JF Donati

IRAP / Obs Midi-Pyrénées, CNRS / Université de Toulouse **L Yu, P Petit** (IRAP)**, C Moutou** (CFHT), **L Malo** (UdeM), **A Cameron** (StAndrews) & **the MaTYSSE consortium**

 \odot hunting for exoplanets : motivation, techniques & limitations

 \odot hunting for exoplanets : motivation, techniques & limitations

What are hot Jupiters and what do we know about them?

 \odot hunting for exoplanets : motivation, techniques & limitations what are hot Jupiters and what do we know about them

C hot Jupiters around young forming Sun-like stars

 \odot hunting for exoplanets : motivation, techniques & limitations what are hot Jupiters and what do we know about them? **C** hot Jupiters around young forming Sun-like stars

 \odot future prospects with SPIRou @ CFHT

\odot a quest for origins

origins of the Solar System & origins of life ✒ study planets / satellites within the Solar System ✒ detect & study worlds outside the Solar System

https://apod.nasa.gov/apod/ap151205.html

a quest for origins

origins of the Solar System & origins of life ✒ study planets / satellites within the Solar System ✒ detect & study worlds outside the Solar System

\odot unveiling the invisible

technically tricky & only possible since last two decades several techniques to reveal distant exoplanets ✒ imaging / velocimetry / photometry / micro-lensing / astrometry

<u></u> direct imaging

extreme flux contrast : 5-9 orders of magnitude tiny angular separation : 1 au \overline{Q} 10 pc = 0.1" (atmospheric turbulence > 0.5") **→** detect a candle next to a lighthouse from a distance of ~2 000 km ✒ coronography / adaptive optics / interferometry ✒ few detections of distant young giant planets, eg HR 8799

C high-precision velocimetry

detect & measure the reflex motion of the host star through the Doppler effect radial velocity (RV) signal yields planet mass (m sin i w/ i: orbit tilt wrt line of sight) e.g. Jupiter on the Sun: 13 m/s — Earth on the Sun: 0.08 m/s

- \rightarrow extreme precision required: 1 m/s = 3 10⁻⁹ x speed of light
- ✒ thermally stable (~0.01 K) evacuated spectrographs
- ✒ very stable wavelength reference
- **→ HARPS @ 3.6m ESO telescope at La Silla (Chile)**
- ✒ most reliable technique & hundreds of planets detected

https://www.eso.org/public/videos/eso1035g/

C high-precision velocimetry

detect & measure the reflex motion of the host star through the Doppler effect radial velocity (RV) signal yields planet mass (m sin i w/ i: orbit tilt wrt line of sight) e.g. Jupiter on the Sun: 13 m/s — Earth on the Sun: 0.08 m/s

- \rightarrow extreme precision required: 1 m/s = 3 10⁻⁹ x speed of light
- ✒ thermally stable (~0.01 K) evacuated spectrographs
- ✒ very stable wavelength reference
- **→ HARPS @ 3.6m ESO telescope at La Silla (Chile)**
- ✒ most reliable technique & hundreds of planets detected

photometric transits

detect & measure the partial occultation of the star by a close-in planet gives access to the planet radius (wrt the stellar radius) e.g. Jupiter on the Sun: $1\% = 10$ mmag — Earth on the Sun: $0.008\% = 80$ ppm ✒ very high photometric precision (a few tens of ppm) ✒ best from space (CoRoT, MOST, KEPLER, TESS, PLATO) \leftrightarrow needs confirmation w/ velocimetry to validate planet ✒ radius + mass yields average bulk density & composition ✒ thousands of planets & hundreds of systems detected with KEPLER

https://www.eso.org/public/videos/eso1011c/

photometric transits

detect & measure the partial occultation of the star by a close-in planet gives access to the planet radius (wrt the stellar radius) e.g. Jupiter on the Sun: $1\% = 10$ mmag — Earth on the Sun: $0.008\% = 80$ ppm ✒ very high photometric precision (a few tens of ppm) ✒ best from space (CoRoT, MOST, KEPLER, TESS, PLATO) ✒ needs confirmation w/ velocimetry to validate planet ✒ radius + mass yields average bulk density & composition ✒ thousands of planets & hundreds of systems detected with KEPLER

