Comparison between single- and three-station IPS measurements

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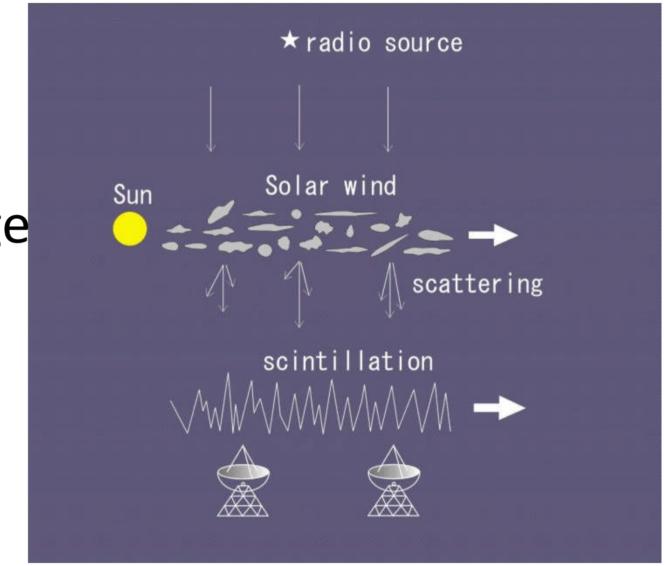
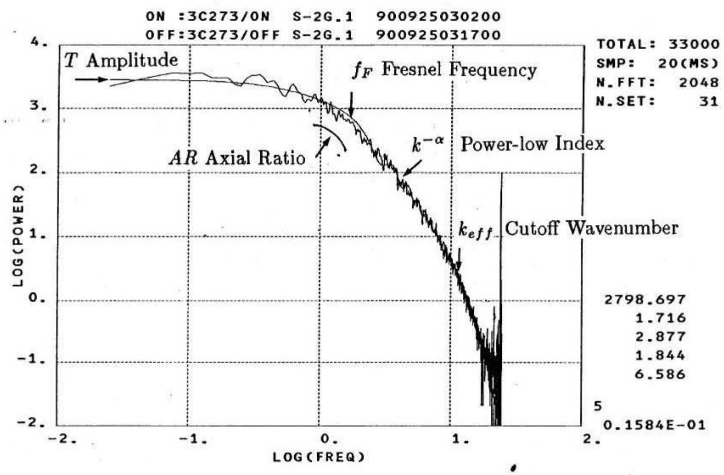
Solar Wind Speed Measurements by IPS

- Cross Correlation Method
  - Multi-station measurements
  - STEL (Kakinuma et al., 1973), Cambridge (Denission & Hewish, 1967), UCSD (Armstrong & Coles, 1972), EISCAT (Bougois et al.)
- Spectral Fit Method
  - Single-station measurements
  - ORT (Ananthkrishnan & Manoharan, 1990), Kashima (Tokumaru et al., 1991), Pushchino, MEXART, Jeju/Korea, …
- Co-spectrum Method
  - Dual-frequency measurements
  - (Scott et al., 1983), Kashima (Tokumaru et al., 1994)





This Work

- Preliminary results from comparison between cross-correlation and spectral fitting methods
  - Simultaneous observations at the same site/system and the same frequency
  - To explore potential of the spectral fitting method for filling multi-station data gap of STEL during winter
    - I intend to develop a fully-automated data processing software

Comparison between Ooty and STEL IPS observations at 327 MHz (Manoharan & Ananthakrishnan, MNRAS, 1990)

