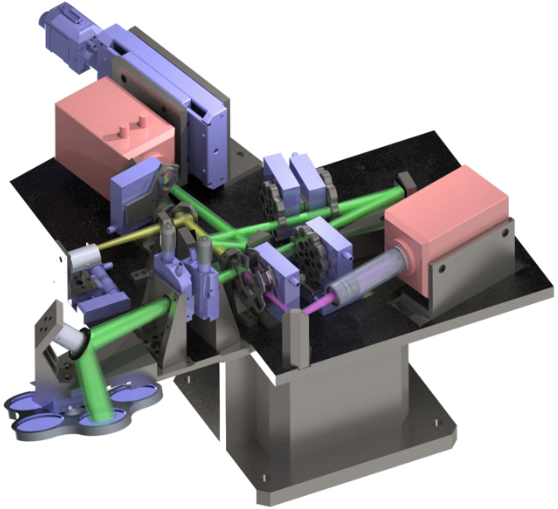
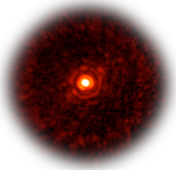




SHARK-VIS

the upcoming high-resolution high-contrast imager for LBT

Fernando Pedichini, and the SHARK-VIS team*

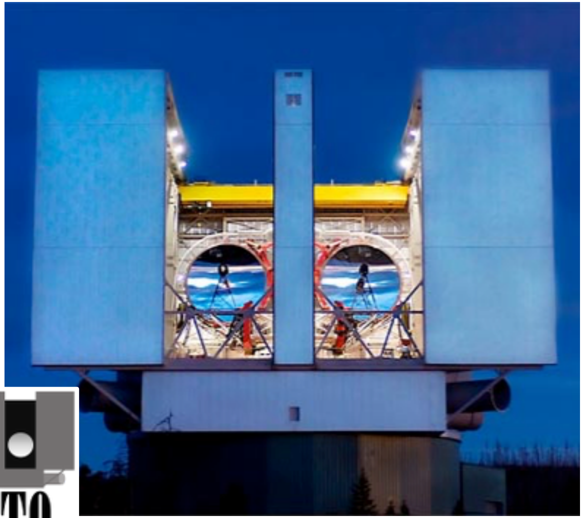
ASI - BREAKTHROUGH workshop 19-20 November 2018

**INAF Osservatorio Astronomico Roma*

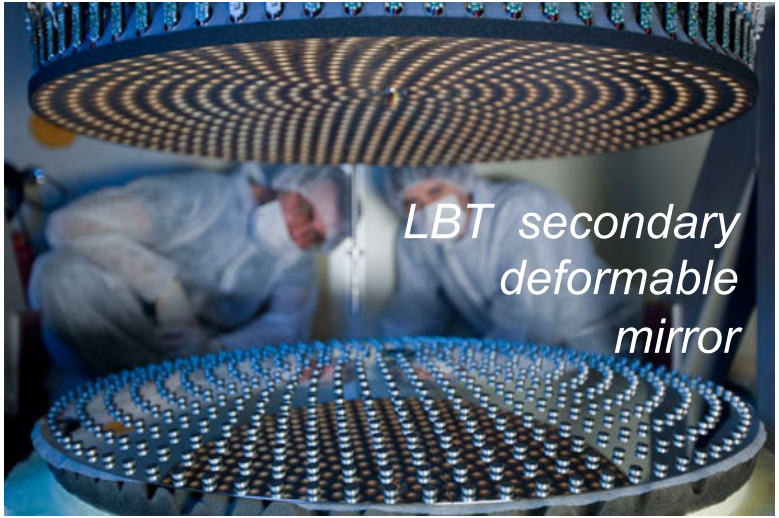
LBT SHARKs

***S**ystem for coronagraphy with **H**igh order **A**daptive optics from **R** to **K** band*

- Pair of synergic instruments (VIS+NIR) to use outstanding AO capabilities of LBT
- Observe at high-contrast and high-resolution a FoV of a few arcsecs



