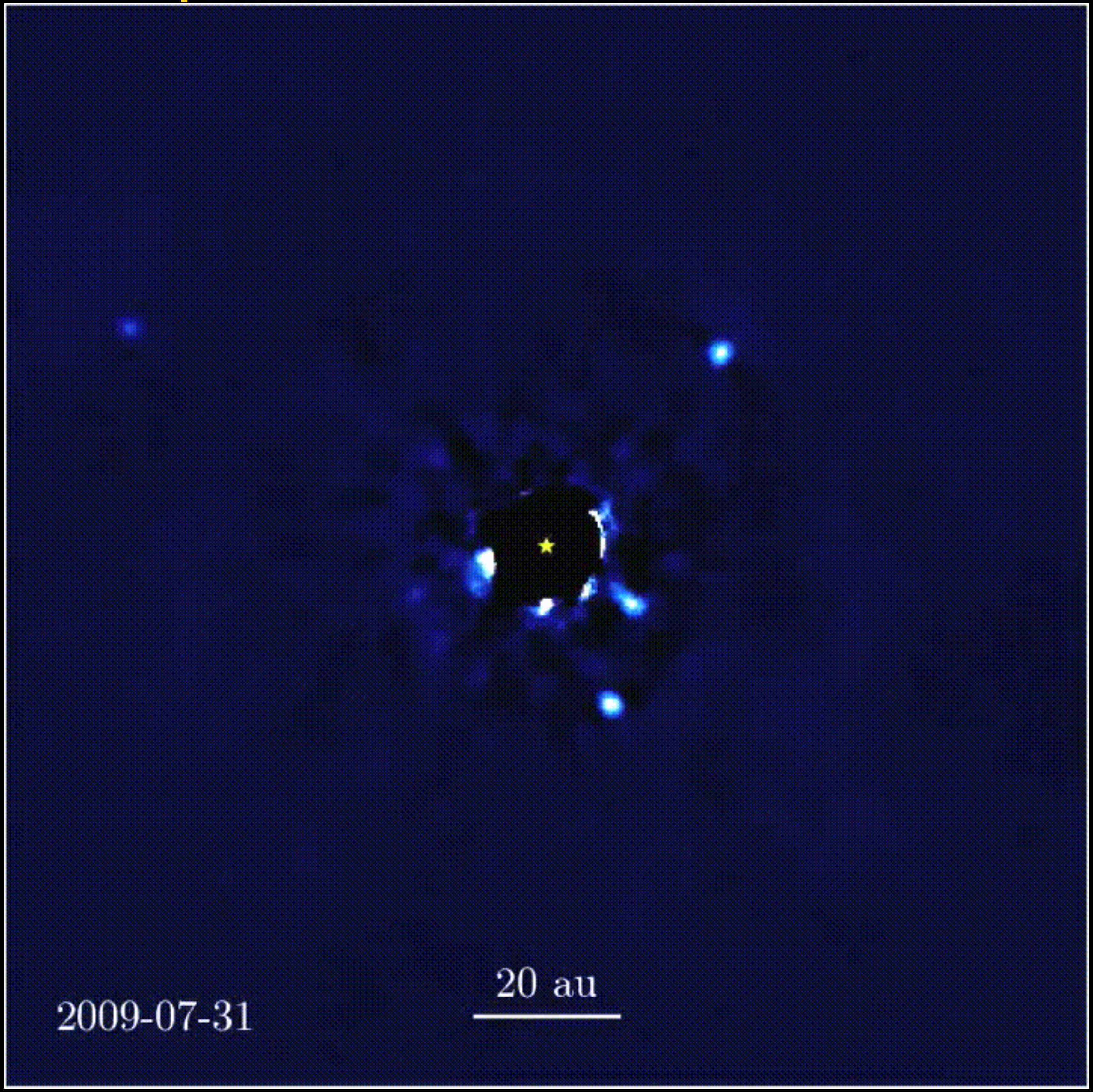
The Gemini Planet Imager Exoplanet Survey: Giant Planet and Brown Dwarf Demographics from 10-100 AU

Eric Nielsen
Stanford

and the GPIES Science Team

ExoPAG
Jan 3, 2020

HR 8799: exoplanets in motion



Movie from Jason Wang and Christian Marois

GPI and friends

The GPI team (a subset)

Jonathan Aguilar, S. Mark Ammons, Pauline Arriaga, Etienne Artigau, Vanessa Bailey, Travis Barman, Steve Beckwith, Sebastian Bruzzone, Joanna Bulger, Ben Burningham, Adam S. Burrows, Eric Cady, Christine Chen, Eugene Chiang, Jeffrey K. Chilcote, Rebekah I. Dawson, Robert J. De Rosa, Ruobing Dong, René Doyon, Zachary H. Draper, Gaspard Duchêne, Thomas M. Esposito, Daniel Fabrycky, Michael P. Fitzgerald, Katherine B. Follette, Jonathan J. Fortney, BJ Fulton, Benjamin Gerard, James R. Graham, Alexandra Z. Greenbaum, Pascale Hibon, Sasha Hinkley, Lea Hirsch, Justin Hom, Andrew Howard, Tara Hufford, Li-Wei Hung, Patrick Ingraham, Rebecca Jensen-Clem, Mara Johnson-Groh, Paul Kalas, Quinn Konopacky, David Lafreniere, James E. Larkin, Samantha Lawler, Eve Lee, Jinhee Lee, Michael Line, Bruce Macintosh, Jerome Maire, Franck Marchis, Mark S. Marley, Christian Marois, Brenda C. Matthews, Stanimir Metchev, Max Millar-Blanchaer, Caroline V. Morley, Katie M. Morzinski, Ruth Murray-Clay, Eric L. Nielsen, Andrew Norton, Rebecca Oppenheimer, David W. Palmer, Rahul Patel, Jenny Patience, Marshall D. Perrin, Charles Poteet, Lisa A. Poyneer, Laurent Pueyo, Roman R. Rafikov, Abhijith Rajan, Julien Rameau, Fredrik T. Rantakyrö, Emily Rice, Malena Rice, Patricio Rojo, Jean-Baptiste Ruffio, M. T. Ruiz, Dominic Ryan, Maissa Salama, Didier Saumon, Dmitry Savransky, Adam C. Schneider, Jacob Shapiro, Anand Sivaramakrishnan, Inseok Song, Rémi Soummer, Sandrine Thomas, Gautam Vasisht, David Vega, J. Kent Wallace, Jason J. Wang, Kimberly Ward-Duong, Sloane J. Wiktorowicz, Schuyler G. Wolff, Joe Zalesky, Ben Zuckerman

The GPIES sample

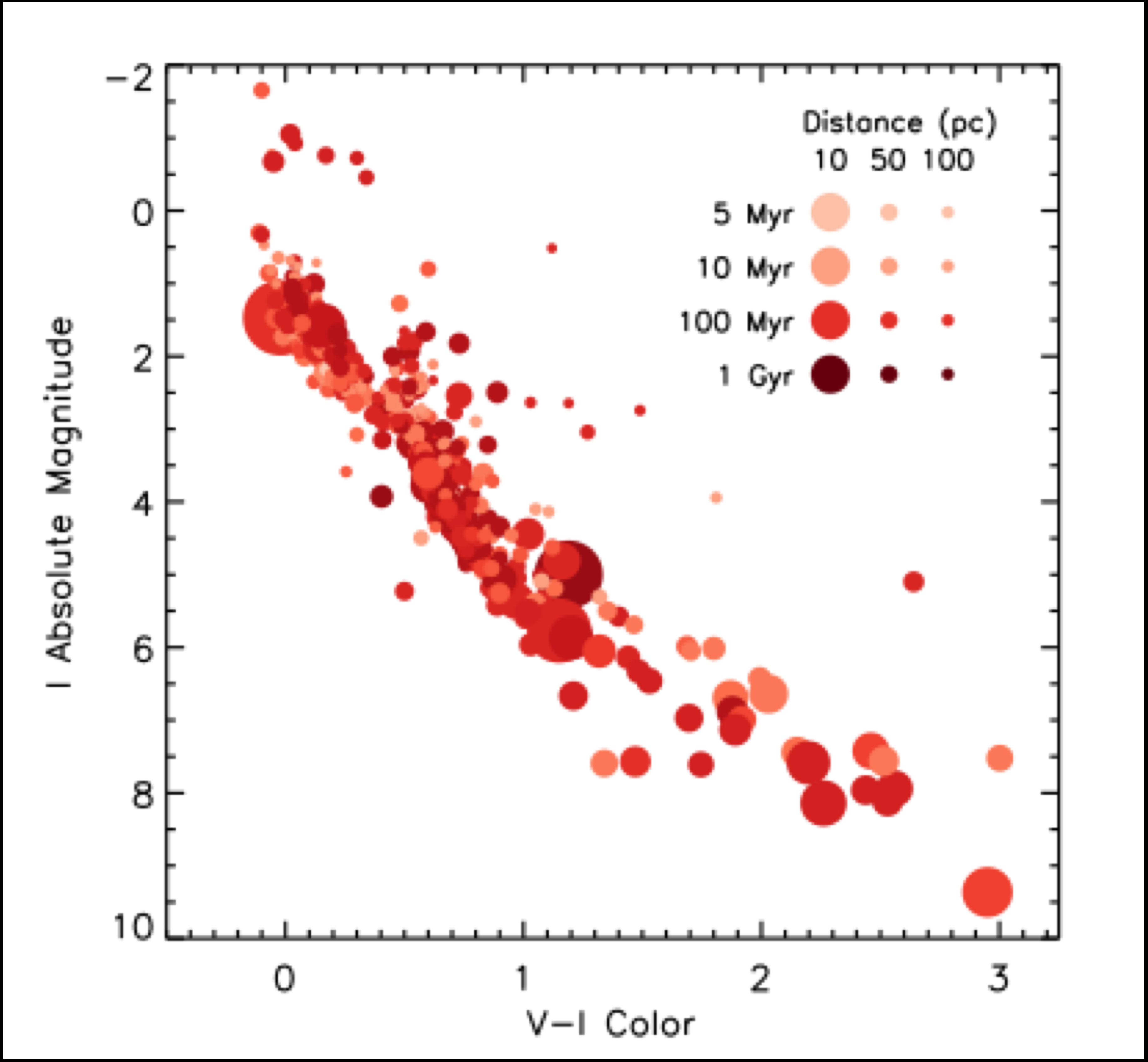


Figure from Robert De Rosa

GPI 2

Moving GPI to Gemini North and upgrading to bring technology into the current era

Funding from NSF MRI and Heising-Simons Foundation

Upgrade planning and design through 2020

Upgrade assembly and integration 2020-2021

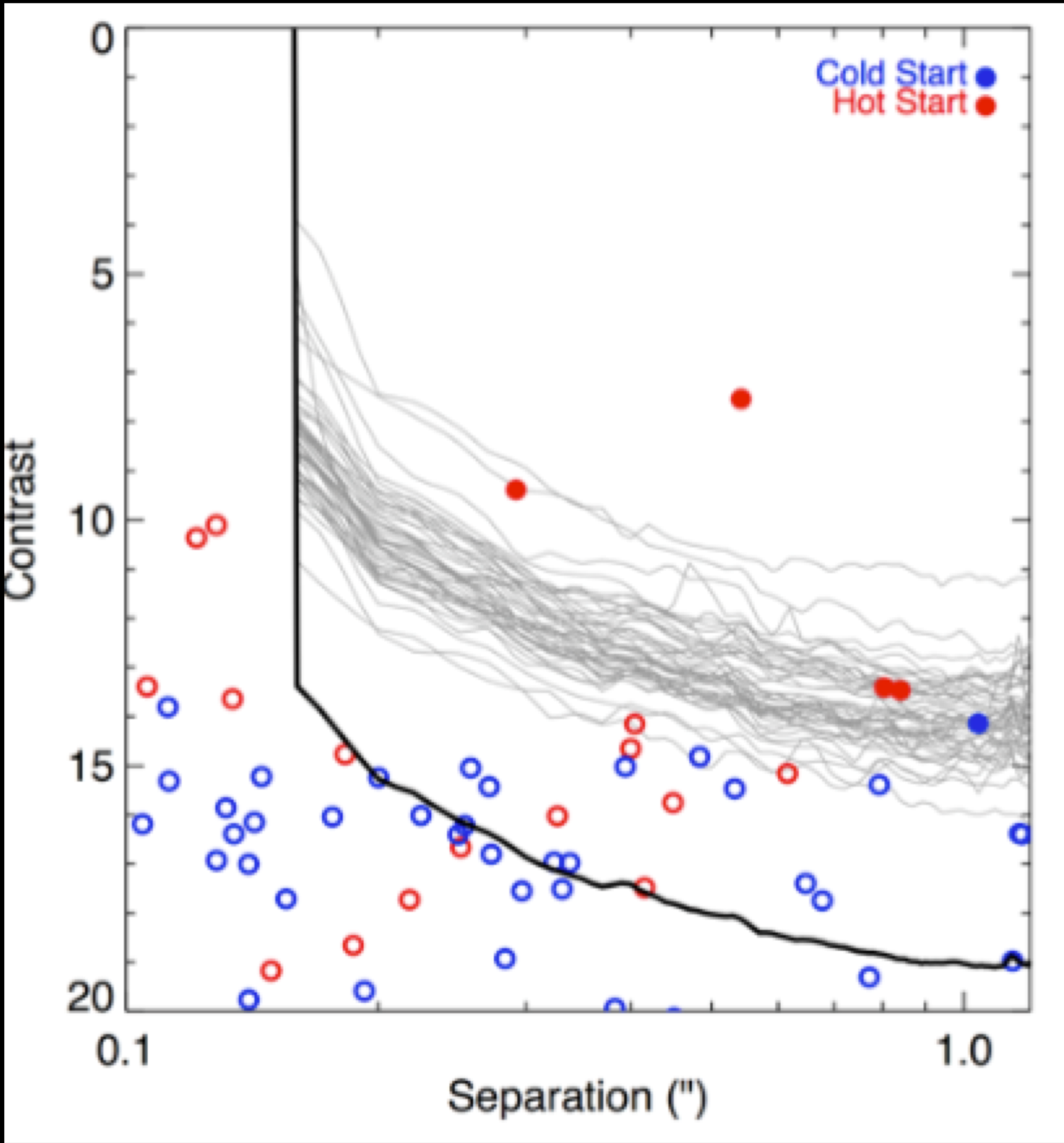
First light 2022

PI: Jeff Chilcote, Quinn Konopacky.

