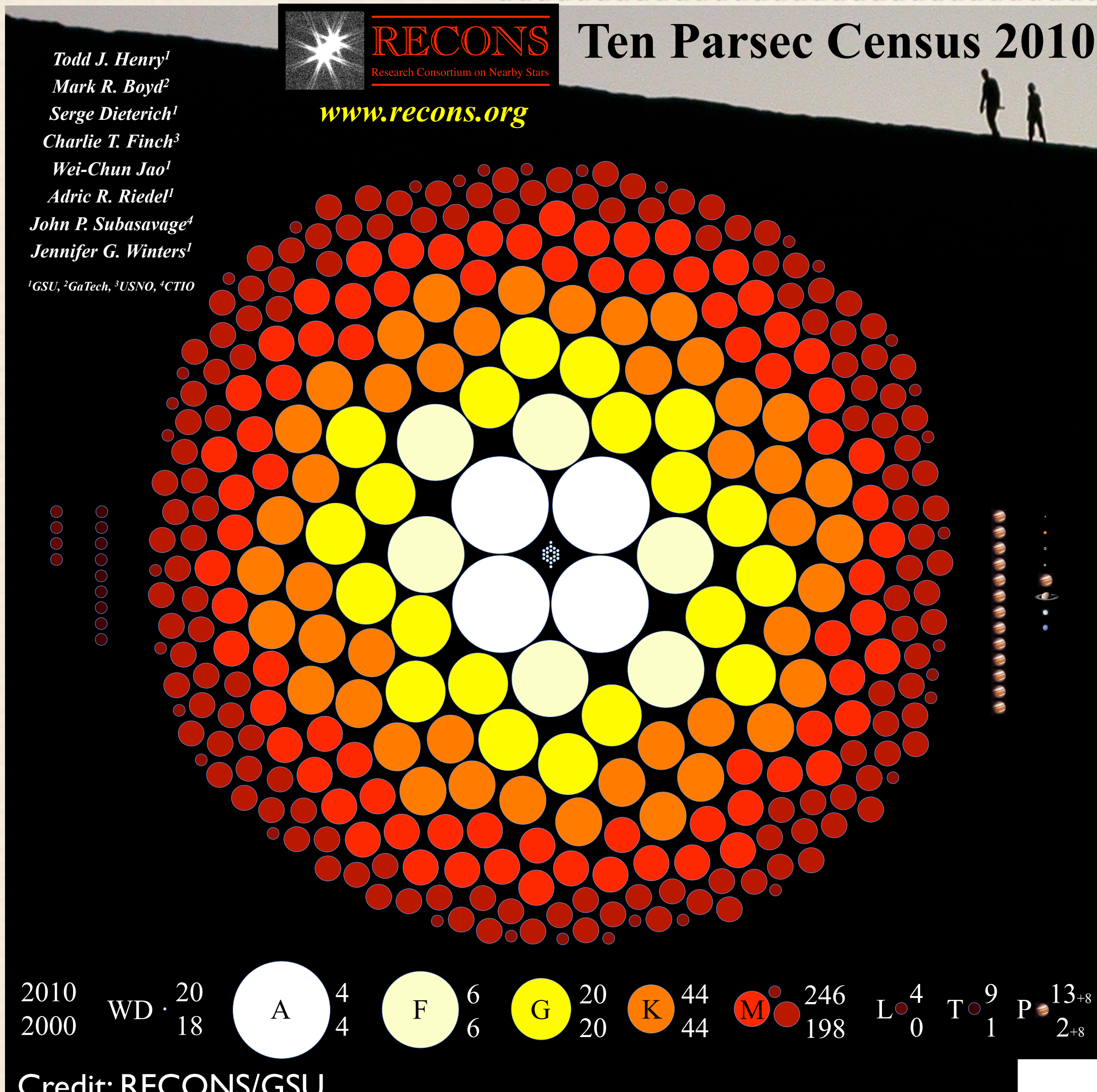
The Occurrence of Warm Dust around Cool Stars

Christopher A. Theissen

Oral Defense Presentation, Friday, Dec. 12th

Committee Members: Dan Clemens (Chair), Catherine Espaillat, Andrew West, and Paul Withers

Some Interesting Background



- Low-mass stars (cool stars; M dwarfs → dM)
  - Most populous type of star in the Galaxy (>70%; West et al. 2008)
  - Extremely faint (can't see any with the naked eye from Earth)
  - Penchant for building terrestrial planets (Dressing & Charbonneau 2013)

THE KEPLER DICHOTOMY AMONG THE M DWARFS:
HALF OF SYSTEMS CONTAIN FIVE OR MORE COPLANAR PLANETS

SARAH BALLARD[1,2] & JOHN ASHER JOHNSON[3]

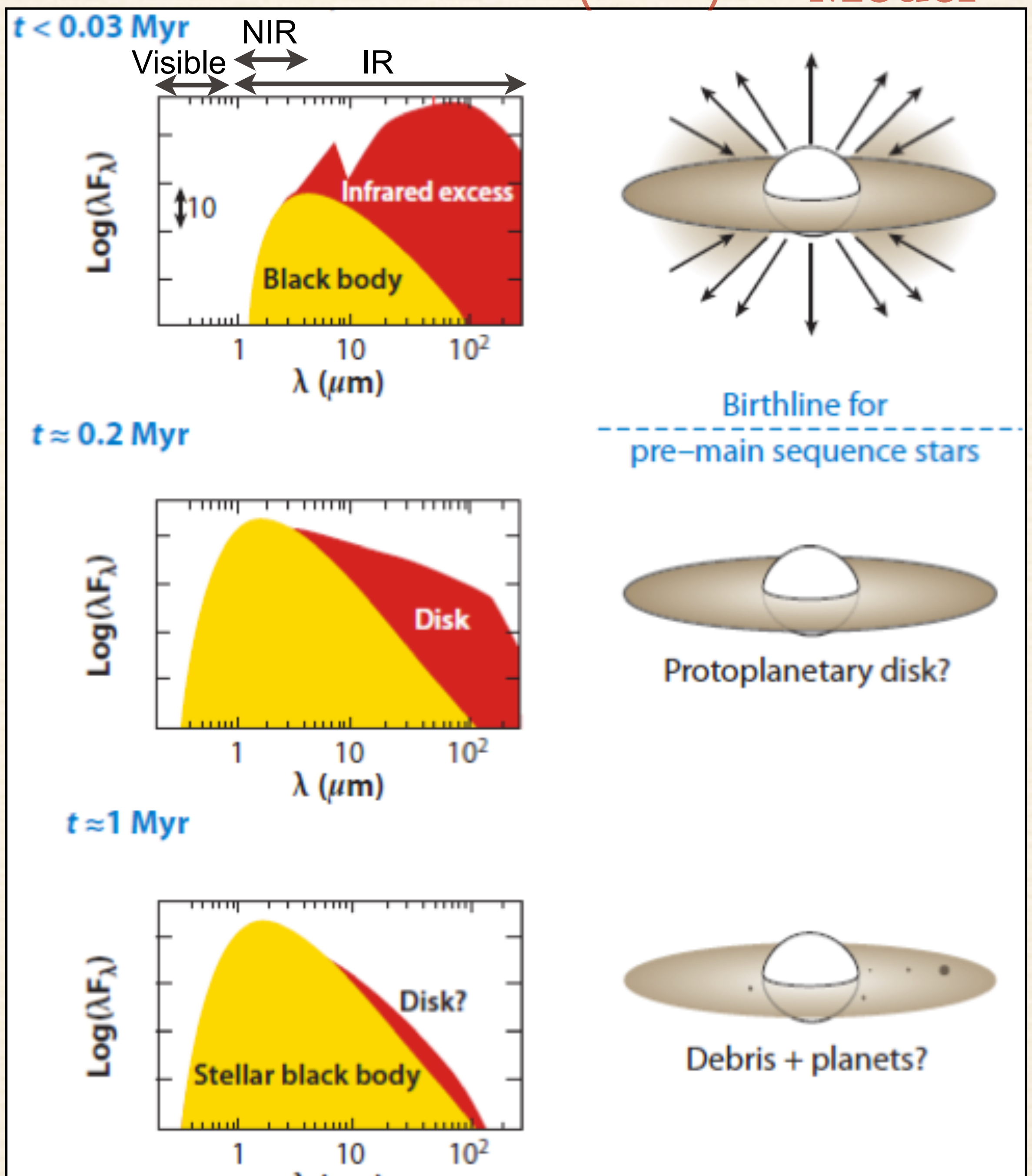
Draft version October 17, 2014

ABSTRACT

We present a statistical analysis of the *Kepler* M dwarf planet hosts, with a particular focus on the

Formation and Evolution of Stars and Disks

Timescale **Observable (SED)** **Model**



Adapted from Lada (1987)

Wednesday, July 22, 15

Formation and Evolution of Stars and Disks

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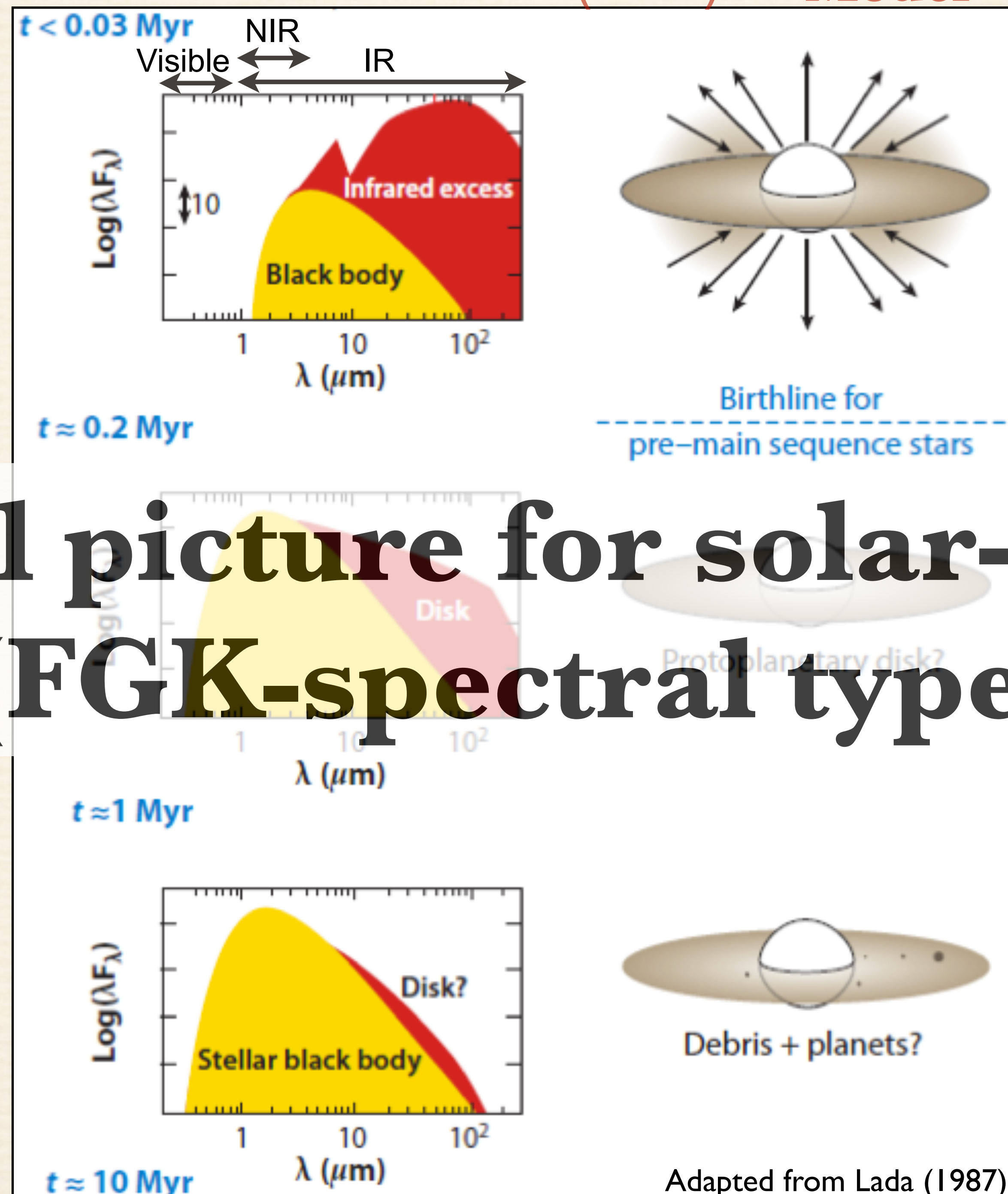
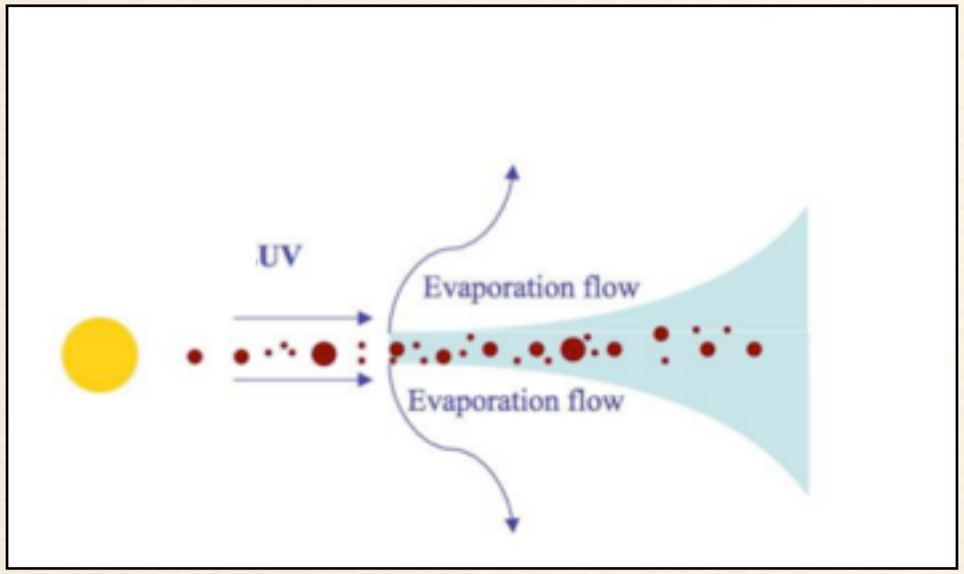


Canonical picture for solar-type stars (FGK-spectral type)

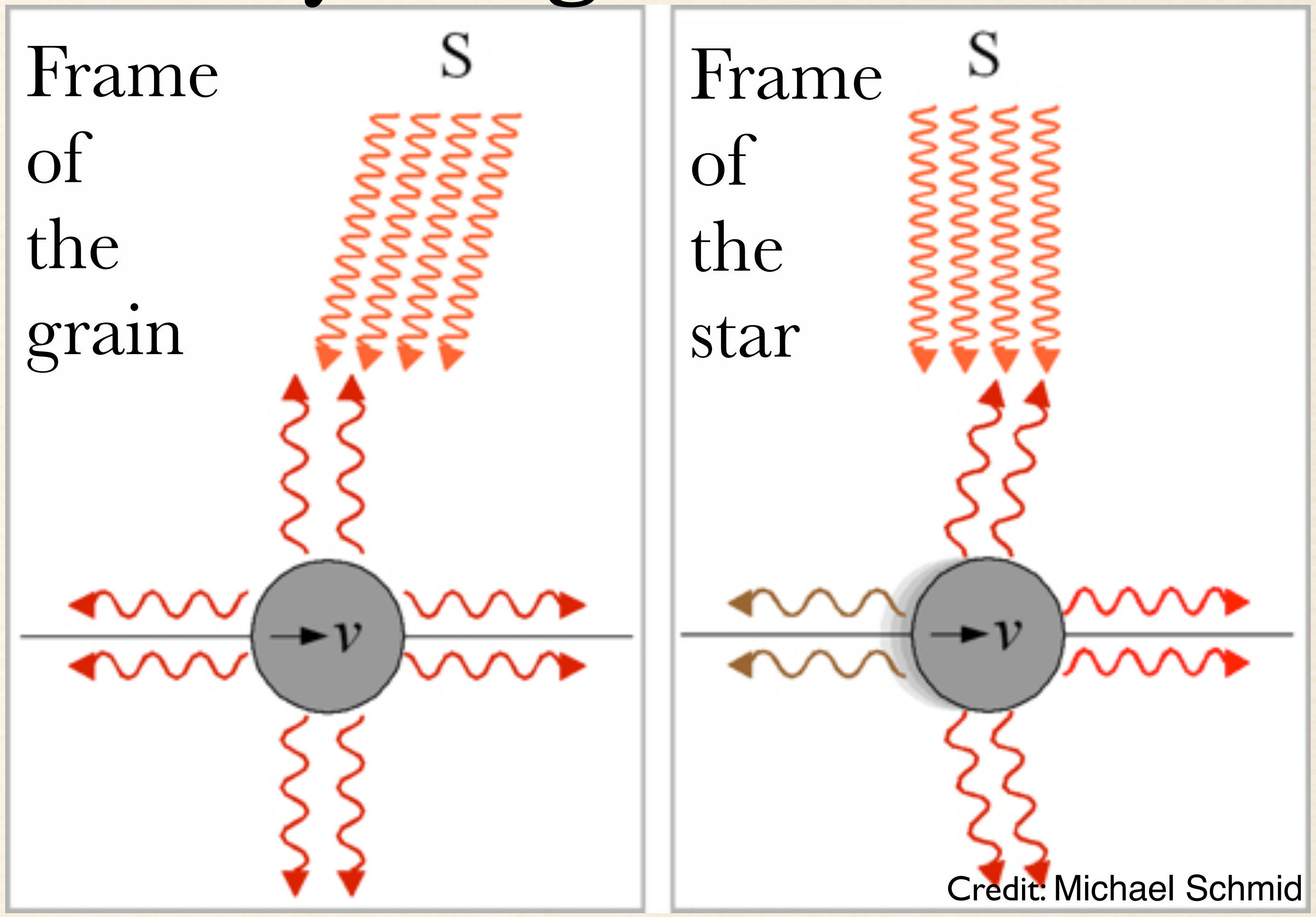
Disk Removal Mechanisms (Radiative Examples)

Photoevaporation (Radiation Pressure)



Adapted from Williams & Cieza (2011)

Poynting-Robertson



Particle will decelerate and spiral inwards

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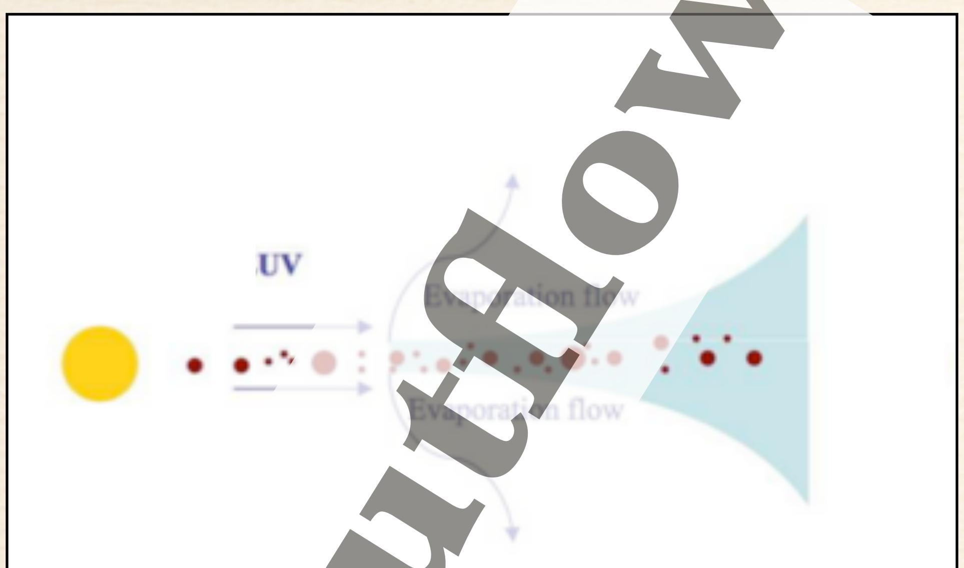

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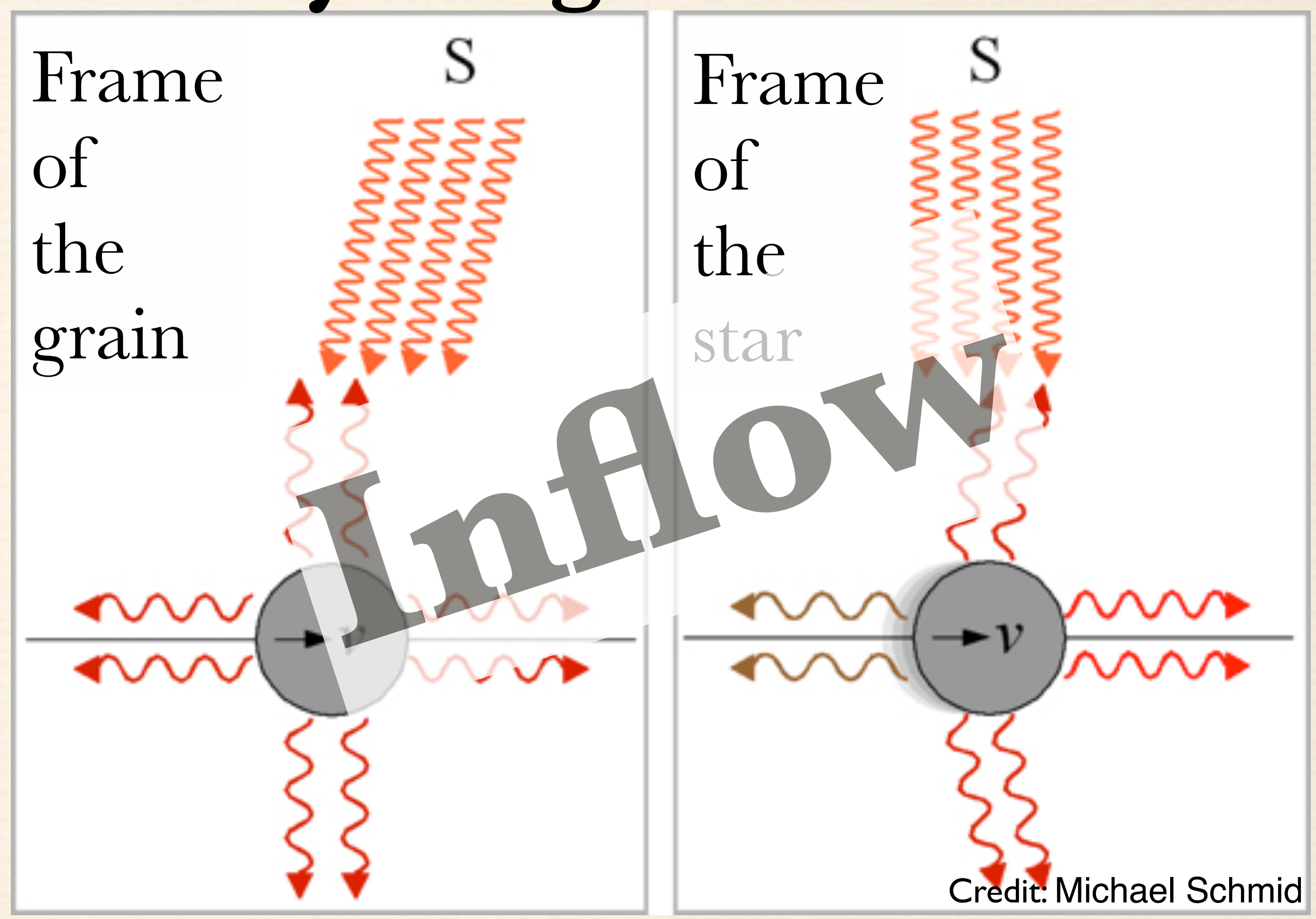

