超大質量ブラックホール Sgr A* のスピン測定を目指して

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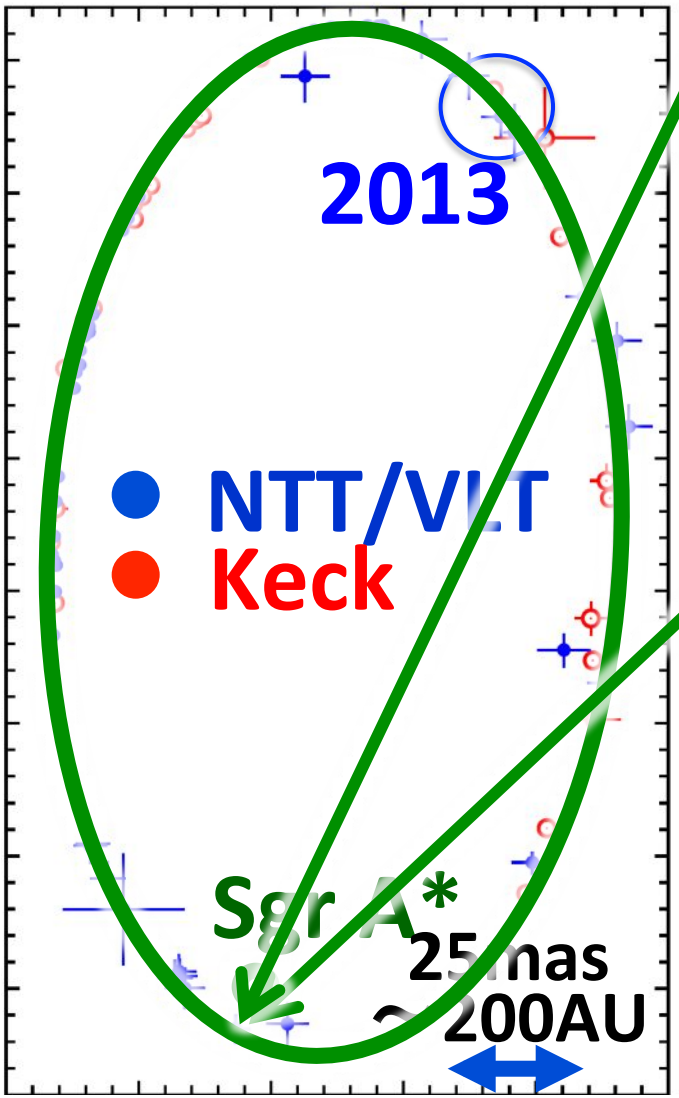
Summary



Gillessen+09

2018 (next pericenter)

Detection of *orbital precession* with Subaru/IRCS, IRD & COM

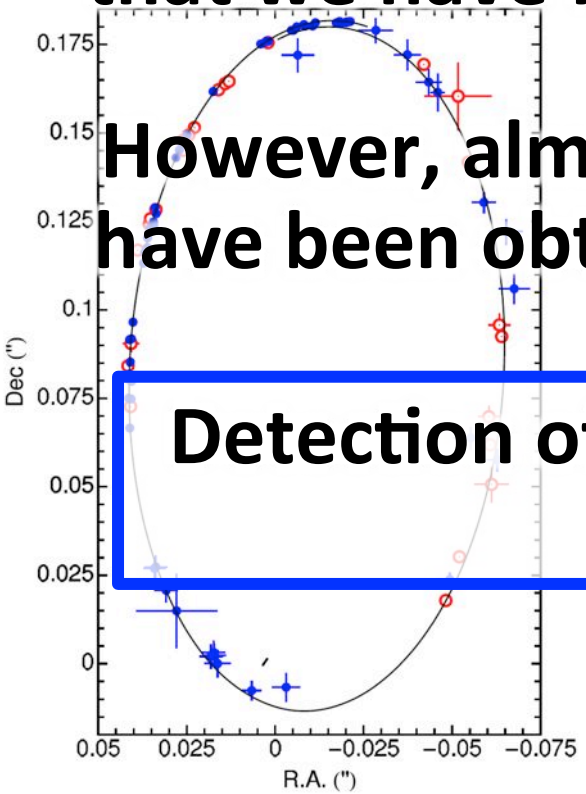
2034 (pericent. after next)

Detection of *Frame dragging effect (i.e., spin of Sgr A*)* with TMT/NIRES & COM

Introduction

Nishiyama: "There is a supermassive BH at the center of …"
Theoretical physicists: "No, it is still a BH *candidate*.
No *direct* evidence for the existence of BH."

