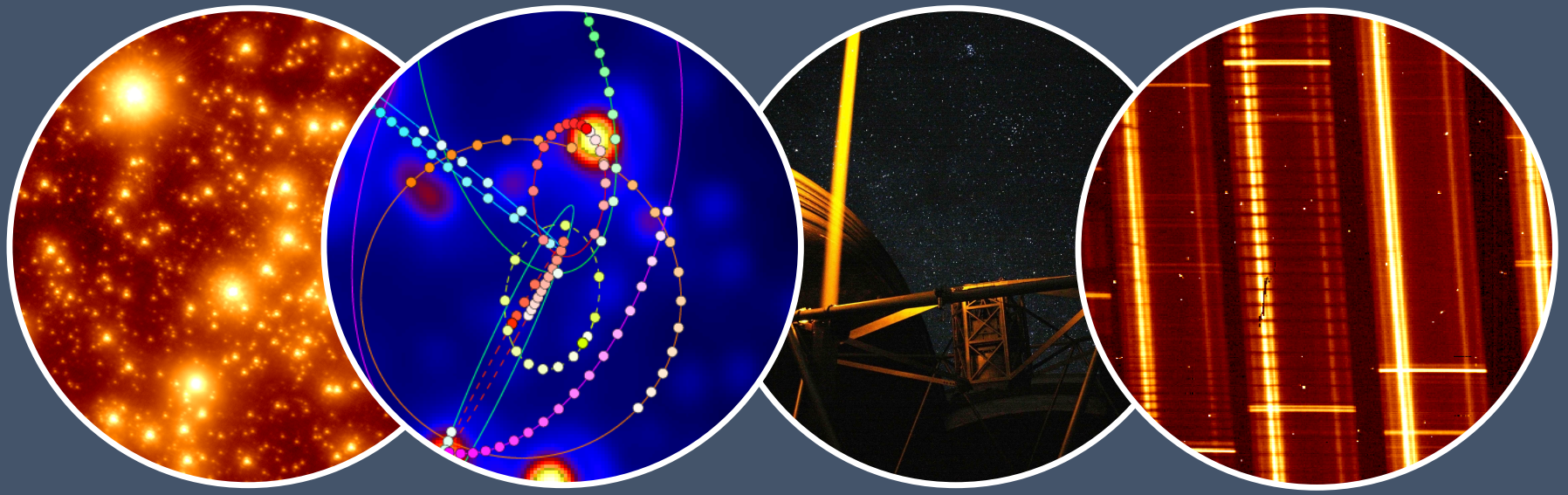


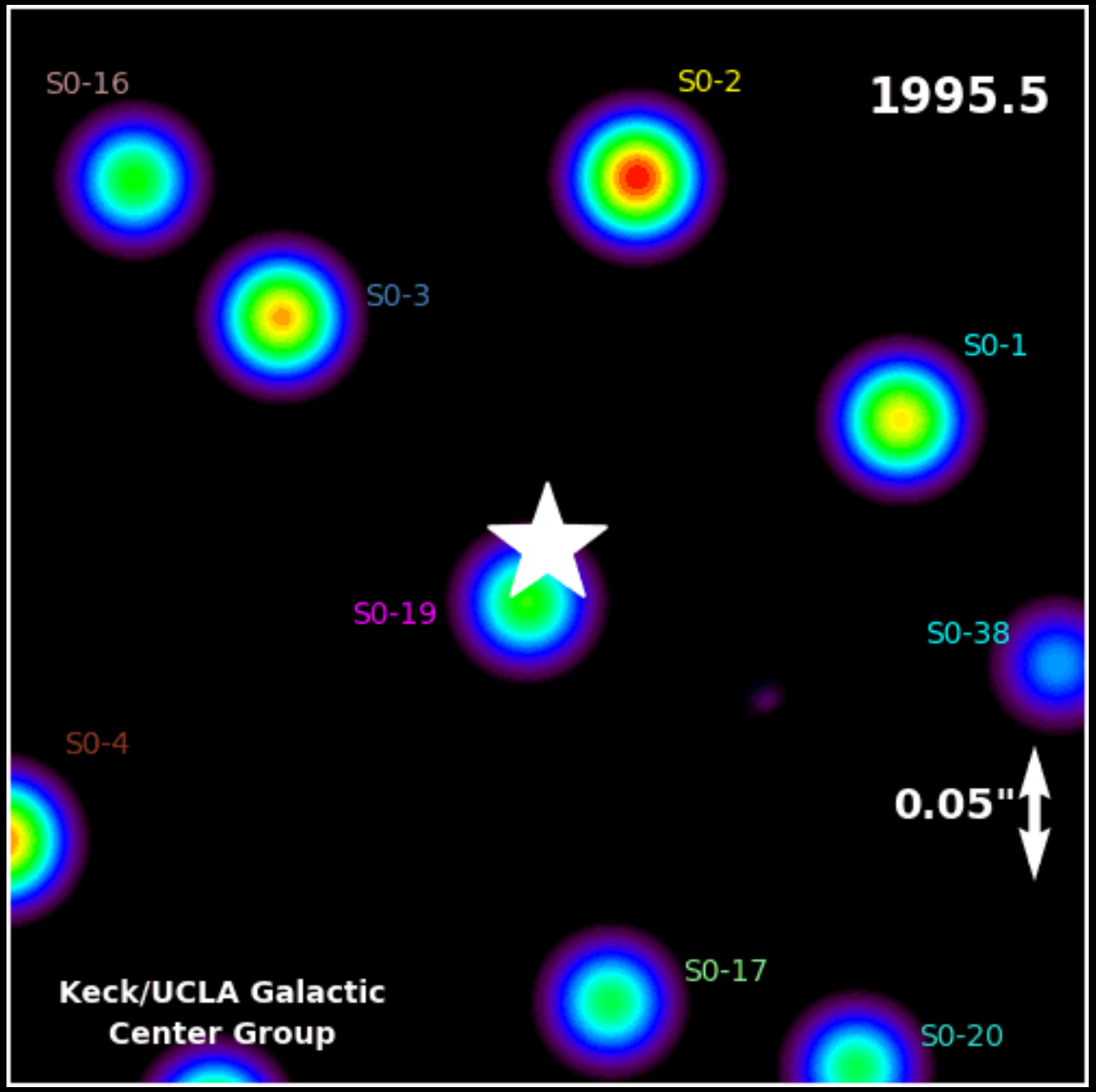
Measuring the effects of General Relativity at the Galactic Center with TMT

