ERIS: a workhorse diffraction limited imager & spectrograph

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on behalf of the ERIS consortium in
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- fundamental AO capability for the VLT
- broad science potential
- on-sky in 2020

ERIS capabilities

AO modes		
	i)	NGS AO
	ii)	LGS AO
	iii)	seeing enhancer (LGS AO without tip-tilt)
	iv)	seeing limited

Observing modes

1. SPIFFI — Integral field spectroscopy
   FoV 0.8", 3.2", 8"; R~3000 & 8000; J-K bands

2. NIX — Imaging
   J-K narrow/broad bands; 13/27 mas pix (26"/55" FoV)
   L-M broad bands; 13 mas pix (26" FoV)

3. NIX — High contrast imaging
   Pupil plane coronagraph (L-M)
   Focal plan coronagraph (L-M)
   Sparse aperture Masking (J-M)

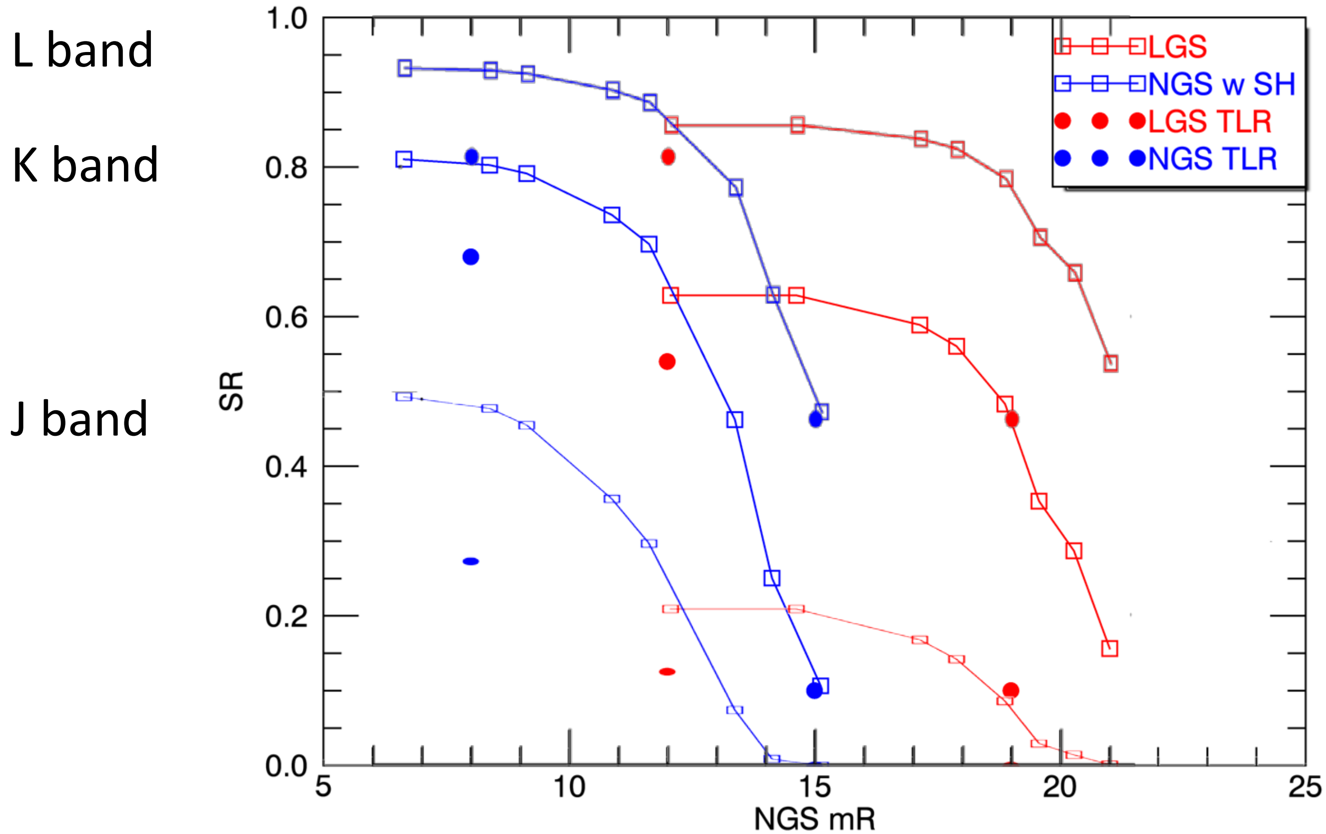
4. NIX — long slit spectroscopy — R=500, L & M band

ERIS design drivers

- Schedule is critical
  - Start of Science Operations in 2020, with 10-15year lifetime
  - Complementary to JWST; some aspects will surpass JWST
  - ERIS will bridge gap to start of E-ELT science operations (2025+)
- Achieving first light in 2020 requires
  - Familiar technology
  - Simple design
- Design choices
  - Avoid optical relay -> longer back focal distance from VLT
  - SCAO: LGS & optical NGS sensors (no IR tip/tilt sensor)

Adaptive Optics Performance

- Strehl ratios significantly better, and achievable to fainter magnitudes, than possible with NACO or SINFONI.
- Major potential at shorter wavelengths.
- Longer wavelengths & fainter magnitudes complementary to SPHERE.



