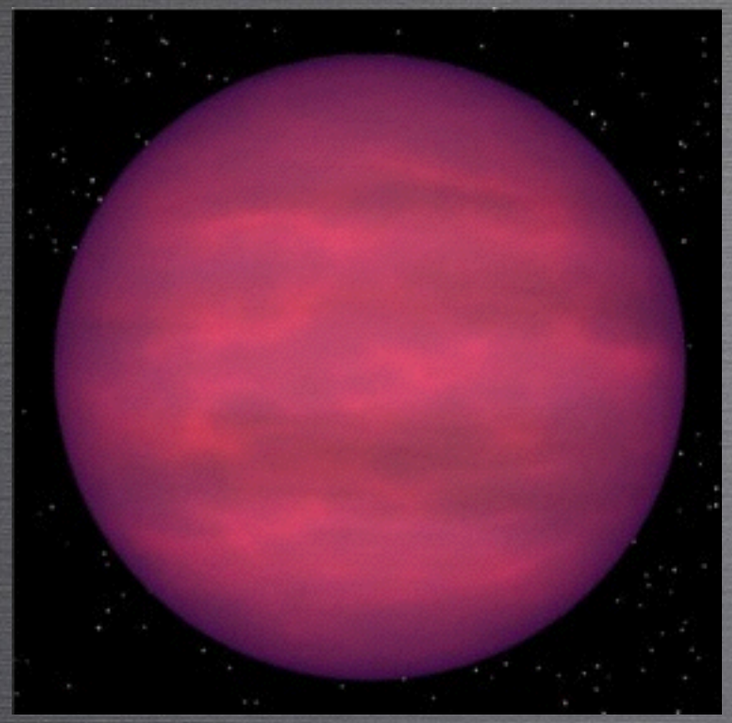
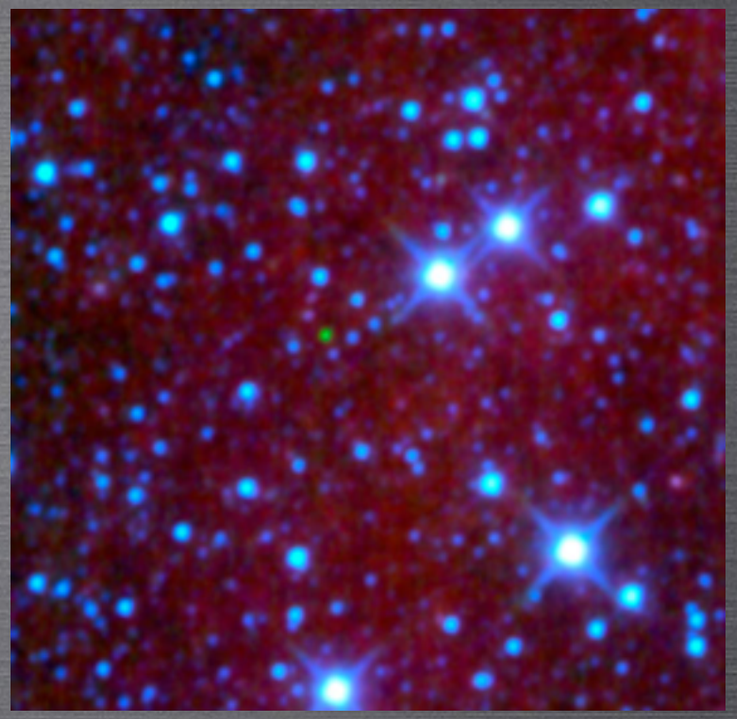




Brown Dwarfs IN Nearby Young Associations

UCLA 2014 SEMINAR

Jonathan Gagné

David lafrenière, René Doyon, Lison Malo, Étienne Artigau, Jackie Faherty, Kelle Cruz, Philippe Delorme

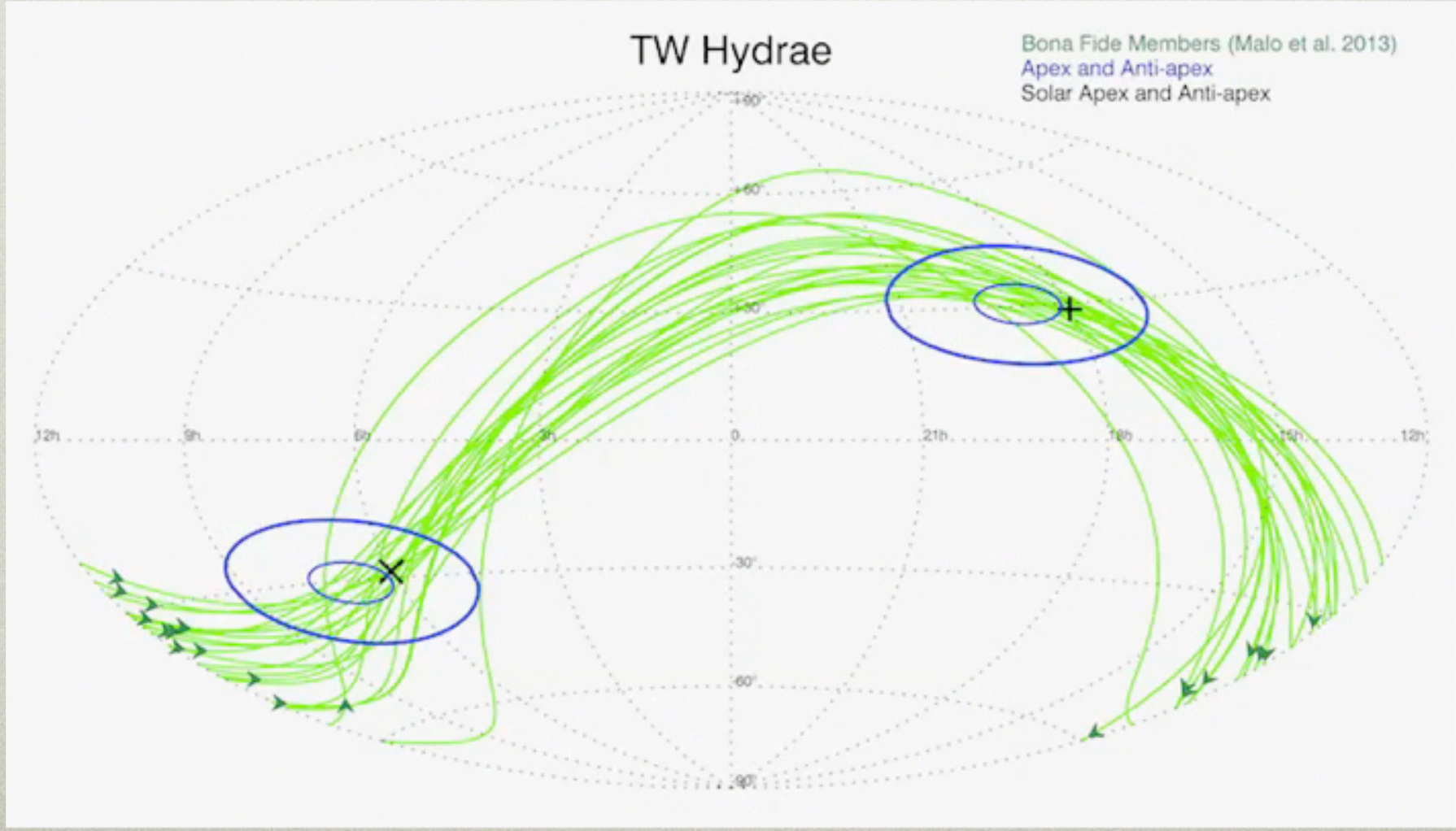
Peter Plavchan, Peter Gao, Elise Furlan

Université de Montréal

BANYAN II

Why Bayesian Analysis ?

- Moving group members are spread over the sky !
- We generally don't have RVs and parallaxe ; important missing information !
- Made its proofs in several other domains of science, it works extremely well !



Sky distribution of proper motions

Gagné et al. 2014a : Additional Material

Bayesian Inference 2/56

OBSERVABLES + MODELS = MEMBERSHIP PROBABILITY

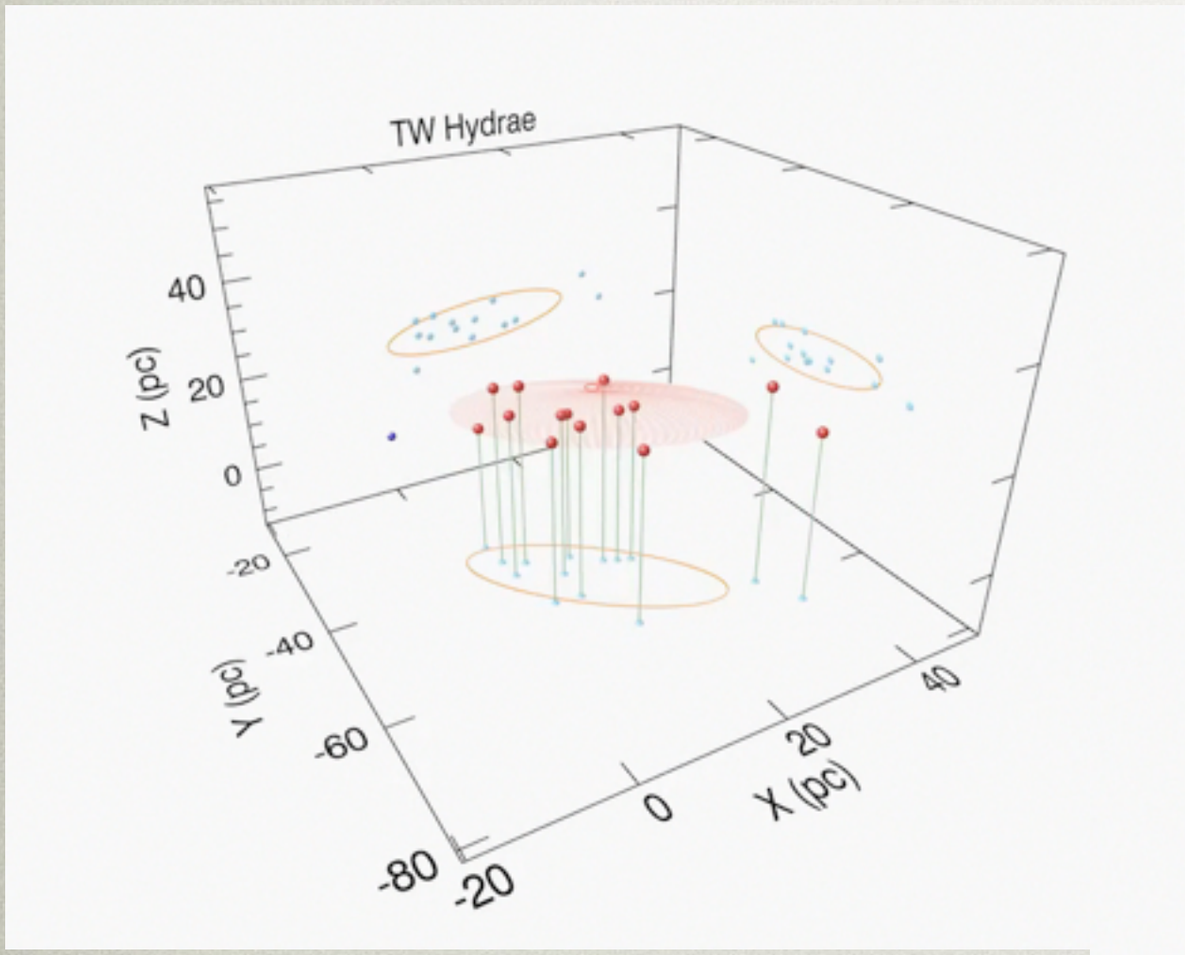
$$\overset{4}{P(H_k|\{O_i\})} = \frac{\overset{2}{P(H_k)}}{\underset{3}{P(\{O_i\})}} \int\int \overset{1}{P(\{O_i\}|H_k, v, \pi)}\, \mathrm{d}v\, \mathrm{d}\pi$$

BAYES' THEOREM

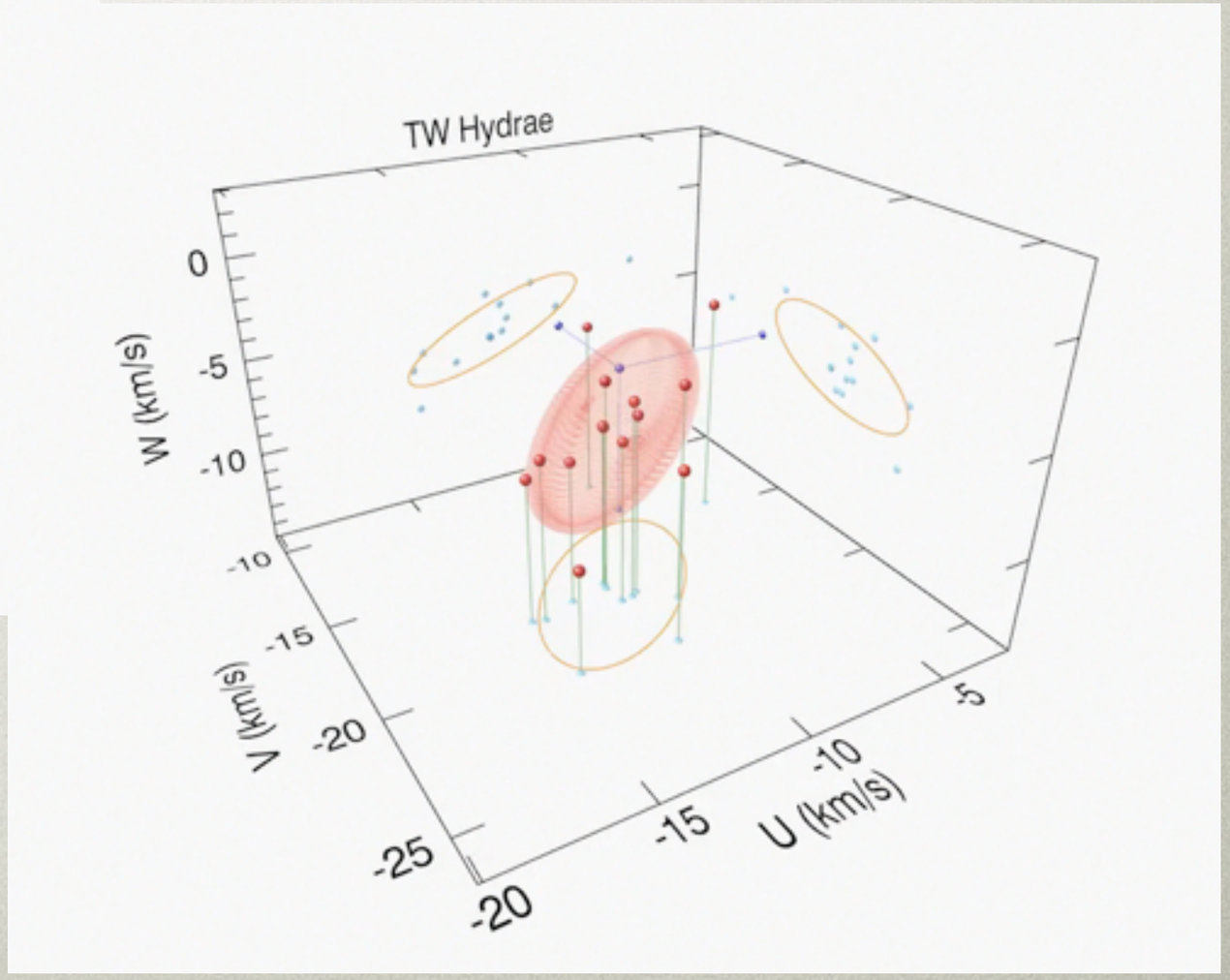
H = Hypotheses **π = Parallaxe**
P = Probability **O = Observable**
v = Radial Velocity

- 1 - LIKELIHOOD = Models + Observations
- 2 - PRIOR PROB. = Population of H
- 3 - EVIDENCE = Normalization
- 4 - POSTERIOR PROB = Final answer
- *v and π are marginalized when we don't have measurements*

Spatial + Kinematic Models



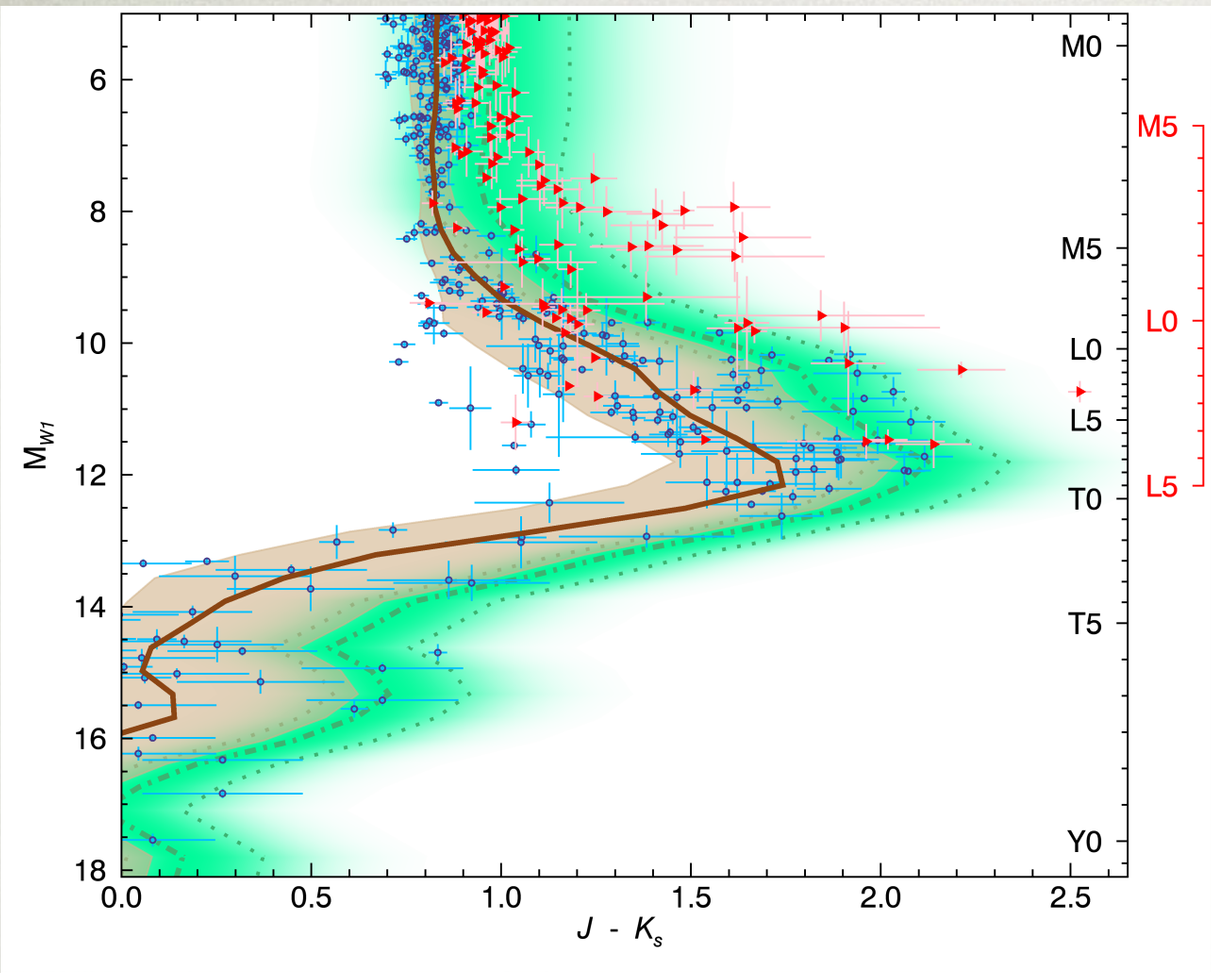
UVW velocity distributions

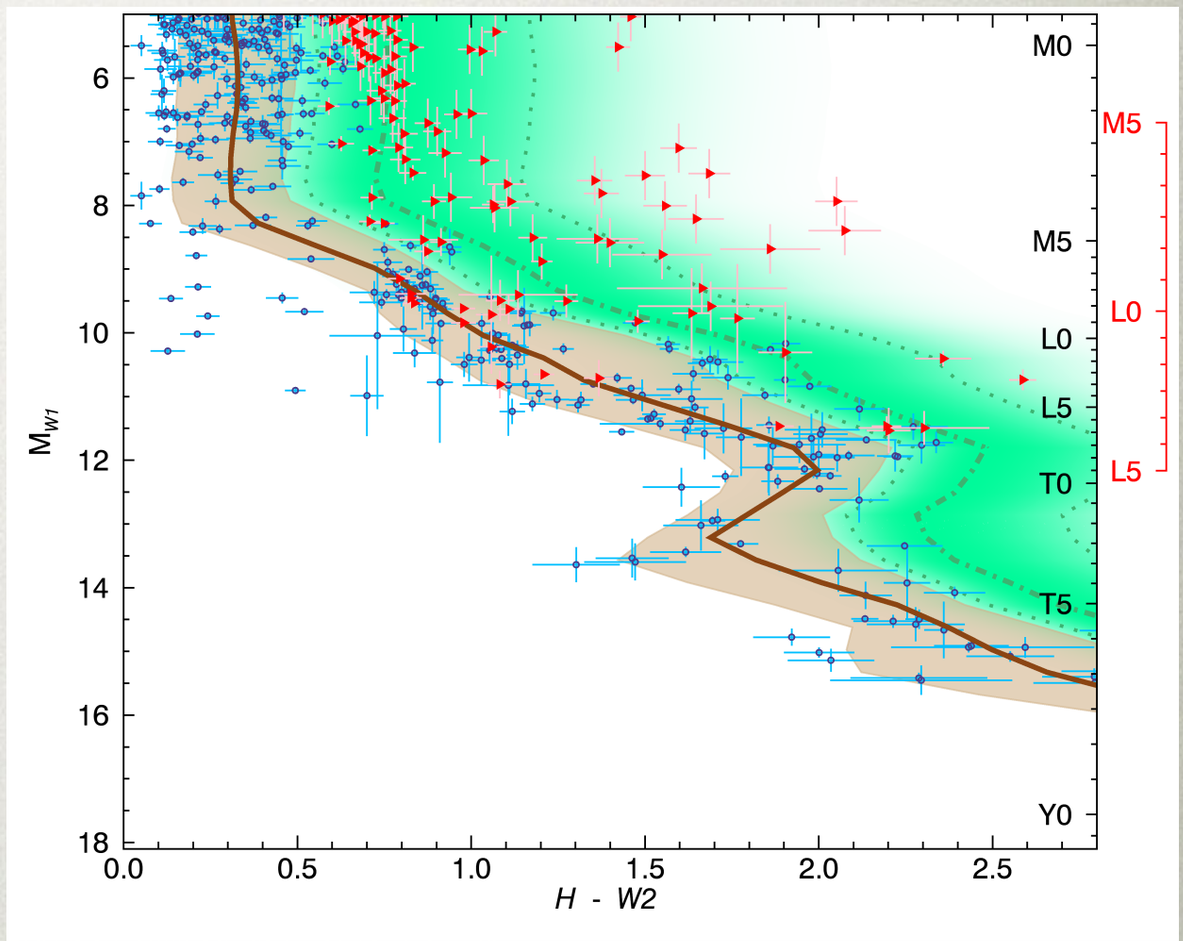


XYZ position distributions

Gagné et al. 2014a : Additional Material

Photometric Model

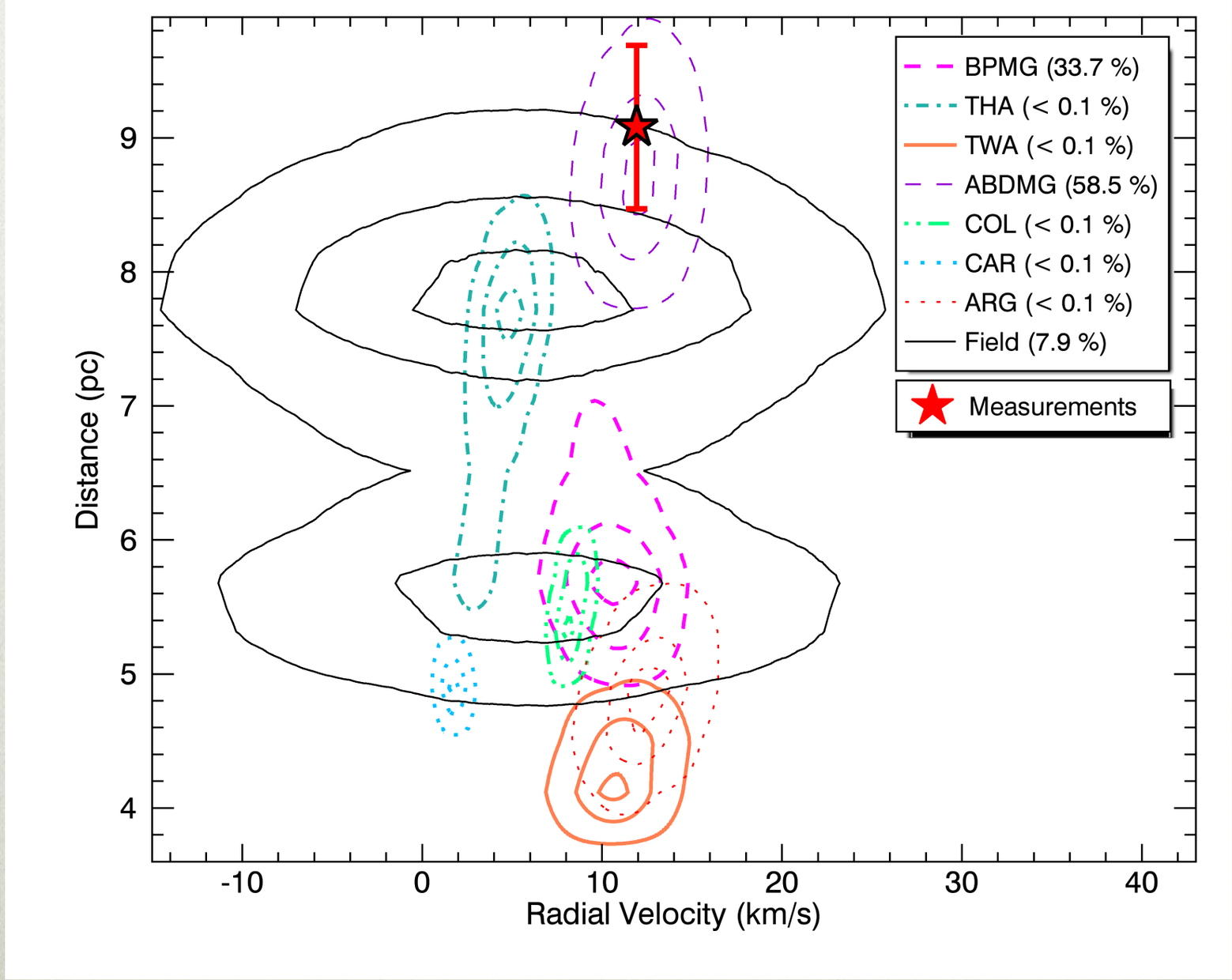




Gagné et al. 2014a

Statistical Predictions

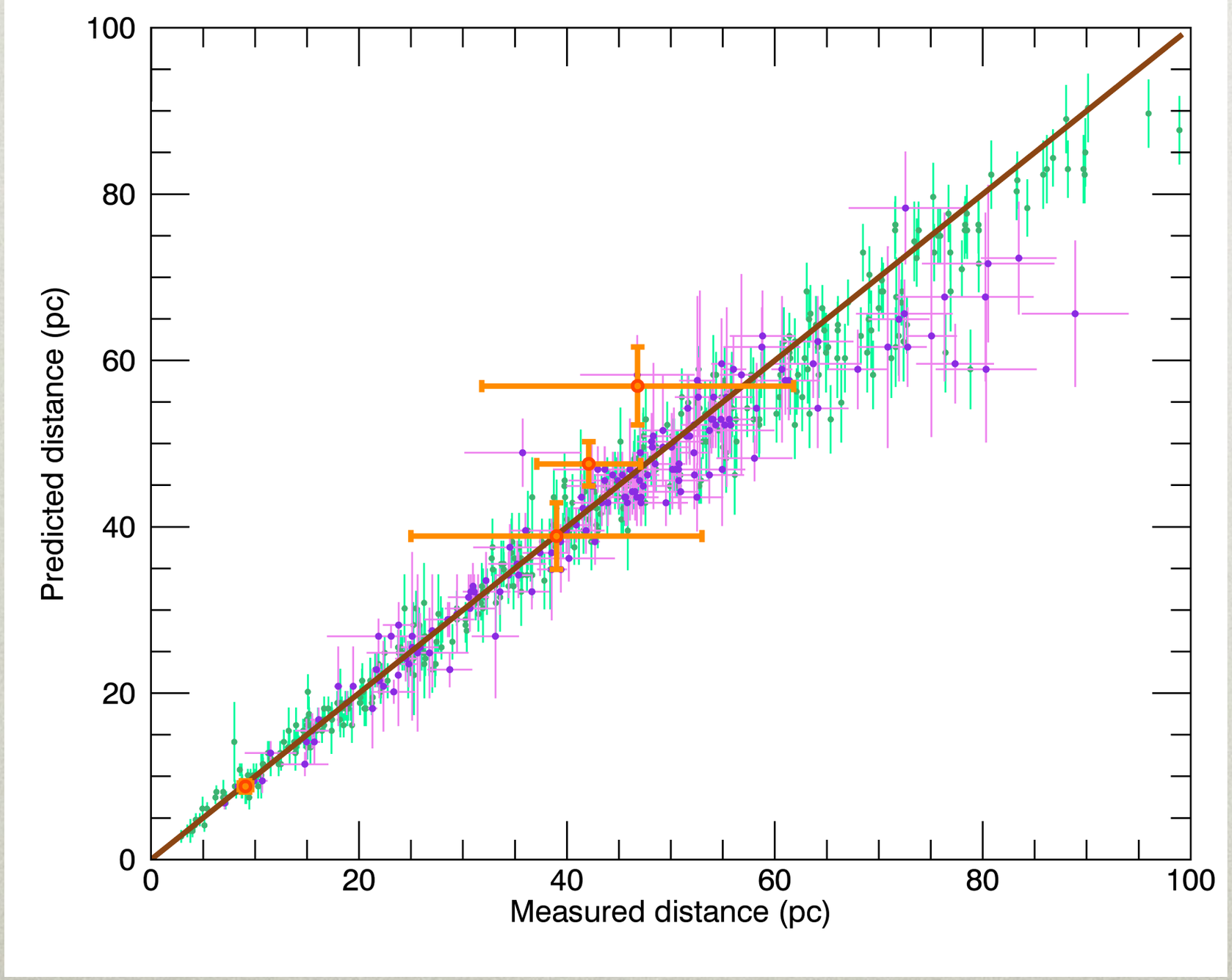
- No "need" of VRAD or PLX
- + We can predict them