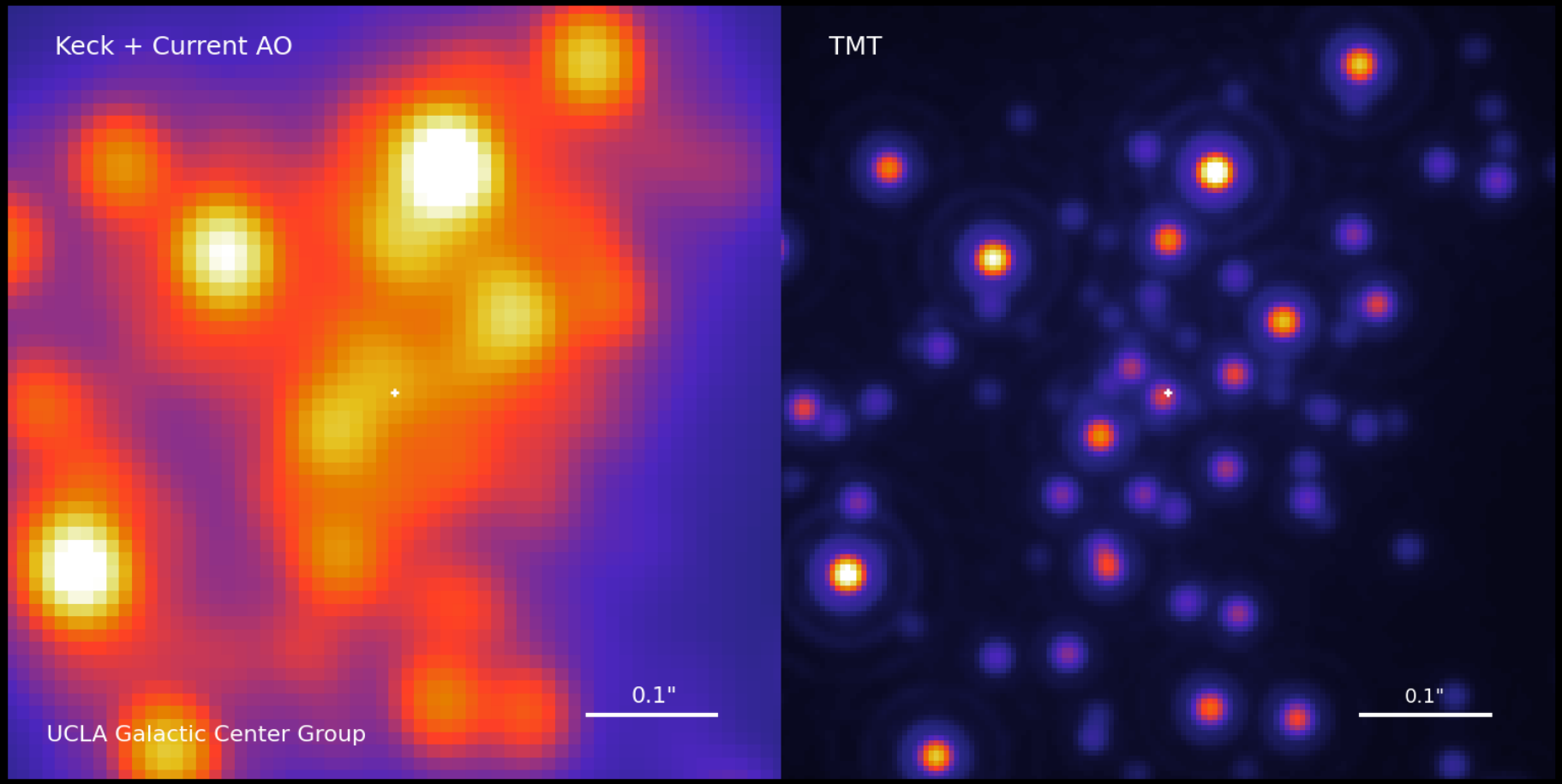
Tuan Do (UCLA)

Andrea Ghez, Jessica Lu, Sylvana Yelda, Gunther Witzel, Breann Sitarski, Mark Morris, Leo Meyer, Shelley Wright, Matthias Schoeck, TMT Astrometry Team, IRIS Instrument & Science Team, NIRFAOS Team

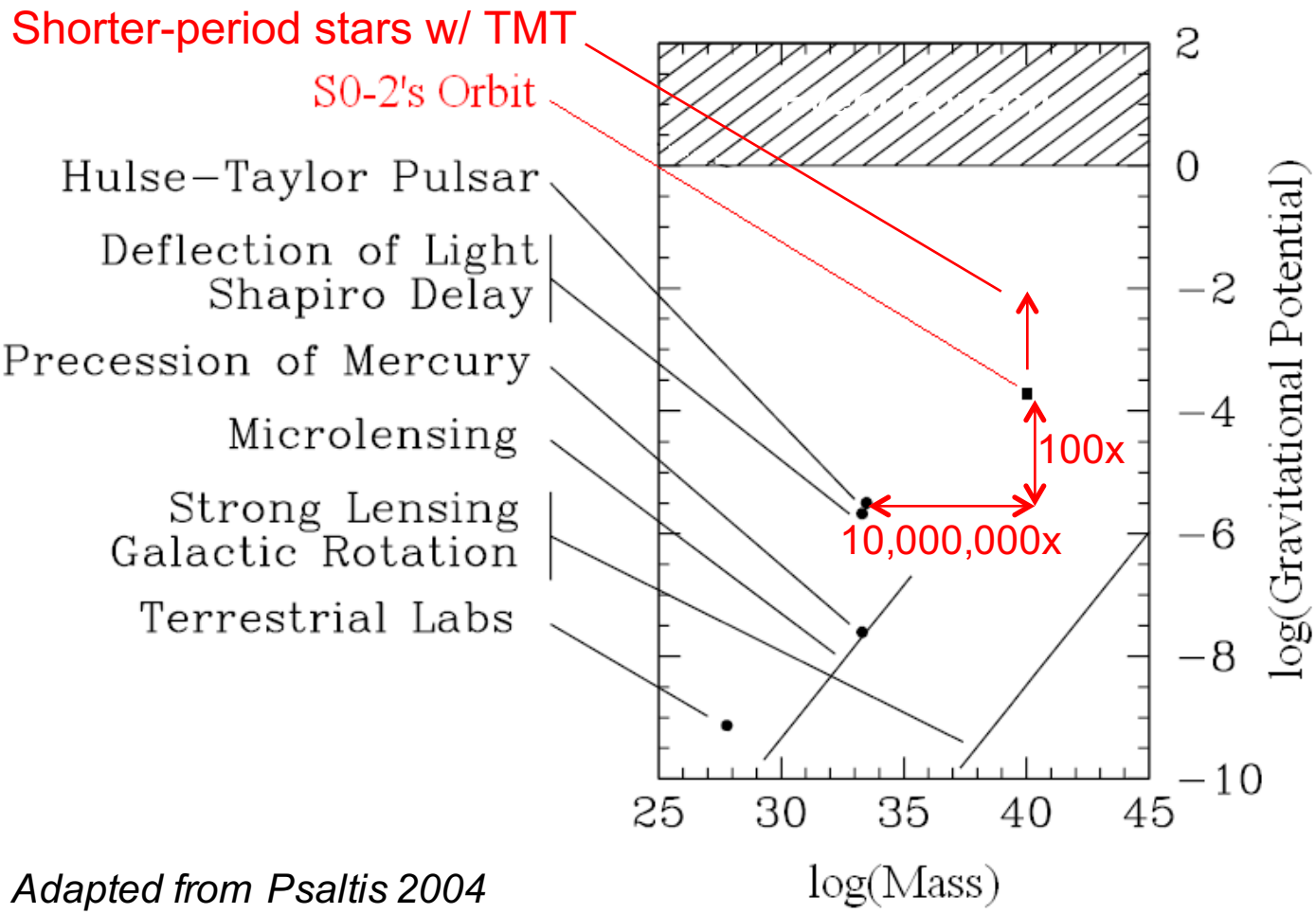
TMT Forum, June 2015


Jason Chu
Photography


S0-16
S0-2
1995.5
S0-3
S0-1
S0-19
S0-38
S0-4
0.05"
S0-17
Keck/UCLA Galactic
Center Group
S0-20