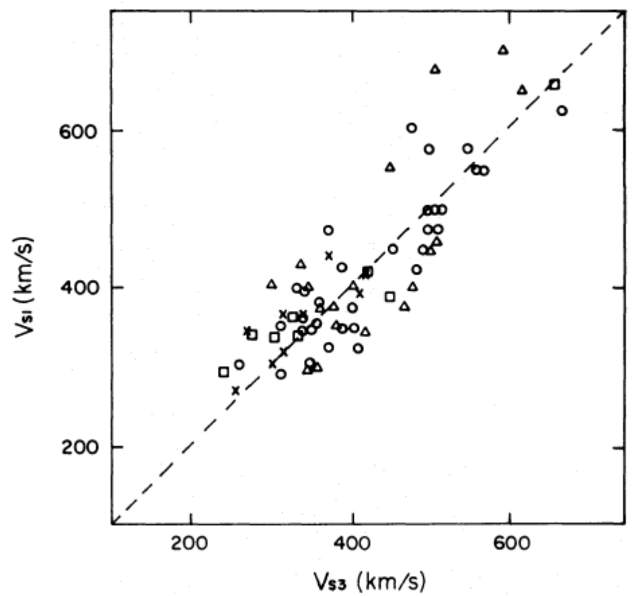
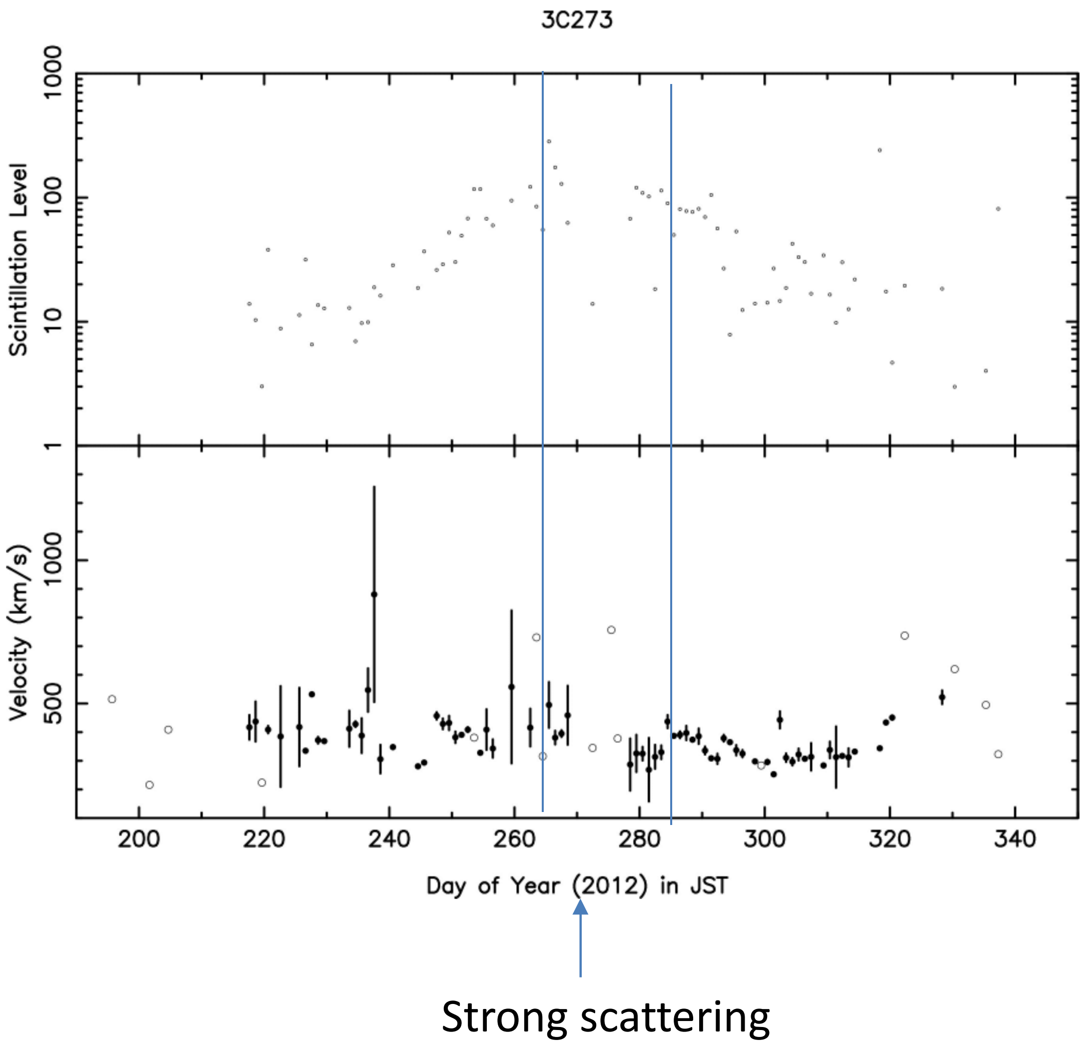


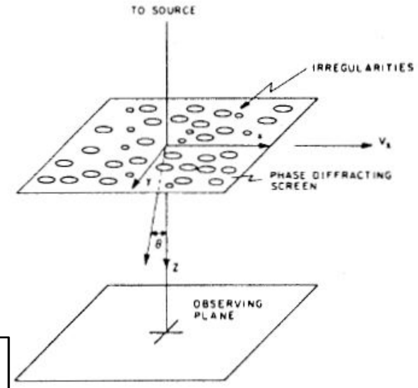
Figure 4. A comparison between the single-station spectral-fitting solar-wind speeds (V_{S1}) and three-station solar-wind measurements (V_{S3}) for (a) 3C 273, 1986 (circle), (b) 3C 273, 1987 (triangle), (c) PKS 1055 + 018, 1987 (square) and (d) CTA 21, 1988 (cross).

Observations

- Solar wind speeds derived from STEL IPS observations at 327 MHz
  - V1: Single-station (Toyokawa) observations: Spectral fitting method
  - V3: Three-station observations; i.e. Cross correlation method
- Source: 3C273
  - Solar offset distance: 16~180 Rs
- Period: 2012 Aug.4-Dec.1
  - Strong scattering region (<0.2 AU): Sep.18~Oct.9
- No. Data: 78
  - Weak scattering data: 64



Models



- Model 1: Thin screen at the point P

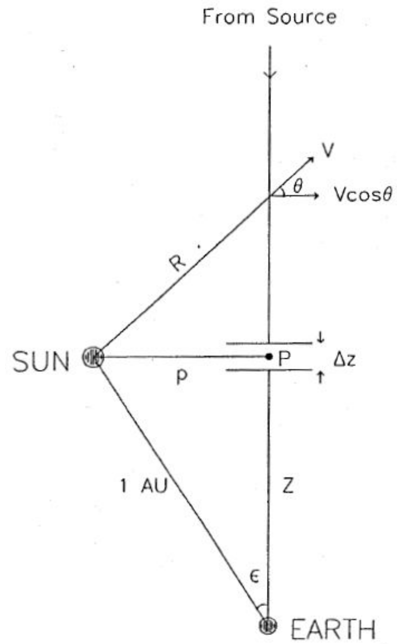
$$P_1\left(k_x = \frac{2\pi f}{V}\right) = C_N \int_{-\infty}^{\infty} \left(k_x^2 + \frac{k_y^2}{AR^2} \right)^{-\alpha/2} \sin^2\left(\frac{k^2}{k_F^2}\right) \times \exp\left(-\frac{k^2}{k_c^2}\right) dk_y$$

