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A. A. Viewga ^a

^a The Planetarium, St. Petersburg, Russia

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THE METHOD FOR STUDIES OF GALAXY AND METAGALAXY FIELD STRUCTURES. MOMENTS OF HIGHER ORDERS AND THE CONFIDENCE INTERVAL[†]

A. A. VIEWGA

The Planetarium, St. Petersburg, Russia

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Agekyan's statistical criterion (Agekyan, 1982) was used for the calculation of higher order moments and finding corresponding confidence intervals.

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A statistical criterion (Agekyan, 1982, Viewga, 1992)

$$A_{2k} = a^{2k} (C_N^2)^{-1} \sum l_{ij}^k, \quad l_{ij} = (x_i - x_j)^2 + (y_i - y_j)^2,$$

$$f(X, Y) = dx_1 dy_1 \dots dx_N dy_N, \quad 0 \leq x_i, y_i \leq 1 \quad (1)$$

is suitable to calculate the high order moments and to find the probability $P[(A_{2k} - MA_{2k})/\sigma_N <> z]$ with any given accuracy. One has identities:

$$(C_N^m)^n = C_N^m + a_{m+1} C_N^{m+1} + \dots + a_{mn} C_N^{mn}. \quad (2)$$

In particular,

$$\begin{aligned} (C_N^2)^2 &= C_N^2 + 6C_N^3 + 6C_N^4, \\ (C_N^2)^3 &= C_N^2 + 24C_N^3 + 144C_N^4 + 180C_N^5 + 90C_N^6, \dots \end{aligned} \quad (3)$$

It is easy to find from (1), that

$$\begin{aligned} MA_2 &= Ml_{12}a^2 = \frac{1}{3}a^2, \\ M(A_2)^2 &= a^4(C_N^2)^{-2}(Ml_{12}^2C_N^2 + 6Ml_{12}l_{13}C_N^3 + 6(Ml_{12})^2C_N^4). \end{aligned} \quad (4)$$

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After integration, (4) can be written as

$$M(A_2)^2 = a^4(C_N^2)^{-2} \left(\frac{17}{90}C_N^2 + \frac{11}{15}C_N^3 + \frac{2}{3}C_N^4 \right), \tag{5}$$

so that, (Agekyan, 1982)

$$\sigma_N^2 = \frac{2N + 3}{45N(N - 1)}. \tag{6}$$

In general, one can write

$$M(A_{2k})^n = \frac{a^{2kn}}{(C_N^2)^n} \sum_{s=2}^{2n} \bar{a}_s C_N^s, \quad \bar{a}_s = \sum_{i_r, j_r \leq s} M \left(\prod_{r=1}^n l_{i_r j_r}^k \right), \tag{7}$$

where $\prod l_{ij}$ are the configurations which are formed by n connections between s objects (all the objects are connected obviously). If $n \geq s$, then some of the connections are repeated; if $n + 2 \leq s \leq 2n$, then the configuration consists of some independent subconfigurations. For example, $M(l_{12}l_{34}) = (Ml_{12})^2$, $n = 2$, $s = 4$. If all $M \prod l_{ij} \equiv 1$, then (7) transforms to (3) (cf. (4)).

A "spiral" configuration $\xi = \prod_{i=1}^n l_{ii+1}$ gives

$$M\xi = \frac{1}{3^n} \sum_{i=1}^{[n/2]} \frac{C_{n-i}^i}{10^i}. \tag{8}$$

The number of configurations of this kind, when $n + 1 = s$, is

$$\frac{n!(n + 1)!}{2!} \tag{9}$$

One obtains,

$$M(A_2)^3 = \frac{a^6}{(C_N^2)^3} \left(\frac{29}{210}C_N^2 + \frac{331}{210}C_N^3 + \frac{1733}{315}C_N^4 + \frac{22}{3}C_N^5 + \frac{10}{3}C_N^6 \right), \tag{10}$$

etc. On the next step one considers $\eta = (A_2 - MA_2)/\sigma_N$ and finds semi-invariants from a connection,

$$\kappa_n = n! \sum_{(m_i)} (-1)^{m_1 + \dots + m_n - 1} (m_1 + \dots + m_n - 1)! \prod_{j=1}^n \left(\frac{M\eta^j}{j!} \right)^{m_j} \frac{1}{m_j!}, \tag{11}$$

$$m_1 + 2m_2 + \dots + nm_n = n.$$

It was found (Petrov, 1972) that

$$\kappa_3 = \frac{2\sqrt{5}}{7} \frac{2N^2 + 3N + 30}{(2N + 3)^{3/2}(N^2 - N)^{1/2}}, \tag{12}$$

$$\kappa_4 = -\frac{2}{7} \frac{2N^3 + 3N^2 + 93N - 315}{(2N + 3)^2(N^2 - N)}, \quad (13)$$

$$\kappa_5 = -\frac{120\sqrt{5}}{77} \frac{2N^4 + 3N^3 - 87N^2 + 1125N - 1890}{(2N + 3)^{5/2}(N^2 - N)^{3/2}}, \dots \quad (14)$$

Then, one has the convergent series, (Petrov, 1972)

$$P(\eta < z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^z e^{-\frac{x^2}{2}} dx - \sum_{n=1}^{\infty} Q_n(z), \quad (15)$$

where

$$Q_n(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} \sum_{(s)} H_{n+2s-1}(z) \prod_{j=1}^n \frac{1}{m_j!} \left[\frac{\kappa_j + 2}{(j+2)!} \right]^{m_j}, \quad (16)$$

$$s = m_1 + \dots + m_n,$$

$$m_1 + 2m_2 + \dots + nm_n = n$$

and

$$H_m(z) = m! \sum_{j=0}^{[m/2]} \frac{(-1)^j z^{m-2j}}{j!(m-2j)!2^j}. \quad (17)$$

The series applies to any distributions of objects and allows to find the confidence interval accurately.

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