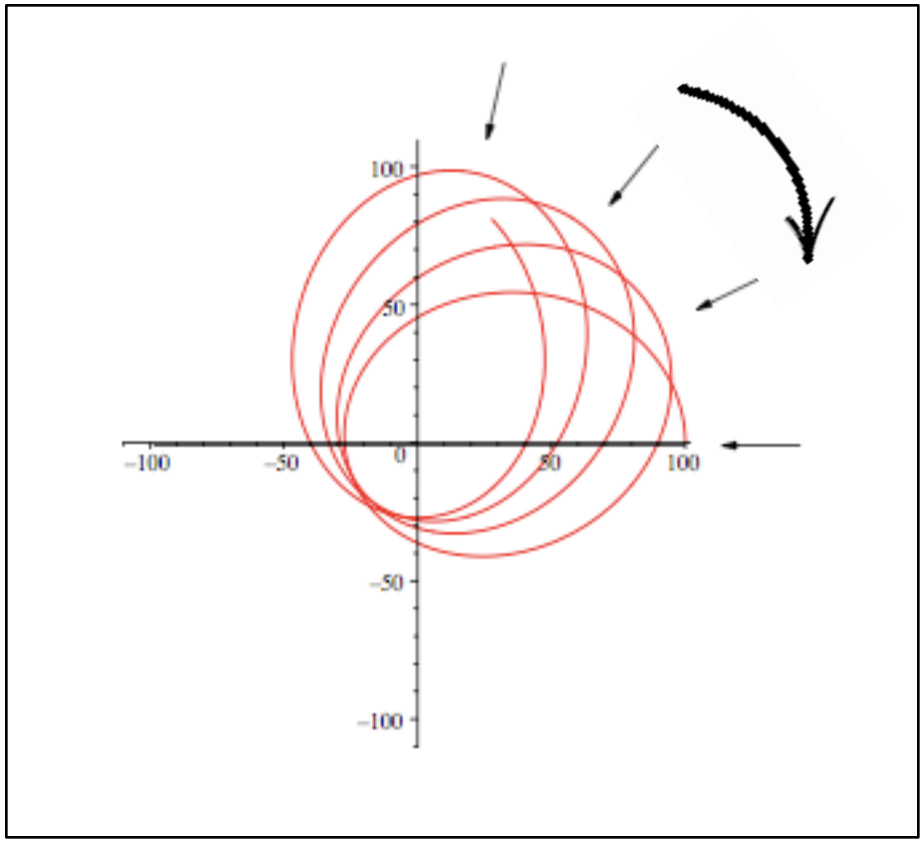

Keck + Current AO
0.1"
UCLA Galactic Center Group
TMT
0.1"

TMT will allow for tests of general relativity in an unexplored, strong-field regime.



Adapted from Psaltis 2004

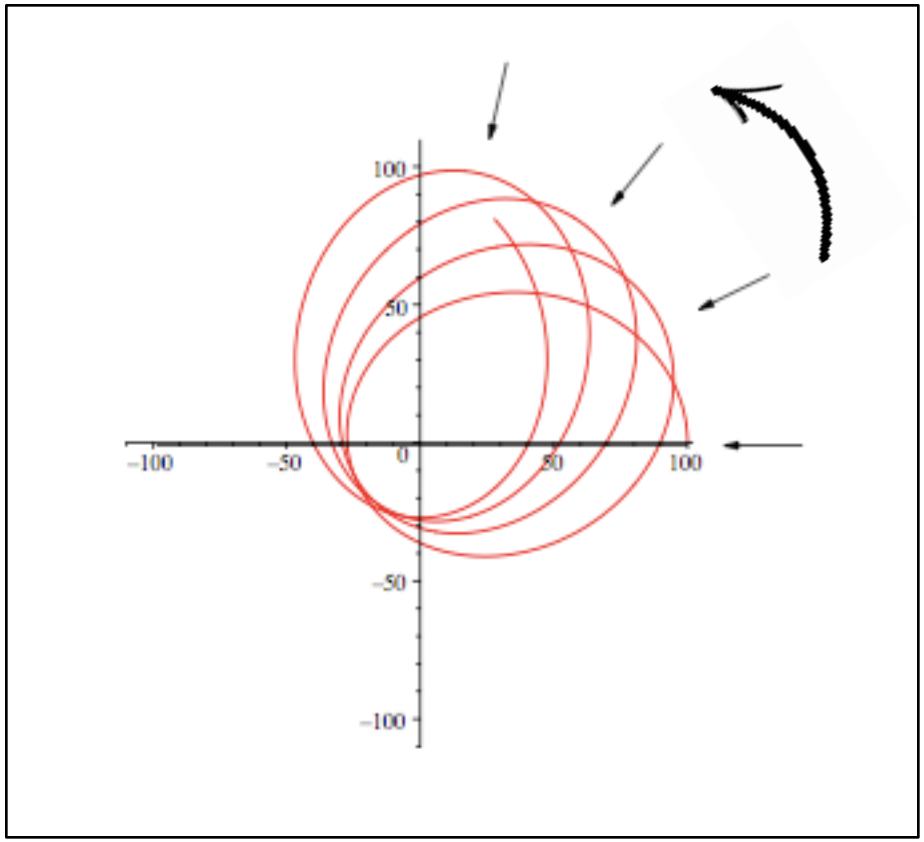
General relativistic precession is most apparent at furthest distance (apoapse)



- **General Relativity**
  - **Prograde precession**
    - $\Delta s \sim a(1-e)\Delta\phi$
      $= 6\pi GM/[c^2 (1-e)]$
    - $\Delta s = 0.8$ mas for S0-2
  - Current Limitations:
    - Source confusion
    - Reference frame

