# High time-resolution imaging and spectroscopy at IRTF

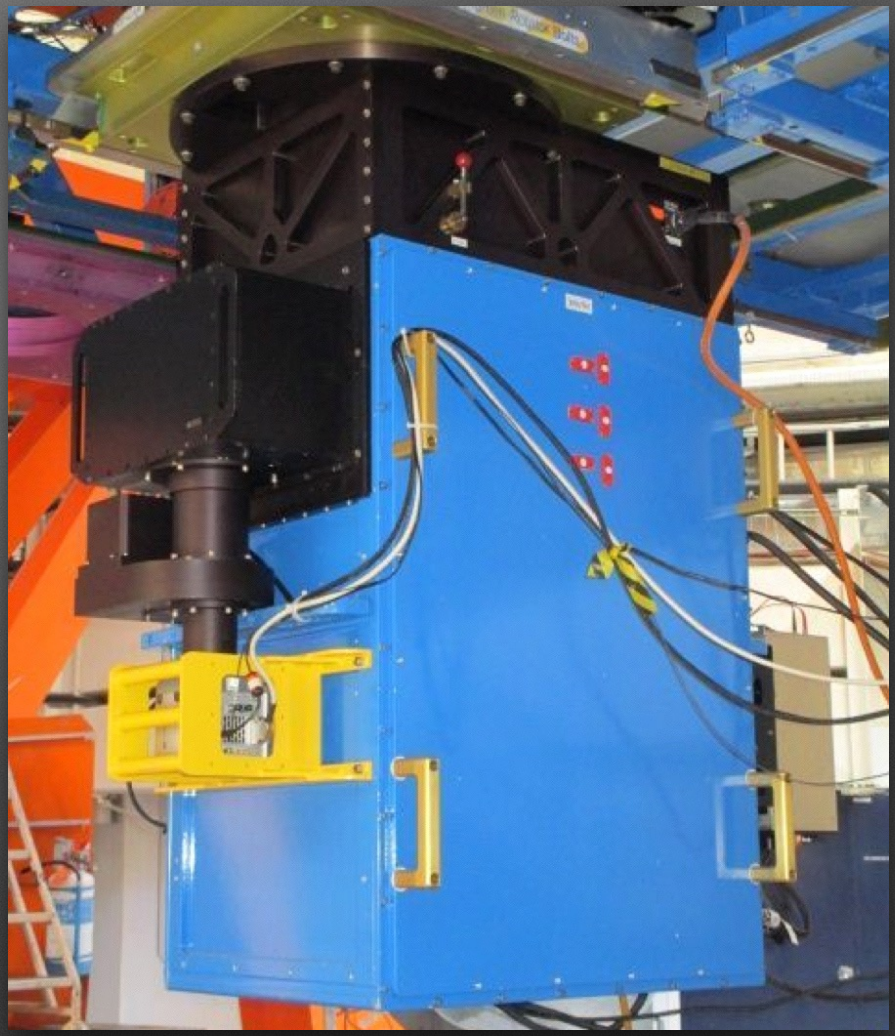
Amanda S. Bosh (MIT, Lowell) and Amanda A. Sickafoose (SAAO, MIT)

