Giant Planet Migration, and Formation of Terrestrial and Super-Earth Planets Around M-stars

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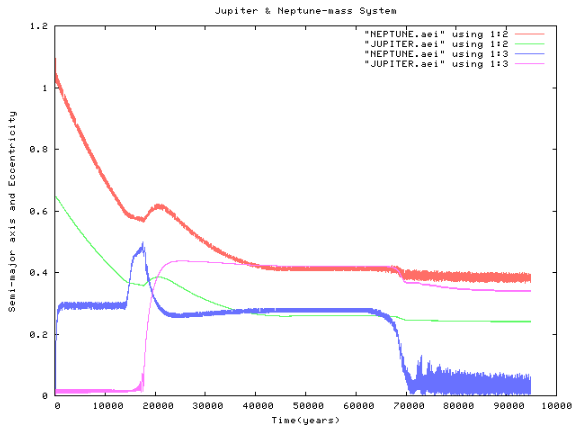
The recent detection of Earth-mass and Super Earth-mass planets around M stars in multi-planetary systems has motivated us in the study of planet formation around M-stars. We have studied the formation of multi-planetary systems with Earth-size planets and Jupiter-Mass planets around M-stars and have shown that in-situ formation of these objects is mostly unlikely. Our simulations indicate that these planets must have formed in outer regions, where icy material can facilitate the growth of protoplanetary embryos, and migrated to closer orbits. As a result, many of these objects may contain ice and water, as they might have accreted them in their formation zone. Our results also show that multi-planetary systems in mutual MMRs, with the combination of giant planet migration and resonance capture is a likely scenario for the formation of habitable super-Earths.



A Jupiter & Neptune mass planetary system,
subject to type-II migration and tidal dissipation

Metal-Rich M-dwarf Planet Hosts: [Fe/H] with K-band Spectra

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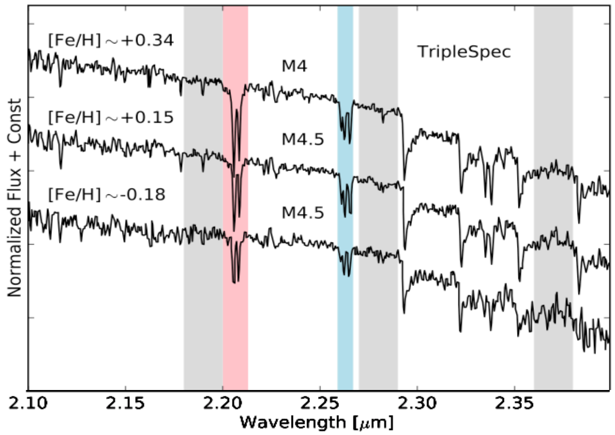


Fig. 1.- (a) K-band spectra of GJ 324 B (top), HIP 57050 (middle), and GJ 783.2 B (bottom). The regions used to calculate the EW of the Na I doublet, the EW of the Ca I triplet, and the H_2O-K index defined by Covey et al. 2010 are shown in red, blue and grey, respectively.

Name	EW [Å]		Index	This Work	
	Na I	Ca I	H2O	Sp. Type	[Fe/H]
HIP 79431	9.699	5.470	0.904	M3.5	+0.60
GJ 849	8.043	5.635	0.955	M1.5	+0.49
GJ 876	8.126	4.721	0.930	M2.5	+0.43
GJ 1214	8.520	4.095	0.895	M4.0	+0.39
GJ 649	5.651	4.722	0.952	M1.5	+0.14
HIP 57050	6.628	4.410	0.890	M4.5	+0.12
GJ 436	5.328	4.456	0.915	M3.0	-0.00
GJ 581	5.108	4.202	0.921	M3.0	-0.02

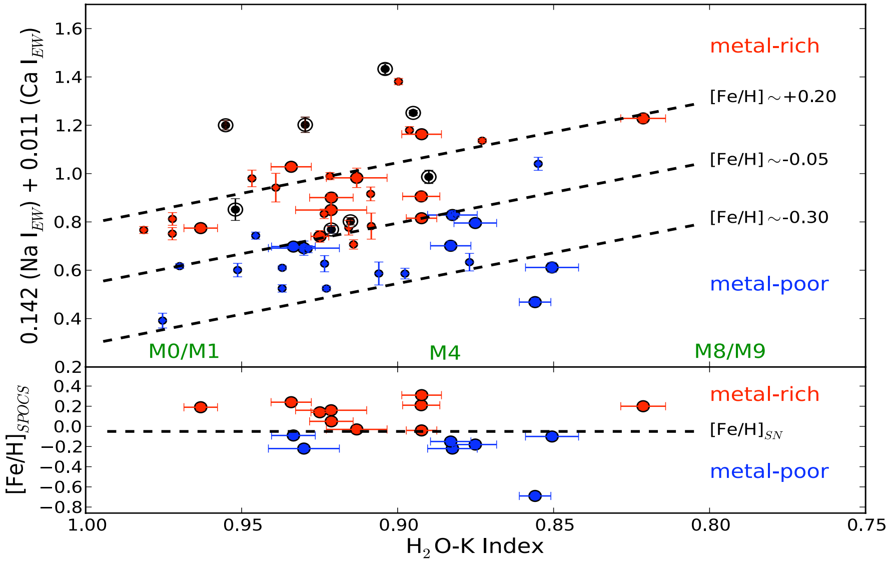
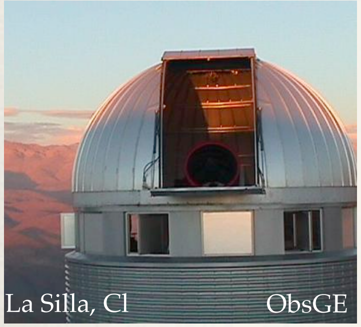


