Yunnan Observatories, Chinese Academy of Sciences

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The statistical properties of early-type stars from LAMOST DR8

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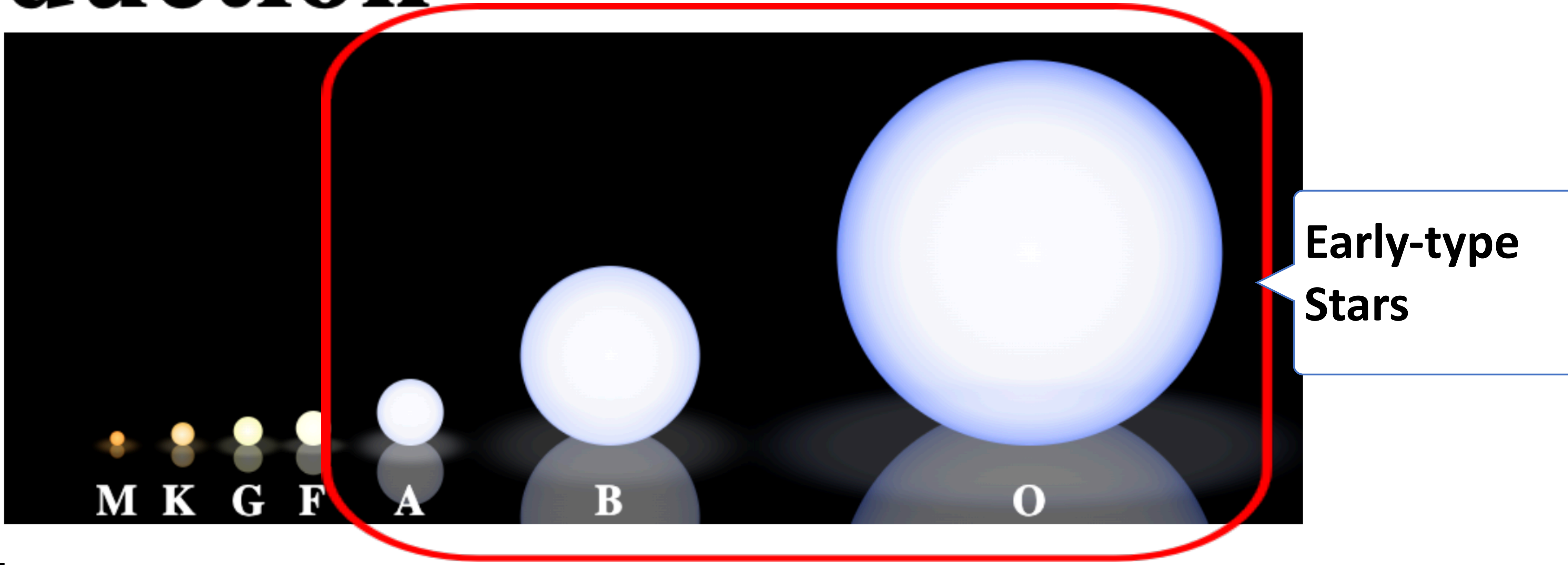
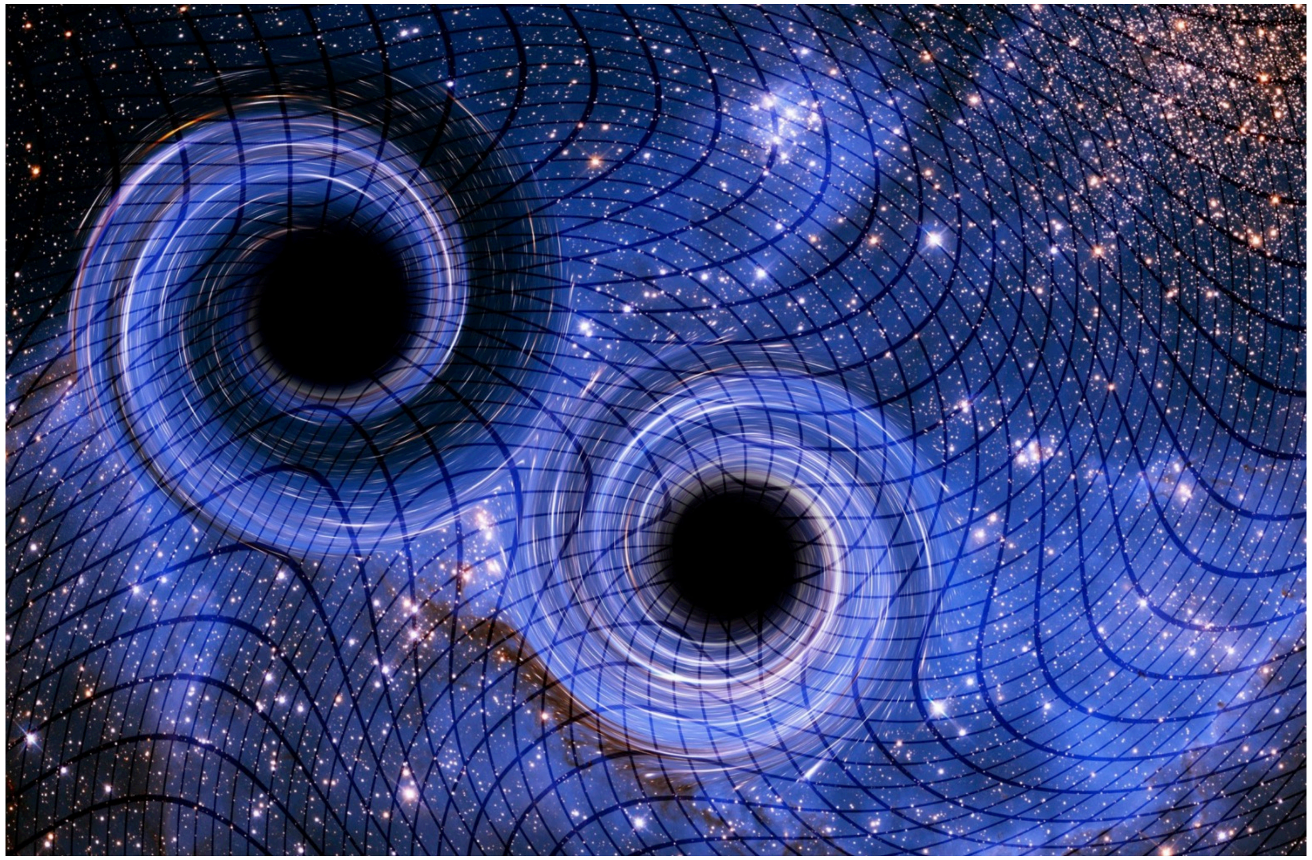
Introduction



Early-type stars

- Massive and luminous
- Mainly comprised of O-, B- and A-type stars
- Contribute to the universe's reionization
- Enrich metallicity in the Galactic environment
- Likely evolve to compact binary
  - Double black holes
  - Double neutron stars
  - Neutron star-black hole