C pollution by stellar activity

stellar magnetic fields generates spots & plages at the surface of the host star impacts RVs & photometry on timescales of days to months & years (rotation, cycle) chromatic signature from activity as opposed to achromatic signature from planet **→** activity of the Sun: a few m/s and 100 ppms at optical wavelengths ✒ distort / drown signal from planet :(✒ need to model & filter-out activity

E pollution by stellar activity

stellar magnetic fields generates spots & plages at the surface of the host star impacts RVs & photometry on timescales of days to months & years (rotation, cycle) chromatic signature from activity as opposed to achromatic signature from planet ◆ activity of the Sun: a few m/s and 100 ppms at optical wavelengths

- ✒ distort / drown signal from planet :(
- ✒ need to model & filter-out activity

What is a hot Jupiter?

close-in giant gaseous planet at a distance of <0.5 au from its host star \bullet orbital period < 10 d and mass > 0.2 M ● large RV signal, typical semi amplitude of ~100 m/s or more ✒ large photometric transit depth of a few %

What is a hot Jupiter?

close-in giant gaseous planet at a distance of <0.5 au from its host star

- \rightarrow orbital period < 10 d and mass > 0.2 M
- ✒ large RV signal, typical semi amplitude of ~100 m/s or more

 ∞ large photometric transit depth of a few %

C first planets detected w/ velocimetry easiest to detect thanks to their large RV signal 51 Peg b (Mayor & Queloz 1995) HD 209458 b (Mazeh et al 2000)

What is a hot Jupiter?

close-in giant gaseous planet at a distance of <0.5 au from its host star

- \rightarrow orbital period < 10 d and mass > 0.2 M
- ✒ large RV signal, typical semi amplitude of ~100 m/s or more
- ✒ large photometric transit depth of a few %

o first planets detected w/ velocimetry easiest to detect thanks to their large RV signal 51 Peg b (Mayor & Queloz 1995) HD 209458 b (Mazeh et al 2000)

Confirmed with photometry HD 209458 b (Charbonneau et al 2000) independent discovery (Henry et al 2000)

What is a hot Jupiter?

close-in giant gaseous planet at a distance of <0.5 au \rightarrow orbital period < 10 d and mass > 0.2 M \bullet large RV signal, typical semi amplitude of \sim \sim \bullet spin and orbit aligned ✒ large photometric transit depth of a few %

C first planets detected w/ velocimetry easiest to detect thanks to their large RV signal 51 Peg b (Mayor & Queloz 1995) HD 209458 b (Mazeh et al 2000)

Confirmed with photometry HD 209458 b (Charbonneau et al 2000) independent discovery (Henry et al 2000)

B RV transit signal Rossiter McLaughlin effect ✒ tilt of orbital axis to spin axis ● coplanar orbit for HD 209458 b

\odot occurrence rate of hot Jupiters

only ~1% of mature Sun-like stars host hot Jupiters (eg Wright et al 2012) less for low-mass stars / M dwarfs higher occurence rates from RV surveys than from photometric transits ? more frequent (~5%) in dense open clusters (Brucalassi et al 2016) ?

\odot occurrence rate of hot Jupiters

only ~1% of mature Sun-like stars host hot Jupiters (eg Wright et al 2012) less for low-mass stars / M dwarfs higher occurence rates from RV surveys than from photometric transits ? more frequent (~5%) in dense open clusters (Brucalassi et al 2016)

O orbital properties

most have circular orbits, some w/ elliptical / tilted orbits most show prograde orbits, sometimes retrograde orbital alignement for cool host stars (eg Brown et al 2017)

Figure 26. Absolute value of the spin-orbit alignment angle, |λ|, as a function of stellar effective temperature temperature for the system of which the system of which the which the which the angle has been measured; no distinction is made by measured; no distinction is made by method. Several systems are only the text for details \mathcal{A} for details. The text for details \mathcal{A} line marks 0◦. The vertical dashed line denotes the dividing temperature of Winn et al. (2010), *T*crit = 6250 K. Blue symbols mark systems with *T*eff *Britannik System System* those systems that occupy the region of uncertainty surrounding the position

