The Brown Dwarfs of our Milky Way

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Motivation

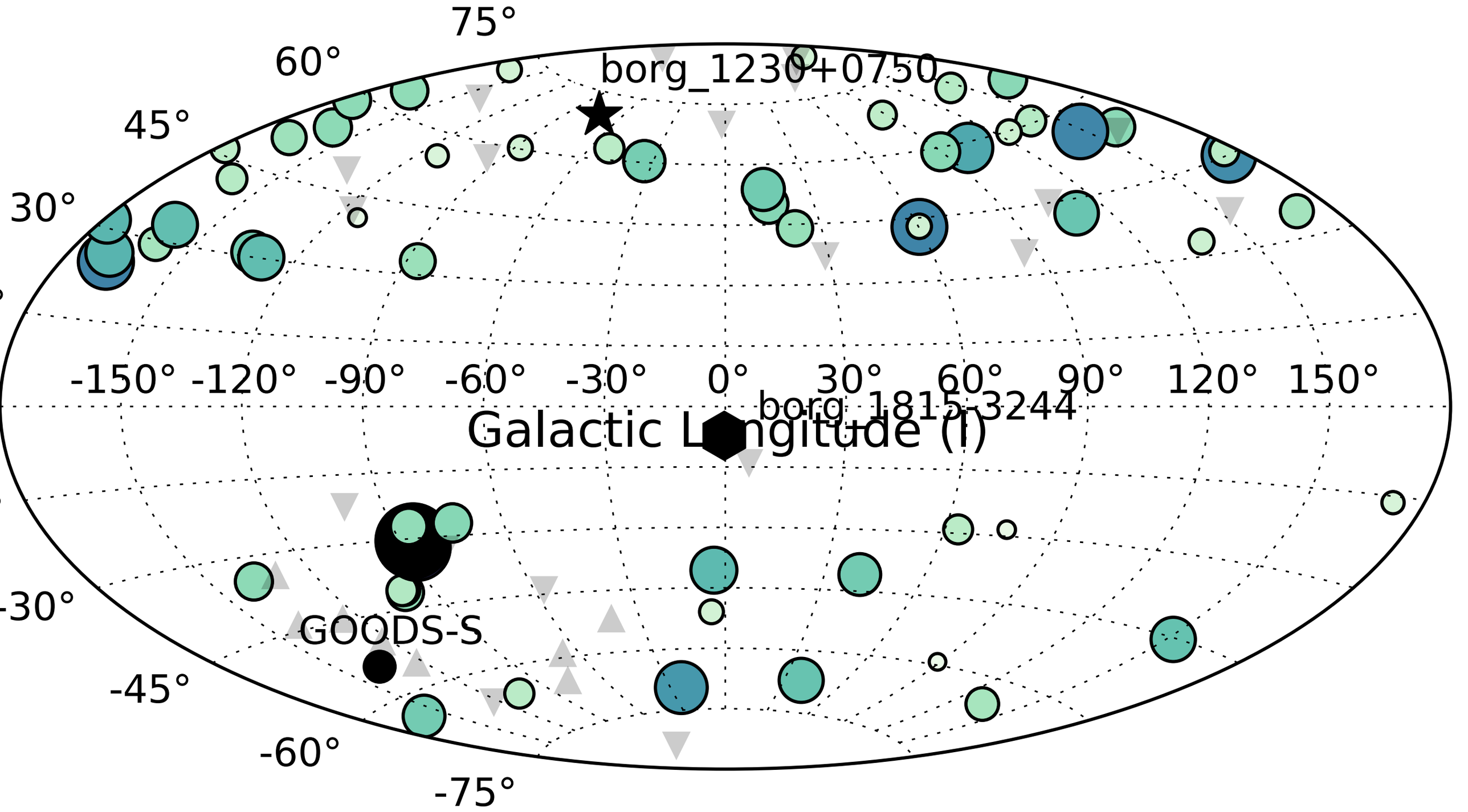
- Extragalactic astronomy has to look through our own Milky Way.
- If you are interested in z>6 galaxies (red, just resolved even with Hubble/WFIRST, and faint)
- Brown Dwarfs in the Milky Way are extremely annoying!
- Brown Dwarfs are also a contaminant in direct imaging efforts of exoplanets.

One's trash is another another's treasure...

- HST/WFC3 (and WFIRST) imaging is a random sampling of sub-solar dwarfs of our Milky Way through all the different components: thin and thick disk as well as the halo.

- Identify brown dwarfs and determine th shape of the Milky Way in these small stars.

BoRG WFC3 Pure Parallel Fields



Counting Stars

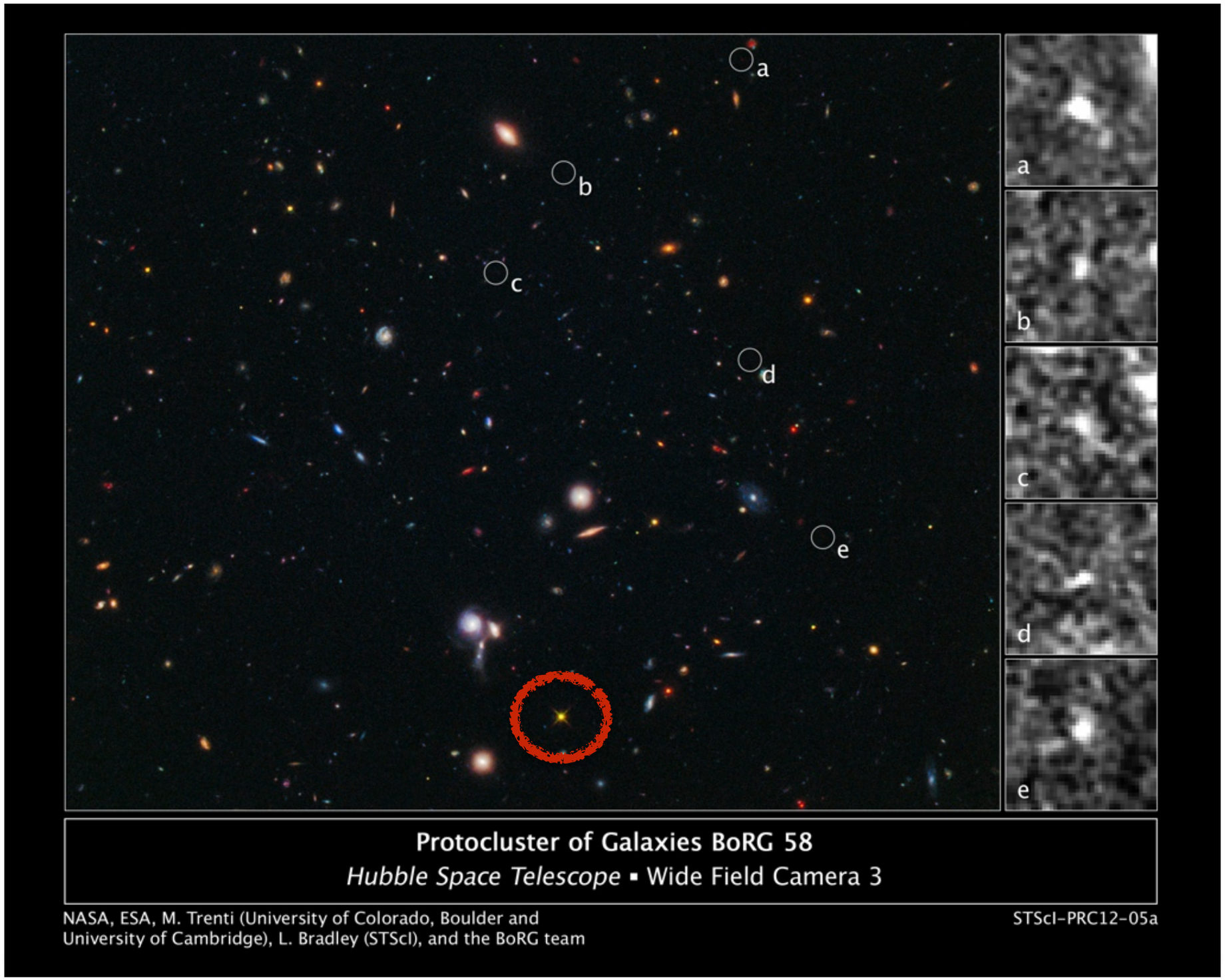
- Counting stars is one of the oldest techniques to determine the shape of our Milky Way (e.g. Herschel 1785, Kapteyn 1922).

- Also the most fraught with issues (insufficient data, conceptual gaps).

- Most times, counts relied on Giants or super-solar stars.

- Recent interest shifted to sub-solar, small stars in which much of the stellar mass of the Milky Way resides.

Bright Origin Reioniziation Galaxies (BoRG) Survey

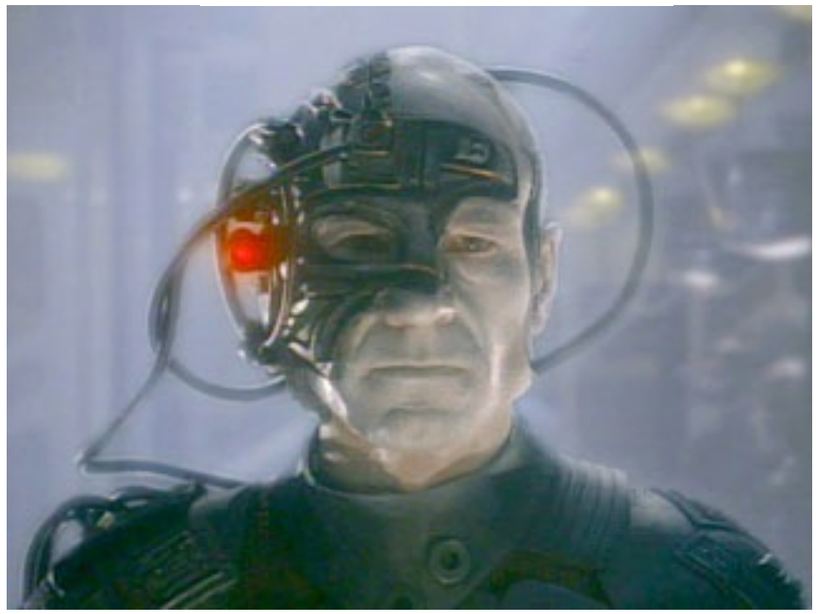


BoRG

- BoRG is a WFC3 pure-parallel survey:
    - COS is looking at a distant quasar.
    - at the same time, WFC3 images a part of the sky nearby.
    - high Galactic Latitude
    - three NIR filters.
    - one optical filter.