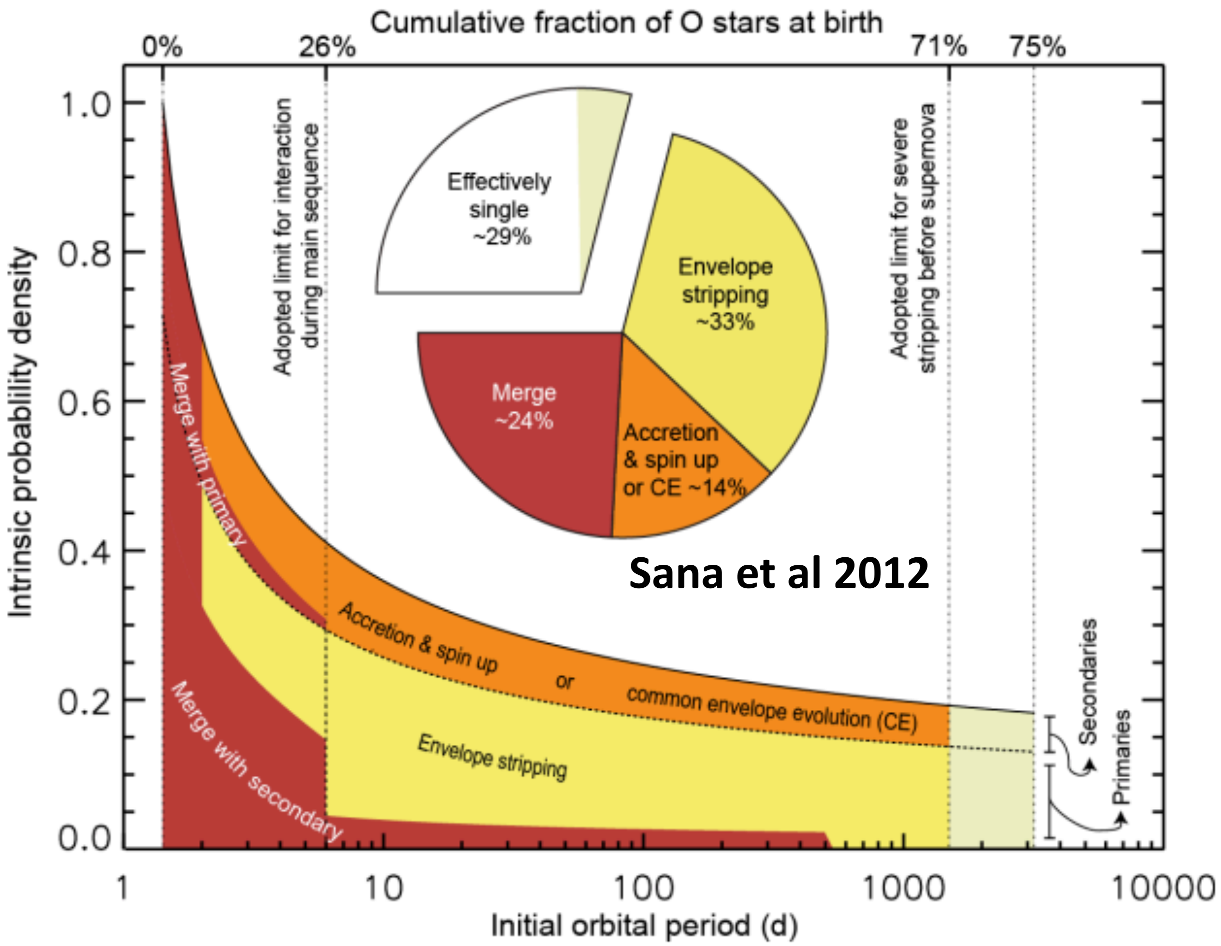
Introduction

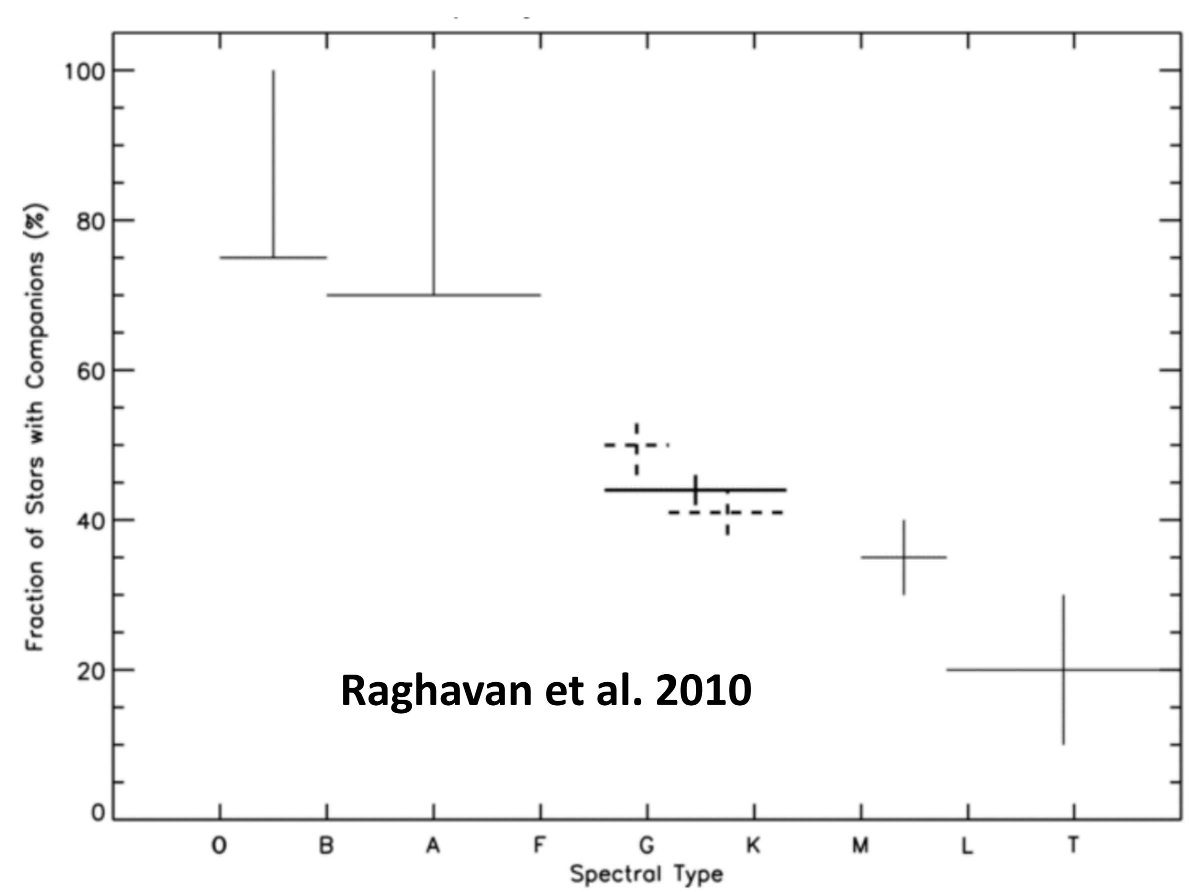


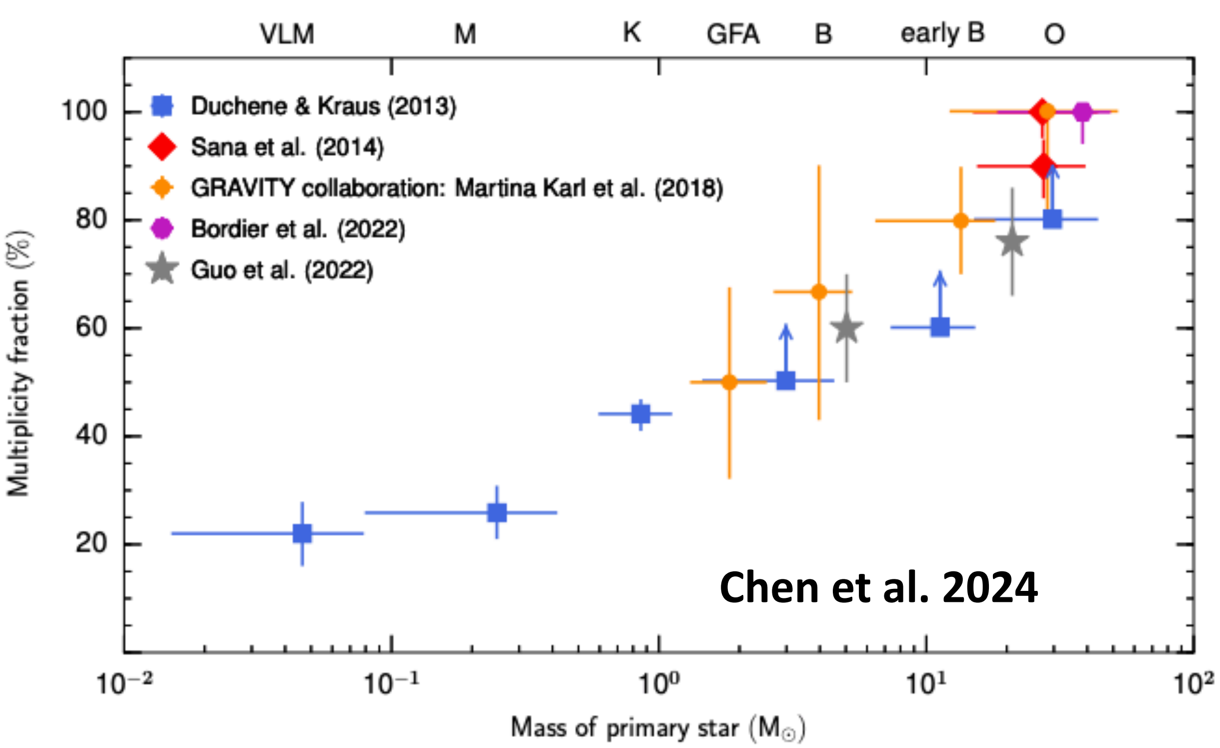
Statistical/multiplicity properties early-type stars

- Intrinsic Binary fraction
- Orbit period distributions
- Mass-ratio distribution

