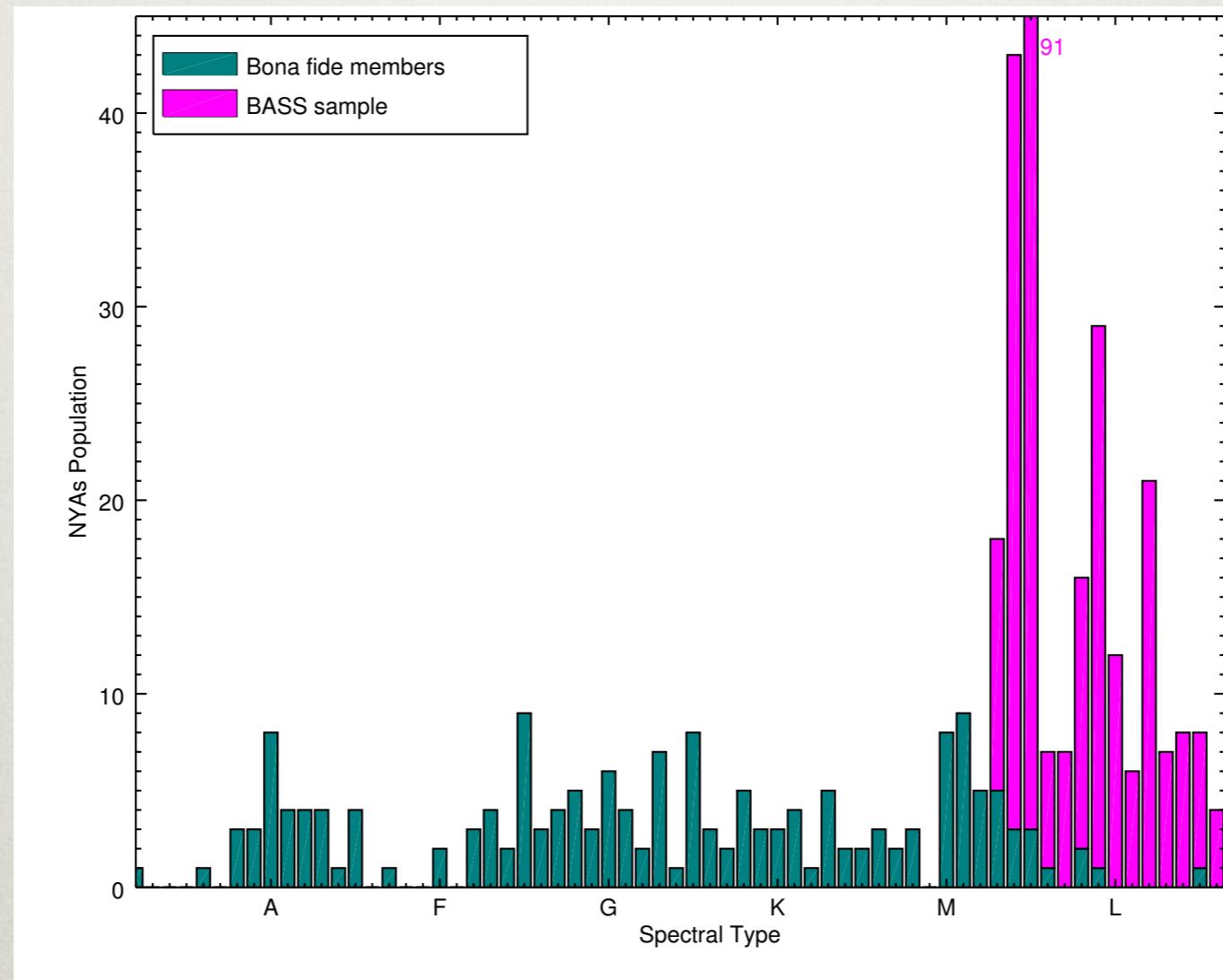


Gagné 2014d (Accepted ApJ)  
arXiv 1410.4864

THE KINEMATIC DISTANCES OF BASS CANDIDATES  
IS CONSISTENT WITH REDDER COLORS / LARGER LUMINOSITY  
THAN FIELD DWARFS

# THE BASS SAMPLE

5/22



Gagné 2014d (Accepted ApJ)  
arXiv 1410.4864

ESTIMATED SPECTRAL TYPES SPAN M5 — L6,  
A LARGELY UNEXPLORED SPACE FOR MG MEMBERS

# SPECTROSCOPIC FOLLOW-UP

6/22

Now What ?

SEVERAL MEASUREMENTS ARE STILL NEEDED TO CONFIRM  
MEMBERSHIP

- Radial velocity : needs hi-resolution spectroscopy  
=> big telescopes, lots of time
- Parallax : need a large temporal coverage  
=> small telescopes, \*\*lots\*\* of time
- Signs of youth : needs low-resolution spectroscopy  
=> easier !



IRTF Telescope

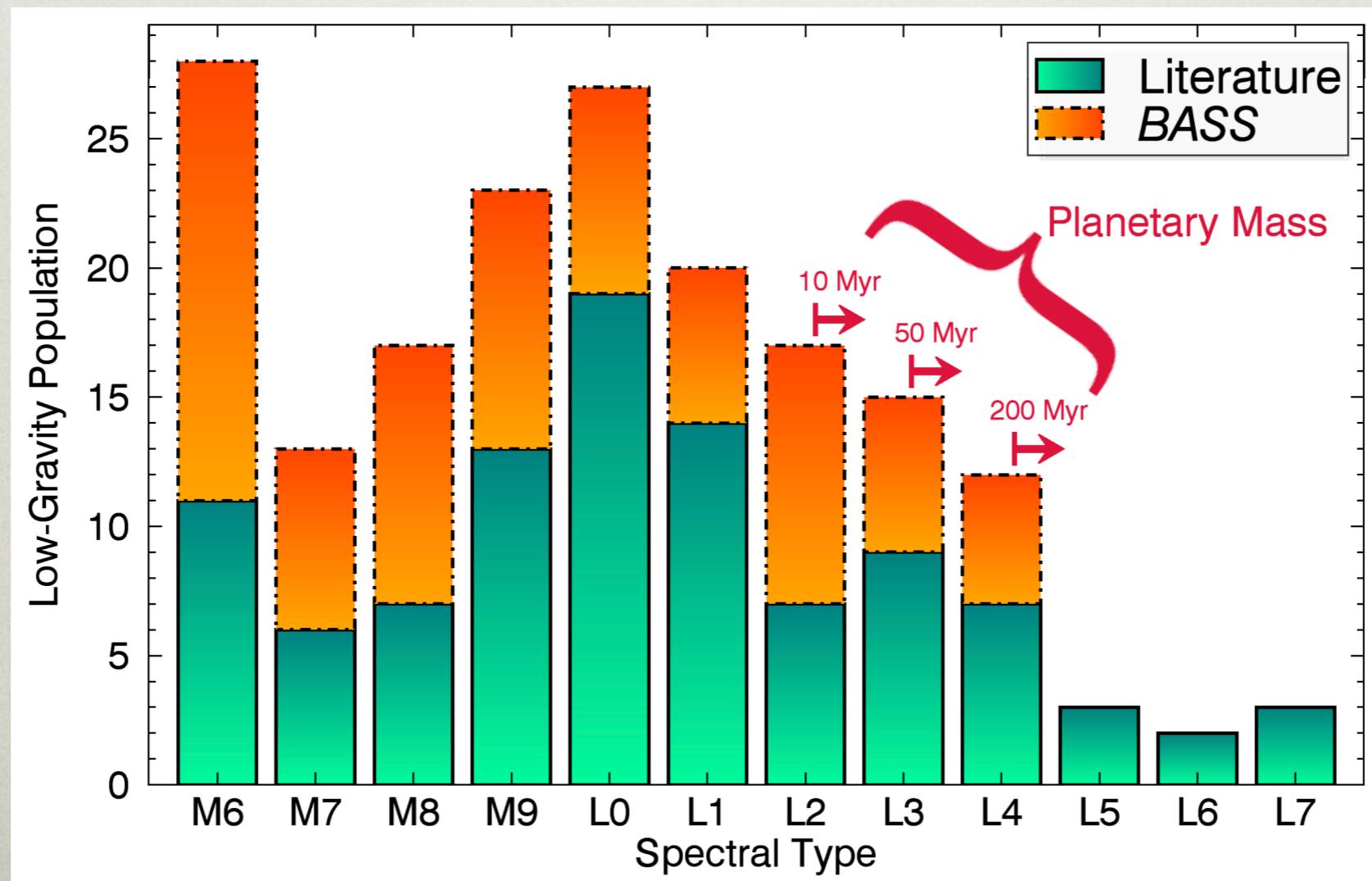
WE THUS START WITH LOW-RESOLUTION NIR SPECTROSCOPY

=> IDENTIFY YOUNG BROWN DWARFS, REJECT CONTAMINANTS

# SPECTROSCOPIC FOLLOW-UP

7/22

- => WE FOLLOWED MORE THAN 200, FROM WHICH 100 ARE HIGH-PRIORITY CANDIDATES
- => DISCOVERED ~ 50 NEW M6 - L4 LOW-GRAVITY DWARFS
- => IDENTIFIED NEW SIGNS OF LOW-G IN ~ 30 KNOWN OBJECTS



# SPECTROSCOPIC FOLLOW-UP

8/22

YOUNG LS ARE QUITE BEAUTIFUL ;

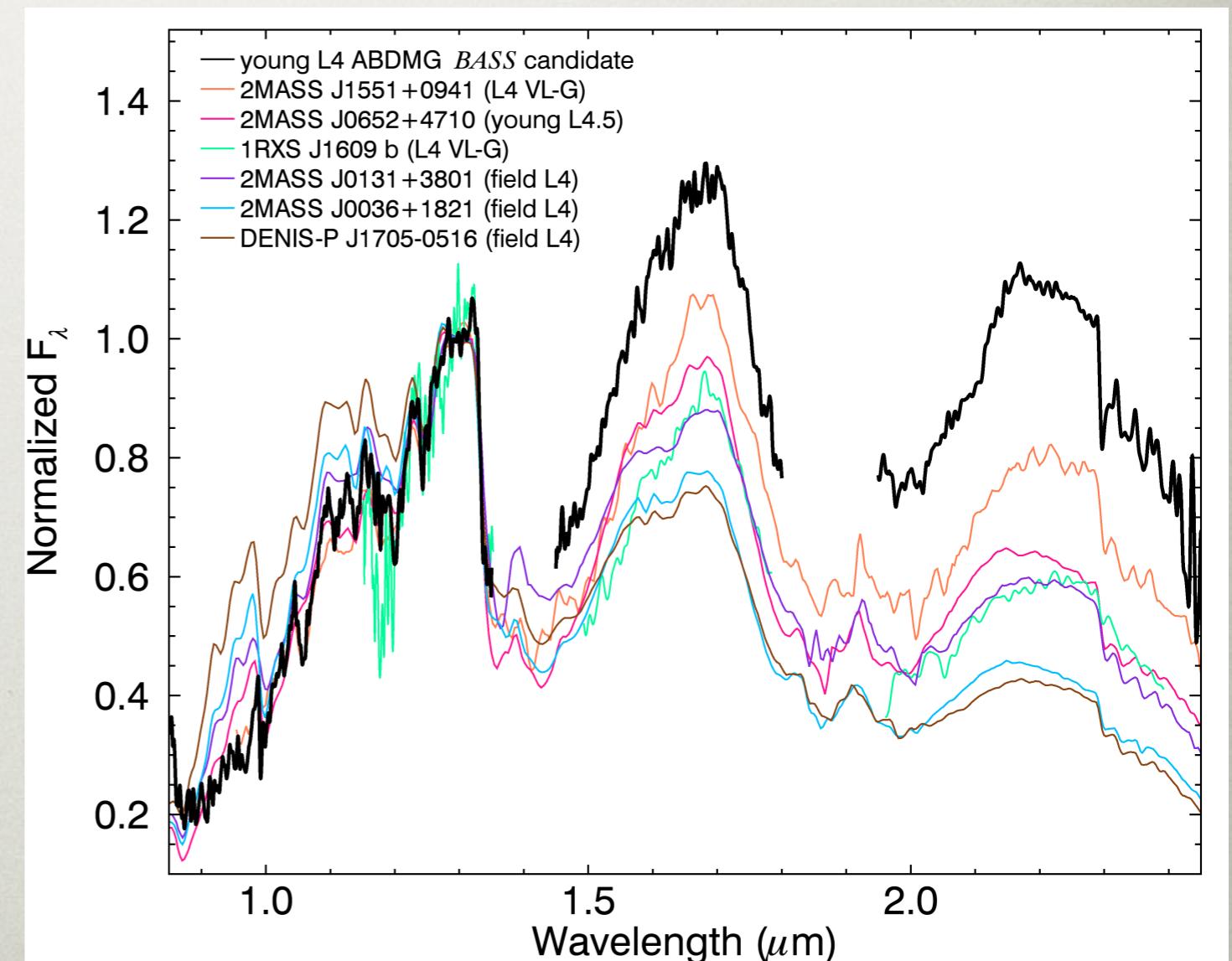
=> TRIANGULAR H-BAND

=> RED SLOPE

=> WEAK ATOMIC LINES  
(Na I, K I)

=> DEEPER VO ABSORPTION

=> DIFFERENT SHAPE IN K BAND



# SPECTROSCOPIC FOLLOW-UP

9/22

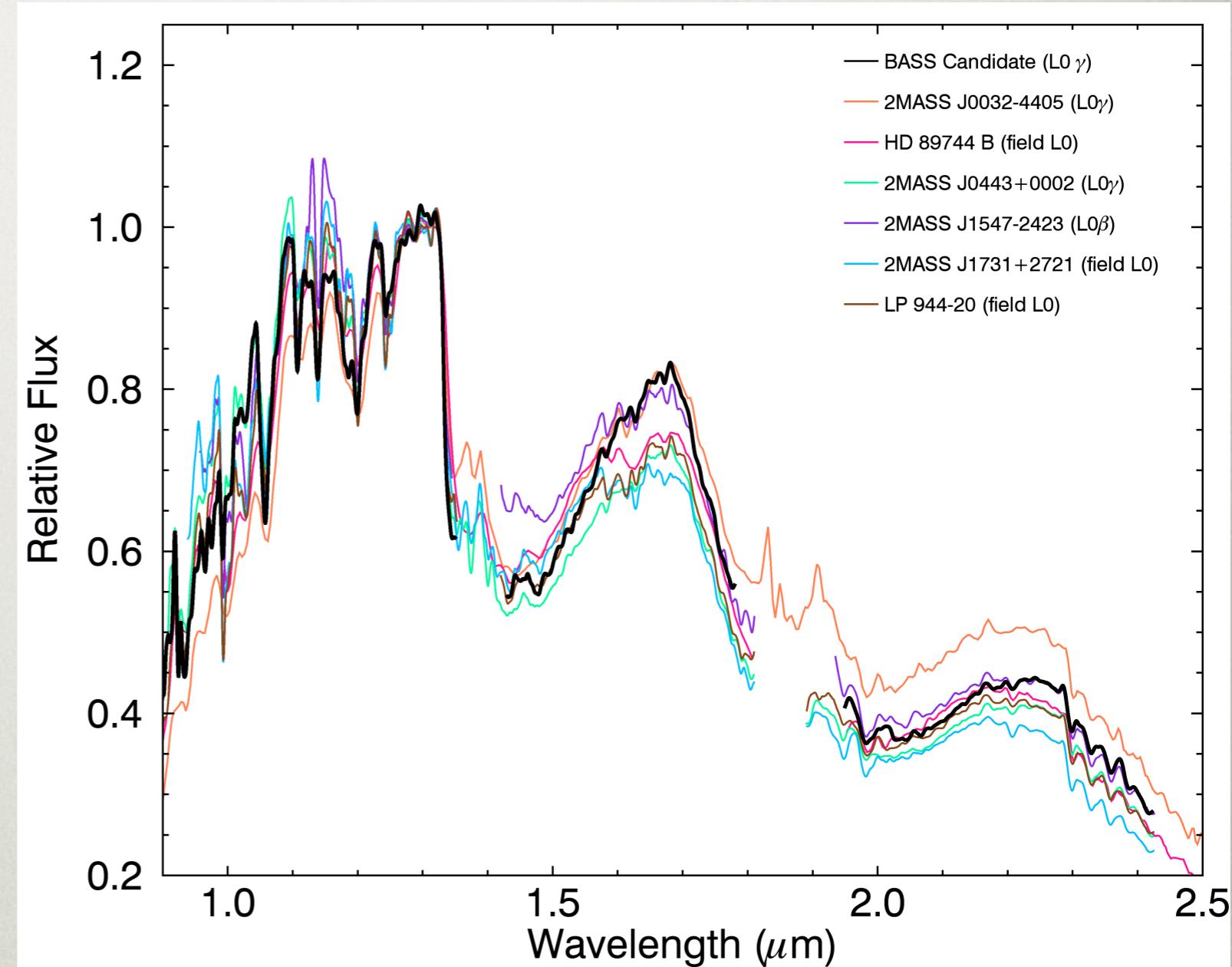
WHY ?