  - Free parameters: C_N, $k_F(=2\pi f_F/V)$, α, AR
  - Fixed parameter: k_c (f_c=6Hz)
  - point-P-Earth distance: z, wavelength: λ

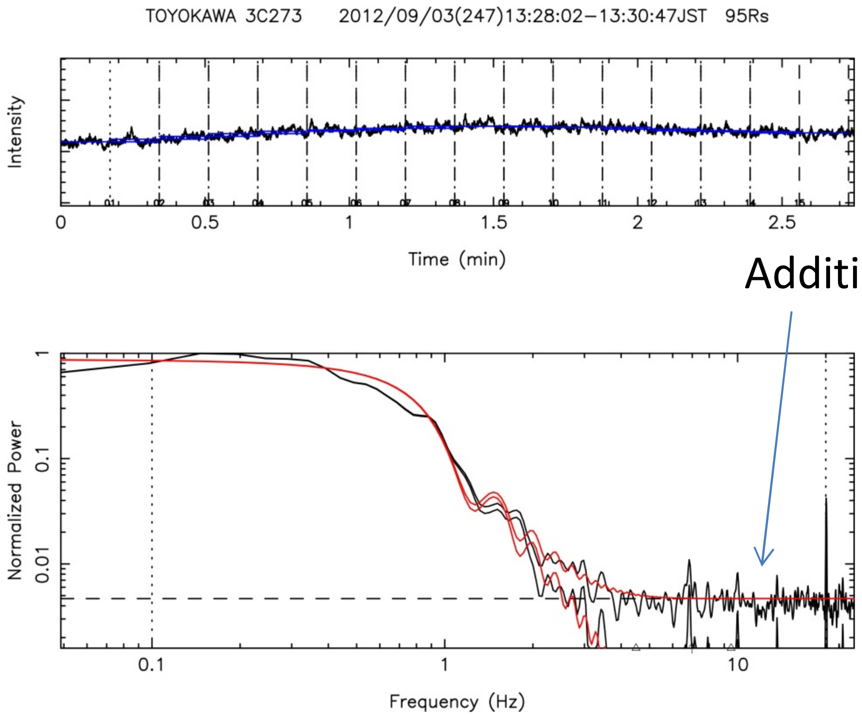
$$f_F = \frac{V}{\sqrt{\pi \lambda z}}$$

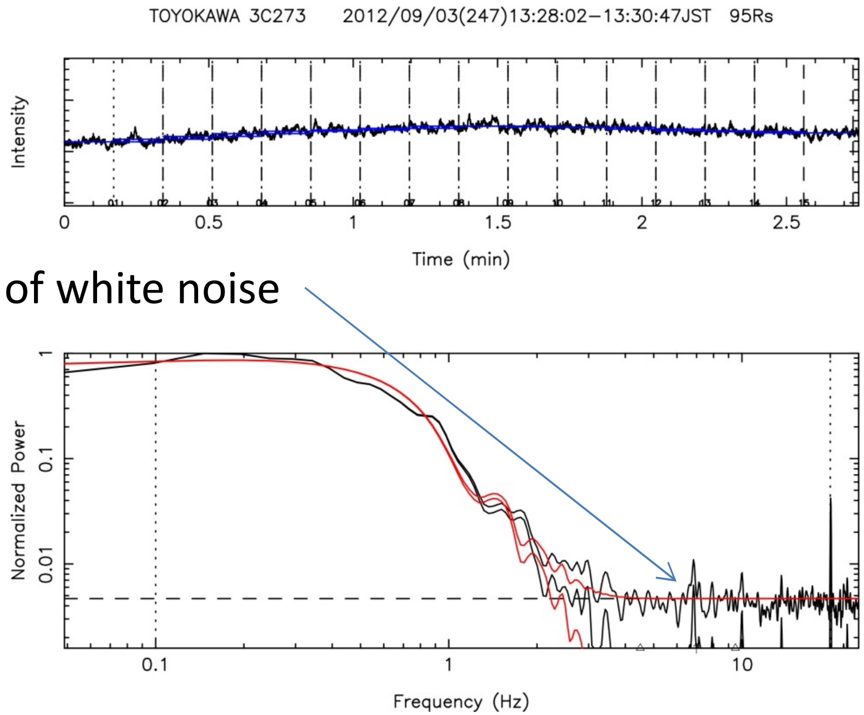
- Model 2: Spherically symmetric distribution
  - Free parameters: C_N, V, α, AR
  - Solar elongation: ε, Sun-Earth distance r_{SE}

$$P_2(f) = \frac{1}{V} \int_0^{\infty} dz \frac{r_{SE}^3 \sin^3 \varepsilon}{\left(r_{SE}^2 + z^2 - 2 r_{SE} z \cos\varepsilon\right)^{3/2}} P_1\left(k_x = \frac{2\pi f}{V_x}\right)$$