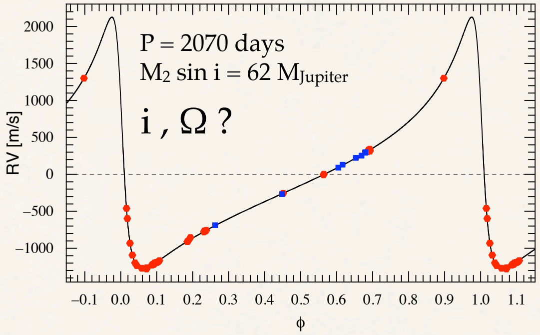
Fig. 2.- A linear combination of the EWs of the Ca I and Na I features versus the K-band Water Index. The big red and blue dots are M-dwarfs with FGK-companions with $[Fe/H]_{SPOCS}>-0.05$ and $[Fe/H]_{SPOCS}<-0.05$, respectively (Valenti & Fischer 2005). The small red and blue dots represent M-dwarfs with $[Fe/H]\geq-0.05$ and $[Fe/H]<-0.05$ respectively, according to the photometric calibration by Johnson & Apps 2009. **The big black dots represent the M-dwarf planet hosts**. The [Fe/H] values for the metallicity calibrators are also plotted versus the H_2O-K index, to emphasize the index's insensitivity to metallicity. The dashed lines in the top panel are iso-metallicity contours for [Fe/H] values of −0.30, −0.05 and +0.20. **According to our determination, all of the M-dwarf planet hosts analyzed in this work have metallicities higher than [Fe/H]=−0.05, with the Jovian planet hosts being more metal-rich than their Neptune host analogs, which is in agreement with the metallicity distribution of FGK-dwarfs with planets.**

Combining radial velocities and astrometry to measure the masses of potential brown-dwarf companions to Sun-like stars