Example PDF for J0355+11

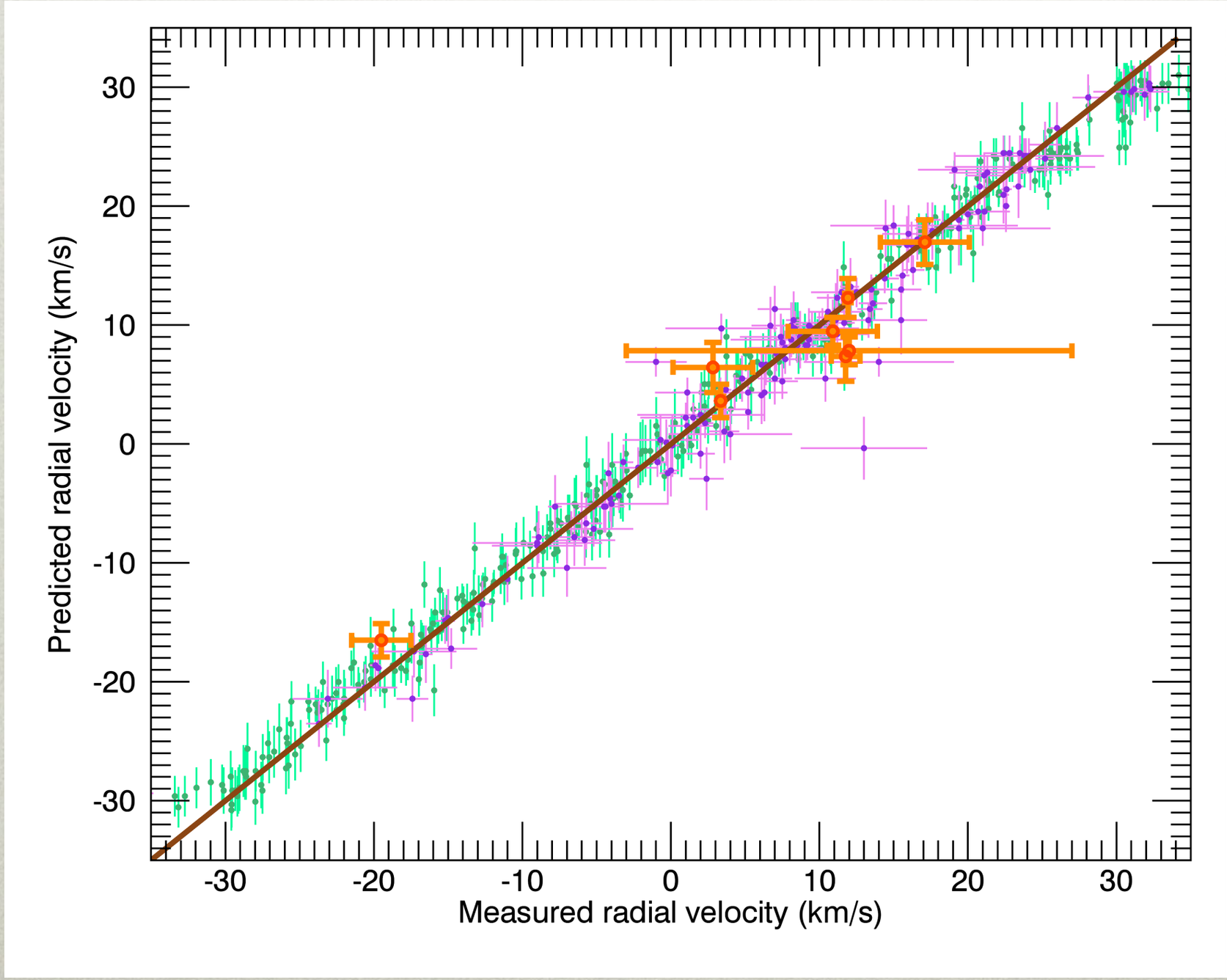
Gagné et al. 2014a

Statistical Predictions



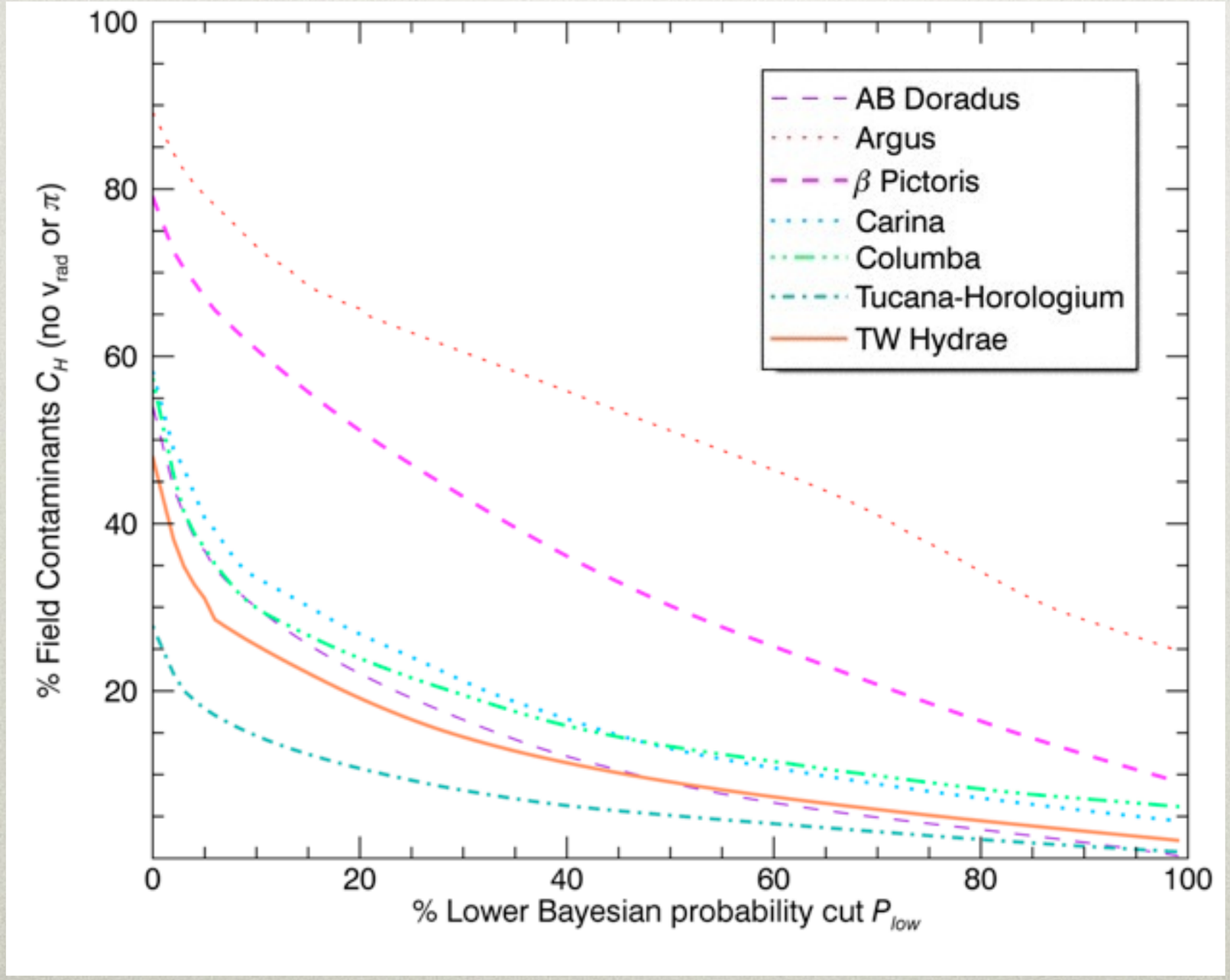
Gagné et al. 2014a

Statistical Predictions



Gagné et al. 2014a

Contamination Rate



Gagné et al. 2014a

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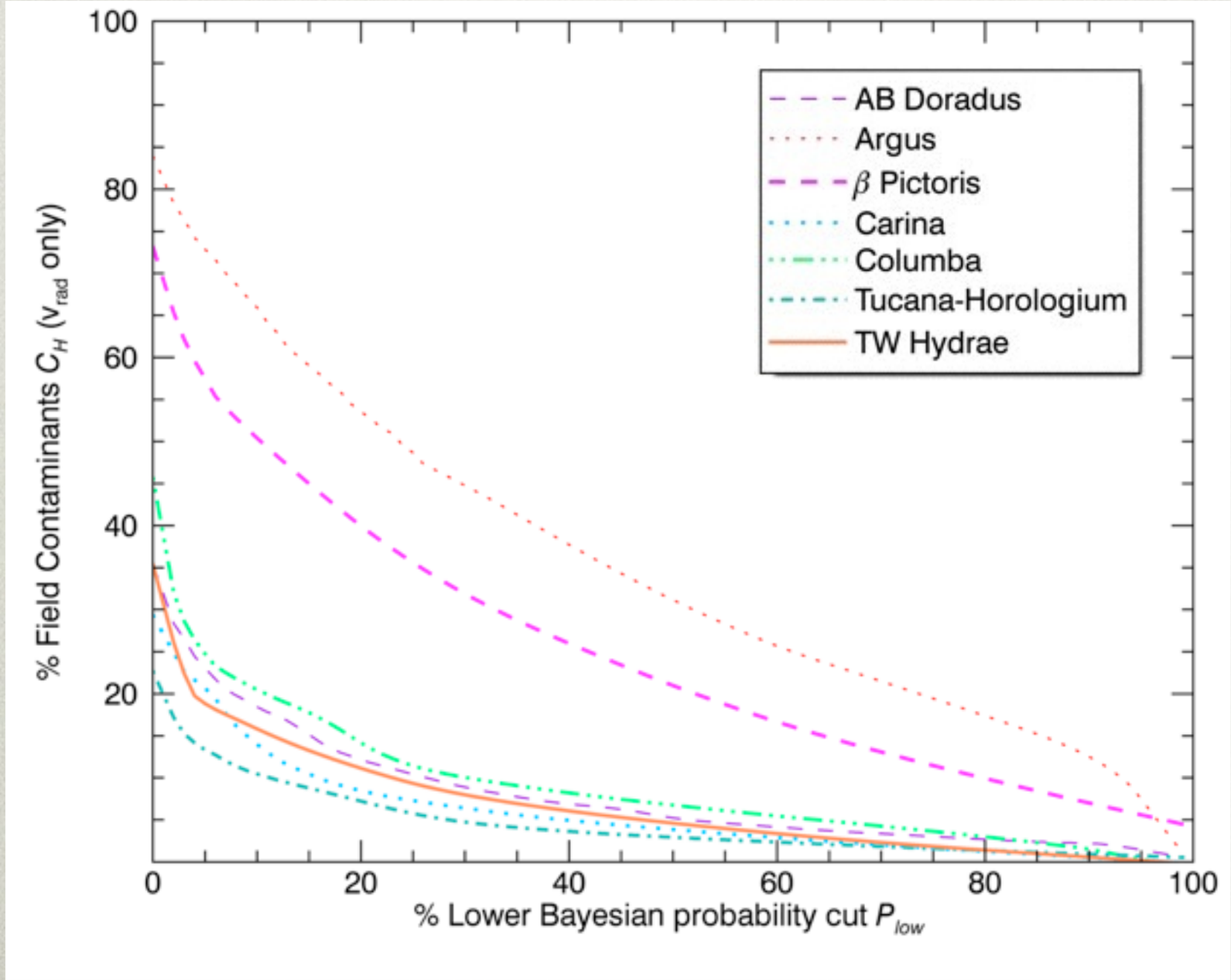

Gagné et al. 2014a

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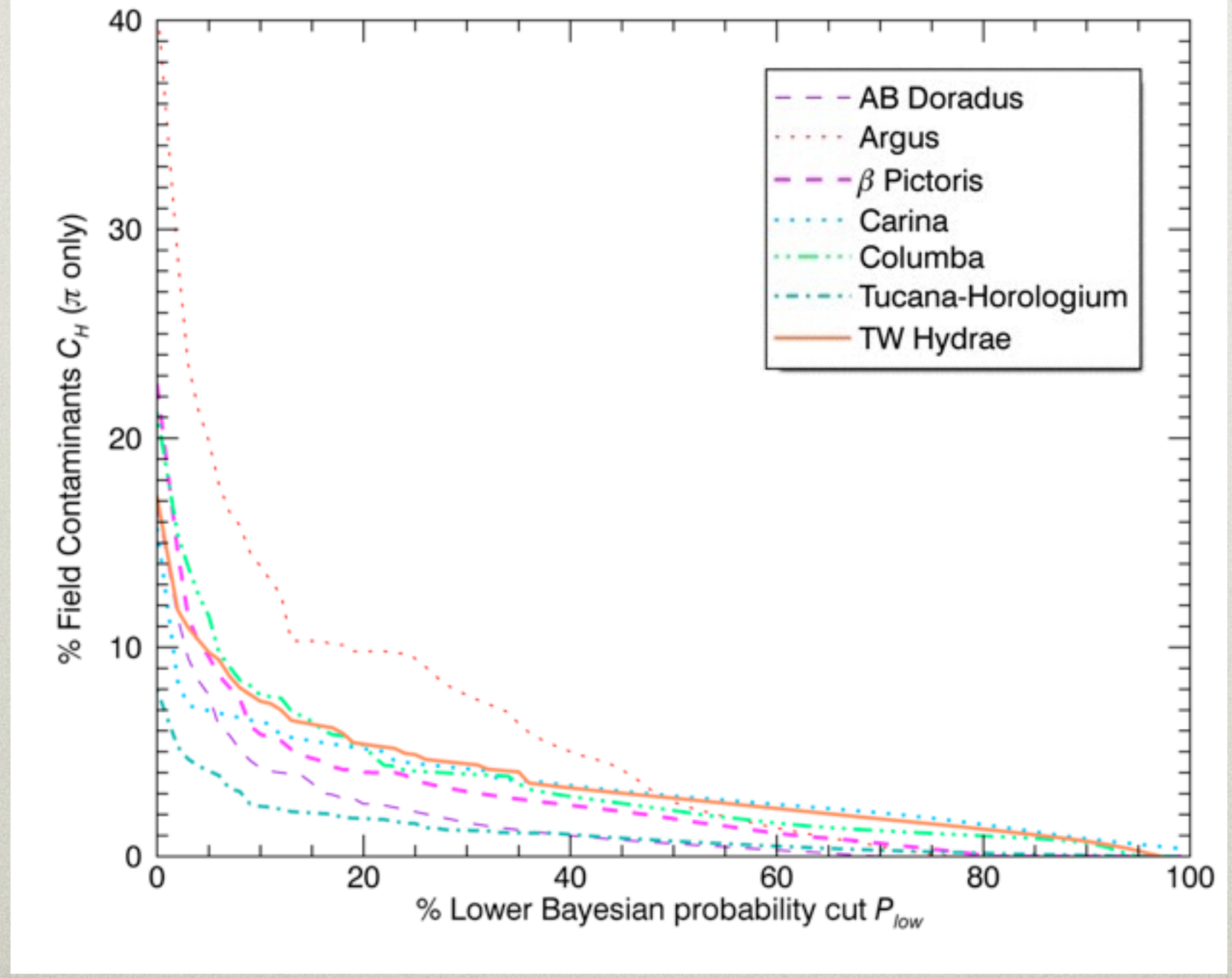
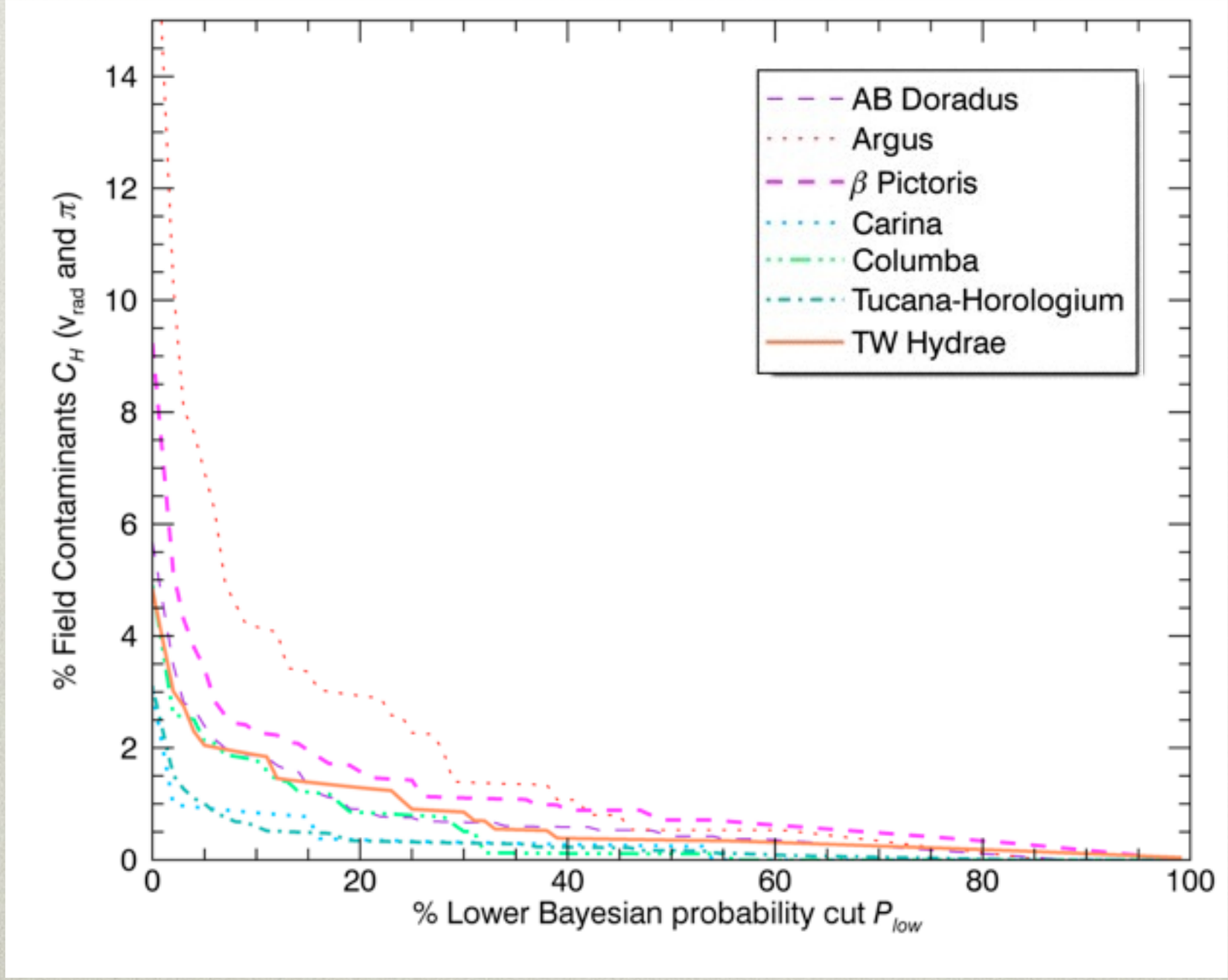


Good news for Gaia !

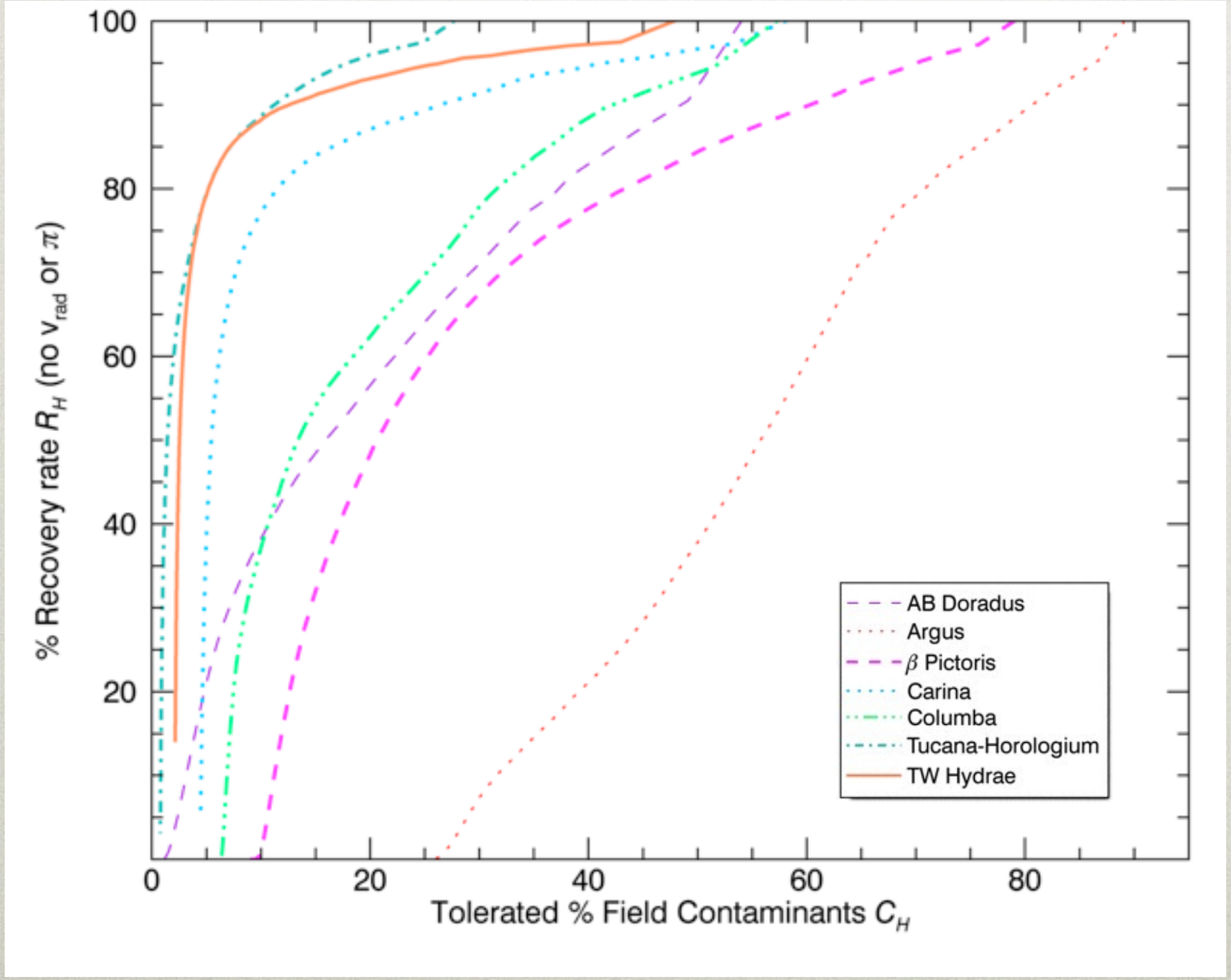
Gagné et al. 2014a

Contamination Rate



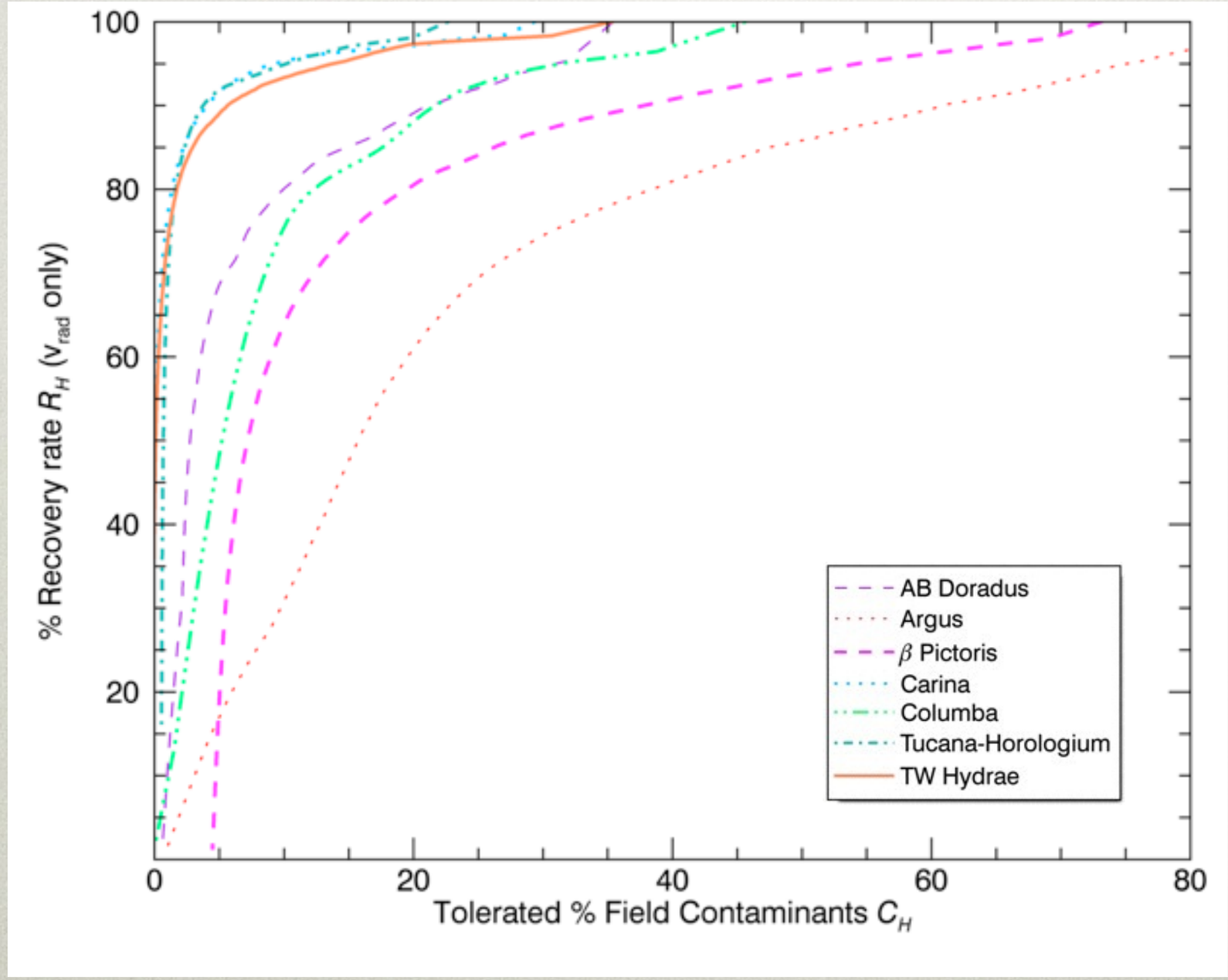
Gagné et al. 2014a

Recovery Rate



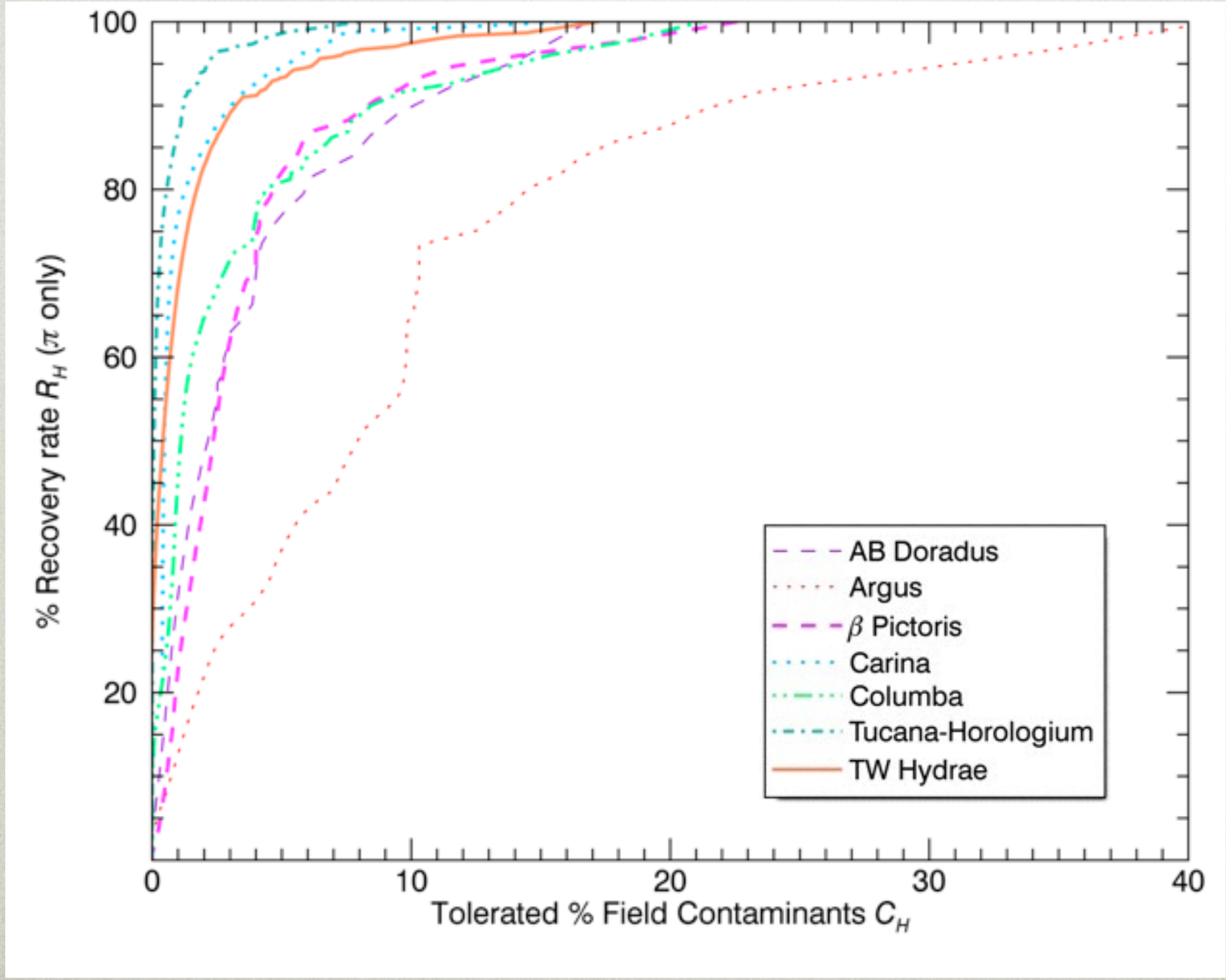
Gagné et al. 2014a

Recovery Rate



Gagné et al. 2014a

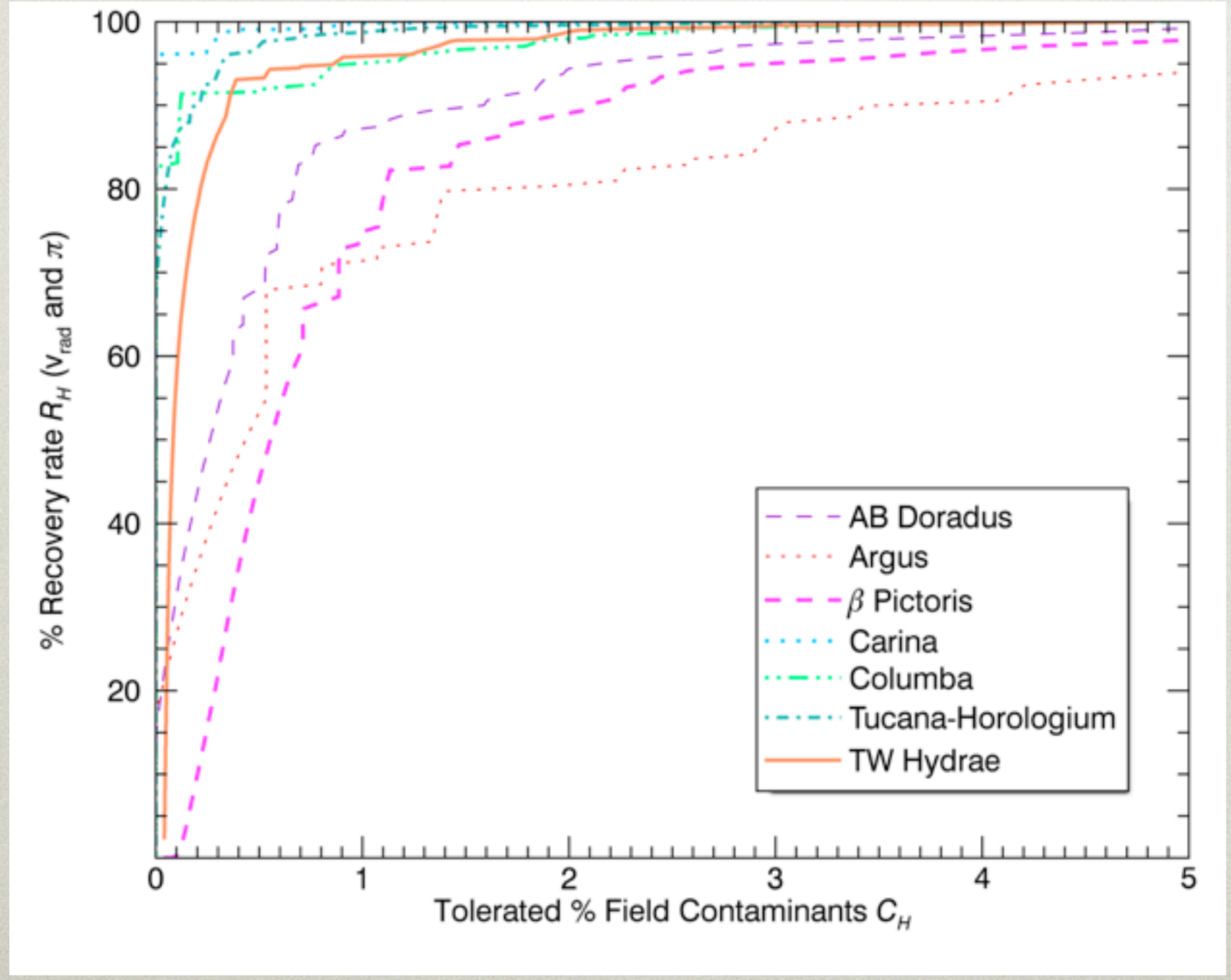
Recovery Rate



Good news for Gaia !