Random sampling is the way to beat (cosmic) variance!

Actually there are two WFC3 parallel programs...



Bright Origin Reioniziation Galaxies (BoRG) Survey

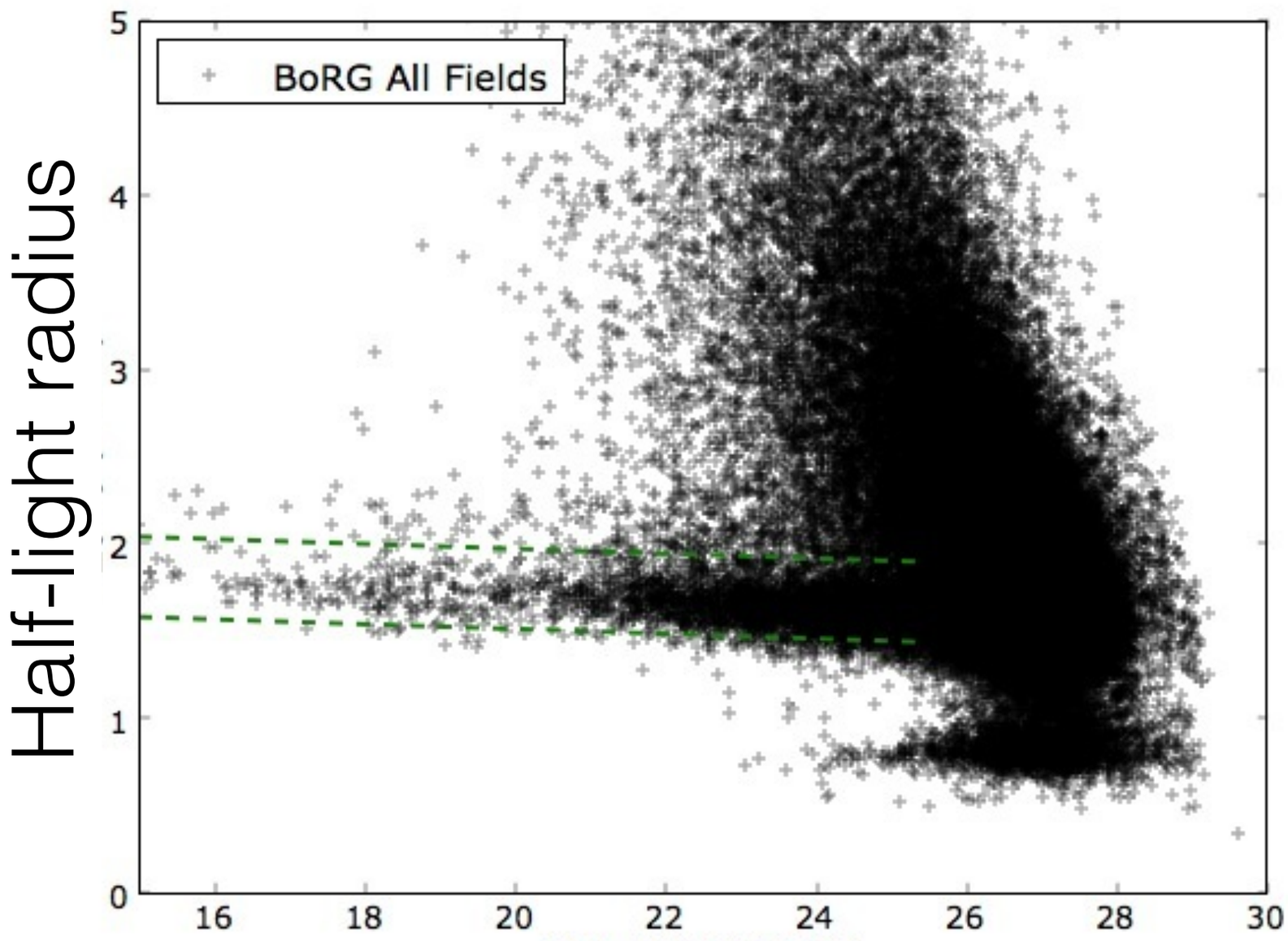
BoRG[z8]

BoRG[z9-10]

Hubble Infrared Pure Parallel Imaging Survey (HIPPIES)

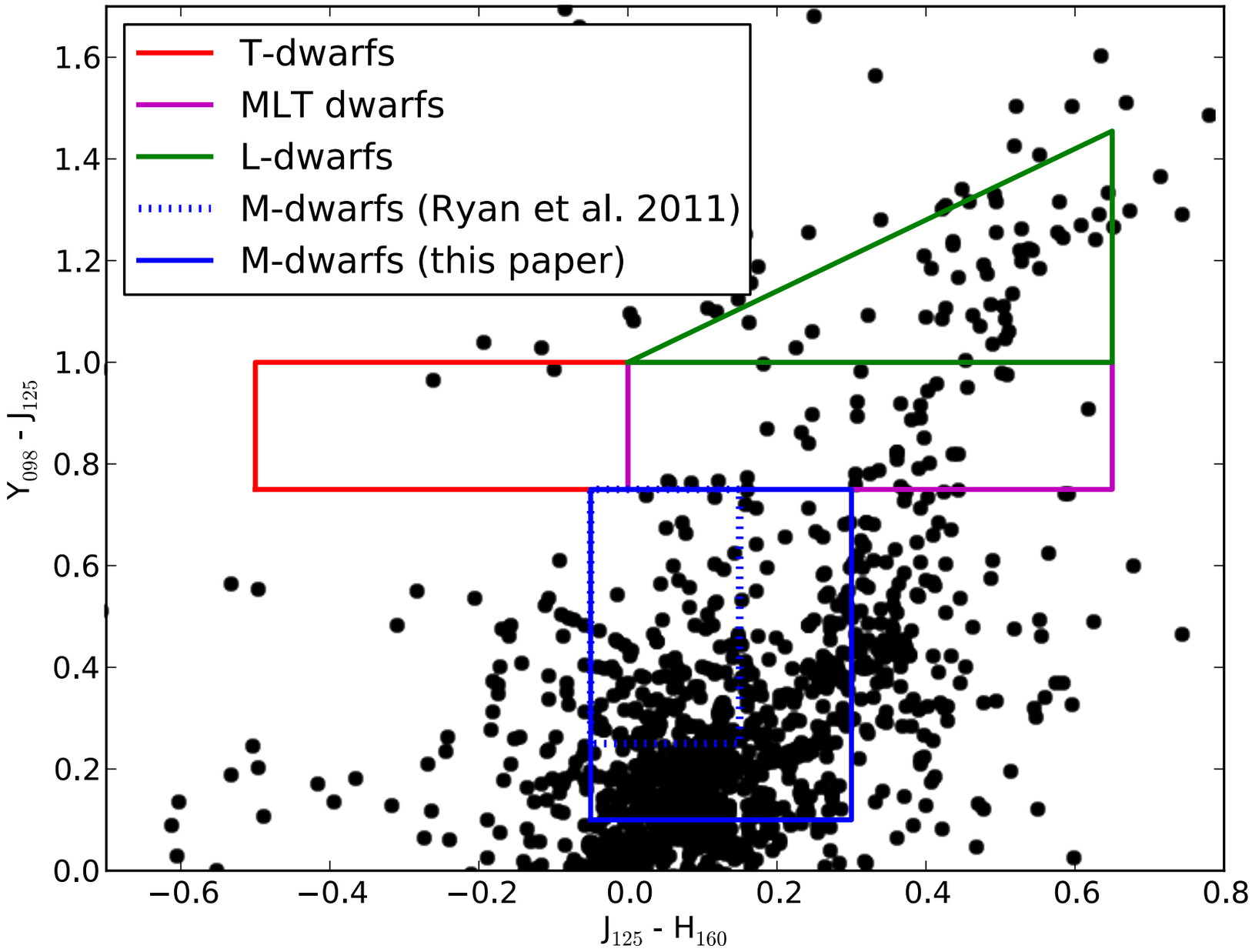
BoRG[z9-10] (cycle-25)