LBTO



Esposito et al. 2012, SPIE

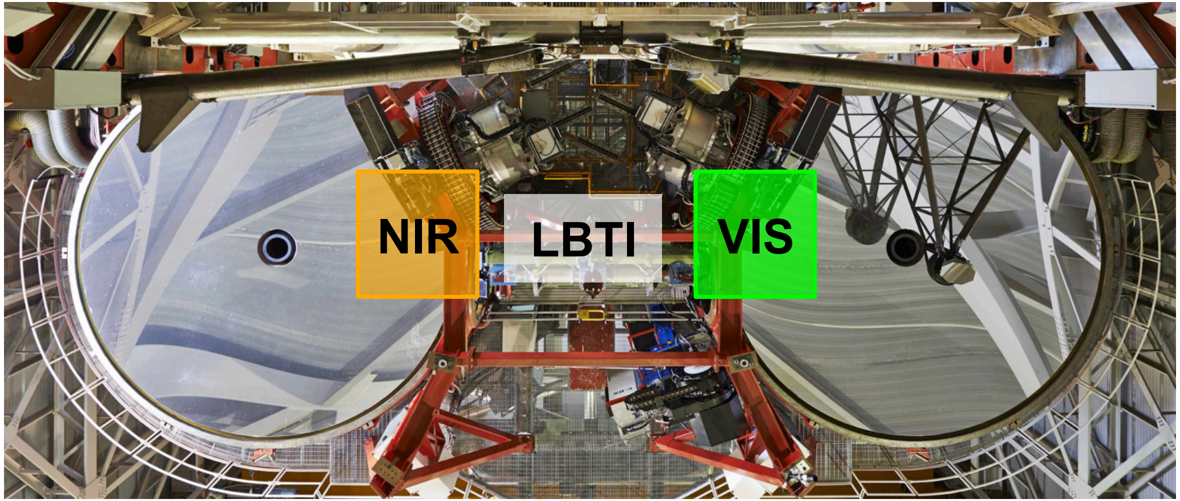
SHARKs @LBT *high contrast and resolution from 0.4 to 5 μm*

NIR

shark-nir

OAPd
P.I. J. Farinato

1.0-1.8 μm range
Coronagraph
Imager
LR spectra (R~700)



Steward Observatory – UoA
P.I. P. Hinz

2.0-5.0 μm range
Coronagraph Imager Interferometer
SHARKs' WFS

VIS

shark-vis

OAR
P.I. F. Pedichini

0.4-0.9 μm range
(fast) imager
Coronagraph
HR IFU ready

SHARK Teams & Co.

INAF-OAR (VIS)

- **F. Pedichini** (P.I., optics)
- **S. Antoniucci** (I.S., science)
- **G. Li Causi** (data reduction)
- **M. Mattioli** (P.M., engineering, SW)
- **R. Piazzesi** (laboratory SW)
- **M. Stangalini** (simulations)
- **V. Testa** (data archive, science)

INAF (VIS + NIR)

INAF Padova NIR channel
J. Farinato and the SHARK-NIR team

INAF Arcetri AO upgrade
E. Pinna and the SOUL team
INAF Trieste (V.O. and Archive)
R. Smareglia, C Knapich
INAF Brera
A. Bianco VPH development lab

Advisory board
S. Esposito (INAF Arcetri)
E. Giallongo (INAF OAR)
R. Ragazzoni (INAF OAPD)