Gagné et al. 2014a

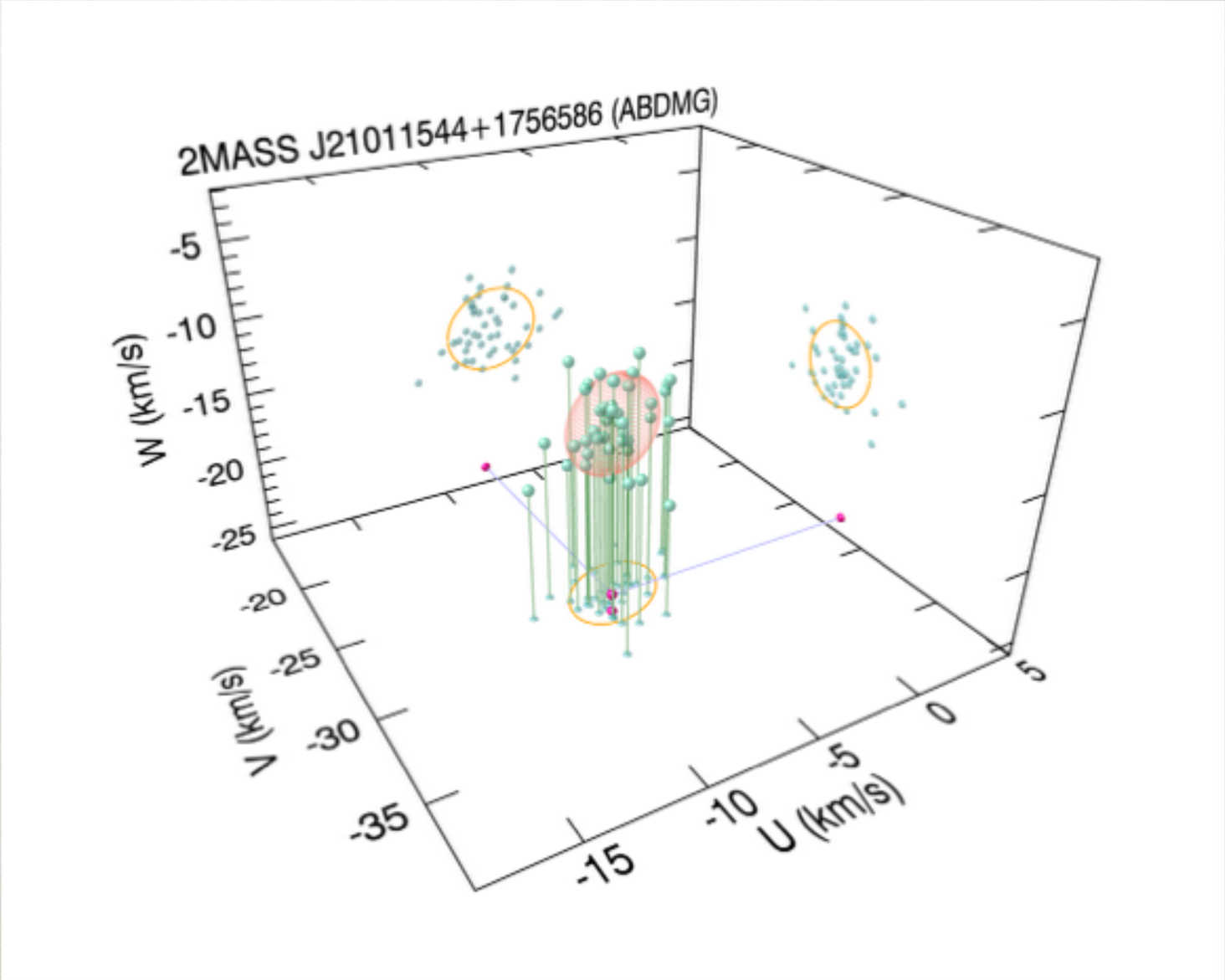
Recovery Rate



Gagné et al. 2014a

Additional Material

- The BANYAN II Web Tool
- Many figures
- All tables in all possible formats
- Many IDL routines and utilities



Example ; Most Probable values
from statistical distances and radial velocities

The BASS Survey

- 2MASS + WISE = 650 000 candidates With Proper Motion Measurements at ~ 10 mas/yr !

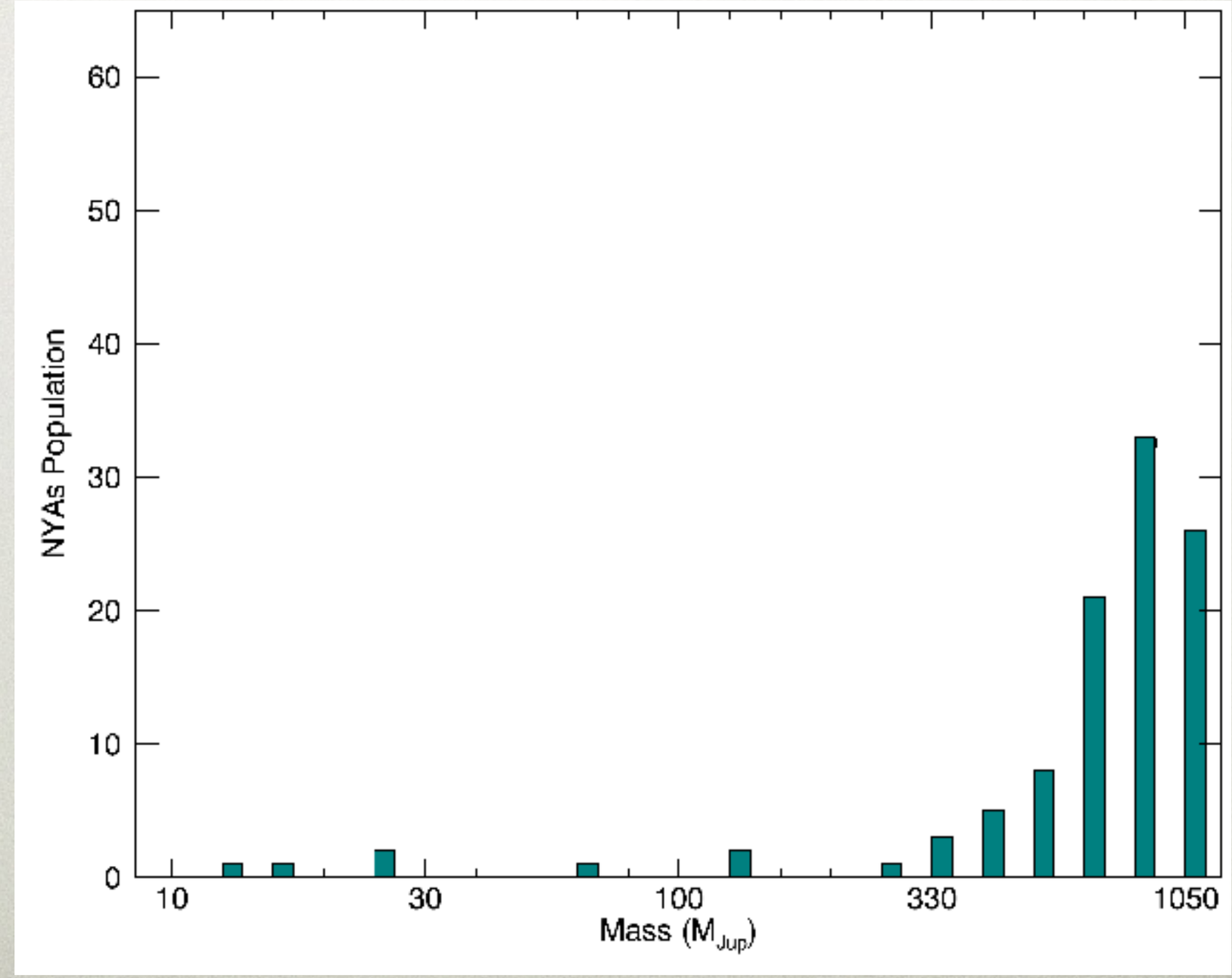
+ Bayesian inference = ~ 300 candidates

- Spectroscopic follow-up (youth)

- Radial velocity follow-up

Best Candidates' Masses

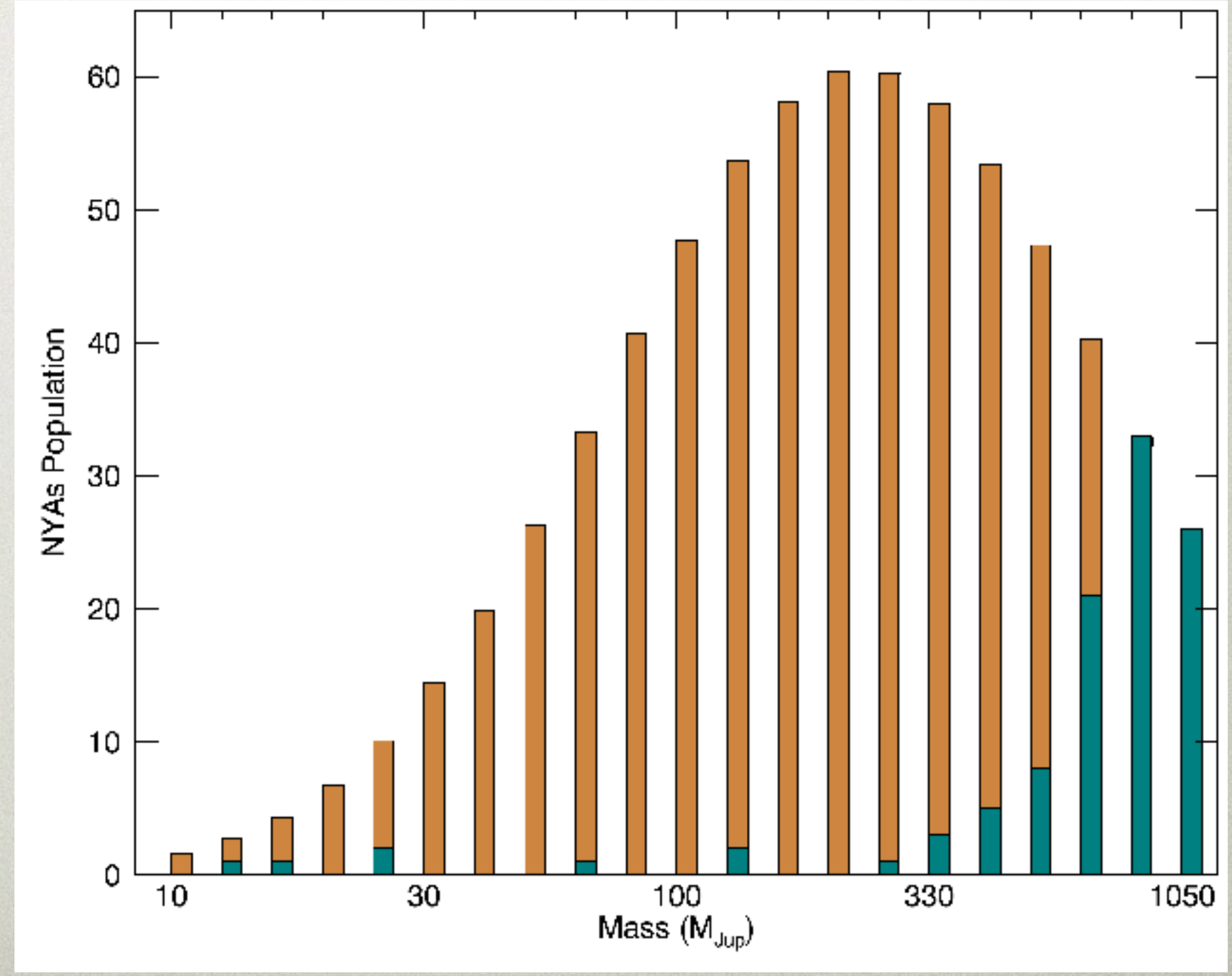
- Members



Gagné et al. 2013, Mem. Sc. It.

Best Candidates' Masses

- Members
- Log-Normal IMF



Gagné et al. 2013, Mem. Sc. It.

Best Candidates' Masses

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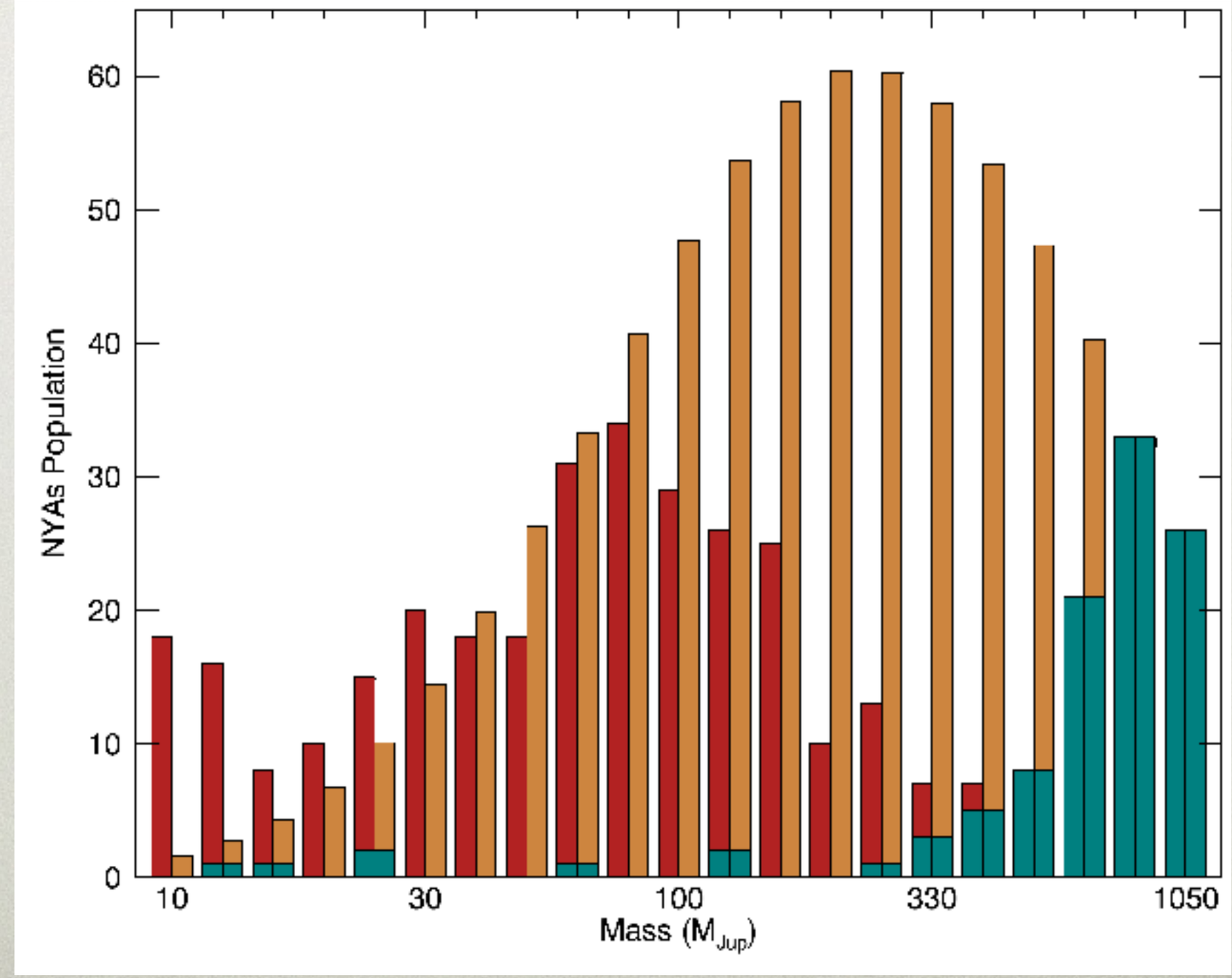
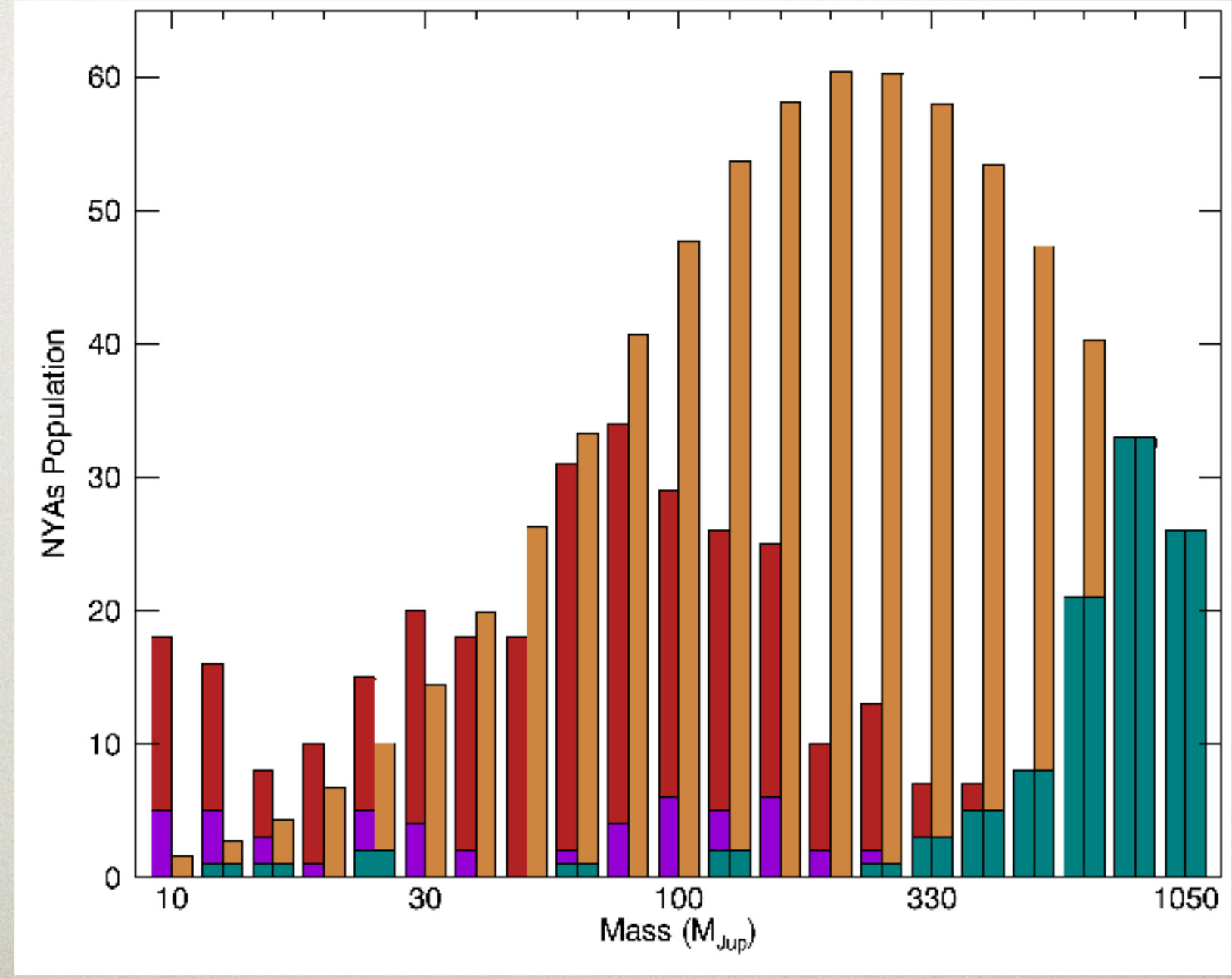
- Log-Normal IMF
- Candidates



Gagné et al. 2013, Mem. Sc. It.

Best Candidates' Masses

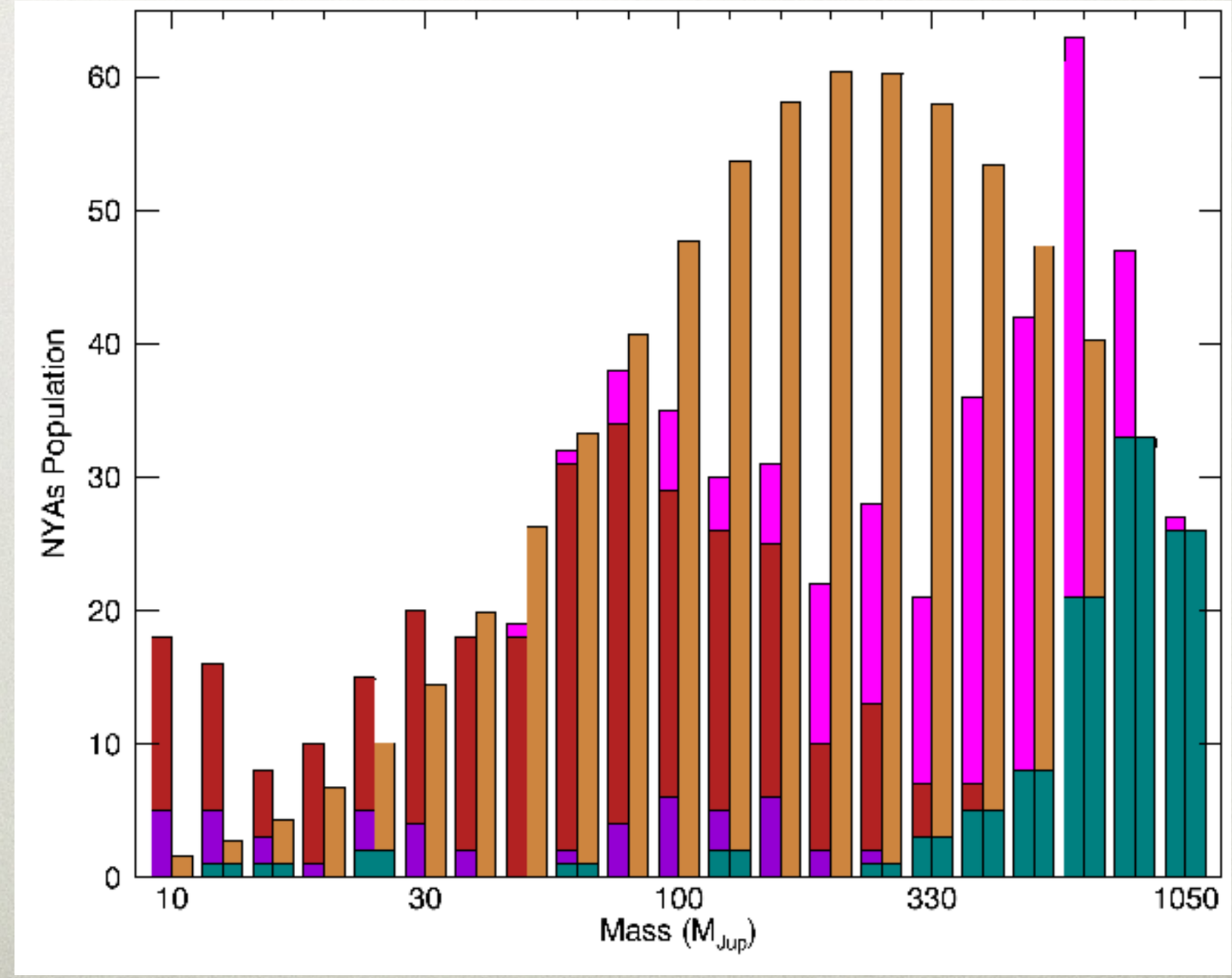
- Members
- Log-Normal IMF
- Candidates
- Young candidates



Gagné et al. 2013, Mem. Sc. It.

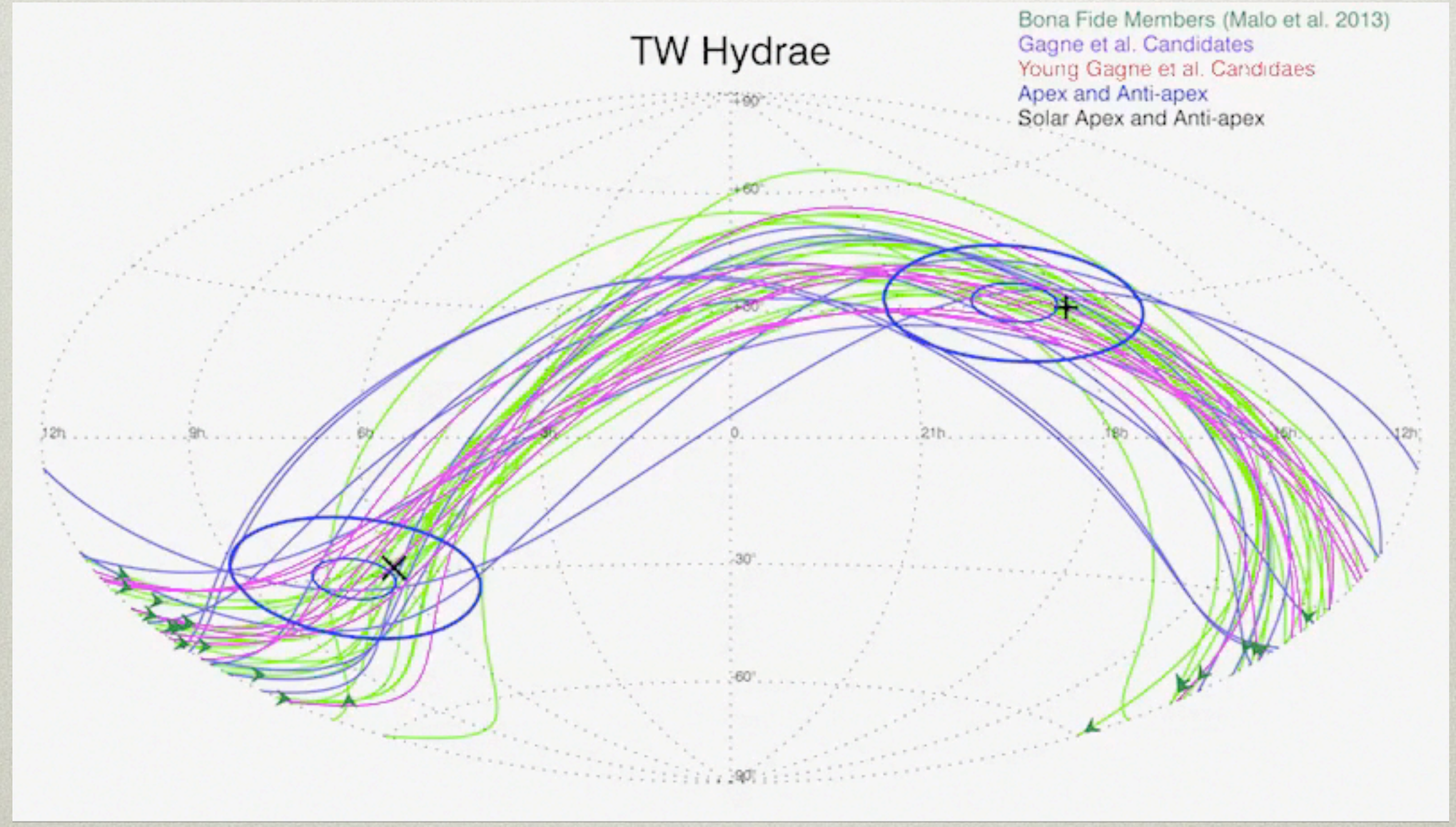
Best Candidates' Masses

- Members
- Log-Normal IMF
- Candidates
- Young candidates
- Lison Malo's < M5 candidates



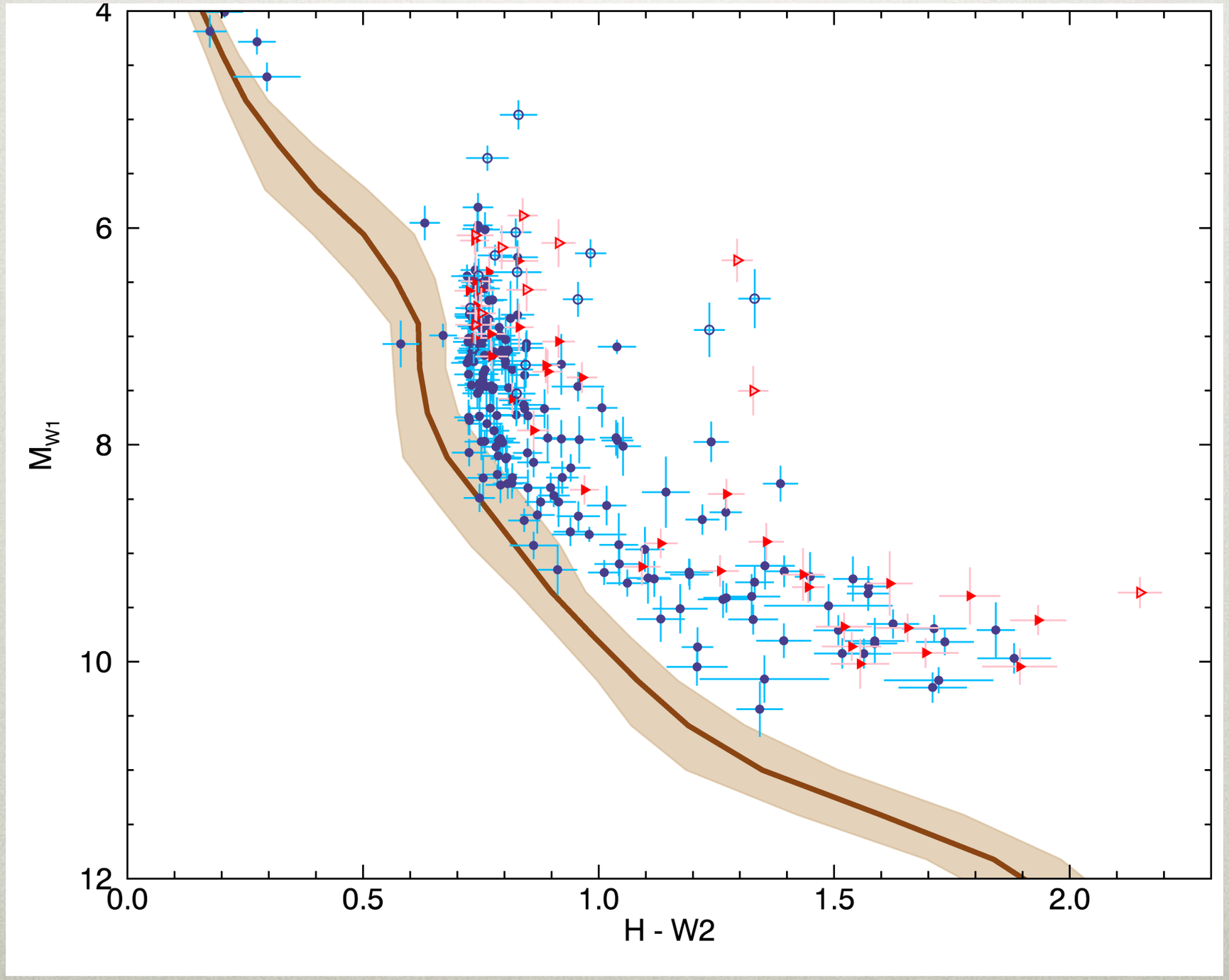
Gagné et al. 2013, Mem. Sc. It.