IRTF Future Directions Workshop, 12-14 February 2018

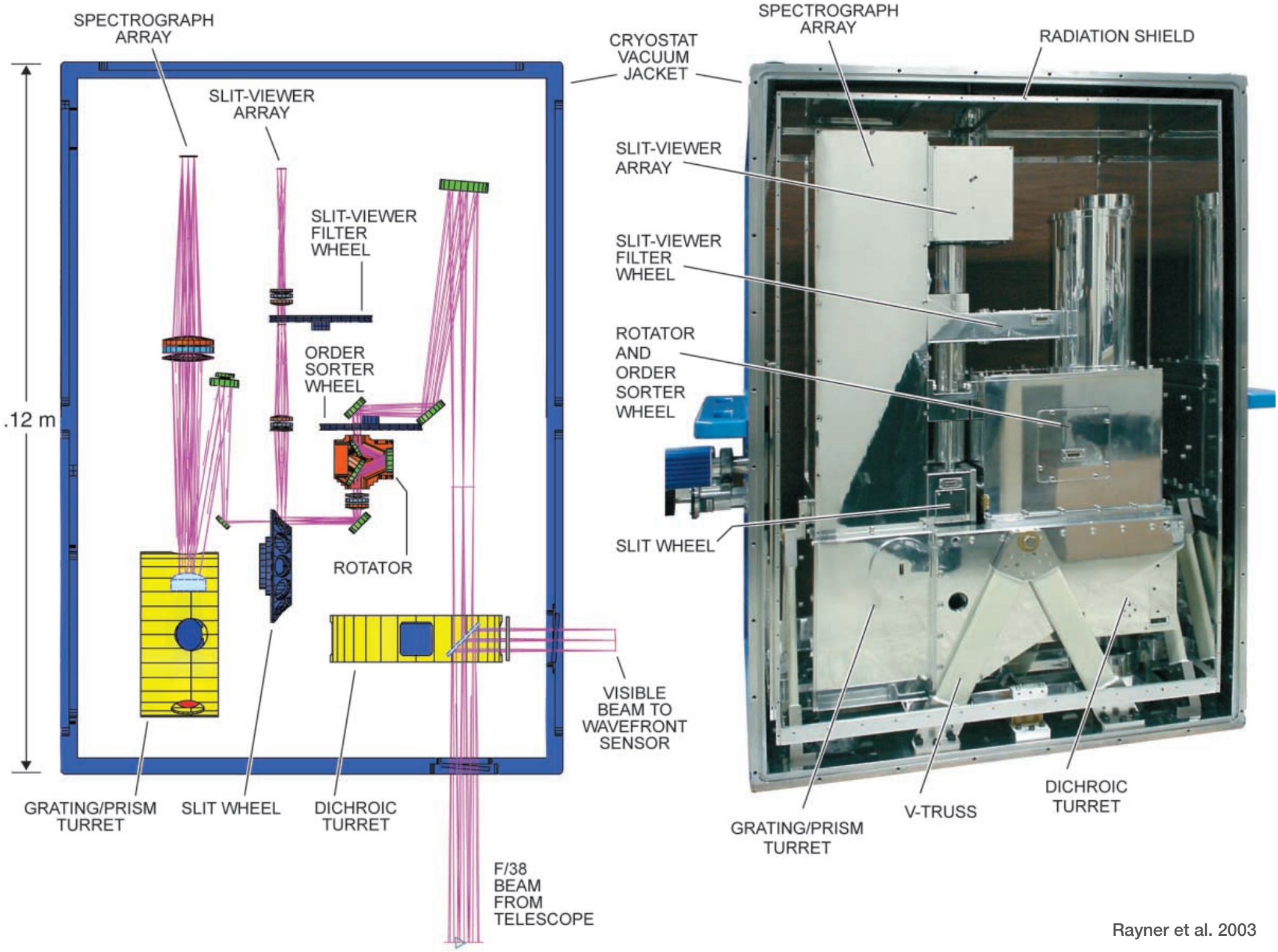
# Time Domain

Time critical
High time resolution
Cadence

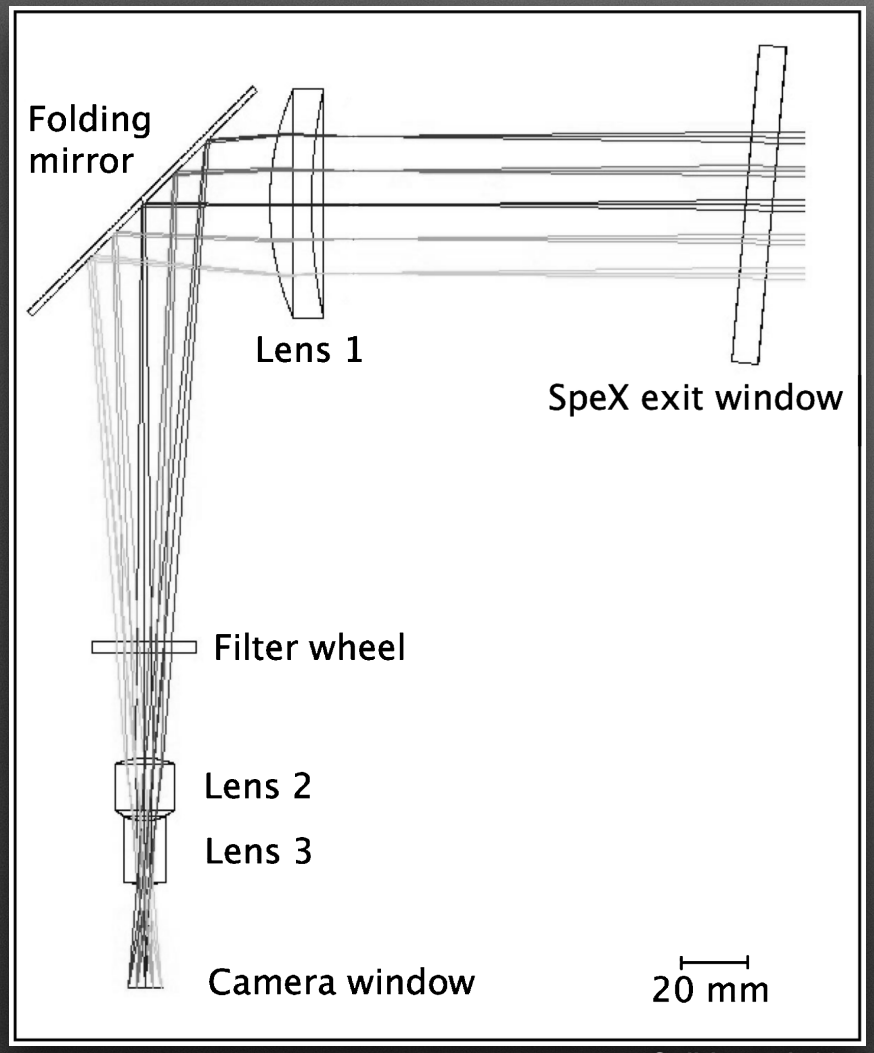
# MORIS and SpeX



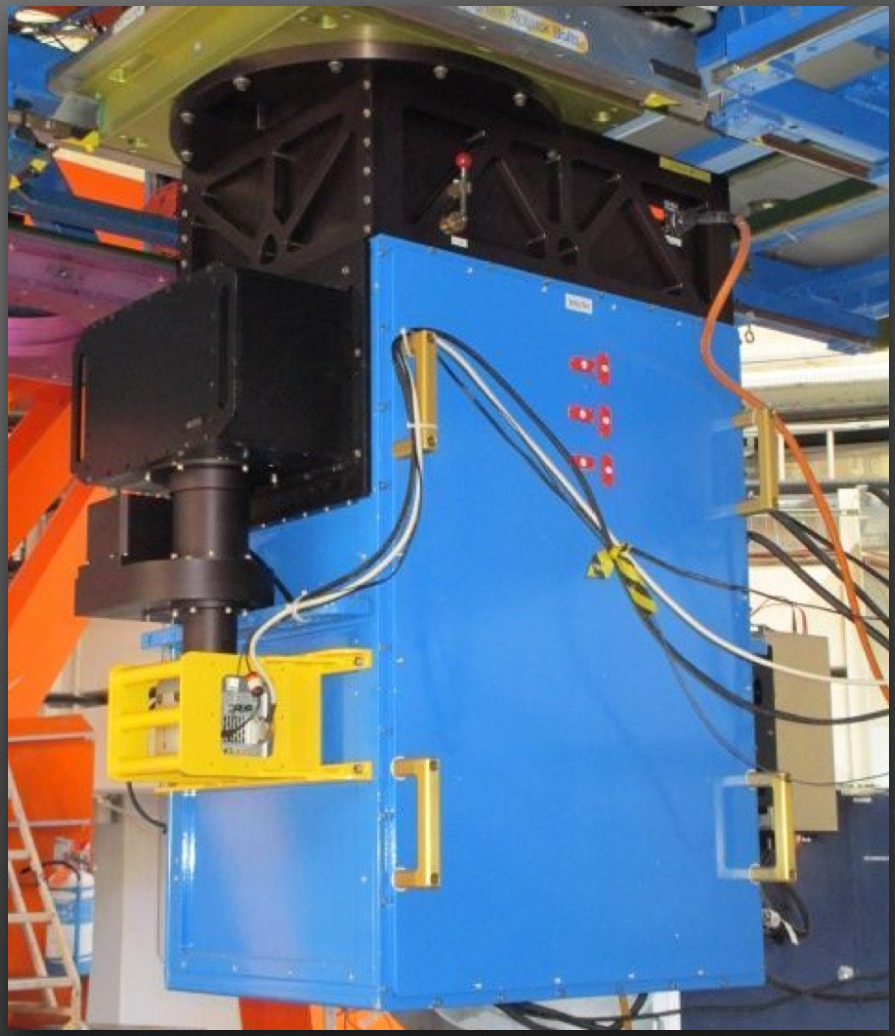