"we now have sufficient (*indirect*) evidence to claim that we have found astrophysical BHs" (Zhang 10)



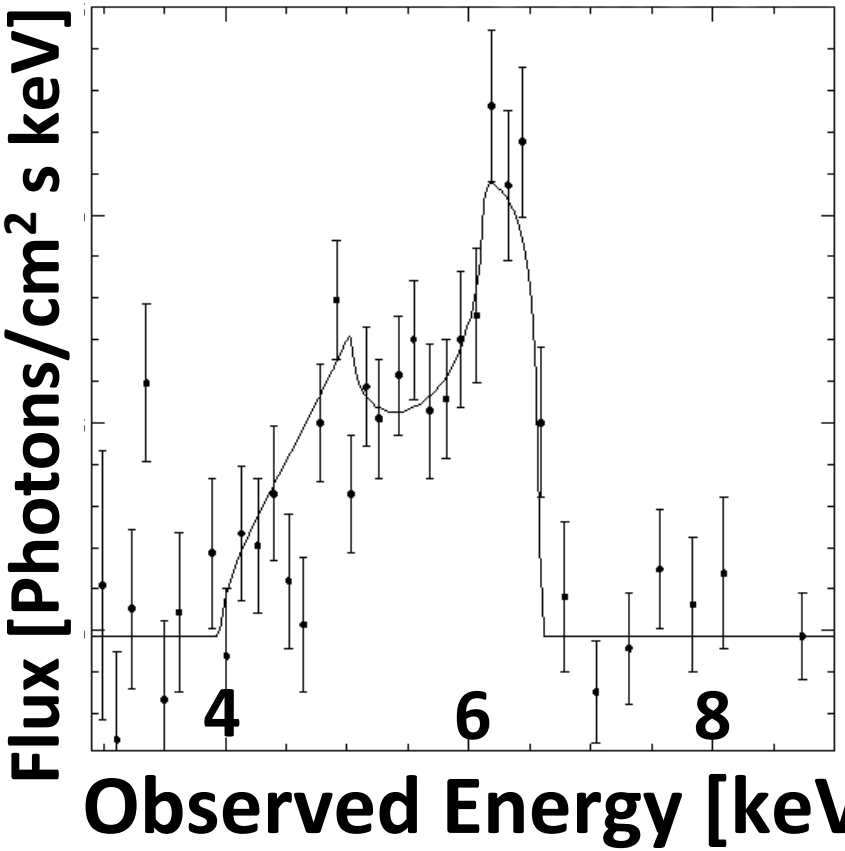
However, almost all of the "sufficient evidence" have been obtained through *Newtonian* gravity.

Detection of General Relativistic (GR) effects around BHs

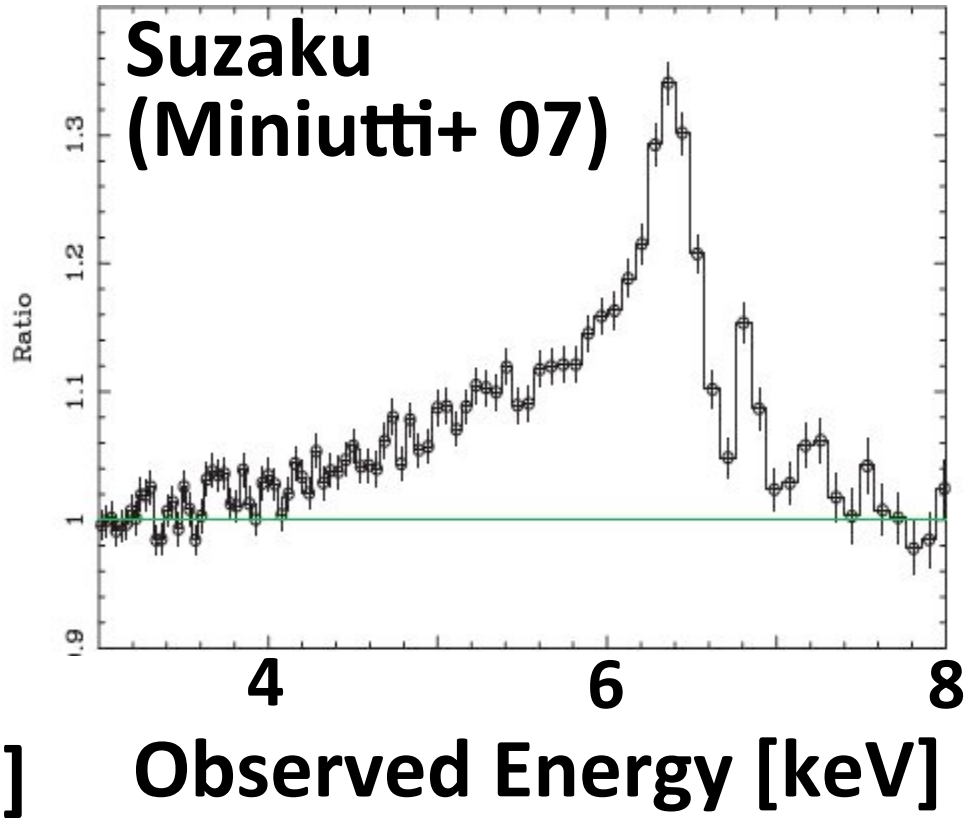
Introduction

Relativistic effects near SMBH: Fe disk line

Fe line of MCG-6-30-15



ASCA (Tanaka+ 95)



Introduction

Relativistic effects near SMBH: Fe disk line light source, continuum, variability (天文月報 2010)
(but, Risaliti+ 13 Nat, but Miller & Turner 13)

