中国科学院云南天文台
YUNNAN OBSERVATORIES,CHINESE ACADEMY OF SCIENCES

Mass-Ratio Distribution of Binaries From the LAMOST-MRS Survey

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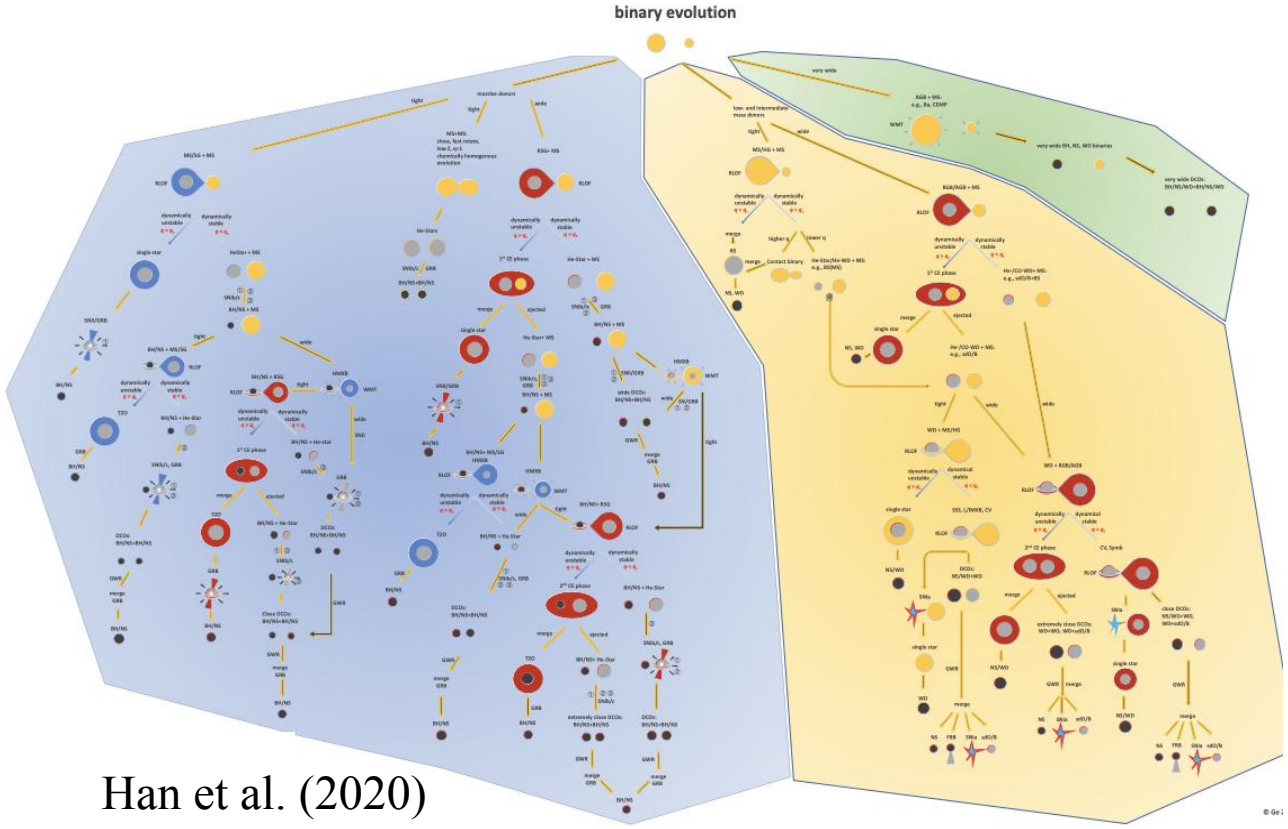
Litomyšl, Binary and Multiple Stars in the Era of Big Sky Surveys

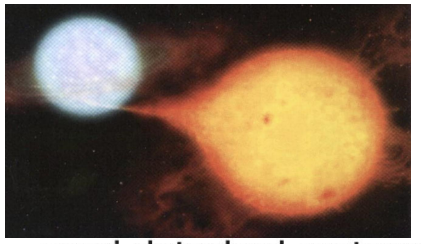
Outline

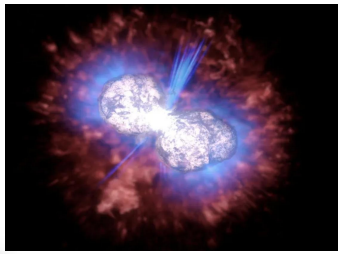
1. Introduction
2. Data
   - LAMOST-MRS
3. Method
4. Results
5. Conclusions

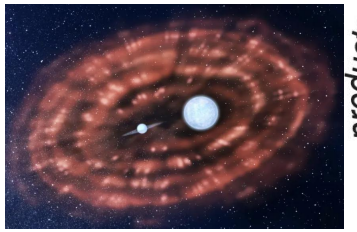
Introduction



Han et al. (2020)







Binary evolution explains most of the mysteries in the world of stars:

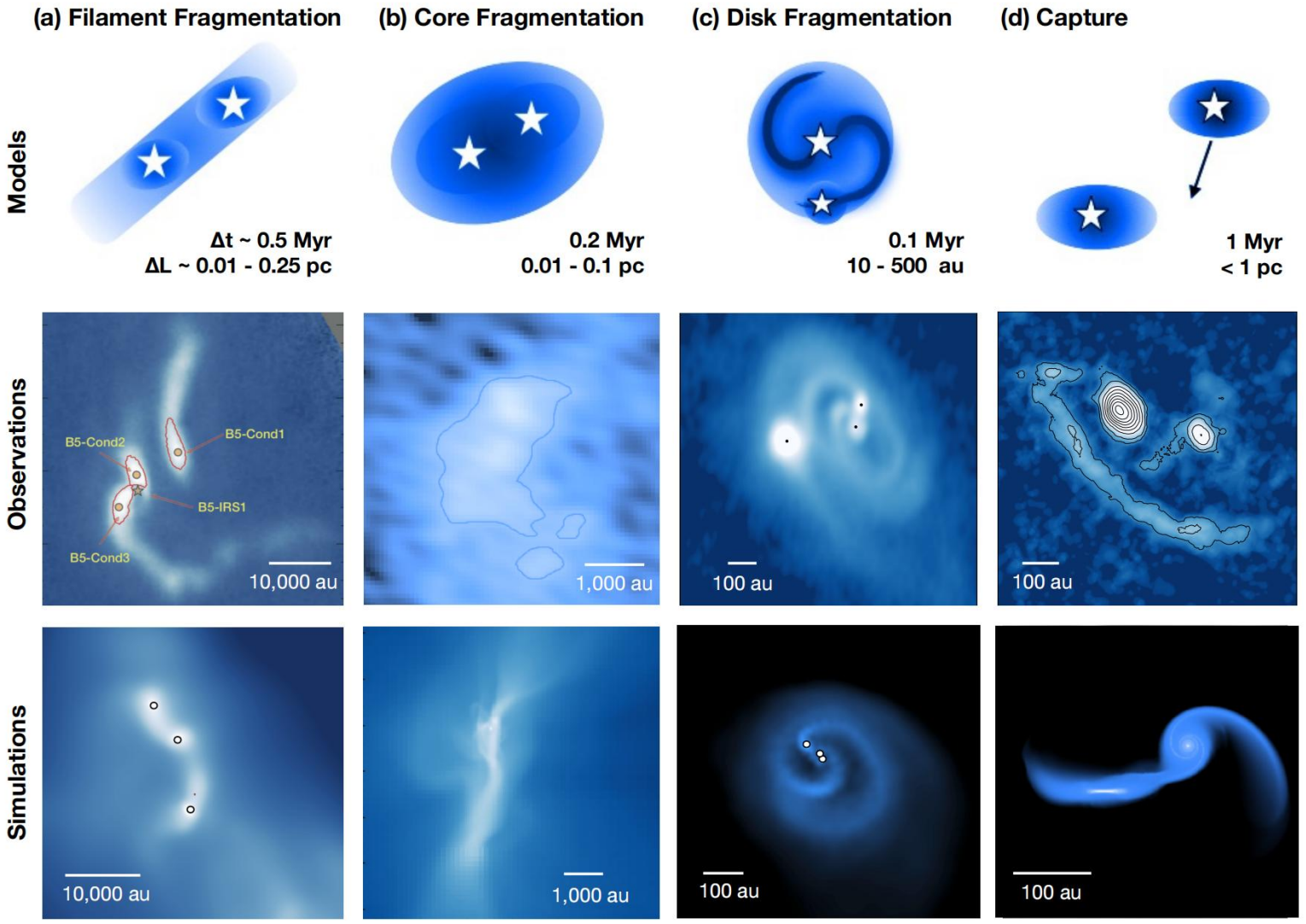
- **the Algol paradox**
- **symbiotic star spectra**
- **the formation of barium stars**

(de Mink et al. 2014)

Statistical properties

Testing and refining current theories of binary formation.

Accurately constraining these properties is crucial for advancing our understanding of binary evolution.

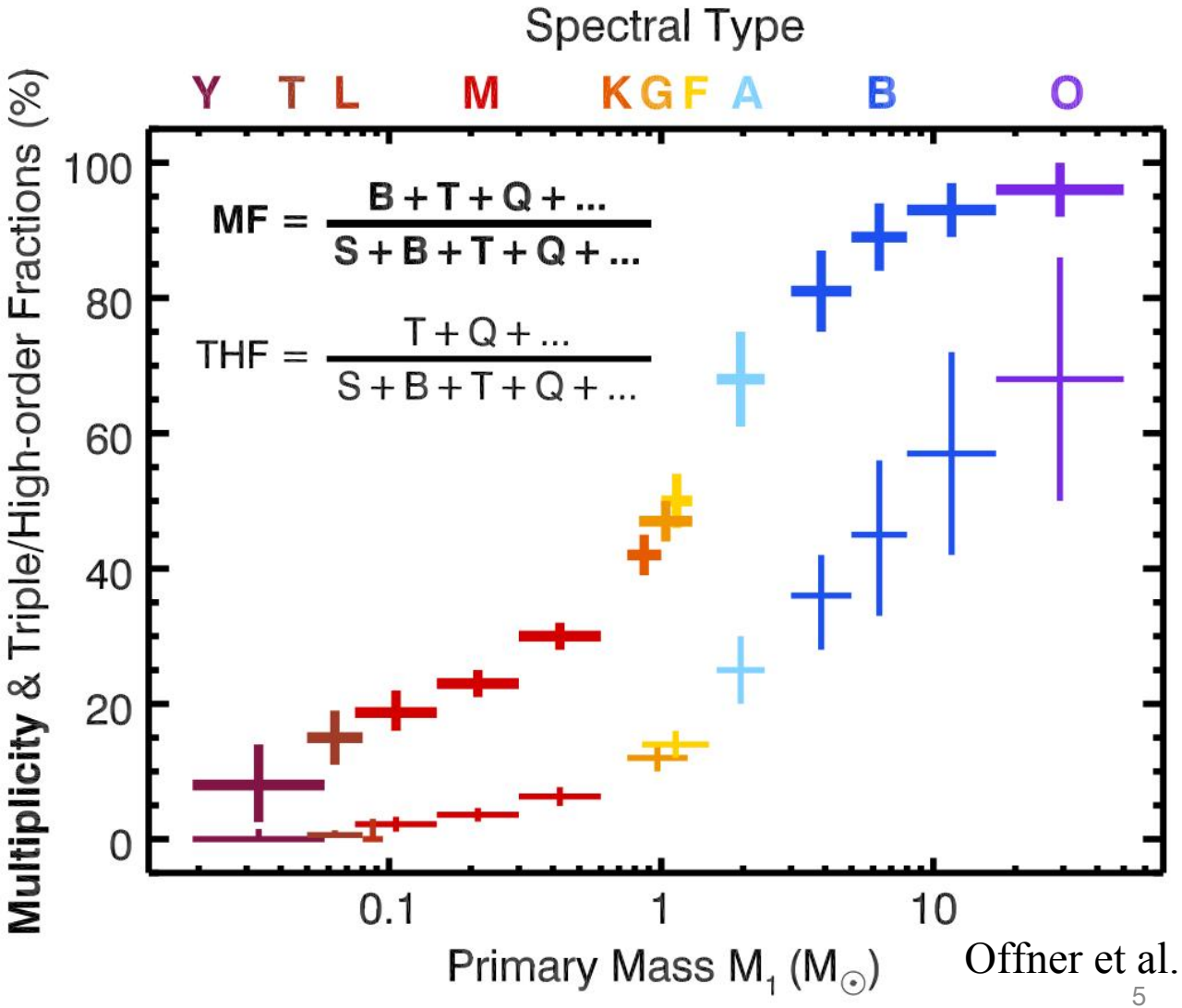


Offner et al. (2022)