irtfweb.ifa.hawaii.edu/~spex/




Rayner et al. 2003




Gulbis et al. 2011



irtfweb.ifa.hawaii.edu/~spex/

# MORIS

## MIT Optical Rapid Imaging System

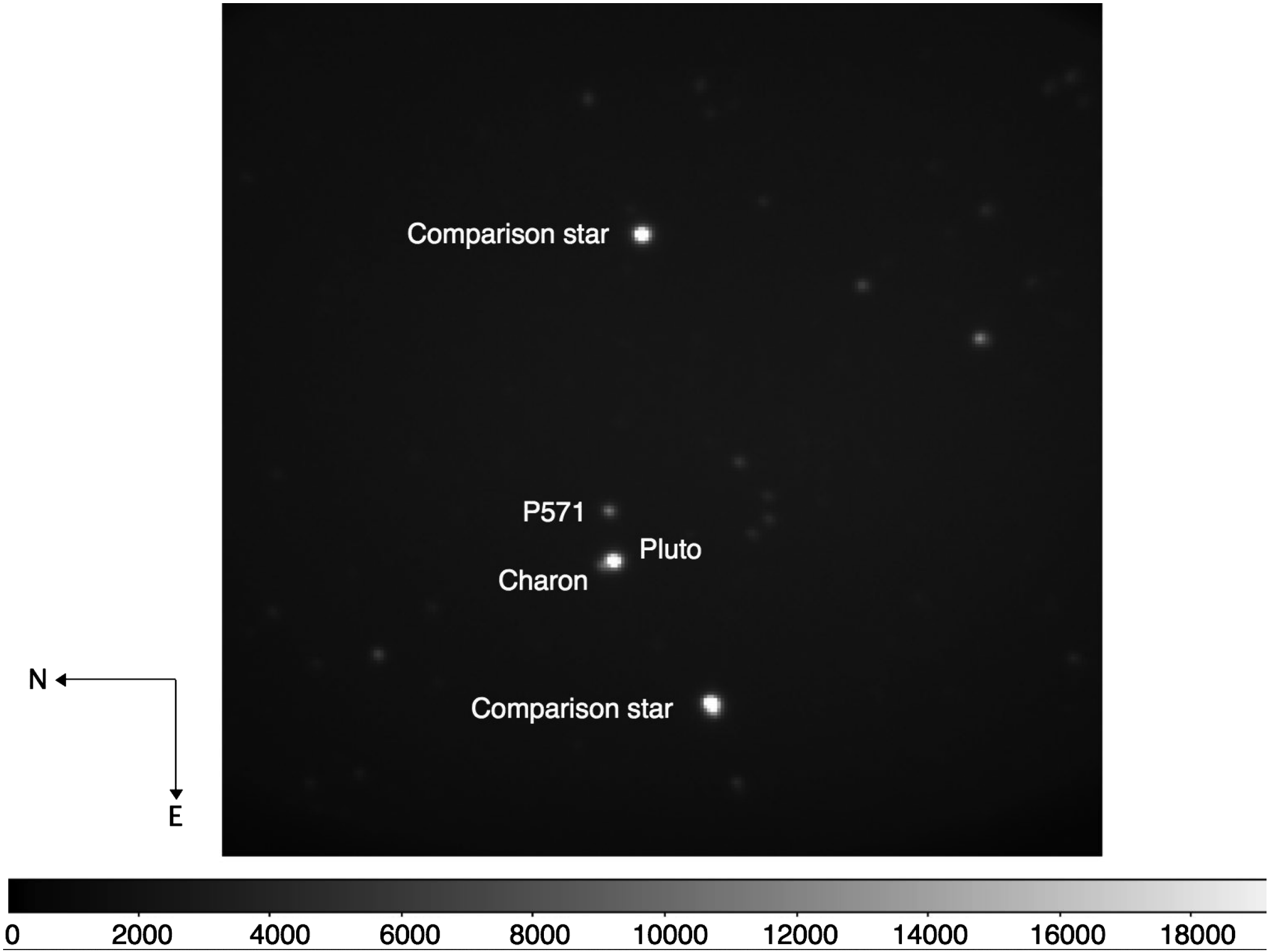
Bosh & Sickafoose; IRTF Future Directions