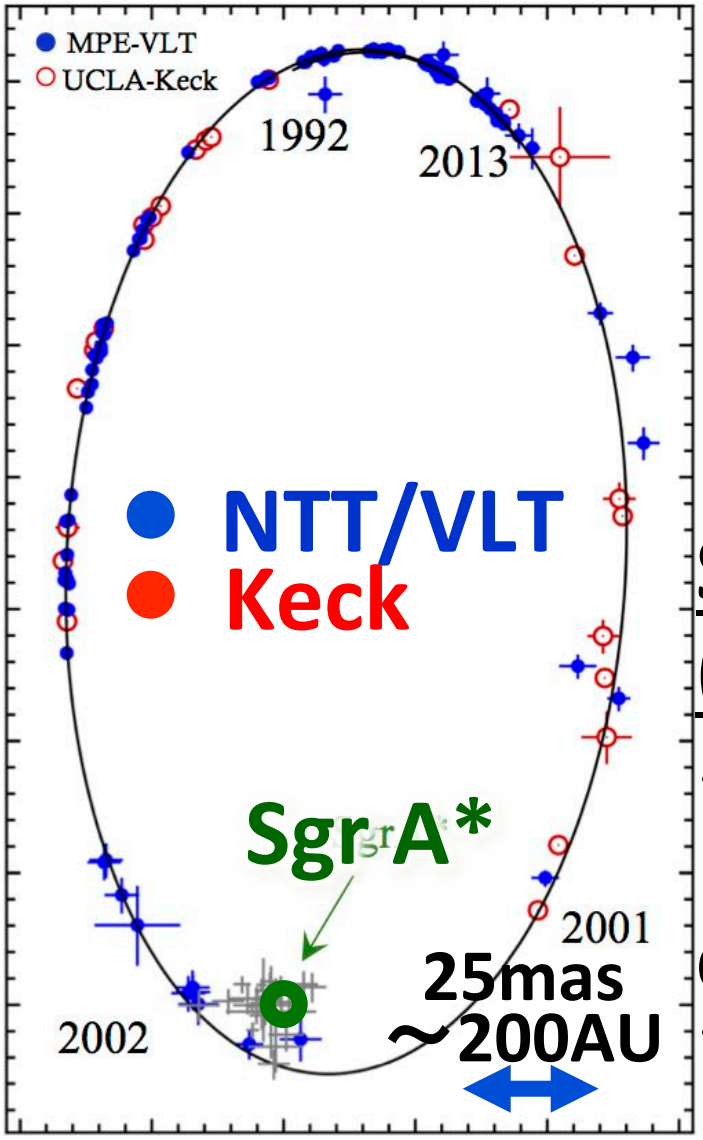
Other claims (QPO, hotspot etc.)
← accretion disk model dependence

I hope to *avoid* subtle argument on accretion disks
← complex physics

→ Detection of GR effects around SMBH *without* accretion disks

Orbiting Stars around SMBH

S2 Orbit



S2 (S0-2)

- Orbital Period：15.5 yr
- Next pericenter：2018
- Pericenter dist.：120AU (~1,400 *Rs*)

Strength of Relativistic Effects (Gravitational Potential):

$\Upsilon(\mathrm{S2}) = [GM_{\mathrm{SgrA*}}/c^2]/r_{\mathrm{peri}} \sim 10^{-3}$

cf. Hulse-Taylor pulsar

$\Upsilon \sim 5\times10^{-6}$

http://www.mpe.mpg.de/369216/The_Orbit_of_S2

GR Effects on S2

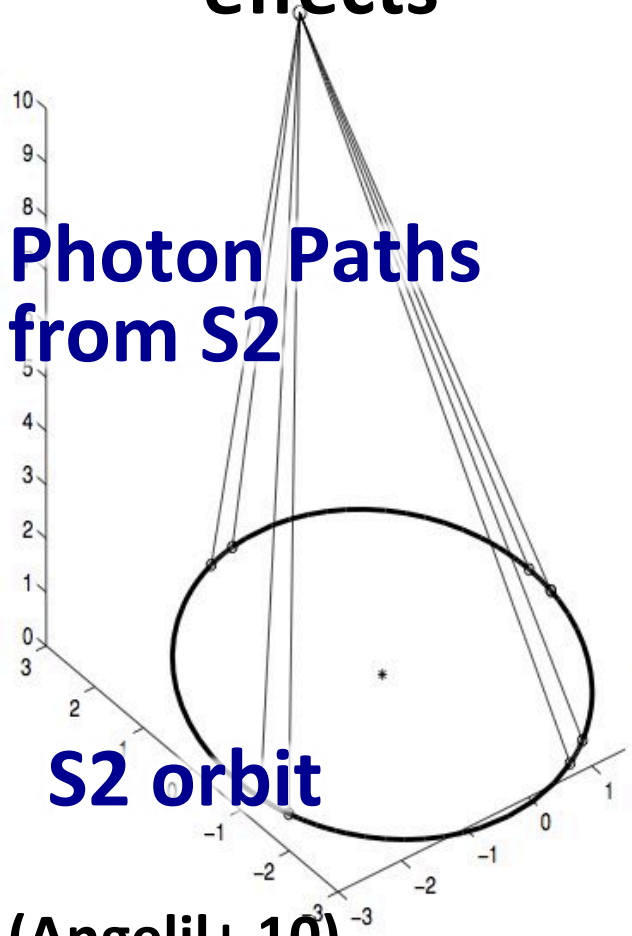
Observations of General Relativistic effects