Introduction

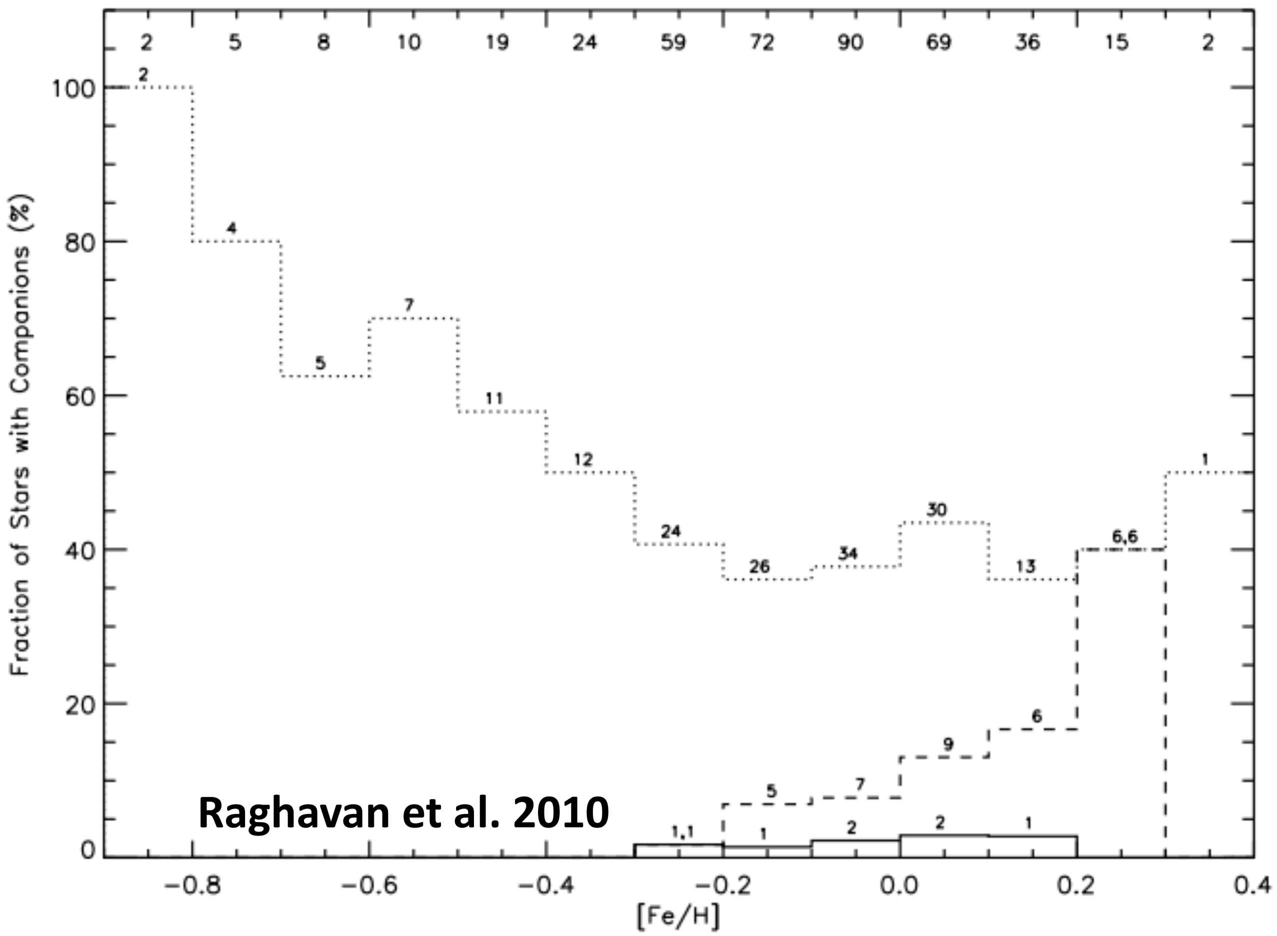


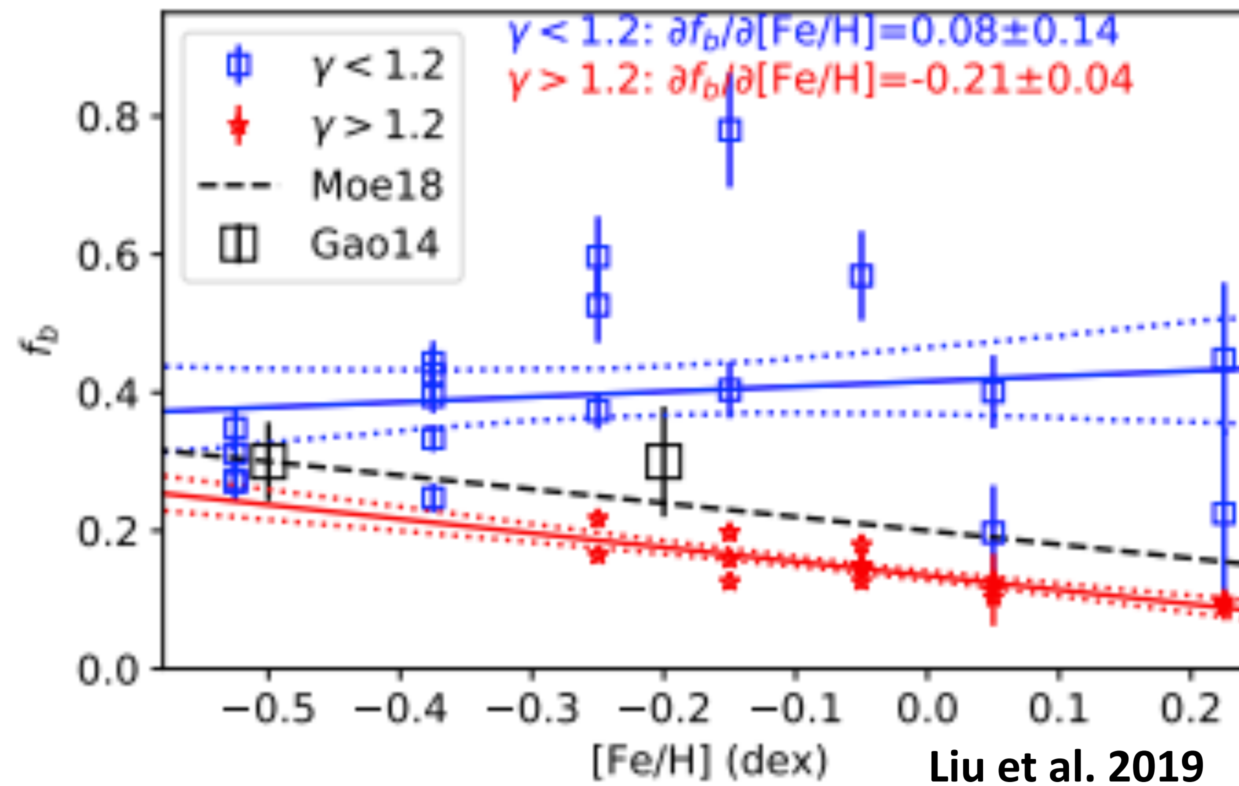




Binary fraction is one of the most critical parameters

Introduction





Binary Fraction and Metallicity

- **Negative Correlation:**
  - Raghavan et al., 2010; Tian et al., 2018; Liu, 2019 observed an anticorrelation.
- **Positive Correlation:**
  - Carney (1983) and Hettinger et al. (2015) reported a positive correlation.
- **No Correlation:**
  - Latham et al. (2002) found no correlation in their sample.

This inconsistency highlights the ongoing debate

Introduction

f_{bin}	Number of samples	Spectral type	reference
0.34 ± 0.02	454	FGK	Raghavan et al. (2010)
0.46 ± 0.03	226	B	Chini et al. (2012)
0.58 ± 0.11	408	B	Dunstall et al. (2015)
0.42 ± 0.04	161	O	Aldoretta et al. (2015)
0.50 ± 0.03	194	O	Sota et al. (2014)
0.51 ± 0.07	45	O	Kobulnicky et al. (2014)
0.68 ± 0.03	243	O	Chini et al. (2012)

Limit of other work:

- Small sample sizes
- Sample is heterogeneous

Limitations in Paper I:

- Observations cadence introduces errors in estimating the intrinsic binary fraction
- Mainly two observations per star

Introduction

Need for Improved Data:

- With the recent release of LAMOST DR8, we have access to more data.
- Examine uncertainties in the method used in Paper I.

Current Study Aim:

- Improve the analysis of binary fraction for early-type stars in the LAMOST DR8 database.
- Use an enlarged sample size (886 stars) with higher observational cadence.
- Determine the dependencies of binary fraction and metallicity.

Data

Low Resolution

Observed Plates： 5923	Total Spectra： 11,817,430	Star： 11,473,644
Galaxy： 263,444	QSO： 80,342	AFGK Stellar Parameters： 7,478,650

