WG3 – Exoplanets

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ULTRASAT
SKYLIGHT TO SPACE

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

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On the Planetary Theory of Everything

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ABSTRACT

Here, we present a simple solution to problems that have plagued (extra)"galactic" astronomers and cosmologists over the last century. We show that "galaxy" formation, dark matter, and the tension in the expansion of the universe can all be explained by the natural behaviors of an overwhelmingly large population of exoplanets throughout the universe. Some of these ideas have started to be proposed in the literature, and we commend these pioneers revolutionizing our understanding of astrophysics. Furthermore, we assert that, since planets are obviously the ubiquitous answer to every current question that can be posed by astronomers, planetary science must then be the basis for all science, and therefore that all current funding for science be reserved for (exo)planetary science - we happily welcome all astronomers and other scientists.

Keywords: Exoplanets — History of astronomy — Interdisciplinary astronomy

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Key Papers

- Host activity – with a focus on M-dwarf flares.
- Planets and minor bodies orbiting White Dwarfs.
- Exoplanet atmospheres.
- Transiting planets.
- Star-Planet interaction.

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Topic	WG3 Key paper
Host Activity	Flare identification techniques and simulation of ULTRASAT data for various spectral types
	NUV variability as a function of spectral type and age
	NUV flare rate catalogue, characteristics as a function of spectral type and age
	Correlation between NUV flare rates/energies and X,FUV, and visible EM radiation
	Implications of NUV flares on habitability
Planets around white dwarfs	Predictions and Methods
	ULTRASAT detection of an exoplanet orbiting a white dwarf
	Occurance rates of planets around white-dwarfs from ULTRASAT
	ULTRASAT detection planetesimals and debris disks around WD
Precision Photometry	Precise photometry for time-series ULTRASAT data
Planets around giants	ULTRASAT exoplanet detection using transition region/corona transits
	ULTRASAT detection of an exoplanet orbiting a giant
Planets around MS stars	Detections of new planets around main-sequence stars from ULTRASAT
Exoplanets atmospheres	ULTRASAT field prediction and escaping atmospheres detectability
	Comparative transits of known exoplanets in the UV
Star planet interaction	Predictions and Methods
	Detections of new planets from SPI-related UV periodic variability

Small Stars Pack a Big Punch

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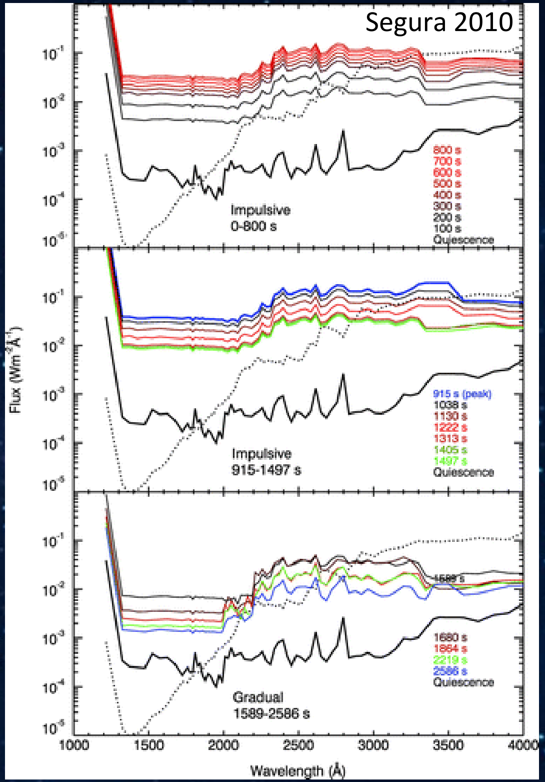
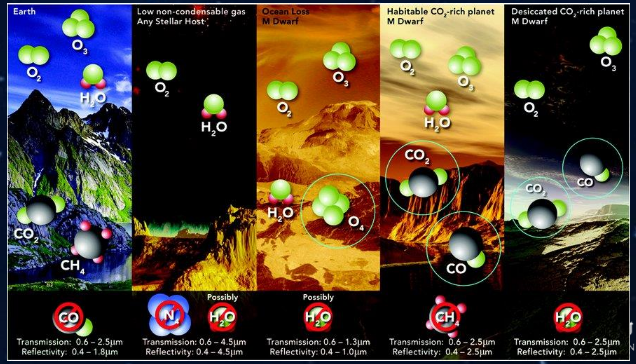
- M-dwarfs exhibit flares with instantaneous flux of more than $\times 10^3$ times their quiescence flux.
- Planetary atmospheric escape can be caused by short wavelength UV radiation that heats the planet's exosphere.
- Surface of short period planets becomes highly irradiated, disintegrating complex molecules.
- These flares are often accompanied by CME/SEPs → Erode an atmosphere from molecules providing atmospheric shielding.
- Can result in a abiotic source of bio-signature molecules such as O_2.