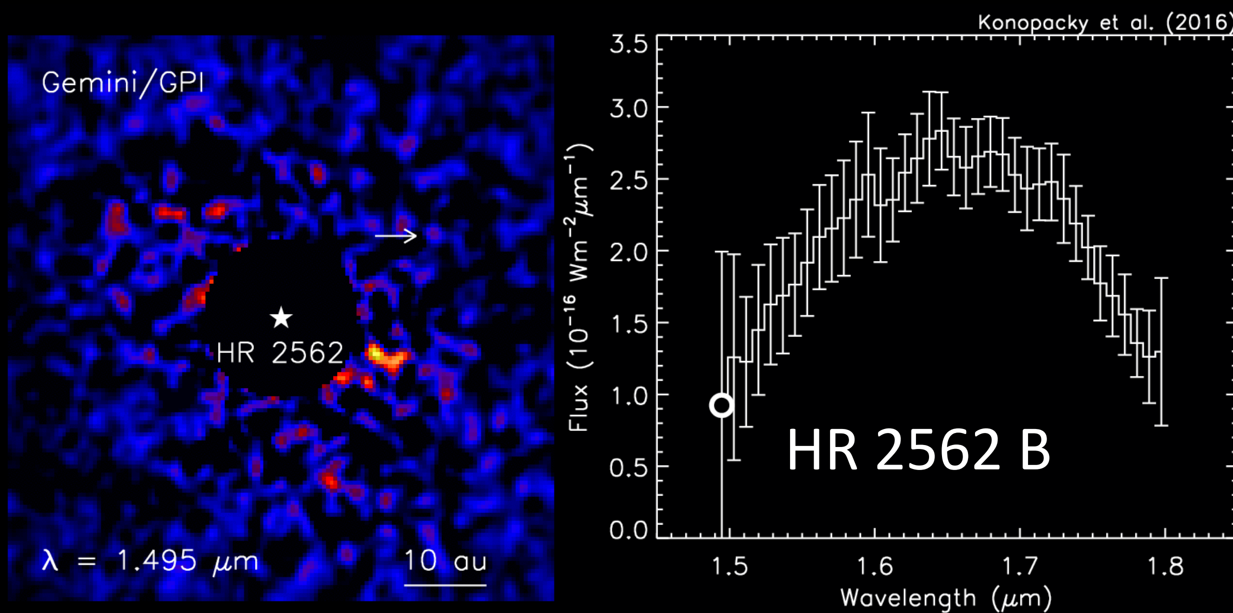
co-I: Bruce Macintosh, Robert De Rosa, Dmitry Savransky, Christian Marois

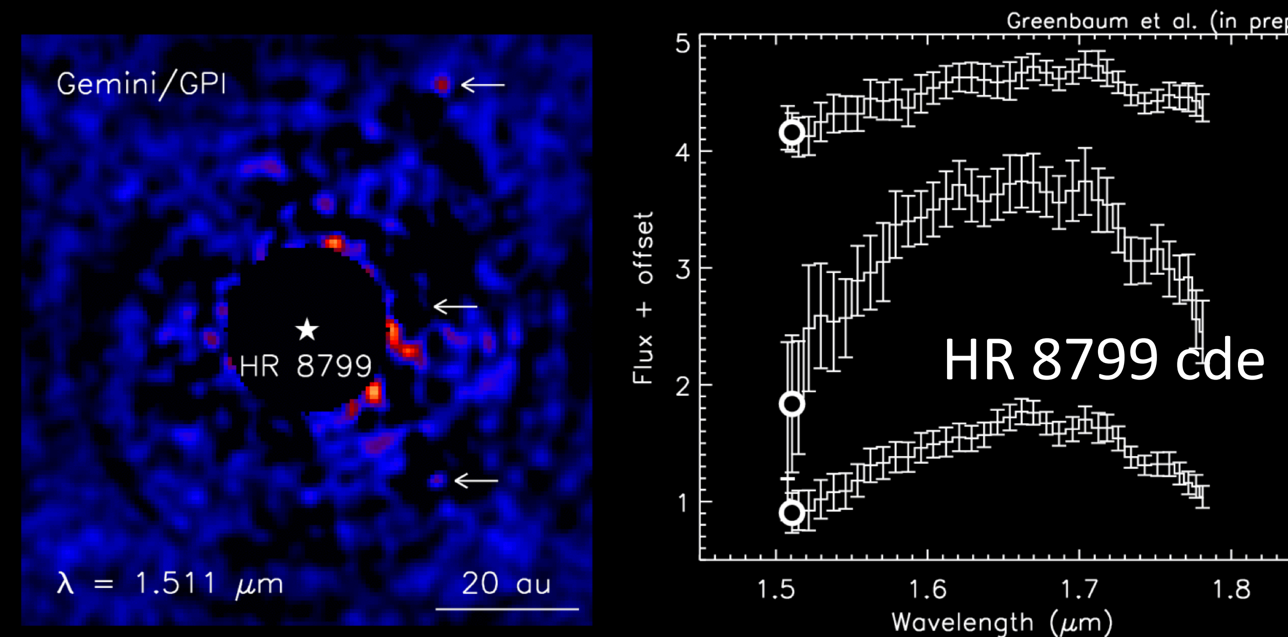
Upgrade features

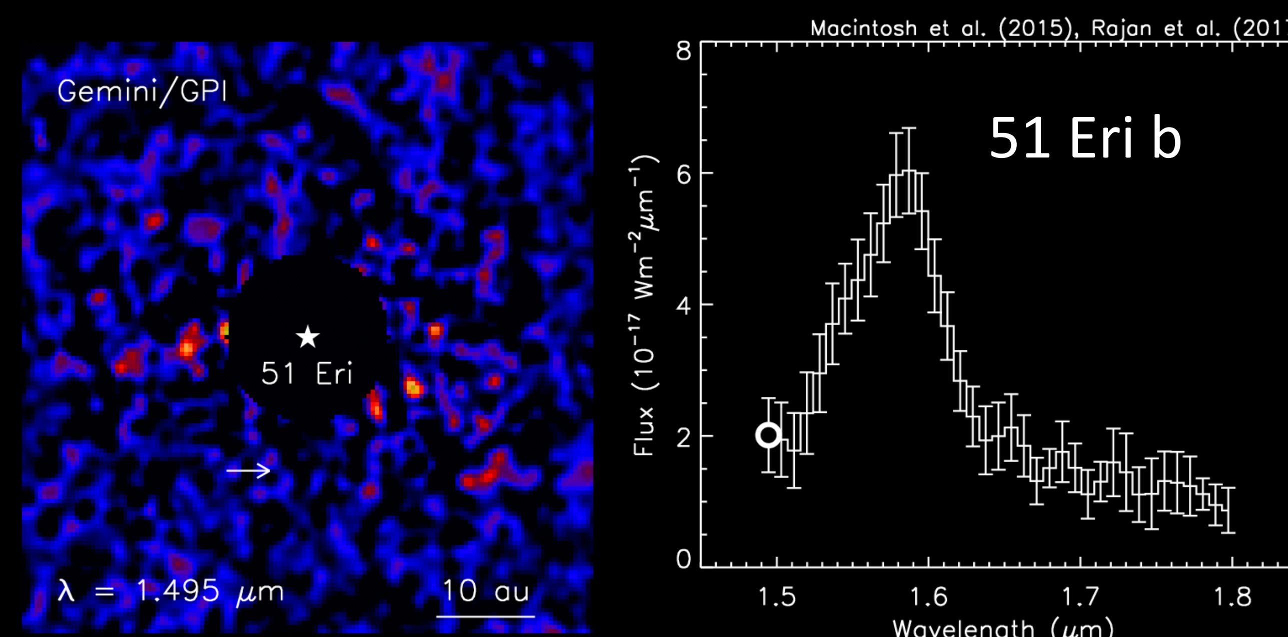
- Upgrade WFS to operate to I~14 mag
  - Targets in Taurus SFR
- Upgrade coronagraph for smaller IWA ~0.1″
- Upgrade realtime computer for higher contrast on bright stars
  - Enables ‘cold start’ planet studies
- Precision broadband IFS mode

