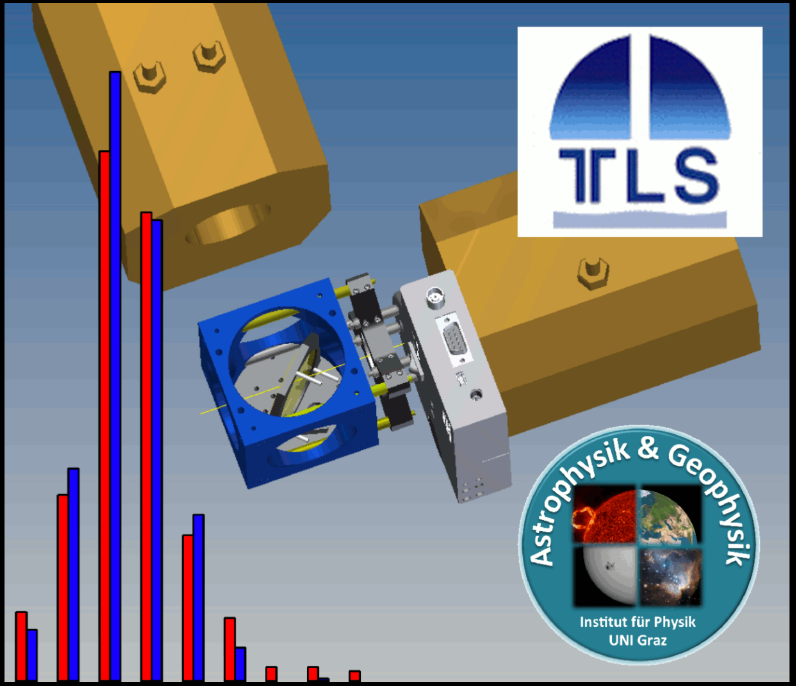
The Graz-Tautenburg Imager: GTI

Eike W. Guenther
Thüringer Landessternwarte Tautenburg

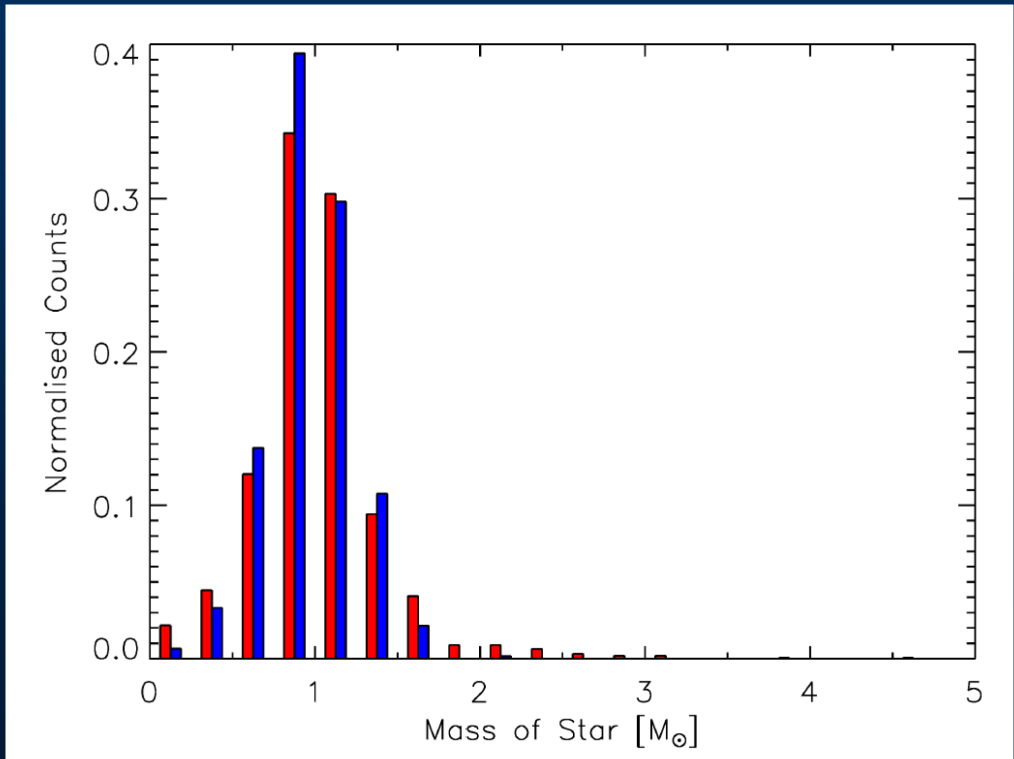
Th. Ratzka, R., Greimel, M., Leitzinger, J., Ramsauer
Institut für Geophysik, Astrophysik und Meteorologie, Uni Graz



