EOSDBによる中性子星EOS解析

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第12回Nuclei in the Cosmos

"Dense Matter" invited talk by Jirina R. Stone

Q1.Is there a "universal" nuclear EoS or do different systems have different EoS?

Q2.Do all NS lies on the M(R) curve?

Q3.Do HIC matter and NS matter have the same EoS?

Q4.What is the nature of the hadronic to quark phase of high density hot matter?

Q1.Is there a "universal" nuclear EoS or do different systems have different EoS?

もし化学平衡にある一様物質で常に同じ組成を持つならば、

状態方程式はいつも同じはず。核子だけとか。

しかしある系の物質が異なる組成をもたらすような歴史がある場合には異な

るハドロン物質の粒子組成が異なる状態方程式を作ると考えるべきだ。

例）違う親星の重力崩壊でできる中性子星

極端な例として白色矮星はハイペロン入りの

混合中性子星と同じ状態方程式を持たない。

また第3世代（TOV方程式の安定解のうち、

中性子星でも白色矮星でもないもの）

の状態方程式は違うはずだ。
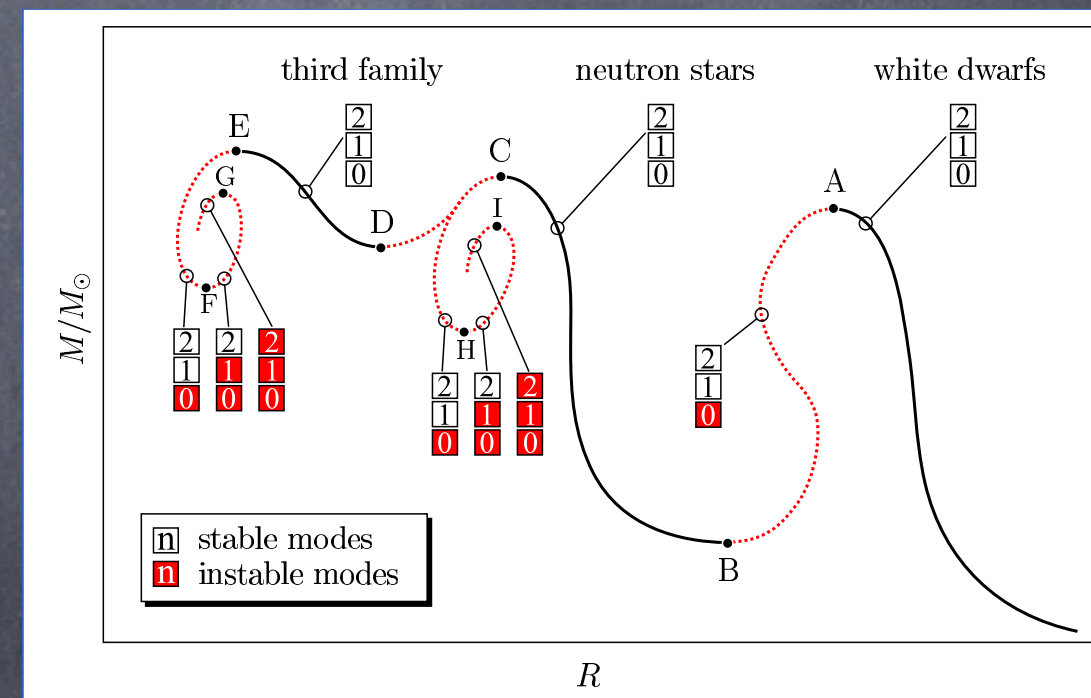
Q2.Do all NS lies on the M(R) curve?
組成の異なる状態方程式があれば、状態方程式はTOV方程式の入力物理だからM(R)曲線は組成毎に違うはず。またTOV方程式の解は一様物質の静水圧平衡の解であることにも注意しなくてはならない。

Q3.Do HIC matter and NS matter have the same EoS?
否。この二つは全く異なる条件下で発展するから。そもそも二つの状況で化学平衡の果たす役割と化学平衡の出現について理解する必要がある。

**Q4.What is the nature of the hadronic
to quark phase of high density hot matter?**
今は誰も分からない。クォーク物質のモデルですら完全には分かっていないし、強い制限はついていないのが主な原因。

回転の振動数によって中性子星の内部構造が違う等、様々な可能性を考慮しつつ、中性子星の観測（LMXBでのM,R同時観測）からEoSへの制限を議論すべき。また飽和密度での非圧縮率などの情報が高密度物質の状態方程式に直接制限を与えられないかも知れない。クォーク相の理解も不十分となると、何を指標に中性子星最大質量と状態方程式の関連を議論すればいよいのか！？

現在世に出ている関連情報を洗いざらい吟味したら何か分かるかも知れない。数百以上ある理論の論文を中心に状態方程式のデータを整理したデータベースを作ろう。

EOSDBへ

EOSDB URL: http://aspht1.ph.noda.tus.ac.jp/eos/　(ID: eosdb, PW: snmatter)

How to Build up EOSDB

Basic Structure

Following SAGA database (Suda et al. 2008); Database(MySQL/CSV), Search&Plot web-system(Perl/CGI/Java)

Dictionaries

Journal(PRC, NPA, APJ, ...)   Phys. Const.(c, hbar, pi, amu, ...)
Constituents(Nucleons, Hyperons, Quarks, Mesons, Lepton, ...)
Method(HFB, RHFB, VF, FRDM, ...)
Variable(Energy, Pressure, Free Energy, Entropy, Charge Ratio, Baryon Chemical Pot., Temperature)
Sym. Energy Info.(Symmetric Energy, Slope L, Incompressibility K)

Compiled Physics Info.

