The Precision Radial Velocity Spectrometer Science Case

PRVS Science Case

- **The science case for PRVS is compelling:**
  - ***Discover terrestrial-mass planets in the habitable zones of ubiquitous low-mass stars for the first time.***
  - ***1.0-1.75 micron single-shot, always available, design affords wide-range of other high-profile science.***

PRVS Science Case

- **Primary science driver:**

  Find terrestrial mass planets in the habitable zones of nearby low-mass stars

  The habitable zones of M stars correspond to orbits of only days or weeks.

PRVS Science Case

- PRVS will lead to a better understanding of the origin of our planet and life on it.
- PRVS will answer questions about the
  - origin of planetary systems
  - diversity of planetary systems
  - physical processes and initial conditions that produce different types of systems
  - frequency of planets that might support life
  - planet formation mechanisms around low-mass stars—is gas accretion suppressed around low-mass stars?

PRVS Science Case

- Methods for exoplanet discovery
  - Radial velocity (196 planets)
  - Pulsar timing (4 planets)
  - Transits (12 planets)
  - Gravitational microlensing (4 planets)
  - Astrometry (1 confirmation)
  - Direct imaging (4 planets?)
- PRVS will be highly complementary to optical RV searches, transit searches, NICI and GPI imaging searches
- No direct competition in the PRVS corner of parameter space in the near future

GEMINI OBSERVATORY PRVS Science Case

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A new hope: Astronomers reach 200-exoplanet milestone

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Science Snapshot
Dan Vergano

In real life, science fiction turns into science with little fanfare, certainly a disappointment for fans of zap guns, teleportation and mini-skirted aliens. Take the discovery of planets circling nearby stars — a minor sensation a few years ago, but now almost humdrum. With little fanfare though, planet detectives have now found an astounding 200 planets orbiting nearby stars.

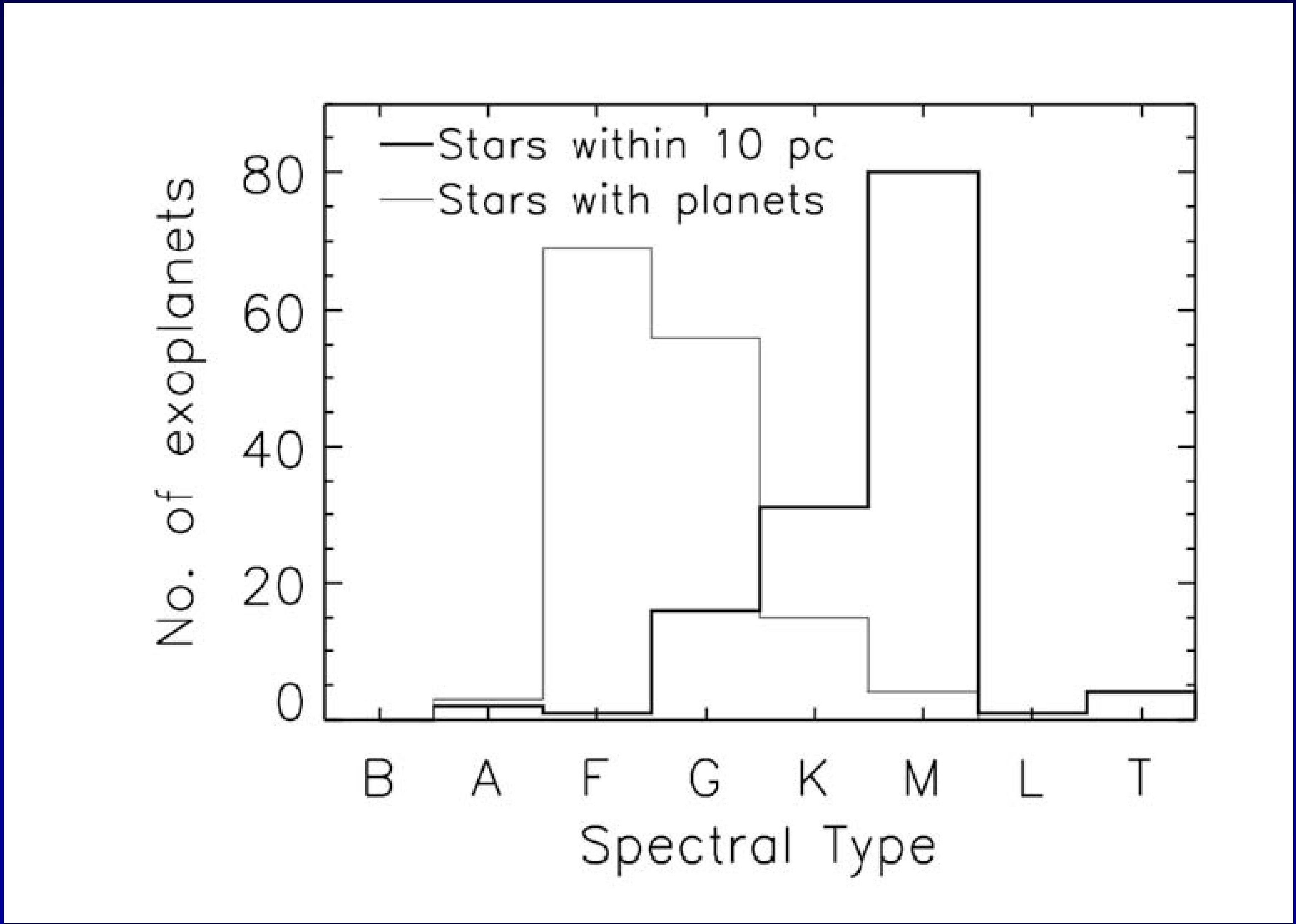
A little more than a decade ago, that number was zero. Since that time,

- Precision radial velocity measurements have produced most of the exoplanet discoveries
- 2078 exoplanet papers published between 1998 and 2005. A very active field!