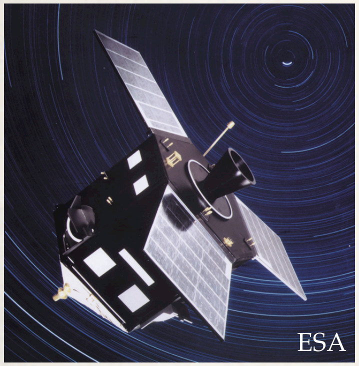
CORALIE



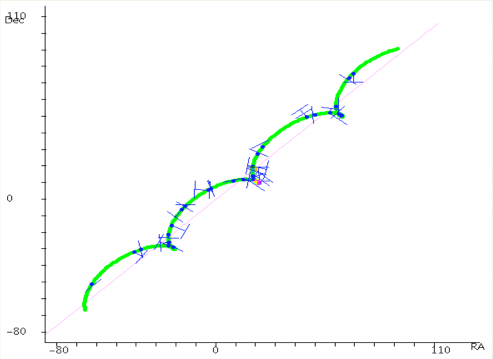
Radial velocities



HIPPARCOS

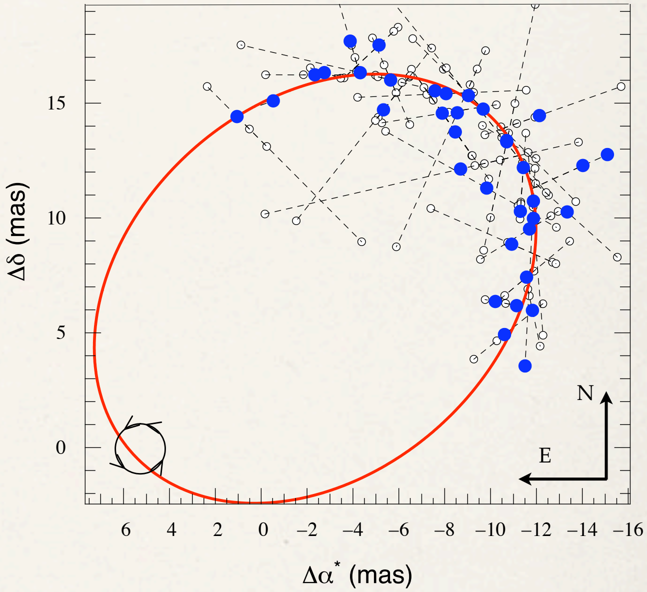


Astrometry



Example of a 3-σ detection: **$M_2 = 90 \pm 12\ M_{Jupiter}$**

a = 14 ± 2 mas i = 49 ± 9 deg Ω = 100 ± 12 deg



analysis sample ⇒ at least ~50% of potential brown-dwarf companions to Sun-like stars are in fact low-mass stars

for more:
please come and talk to me!

Johannes Sahlmann
Observatoire de Genève, Switzerland

STRESS
STEREO TRansiting Exoplanet and Stellar Survey

Vinothini Sangaralingam(1,a),Ian Stevens(a)

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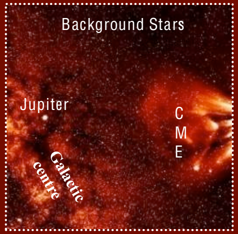
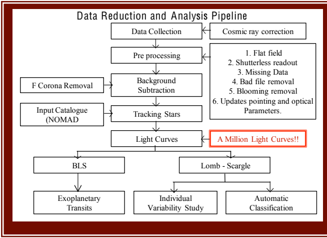
Abstract:

The Heliospheric Imager (HI) instruments on board the two STEREO (Solar TErrestrial RElations Observatory) spacecraft provides an excellent opportunity for space based stellar photometry. The HI instruments provide a wide area coverage (20X20 degrees and 70X70 degrees for the HI-1 and HI-2 instruments respectively) and long continuous periods of observations (20 days and 70 days respectively). Using HI – 1A which has a pass band of 650nm to 750nm and an integrated cadence of 40 minutes, we have gathered photometric information for more than a million stars brighter than 10th magnitude for a period of 36 months. Here we present some early results from this study on prospective transiting exoplanet candidates as well as on a range of variable stars and the future prospects for the data.

HI-1A image showing a CME, the Galactic centre and Jupiter.

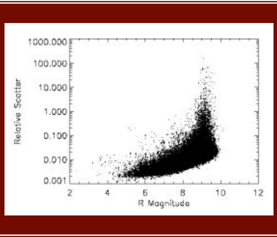


	HI - 1	HI – 2
Field of view	20˚ X 20˚	70˚ X 70˚
Plate scale	35.15"/pixel	2.05'/pixel
Cadence	40 min	2 hours
Passband	6500Å - 7500Å	4000Å - 10000Å



Data Reduction and Analysis Pipeline

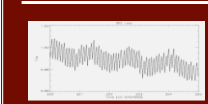
Data Collection ← Cosmic ray correction
Pre processing ← 1. Flat field 2. Shutterless readout 3. Missing Data 4. Bad file removal 5. Blooming removal 6. Updates pointing and optical Parameters.
F Corona Removal → Background Subtraction
Input Catalogue (NOMAD → Tracking Stars
Light Curves ← A Million Light Curves!!
BLS → Exoplanetary Transits
Lomb - Scargle → Individual Variability Study; Automatic Classification



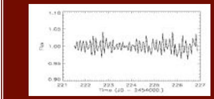
- A plot of Relative scatter in the lightcurves against R magnitude :
  Lower cut-off of the scatter
  < 1 %, Rmag < 9.
  ~ few % , fainter than 9th mag.
- Nyquist frequency – 18 cycles/day
- Suitable for study of variables like β Cepheid, δ Scuti, γ Doradus and exoplanetary transits.
- Not for short period variables like the ro-AP stars or longer period Cepheids.

Stellar Variability Results :

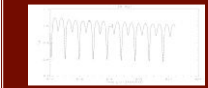
Known variables:



80 Leo – γ Dor –
V : 6.37 – A0



44 Tau – δ Scuti –
V : 5.3 – F2



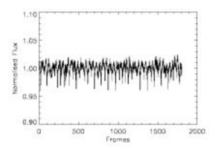
DX Aqr –
Eclipsing Binary–
V : 6.3 – A0/A1

BF Oph – delta
Cepheid –
V : 7.3 – G0

Note : Magnitude and spectral information is from Simbad Database (http://simbad.u-strasbg.fr/simbad/).