The key Question:

How does the frequency of planets change with the mass of the host stars?

The frequency of planets for stars of different masses

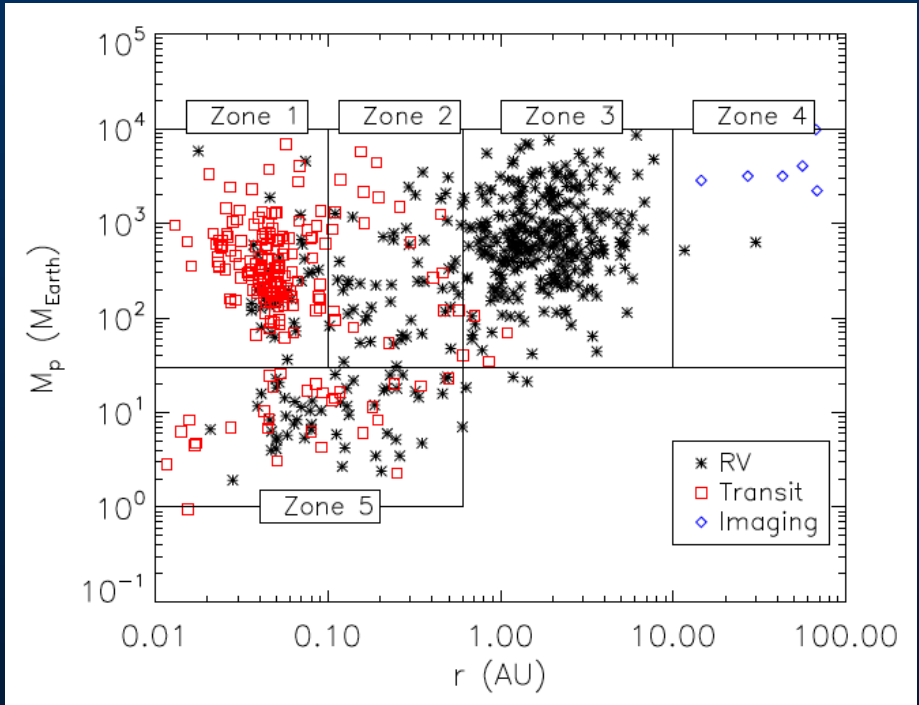


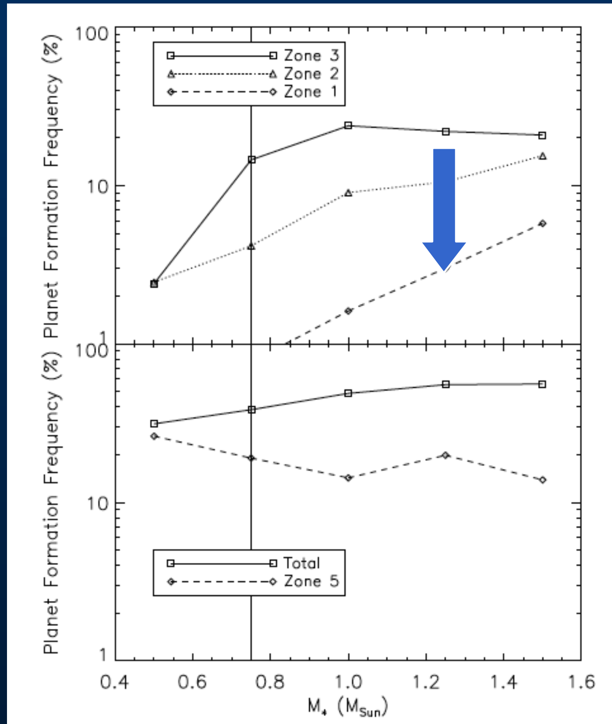
RED: Normalized distribution of the known planets for stars with different masses. The distribution of planets shows a considerable lack of known planets for stars more massive than 1.3 M_{sun} .