**INFLATED RADIUS + SMALLER  
MASS = LOWER G, LOWER P**

=> LESS PRESSURE  
BROADENING

=> THICKER CLOUDS

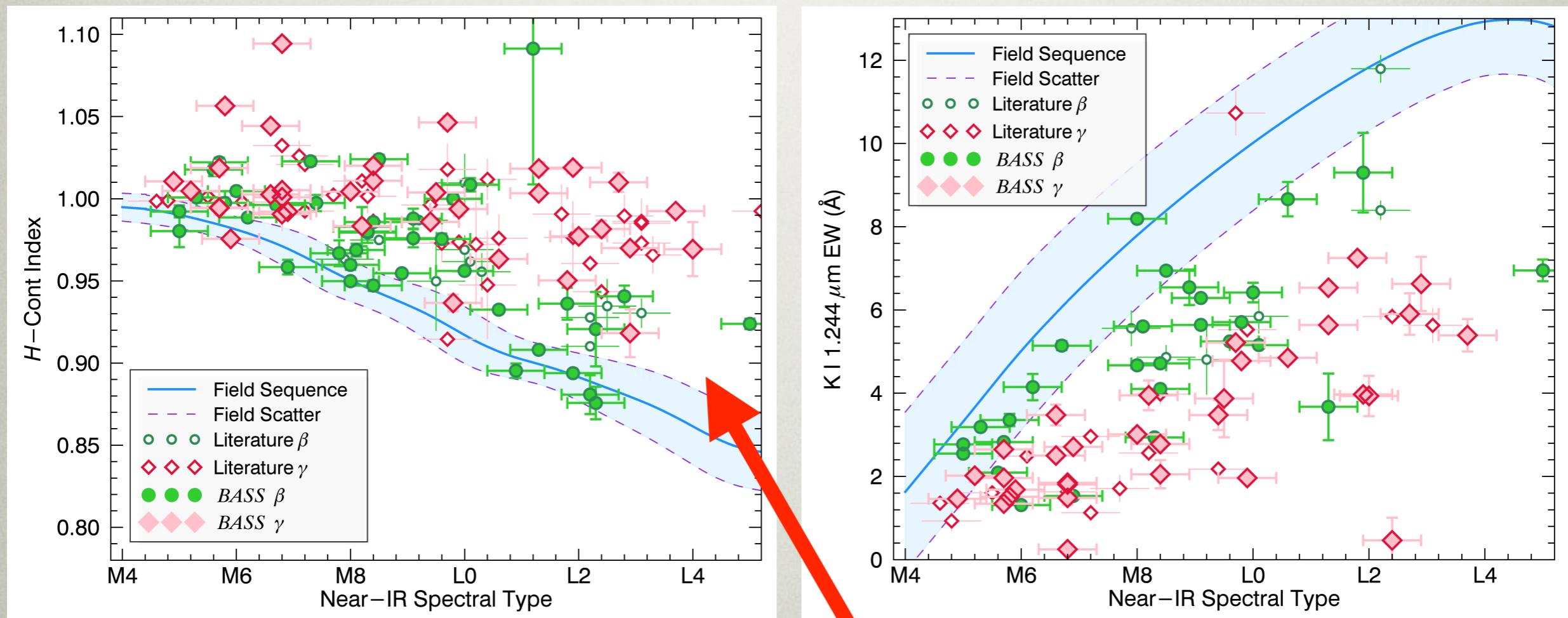
=> LESS CIA OF H<sub>2</sub>



# SPECTROSCOPIC FOLLOW-UP

10/22

WE USED THE ALLERS & LIU (2013) + VISUAL COMPARISON TO ASSIGN SPT + GRAVITY CLASS



Gagné et al., in prep.

Lots of new low-G brown dwarfs !

# PHOTOMETRIC SEQUENCES

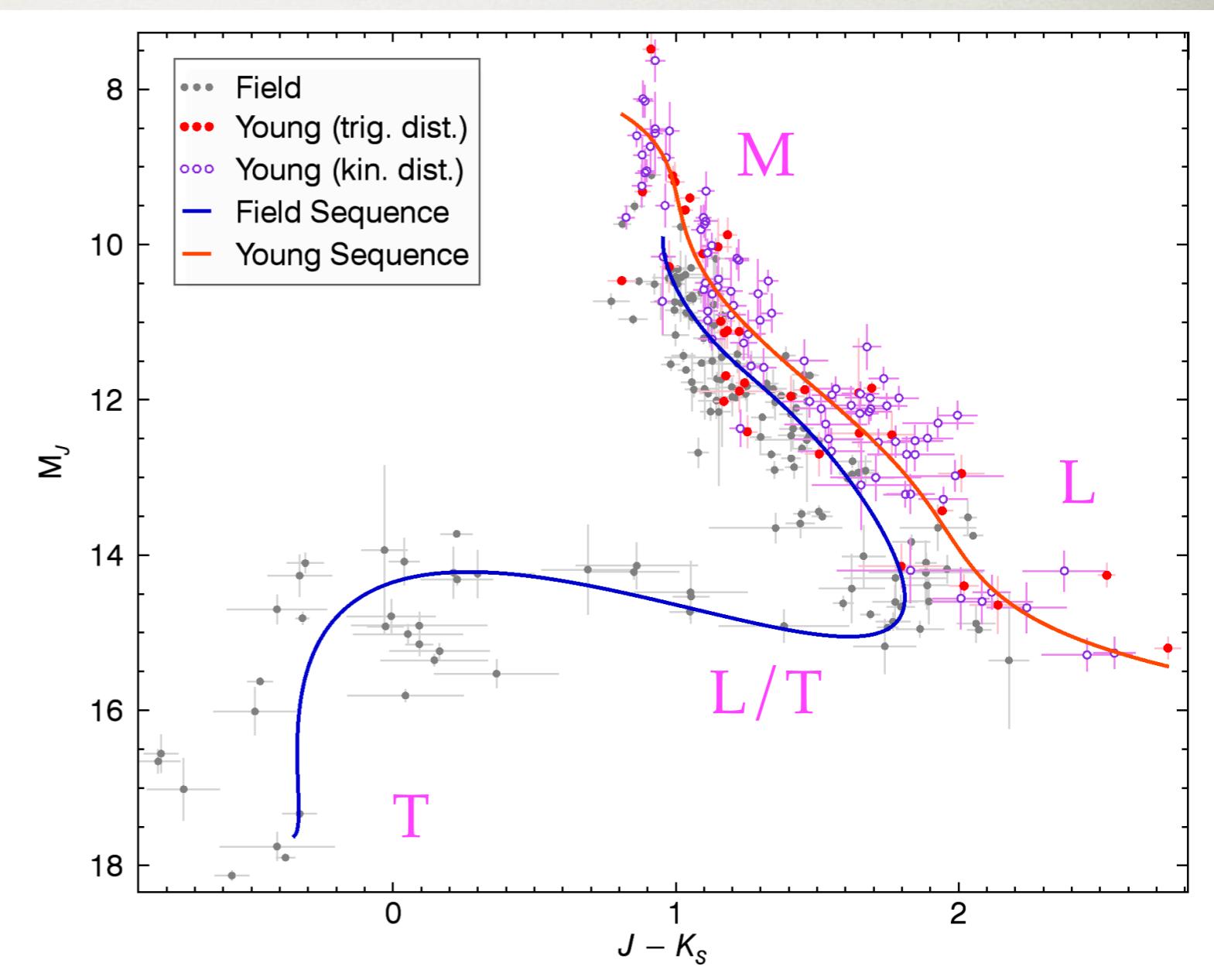
11/22

KINEMATIC DISTANCES ALLOW US TO CREATE KICK-ASS CMD DIAGRAMS :

=> FILLED RED = LOW-  
GRAVITY + PLX

=> OPEN PURPLE = LOW-  
GRAVITY + KINEMATIC  
DISTANCE

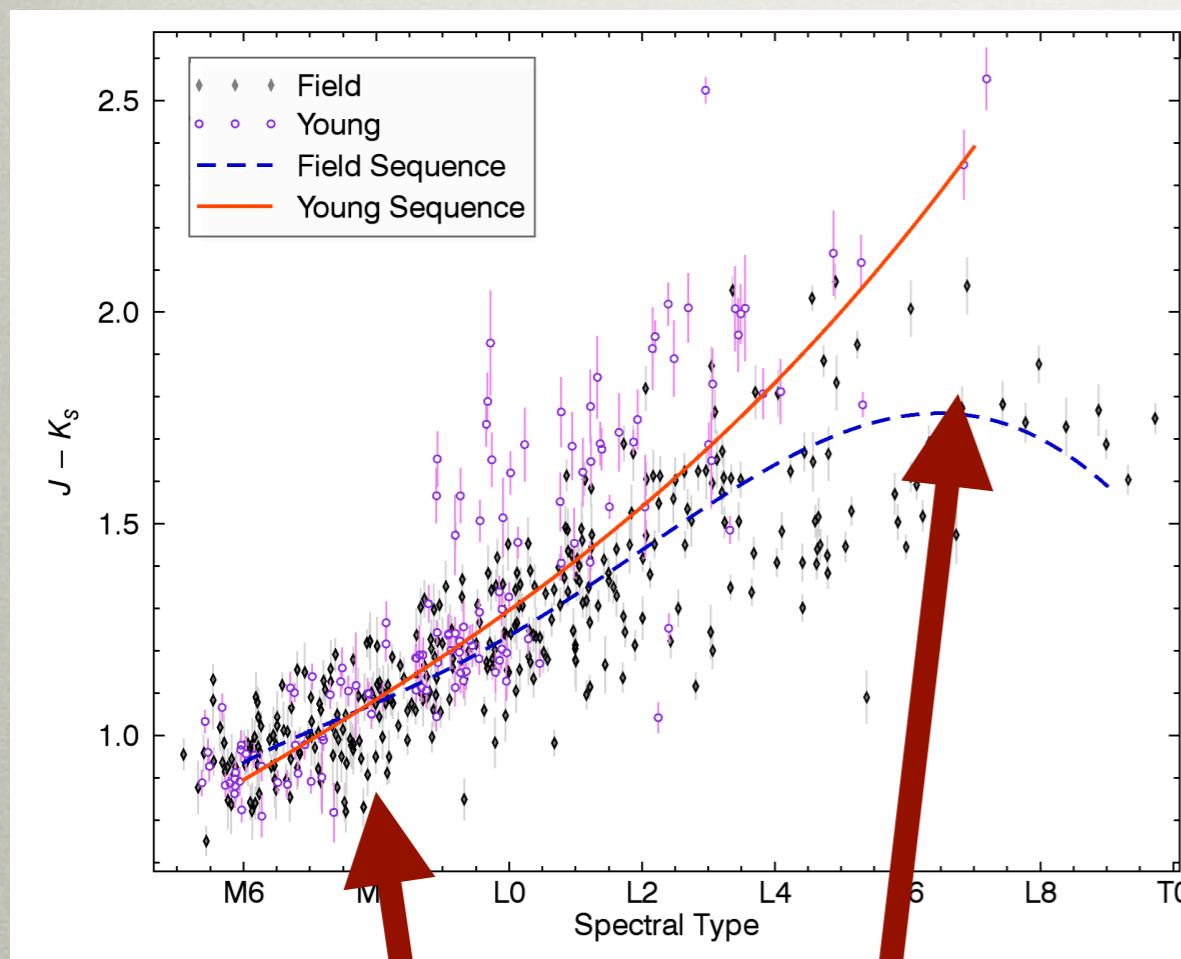
=> BLACK = FIELD



# PHOTOMETRIC SEQUENCES

12/22

WE DEFINE NEW M6 - L7 EMPIRICAL SEQUENCES :



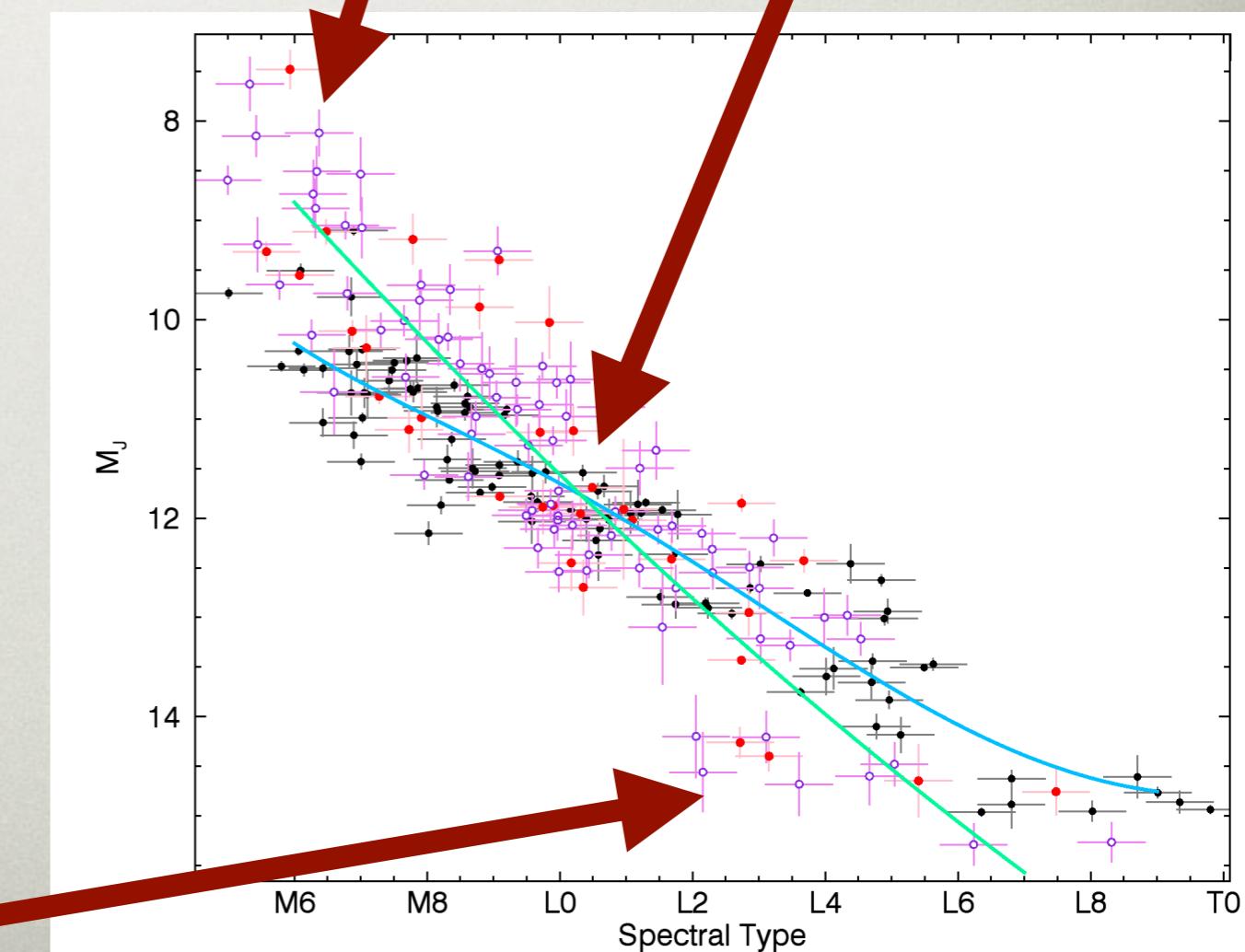
Gagné et al., in prep.