New Variable Candidates:

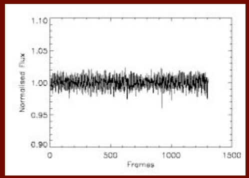
HD 13018 :



V Mag : 6.7
Type : A3
Found Period :
Binary : 2.574 Days
δ Scu – 0.05 Days

HD 219256 :

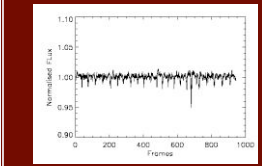
V Mag : 7.53
Type : A3
Found Period :
2.977 Days

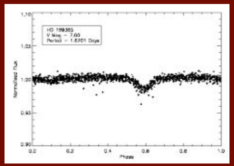


Unconfirmed but suspected variable (Koen & Eyer, 2002).

Transit Search Results:[2]

HD 189365 :

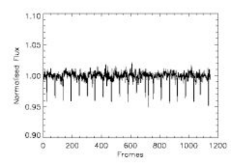


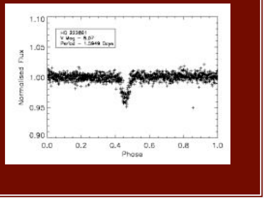


V Mag : 7.00
Type : K0
Found Period :
1.6701 Days

HD 222891 :

V Mag : 8.07
Type : F8
Found Period :
1.5949 Days





[2] - Work done with Gemma Whittaker, University of Birmingham, UK

Exoplanet Transit Observations: First Study in Turkey

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Abstract. We present the results of the first transiting exoplanet observation project in Ankara University Observatory, Turkey. Using a 40 cm Schmidt-Cassegrain telescope and an Apogee ALTA U47 CCD Camera, we observed a known transiting exoplanet TrES-3 b. Light curve has been analysed using the Phoebe 0.29d code, based on the Wilson-Devinney method. It can be said that Phoebe code is a useful tool for exoplanets since we find agreeable results for radii and inclination.

Introduction

The number of planets detected by the transit method is inreasing rapidly. Our first transiting exoplanet observation in Turkey is performed at the Ankara University Observatory (AUO). Observed light curve has been analysed using the Phoebe 0.29d code (Prsa and Zwitter 2005), based on Wilson-Devinney method (Wilson and Devinney 1971).

The Phoebe code is frequently used for light curve analysis of eclipsing binary systems. We have decided to use the Phoebe code in this study (for similar study see Poddany, 2008). We changed some default values in Phoebe code and we also used the semi-major axes, orbital period and temperature values from the latest publications.

Observations & Data Reduction

The first TrES-3b observation in the Ankara University Observatory was performed on August 5th 2009 with the f/10-16" Schmidt-Cassegrain Meade LX200GPS telescope equipped with a Apogee ALTA U47 (1024x1024) CCD camera. The light curve consists of 203 R-band images with 25s exposure. The other observation was performed on May 10th 2010 and light curve consists of 1103 R-band images with 15s exposure.

GSC 3089 995 and GSC 3089 741 were used as comparison and check stars, respectively. All CCD images were reduced by standard IRAF procedures.

Light of minima time is calculated by using the software Minima 25d (Nilson, 2005) where the minima times can be obtained by different methods like Parabolic Fit, Tracing Paper, Bisectors of Chords, Kwee and van Woerden, Fourier Fit and Sliding Integrationas. Weighted average values for the minima times are 2455049.29922±0.00013, 2455327.51708±0.00057.

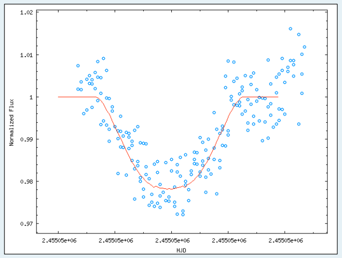

Fig. 1. Photometric time series for 2009 August 5

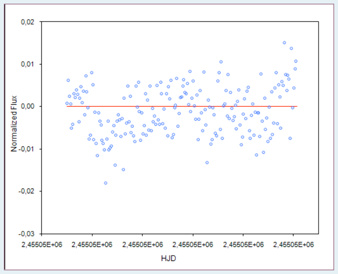

Fig. 2. Residuals of the fit.

Analysis of the Light Curves

We used the data from the earlier transit for light curve analysis in Phoebe code (Prsa & Zwitter 2005). Semi-major axes, orbital period and star temperature are used as 0.02283 AU, 1.306 day, 5650 K, respectively (Southworth, 2010).

First of all we used black-body model instead of stellar atmosferic models because the planet temperature is lower than 3500 K. According to the temperature of the host star we also assumed the albedo values and the gravity darkening coefficients respectively 0.5 (Rucinski, 1969) and 0.32 (Lucy, 1968).

