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Scientific Studies in Association with the Shuttle Solar Backscatter Ultraviolet (SSBUV) Project

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Principal Investigator:

John E. Frederick
Department of the Geophysical Sciences
The University of Chicago
5734 South Ellis Avenue
Chicago, IL 60637

Phone: (312) 702-3237
Facsimile: (312) 702-9505

(NASA-CR-193404) SCIENTIFIC STUDIES IN ASSOCIATION WITH THE SHUTTLE SOLAR BACKSCATTER ULTRAVIOLET (SSBUV) PROJECT Semiannual Progress Report, 1 Jan. - 30 Jun. 1993 (Chicago Univ.) 52 p

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I. Introduction

During the past reporting period efforts focused on performing detailed comparisons between measurements made by the SBUV/2 instruments carried on NOAA-9 and NOAA-11 and the first three flights of SSBUV. The quantities to be compared here are the measurables, being the ratio of emergent radiance (I) in the vertical direction to the incoming solar irradiance (F). We define the backscatter albedo, A(w,j), by:

$$A(w,j) = I(w,j)/F(w,j) \tag{1}$$

where w=1,2,...,12 refers to wavelength, and j indicates the instrument and flight on which the data were obtained. The values of j are as defined below:

j=N9	NOAA-9 SBUV/2
j=N11	NOAA-11 SBUV/2
j=S1	SSBUV-1
j=S2	SSBUV-2
j=S3	SSBUV-3

The comparisons to be made are NOAA-9 to SSBUV-1 (N9,S1), NOAA-11 to SSBUV-2 (N11,S2), and NOAA-11 to SSBUV-3 (N11,S3). For the comparisons the N-values contained in the data files supplied by GSFC were converted to albedos via:

$$A(w,j) = 10^{-N(w,j)/100} \tag{2}$$

As an example, consider the comparison of data from NOAA-11 to SSBUV-2. The desired situation is obviously:

$$A(w,N11) = A(w,S2) \tag{3}$$

for all 12 wavelengths for all coincidences between the instruments. In practice, the equality will not hold owing to the lack of exact spatial-temporal coincidence between the measurements and differences in the calibrations of the instruments. The comparisons described below were designed to characterize the differences between the NOAA and SSBUV data sets.

II. The Initial Comparisons

On any SSBUV mission let there be i=1,2,...,N matchups with a NOAA satellite. Useful indices to use in a comparison are (1) the mean percent difference between the matchups, P_1, and (2) the mean absolute percent difference, P_2, defined as:

$$P_1(w,N11,S2) = (100/N) \sum_{i=1}^{N} \{[A(w,N11,i)-A(w,S2,i)]/A(w,S2,i)\} \quad (4)$$

and

$$P_2(w,N11,S2) = (100/N) \sum_{i=1}^{N} \mathrm{ABS}\{[A(w,N11,i)-A(w,S2,i)]/A(w,S2,i)\} \quad (5)$$

where the operator "ABS" takes the absolute value of a quantity. Equations 4 and 5 refer to the comparison of NOAA-11 and SSBUV-2. Analogous expressions apply to the comparisons NOAA-9/SSBUV-1 and NOAA-11/SSBUV-3.

If differences between individual NOAA and SSBUV matchups resulted only from the lack of exact spatial-temporal coincidence, and the associated variability was random, then a large degree of cancellation will occur in the summation of equation 4. The value of $P_1(w,N11,S2)$ would then indicate only the calibration offset between the two instruments. In practice there is no guarantee that this theoretical cancellation will occur. The mean absolute percent difference, $P_2(w,N11,S2)$, provides an index of the typical offset between NOAA and SSBUV without regard to the sign of this difference.

Table 1 presents the percent differences between (A) NOAA-9 and SSBUV-1, (B) NOAA-11 and SSBUV-2, and (C) NOAA-11 and SSBUV-3 at each of the 12 wavelengths from 255.5 nm to 339.8 nm. The mean percent differences are always positive, indicating that on average the albedos measured by the NOAA satellites are larger than those from SSBUV. This inequality does not hold on a point-by-point basis as evidenced by the values of P_2 being consistently larger than P_1. In the NOAA-9/SSBUV-1 comparisons the percent differences are unreasonably large. This may indicate the change in calibration of the NOAA-9 sensor during its five years in orbit as of the flight of SSBUV-1. As noted in the following section, these large percentage offsets are only one aspect of the poor agreement between NOAA-9 and SSBUV-1. In the cases of NOAA-11 compared to SSBUV-2 and SSBUV-3, the mean percent differences are always less than 8%. The differences at wavelengths longer than 300 nm tend to be greater than at shorter wavelengths. This likely arises from the influence of variable cloudiness.

III. Comparisons Based on Regression Models

During a given flight of SSBUV the matchups with NOAA occur over a range of latitudes and solar zenith angles. The absolute values of the albedos to be compared, say A(w,N11) and A(w,S2), show a significant range of variation. For example, the SSBUV-2 albedos for matchup with NOAA-11 at w=273.5 nm range from $1.6\text{-}1.7\times10^{-4}$ to $2.7\text{-}2.8\times10^{-4}$. At w=301.9 nm the analogous range is from 1.0×10^{-3} to over 4.0×10^{-3}. This variability in the matchups allows one to determine if the NOAA and SSBUV albedos covary in the same way. Specifically, a regression model of the form:

$$A(w,N11) = c_0 + c_1 A(w,S2) \tag{6}$$

can be applied to the matchups. Based on equation 3 the expected values of the regression coefficients are c_0=0.0 and c_1=1.0. Furthermore, in the ideal case one would expect the SSBUV measurements to explain $100r^2$=100% of the variance in the NOAA albedos, where r is the correlation coefficient between A(w,N11) and A(w,S2). Alternately, a plot of A(w,N11) versus A(w,S2) should be a straight line with a slope of c_1=1.0 and an intercept c_0=0.0.

Figure 1 (parts "a" through "l") plots A(w,N9) versus A(w,S1) for each of the 12 wavelengths. Figure 2 presents A(w,N11) versus A(w,S2), and Figure 3 presents A(w,N11) versus A(w,S3). Tables 2, 3, and 4 include the results of the regression defined by equation 6. The tables present the best estimates for c_0 and c_1, an uncertainty range for these coefficients defined to be two standard errors, and the percent of the variance in the NOAA albedos explained by the SSBUV measurements ($100r^2$ in %). There is a 95% probability that the true values of c_0 and c_1 lie within plus or minus two standard errors of the best estimates. In view of the unusual behavior in the NOAA-9/SSBUV-1 matchups, we begin by discussing the NOAA-11/SSBUV-2 and NOAA-11/SSBUV-3 analyses.

The relationships depicted in Figure 2 (N11,S2) and Figure 3 (N11,S3) are in qualitative agreement with expectations. The albedos recorded by NOAA-11 and SSBUV have similar magnitudes, and the plots have positive slopes. However, inspection of Tables 3 and 4 reveals an unexpected disagreement between the data sets. All of the values of c_0 differ significantly from the expected value of 0.0, and all values of c_1 are significantly smaller than 1.0. The best estimates of c_1 lie in the range 0.140 to 0.597 for the NOAA-11/SSBUV-2 comparison. The corresponding range for the NOAA-11/SSBUV-3 comparison is 0.228 to 0.628. The smallest value of c_1 occurs at w=297.5 nm in both cases, while the largest values appear at 331.2 and 339.8 nm. This comparison demonstrates that albedos from NOAA-11 show much less variability among the matchups than do the albedos from SSBUV.

A major objective of SSBUV is to detect systematic calibration drifts in the NOAA instruments. However, the disagreement revealed in Tables 3 and 4 has a different character. The results suggest that a given percentage change in the true atmospheric albedo leads to different percent changes in the outputs of the NOAA-11 and SSBUV instruments. If this interpretation is correct, then this problem has implications for our ability to quantify changes in ozone using SBUV-type instruments. Although this topic has great potential importance, we can not pursue it further using only the data available to us.

The comparisons between NOAA-9 and SSBUV-1 shown in Figure 1 and Table 2 reveal bizarre behavior. The correlation between the two data sets is negative ($c_1<0.0$), and with the exception of w=339.8 nm, this correlation is statistically significant at the 95% confidence level. The absolute values of c_1 are all in the range $4\text{-}9\times10^{-2}$. This shows that the output of the NOAA-9 instrument is only weakly linked to that of SSBUV-1. We know of no physical mechanism that can explain the negative sign of the correlation.

IV. Future Plans

We are currently developing a new regression model that will normalize the NOAA albedos to those measured during a single flight of SSBUV. This effectively uses the SSBUV signals as a calibration standard. Unlike the regressions used in this report, the new model will account for the small differences in solar zenith angle between the matched NOAA and SSBUV measurements. A Final Report on work done under this grant will be prepared. A modified version of the report will serve as a paper for submission to a refereed journal.

Table 1-A. Percent Differences Between NOAA and SSBUV Albedos

A. NOAA-9 Compared to SSBUV-1

Wavelength (nm)	Mean Percent Difference P_1	Mean Absolute % Difference P_2
255.5	38.4	55.3
273.5	35.9	55.3
283.0	39.3	58.1
287.6	39.9	59.4
292.2	41.3	61.4
297.5	43.6	65.8
301.9	44.8	73.8
305.8	56.4	104.6
312.5	245.9	309.0
317.5	415.6	469.4
331.2	281.3	322.2
339.8	227.3	263.7

Table 1-B. Percent Differences Between NOAA and SSBUV Albedos

B. NOAA-11 Compared to SSBUV-2

Wavelength (nm)	Mean Percent Difference P_1	Mean Absolute % Difference P_2
255.5	6.6	11.8
273.5	3.5	11.3
283.0	2.7	11.4
287.6	2.2	11.5
292.2	2.6	12.1
297.5	3.2	15.1
301.9	6.0	26.1
305.8	7.3	27.4
312.5	6.4	19.7
317.5	5.3	16.9
331.2	3.4	14.4
339.8	3.5	15.3

Table 1-C. Percent Differences Between NOAA and SSBUV Albedos

C. NOAA-11 Compared to SSBUV-3

Wavelength (nm)	Mean Percent Difference P_1	Mean Absolute % Difference P_2
255.5	7.2	12.1
273.5	4.6	10.9
283.0	3.2	10.7
287.6	3.0	10.8
292.2	2.8	11.3
297.5	3.2	15.3
301.9	8.1	27.4
305.8	7.8	26.6
312.5	7.8	20.9
317.5	7.6	19.3
331.2	6.3	17.6
339.8	5.9	17.7

Table 2. Results of the Comparison of NOAA-9 with SSBUV-1
[Regression model of the form $A(w,N9) = c_o + c_1 A(w,S1)$]

Wavelength w (nm)	c_0	$2(se)_0$*	c_1	$2(se)_1$*	$100r^2$ (%)
255.5	1.01E-04	1.24E-06	-8.72E-02	1.35E-02	62.51
273.5	9.56E-05	8.29E-07	-7.39E-02	9.12E-03	72.41
283.0	1.27E-04	1.07E-06	-7.20E-02	8.97E-03	72.07
287.6	1.55E-04	1.47E-06	-7.22E-02	9.97E-03	67.74
292.2	1.98E-04	2.08E-06	-6.87E-02	1.10E-02	61.15
297.5	2.78E-04	3.03E-06	-6.79E-02	1.12E-02	59.65
301.9	3.88E-04	3.88E-06	-6.05E-02	9.40E-03	62.34
305.8	6.12E-04	8.28E-06	-4.84E-02	9.20E-03	52.47
312.5	3.30E-03	1.31E-04	-7.35E-02	2.23E-02	30.25
317.5	8.29E-03	4.04E-04	-8.71E-02	3.46E-02	20.28
331.2	2.09E-02	1.37E-03	-6.65E-02	5.54E-02	5.44
339.8	2.37E-02	1.80E-03	-6.35E-02	6.80E-02	3.37

* $2(se)_k$ = 2 standard errors of c_k

Table 3. Results of the Comparison of NOAA-11 with SSBUV-2
[Regression model of the form $A(w,N11) = c_o + c_1 A(w,S2)$]

Wavelength w (nm)	c_0	$2(se)_0$*	c_1	$2(se)_1$*	$100r^2$ (%)
255.5	1.90E-04	7.46E-06	2.09E-01	3.26E-02	62.67
273.5	1.82E-04	5.79E-06	1.95E-01	2.59E-02	69.73
283.0	2.39E-04	7.36E-06	1.89E-01	2.50E-02	70.09
287.6	2.97E-04	8.66E-06	1.82E-01	2.36E-02	70.74
292.2	4.07E-04	1.03E-05	1.56E-01	2.12E-02	68.82
297.5	6.68E-04	2.02E-05	1.40E-01	2.56E-02	54.82
301.9	1.48E-03	1.27E-04	3.14E-01	5.17E-02	60.02
305.8	4.80E-03	5.35E-04	3.93E-01	5.80E-02	65.20
312.5	1.87E-02	2.74E-03	4.92E-01	7.01E-02	66.79
317.5	2.70E-02	4.58E-03	5.27E-01	7.69E-02	65.66
331.2	3.40E-02	7.77E-03	5.97E-01	8.65E-02	66.04
339.8	3.44E-02	8.46E-03	5.97E-01	9.18E-02	63.33

* $2(se)_k$ = 2 standard errors of c_k

Table 4. Results of the Comparison of NOAA-11 with SSBUV-3
[Regression model of the form $A(w,N11) = c_o + c_1 A(w,S3)$]

Wavelength w (nm)	c_0	$2(se)_0$*	c_1	$2(se)_1$*	$100r^2$ (%)
255.5	1.72E-04	1.25E-05	2.94E-01	5.42E-02	49.33
273.5	1.53E-04	8.48E-06	3.29E-01	3.82E-02	70.99
283.0	2.00E-04	1.03E-05	3.21E-01	3.51E-02	73.54
287.6	2.49E-04	1.26E-05	3.15E-01	3.46E-02	73.25
292.2	3.37E-04	1.62E-05	2.96E-01	3.37E-02	71.89
297.5	6.11E-04	2.94E-05	2.28E-01	3.63E-02	56.54
301.9	1.93E-03	2.21E-04	2.88E-01	7.52E-02	32.66
305.8	6.17E-03	9.77E-04	3.93E-01	8.77E-02	39.90
312.5	2.10E-02	4.36E-03	5.21E-01	9.76E-02	48.47
317.5	2.90E-02	6.86E-03	5.64E-01	1.04E-01	49.54
331.2	3.71E-02	1.09E-02	6.21E-01	1.12E-01	50.59
339.8	3.69E-02	1.15E-02	6.28E-01	1.14E-01	50.24

* $2(se)_k$ = 2 standard errors of c_k

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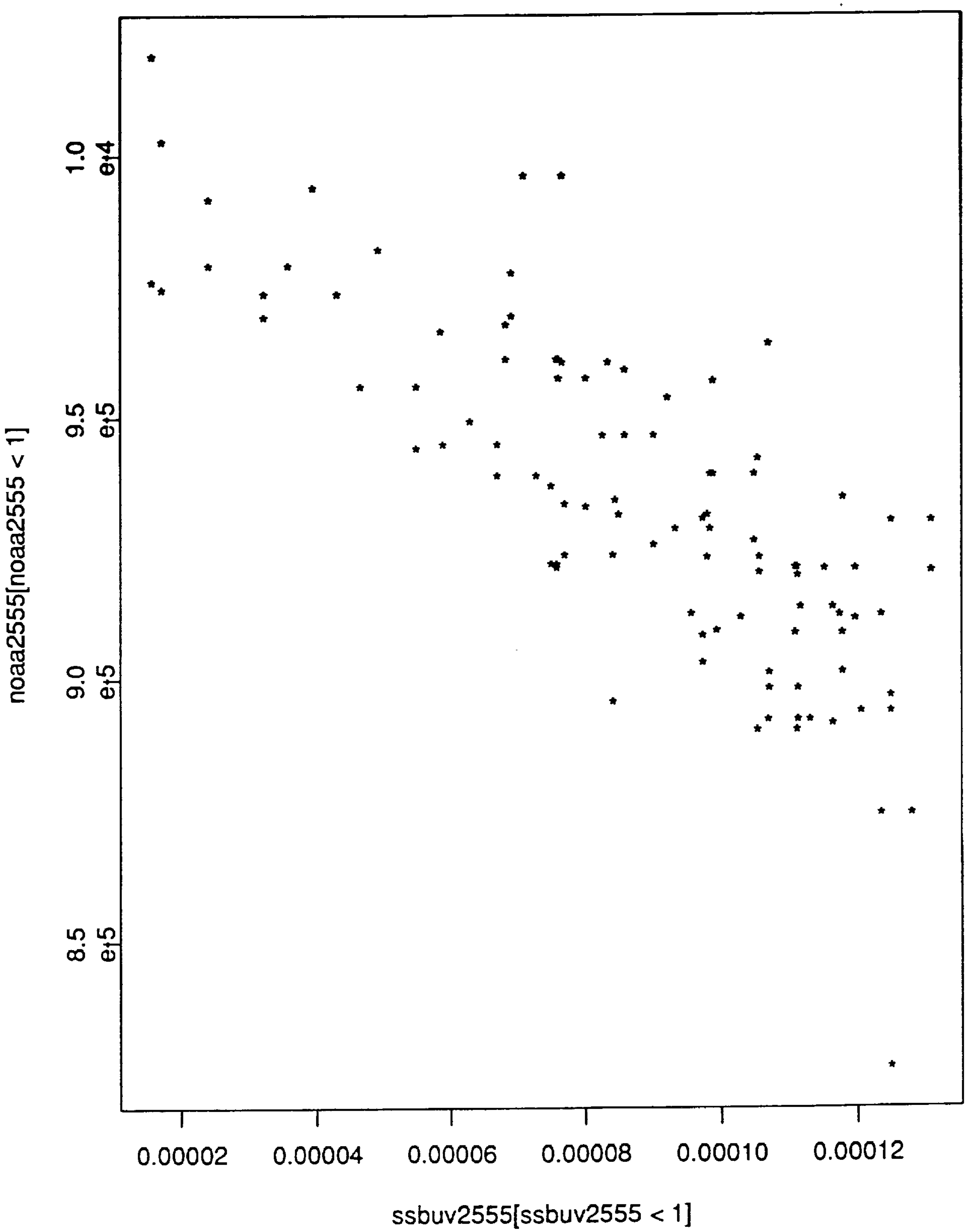