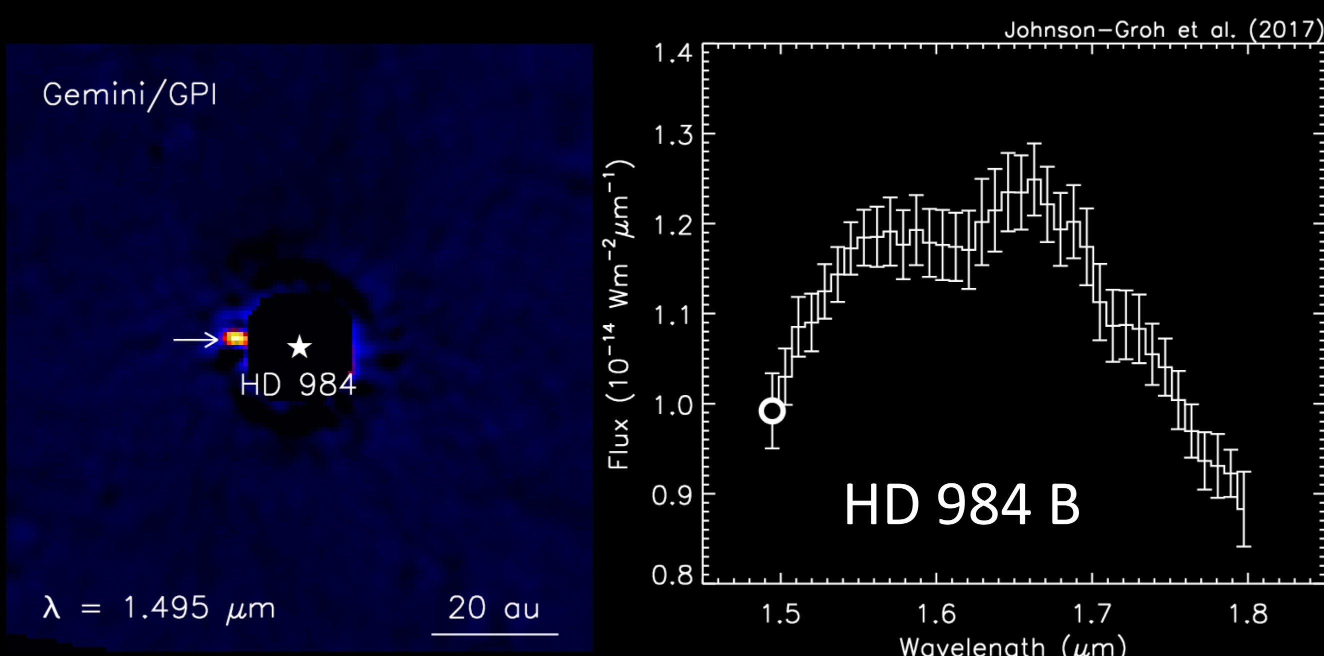


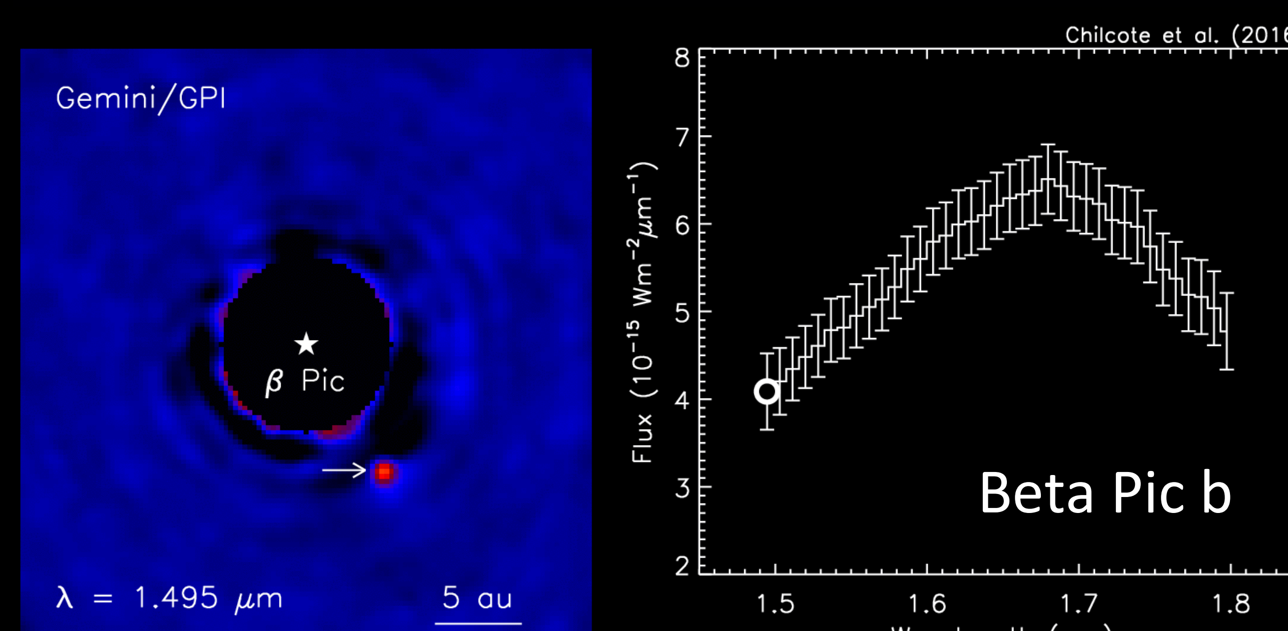
Brown dwarfs and planets with GPIES





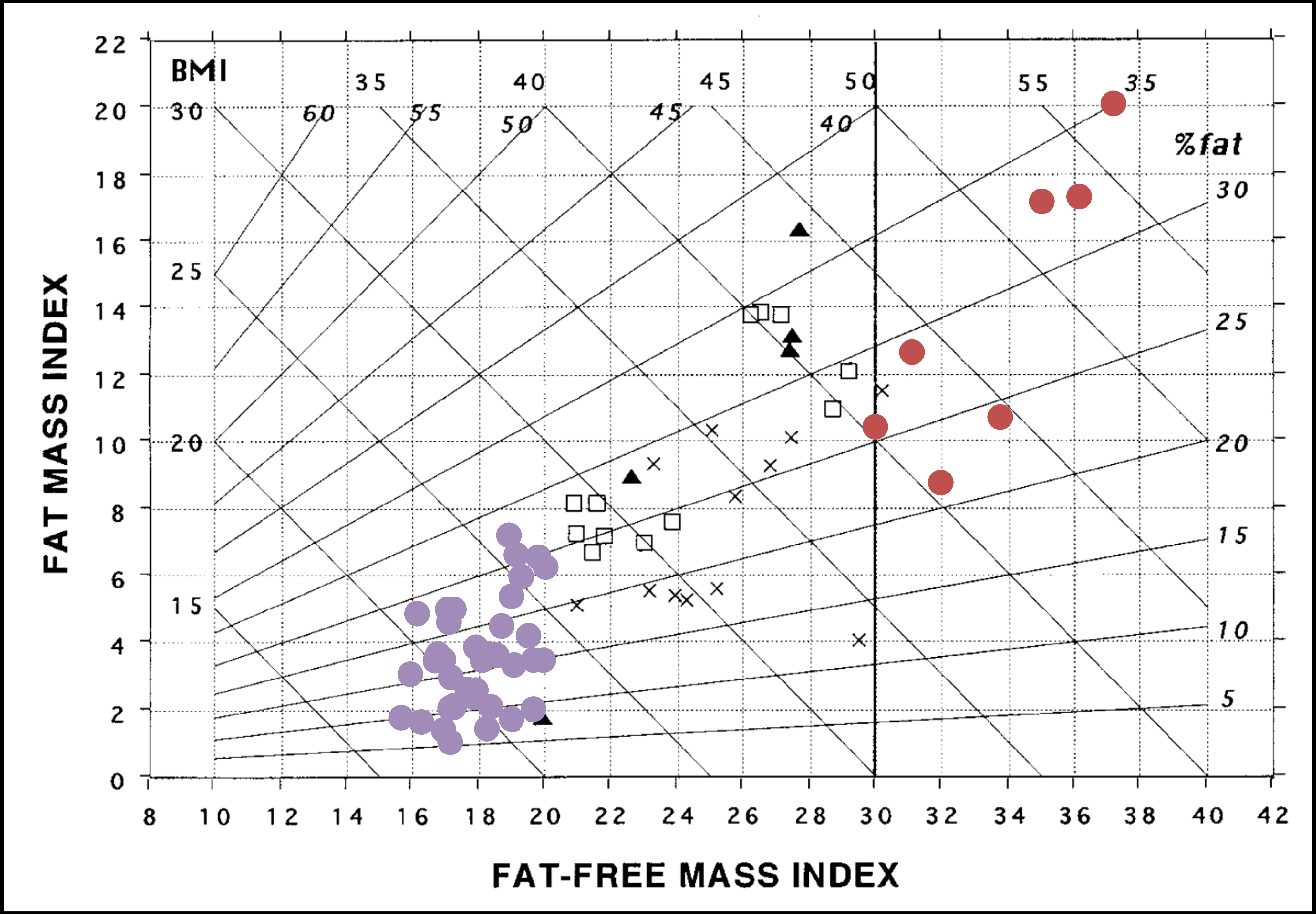




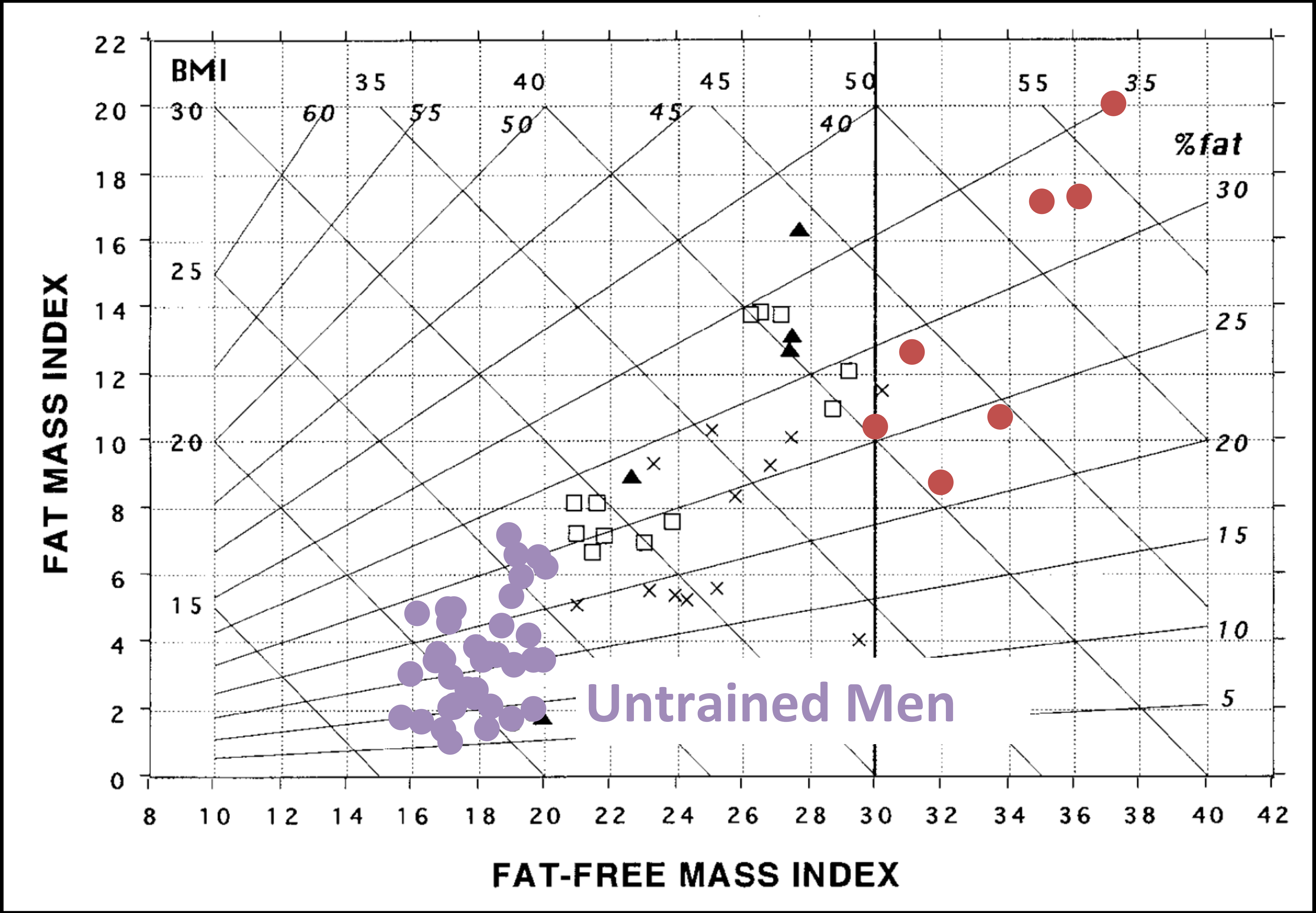


Figures from Robert De Rosa

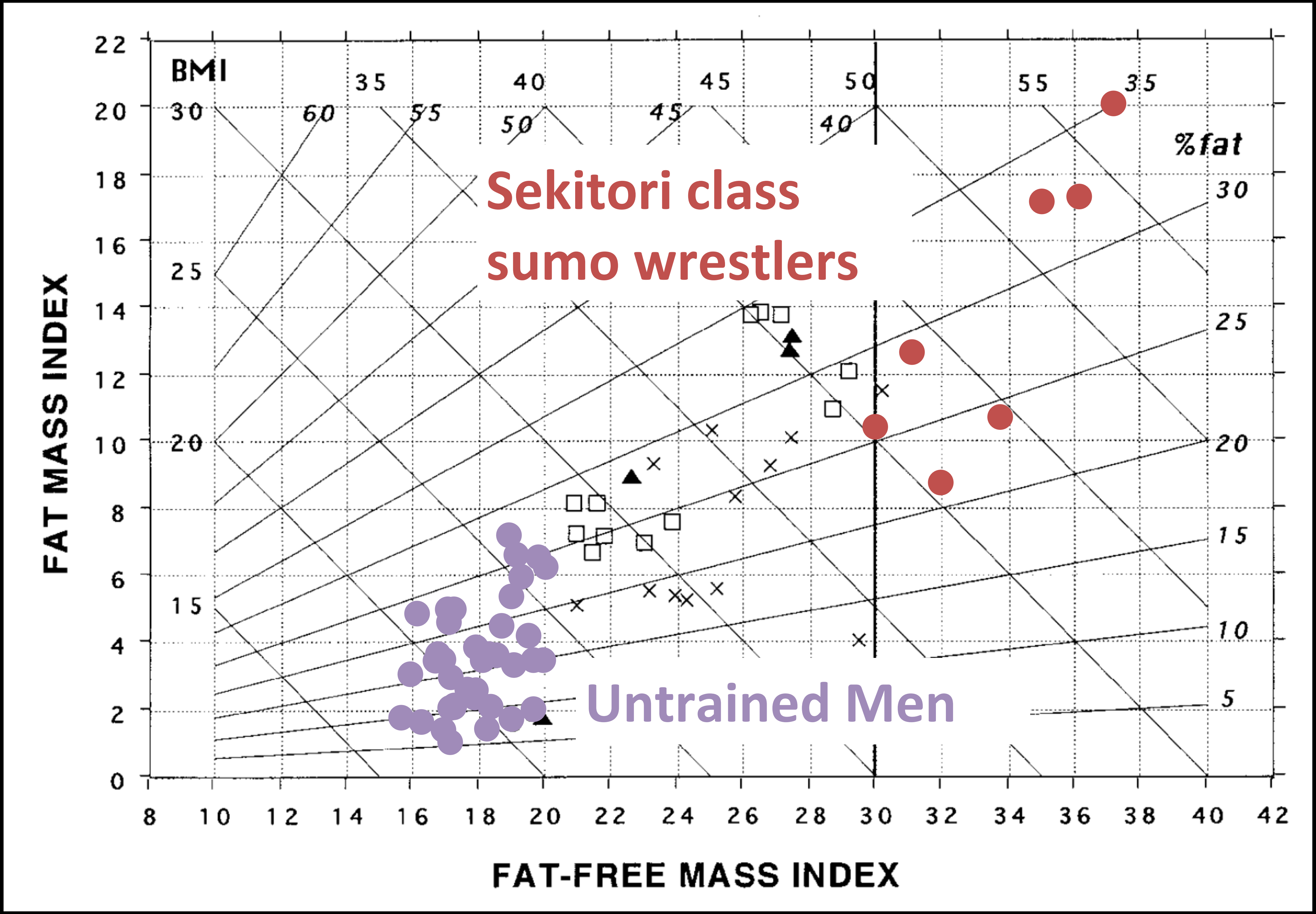
Demographics



Demographics



Demographics



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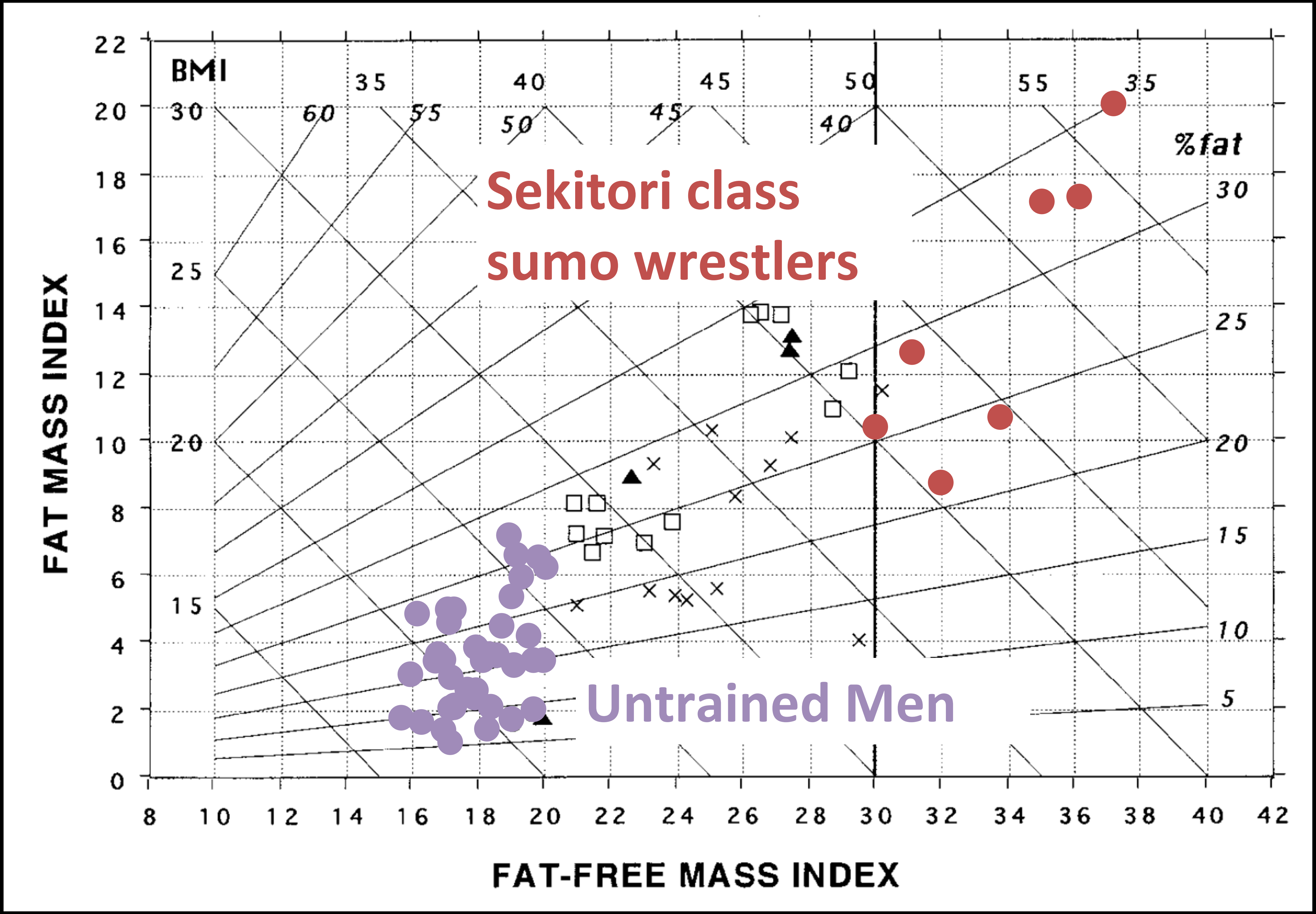