Table 1. Photometric solution for TrES-3b

	This study	**Sozzetti et al. (2009)**	**Southworth (2010)**
Star Size ($R_\odot$)	0.760	$0.829^{+0.015}_{-0.022}$	$0.818^{+0.011}_{-0.013}$
Planet Size (R_j)	1.168	$1.336^{+0.031}_{-0.036}$	$1.305^{+0.027}_{-0.025}$
Inclination	82°.60	81°.85±0.16	82°.07±0.17
Star Mass ($M_\odot$)	0.926	$0.928^{+0.028}_{-0.048}$	$0.929^{+0.014}_{-0.013}$
Planet Mass (M_J)	2.095	$1.910^{+0.075}_{-0.080}$	$1.910^{+0.060}_{-0.070}$

The fitting process was started with mass ratio 0.1 and inclination 88°. Fits are repaeted for different combinations until the synthetic light curves were in good agreement with the observed data. Finally, mass ratio as 0.00197 gave the best solution for our light curves.

Results are given in Table 1. The observational points and the computed light curve are shown in Figure 1 and the residuals of the fit are shown in Figure 2.

Conclusions

The mass ratio of the system was obtained as 0.00197 in the simultaneous light curve analysis. With these agreeable results we can say that well-known Phoebe Code is a useful software for exoplanets.

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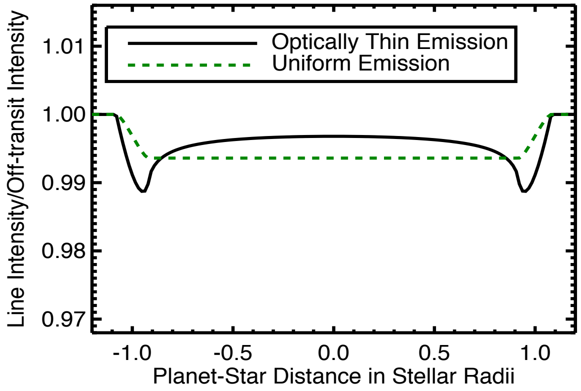
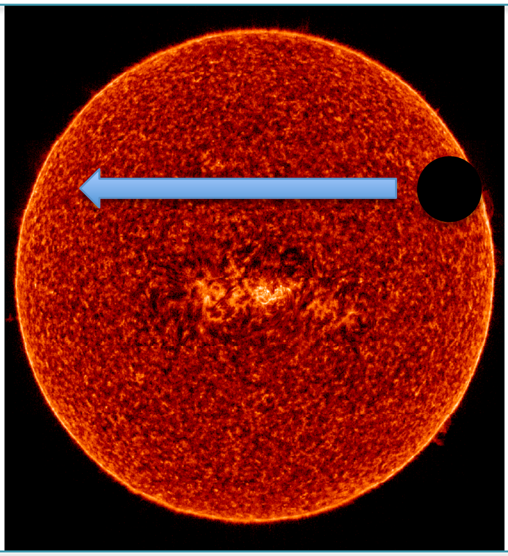
2010 Sagan Exoplanet Summer Workshop
Pasadena, CA, 26-30 July 2010

Limb-Brightened Exo-Planetary Transits



•Transits of limb brightened emission lines have double-U shaped light curves[1]



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•Limb brightened transits have larger depths than the continuum

• HD 209458 Si IV emission at 1394Å has a Double-U light curve

[1] Assef, Gaudi and Stanek, ApJ 701:1616–1626, 2009.

The LCOGT Network

Avi Shporer, Tim Brown, Tim Lister, Rachel Street, Yiannis Tsapras,
Nairn Baliber, Federica Bianco, Eric Depange, Andy Howell

Motivated by the increasing need for observational resources for the study of time domain astronomy, the Las Cumbres Observatory Global Telescope (LCOGT; http://lcogt.net) Network aims to build a global network of robotic telescopes for scientific research and research-based education. Once completed, the network will become a unique tool, accessible by the astronomical community and capable of continuous (24/7) monitoring from both the Northern and Southern Hemispheres. The network currently includes 2 x 2m telescopes, already making an impact in the field of exoplanet research. In the next few years they will be joined by at least 12 x 1m telescopes and at least 20 x 0.4m telescopes, in 6 to 8 sites. The increasing amount of LCOGT observational resources in the coming years will be of great service to the astronomical community in general, and the exoplanet community in particular.

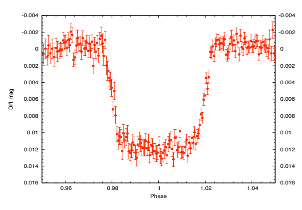

Figure 1: Combined transit light curve of WASP-24b (Street et al. 2010) taken by LCOGT FTN and FTS in the Z band.

LCOGT Science

The LCOGT science team includes two UCSB faculty members and close to 10 postdocs and project scientists. Within the domain of time-variable astronomy LCOGT focuses primarily on two observational fields: SuperNovae and Exoplanets. LCOGT is taking part in most of the important SuperNovae surveys, including the SuperNova Legacy Survey, Pan-STARRS, the Palomar Transient Factory, and the La Silla/QUEST SuperNova search. The study of exoplanets is carried out through observations of microlensing and transiting planets. A few results are presented here.