Identifying Stars



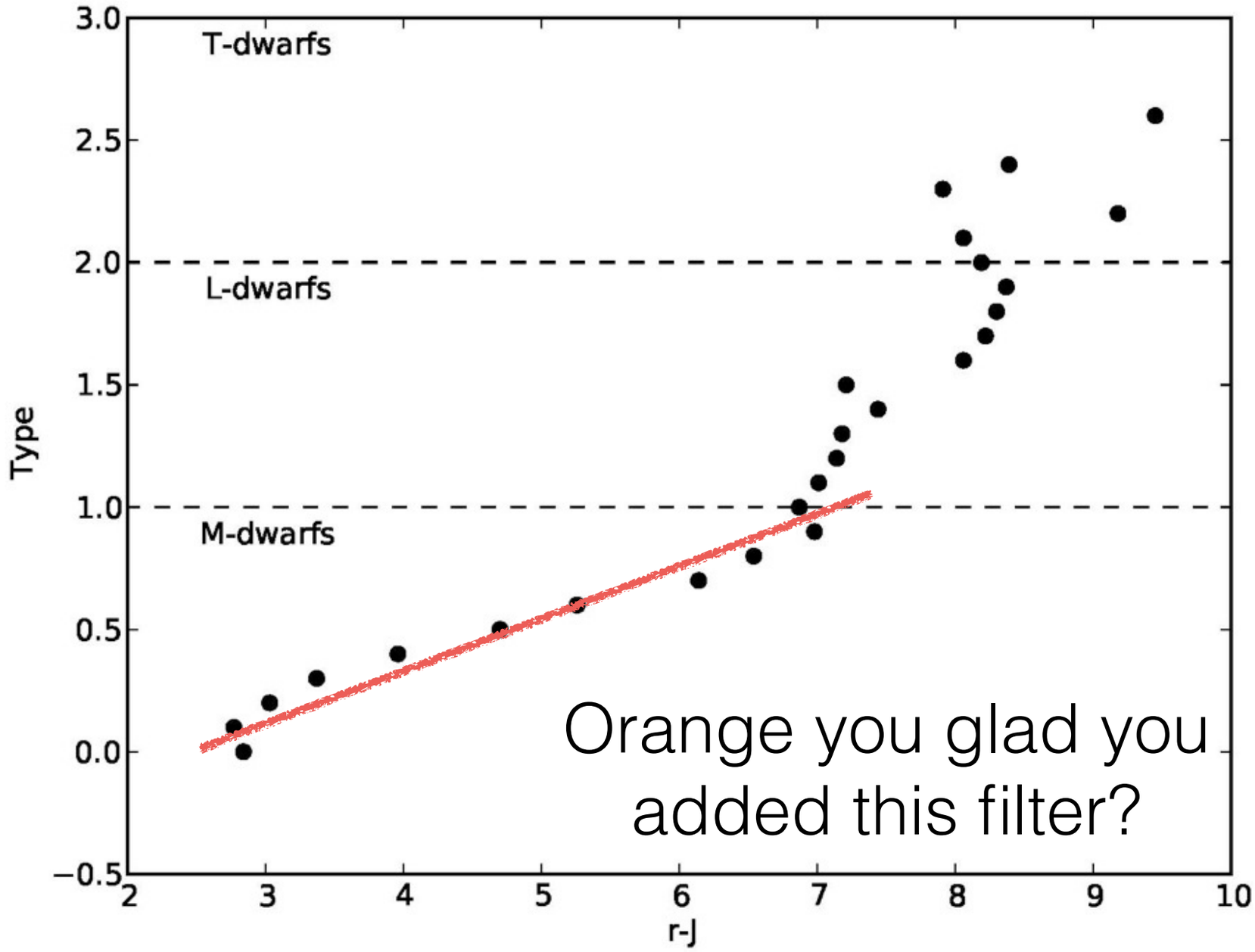
Holwerda+ 2014

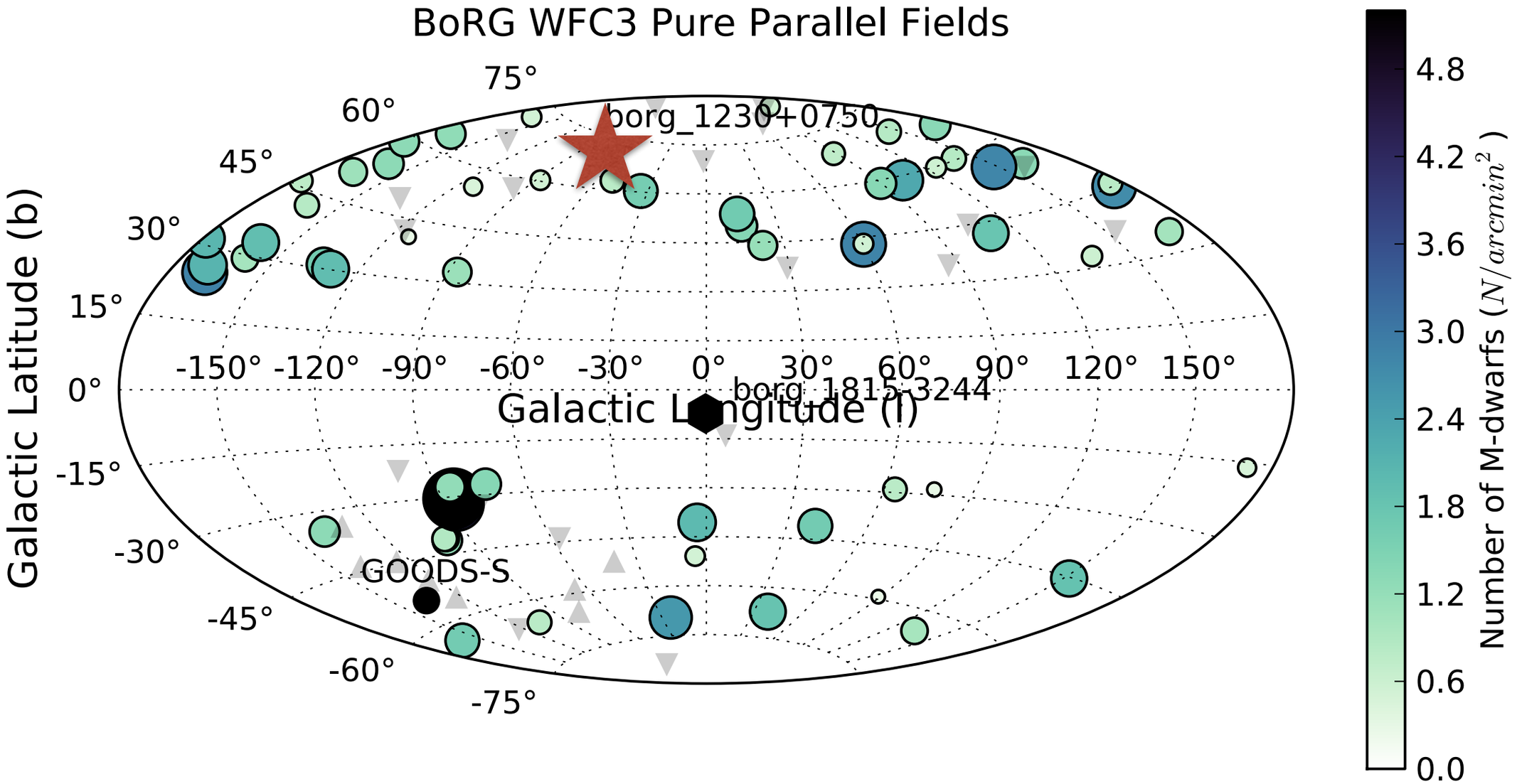
Identifying Brown Dwarfs



Ryan+ 2011, Holwerda+ 2014

Subtype M-dwarfs?