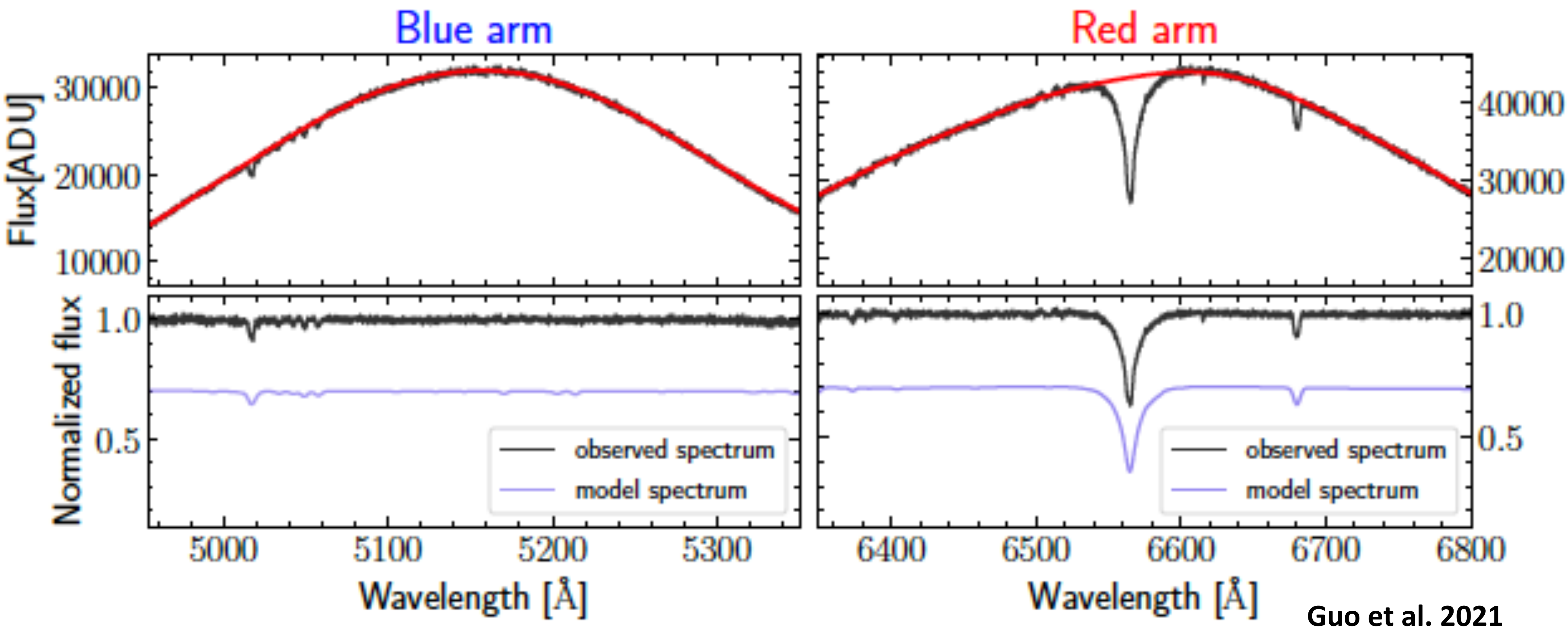
Medium Resolution

	Medium-resolution non time-domain data	Medium-resolution time-domain data	Total
Total spectra	2,211,338	8,274,878	10,486,216
Star parameter	1,103,320	1,045,150	2,148,470

LAMOST

- 4-meter quasi-meridian reflecting Schmidt telescope
- Both medium and low-resolution spectrographs
- Medium Resolution Survey (MRS R=7500)
  - Began from 2018
  - Wavelength range
    - Blue arm: 495 -535 nm
    - Red arm: 630 -680 nm

Data

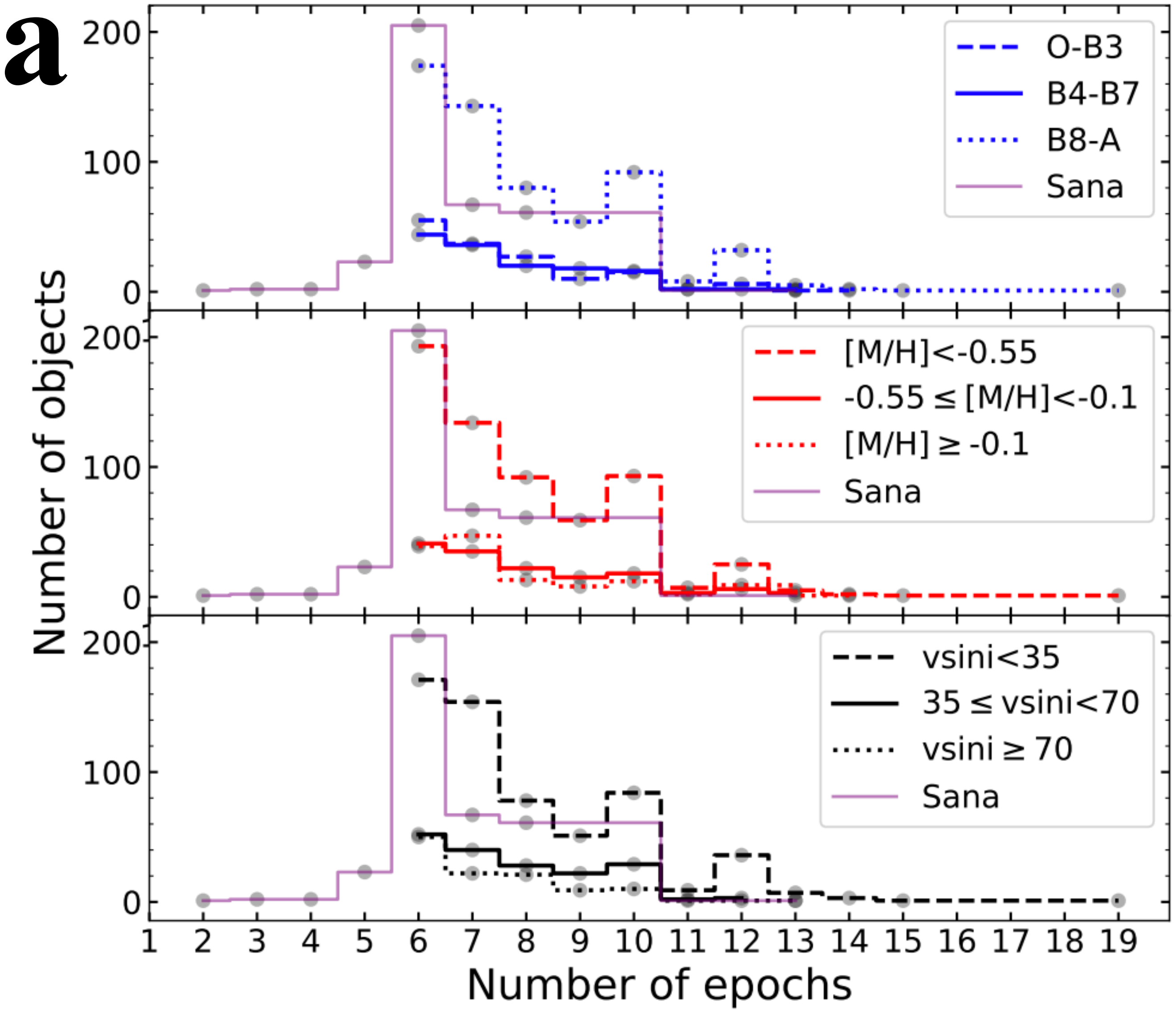


Guo et al. 2021

Sample

- Guo et al. 2022： Identified 9,382 early-type stars
- Guo et al. 2021： Derive the atmospheric parameters
- Zhang et al.2022: A robust self-consistent method to measure the RVs

Data



Group	Number
B8-A	592
B4-B7	140
O-B3	154
Metal-poor: [M/H] < -0.55	612
Metal-medium: $-0.55 \leq$ [M/H] < -0.1	143
Metal-rich: [M/H] ≥ -0.1	131
Low $v \sin i$: $v \sin i < 35\,\mathrm{km\,s^{-1}}$	595
Medium $v \sin i$: $35 \leq v \sin i < 70$	176
High $v \sin i$: $v \sin i \geq 70\,\mathrm{km\,s^{-1}}$	115

Guo et al. 2022

Sample Selection and Grouping

- Sample Selection:

  Selected 886 stars with more than six observations from Guo et al. (2021)
- Grouping Criteria:

  Stars are grouped based on three observables:Teff,[M/H],v sin i
- Grouping Strategy:

  Divided into low, medium, and high groups

Criterion for the binary (Sana et al. 2013)

(Dunstall et al. 2015; Mahy et al. 2021; Banyard et al. 2021)

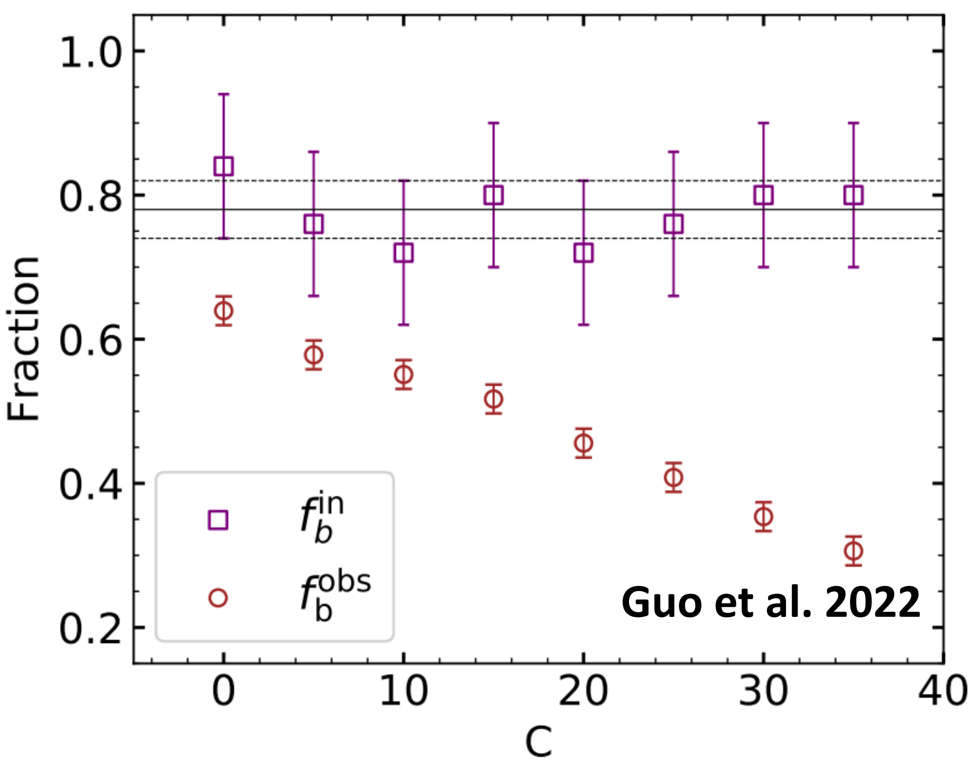
A star is a binary if its RVs satisfy:

$$\frac{|v_i - v_j|}{\sqrt{\sigma_i^2 + \sigma_j^2}} > 4 \text{ and } |v_i - v_j| > C$$