Statistical properties

Input parameters for binary population synthesis models

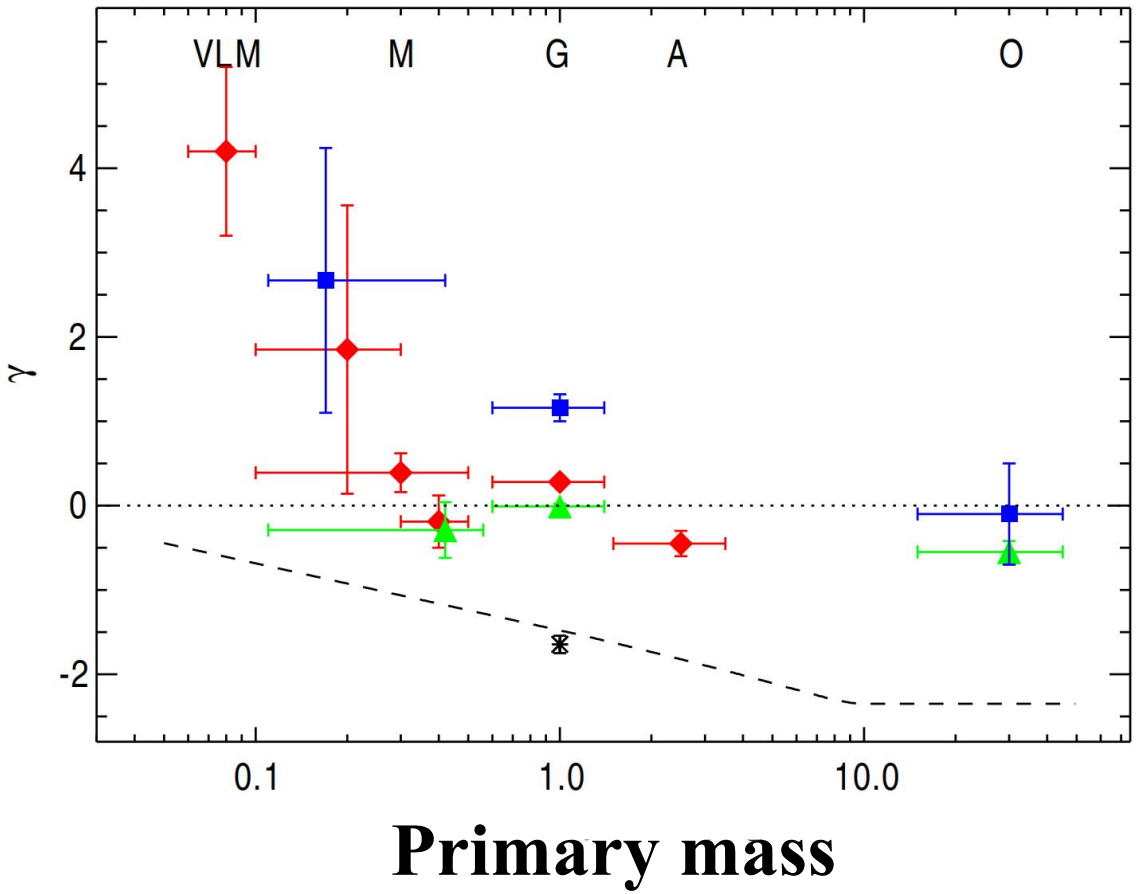
- **binary fraction**
- **orbital period distribution**
- **mass ratio distribution**
- **eccentricity distribution**



Offner et al. (2022)

Statistical properties

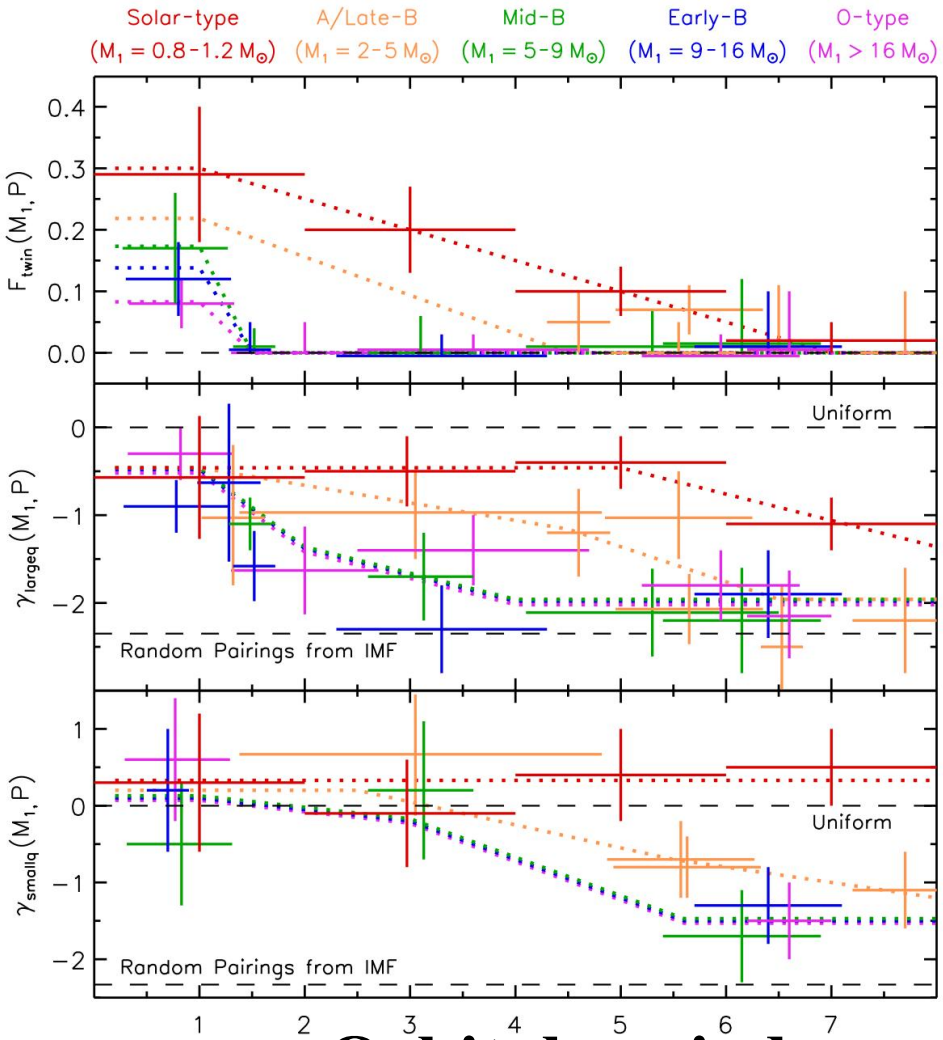
mass ratio distribution



Duchene et al. (2013)

q ~ 1

q < 1

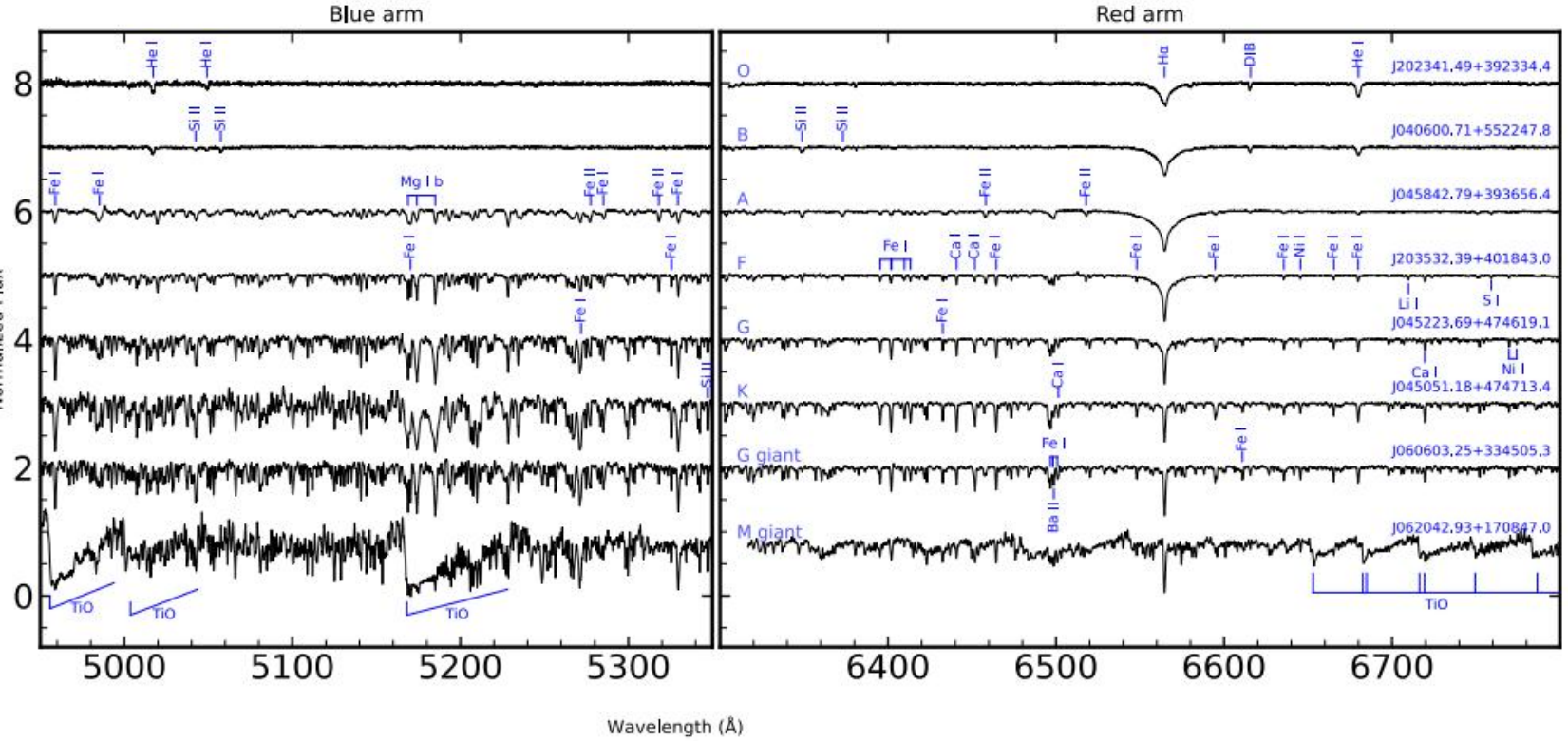


Moe et al. (2017)