Candidates' PM



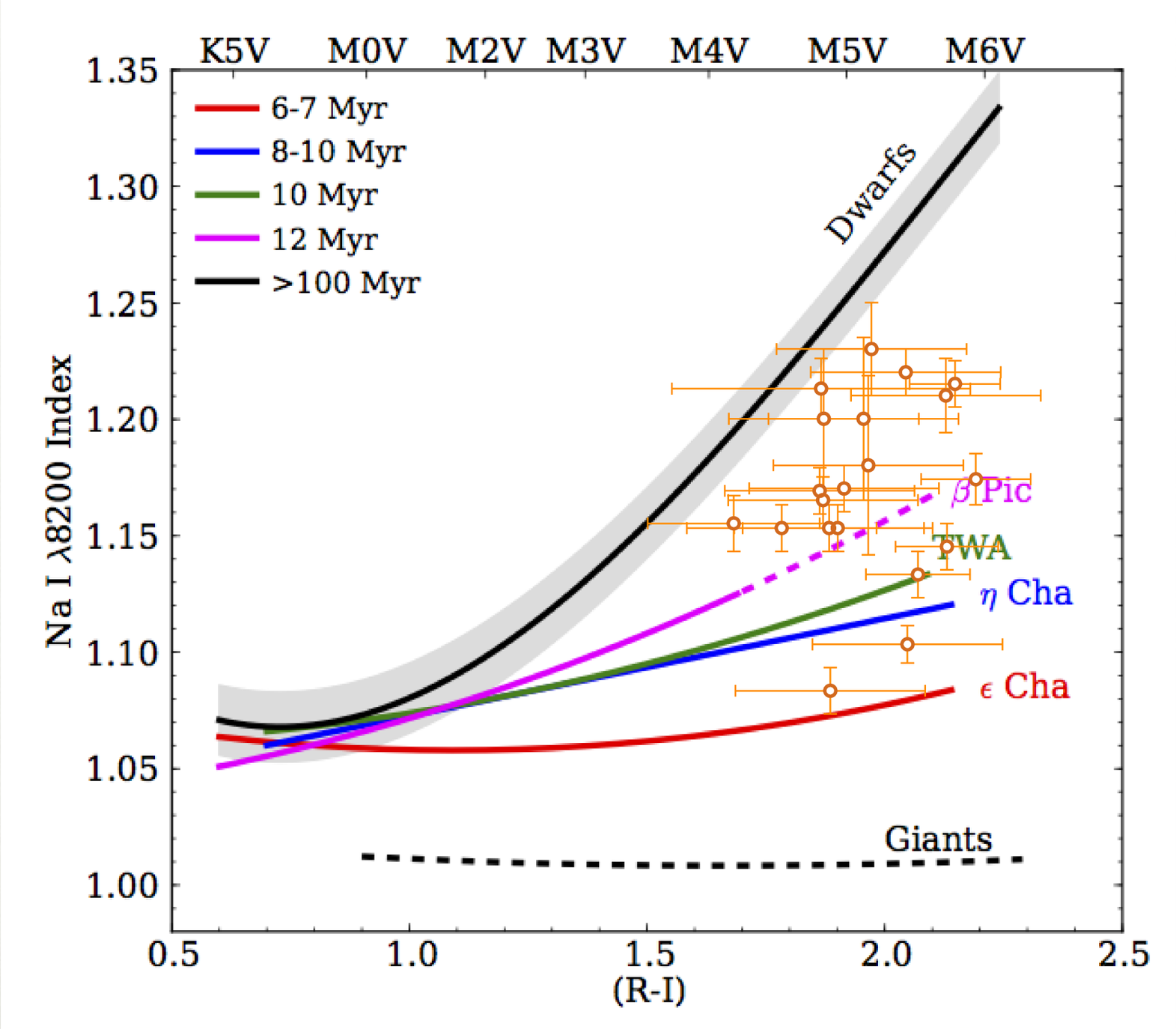
Gagné et al., in preparation

Candidates' Photometry



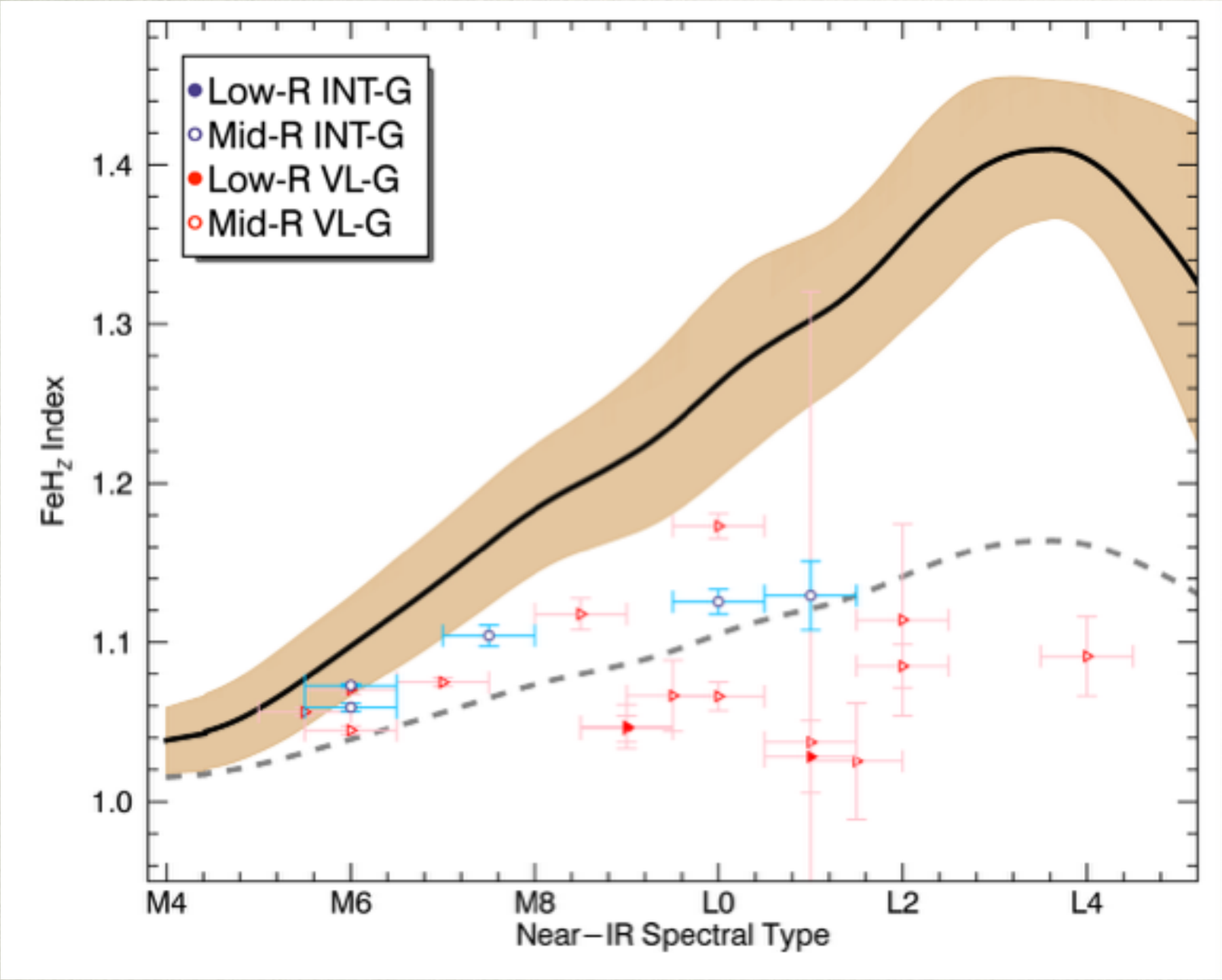
Gagné et al., in preparation

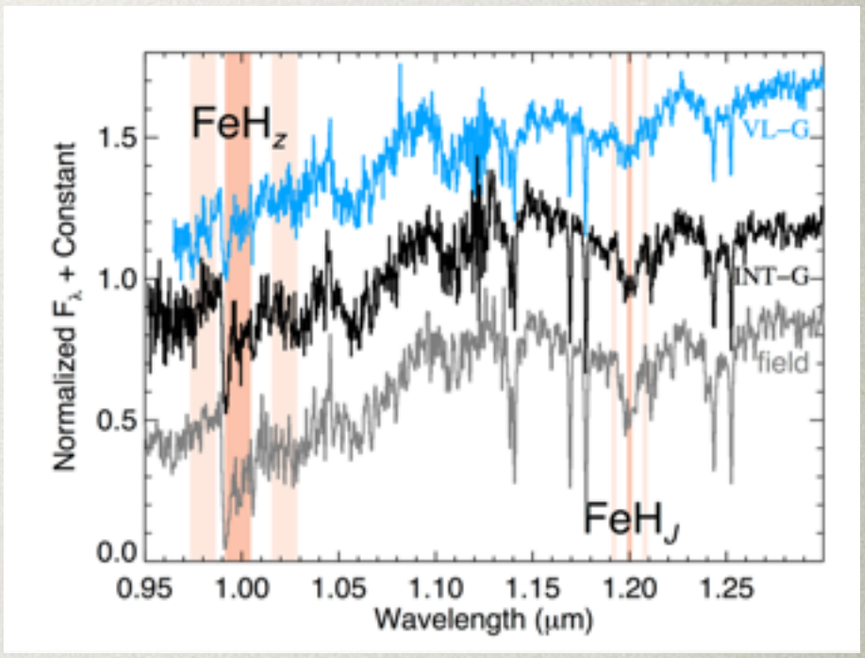
Young Candidates



Gagné et al., in preparation

Young Candidates

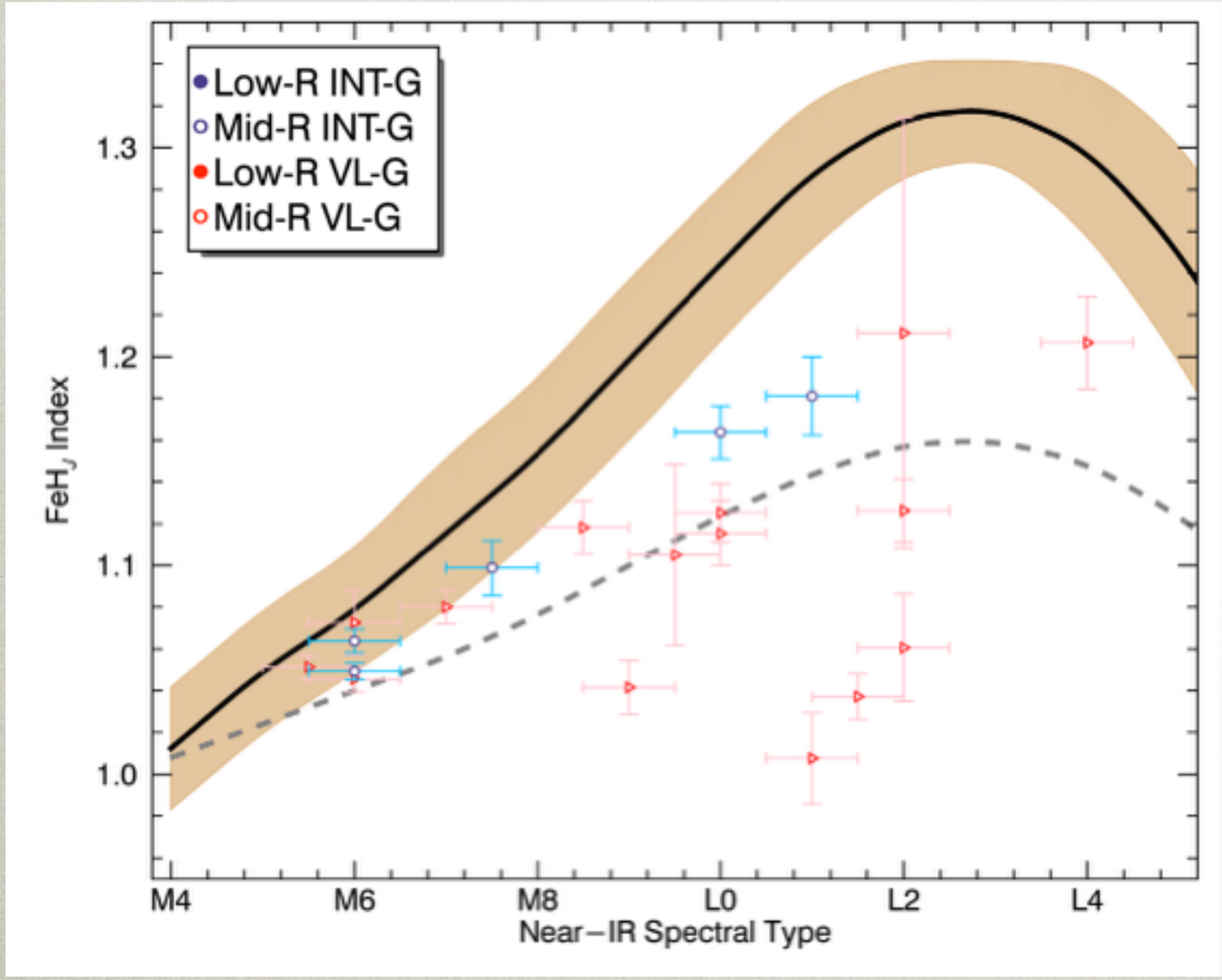


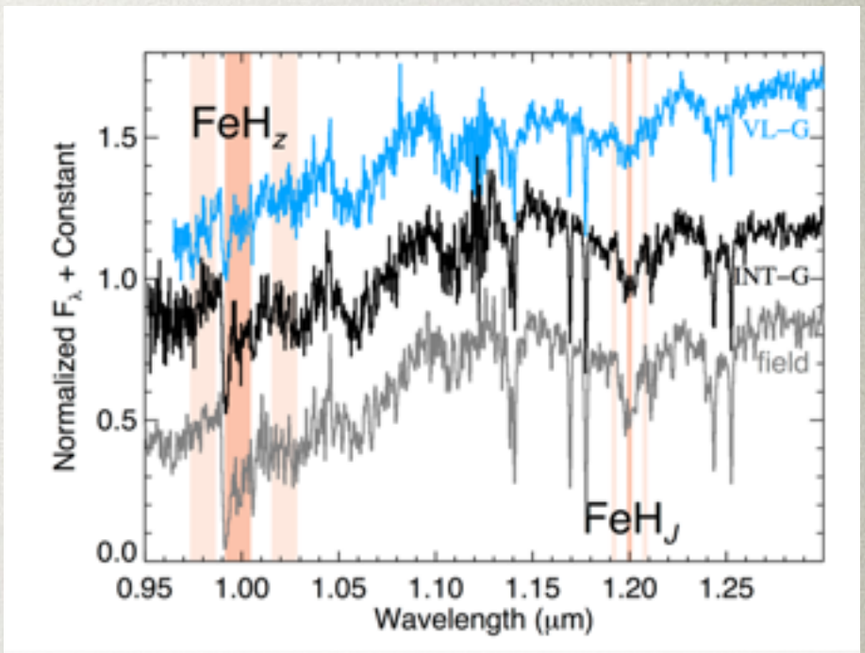


Allers & Liu 2013

Gagné et al., in preparation

Young Candidates

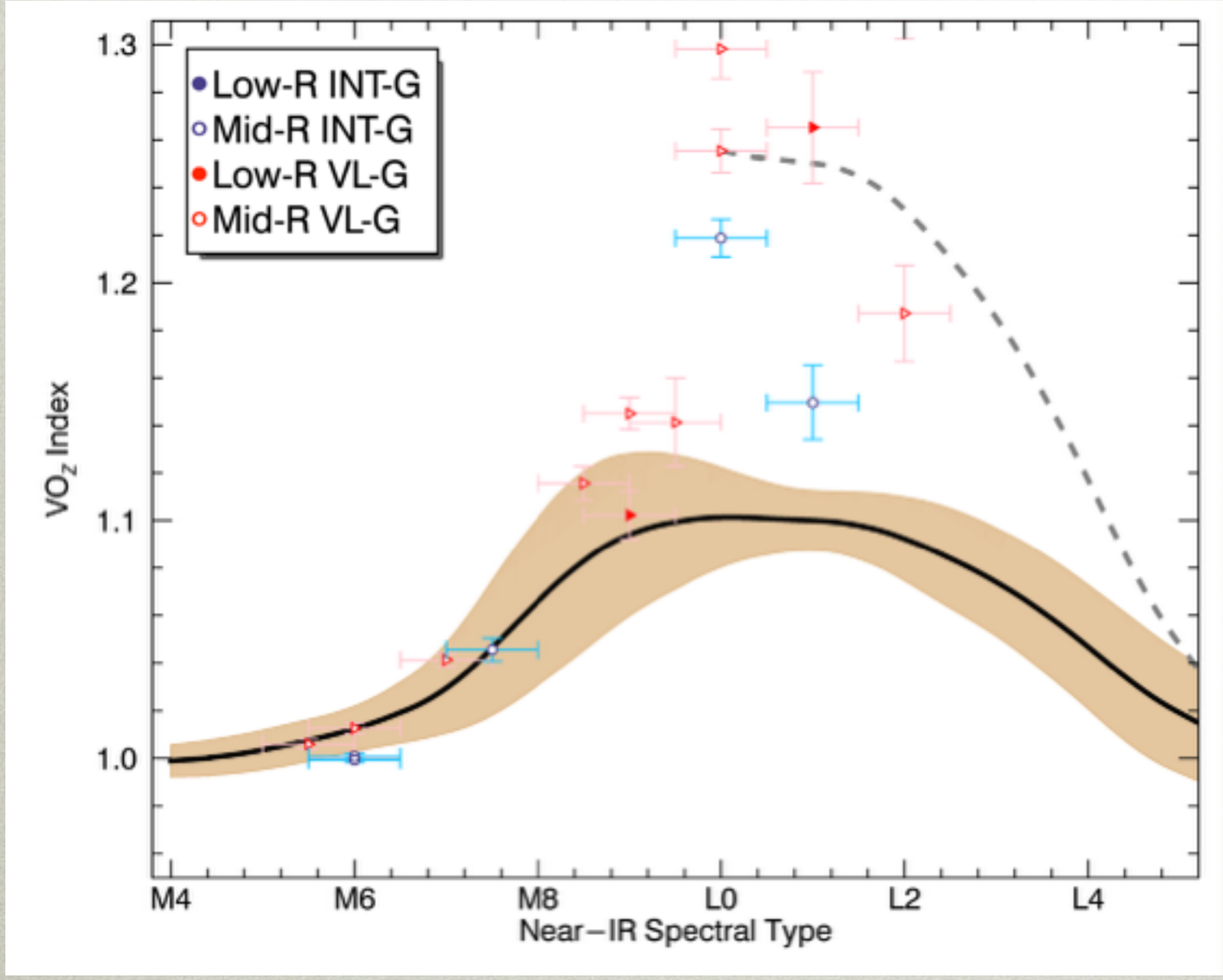




Allers & Liu 2013

Gagné et al., in preparation

Young Candidates



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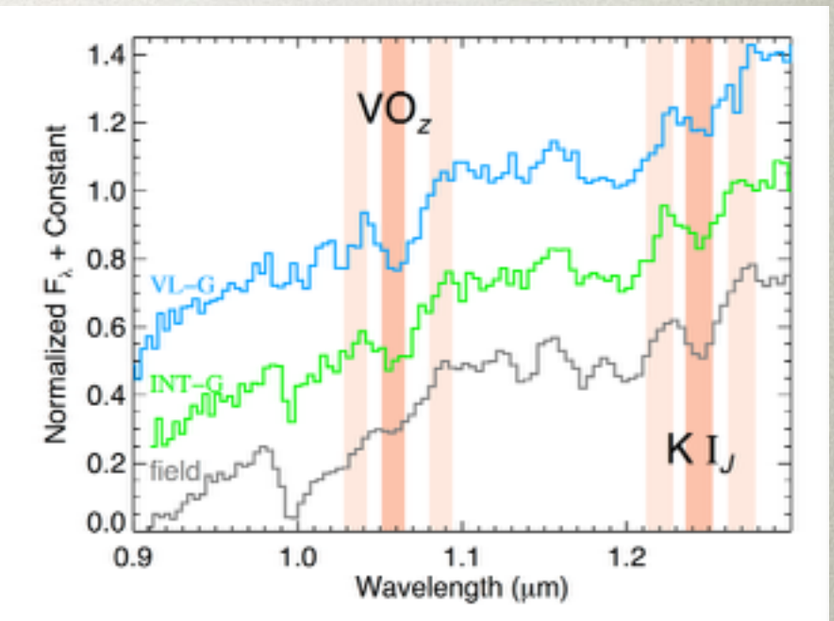
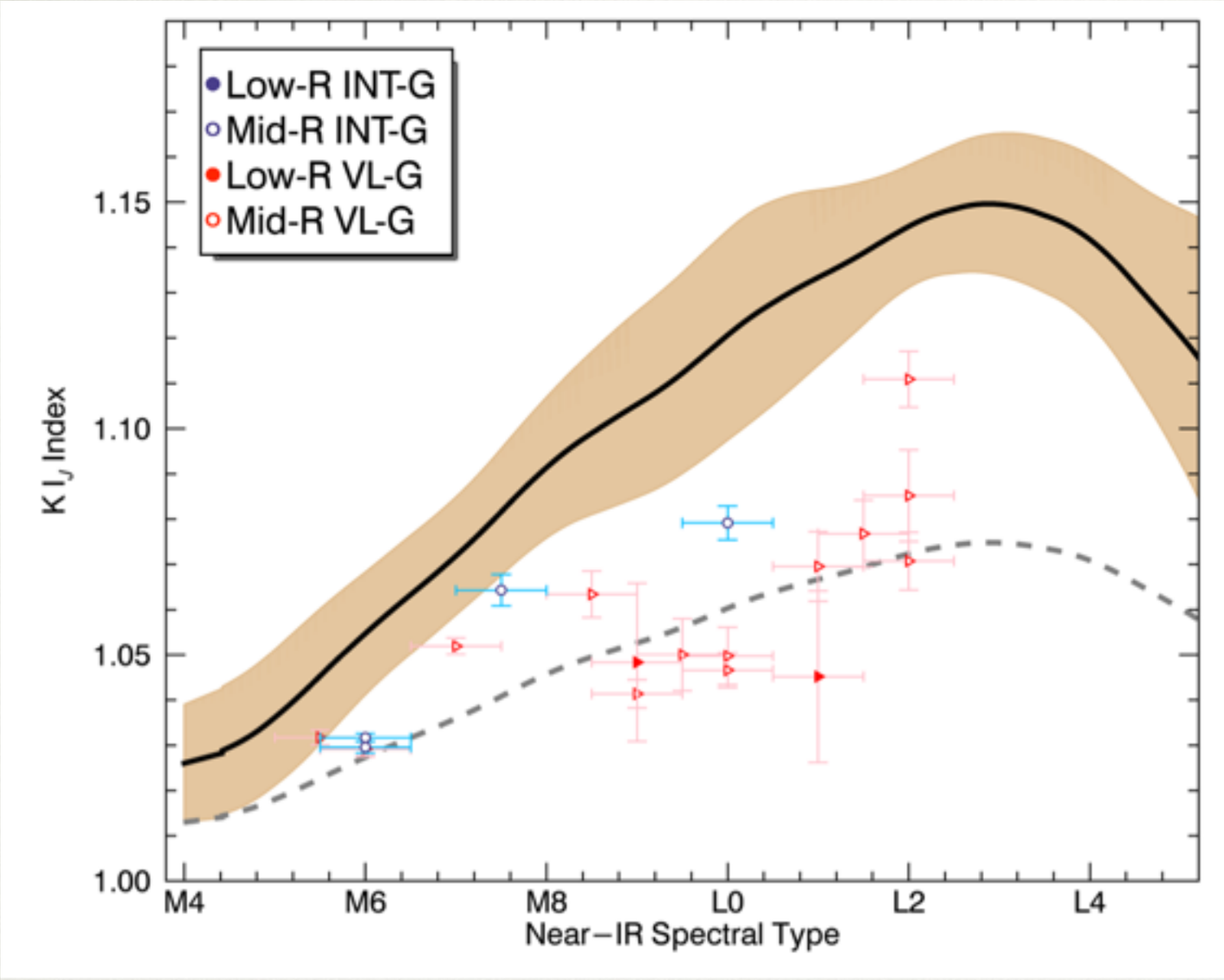
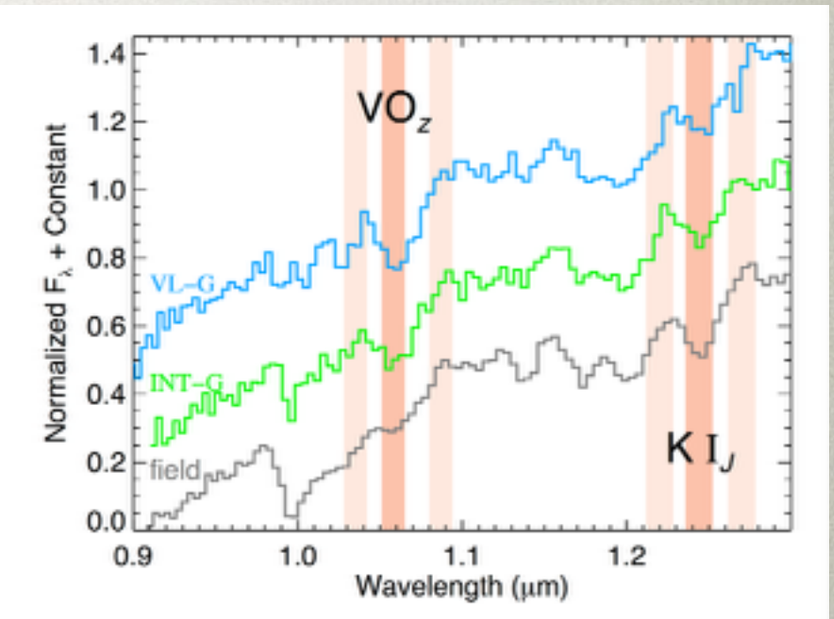