A few other projects are currently on-going at LCOGT. Among them is the commissioning of a high-speed camera mounted on FTN, to be used for lucky imaging and observations of Kuiper Belt Objects occultations, and other short time scale phenomena. In addition, members of the LCOGT science team are involved in the study of other variable stars (e.g., Lister et al. 2009a) and open clusters (e.g., Cieza & Baliber 2007).

LCOGT is also developing a medium-resolution (R=25,000) fiber-fed spectrograph, for stellar spectroscopy. It will reach a radial velocity accuracy on the order of 100 m/s, making it capable of identifying planetary transit false positives. The spectrograph is expected to be mounted on the Byrne Observatory telescope for on-sky testing during 2010, and will eventually be mounted on the 1m telescopes.

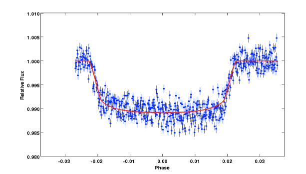

Figure 2: Transit light curve of a HATNet candidate taken by LCOGT FTN, cadence was 2 frames per minute and the observed drop in flux is about 1%. This candidate is now confirmed as a planet, to be published soon.

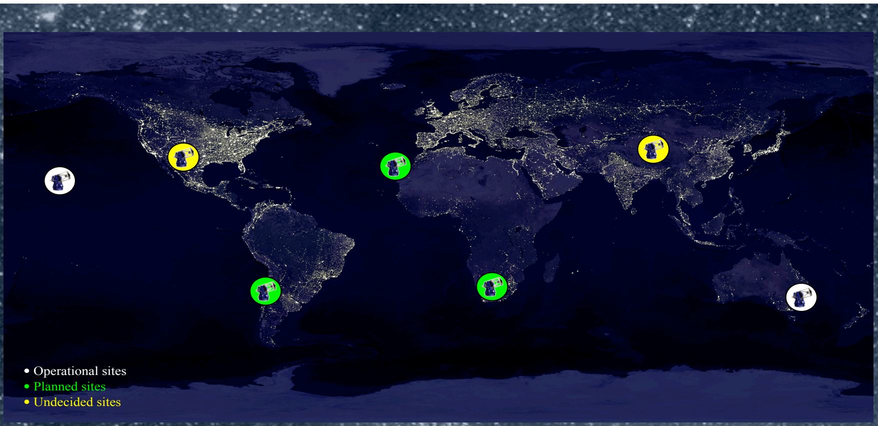

Figure 3: The LCOGT network. The two operational sites, Mt. Haleakala (Hawaii) and Siding Spring (Australia) are marked in white. The three planned sites, CTIO (Chile), SAAO (South Africa) and Tenerife (Canary Islands, Spain) are marked in green. Two additional sites will be located in Asia and Southwest North America, marked in yellow, although their exact location is undecided yet.

LCOGT and ExoPlanets

Transits: LCOGT scientists are collaborating with most of the transiting planet surveys, including WASP (North and South), HATNet, TrES, MEarth, CoRoT and Kepler. Light curves obtained with LCOGT telescopes were part of the discovery of many of the currently known transiting planets, e.g., WASP-16b (Lister et al. 2009b), WASP-24b (Street et al. 2010), TrES-3 (O'Donovan et al. 2007) and CoRoT-9b (Deeg et al. 2010). LCOGT also participates in follow-up studies of known transiting exoplanets. For example, Hidas et al. (2010) and Shporer et al. (2010) describe multisite follow-up campaigns led by LCOGT researchers where in each a complete coverage of the 12 hour transit of HD 80606b was obtained.

Microlensing: The LCOGT-based RoboNet network (http://robonet.lcogt.net; Tsapras et al. 2009) is a fully robotic network dedicated to the follow-up of planetary microlensing alerts. The network currently includes FTN, FTS and the Liverpool Telescope. The unique continuous observing capability of the future LCOGT network will allow for complete coverage of microlensing events.

Near-Future Plans

In the next 1-2 years LCOGT will deploy telescopes at several sites. The deployment of the network in the Southern hemisphere will commence first. Construction has already begun at CTIO (Chile) and SAAO (South Africa). At CTIO we plan to put 3 x 1m and 6 x 0.4m telescopes on the ridge next to the 2MASS telescope, and at SAAO we plan to put up to 3 x 1m and 4 x 0.4m telescopes. The third node of our 0.4m and 1m network in the South will be in Australia, possibly at Siding Spring next to FTS, but we are considering other sites as well. In the North, we are now negotiating a site agreement with the IAC to put telescopes at Tenerife (Canary Islands, Spain). Our intention is to have two other Northern nodes of the network in Asia and Southwest North America, where a few possibilities are being investigated.