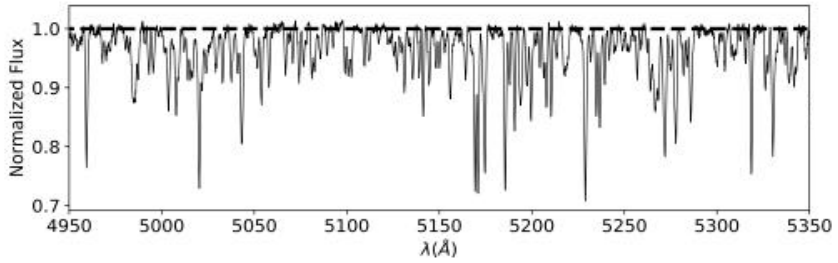
Data

LAMOST-MRS

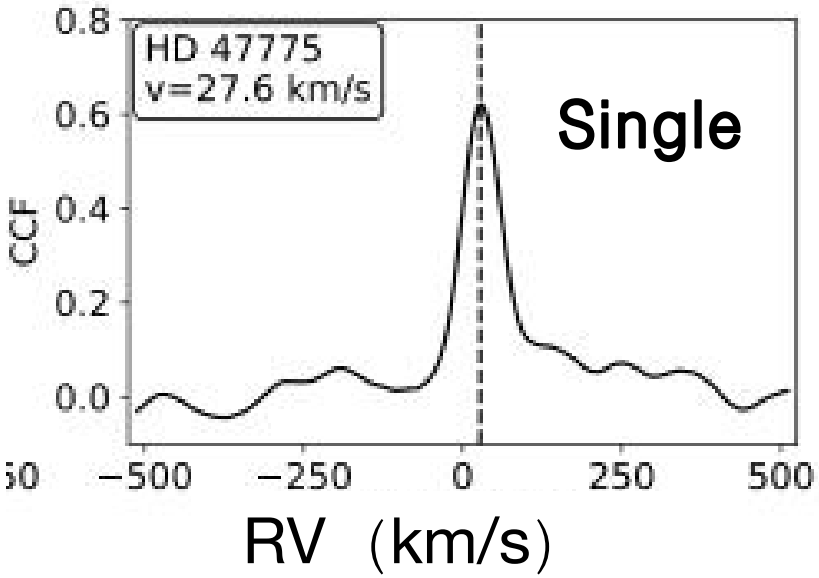
- Fiber： 4000
- Resolution：~7500



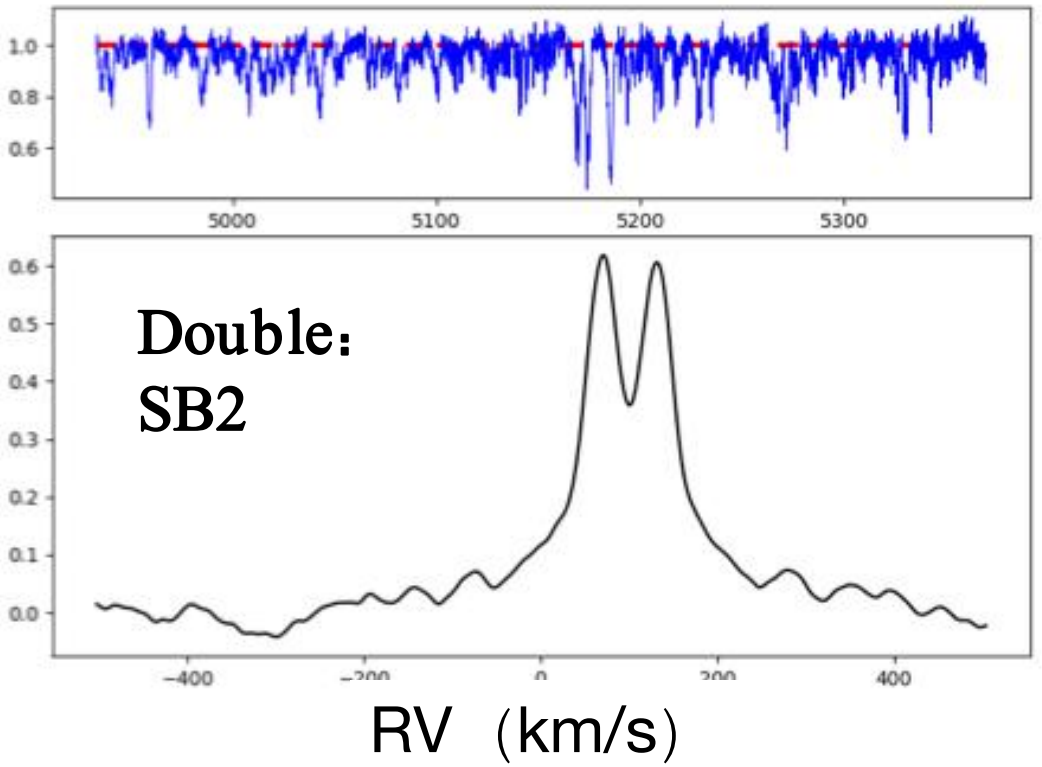
Data



$$\mathrm{CCF}(h) = \int_{-\infty}^{+\infty} f(x)g(x+h)\mathrm{d}x$$



Peak： number, position, and amplitude



Li C, et al. (2021)： LAMOST-MRS DR7

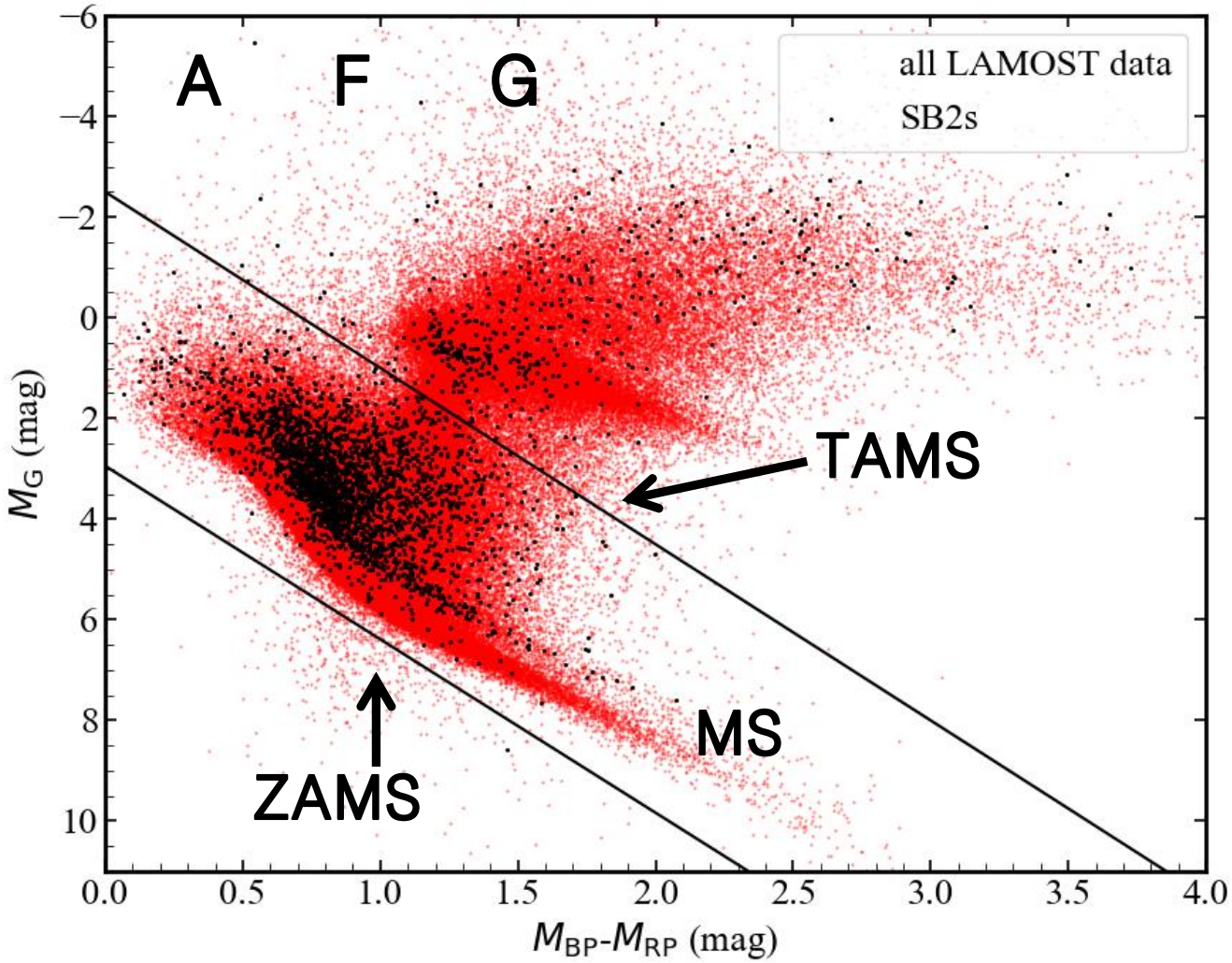
3133 SB2, 132 SB3

Data

Cross-match with *Gaia* DR2

G、Bp、Rp magnitude

HR Diagram

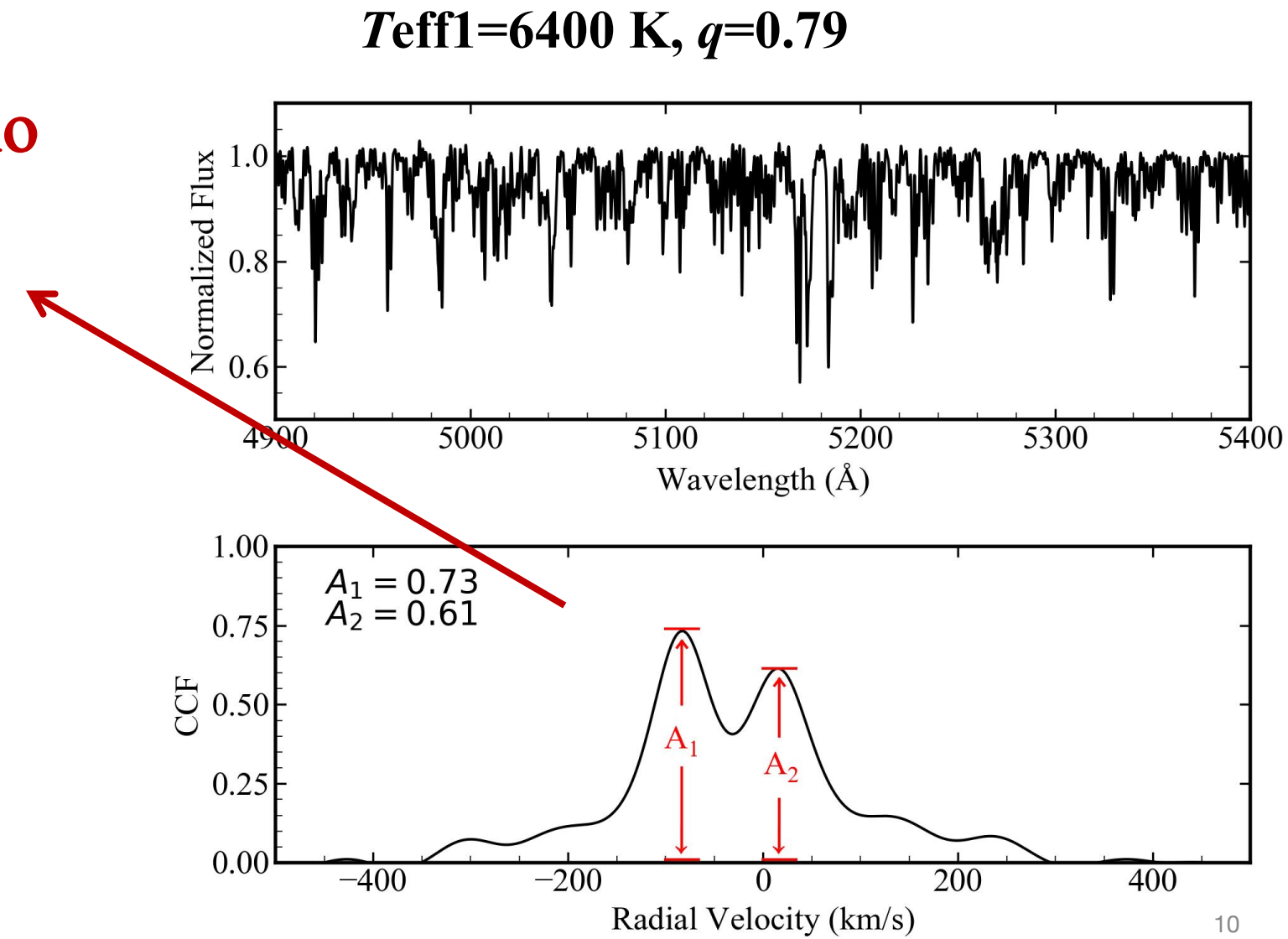


Method——PAR

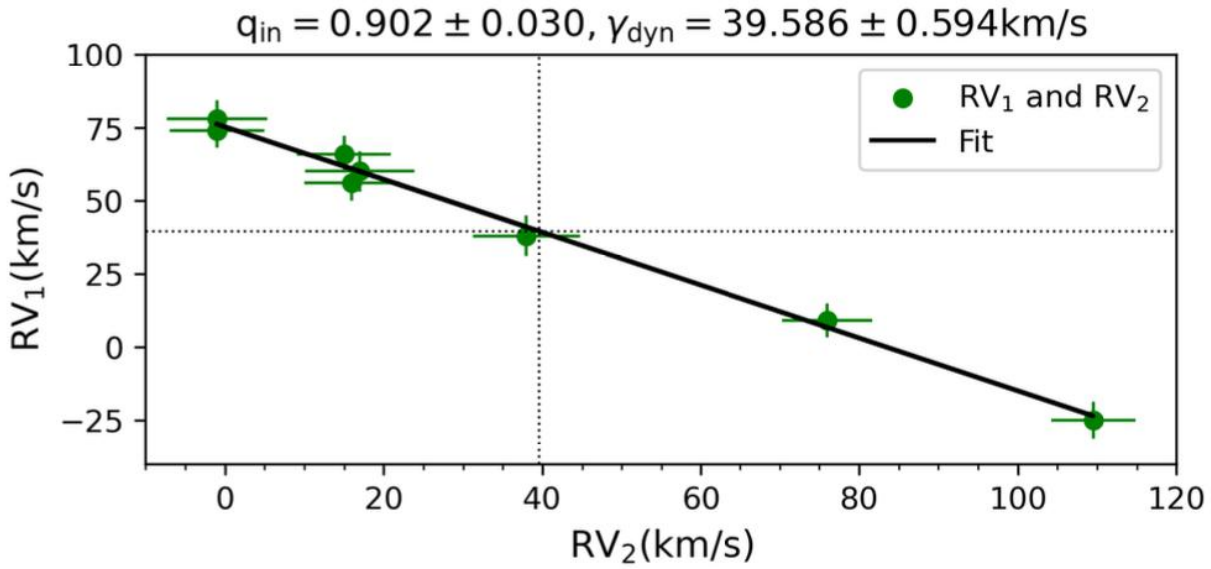
Peak-amplitude ratio (PAR)