| | MORIS | SPEX |
|---|---|---|
| DETECTOR | Andor iXon Ultra 897 | Teledyne H2RG |
| FOV | 512x512<br>16 µm<br>1 x 1 arcmin | 2048x2048<br>18 µm |
| READ NOISE | 6 e- for 1MHz, 2.5x | 5 e- for 32 NDR |
| DATE | 11/2016 | 8/2014 |

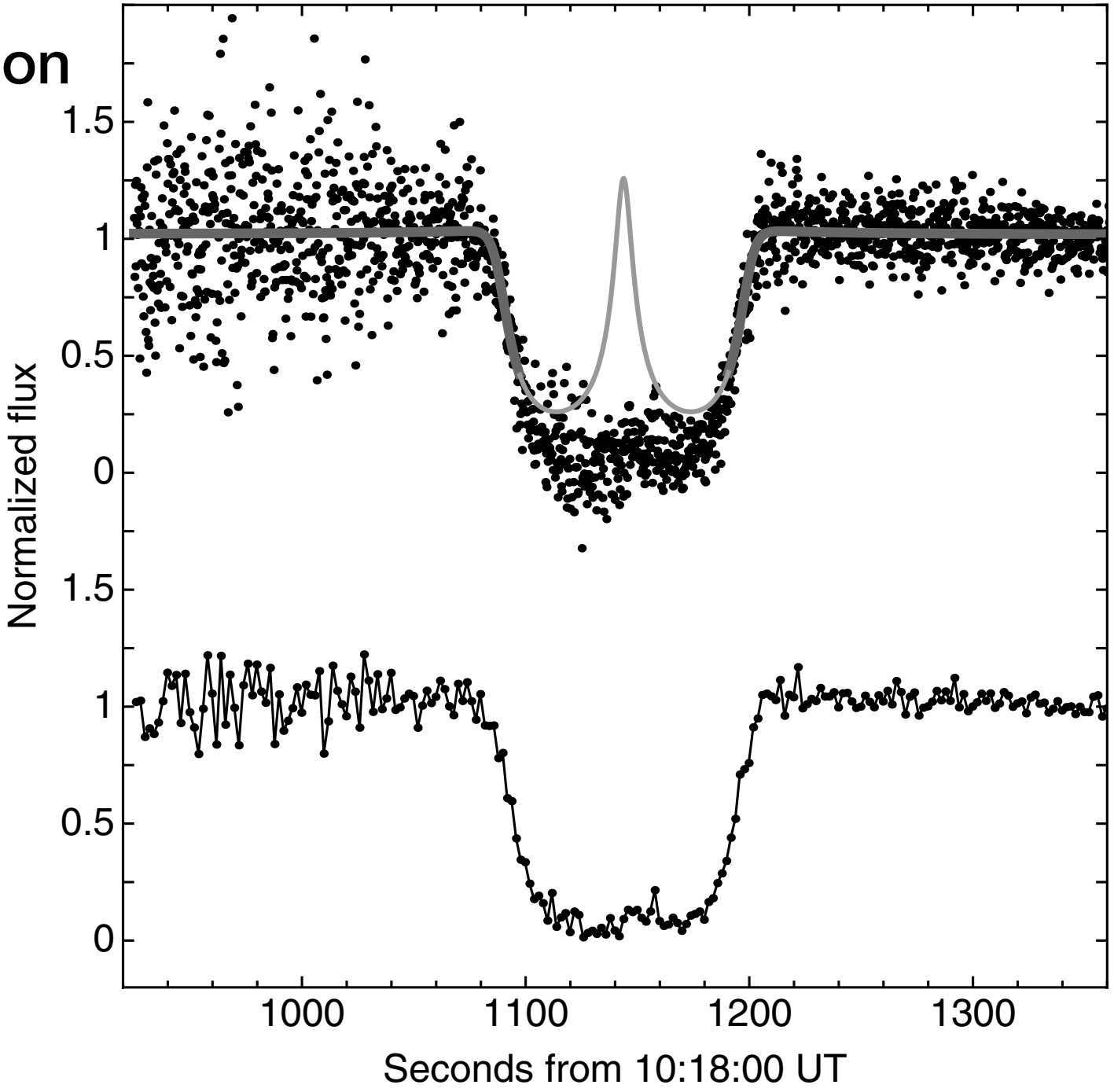
# High time resolution with MORIS and SpeX