BLUE: If we take only close-in planets <0.1AU) into account, this lack is even more pronounced (blue).
Data taken from
www.exoplanet.eu

---> This distribution has certainly nothing to do with true frequency of planet, because existing surveys are heavily biased towards low-mass stars.

Predictions from theory (core-accretion scenario):





According to Hasegawa & Pudritz (2013) intermediate-mass stars have many close-in planets, because hot Jupiters are assumed to form in the "dead-zone" close to the star that contains a large fraction of matter

CoRoT observations of short period planets of intermediate-mass stars

The CoRoT Survey:
24.7% of the stars are A+B stars with $M^* > 1.8\ M_{sun}$.

Expected was to find 6 to 10 sub-stellar objects of intermediate-mass stars.

--> 10 A+B star candidates ($15\ M_{sun} < M_* < 1.8\ M_{sun}$)
--> 5 F0V-F5V candidates ($1.3\ M_{sun} < M_* < 1.7 M_{sun}$)

--> Only one additional planet of an F-star
(3 planets of F-stars found previously) and
--> Only one BD of an A-star found!

New transit surveys

Transit search programs are better suited to detect short-period planets of intermediate-mass stars than RV-surveys, because they are not affected by the rapid rotation of the stars.

- **K2** (ongoing): 150 ppm for a V = 12 mag star in 1 hour integration time, number of observed stars in the K2 mission will be about 4 -5 times larger than the number of stars observed by CoRoT.

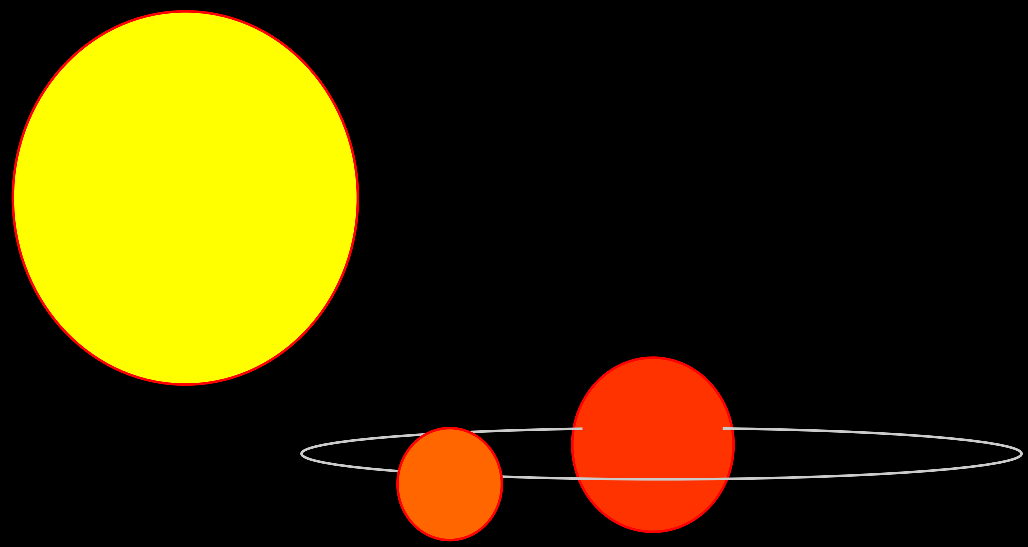
- **TESS** (2017+): 500000 stars in total; 200 ppm in 1 hour for I=10 mag star; main targets F5-M5 stars, but A-stars will also be covered; mostly planets with periods < 20 days.

  --> PSF of TESS of 44x44 arcsec.

