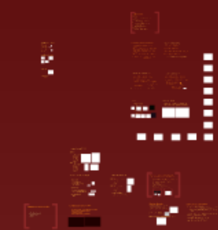
WFCAM Transit Survey: search for planets around cool stars

Image credit: J. Pinfield



Brigitta Sipőcz
University of Hertfordshire

WTS team: D. Pinfield (PI), H.R.A. Jones, N. Goulding, (UHerts, UK); S. Hodgkin (PI), G. Kovács (IoA, Cambridge, UK); R. Saglia, J. Koppenhoefer, M. Cappetta, J. Zendejas, (MPE, Germany); D. Barrado, P. Cruz, H. Stoev , E. Martin (CAB, Madrid, Spain); E. Palle, F. Murgas (IAC,Tenerife, Spain) J. Birkby, I. Snellen, B. Nefs (Leiden, The Netherlands); Y. Pavlenko, M. Kuznetsov (MAO, Ukraine) and many others

WFCAM Transit Survey: search for planets around cool stars

Image credit: J. Pinfield

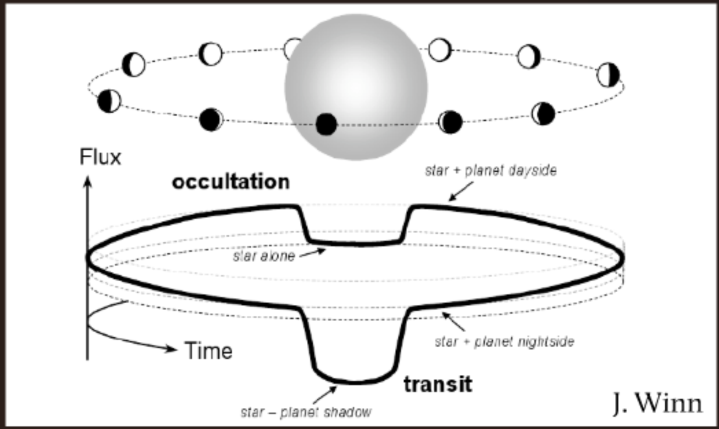
Brigitta Sipőcz
University of Hertfordshire

WTS team: D. Pinfield (PI), H.R.A. Jones, N. Goulding, (UHerts, UK); S. Hodgkin (PI), G. Kovács (IoA, Cambridge, UK); R. Saglia, J. Koppenhoefer, M. Cappetta, J. Zendejas, (MPE, Germany); D. Barrado, P. Cruz, H. Stoev , E. Martin (CAB, Madrid, Spain); E. Palle, F. Murgas (IAC,Tenerife, Spain) J. Birkby, I. Snellen, B. Nefs (Leiden, The Netherlands); Y. Pavlenko, M. Kuznetsov (MAO, Ukraine) and many others

Outline

- Motivation: M dwarf & planet background
- the WFCAM Transit Survey
- the M dwarf sample
- Results
- Conclusions and future prospects

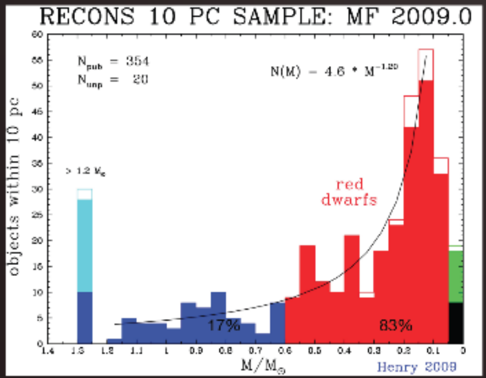
Transiting planets



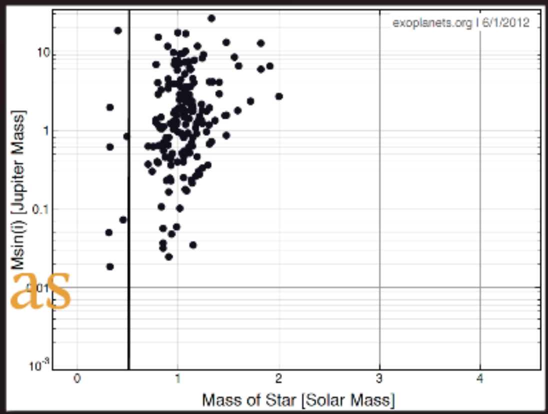
- Resolves sin i ambiguity
    - planet mass
- Transit depth linked directly to planet radius
    - planet density
- low geometric probability
    - a survey needs many targets → wide field cameras
- Transmission spectroscopy

M dwarfs and their planets

- theories predict different M dwarf planet distributions



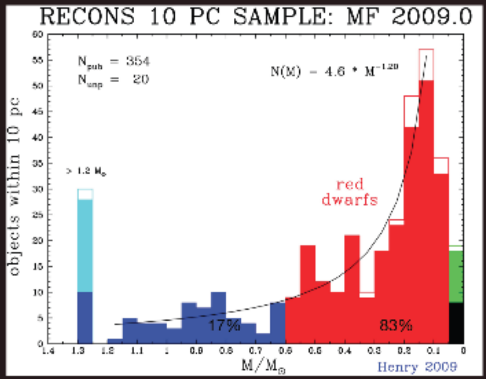
- Core accretion
  - low mass host → low mass disk
  - lack / fewer gas giants, but rocky planets are common



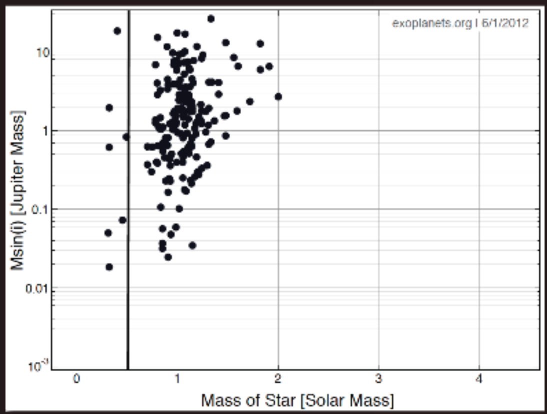
- Gravitational instability
  - giant formation may be as efficient as around more massive stars

M dwarfs and their planets

- M dwarfs dominate the stellar population



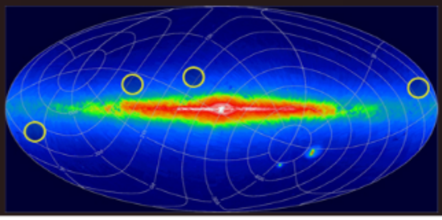
- lower primary mass
  - higher RV signature
- smaller stellar radius
  - better sensitivity for smaller planets
- marketing argument: habitability
  - habitable zone is closer to the star