Another site now being commissioned is the Byrne Observatory at UC's Sedgwick Reserve in the Santa Ynez valley, approximately 30 miles from LCOGT's base in Goleta. This site currently has a 0.8m telescope and will be used for testing new instruments and for education.

LCOGT.net

Current Status

The network currently consists of two 2m telescopes, Faulkes Telescope South (FTS), located at Siding Spring Observatory, Australia, and Faulkes Telescope North (FTN), located on Mt. Haleakala on the Hawaiian island of Maui. Two 0.4m telescopes are also located within the FTN clamshell dome, currently being commissioned.

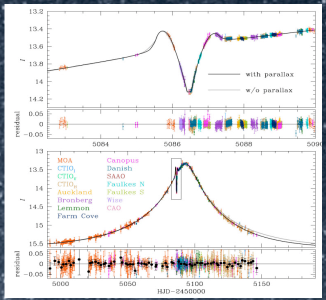

Figure 4: Combined light curve of the anomalous microlensing event MOA-2009-BLG-266, where LCOGT FTN and FTS made a significant contribution (Preliminary model by C. Han). The unique continuous observing capability of the future LCOGT network will allow complete coverage of similar events.

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Tsapras et al. 2009, AN, 330, 4

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WASP-36 b: a New Transiting Planet

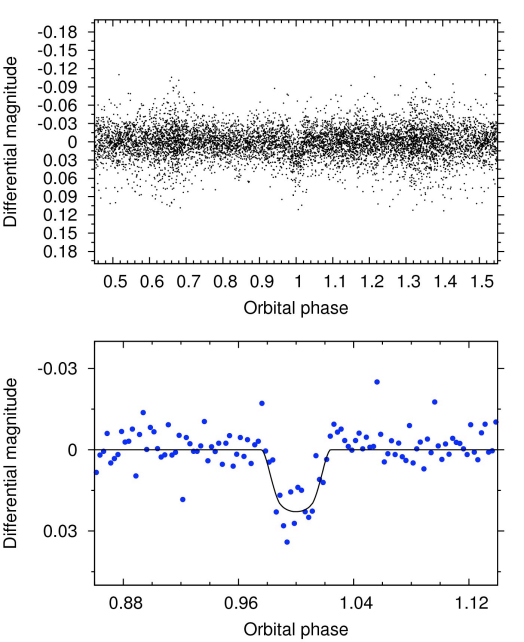
Principal collaborators:
David Anderson, Coel Hellier (Keele)
Andrew Cameron (St. Andrews)
and the SuperWASP team

System parameters:

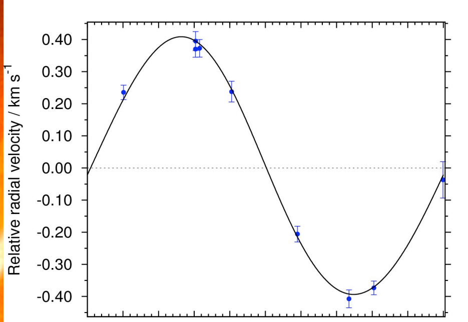
Stellar mass = 1.0 M_s
Stellar radius = 1.0 R_s
Planet mass = 2.4 M_J
Planet radius = 1.4 R_J
Orbital period = 1.5 days

My research interests:

Discovery of transiting planets with SuperWASP
Characterisation of planetary atmospheres with secondary eclipse photometry
Detecting cyclotron emission from planets at radio wavelengths
Measuring stellar rotation with SuperWASP



SuperWASP photometry



CORALIE / Euler RVs

Are Sulfur Aerosols a Solution The Faint Young Sun Paradox?

Megan Smith
Penn State/U of Washington

Question: Can sulfur aerosols solve the faint young Sun paradox and warm the surface of the early Earth?

BACKGROUND

Previous research by Kasting et al. (1989) proves that S_8, a strong absorber in the near ultraviolet, could have formed an ultraviolet shield in the anoxic atmosphere of the early Earth. This layer is analogous to the modern ozone layer. It is therefore likely that amorphous sulfur would have been in the atmosphere , too. On Venus, the sulfur cycle is controlled by the photochemistry shown in Fig. 1.

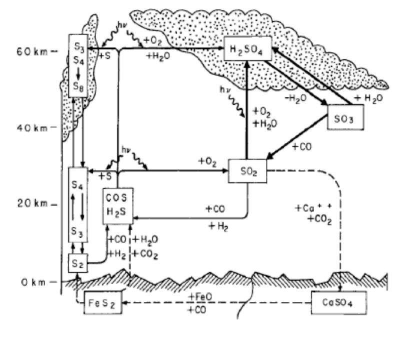


Fig. 1: Sulfur photochemistry on Venus (Prinn and Fegley, 1987)

METHODS

The particle properties (shown in Fig 2) are inserted into 1-D photochemical and climate models.