- $v_i(j)$ is the RV measured from the spectrum at epoch $i(j)$
- $i(j)$ is the associated uncertainty

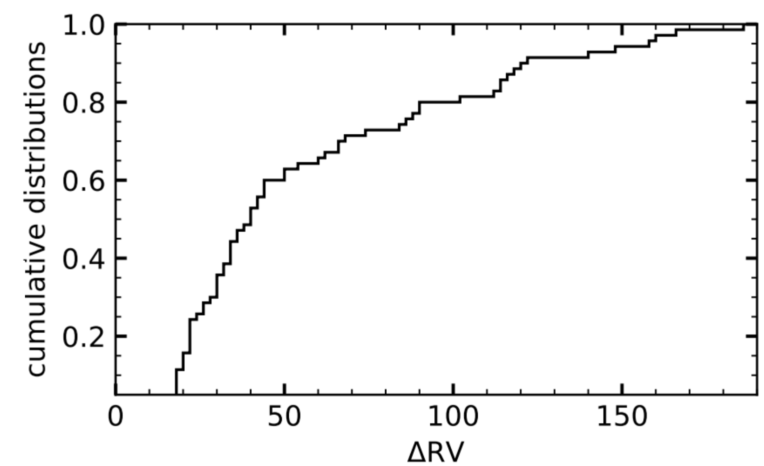
Threshold C: filter stars with pulsations

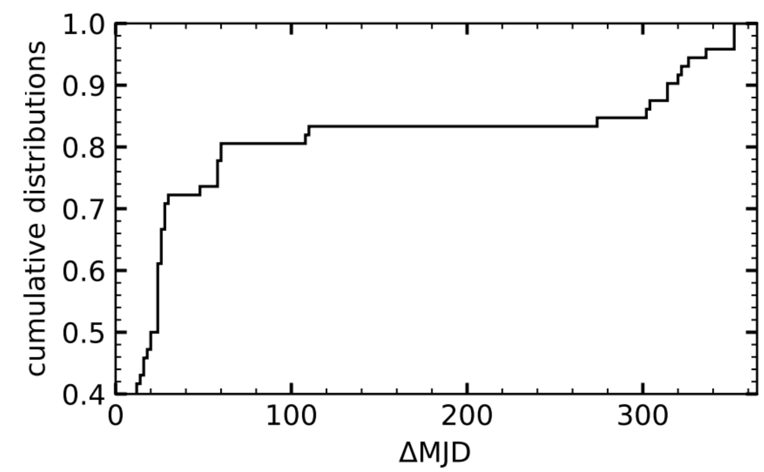
- O-type stars:C=20 km/s
  Sana et al. 2012
- B-type stars:C=16 km/s
  Dunstall et al. 2015



Correction for the binary fraction

Construct two synthetic cumulative distributions(CDF) (Sana et al. 2013)

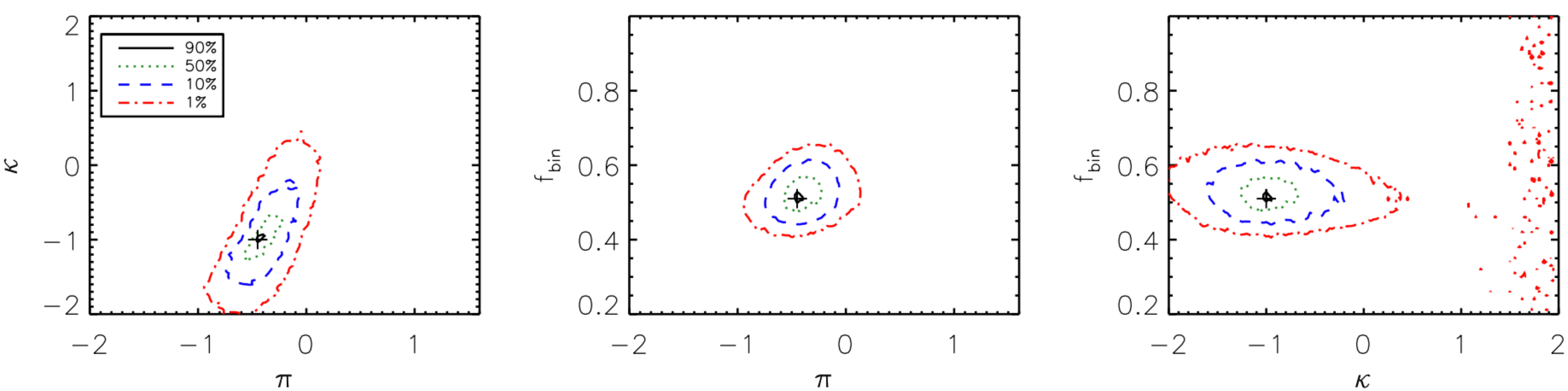




Parameter	Power law	Parameter Range	Power Index	Index Range	Step
P(d)	$f(P) \propto P^{\pi}$	1 - 1000	π	-2.50- 2.50	0.1
q	$f(q) \propto q^{\gamma}$	0.1 - 1.0	γ	-4 - 1.00*	0.1
$f_{\rm b}^{\rm in}$	-	-	-	0.20 - 1.00	0.04

Global merit function (GMF)

$$\Xi' = P_{\rm KS}(\Delta RV) \times P_{\rm KS}(\Delta MJD) \times B(N_{\rm bin}, N, f_{\rm bin}^{\rm simul})$$