- spectral energy peak in infrared
- faint objects

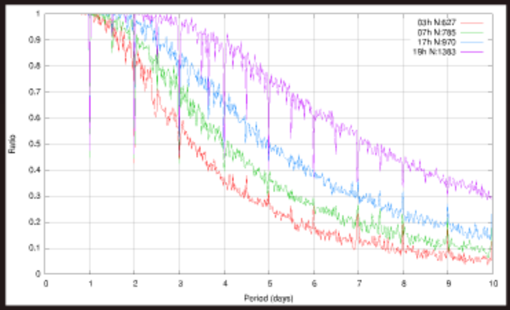
WFCAM Transit Survey

- UKIRT queue scheduled, poor sky backup survey
- Planets around M dwarfs & low mass binaries, M dwarf variability, cool WDs, etc.
- 4 fields of 106'x53' FOV with 0.4" pixels



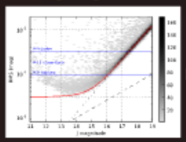
name	centre RA, DEC	galactic	No. epochs	stellar objects	M dwarfs
19	19.58+36.44	70.03+07.83	1263	59270	6495
17	17.25+03.74	24.94+23.11	948	15343	2482
07	07.09+12.94	202.89+08.91	756	21224	3135
03	03.65+39.23	154.99-12.99	591	15159	3498

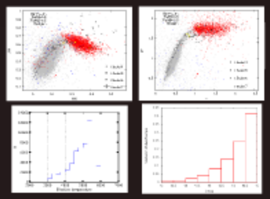
WTS fields summary as of 2012 Aug, listed numbers are for J<17

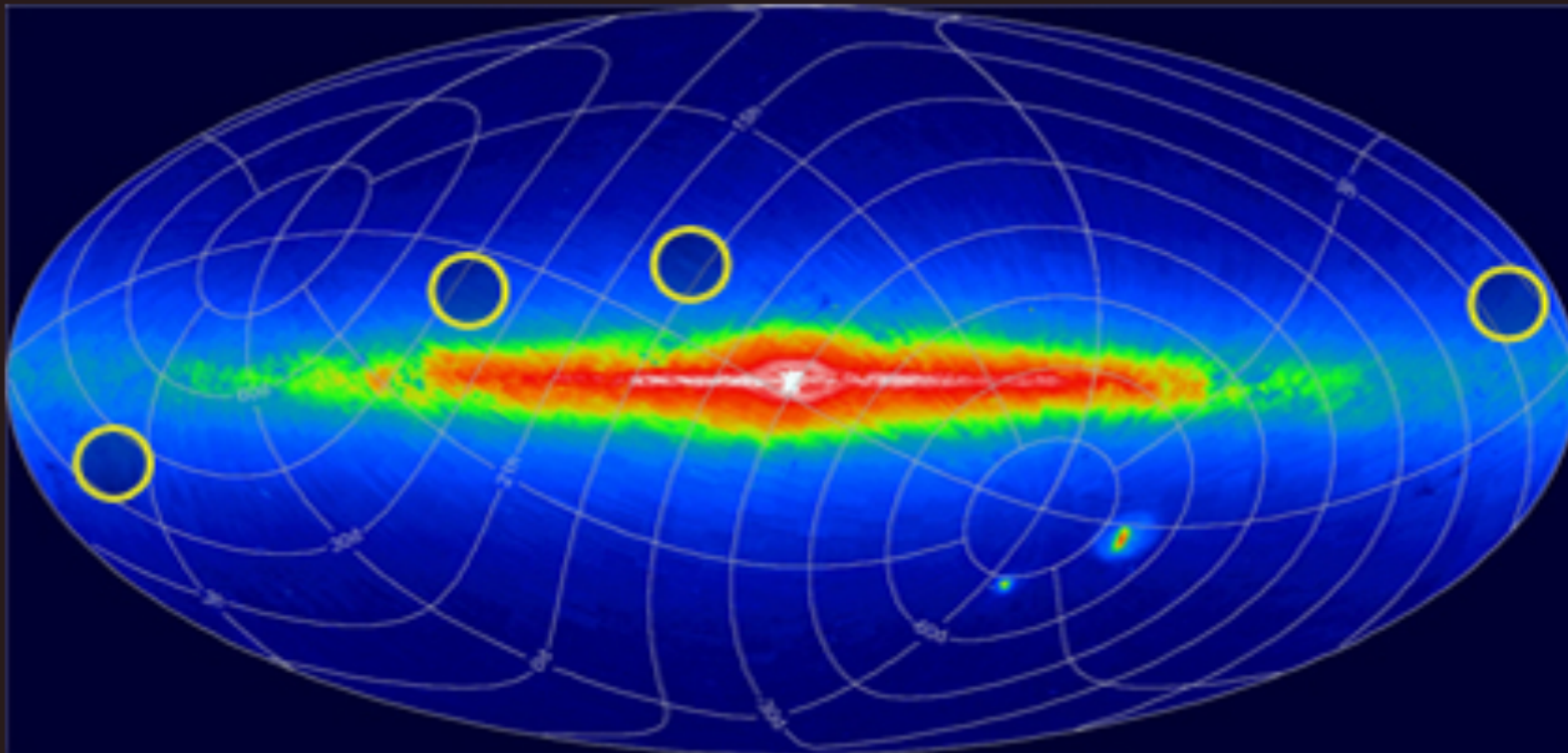


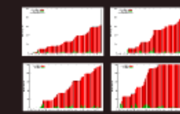
- a total of ~15000 M dwarfs in WTS (J<17 mag)
  - SED fitting (grizZYJHK)/colour-colour cuts
  - model dependency (200-300K)

    ongoing work to improve the sample and to add kinematics
  - noise properties:



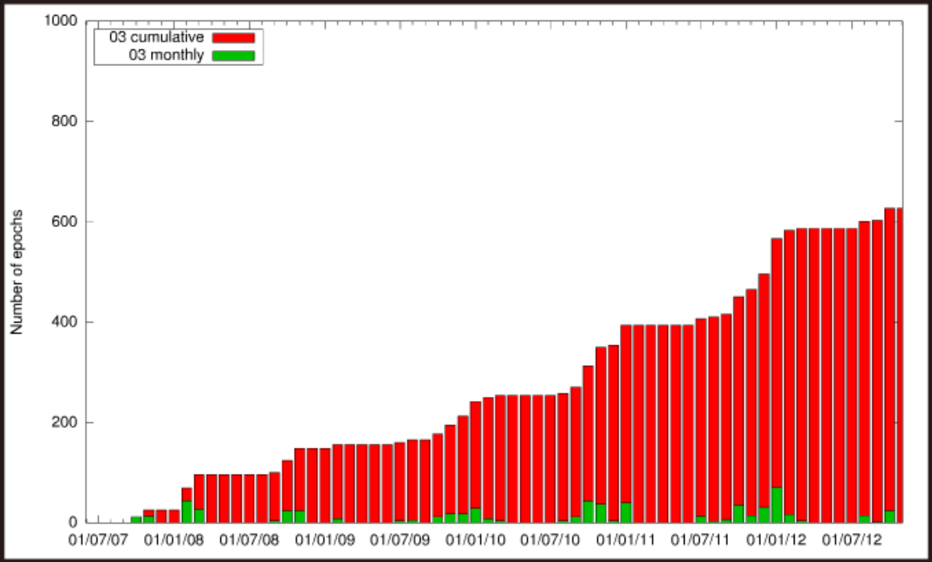


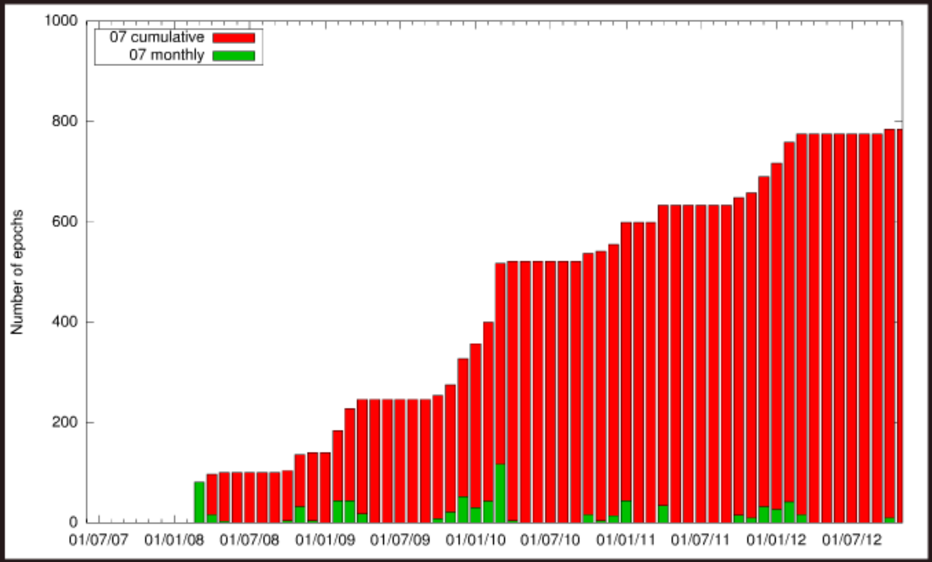


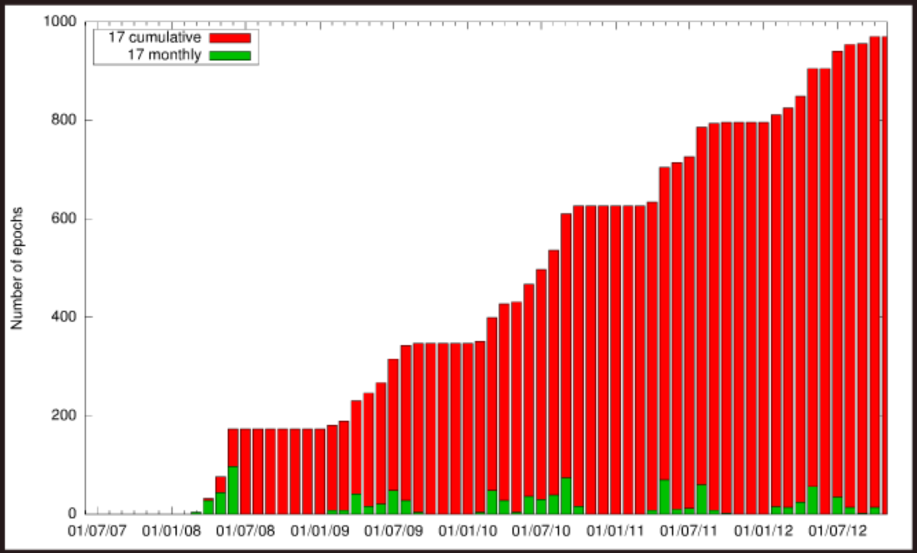


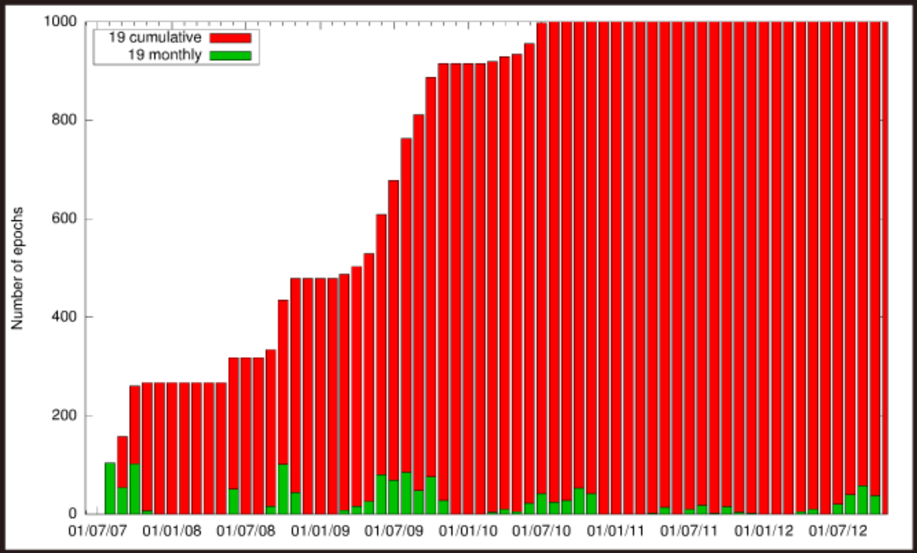
name	centre RA, DEC	galactic	No. epochs	stellar objects	M dwarfs
19	19.58+36.44	70.03+07.83	1263	59270	6495
17	17.25+03.74	24.94+23.11	948	15343	2482
07	07.09+12.94	202.89+08.91	756	21224	3135
03	03.65+39.23	154.99-12.99	591	15159	3498

WTS fields summary as of 2012 Aug, listed numbers are for J<17


03 cumulative
03 monthly
Number of epochs
1000
800
600
400
200
0
01/07/07
01/01/08
01/07/08
01/01/09
01/07/09
01/01/10
01/07/10
01/01/11
01/07/11
01/01/12
01/07/12

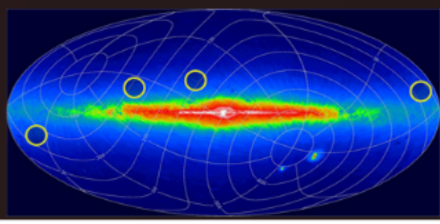

07 cumulative
07 monthly
Number of epochs
1000
800
600
400
200
0
01/07/07
01/01/08
01/07/08
01/01/09
01/07/09
01/01/10
01/07/10
01/01/11
01/07/11
01/01/12
01/07/12


17 cumulative
17 monthly
Number of epochs
1000
800
600
400
200
0
01/07/07
01/01/08
01/07/08
01/01/09
01/07/09
01/01/10
01/07/10
01/01/11
01/07/11
01/01/12
01/07/12


19 cumulative
19 monthly
Number of epochs
1000
800
600
400
200
0
01/07/07
01/01/08
01/07/08
01/01/09
01/07/09
01/01/10
01/07/10
01/01/11
01/07/11
01/01/12
01/07/12