C occurrence rate of hot Jupiters

only ~1% of mature Sun-like stars host hot Jupiters (eg Wright et al 2012) less for low-mass stars / M dwarfs higher occurence rates from RV surveys than from photometric transits ? more frequent (~5%) in dense open clusters (Brucalassi et al 2016)

\odot orbital properties

most have circular orbits, some w/ elliptical / tilted orbits most show prograde orbits, sometimes retrograde orbital alignement for cool host stars (eg Brown et al 2017)

\odot planet properties

inflated radii by up to 2x (eg Zhao et al 2014) atmospheres detected from transit photometry & spectroscopy evaporating atmospheres / mass loss ?

C occurrence rate of hot Jupiters only ~1% of mature Sun-like stars host hot Jup less for low-mass stars / M dwarfs higher occurence rates from RV surveys than more frequent (~5%) in dense open clusters (

O orbital properties

most have circular orbits, some w/ elliptical most show prograde orbits, sometimes ret orbital alignement for cool host stars (eg B

\odot planet properties

inflated radii by up to 2x (eg Zhao et al 2014) atmospheres detected from transit photometry & spectroscopy evaporating atmospheres / mass loss ?

Star / planet formation

dark cloud collapsing on its own weight, forming accretion disc accretion disc yielding central star (T Tauri) and protoplanetary disc giant planets / hot Jupiters shape early planetary system architecture ✒ key role in formation of planetary systems

Star / planet formation

dark cloud collapsing on its own weight, forming accretion disc accretion disc yielding central star (T Tauri) and protoplanetary disc to giant planets / hot Jupiters shape early planetary system architecture \bullet key role in formation of planetary systems

<u>O</u> in-situ formation ?

not enough disc material to form hot Jupiters in situ giant planet first formed at several au's, then migrate inwards formed by accretion of smaller planets (Batygin et al 2016; Boley et al 2016) ? ✒ possible for hot Neptunes, unlikely to occur for hot Jupiters

Star / planet formation

dark cloud collapsing on its own weight, forming accretion disc accretion disc yielding central star (T Tauri) and protoplanetary disc giant planets / hot Jupiters shape early planetary system architecture \leftrightarrow key role in formation of planetary systems

C in-situ formation ?

not enough disc material to form hot Jupiters in situ giant planet first formed at several au's, then migrate inwards formed by accretion of smaller planets (Batygin et al 2016; Boley et al 2016) ✒ possible for hot Neptunes, unlikely to occur for hot Jupiters

planet-planet / star-planet interaction

giant planet formed at several au's beyond ice line kicked on elliptical orbit through gravitational interaction w/ nearby planet / star orbit aligned & circularized through tidal effects with host star $\bullet\bullet$ able to produce both aligned & misaligned hot Jupiters

✒ needs 100-1000 Myr to align & circularize orbits

O planet-disc interaction

giant planet depletes co-orbital region & generate spiral density structures (wakes) differential torque from inner & outer wakes induces inward (type-II) migration hot Jupiters migrate on timescales of 0.01-0.1 Myr

✒ generates hot Jupiters on circular orbits (Lin et al 1996)

\odot planet-disc interaction

giant planet depletes co-orbital region & generate spiral density structures (wakes) differential torque from inner & outer wakes induces inward (type-II) migration hot Jupiters migrate on timescales of 0.01-0.1 Myr

● generates hot Jupiters on circular orbits (Lin et al 1996)

Formatio

O planet-disc interaction

giant planet depletes co-orbital reg differential torque from inner & on hot Jupiters migrate on timescales \bullet generates hot Jupiters on

\odot magnetospheric gaps

host stars trigger strong large-scale dynamo magnetic fields forces disc material into corotation w/i smallest of either Alfven / Kepler radius disrupts the central disc regions, generate magnetospheric gap & accretion funnels ✒ stop planet migration at inner disc edge (Lin et al 1996) ✒ hot Jupiters survive if disc dissipates before field weakens

 $♦$ validating hot Jupiter formation w/ young stars ?