No clouds

Thick clouds

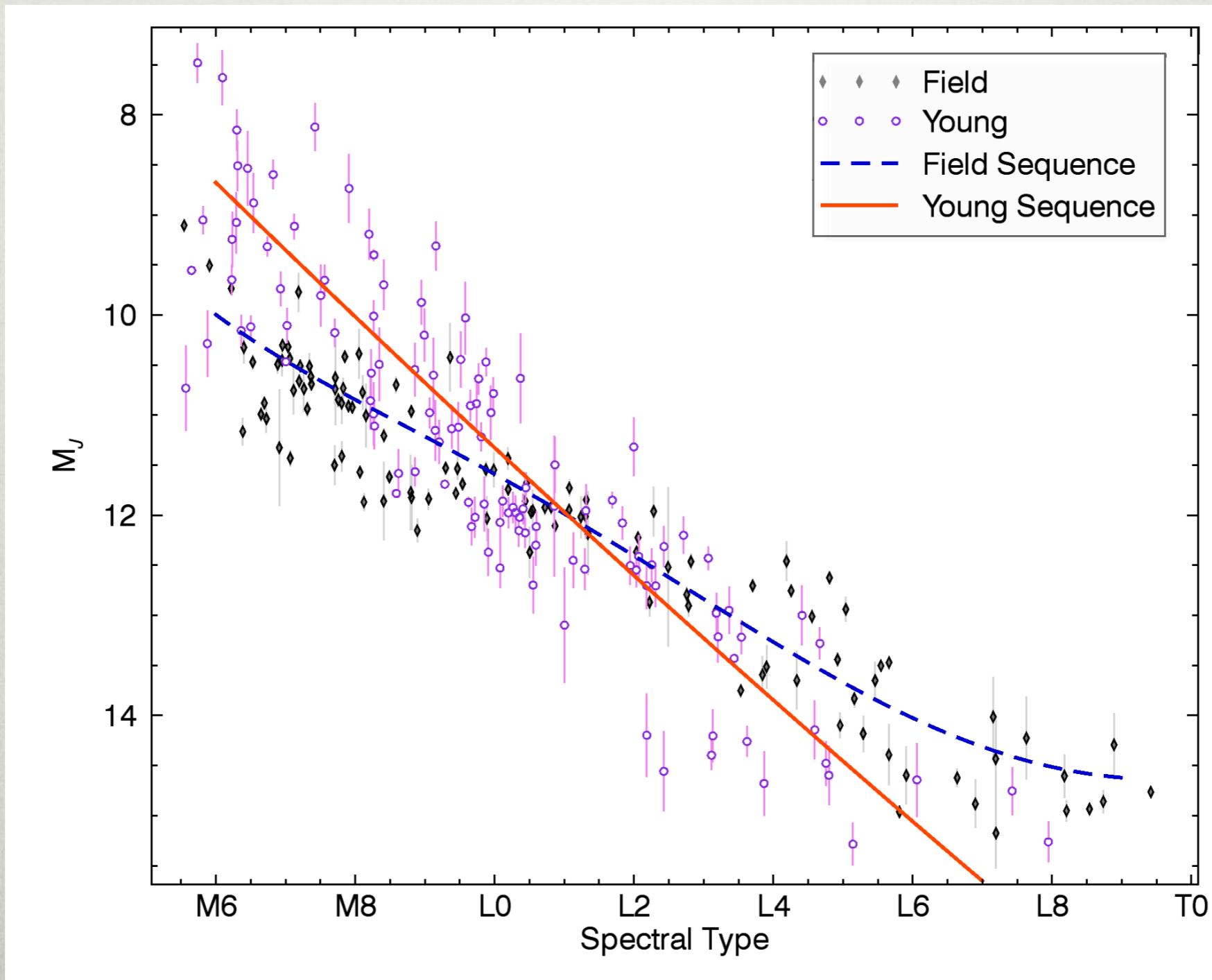
Inflated radii = brighter

Clouds block the light !