- MORIS
  - dead time 1.7 ms for 512 rows at default vertical shift speed
  - 3.5 frames/sec for full frames at 1MHz readout rate
  - 35 frames/sec at 10 MHz
  - with binning and sub-framing, can get to hundreds of frames/sec
- SpeX movie mode
  - data streamed to two SRAMs alternately
  - 2 frames/sec for full 1024x1024 frames
  - 10 frames/sec using prism mode (0.8-2.5 micron) with 512x100 subarray
  - with sub-framing (less wavelength range), can get faster

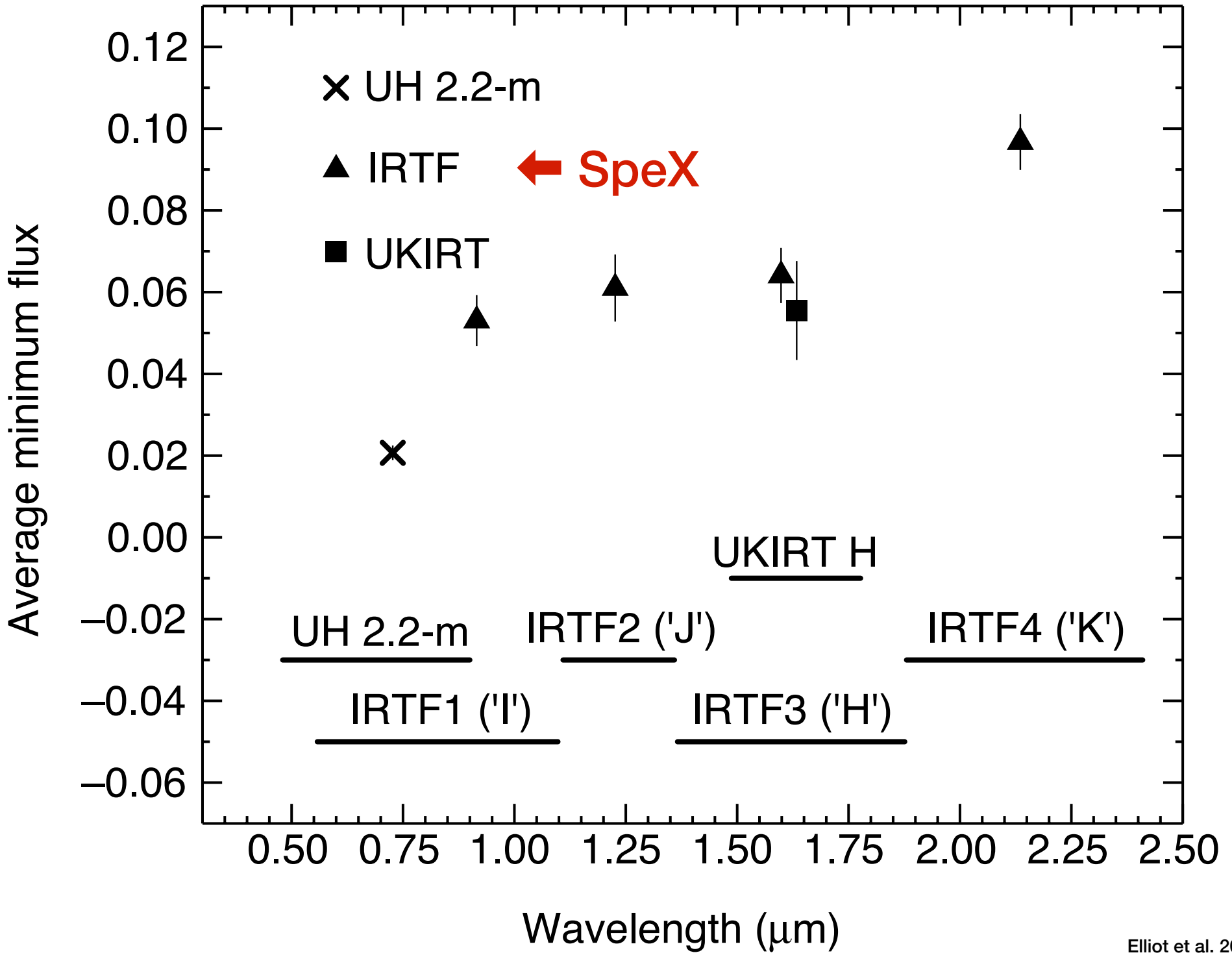
# Applications


Comparison star
P571
Pluto
Charon
Comparison star
N
E
0
2000
4000
6000
8000
10000
12000
14000
16000
18000