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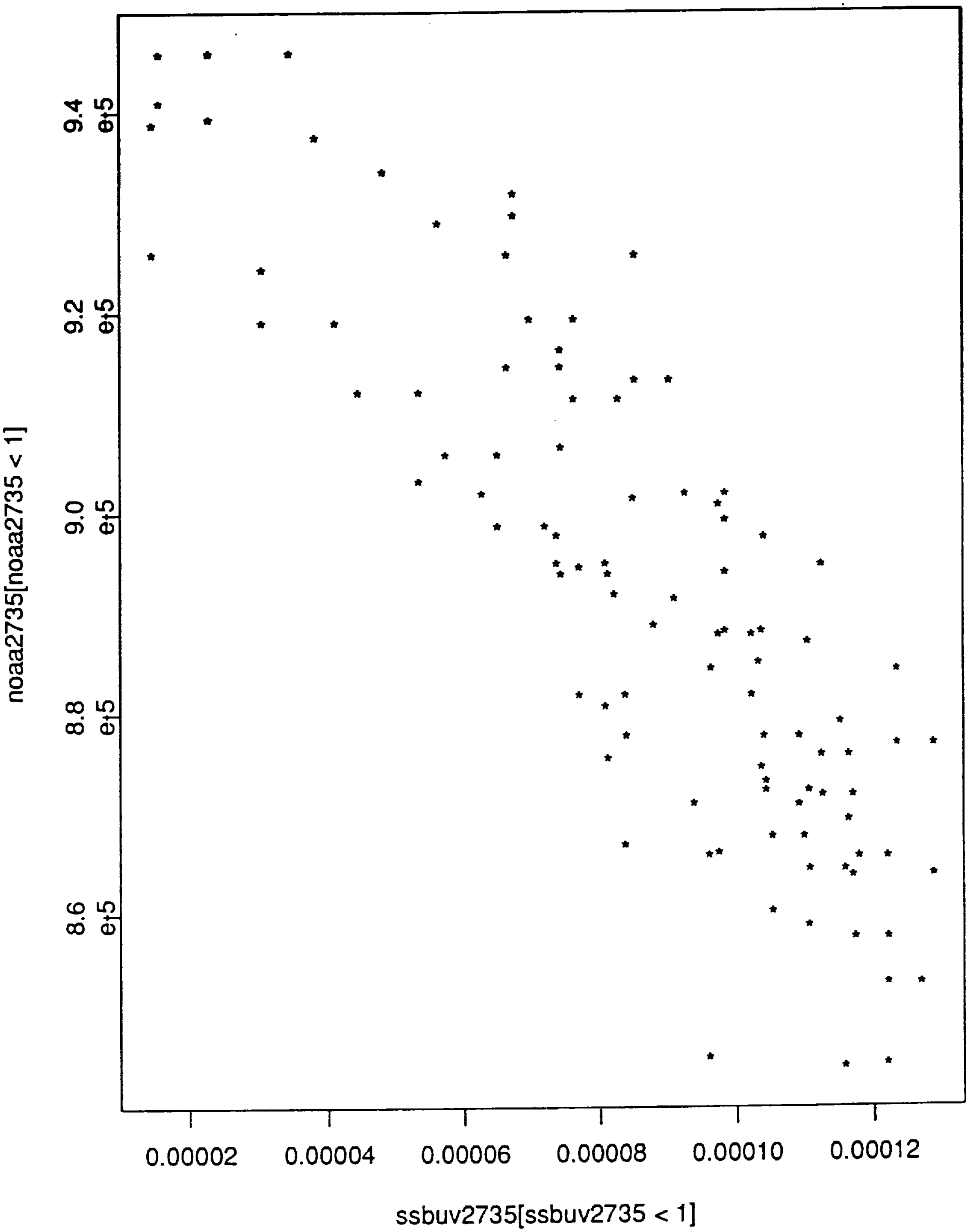

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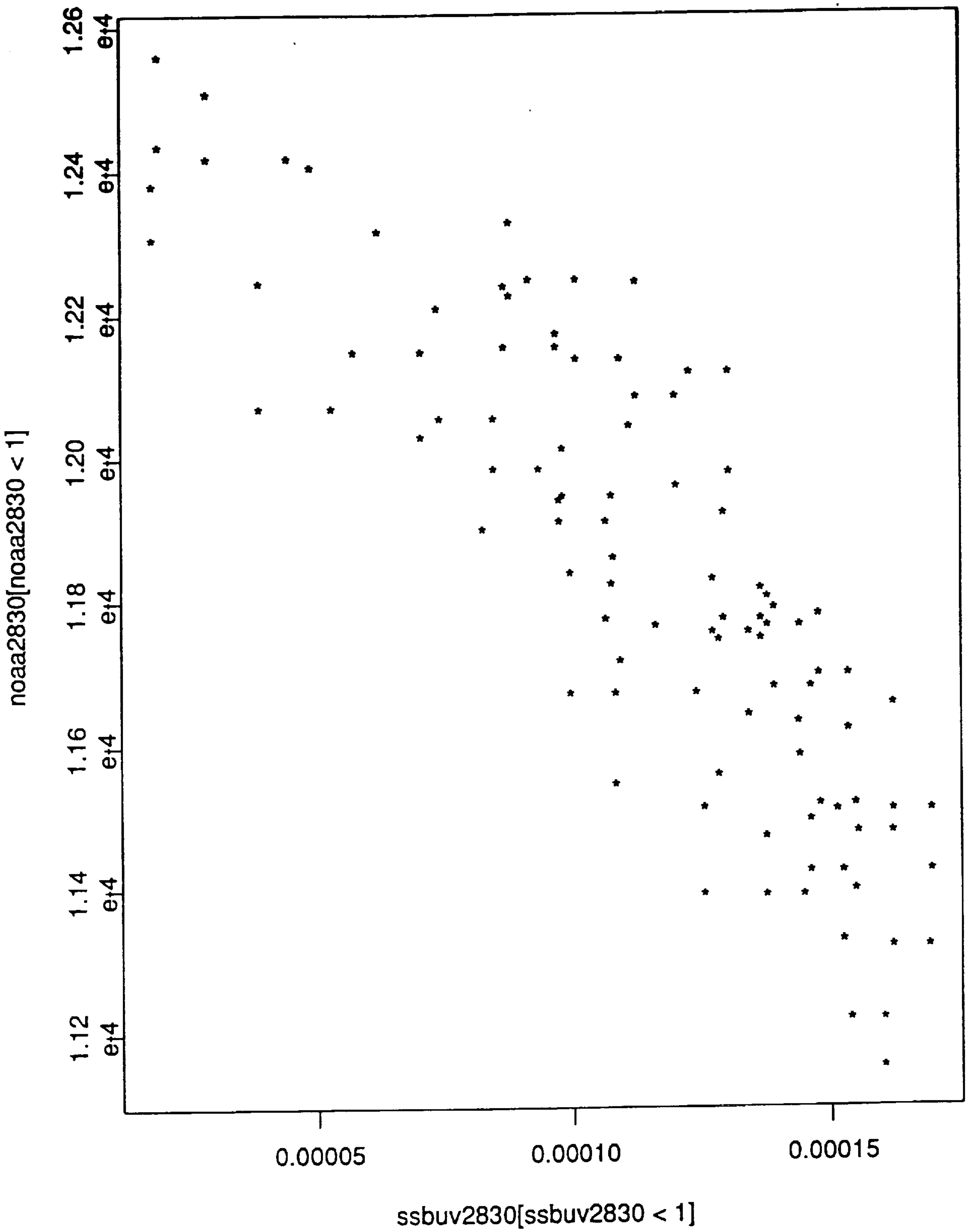

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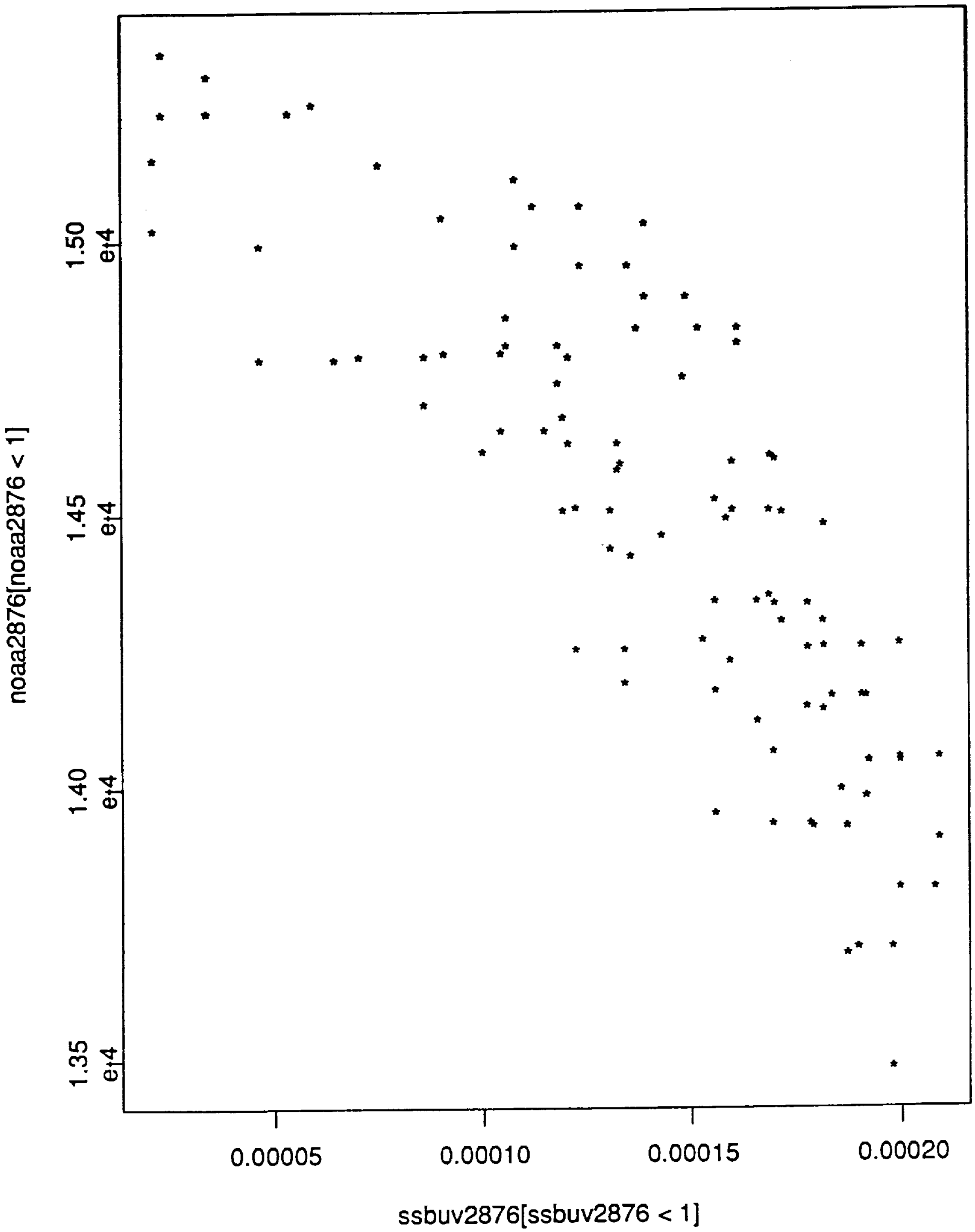

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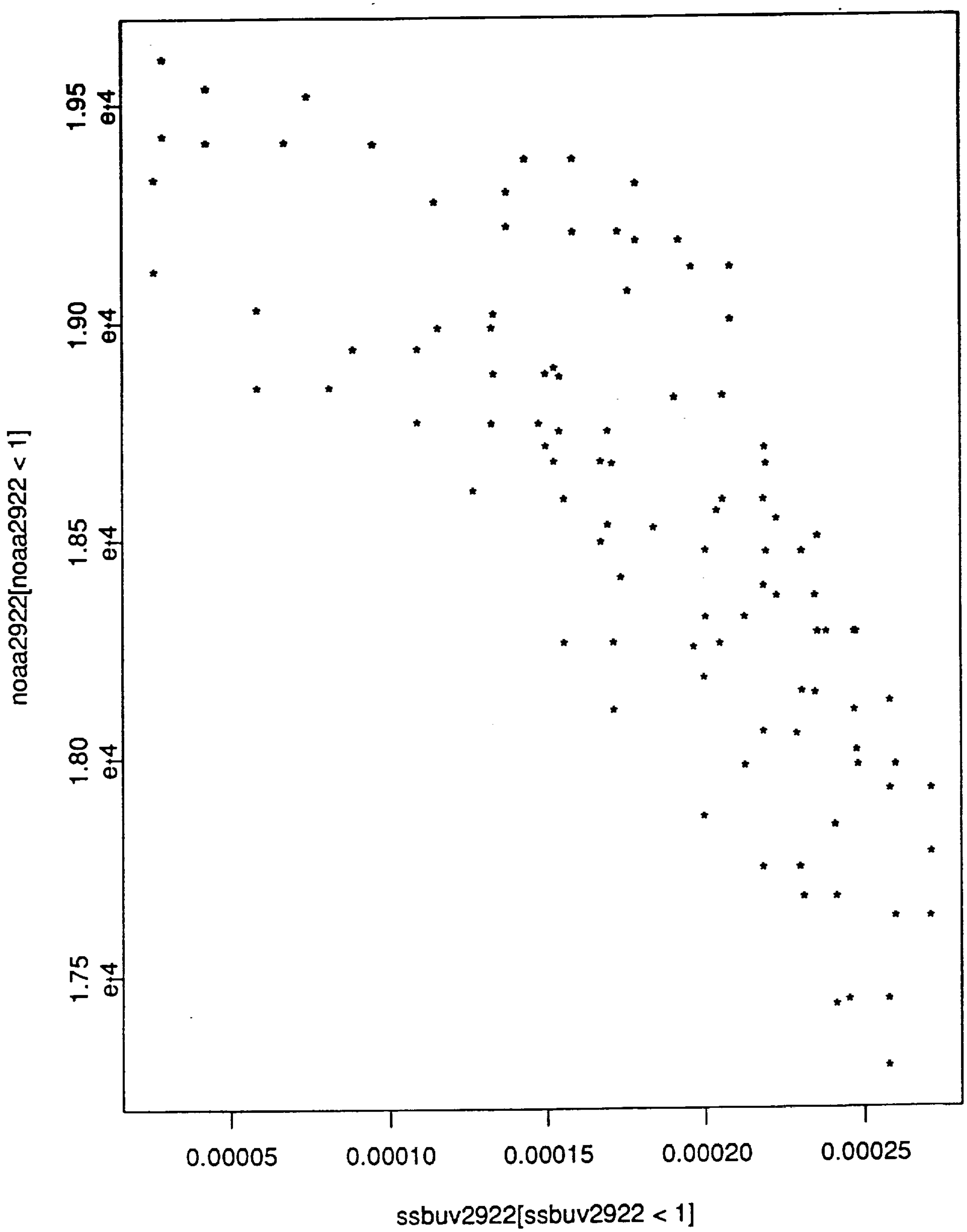

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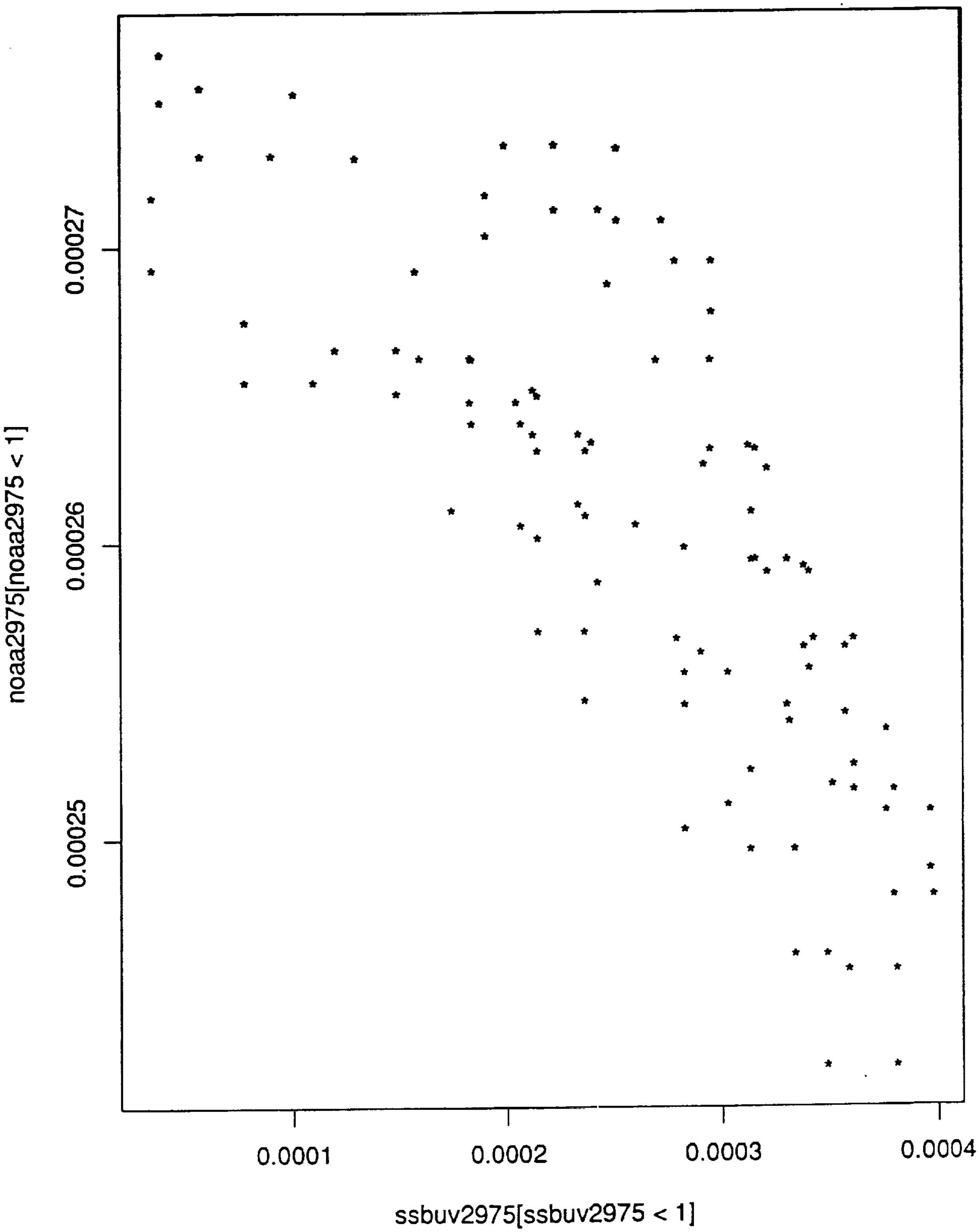