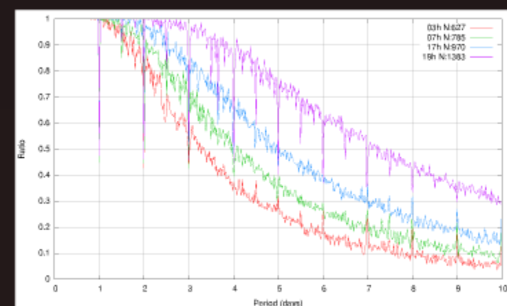
WFCAM Transit Survey

- UKIRT queue scheduled, poor sky backup survey
- Planets around M dwarfs & low mass binaries, M dwarf variability, cool WDs, etc.
- 4 fields of 106'x53' FOV with 0.4" pixels

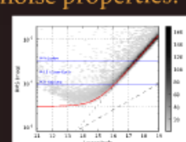
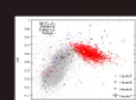
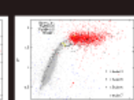
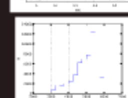
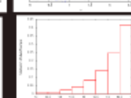


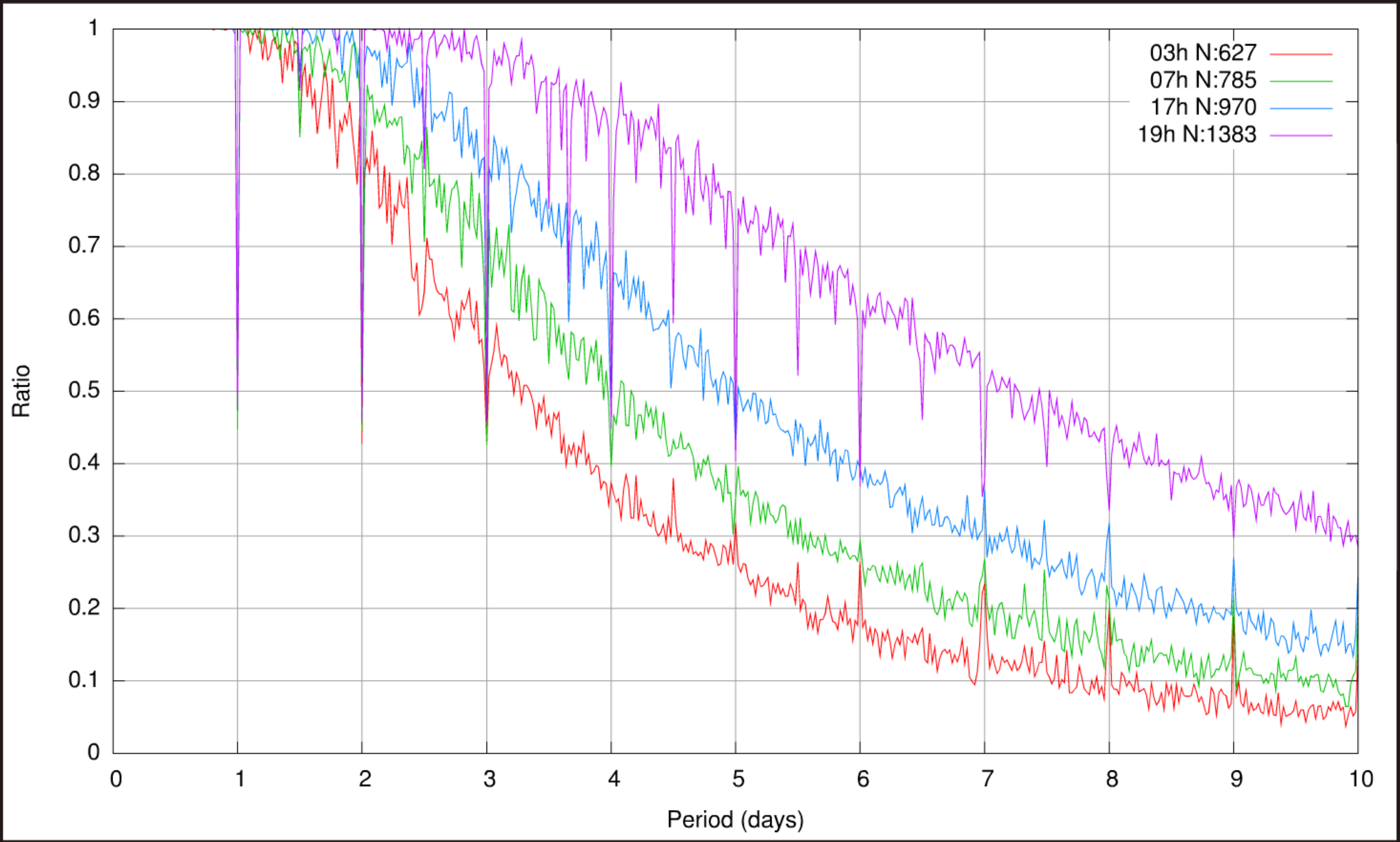
name	centre RA, DEC	galactic	No. epochs	stellar objects	M dwarfs
19	19.58+36.44	70.03+07.83	1263	59270	6495
17	17.25+03.74	24.94+23.11	948	15343	2482
07	07.09+12.94	202.89+08.91	756	21224	3135
03	03.65+39.23	154.99-12.99	591	15159	3498

WTS fields summary as of 2012 Aug, listed numbers are for J<17



- a total of ~15000 M dwarfs in WTS (J<17 mag)
  - SED fitting (grizZYJHK)/colour-colour cuts
  - model dependency (200-300K)
    - ongoing work to improve the sample and to add kinematics
  - noise properties:

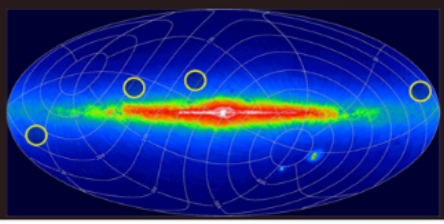








03h N:627
07h N:785
17h N:970
19h N:1383
Ratio
Period (days)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10

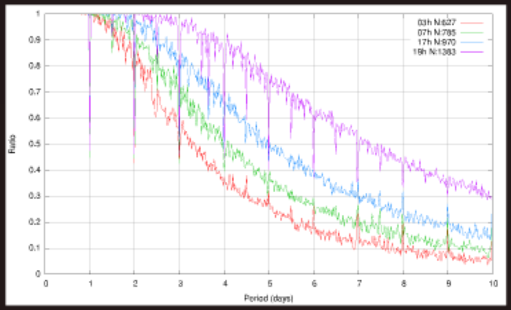
WFCAM Transit Survey

- UKIRT queue scheduled, poor sky backup survey
- Planets around M dwarfs & low mass binaries, M dwarf variability, cool WDs, etc.
- 4 fields of 106'x53' FOV with 0.4" pixels