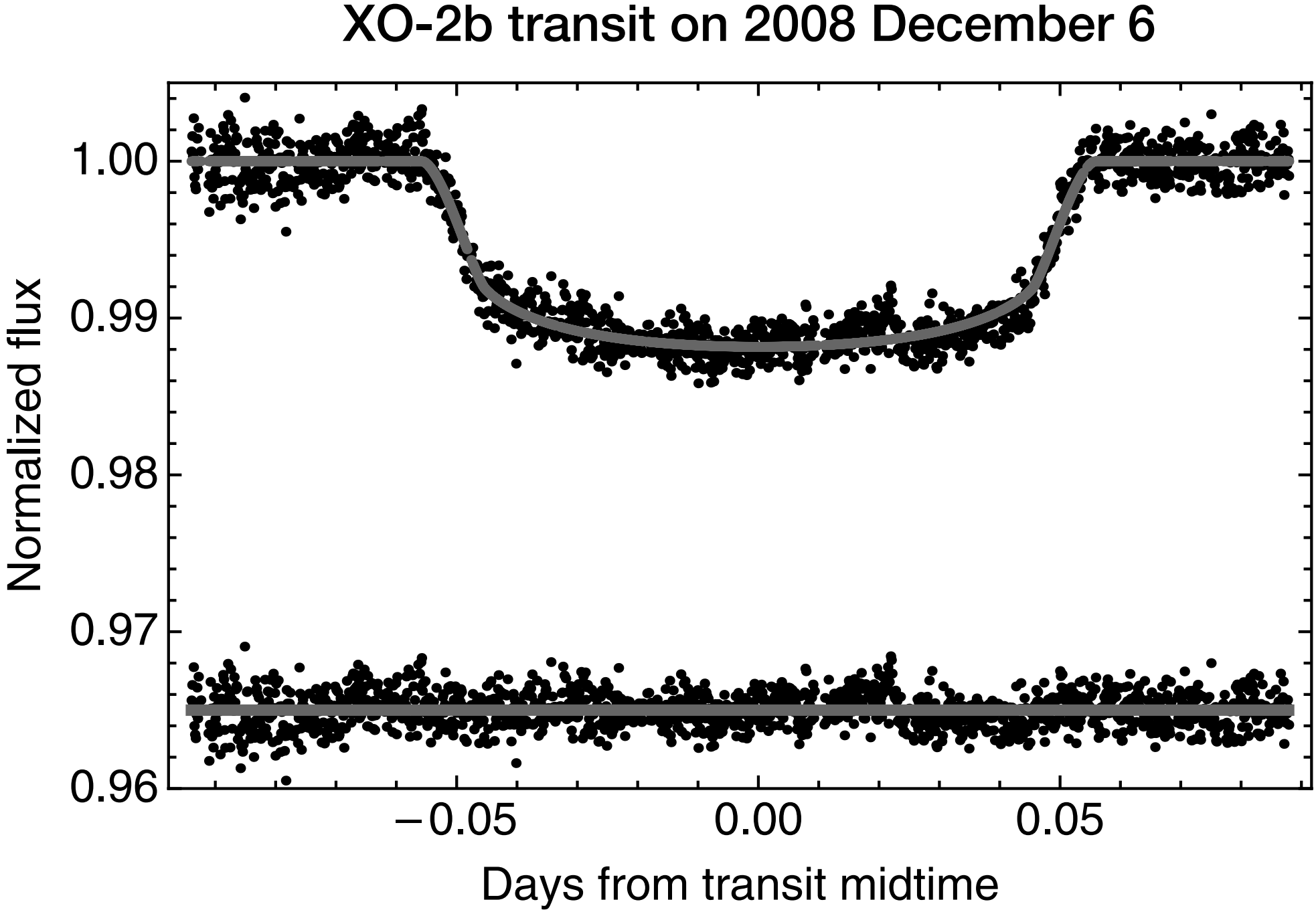
# Pluto occultation




Gulbis et al., 2011

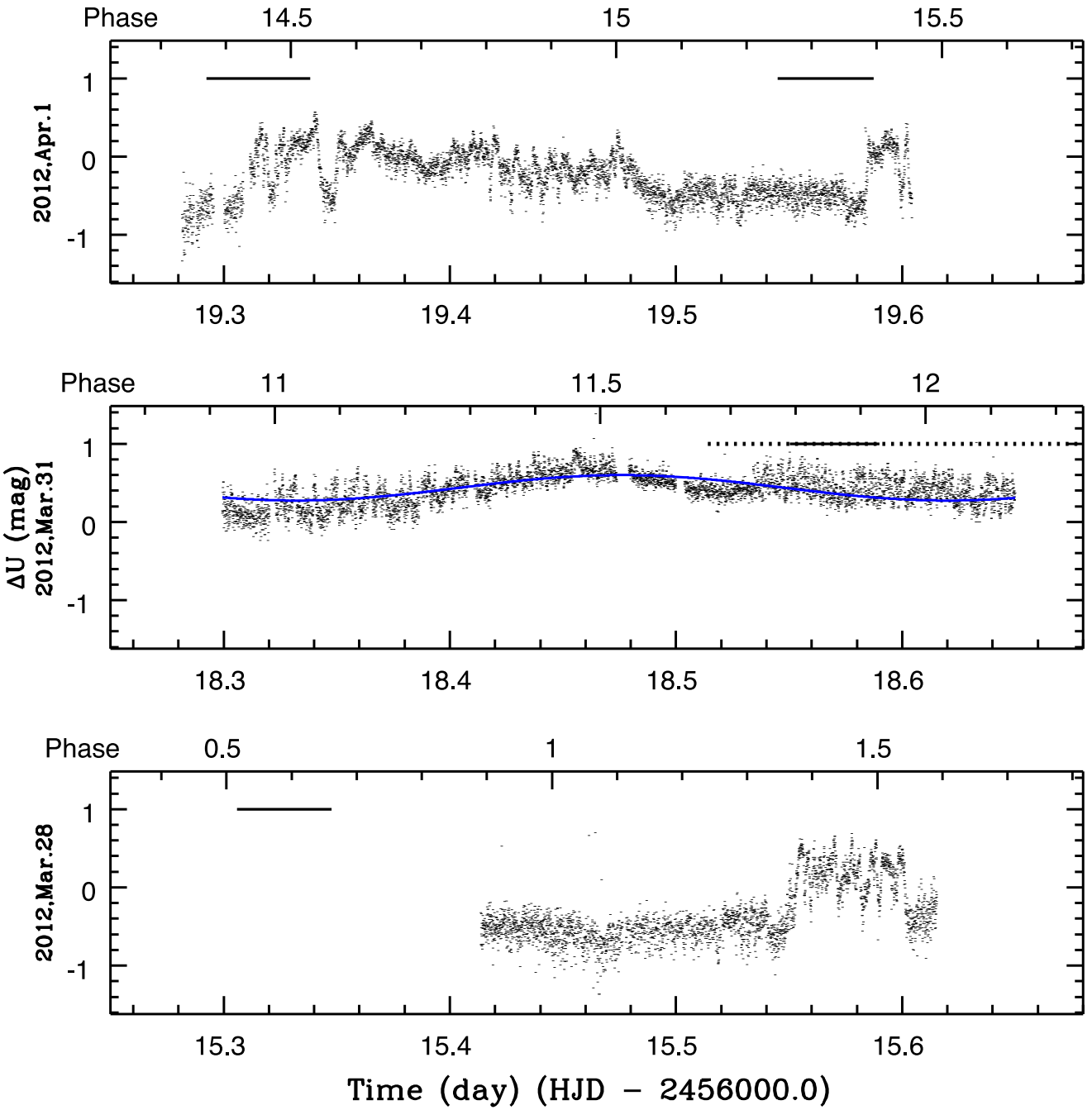



Elliot et al. 2003


XO-2b transit on 2008 December 6
Normalized flux
1.00
0.99
0.98
0.97
0.96
−0.05
0.00
0.05
Days from transit midtime
Gulbis et al. 2011


NASA IRTF - MIT Asteroid Rapid Response Program
Object: 2012 KT42
Distance:
6.87 Earth radii
29 May 2012
06:26:32 UT

# Low-mass x-ray binary XSS J1227.0-4859 with SHOC at SAAO




de Martino et al. 2014

# ADS search for MORIS

- Solar system occultations
  - Gulbis et al. 2011 (Pluto), Gulbis et al. 2012 (Pluto), Gulbis et al. 2014 (Chiron), Gulbis et al. 2015 (Charon), Ruprecht et al. 2015 (Chiron), D'Aversa et al. 2017 (Ganymede)
- Exoplanet transits
  - Gulbis et al. 2011, Jones et al. 2012, Schlawin et al. 2014
- Comets
  - Fernandez et al. 2014
- KBOs
  - Holler et al. 2016
- NEOs
  - Polishook et al. 2012

# Future Directions in High Time Resolution

# Future Directions in High Time Resolution

FOV

SNR

R

# Future Directions in High Time Resolution

FOV

60”

# Future Directions in High Time Resolution

FOV

60”➜600”?
on-chip comps

# Future Directions in High Time Resolution

FOV

60”➜600”?
on-chip comps

| | ANDOR ULTRA 897 | ANDOR ULTRA 888 |
|---|---|---|
| FORMAT | 512x512 | 1024x1024 |
| PIXEL SIZE | 16 micron | 13 micron |
| LINEAR FOV | 60” | 97” |
| WELL DEPTH | 180,000 e | 80,000 e |

# Future Directions in High Time Resolution

FOV

60”➜600”?
on-chip comps

SpeX:
60” field stop
at side port

| | ANDOR ULTRA 897 | ANDOR ULTRA 888 |
|---|---|---|
| FORMAT | 512x512 | 1024x1024 |
| PIXEL SIZE | 16 micron | 13 micron |
| LINEAR FOV | 60” | 97” |
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60”➜600”?
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dichroic earlier
in the beam
(Robo-AO?)

# Future Directions in High Time Resolution

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dichroic earlier
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(Robo-AO?)

small telescope
piggybacking
on IRTF

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~~on IRTF~~

SNR

fainter occ stars
smaller exoplanets
fainter host stars
smaller NEOs
smaller KBOs

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FOV

60”➜600”?
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~~small telescope~~
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SNR

fainter
smaller
more!