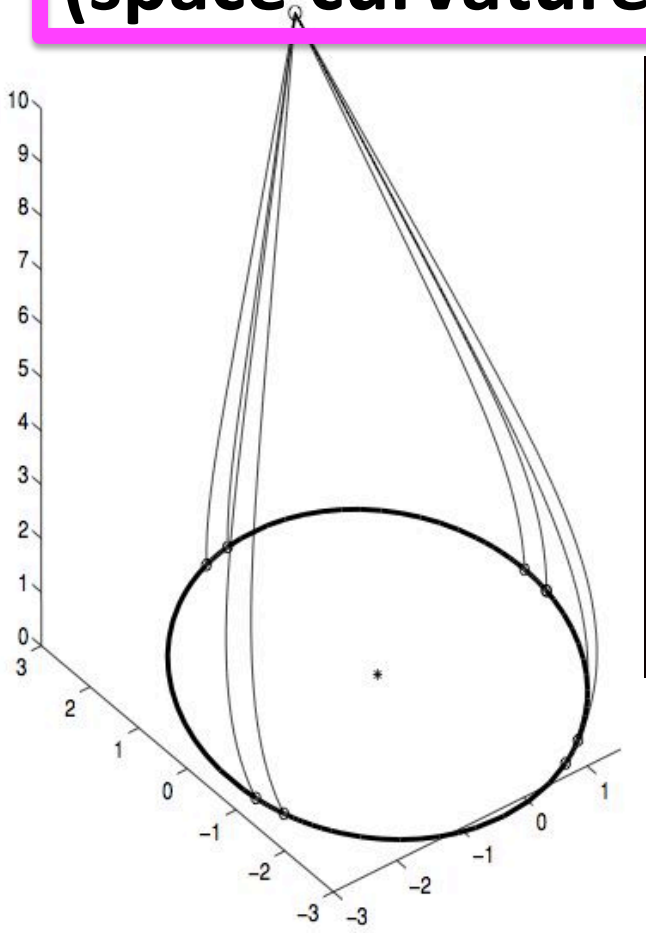
No **Relativistic effects**

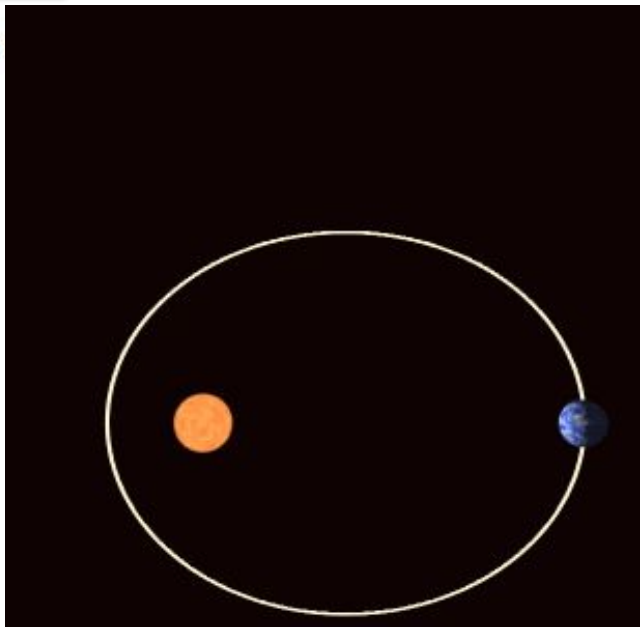
Schwarzschild BH (space curvature)

Photon Paths from S2

S2 orbit







(Angelil+ 10)

GR Effects on S2

Observations of General Relativistic effects

No **Relativistic effects**

Schwarzschild BH (space curvature)

Kerr BH (frame dragging)