Allers & Liu 2013

Young Candidates

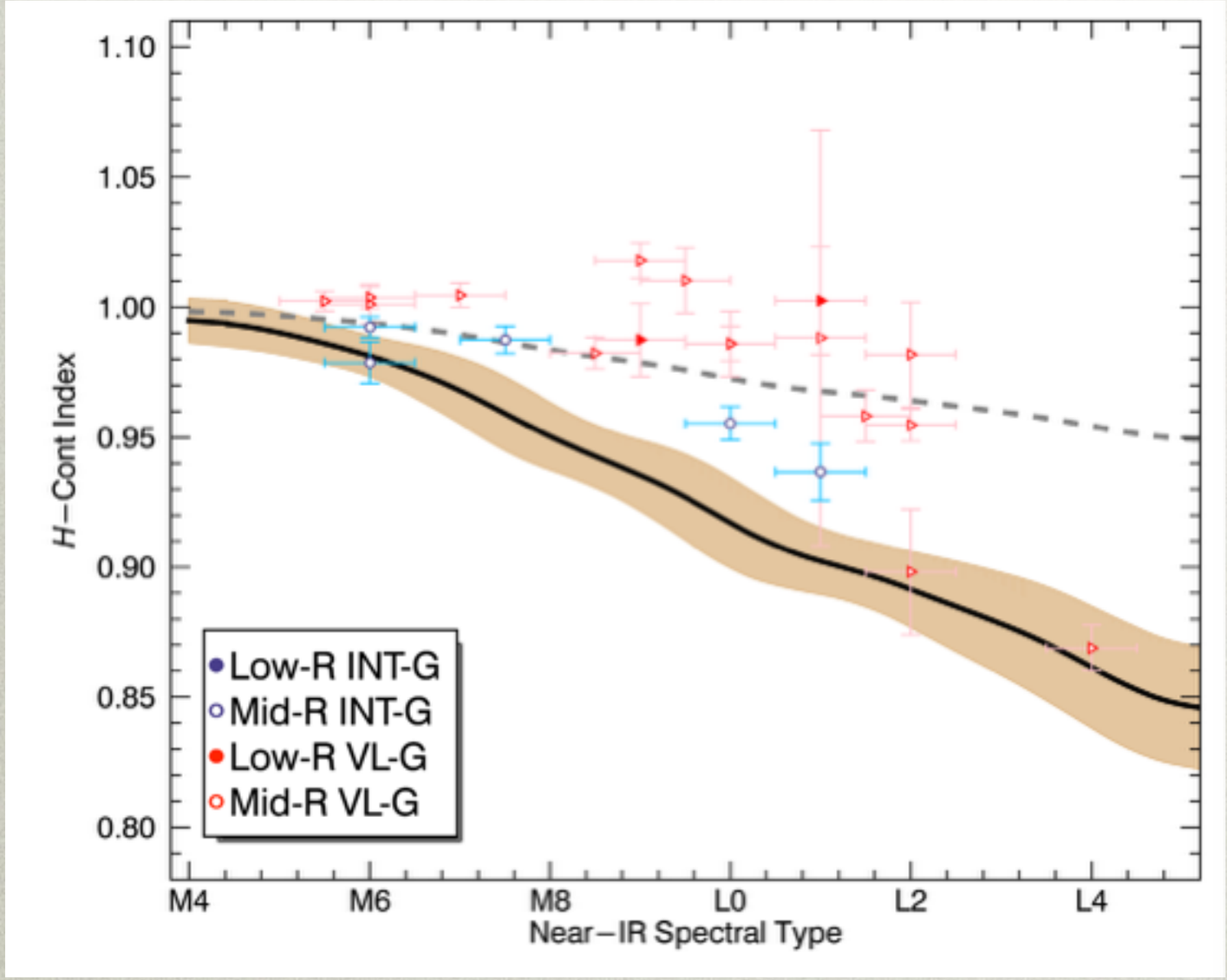


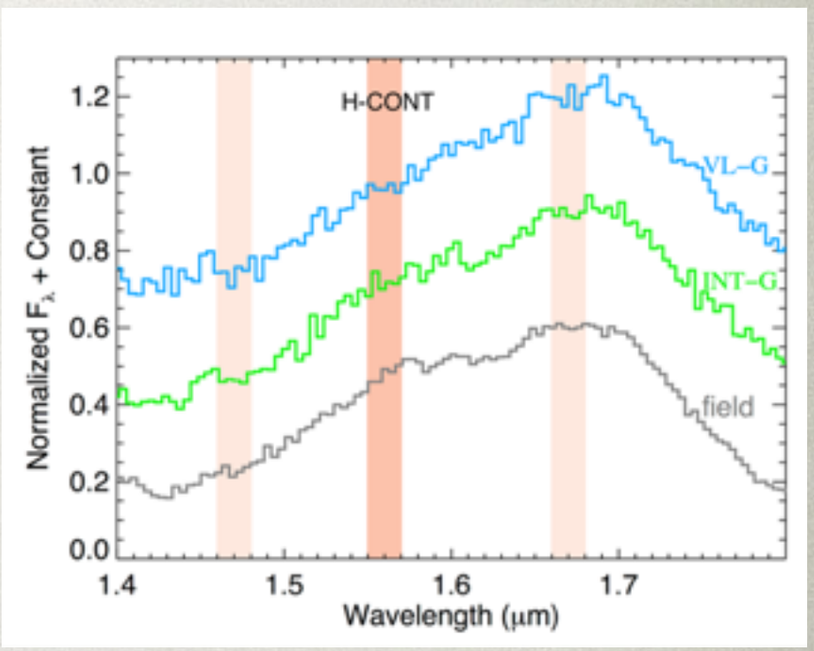
Gagné et al., in preparation



Allers & Liu 2013

Young Candidates

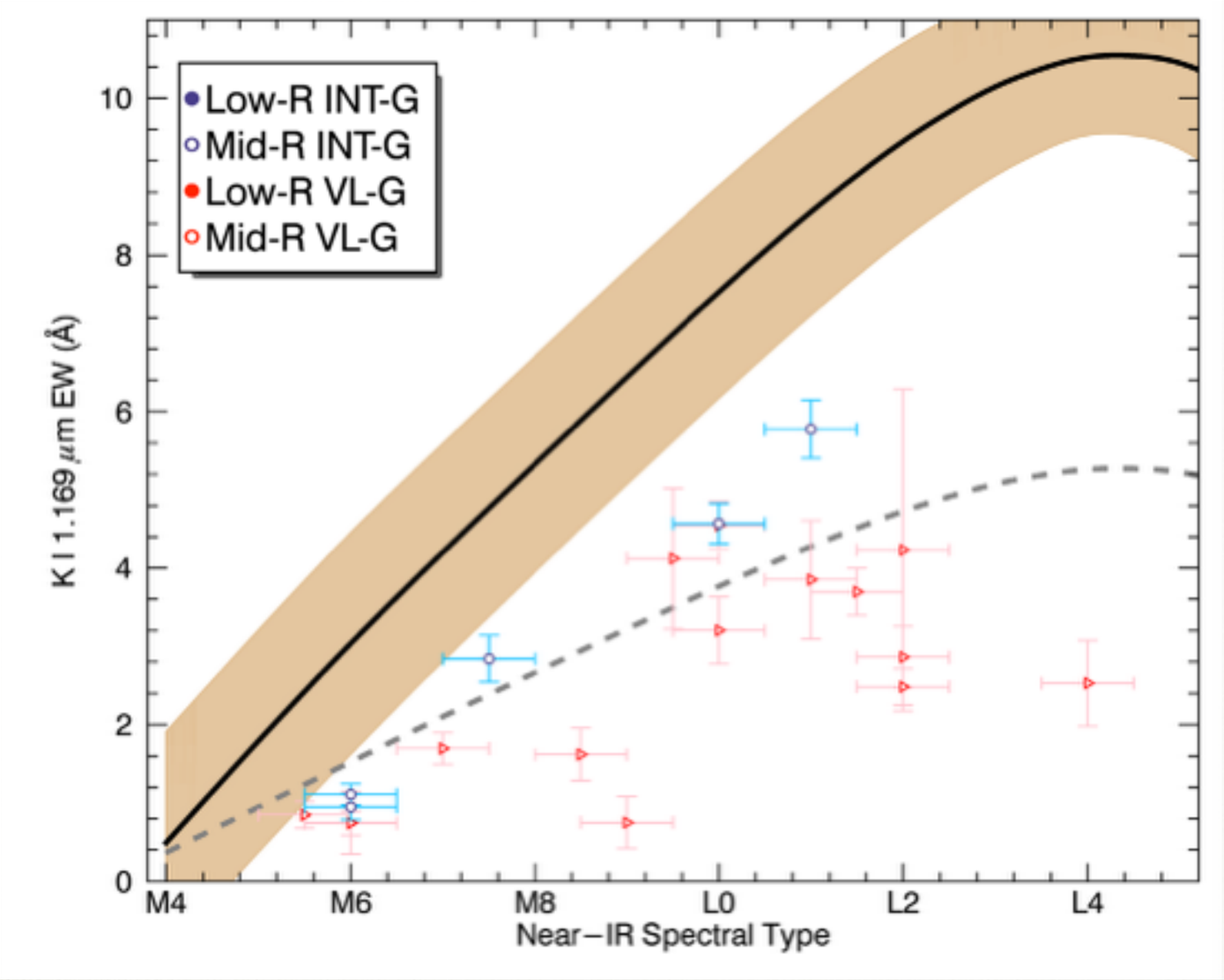


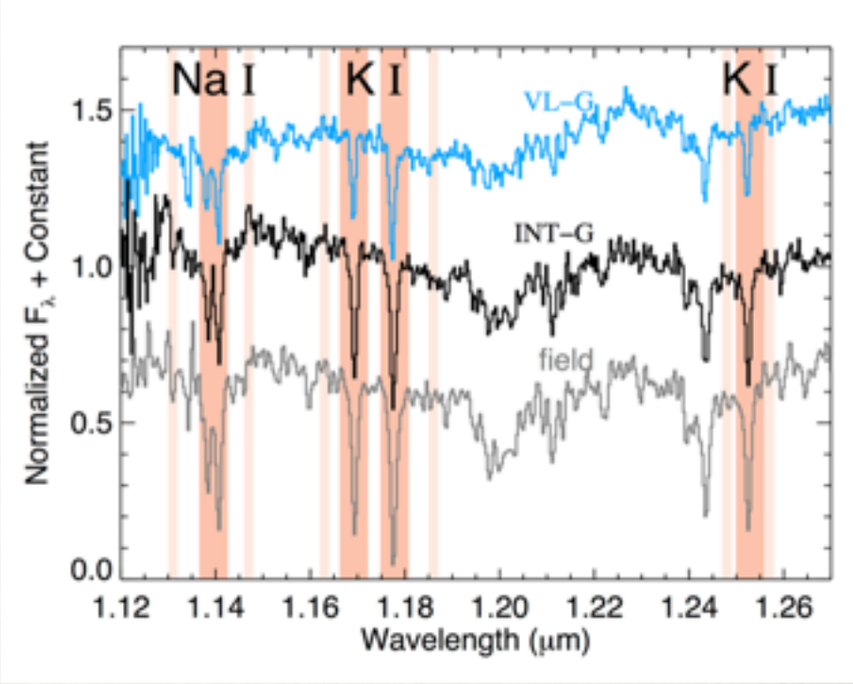


Allers & Liu 2013

Gagné et al., in preparation

Young Candidates

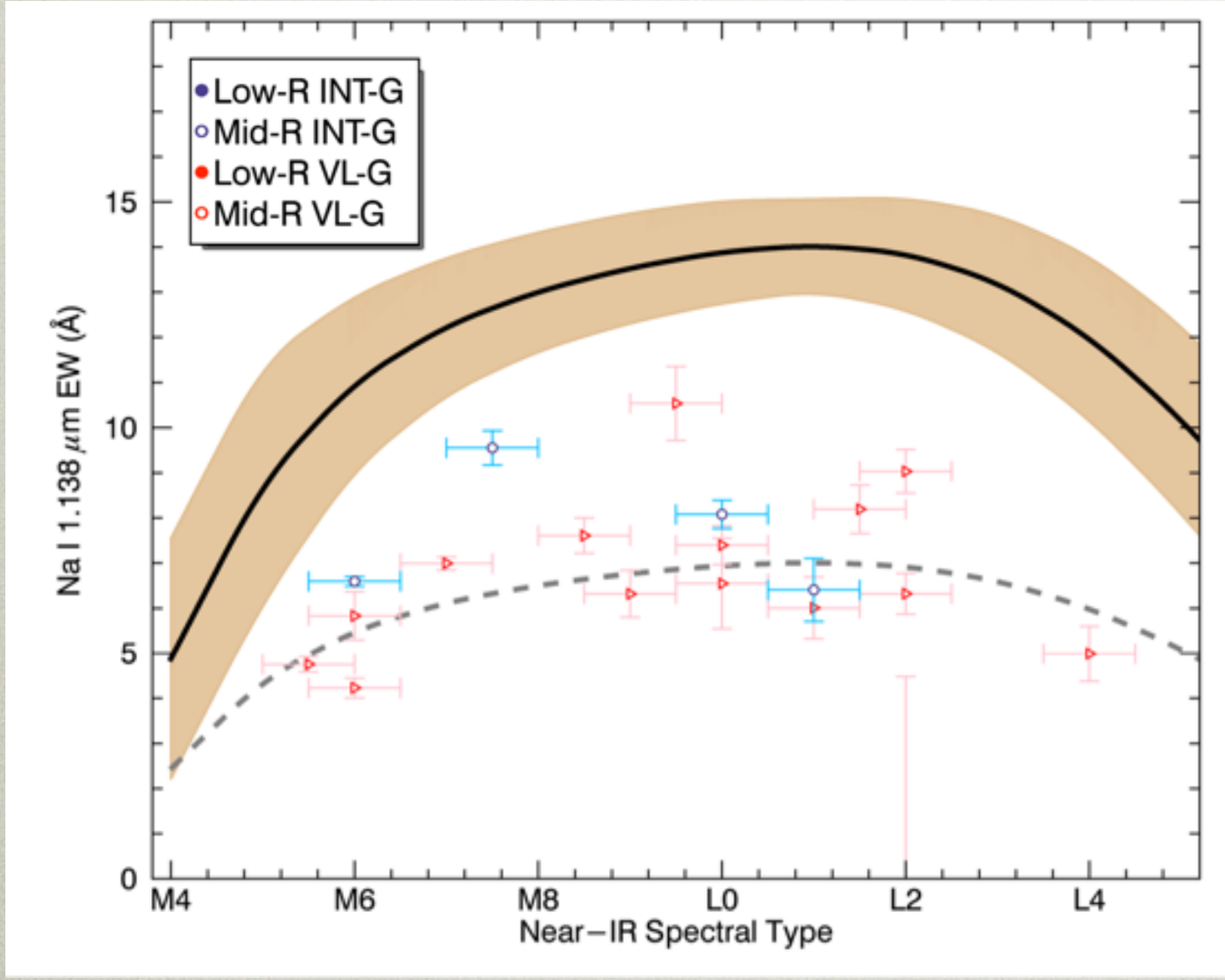




Allers & Liu 2013

Gagné et al., in preparation

Young Candidates



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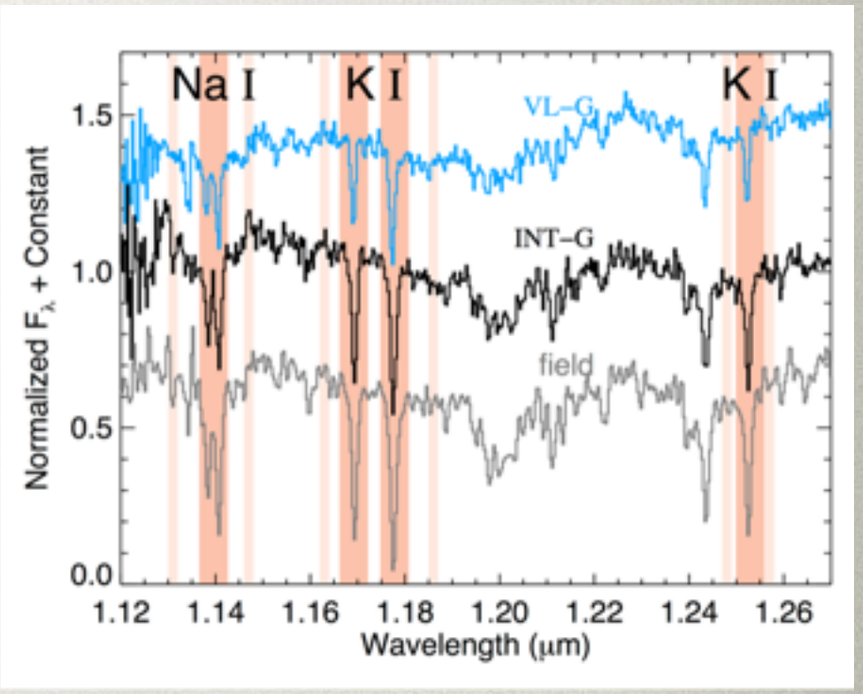

Allers & Liu 2013

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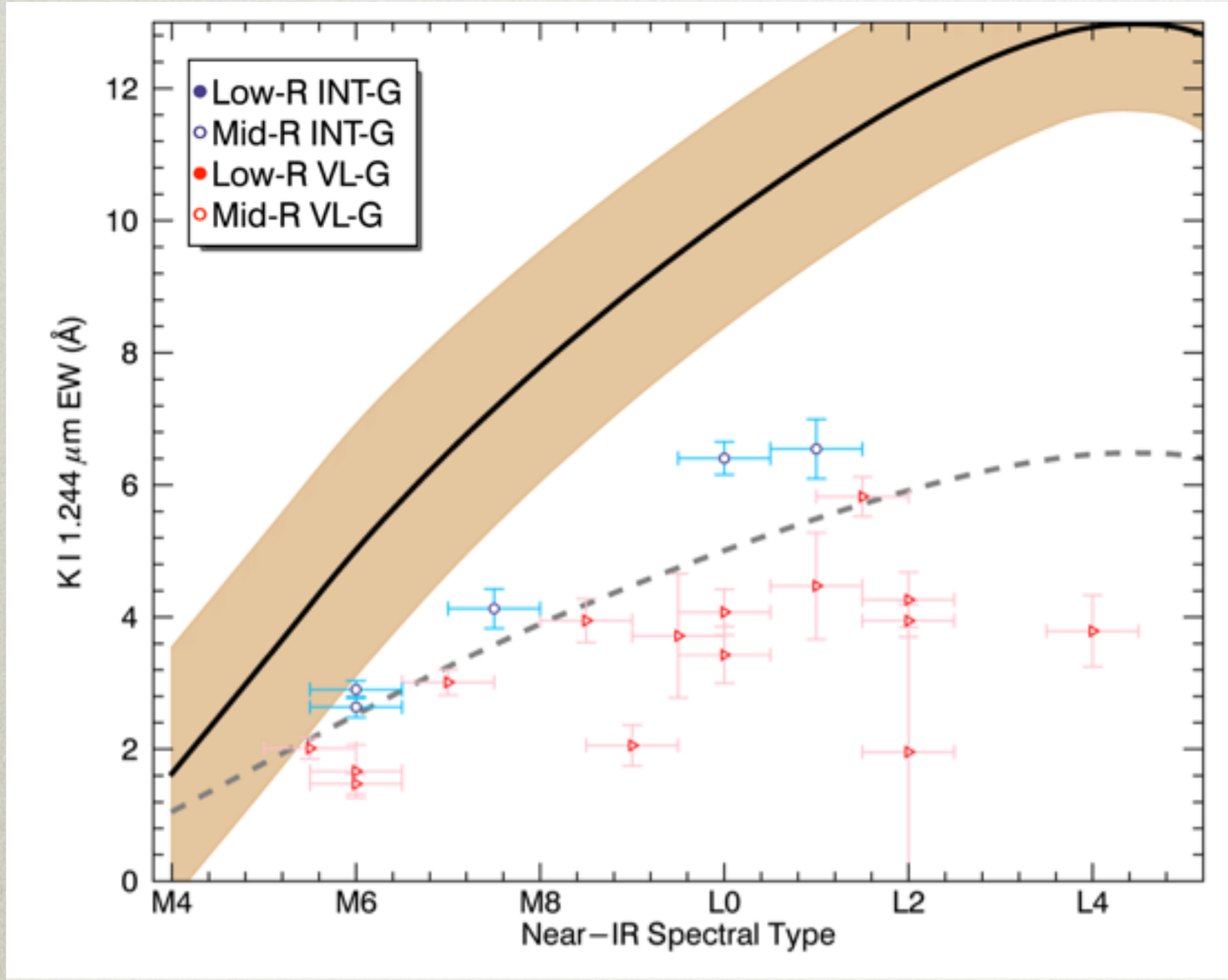

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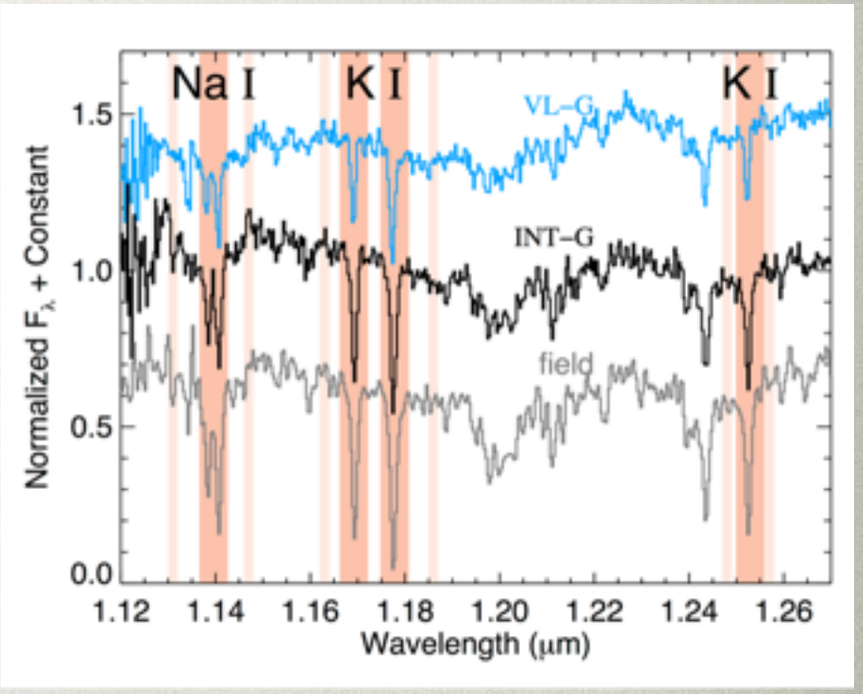

Allers & Liu 2013

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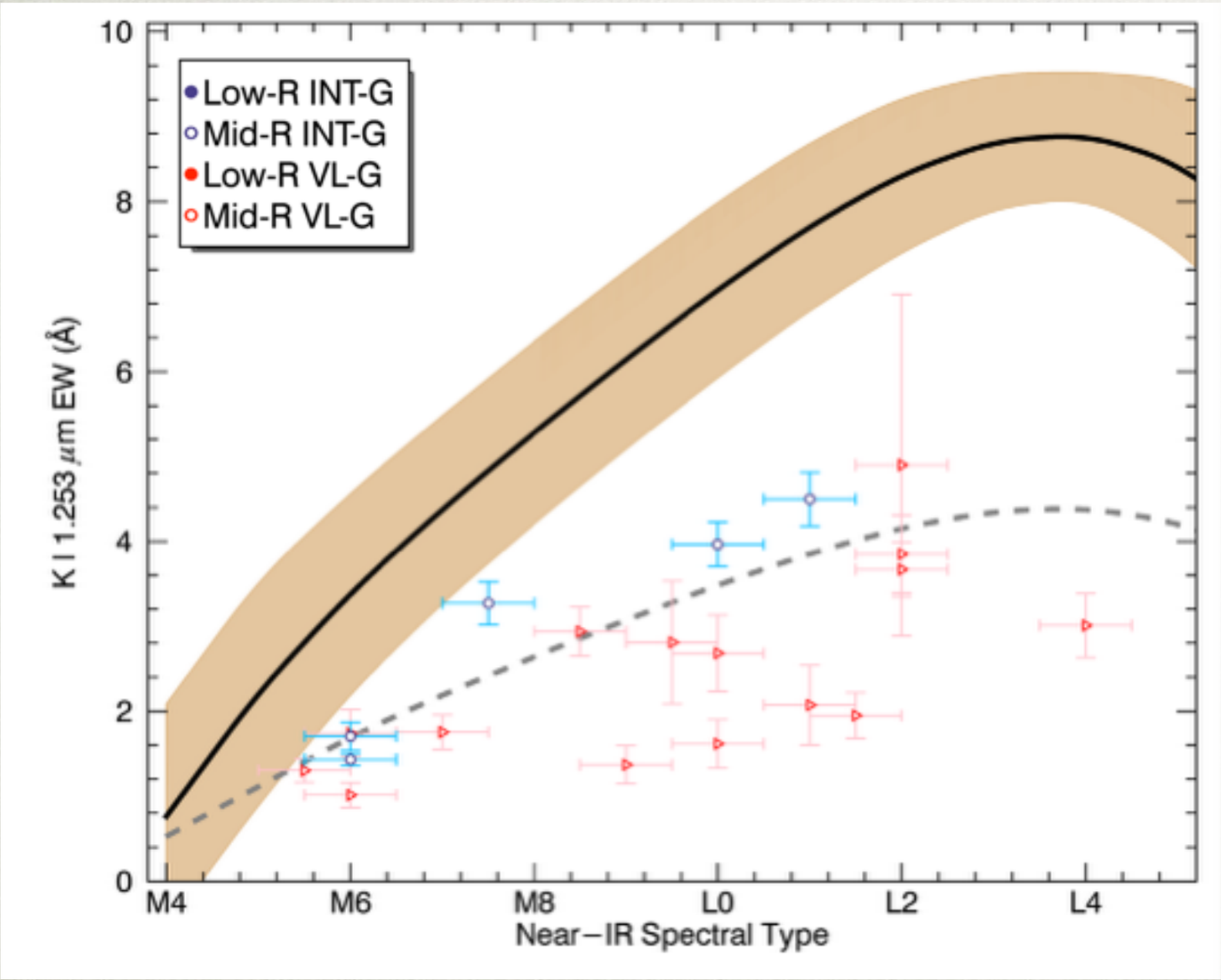
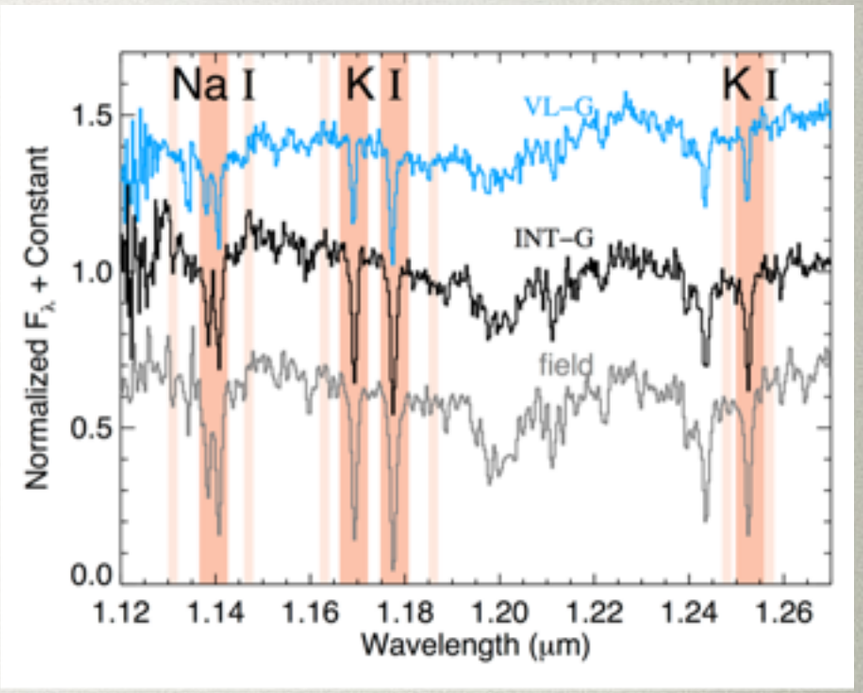


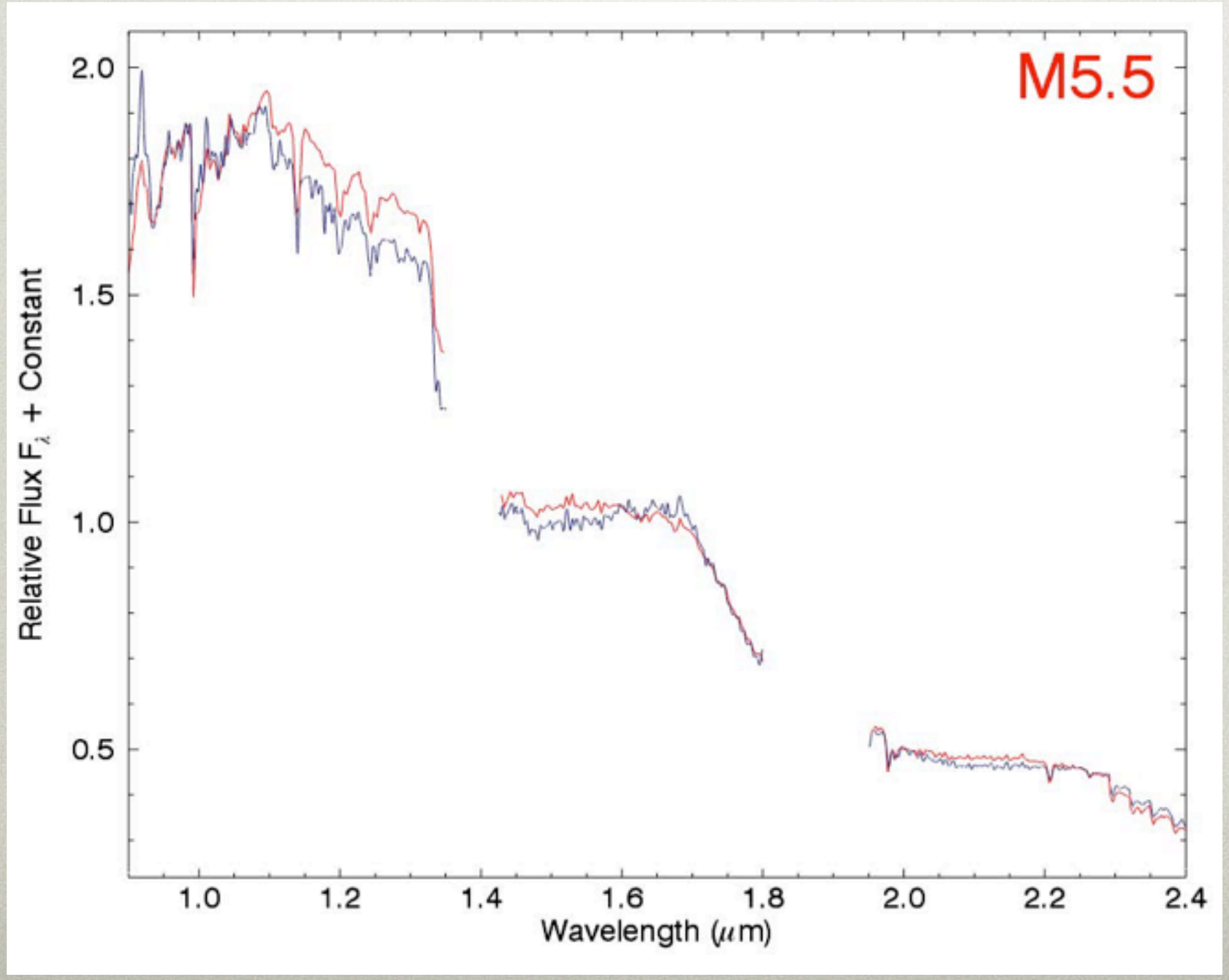


Allers & Liu 2013

Gagné et al., in preparation

Young Candidates

New young BDs spectra in dark blue, field templates in color :



Gagné et al., in preparation

Follow-up

- ~ 75 % young when prob. > few %

- ~ 50 % for Argus and AB Doradus

- 31 systems with low na I (optical)

- 23 systems with low-G (NIR)

- 7 young companions

= 57 new young objects !

8 in TWA, 15 in BPMG, 6 in CAR, 17 in THA,
5 in COL, 1 in ARG, 5 in ABDMG

Global Status of spectral follow-up

For High-Priority targets

- 76 / 136 M4 - M5 in the optical (GMOS, Magellan)

- 66 / 143 > M5 in the NIR (SpeX, GNIRS, FIRES, SIMON, OSIRIS, F2)

Nice Results from the BASS Survey

2MASS J0103

- Binary M5 + M5
- Parallaxe + RV
- New latest-type bona fide member of THA !
- 12 - 14 M_{JUP} COMPANION
- 84 A.U.
- Comoving M8.5 !
- Companion has VL-G !