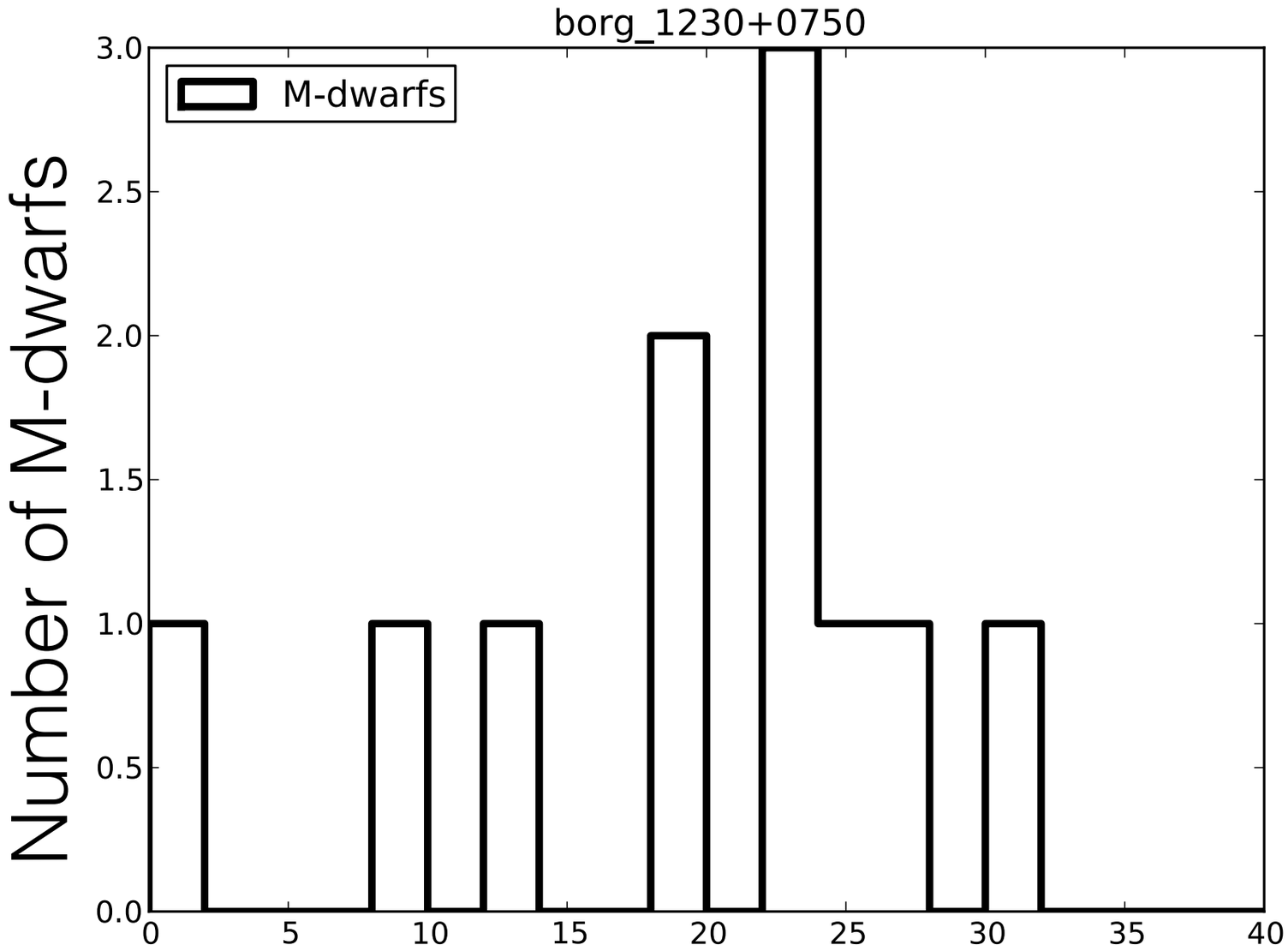




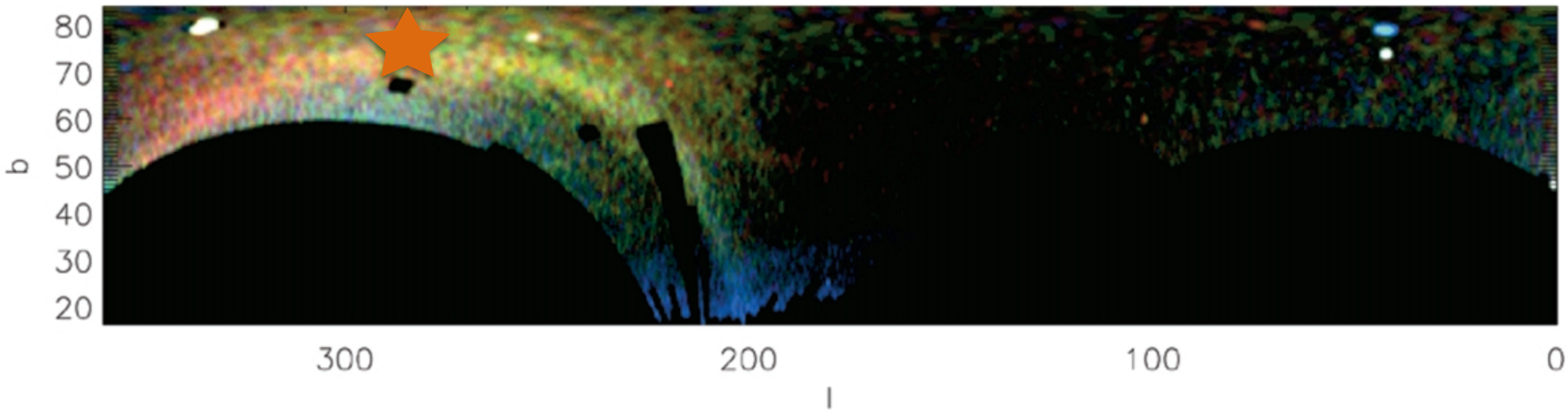
- Typically find 0-5 M-dwarfs in a WFC3 field.
- One field stands out with 22 (!) M-dwarfs.