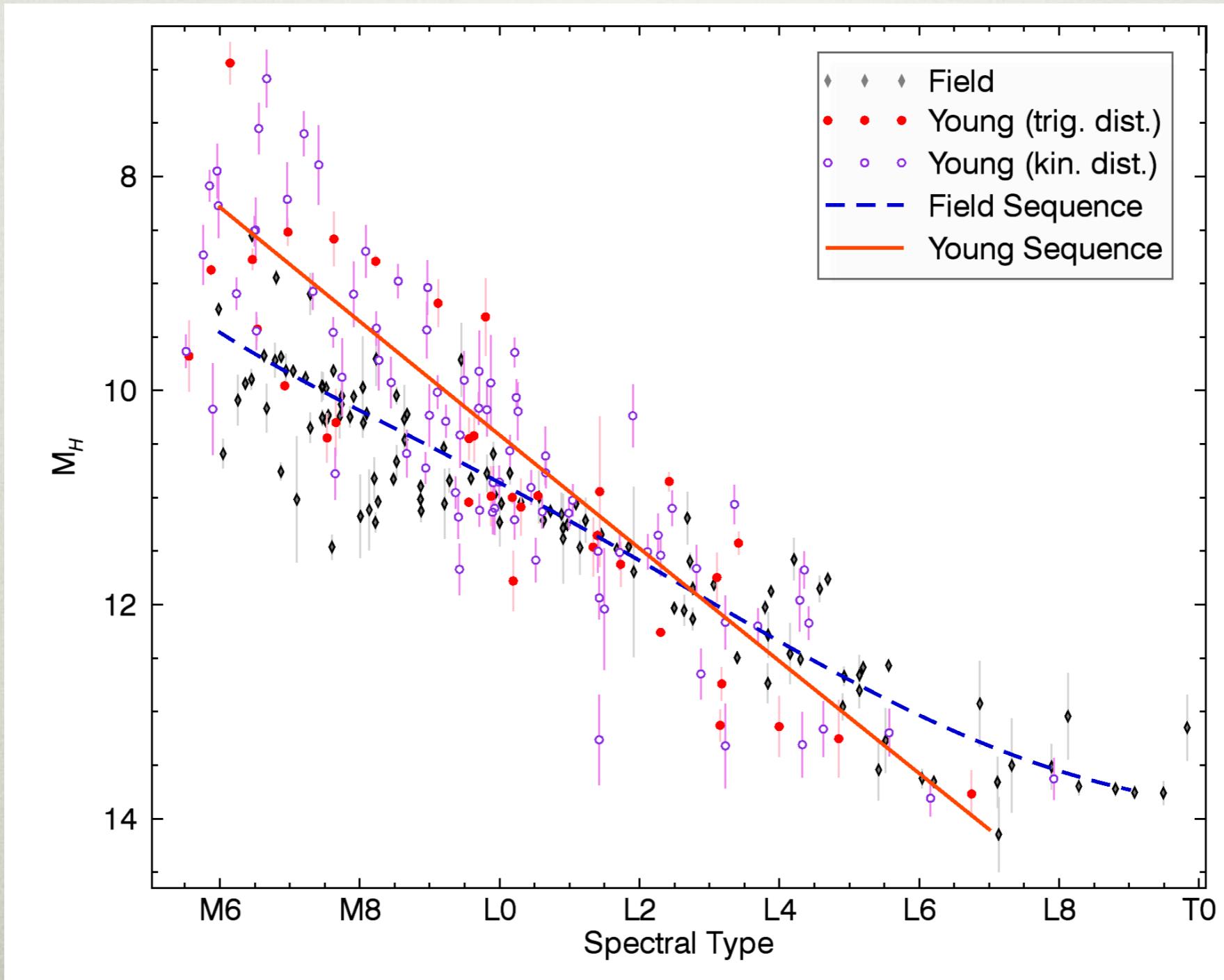
# PHOTOMETRIC SEQUENCES

13/22



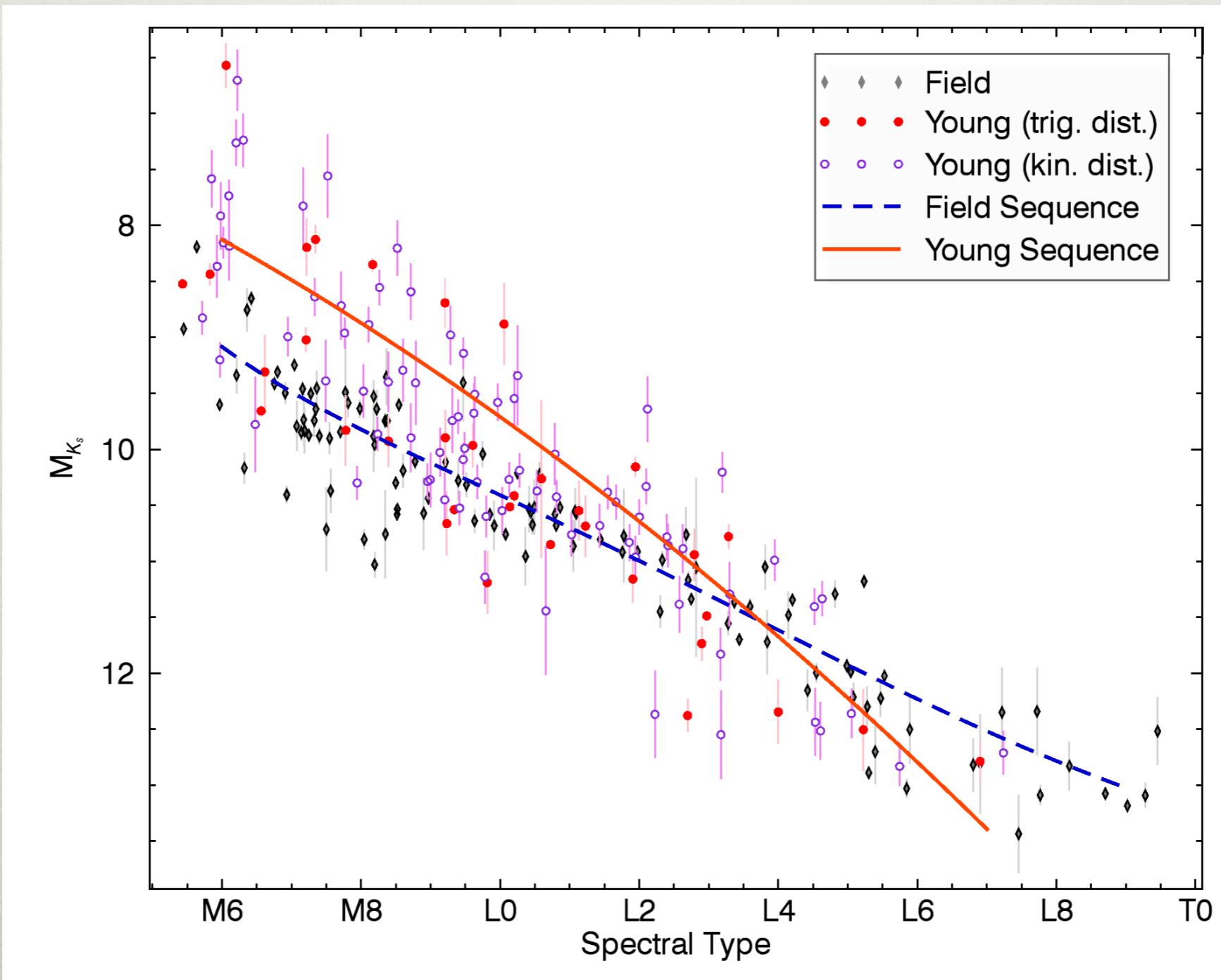
# PHOTOMETRIC SEQUENCES

13/22



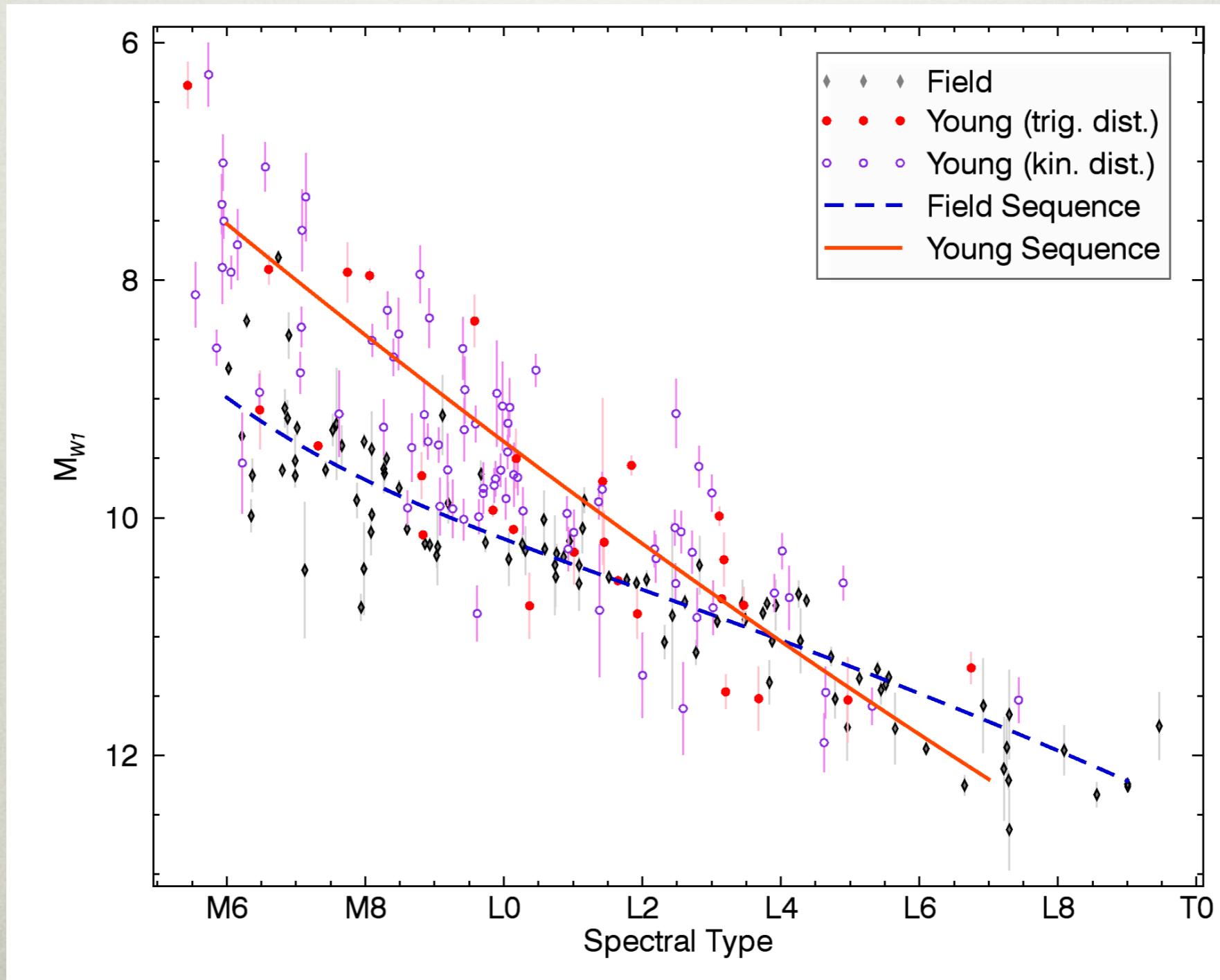
# PHOTOMETRIC SEQUENCES

13/22



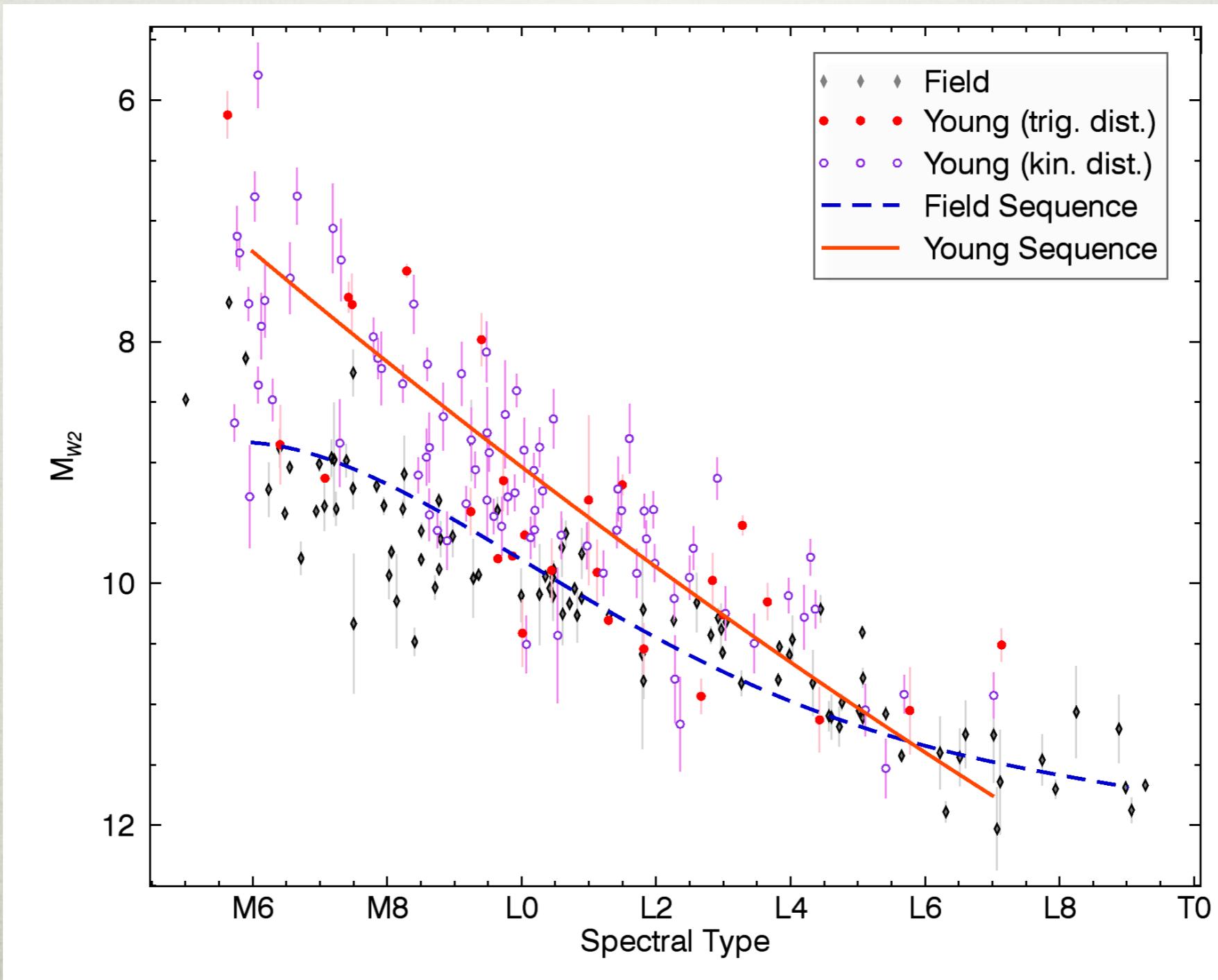
# PHOTOMETRIC SEQUENCES

13/22



# PHOTOMETRIC SEQUENCES

13/22

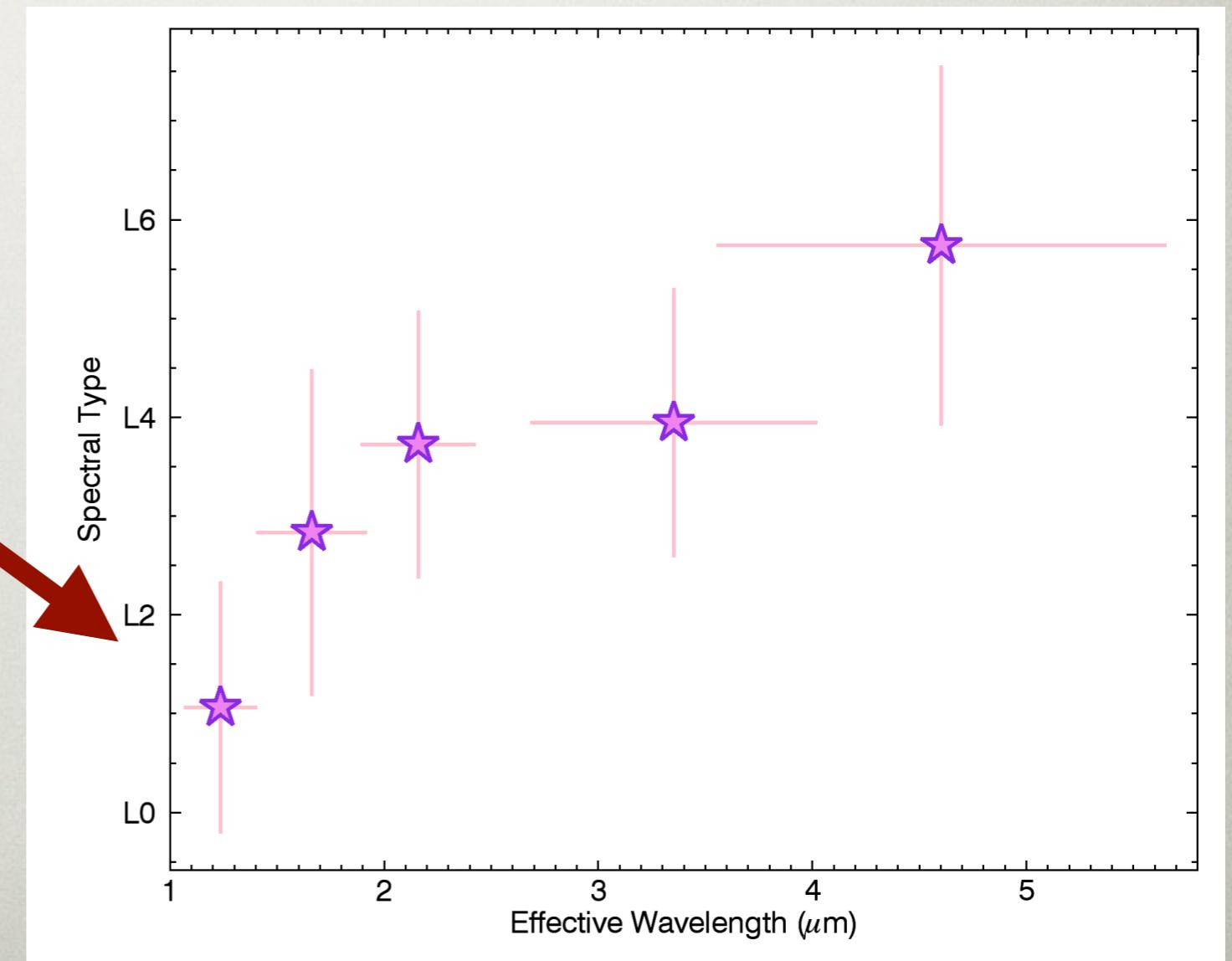


# PHOTOMETRIC SEQUENCES

14/22

**ABSOLUTE MAGNITUDE - SPECTRAL TYPE SEQUENCES CROSS  
AT DIFFERENT SPECTRAL TYPES IN DIFFERENT FILTERS !**

Clouds are more opaque at  $\sim 1 \mu\text{m}$



**WARNING : PRELIMINARY RESULTS AHEAD !**

**I AM WARNING YOU**



# PHYSICAL PARAMETERS

15/22

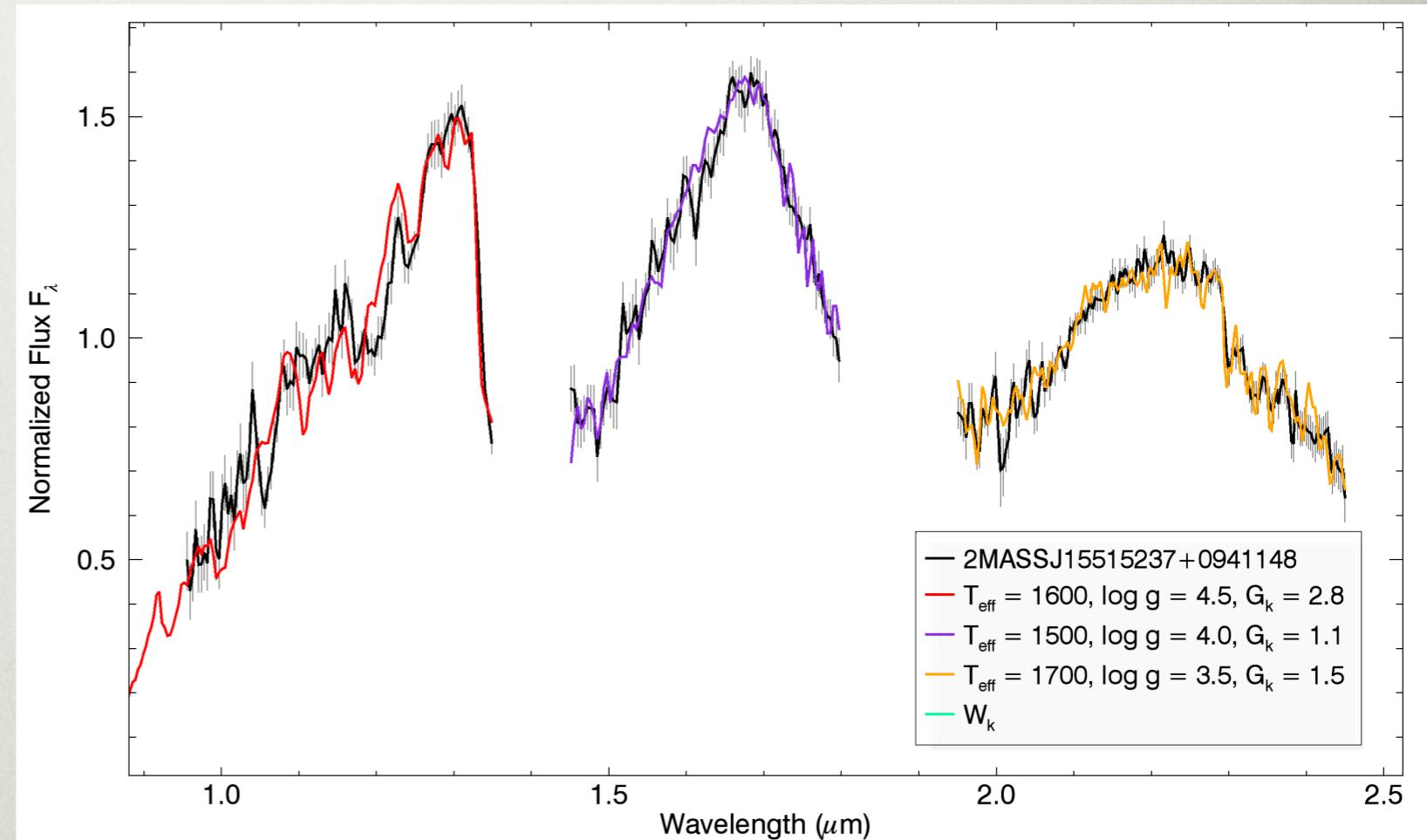
WE USE

CIFIST2011/BT-SETTL  
MODELS +  
AMES-COND ISOCHRONES

TO INVESTIGATE :

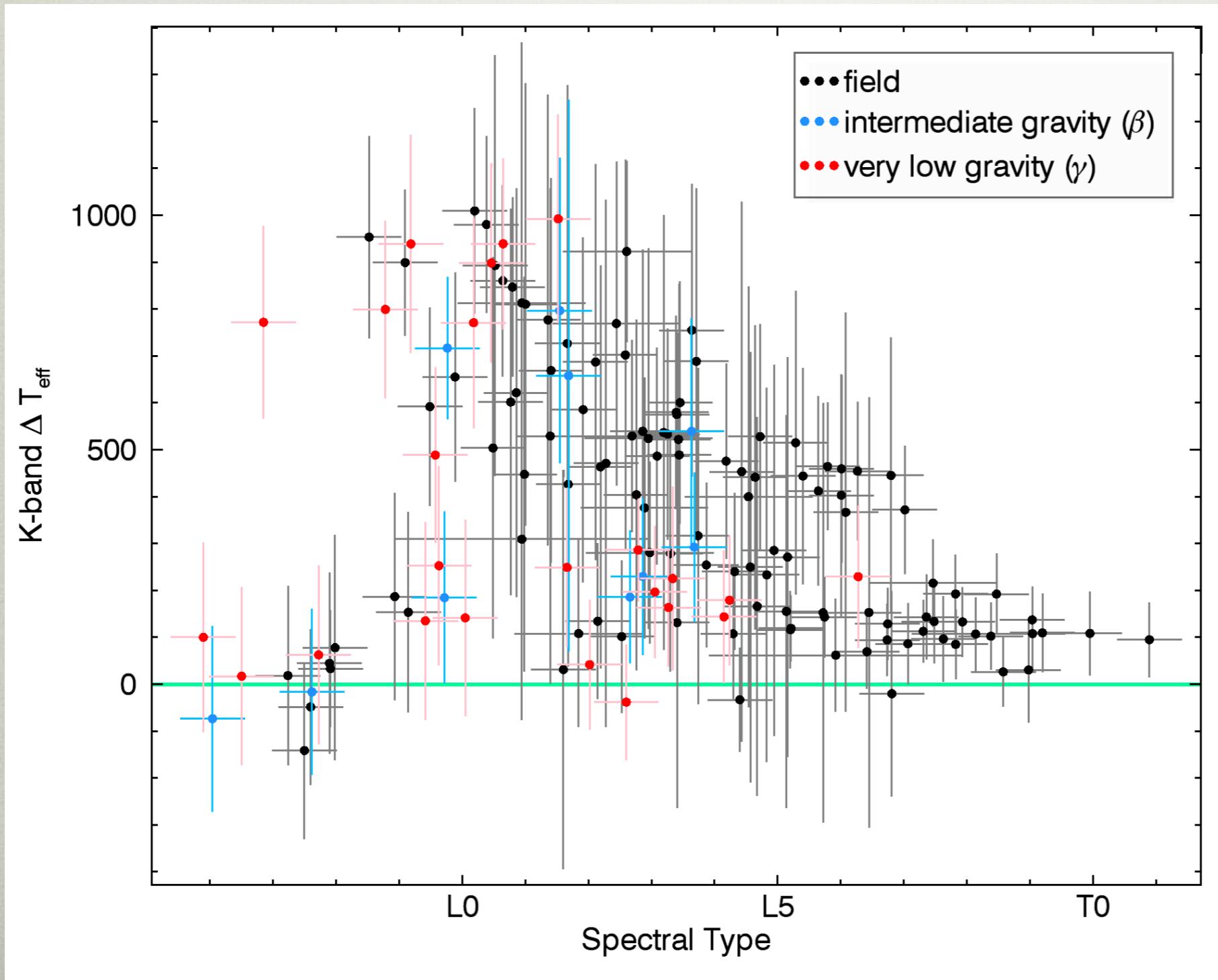
- MASS
- TEMPERATURE
- LOG G

... WORK IN PROGRESS !