PRVS Science Case

- PRVS will search for planets around low-mass stars
  - M dwarfs are much more numerous than more massive stars
  - Optical RV surveys are limited to stars more massive than early M dwarfs (>0.3 Msun); lower mass stars are too faint for optical RV surveys
  - Precision of 1 to 3 m/s is required to detect earth-mass planets

PRVS Science Case



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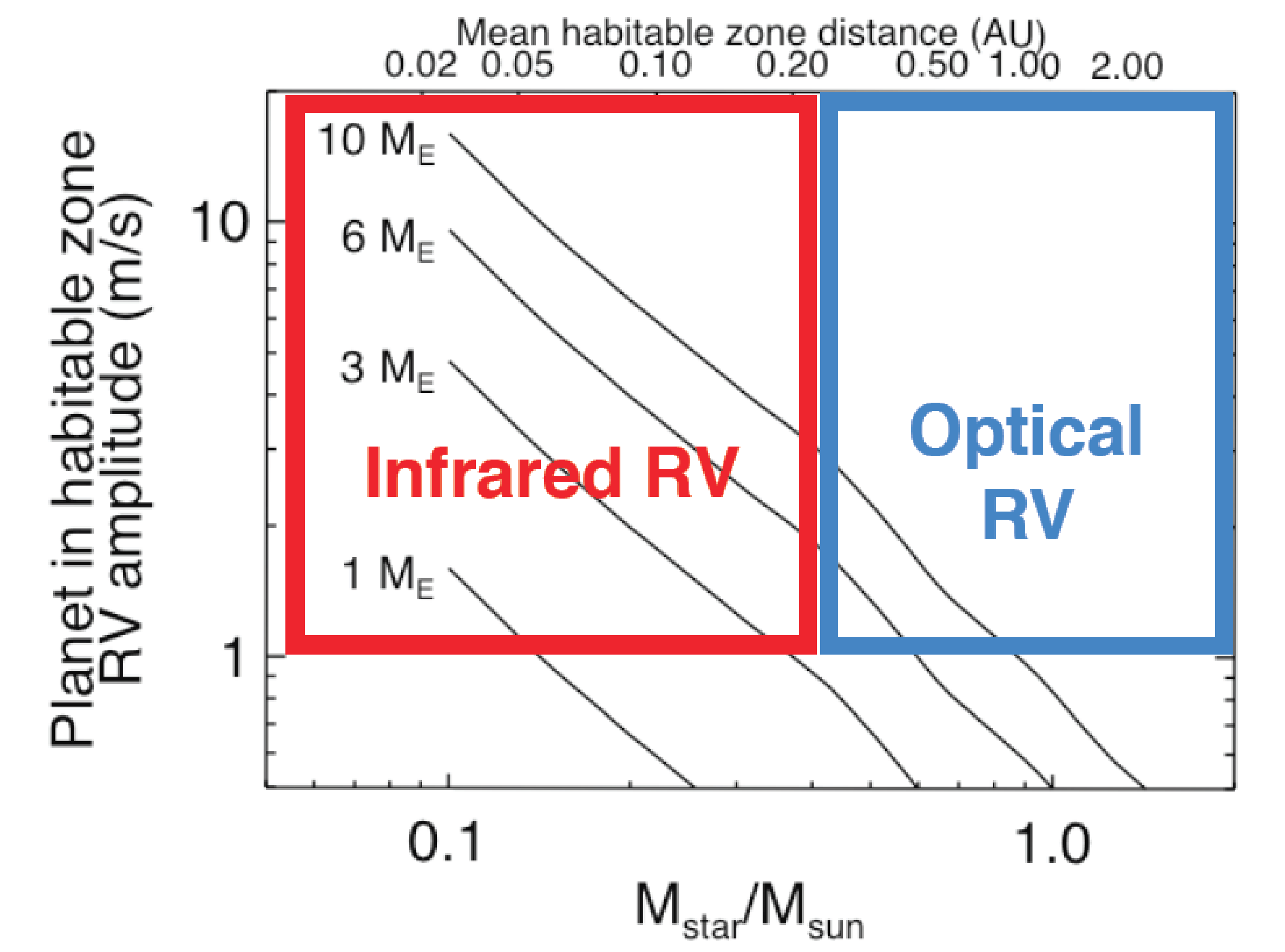

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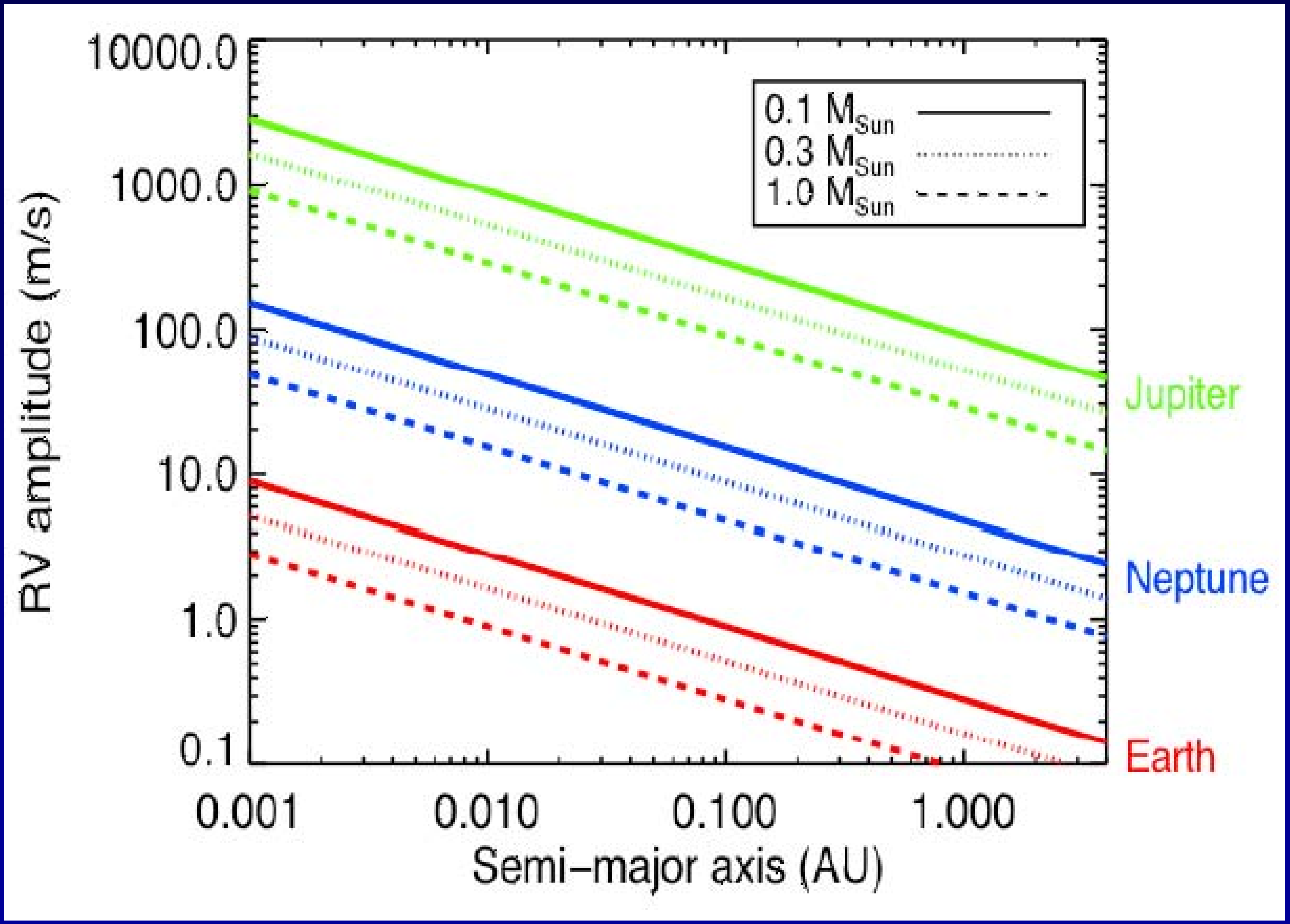