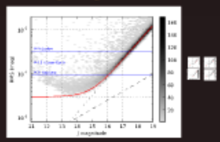


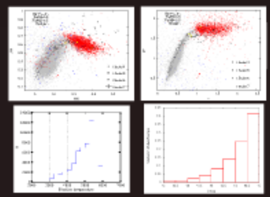
name	centre RA, DEC	galactic	No. epochs	stellar objects	M dwarfs
19	19.58+36.44	70.03+07.83	1263	59270	6495
17	17.25+03.74	24.94+23.11	948	15343	2482
07	07.09+12.94	202.89+08.91	756	21224	3135
03	03.65+39.23	154.99-12.99	591	15159	3498

WTS fields summary as of 2012 Aug, listed numbers are for J<17



- a total of ~15000 M dwarfs in WTS (J<17 mag)
  - SED fitting (grizZYJHK)/colour-colour cuts
  - model dependency (200-300K)
    ongoing work to improve the sample and to add kinematics
  - noise properties:



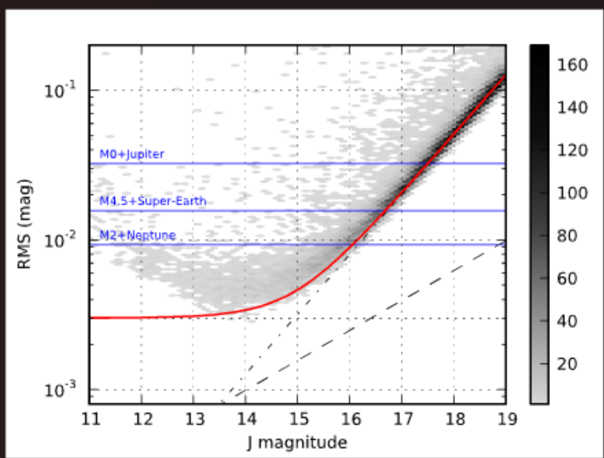


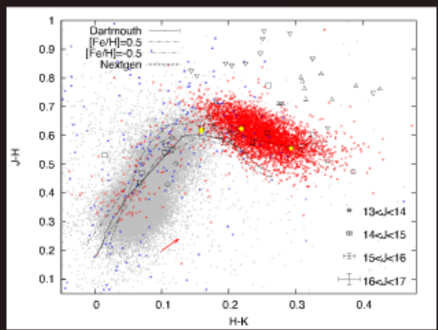
M dwarfs in WTS

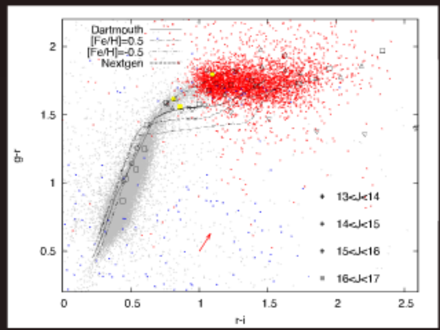
- SED fitting (grizZYJHK)/colour-colour cuts
- model dependency (200-300K)

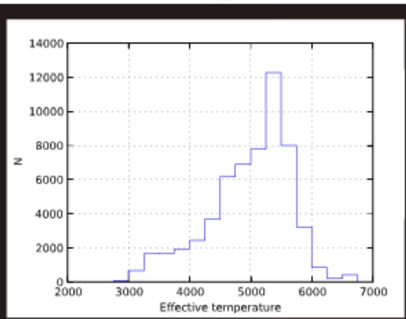
  ongoing work to improve the sample and to add kinematics

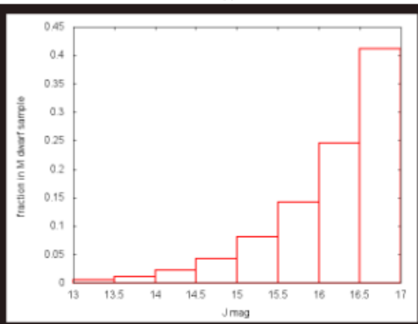
- noise properties:



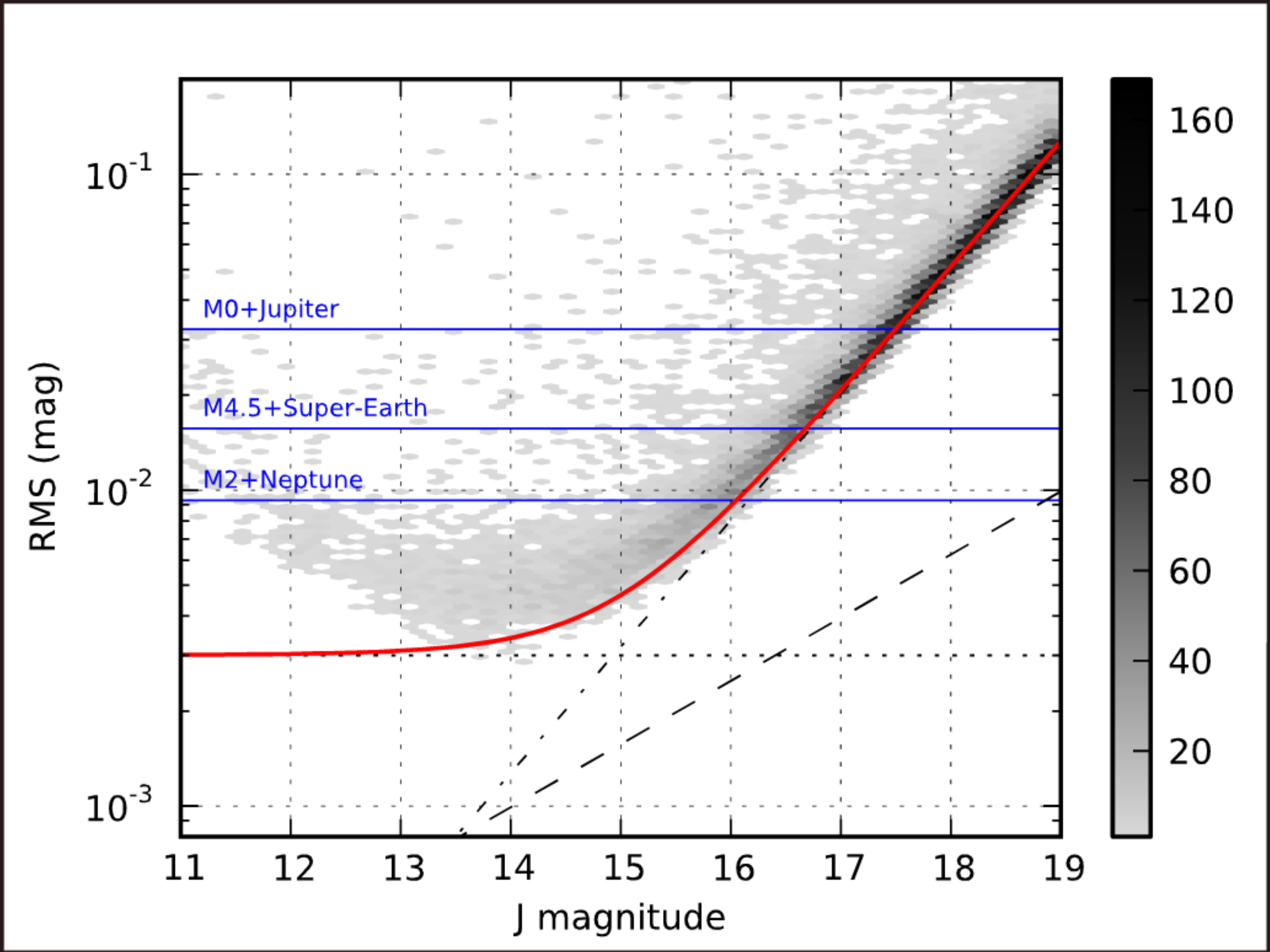


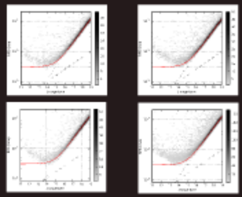


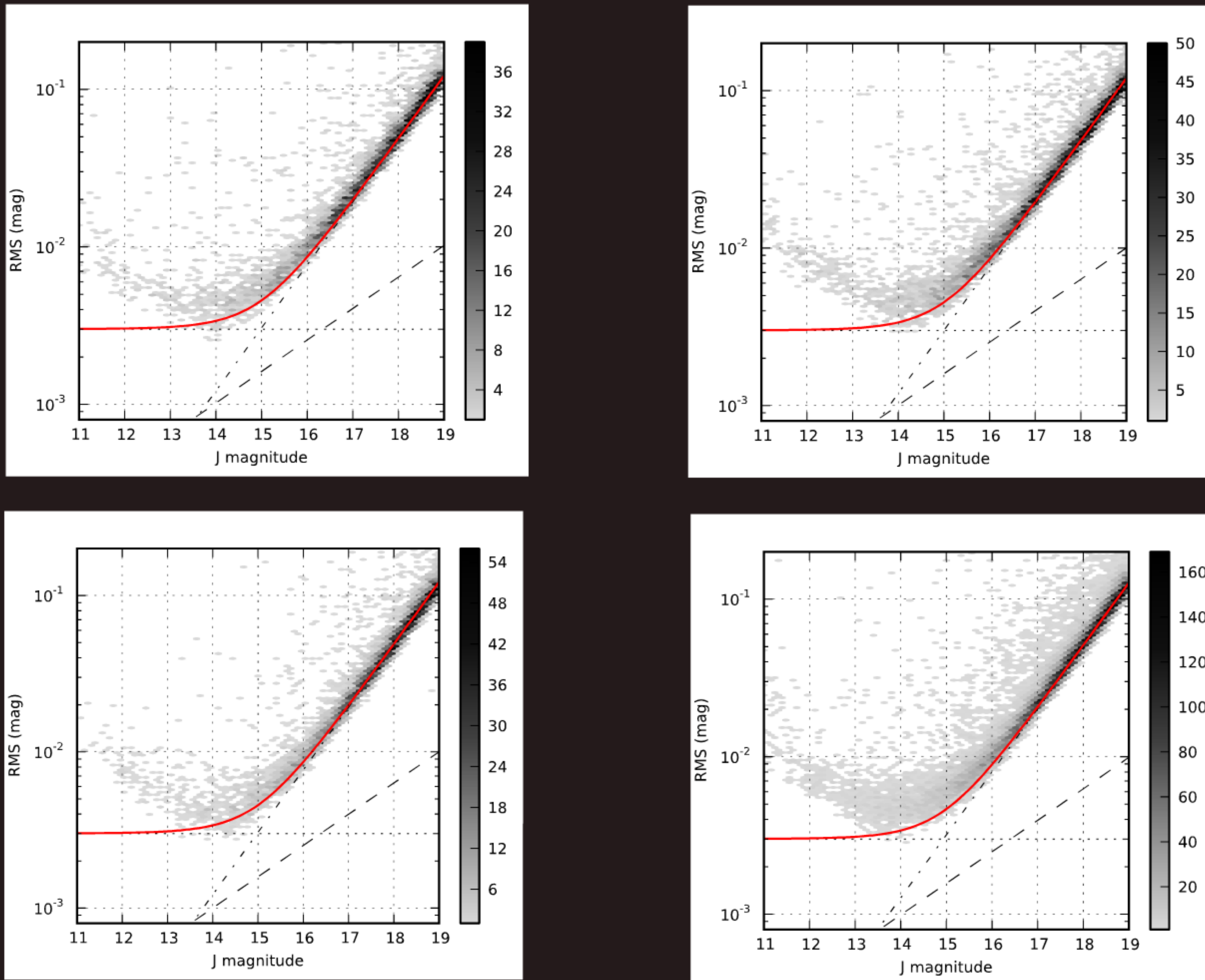




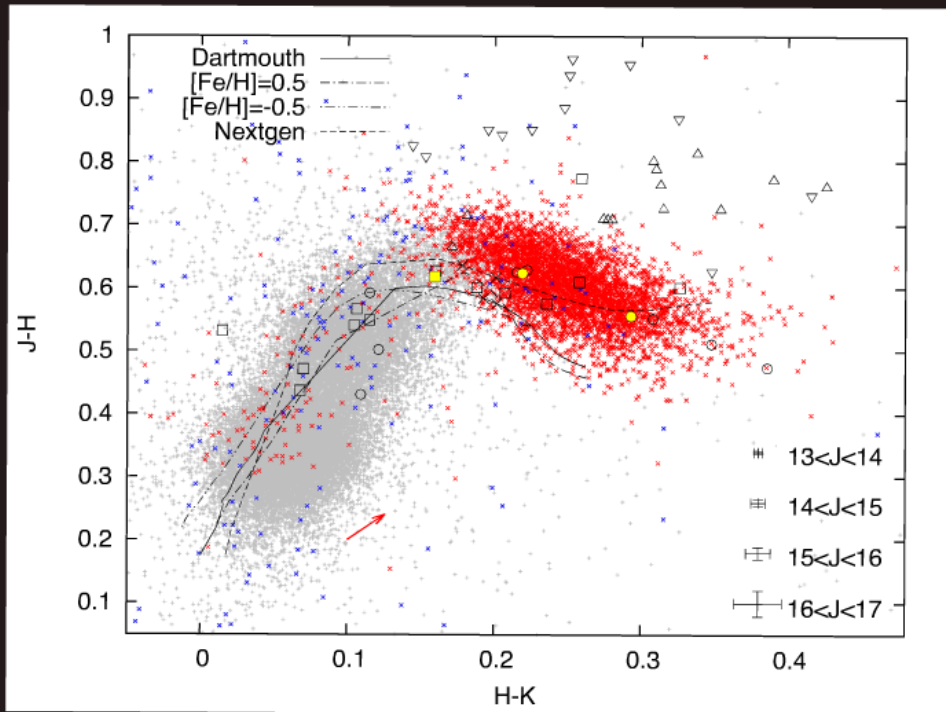
• noise properties:

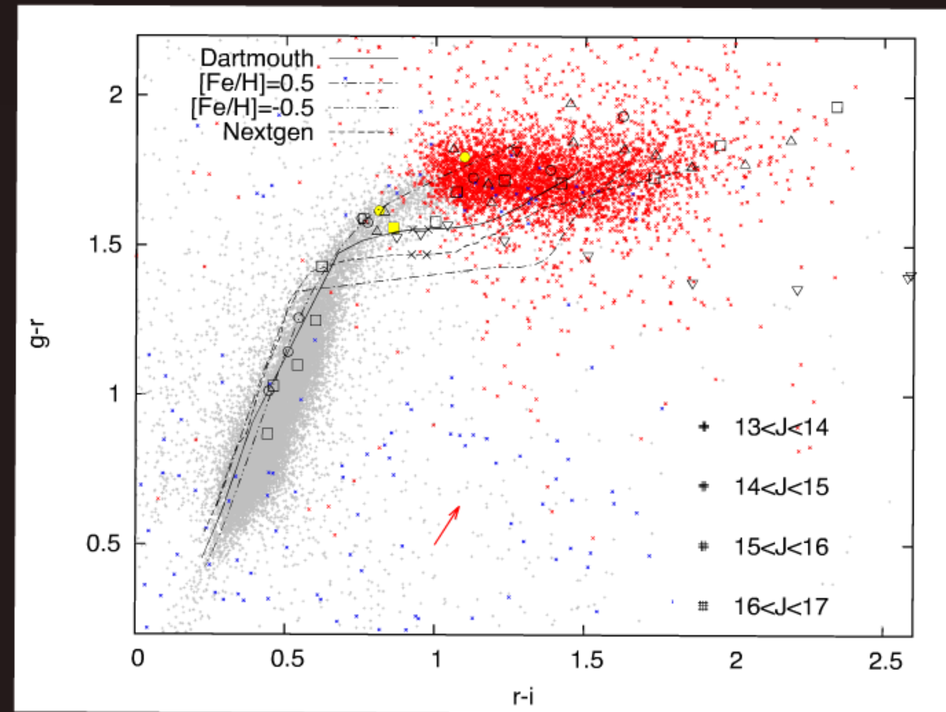


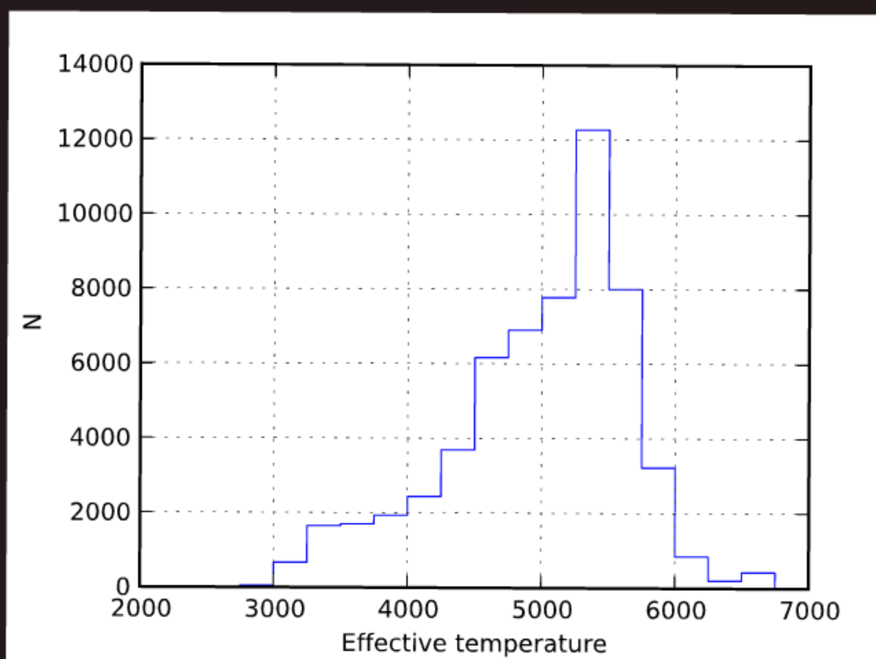


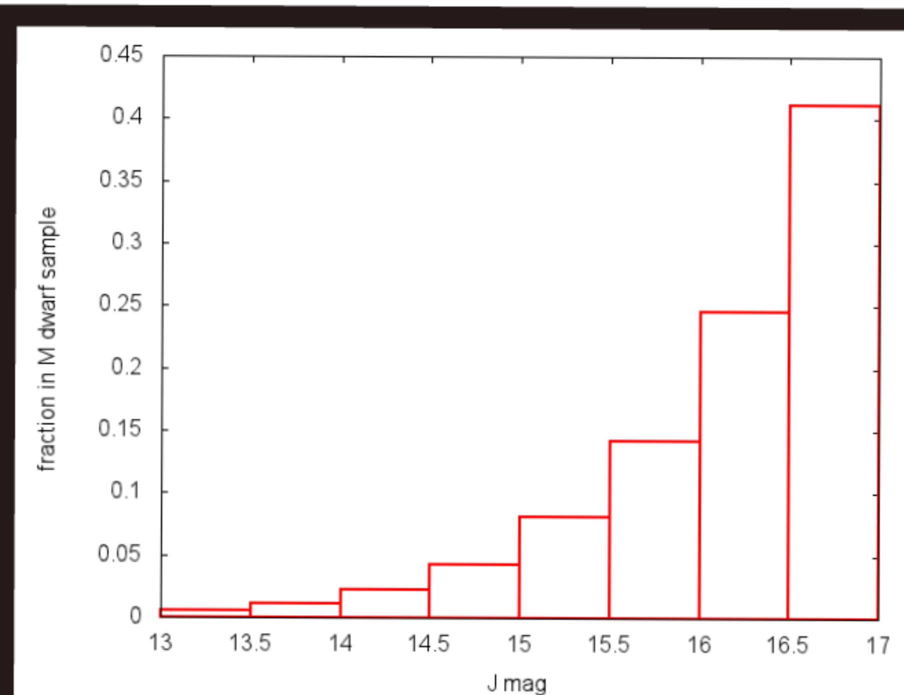


RMS (mag)
10^-1
10^-2
10^-3
11 12 13 14 15 16 17 18 19
J magnitude
36 32 28 24 20 16 12 8 4
RMS (mag)
10^-1
10^-2
10^-3
11 12 13 14 15 16 17 18 19
J magnitude
50 45 40 35 30 25 20 15 10 5
RMS (mag)
10^-1
10^-2
10^-3
11 12 13 14 15 16 17 18 19
J magnitude
54 48 42 36 30 24 18 12 6
RMS (mag)
10^-1
10^-2
10^-3
11 12 13 14 15 16 17 18 19
J magnitude
160 140 120 100 80 60 40 20


Dartmouth
[Fe/H]=0.5
[Fe/H]=-0.5
Nextgen
13<J<14
14<J<15
15<J<16
16<J<17
J-H
H-K
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.1
0.2
0.3
0.4


Dartmouth
[Fe/H]=0.5
[Fe/H]=-0.5
Nextgen
13<J<14
14<J<15
15<J<16
16<J<17
g-r
r-i
0.5
1
1.5
2
0
0.5
1
1.5
2
2.5


N
Effective temperature
0
2000
4000
6000
8000
10000
12000
14000
2000
3000
4000
5000
6000
7000


fraction in M dwarf sample
J mag
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
13
13.5
14
14.5
15
15.5
16
16.5
17

Automating candidate selection

- simulation helps fine tuning the candidate selection
- introduce a method for candidate selection which eliminates the least objective parts (e.g. massive eyeballing)
- capable of fast regeneration of candidates with a new lc release
- introduce a system which does NOT cut, but score

- two types of scores:
  - detection score (quality of detection)
  - planet/EB score

Detection score (sD)

- should reflect the quality of the detection

- data available for automated scoring:
  - WFCAM + SDSS photometry → SED fitting

↓

Star: temperature and radius

  - WFCAM J light curve → BLS

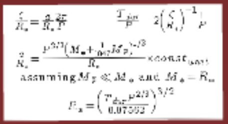
↓

Detection: period, depth, duration, number of transits, in-transit points, etc.