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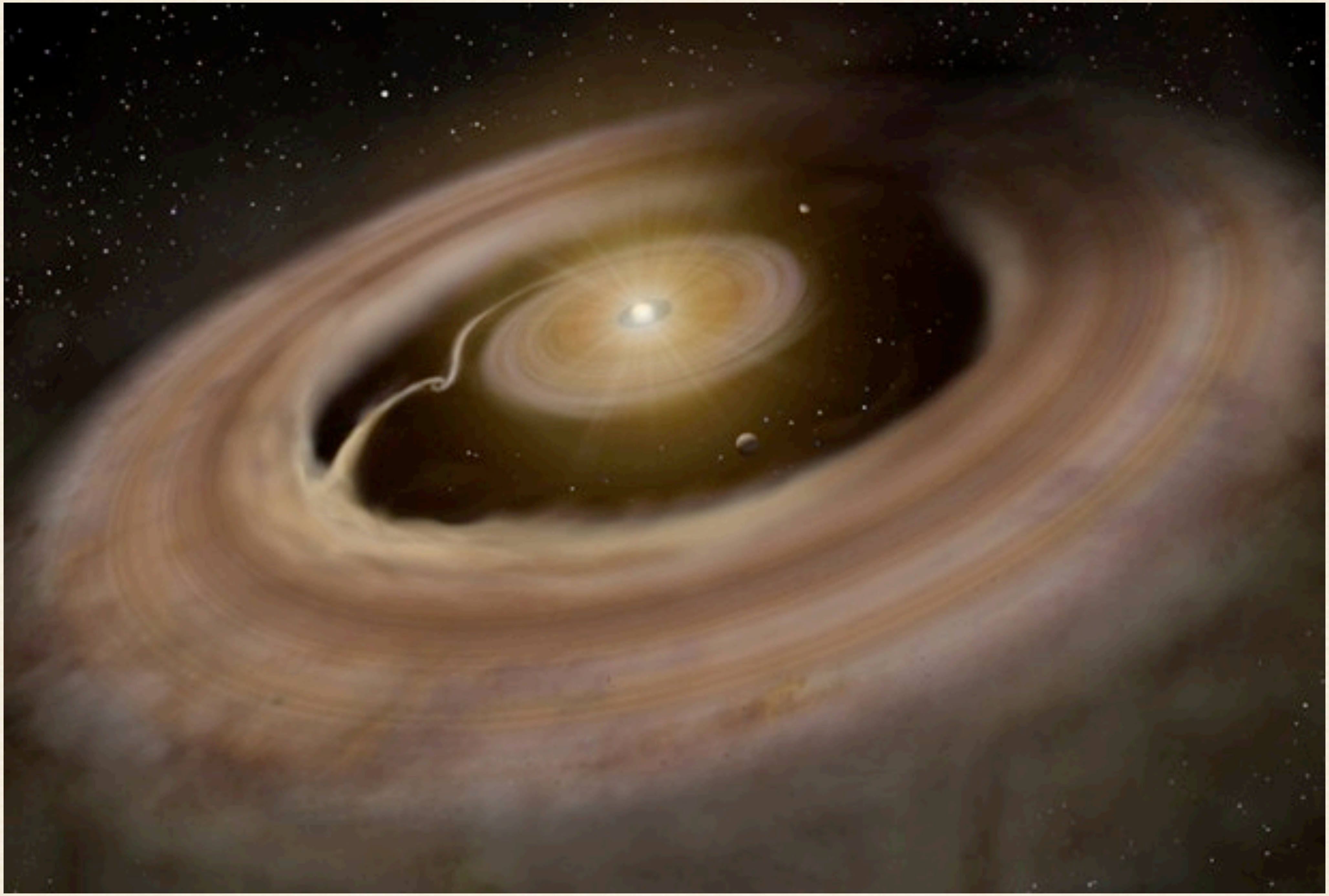
Disk Removal Mechanisms (Grain Growth/Planets)



Credit: NAOJ

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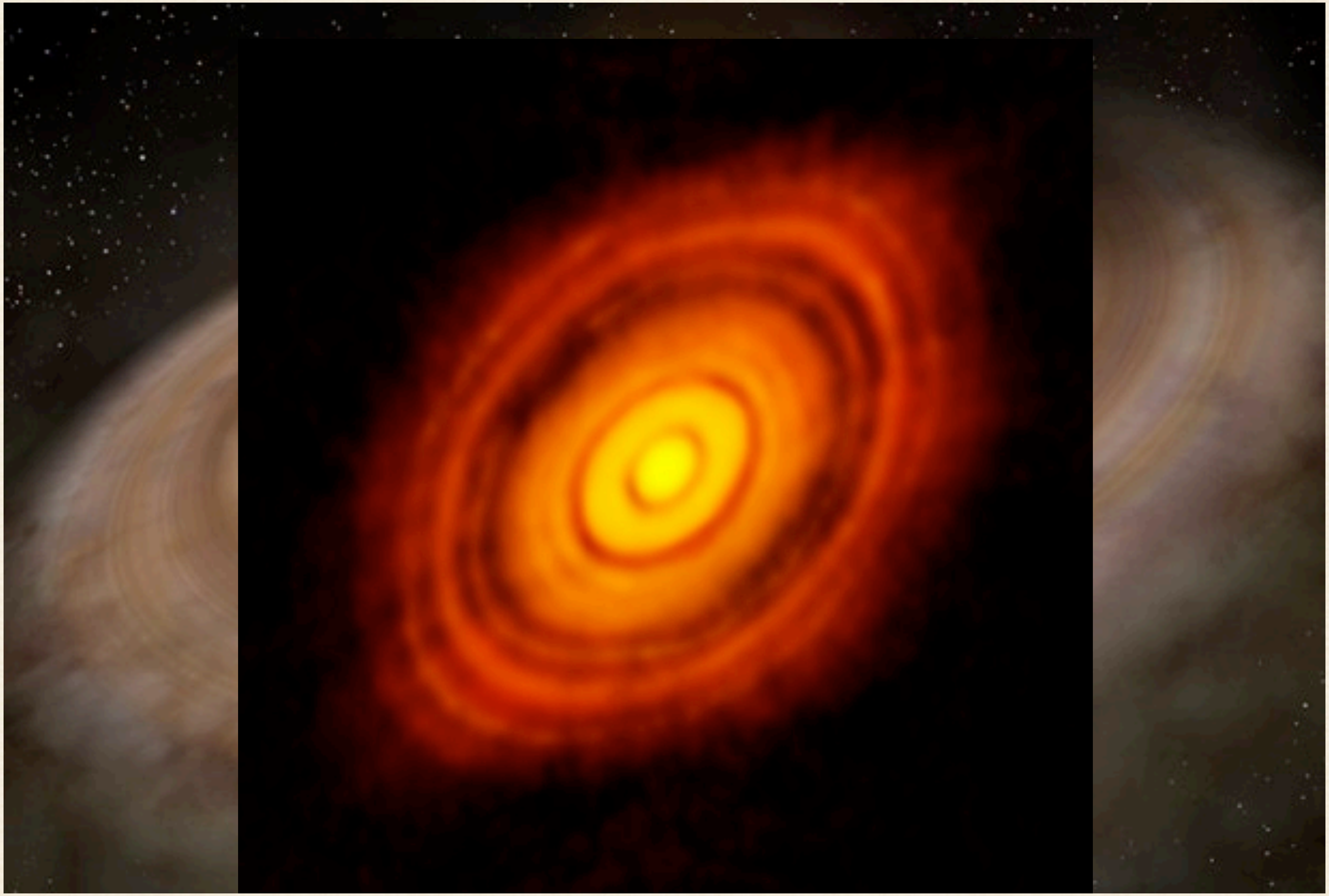

Credit: ALMA Credit: NAOJ

Motivating Questions

- What is the timescale for disk dispersal around low-mass stars?
  - Multiple mechanisms play an important role in removing disks around stars. What are the dominant dispersal mechanisms for low-mass stars, and how does that affect their disk evolution?

What's up with M dwarfs?

WHERE ARE THE M DWARF DISKS OLDER THAN 10 MILLION YEARS?

PETER PLAVCHAN, M. JURA, AND S. J. LIPSCY[1]
Department of Physics and Astronomy, University of California, Los Angeles, CA 90095; plavchan@astro.ucla.edu
Received 2004 October 18; accepted 2005 June 6

ABSTRACT

We present 11.7 μm observations of nine late-type dwarfs obtained at the Keck I 10 m telescope in 2002 December and 2003 April. Our targets were selected for their youth or apparent *IRAS* 12 μm excess. For all nine sources, excess infrared emission is not detected. We find that stellar wind drag can dominate the circumstellar grain removal and plausibly explain the dearth of M dwarf systems older than 10 Myr with currently detected infrared excesses. We predict that M dwarfs possess fractional infrared excesses on the order of $L_{IR}/L_* \sim 10^{-6}$ and that this may be detectable with future efforts.

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WARM DUST AROUND COOL STARS: FIELD M DWARFS WITH *WISE* 12 OR 22 μm EXCESS EMISSION

CHRISTOPHER A. THEISSEN AND ANDREW A. WEST
Department of Astronomy, Boston University, 725 Commonwealth Avenue, Boston, MA 02215, USA; ctheisse@bu.edu
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ABSTRACT

Using the Sloan Digital Sky Survey Data Release 7 (SDSS DR7) spectroscopic catalog, we searched the *WISE* AllWISE catalog to investigate the occurrence of warm dust, as inferred from IR excesses, around field M dwarfs (dMs). We developed SDSS/*WISE* color selection criteria to identify 175 dMs (from 70,841) that show IR flux greater than the typical dM photosphere levels at 12 and/or 22 μm, including seven new stars within the Orion OB1 footprint. We characterize the dust populations inferred from each IR excess and investigate the possibility that these excesses could arise from ultracool binary companions by modeling combined spectral energy distributions.

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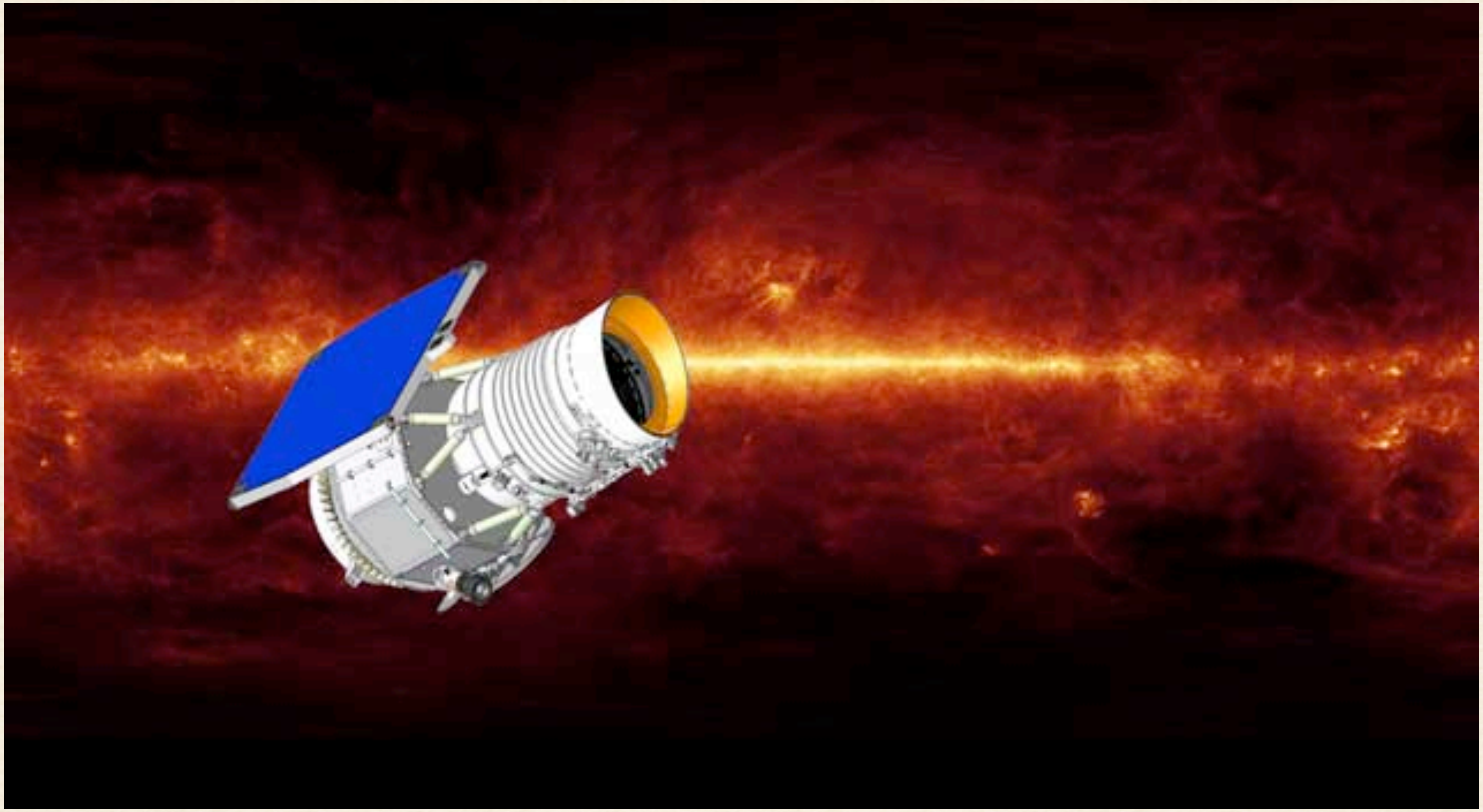
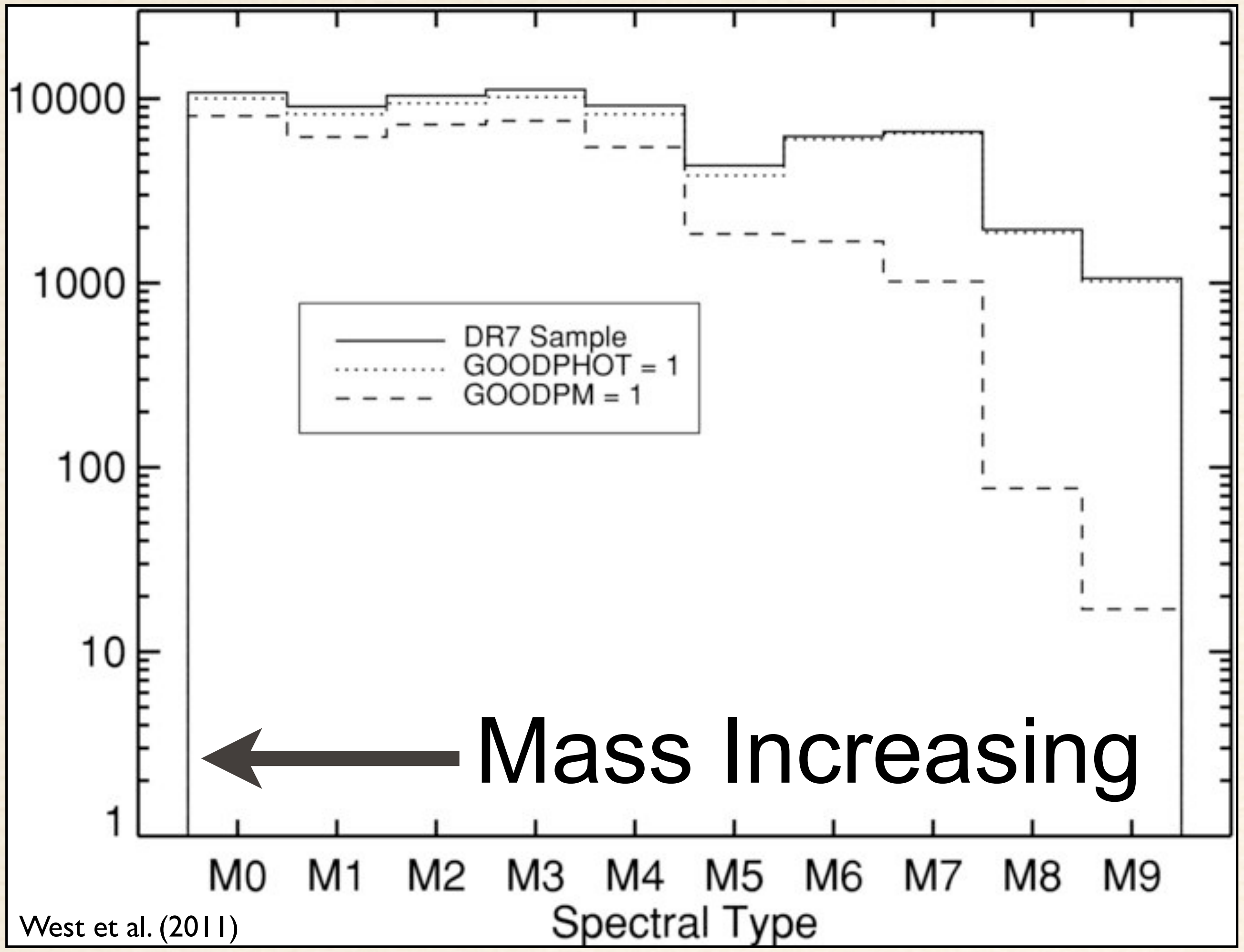
The *Wide-field Infrared Survey Explorer* *(WISE)*



Credit: NASA/IPAC

Strength in Numbers



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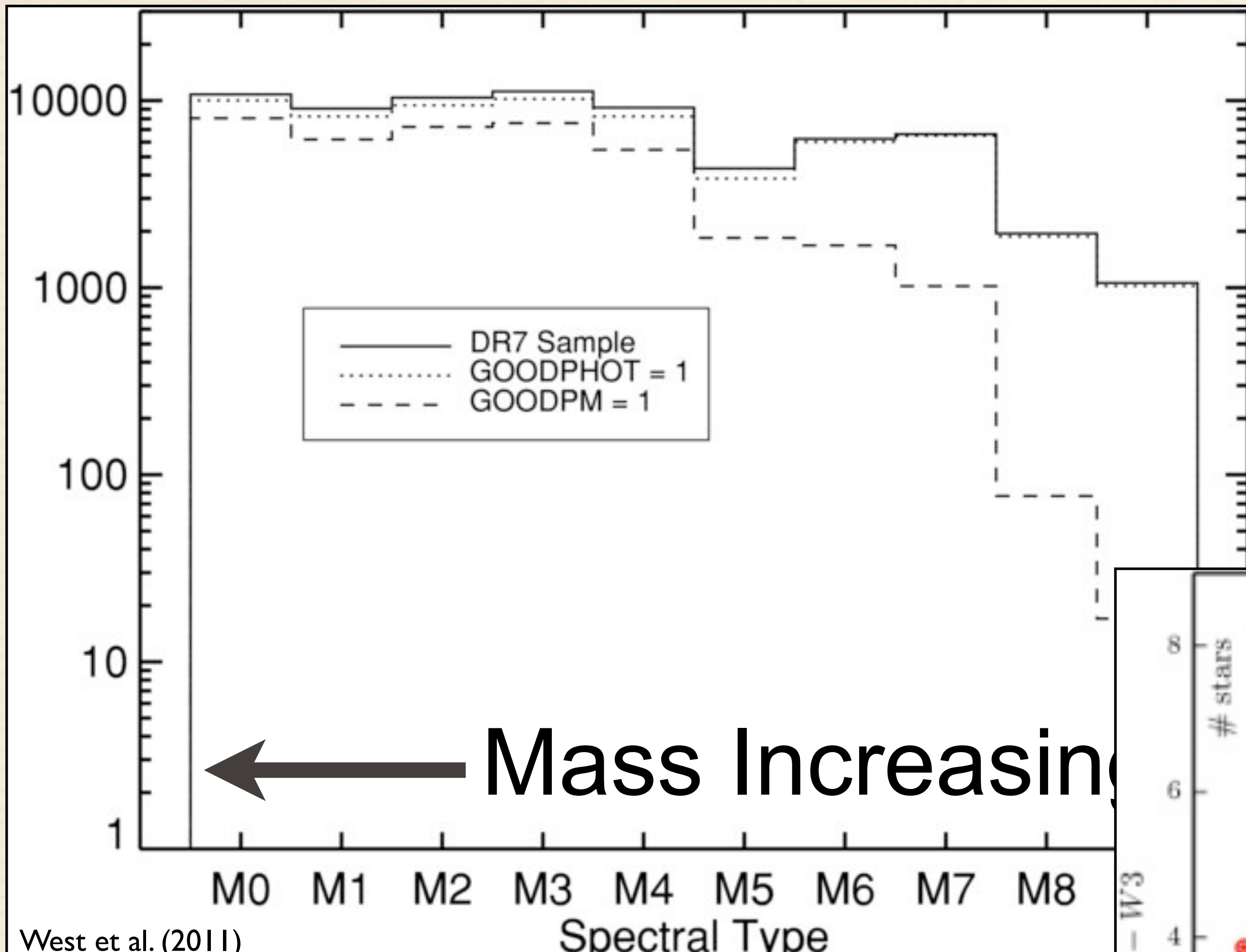
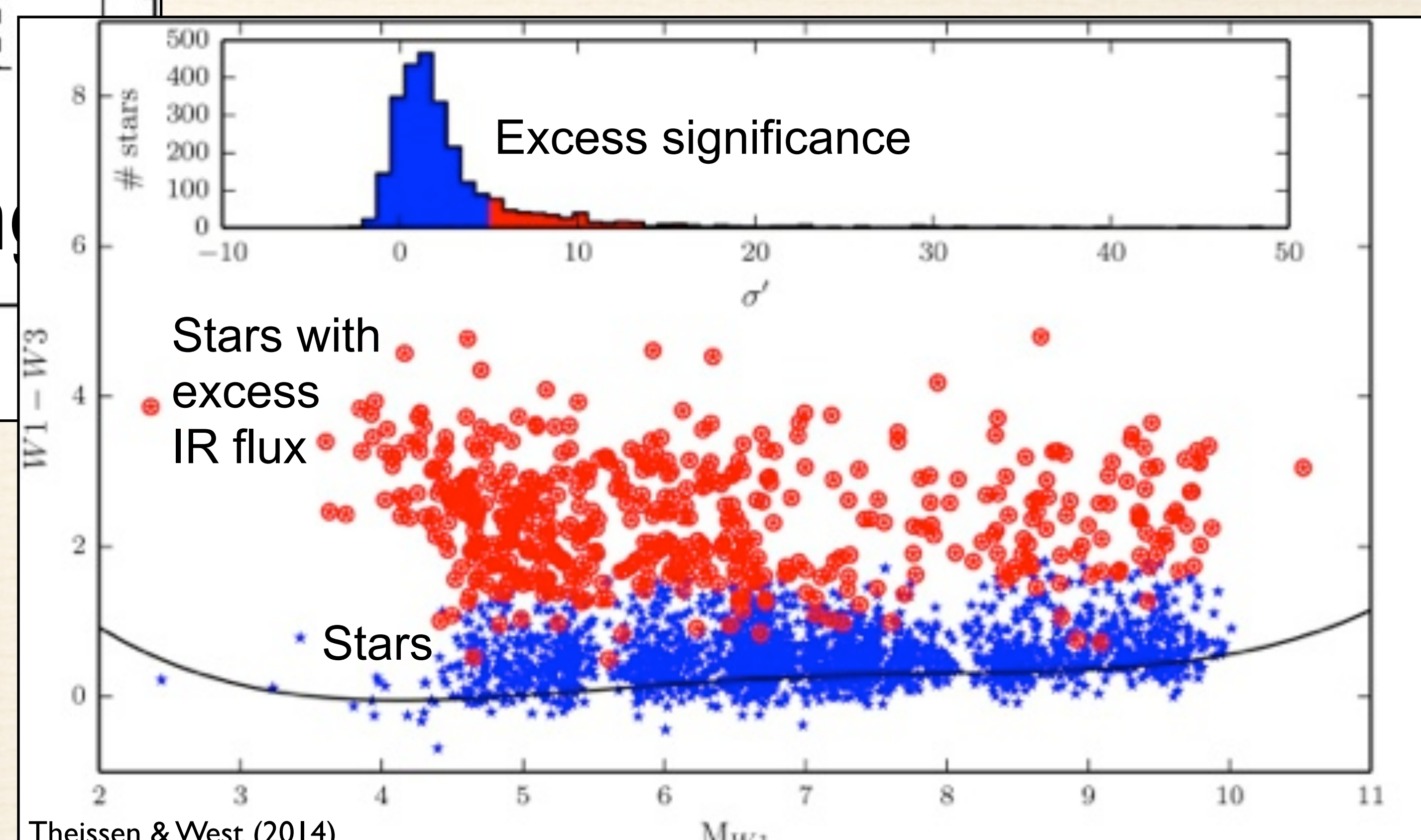


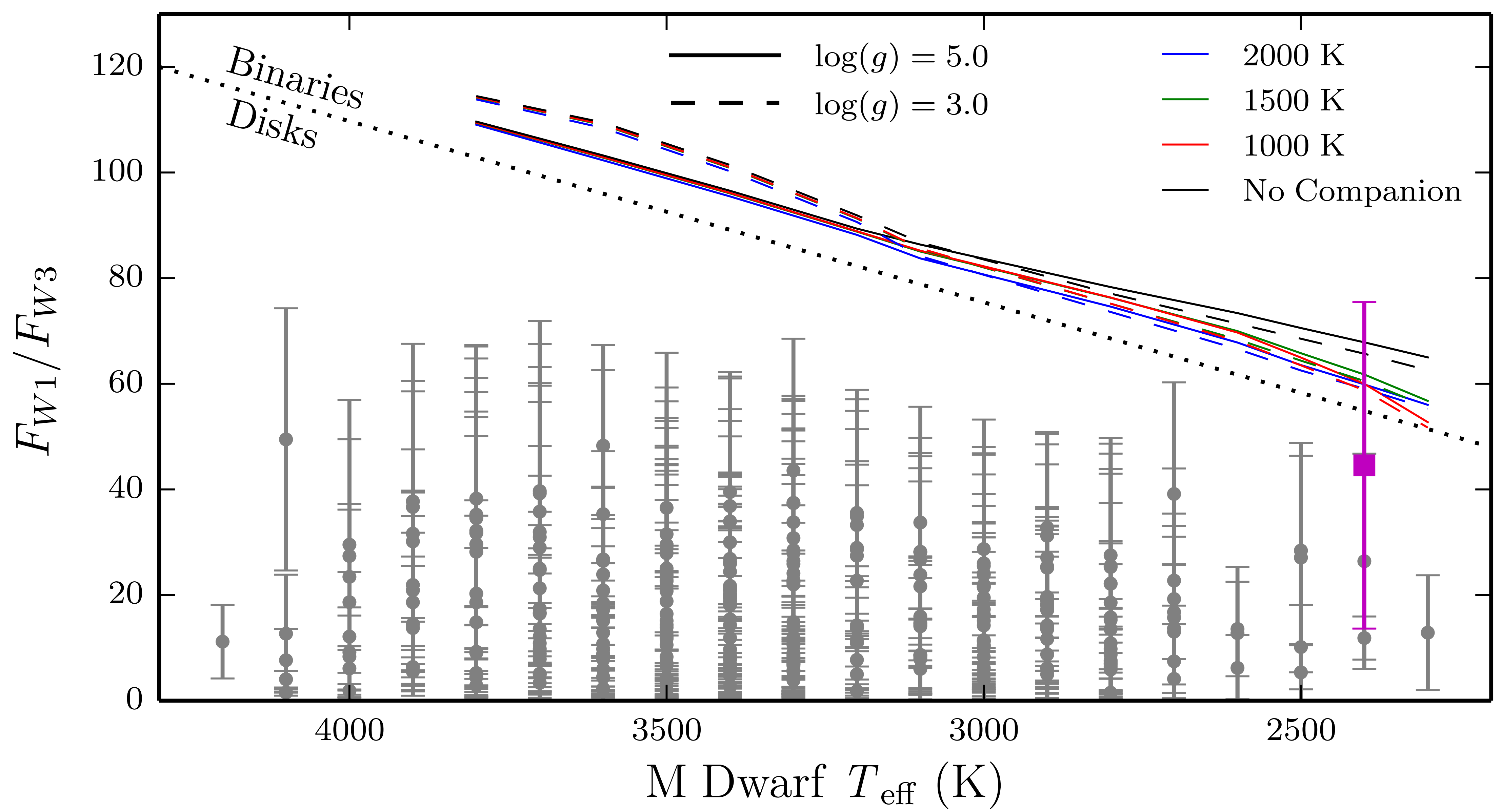
West et al. (2011)

WISE color-magnitude criteria to select stars with excess IR flux.