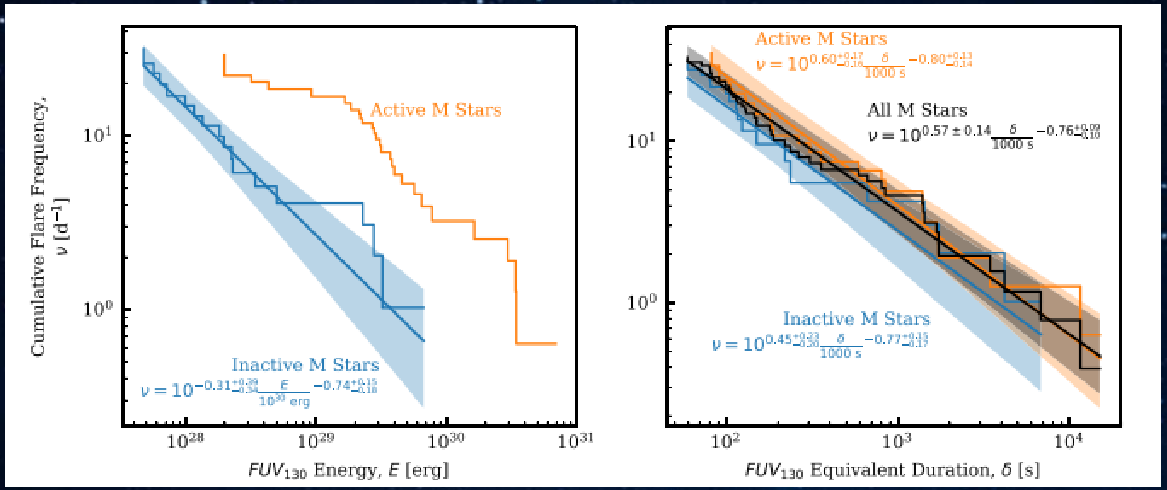


Segura 2010

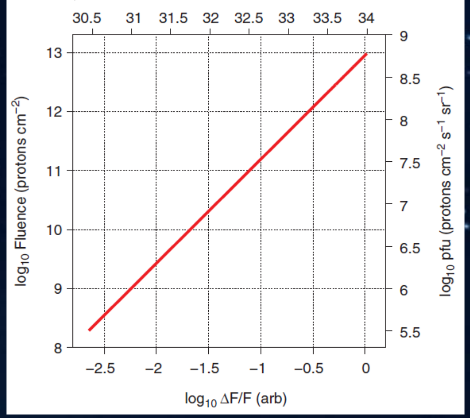


Current Challenges

- The high-energy – low frequency flares are the ones to dominate atmosphere evolution and habitability – and those are poorly constrained (See P. Rekhi talk).
- We need better grasp of the variability between host of similar type and classification.
- We need to better understand the relation between CMEs and flares.