- **PLATO** (2024+): 500000 stars in total; 25 ppm for V=11 mag star in 1 hour; planets with periods < 1 years; stellar parameters from oscillations; 32 cameras with overlap.

  --> PSF of PLATO 45x45 arcsec

Because stellar spots and grazing binaries can be easily excluded, the main source of false-positives are eclipsing binaries within the PSF



Excluding false-positives

"All" we have to do for obtaining the statistics of planets is to exclude false-positives (FPs).

The FP removal is done in the following way:

- Detailed modelling of the light-curves (most FPs are excluded in this step).
- Use GAIA results, or obtain low-resolution spectroscopy to exclude giant stars.

→ **Seeing-limited observation in- and out-of transit to exclude eclipsing binaries with separation 2-45 arcsec (99.8% of the area).**

→ **Multi-colour observations to exclude binaries with separation<2 arcsec.**

- (CoRoT: AO-imaging + NIR spectroscopy to exclude binaries with separations <2 arcsec.)
- (Radial-velocity observations to determine the mass of the planet, or to exclude binaries with grazing eclipses, if needed.)

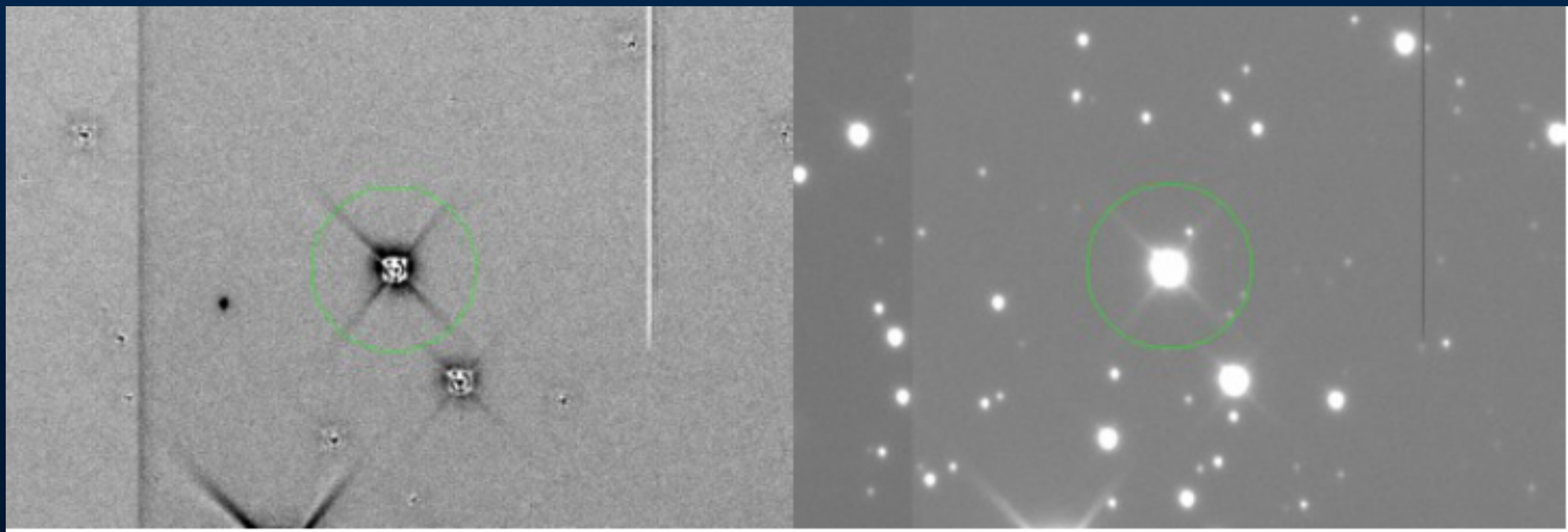
CoRoT experience I

Removing eclipsing binaries with separations of 2-30 arcsec from the target

CoRoT had a photometric mask with a size of (typically) 30x16 arcsec.

By taking one image during transit and one out of transit it was possible to find out whether any of the faint stars within the mask is a binary which is causing the transit.