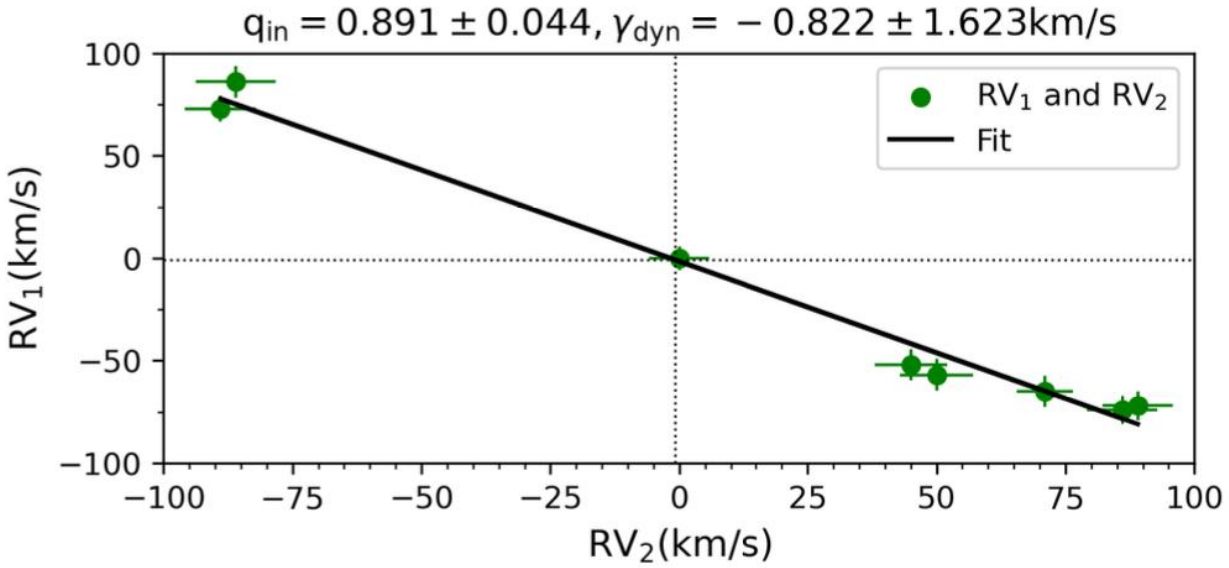
A2/A1

luminosity ratio/ mass ratio



Method——PAR





$$RV_1 = \gamma_{dyn}(1 + q_{in}) - q_{in}RV_2$$

(Wilson, O. C. 1941)

- $q_{in} = 0.902 \pm 0.030$,
  $\gamma_{dyn} = 39.586 \pm 0.594$km/s,

  PAR: $q_{in} = 0.881 \pm 0.138$。

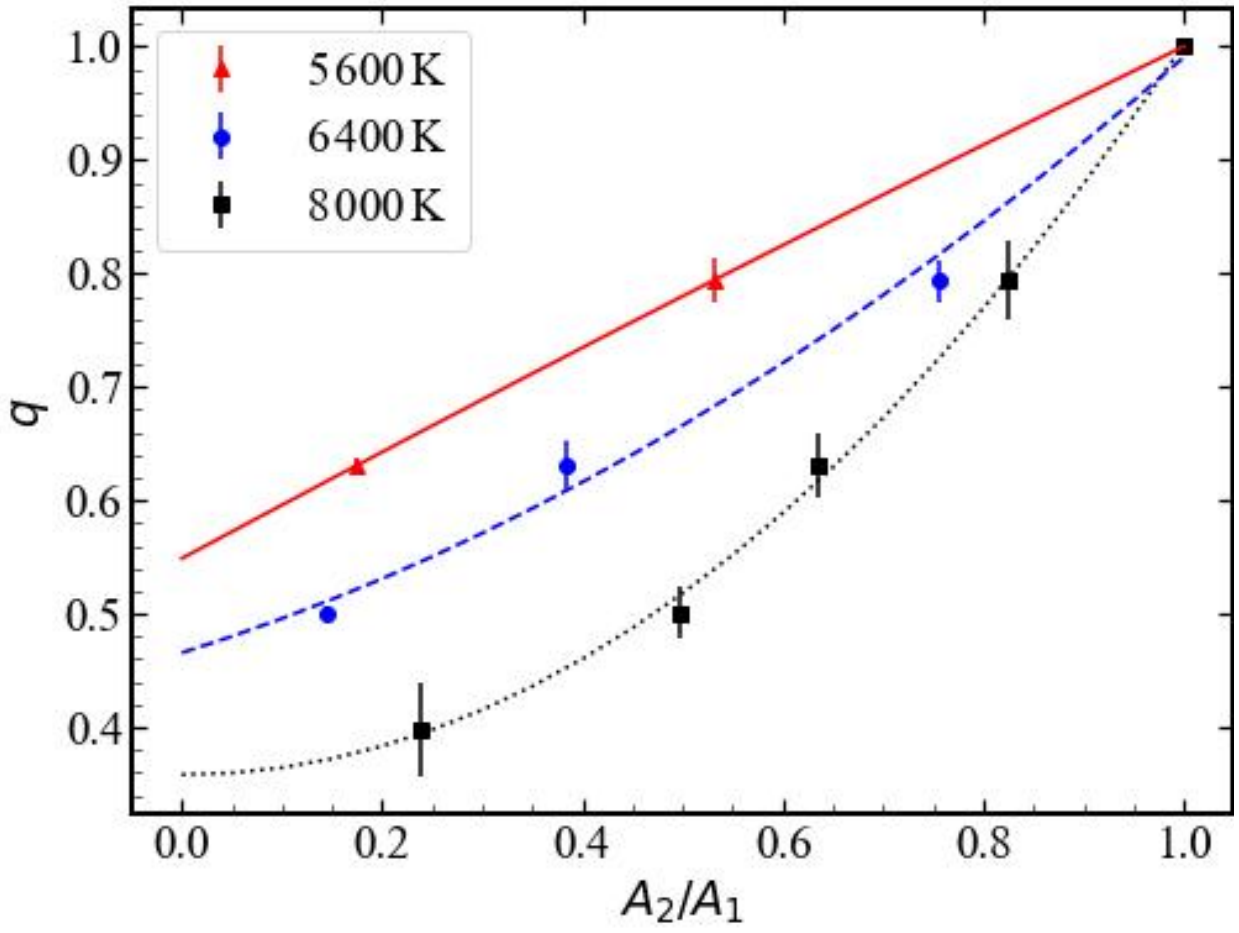
- $q_{in} = 0.891 \pm 0.044$,
  $\gamma_{dyn} = -0.822 \pm 1.623$km/s,

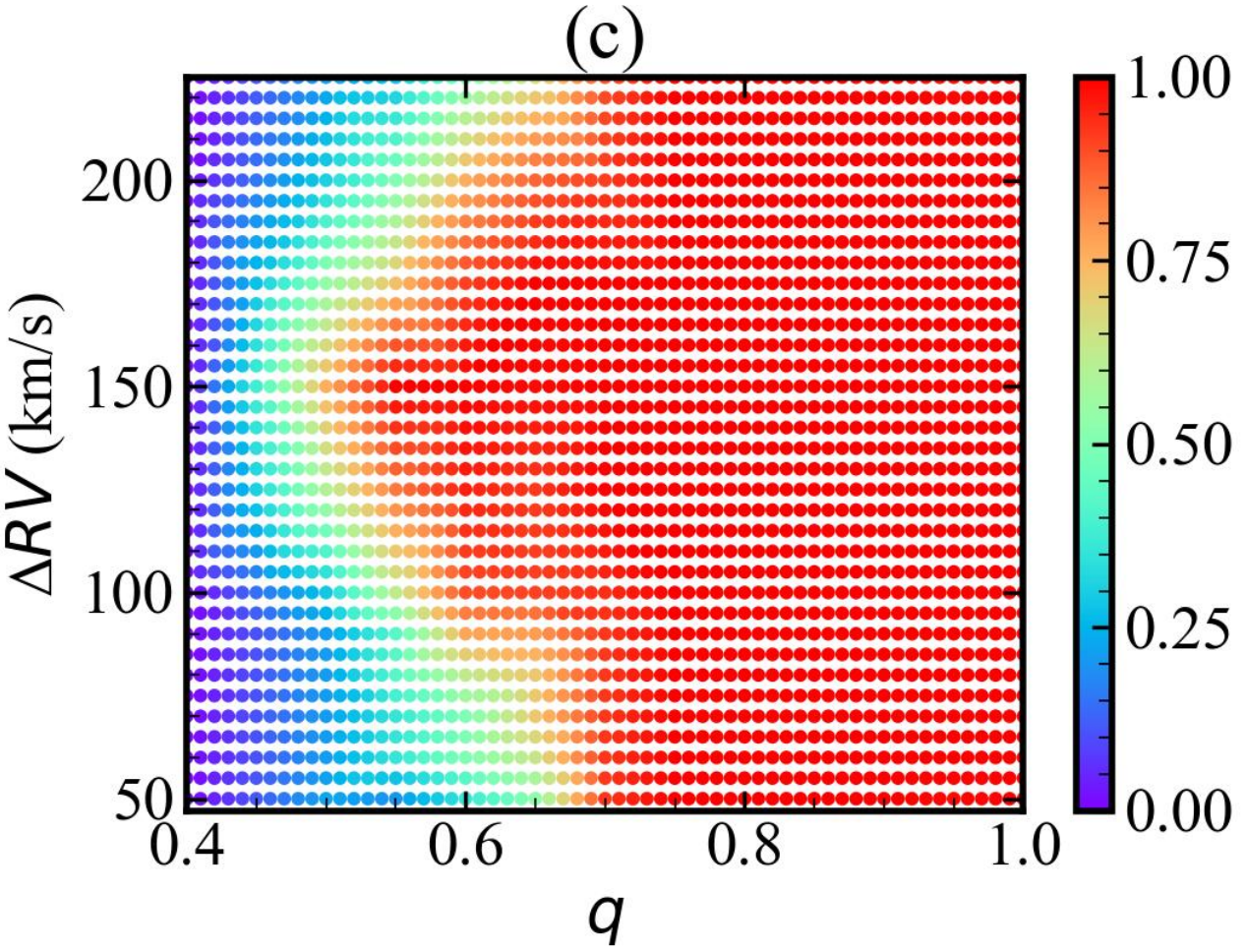
  PAR: $q_{in} = 0.872 \pm 0.136$

Method——PAR (Li et al. 2022, ApJ, 933, 119)

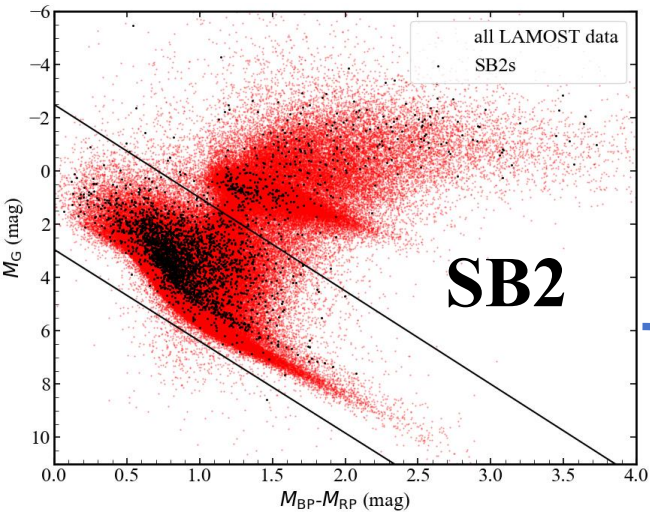
PAR --> Mass ratio

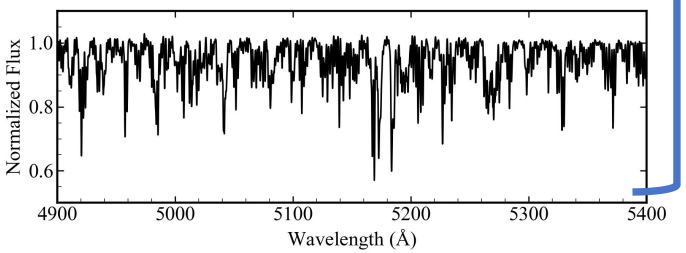
The relationship between SB2 detection efficiency, mass ratio, and radial velocity difference： correcting for selection effects in SB2 detection.