Science Themes

- As a facility workhorse instrument, ERIS will address many science themes.
- Those highlighted by the Science Team include:

1. High Redshift Galaxy Evolution (N. Förster Schreiber)
   JHK Integral Field Spectroscopy

2. Direct Imaging of Exoplanets (S. Quanz & M. Kenworthy)
   Coronography, Sparse Aperture Masking, LM Spectroscopy

3. Galactic Center (S. Gillessen)
   Astrometric Imaging & HK Integral Field Spectroscopy

Galaxy Evolution at High Redshift

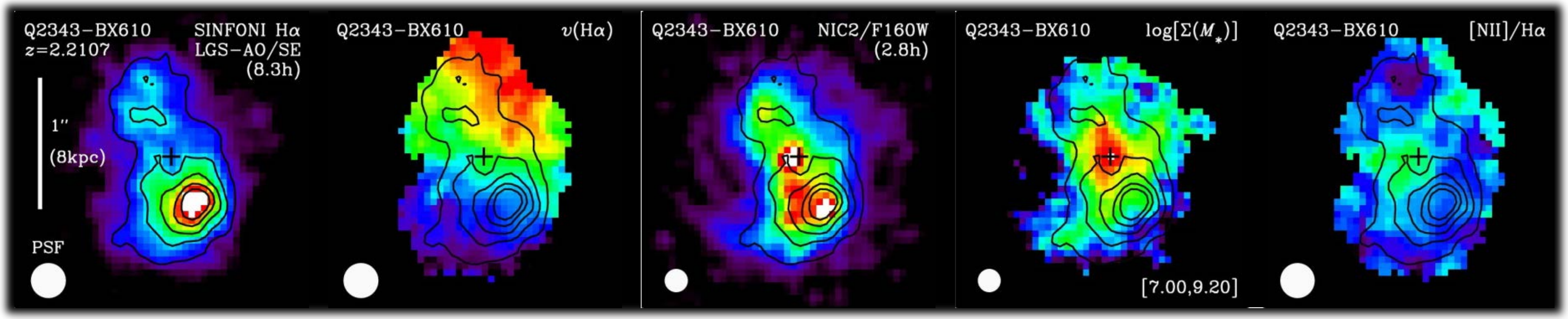
Signatures of physical processes driving mass assembly & structural transformations are on scales ≲ 1 kpc and a few 10s of km/s:

- Growth of bulges & disks
- Inflows in disks
- Imprint of clumps & (minor) mergers in kinematics
- Star formation (in clumps vs interclump)
- Feedback & quenching (outflows from star formation & AGN)

IFUs are the most efficient way to fully map galaxies.

- Spatial & spectral resolution are needed not only to resolve structural/kinematic components, but to resolve them *from each other.*

Star formation | Kinematics | Stellar light | Stellar mass | Nebular physics



Q2343-BX610 (z=2.21)

AO samples of high redshift galaxies

- Still very limited – about 120 galaxies at z ~ 1 – 3.5, a majority from SINFONI
- Most target galaxies at z ~ 2 – where AO performs best & instruments are sensitive
- Covers a mixed bag of bright and/or high-sSFR and/or strongly lensed objects (except for a few efforts such as SINS/zC-SINF)

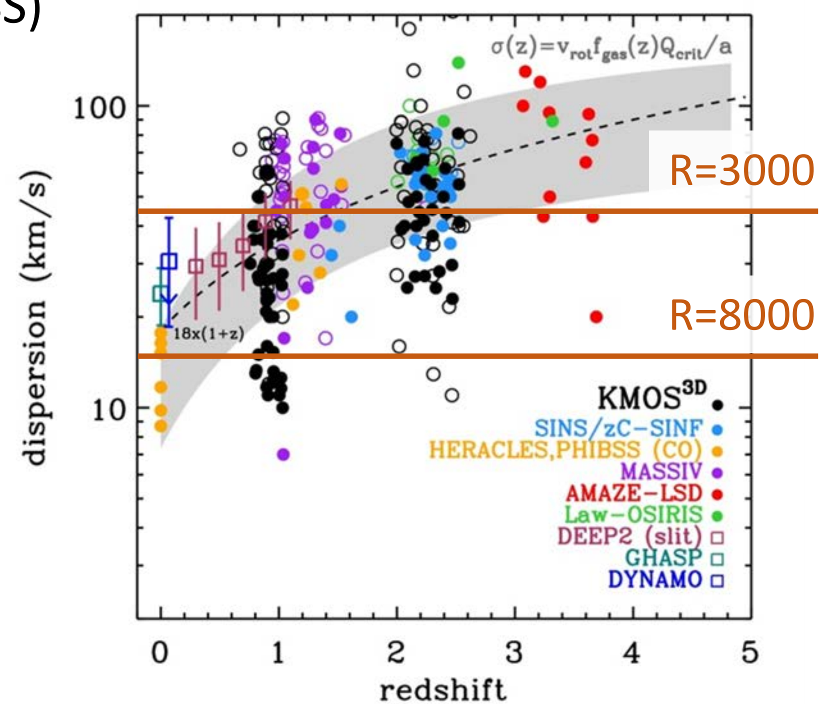
"census" instruments like KMOS yield 1000s with seeing limited data (>500 from each of KMOS^{3D} and KROSS)

ERIS is needed for detailed studies of KMOS samples at z = 1-2

- clumpy structures smaller than 1kpc
- σ_0 significantly lower than at z ~ 2
- inflow signatures: characterise higher order moments of emission lines