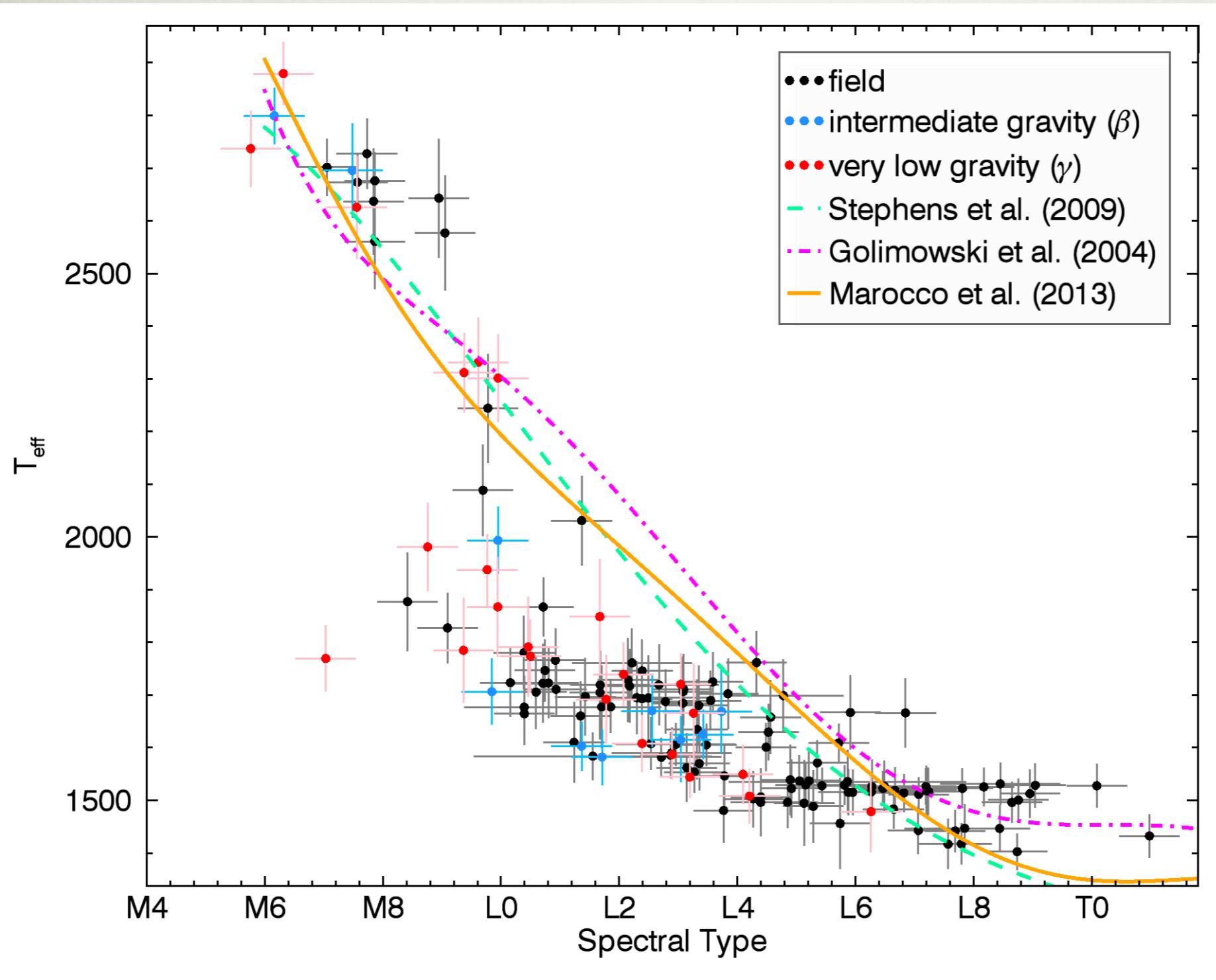
# PHYSICAL PARAMETERS

17/22



# PHYSICAL PARAMETERS

16/22



# PHYSICAL PARAMETERS

18/22

## HISTOGRAM FOR ESTIMATED MASSES OF LOW-G BDS IN BASS :

WHY SO MANY 13  
 $M_{Jup}$  ??

=> SELECTION EFFECTS  
UNLIKELY

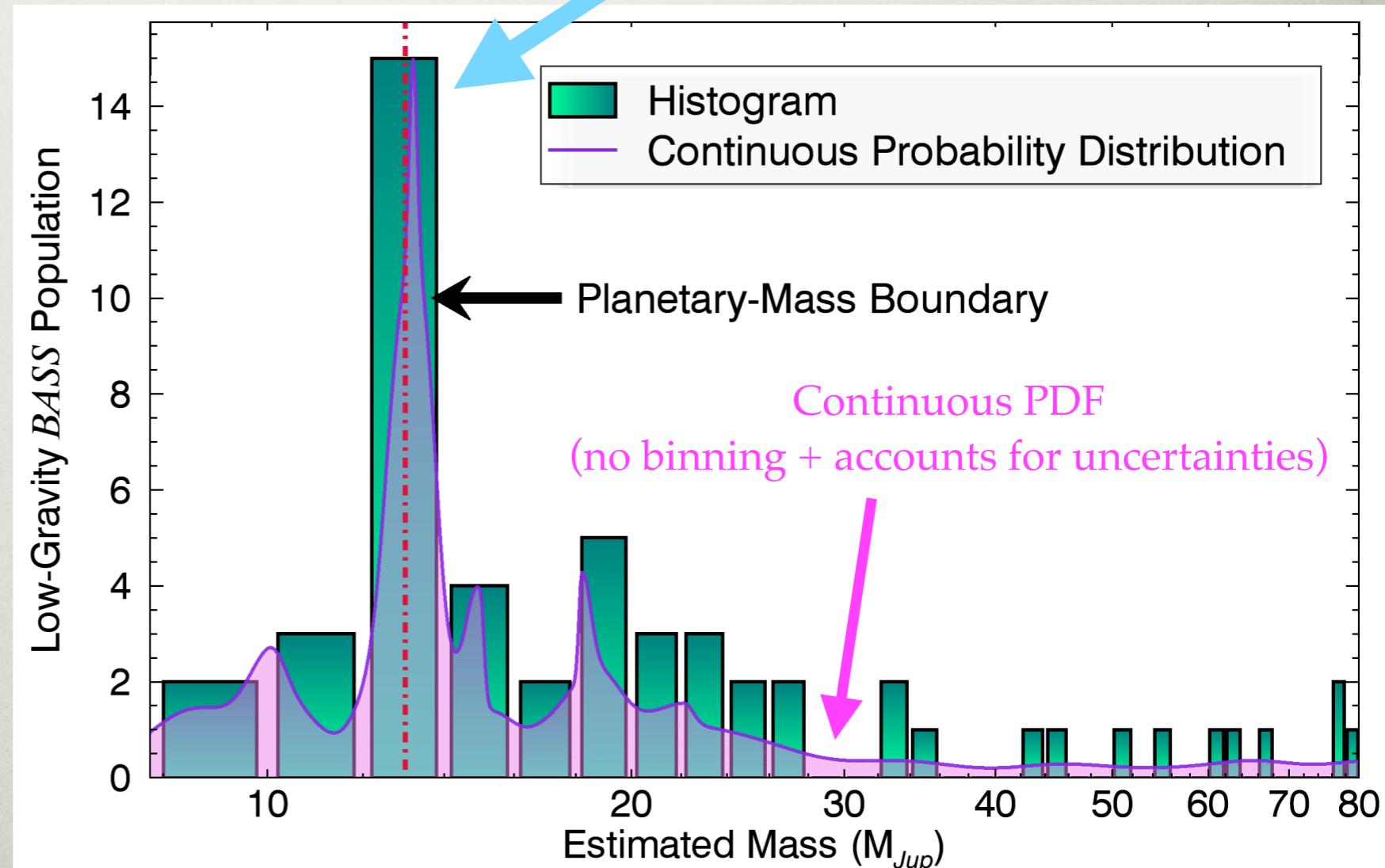
=> IS IT AN EFFECT OF  
ISOCHRONES FOLDING  
ON THEMSELVES ?

=> OR IS THERE SOME  
UNDERLYING PHYSICAL  
EXPLANATION ?

=> FLOATING PLANETS ?

and other wild speculation ?

What the heck ?



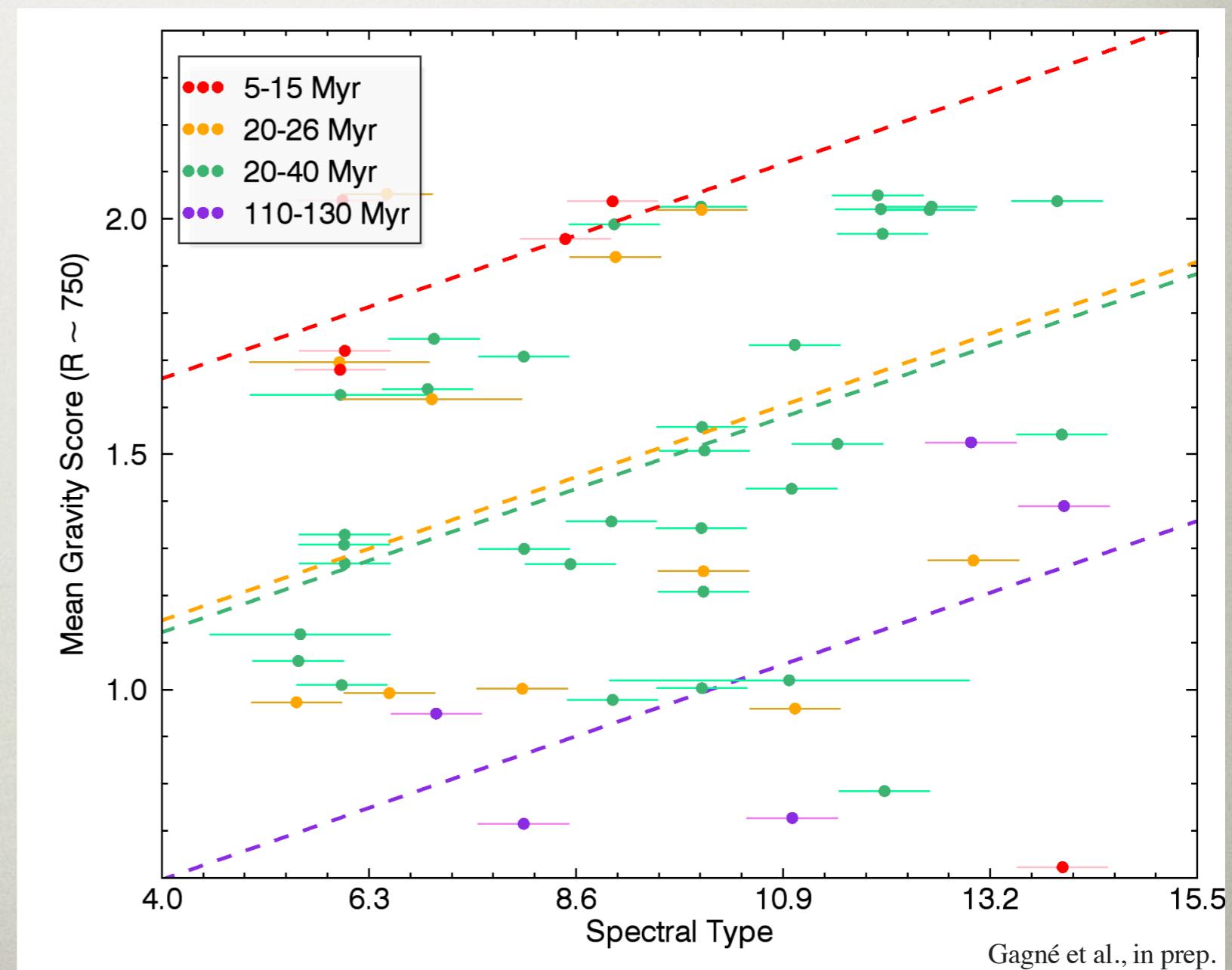
Gagné et al., in prep.

# AGE CALIBRATION ?

19/22

CAN WE CALIBRATE THE AGE OF BDs FROM THEIR NIR SPECTRA ?

=> MEAN GRAVITY SCORE FROM  
ALLERS & LIU (2013) SEEMS TO  
CORRELATE WITH AGE !