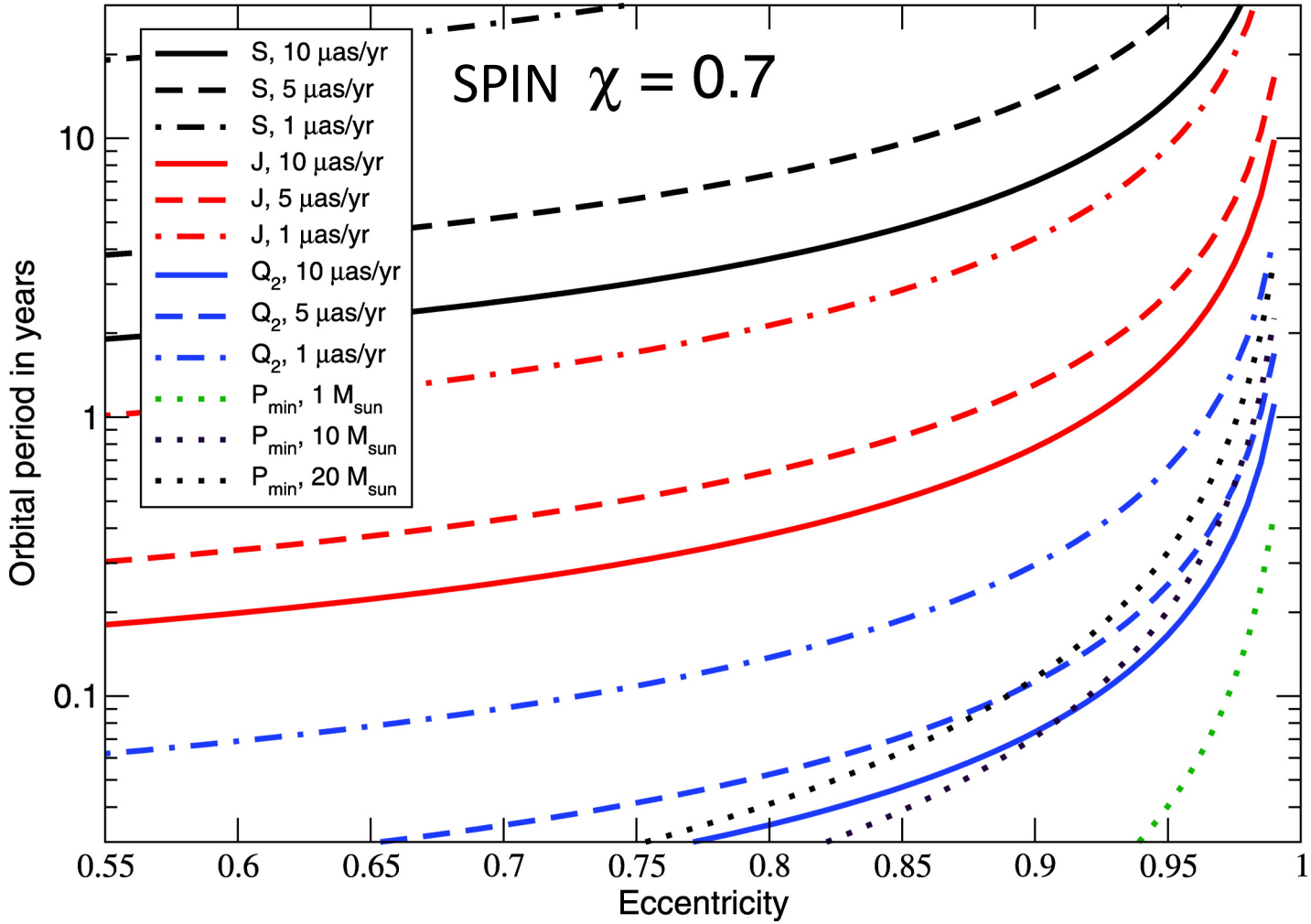
Munyaneza et al. 1998; Jaroszynski 1998; Fragile & Mathews (2000), Rubilar & Eckart 2001 (shown), Weinberg et al. 2005, Will 2008

Need more than one star to resolve possible degeneracy with extended mass precession

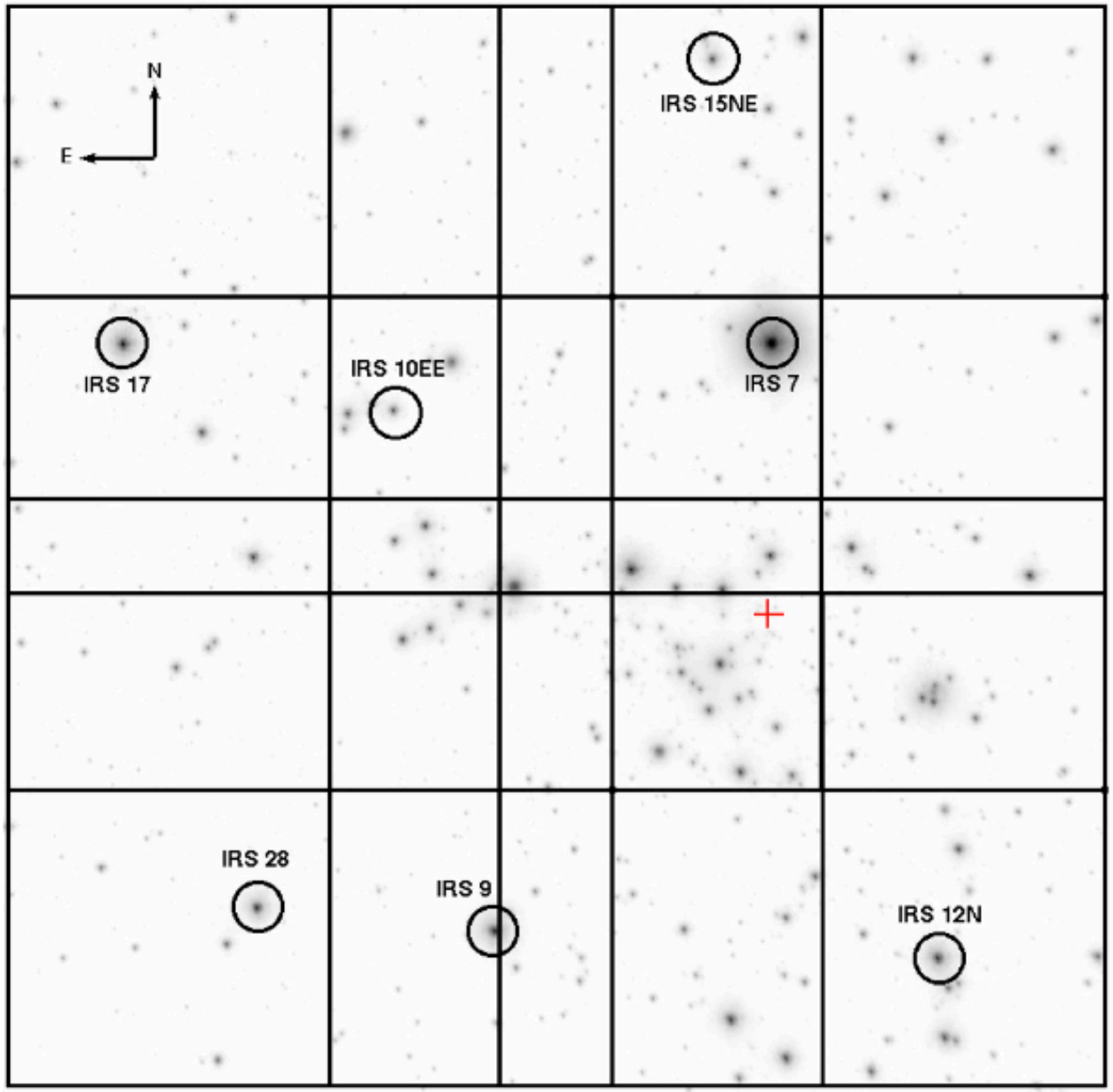


- **Extended mass**
  - **Retrograde precession**
  - *Expectation*
    - *~1/2 size of GR precession shift*
    - *Stellar remnants (~1000 M_o) (Morris 1993; Miralda-Escude & Gould 2000)*
    - *Cold dark matter particles (~1000 M_o) (Gondolo & Silk 1999; Ullio et al. 2001; Merritt et al. 2002; Gnedin & Primack 2004; Bertone & Merritt 2005)*