Note: Many of such FPs can be identified using the centroid method during the LC analysis.



Requirements for Imager I

- Since the targets are V=10-12 we need to exclude binaries of

  V=15-17 for Jupiter-size planets,

  V=15-19 for Neptune-size planets,

  V=18-21 for planets of 1-2 R_{Earth} (note there are typically at least one such star per square-arcmin closer than 30° to the plane of the MW.)

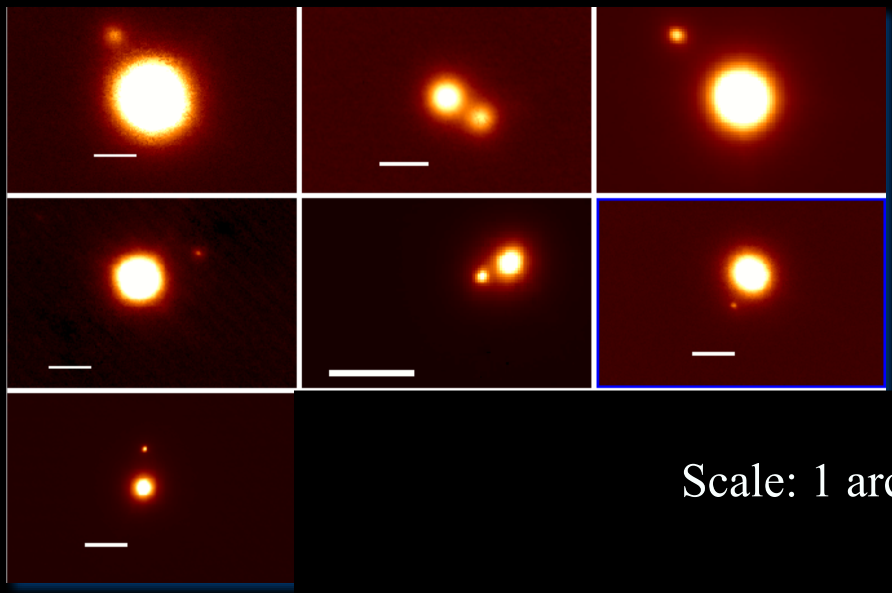
- FOV >10x10 arcmin to have enough comparison stars of roughly equal brightness as the target.

CoRoT experience II

Excluding eclipsing binaries with separations < 2 arcsec from the target (Guenther et al. 2013; Guenther & Tal-Or 2010).

Expectation: ~6% of the stars should have such companions.
CoRoT Result: 30-40% have one!

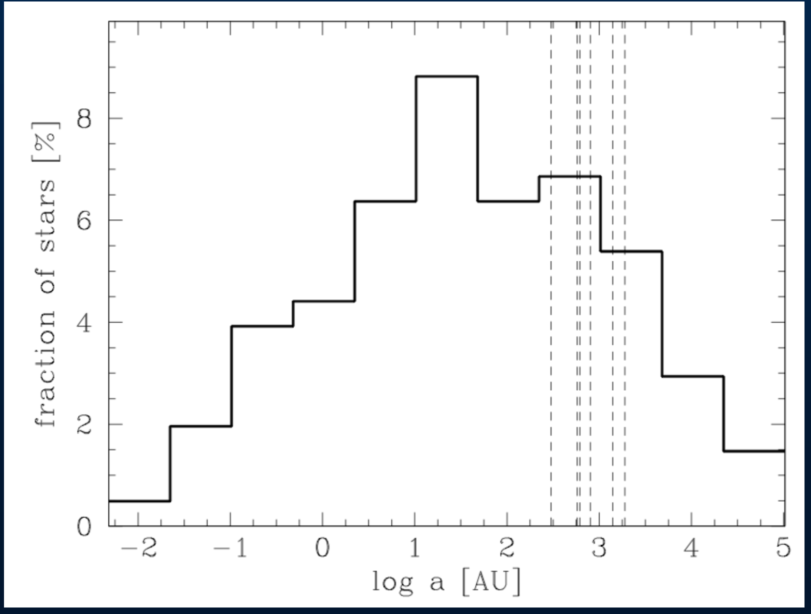
Santerne et al. (2015) finds RV-measurements of 129 giant-planet candidates found by Kepler a FP-rate: 54.6+/-6.5%.