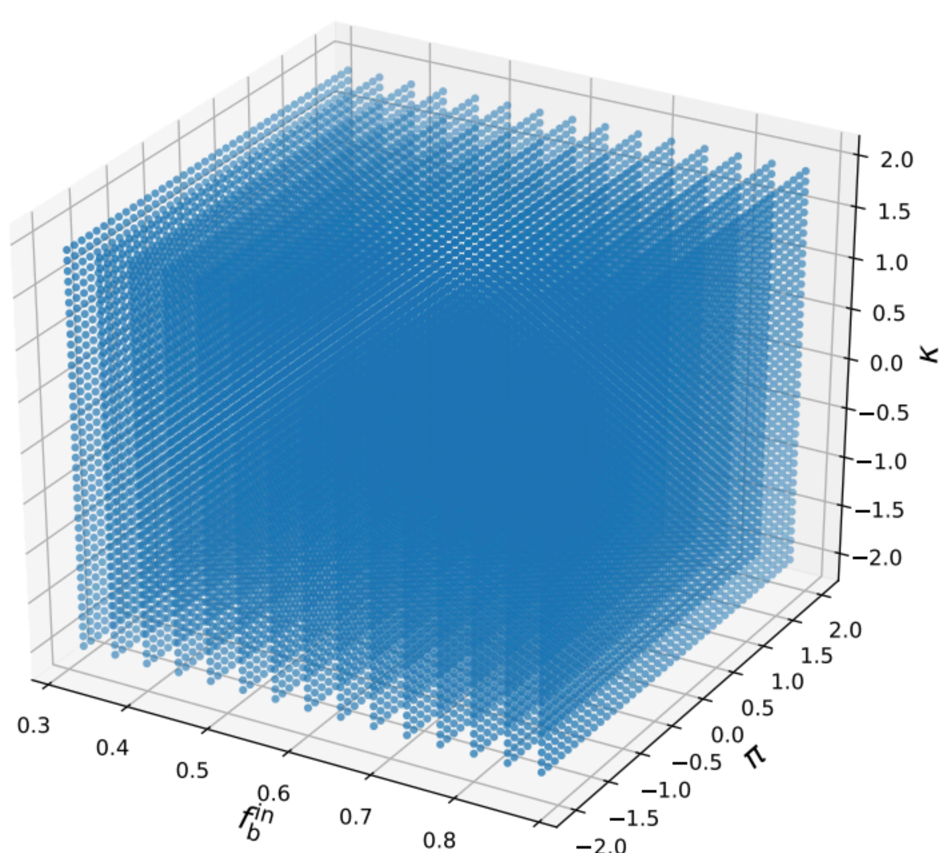
Validation

Self-consistency test

Sana et al. (2013): π=-0.40±0.4， κ=-0.9±0.4， fb=52±5%

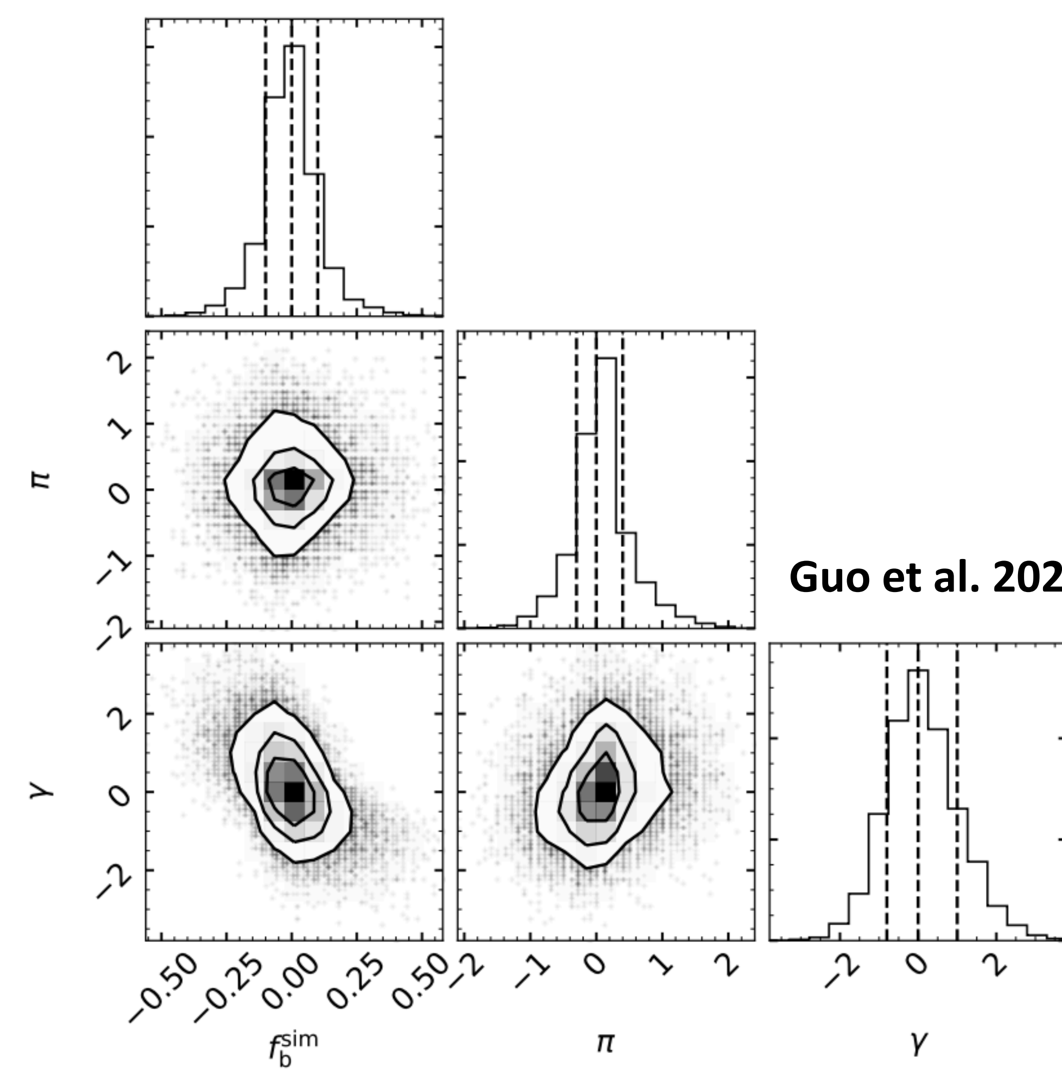
This work: π=-0.45±0.3， κ=-1.0±0.4， fb=51±4%

Applicability of the GMF for our sample



Guo et al. 2022

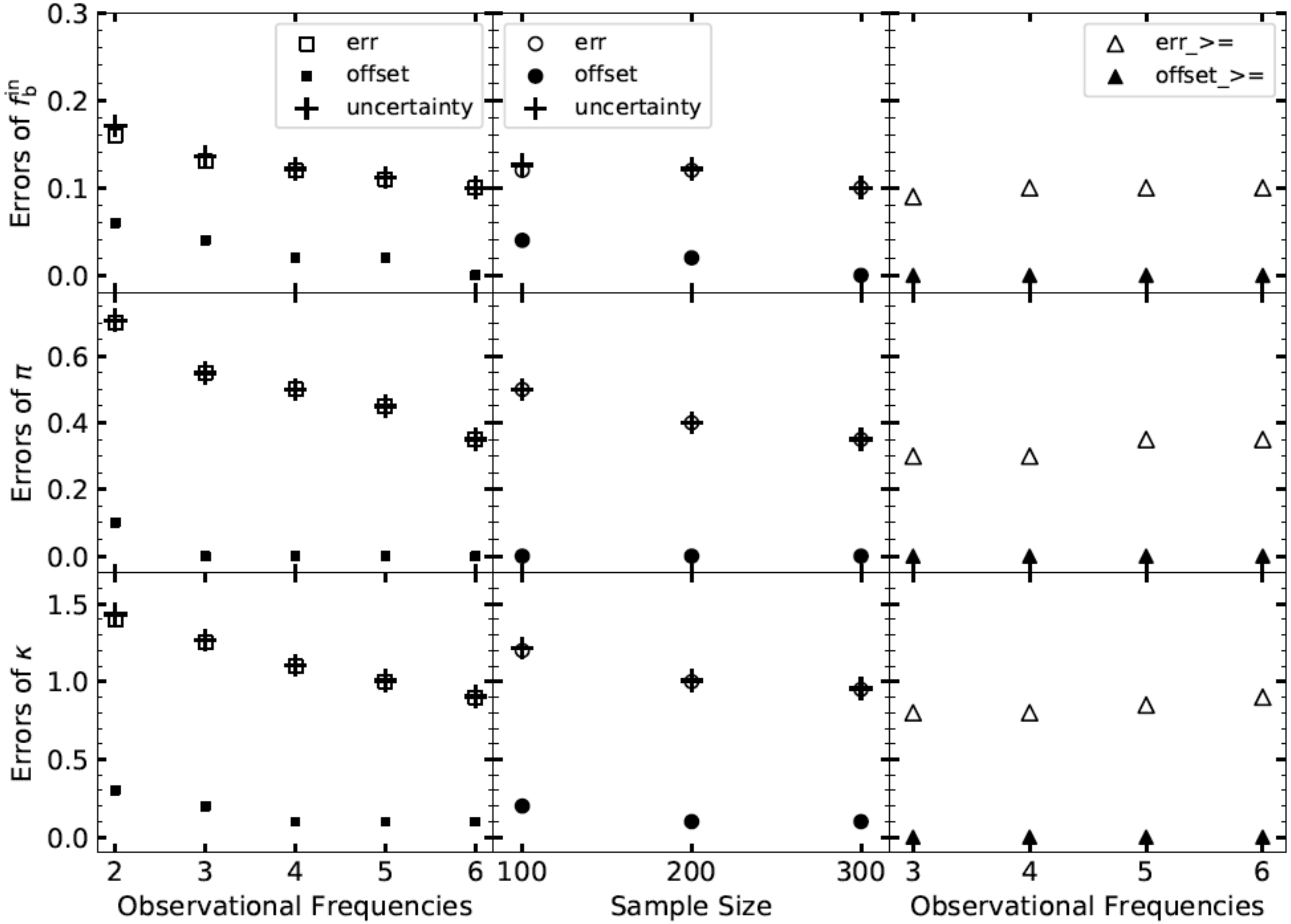
Known input sets



Guo et al. 2022

Uncertainty f_b^{in}=0.1, π=0.35, and γ=0.9.