WORLDWIDE

Steward Observatory
P. Hinz and LBTI team + NIR camera

Georgia State University
S. Jefferies, M. Hart

LBTO
J. Christou and the MGIO crew

LEIDEN Universiteit VIS NCPA and HRS

MPIA NIR controls

IPAG NIR coronagraph masks

VIS and NIR Science teams
90+ researchers, 30+ affiliations

SHARK-VIS compact and ADI-optimized

FoV: 1-10″ @ 6-3.5 mas/pixel
Spectral range: 0.4 to 0.9 μm

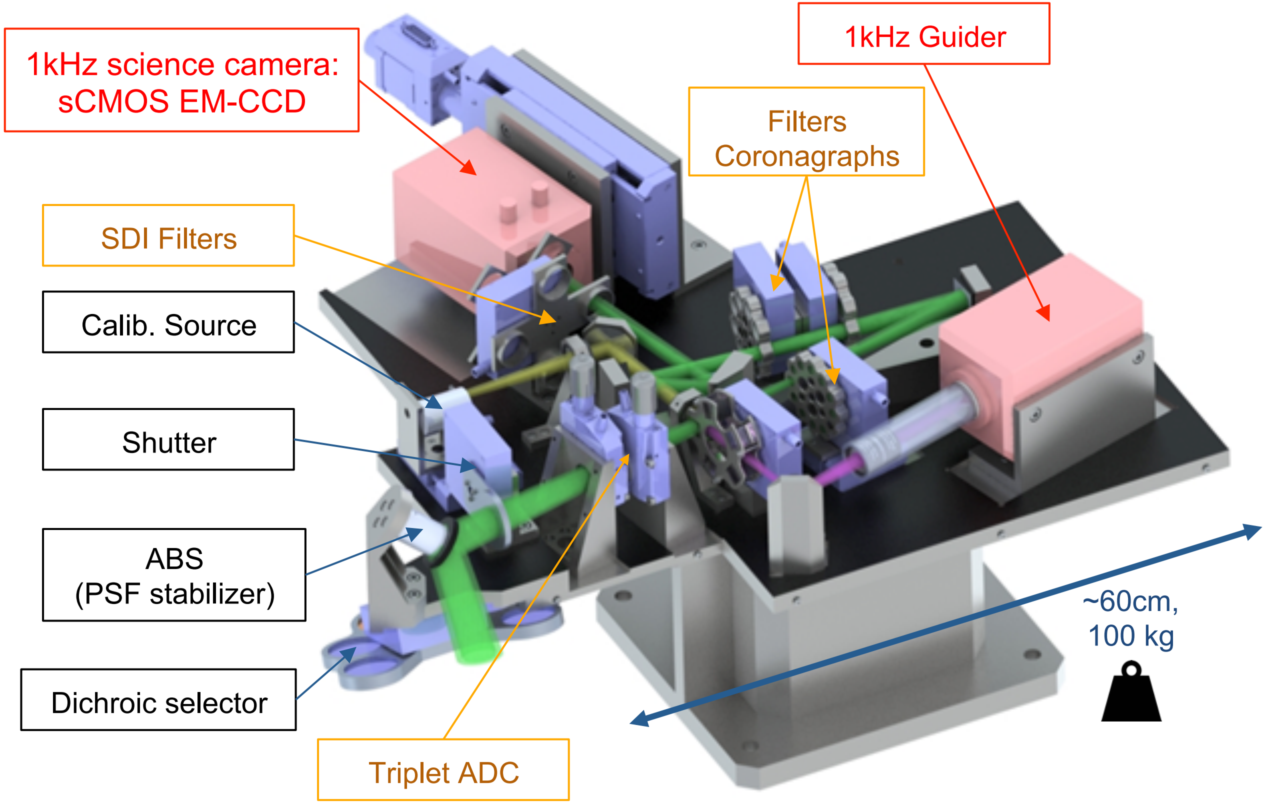
Imager, SDI, Coro
High troughput

Fast IMAGING at 1kHz

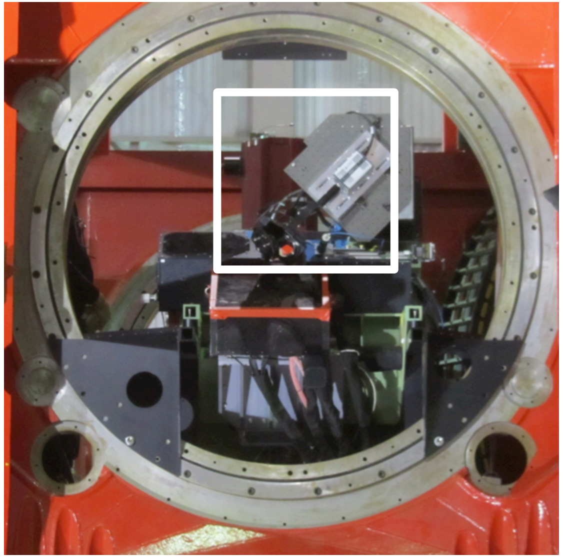
Active PSF stabilization
NCPA off-load to M2