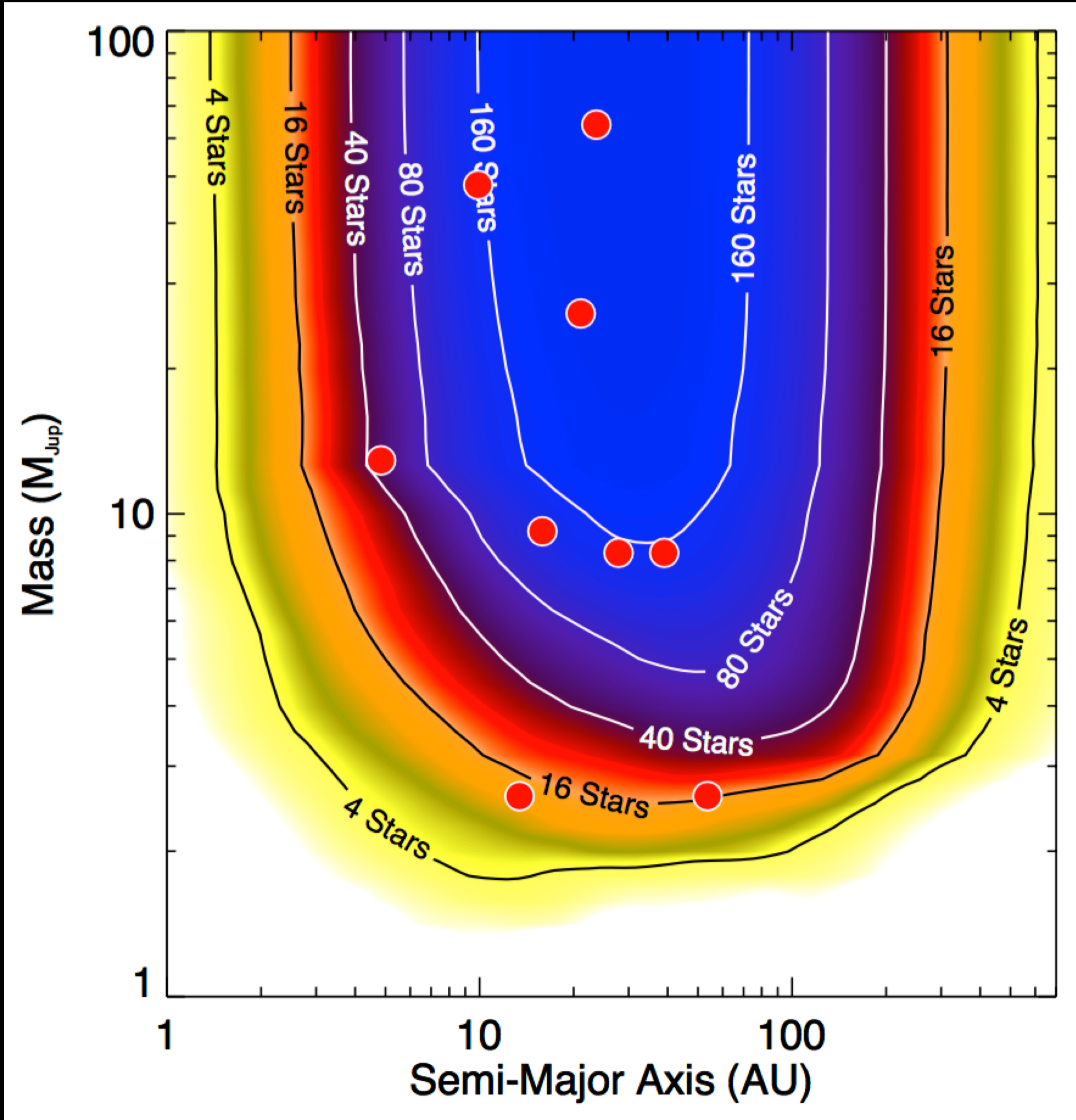
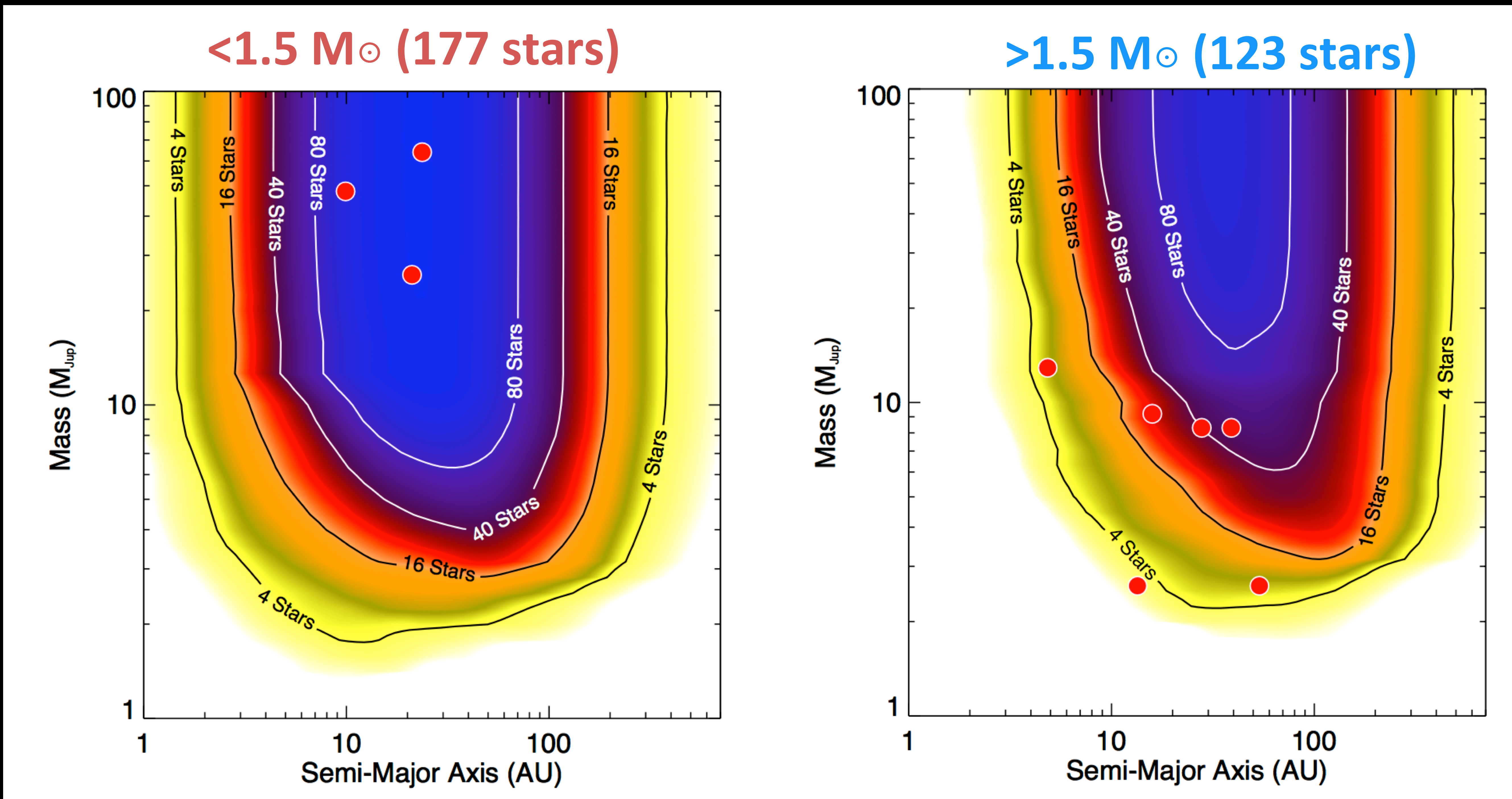


Hierarchical differences in body composition of professional Sumo wrestlers
Hattori et al. Annals of Human Biology, 1999.

GPIES: the first 300 stars



A stellar mass/giant planet occurrence correlation



Nielsen et al. 2019

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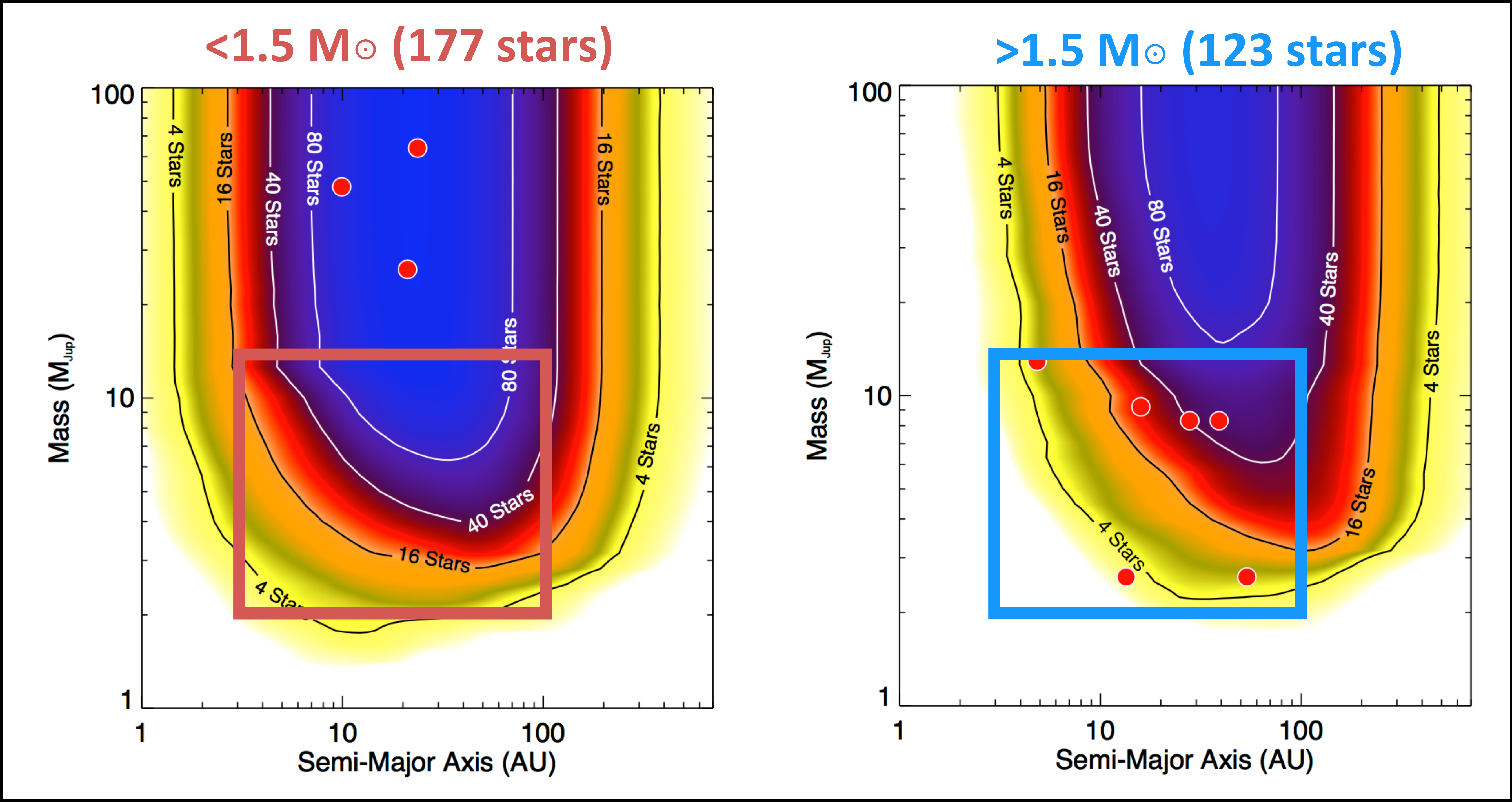