Photon Paths from S2

S2 orbit

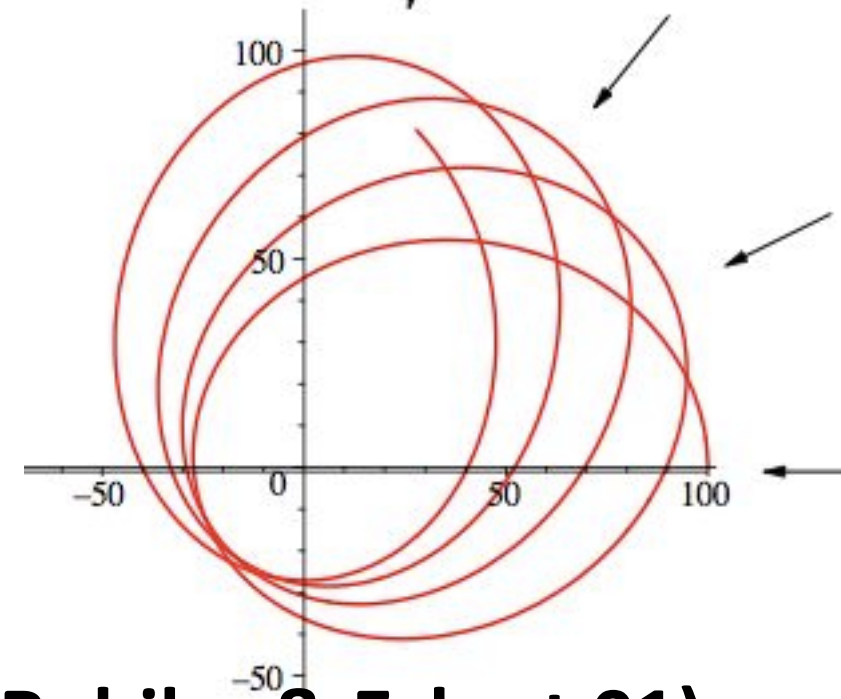
(Angelil+ 10)

GR Effects on Stellar Orbits

Observations of General Relativistic effects

1. Astrometry

Periapse Shift
(Prograde Precession)



(Rubilar & Eckart 01)

S2

Shift ~ 1 mas/orbit @apocenter

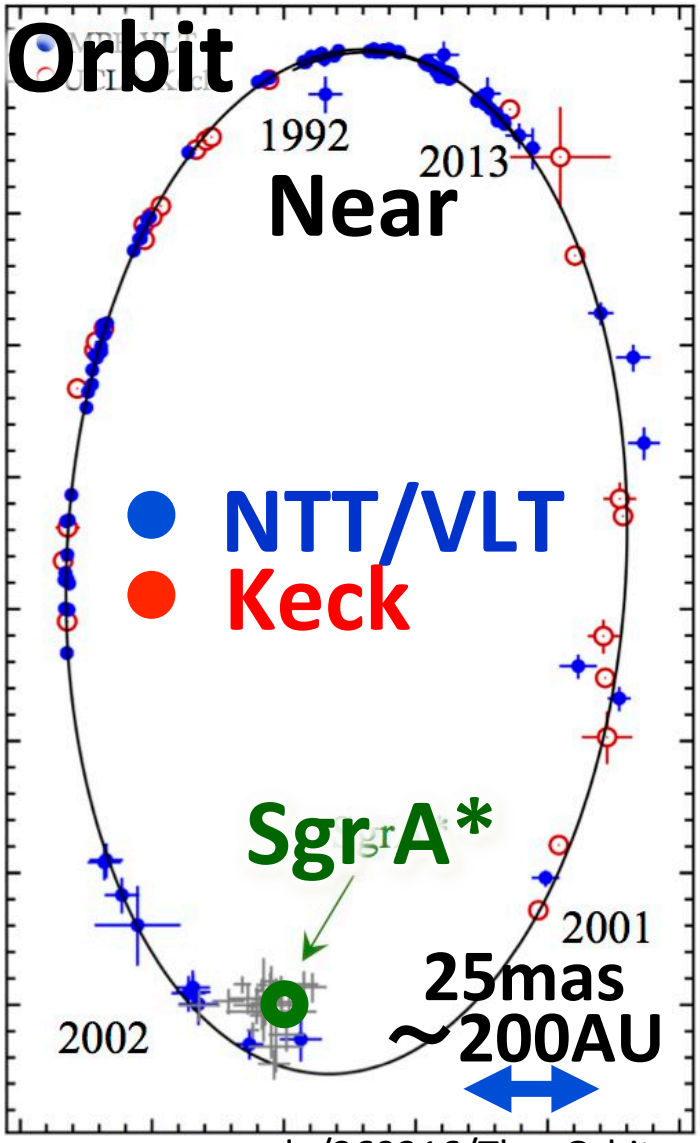
cf. current accuracy ~ 0.1 mas (Yelda+11)

Next apocent.: 2025!