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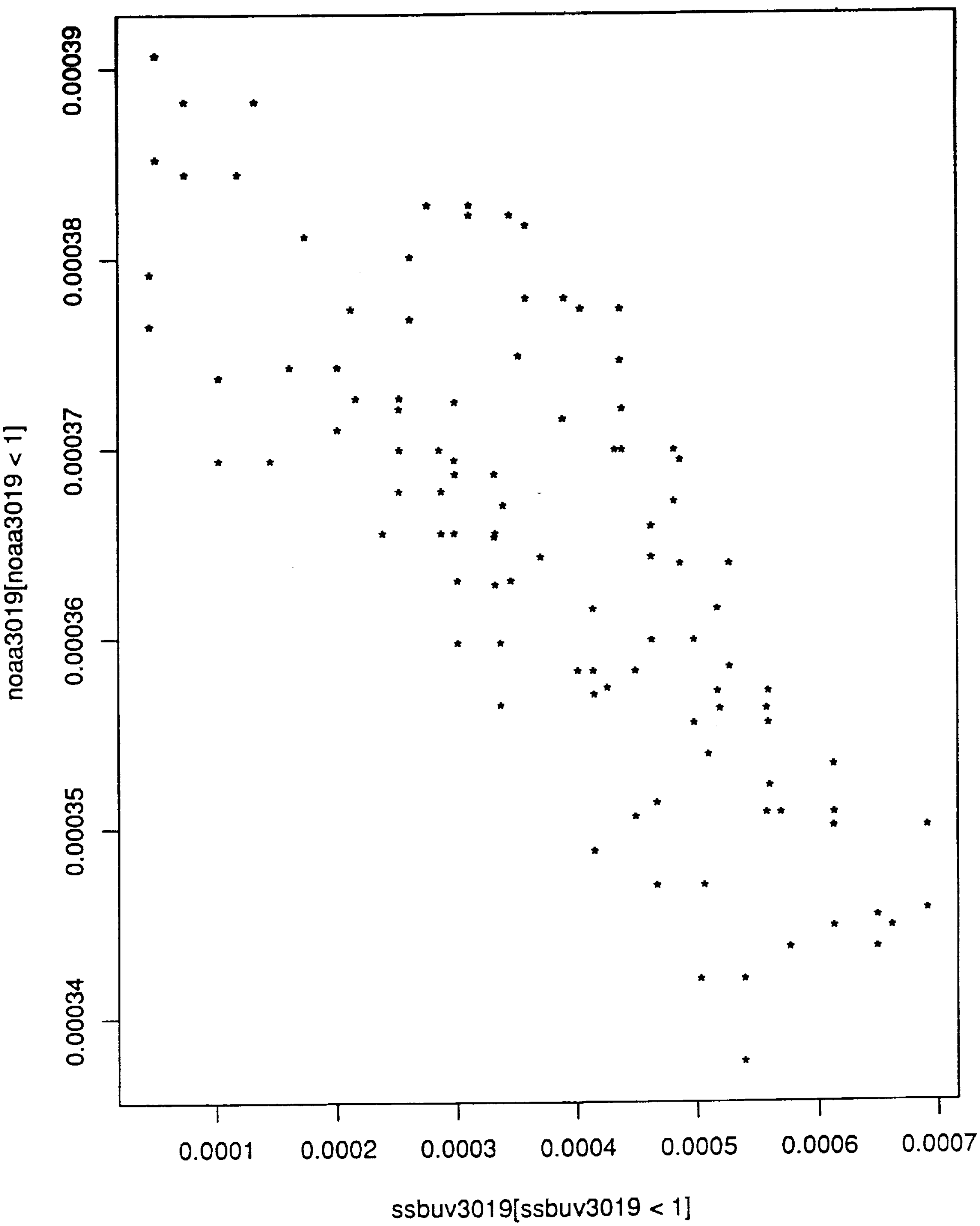

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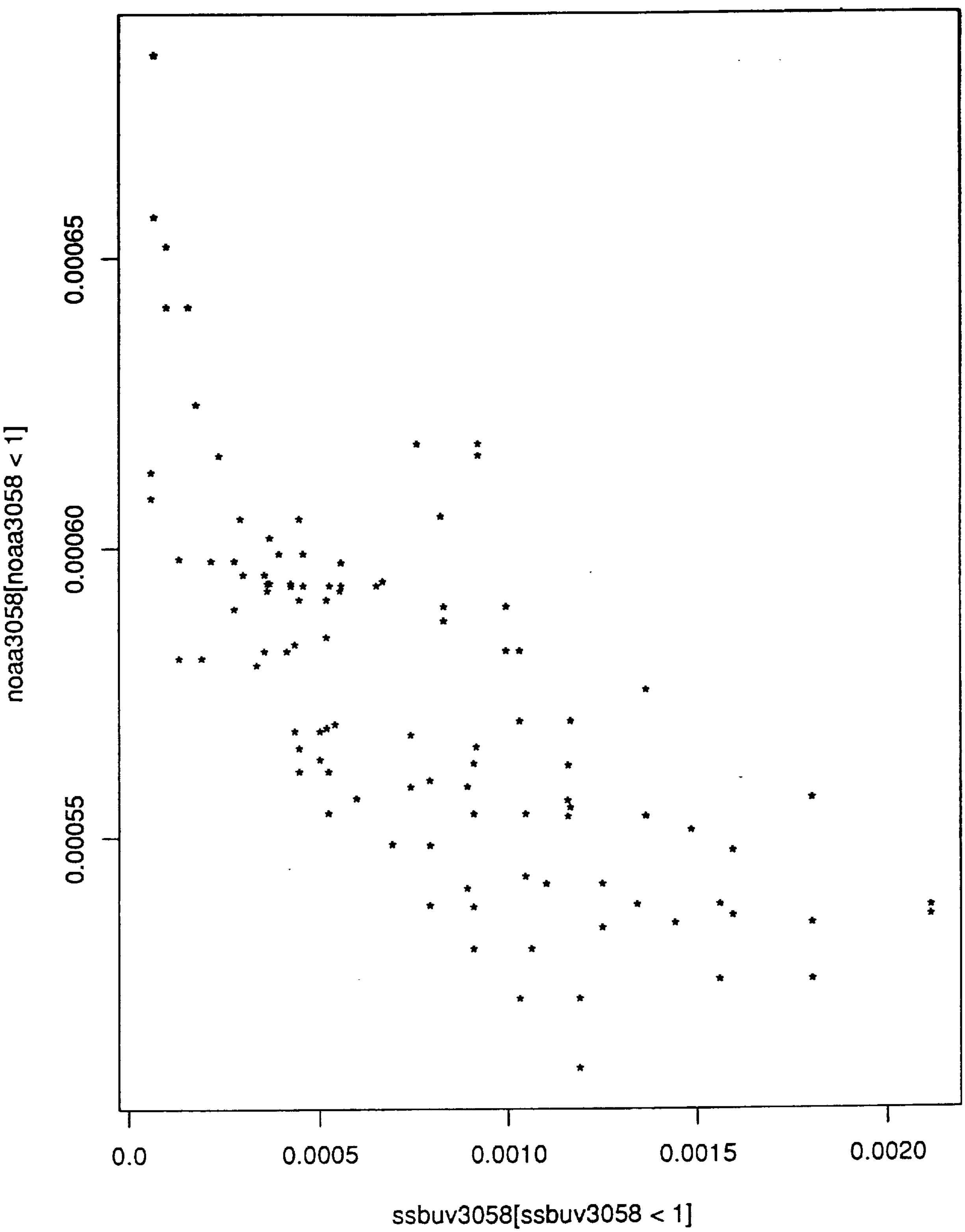

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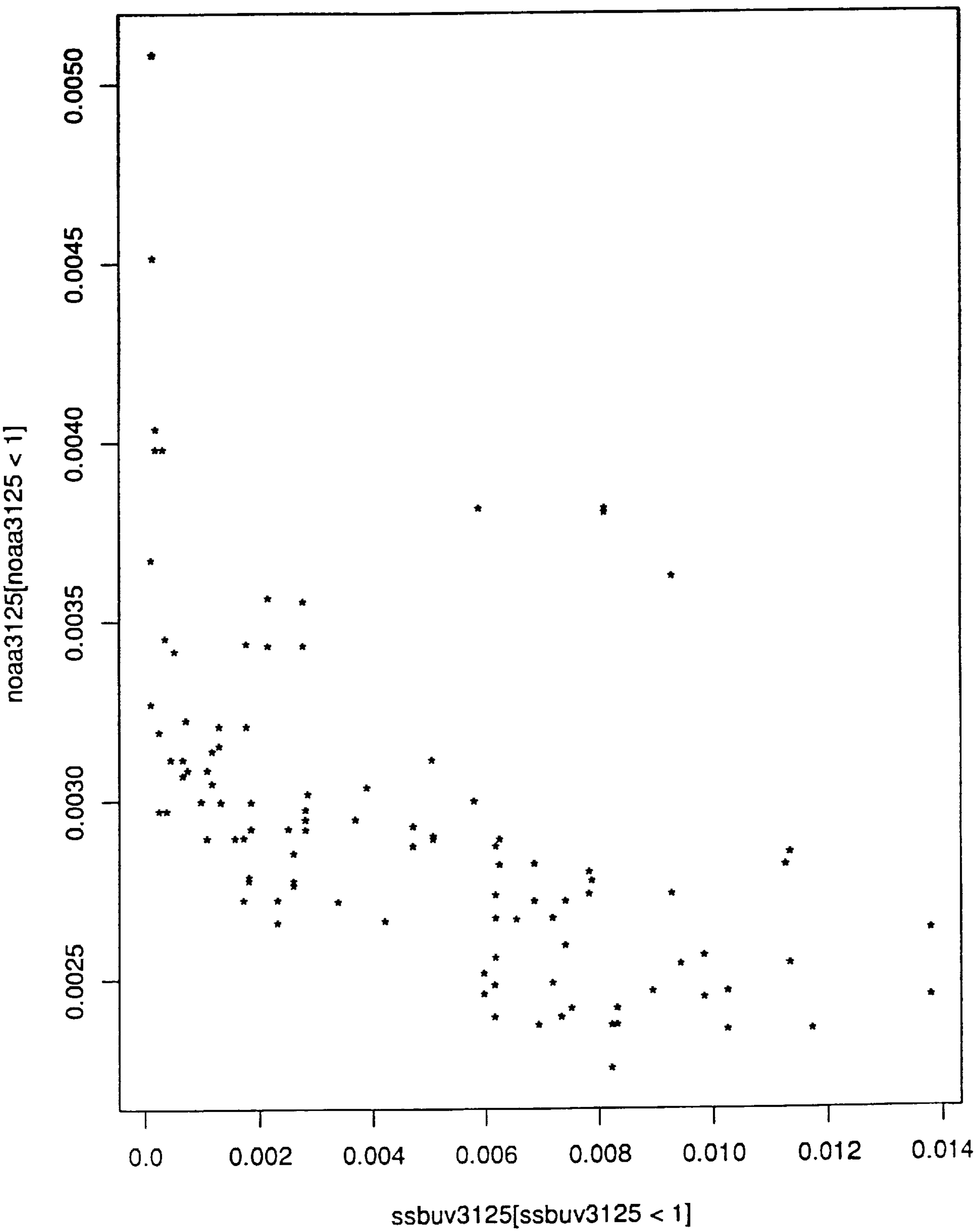

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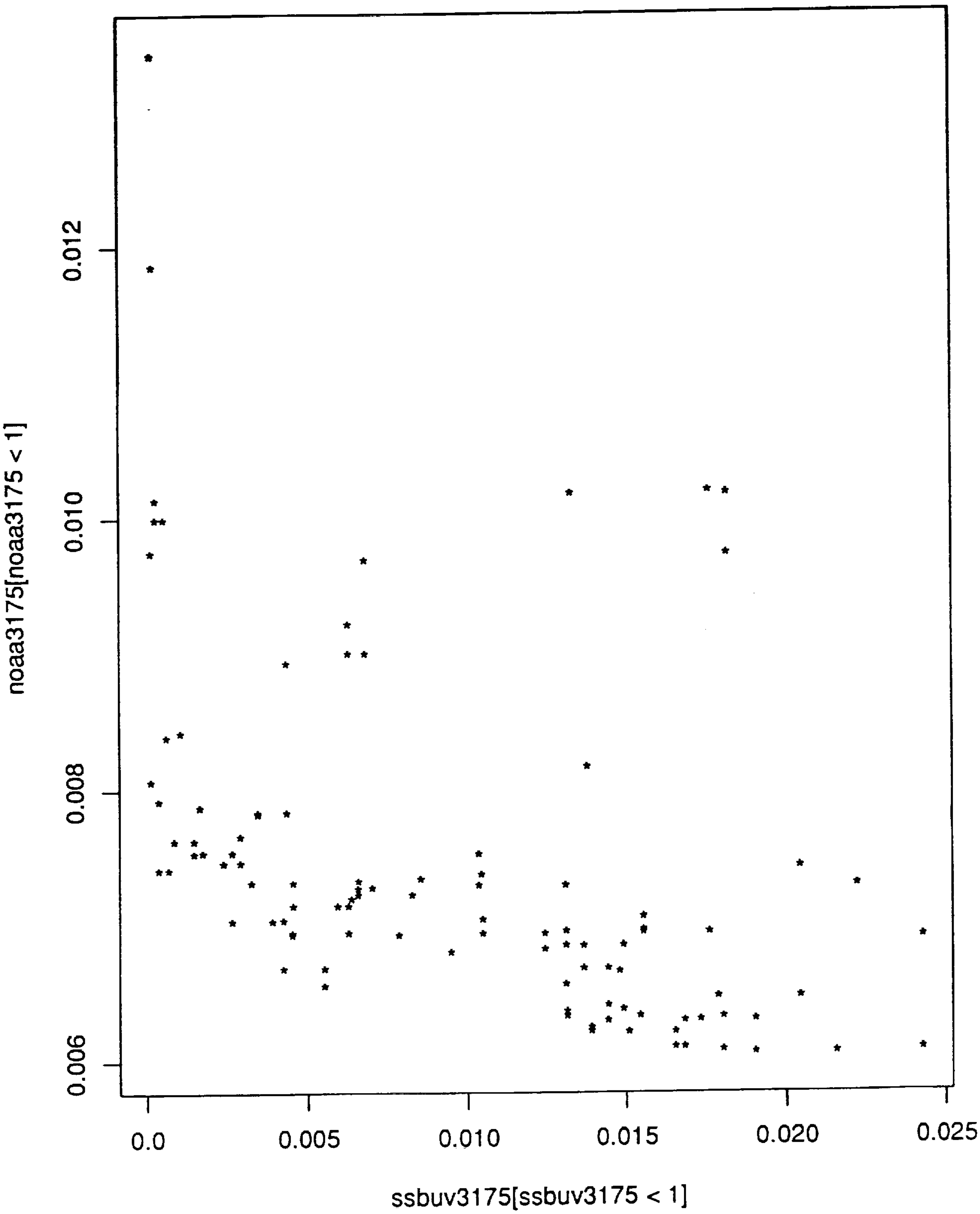

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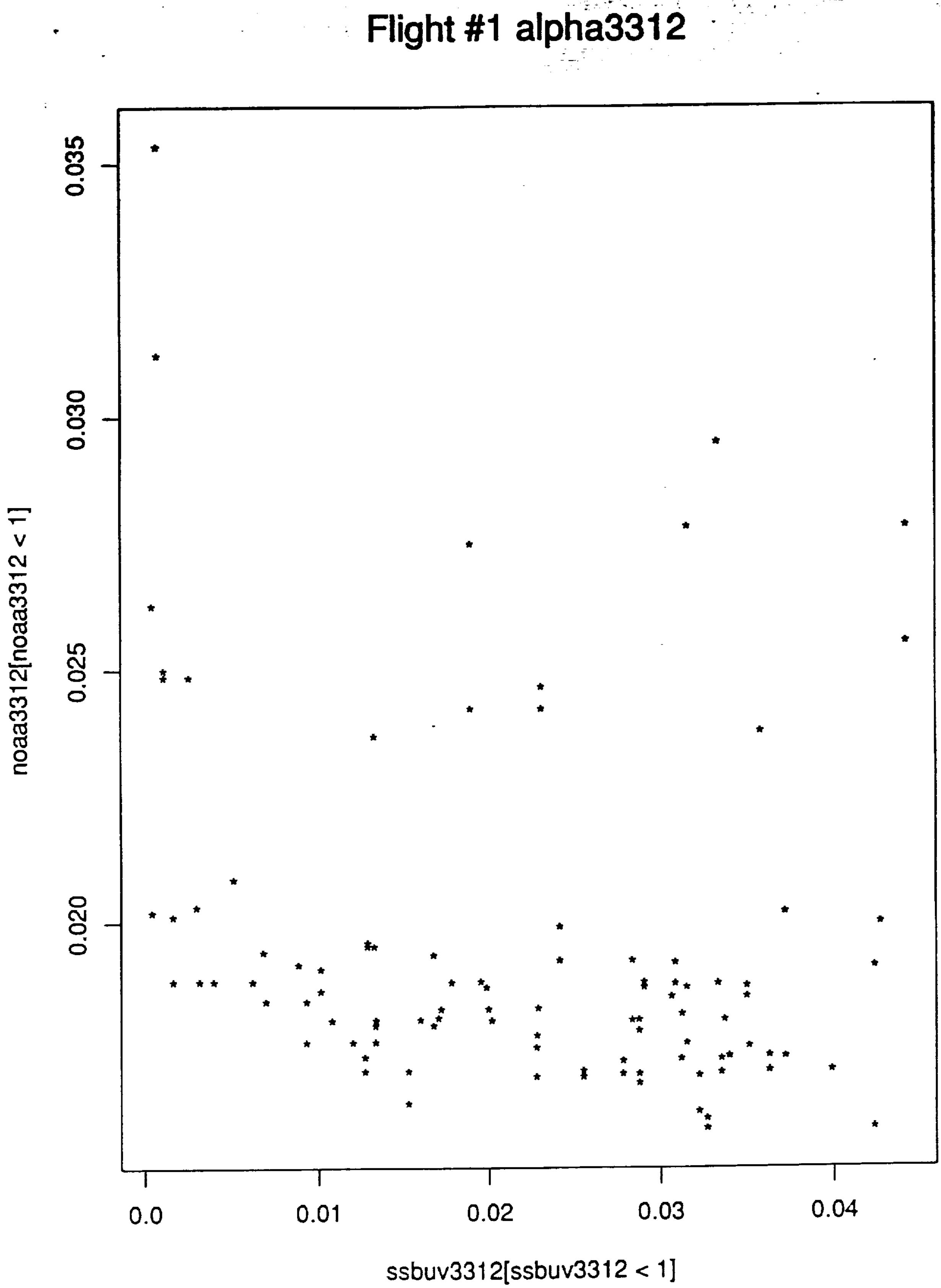
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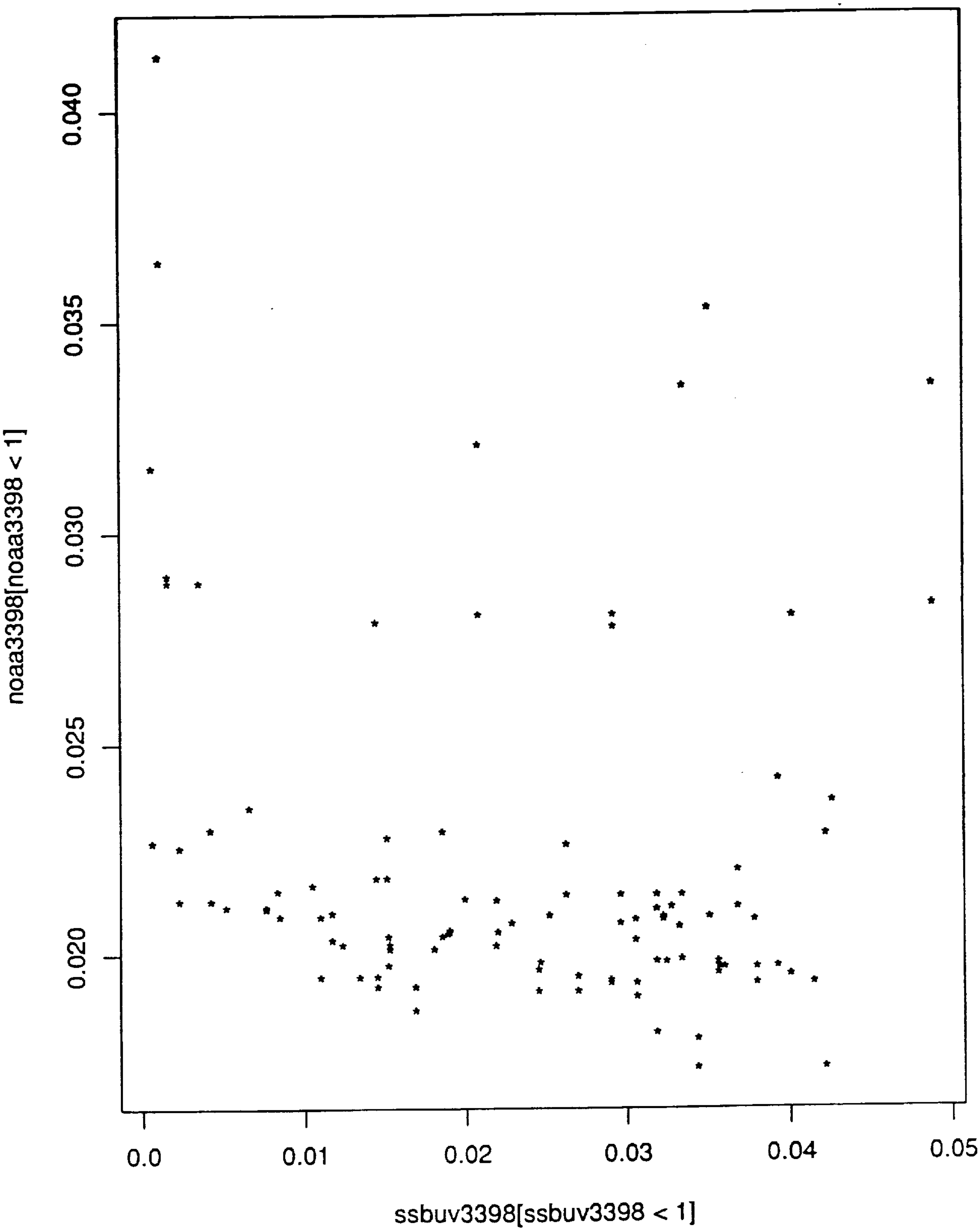