-> optimize also for J-band

-> R > 3000 spectroscopy



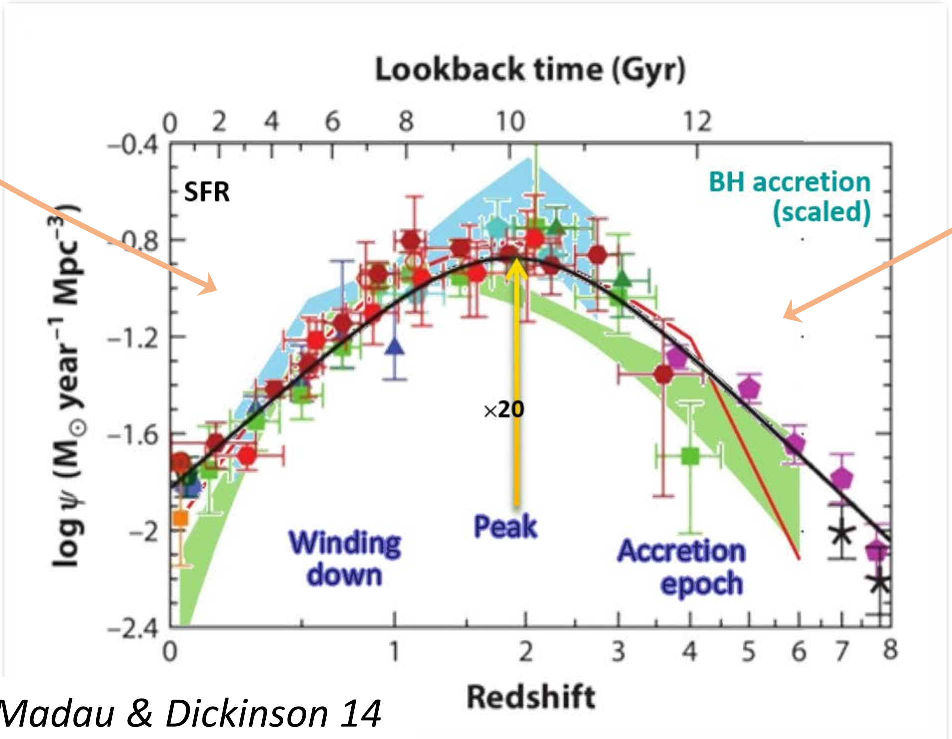
Wisnioski+ 15

Galaxy Evolution: ERIS and JWST

- No current/planned space-based instrumentation will provide the necessary *spectral* resolution for kinematic studies of galaxies

JWST: single IFU with R<3000
MOS for surveys of faint galaxies, multi-line diagnostics
-> detailed census of galaxy populations at high redshift

ERIS: AO performance & sensitivity in JHK bands, new R~8000 grating
-> physical mechanisms of galaxy evolution & star formation shutdown

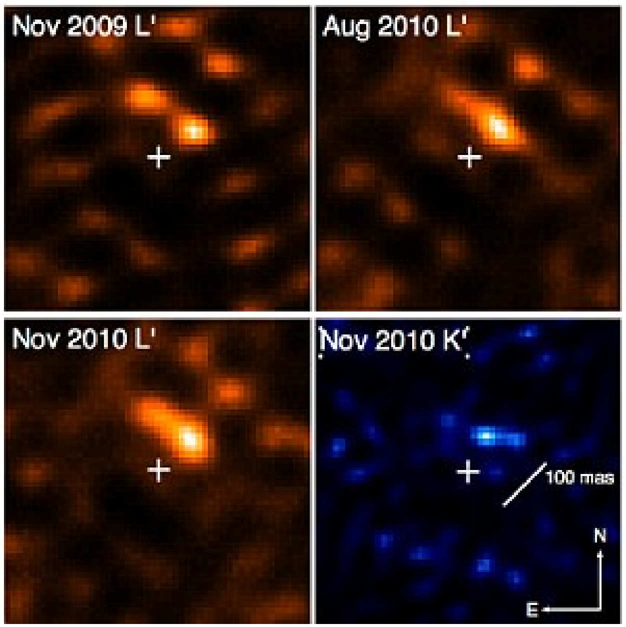


Madau & Dickinson 14

Detecting planets with high contrast L band imaging

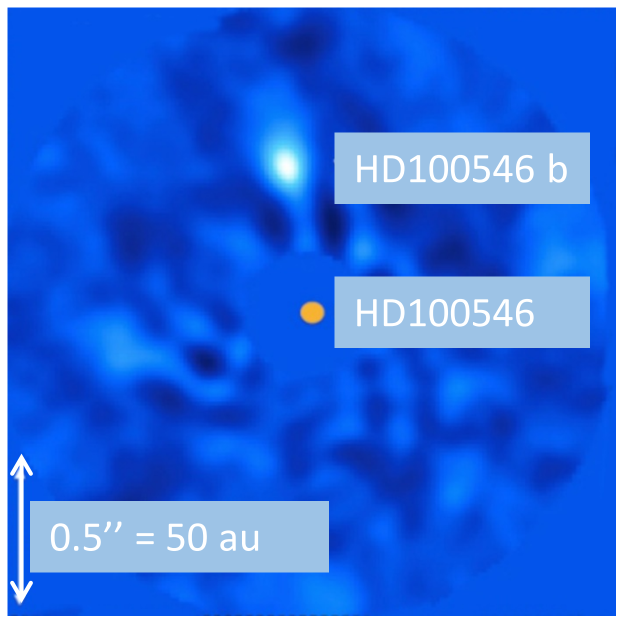
- Detection of cold (old or lower mass) planets more common in L band.
- Also young planets in circumstellar disks: warm circumplanetary material & high extinction mean L/M band highly competitive. These proto planets have not been seen at shorter wavelengths.