Holwerda+ 2014

This one field puts a lot of those M-dwarfs at 25 kpc



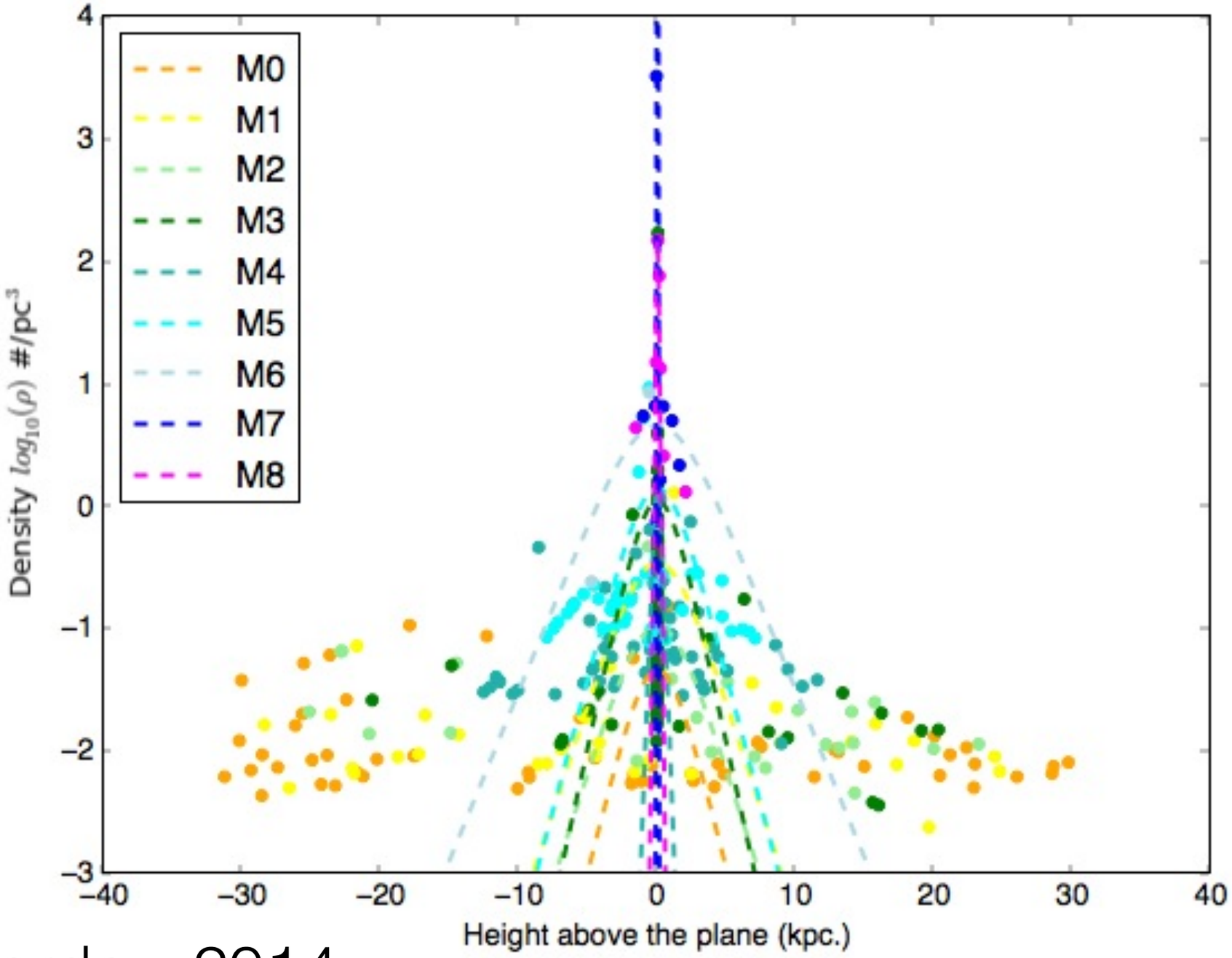
Holwerda+ 2014



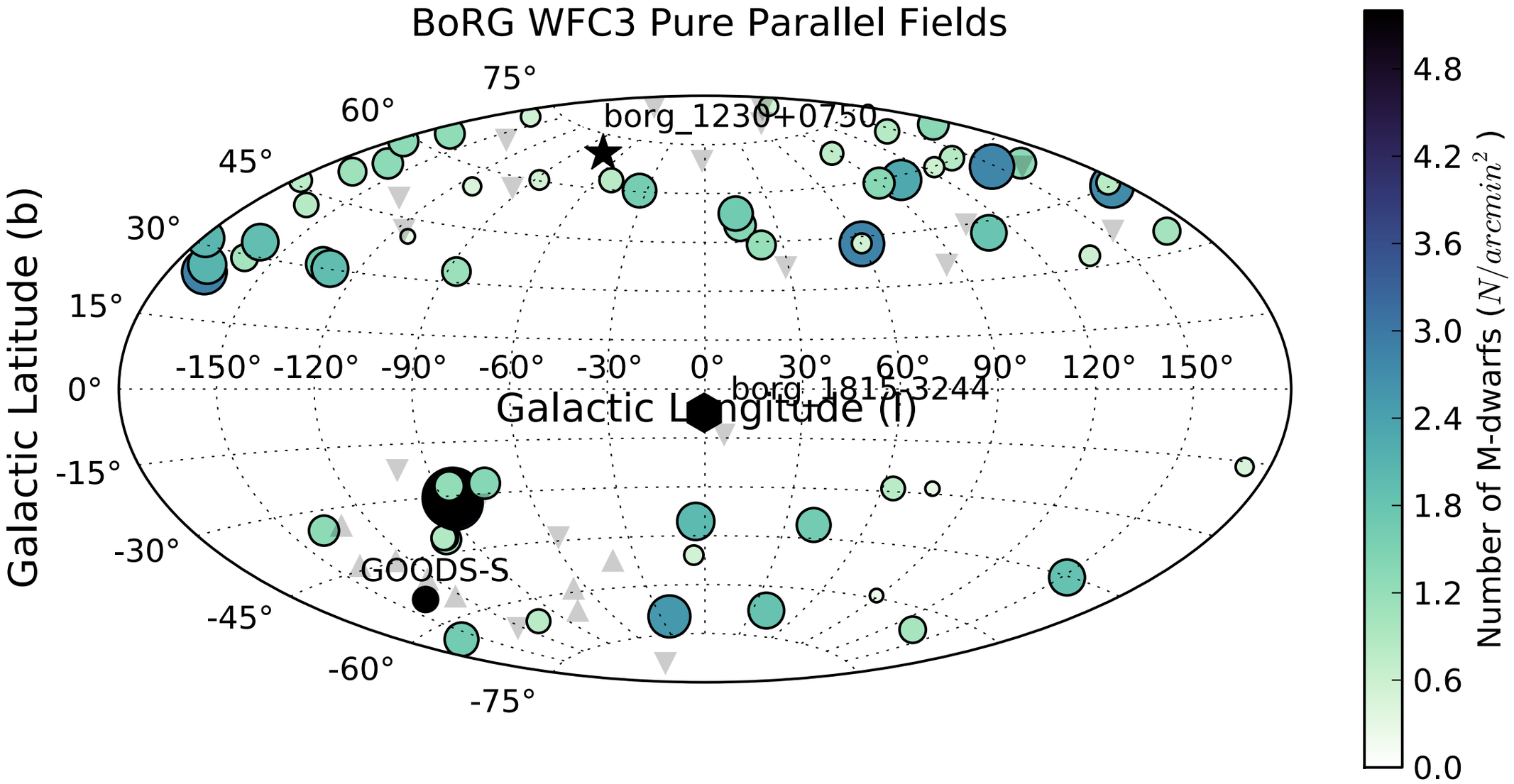
Belokurov et al., 2006, ApJL, 642, L137

It is right on the Sagittarius stream!
Rediscovered in M-dwarfs.
10x the contrast as SDSS stars.

Scale-height



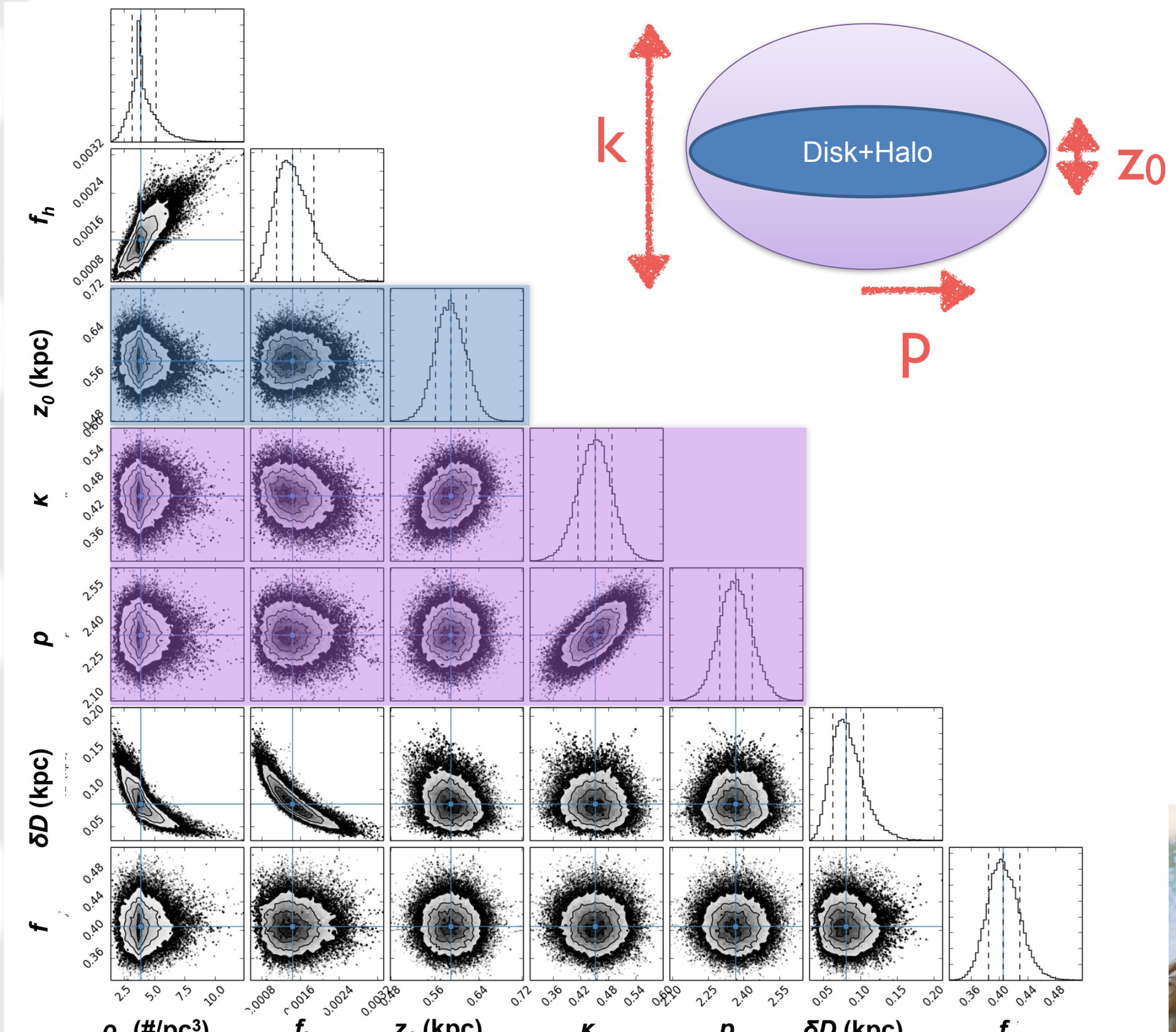
Holwerda+ 2014



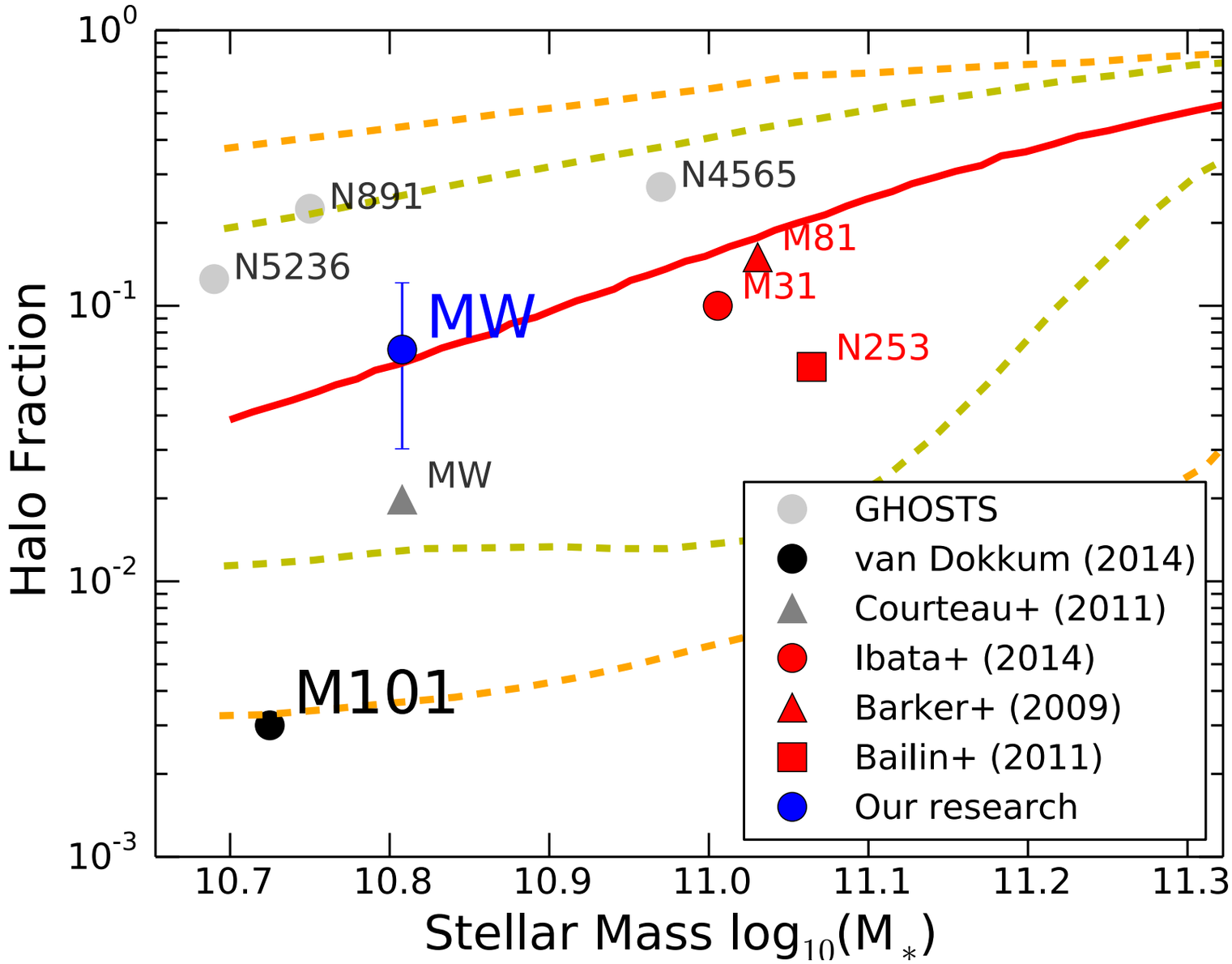
- MCMC fit of full catalog and MW parameter space
  - disk only
  - disk+halo

van der Vlugt & van Vledder+ MNRAS, 2016

emcee
The MCMC Hammer



- Z_0 = 300 pc
- A total of 58 billion M-dwarfs.
- 7% in the halo.