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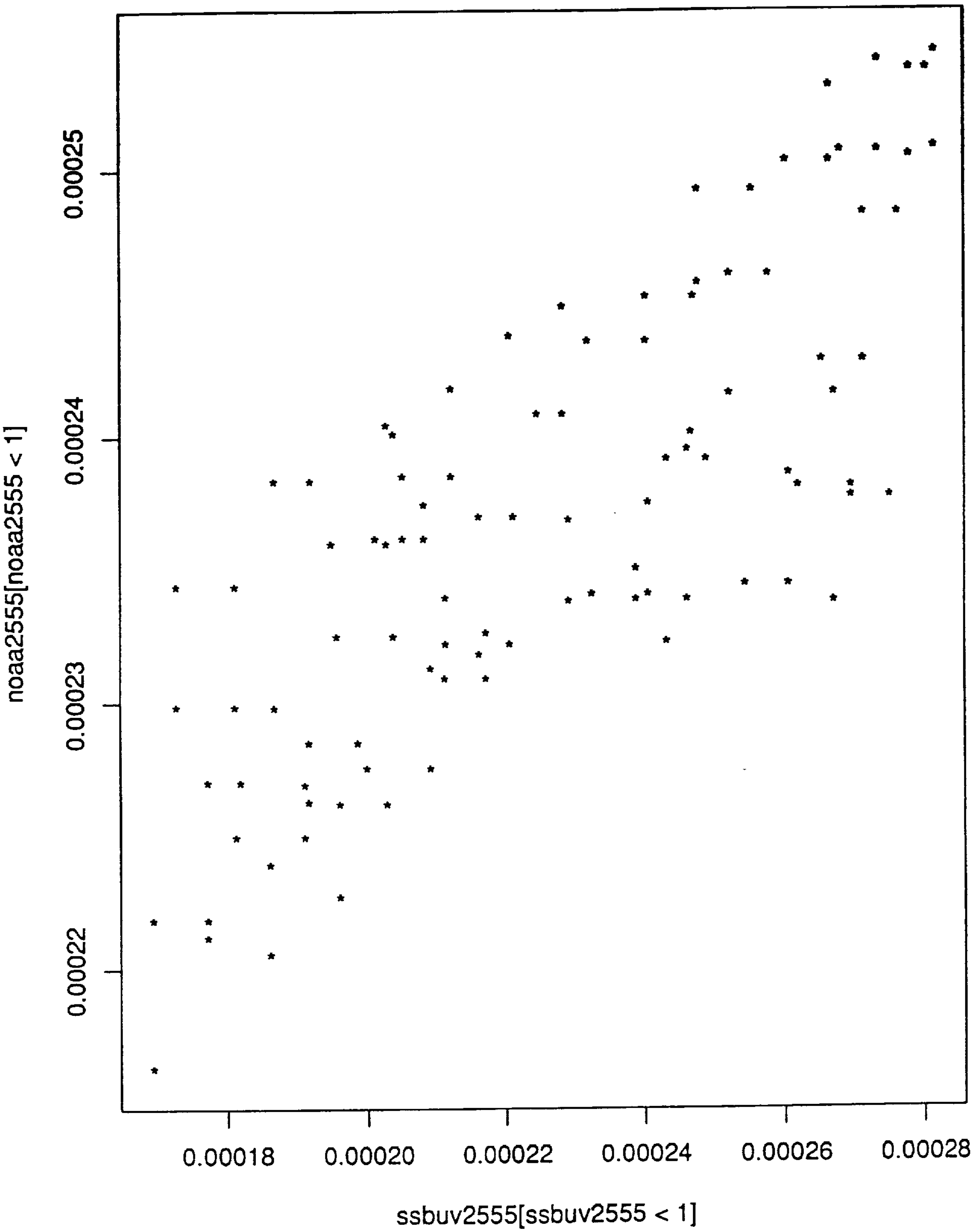

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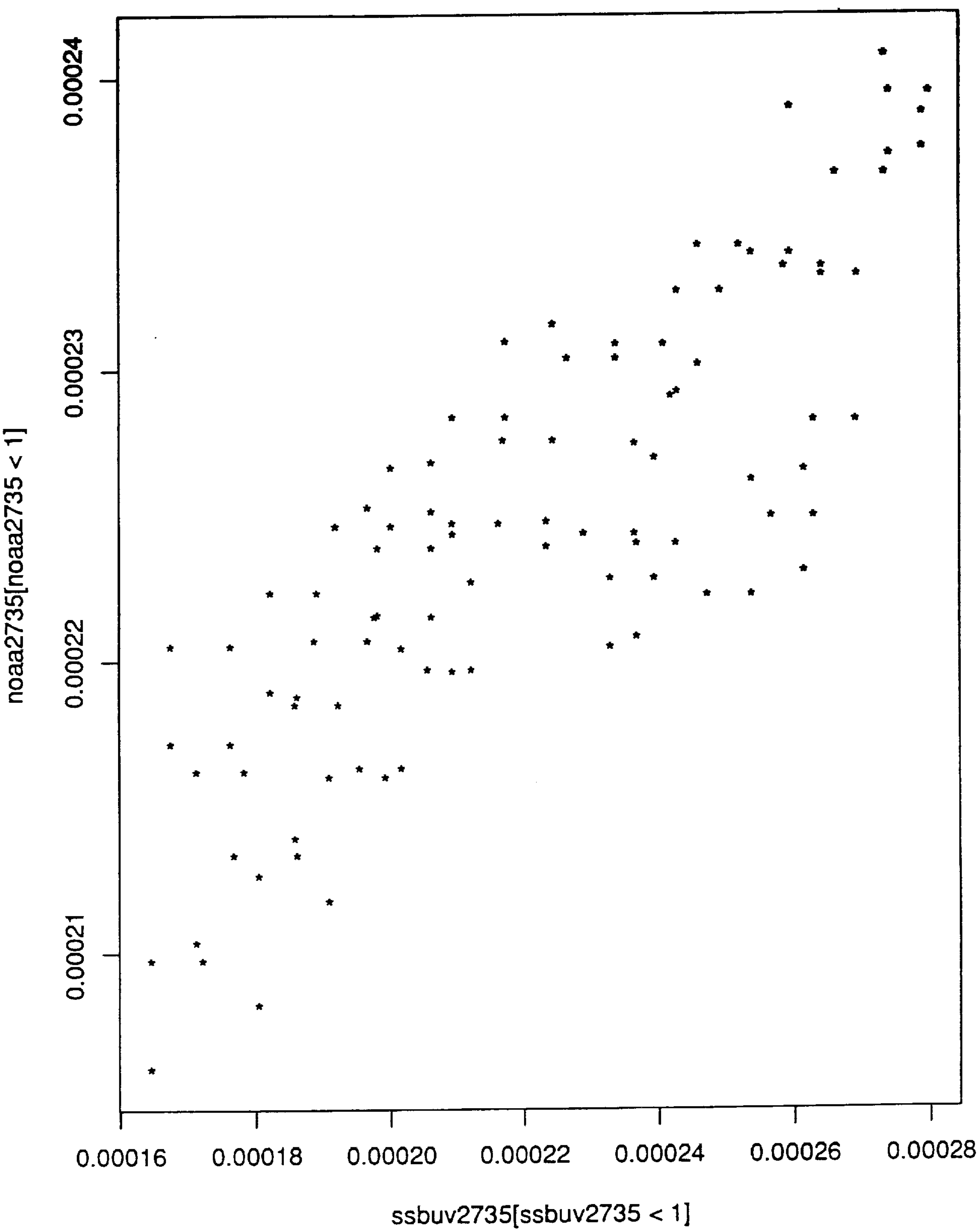

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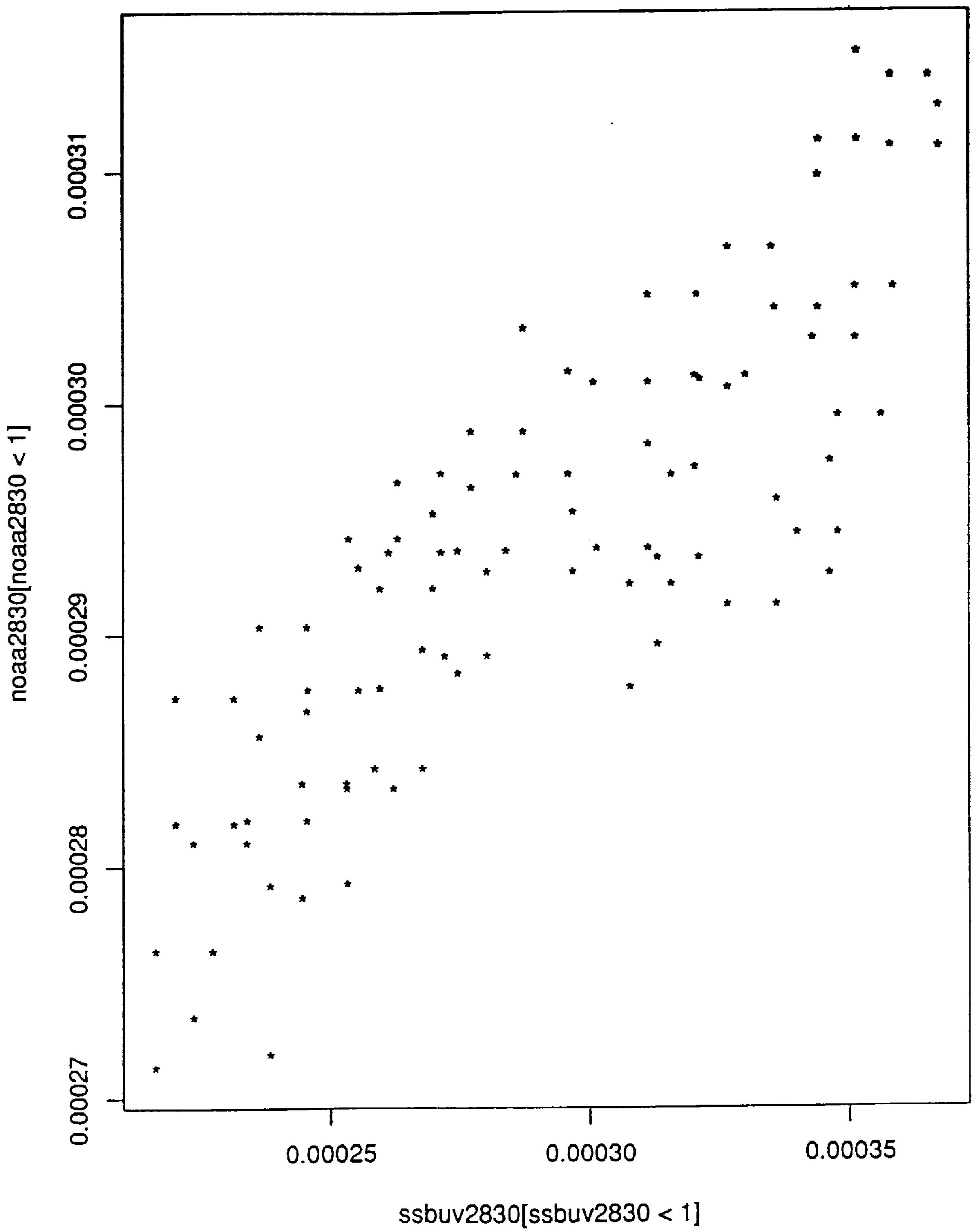

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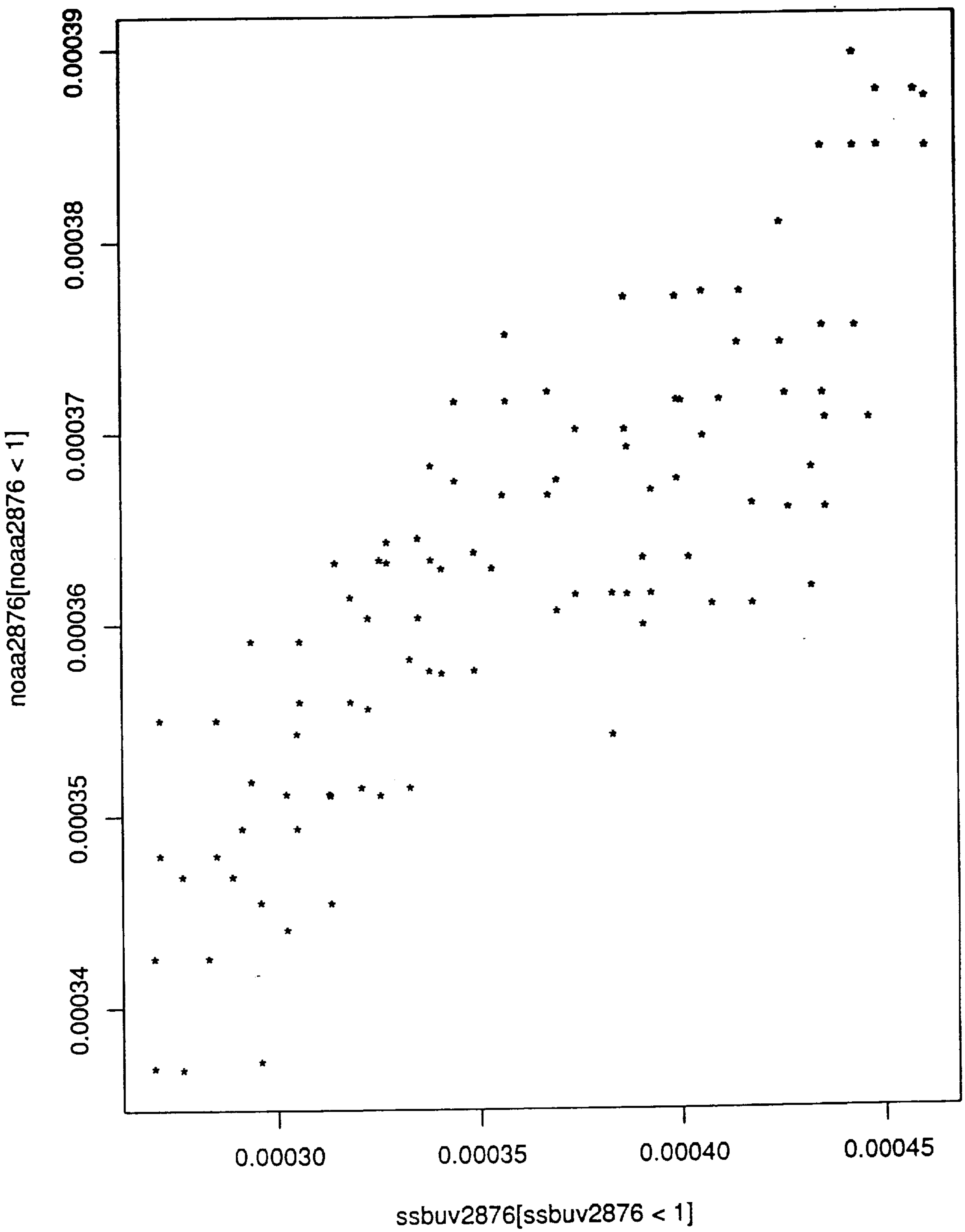