Spectral Fitting Analysis
(left) Model 1, (right) Model 2





Addition of white noise

V=459 km/s, AR=1.07, α= 3.8

V=462 km/s, AR=0.88, α= 3.4

1. Least Squares Fitting: Marquardt Method
2. Fitting in Log-Log Space
3. Weighting Function: 1/N

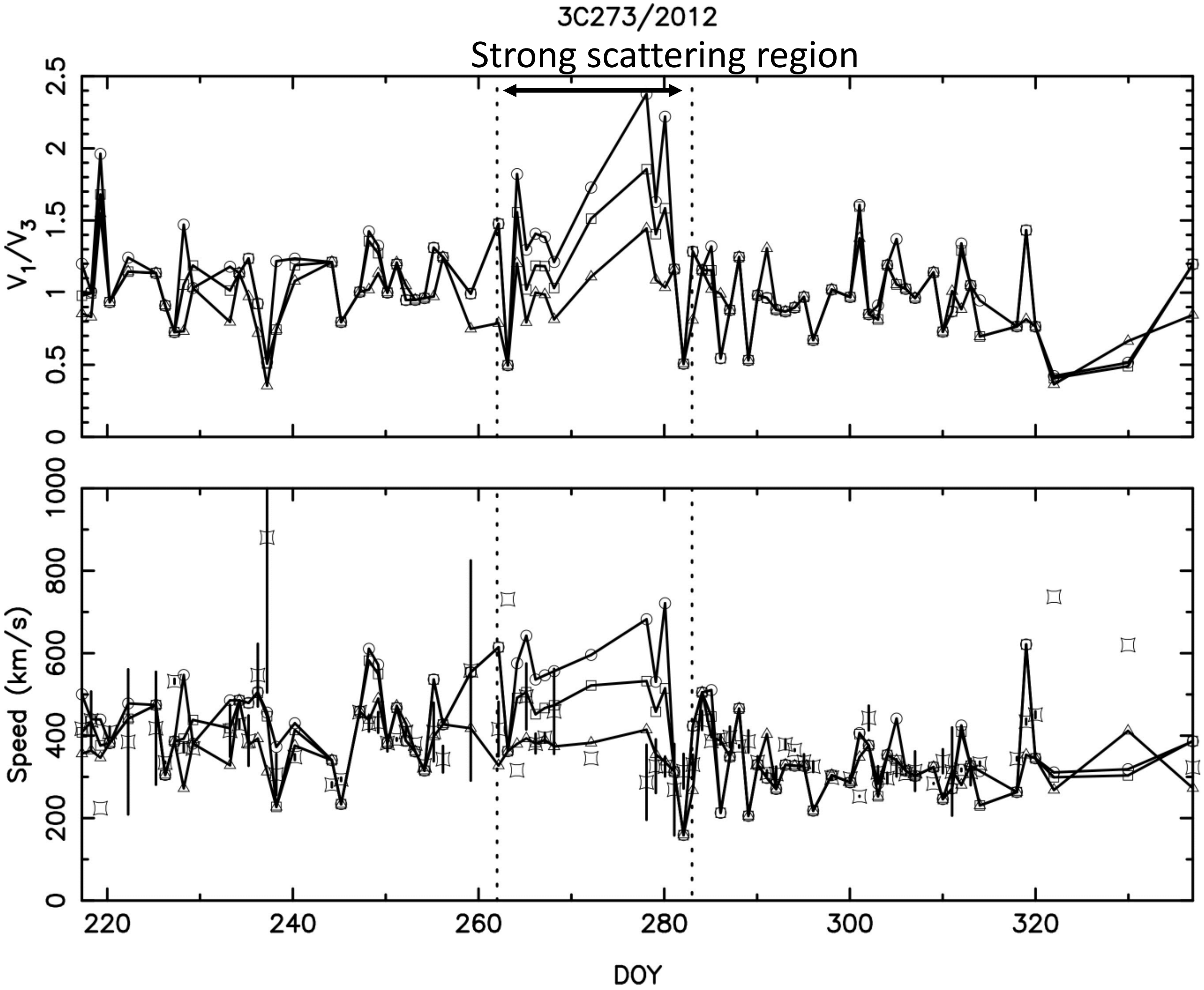
$$\sum_{i=1}^{N} W_i (\log(O_i) - \log(C_i))^2 \rightarrow \min$$

Initial Values for C_N, f_F (V), AR, α and Fixed Values for f_C (S_i)

- C_N: Level of the flat part at low frequencies
- Fresnel Frequency (Model 1) f_F=400km/s/$(\pi\lambda z)^{1/2}$, Speed (Model 2) V=400km/s
- AR=1.5
  - Kojima & Kakinuma, 1988 for 0.3AU
  - Cf. Scott et al., 1983, 1.3±0.3 for >35 Rs
- α=11/3 (Kolmogorov)
  - Woo & Armstrong, 1979 for >15 Rs