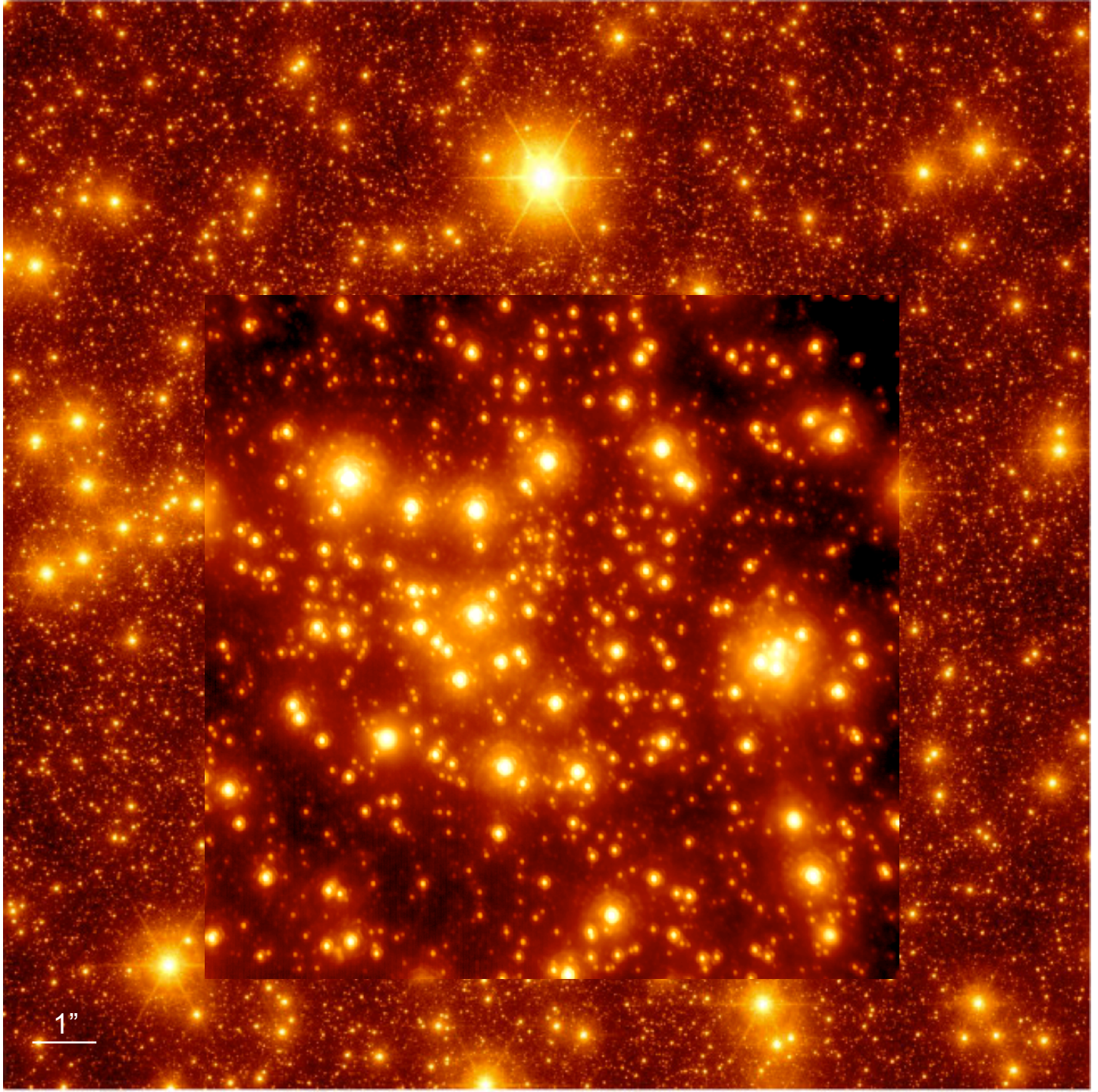
Testing the ‘no hair’ theorem will be possible



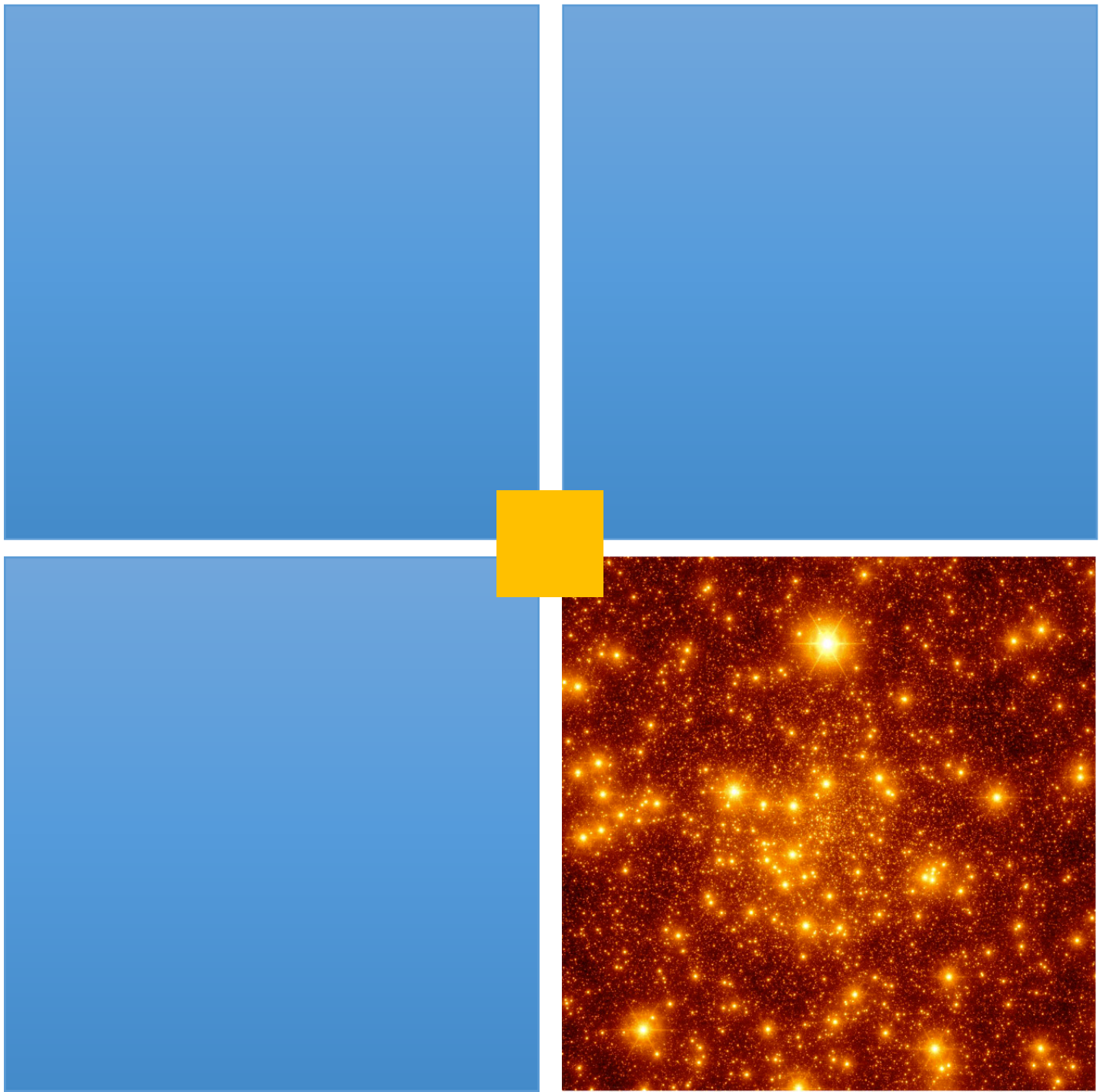
From Will et al. (2008)