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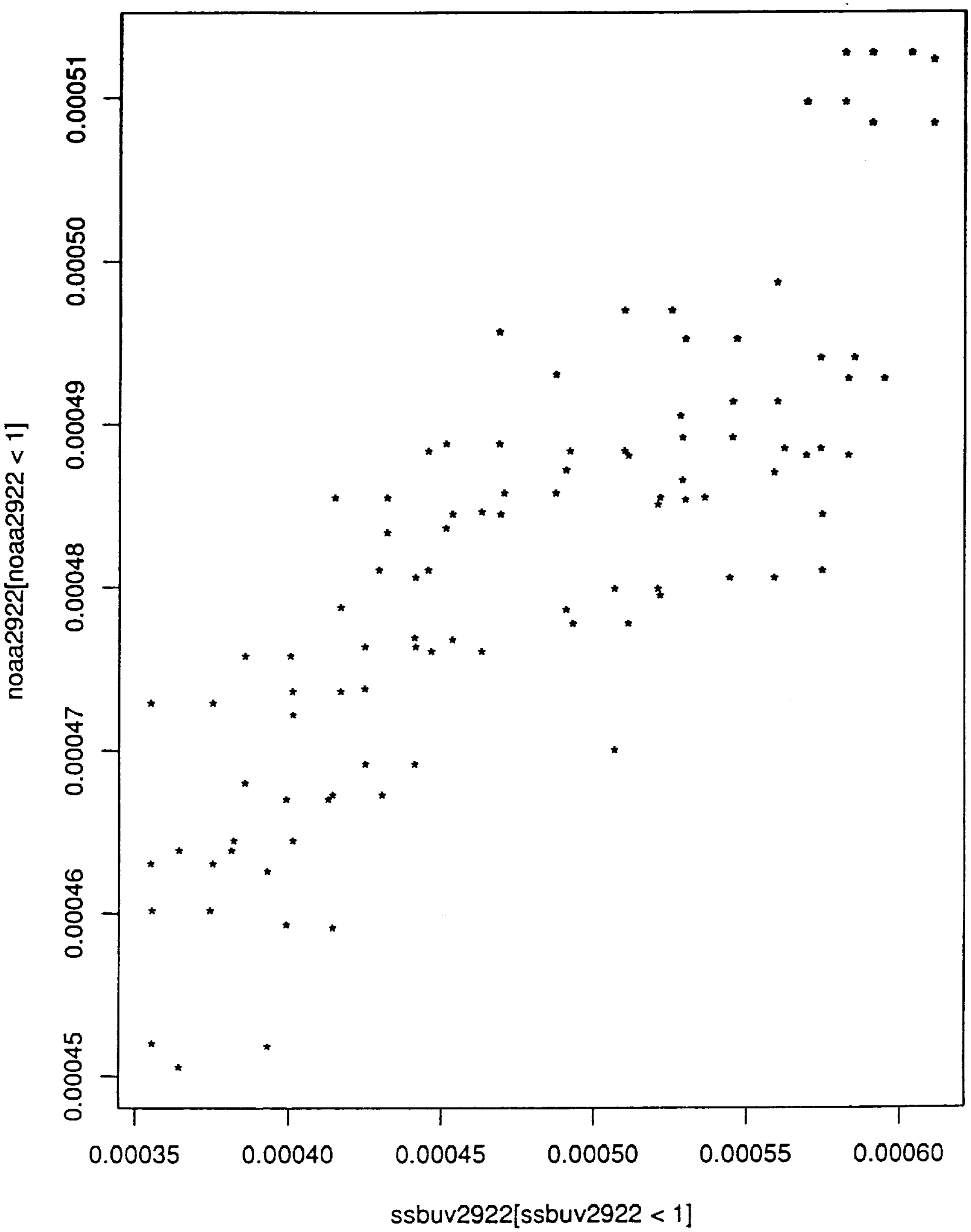

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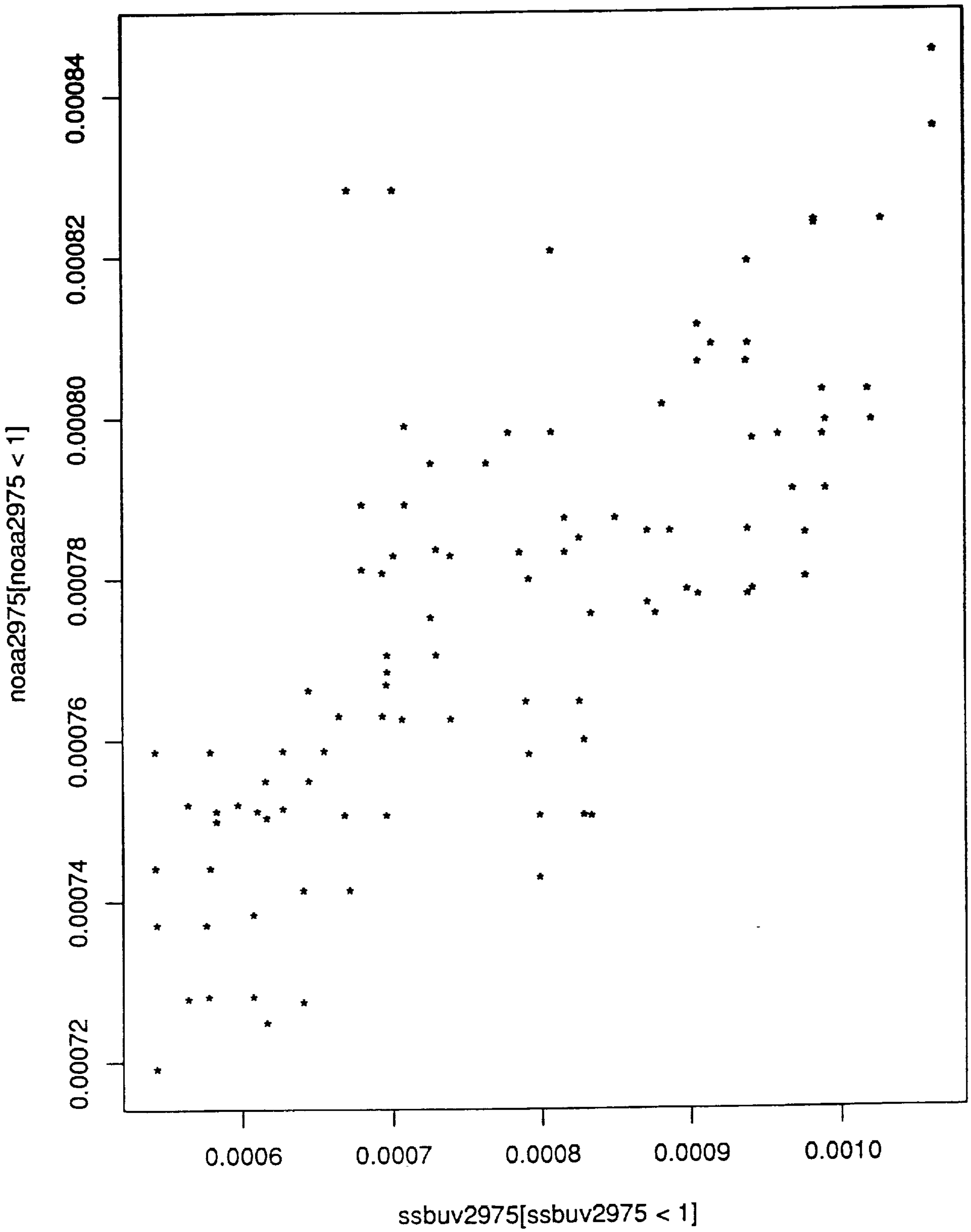

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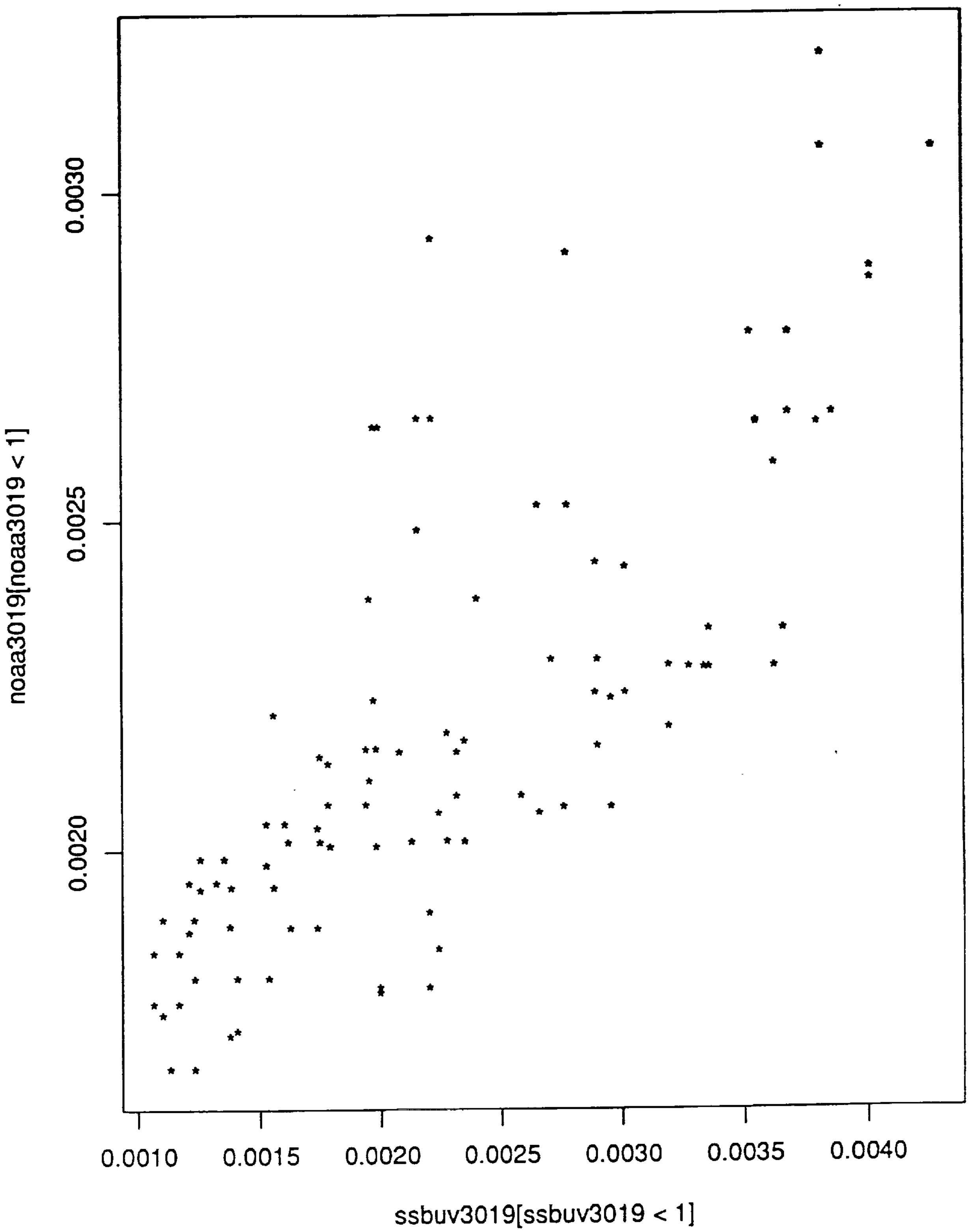

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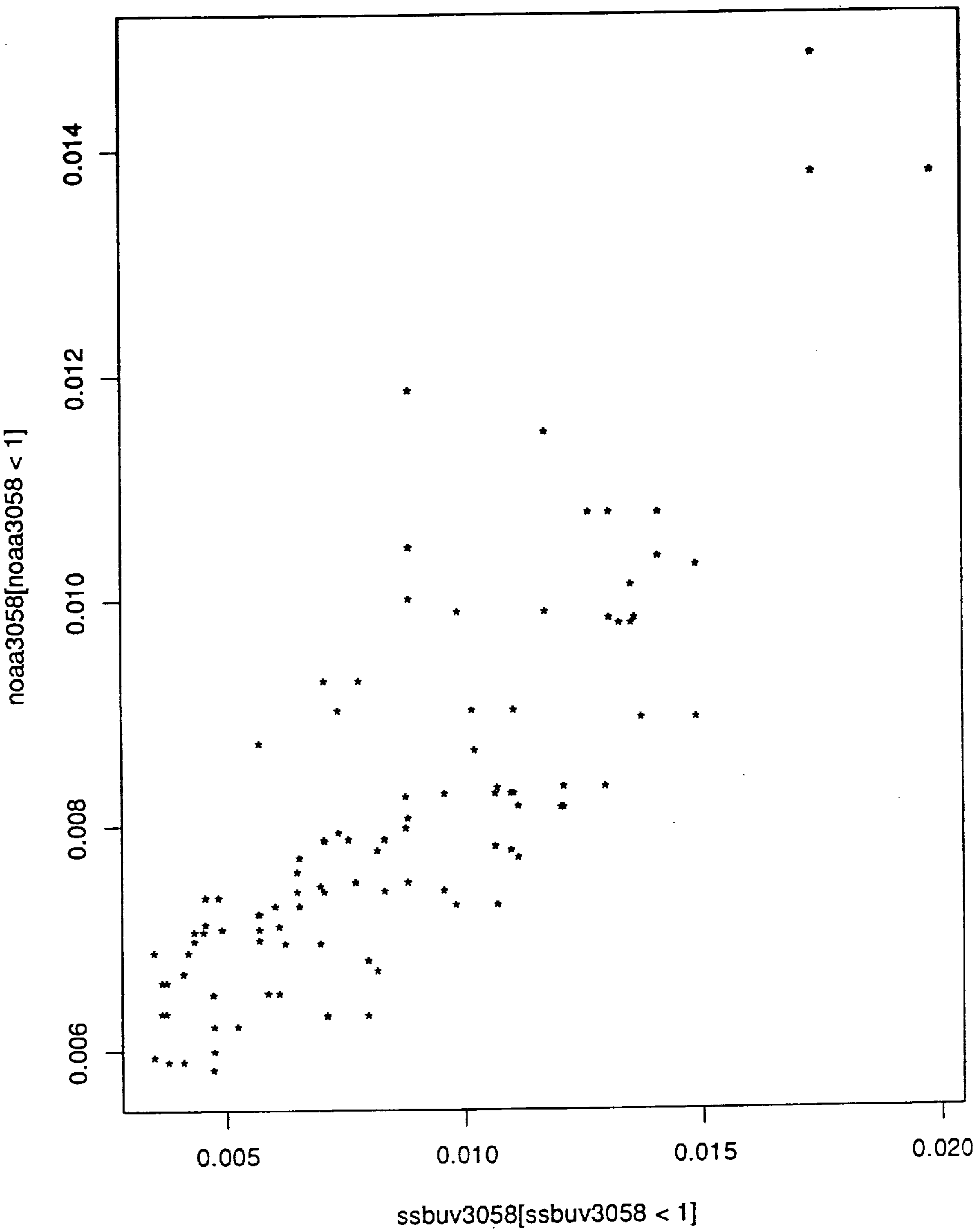

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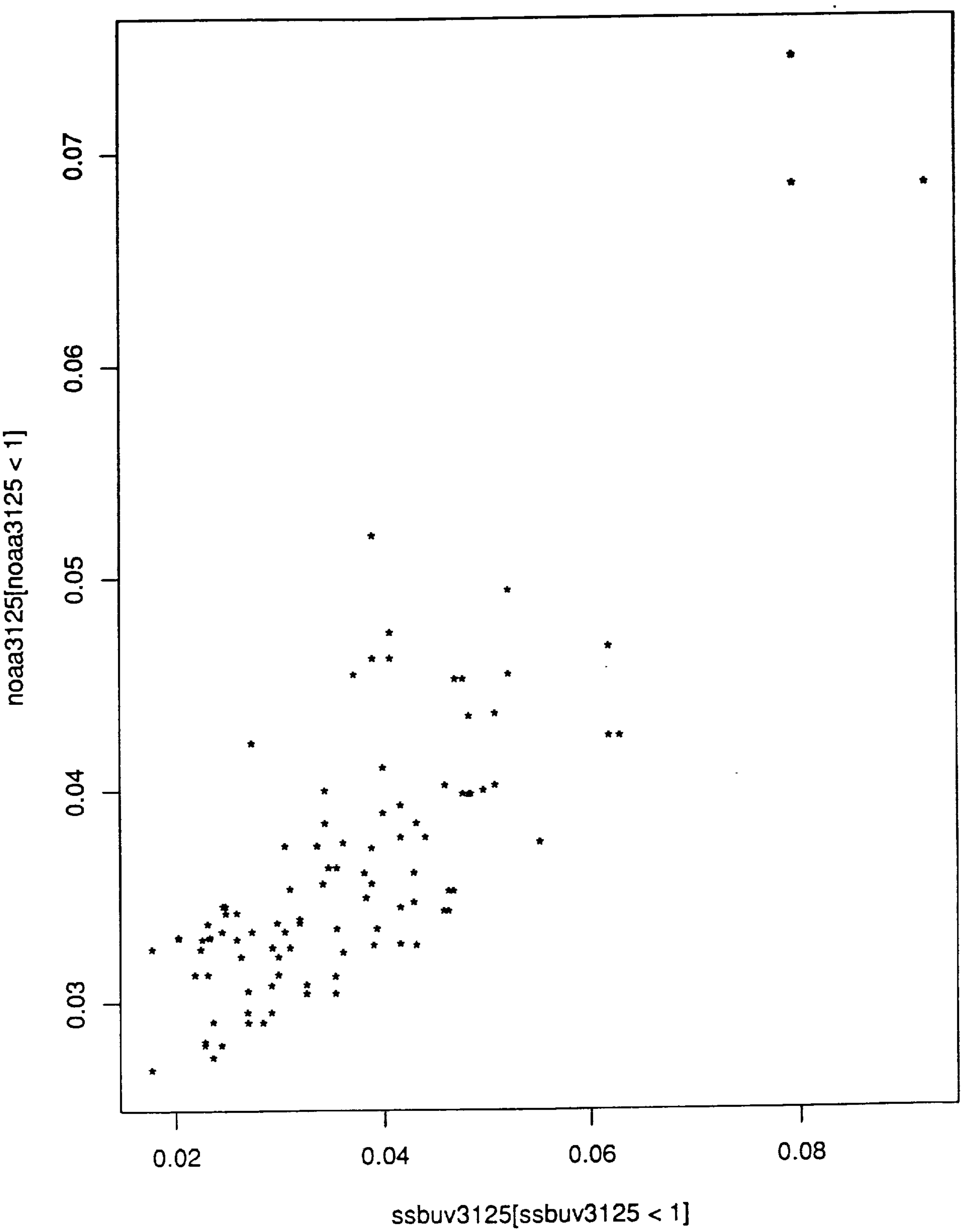