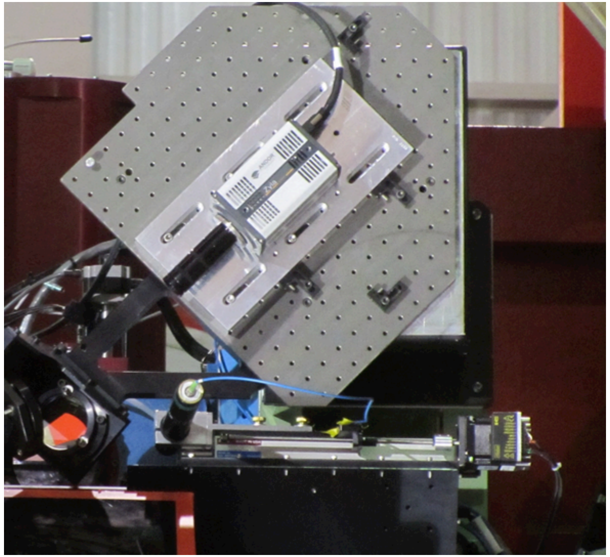
AO limited performance
Field & Pupil coronagraphs

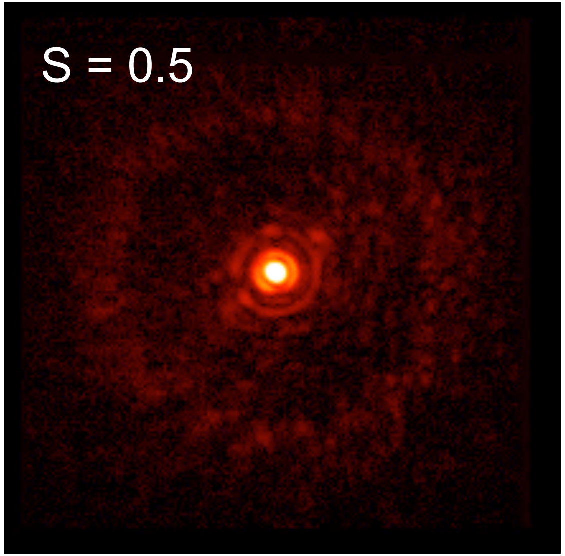
IFU ready for High Resolution and Contrast Spectroscopy



Where it all began: ForeRunner (2014-15)







LBTI-AO 550 modes 990Hz

NCPA 30nm removal by modes offset

ANDOR sCMOS imager

200 x 200 pix at **3.73mas/pix**

1ms exposure 1.5e- RON,

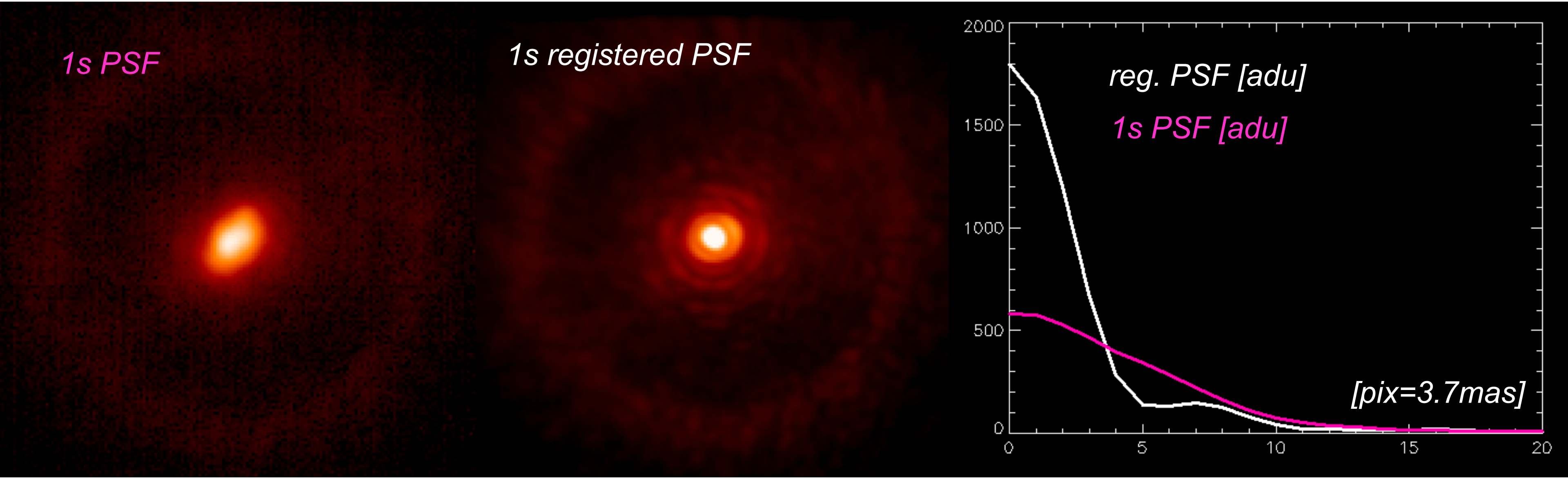
630nm 40nm bandwidth

Diffraction-limited PSF at 630 nm,

18 mas FWHM, 20 min exposure

average seeing 1.2″

ForeRunner: 1s in slow motion (eqv. to R=7.7)