Theissen & West (2014)

Other Explanations for IR Excess - Ultra-cool Binaries



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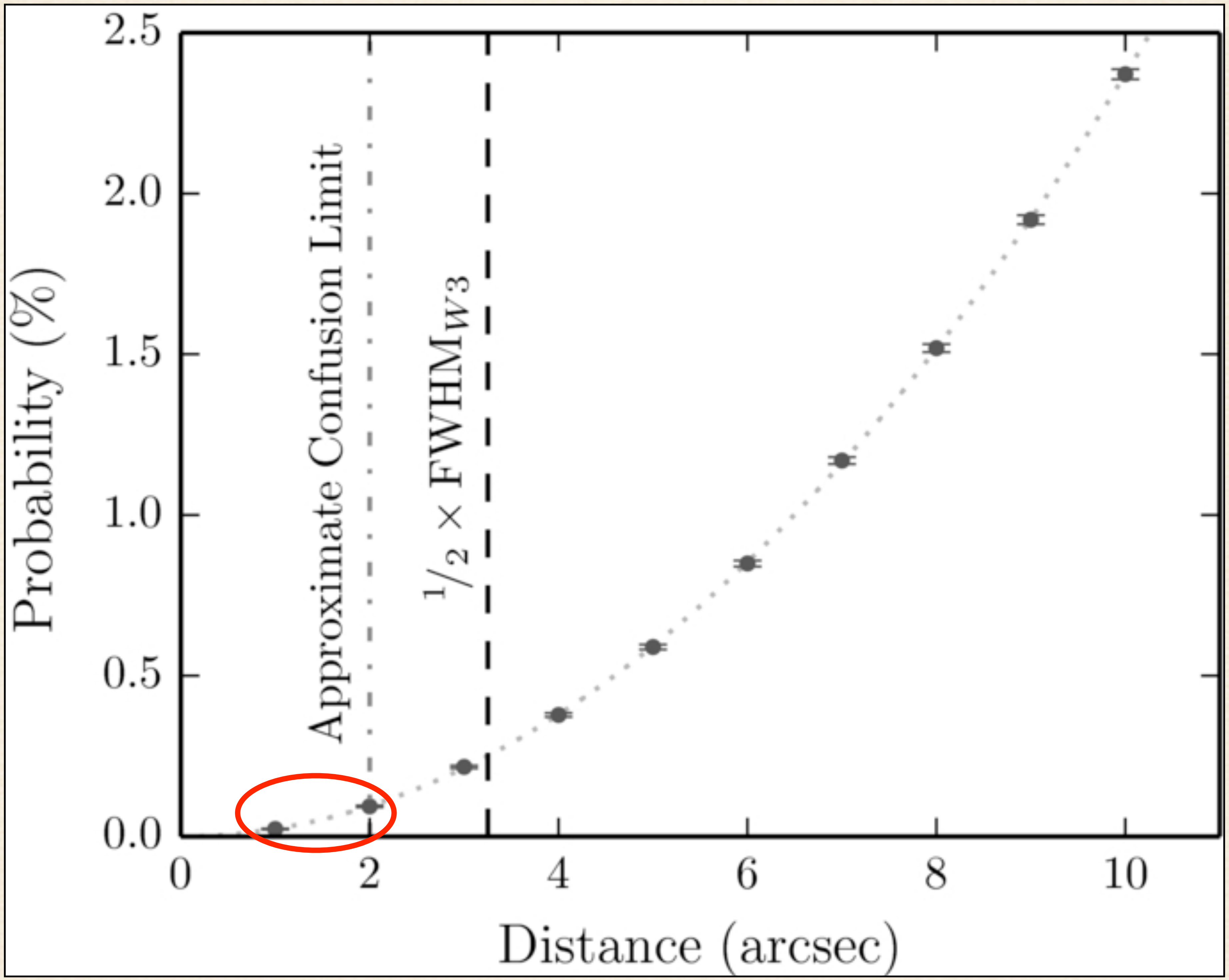
Other Explanations for IR Excess - chance alignment with a Galaxy



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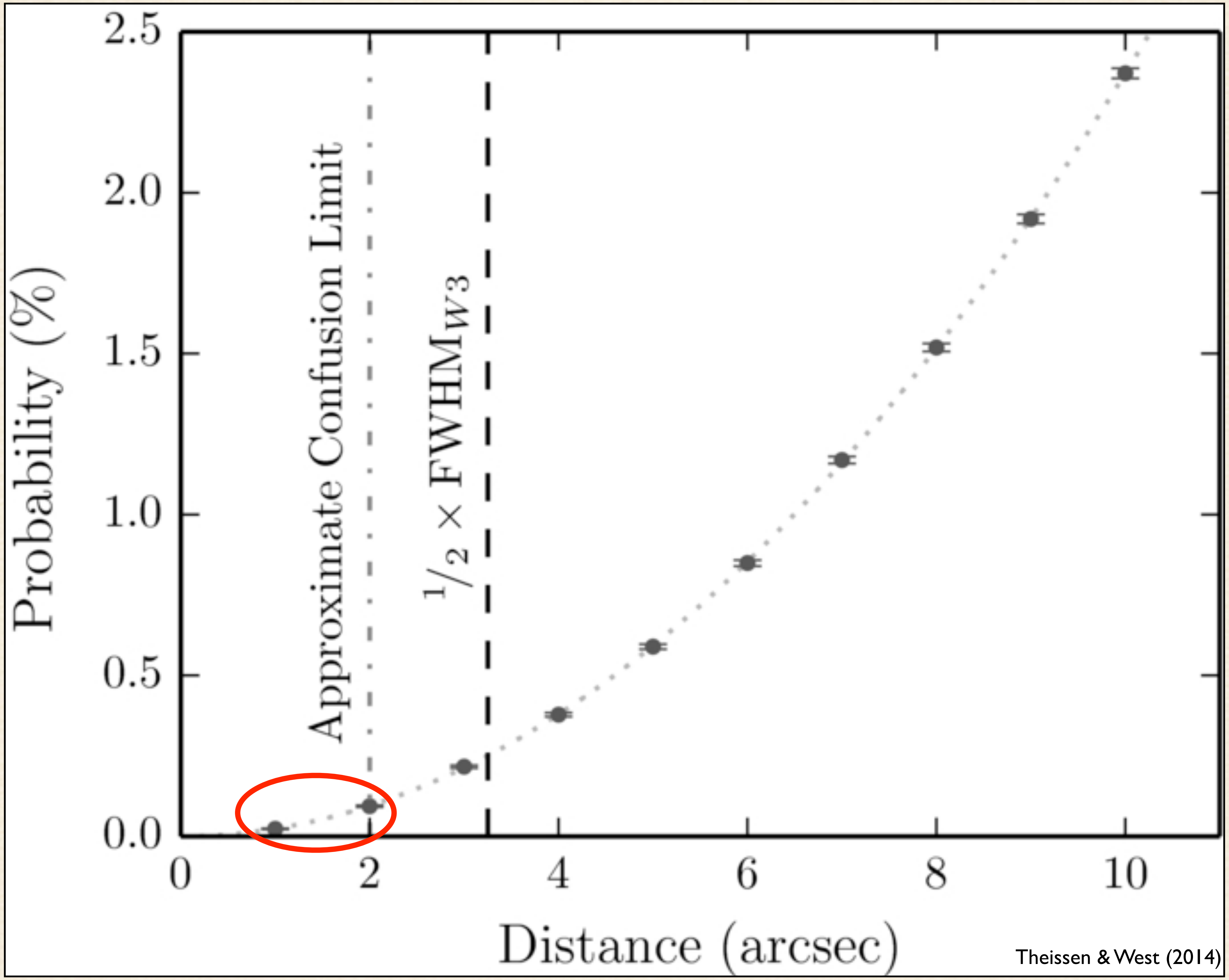
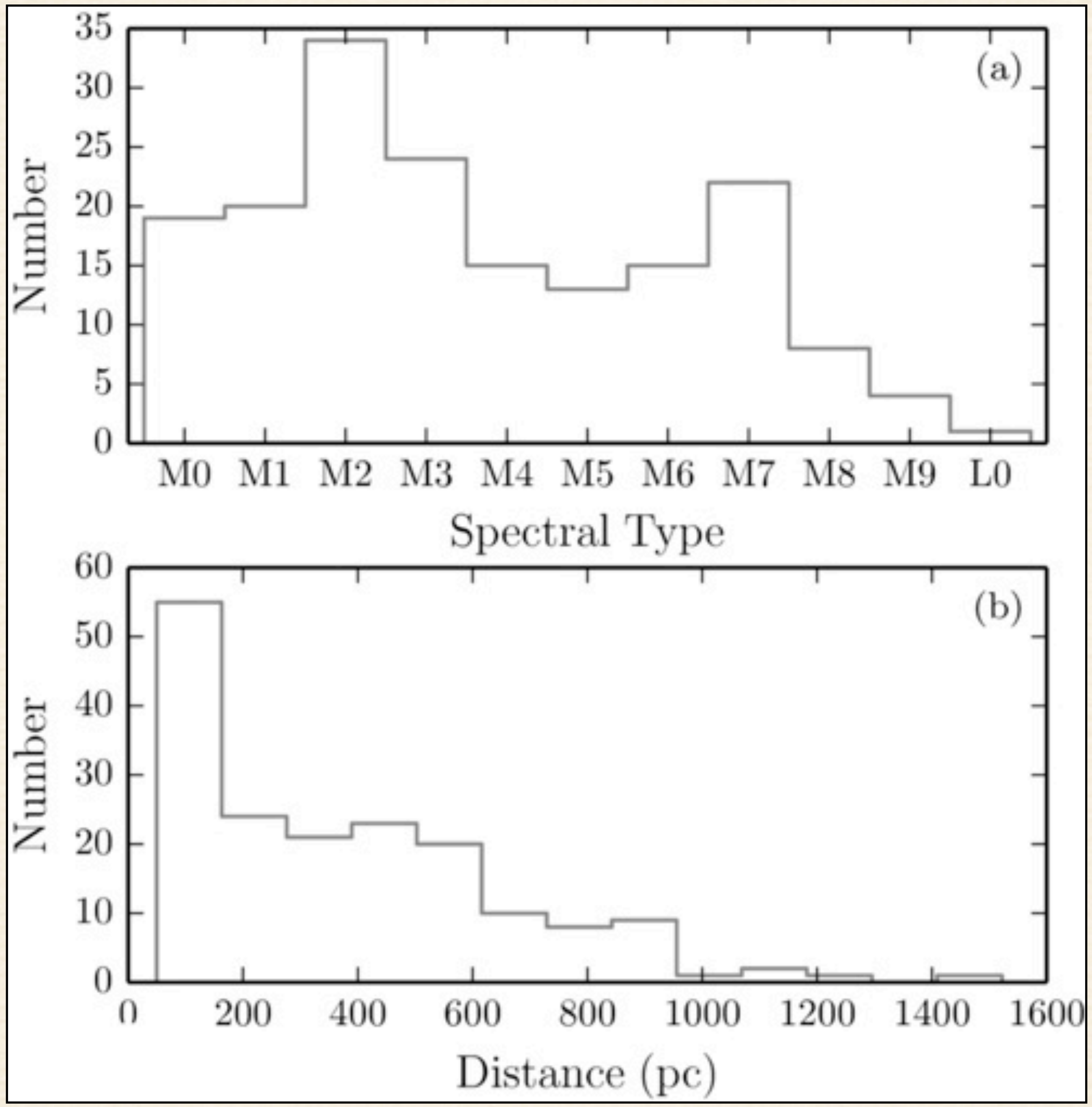
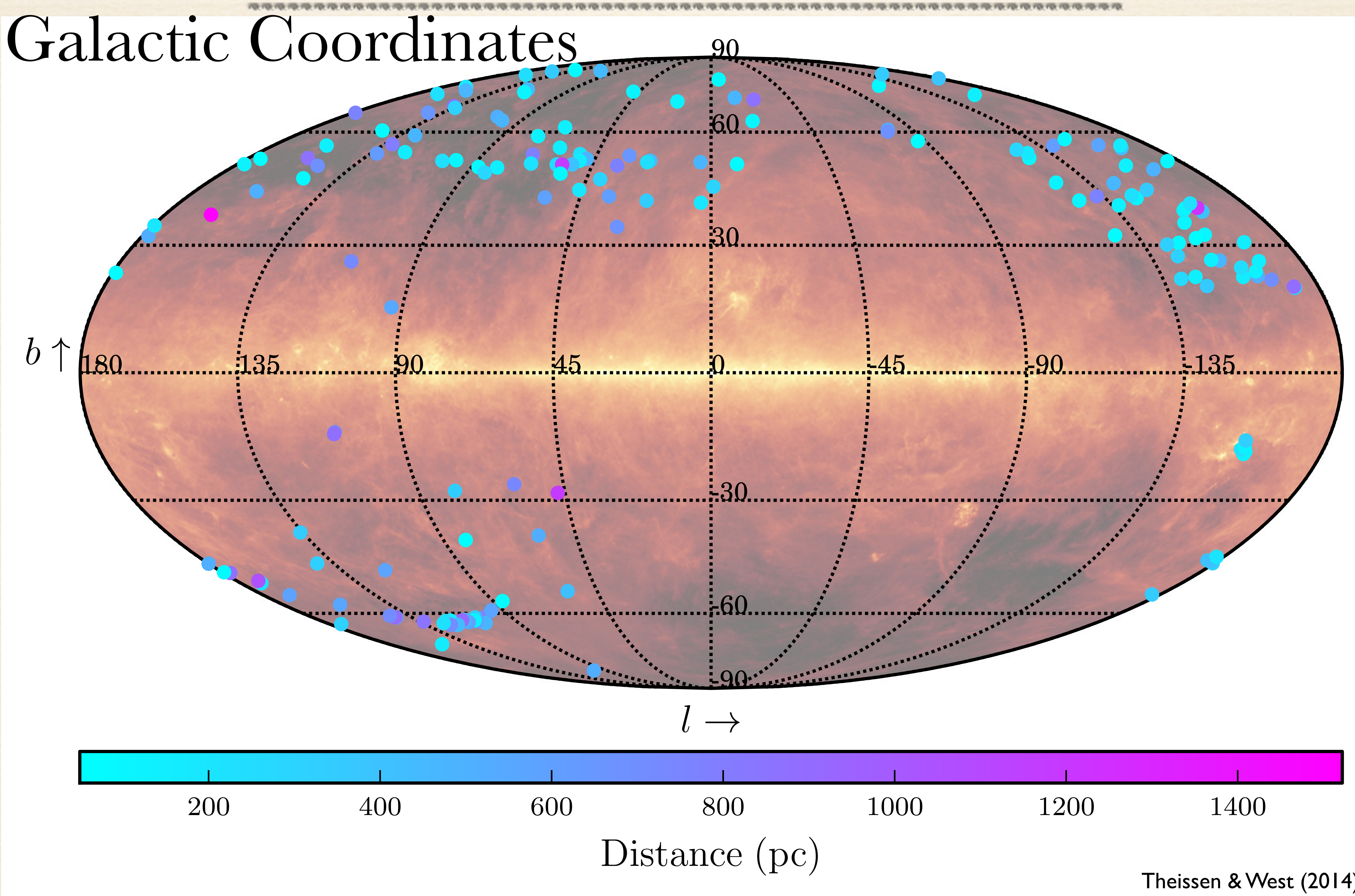


The Final Sample



Theissen & West (2014)

Where did we find them?



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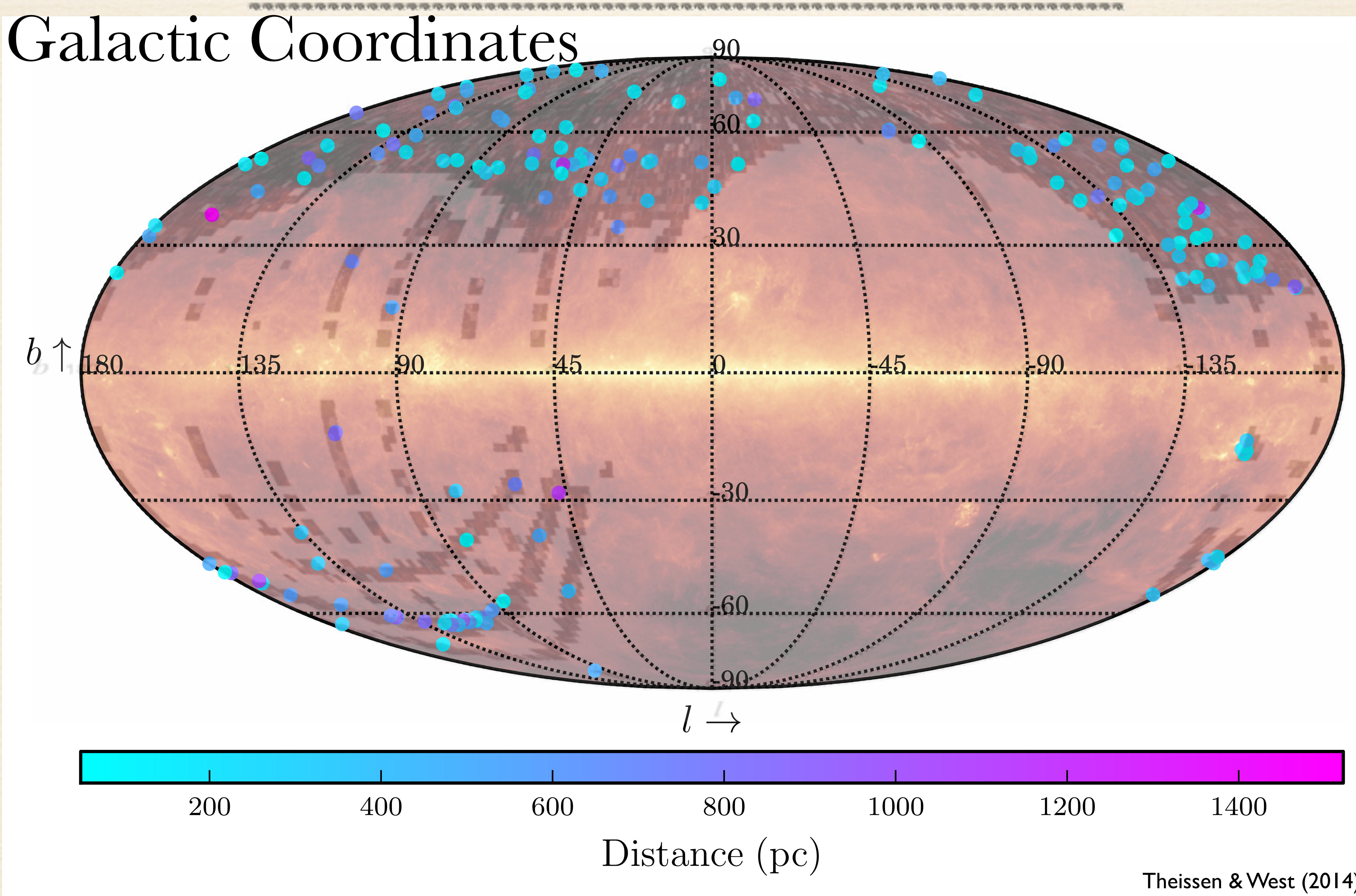
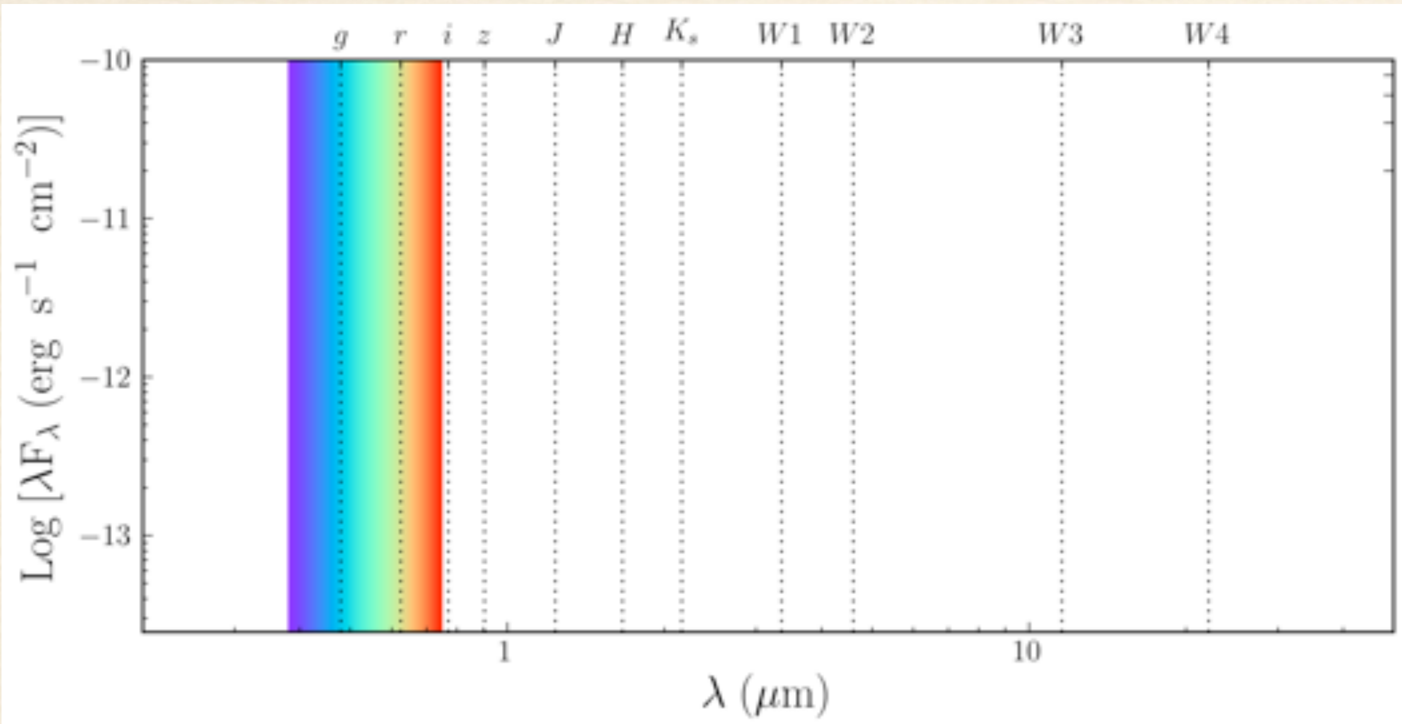