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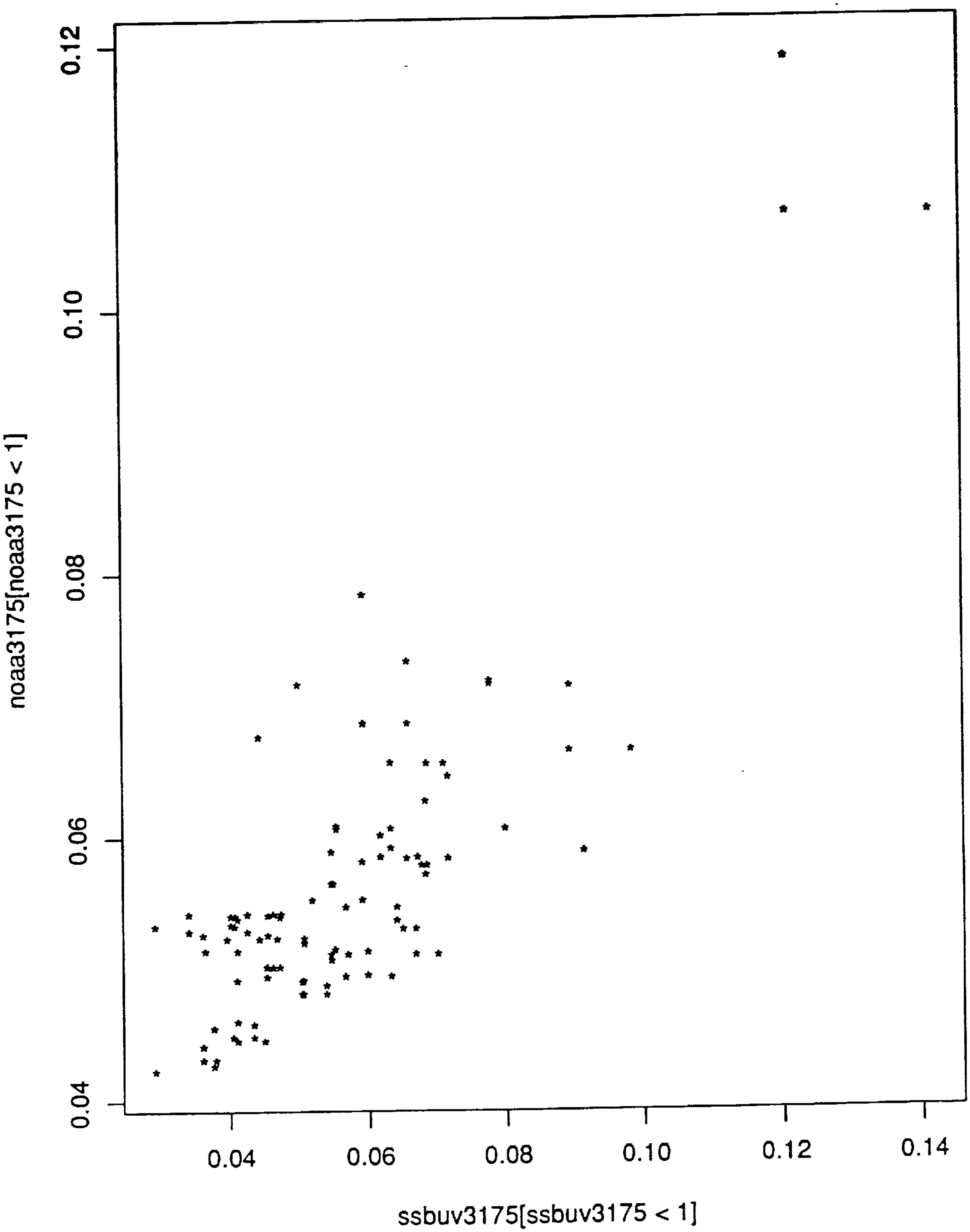

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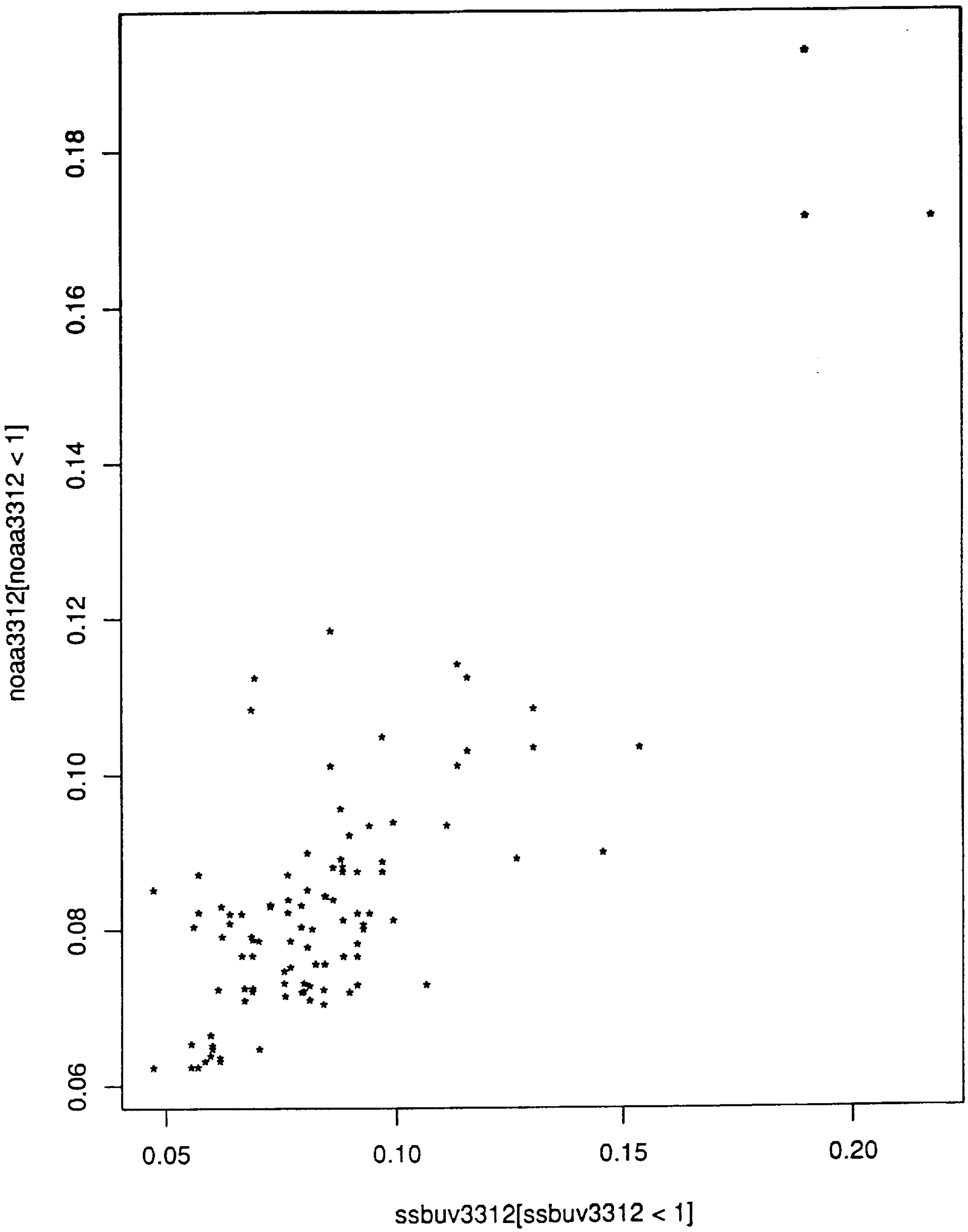

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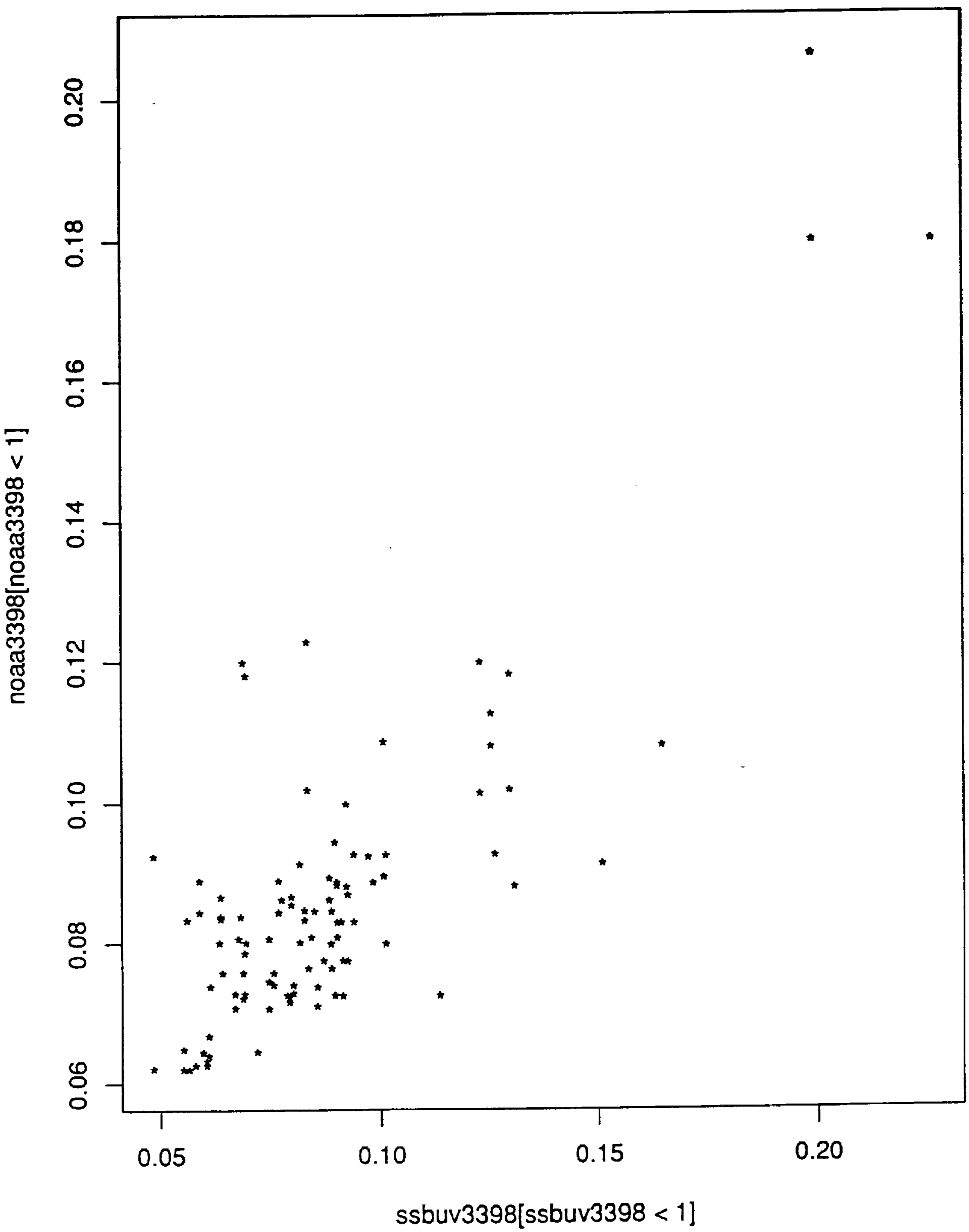

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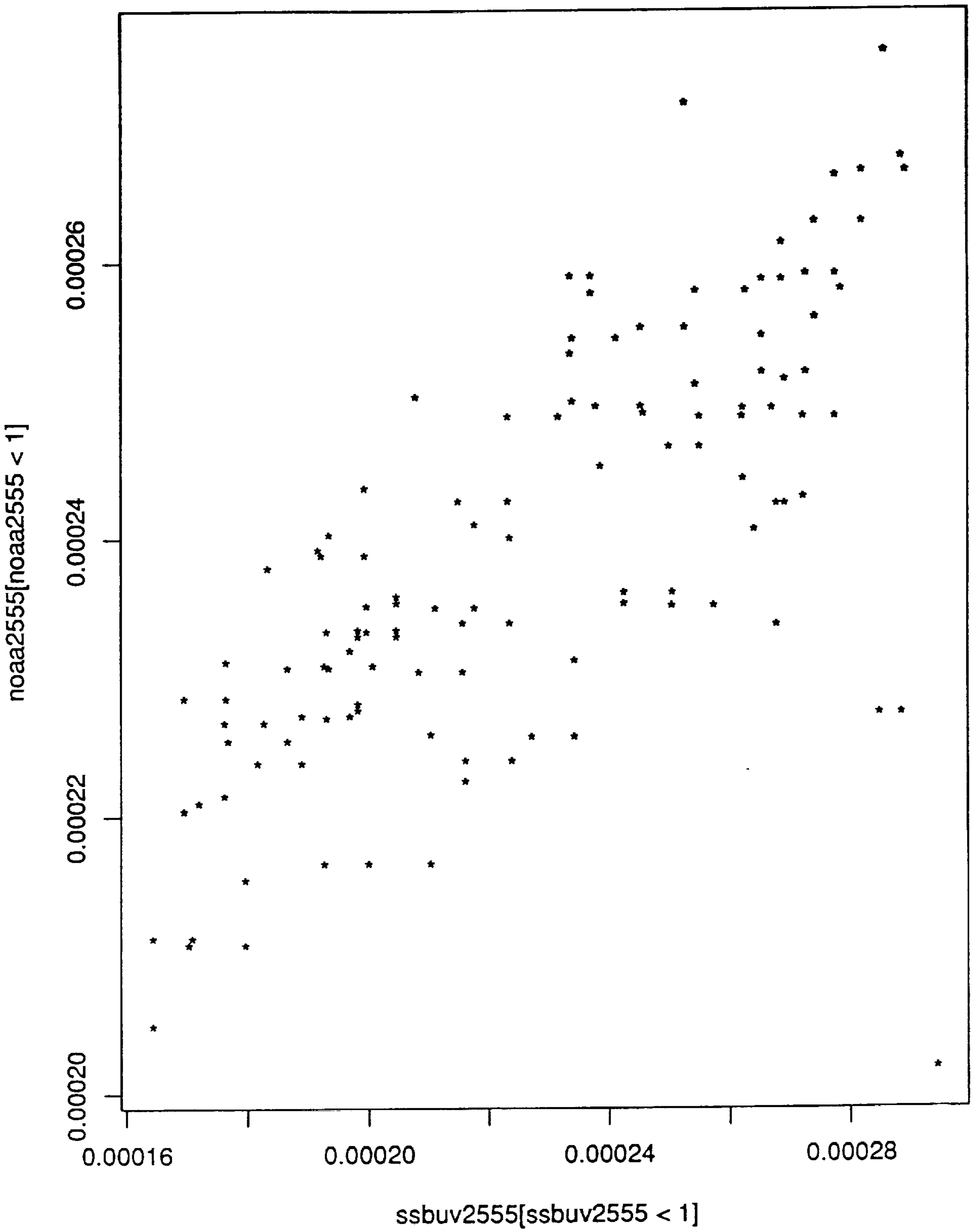

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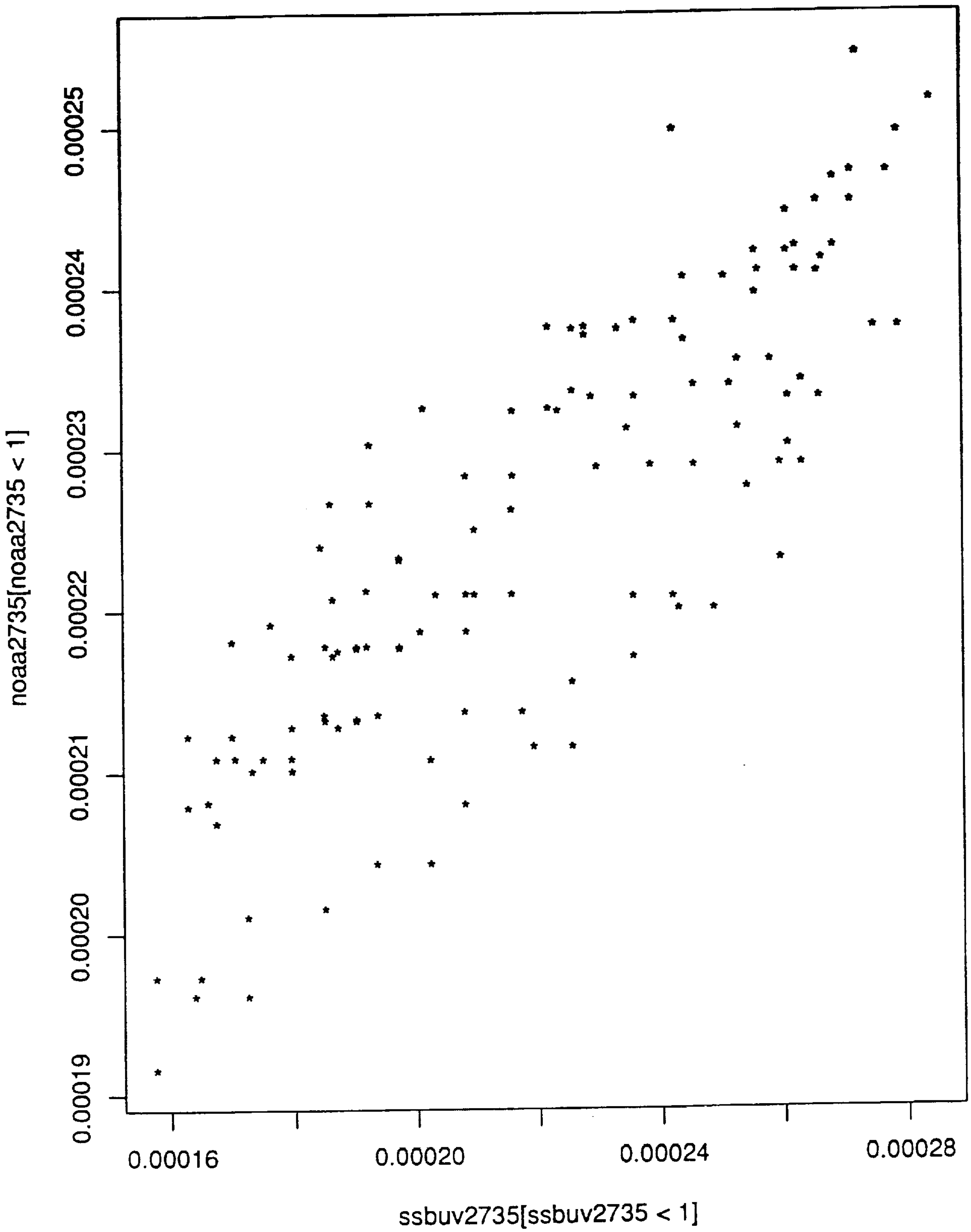