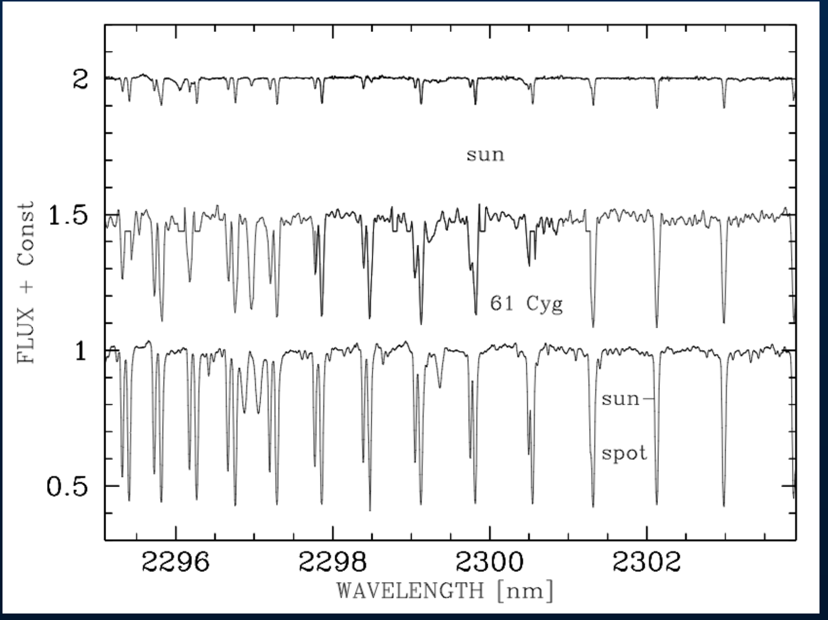


Scale: 1 arcsec

CoRoT experience III

- Projected distances found in AO-observations: 300 and 1900 AU.
- Companions within separations of less than 300 AU can be excluded by means of high-resolution NIR-spectroscopy (brightness difference of M-star to G-star much smaller in NIR). Future: CARMENES & CRIRES+.





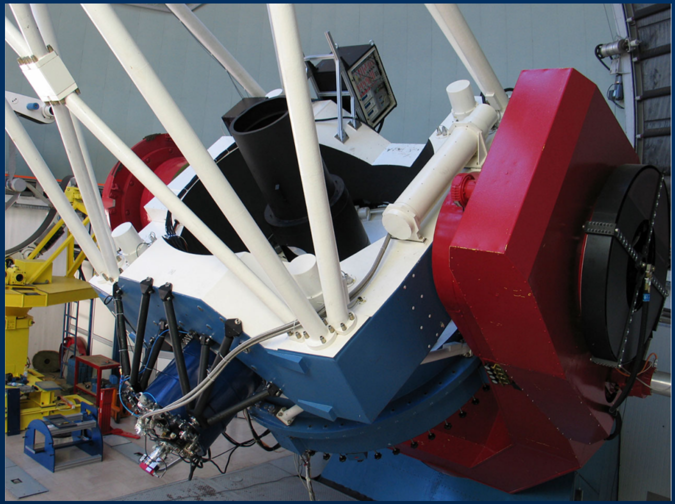
Requirements for Imager II

- If the eclipsing binaries were physical companions, the companions MUST have a much later spectral types (e.g. M-stars), and the transits MUST then be deeper in the red than in the blue.

- What is needed is an imager with just two channels were the S/N in both channel is about the same.

- Example: Triple star-system consisting of a G-star primary and two eclipsing M-stars which mimics a star with Jupiter-sized planet. Such a system would have transits that is 0.6% deep in B and 2.3% in R.

Existing multi-channel Imagers



Disadvantages:

-- FOV often small.

-- Light distributed over too many channels.