Yelda et al. (2010)


1”

34”x34”
FOV



The astrometric error budget so far looks promising…

Focal plane measurement errors

Optical-mechanical errors

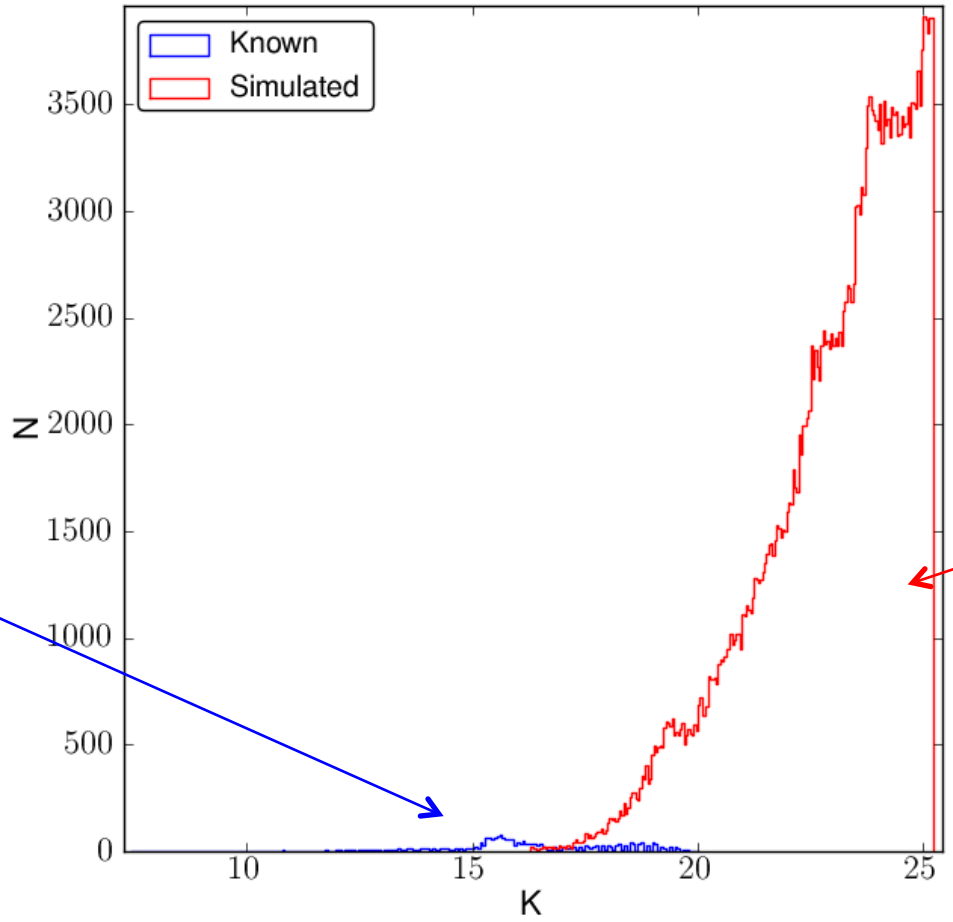
Atm. Refraction Errors

Residual Turbulence

Reference objects and catalog errors

From Shoeck et al.

What is the effect of confusion with TMT?