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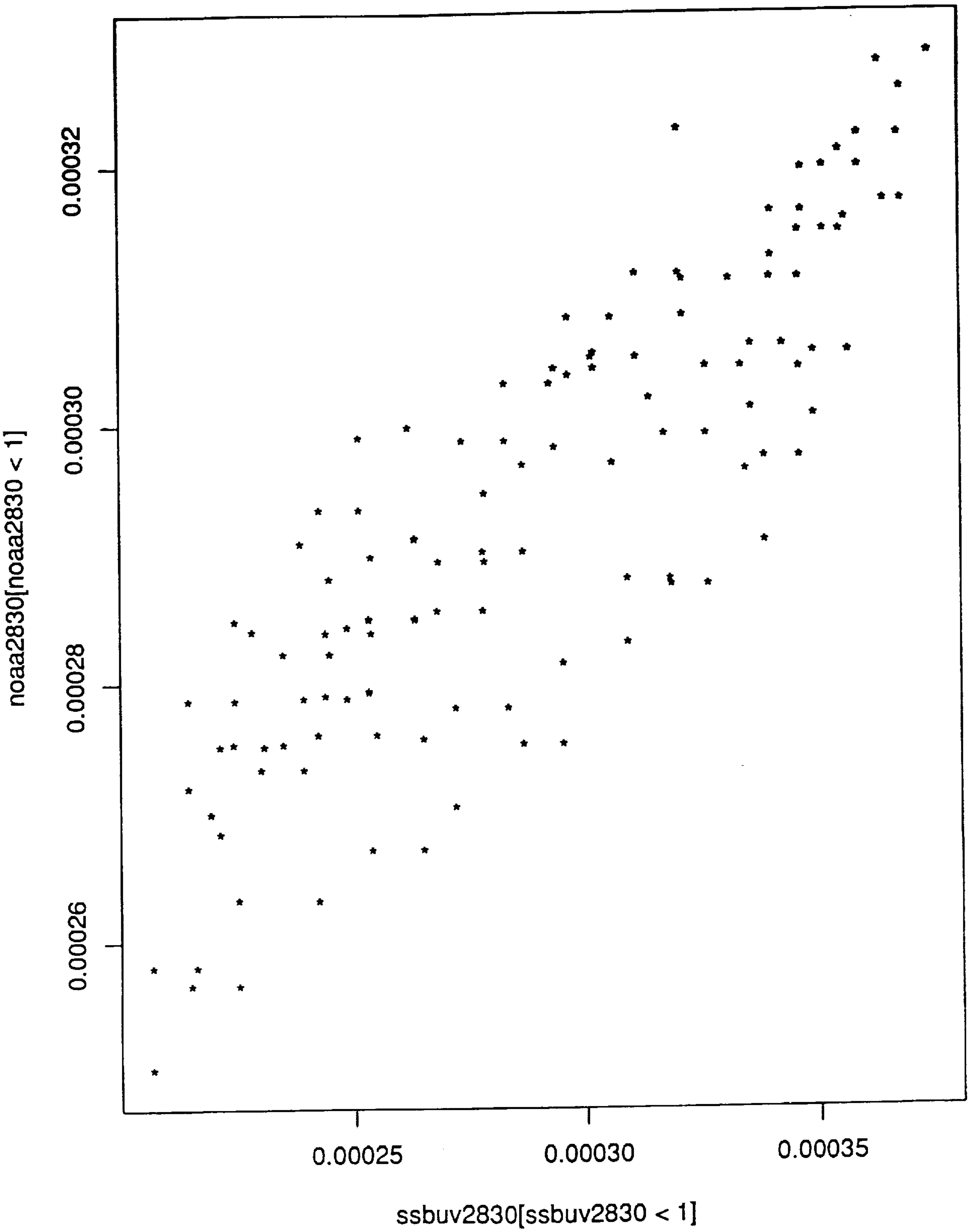

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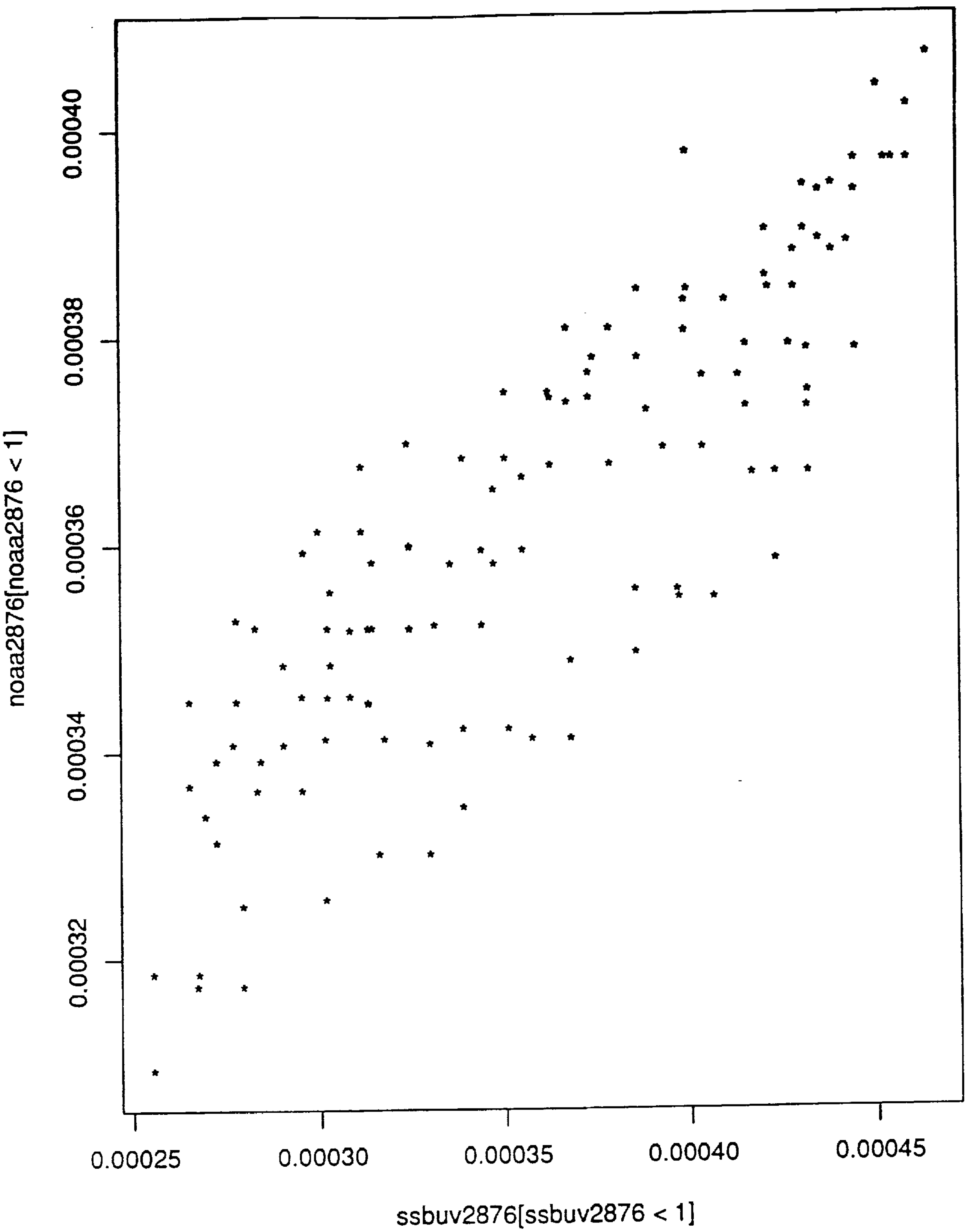

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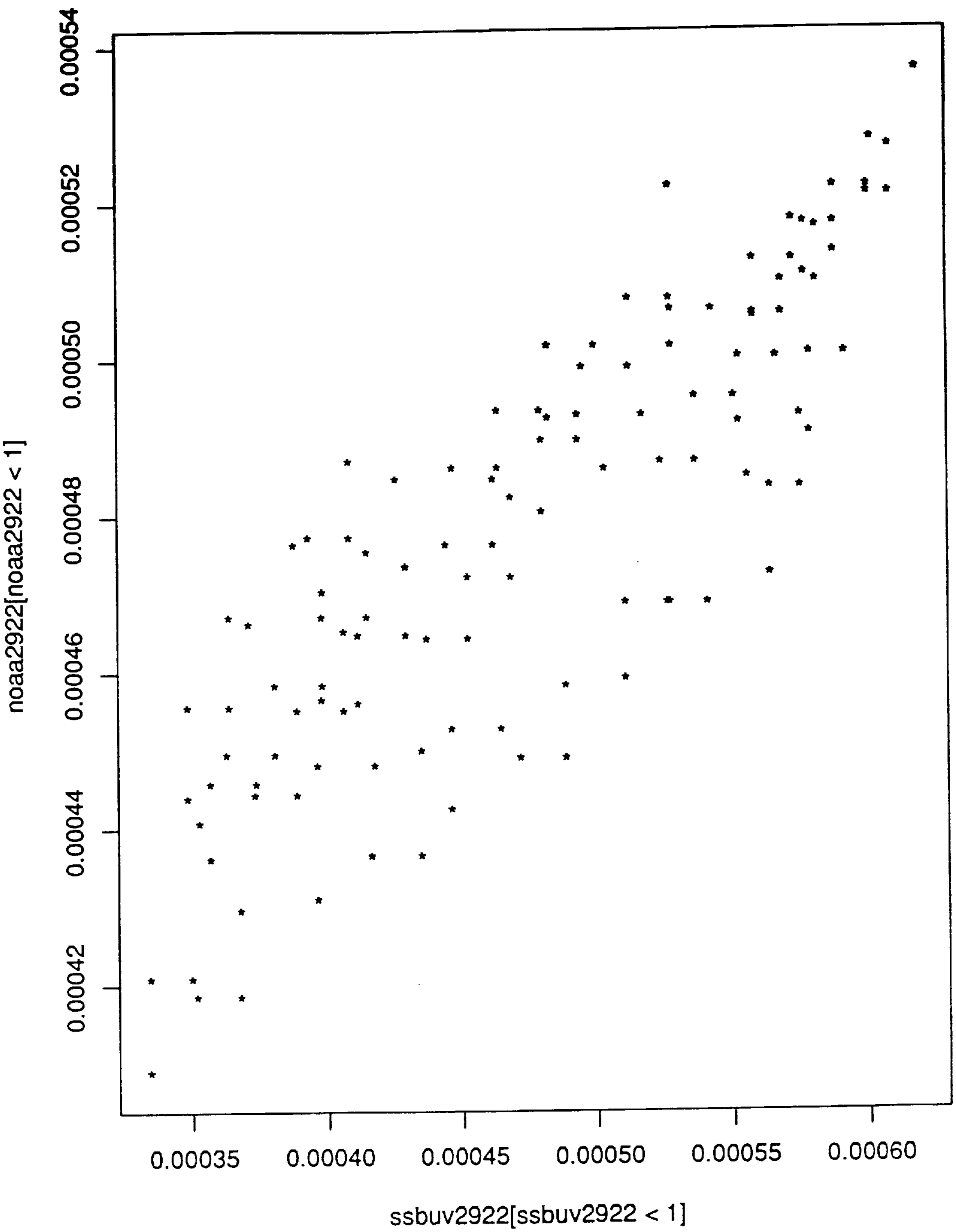

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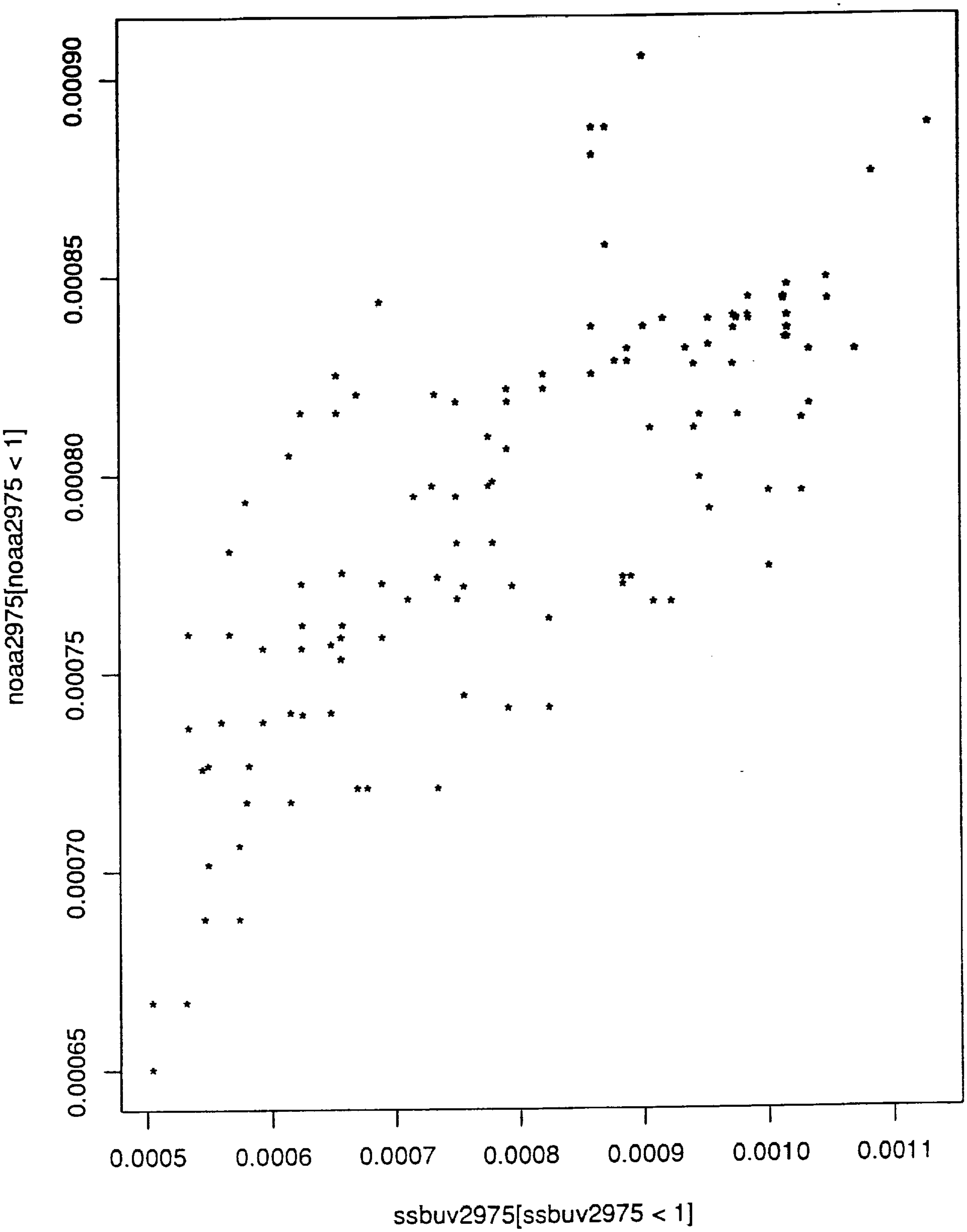

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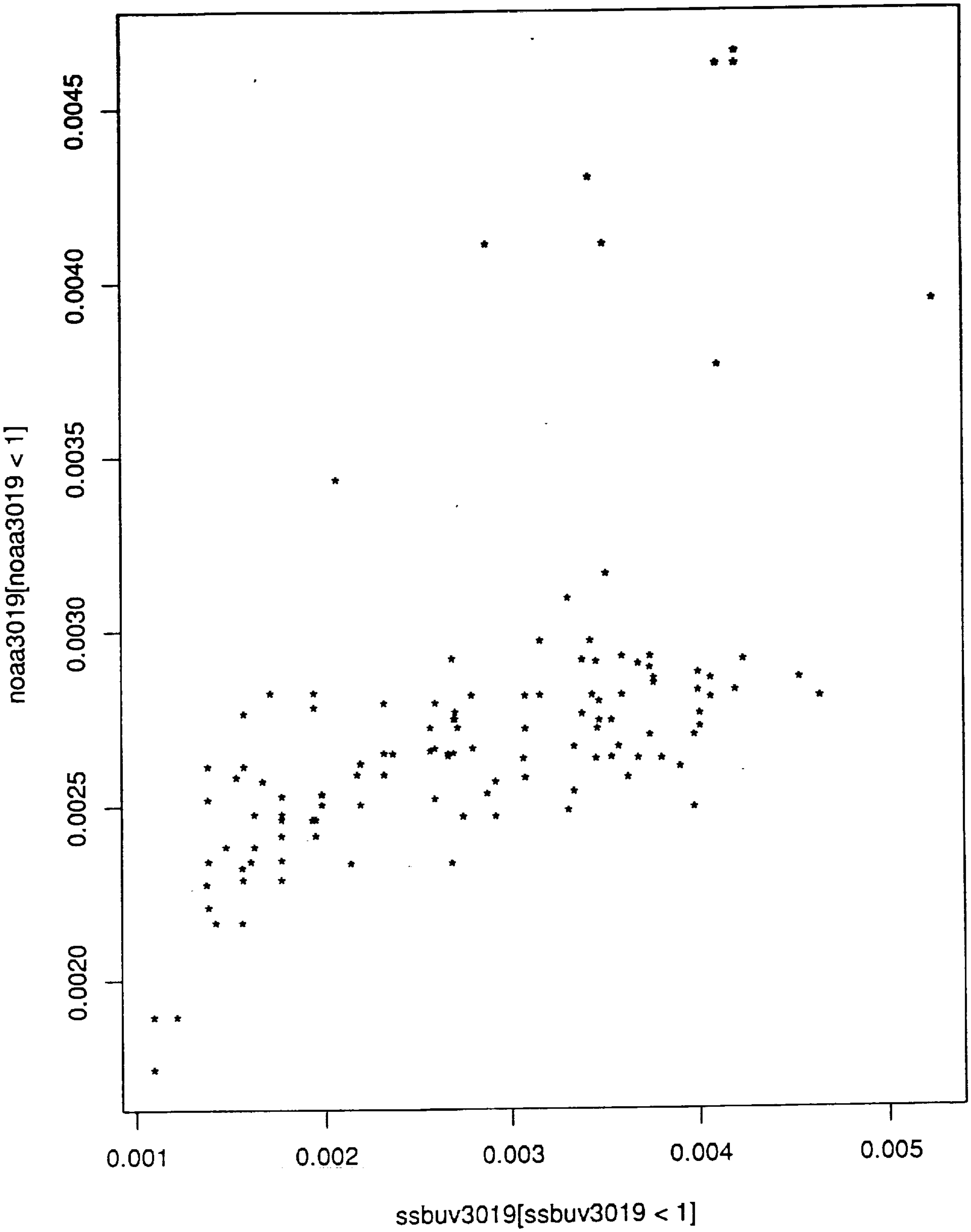