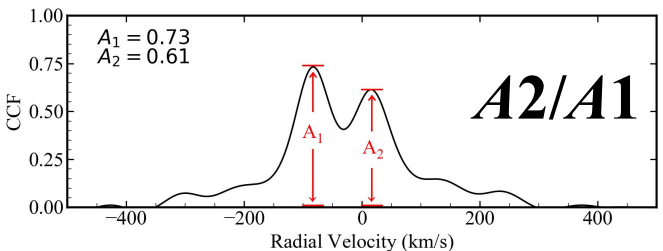




Results——Mass Ratio Distribution

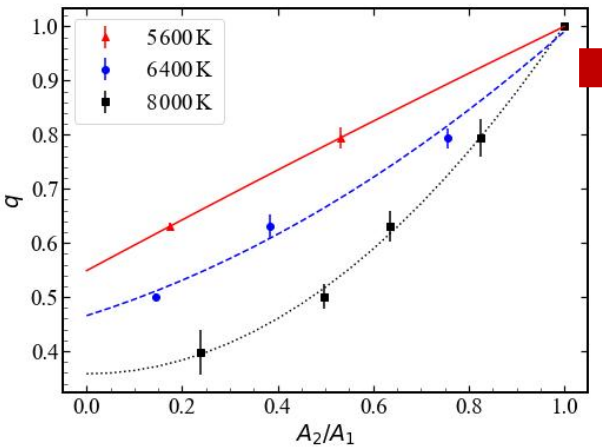


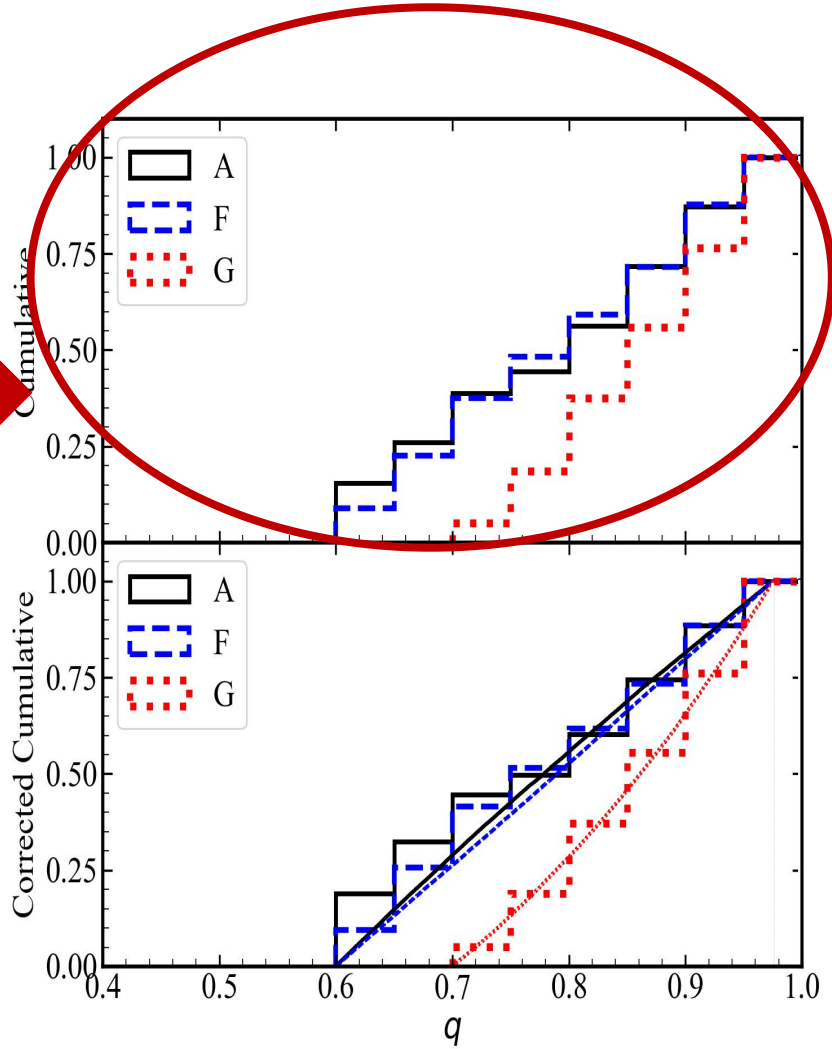




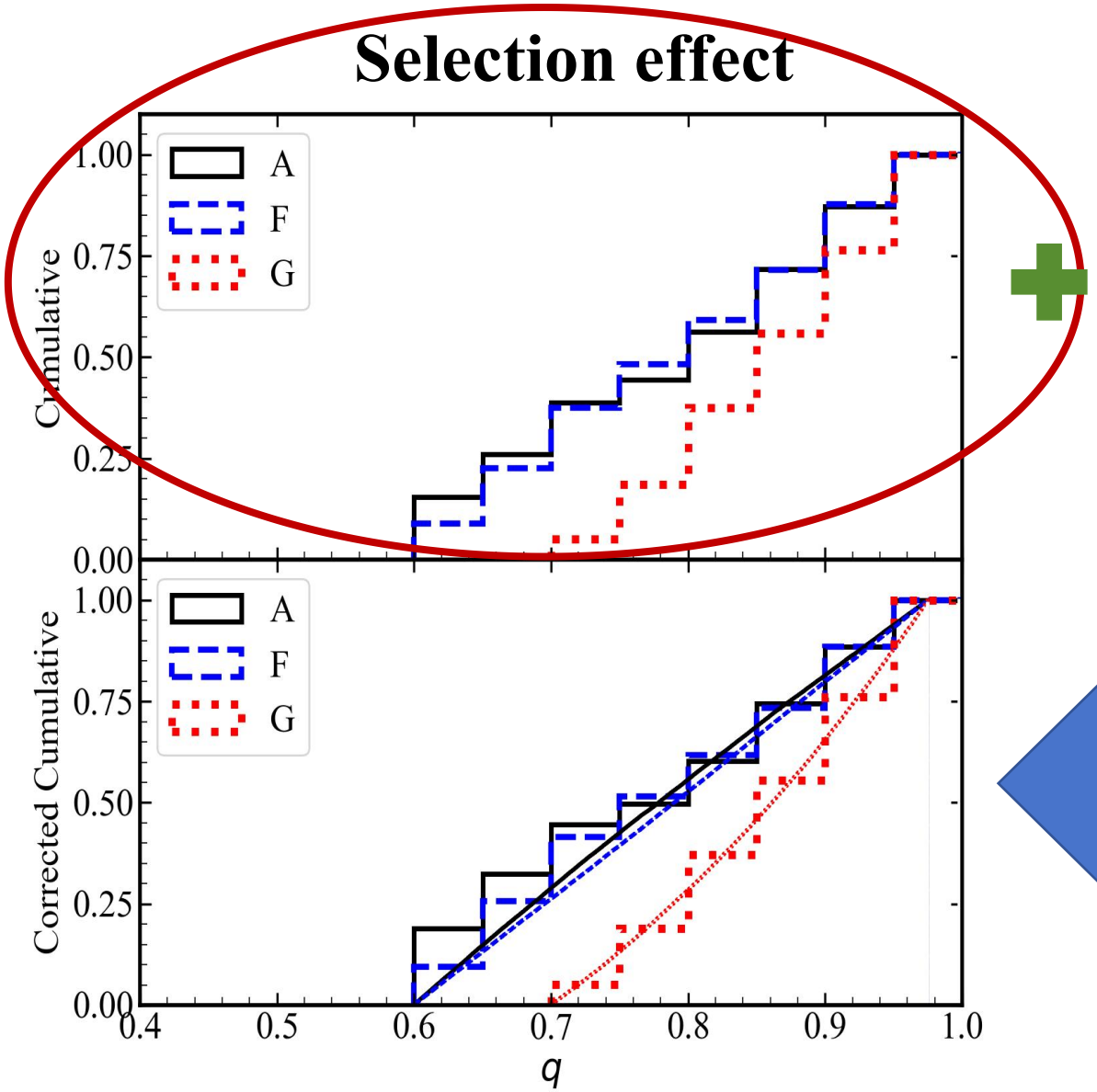
PAR

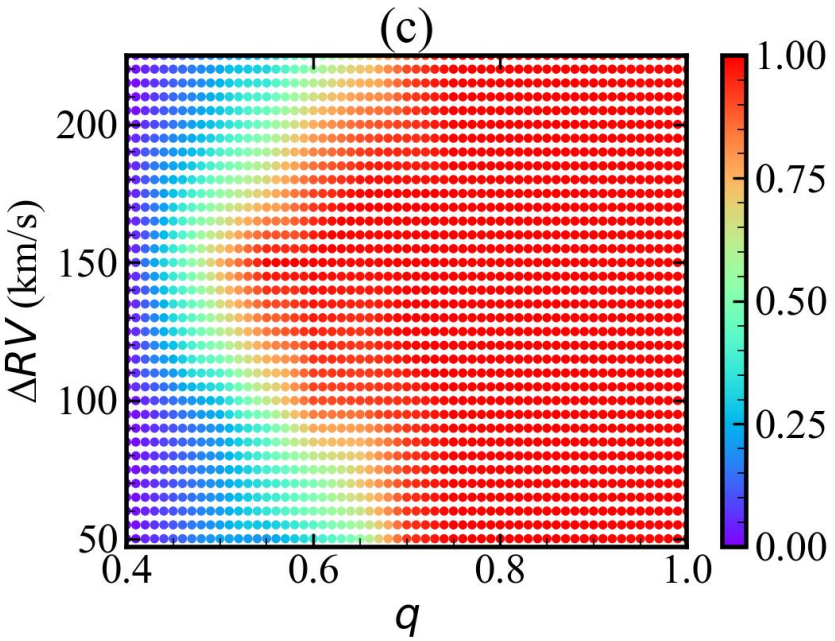
formula





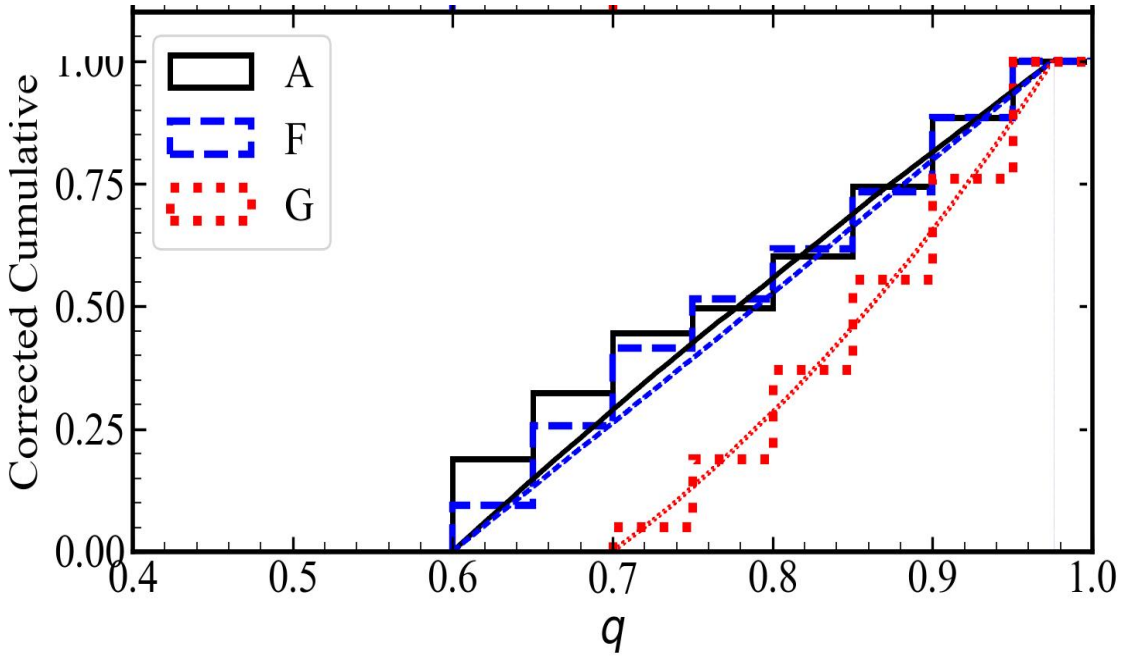
Results——Mass Ratio Distribution





power law equation： $dn/dq \propto q^{\gamma}$

Results——Mass Ratio Distribution

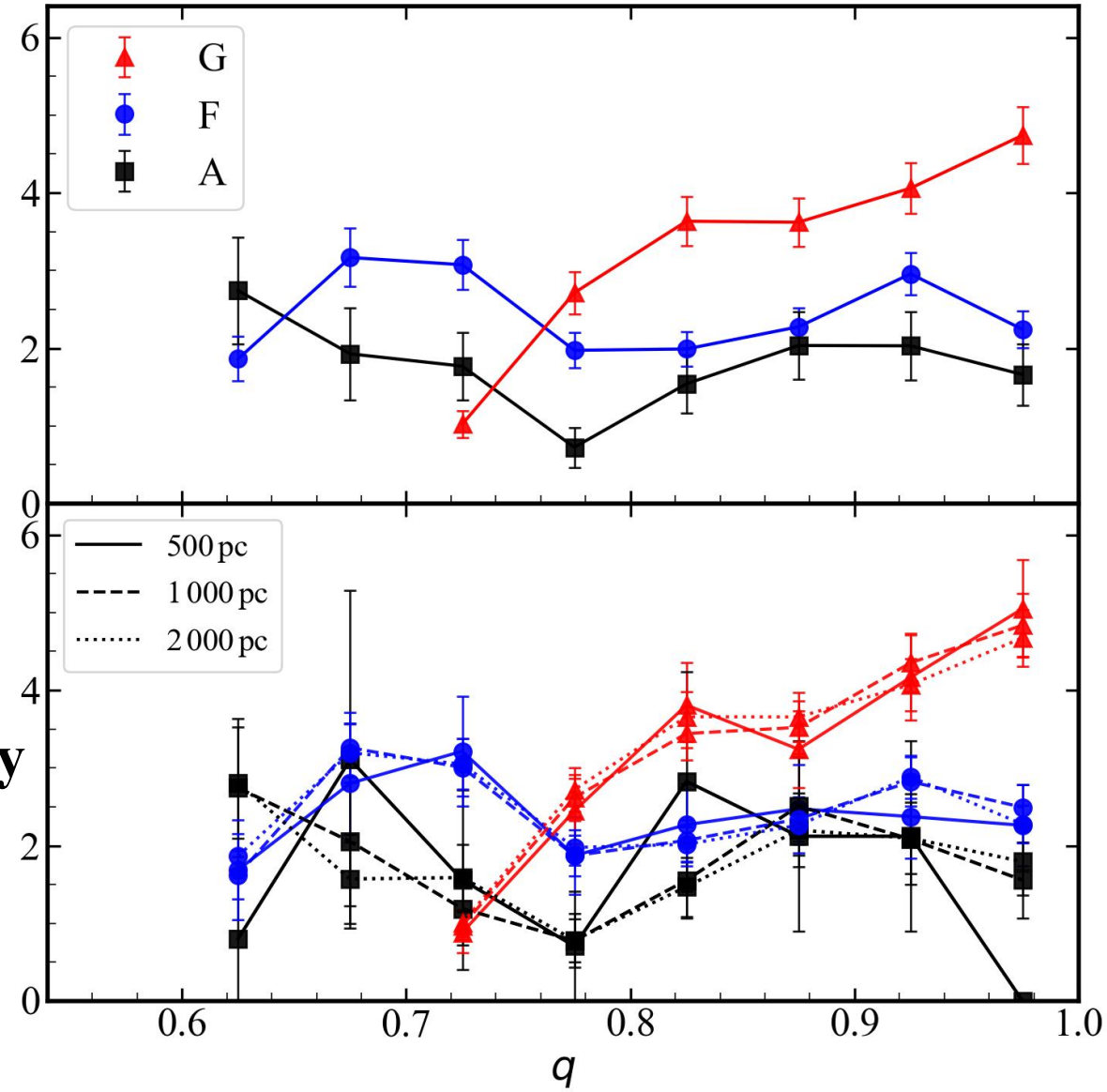


Index of mass ratio distribution：

A： −0.42 ± 0.27