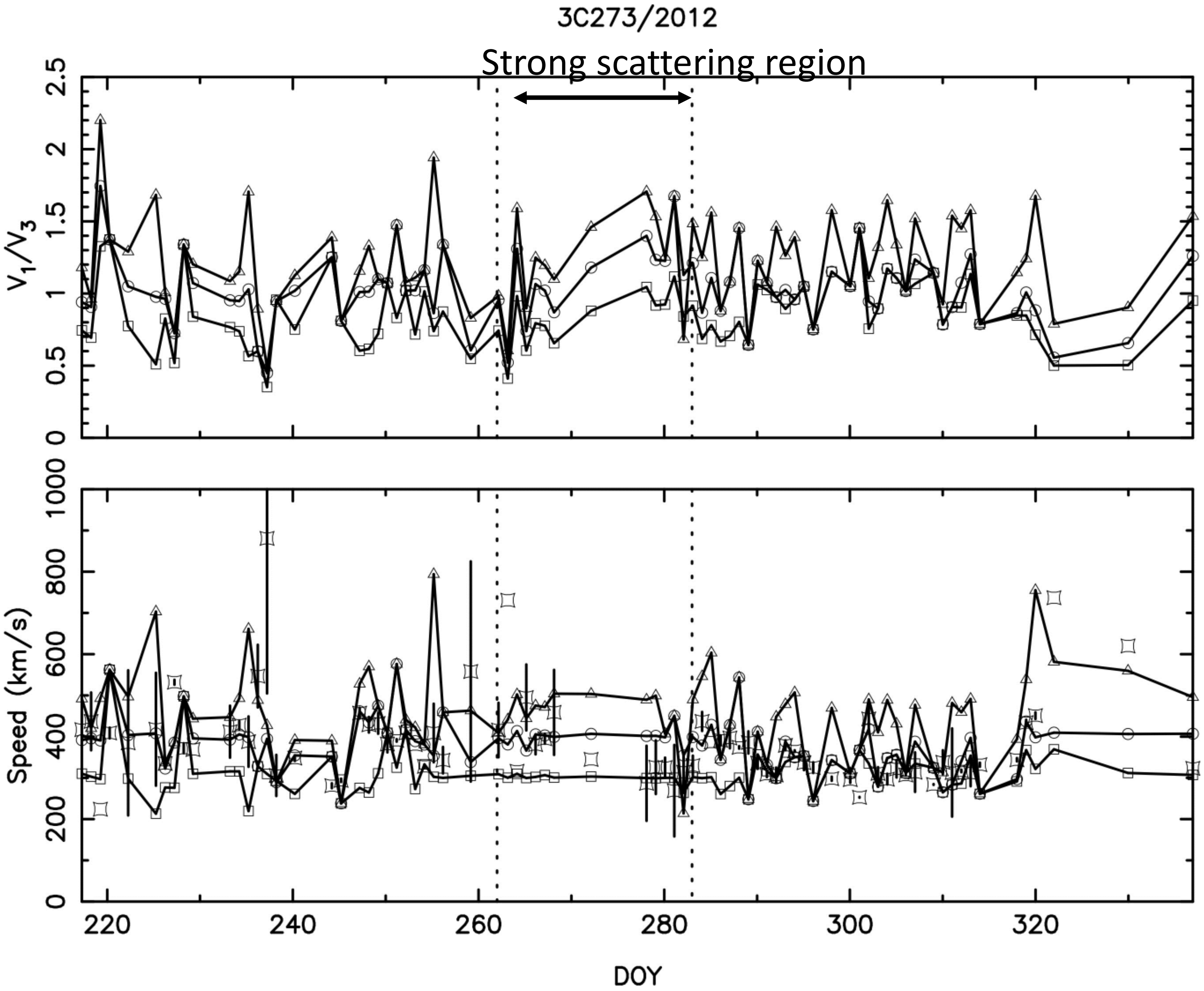
- Inner scale (fixed parameter)
  - (Model 1) f_C = 6 Hz
  - (Model 2) S_i =213.9458×sinε or 90 km, k_C=3/S_i

Dependence on Initial Values: Model 1 with Different Initial Fresnel freq.; i.e. V



No significant difference is found except for the strong scattering region, where single-station data tend to higher speeds.

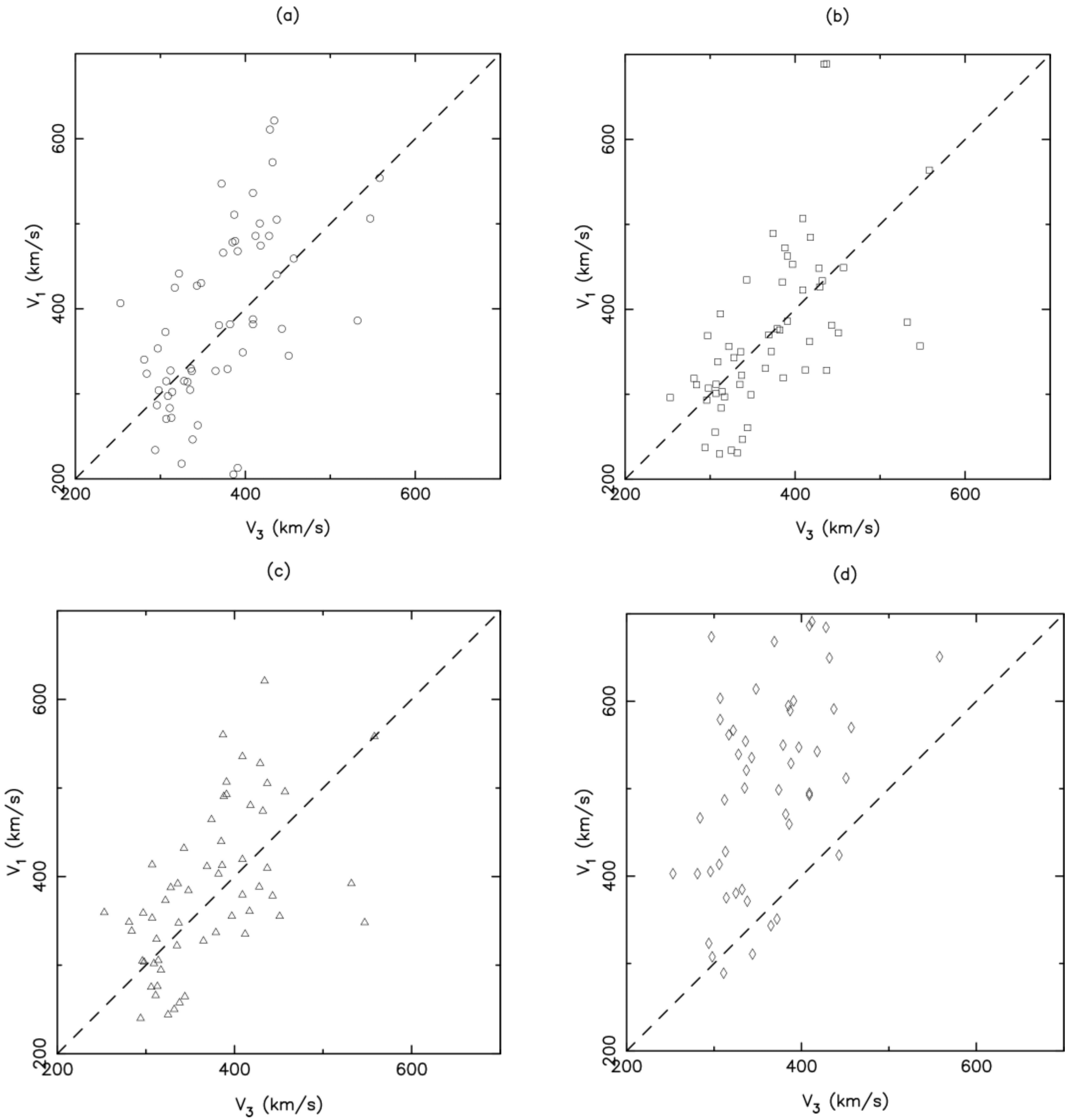
Dependence on Initial Values: Model 2 with Different Initial V