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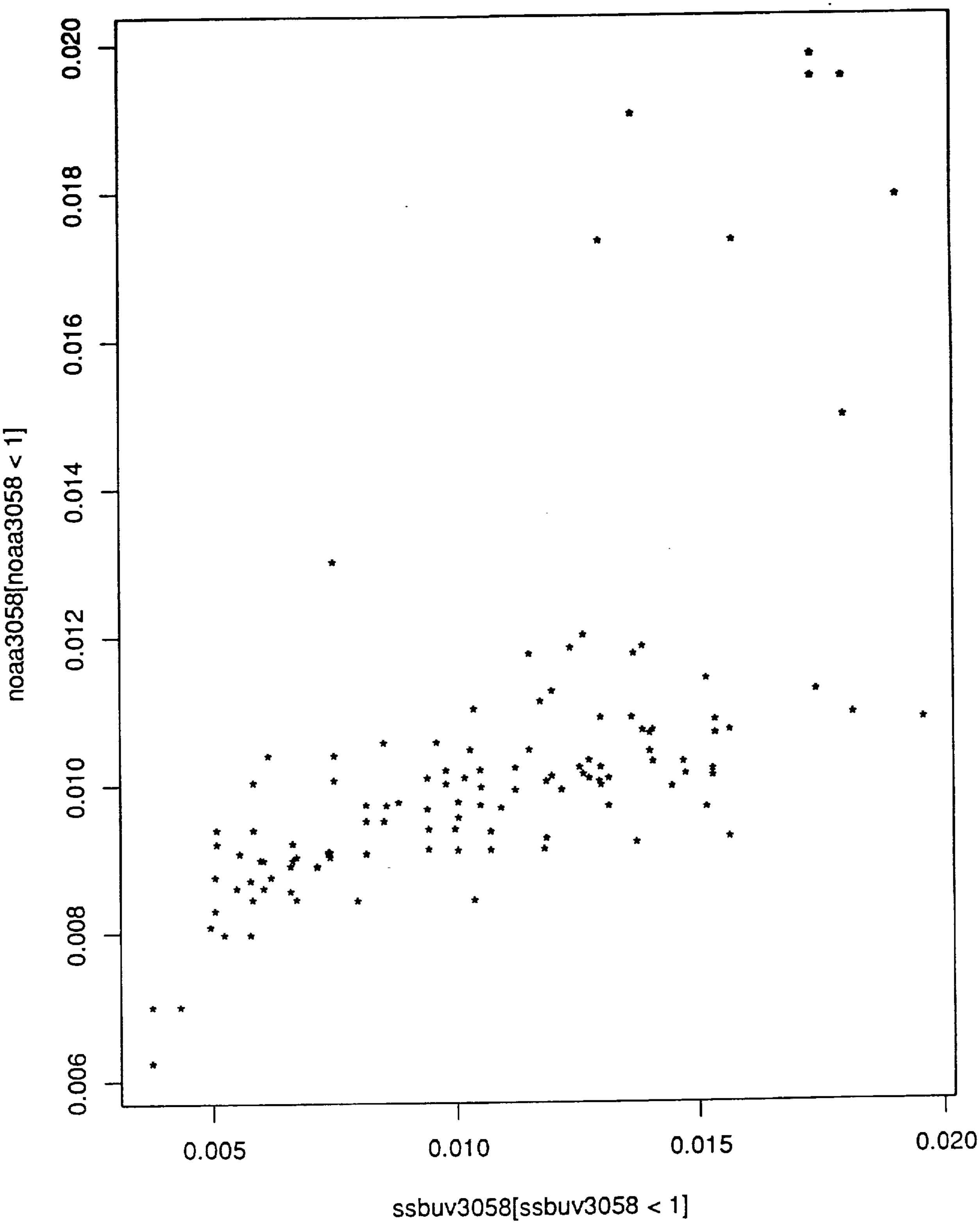

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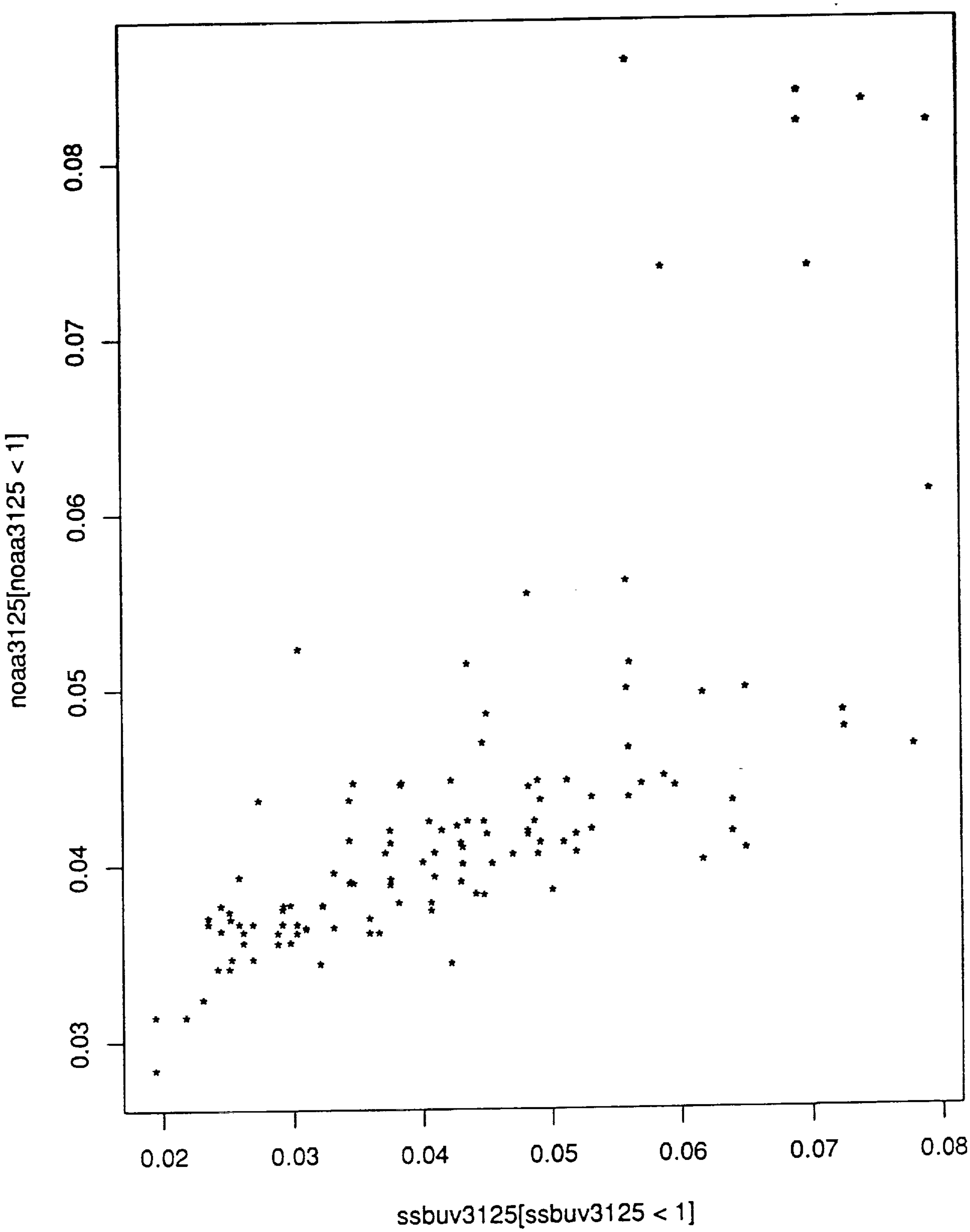

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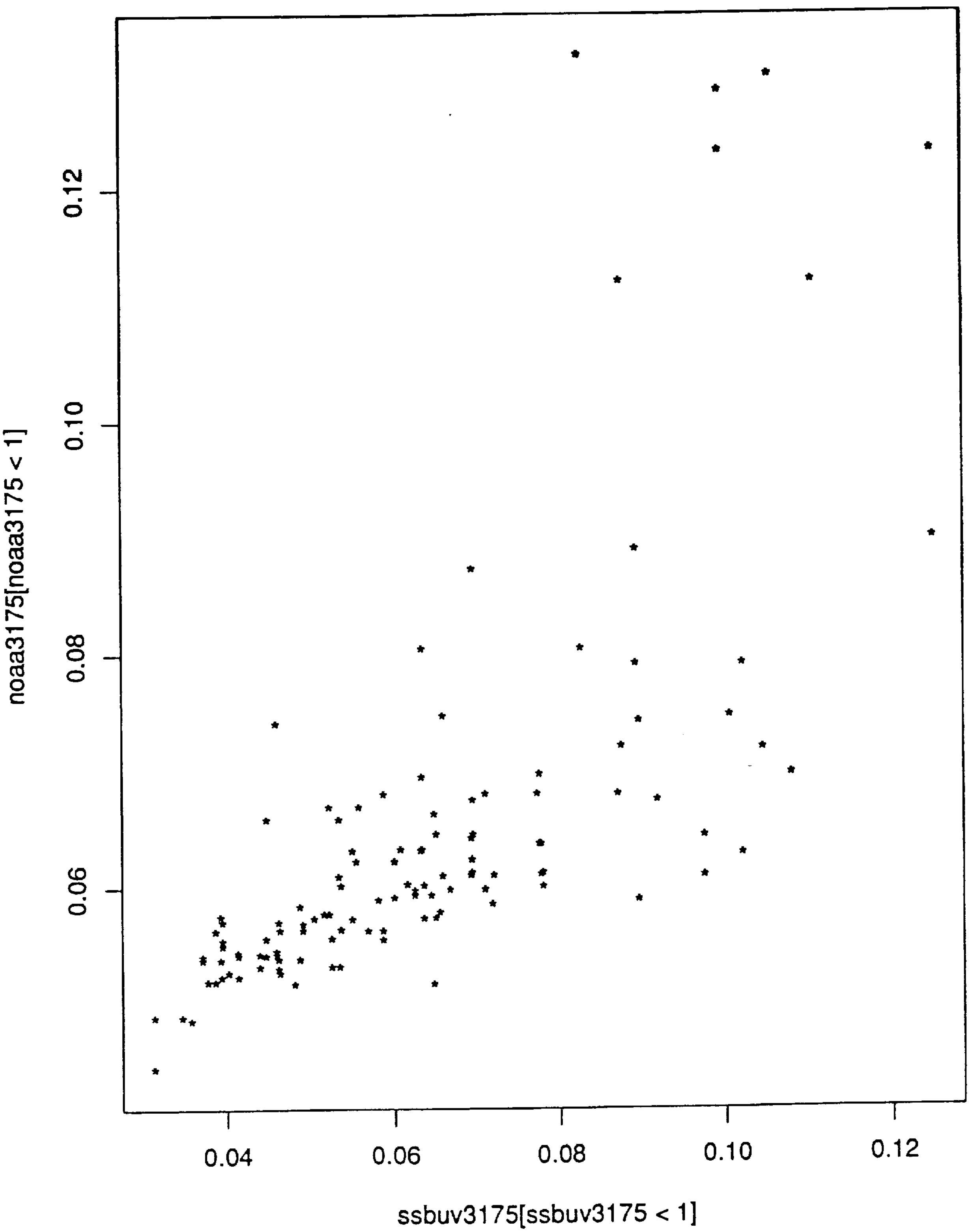

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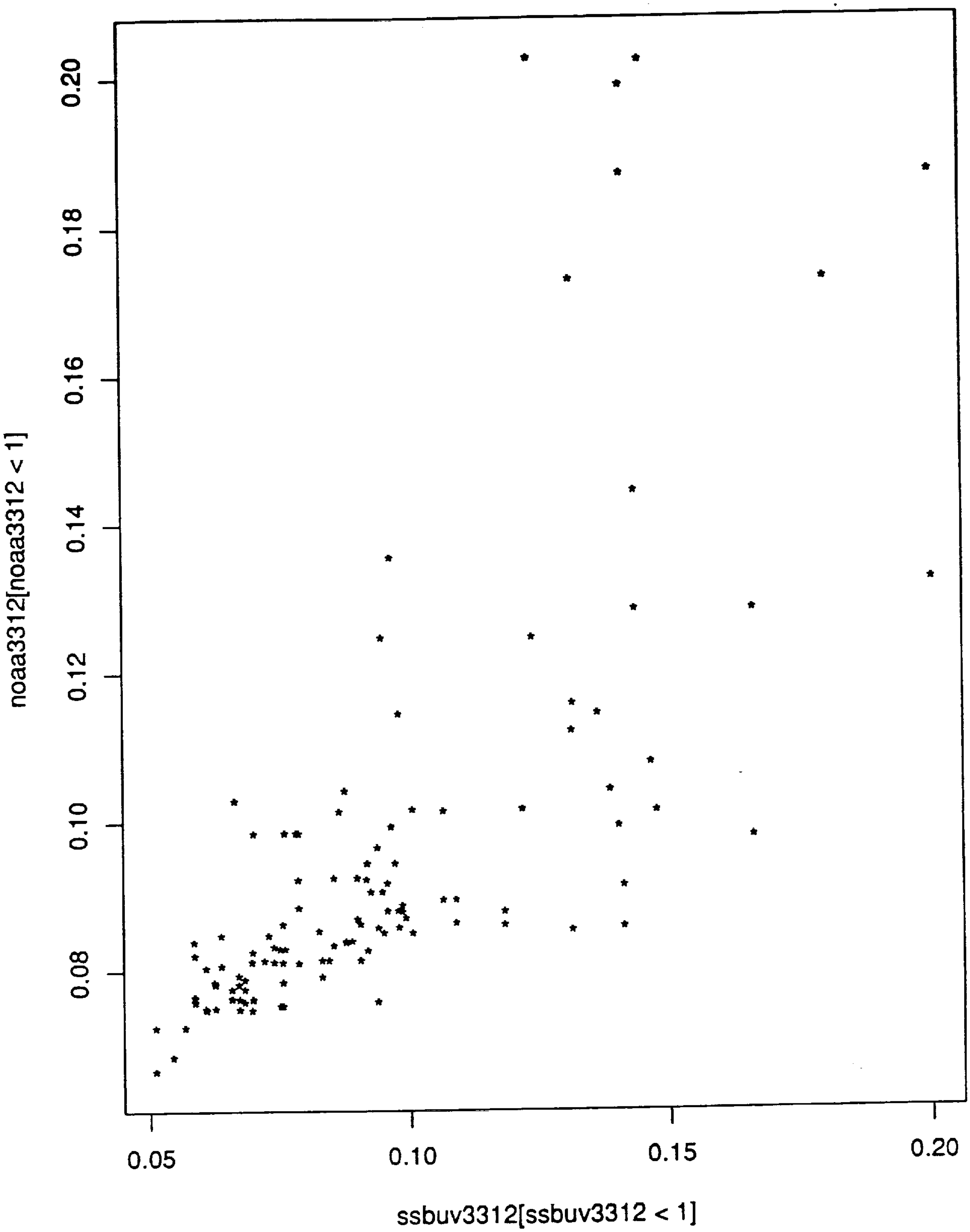

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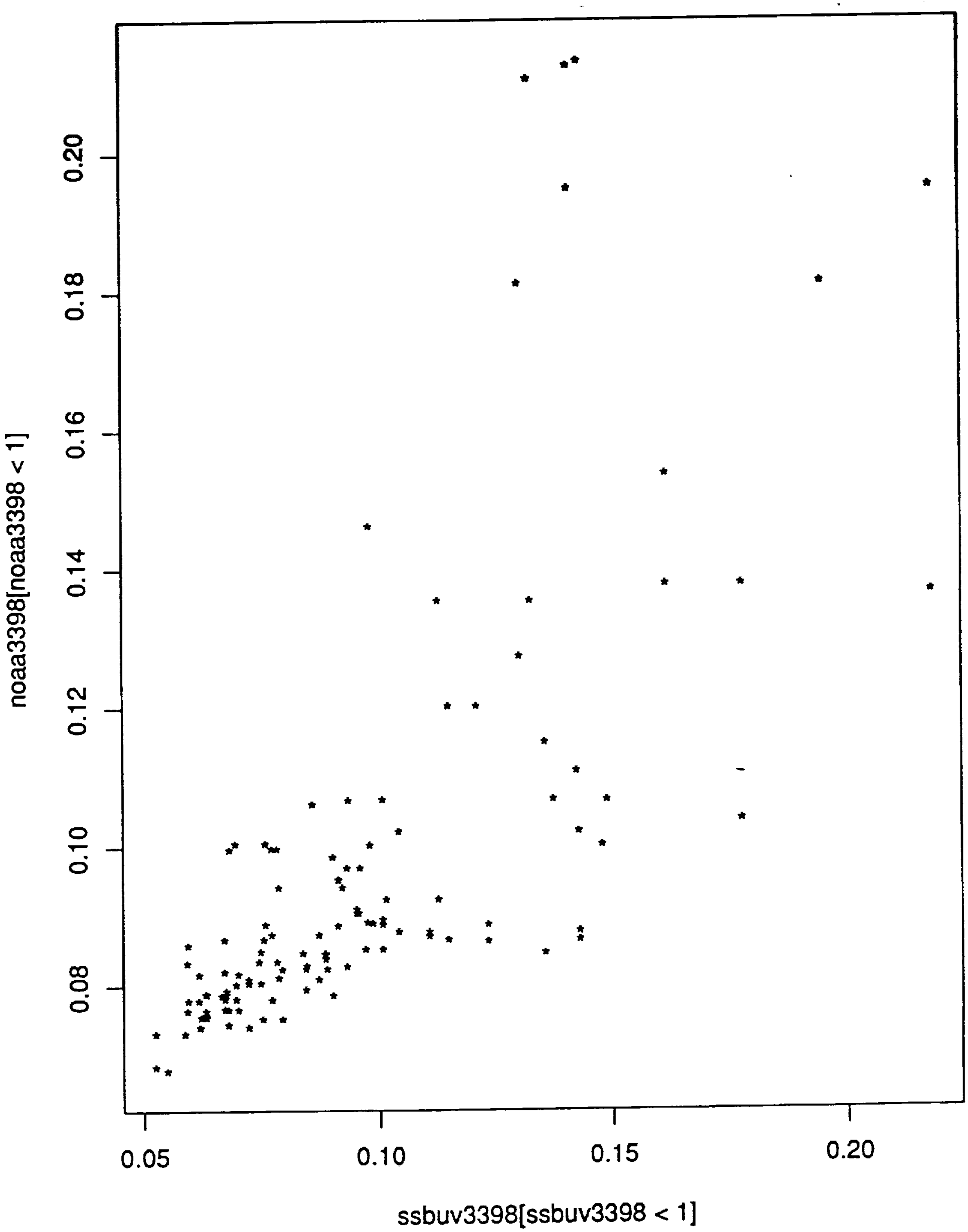

3 l