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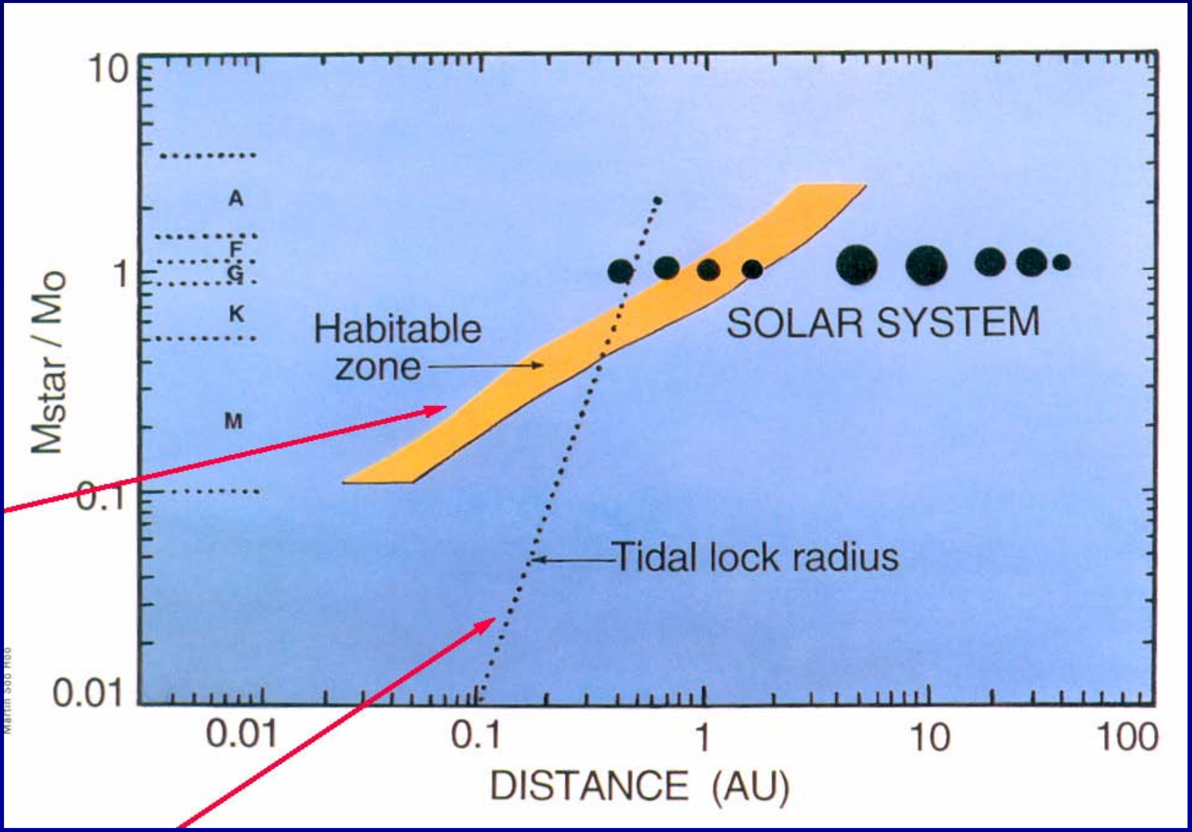
- The habitable zones of low-mass stars are more accessible to RV surveys because the orbital periods are shorter