Combining Surveys for SEDs



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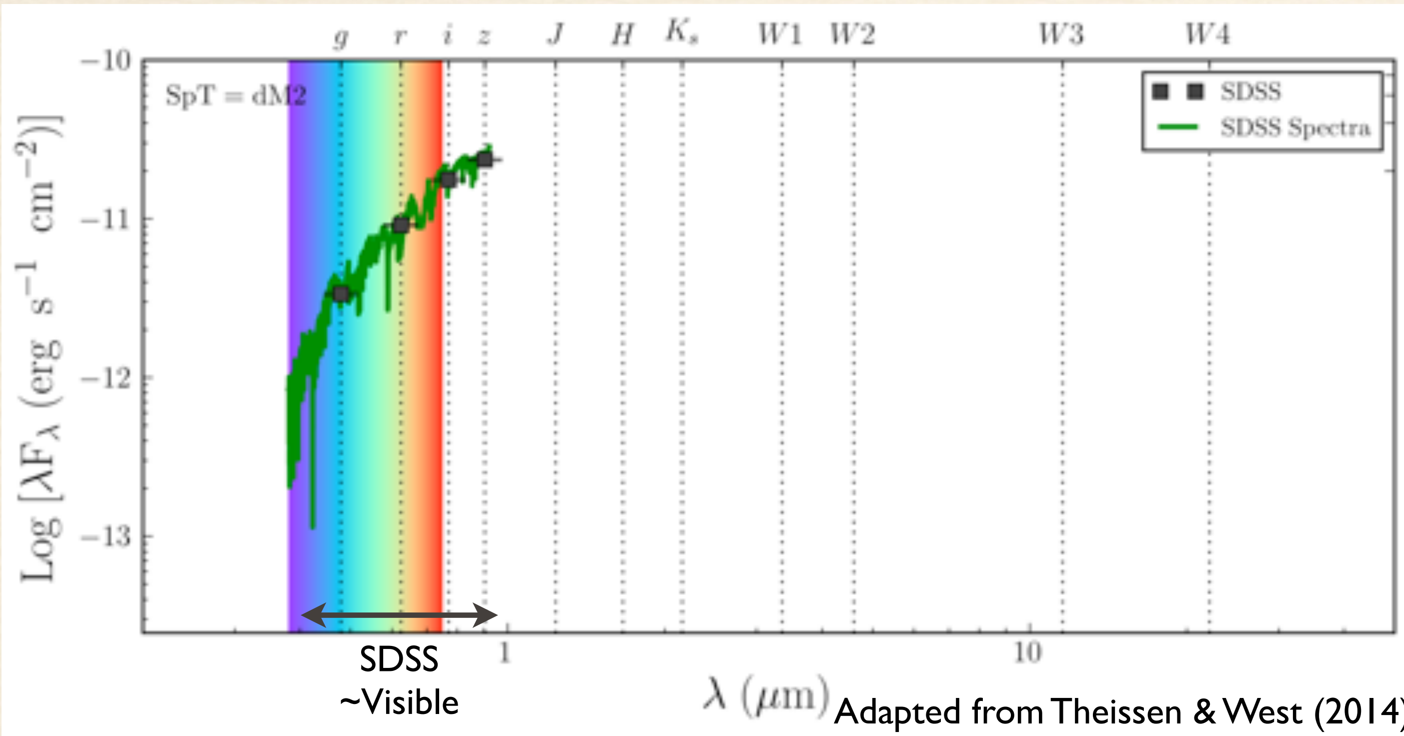

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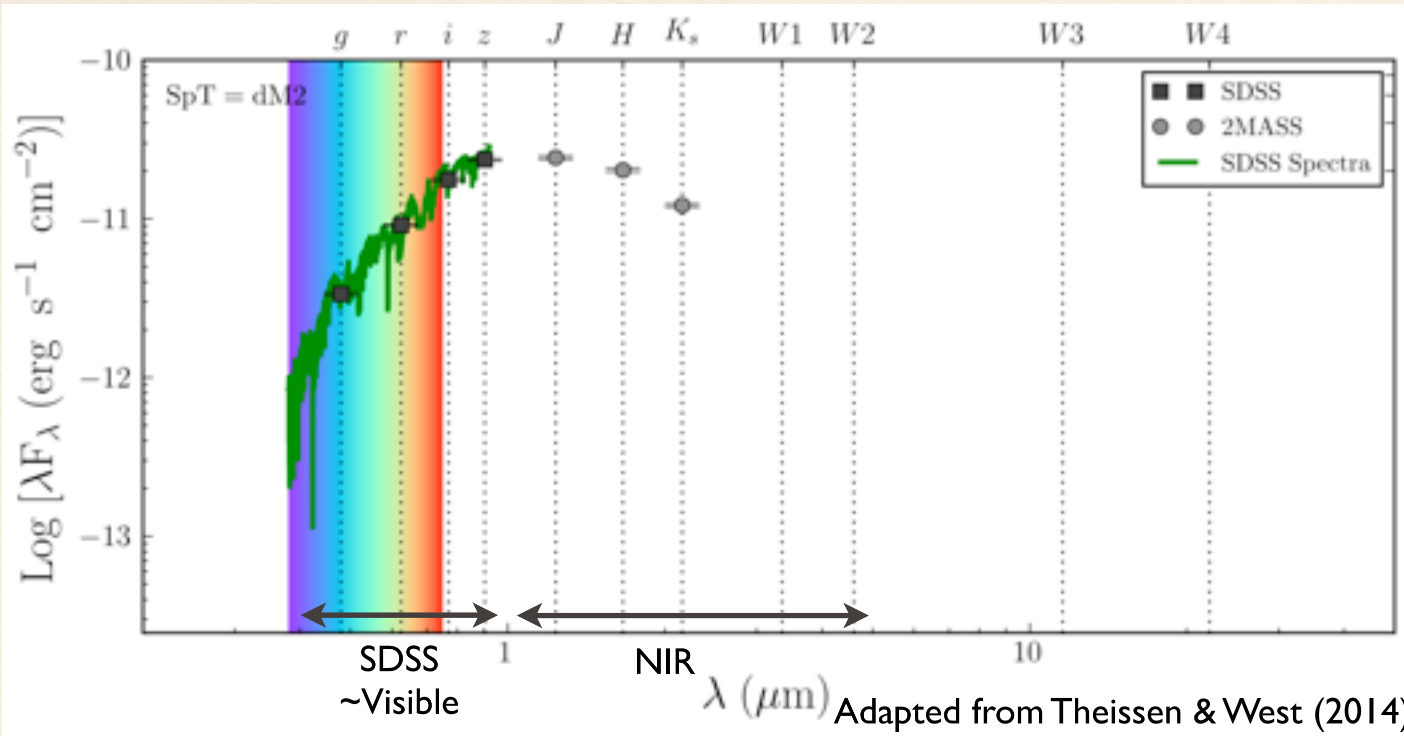

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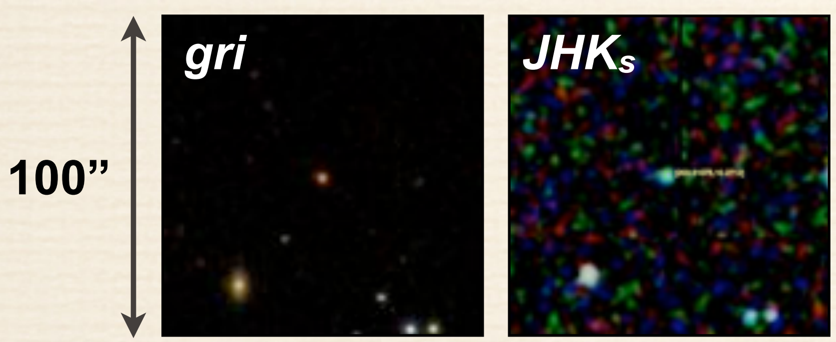

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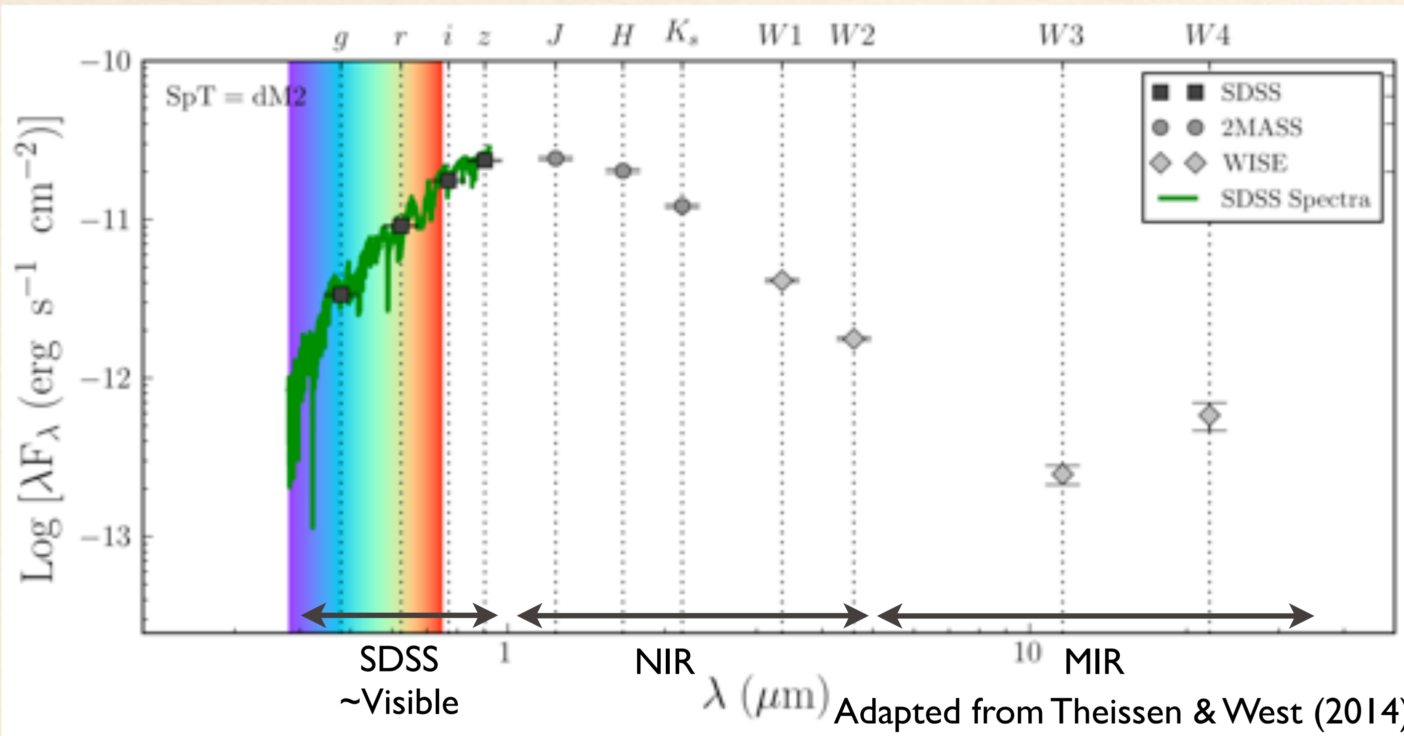

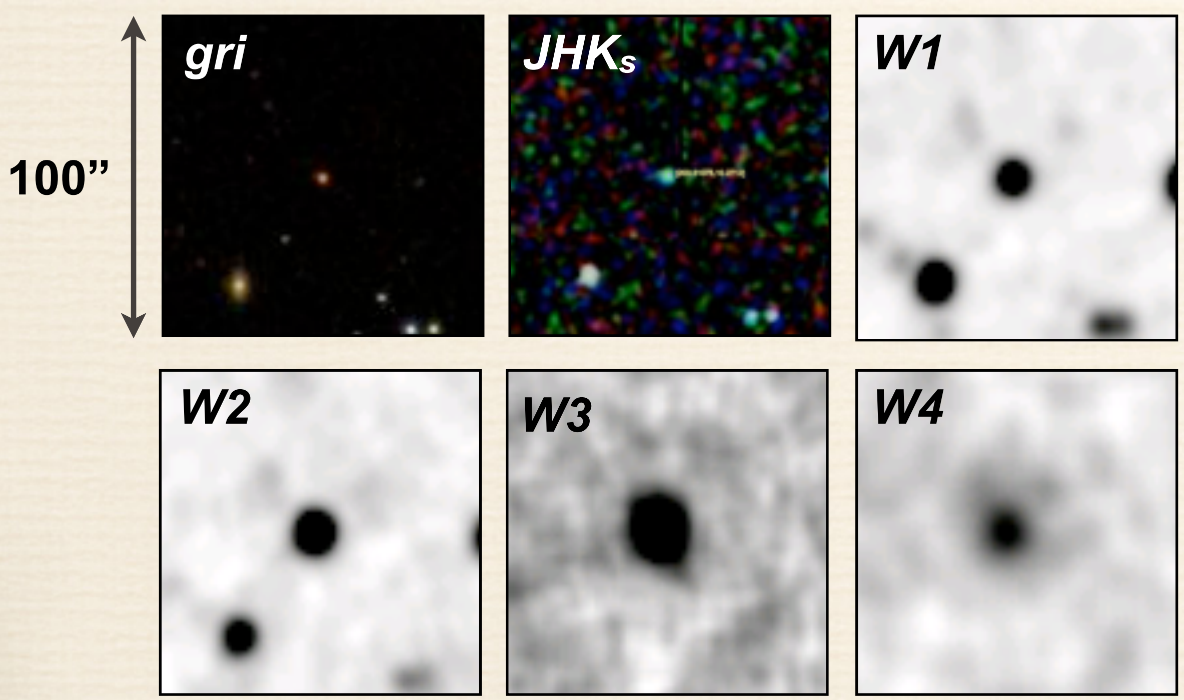

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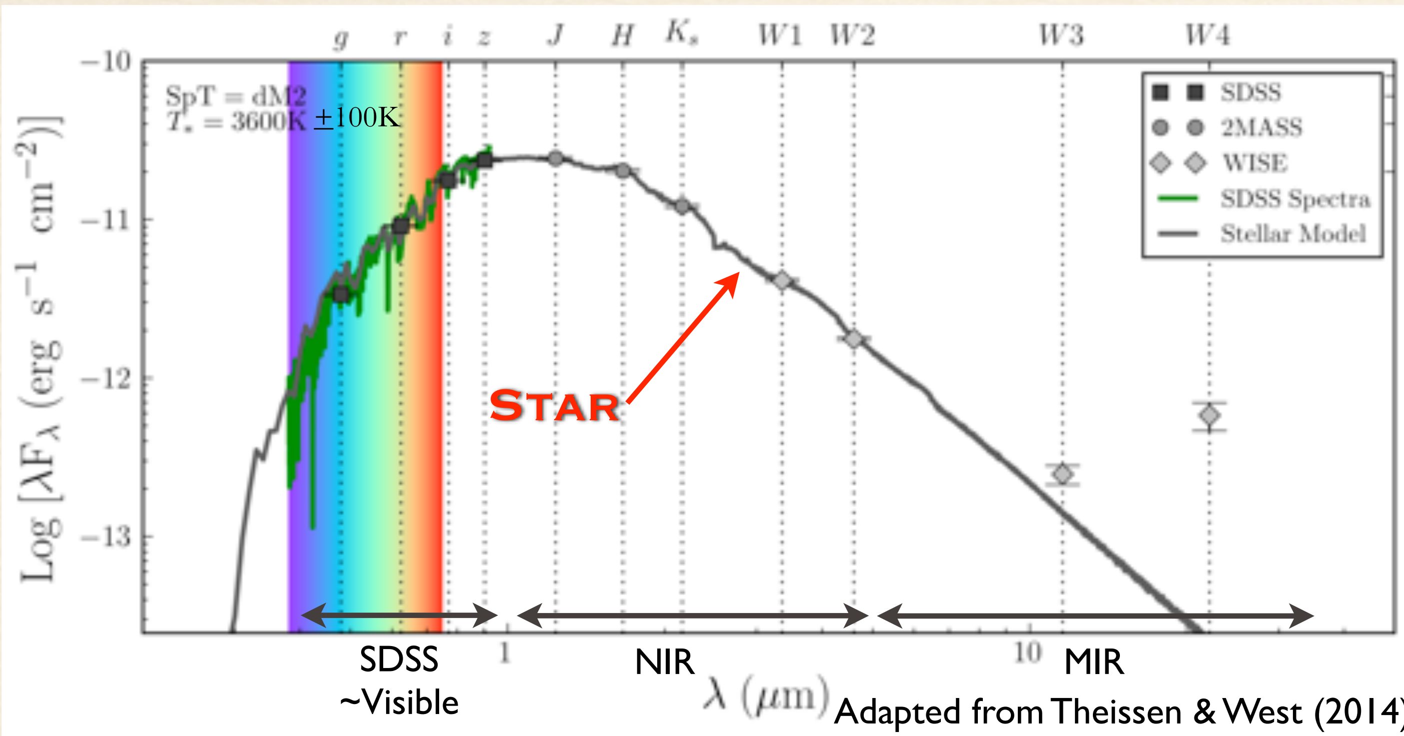

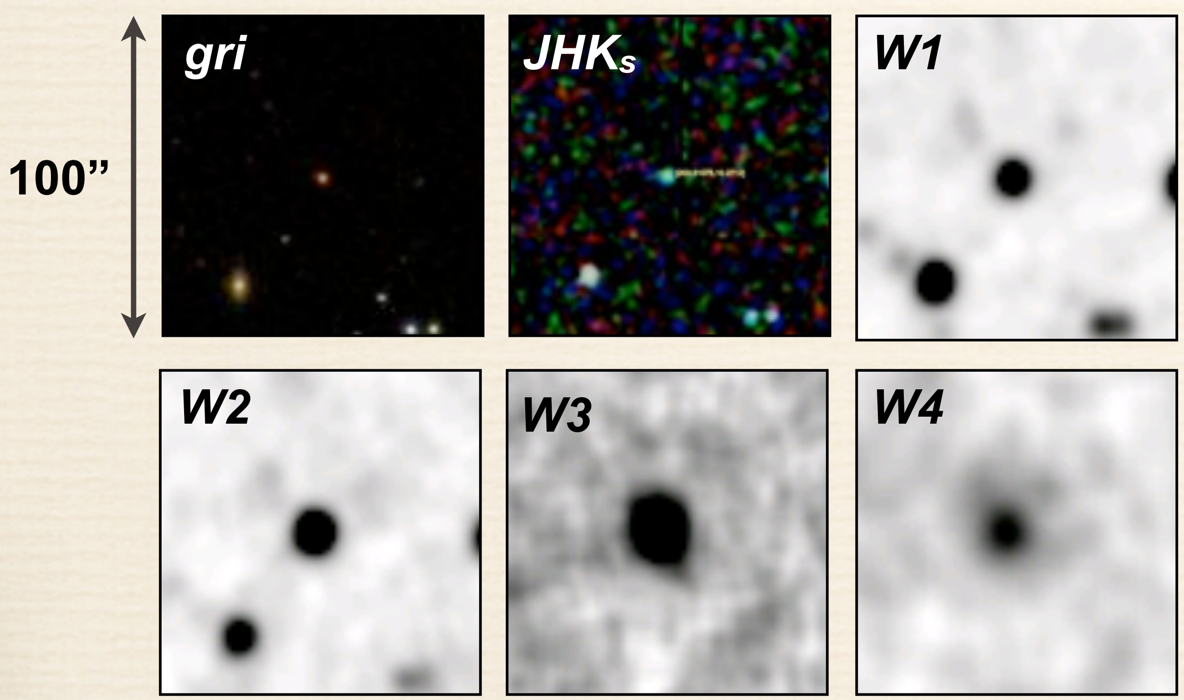

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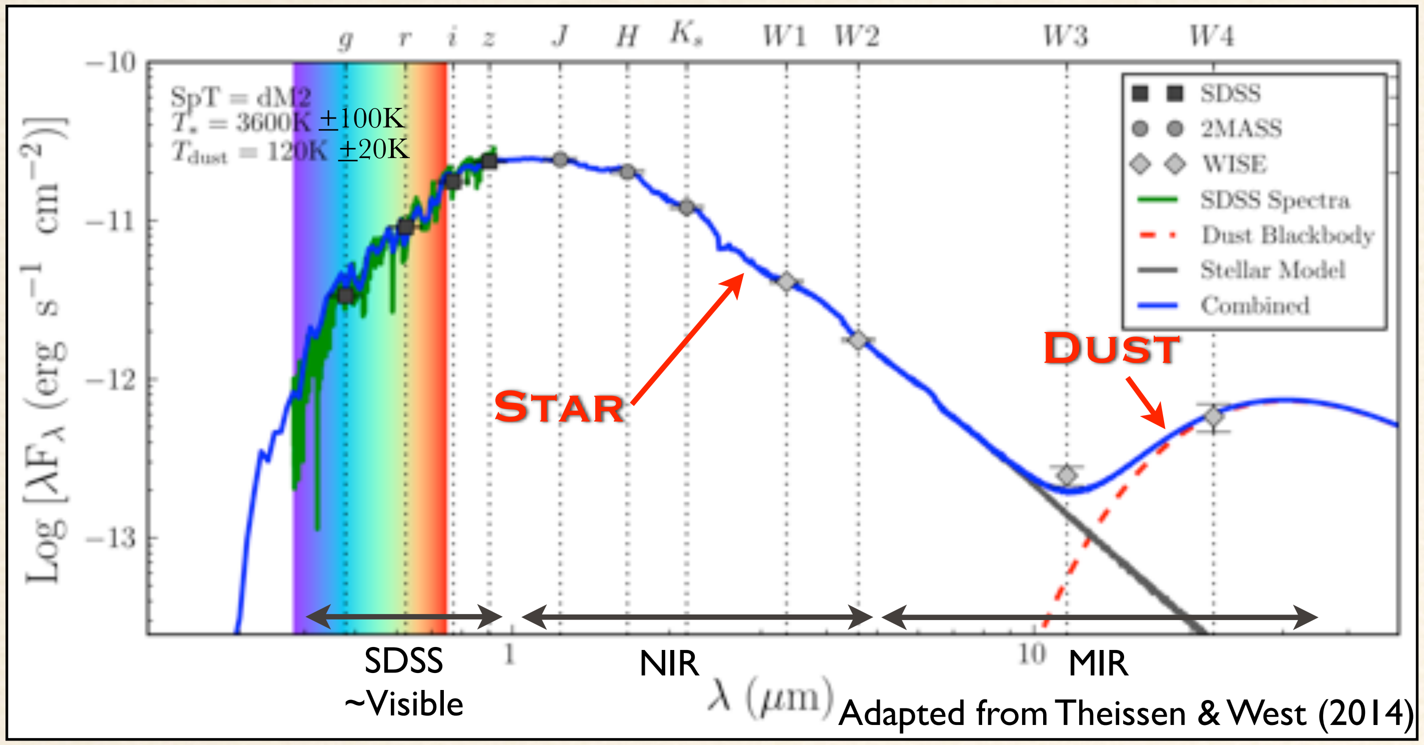

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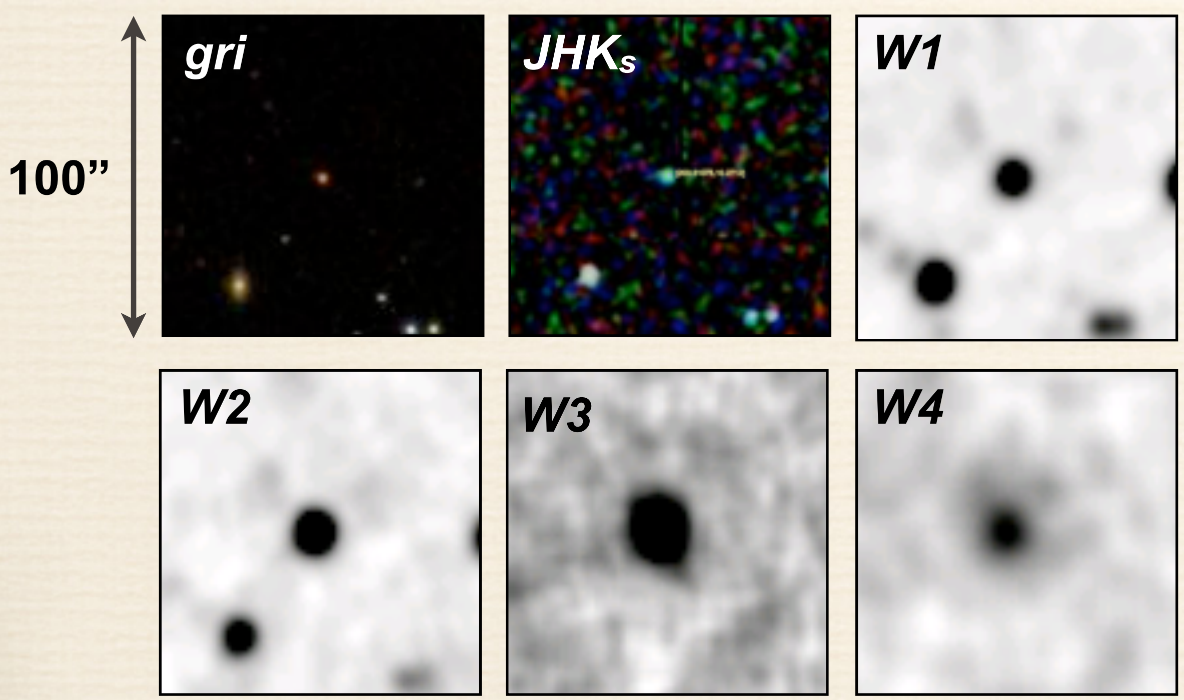