GR Effects on S2 RV

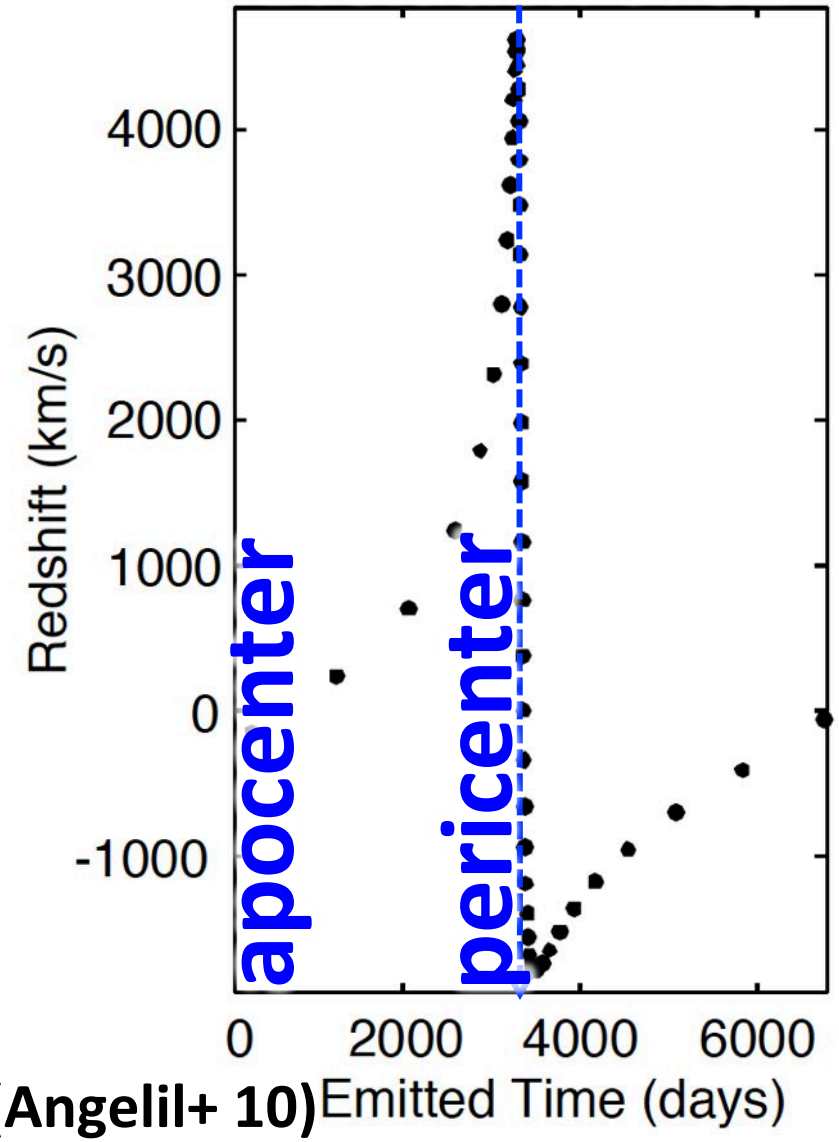
2. Radial Velocity (RV)

S2 Orbit



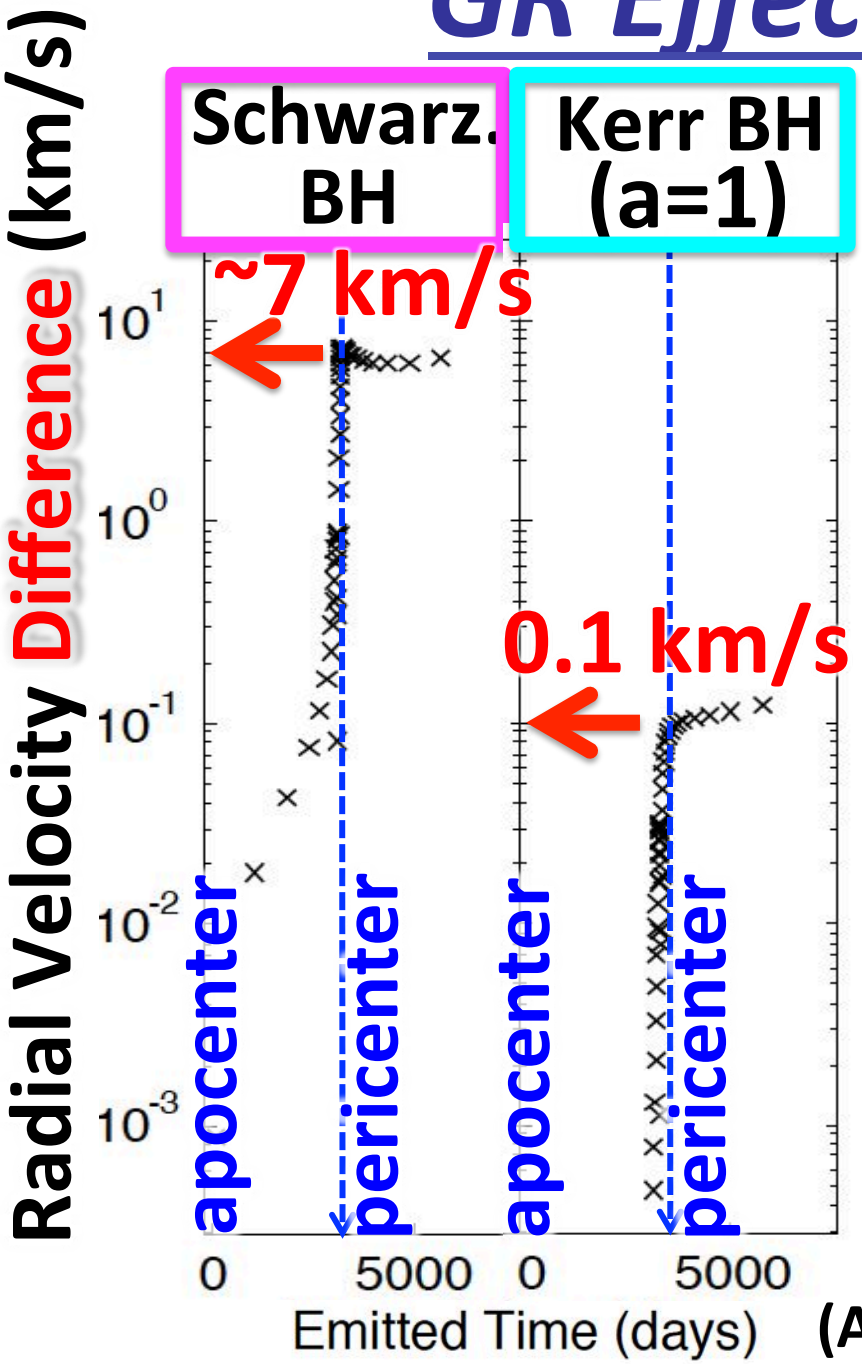
http://www.mpe.mpg.de/369216/The_Orbit_of_S2