Papers from 20 min of ForeRunner

The Astronomical Journal, 154:74 (5pp), 2017 August https://doi.org/10.3847/1538-3881/aa7ff3

CrossMark

High Contrast Imaging in the Visible: First Experimental Results at the Large Binocular Telescope

F. Pedichini[1,2], M. Stangalini[1,2], F. Ambrosino[1], A. Puglisi[2,3], E. Pinna[2,3], V. Bailey[4], L. Carbonaro[3], M. Centrone[1], J. Christou[5], S. Esposito[2,3], J. Farinato[2,6], F. Fiore[1,2], E. Giallongo[1,2], J. M. Hill[5], P. M. Hinz[7], and and L. Sabatini[1]
[1] INAF-Osservatorio Astronomico di Roma, I-00078 Monte Porzio Catone (RM), Italy; fernando.pedichini@oa-roma.inaf.it
[2] ADONI, INAF ADaptive Optics National laboratory of Italy, Italy
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[5] LBTO, University of Arizona, 933 N. Cherry Ave, Room 552, Tucson AZ 85721, USA
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[7] CAAO, Steward Observatory, University of Arizona, Tucson AZ 85721, USA
Received 2016 May 25; revised 2016 September 8; accepted 2016 September 8; published 2017 July 28

The Astrophysical Journal, 849:85 (8pp), 2017 November 10 https://doi.org/10.3847/1538-4357/aa8e98

CrossMark

SFADI: The Speckle-free Angular Differential Imaging Method

Gianluca Li Causi[1,2,3], Marco Stangalini[2,3], Simone Antoniucci[2,3], Fernando Pedichini[2,3], Massimiliano Mattioli[2,3], and Vincenzo Testa[2,3]
[1] INAF Istituto di Astrofisica e Planetologia Spaziali—Via Fosso del Cavaliere 100, Roma, Italy; gianluca.licausi@oa-roma.inaf.it
[2] INAF Osservatorio Astronomico di Roma—Via Frascati 33, I-00078, Monte Porzio Catone (RM), Italy
[3] ADONI Adaptive Optics National Lab of Italy
Received 2017 July 25; accepted 2017 September 5; published 2017 November 6

Journal of Astronomical Telescopes, Instruments, and Systems 3(2), 025001 (Apr–Jun 2017)

Speckle statistics in adaptive optics images at visible wavelengths

Marco Stangalini,[a,b,*] Fernando Pedichini,[a,b] Enrico Pinna,[b,c] Julian Christou,[d] John Hill,[d] Alfio Puglisi,[b,c] Vanessa Bailey,[e] Mauro Centrone,[a] Dario Del Moro,[f] Simone Esposito,[b,c] Fabrizio Fiore,[a,b] Emanuele Giallongo,[a,b] Phil Hinz,[g] and Amali Vaz[g]
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[d]University of Arizona, LBTO, Tucson, Arizona United States
[e]KIPAC-Stanford University, Stanford, California, United States
[f]Universitá di Roma Tor Vergata, Rome, Italy
[g]University of Arizona, CAAO, Steward Observatory, Tucson, Arizona, United States