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EM mode

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60”➜600”?
on-chip comps

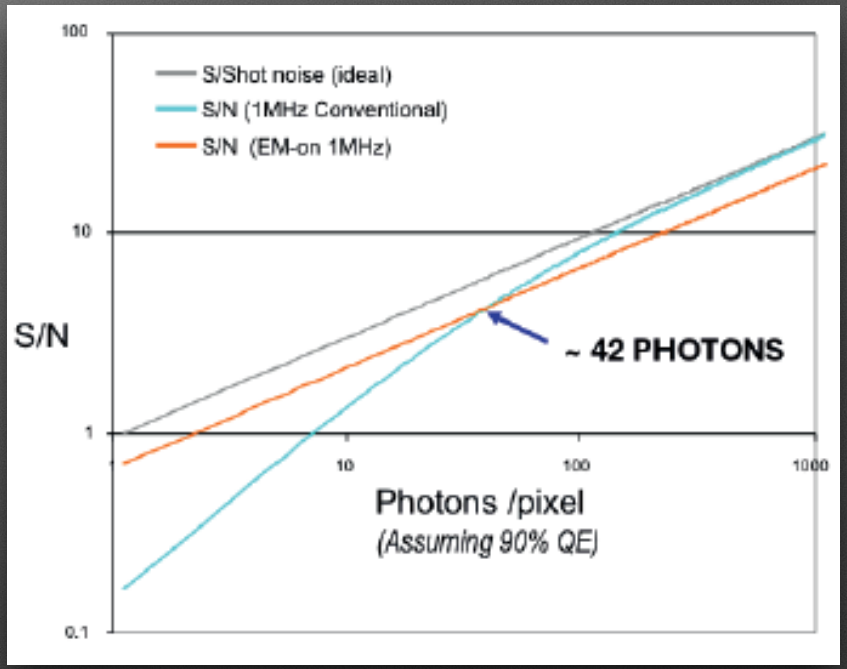
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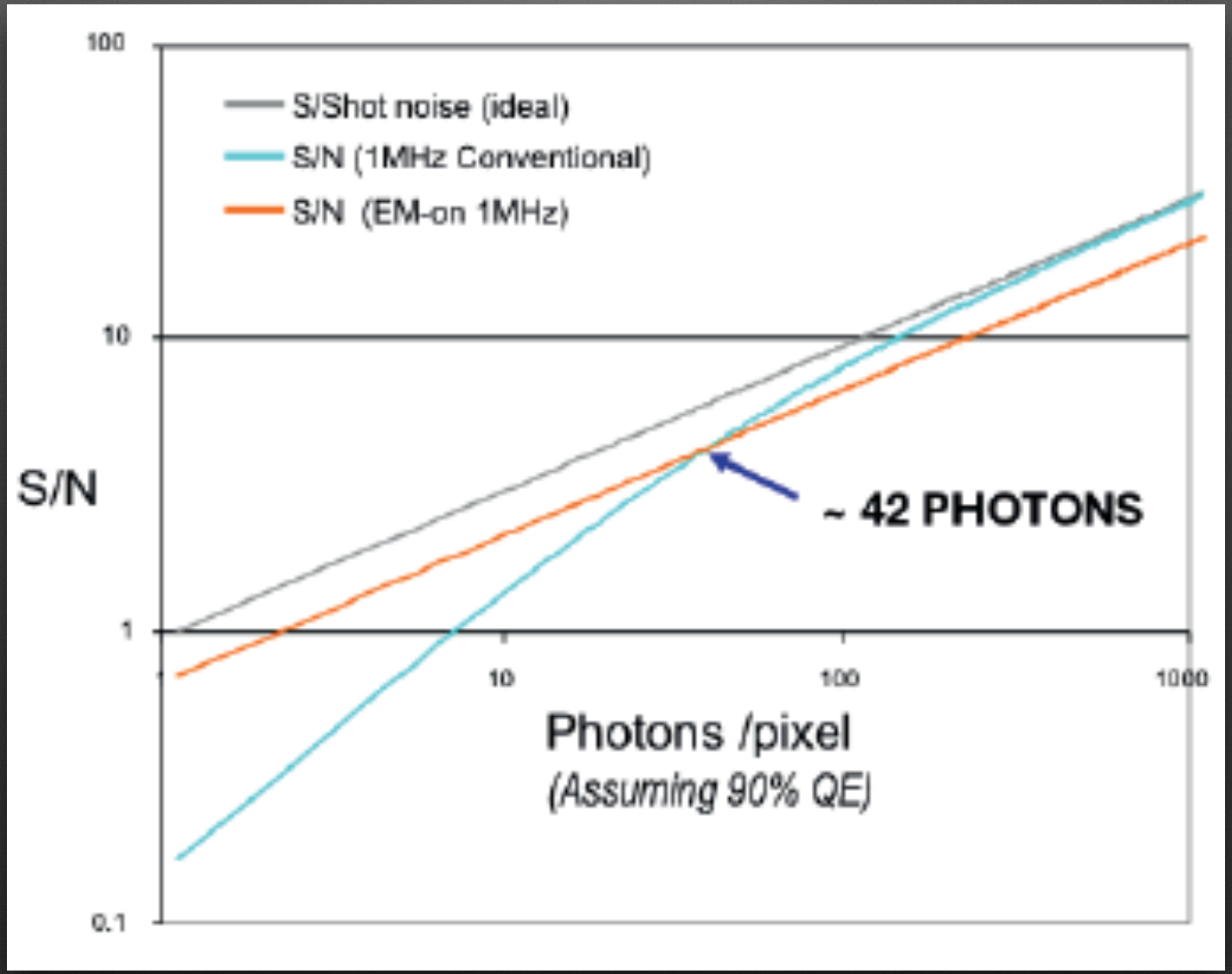
SNR

fainter
smaller
more!

EM mode



# Conventional vs. Electron-Multiplying Modes




andor.com

# Future Directions in High Time Resolution

| FOV | SNR |
| --- | --- |
| 60”➜600”? | fainter |
| on-chip comps | smaller |
| | more! |
| dichroic earlier | |
| in the beam | EM mode |
| (Robo-AO?) | |
| ~~small telescope~~ | |
| ~~piggybacking~~ | AO |
| ~~on IRTF~~ | |

# Future Directions in High Time Resolution

| FOV | SNR | R |
| --- | --- | --- |
| 60”➜600”? | fainter | |
| on-chip comps | smaller | |
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# Future Directions in High Time Resolution

| FOV | SNR | R |
| --- | --- | --- |
| 60”➜600”? on-chip comps | fainter smaller more! | composition particle sizes stellar parameters |
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| FOV | SNR | R |
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| 60”➜600”? on-chip comps | fainter smaller more! | composition particle sizes stellar parameters |
| dichroic earlier in the beam (Robo-AO?) | EM mode | low-res optical spectra |
| ~~small telescope piggybacking on IRTF~~ | AO | |

# Future Directions in High Time Resolution

| FOV | SNR | R |
| --- | --- | --- |
| 60”➜600”? on-chip comps | fainter smaller more! | composition particle sizes stellar parameters |
| dichroic earlier in the beam (Robo-AO?) | EM mode | low-res optical spectra |
| ~~small telescope piggybacking on IRTF~~ | AO | dual channels in the optical |