Systematic difference exists between different initial values of V.

Initial value dependence is thought to result from strong coupling between parameters.

Correlation between V1 and V3 Model 1



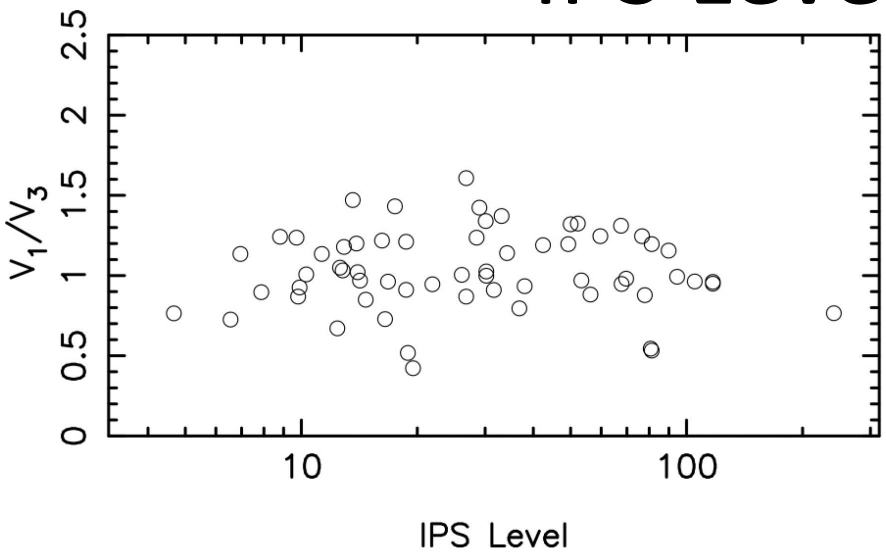
(a) 4 para: C_N, $f_F(V)$, AR, α
ρ= 0.465258
The best correlation is obtained.

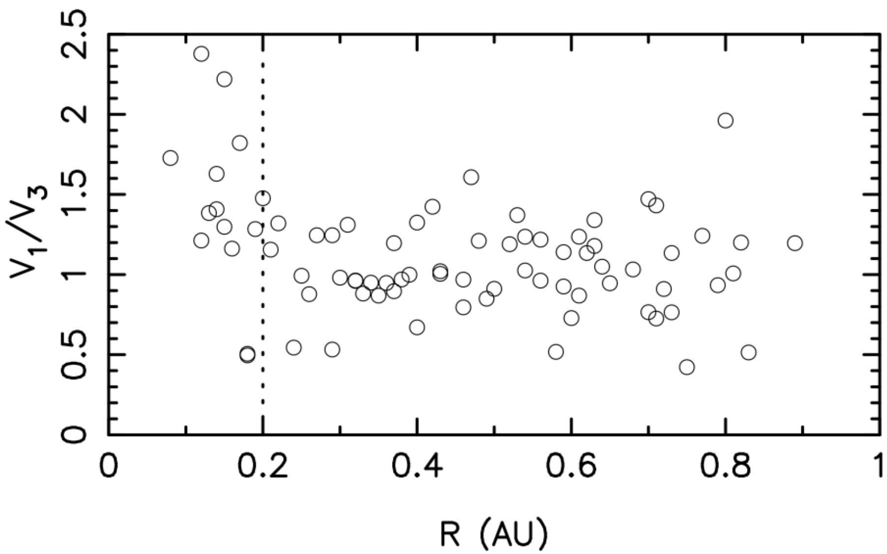
(b) 3 para: C_N, $f_F(V)$, AR
(α=11/3)
ρ= 0. 266111

(c) 3 para: C_N, $f_F(V)$, α
(AR=1.5)
ρ= 0. 228365

(d) 2 para: C_N, $f_F(V)$
(α=11/3, **AR=1.5**)
ρ= 0. 433643
Note that V1 is systematically higher than V3. →Owing to bad fixed values for AR.