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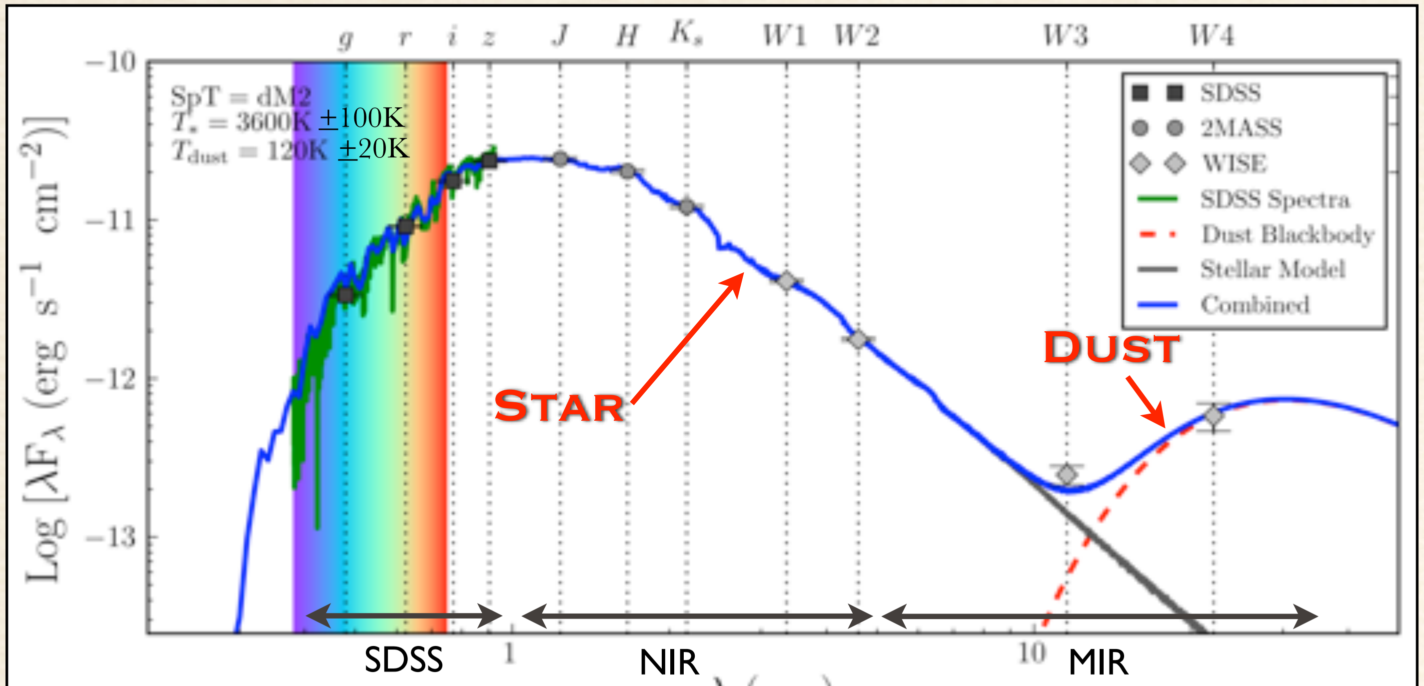

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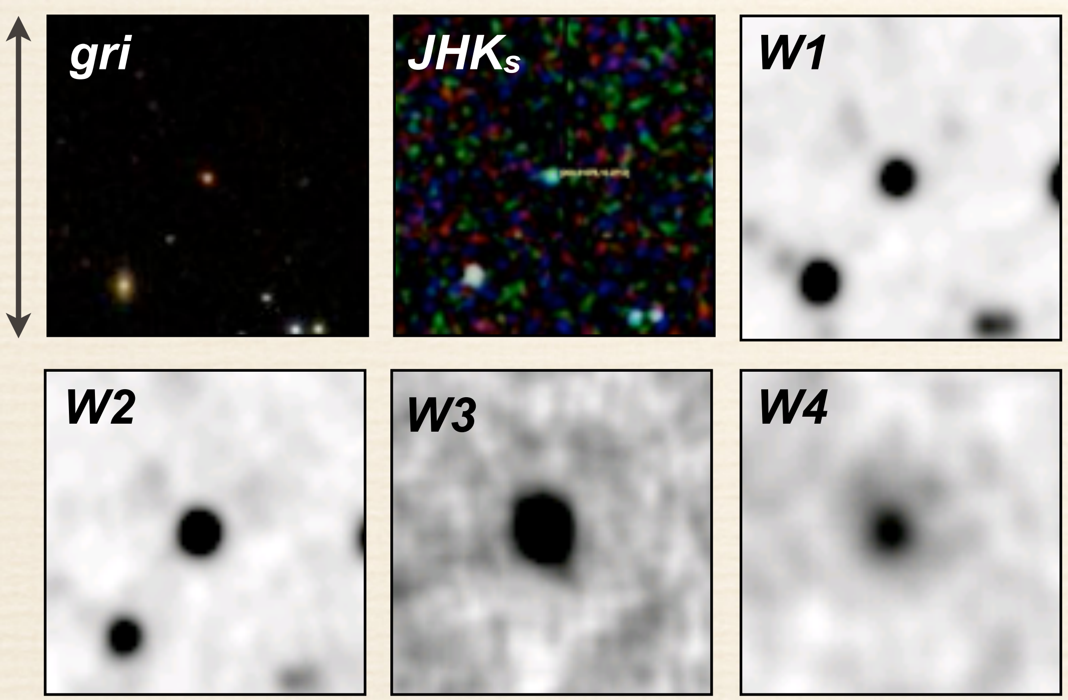
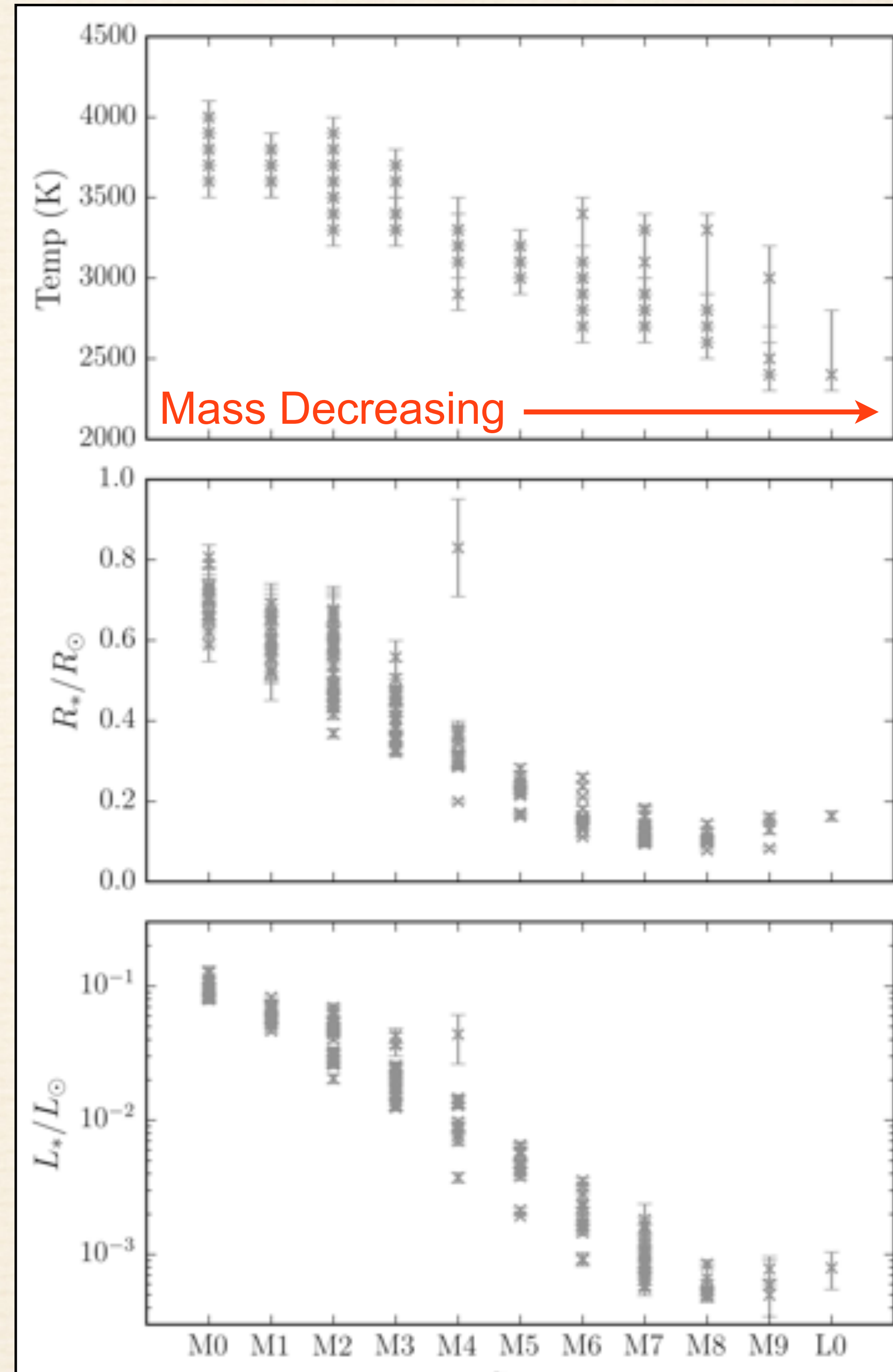
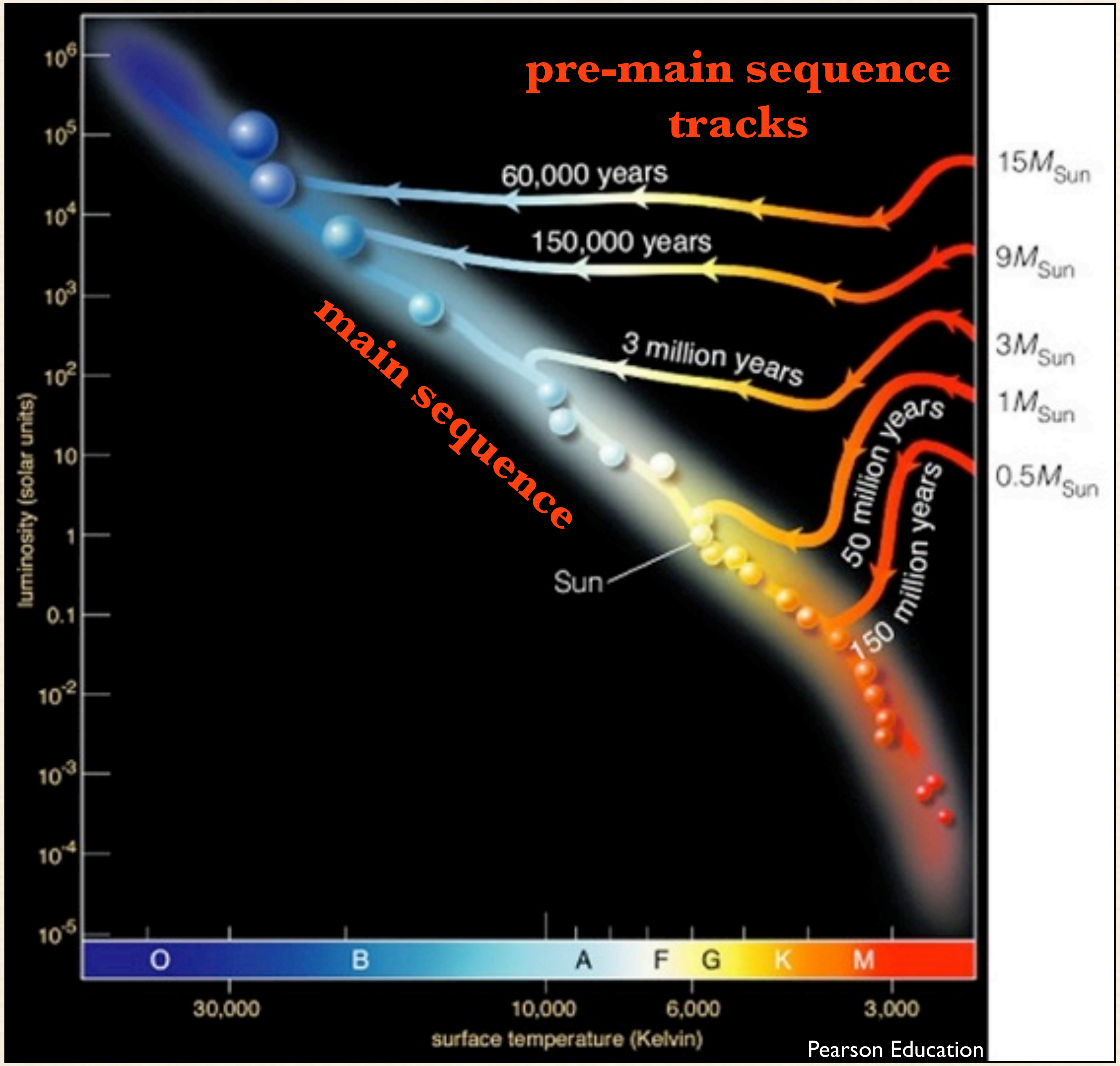
100”





Theissen & West (2014)

Aging a Star:
Part 1: Surface Gravity aka log(g)



Wednesday, July 22, 15

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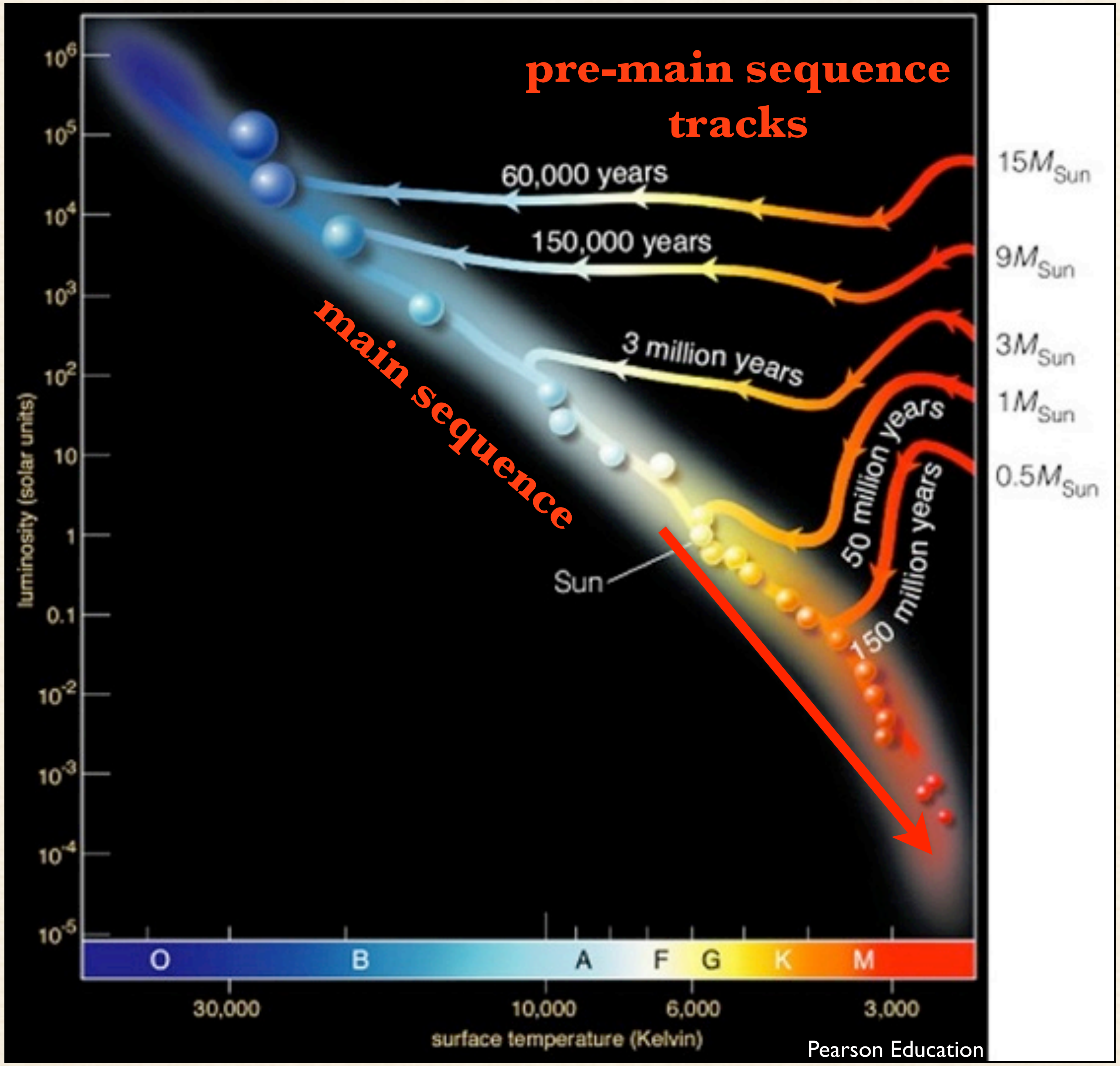

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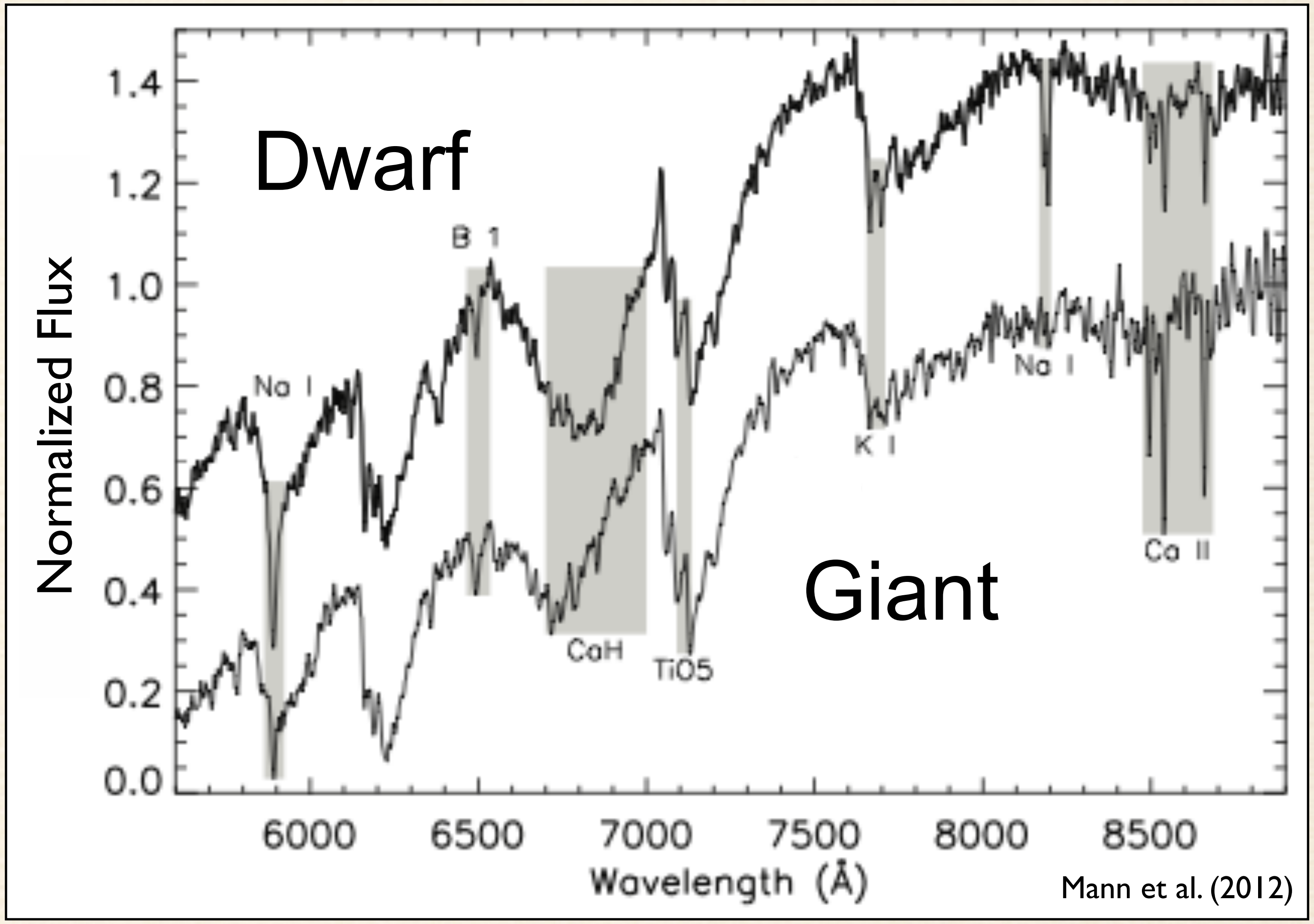

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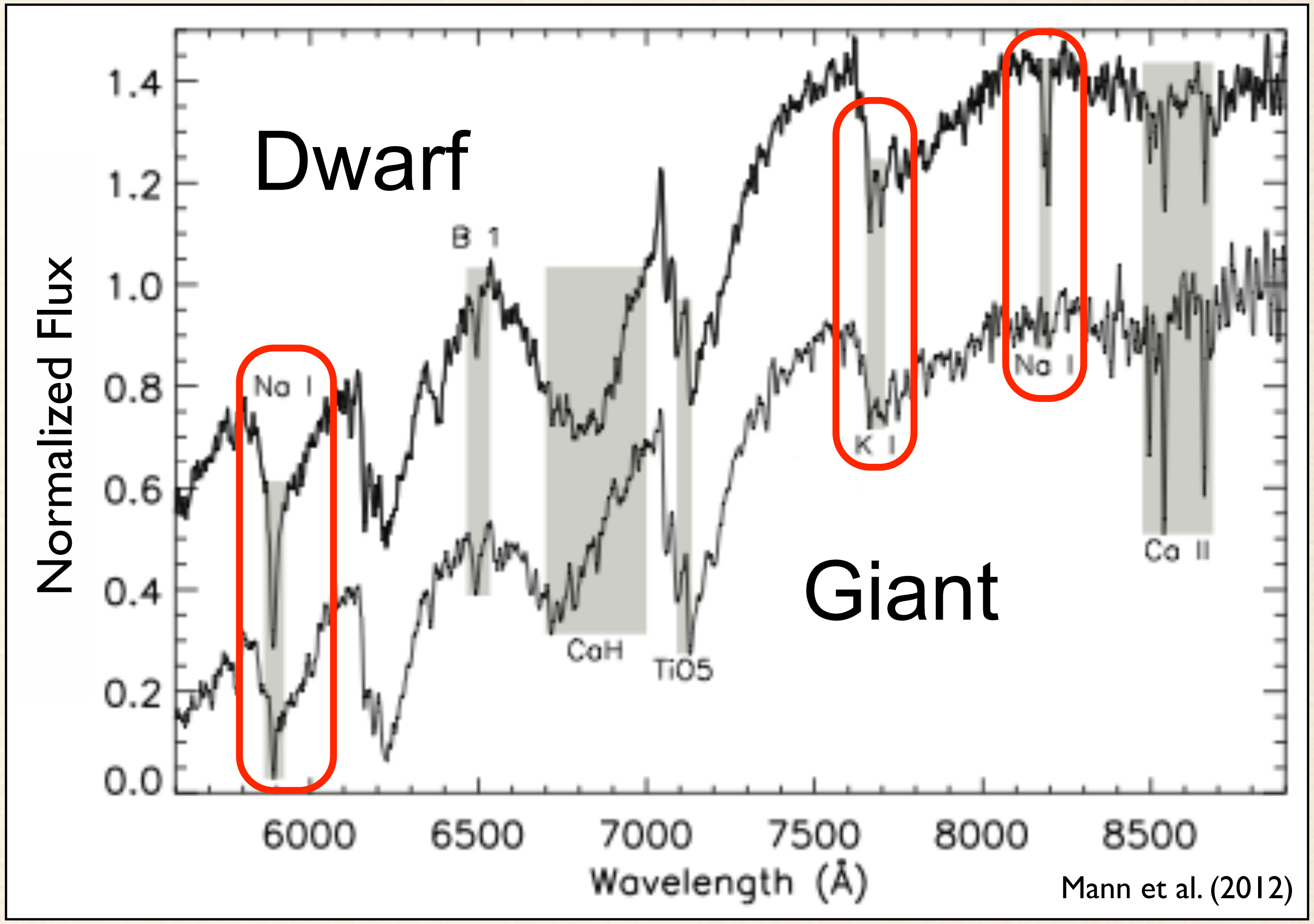