-- S/N very different in the different channels.

-- Very limited amount of observing time available.

---> New instrument(s) needed for TESS and particularly for PLATO

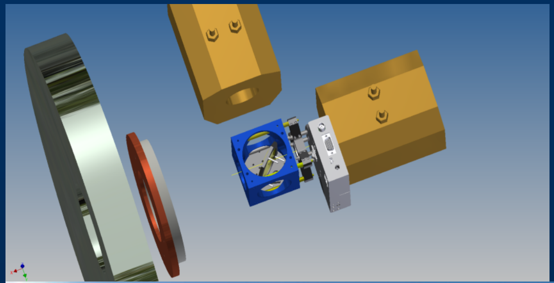
Instrument	Telescope	No. of Channels	Field of View [arcmin]
GTI	OSN 0.9	2	13.0 x 13.0
GROND	ESO/MPG 2.2	7	5.3 x 5.3
MAIA	Mercator 1.2	3	9.0 x 6.6
BUSCA	Calar Alto 2.2	4	12.0 x 12.0
ULTRACAM	WHT	3	5.0 x 5.0
	Danish 1.54	2	0.8 x 0.8

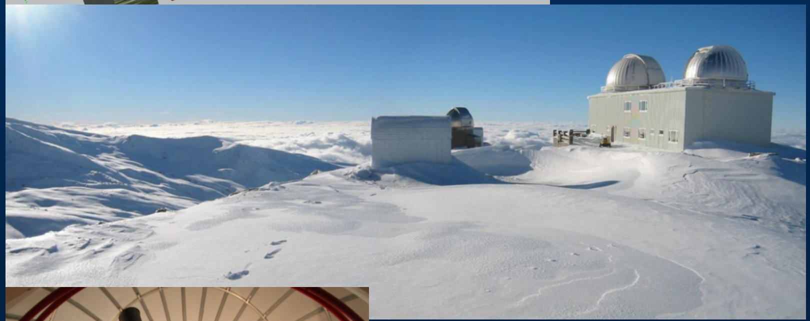
The Graz-Tautenburg Imager

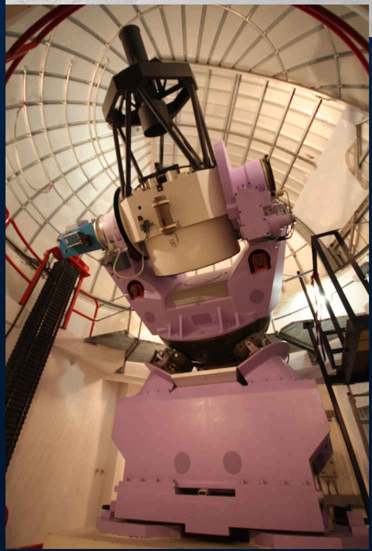
Table 1: Expected performance of GTI on the OSN 0.9 m telescope using 15 minute exposures. The first column gives the brightness, the second column the spectral type of the target. The last column lists the signal to noise ratio for the given wavelength range. The listed wavelength ranges can be measured with the specified dichroics.

V [mag]	SpecType	Dichroic	Arm	Wavelength [µm]	S/N
14	A5V	#1	Blue	380-550	2860
14	A5V	#1	Red	584-700	1860
14	G2V	#1	Blue	380-550	2320
14	G2V	#1	Red	584-700	2180
14	M3V	#1	Blue	384-550	1490
14	M3V	#1	Red	584-700	3040
21	G2V	#1	Blue	380-550	49
21	G2V	#1	Red	584-700	36
14	G2V	#2	Blue	380-490	1580
14	G2V	#2	Red	520-700	2630
14	G2V	#3	Blue	400-790	4550
14	G2V	#3	Red	830-950	1390
14	M3V	#3	Blue	400-790	4550
14	M3V	#3	Red	830-950	2850

Beamsplitters (Thorlabs, Inc.)	380 - 550 nm / 584 - 700 nm (#1) 380 - 490 nm / 520 - 700 nm (#2) 400 - 790 nm / 830 - 950 nm (#3)







Thank you