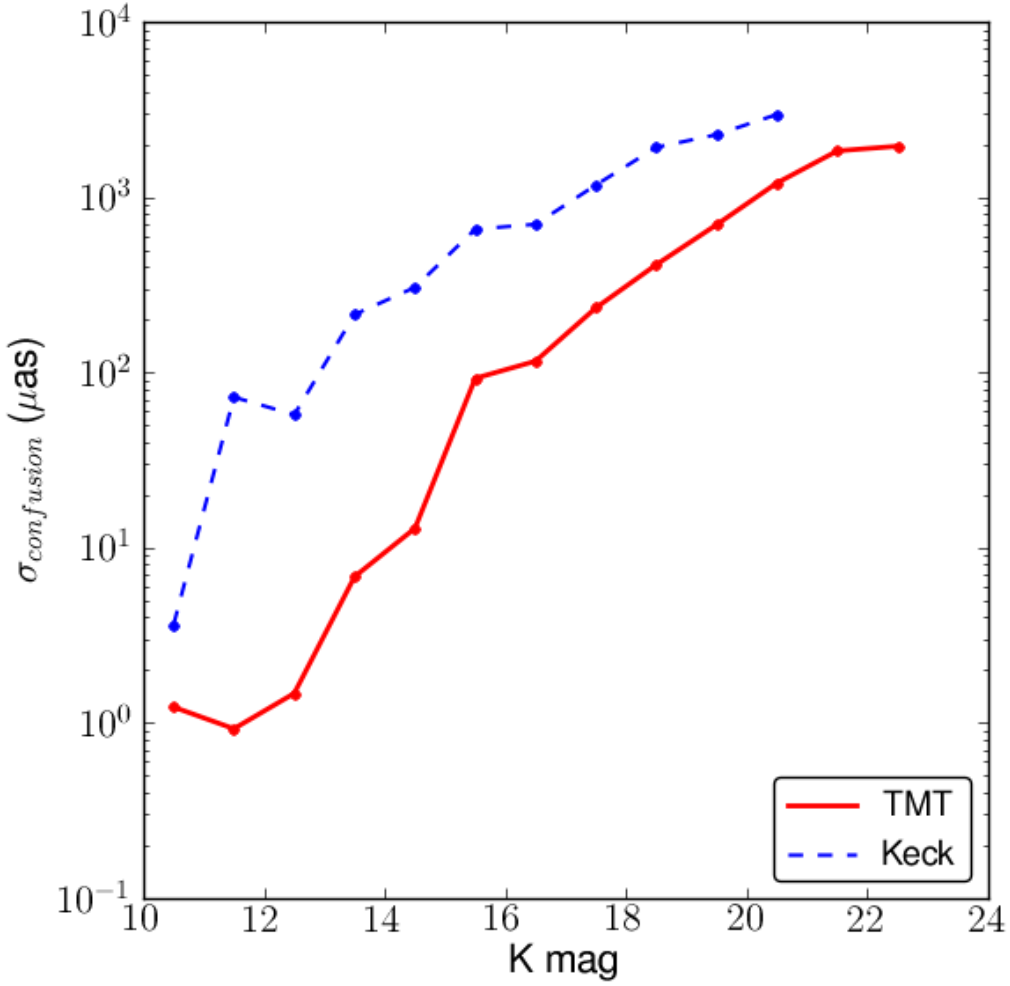


~3000 stars

~300,000 stars

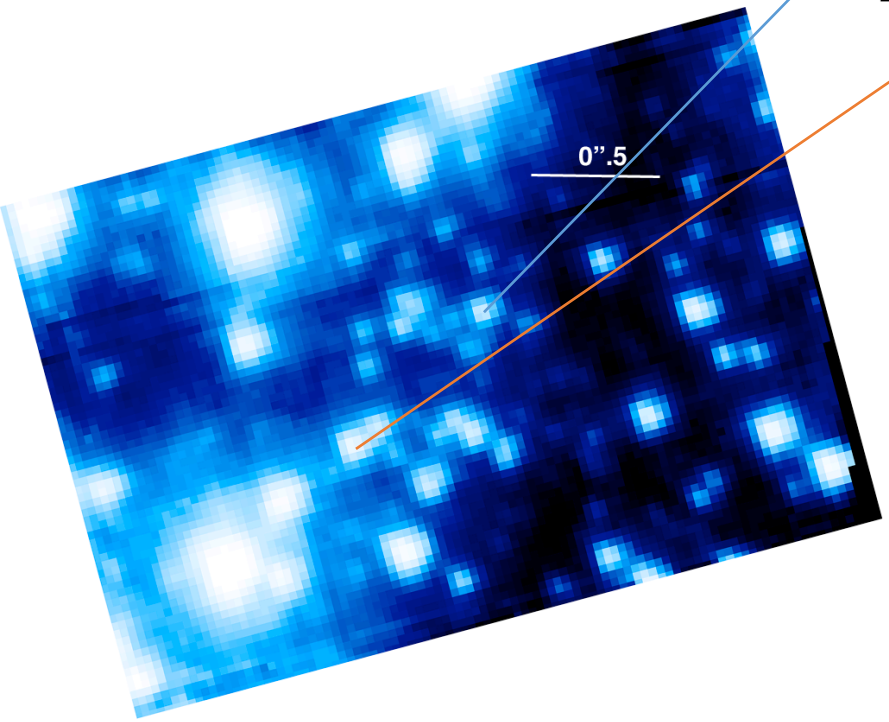
Yelda et al. (2014)

Confusion will dominate single-epoch error budget for stars with K > 15 (σ > 10 uas).

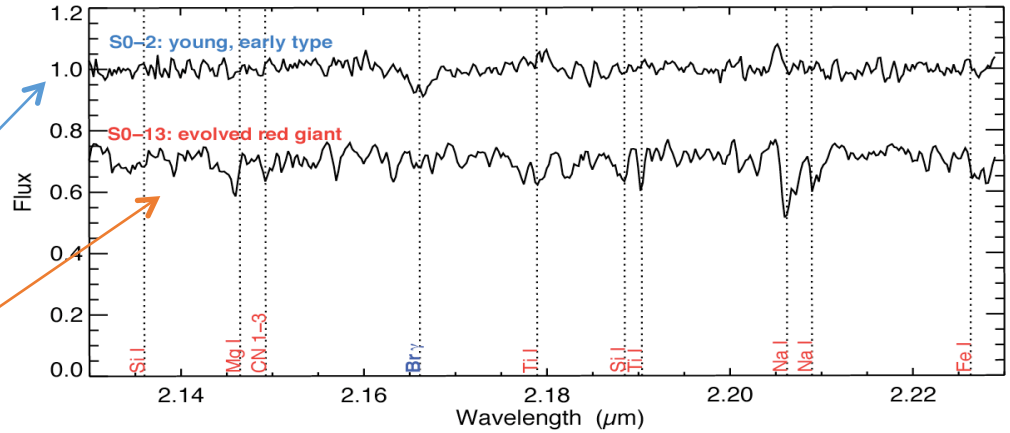


Yelda et al. (2014)

Integral field spectroscopy is critical for GR experiment and for astrophysical science



Collapsed spectral cube of central 2"x4"