Loyd et al. 2018



Tilley 2019

M–Dwarf flares with ULTRASAT

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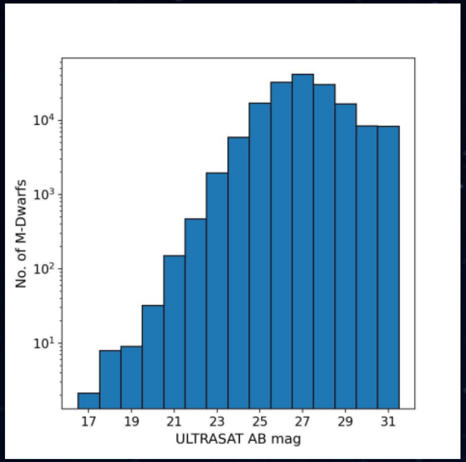
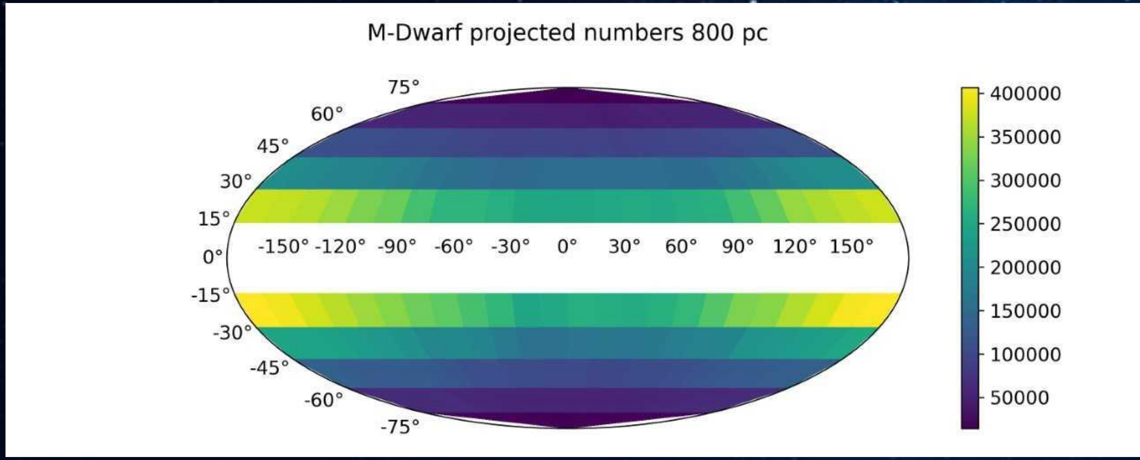
- ULTRASAT high galactic latitude fields wil contain ~35 M0-M2 stars and ~10 M3-M6 stars visible in quiescence.
- With a limit of 24 magnitude, we expect to determine the quiescence level of ~ 2800 M0-M2 stars and ~ 1000 M3-M6 stars.





- In each exposure: 50 (100) flaring M0-2 (M3-6) flares in each image
- **These would add up to O(10^6) M-dwarf flares detected by ULTRASAT over 6 months of continuous exposure → many of which in the low frequency - high energy regime.**

Simultaneous ground observations: Visible and FUV indicators

See discussion by E. Gilbert

Wide FoV: Simultaneous observations in the visible with, e.g., LAST

Photometry: 8 channels with PAST

Fast cadence: CaII H&K and Hα with W-FAST

FUV indicators: High spectral resolution observation with MAST - HighSpec

Weizmann Telescope projects

Project	FAST	LAST	MAST	PAST	SoXS	G-CLEF	ULTRASAT
Telescopes	55 cm	48 x 28 cm	20 x 60 cm	4 x 36 cm	350 cm	650 cm 22500 cm	33 cm
Task	Fast Photometric Survey	Photometric Survey	Spectroscopy	Multi-Band Photometry	Spectroscopy	Spectroscopy	UV Imaging Survey
Goal	Detection	Detection	Characterization	Characterization	Characterization	Characterization	Detection
Location	Neot-Smadar	Neot-Smadar	Neot-Smadar	Neot-Smadar	Chile	Chile	Space
Leader	Ofek	Ofek Ben-Ami	Ben-Ami Ofek	Ofek Ben-Ami	Gal-Yam	Ben-Ami	Waxman
Status	Operating	Commissioning	Construction	Design	Commissioning	Design	Construction

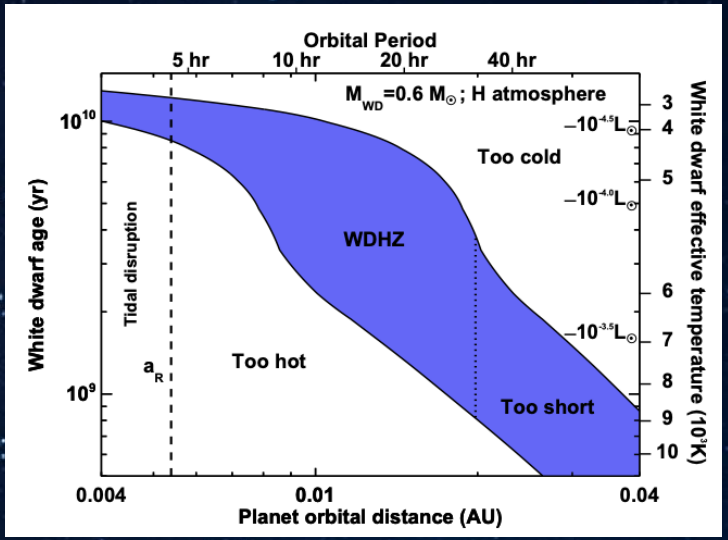
The Search for planets orbiting White Dwarfs