RECURRENCE QUANTIFICATION ANALYSIS AS A POST-PROCESSING TECHNIQUE IN ADAPTIVE OPTICS HIGH-CONTRAST IMAGING

M. Stangalini[1,2], G. Li Causi[3,1], F. Pedichini[1,2], S. Antoniucci[1,2], M. Mattioli[1,2], J. Christou[4], G. Consolini[3], D. Hope[5], S. M. Jefferies[6,7], R. Piazzesi[1,2], V. Testa[1,2]
[1]INAF-OAR National Institute for Astrophysics, Via Frascati 33, 00078 Monte Porzio Catone (RM), Italy
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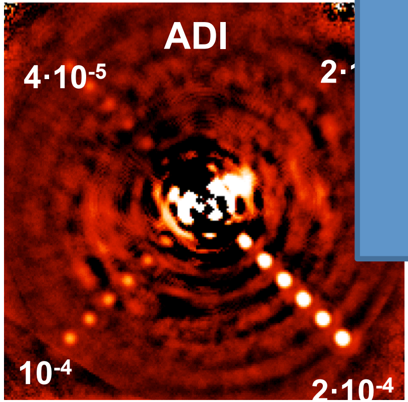
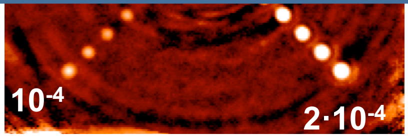
[3]INAF-IAPS, National Institute for Astrophysics, Via del Fosso del Cavaliere 100, 00133 Rome, Italy
[4]LBTO, University of Arizona, Tucson AZ 85721, USA
[5]Hart Scientific Consulting International LLC, 2555 N. Coyote Dr. 114, Tucson, AZ 85745
[6]Georgia State University, Atlanta, GA 30303, USA
[7]University of Hawaii, Institute for Astronomy, Maui, Hawaii', USA

- **4 refereed papers + 1** *in prep.*
- **13** *SPIE technical papers*
- **1** *SDW paper*

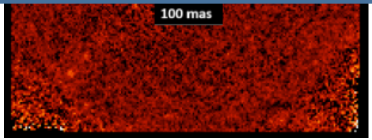
ForeRunner performance $2 \cdot 10^{-5}$ @ 100mas

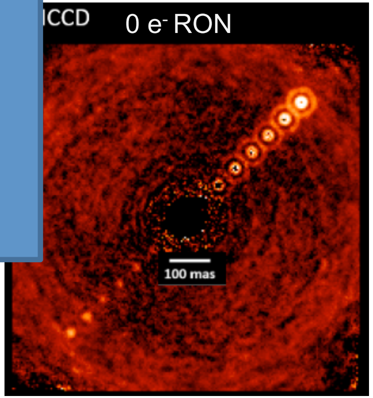
- Fast cadence detector are fundamental to Observe in-between speckles
- Fast cadence and ultra-low-noise detectors are fundamental to achieve the sky limit (NoNOISE project with INAF Brera)