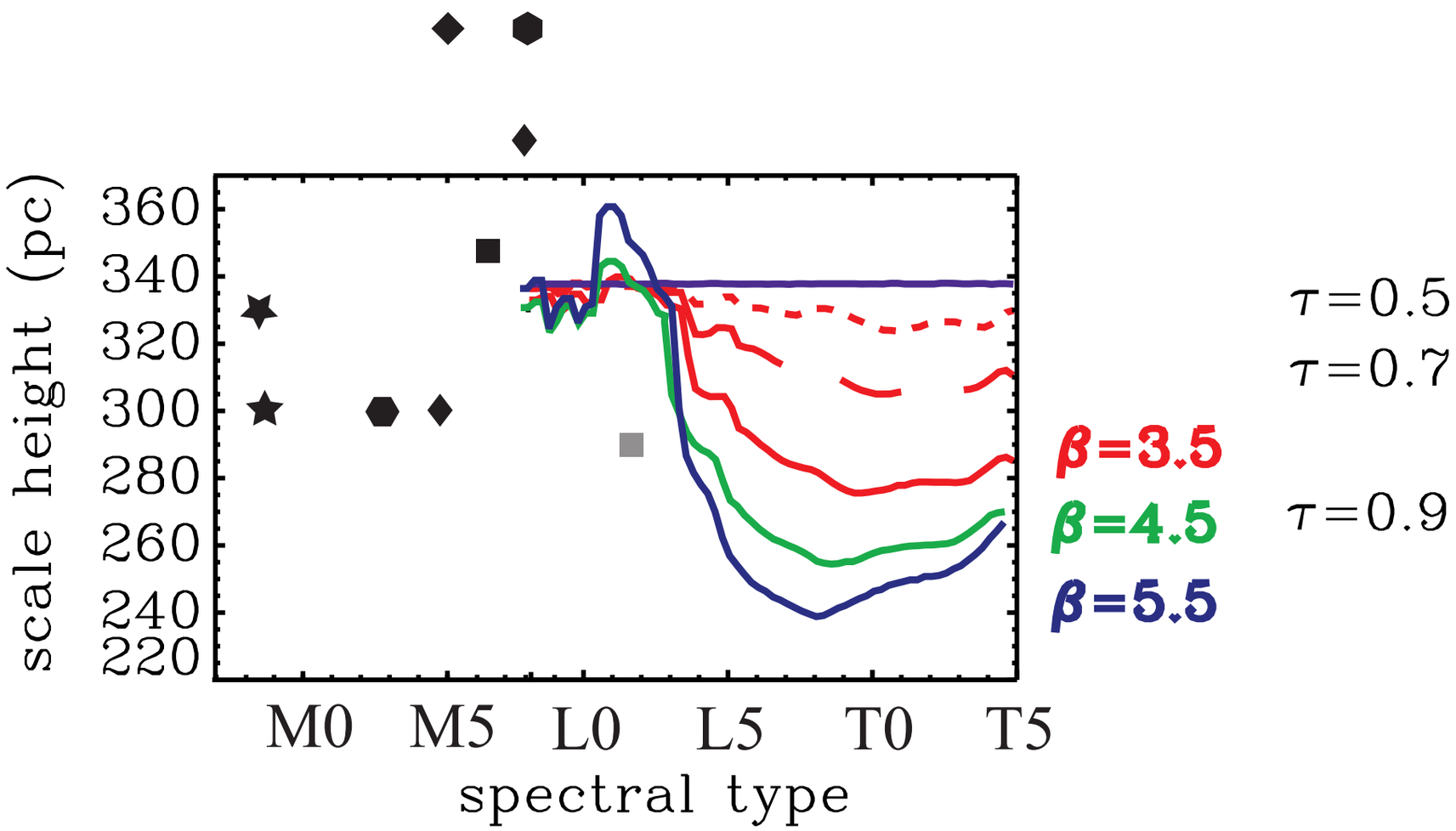
van der Vlugt & van Vledder+ MNRAS, 2016

MCMC Parameters

BoRG[z9] doubles BoRG[z8], cycle-25 will double the number of fields and lines-of-sight again.

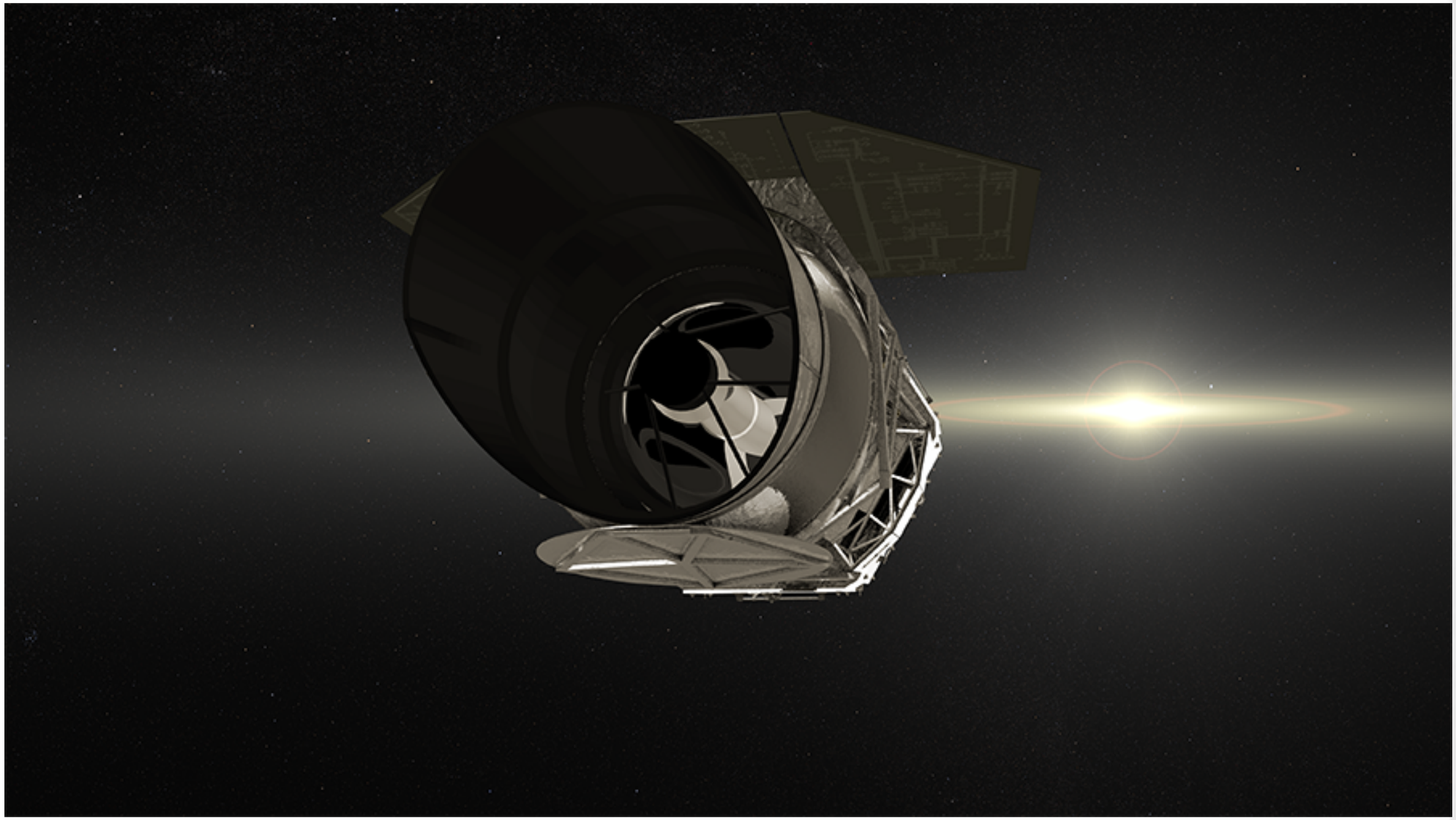
- Where are we? (position of the Sun: radius, height)
- Scale-length of the disk.
- Brown Dwarf *Sub*type
- Thick disk? Bulge? Broken power law halo?