Habitable zone inside 0.3 AU for M dwarfs

Tidally locked planets may or may not be good places to look for life

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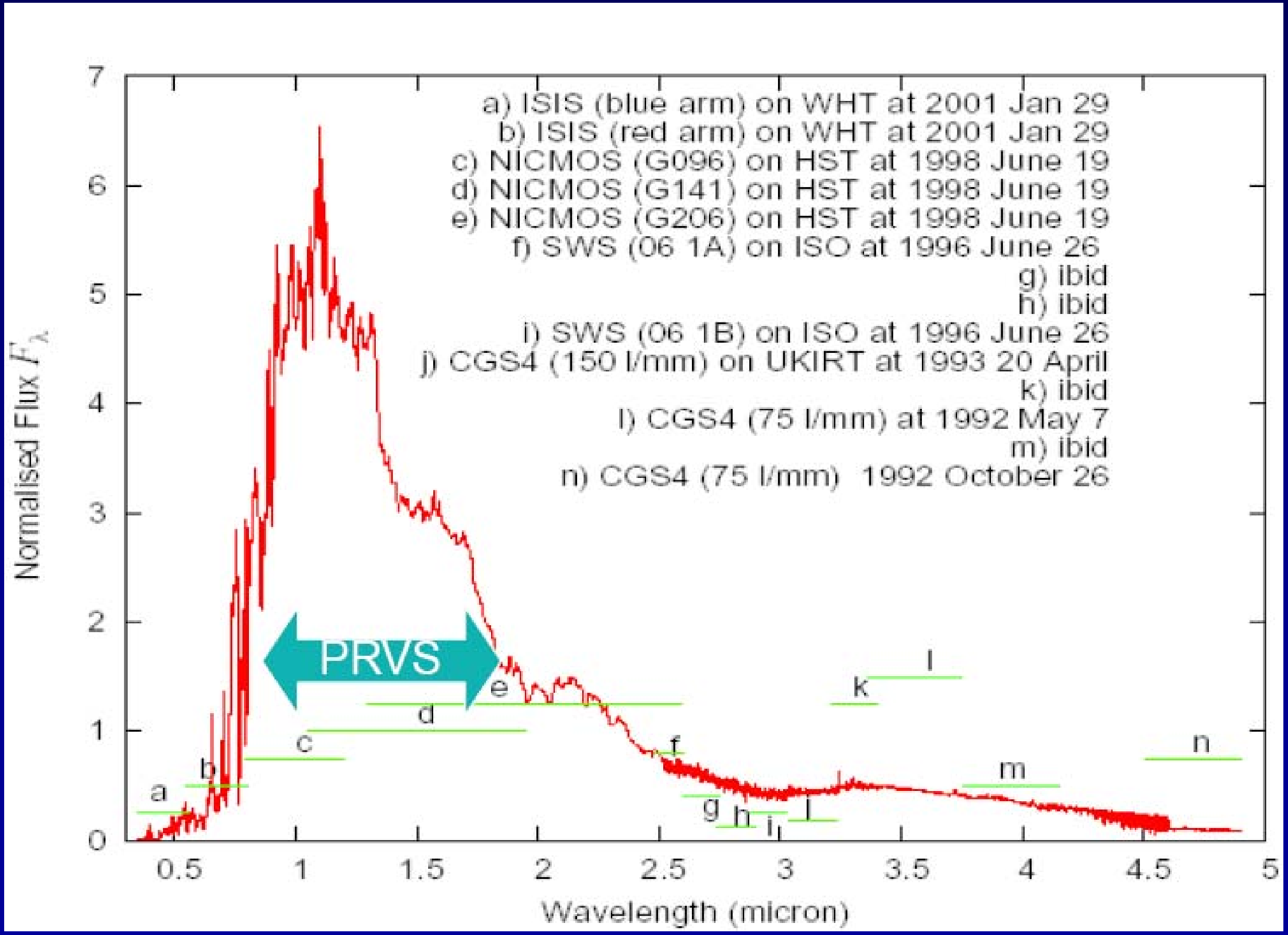
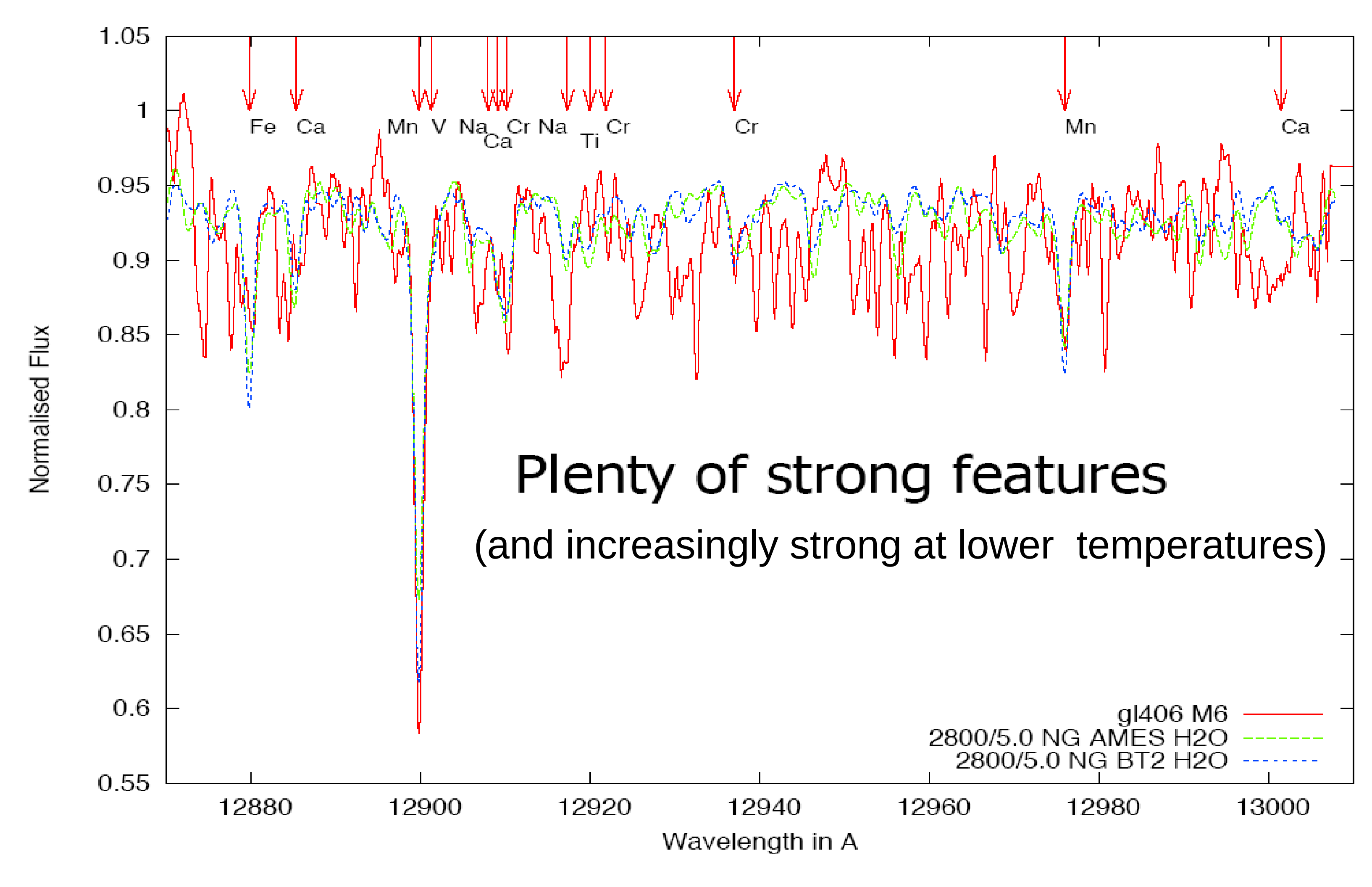
M dwarfs flux peaks at 1 to 1.5 μm



Pavlenko et al. (2006)