Nielsen et al. 2019

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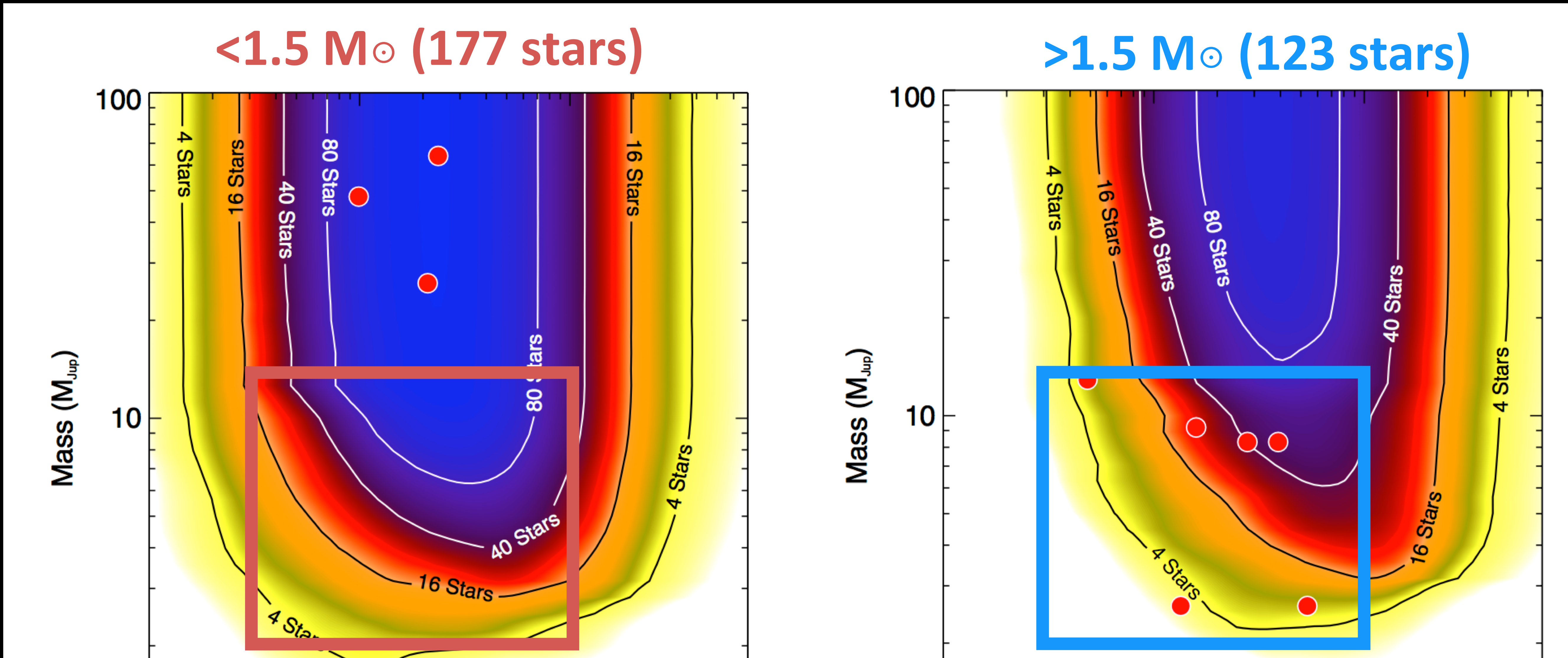
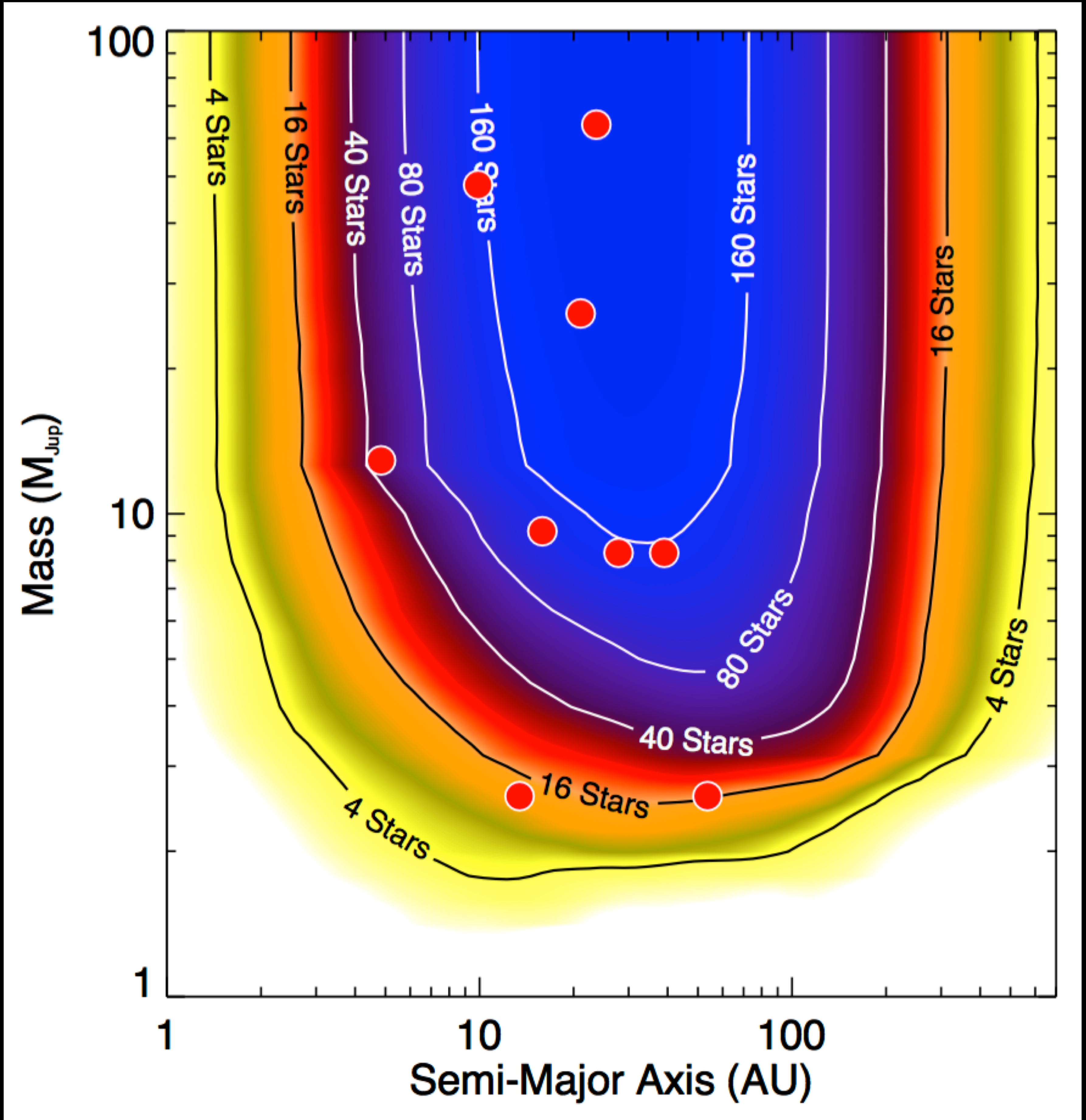


Conclusion 1: wide-separation giant planets are more common around higher-mass stars

Nielsen et al. 2019

Planets and brown dwarfs



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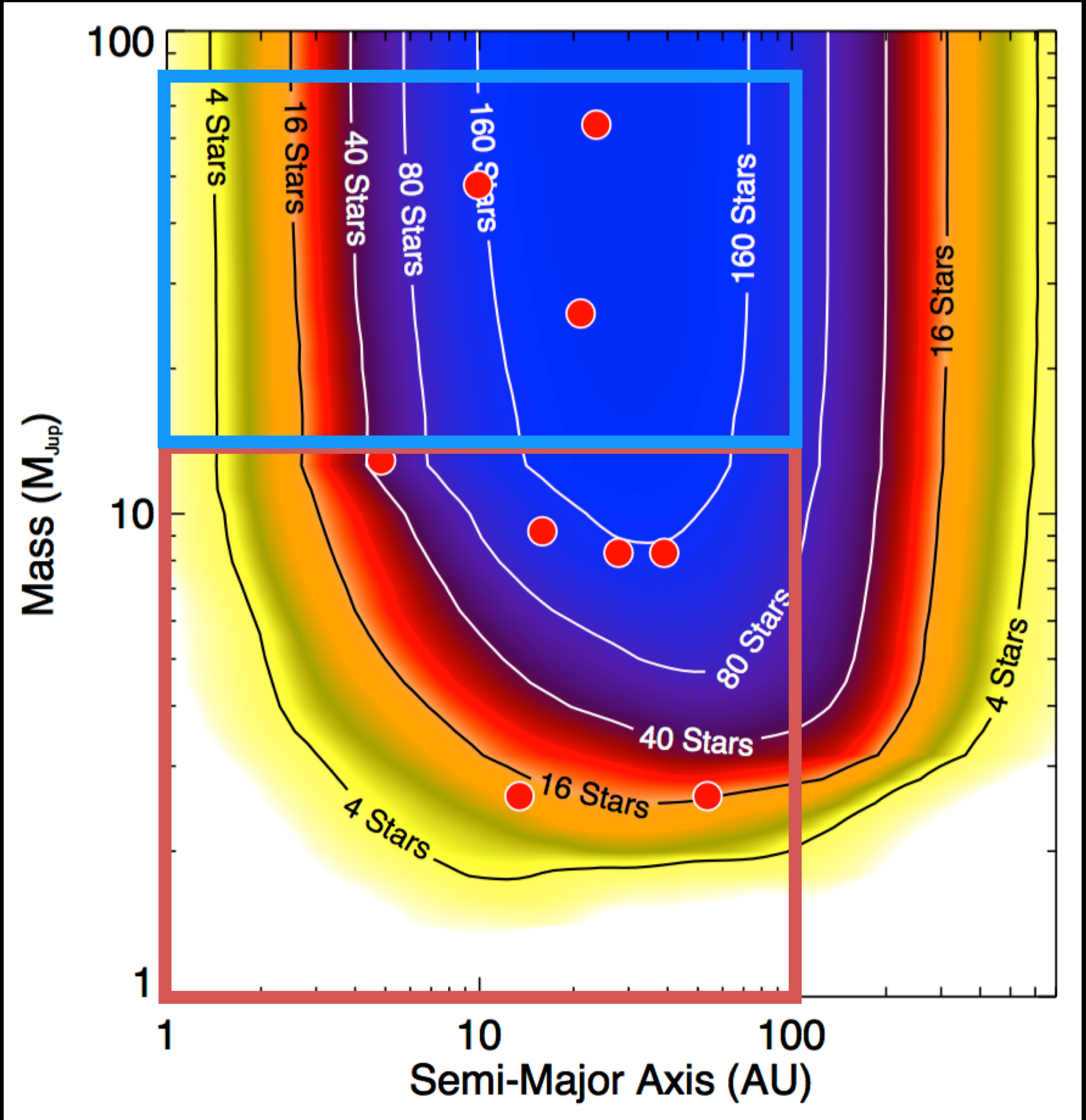

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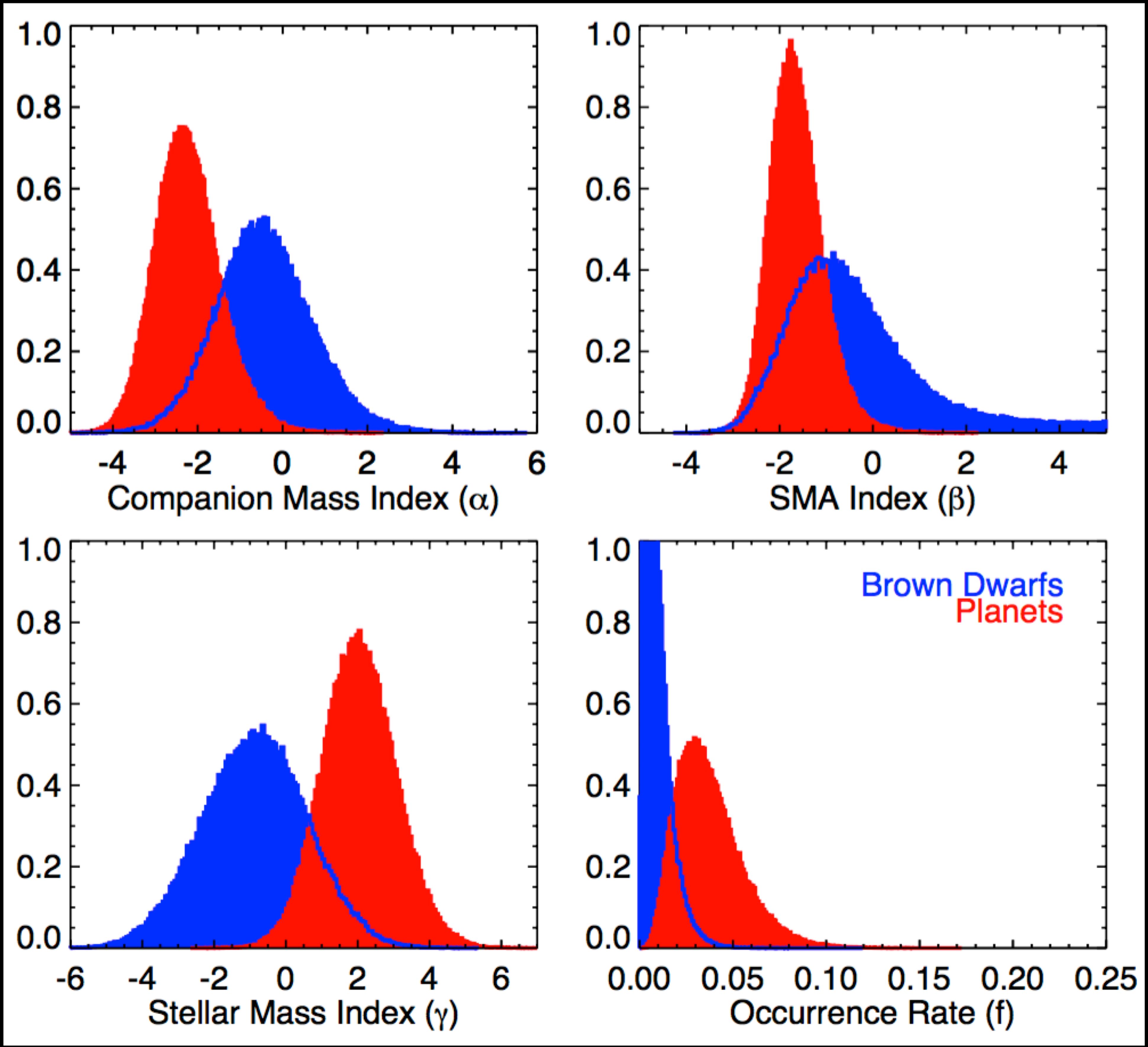