Scale-height and Cooling



Ryan+ 2017

WFIRST



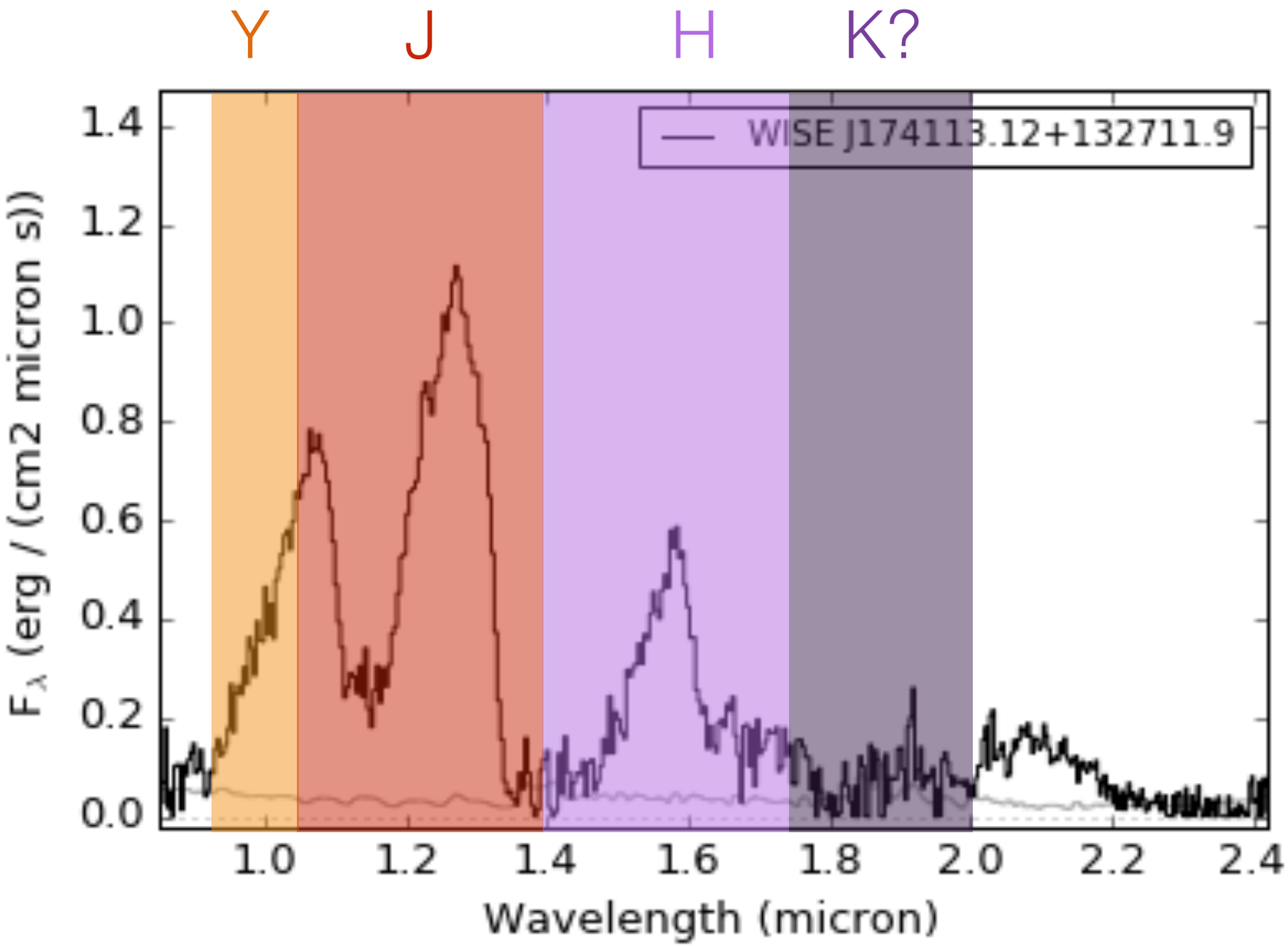
Astronomy 2020 - 6/27/2017 - B.W. Holwerda

WFC Filters

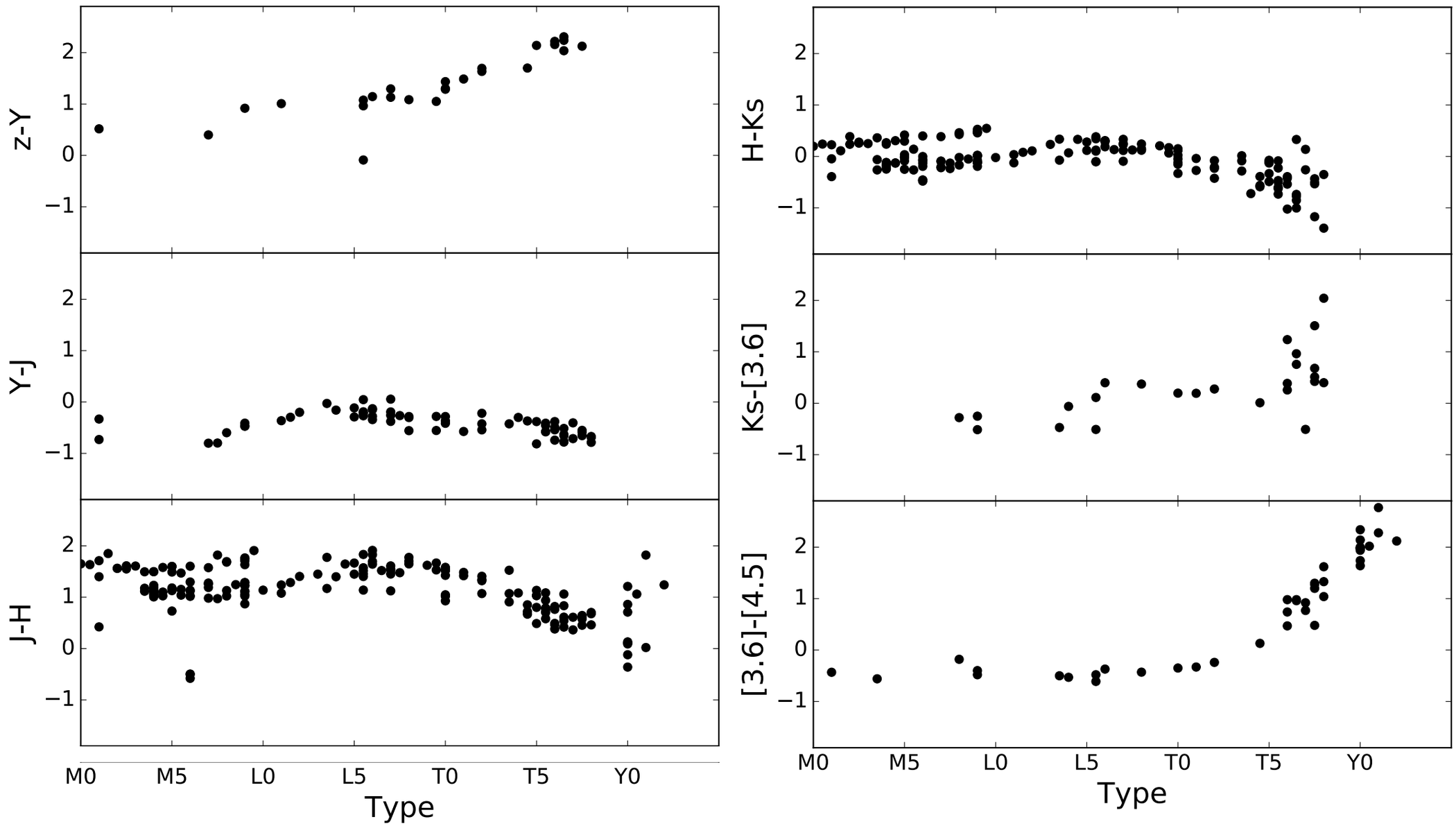
Band	Element name	Min (μm)	Max (μm)	Center (μm)	Width (μm)	R
R	R062	0.48	0.76	0.620	0.280	2.2
Z	Z087	0.76	0.977	0.869	0.217	4
Y	Y106	0.927	1.192	1.060	0.265	4
J	J129	1.131	1.454	1.293	0.323	4
H	H158	1.380	1.774	1.577	0.394	4
K?	F184	1.683	2.000	1.842	0.317	5.81
Wide	W146	0.927	2.000	1.464	1.030	1.42
GRS	G150	0.95*	1.90*	1.445	0.890	461λ(2pix)

* Grism bandpass is adjustable, up to $\lambda_{max} \leq 2 \times \lambda_{min}$