MORE INFOS IN THE FOLLOWING TALKS
by
LI CAUSI and STANGALINI

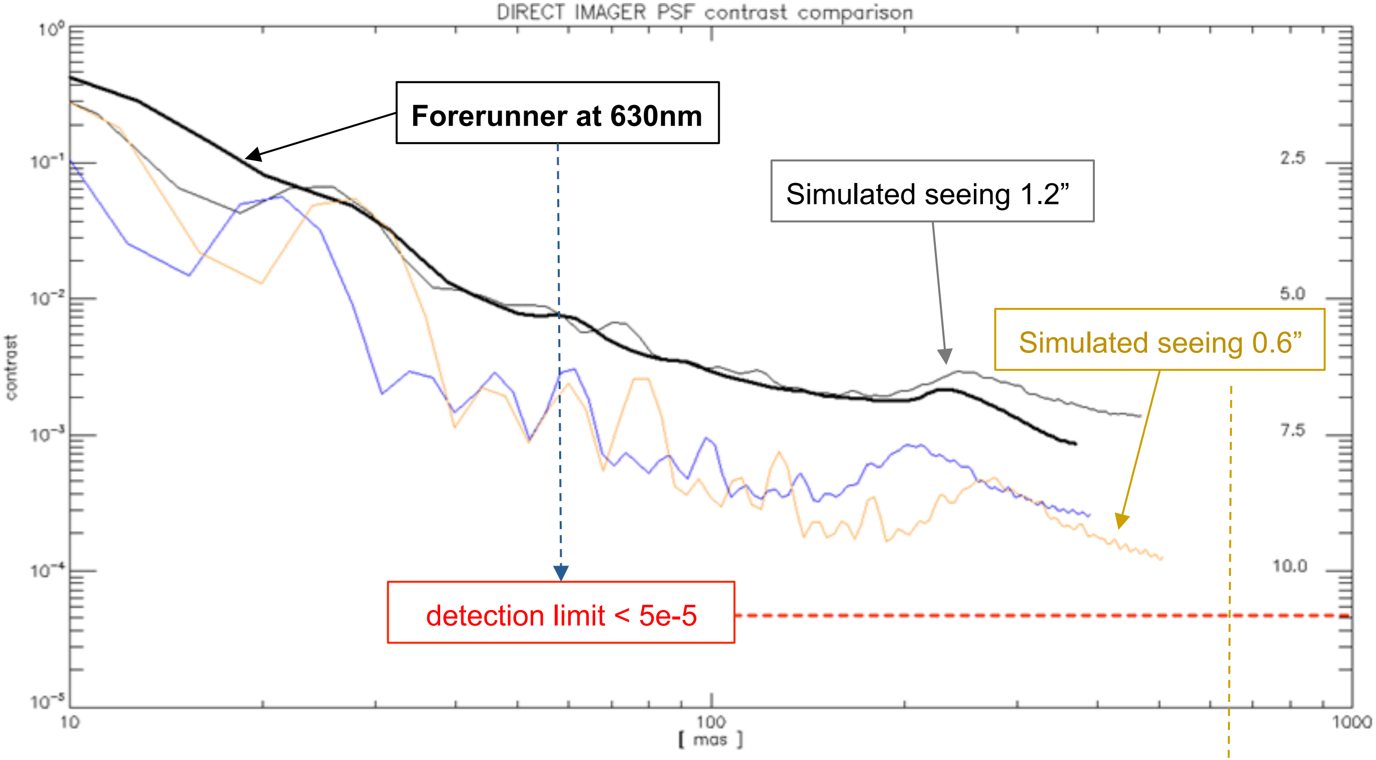




FINAL SHARK-VIS expected contrast $1 \cdot 10^{-6}$ @ 100 mas
(2h, no-coro, bright star regime - R < 8)

Li Causi et al. 2017, ApJ, 849:85 *Stangalini et al.*

SHARK-VIS 1h-exposure expected performance



High-contrast imaging analysis heavily relies on complex post-processing techniques
(e.g. various types of differential imaging: ADI, SDI, ...)

Expected contrast @100-150 mas from 1e-5 to 1e-6 with good seeing and post-processing

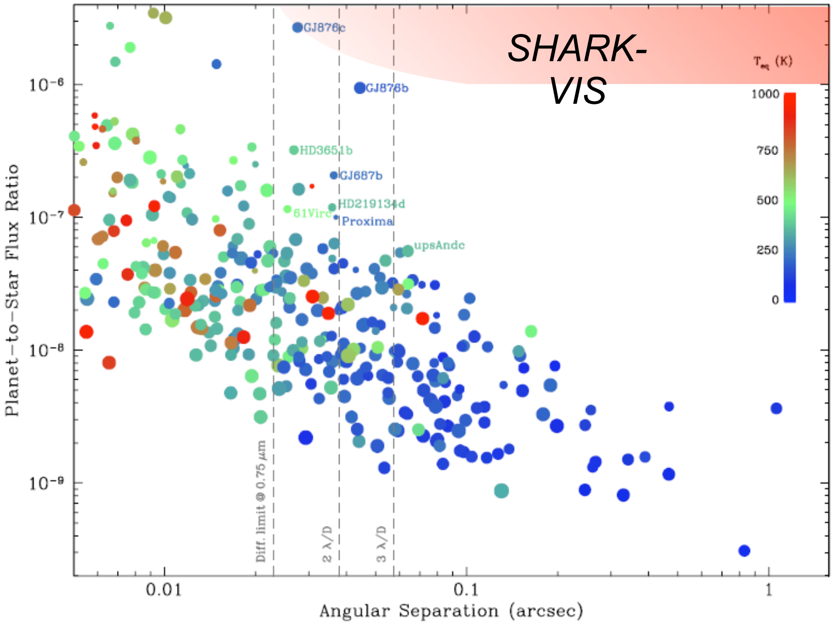
SHARKs SCIENCE in synergy with LMIRCAM

Primary cases:

- Accreting planets and BDs
- Jets from young stellar objects
- Minor bodies and moons in Solar System
- Accretion disks

VIS special cases:

- Accreting planets in H-alpha
- Jupiter moon Io Volcanoes
- Pathfinder for reflected-light planets