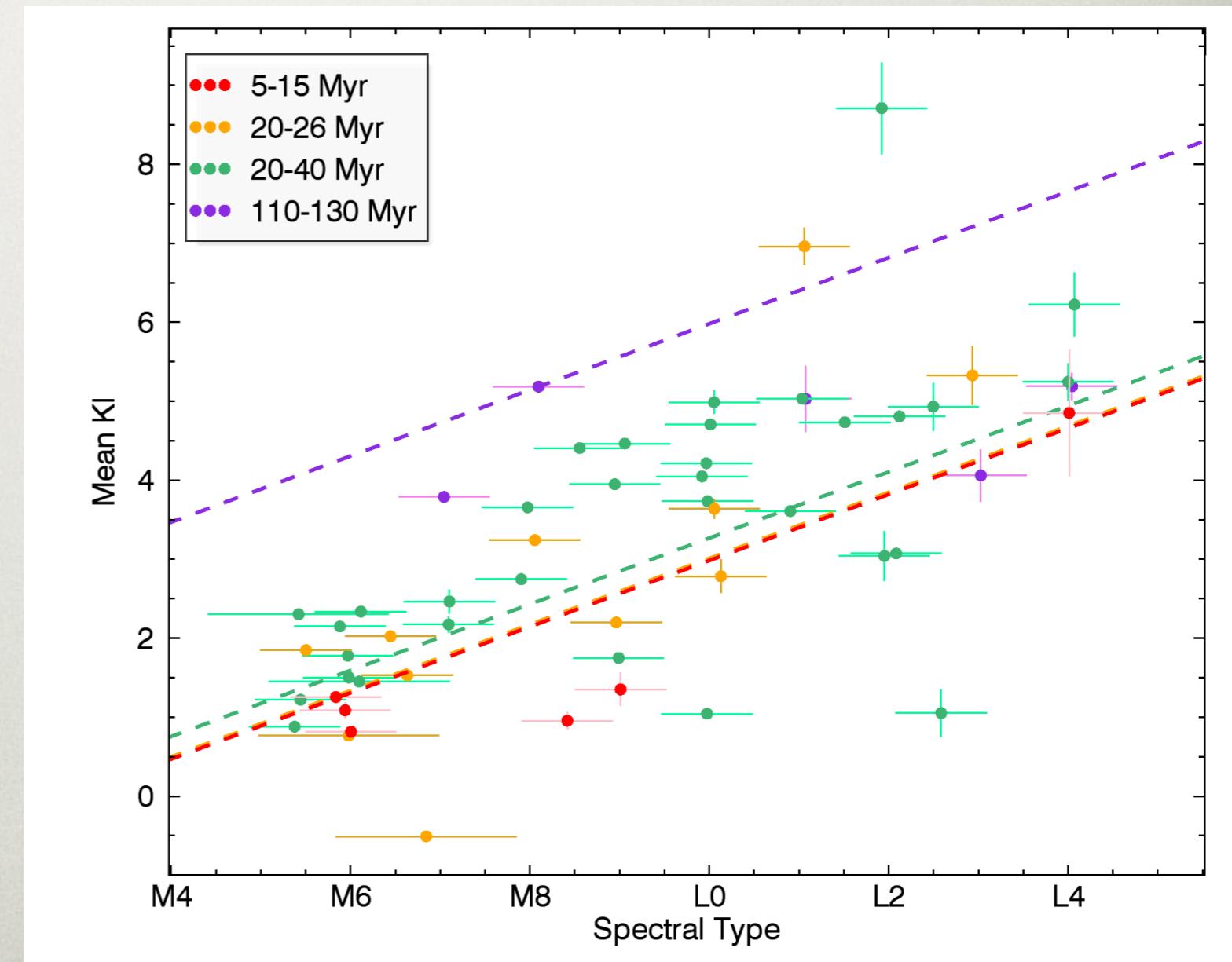


# AGE CALIBRATION ?

20/22

CAN WE CALIBRATE THE AGE OF BDs FROM THEIR NIR SPECTRA ?

=> SO DOES THE MEAN K I  
EQUIVALENT WIDTH

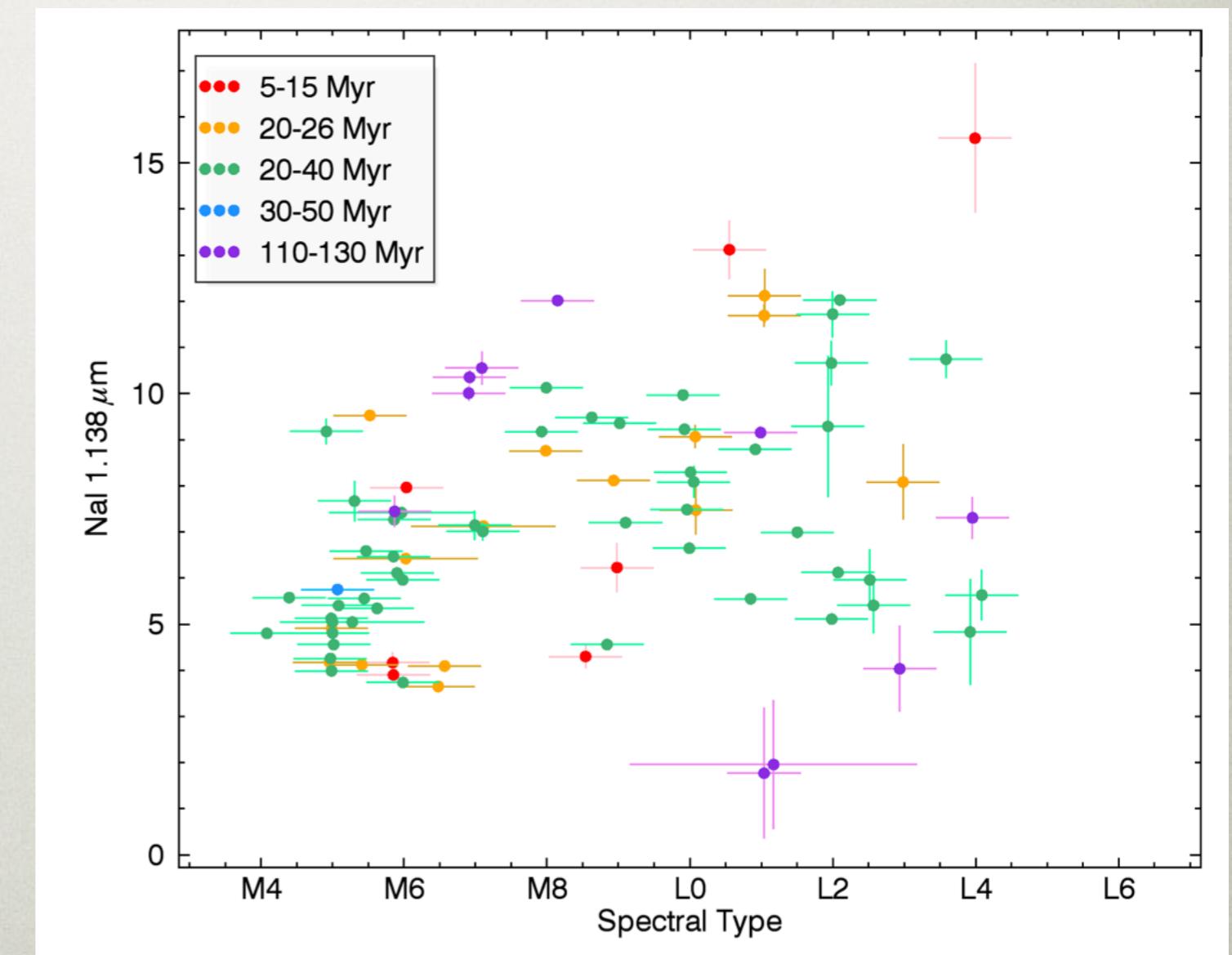


# AGE CALIBRATION ?

21/22

CAN WE CALIBRATE THE AGE OF BDs FROM THEIR NIR SPECTRA ?

=> NOT SO OBVIOUS IN  
THE CASE OF Na I

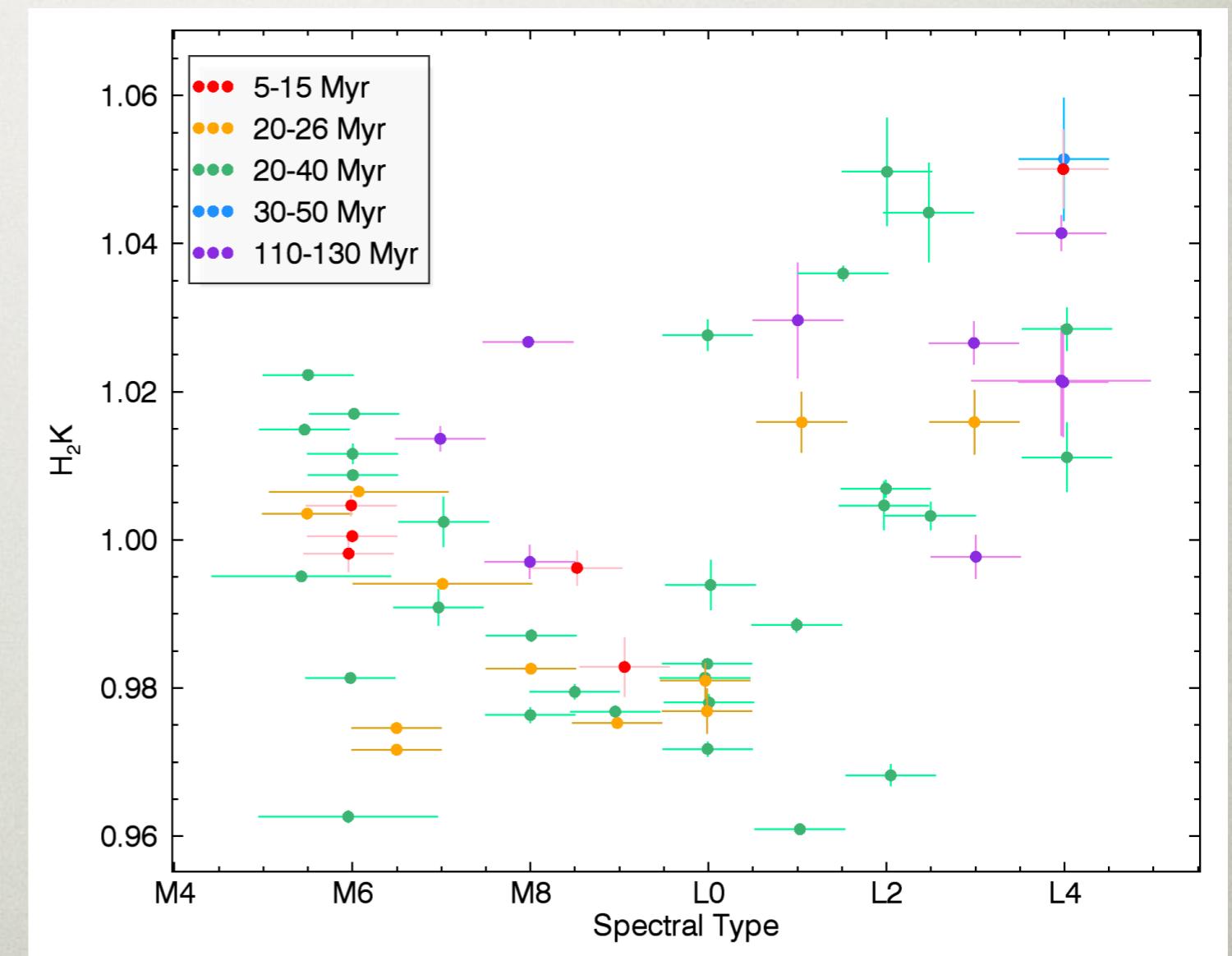


# AGE CALIBRATION ?

22/22

CAN WE CALIBRATE THE AGE OF BDs FROM THEIR NIR SPECTRA ?

=> OR USING CANTY  
2013's H<sub>2</sub>K





THANK YOU !

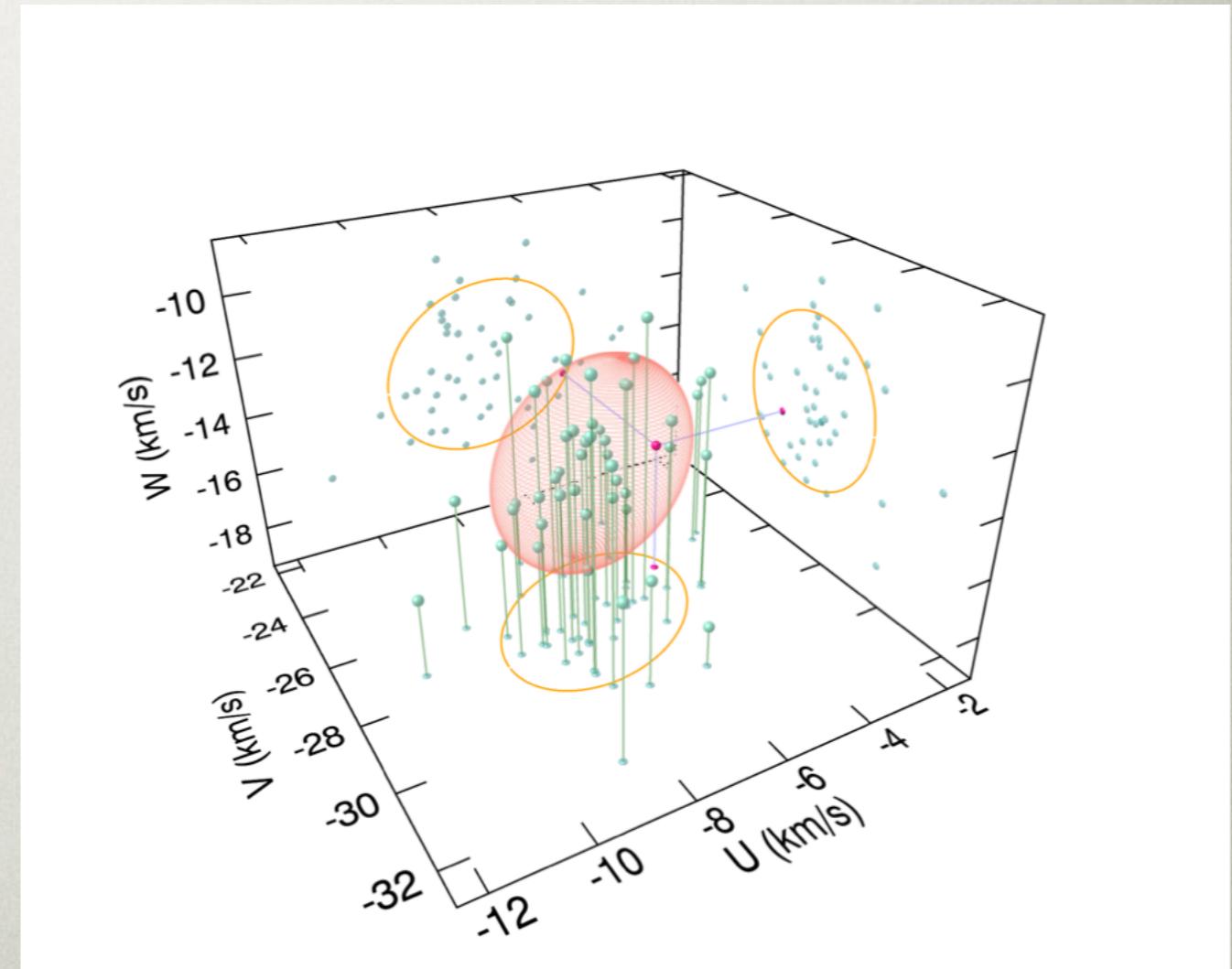
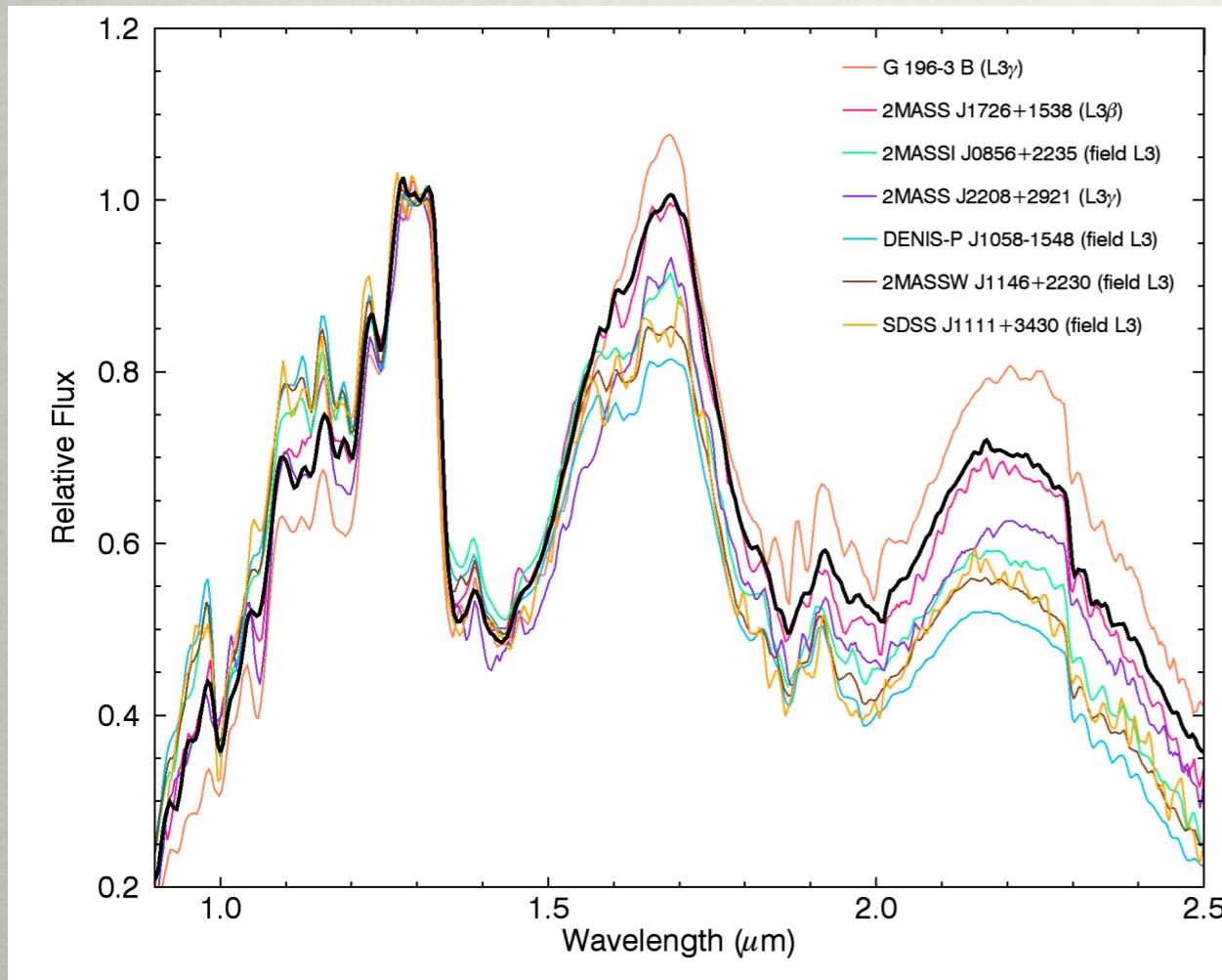
CARNEGIE INSTITUTE, 2014