WFIRST Brown Dwarfs

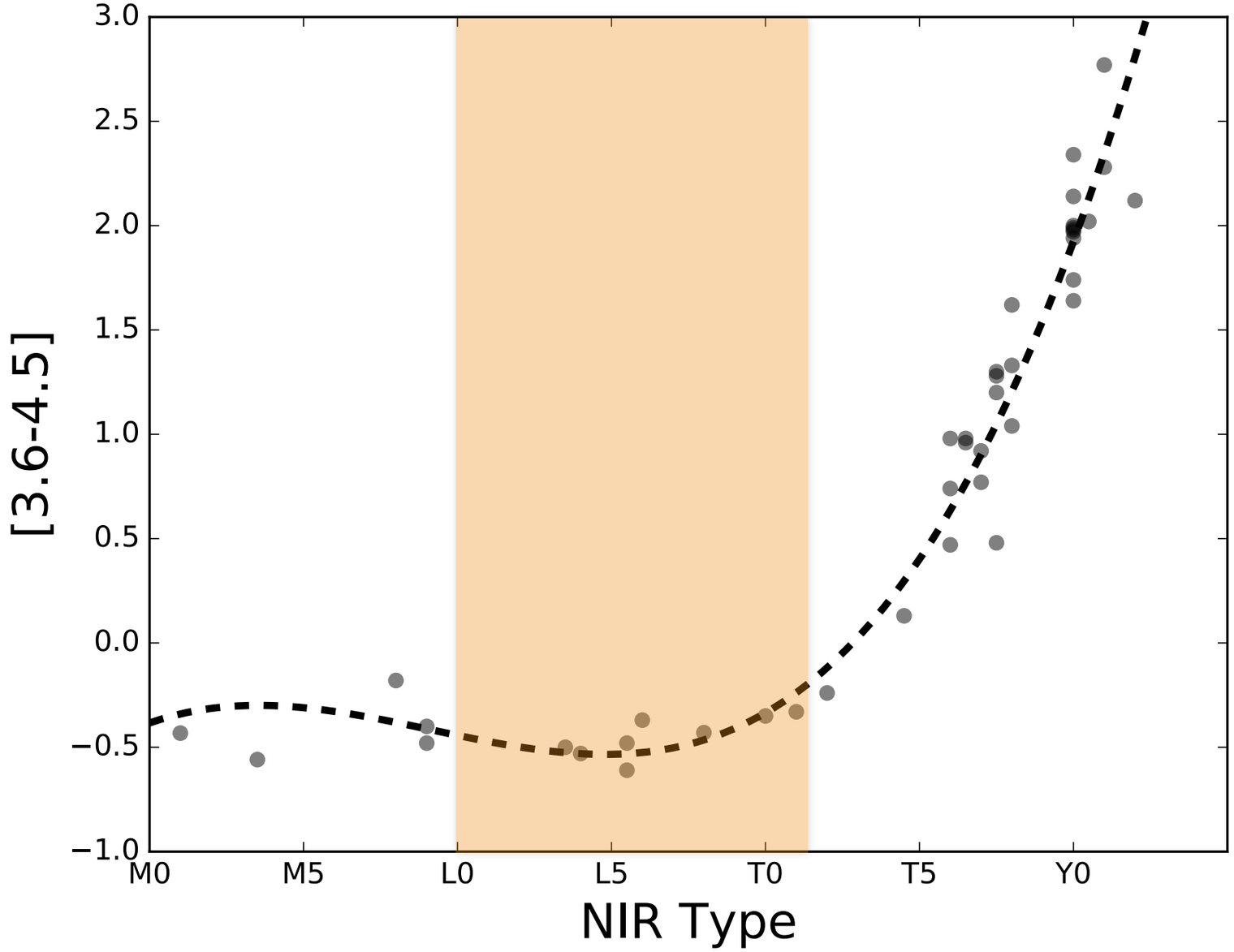


Sub-typing Brown Dwarfs



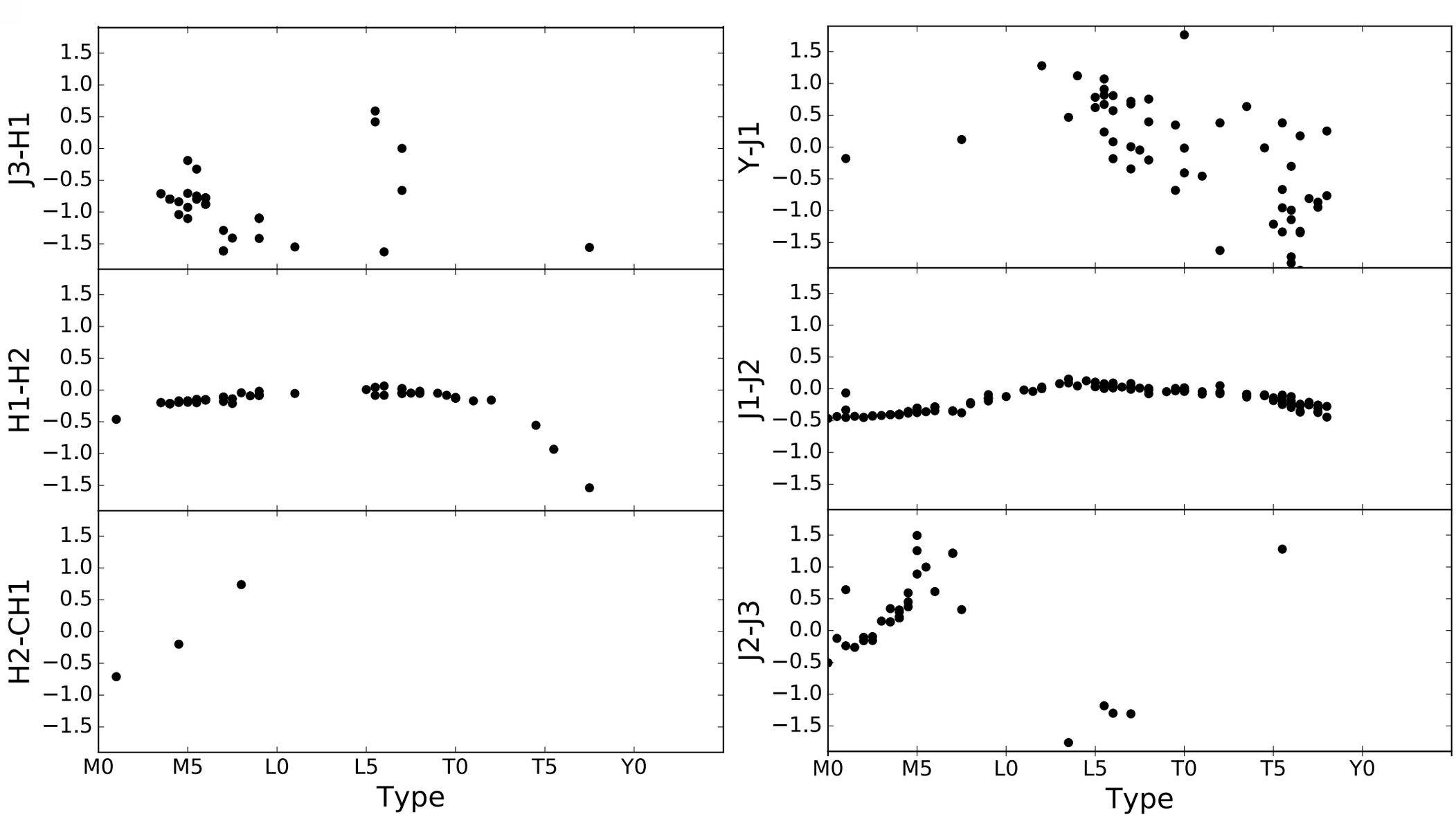
Holwerda+ *in prep.*

Spitzer sub-typing



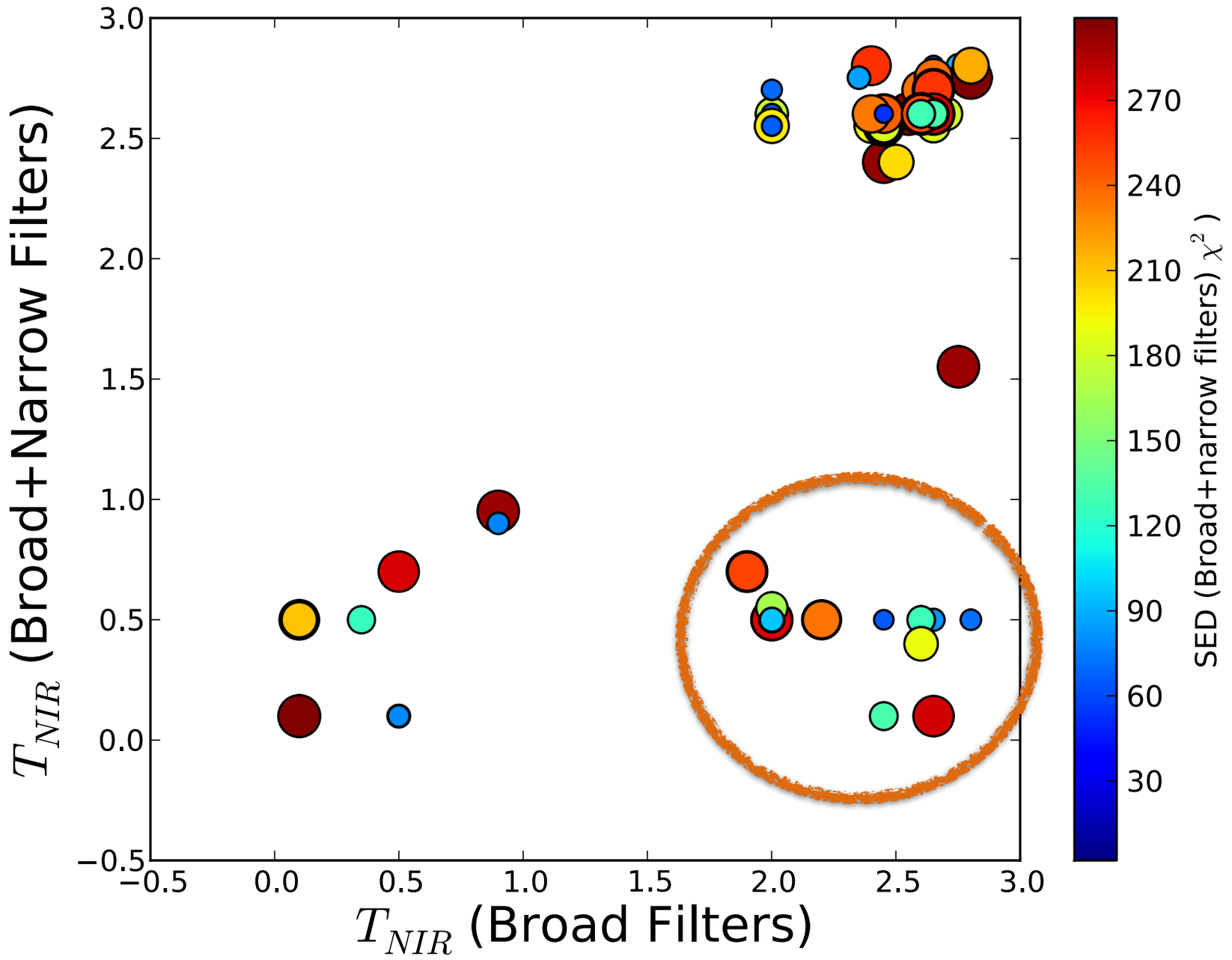
Holwerda+ *in prep.*

Sub-typing



Holwerda+ *in prep.*

SED fits?



Holwerda+ *in prep.*

WFIRST Applications

- NIR wide-field imaging surveys are happening.
  - not just deep fields (HLS, Microlensing, Bulge)
  - but snapshots, pure-parallels (coronograph)!
- Find the stars (likely Brown Dwarfs) and type (M/L/T?) with broad colors.
- Sub-type brown dwarfs either
  - as part of the MCMC model,
  - or using grism or narrow-band filter information.
  - or proper motion (Sanderson's talk).
- Milky Way disk thickness and (sub)type and compare to cooling models.
- Estimate GIMF for different Milky Way components, disk, halo etc.

Thank you!

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