T Tauri stars (TTSs)

young Sun-like stars (0.5-15 Myr) no longer embedded in dust cocoon contraction not completed yet, w/ radii $3-1.2$ R_o for a 1 M_o star either accreting from their discs (classical) or disc-free (weak-line)

T Tauri stars (TTSs)

young Sun-like stars (0.5-15 Myr) no longer embedded in dust cocoon contraction not completed yet, w/ radii 3 -1.2 R_o for a 1 M_o star either accreting from their discs (classical) or disc-free (weak-line)

<u>O</u> rotation & activity

rotation rates 3-100x faster than the Sun (periods 8-0.25 d) **^{●◆} extremely active stars with strong large-scale magnetic fields** ✒ very difficult to detect planets, even hot Jupiters

> **OM** Garlick © M Garlick

Hot Jupiters around Fightion

T Tauri stars (TTSs)

young Sun-like stars (0.5-15 Myr) no longe contraction not completed yet, w/ radii 3either accreting from their discs (classical)

C rotation & activity

rotation rates 3-100x faster than the S \rightarrow extremely active stars with str **► very difficult to detect planets,**

\odot the MaTYSSE programme

spectropolarimetric monitoring of TTSs from CFHT (Hawaii) & TBL (Pic du Midi) model magnetic fields & activity w/ tomographic imaging search for potential hot Jupiters

© M Garlick

OM Garlick

HYPERON

La sculpture représentant l'hypéron, située entre le Casino et le Musée Salies, et $\mathcal V$ domine le boulevard éponyme. Le boulev

> 1950 : LE GROUPE PMS BLACKETT DECOUVRE UNE NOUVELLE PARTICULE A L'OBSERVATOIRE DU PIC DU MIDI 1953: LE CONGRES INTERNATIONAL SUR LE RAYONNEMENT

COSMIQUE REUNI A BAGNERES NOMME CETTE PARTICUL **HYPERON**

CE MONUMENT REPRESENTE LA TRACE DE L'HYPERON

³⁸ YAN, « Au Pic du Midi les ermites de la science cherchent à percer le mystère des rayons cosmiques », *Point de vue et images du monde*, ⁿ° 225, 23 avril 1953. A Luchon, Jean Robic gagne l'étape et ravi le maillot au

Opic du Midi 1953

HYPERON

La sculpture représentant l'hypéron, située entre le Casino et le Musée Salies, et $\mathcal V$ domine le boulevard éponyme. Le boulev

> 1950 : LE GROUPE PMS BLACKETT DECOUVRE UNE NOUVELLE PARTICULE 1953: LE CONGRES INTERNATIONAL SUR LE RAYONNEMENT COSMIQUE REUNI A BAGNERES NOMME CETTE PARTICUL

HYPERON

CE MONUMENT REPRESENTE LA TRACE DE L'HYPERON

³⁸ YAN, « Au Pic du Midi les ermites de la science cherchent à percer le mystère des rayons cosmiques », *Point de vue et images du monde*, ⁿ° 225, 23 avril 1953. A Luchon, Jean Robic gagne l'étape et ravi le maillot au

rotational modulation of spectral lines

magnetic spots generate line profile variations & Zeeman signatures induce RV variations of several km/s, much larger than those from hot Jupiters ✒ compute average line profiles from ~7000 spectral lines ✒ monitor temporal variations / modulation of line profiles

Hot Jupiters around young stars 1.8 km s−1 velocity bin) in the circular polarization profile profile profile pro

\sum Peaconal moderation rotational modulation of spectral lines

peak S/N (per 2.6 km s−1 velocity bin) of each observation. Column 5 lists bin

Dec 28 10:50:17 19.9565 190 2.8 1.619.050 190 2.8 1.619.050 190 2.8 1.619.050 190 2.8 1.619.050 191 2.819.050

Dec 29 07:37:39 20.82273 20.82273 20.82273 20.82273 20.82273 20.82273 20.82273 20.82273 20.82273 20.82273 20.8

Dec 30:00:02 21.76183 200 2.76183 200 2.76183 200 2.76183 200 2.76183 200 2.76183 200 2.76183 200 2.76183 200 2