LkCa 15 b



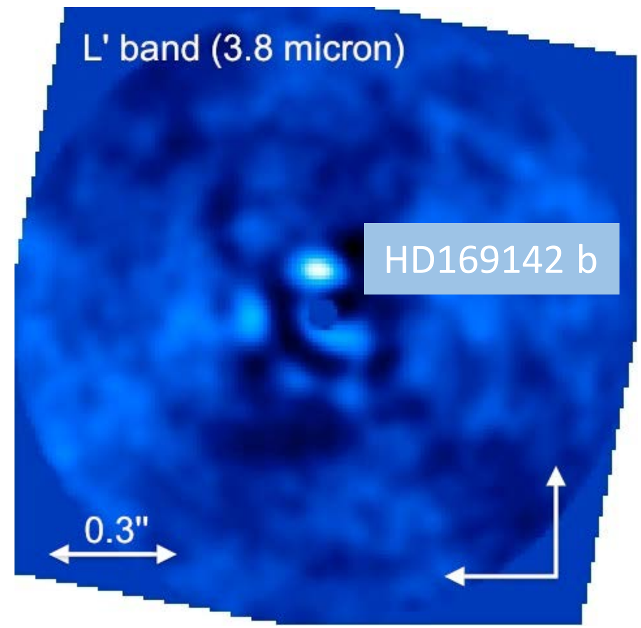
Keck SAM K & L band

HD100546 b



VLT/NACO L band APP,
VLT/NACO M band

HD169142 b



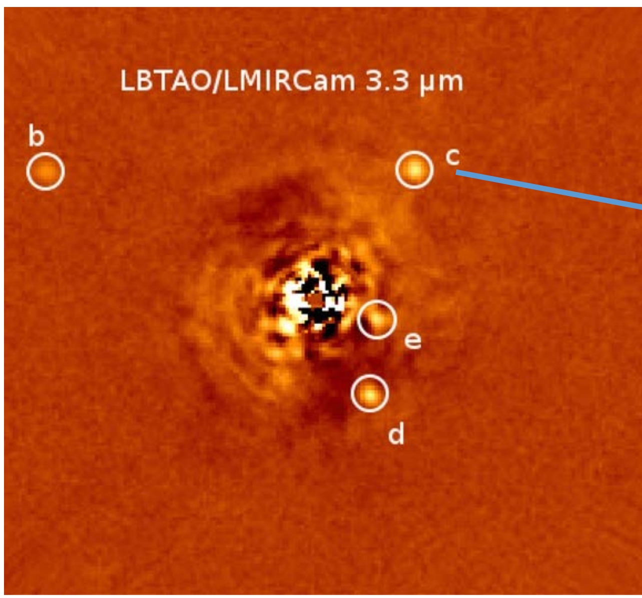
VLT/NACO L band AGPM

Kraus & Ireland 2012; Quanz et al. 2013,2015; Reggiani et al. 2014;
Biller et al. 2014; Currie et al. 2014

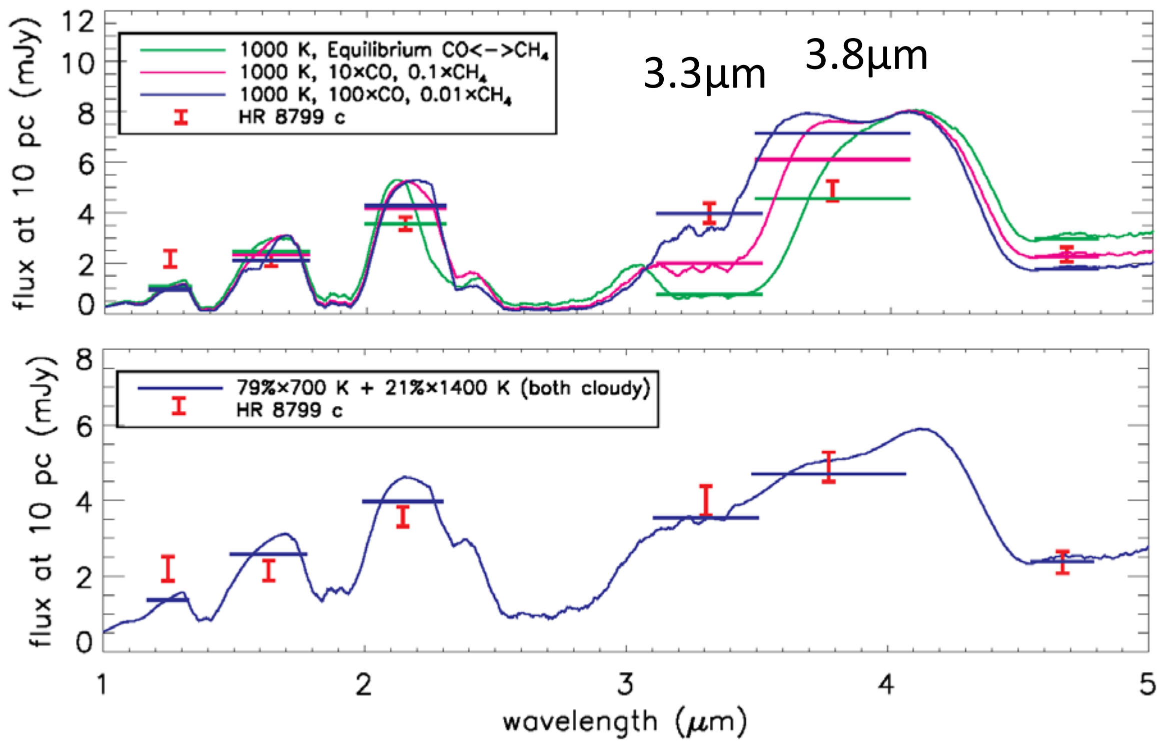
L and M band: unique probe of gas giant planet atmospheres