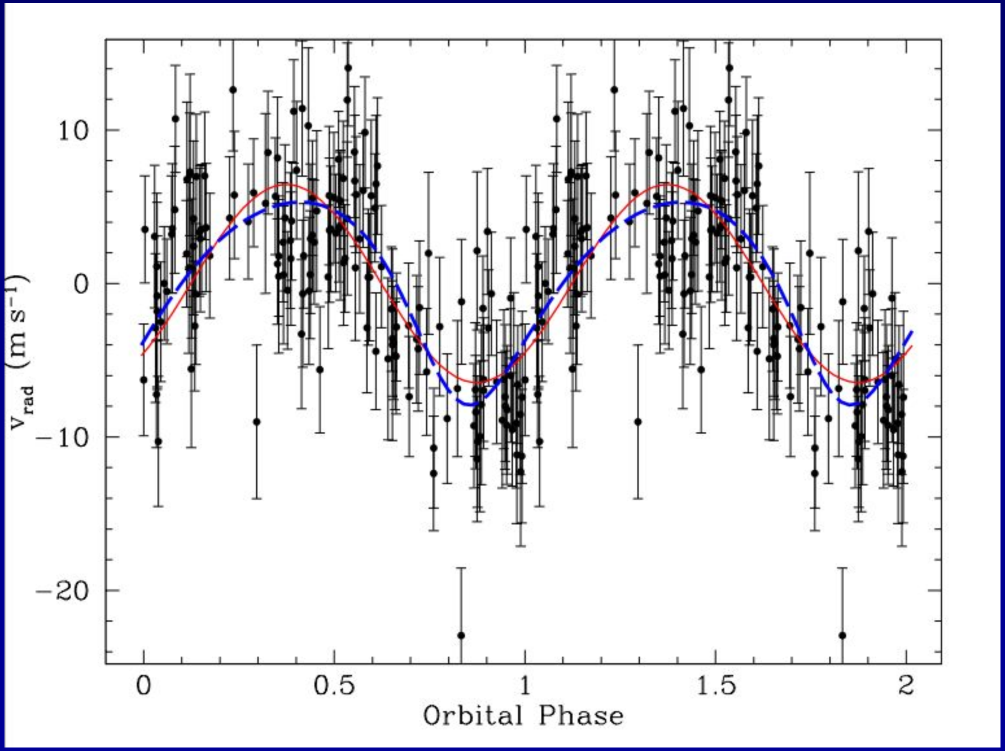
PRVS Science Case



Data from Mclean et al. (2007)

PRVS Science Case

Low mass planets are already being discovered around M dwarfs, but it is tough even for Keck



Gl876 (M4V), 4.7pc

1.9 day period

Msini=7.5MEarth

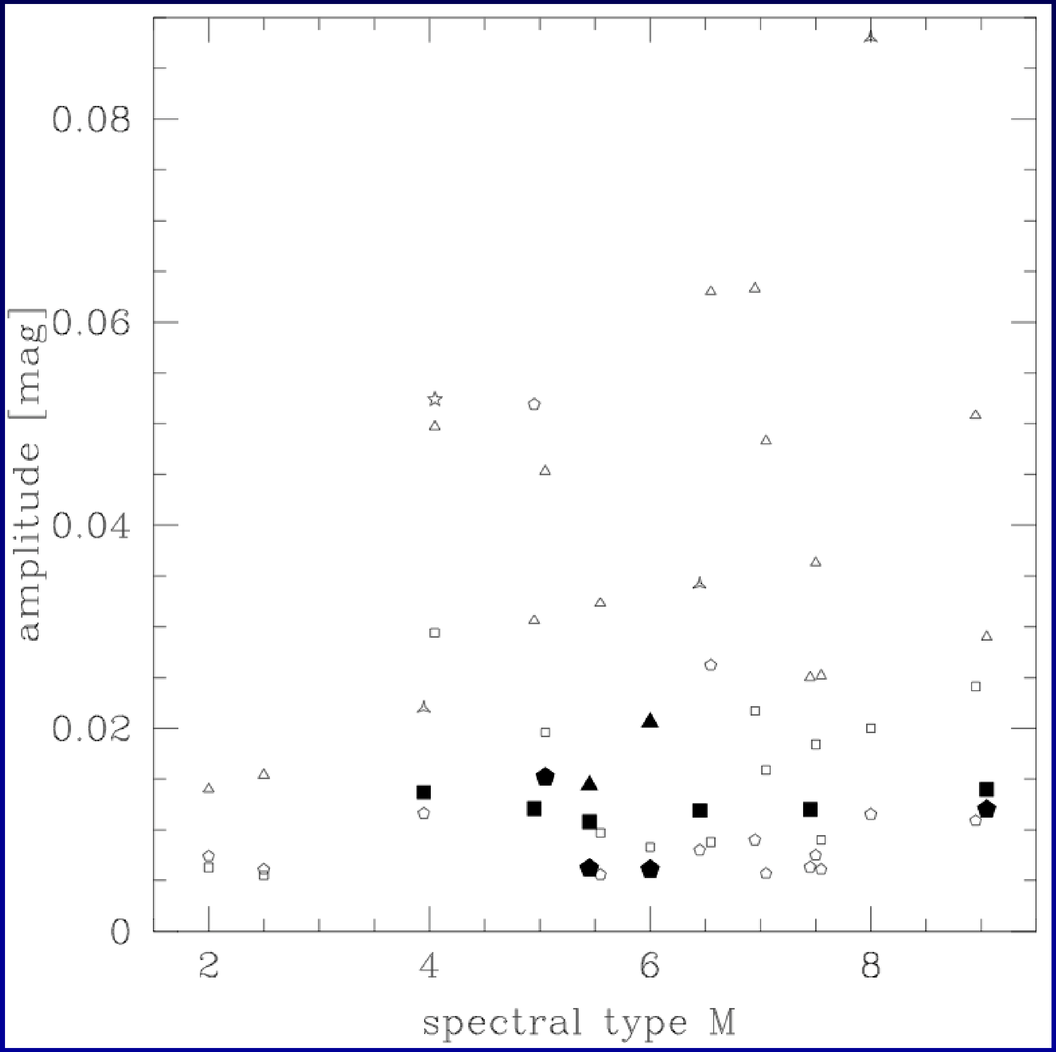
1997-2005 Keck monitoring including data on 6 consecutive nights

Rivera et al. (2005)

PRVS Science Case

What about stellar variability?