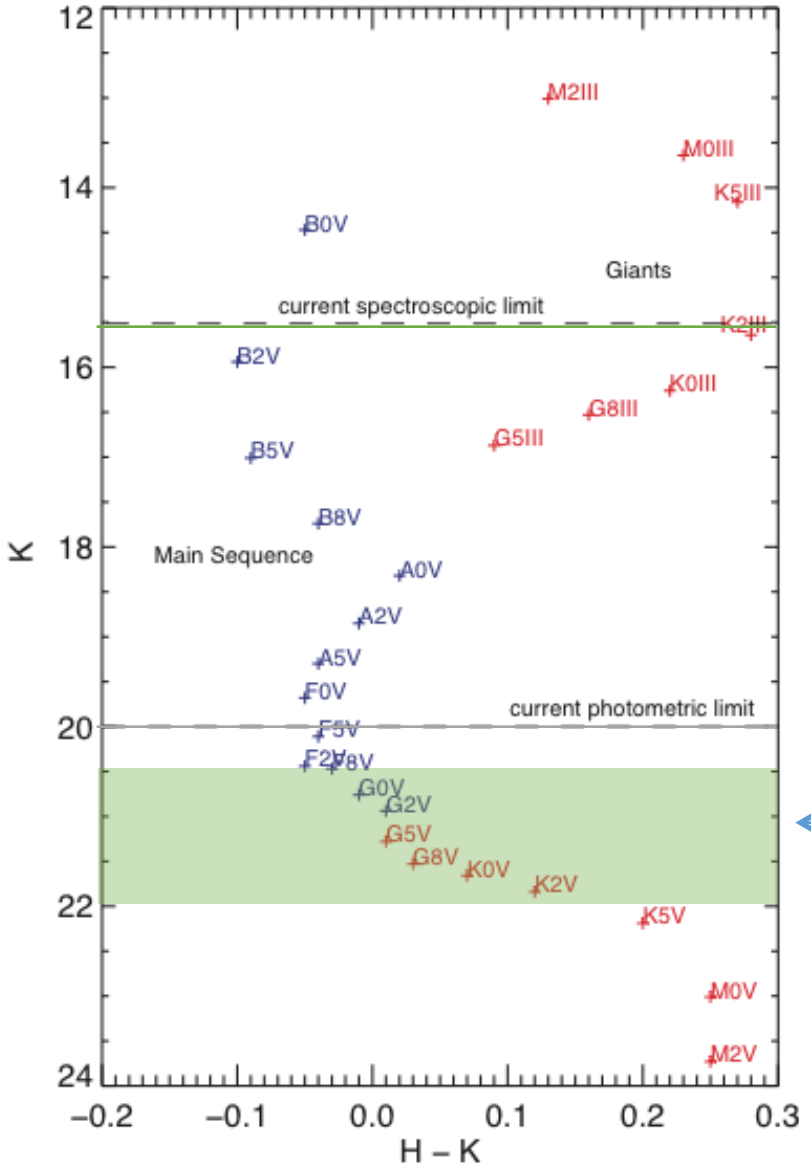
Keck LGS AO OSIRIS spectra

Spectral types can be used to separate the luminosity function of young and old stars.

Necessary to obtain all 6 orbital parameters as well as the potential and GR effects.

Do et al. (2009)

IRIS will greatly increase our knowledge of stellar populations in nearby galactic nuclei



IRIS will be able to obtain spectroscopy for stars of ≤1 $M_\odot$ at the Galactic center (current limits at ~10 $M_\odot$).

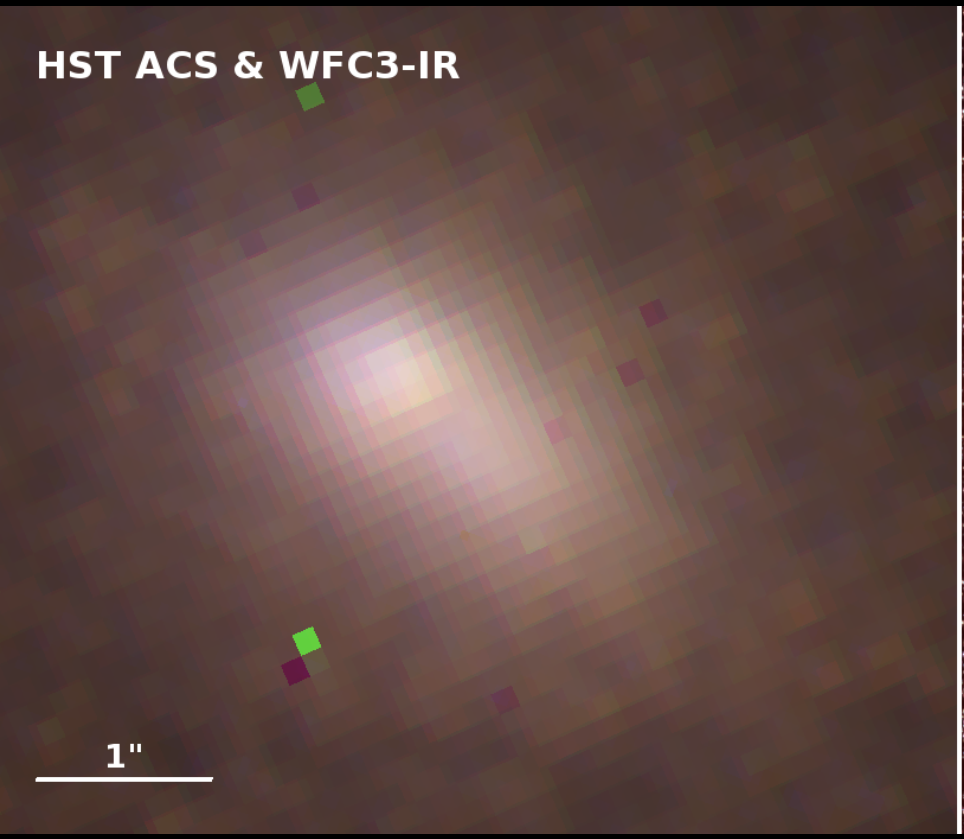
We expect ~5 magnitude gain in sensitivity

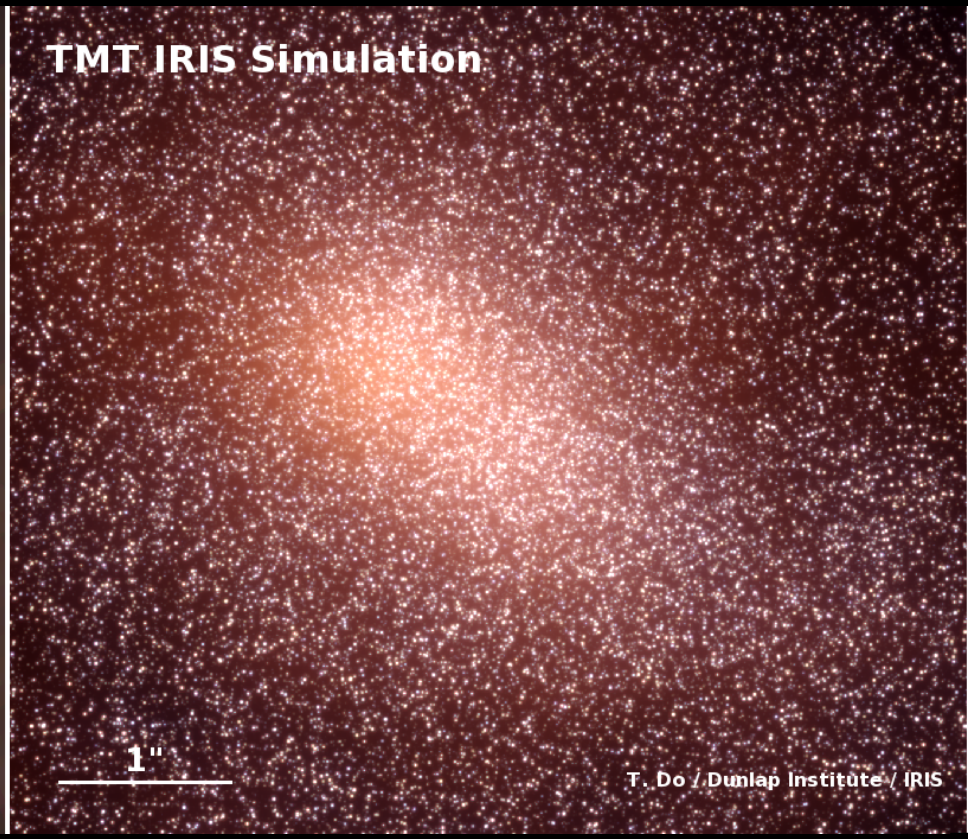
← TMT *spectroscopic* point source sensitivity

Theoretical CMD at the Galactic center + extinction

Do et al. (2013)


From NCSA, UCLA Galactic Center Group


HST ACS & WFC3-IR
1"


TMT IRIS Simulation
1"
T. Do / Dunlap Institute / IRIS