F： 0.03 ± 0.12

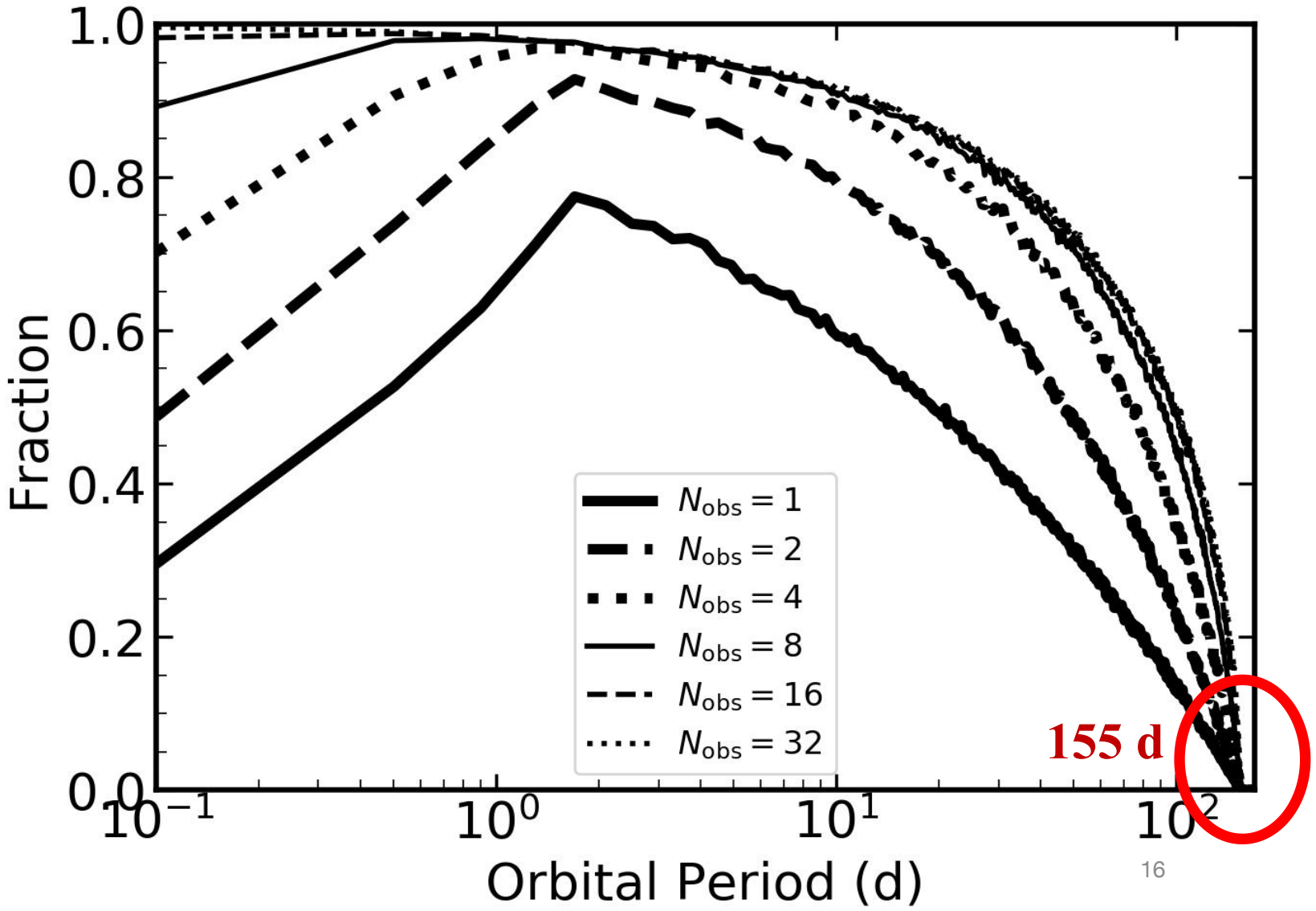
G： 2.12 ± 0.19 **(a compariable companion)**



Discussions——Period Range

The detection efficiency of binary systems also depends on the orbital period and the timing of observational epochs.

The CCF method is capable of detecting SB2 systems with orbital periods shorter than 155 days.



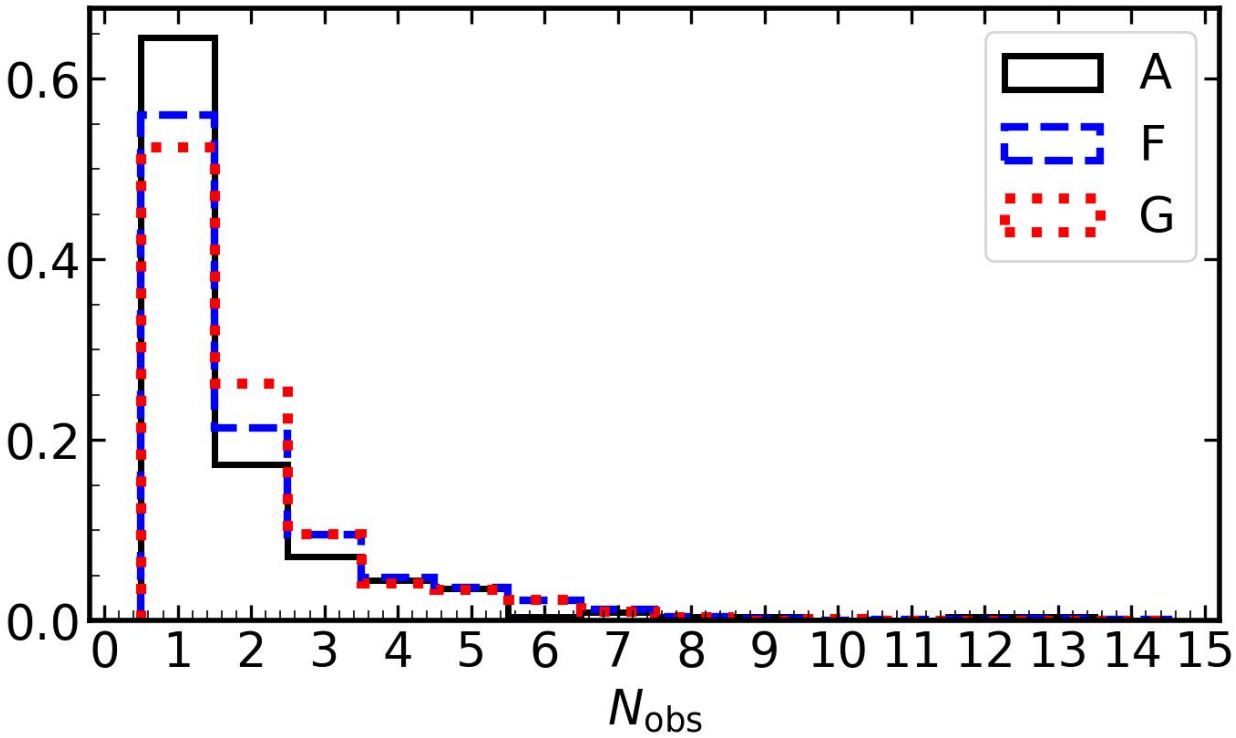
Discussions——Close Binary Fraction

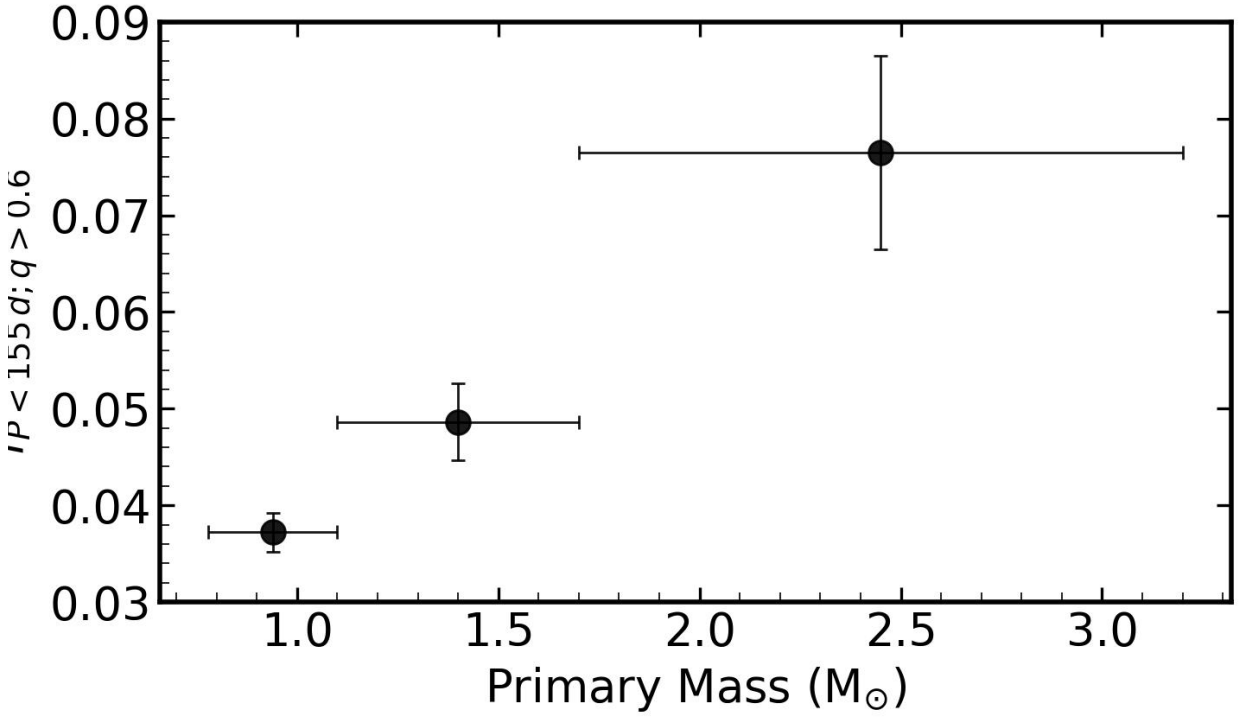
Distribution of SB2 observational epoches