Radial Velocity Evolution of S2

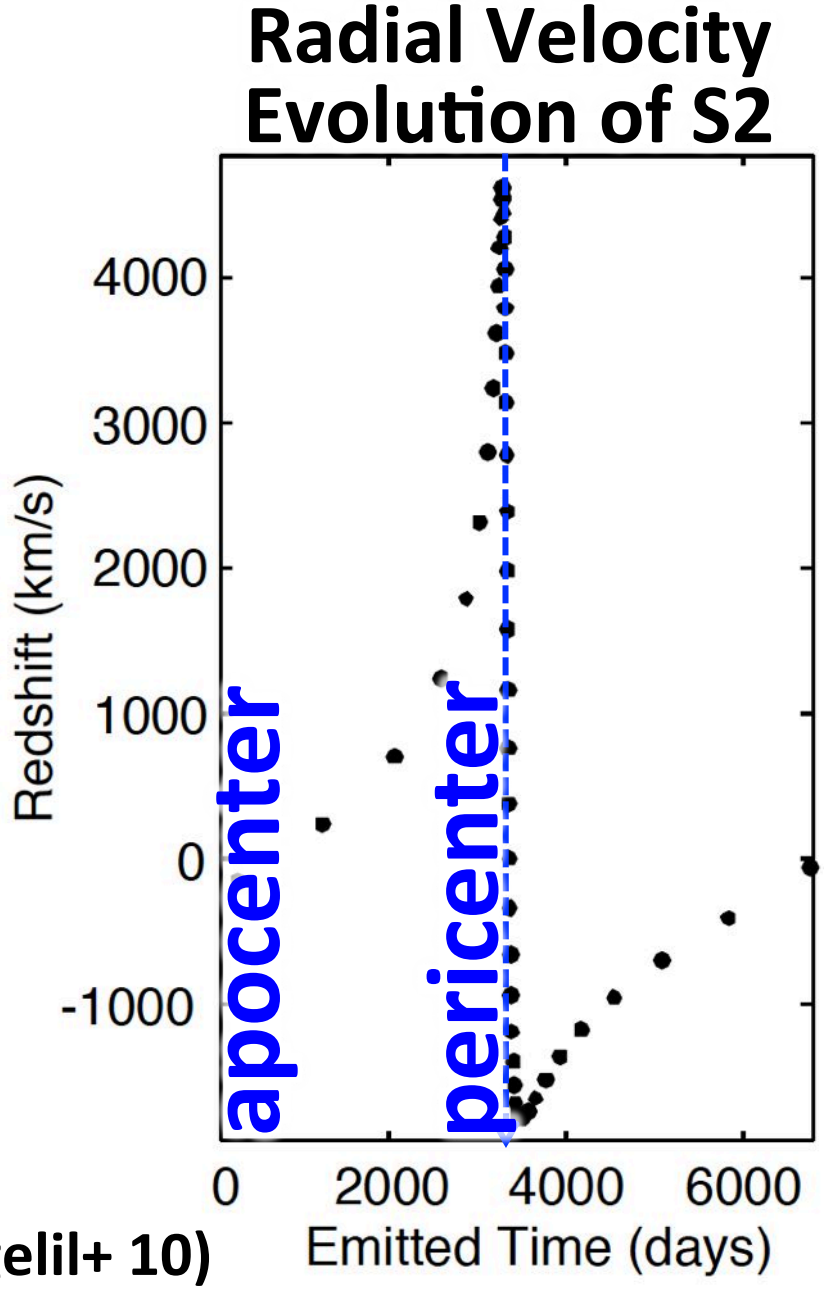


(Angelil+ 10)