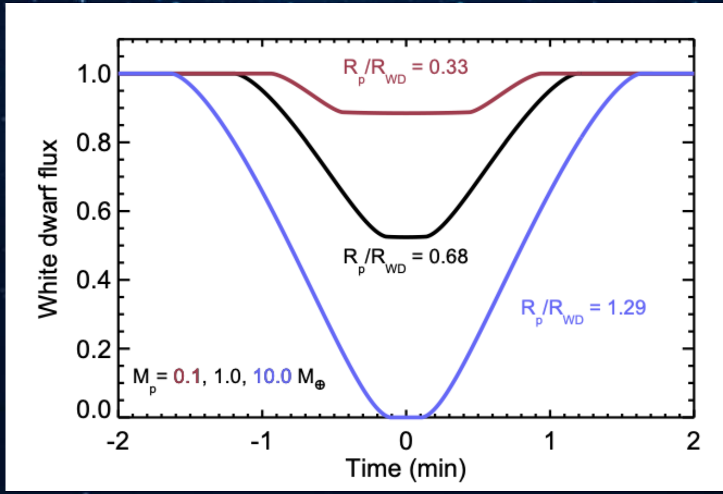
In recent years, we have accumulated indirect evidence for the presence of planets and debris around WDs.

In several cases, there are direct evidence for integrating bodies and sub-stellar object in a stable orbit

The detection of short-period planets in stable orbit around WDs required prioritizing cadence over precision.

Any transiting planet detected in stable orbit around a WD offers ideal radius ratio for follow-up observations through transit spectroscopy!!!





The Search for planets orbiting White Dwarfs

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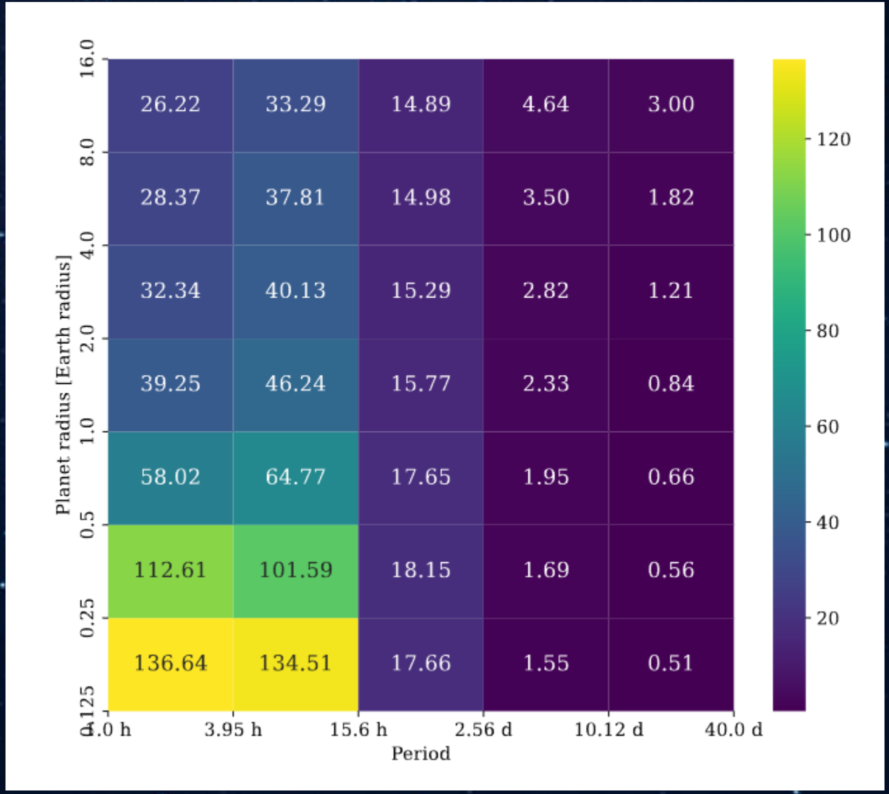
- ULTRASAT low-cadence survey will monitor $N_{WD} \approx 32{,}000$ WDs (40 fields in each hemisphere, 400 WDs per field)
- 800 WDs will be monitored in the high-cadence field

We assume 3 transits are required for detection
We assume occupancy of 68% of the current upper limit (van Slujis & van Eylen 2018)