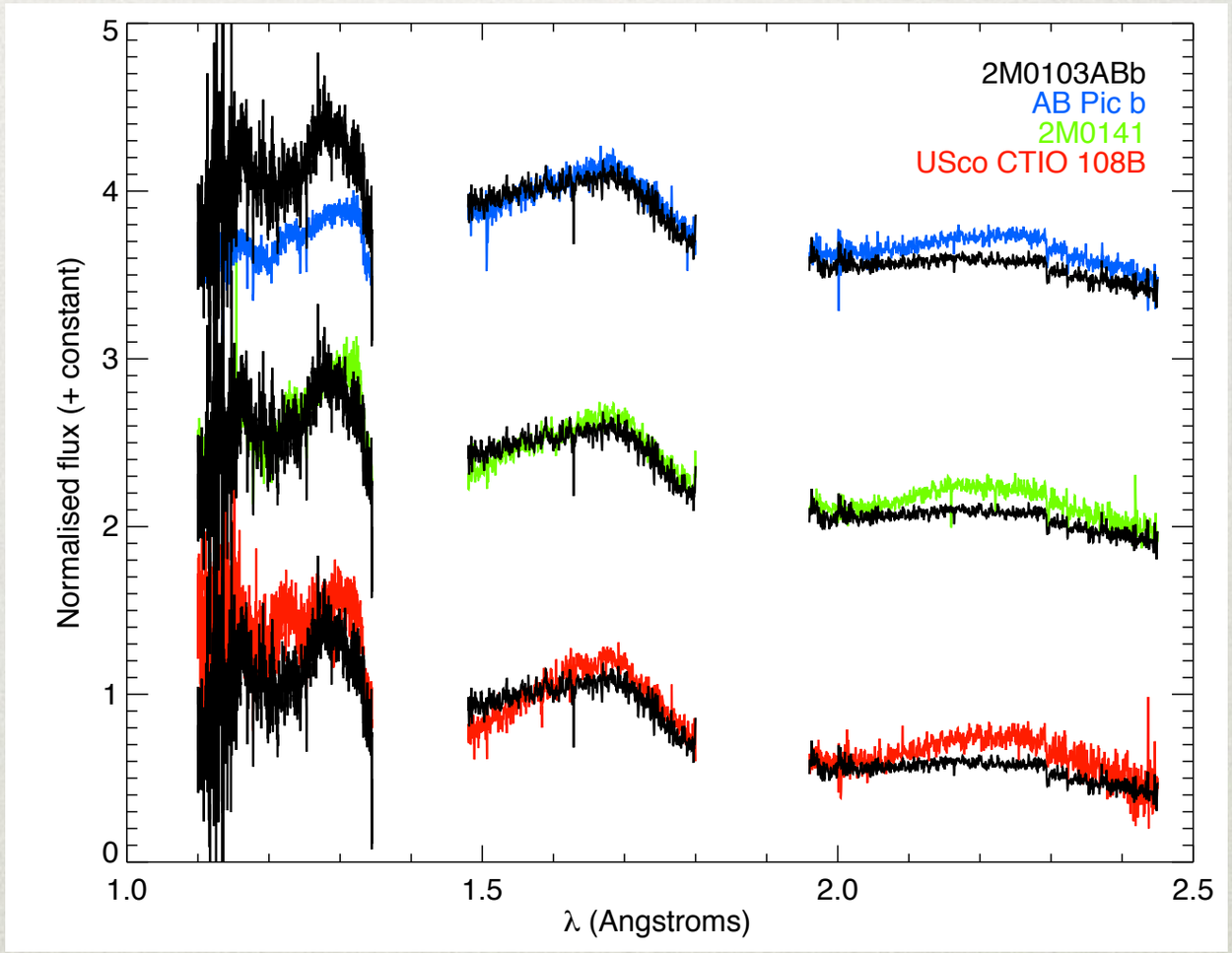
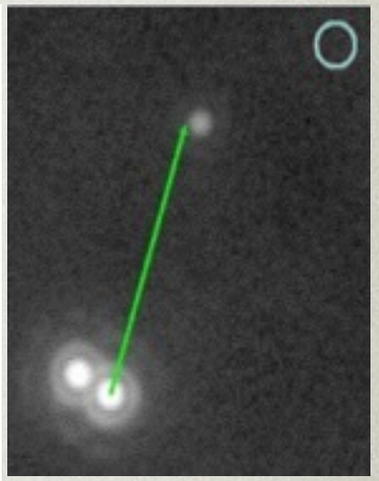


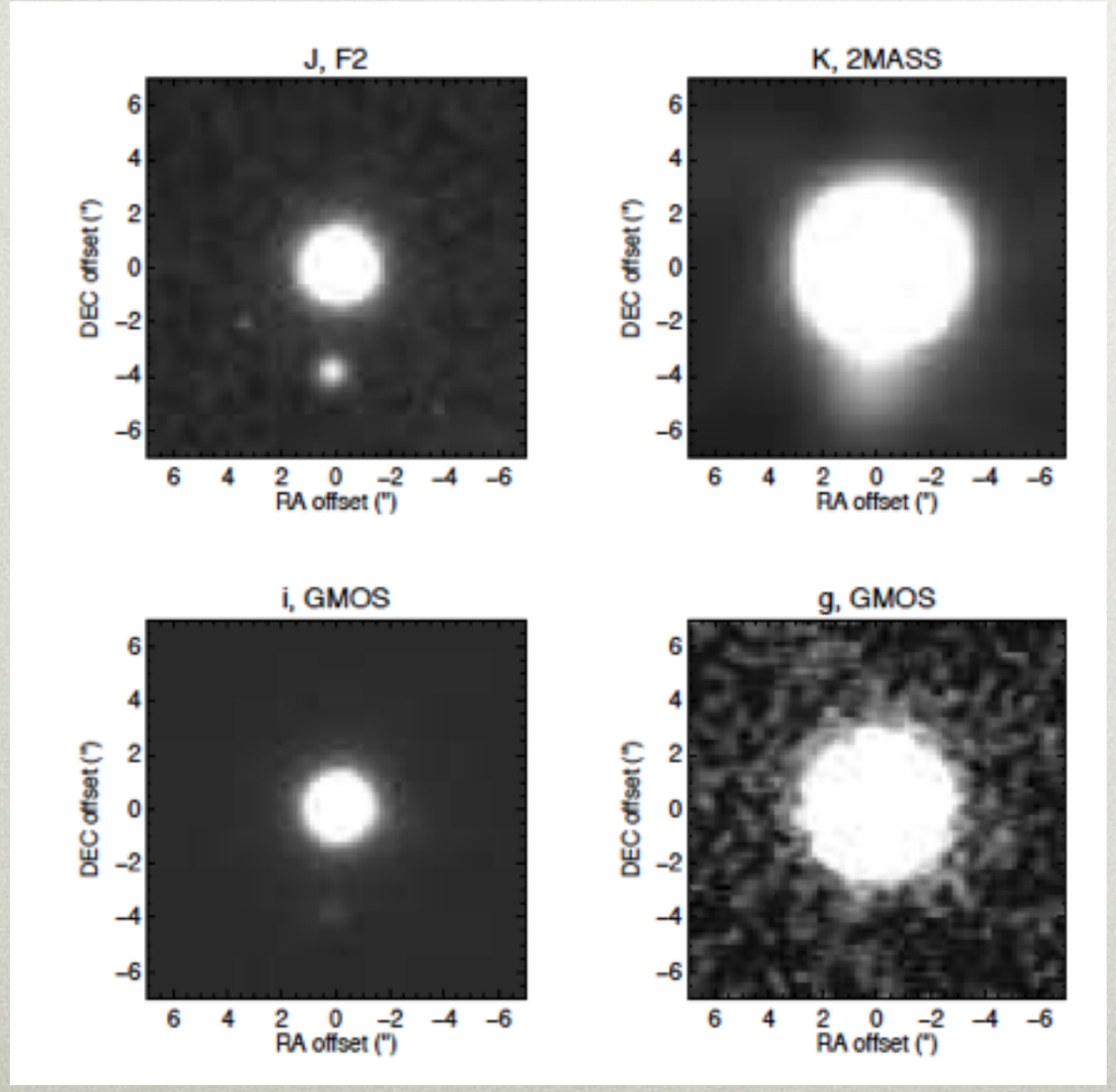
Figure by M. Bonnefoy
Gagné et al., in prep.

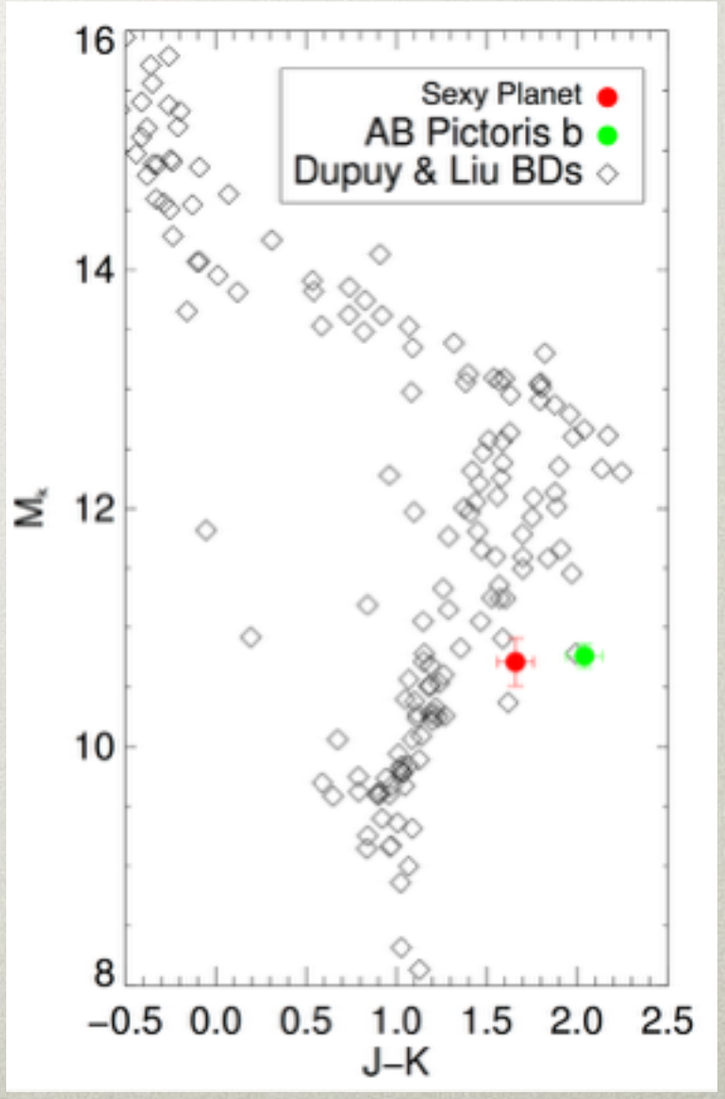


Delorme et al., 2013

A twin to AB Pic B

- Étienne Artigau's project ; search for large-separation for planets in BASS
- Found a young L4 planet !

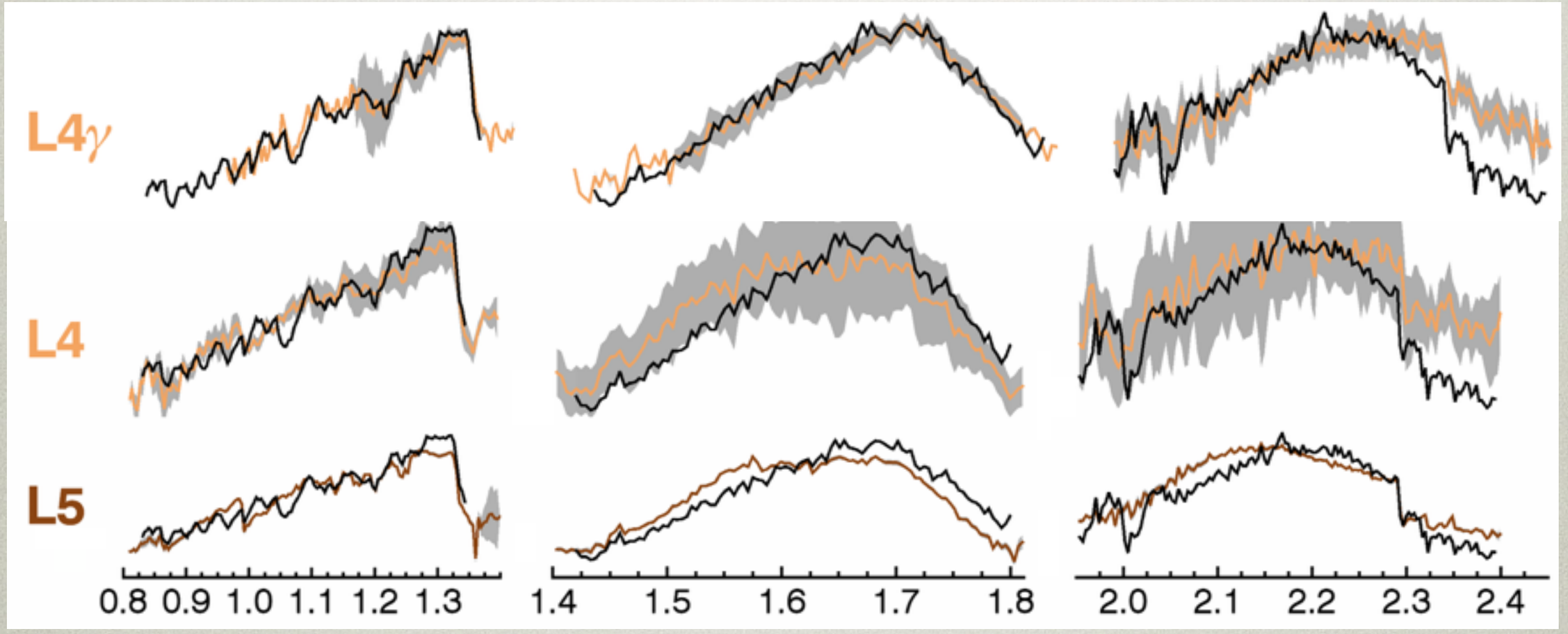




Artigau et al., in prep.

A twin to AB Pic B

We got a FIRE spectrum !



Artigau et al., in prep.

Black line is the planet, color lines are templates

2 NEW BDs in TWA

To appear in ApJ Letters.
Preprint typeset using LaTeX style emulateapj v. 04/17/13

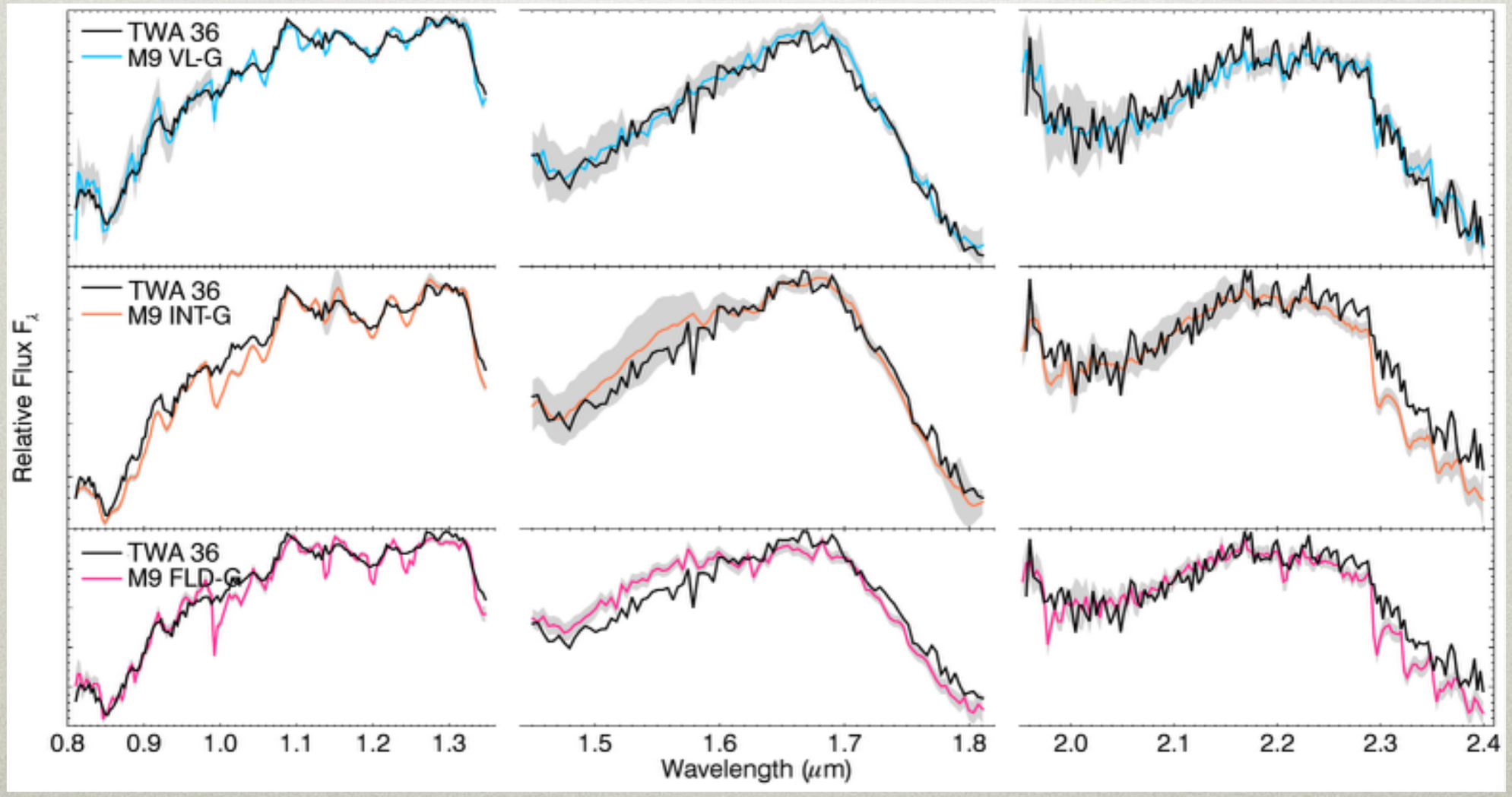
THE COOLEST ISOLATED BROWN DWARF CANDIDATE MEMBER OF TWA

Jonathan Gagné[1], Jacqueline K. Faherty[2,3,4], Kelle Cruz[5,6], David Lafrenière[1], René Doyon[1], Lison Malo[1], Étienne Artigau[1].
[1]Département de Physique and Observatoire du Mont-Mégantic, Université de Montréal, C.P. 6128 Succ. Centre-ville, Montréal, Qc H3C 3J7, Canada
[2]Departamento de Astronomía, Universidad de Chile, Cerro Calán, Las Condes, Chile
[3]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA
[4]Hubble Fellow
[5]Department of Astrophysics, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10034
[6]Department of Physics & Astronomy, Hunter College, 695 Park Avenue, New York, NY 10065, USA.

To appear in ApJ Letters.

2 NEW BDs IN TWA

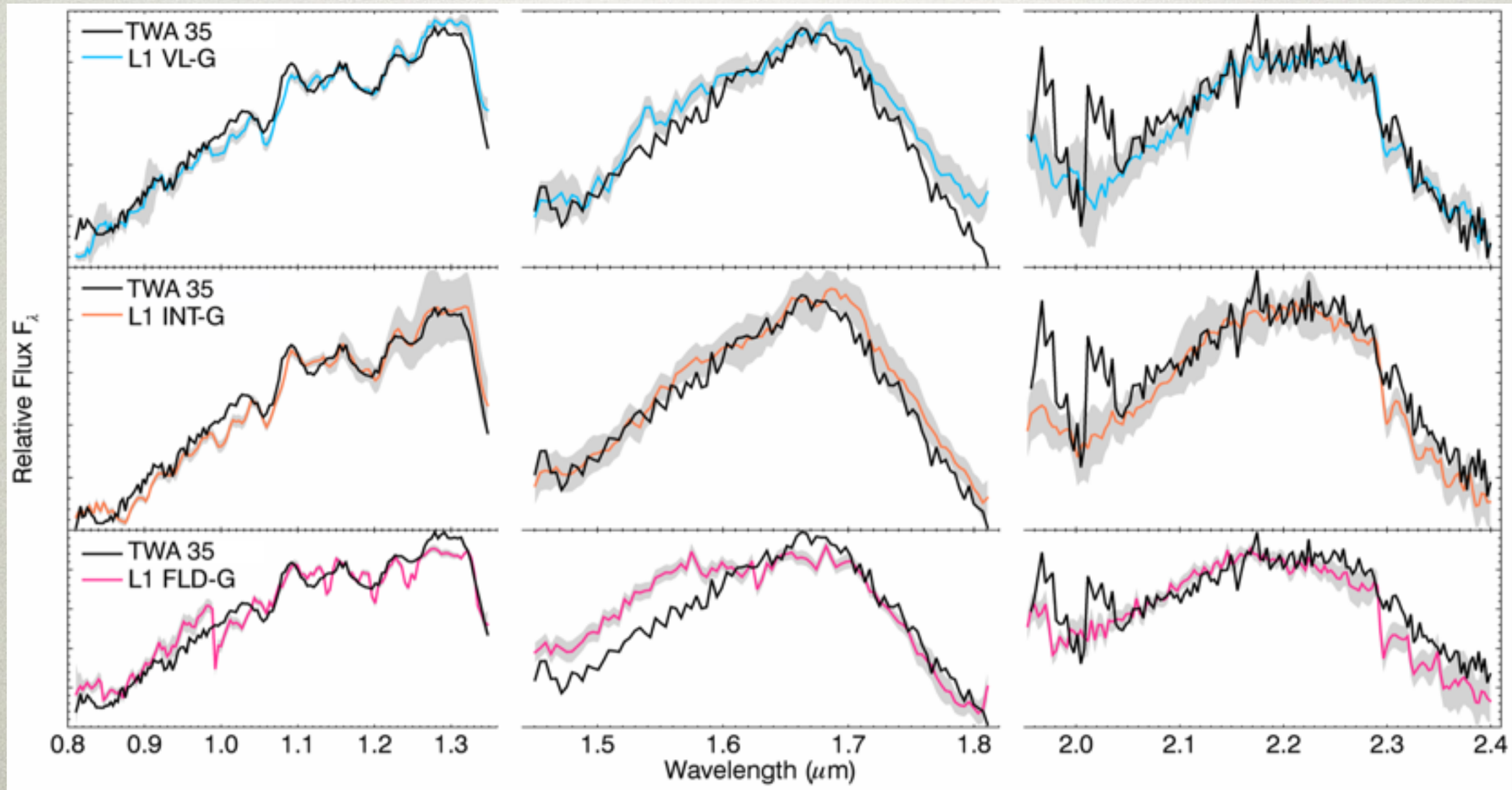
- A new low-g M9 candidate in TWA



Gagné et al. 2014b

2 NEW BDs in TWA

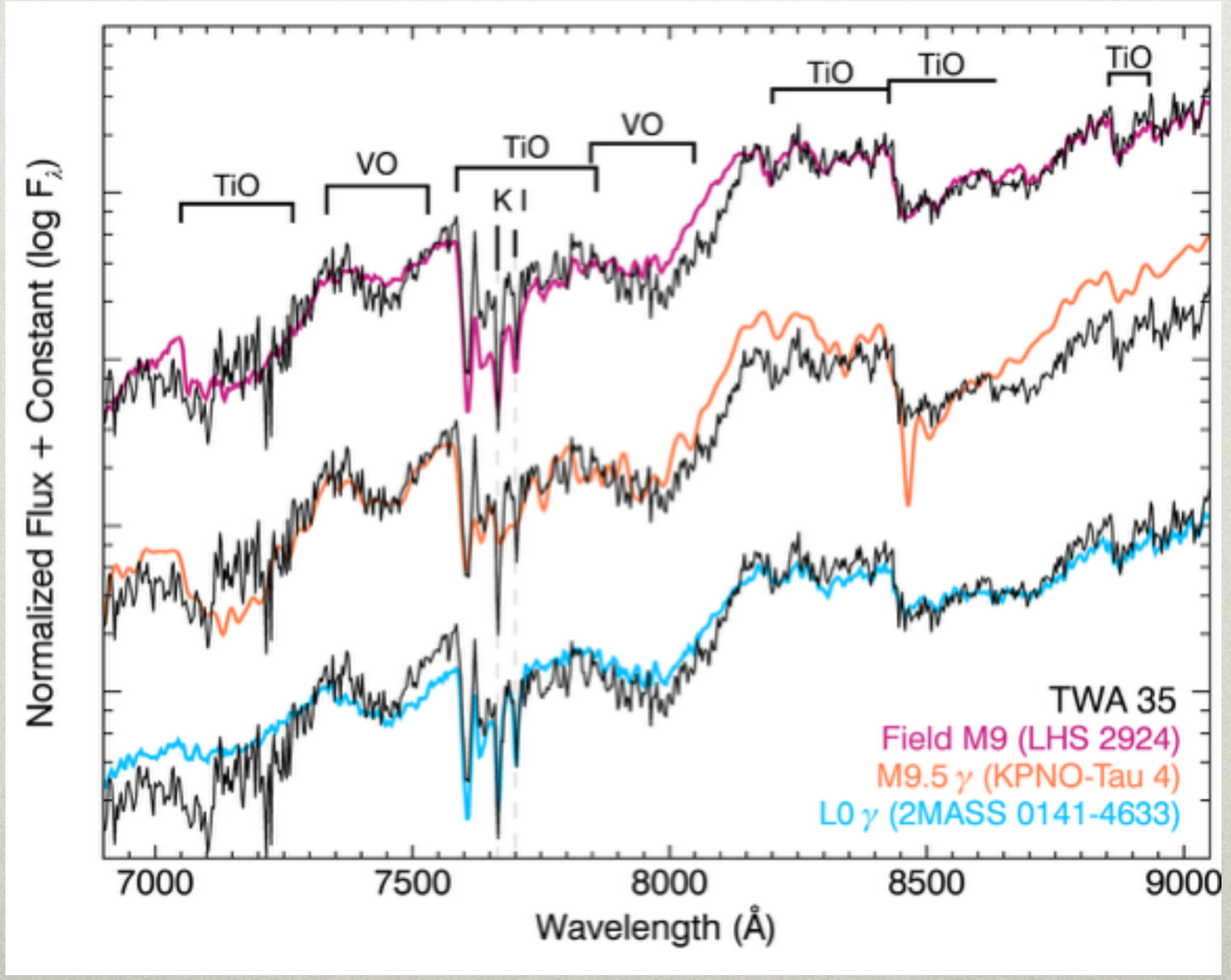
- And a new L1 candidate in TWA !



Gagné et al. 2014b

2 NEW BDs in TWA

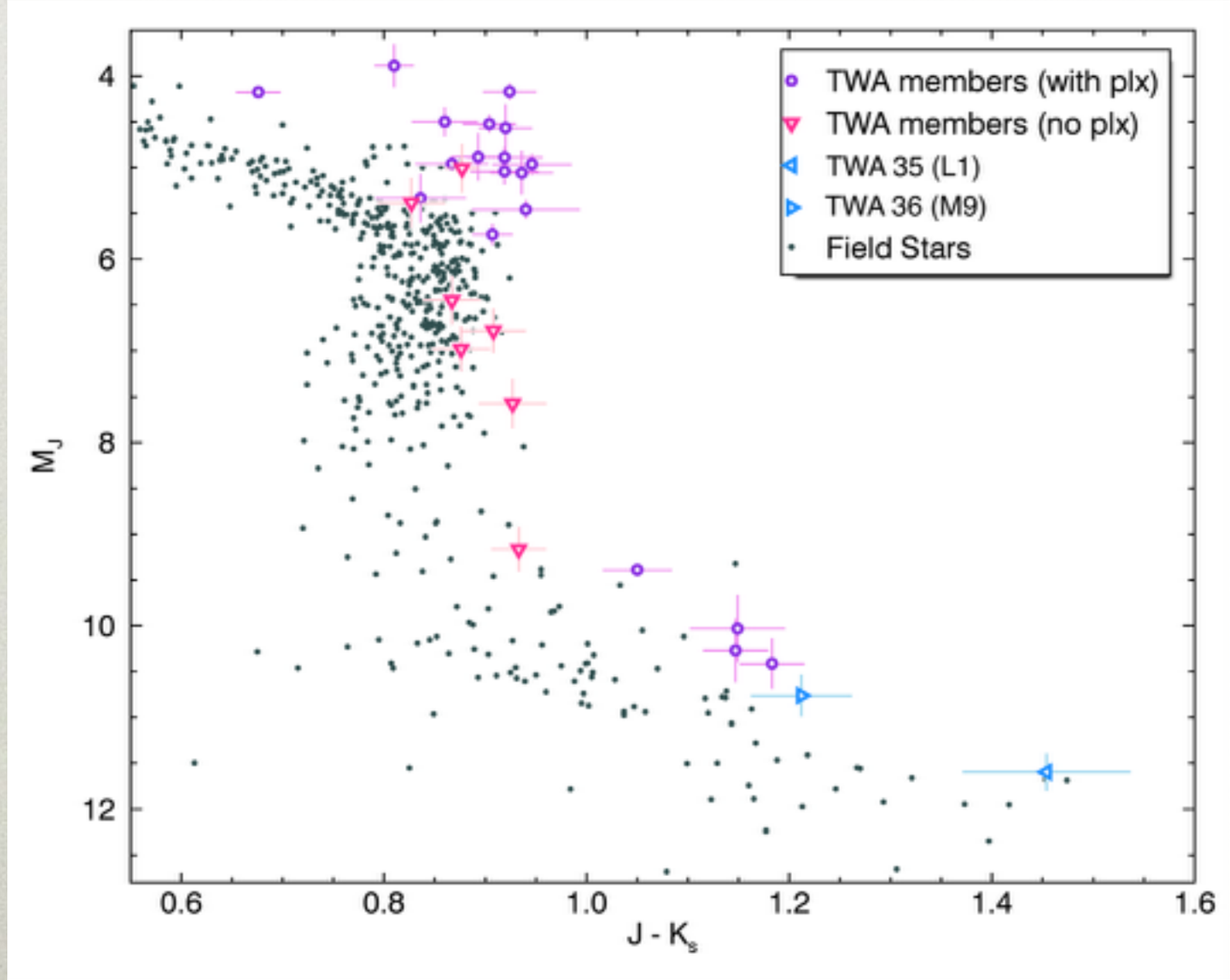
- The NIR L1 has an M9.5 optical spectral type



Gagné et al. 2014b

2 NEW BDs in TWA

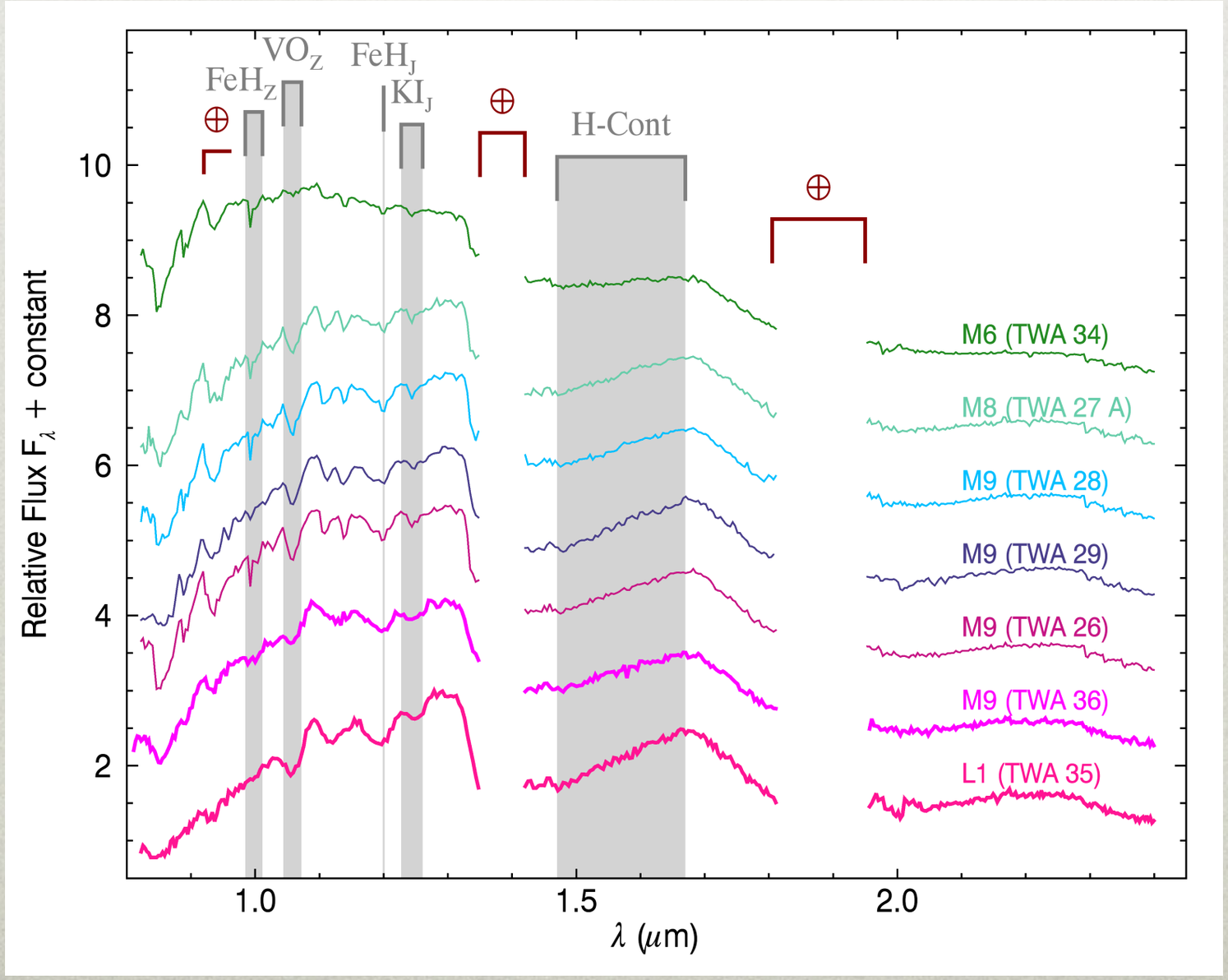
- With statistical distance predictions…
- We can predict their position in a CMD :



Gagné et al. 2014b

2 NEW BDs IN TWA

- Compared to other TWA candidates / members :