Basic EoS properties such as thermodynamical quantities symmetric energies S, L and K as a function of baryon densities with various models.

EOSDB beta ver. manual v.1

Let's show you how to use our EOSDB!
Now you can see the following image on our website.
As mentioned in "About EOSDB", you can "search and plot" various EOS here.
First of all, please let us explain the outlook of this system.
The both upper menu bar and the left side one are the same function.

The main system

You can see a list of compiled data. see the next page about the details of this menu.

Don't open it. This is for poor developers.

Any questions and requests are welcome! Please feel free to contact us.

Welcome to EOSDB!

| EOSDB Top | Search and Plot | Entry Info. | For Developers | About Us

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About EOSDB

As of 6th-June-2012, EOSDB containts the following number of EoS information;

1. E0001
2. E0002
3. E0003
4. E0004
5. E0005
6. E0006
7. E0007
8. E0008

Hubble space telescope.
Source: Wikimedia Commons/NASA

Click "Search and Plot" from menu bar, then you can get "About EOSDB" which is a list of compiled data.

Each page corresponding to its entry number contains the following information;
1. Original Paper Info.
2. Manual for EoS Table
3. Physics Constants used in each calculation
4. Assumed Constituents
5. Theoretical/Experimental/Observed Method to derive each EoS and its strong/weak point etc. as comment
6. Saturation density [fm^{-3}]
7. Saturation energy [MeV]
8. Symmetric energy properties like
    Symmetric Energy E_{sym} [MeV]
    Symmetric Energy a4 at the saturation density [MeV]
    Its Slope to baryon density L [MeV]
    Incompressibility K [MeV]
9. Max. Mass of Cold Neutron Star [M_{solar}]
10. Tabulated data

If you want to know some information on the original article, open tabulated data and more, click each entry number. After sending your query from "Search and Plot" page, you can access them from search result list directly as shown later.

This is our "Search and Plot" system. You can see some query options such as graphic options.
Our EOSDB style follows "SAGA database for metal poor stars" which was published in 2008.

[Ref] 1) T.Suda, S.Yamada, Y. Katsuta, Y, Komiya, C. Ishizuka, W. Aoki and M.Y. Fujimoto,
Mon. Not. of Roy. Astron. Soc. Vol. 412, Issue 2, pp. 843-874, 2011
2) T.Suda, Y.Katsuta, S.Yamada, T.Suwa, C.Ishizuka, Y.Komiya, K.Sorai, M.Aikawa, and M.Y.Fujimoto,
Publ. of Astron. Soc. of Japan, Vol. 60, pp.1159-1171, 2008

As of 6th Jun. 2012,
"Category" option is not working unfortunately,
so you can choose what you like.
Now we are improving this function in order to
control the axis option which is shown in lower panel.
ex.) If the "Symmetric Energy" is selected,
    only "RhoB, Esym, L and K" will be appeared
    as axis option in the pull-down menu.

Sending a query with "RhoB as Xaxis and Esym as Yaxis",
searching data which contains symmetric energy as a function of baryon
densities.

We have collected symmetric energy slope L and incompressibility K as well
related variables with symmetric energy.

If you want to know nuclear saturation properties of each EOS,
then select thermodynamical variables listed in the box, i.e., Pressure,
Energy and Entropy.

As a sample query,
we select "RhoB" as X-axis and "Energy" as Y-Axis, after that, press the "search" button. Then EOSDB looks for data which contains both baryon density and energy. The results appear like the lower panel.

Search Result

Results : 8

#	○	Reference	Min. RhoB	Max. RhoB	Min. EpB	Max. EpB
1	☐	GShenFSUgold2.1	1.000003E-08	1.49624	-16.22081	435.6136
2	☐	HShen98	7.581421E-11	1.512692	-16.2359	442.3408
3	☐	HShen11N	7.581422E-11	6.022137	-16.2359	2425.945
4	☐	HShen11Y	7.581422E-11	6.022137	-16.23612	1255.985
5	☐	LS220	1.513185E-09	1.513185	-0.6279034	652.5623
6	☐	LS375	1.513185E-09	1.513185	-0.578853	1939.335
7	☐	LS180	1.513185E-09	1.513185	-0.6532795	506.8816
8	☐	Hempel10TMA	0	10	-8.594929	1539.711

1

Each row of the result table shows the reference name and the min. and max. values of x-axis and y-axis, respectively. If you click each reference name, then you can see the entry information directly as mentioned before.

Can you see check boxes in the 2nd left column? When you want to plot not all but some data, then check the check box at the data to see and press "plot" button. To plot all data simultaneously, press "plot_all" button.