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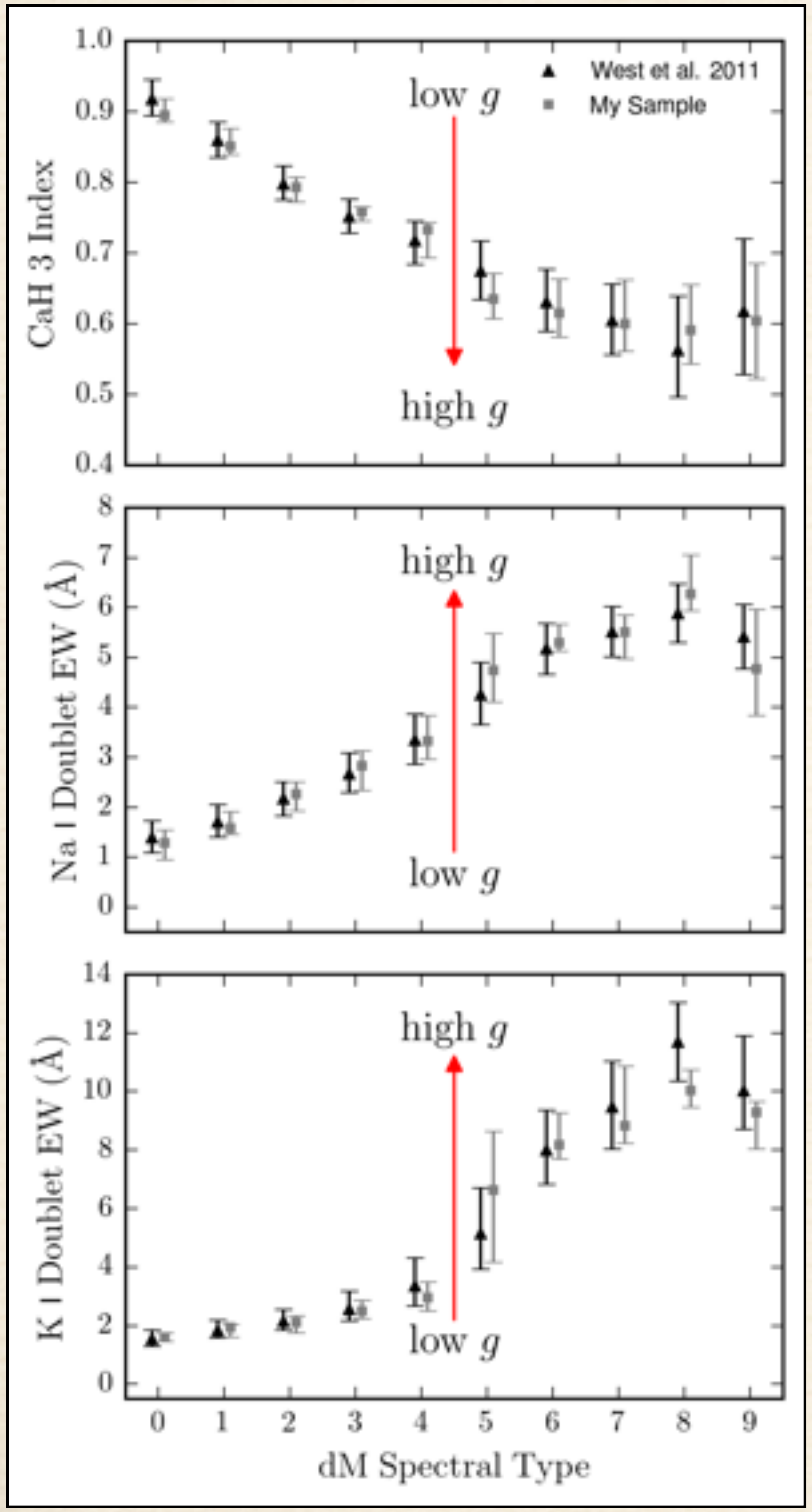

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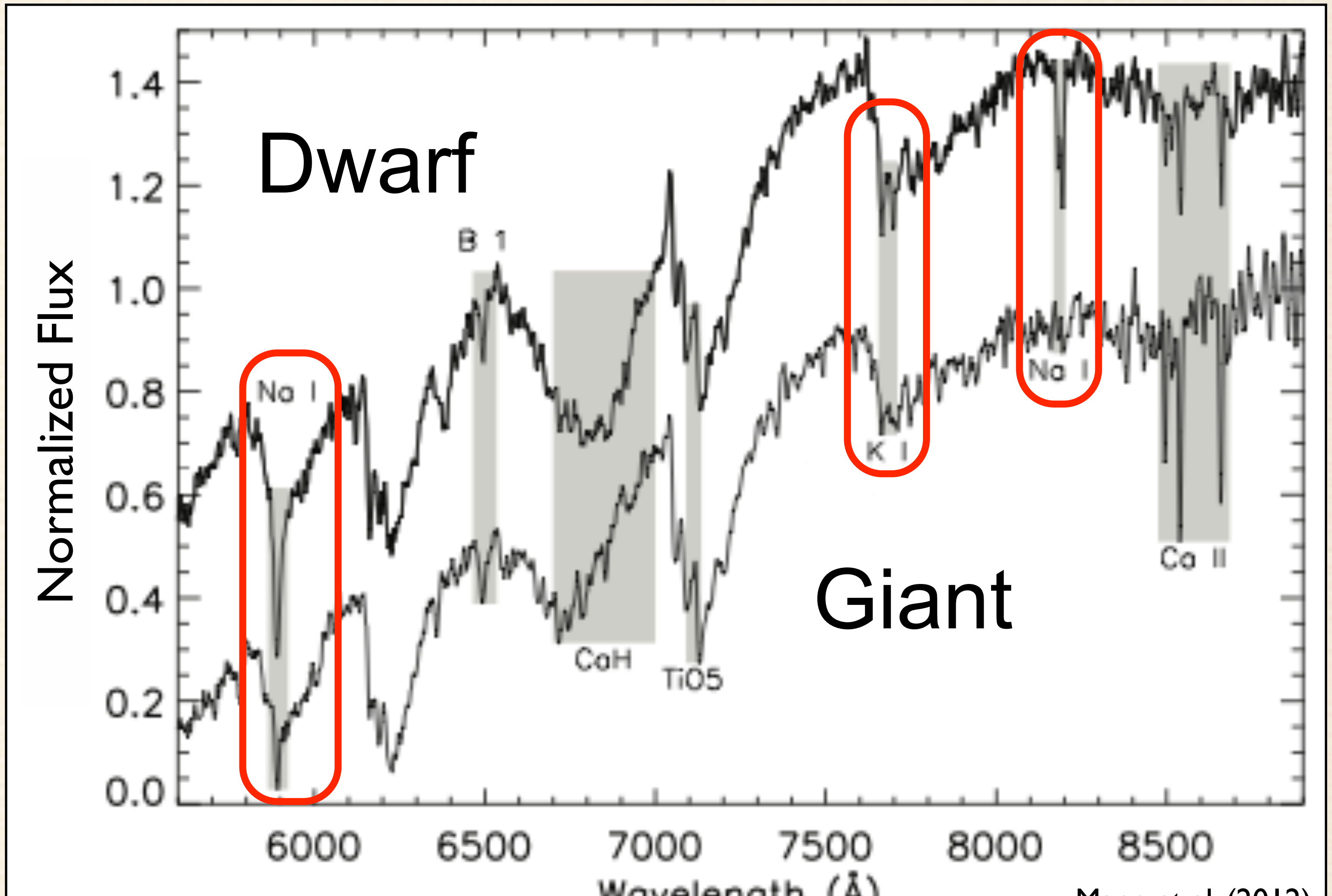
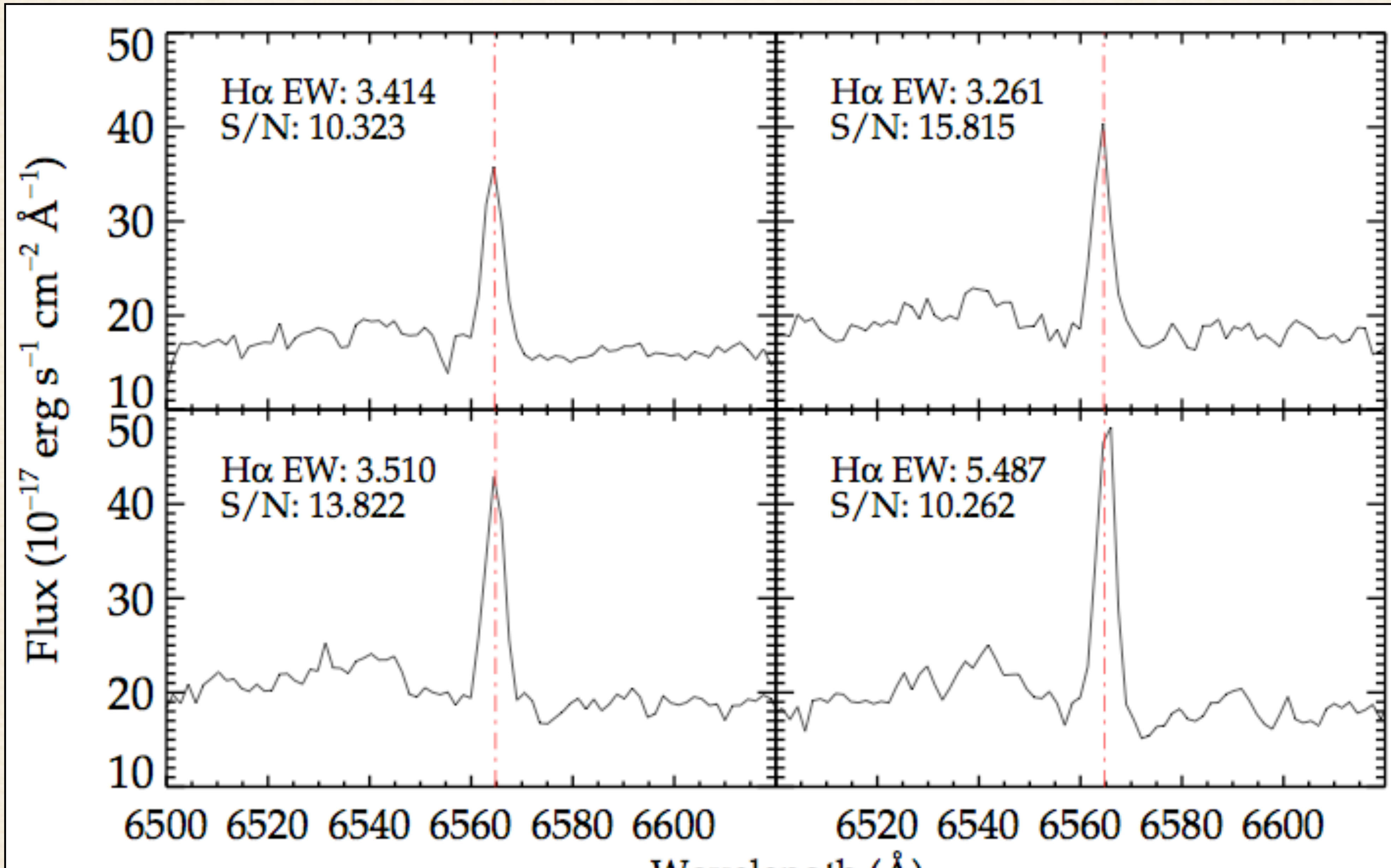


Mann et al. (2012)

Aging a Star:
Part 2: Hydrogen Balmer emission



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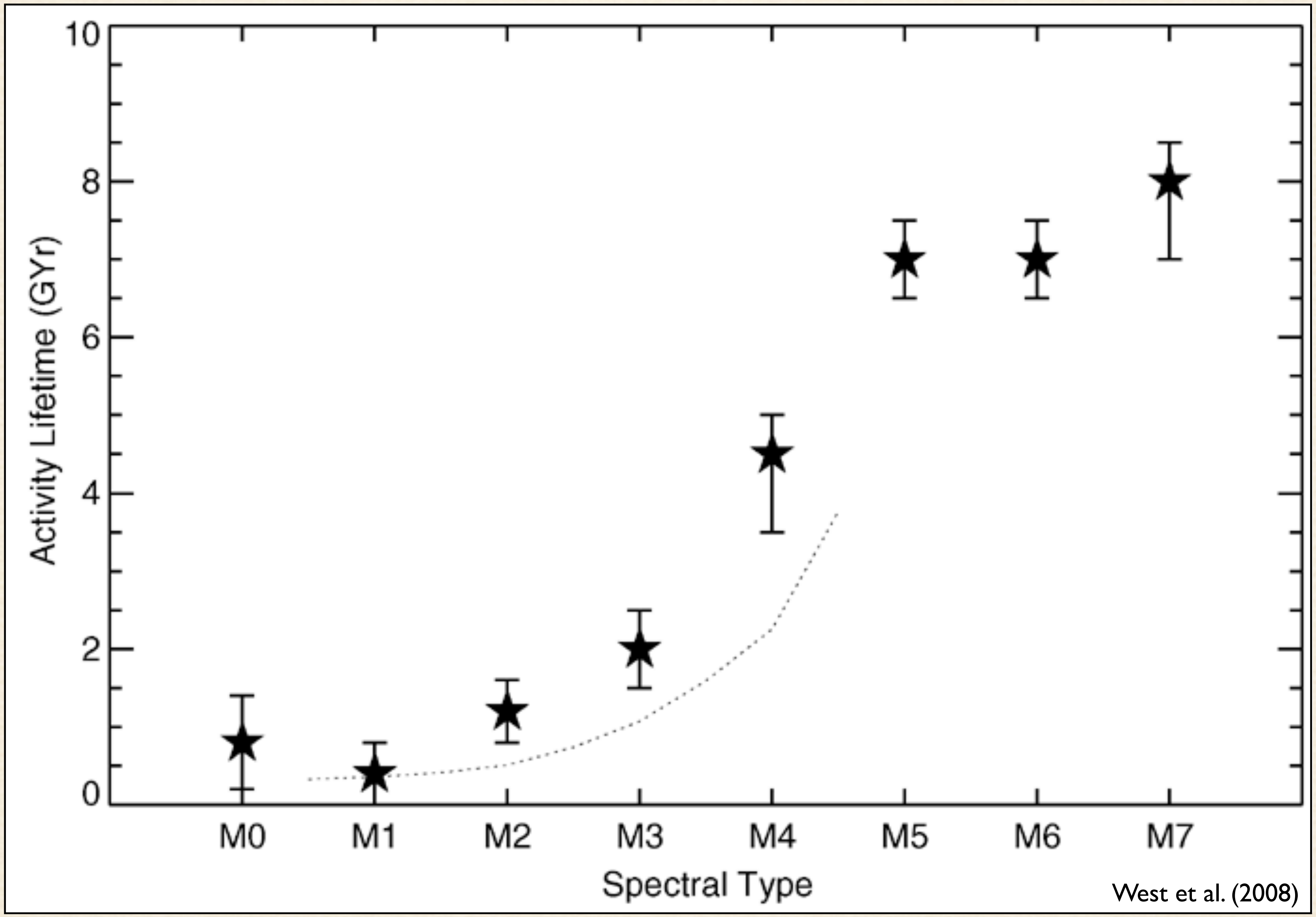

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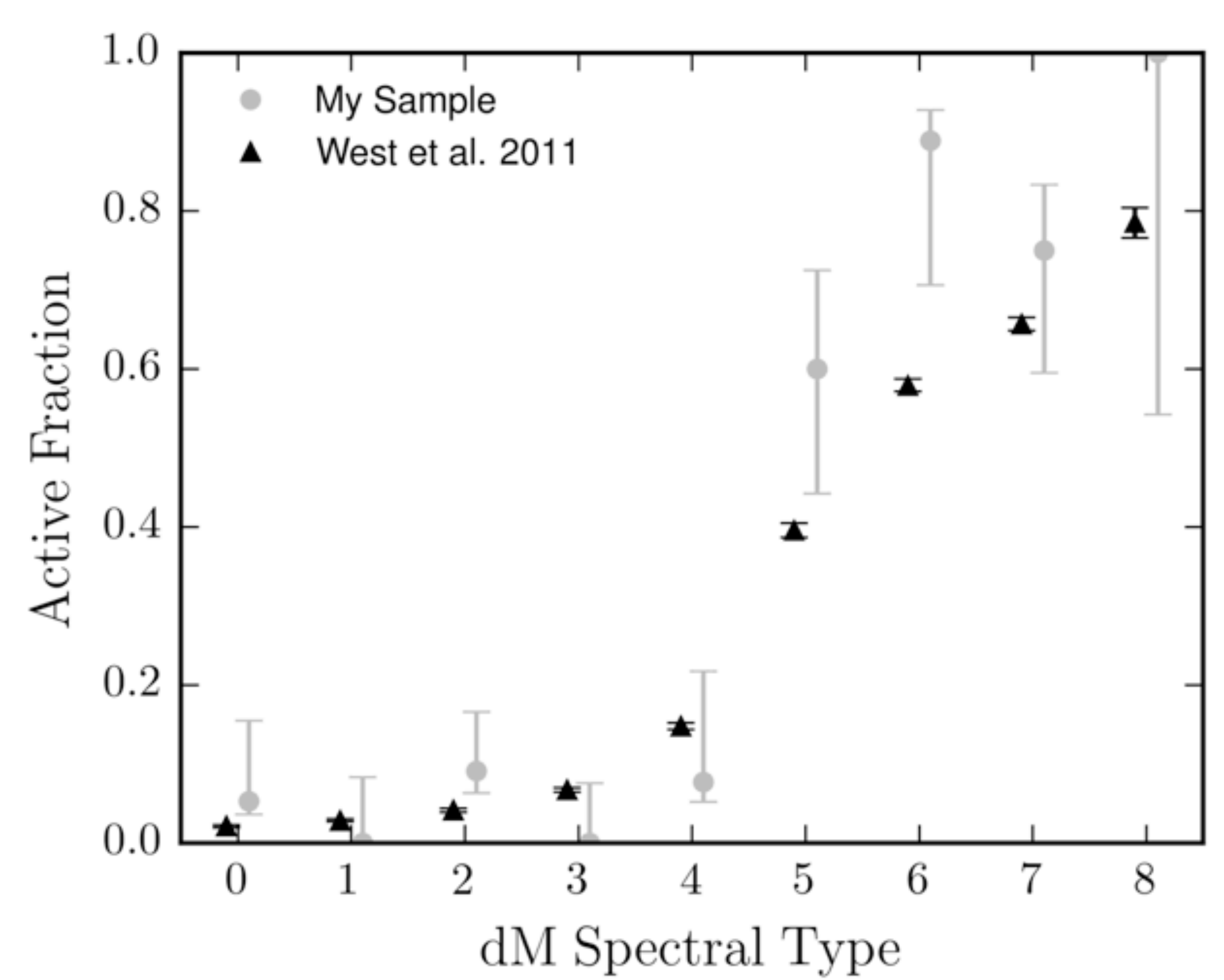

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Motivating Questions

- What is the timescale for disk dispersal around low-mass stars?
  - Multiple mechanisms play an important role in removing disks around stars. What are the dominant dispersal mechanisms for low-mass stars, and how does that affect their disk evolution?

We don't have the ability to probe ages < 100 Myr, but the majority of our stars appear to have ages > 1 Gyr.

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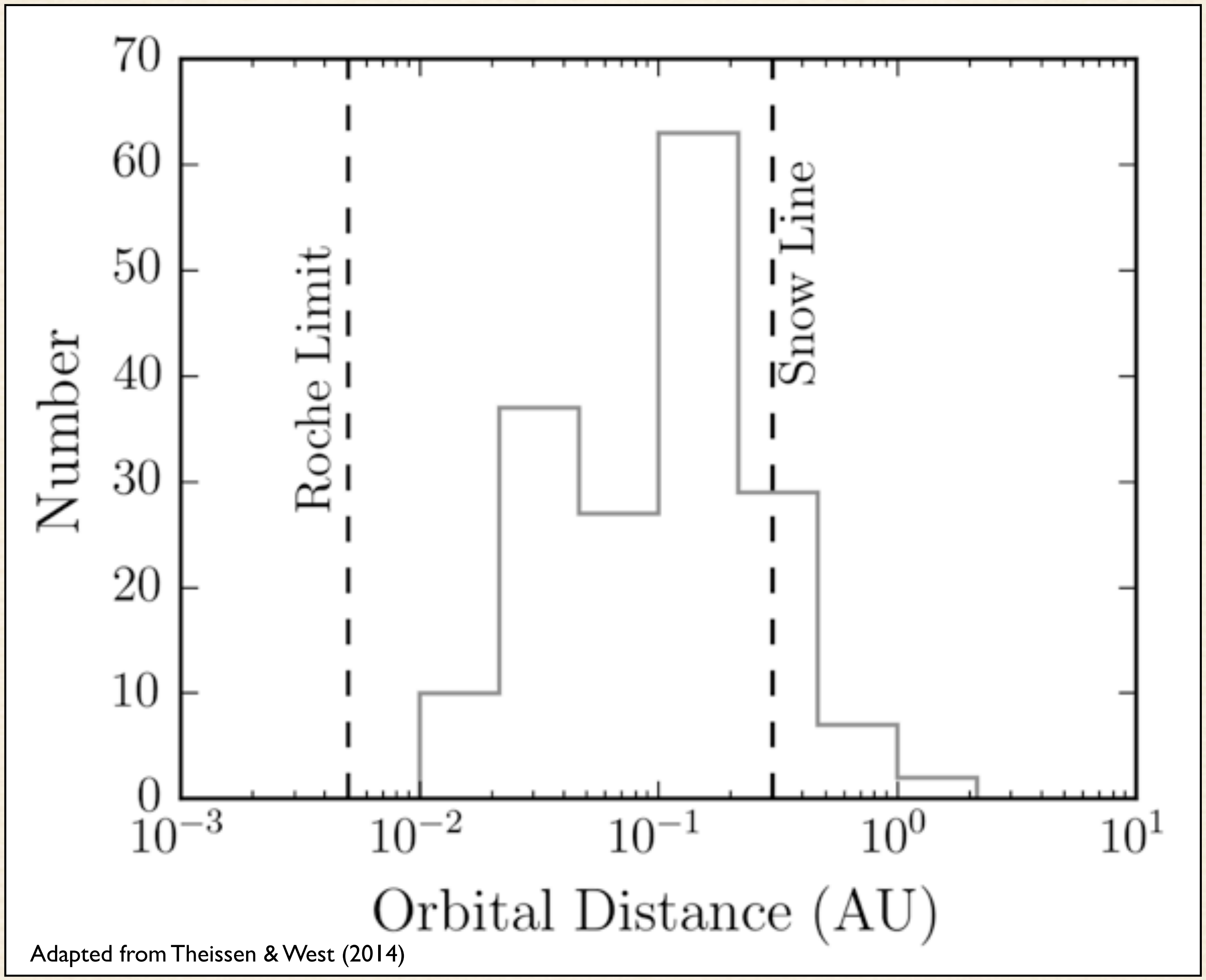
  - Formation theories suggest that field stars should have already dispersed their primordial disks.