- ERIS follow-up of SPHERE/GPI NIR detections
- investigating clouds and non-equilibrium chemistry
- Combining SPHERE (JHK) & ERIS (LM) data vastly enhances scientific analysis

The HR8799 system



SPHERE **ERIS**

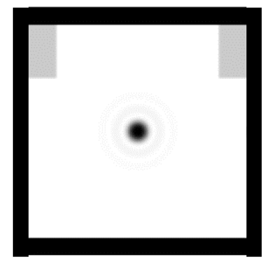


e.g., Skemer et al. 2012;
cf. Lee et al. 2014

Exploplanets: ERIS and JWST

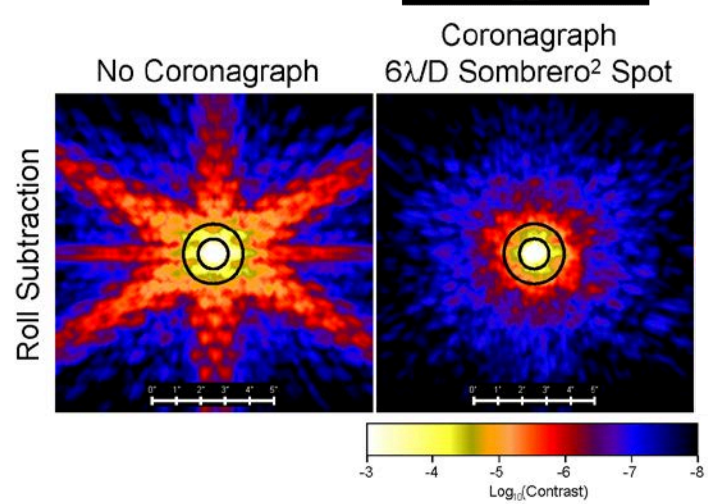
Contrast	vs	Sensitivity
Speckle noise		Background noise
ERIS is superior at radii <1”		JWST is superior for faint primaries

- NIRCam (JWST) will reach ~10mag at 0.5”
- NACO & LMIRCam (LBT) already achieve 12mag
- ERIS will do better



Coronagraph:
HWHM = 0.82”
6λ/D @ 4.3µm

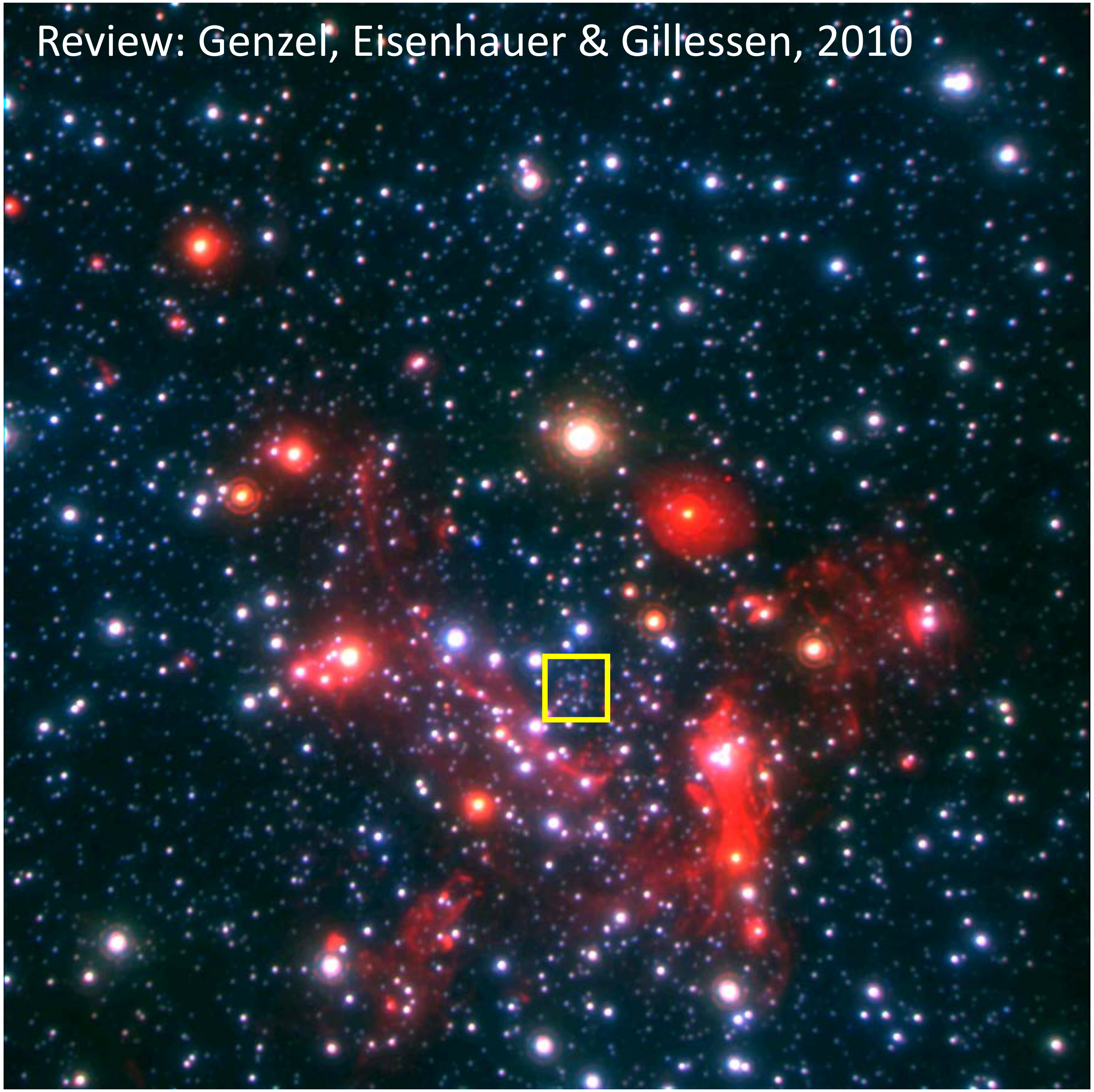
Lyot stop (with impact of segments)