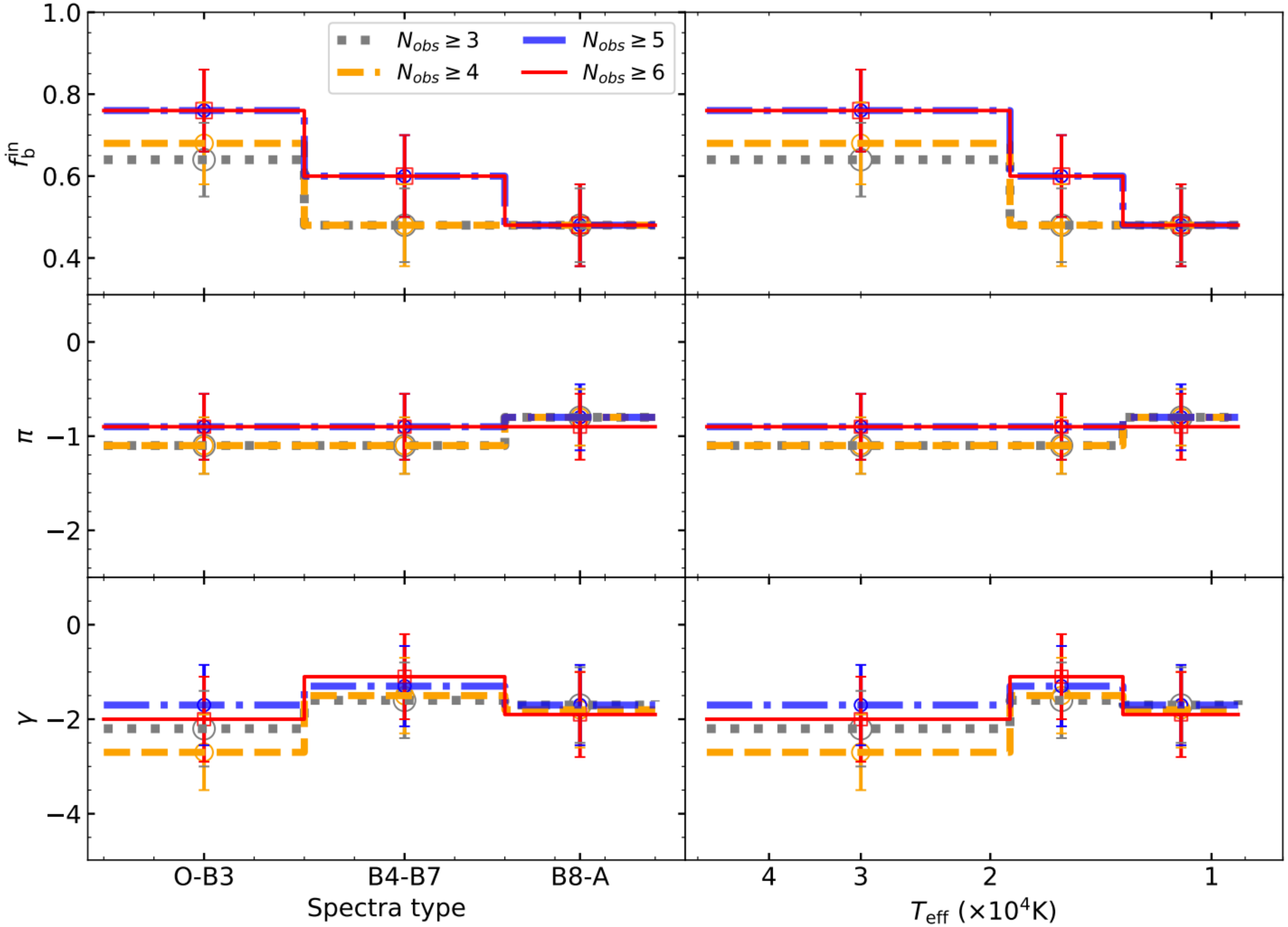
Impact of observational frequency and sample size



Both big sample size and a large observational frequency would reduce the uncertainty of the method

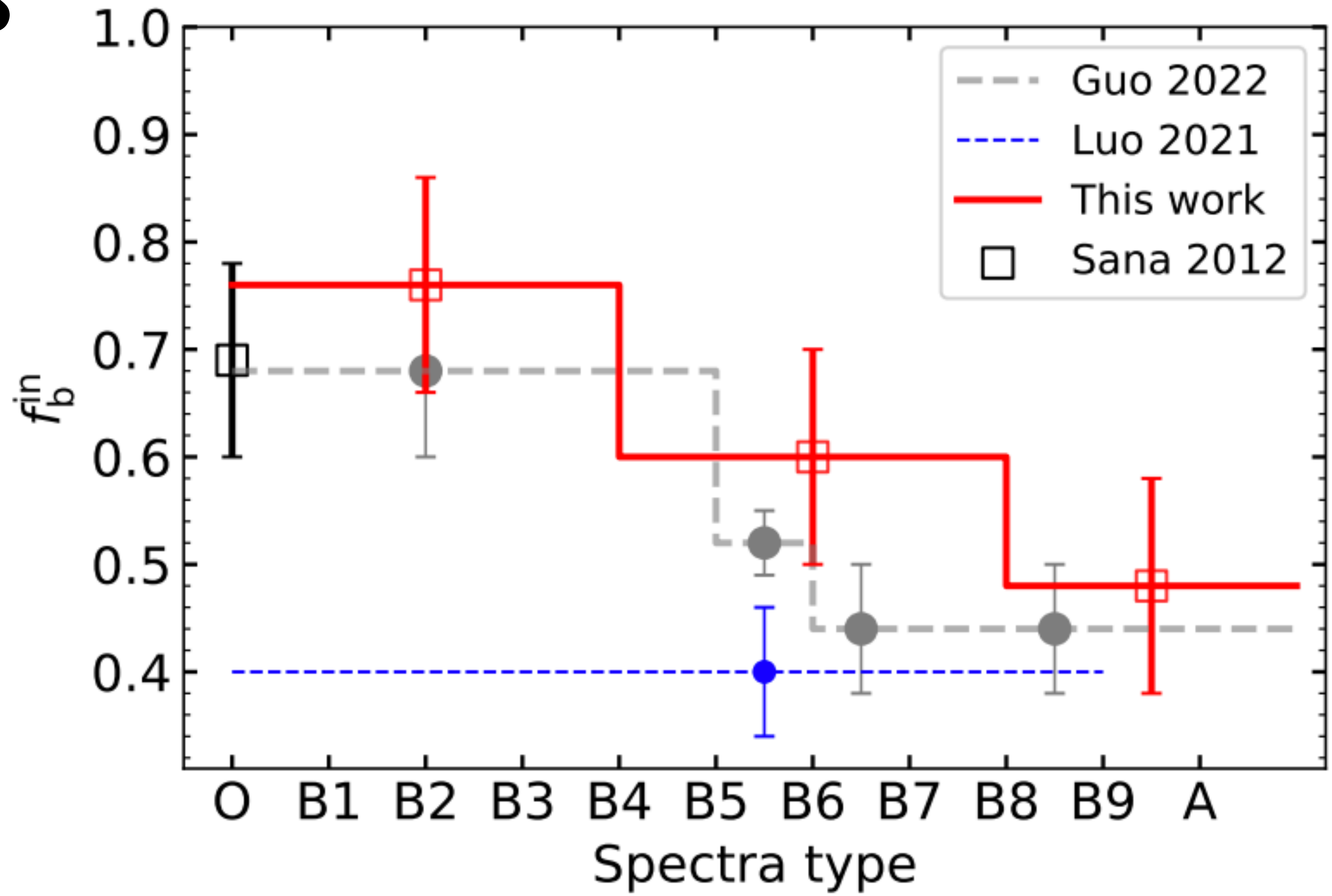
- Same sample different observational frequencies
- Same observational frequencies different sample
- Real sample

Results



- Binary Fraction
- 76% ± 10% 60% ± 10% 48% ± 10%

Results

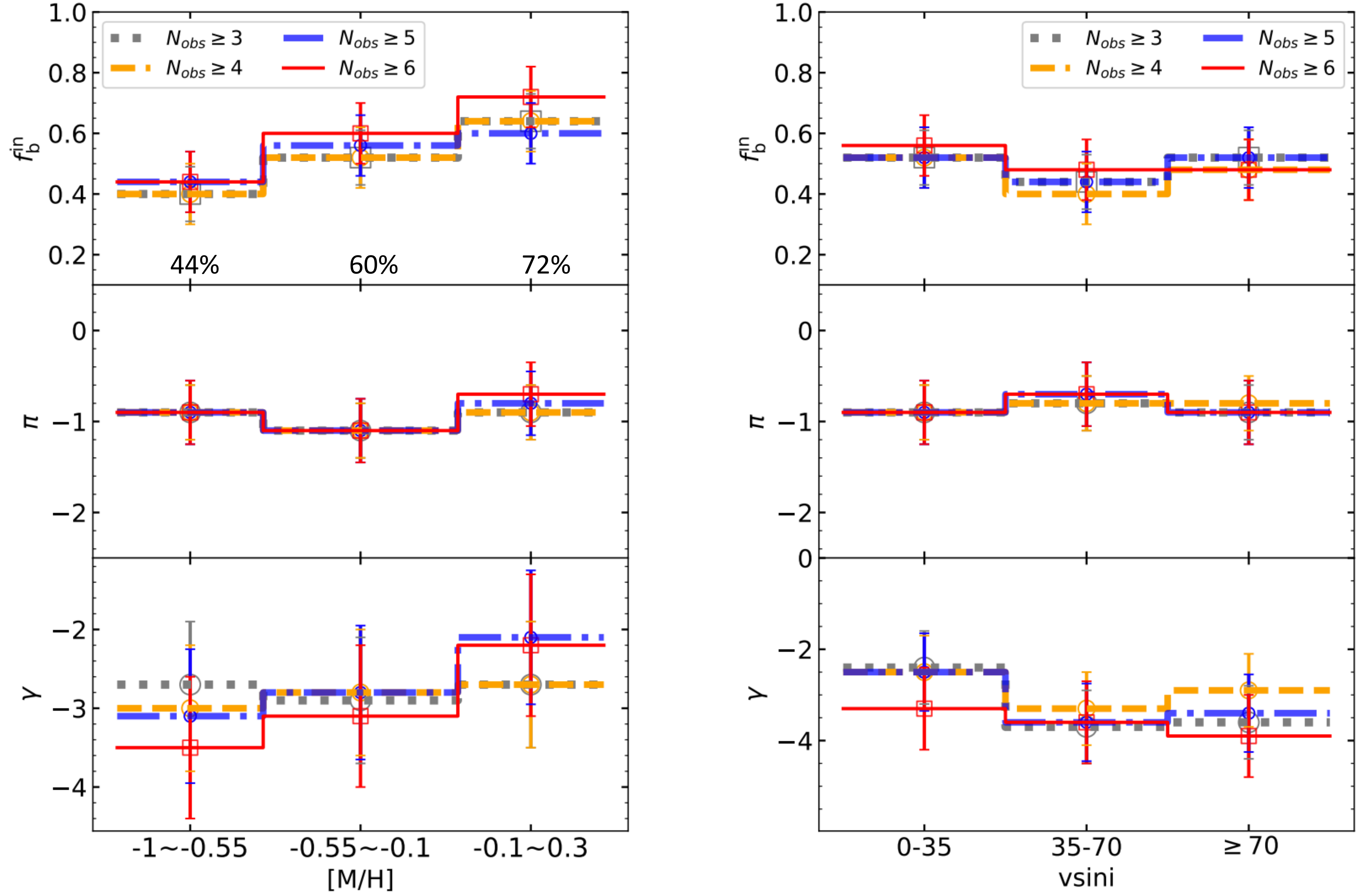


O-B3 Type Stars: Consistent with Galactic O-type stars (Sana et al. 2013)

Due to fewer observations

- Larger fb than OB stars from LAMOST DR5 (Luo et al. 2021)
- Lower fb in Guo et al. (2022)

Results



- Binary fraction increases with [M/H].
- Correlation between the statistical parameters and v sin i.