Jan 07:19:42 29.80976 190 2.7 3.400 2.7 3.400 2.7 3.400 2.7 3.400 2.7 3.400 2.7 3.400 2.7 3.400 2.7 3.400 2.7 3

Jan 08 06:20:11 30.76836 190 2.7 3.574

Jan 09 06:15:12 31.76484 190 2.9 3.754

Alan 10 06:15:60 32.7653 170 3.7653 170 3.7653 170 3.7653

Jan 11 07:25:26 33.8148 220 2.34.8148 220 2.34.8148 220 2.34.8148 220 2.34.8148 220 2.34.8148 220 2.3 4.125

Jan 14 06:17:48 36.76631 190 2.8 4.658 36.768 36.768 36.768 36.768 36.768 36.768 36.768 36.768 36.768 36.768

Jan 15 06:12:46 37.76274 150 3.5 4.839 3.5 4.839 3.76274 150 3.5 4.839 3.76274 150 3.76274 3.76274 150 3.762

Dec 20:13:43 11.88992 170 2.88992 170 2.88992 170 2.89992 170 2.89992 170 2.89992 170 2.89992 170 2.89992 170 2

Dec 21 08:33:48 12.86217 170 2.86217 170 2.86217 170 2.86217 170 2.86217 170 2.862

Dec 22 09:29:48 13.90104 180 2.7 0.766 180 2.7 0.90104 180 2.7 0.90104 19104 1910

Dec 28 12:29 20.019.02.9999 20.019.02.9999 20.019.02.9999

Dec 29 08:59 20.8758 20.98758 160 3.3111 20.98758 160 3.3111 20.8758 160 3.3111 3.3111 3.3111 3.3111 3.3111 3.

Dec 30 07:26:53 21.8153 21.8154 21.8154 21.8154 21.8154 21.8154 21.8154 21.8154 21.8154 21.8154 21.8154 21.815

Jan 17 08:35:55 29.86285 170 2.86285 170 2.86285 170 2.86285 170 2.86285 170 2.86285 170 2.86285 170 2.8 6.590

Jan 1980 3.82174 3.82174 180 3.82174 180 3.82174 180 3.82174 180 3.82174 180 3.82174 180 3.82174 180 3.840 4.8

magnetic spots generate line profile variations & Zeeman signatures induce RV variations of several km/s, much larger than those from hot Jupiters **Example 20 12:55:28 12.5339 12.5354 2.5 1.4354 2.55 1.4354 2.55 1.4354 2.55 1.435 2.55 1.4354 2.55 1.435 2.55 Example 20 2.808 2.4 12.8088 2.4 12.8088 2.4 12.8088 2.4 12.8088 2.4 12.8088 2.4 12.8088 2.4 12.8088 2.4 12.8** Dec 22 08:14:51 13.8486 200 2.615 13.8486 200 2.615 13.8486 200 2.615 13.8486 2.615 13.8486 2.615 13.8486 2.6

Hot Jupiters around young stars 1.8 km s−1 velocity bin) in the circular polarization profile profile profile pro

\sum Peaconal moderation rotational modulation of spectral lines

peak S/N (per 2.6 km s−1 velocity bin) of each observation. Column 5 lists bin

magnetic spots generate line profile variations & Zeeman signatures induce RV variations of several km/s, much larger than those from hot Jupiters **Example 20 12:55:28 12.5339 12.5354 2.5 1.4354 2.55 1.4354 2.55 1.4354 2.55 1.435 2.55 1.4354 2.55 1.435 2.55** \bullet **monitor temporal variations / modulation of line profiles**

\odot tomographic imaging

reconstruct 2D brightness & magnetic map from series of (1D) line profiles use maximum entropy principle to infer simplest map compatible with data ✒ large fraction of the star covered with cool spots / warm plages ✒ large-scale field 2-3 orders of magnitude stronger than solar ✒ surface differential rotation shearing the surface ✒ temporal evolution of surface features ✒ use results to filter-out RV curves from ''activity jitter''