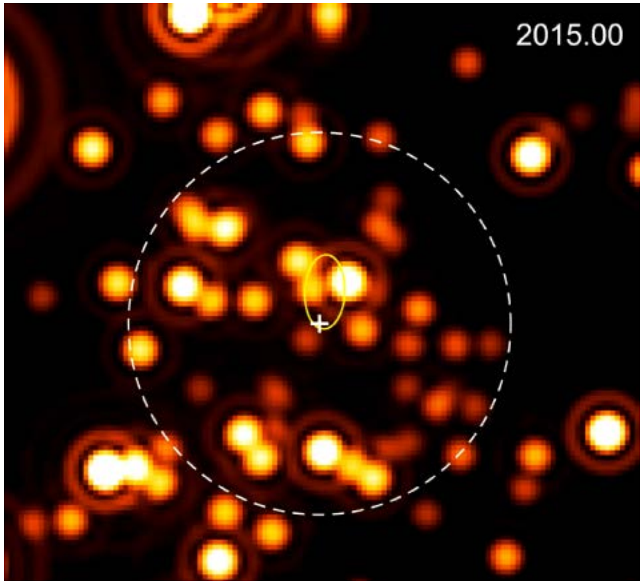


PSF @ 4.6µm
(circle radii 0.58, 1.17”)