Simple Disk Modeling



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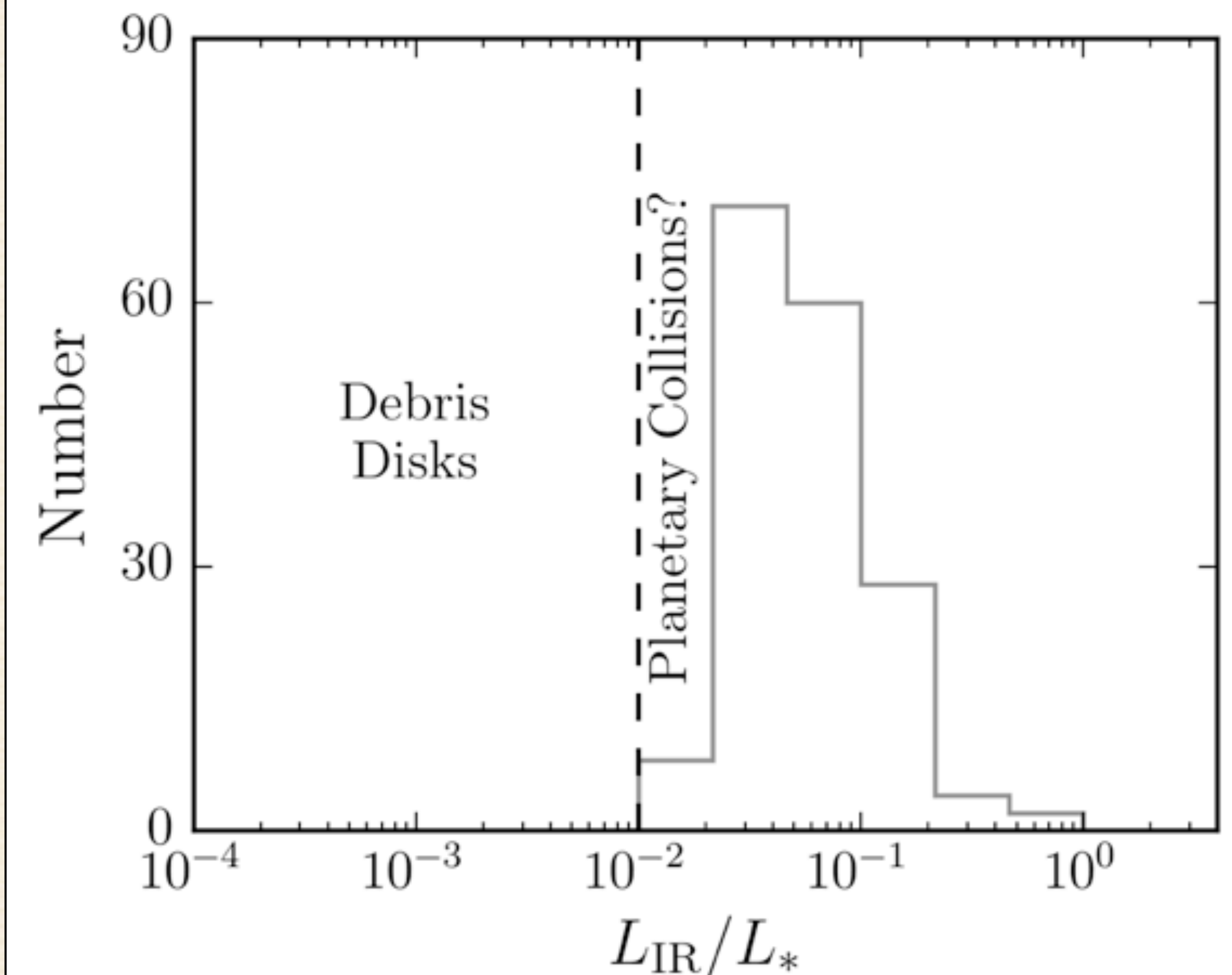

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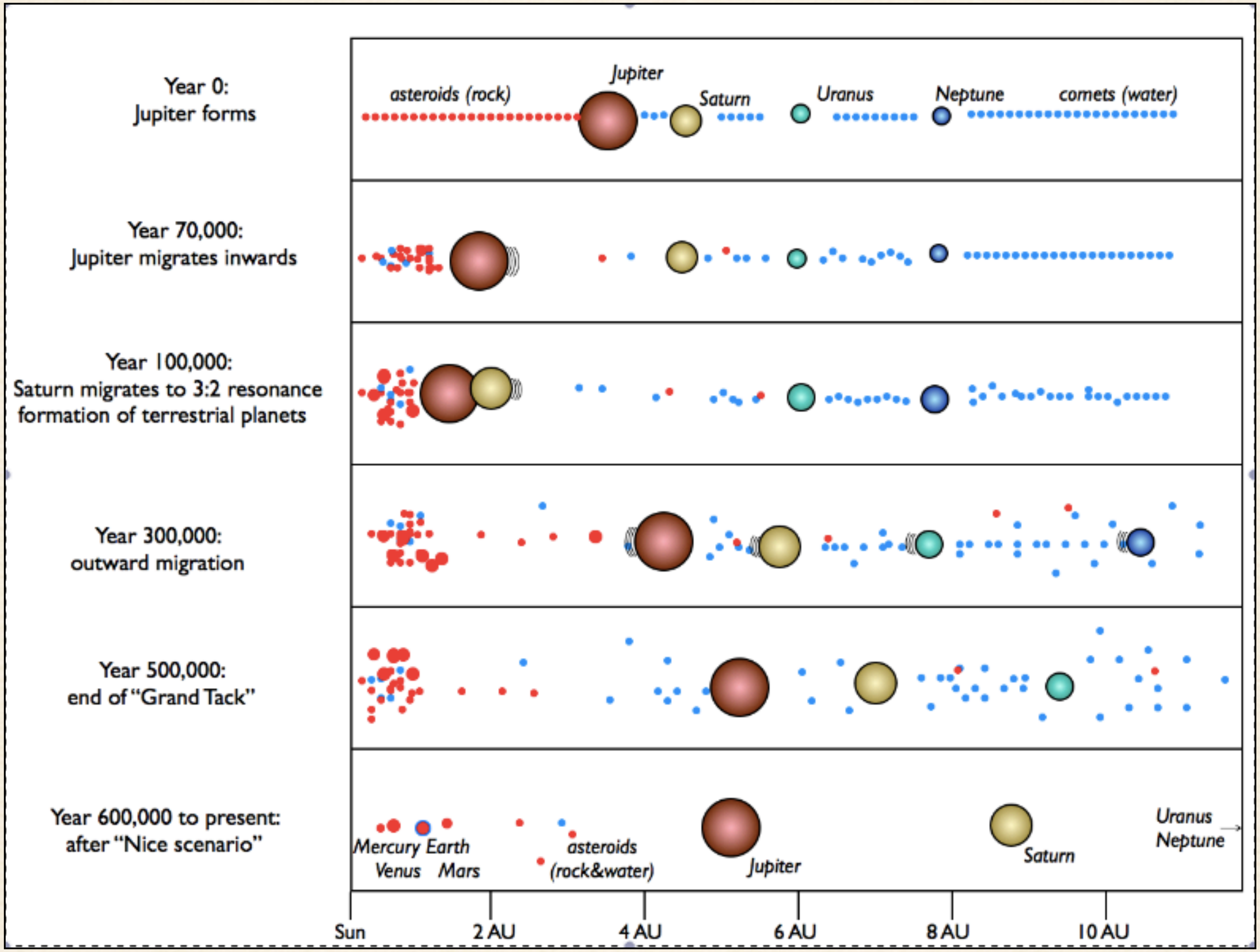
Possible Clues Leading to Collisions - The Grand Tack Scenario



Adapted from Walsh et al. (2013)

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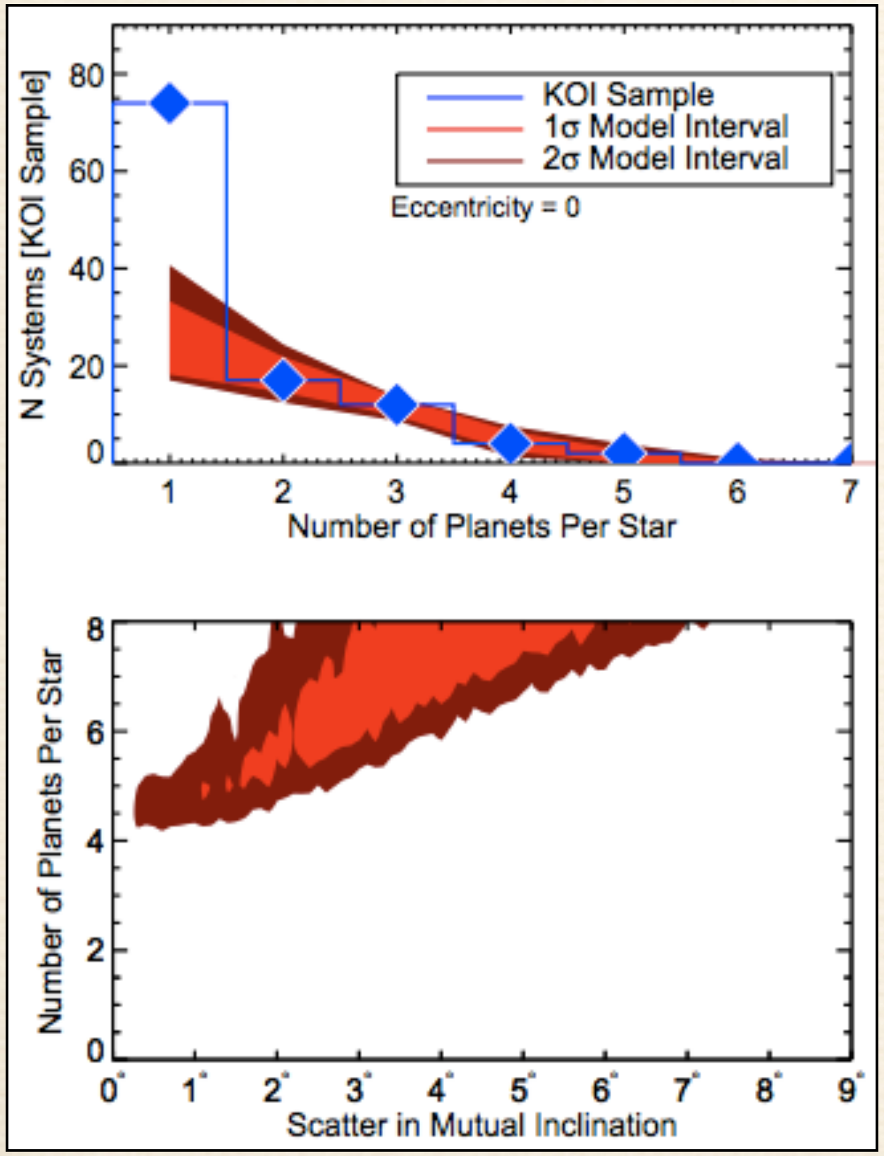

Ballard & Johnson (2014)

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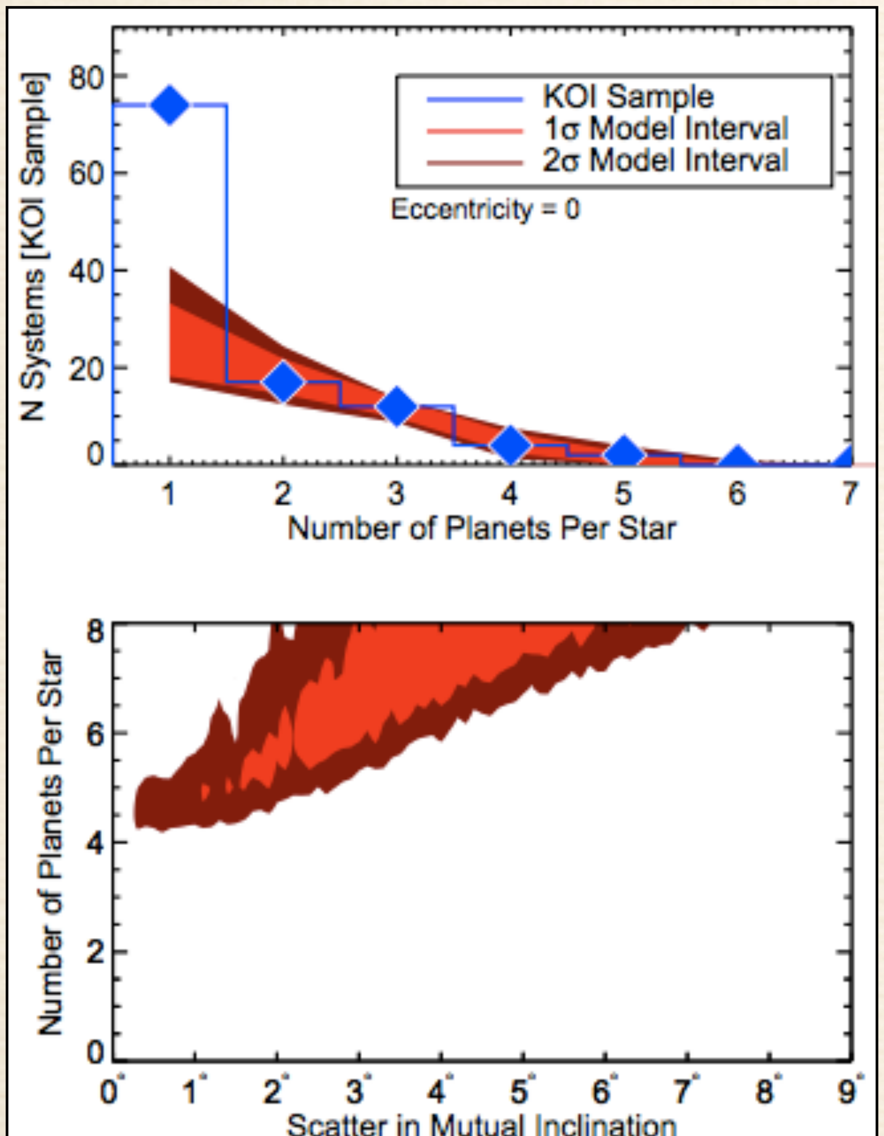


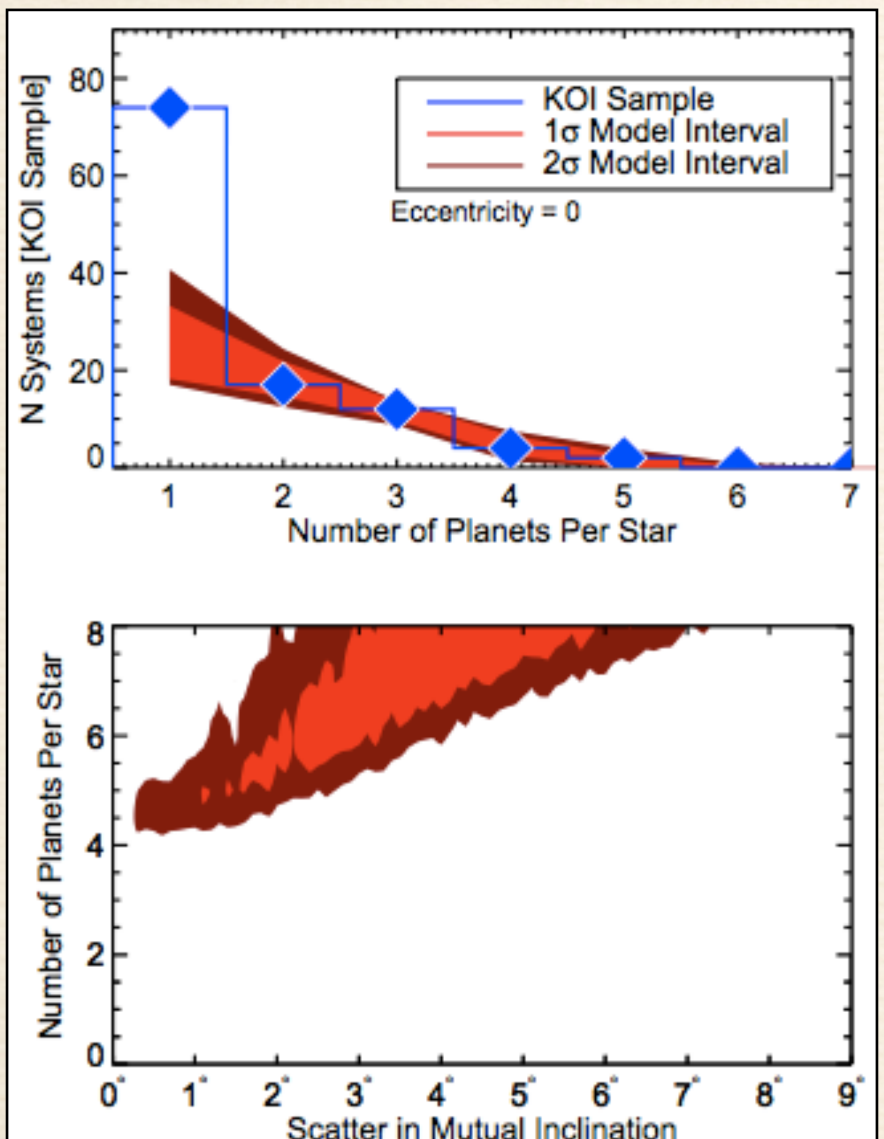
Ballard & Johnson (2014)

Singles	Multis
slower stellar rotation rates	faster stellar rotation rates
farther from the Galactic plane	closer to the Galactic plane

Possible Clues Leading to Collisions - The *Kepler* Dichotomy

Kepler has found lots of multi-transiting and single-transiting planetary systems.

- Both populations cannot be explained by the same planetary architecture (Ballard & Johnson 2014).



Ballard & Johnson (2014)

Singles (Older?)	Multis (Younger?)
slower stellar rotation rates	faster stellar rotation rates
farther from the Galactic plane	closer to the Galactic plane

Motivating Questions

- What is the timescale for disk dispersal around low-mass stars?
  - Multiple mechanisms play an important role in removing disks around stars. What are the dominant dispersal mechanisms for low-mass stars, and how does that affect their disk evolution?
- What are the possible causes of warm dust around field stars?
  - Formation theories suggest that field stars should have already dispersed their primordial disks.
- How frequently do we see warm dust around low-mass field stars?
  - Potential effects on the formation of (exo-)planetary systems and habitability of said systems.

Back of the Envelope

Number of collisional events per star (over the lifetime of stars surveyed), N_g

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$N_g \sim 100$

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Number of collisional events per star (over the lifetime of stars surveyed), N_g

$N_g \sim 100$

For solar-type stars, $N_g \sim 0.2$

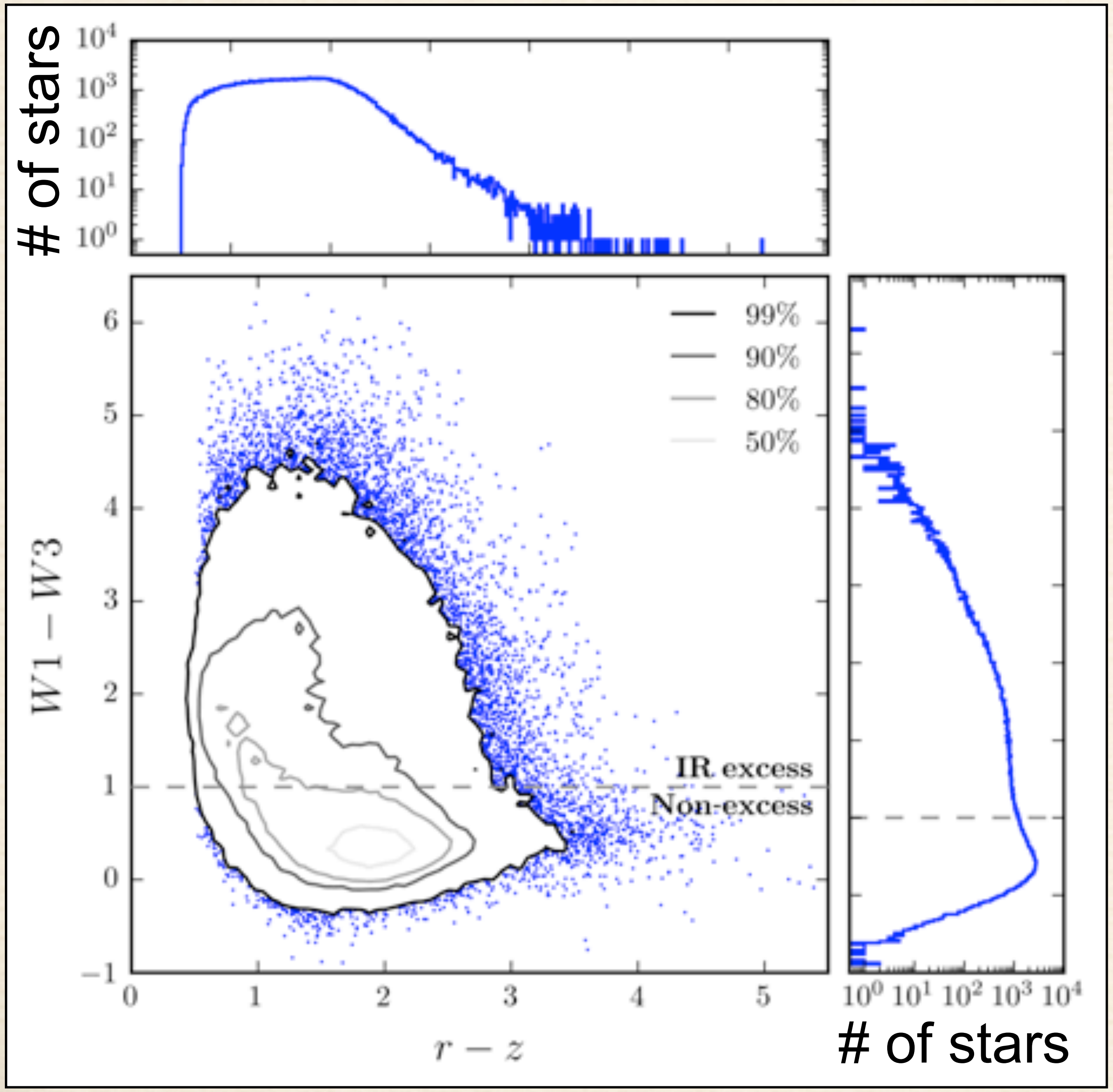
Motivating Questions

- How frequently do we see warm dust around low-mass field stars?
  - Potential effects on the formation of (exo-)planetary systems and habitability of said systems.

Far more frequently than around Solar-type stars. This is possibly due to a higher-number of terrestrial planets formed around low-mass stars, all with close in orbits.

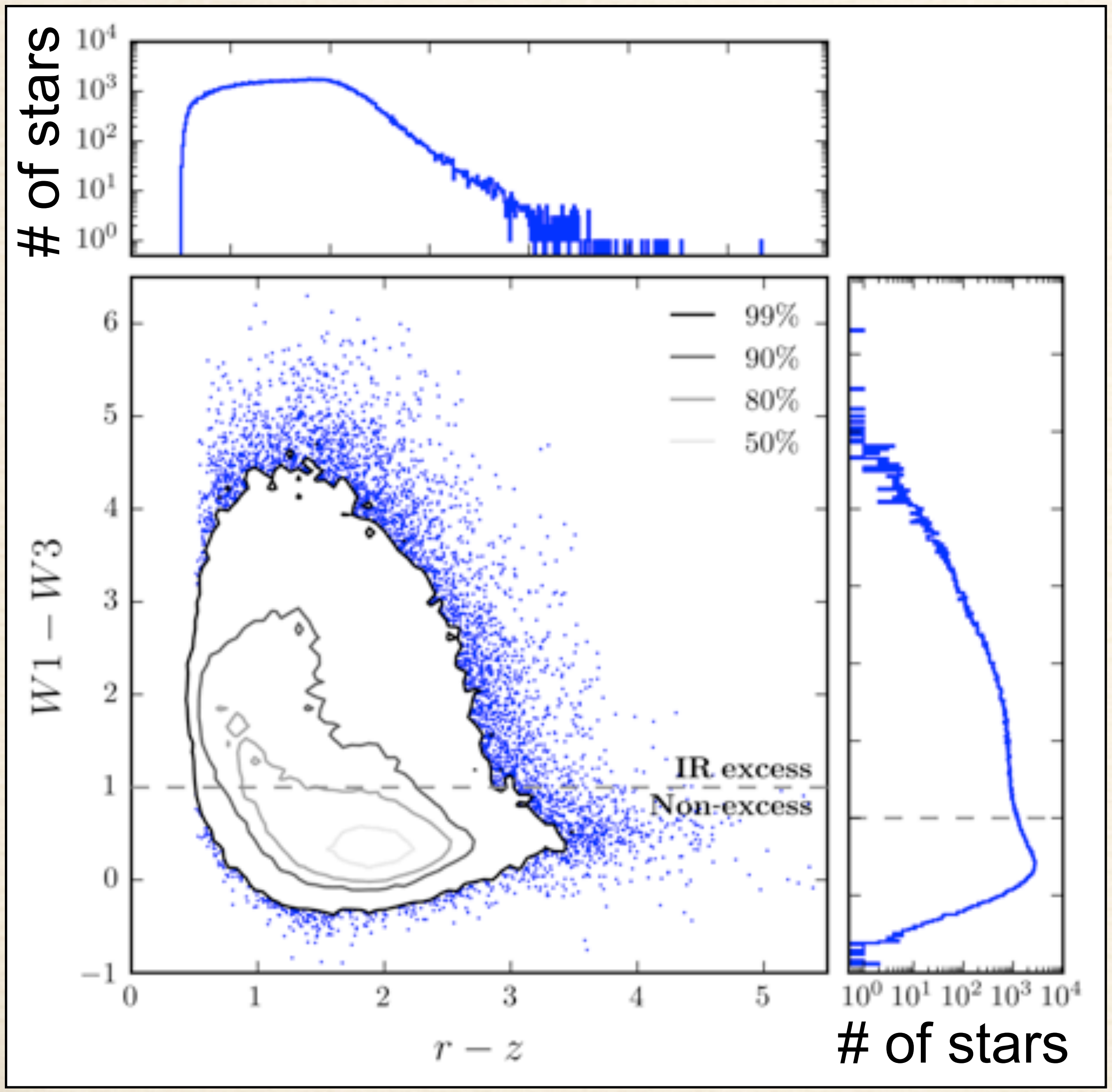
Current & Future Work

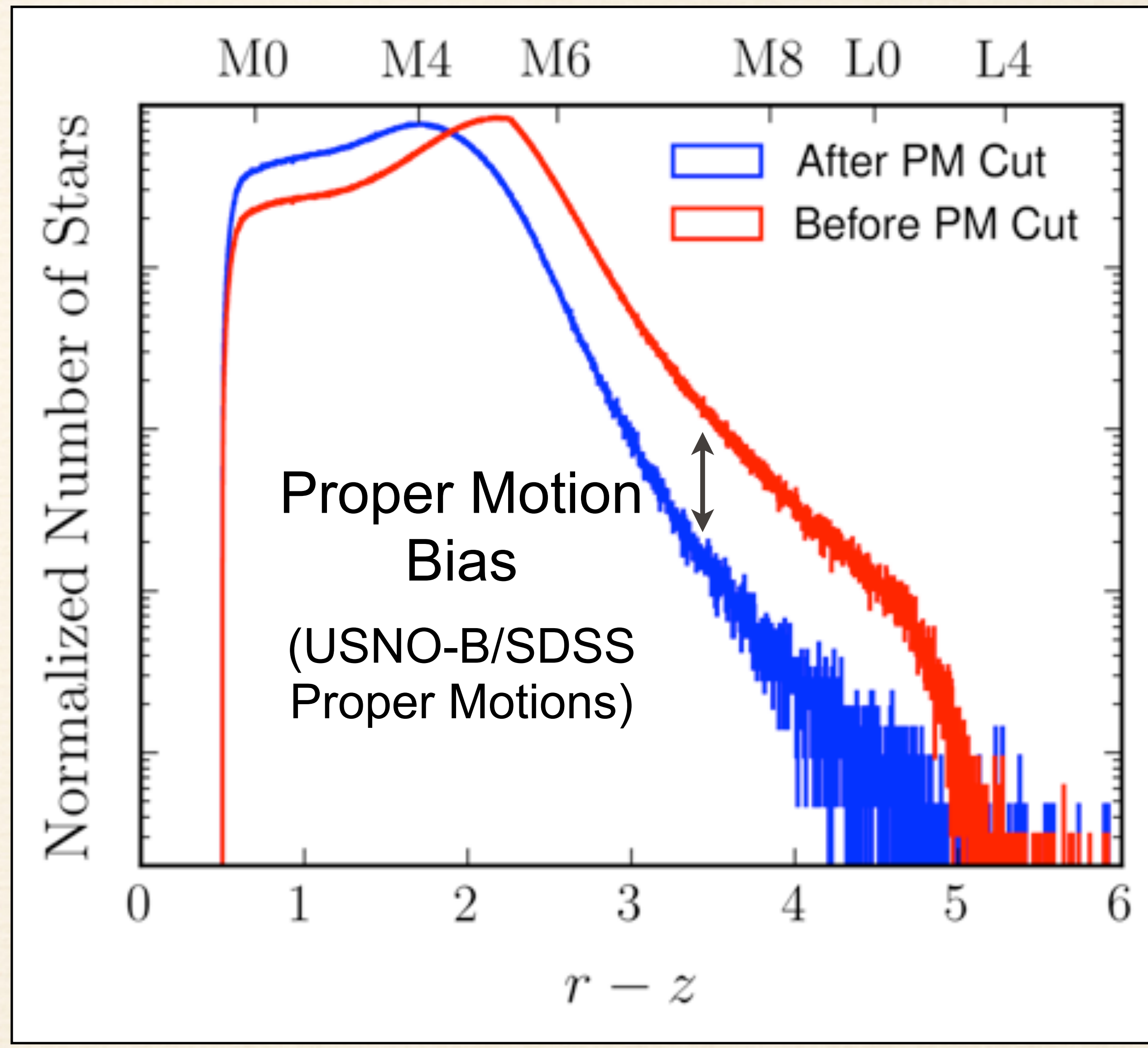
SDSS Data Release 10: Over 50 million photometric M dwarfs!



