CHARACTERIZING EXOPLANETS WITH HIGH DISPERSION CORONAGRAPHY ON TMT

DIMITRI MAWET, CALTECH, NOVEMBER 2017 HDC TEAM @ CALTECH/JPL: J. WANG, J. JOVANOVIC, J-R DELORME, J. LLOP, N. KLIMOVICH, Y. XIN, W. XUAN, J. WALLACE, J. FUCIK, G. RUANE EXOPLANET ATMOSPHERES: B. BENNEKE (NOW AT U. MONTREAL), R. HU (JPL), S. DOMOGAL-GOLDMAN (GSFC), G. ARNEY (GSFC), J. FORTNEY KPIC HDC COLLABORATORS: M. FITZGERALD (UCLA), FROM WMKO: P. WIZINOWICH, S. CETRE, B. FEMENIA, S. LILLEY, E. WETHERELL, S. RAGLAND

HIGH DISPERSION CORONAGRAPHY

Wang et al. 2017, Mawet et al. 2017



HIGH RESOLUTION SPECTROSCOPIC CHARACTERIZATION OF EXOPLANETS

 Unambiguous identification of molecules such as CO, CH₄, CO₂, O₃, O₂

PROOF OF CONCEPT AT MEDIUM RESOLUTION WITH OSIRIS AND HR8799

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HR8799c



Konopacky et al. 2013

HR8799b



Barman et al. 2015

HIGH RESOLUTION SPECTROSCOPIC CHARACTERIZATION OF EXOPLANETS

- Unambiguous identification of molecules such as CO, CH₄, CO₂, O₃, O₂
- Line broadening:
 - => spin measurements
 - => planet accretion history
 - => final mass and atmospheric composition
 - => formation of moons and rings

MEASURE PLANET SPIN



HIGH RESOLUTION SPECTROSCOPIC CHARACTERIZATION OF EXOPLANETS

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- Line broadening:
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- Time Domain Analysis of line profile:
 - => Doppler imaging
 - => Global circulation
 - => Cloud coverage and weather

DOPPLER MAPPING OF GIANT PLANETS



Crossfield et al. 2014

HIGH RESOLUTION SPECTROSCOPIC CHARACTERIZATION OF EXOPLANETS

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- Contrast gains:
 - => gains $\alpha \sqrt{N_{\text{lines}}}$ (# lines resolved)
 - => Sidesteps chromatic speckle noise present and inevitable at low res



ASTROBIOLOGIST'S FLOWCHART TO CHAMPAGNE



BIOSIGNATURES AT HIGH R



Wang J., Mawet D., Hu R., Benneke B. 2017

DETECTING BIO-SIGNATURE GASES WITH HDC ON TMT



planet signal is ~10⁻⁸

Wang et al. 2017

DETECTING BIO-SIGNATURE GASES WITH HDC AT TMT



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Wang et al. 2017

DETECTING BIO-SIGNATURE GASES WITH HDC AT TMT



planet signal is ~10⁻⁸

BOTTOM LINE

- HDC might be the only way to tease out biomarkers from Earth-like and super-Earth exoplanets
- HDC enables detailed characterization from optical to infrared: composition, spin, cloud mapping
- Strong synergies with transit spectroscopy and RV: fiber-fed diffraction limited high-resolution spectrographs

PSI strawman concept



HRS CONCEPTUAL DESIGN (MODIUS)

Echelle Grating

Fiber

9-channel Multiplexing using H4RG, 25-channel possible (reduced bw)



HIGH DISPERSION CORONAGRAPHY DEMONSTRATOR IN THE CALTECH EXOPLANET TECHNOLOGY LAB



Mawet et al. 2017

HIGH DISPERSION CORONAGRAPHY SCIENCE DEMONSTRATOR WITH KPIC



Keck Planet Imager and Characterizer

KPIC HDC MODULE



PERSPECTIVES

- Theoretical studies/numerical simulations:
 - Refine HDC simulators (exo-zodis, telescope/system emissivity, speckle chromaticity)
 - Refine theoretical models of exoplanet atmospheres
 - Better spectroscopic templates
 - Capture diversity of planets
 - Archean Earth modeling
- HDC science demonstrators:
 - KPIC @ Keck/NIRSPEC
 - SCExAO @ Subaru/IRD
 - Hirise @ VLT/CRIRES
 - PARVI @ Palomar

COLLABORATORS

- <u>Caltech</u>: J. Wang, N. Jovanovic, G. Ruane, J.-R. Delorme, R. Dekany, J. Fucik, N. Klimovich, J. Llop, R. Riddle, K. Matthews
- JPL: J.K. Wallace, E. Serabyn, G. Vasisht, R. Bartos, M. Bottom, AJ Riggs
- <u>W.M. Keck Observatory</u>: P. Wizinowich, S. Cetre, B. Femenia, S. Lilley, E. Wetherell, S. Ragland
- <u>University of Hawaii</u>: M. Chun, C. Bond, C. Baranec, D. Hall, D. Atkinson, S. Goebel, C. Lockhart, E. Warmbier
- <u>University of Liege</u>: O. Absil, E. Huby*, B. Carlomagno, C. Gomez, A. Jolivet, J. Surdej, S. Habraken, C. Delacroix**
- <u>Uppsala University</u>: E. Vargas, P. Forsberg, M. Karlsson
- <u>UCLA</u>: **M. Fitzgerald**
- <u>Subaru</u>: O. Guyon
- <u>LAM</u>: T. Fusco
- <u>Arcetri</u>: S. Esposito, C. Plantet
- <u>ANU</u>: F. Rigault
 - (*) ULg -> ObsPM
 - (**) ULg -> Cornel