- only 1 : >55%
- < 5 : ~96%

Close Binary Fraction:

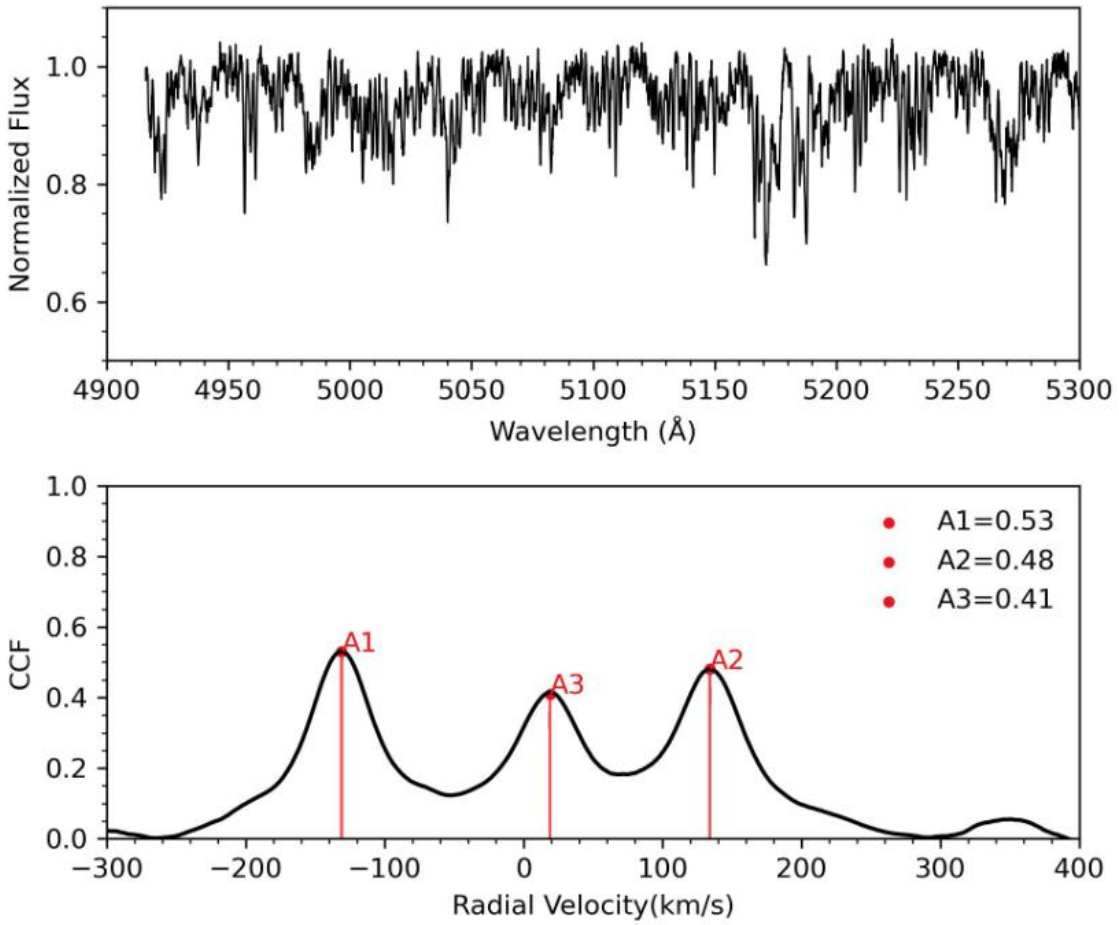
- A: 7.6 ± 0.5%
- F: 4.9 ± 0.2%
- G: 3.7 ± 0.1%



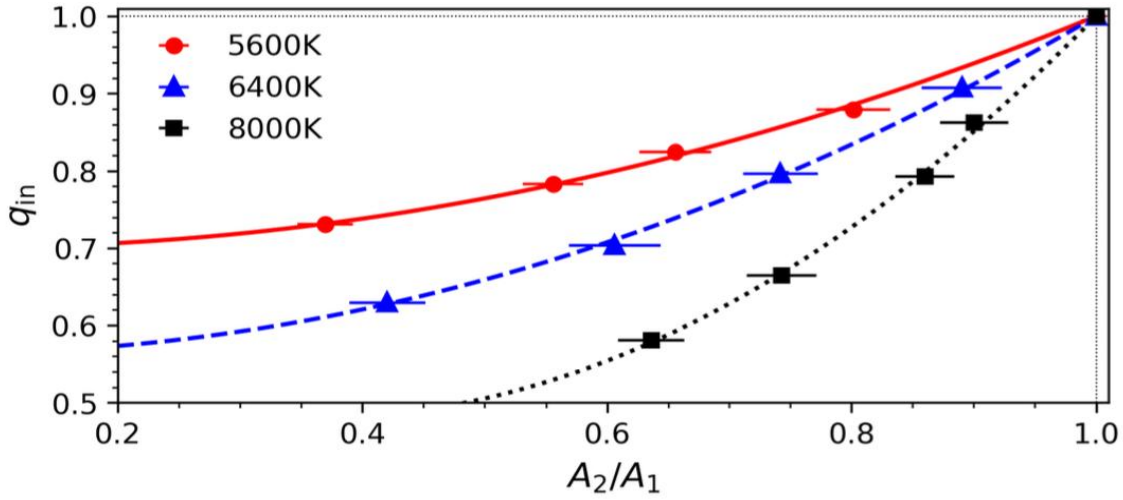


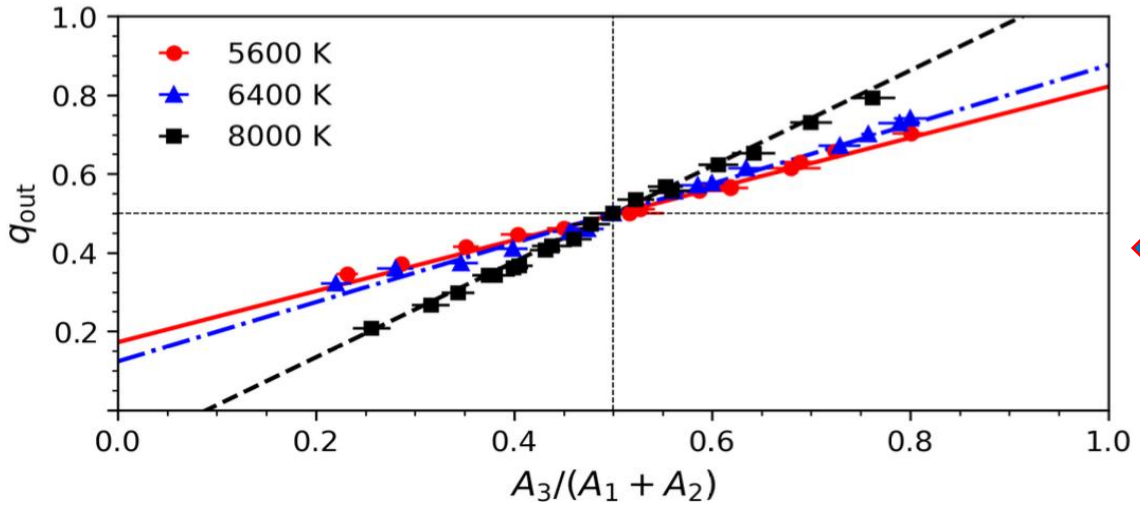
Mass Ratio Distribution of Hierarchical Triple Systems (He, Li, et al. 2023)

We use the PAR method to determine the mass ratio distribution of triple systems.



Mass Ratio Distribution of Hierarchical Triple Systems (He, Li, et al. 2023)





$$q_{in} = 0.348 \pm 0.044 \times (\frac{A_2}{A_1})^2 - 0.051 \pm 0.064 \times \frac{A_2}{A_1} + 0.702 \pm 0.021 \quad (5200K \leq T_{eff} \leq 6000K) \tag{4}$$

$$q_{in} = 0.495 \pm 0.054 \times (\frac{A_2}{A_1})^2 - 0.061 \pm 0.082 \times \frac{A_2}{A_1} + 0.566 \pm 0.028 \quad (6000K \leq T_{eff} \leq 7200K) \tag{5}$$

$$q_{in} = 1.256 \pm 0.046 \times (\frac{A_2}{A_1})^2 - 0.894 \pm 0.068 \times \frac{A_2}{A_1} + 0.638 \pm 0.023 \quad (7200K \leq T_{eff} \leq 8000K) \tag{6}$$

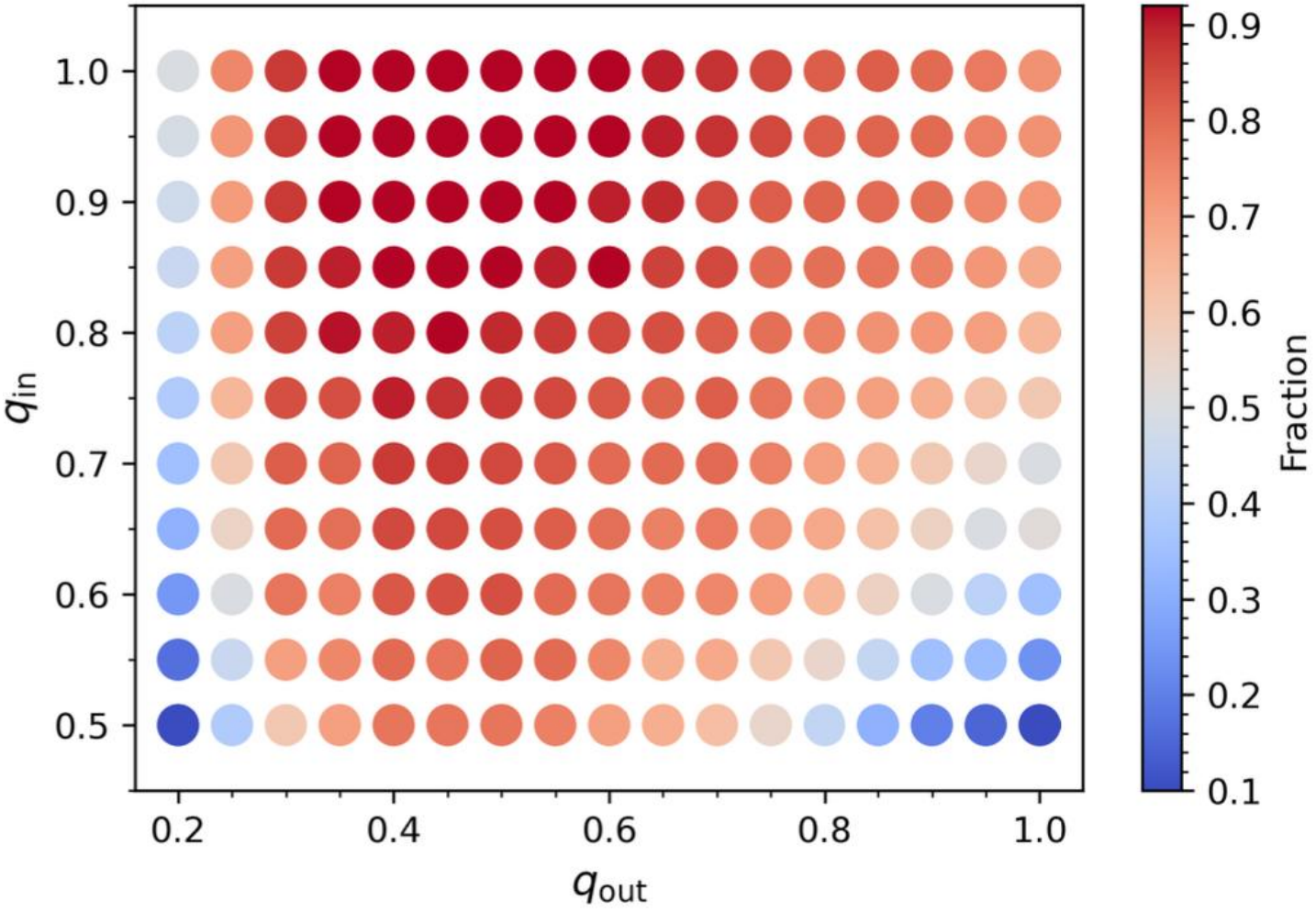
$$q_{out} = 0.650 \pm 0.011 \times \frac{A_3}{A_1 + A_2} + 0.172 \pm 0.006 \quad (5200K \leq T_{eff} \leq 6000K) \tag{7}$$