Nielsen et al. 2019

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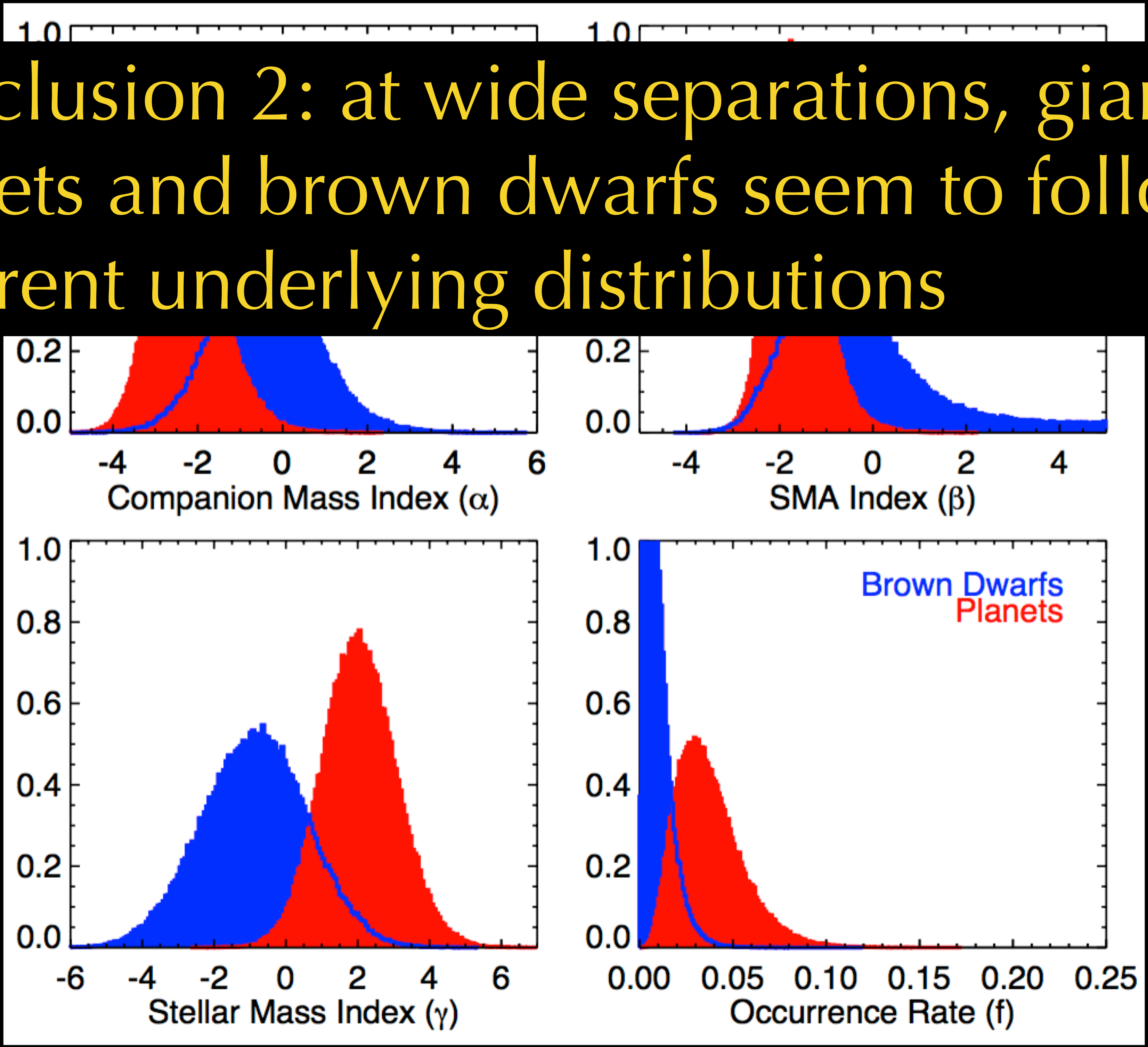
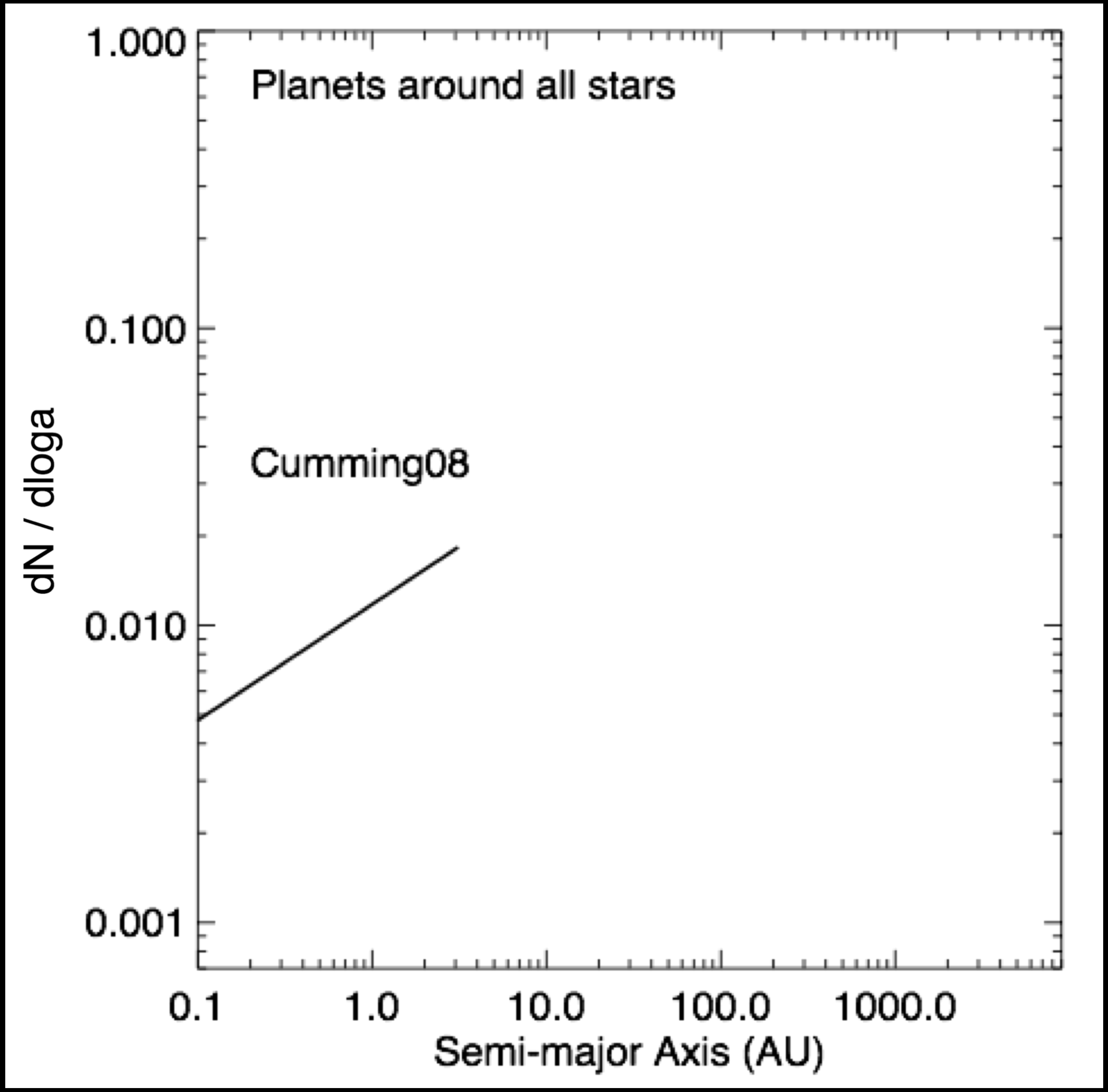


Conclusion 2: at wide separations, giant planets and brown dwarfs seem to follow different underlying distributions

Nielsen et al. 2019

Giant planets demographics vs. semi-major axis



Nielsen et al. 2019

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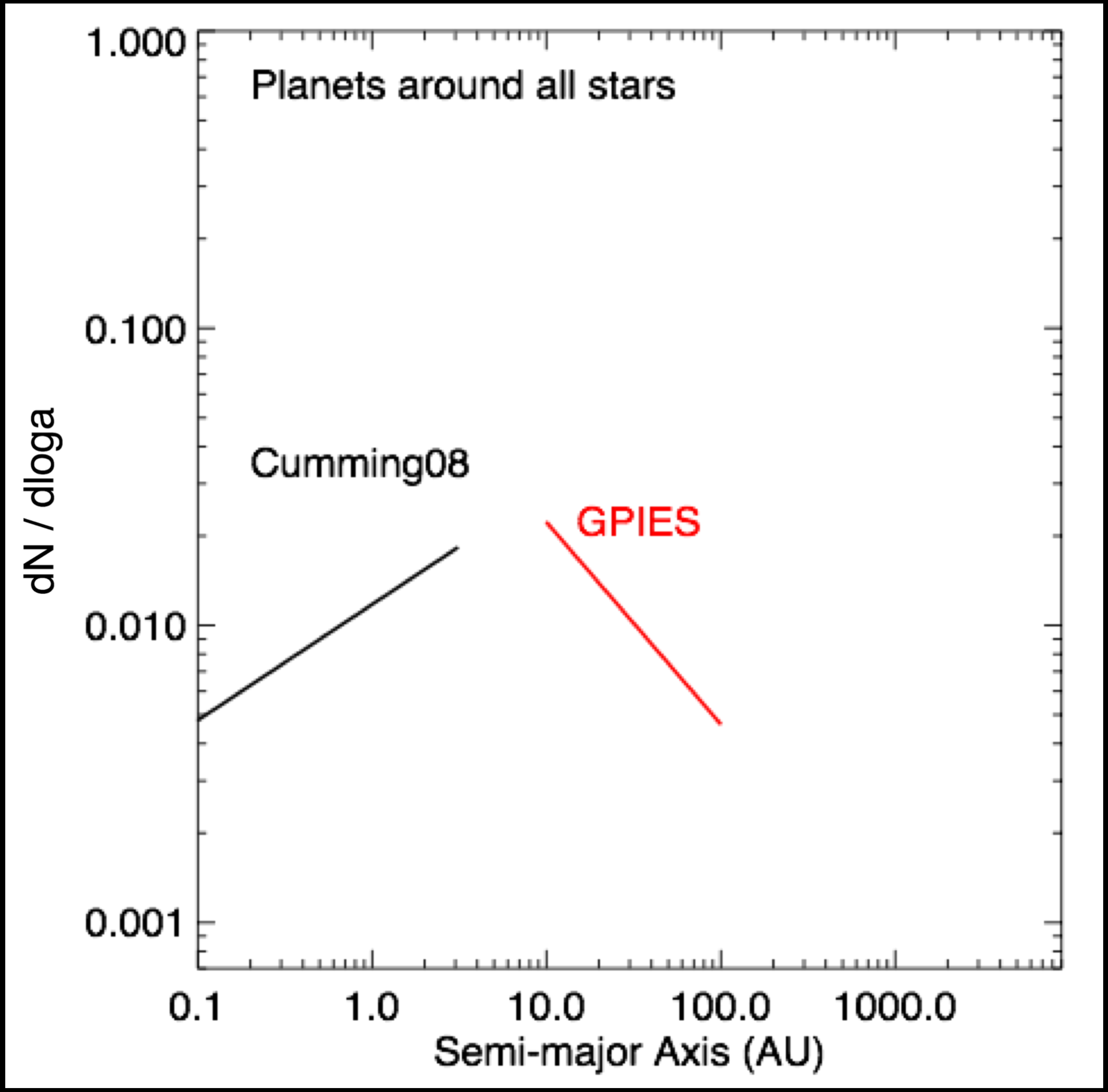

Nielsen et al. 2019

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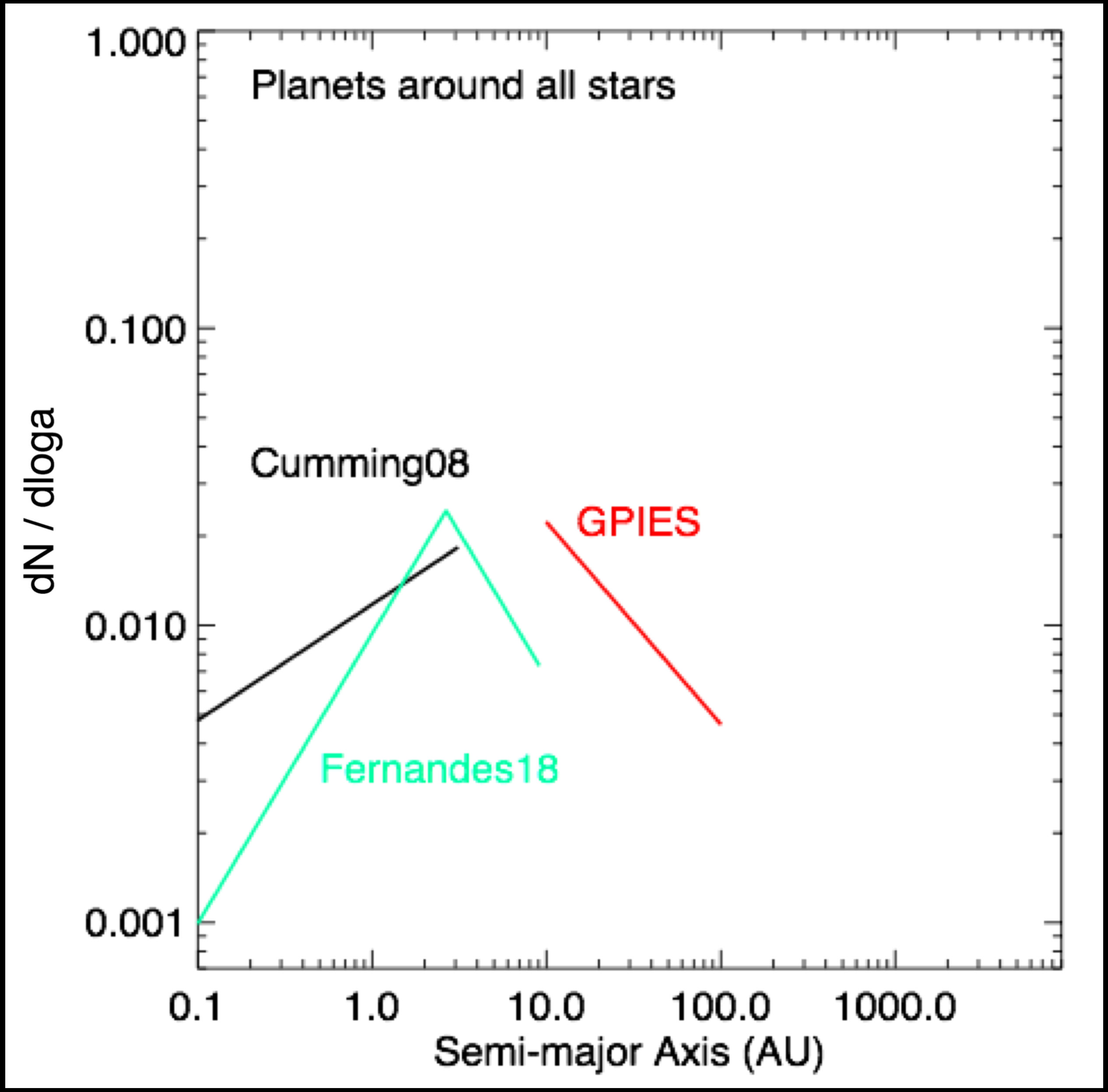