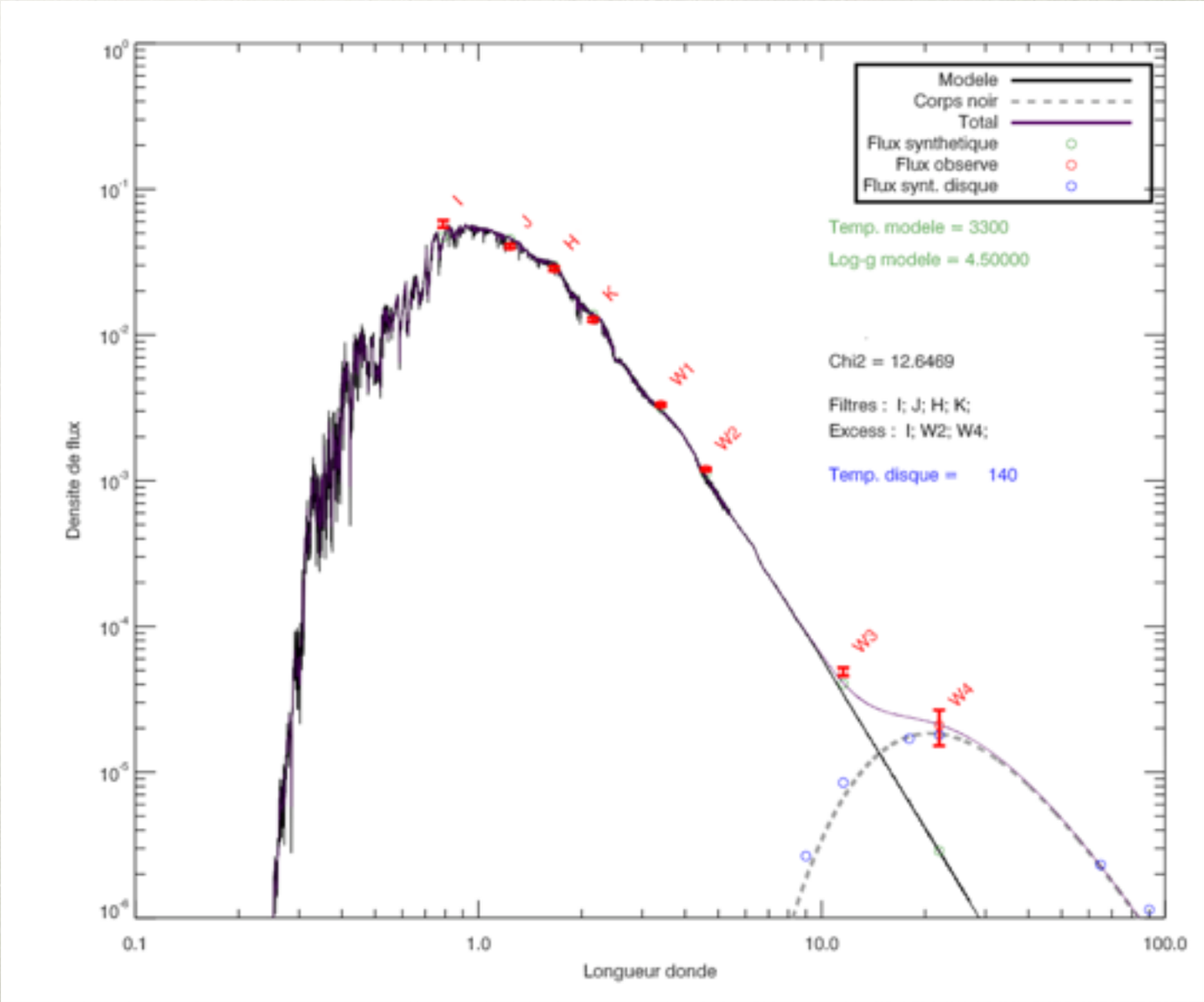


Gagné et al. 2014b

CANDIDATES WITH W3 EXCESS

Anne Boucher's project

- M5.5 + M7.5 + M8.5 in TWA
- **M5** in BPMG
- ~ M5 + M8 in CAR
- ~ L1 in THA
- ~ M6 + M4 in COL
- ~ M7 in ARG



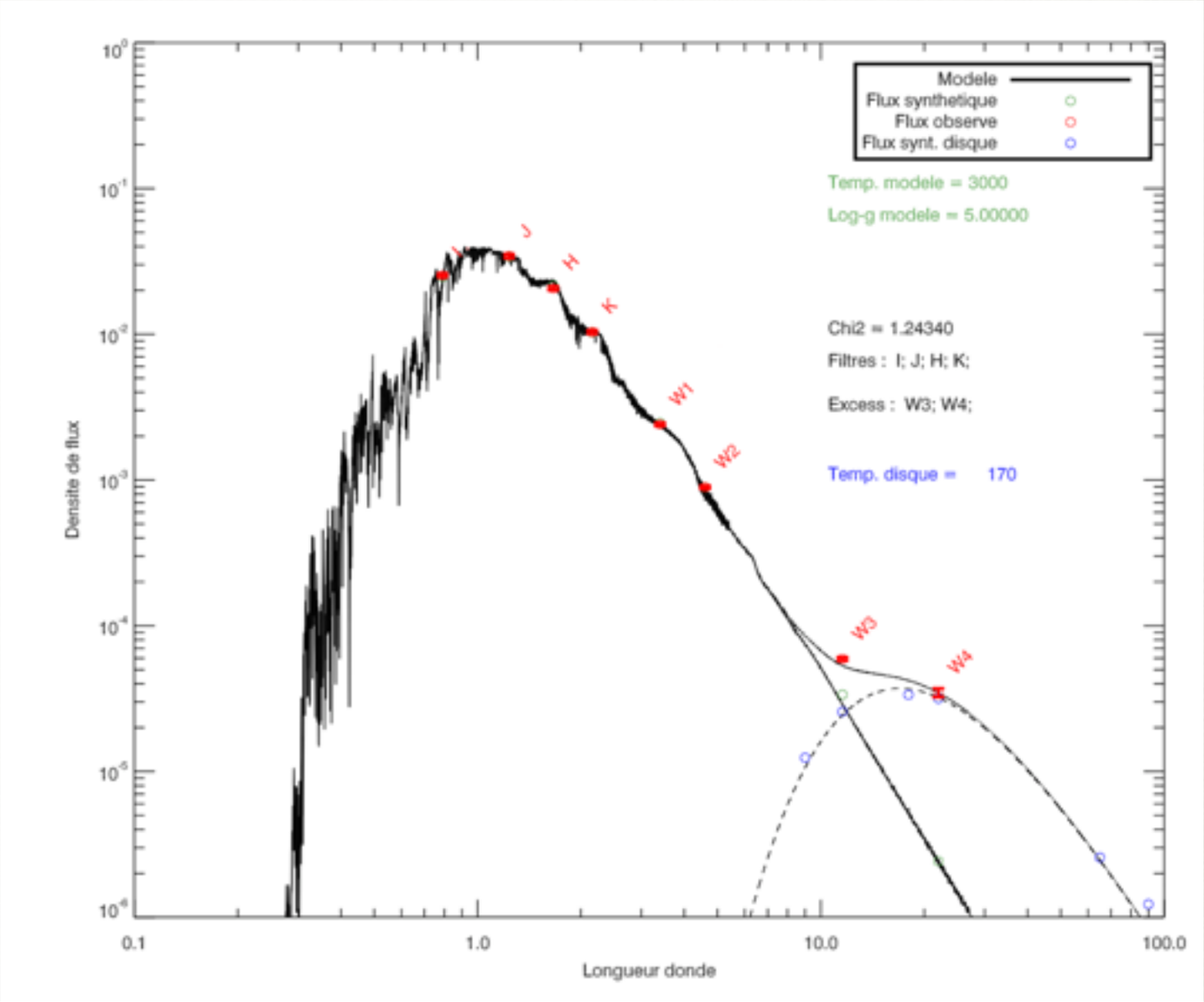
Boucher et al., in prep.

Purple = Young, Bold = Figure

CANDIDATES WITH W3 EXCESS

Anne Boucher's project

- M6 + M8 + M8.5 in TWA
- M5 in BPMG
- ~ M5 + M8 in CAR
- ~ L1 in THA
- **~ M6** + M4 in COL
- ~ M7 in ARG



Boucher et al., in prep.

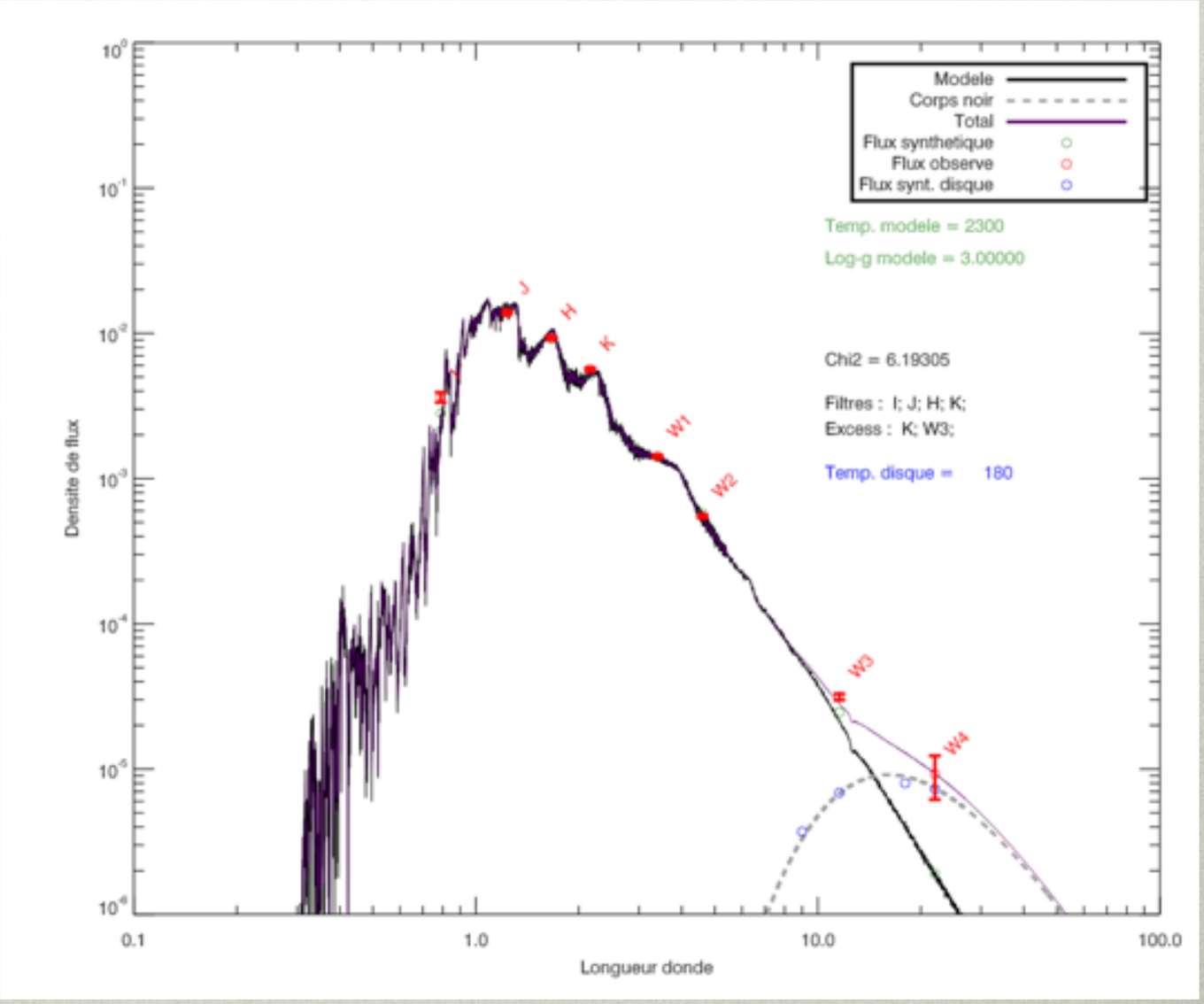
Purple = Young, Bold = Figure

CANDIDATES WITH W3 EXCESS

49/56

Anne Boucher's project

- M6 + M8 + M8.5 in TWA
- M5 in BPMG
- ~ M5 + **M8** in CAR
- ~ L1 in THA
- ~ M6 + M4 in COL
- ~ M7 in ARG



Boucher et al., in prep.

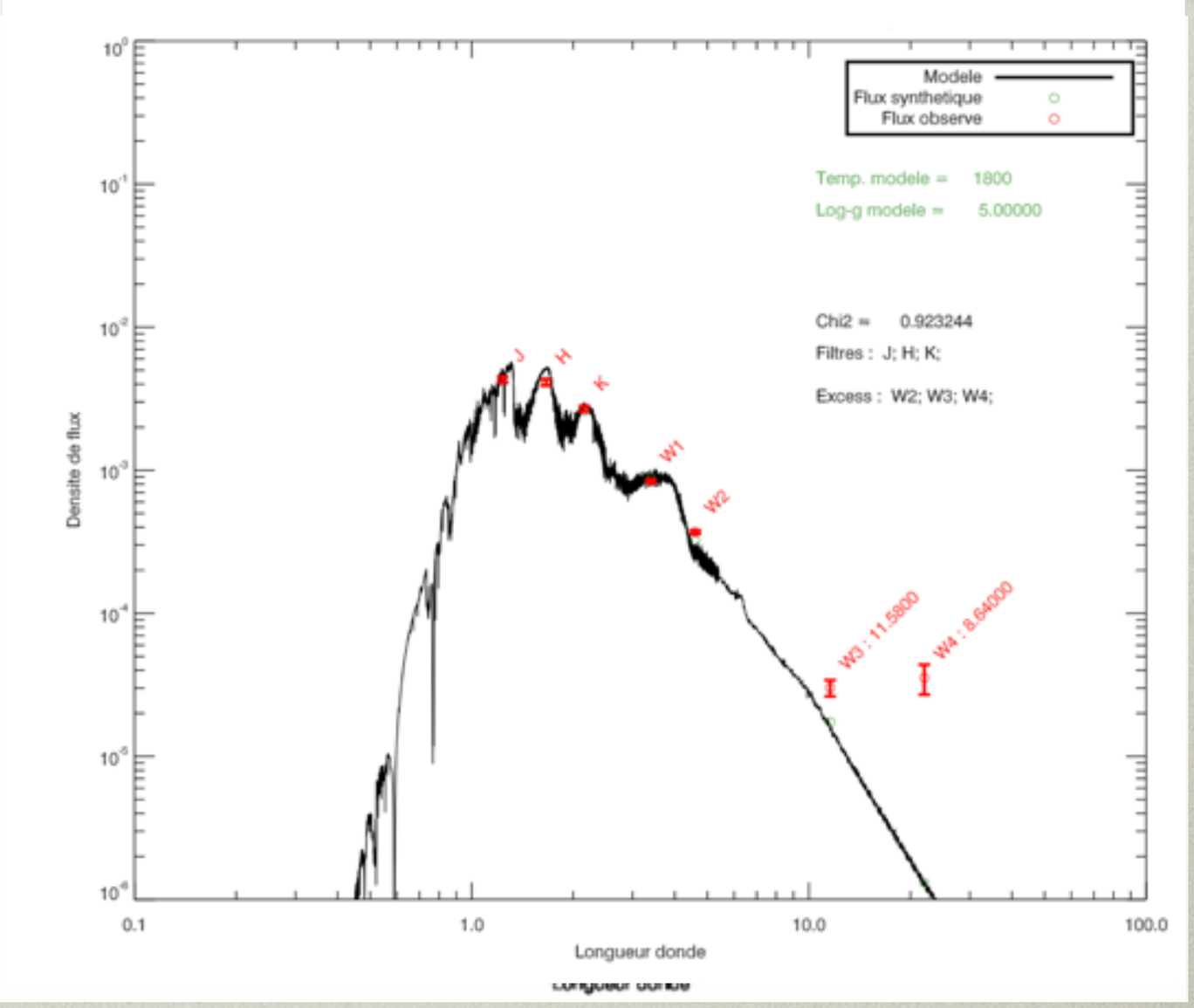
Purple = Young, Bold = Figure

CANDIDATES WITH W3 EXCESS

50/56

Anne Boucher's project

- M6 + M8 + M8.5 in TWA
- M5 in BPMG
- ~ M5 + M8 in CAR
- **~ L1** in THA
- ~ M6 + M4 in COL
- ~ M7 in ARG

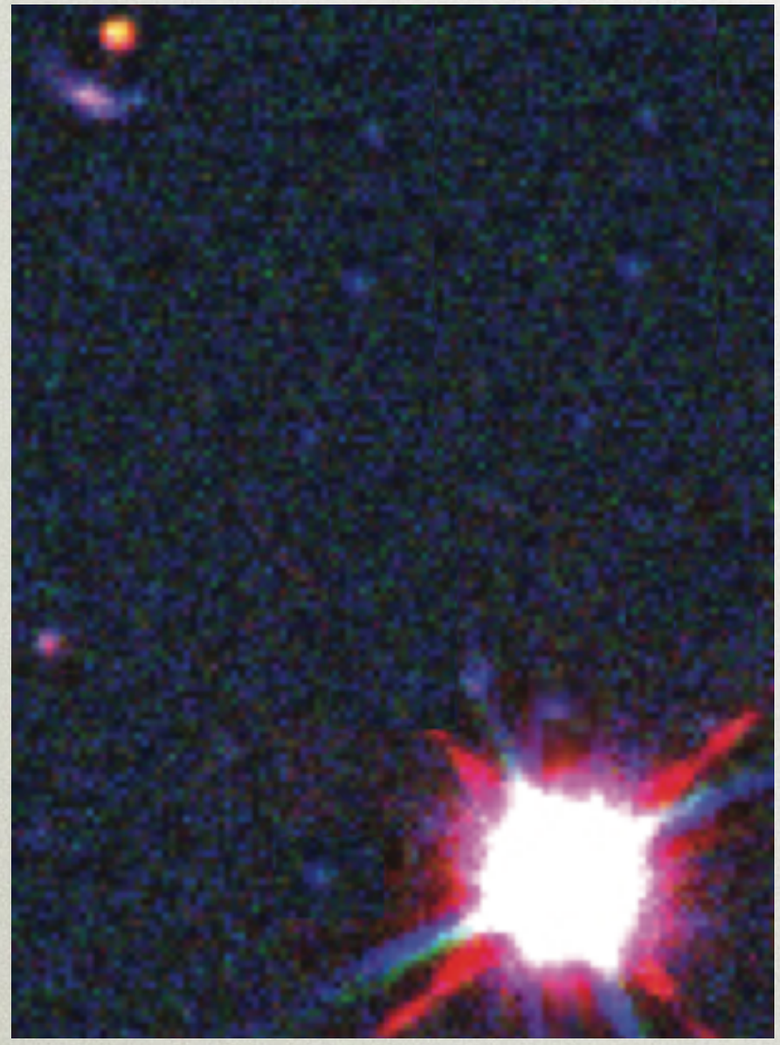


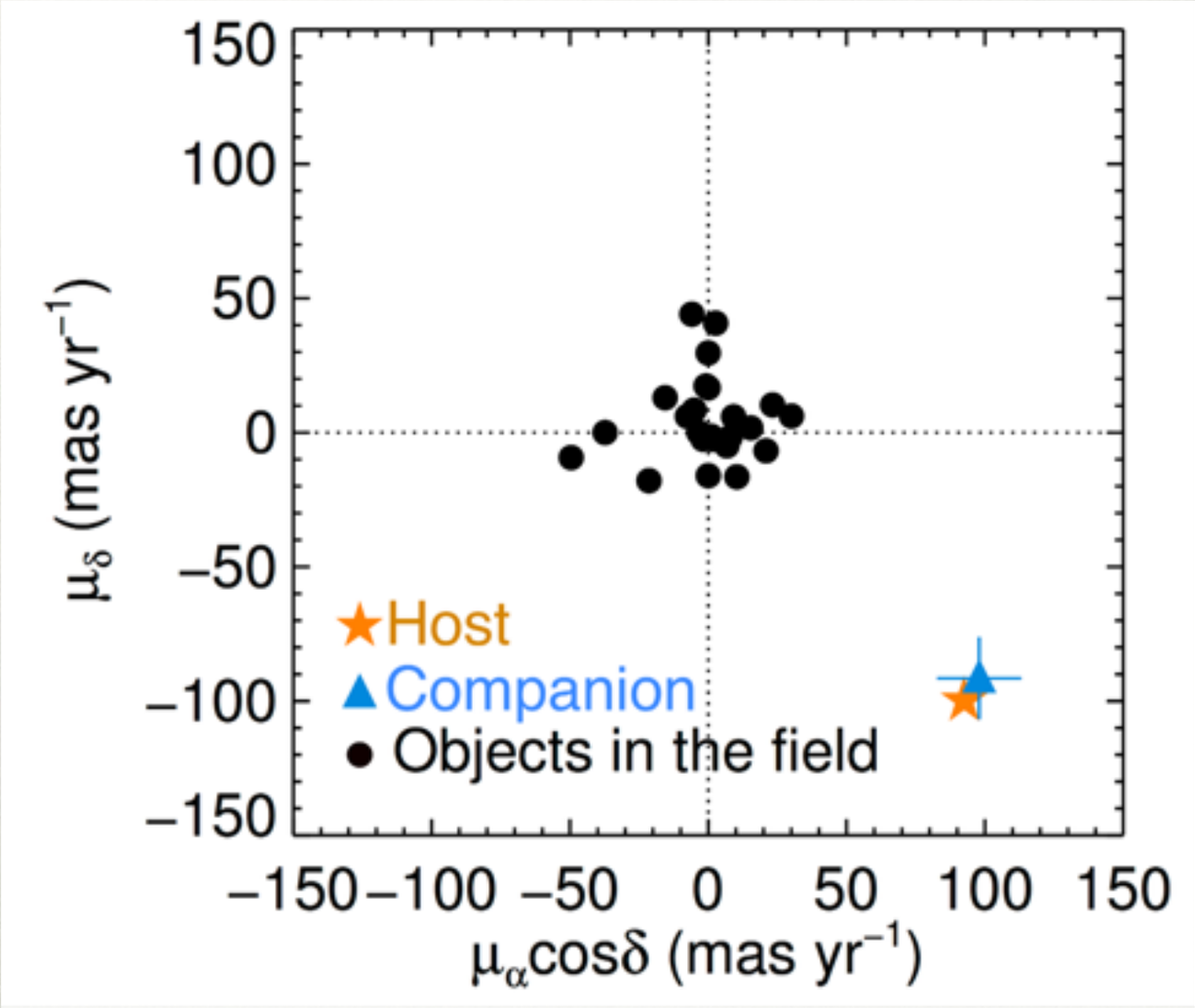
Boucher et al., in prep.

Purple = Young, Bold = Figure

Other Nice BANYAN Results

A new Young T3 Planet

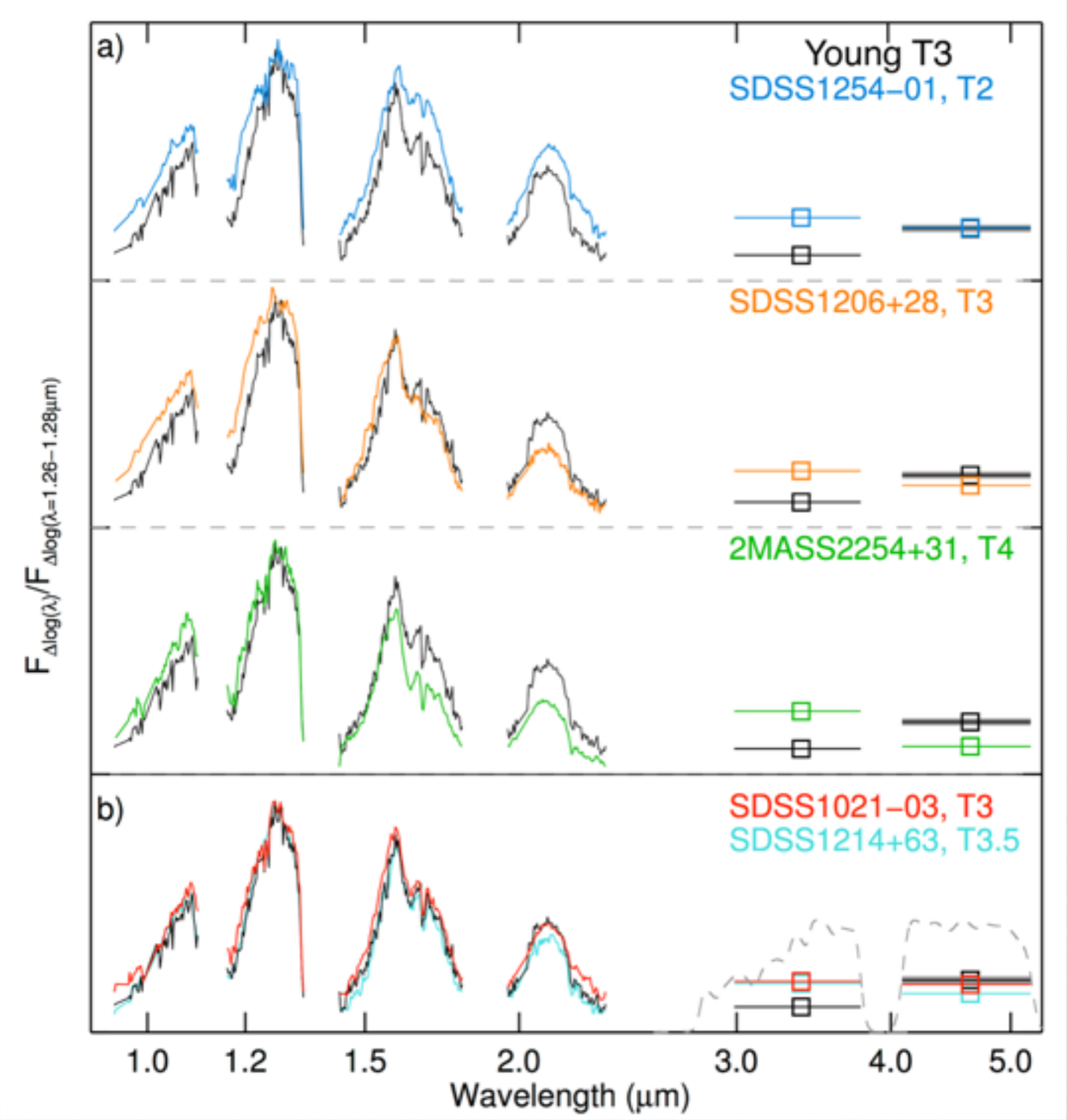




Naud et al., accepted in the ApJ

A new Young T3 Planet

- Co-moving companion to a young M3 AB Doradus candidate
- Spectral type is T3.5
- Low-G ; 10-12 M_{Jup} !
- Soon in astro-ph !



Naud et al., accepted in the ApJ

BANYAN III !

ACCEPTED TO APJ
Preprint typeset using LaTeX style emulateapj v. 08/13/06

BANYAN. III. RADIAL VELOCITY, ROTATION AND X-RAY EMISSION OF LOW-MASS STAR CANDIDATES IN NEARBY YOUNG KINEMATIC GROUPS

LISON MALO*, ÉTIENNE ARTIGAU, RENÉ DOYON, DAVID LAFRENIÈRE, LOÏC ALBERT AND JONATHAN GAGNÉ
Département de physique and Observatoire du Mont-Mégantic, Université de Montréal, Montréal, QC H3C 3J7, Canada

Accepted to ApJ

- 219 RV measurements
- 3 New bona fide in β Pic ; M3+M3, M4, M2.5 binary.
- 130 very strong candidates, only PLX missing !
- X ray luminosity for < M5 can be used to discern field or ABDMG members from other groups !

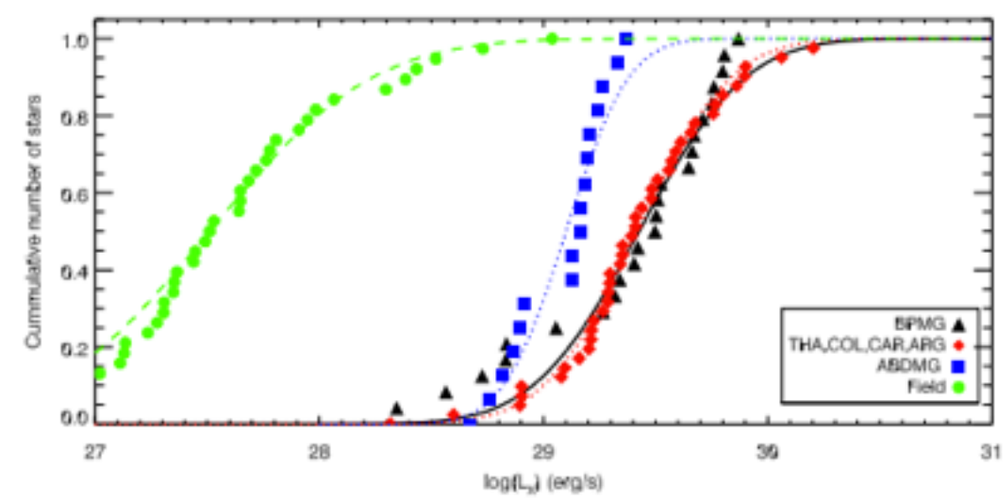


FIG. 7.— Cummulative distribution of log L_X^s for candidate members excluding binary systems compared to old field log L_X distribution.

Malo et al., 2014

BANYAN III !