- Rockenfeller et al. (2006) find that around 30% of M dwarfs are variable in I band
- About 50% of L dwarfs variable
- Low-mass stars show less variability in the IR



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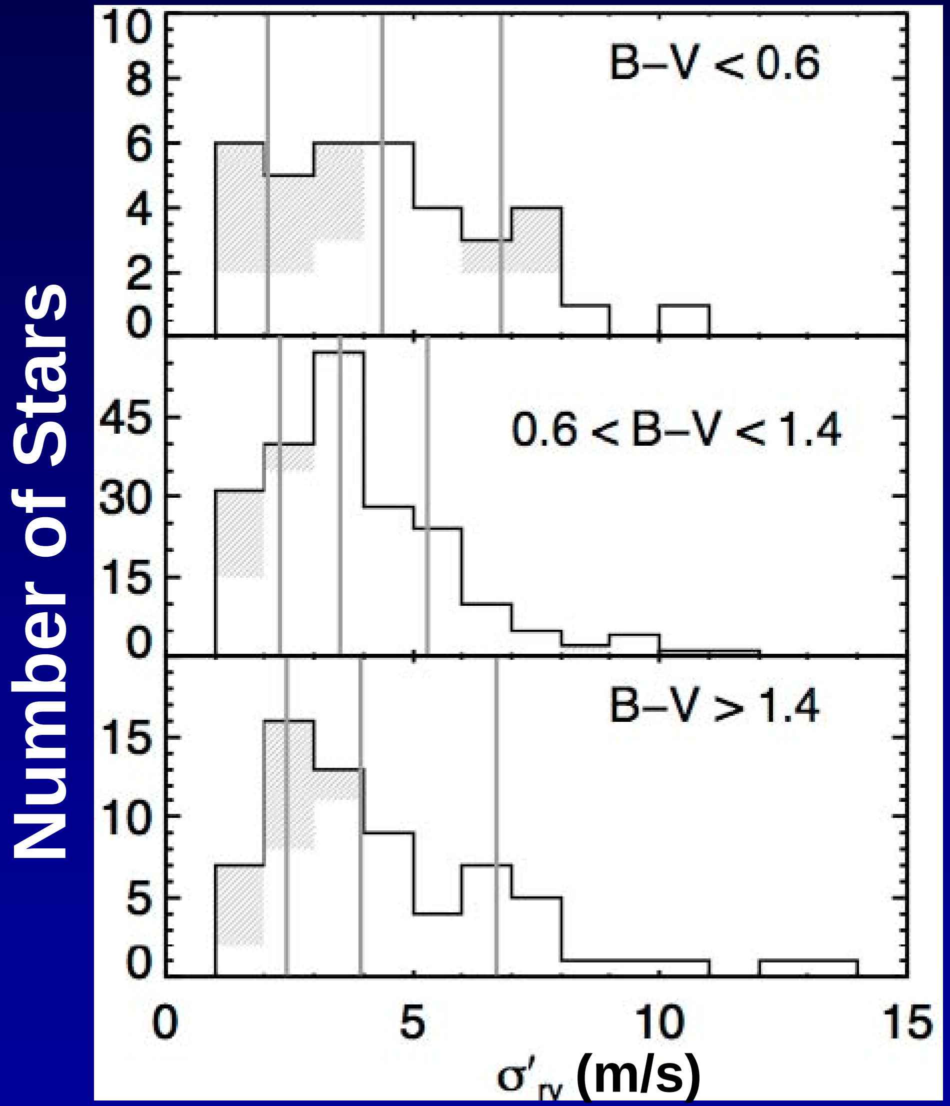


- M dwarfs may show less jitter than more massive stars
- M dwarf activity probably limited to only the youngest stars

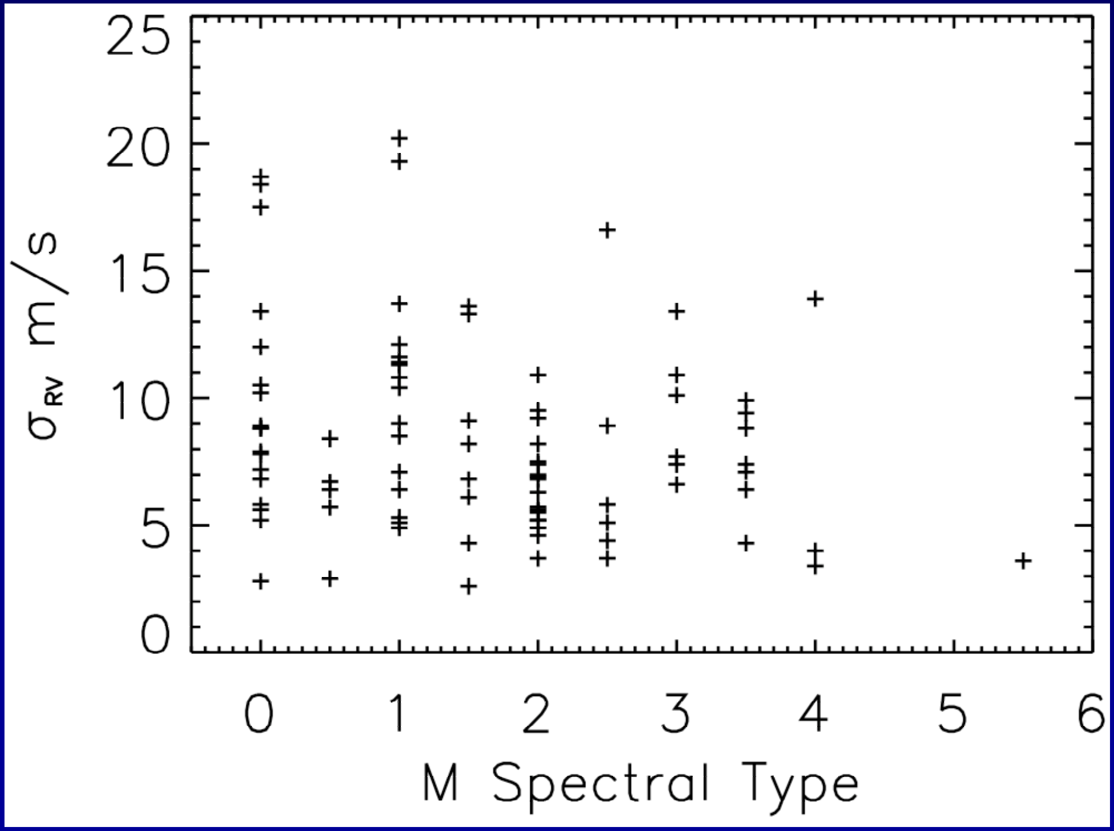
Keck Sample, Wright (2005)