Nielsen et al. 2019

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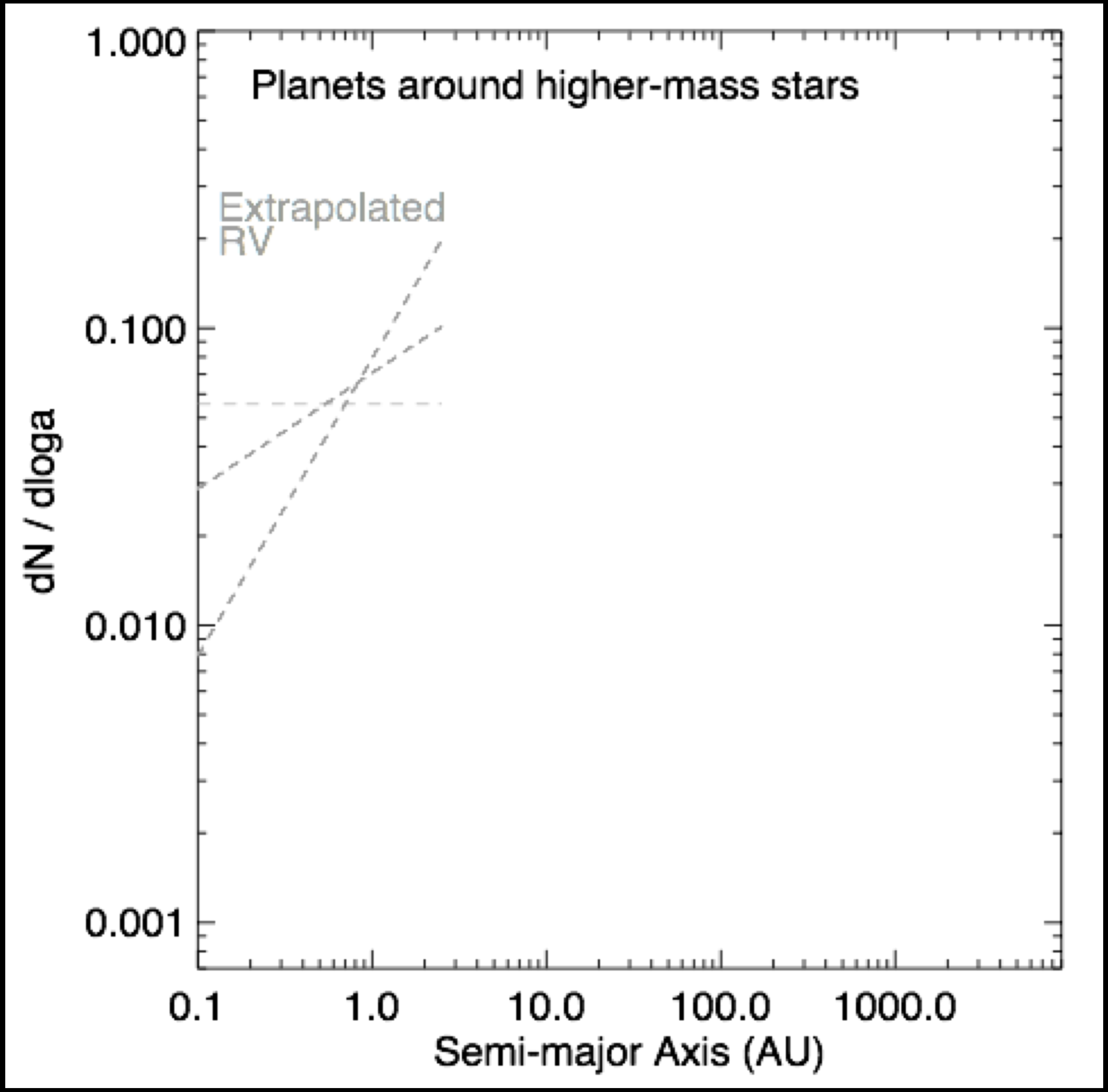

Nielsen et al. 2019

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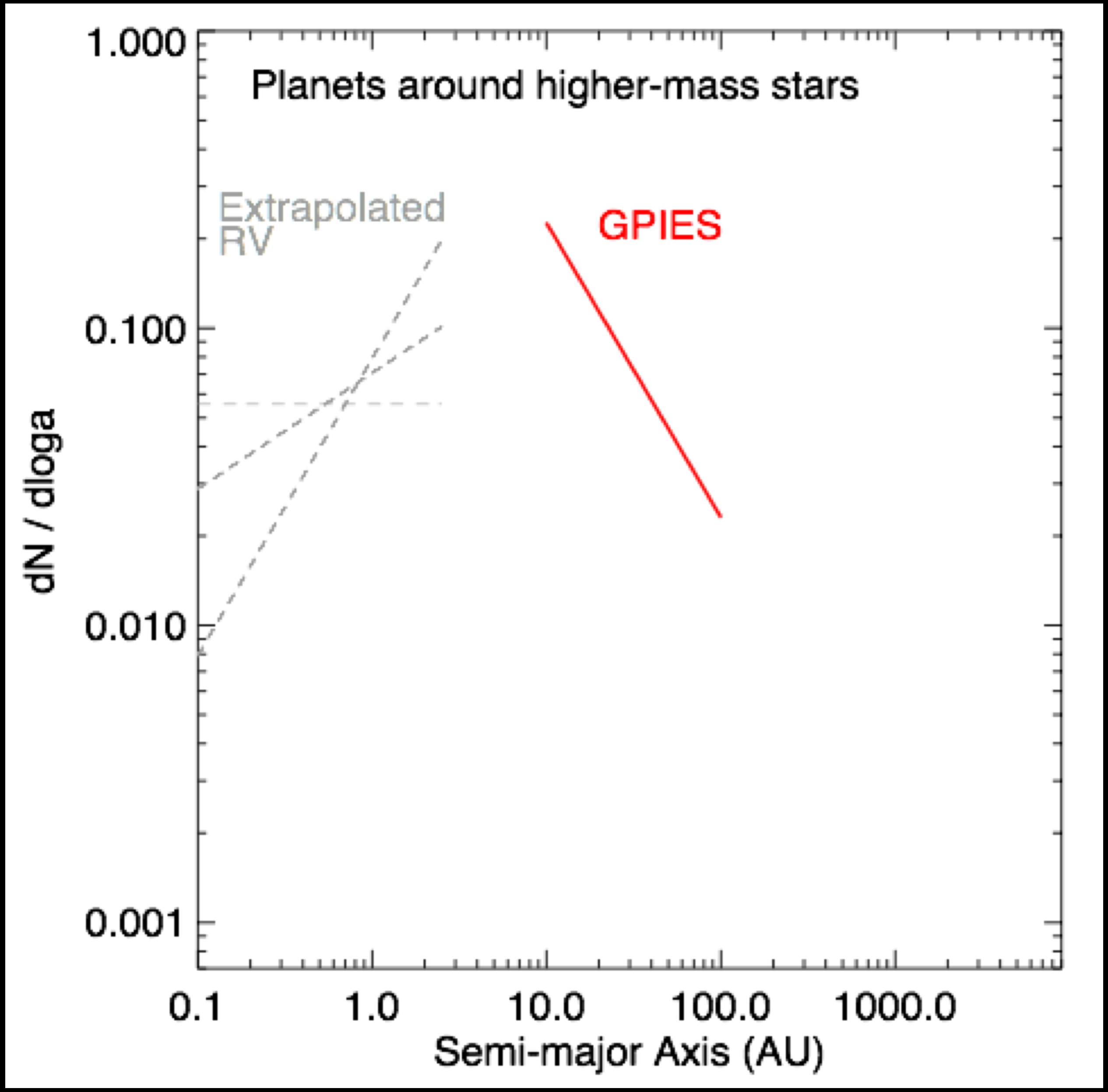

Nielsen et al. 2019

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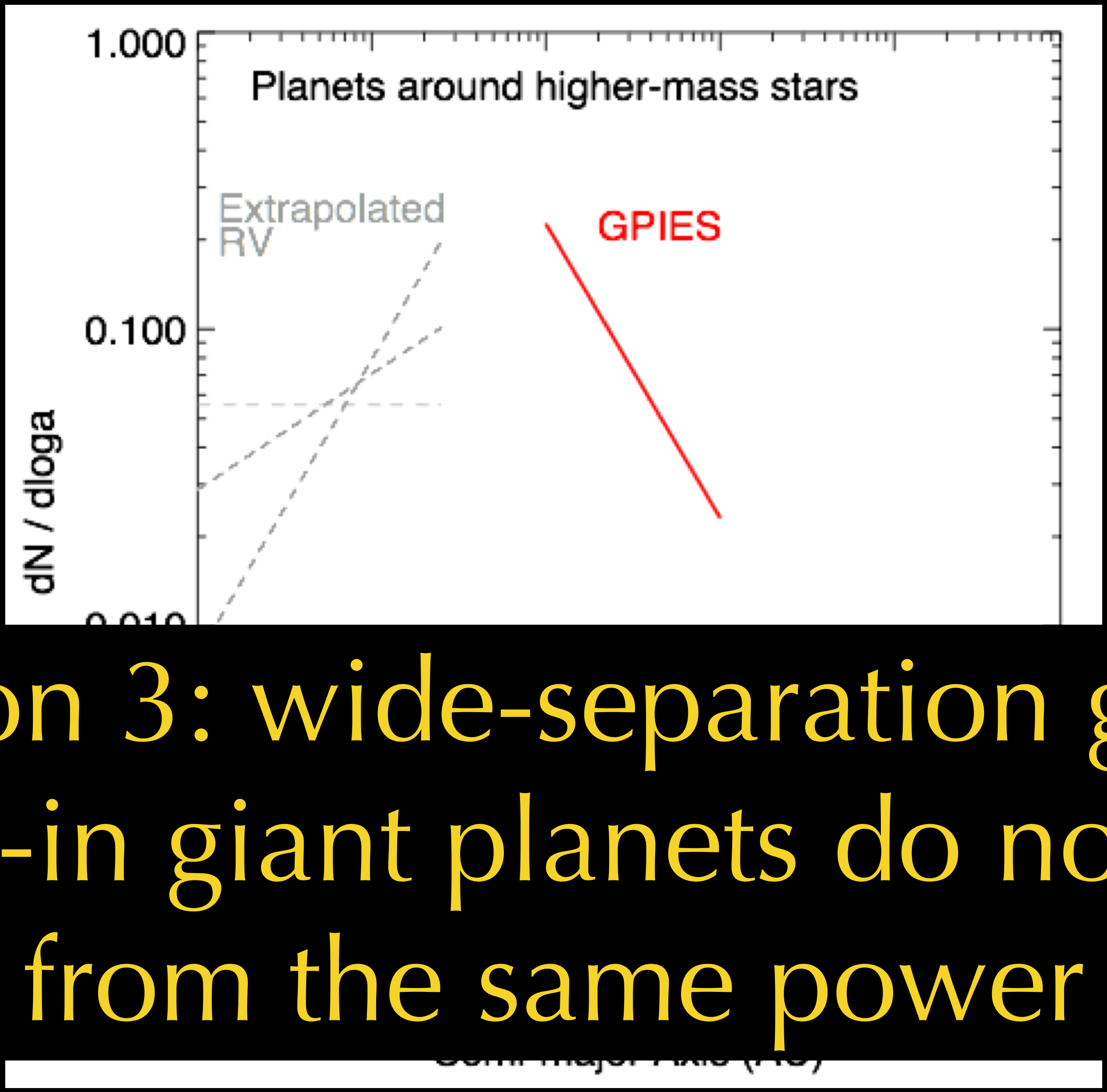


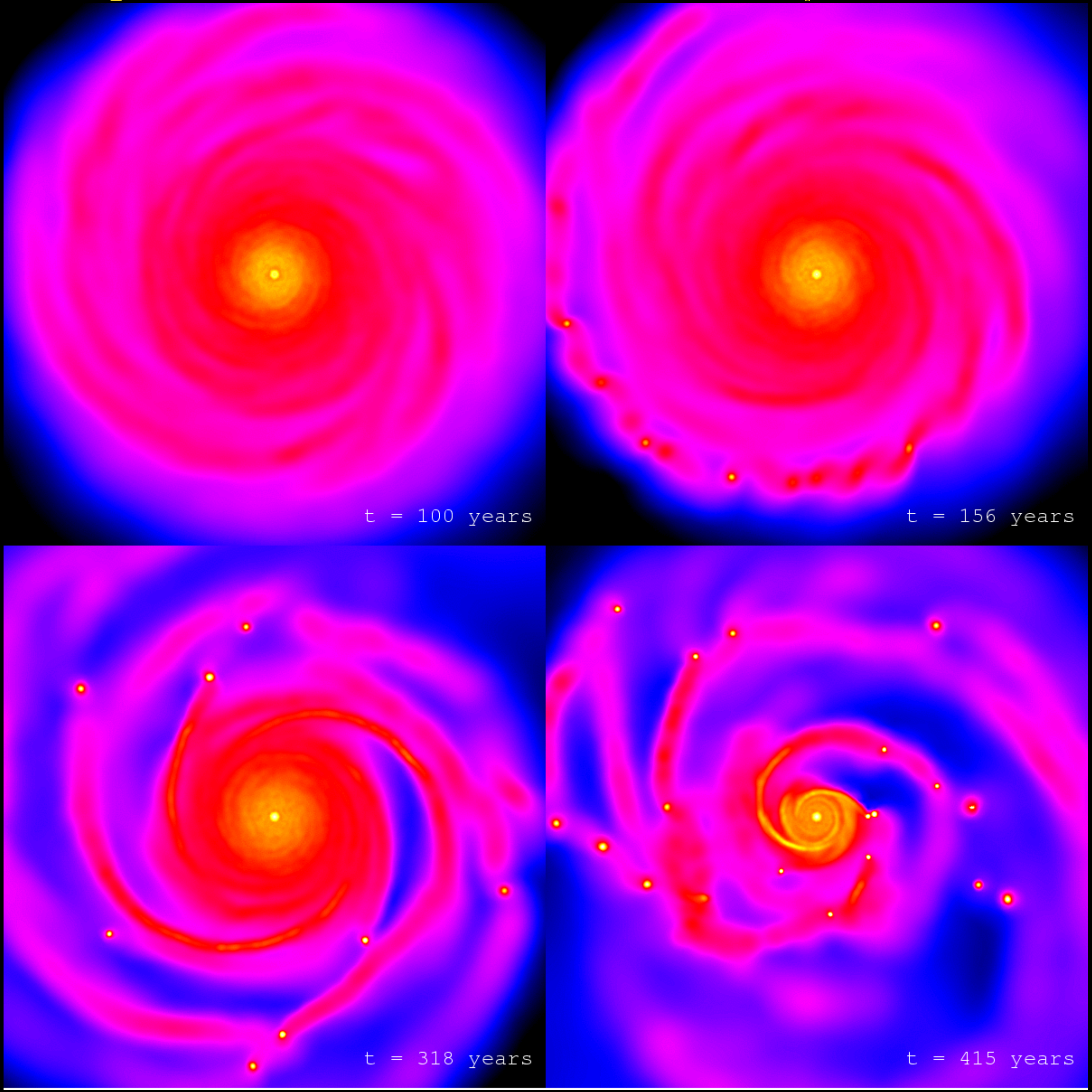
Conclusion 3: wide-separation giant planets and close-in giant planets do not appear to be drawn from the same power law