Summary

- Collect 886 early-type stars with more than six observations from LAMOST DR8, divide the sample based upon effective temperature, the metallicity [M/H] and the projection rotation velocity.
- **Intrinsic Binary Fraction**:
  - Increases with Teff and is positively correlated with metallicity
  - Projection Velocity: No correlation with Vsini
- **Orbital Period & Mass Ratio**:
  - No clear correlation with Teff or [M/H], potentially due to short observational cadence
- Examined **uncertainties** related to sample size and observation frequency
  - Found that larger sample sizes and higher frequencies reduce statistical uncertainties

THE END

Thank you！

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Funding and Supports (NSFC & CAS-BR)

- Senior position
- Research start-up fund (1-3 million RMB)
- Living subsidy (>1 million RMB pre-tax)
- Competitive salary and benefits
- A transitional apartment

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Other job positions (YNAO-Phoenix program)

- Talent Recruitment (Full-time / Flexible)
- Young Science and Technology Talents
- Special Research Assistants
- Postdoctoral Fellows (0.2-0.3 million RMB/yr pre-tax & a free apartment)

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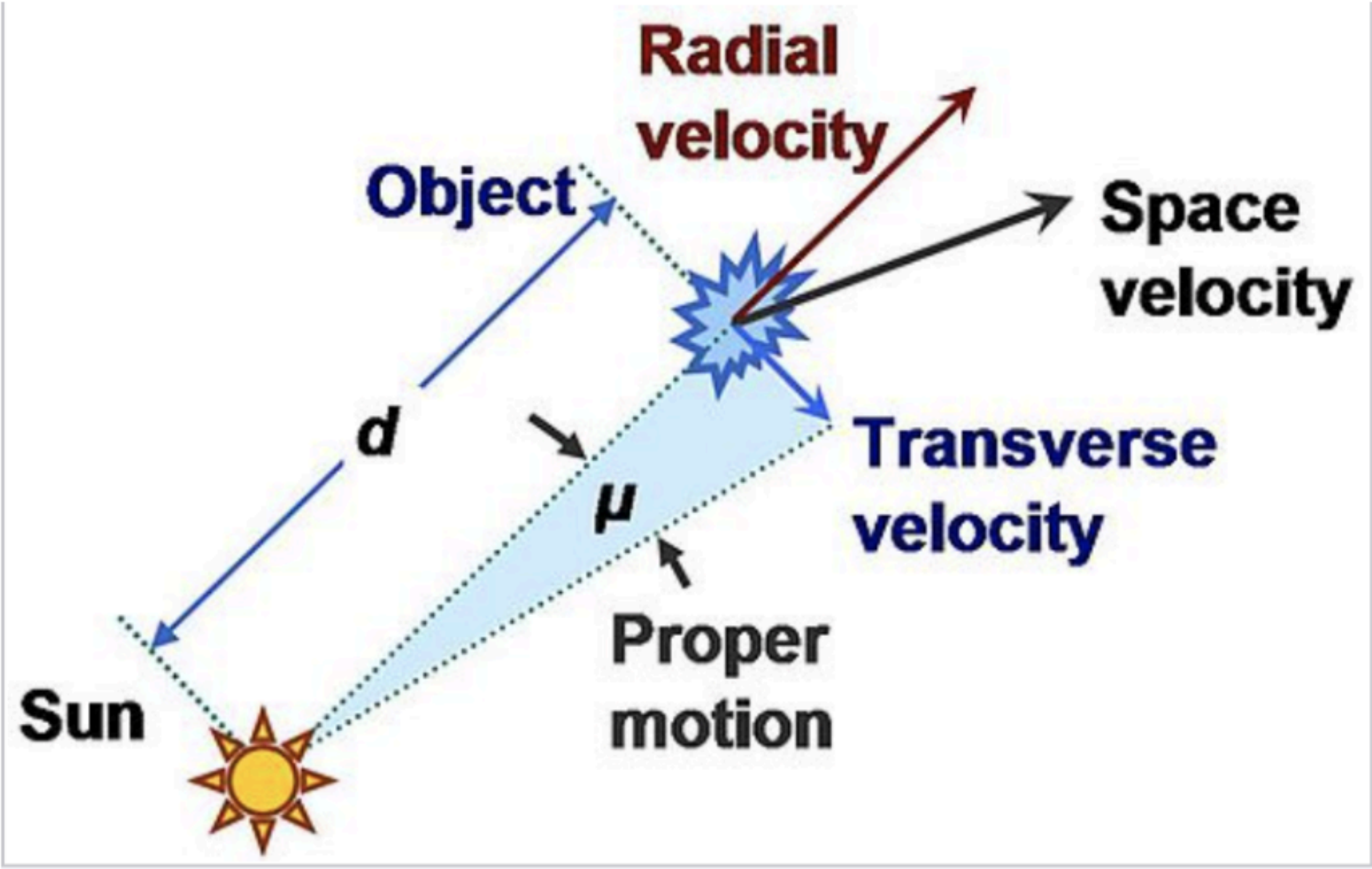
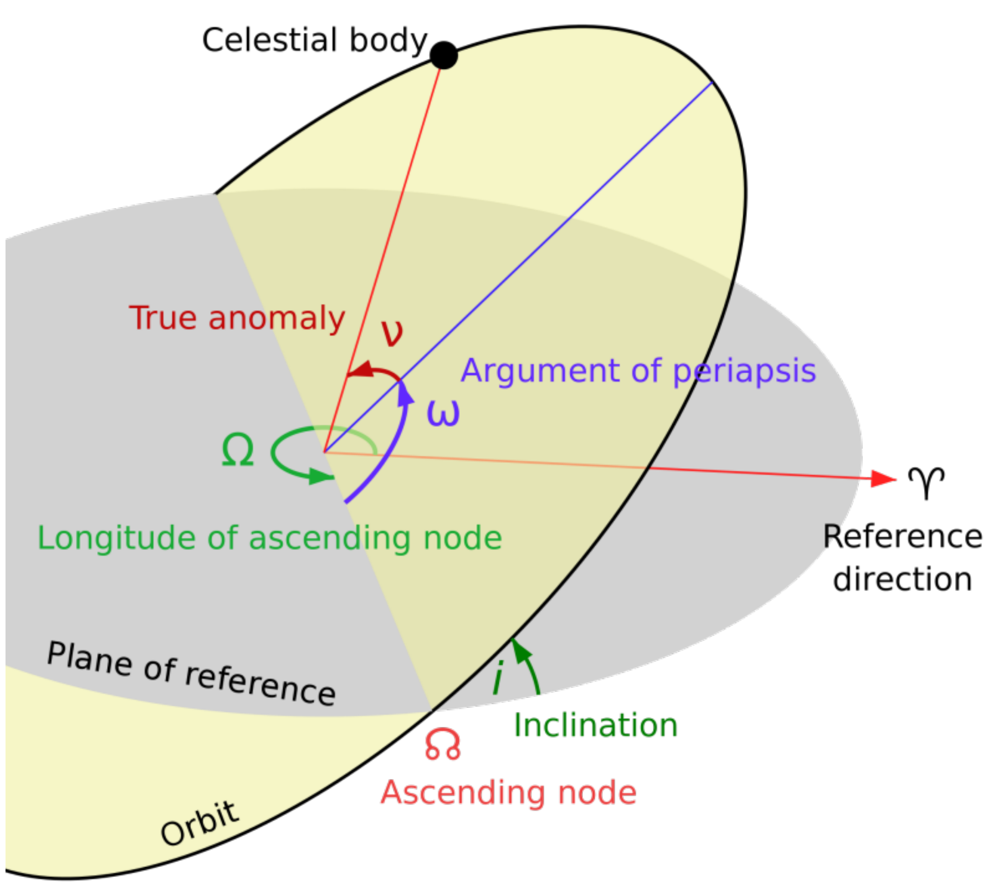

Radial velocity
Object
Space velocity
d
μ
Transverse velocity
Proper motion
Sun

Name	Comment
P	orbital period
q	mass ratio
e	eccentricity
m_1	mass of the primary
i	angle of inclination
ω	longitude of the periastron
T_0	the time of periastron passage



早型星的双星比例和参数分布->结果