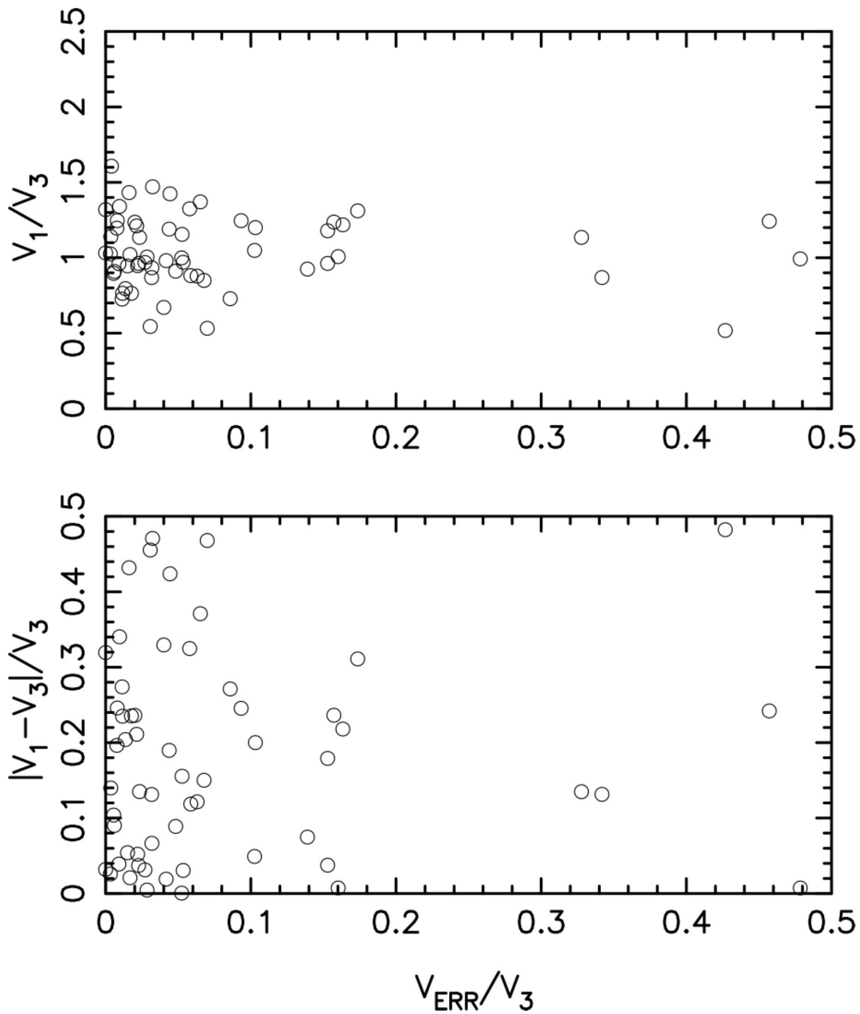
Dependence of Radial Distance R and IPS Level: Model 1





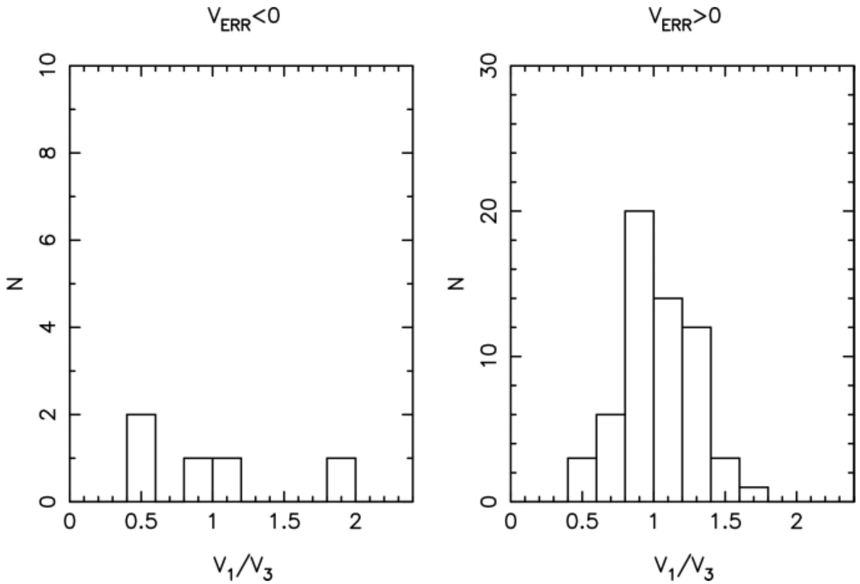
- No systematic trend is found in the IPS level vs V1/V3 plot.
  - Note that 3C273 is a very strong source.
- No systematic trend is found in the R vs V1/V3 plot for R>0.2 AU.
  - In the strong scattering, V1/V3 tends to be >1.
- Cf. No dependence on initial values of the spectral fitting method