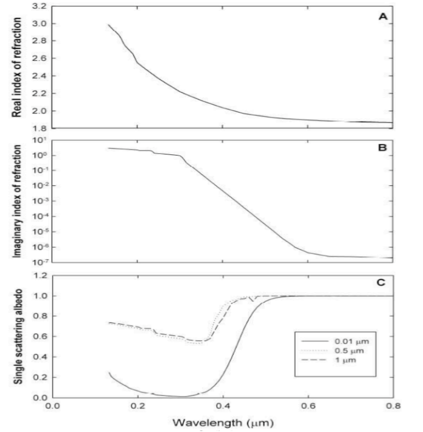


Fig. 2: (A) The real index of refraction and (B) the imaginary index of refraction of elemental sulfur input into the Mie scattering code of Mätzler, 2002. (C) The single scattering albedo for three different particle sizes, as calculated by the Mie scattering code of Mätzler, 2002.

RESULTS

Three different simulations were run with the climate model:

- No particles included
- S_8 particles only
- Amorphous sulfur particles only

The surface temperatures produced are reported in Table 1.

Table 1: Surface temperatures from the climate model output.

Simulation	Surface Temperature
Control	283.7 K
Only S_8 Particles	281.0 K
Only amorphous sulfur particles	281.1 K

CONCLUSION

The answer to the question is NO. Sulfur aerosols do not warm the surface! More research should be done (e.g. adding a particle size distribution and continuing the investigation of greenhouse gases in the early atmosphere).

Fiber-stabilized PSF for sub-m/s Doppler precision at Lick Observatory

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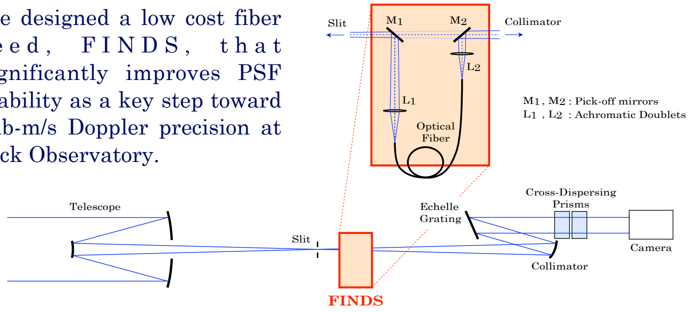
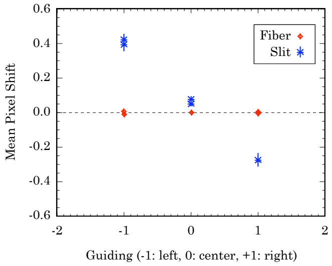
[(2)] ZAH-Landessternwarte Heidelberg, Germany

We designed a low cost fiber feed, FINDS, that significantly improves PSF stability as a key step toward sub-m/s Doppler precision at Lick Observatory.



Guiding Test

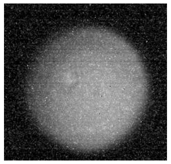
- B star with and without fiber
- Guiding left of the slit (~1.5” to the left), centered on the slit and right of the slit (~1.5” to the right).
- **Line position 20x more stable with fiber**

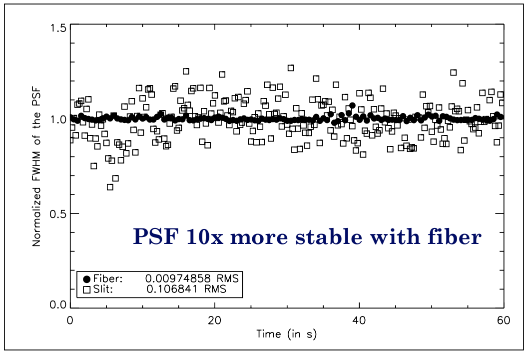


Pupil illumination and PSF stability

Slit

Fiber





PSF 10x more stable with fiber

Radial velocities

	With fiber			Without fiber			
Target	**RMS**	**SNR**	**Scaled RMS**	**RMS**	**SNR**	**Scaled RMS**	**Improvement**
HD161797	5.4 m.s^{-1}	113	3 m.s^{-1}	4.9 m.s^{-1}	172	4.2 m.s^{-1}	28%
HD143761	9.2 m.s^{-1}	92	4.2 m.s^{-1}	8.2 m.s^{-1}	144	5.9 m.s^{-1}	28%
HD166620	5.4 m.s^{-1}	93	2.5 m.s^{-1}	8.4 m.s^{-1}	87	3.65 m.s^{-1}	31%

Table 1. Radial velocities with and without fiber feed for three test stars: HD161797, HD143761 and HD166620.

Conclusions

Stable line position, well-behaved pupil illumination and more stable PSF (by a factor 10) and improvement of the Doppler precision by 30%

We acknowledge the support of the Planetary Society, NSF and NASA.

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