Planet score (sP)

- should reflect the planet likeness of the target
- derived properties available for automated scoring:
  - WFCAM + SDSS photometry
  - WFCAM J light curve
    - planet radii vs temp
    - star radius from BLS

Host star radius estimation from BLS



Follow-ups

Initial data

- WTS J-band light curves: input for BLS → period and epoch
- Multicolor photometry: WFCAM and SDSS colours → Teff/spectral type

Candidates

- < 10 high priority planet candidates, all but two are rejected during follow-ups
- candidate tracking system

Follow-up photometry

- using 2 m class telescopes (INT, LT, ESO 2.2m, ...)
- confirmation of the transit and its wavelength independence
- improving ephemeris and planetary model

Low-res spectroscopy

- using 4m class telescopes (WHT, CAHA 3.5m, TNG, ...)
- spectral typing, identifying blends, solving binary systems

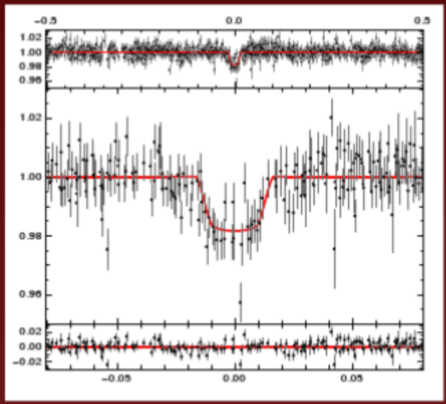
High-res spectroscopy

- using HDS on the Hobby-Eberly Telescope, HiRES on Keck 1
- RV measurements and characterization of the planet host

Planets in the WTS

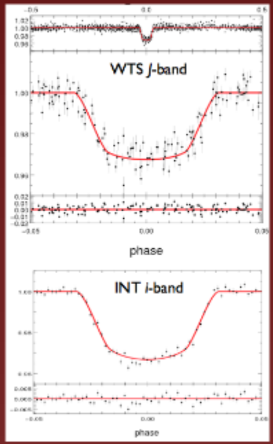
- WTS-1b (Michele Cappetta's talk)

  Teff~6250K
  P=3.352 days
  R~1.60 RJ
  M~4.03 MJ
  J=15.3 mag



- WTS-2b (Jayne Birkby's talk)

  Teff~4900 K
  P=1.0187 days
  R~1.35 RJ
  M~1.08 MJ
  J=13.9 mag

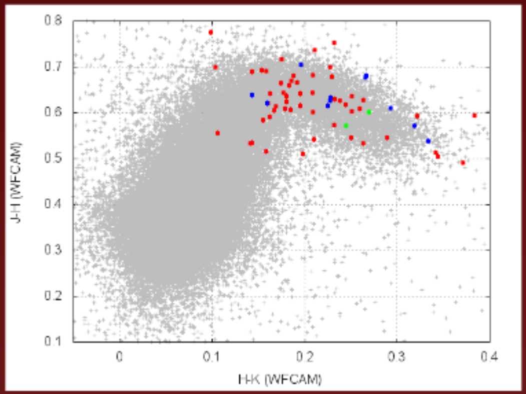


- M dwarf hot Jupiters (Gábor Kovács' talk)

  Using the null detection, sample size, simulated
  sensitivity -> upper limit on occurrence ratios

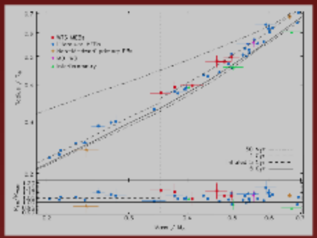
Eclipsing binaries

- Resolved radii and mass of EBs
  - ~70 low mass pairs, 14 have spectroscopy

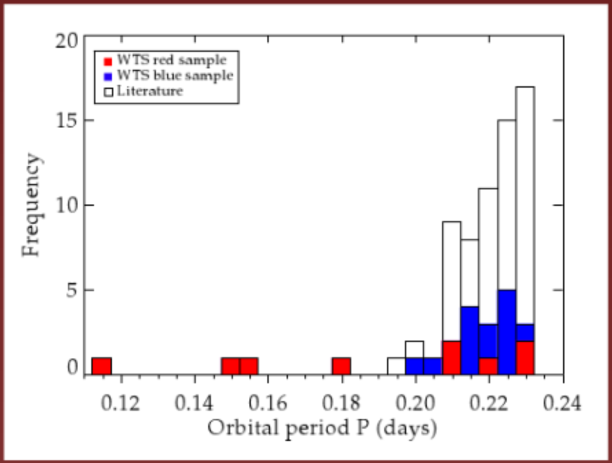


  - 3 resolved systems published

(Birkby et al., 2012)



- Ultra short period eclipsing binaries (Nefs et al., 2012)



Summary & conclusions

- WTS provides multi-epoch photometry (3mmag at bright end ; 2% at J=17)
  astrometry (5 years, ~10mas/epoch)

→ Future plan to publish both the photometry and astrometry catalogues

- ground based infrared surveys with poor-sky, irregular observing patterns are capable of finding exoplanets
  WTS-1b & WTS-2b

- no hot Jupiters in the 19hr field M dwarf sample
  upper limit of on short period giant planets occurance

- follow-up is very hard for such deep surveys

WFCAM Transit Survey:
search for planets around cool stars

Image credit: J. Pinfield

Brigitta Sipőcz
University of Hertfordshire

WTS team: D. Pinfield (PI), H.R.A. Jones, N. Goulding, (UHerts, UK); S. Hodgkin (PI), G. Kovács (IoA, Cambridge, UK); R. Saglia, J. Koppenhoefer, M. Cappetta, J. Zendejas, (MPE, Germany); D. Barrado, P. Cruz, H. Stoev , E. Martin (CAB, Madrid, Spain); E. Palle, F. Murgas (IAC,Tenerife, Spain) J. Birkby, I. Snellen, B. Nefs (Leiden, The Netherlands); Y. Pavlenko, M. Kuznetsov (MAO, Ukraine) and many others