Relation between errors of multi-and single-station measurements: Model 1



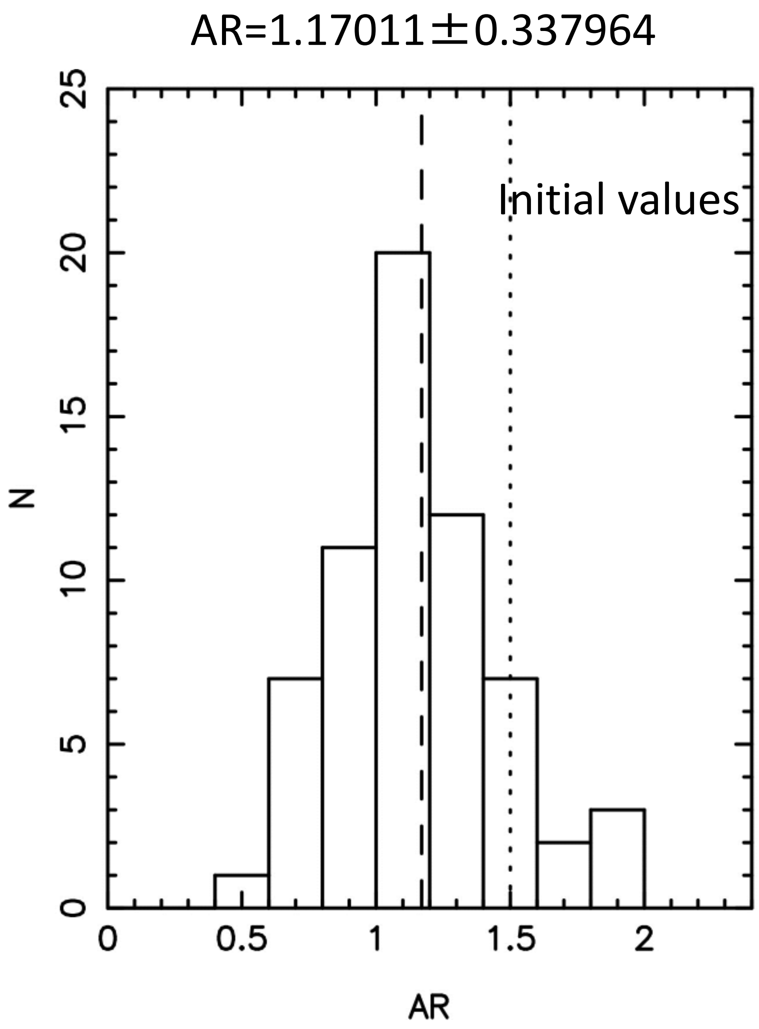
V_{ERR}: Error estimates from cross-correlation method. $V_{ERR} < 0$ means two-station measurements.

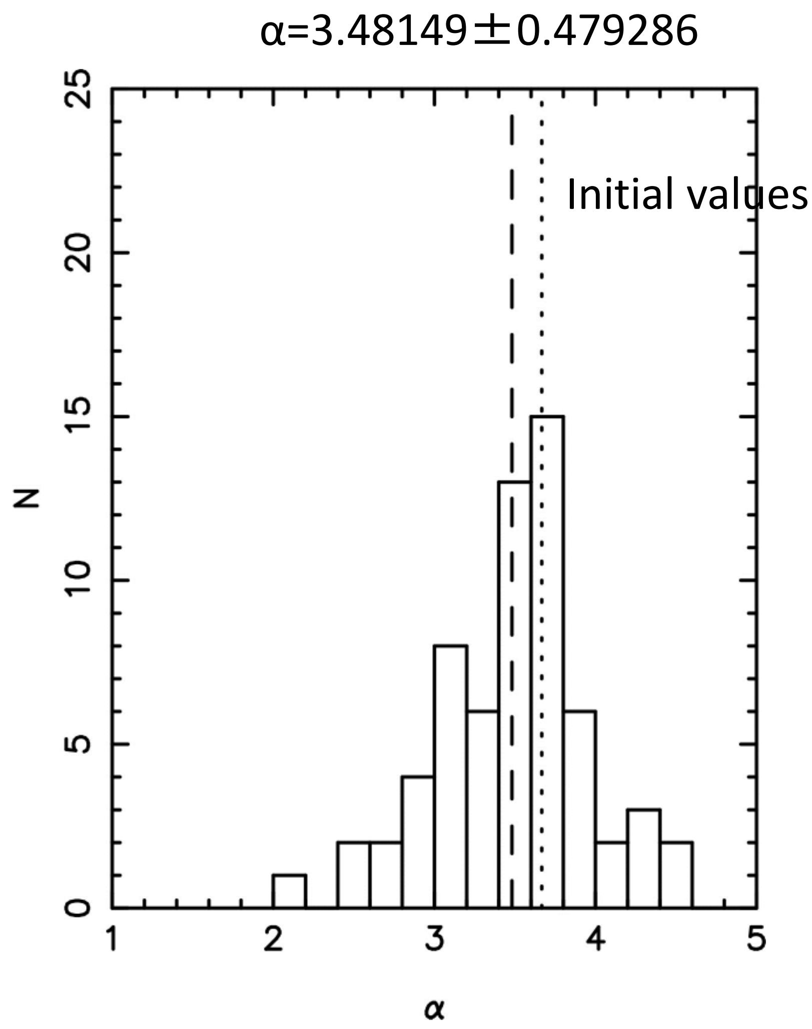
- No systematic trend in V_{ERR}/V vs V1/V3 or |V1-V3|/V3
- When $V_{ERR} < 0$, V1/V3 shows a larger scatter.



Histograms of AR and α determined from spectral fitting analysis

Model 1: 4 free parameters





Summary

- The spectral fitting analysis with Model-1 and 4 free parameters yields the best result, while its correlation coefficient is 0.47 (meaningful but poor).
- The effect of strong scattering biases V1 to higher speed.
- No significant dependence on either radial distance or IPS level is found.
- Discrepancy between V1 and V3 does not correlate with V_{ERR}. However, large discrepancy occurs for V3 derived with two-station measurements (V_{ERR} = -999).
- AR ~ 1.0 (isotropic) and α~3.5 (~Kolmogorov)
- Further improvement is needed.