# BASS DISCOVERIES

EXTRA 1

(1) A NEW LOW-GRAVITY L3 BONA FIDE MEMBER IN AB DORADUS !

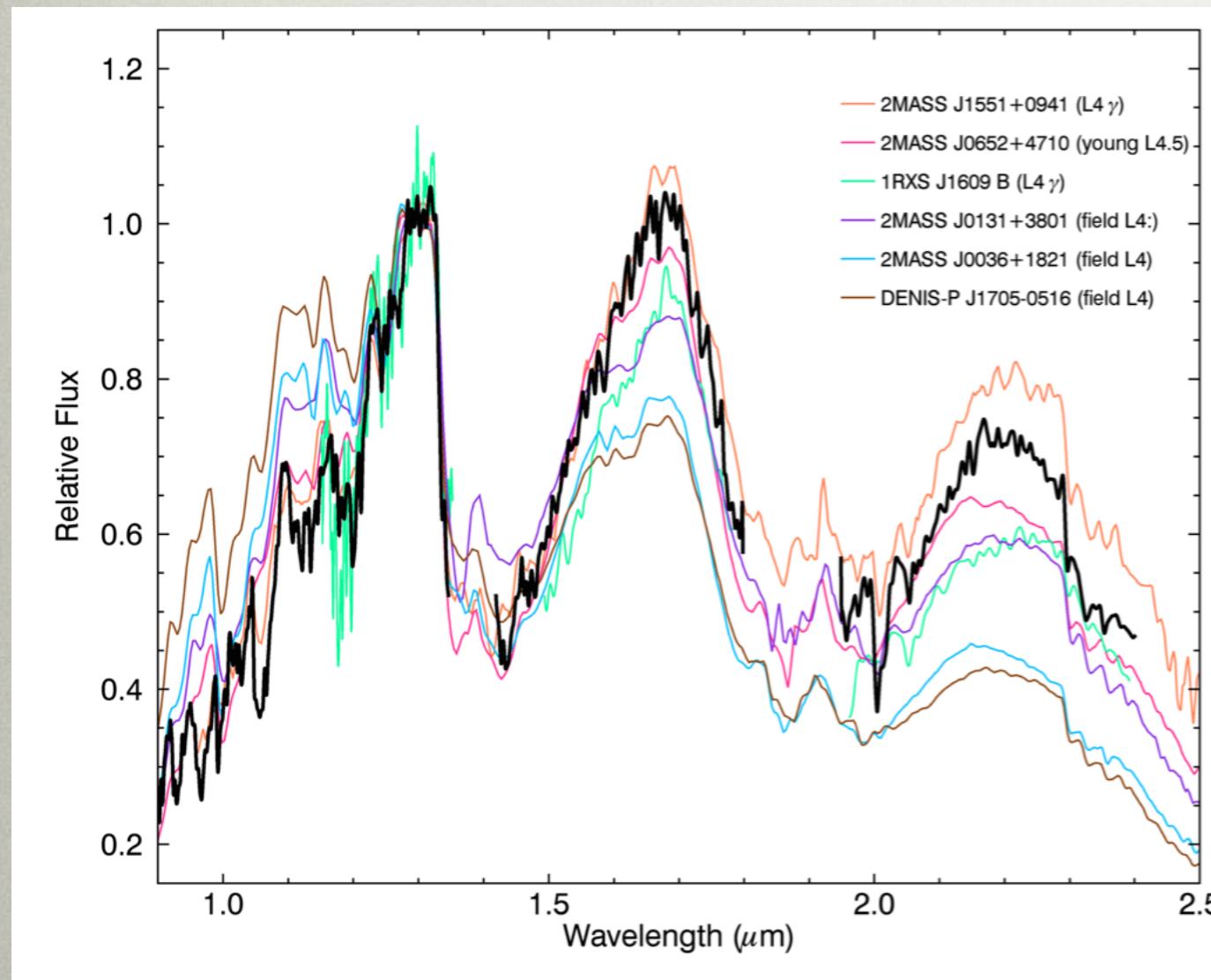
ESTIMATED MASS :  $18 M_{Jup}$



# BASS DISCOVERIES

EXTRA 2

## (2) A NEW LOW-GRAVITY L4 PLANETARY-MASS COMPANION TO A LOW-GRAVITY M6 CANDIDATE MEMBER OF TUCANA-HOROLOGIUM



ESTIMATED MASS :  $13 M_{Jup}$



Artigau et al., in prep.

$R \sim 6000$  resolved spectrum of the companion !

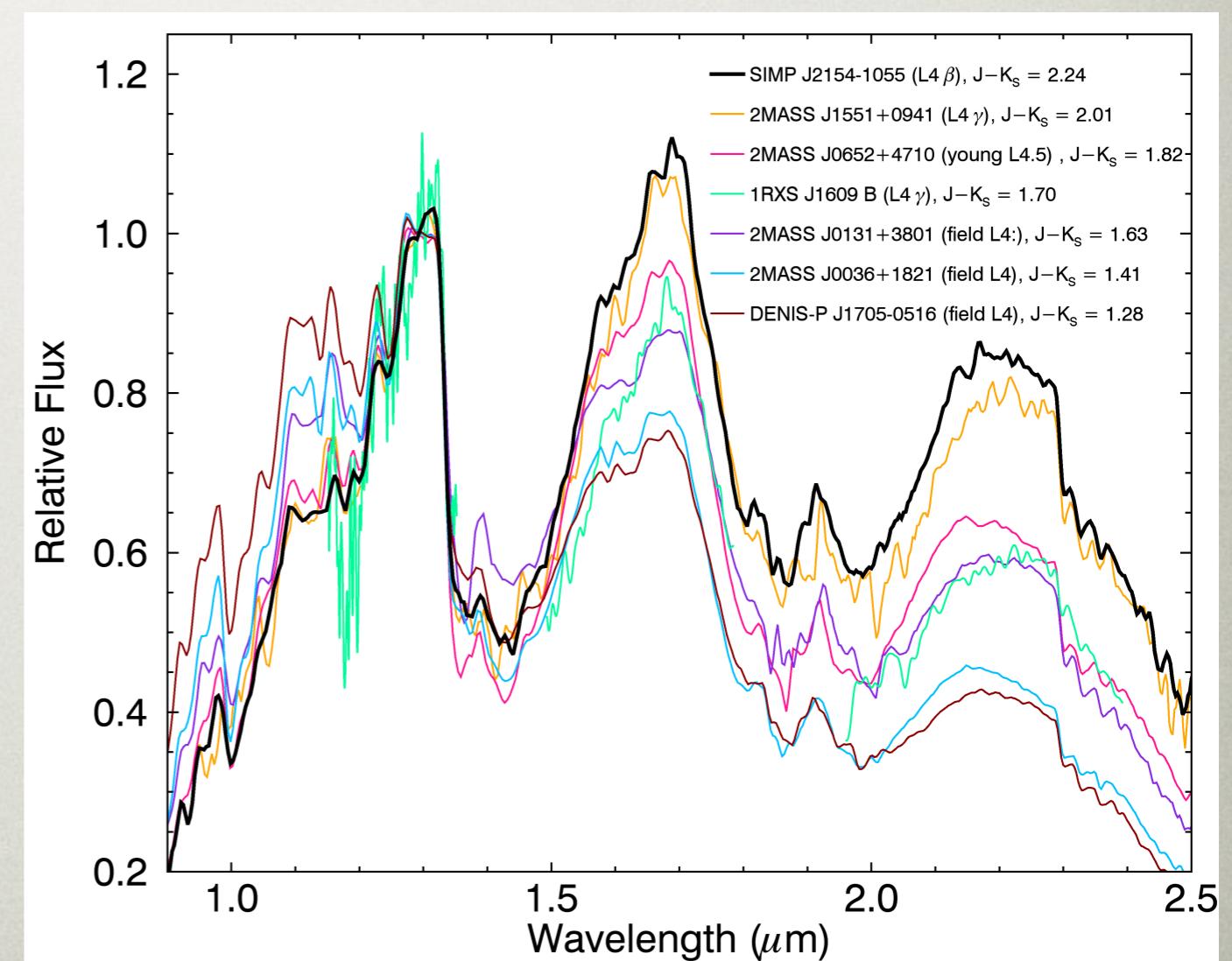
# BASS DISCOVERIES

EXTRA 3

(3) A NEW LOW-GRAVITY L4 CANDIDATE MEMBER OF ARGUS

... THAT WAS ACCIDENTALLY DISCOVERED IN THE SIMP SURVEY !