PRVS Science Case

- No evidence for increasing jitter with later type for M dwarfs

M dwarf survey of

Endl et al. (2006)



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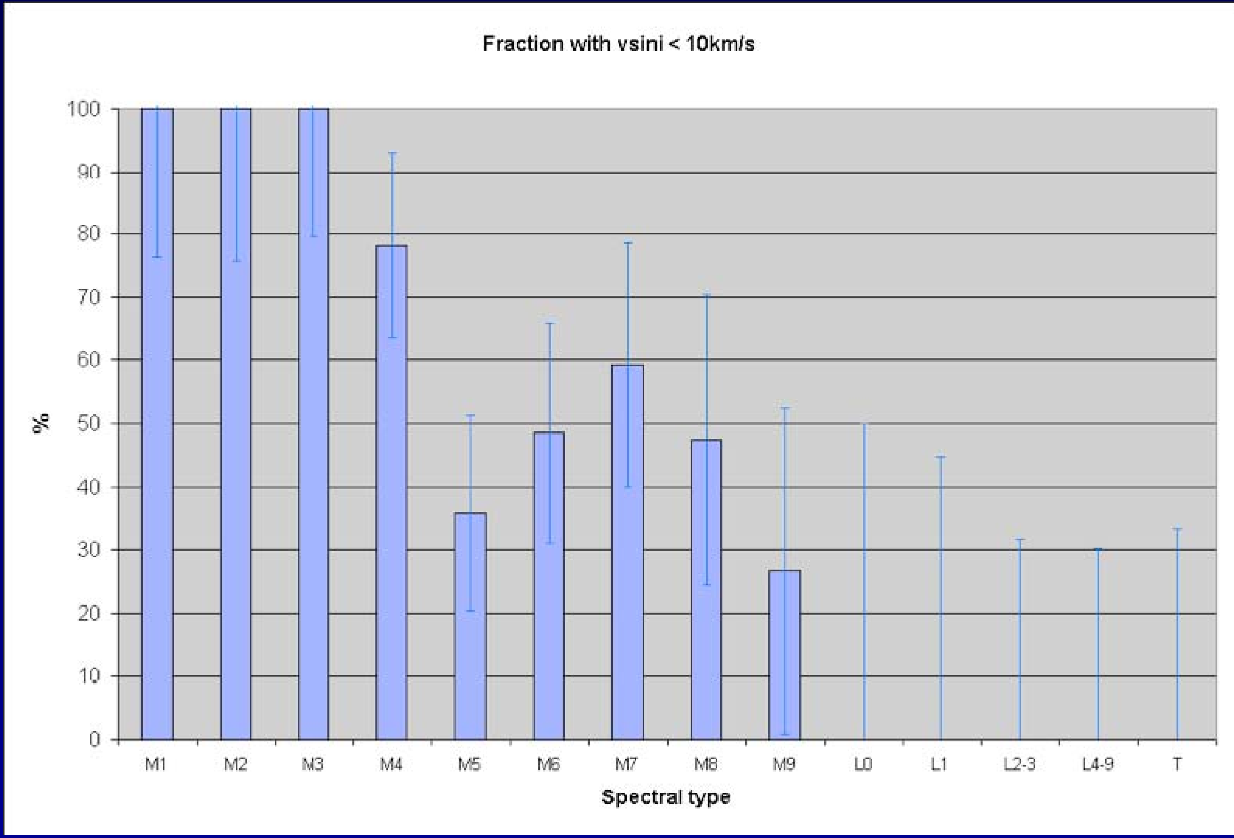
What about rotation?

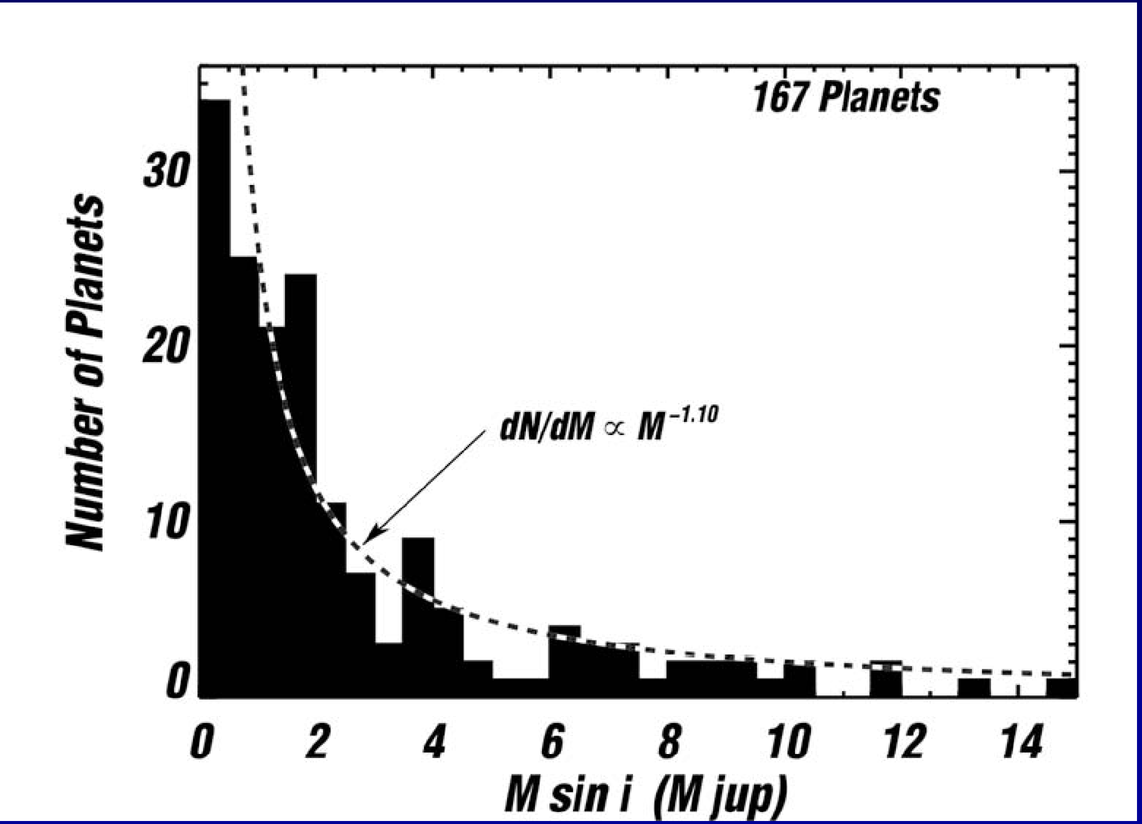
- Later M dwarfs rotate more rapidly
- However, many planets have been discovered by optical RV surveys around stars with v sin i up to 10 km/s