\odot tomographic imaging

reconstruct 2D brightness & magnetic map from series of (1D) line profiles use maximum entropy principle to infer simplest map compatible with data ✒ large fraction of the star covered with cool spots / warm plages ✒ large-scale field 2-3 orders of magnitude stronger than solar ✒ surface differential rotation shearing the surface ✒ temporal evolution of surface features ✒ use results to filter-out RV curves from ''activity jitter''

\odot tomographic imaging

reconstruct 2D brightness & magnetic map from series of (1D) line profiles use maximum entropy principle to infer simplest map compatible with data ✒ large fraction of the star covered with cool spots / warm plages ✒ large-scale field 2-3 orders of magnitude stronger than solar ✒ surface differential rotation shearing the surface ✒ temporal evolution of surface features

 \bullet use results to filter-out red curves from "activity jitter"

\odot tomographic imaging

reconstruct 2D brightness & magnetic map from series of (1D) line profiles use maximum entropy principle to infer simplest map compatible with data ✒ large fraction of the star covered with cool spots / warm plages ✒ large-scale field 2-3 orders of magnitude stronger than solar ✒ surface differential rotation shearing the surface ✒ temporal evolution of surface features

 \bullet use results to filter-out red curves from "activity jitter"

\odot tomographic imaging

reconstruct 2D brightness & magnetic map from series of (1D) line profiles use maximum entropy principle to infer simplest map compatible with data ✒ large fraction of the star covered with cool spots / warm plages ✒ large-scale field 2-3 orders of magnitude stronger than solar ✒ surface differential rotation shearing the surface ✒ temporal evolution of surface features ✒ use results to filter-out RV curves from ''activity jitter''

filtering RV curves from activity jitter w/ tomographic imaging youngest known hot Jupiter detected on ~2 Myr-old TTS V830 Tau planet RV signal ~20x smaller than activity jitter, small eccentricity

filtering RV curves from activity jitter w/ tomographic imaging youngest known hot Jupiter detected on ~2 Myr-old TTS V830 Tau planet RV signal ~20x smaller than activity jitter, small eccentricity **produces and magnetic activity**

filtering RV curves from activity jitter w/ tomographic imaging youngest known hot Jupiter detected on ~2 Myr-old TTS V830 Tau planet RV signal ~20x smaller than activity jitter, small eccentricity **produces and magnetic activity**

 \odot modeling activity using Gaussian Process Regression (GPR) model activity as correlated noise, eg a Gaussian process (GP) of known covariance assume pseudo-periodic covariance function (eg Haywood et al 2014) ✒ reproduces rotational modulation & spot evolution

C modeling activity using Gaussian Process Regression (GPR) model activity as correlated noise, eg a Gaussian process (GP) of known covariance assume pseudo-periodic covariance function (eg Haywood et al 2014) ✒ reproduces rotational modulation & spot evolution

\odot covariance function

c(t,t') = θ^2 exp[-(t-t')² / φ^2 - sin²{ π (t-t')/ χ } / ψ^2] with θ , φ , χ and ψ four hyper parameters characterizing the GP θ amplitude - φ spot lifetime - χ rotation period - ψ allowed smoothness

C modeling activity using Gaussian Process Regression (GPR) model activity as correlated noise, eg a Gaussian process (GP) of known covariance assume pseudo-periodic covariance function (eg Haywood et al 2014) ✒ reproduces rotational modulation & spot evolution

covariance function

c(t,t') = θ^2 exp[-(t-t')² / φ^2 - sin²{ π (t-t')/ χ } / ψ^2] with θ, φ, χ and ψ four hyper parameters characterizing the GP $θ$ amplitude - $φ$ spot lifetime - $χ$ rotation period - $ψ$ allowed smoothness

C likelihood estimation & Bayesian formalism subtract planet signal & model activity for given set of GP parameters estimate likelihood w/ log \mathcal{L} = -n log(2 π) / 2 - log $|C+\Sigma|$ / 2 - y^T (C+ Σ)⁻¹ y / 2 where C is the covariance matrix and Σ the diagonal variance matrix