Krist et al. 2007

The Galactic Center – a unique laboratory





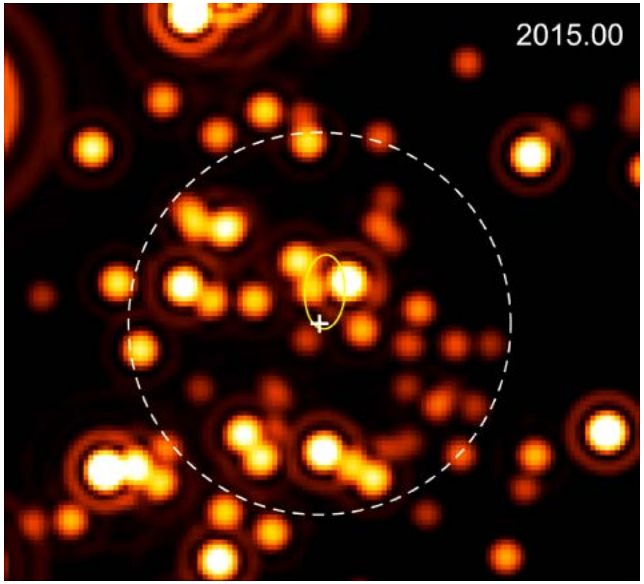
The Galactic Center showcase star: S2

VLT & Keck data suitably combined

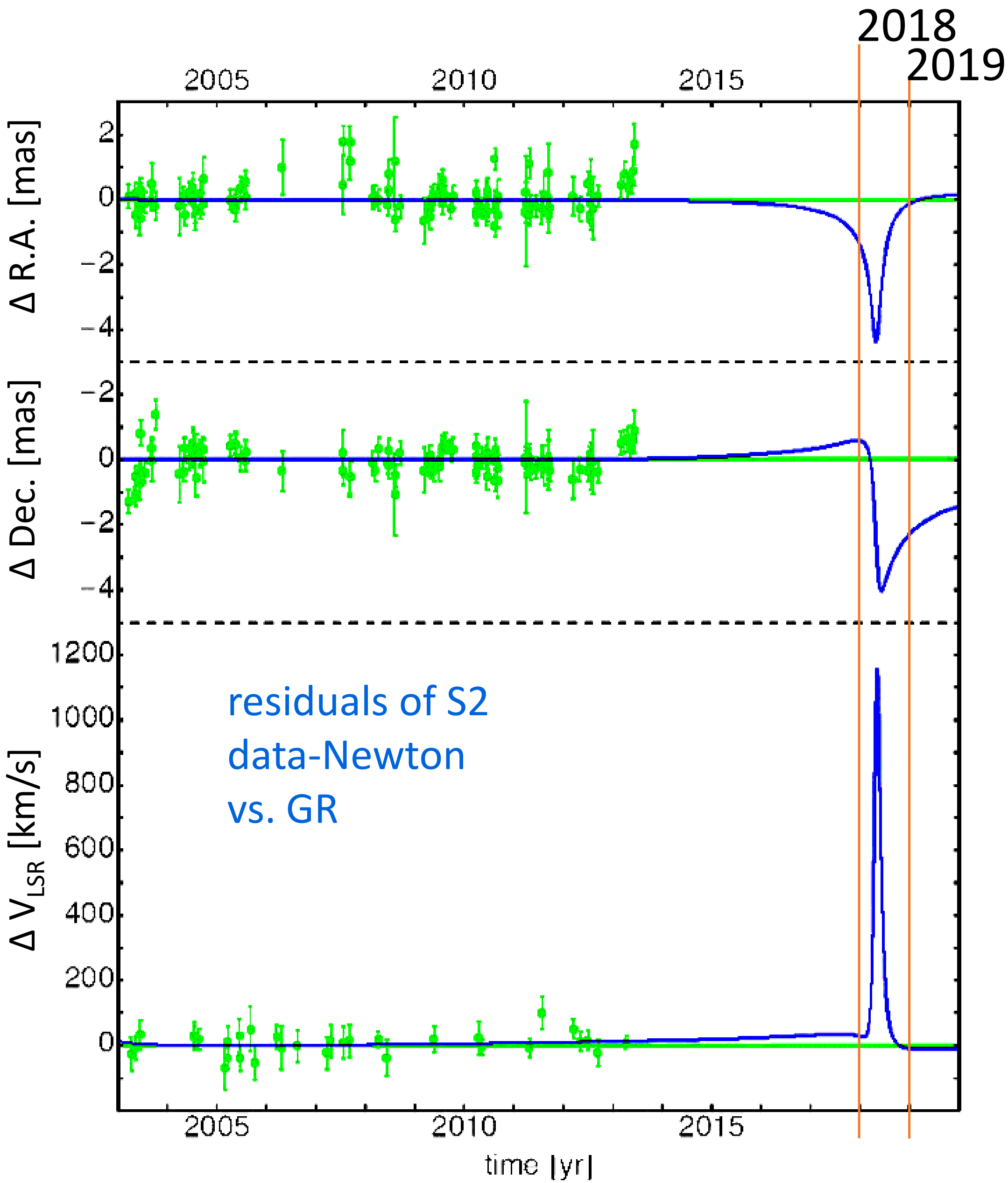
(Gillessen et al. 2009ab, Ghez et al. 2008, as well as newer data)

- period: 15.9 years
- semi major axis: 125 mas
- eccentricity 0.88

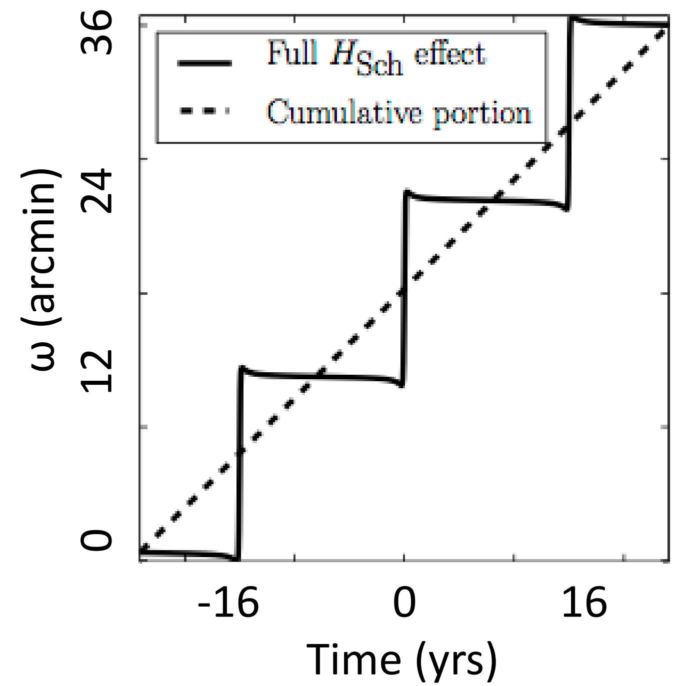
- $M = 4.30 \pm 0.06 \pm 0.35 \times 10^6\ M_{\square}$
- $R_0 = 8.28 \pm 0.15 \pm 0.30$ kpc