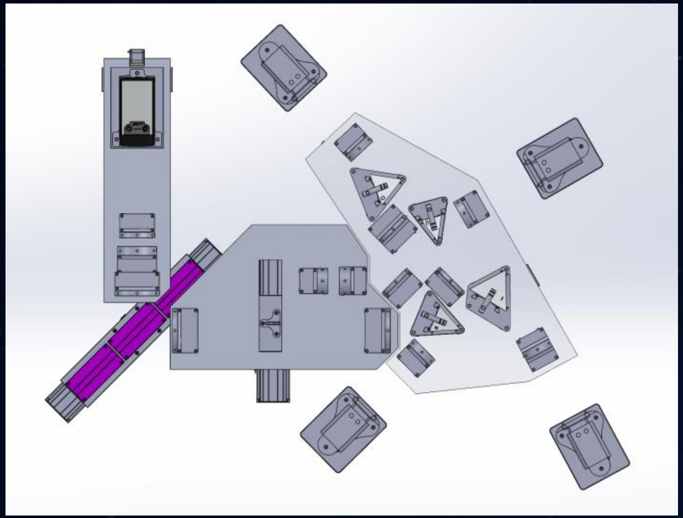
➢ ULTRASAT is sensitive to planets in the entire CHZ, with maximal number of detected planets well over 100.

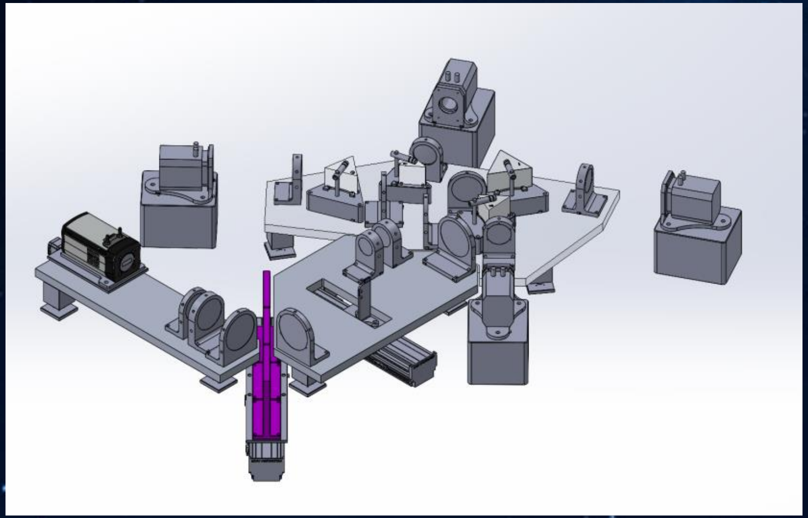
➢ Planets at wider orbits can also detected (mainly via the high-cadence survey) with a smaller statistical impact.



The Search for planets orbiting White Dwarfs

- Initial candidate list of WDs within the ULTRASAT low-cadence fields can be based on GAIA WD catalogue (Gentile-Fusillo et al. 2021).
- Spectral classification using, e.g., SoXS, MAST-DeepSpec (I. Irani).
- RV follow-up using, e.g., MAST-HighSpec and G-CLEF@Magellan (Y. Sofer-Rimalt).
- LAST key science goal is an encompassing search of planets orbiting WDs (Y.M. Shani).