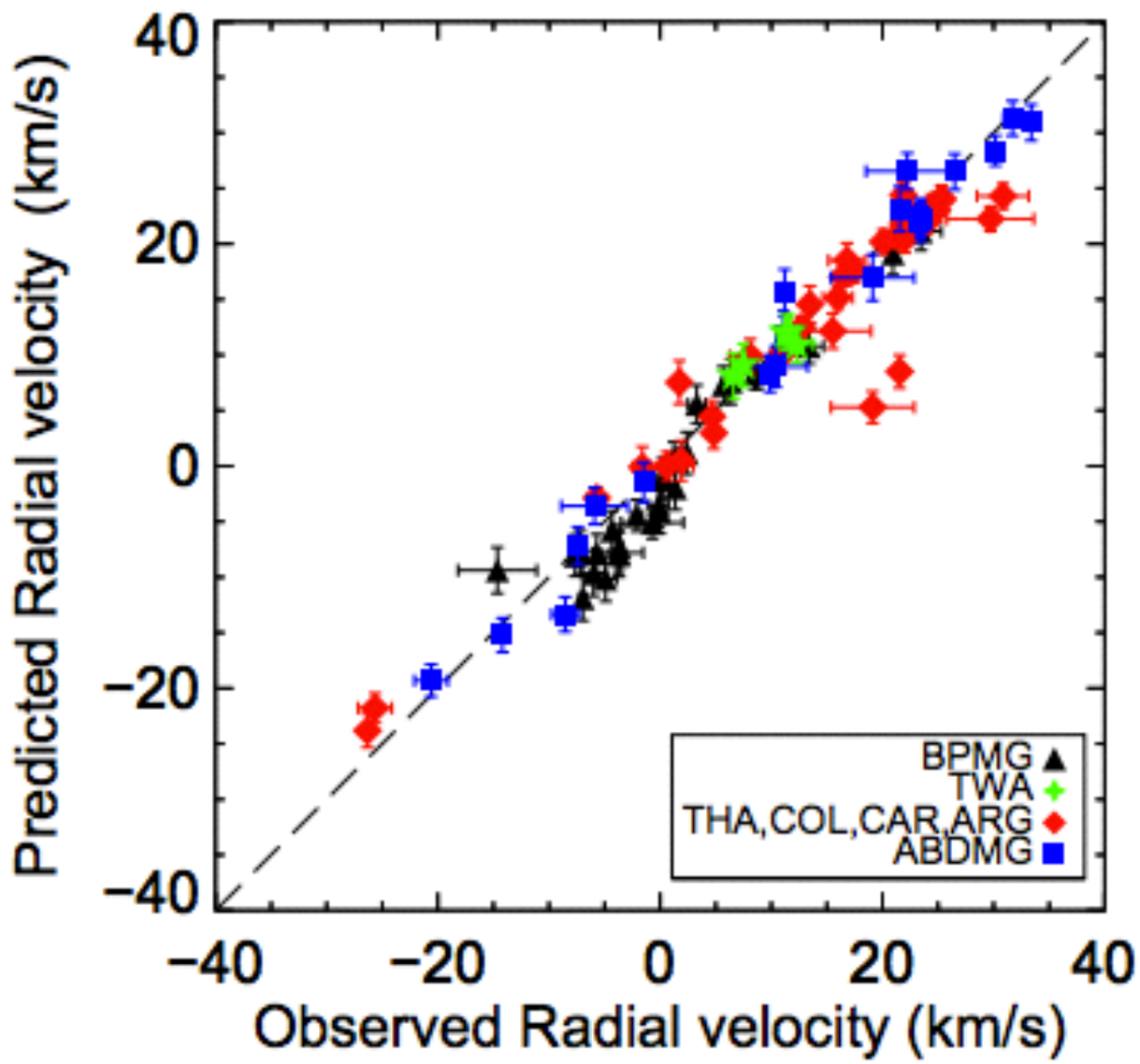
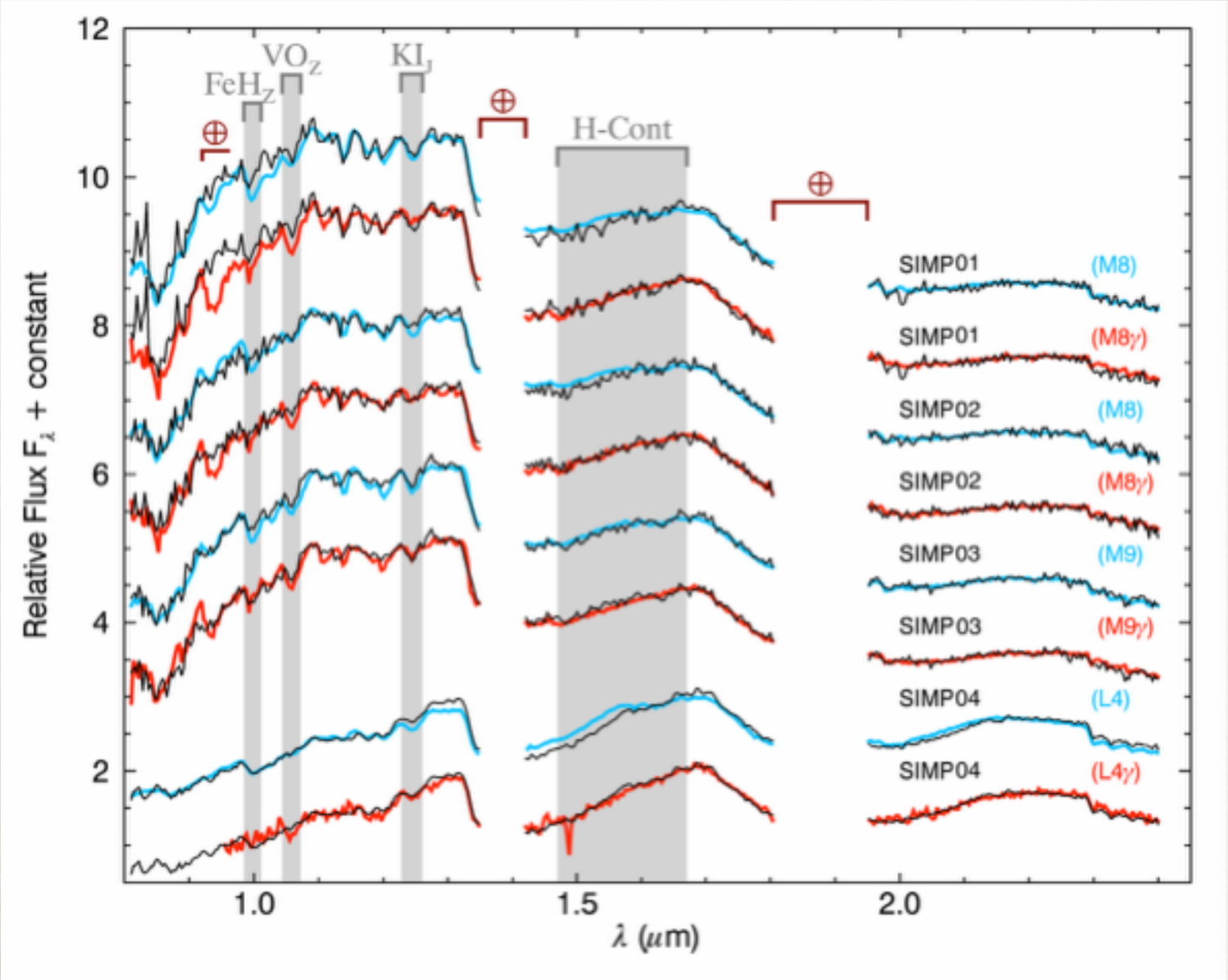


FIG. 3.— Comparison between predicted and observed radial velocities for the 111 candidate members ($P_\nu > 90\%$ and excluding known binary).

Malo et al., 2014

4 NEW Young BDs from SIMP

- SIMP ; Proper Motion survey for new BDs in Montreal.
- Found a few years ago, but not recognized as young !
- But now we know how to tell !
- An ApJ letter is in prep.
- The full SIMP survey will be out soon (Robert et al., in prep.)



Gagné et al., in preparation

Near Future :

- Precise NIR RVs with Peter Plavchan
- Search for Neptune-mass Planets around M dwarfs
- With CShell + Gas cell
- NIR = Active M dwarfs are ok !
- Part of a 6-months IPAC Exchange Program

Thanks !

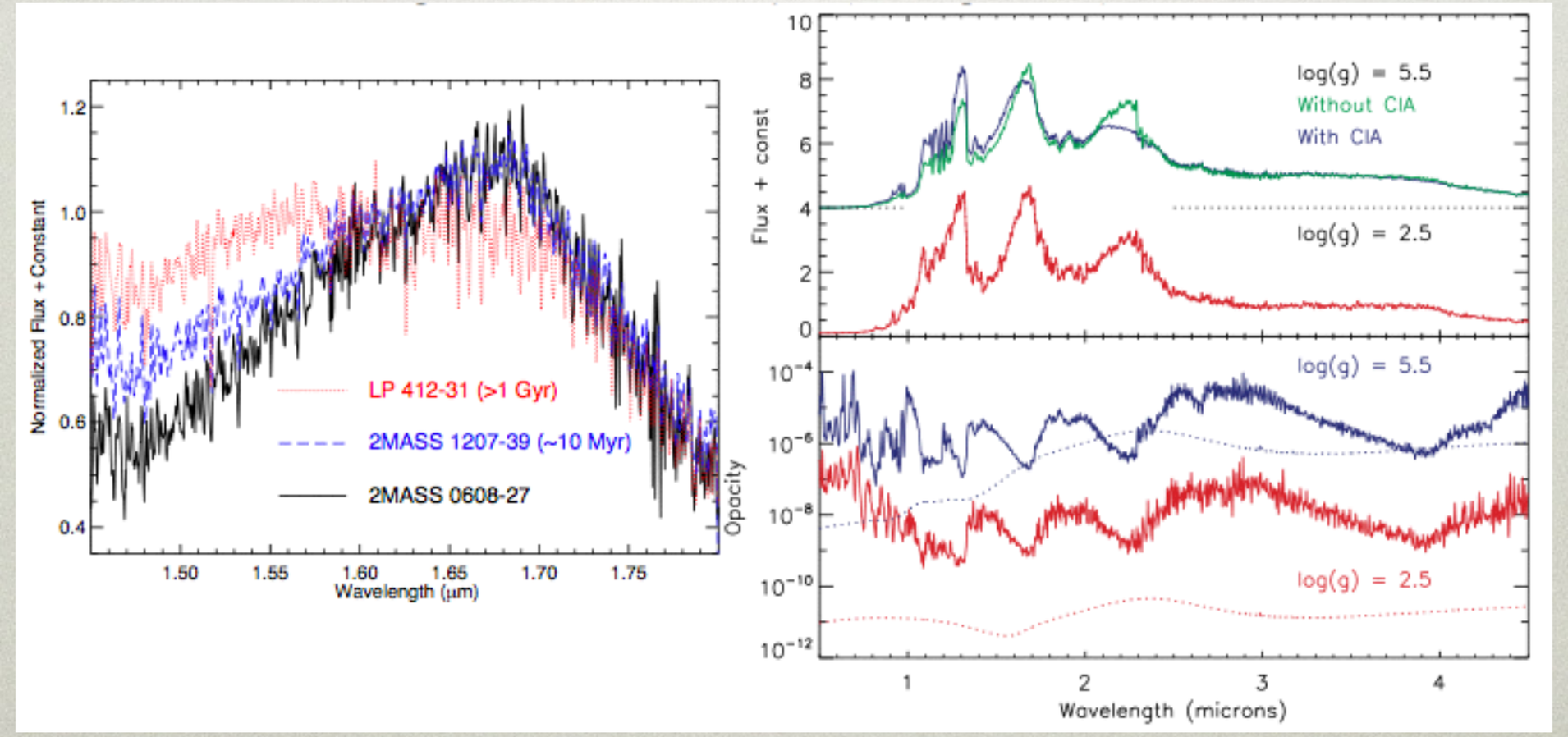
UCLA 2014 seminar

Université de Montréal

Additional slides

Young Brown Dwarfs extra 1

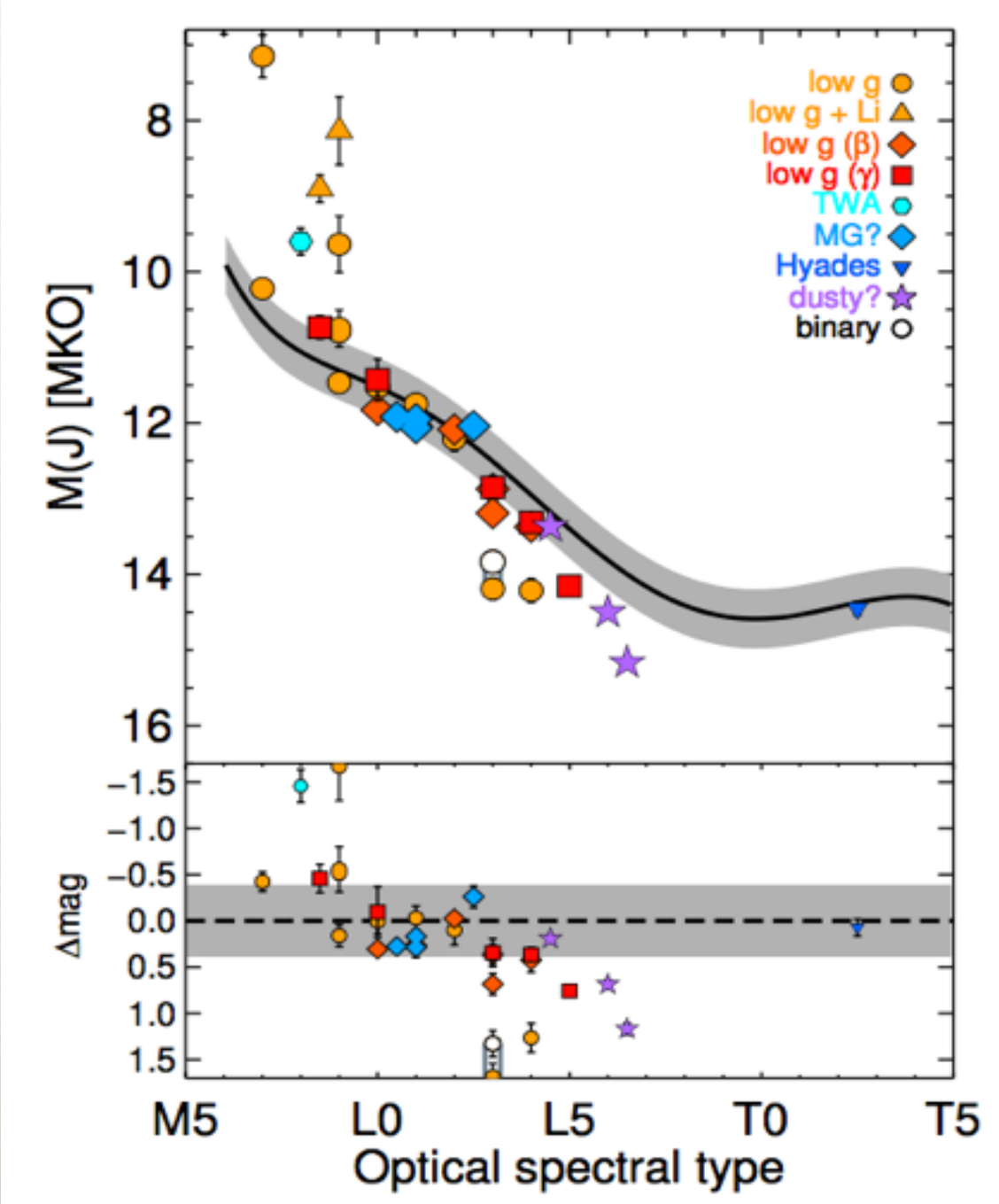
- Low pressure = < H2 collision-induced absorption
- = Peaked H-band continuum



Rice et al. 2010, 2011

Young Brown Dwarfs extra 2

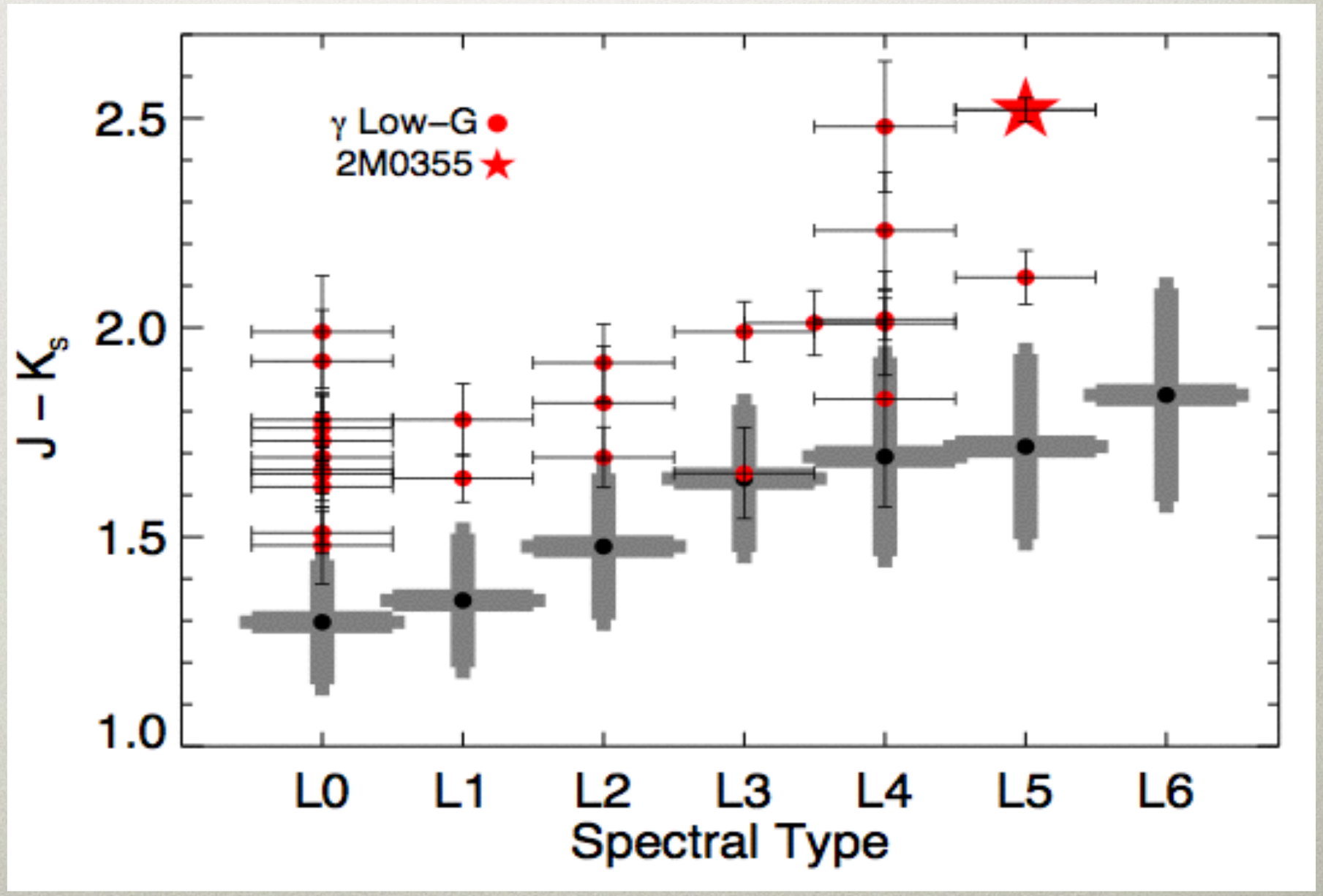
- Low gravity = More dust
- Larger = Brighter
- Dustier = Fainter
- => Competing effects



Liu et al. 2013

Young Brown Dwarfs extra 3

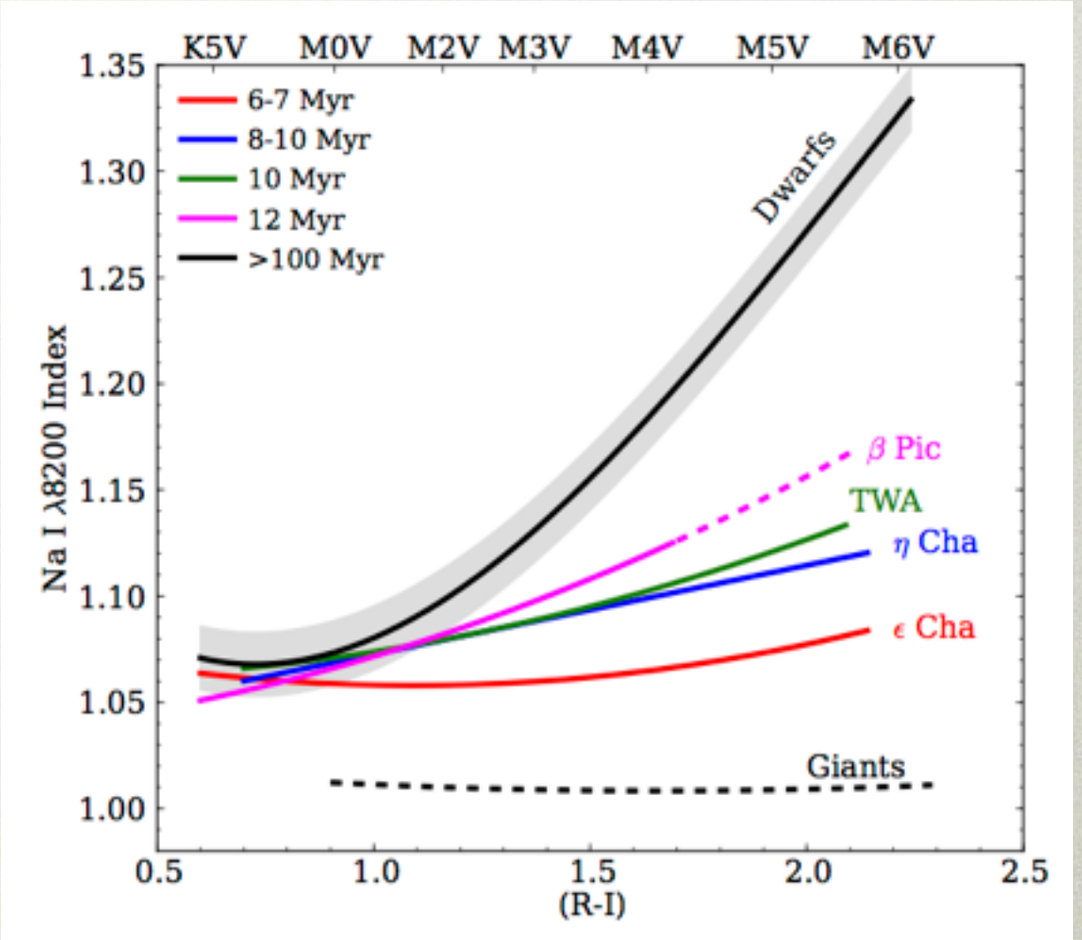
Less CIA and more dust = Redder :



Faherty et al. 2013

Young Brown Dwarfs extra 4

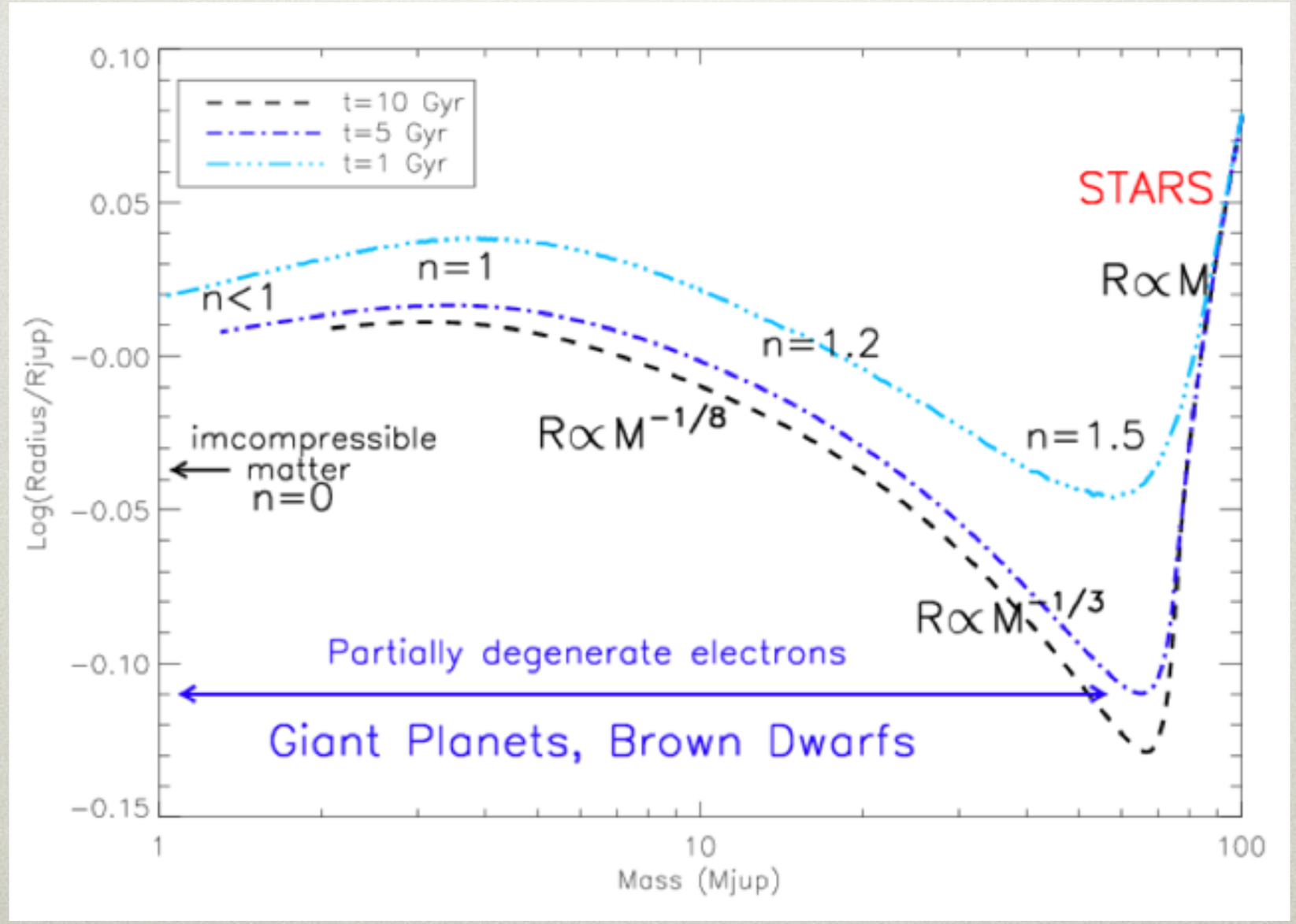
- Youth = Low gravity
- = Low pressure
- = < Pressure Broadening
- = Narrower atomic lines



Na I VS age (Lawson 2009)

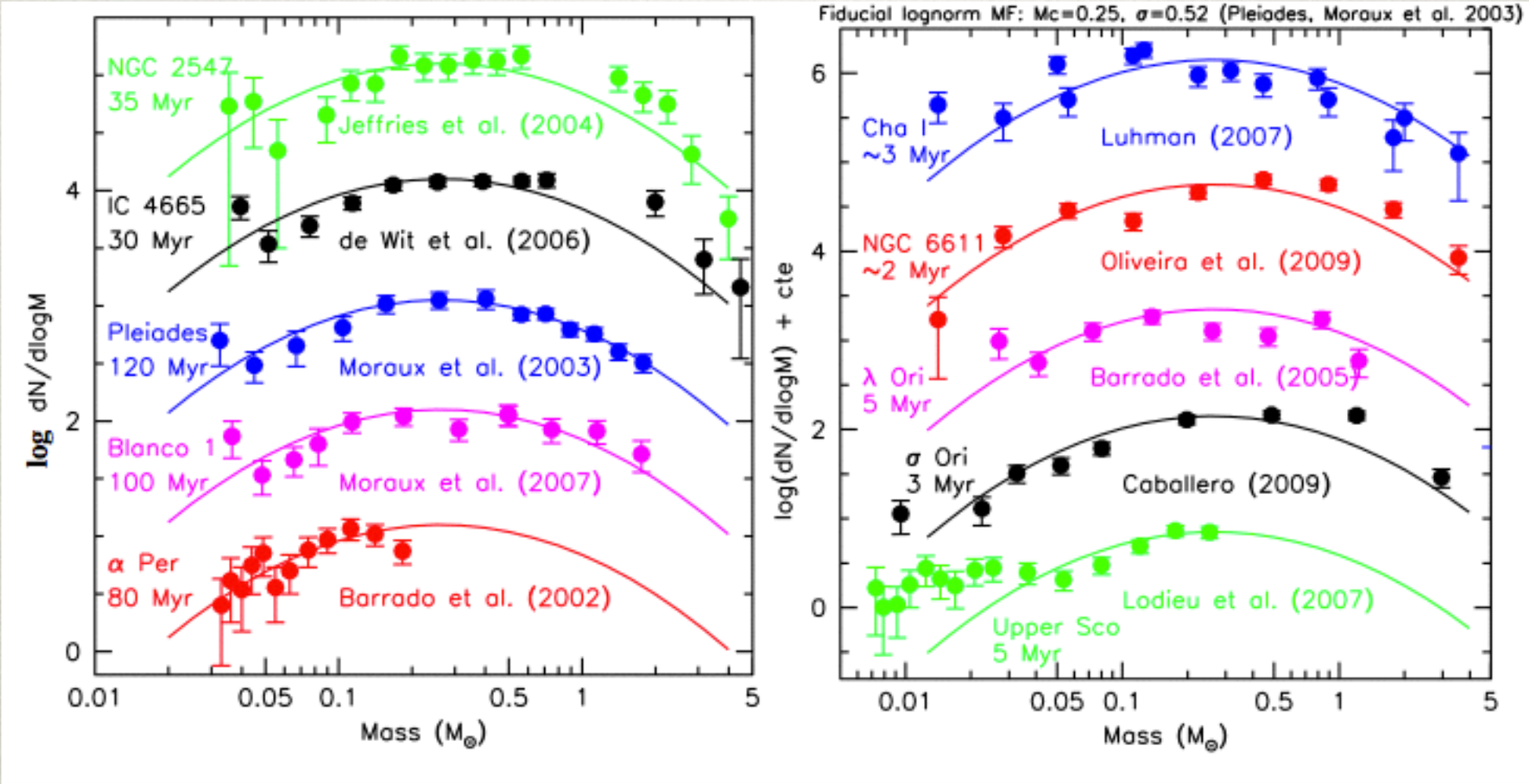
RADIUS OVER TIME EXTRA 5

Young dwarf's radii are inflated :



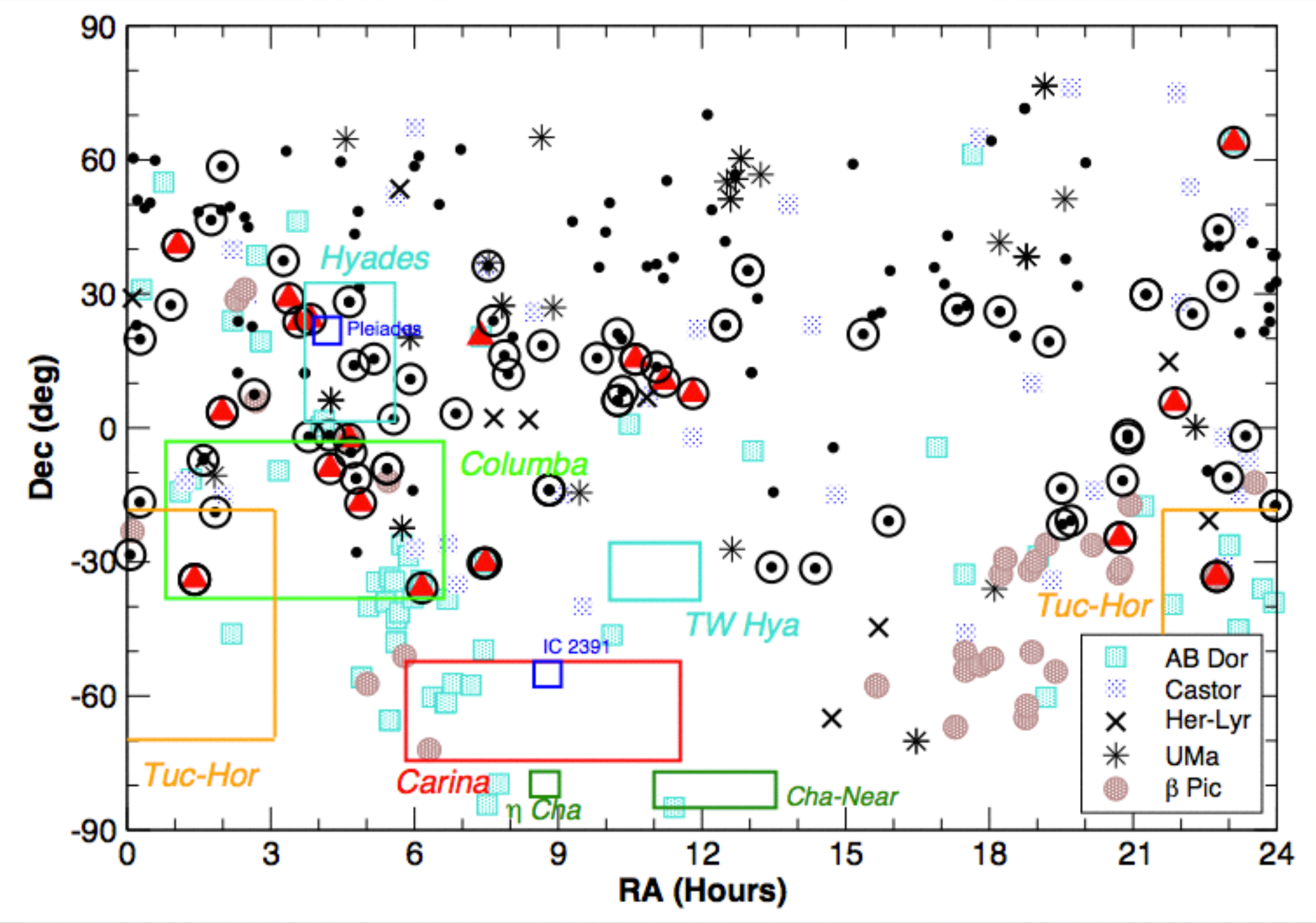
Chabrier et al. 2009

LOG-NORMAL IMF EXTRA 6



Jeffries 2012

NYAs over the sky extra 7



Shkolnik et al. 2012