Precession is detectable with AO on VLT

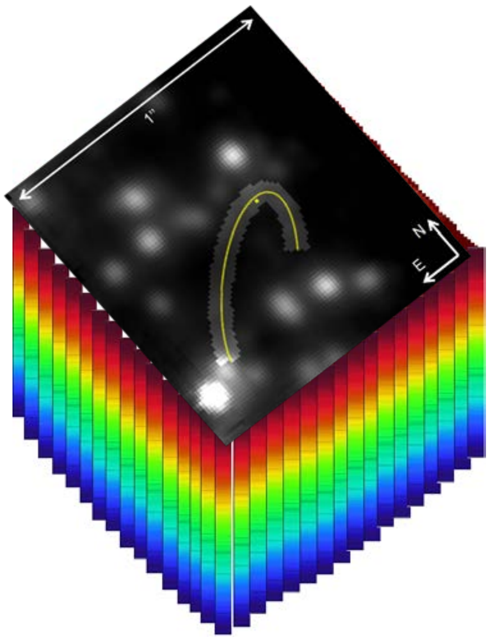


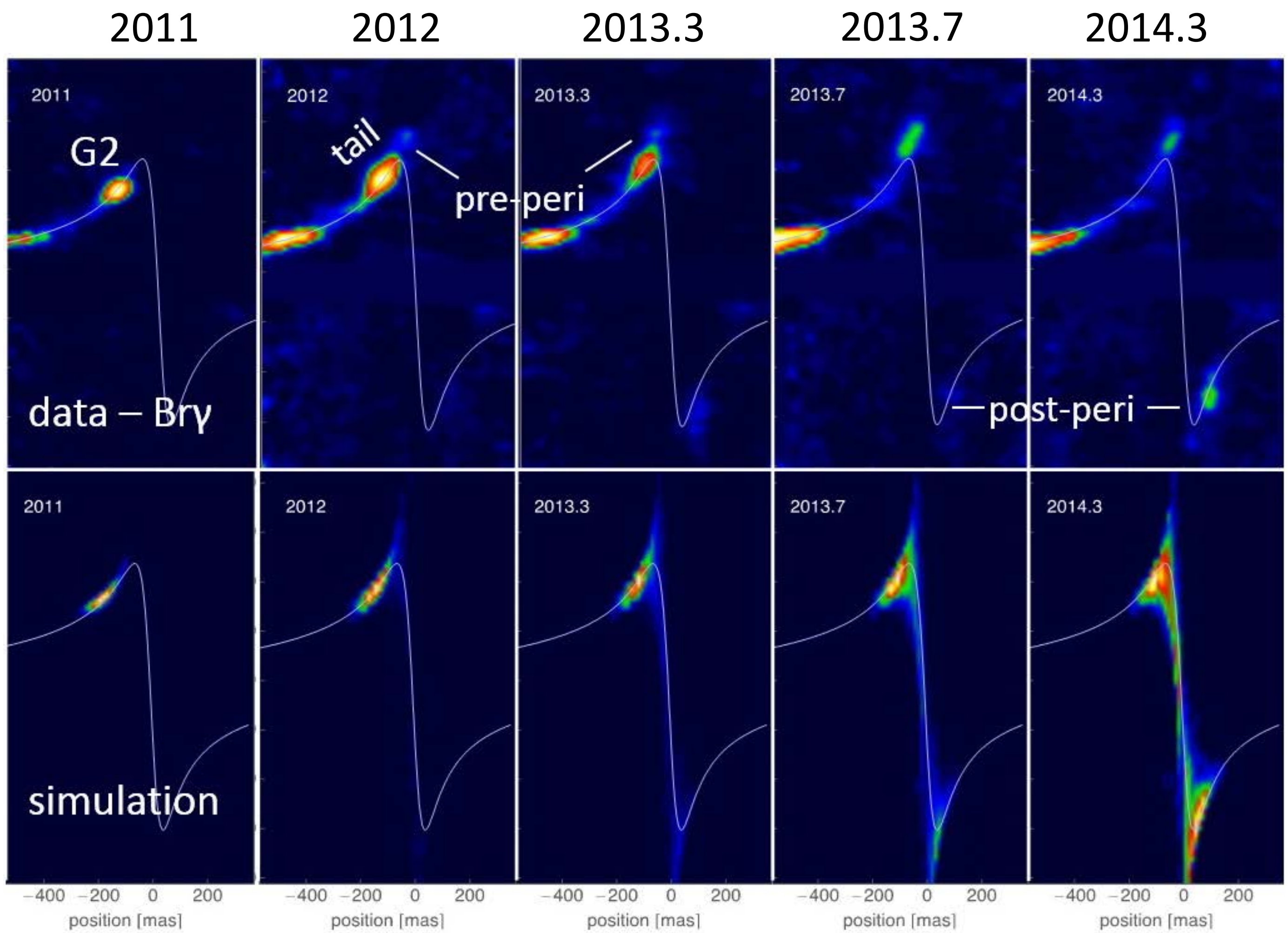
$$\text{S2:} \quad \Delta\Phi_s = \frac{3\pi}{1-e^2}\left(\frac{R_S}{a}\right) \sim 12'$$



A gas cloud on its way to Sgr A*

- Tidal disruption unfolding in front of SINFONI
- Evolution (traced back to 2006) qualitatively well described by test particles





Summary of key points

- ERIS will replace & enhance NACO & SINFONI as a fundamental AO capability from 2020 to beyond 2030.
- Broad science potential, both complementary to & competitive with JWST
- Science themes include
  - Galaxy evolution at high redshift
  - Exoplanets (protoplanets, atmospheres, etc)
  - Astrometry in the Galactic Center