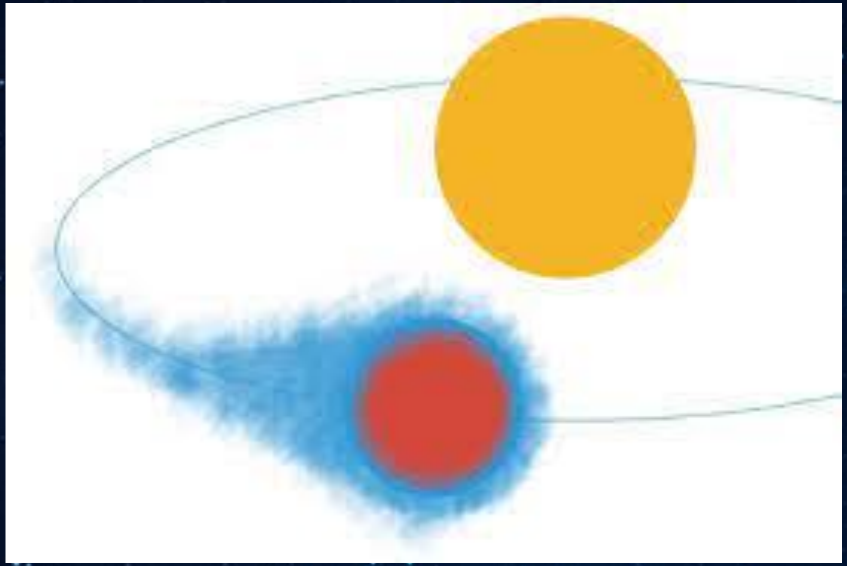


Exoplanets Atmospheres

Chromospheric transits as seen by ULTRASAT

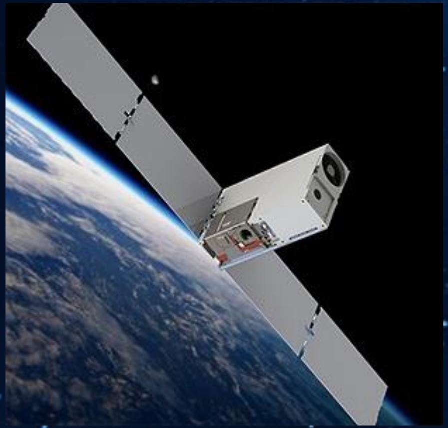
HST/STIS spectrum of Proxima Cen.

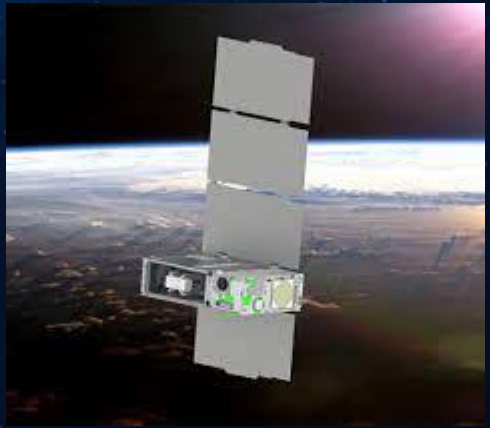
An escaping atmosphere will result in deeper transits in the NUV, as the optical depth of the escaping atmosphere is higher at shorter Wavelengths.