ESTIMATED MASS :  $10 M_{Jup}$

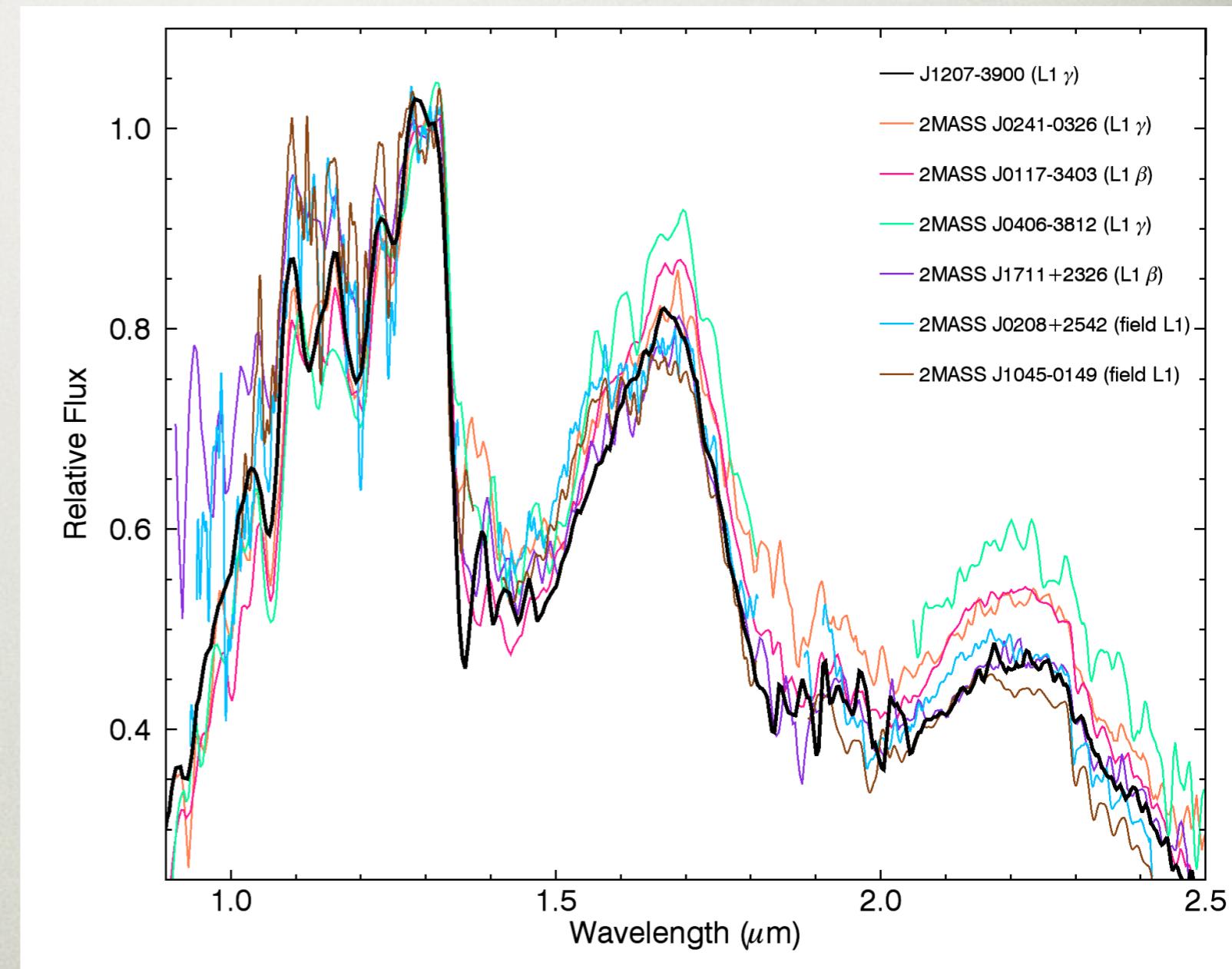


# BASS DISCOVERIES

EXTRA 4

## (4) THE FIRST L DWARF CANDIDATE MEMBER OF TW HYDRAE

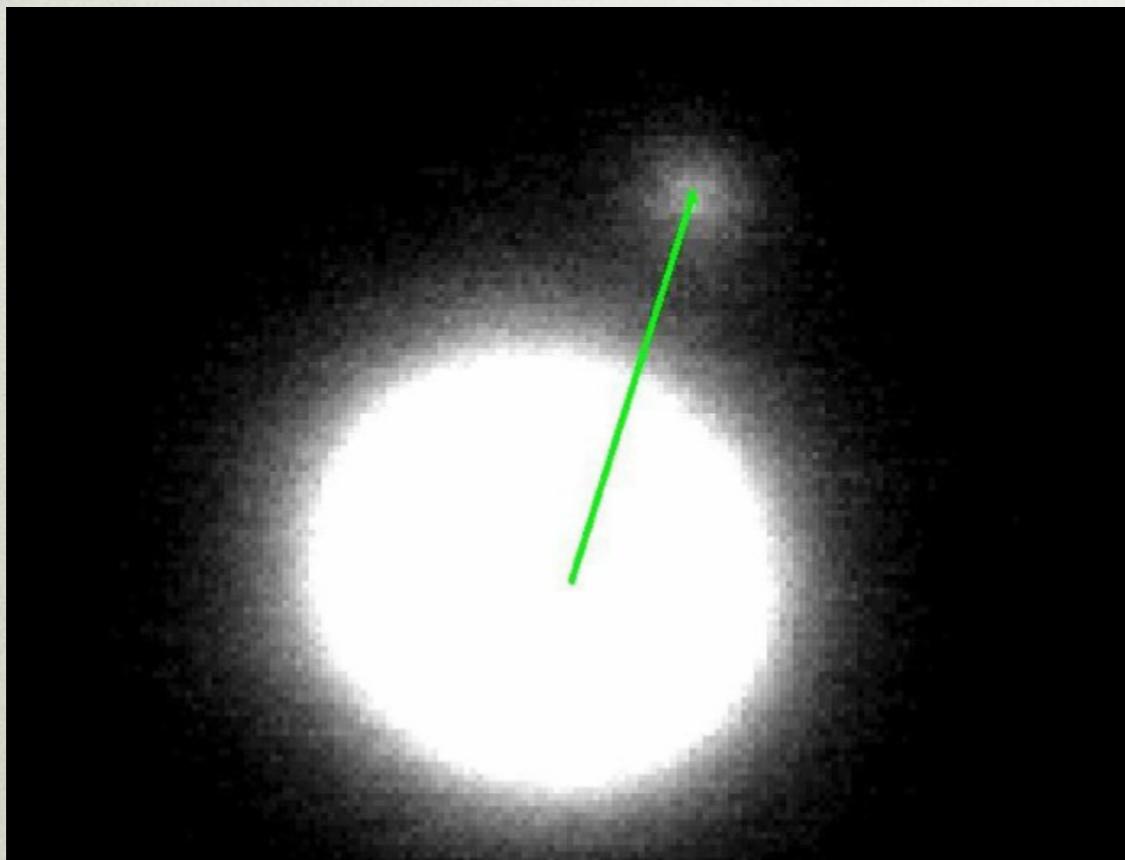
ESTIMATED MASS :  $12 M_{Jup}$



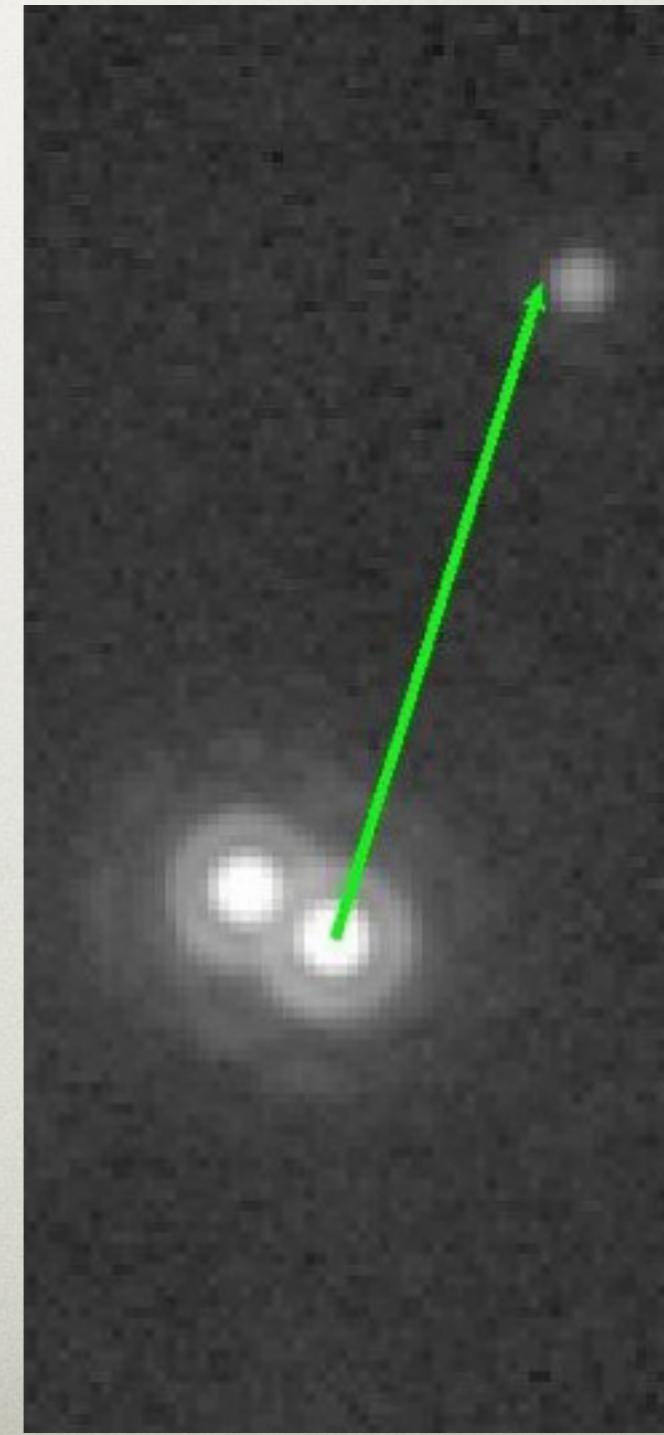
# BASS DISCOVERIES

EXTRA 5

(5) JO103-5515, THE M5 + M5 + 12-14 MJUP COMPANION IN TUCANA-HOROLOGIUM



Naco *H*-band



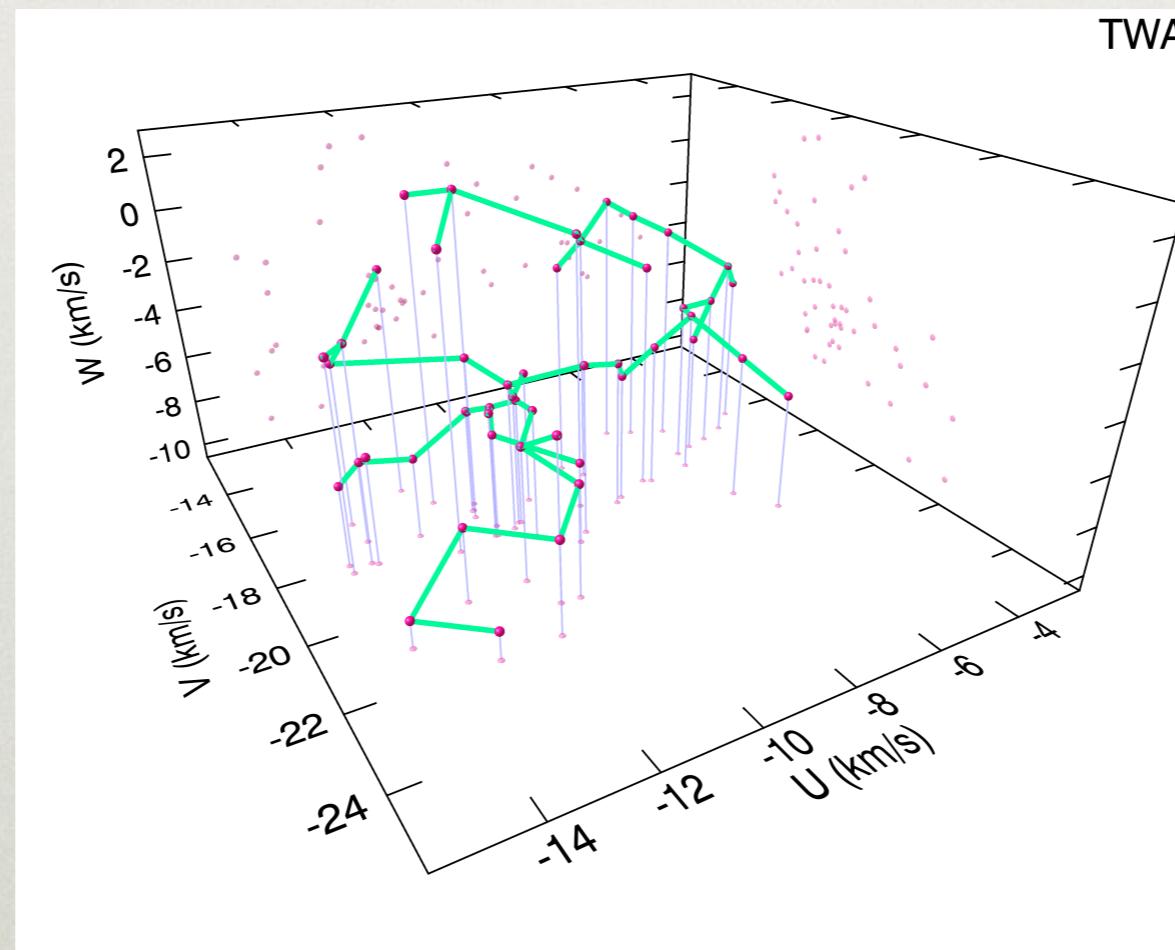
Naco *L'*-band

Delorme et al., 2013  
2013A&A...553L...5D

# MASS SEGREGATION ?

EXTRA 6

WITH THE METHOD OF MINIMAL SPANNING TREES,  
=> WE DO NOT NEED TO KNOW THE CENTER OF MASS <=

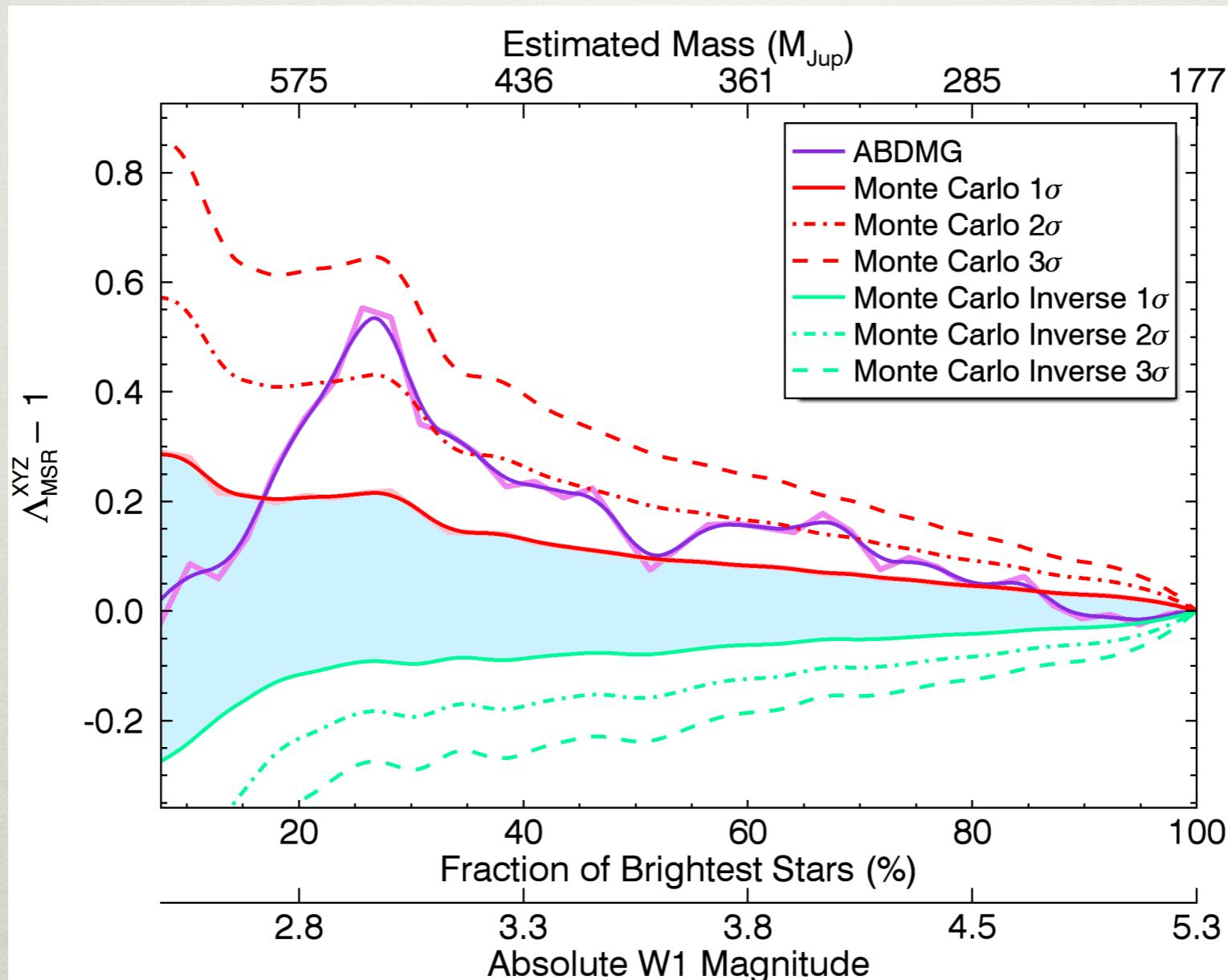


Gagné 2014d (Accepted ApJ)  
arXiv 1410.4864

- (1) BUILD THE SHORTEST NETWORK THAT CONNECTS ALL UVW POINT
- (2) NO LOOPS ARE ALLOWED
- (3) MEASURE THE TOTAL LENGTH OF THE NETWORK

# MASS SEGREGATION ?

EXTRA 7



Gagné 2014d (Accepted ApJ)  
arXiv 1410.4864

- (4) BUILD MST FOR N BRIGHTEST MEMBERS
- (5) REPEAT FOR N RANDOM MEMBERS

# MASS SEGREGATION ?

EXTRA 8

---

**MASS SEGREGATION IS DETECTED AT ~ 2-3 SIGMA FOR :**

- AB Doradus (both spatial and dynamical)
- $\beta$  Pictoris (spatial only)
- Columba (dynamical only)
- Including BASS candidates increases these detections to 2 - 4 sigma + Tucana starts showing spatial + dynamical mass segregation !

**=> WE MUST MEASURE PARALLAX, RV AND CONFIRM YOUTH FOR  
MORE SUBSTELLAR MEMBERS TO VERIFY THIS**



THANK YOU !

CARNEGIE INSTITUTE, 2014