C modeling activity using Gaussian Process Regression (GPR) model activity as correlated noise, eg a Gaussian process (GP) of known covariance assume pseudo-periodic covariance function (eg Haywood et al 2014) ✒ reproduces rotational modulation & spot evolution

covariance function

c(t,t') = θ^2 exp[-(t-t')² / φ^2 - sin²{ π (t-t')/x } / ψ^2] with θ, φ, χ and ψ four hyper parameters characterizing the GP ϑ amplitude - φ spot lifetime - χ rotation period - ψ allowed smoothness

C likelihood estimation & Bayesian formalism subtract planet signal & model activity for given set of GP parameters estimate likelihood w/ log \mathscr{L} = -n log(2 π) / 2 - log $|C+\Sigma|$ / 2 - y^T ($C+\Sigma$)⁻¹ y / 2 where C is the covariance matrix and Σ the diagonal variance matrix

MCMC simulation

derive posterior distributions of planet & GP parameters at the same time

G filtering RV curves from activity jitter with GPR planet RV signal confirmed with GPR & Bayesian approach ✒ posterior distributions on planet (& GP) parameters

G filtering RV curves from activity jitter with GPR planet RV signal confirmed with GPR & Bayesian approach **••** posterior distributions on planet (& GP) parameters

thot Jupiters detected on disc-less TTSs

0.70 M_a hot Jupiter detected at 0.057 au around the 2-Myr-old V830 Tau 1.3 M_a hot Jupiter detected at 0.10 au around the 15-Myr-old TaP 26 ✒ planets detectable around active stars ✒ hot Jupiters w/ circular orbits present at early stage of planet formation ✒ most likely produced through planet-disc interaction

Chot Jupiters detected on disc-less TTSs

0.70 Ma hot Jupiter detected at 0.057 au around the 2-Myr-old V830 Tau 1.3 Ma hot Jupiter detected at 0.10 au around the 15-Myr-old TaP 26 ✒ planets detectable around active stars of hot Jupiters w/ circular orbits present at early stage of planet formation ✒ most likely produced through planet-disc interaction

\odot open questions

more frequent than on mature stars? role of magnetic fields on planet survival? impact on early architecture of planetary systems? temperature / luminosity of newborn planets? io-Jupiter like star-planet interactions? transiting planets?

Future prospects

Co characterize newborn hot Jupiters

new extensive monitoring campaign about to begin for both stars multi wavelengths observations, including nIR spectroscopy & radio (LOFAR) high-precision photometry with Kepler / K2 to detect potential transit **← Louise Yu starting her PhD thesis @ IRAP / OMP**

Future prospects

C characterize newborn hot Jupiters

new extensive monitoring campaign about to begin for both stars multi wavelengths observations, including nIR spectroscopy & radio (LOFAR) high-precision photometry with Kepler / K2 to detect potential transit Serve See Louise Yu starting her PhD thesis @ IRAP / OMP

SPIRou @ CFHT & SPIP @ Pic du Midi

high-precision velocimeter / spectropolarimeter for CFHT focus on star / planet formation & planetary systems of nearby M dwarfs integrated at IRAP / OMP now, first light @ CFHT in 2017 SPIP: twin copy for Pic du Midi, funded, first light in 2020

SPIROU

- ✒ spirou.irap.omp.eu
- **← [@SPIRou_astro](https://twitter.com/SPIRou_astro) on twitter**

Future prospects

C characterize newborn hot Jupiters

new extensive monitoring campaign about to begin for both stars multi wavelengths observations, including nIR spectroscopy & radio (LOFAR) high-precision photometry with Kepler / K2 to detect potential transit Serve \rightarrow Louise Yu starting her PhD thesis @ IRAP / OMP

SPIRou @ CFHT & SPIP @ Pic du Midi

high-precision velocimeter / spectropolarimeter for CFHT focus on star / planet formation & planetary systems of nearby M dwarfs integrated at IRAP / OMP now, first light @ CFHT in 2017 SPIP: twin copy for Pic du Midi, funded, first light in 2020

✒ spirou.irap.omp.eu

→ [@SPIRou_astro](https://twitter.com/SPIRou_astro) on twitter

https://vimeo.com/47408739

WORLDS THE KEPLER PLANET CANDIDATES

© Alex Parker