We expect that in several bona-fide cases, the signature of an escaping atmosphere will be several millimag (e.g., WASP-12b; Fossati et al. 2010).

Will require a dedicated observing program beyond the standard surveys.





Chromospheric transits as seen by ULTRASAT

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HST/STIS spectrum of Proxima Cen:

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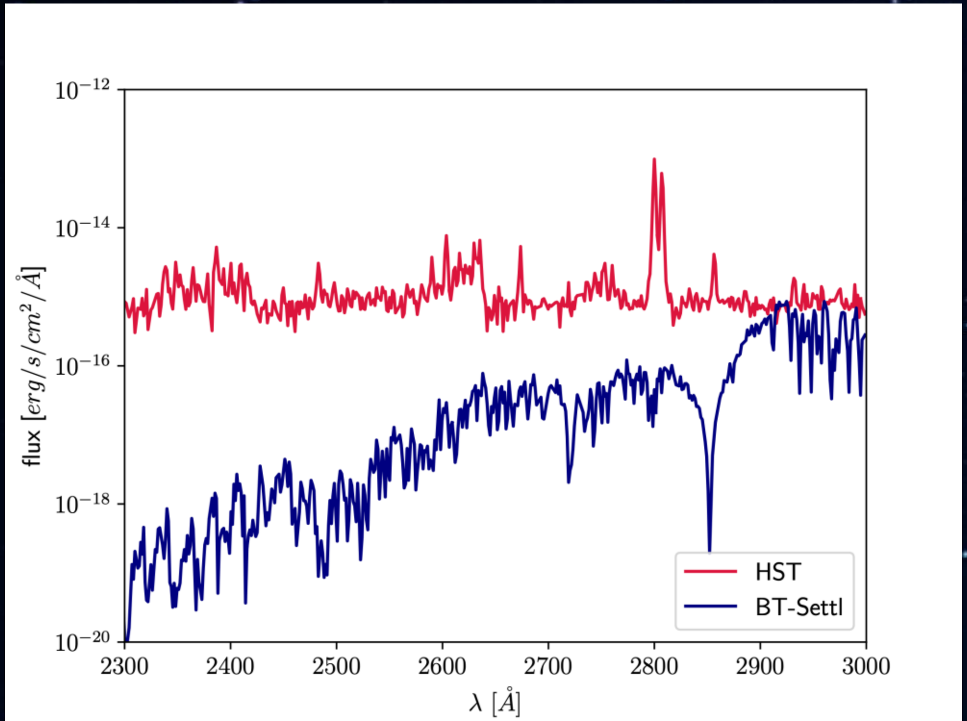
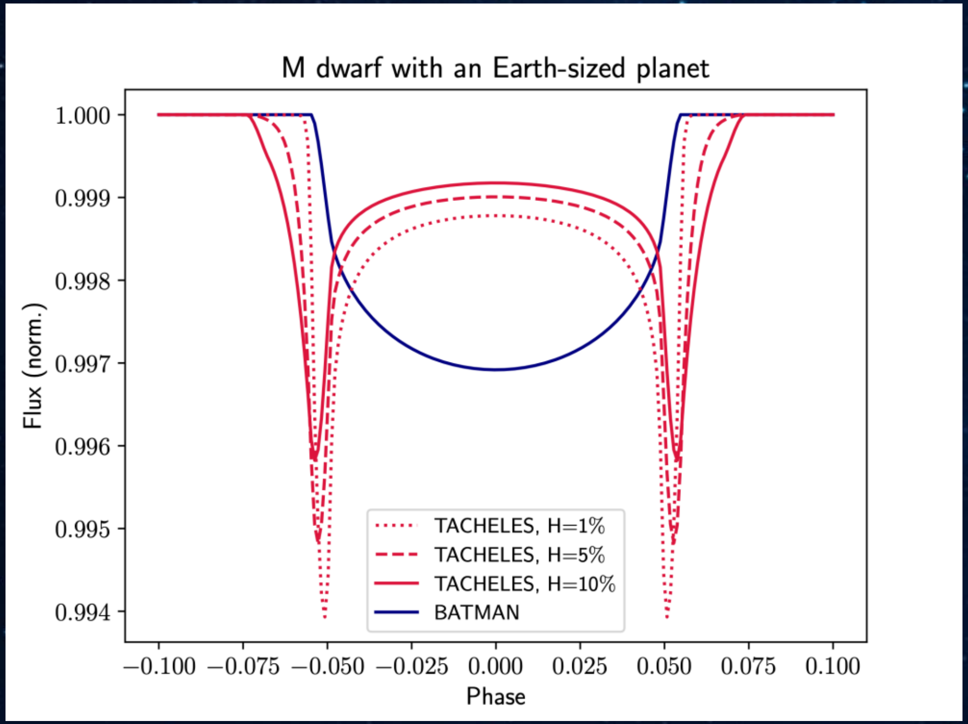