Nielsen et al. 2019

Bottom-up: core accretion

Alan Brandon/Nature

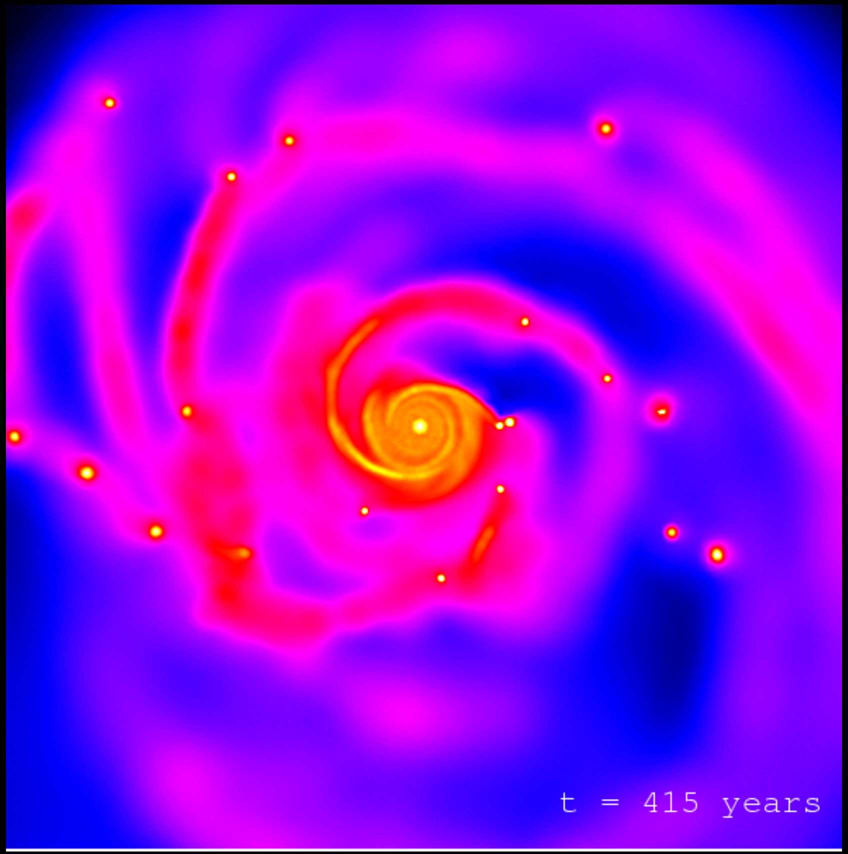
Top-down: gravitational instability



Lufkin et al. 2004

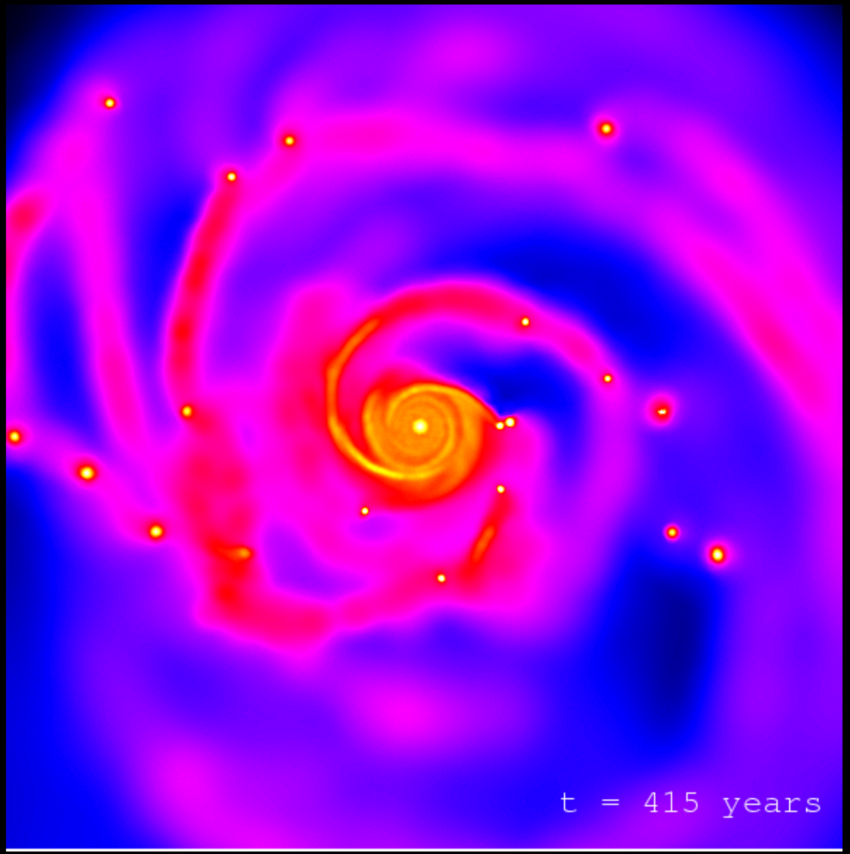
Comparing to predictions

Core accretion



Gravitational Instability

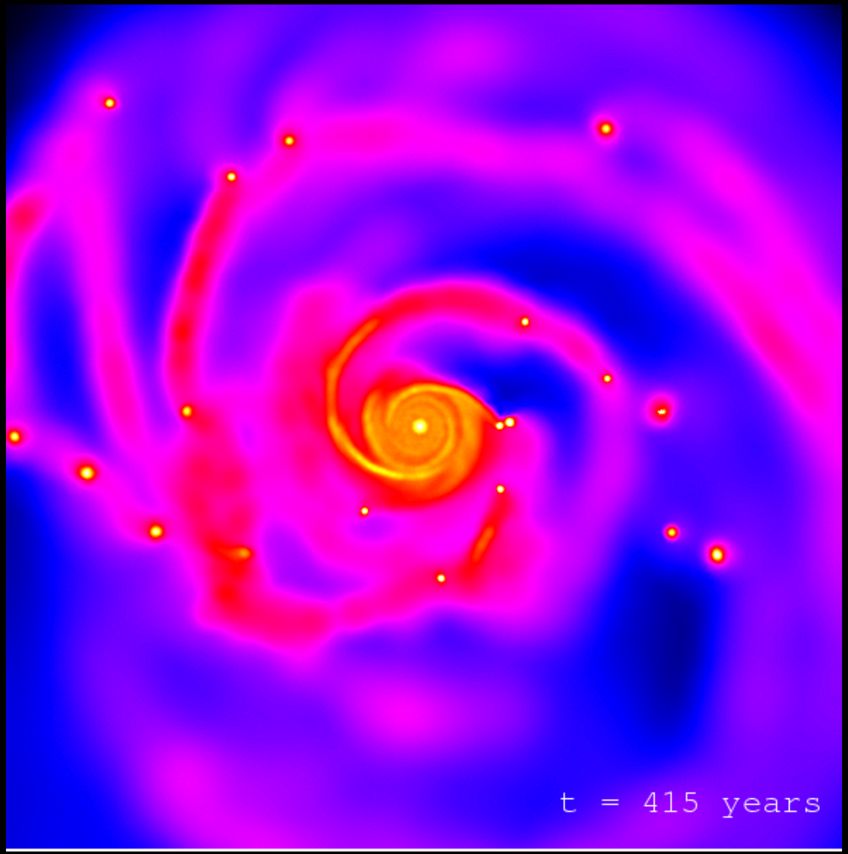
Comparing to predictions



Core accretion
—More companions around higher-mass stars

Gravitational Instability
—Weak dependence on mass of host star

Comparing to predictions



Core accretion
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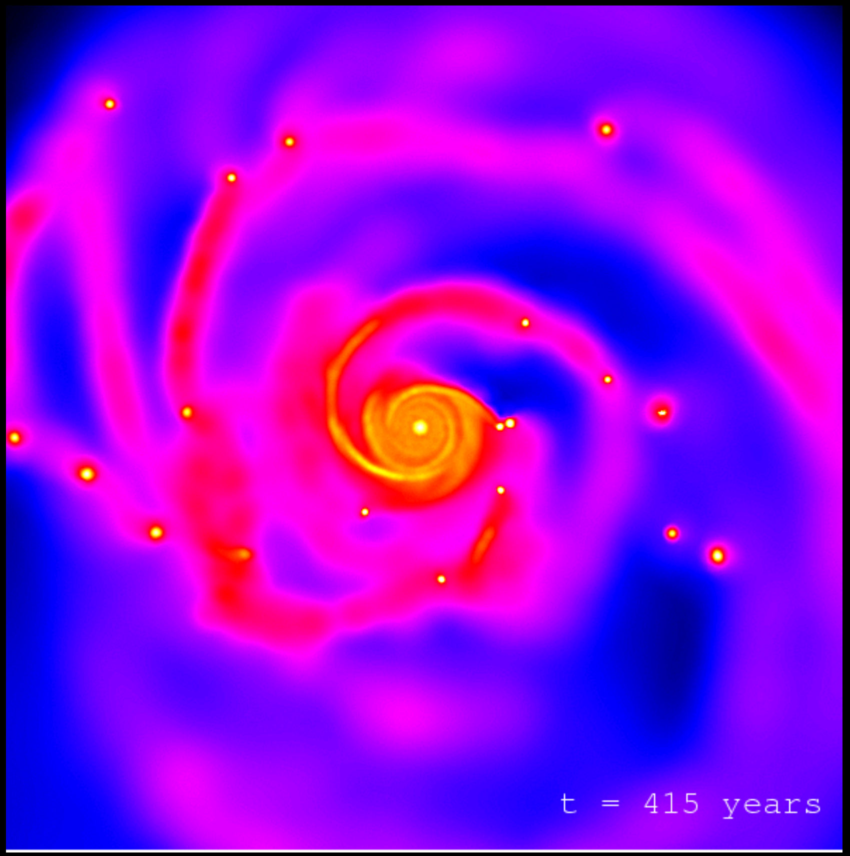
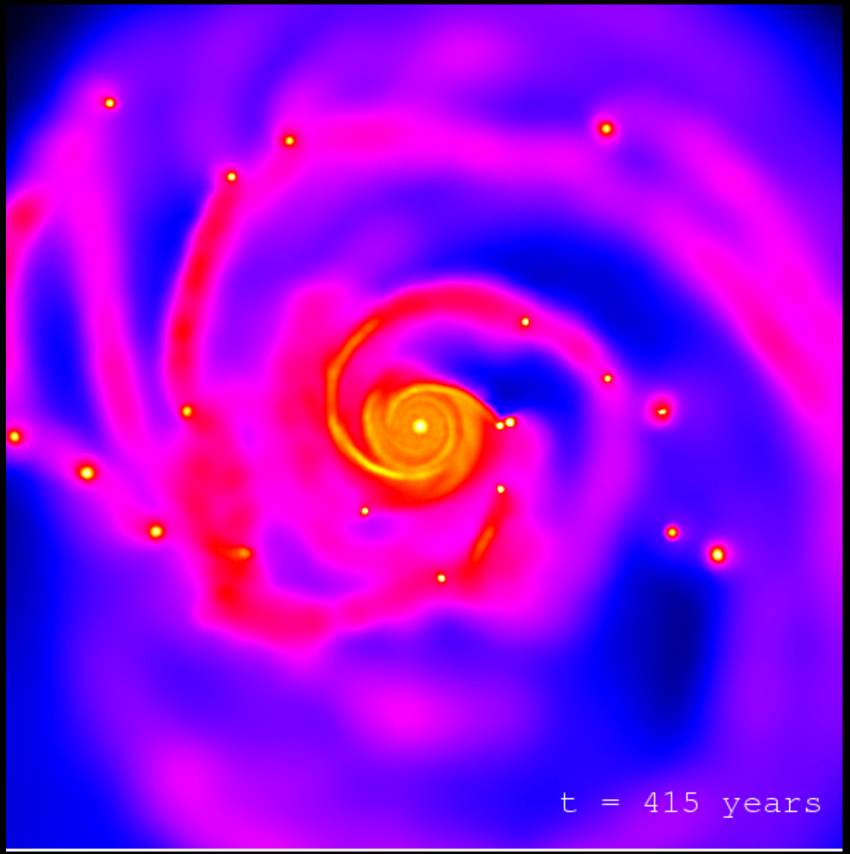


Core accretion
—More companions around higher-mass stars
—More low-mass companions than high-mass
—More close-in companions than farther-out

Gravitational Instability
—Weak dependence on mass of host star
—More high-mass companions than low-mass
—Should be at much larger orbital separations

Comparing to predictions



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GPIES Planets

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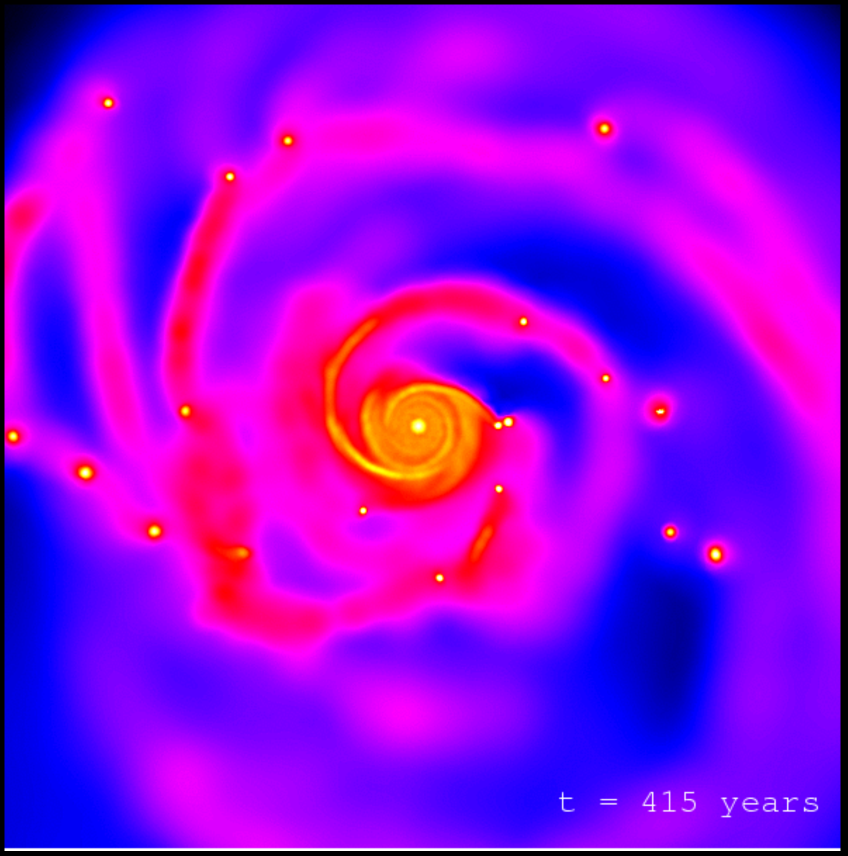

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GPIES Planets

GPIES Brown dwarfs

Conclusions

From the first half of the GPIES survey, we see a trend between stellar mass and wide-separation giant planet occurrence rate

Wide-separation giant planets and brown dwarfs seem to be following different underlying populations

Close-in RV giant planets and wide-separation giant planets do not seem to be following the same distributions

These trends are consistent with wide-separation giant planets forming by core accretion, and wide-separation brown dwarfs forming by gravitational instability