- Even though rotation reduces the precision of the RV measurements, there are sufficient M dwarfs with low rotation velocities for the PRVS survey

PRVS Science Case

Plenty of low-mass planets have been discovered despite strong bias against detection



Butler et al. 2006

PRVS Science Case

- A conservative estimate of a 5 year PRVS survey of 700 local M-dwarfs should turn up ~80 planets less massive than 100 $M_{\oplus}$
- Hundreds of M-dwarfs ~0.15 M_{sun} with J<12 are available for survey (projected S/N=300 in 1 hour at J=12; exposure for J=9 is 300 sec)

PRVS Science Case

- Example Mock Surveys including stellar and instrumental properties:

S/N:	300				125			
Nights/year :	100		50		100		50	
V sin *i* / km/s:	All	<10	All	<10	All	<10	All	<10
~ Sp. Type	Number of Stars				Number of Stars			
M2.5 V	77	90	35	41	90	90	45	45
M3.0 V	77	90	35	41	90	90	45	45
M4.0 V	77	90	35	41	90	90	45	45
M5.0 V	77	90	35	41	90	90	45	45
M6.0 V	77	58	35	41	90	90	45	45
M6.5 V	35	17	35	17	80	90	45	45
M8.0 V	10	5	10	5	80	59	45	45
M9.0 V	3	1	3	1	38	17	29	14
L1.0	1	0	1	0	15	1	11	1
Total	434	441	224	228	663	617	355	330

In 50 n/yr we could survey 200+ stars; with 100 n/yr the sample could be increased to 400+.

PRVS Science Case

- Surveys will be refined using
  - Discovery of more M, L, T, and Y dwarfs using, e.g., UKIDSS and PanSTARRS, etc.
  - Measurement of $v \sin i$ values for survey stars
  - Improved understanding of RV information in M-dwarf spectra
  - Test data from prototype “Pathfinder” instrument constructed at Penn State
    - Funded by Penn State
    - Demonstrate and test calibration techniques
    - Test bed for IR stability measurements
    - Will be used at HET

PRVS other science

- Planetary atmospheres
- Exoplanetary atmospheres
- Brown dwarf astmospheres
- Low-mass spectroscopic binaries
- Rotational velocities of young and low-mass stars
- Hot protostellar disks
- Stellar magnetic fields and stellar activity
- Astroseismology
- Jet and shock physics
- Masses and ages of star clusters in spiral galaxies
- Fine structure constant measurements
- Absorption lines in the foreground of GRBs

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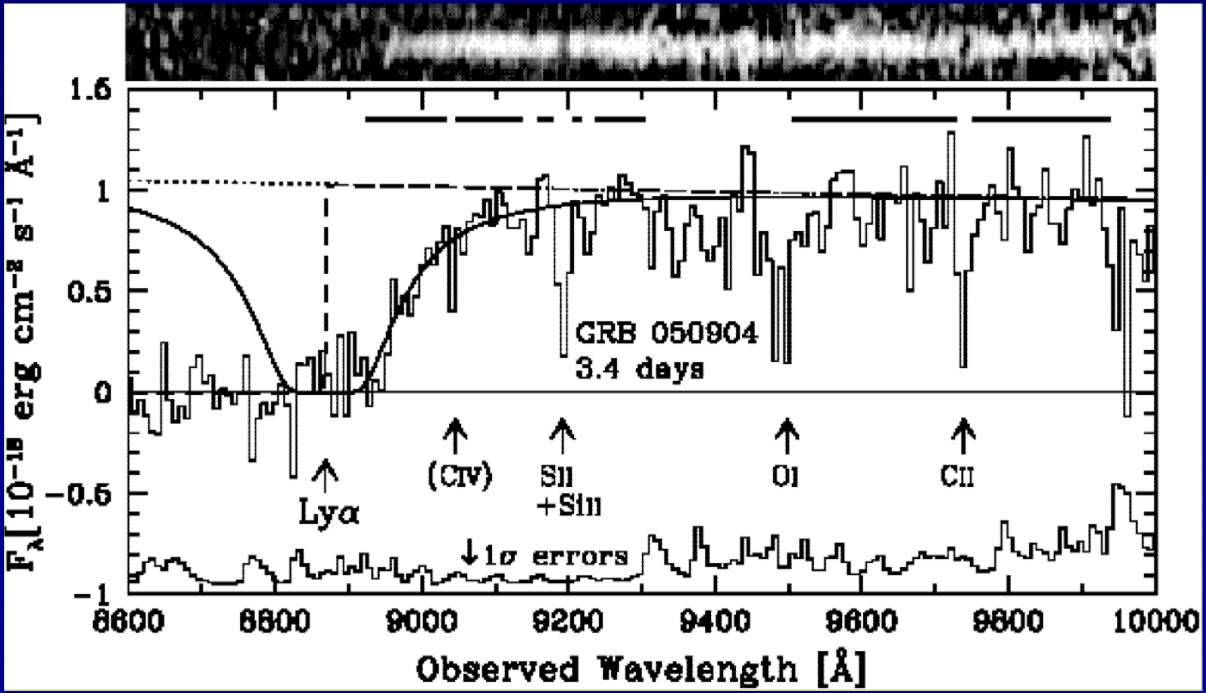
Other PRVS science

- z=7-12 cosmology
- Probe ionization history of the universe by taking spectra of GRBs
- Requires rapid follow-up, queue scheduling



z=6.29 GRB spectrum
3 days after burst

Totani et al. 2006

Conclusion

- The PRVS science case is compelling: PRVS could detect the first earth-mass planet in a habitable zone
- Great public interest
- Active research community
- Key part of the Aspen science mission
- Conservative design that is likely to achieve its science goals
- No competition yet in this area of planet discovery parameter space