$$q_{out} = 0.753 \pm 0.023 \times \frac{A_3}{A_1 + A_2} + 0.123 \pm 0.012 \quad (6000K \leq T_{eff} \leq 7200K) \tag{8}$$

$$q_{out} = 1.214 \pm 0.018 \times \frac{A_3}{A_1 + A_2} - 0.109 \pm 0.008 \quad (7200K \leq T_{eff} \leq 8000K) \tag{9}$$

The relationship between mass ratios and amplitude ratios.

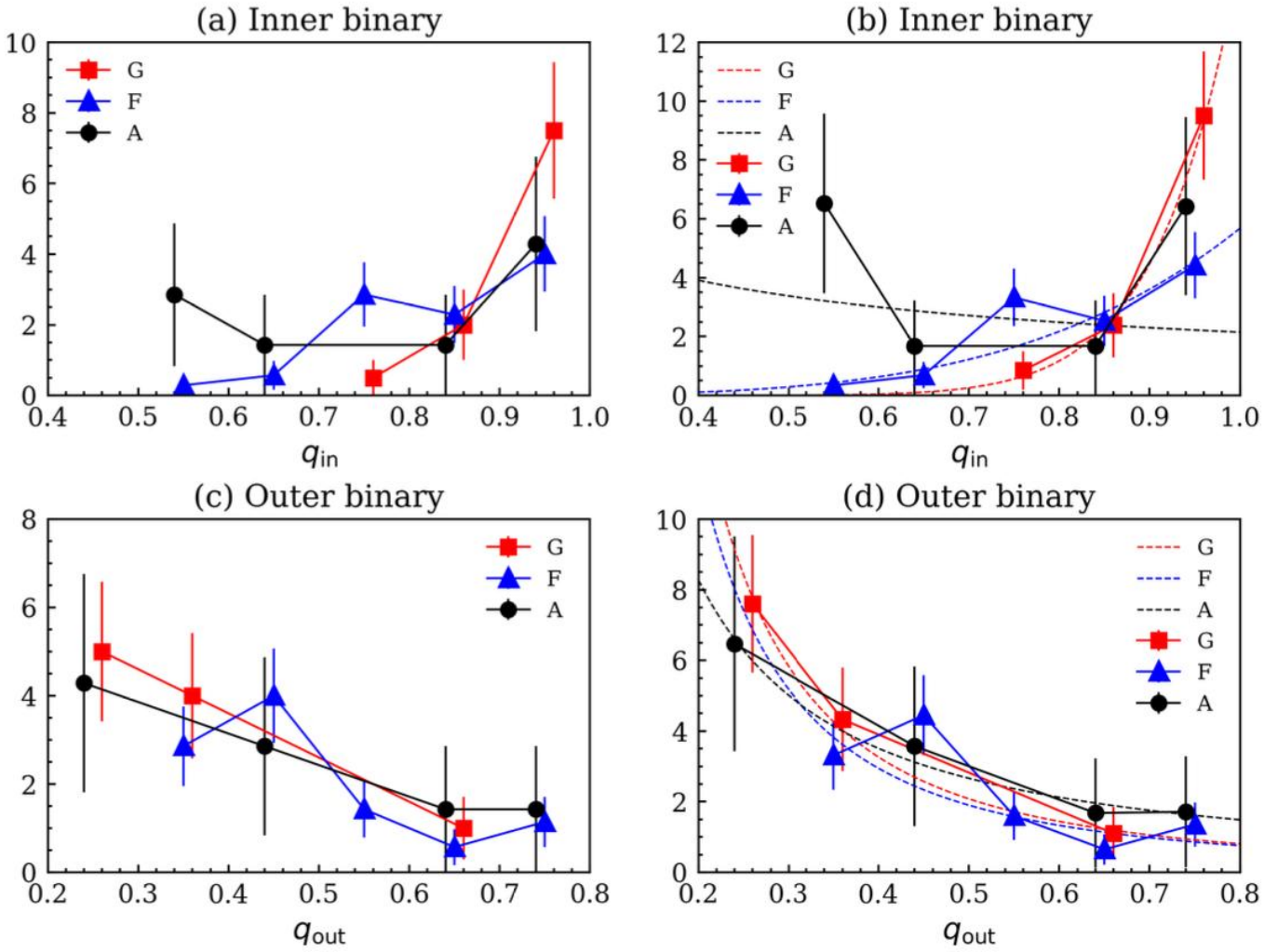
The spectroscopic triples (STs) detection efficiency



Detection efficiency under different qin and qout.

We define detection efficiency as the percentage of synthetic spectra identified as SB3 using the CCF method.

Mass Ratio Distribution of Hierarchical Triple Systems (He, Li, et al. 2023)



Inner binary ($dN/dq_{in} \propto q_{\gamma in}$):

A: -0.654 ± 2.915

F: 4.304 ± 1.125

G: 11.371 ± 1.309

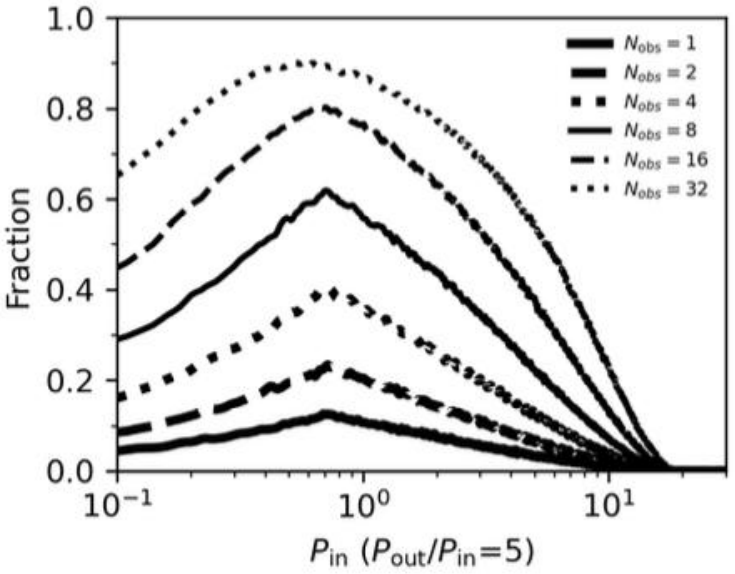
Outer binary ($dN/dq_{out} \propto q_{\gamma out}$):

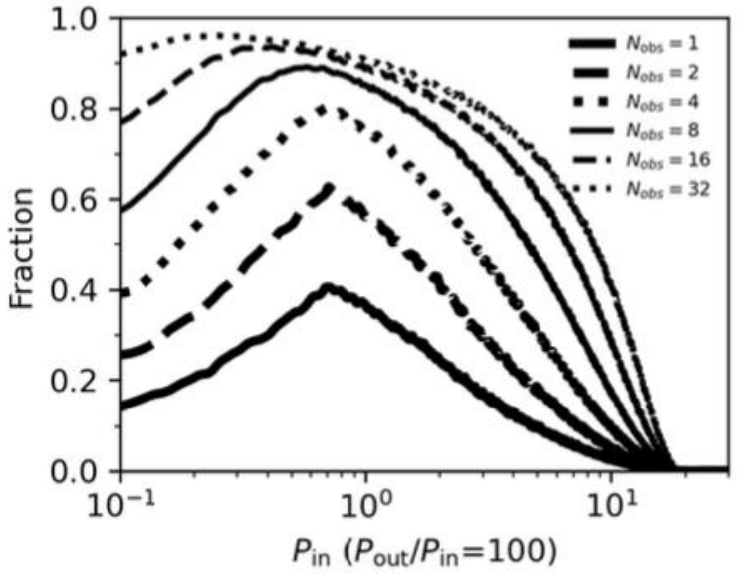
A: -1.238 ± 0.141

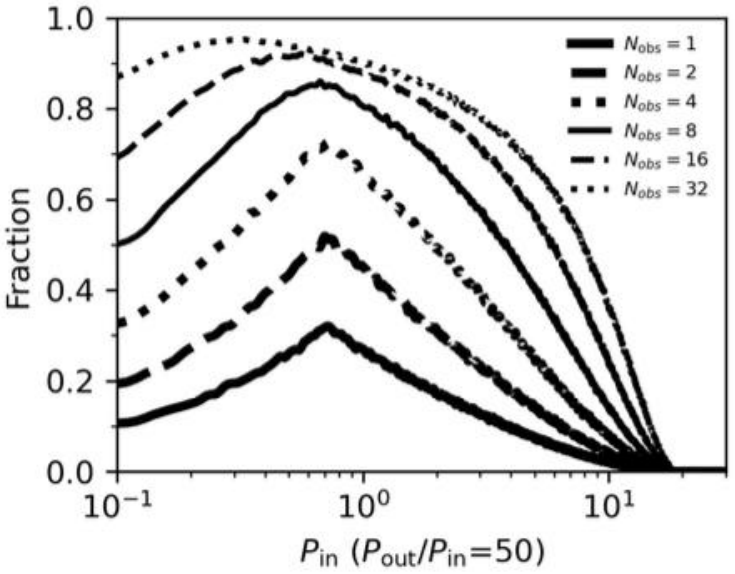
F: -1.962 ± 0.853

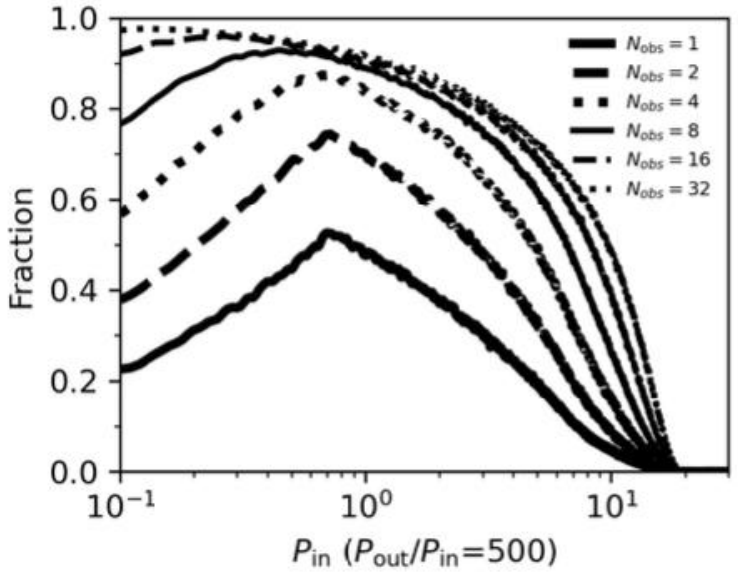
G: -2.016 ± 0.172

Mass Ratio Distribution of Hierarchical Triple Systems (He, Li, et al. 2023)









The fraction of triple systems where the inner binary star has an orbital period of less than 20 days:

- A: 7.9 ‰
- F: 5.0 ‰
- G: 2.6 ‰

There is likely mass transfer between the inner binary stars.

Conclusions

Peak-amplitude ratio

- ✓ mass ratio distribution of A、F、G-type binary and triple systems
- ✓ close binary fraction

G-type stars have a relatively high probability of forming twin binary systems.

Thank you for your attention!