Simulated transit using the TACHELES model:



Perdelwitz et al. (in prep.)

Chromospheric transits as seen by ULTRASAT

Exoplanet Transits with ULTRASAT

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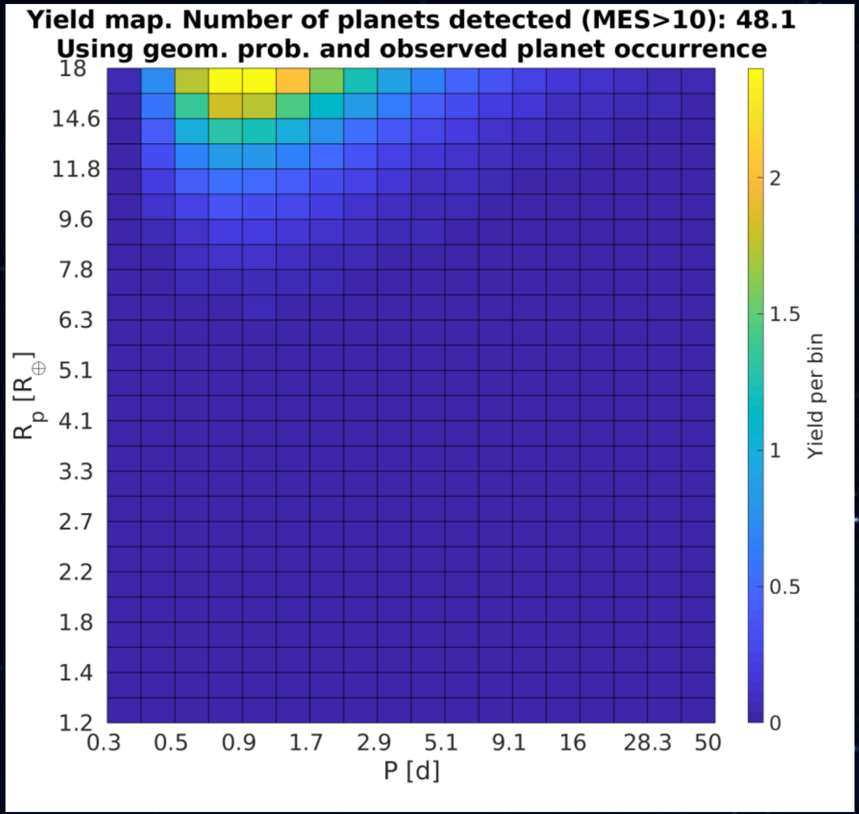
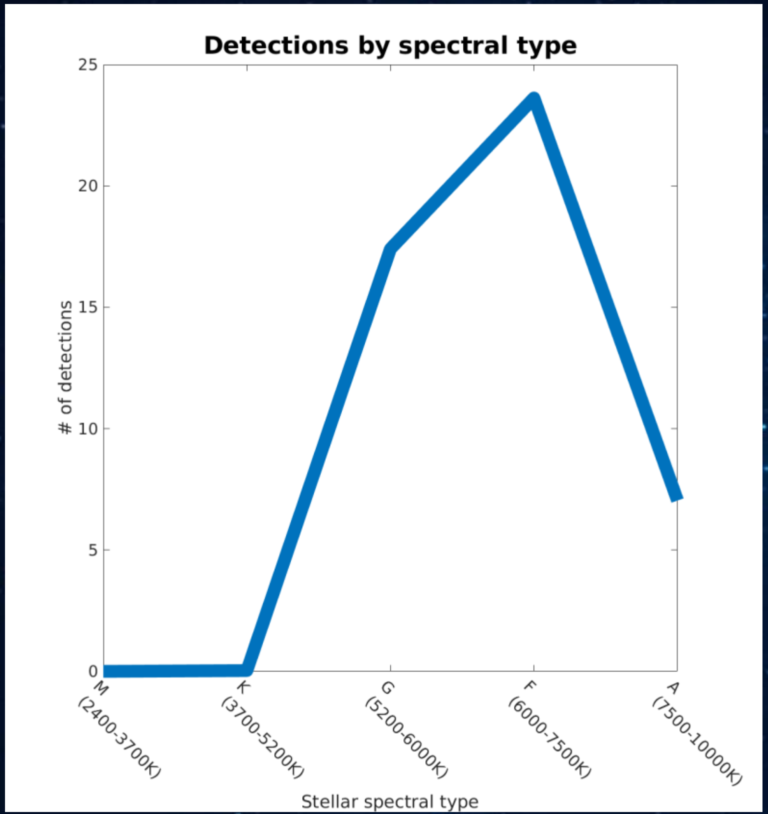




- Assuming main-sequence blackbody radiation.
- Requires re-evaluation (towards *more* detections) in light of significant non-blackbody contribution for M-dwarfs (M-giants ?)

(see V. Perdelwitz talk, "What do we expect to see with ULTRASAT?“)

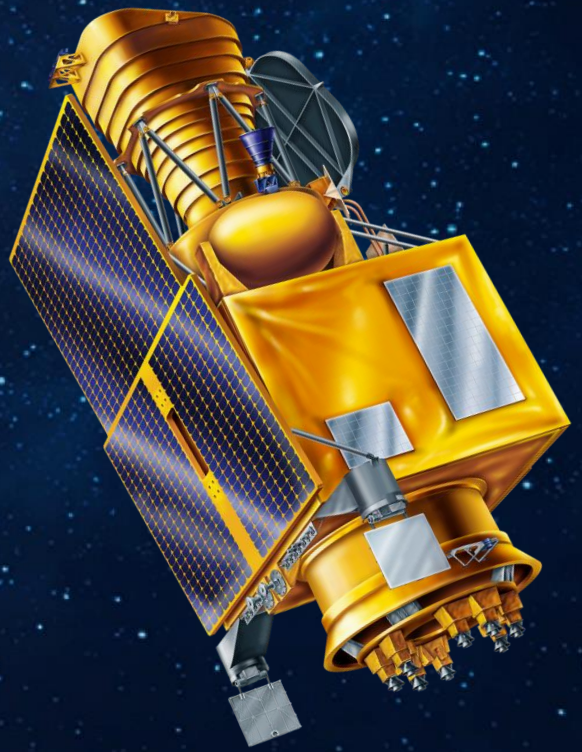
WG3 input required

Field selection considerations:
- Changing the high cadence field every year vs. re-visit.
- No. of known planetary systems in each field.

Required follow-up facilities and coordination.

Precision methods for ULTRASAT (B. Zackay).
Optimized LC analysis tools (AnalyticLC; Y. Judkovsky)

Observing campaigns beyond the standard survey modes.



Thanks!