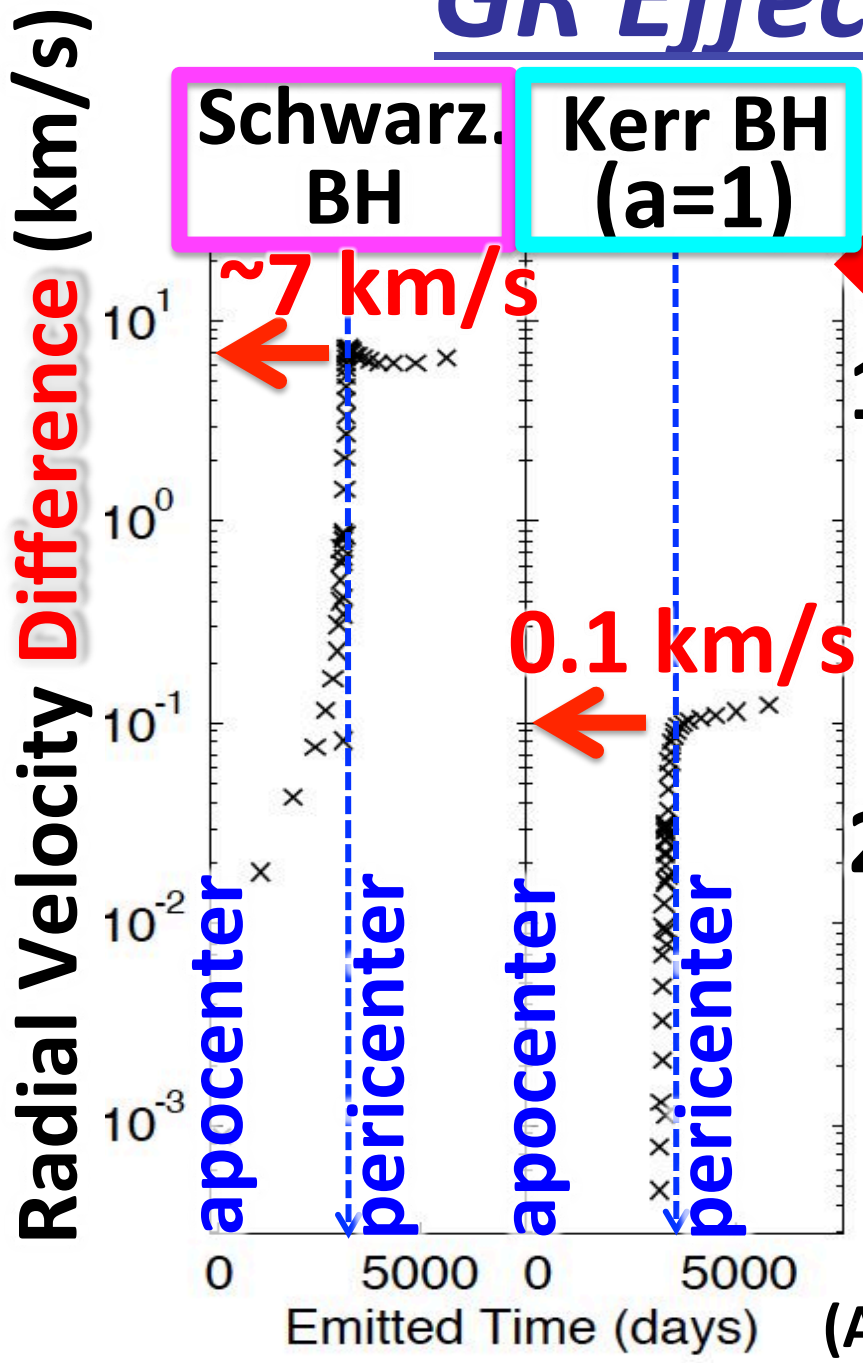
GR Effects on S2 RV



(Angelil+ 10)



GR Effects on S2 RV



(Angelil+ 10)

- Orbital Shift of S2 due to

1. Schwarz. BH
   → Difference from a pure Kepler orbit:
   ~7 km/s (~2.5 km/s, 3σ)
2. Kerr BH (frame dragging)
   → **< 0.1 km/s (~0.03 km/s, 3σ)**

S2 Spectroscopy with TMT

Expected RV accuracy for S2

~2.5 km/s

~0.03 km/s

	Keck OSIRIS	Subaru IRCS	Subaru IRD
Band	*K*	*K*	*H*
R	3,600	~20,000	70,000
Calibration	OH	OH	Laser COM
SN	20	10	10
	δRV ∝ (1/R) (1/SN) (1/num. line)^1/2		
δRV [km/s]	20	~4.0	~2.0
δRV w/ COM	-		~0.2

H=15.4, K=14.0, exposure=2h

S2 Spectroscopy with TMT

Expected RV accuracy for S2

~2.5 km/s

~0.03 km/s

	Keck OSIRIS	Subaru IRCS	Subaru IRD	TMT NIRES
Band	*K*	*K*	*H*	*K*
R	3,600	~20,000	70,000	20,000
Calibration	OH	OH	Laser COM	OH?
SN	20	10	10	~400
	δRV ∝ (1/R) (1/SN) (1/num. line)^1/2			
δRV [km/s]	20	~4.0	~2.0	<~0.2
δRV w/ COM	-		~0.2	<~0.02

H=15.4, K=14.0, exposure=2h

GC Studies in the Future