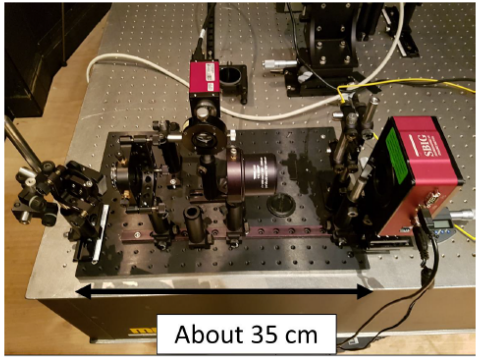


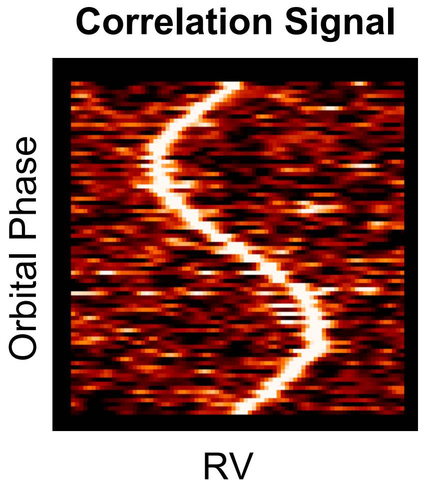
Lovis et al. 2017

HCS SHARK-VIS upgrade with SCAR Coro + IFU

The LEXI IFU prototype developed at Leiden can be coupled with SHARK-VIS to perform HCS (HCI+HDS) with R=100000 at LBT.

The SHARK-VIS team has just started a conceptual study in collaboration with: C. Keller, S. Haffert, R. Gratton, and V. D’Orazi



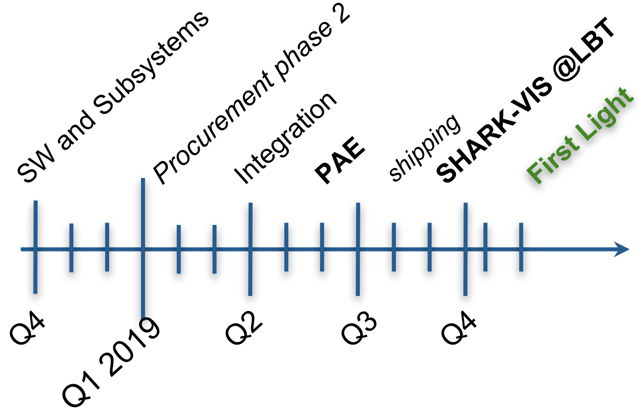


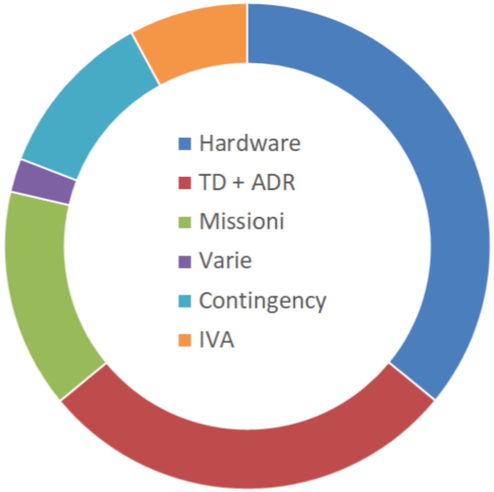
Simulations based on the ForeRunner data set, assuming:

- Gauss coronagraph
- Single-mode fibers IFU
- R 100000 spectrograph
- Planet with a 40km/s Max doppler
- Target contrast **2e-6 at 100mas**
- 20 min exp. for each orbital phase (80 steps)

SHARK-VIS Project Status

Timeline





~900k€ + 21.1 FTE

Already funded:
75%
680k€
next funding in 2019
220k€

to be funded
IFU and HCS:
300k€ + 4 FTE

Take home messages

- ✓ SHARK-VIS is a powerful facility in the northern hemisphere for λ/D imaging at visible
- ✓ 1e-6 contrast at 100mas no coronagraph expected using post processing with fast imaging
- ✓ Exciting new capabilities with dedicated SCAR coronagraph + IFU to perform R~100000 spectroscopy

Thank You