Current & Future Work

SDSS Data Release 10: Over 50 million photometric M dwarfs!

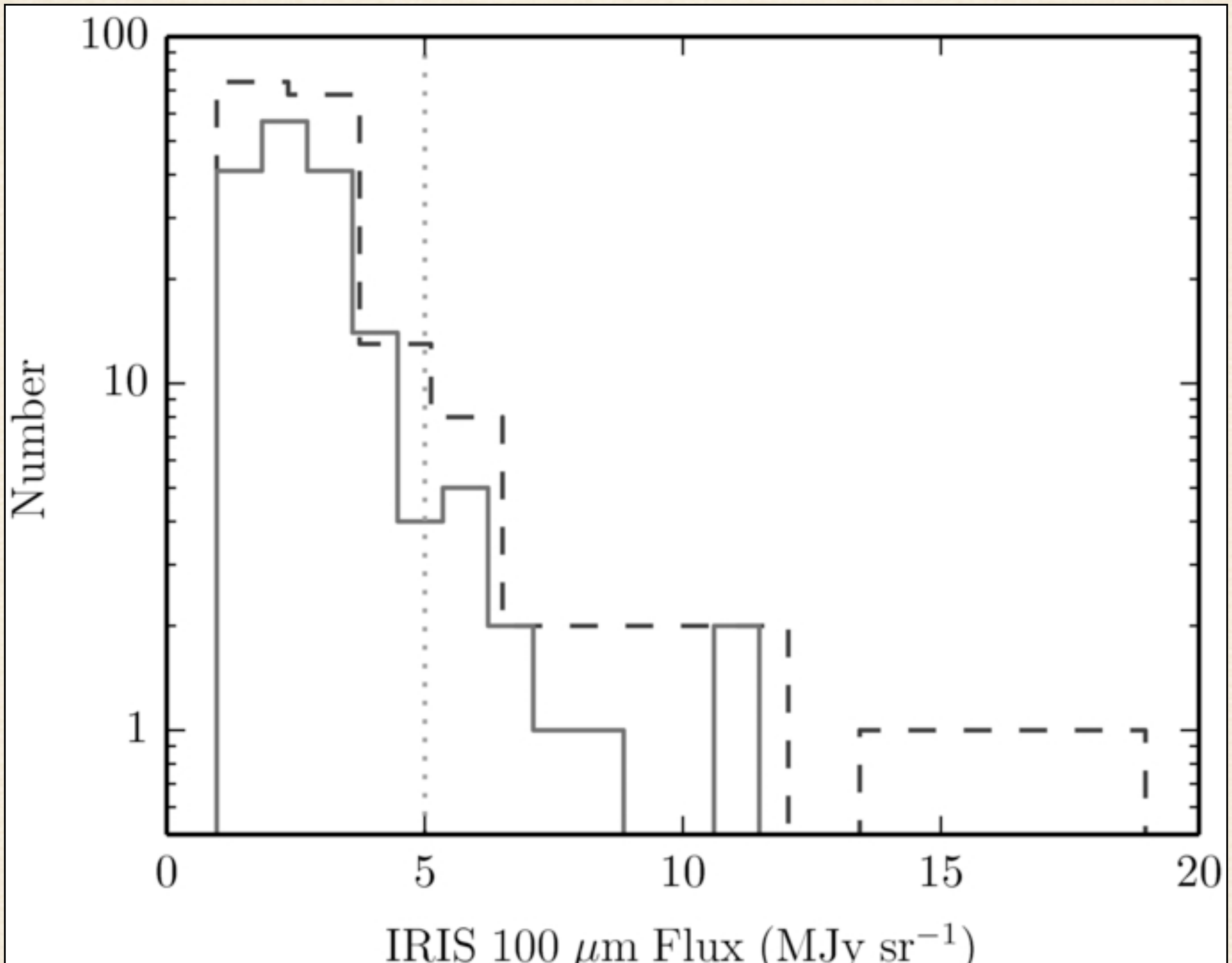




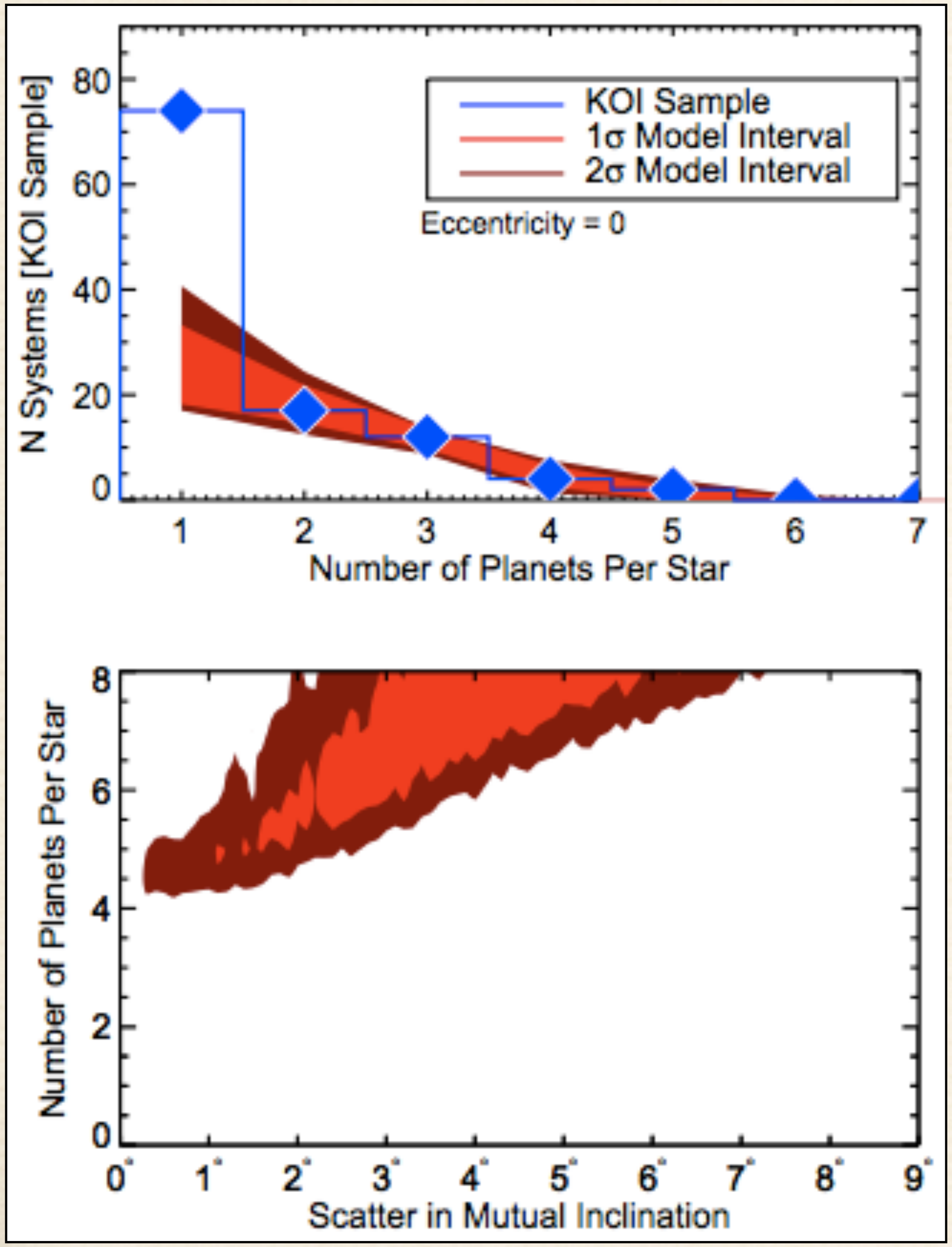
Final Thought

If terrestrial planets around M dwarfs are prone to collisions, this is just one more complication in finding a "habitable" Earth analog around a low-mass star.

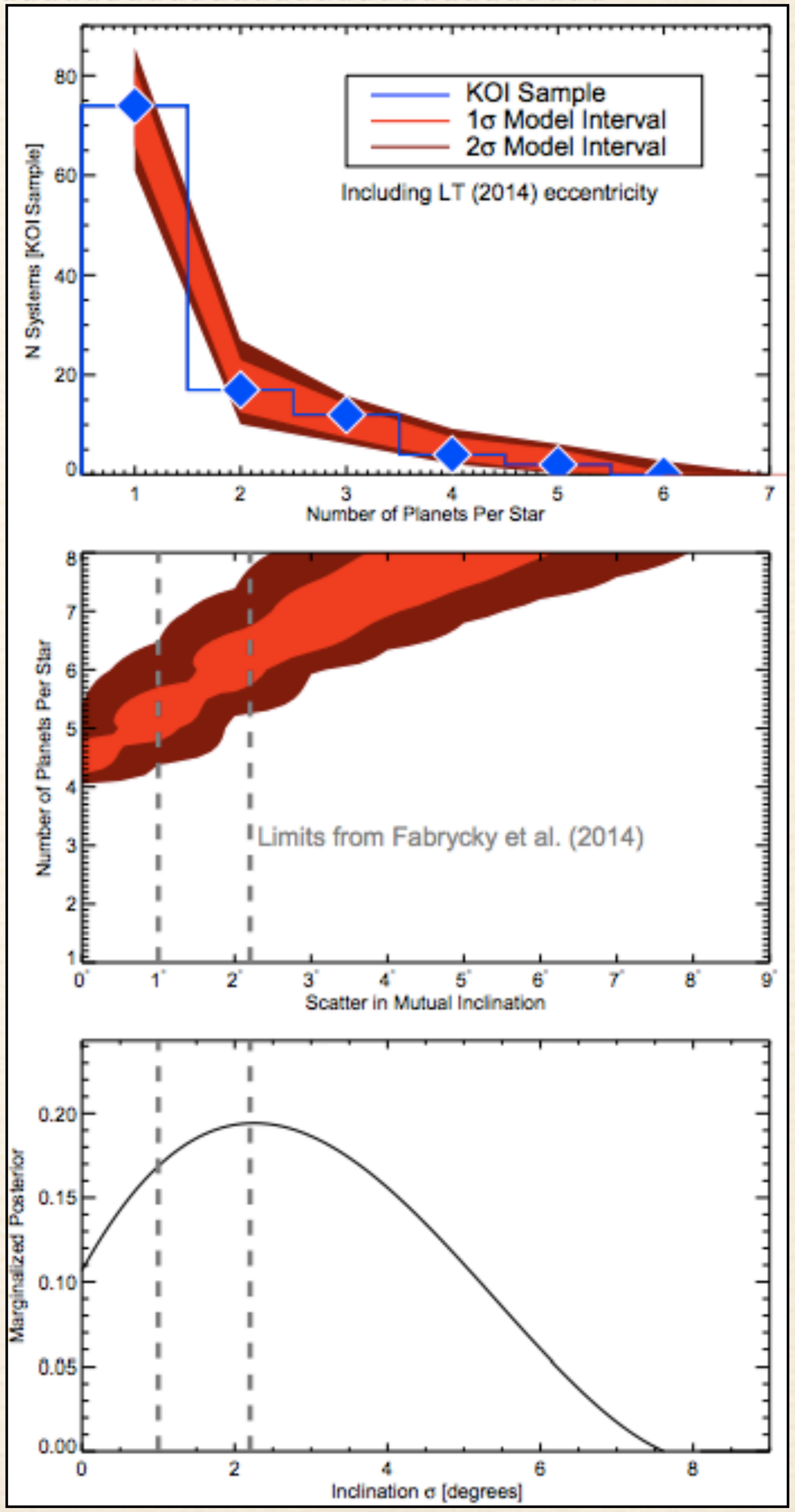
Other Explanations for IR Excess



Possible Clues Leading to Collisions - The *Kepler* Dichotomy (Part 2)



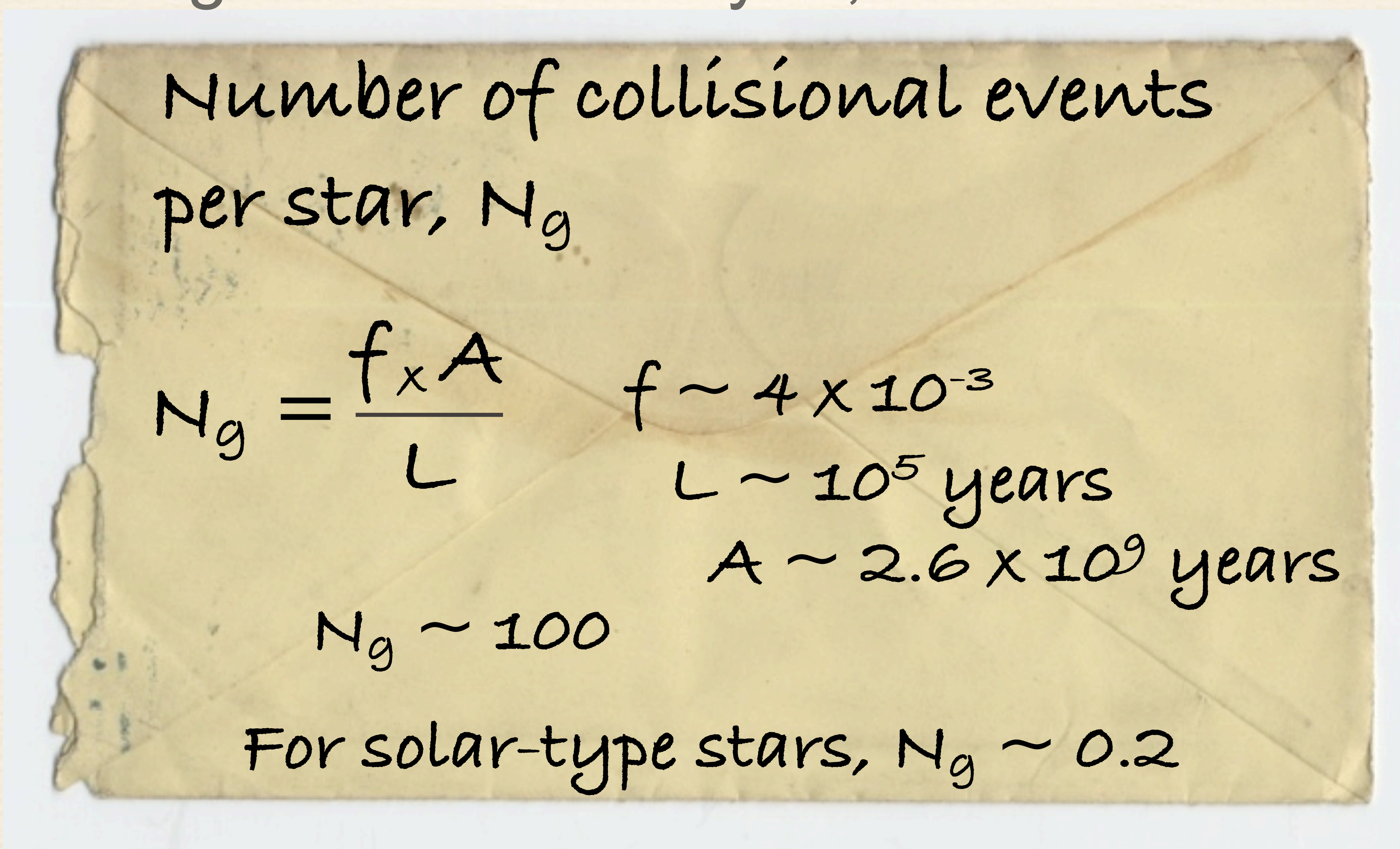
Ballard & Johnson (2014)



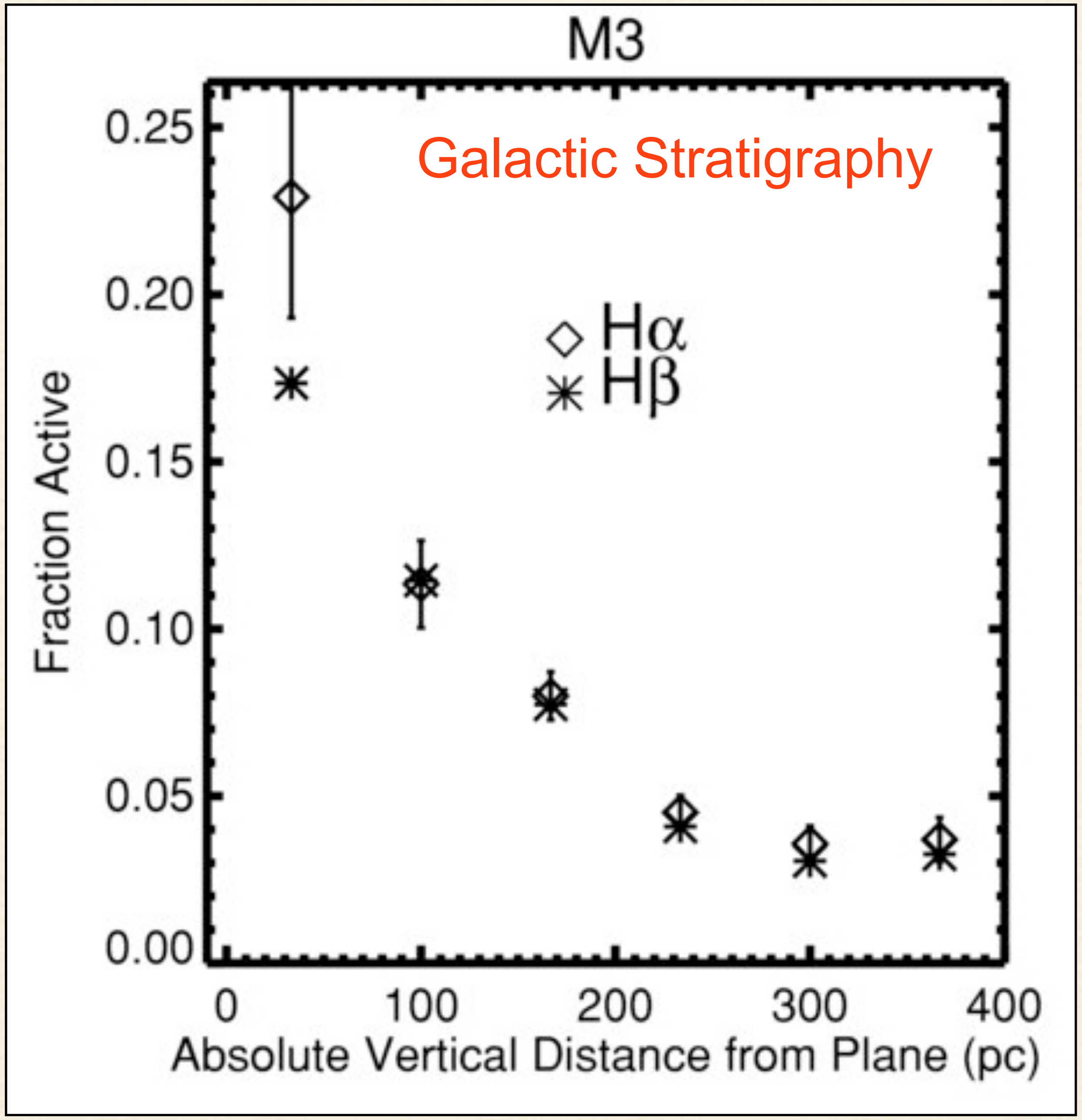
Ballard & Johnson (2014)

Back of the Envelope

Fraction of stars observed with dust, f
Lifetime of collisional products, L
Age of stars surveyed, A



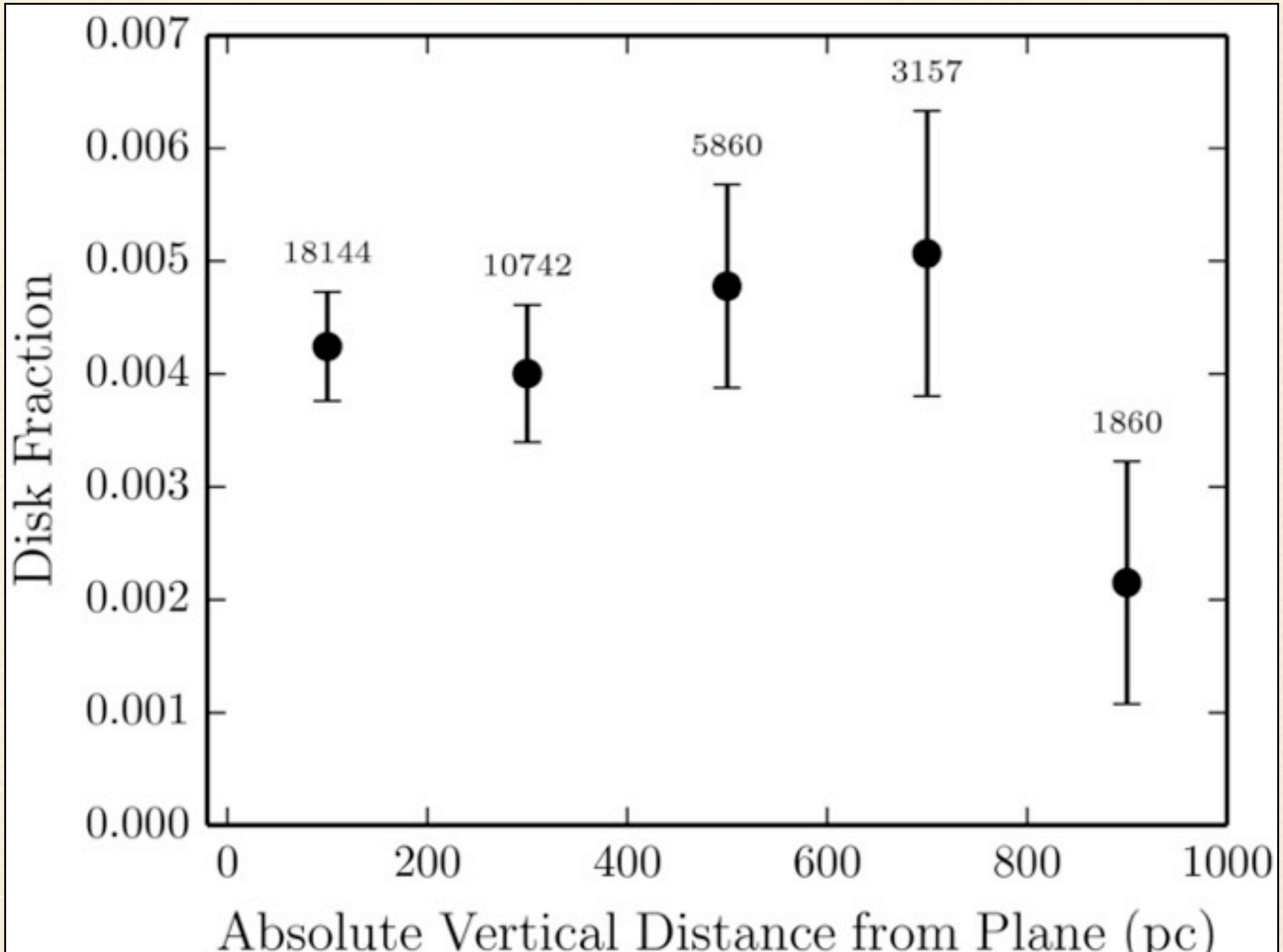
Is There an Age Effect?



Adapted from West et al. (2011)

Is There an Age Effect?

$$\frac{\text{\# stars w/ IR excess}}{\text{Total \# stars}} =$$



Theissen & West (2014)