"AND operation in query"

You can find a data which contains specified graphic options with bibliographical criteria such as "Author", "Reference" and "Publication Year".

For example, in the case of the left panel, 5 of 8 results shown in previous page satisfy the criterion as you can see in the lower panel.

This is the plot page. The sample query was performed with graphic option "X:RhoB and Y:EpB" then you can see them at the labels of each axis, respectively. When you press "Plot All" button, there is too many labels in the figure to see the plotted data. In order to avoid this situation, let's change the default setups which are checked in the right panels. For example, we'll check the "Outside" button now.
Here, you can put a new name to the figure in "Title" window, move the labels with "LEGEND" options, change label-notes with "LABEL" windows, arrange the axis-scale with "SCALE", the plot ranges with "Range" windows and furthermore you can download the image as png/ps/eps/pdf/tabulated numerical data with zip!
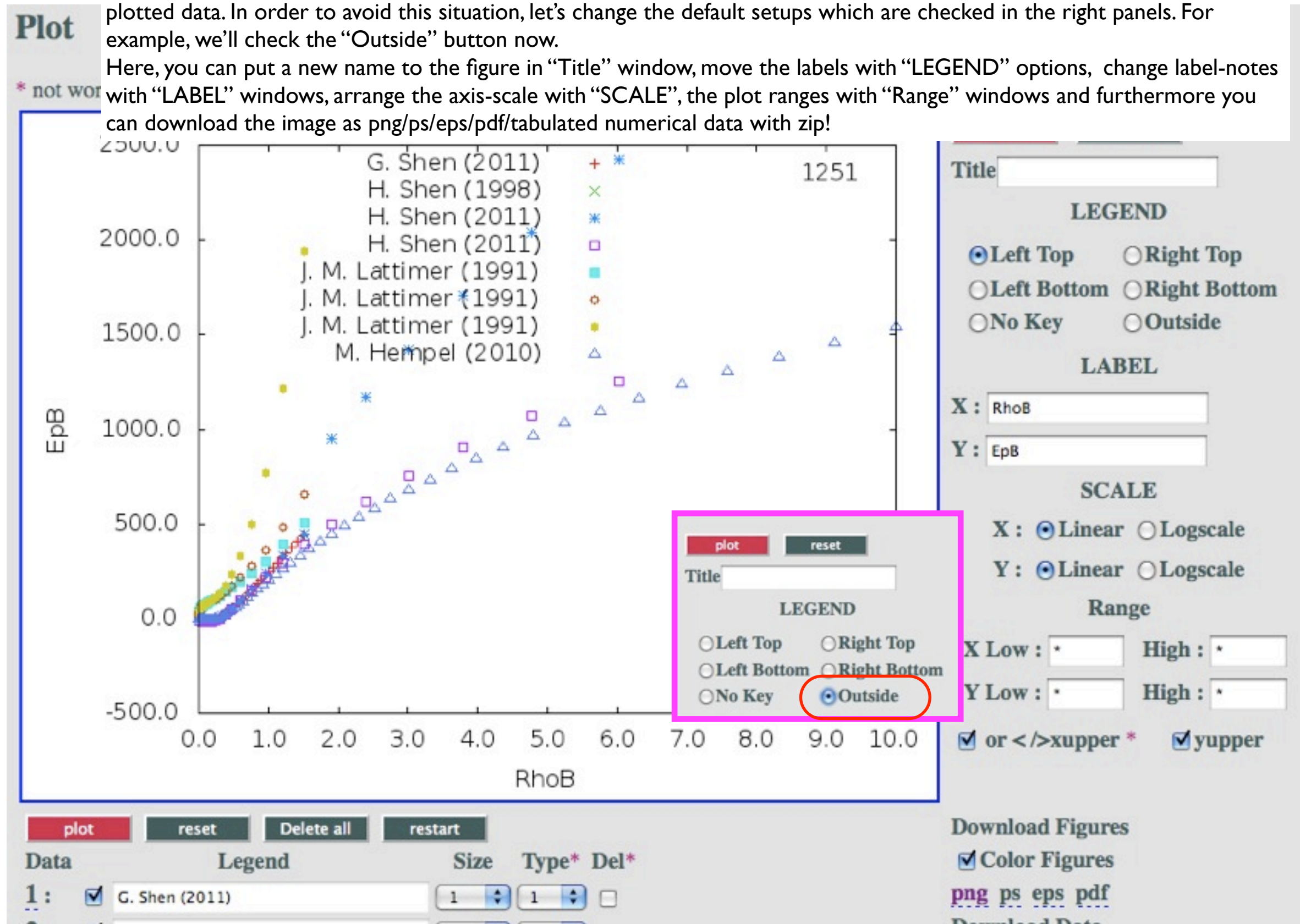
Can you see that the position of labels changed from previous image to the "Outside" of the figure? Then next, we'll show you the way to change the plot range. As shown in pink box, you can arrange it at the right bottom "Range" panels.
Now put "2.0" as "X High" and "1000" as "1000" for example.
We change the "SCALE" from "X:Linear" to "X: Log-scale" as well. Then what happens?

Plot

* not working

Plot

* not working
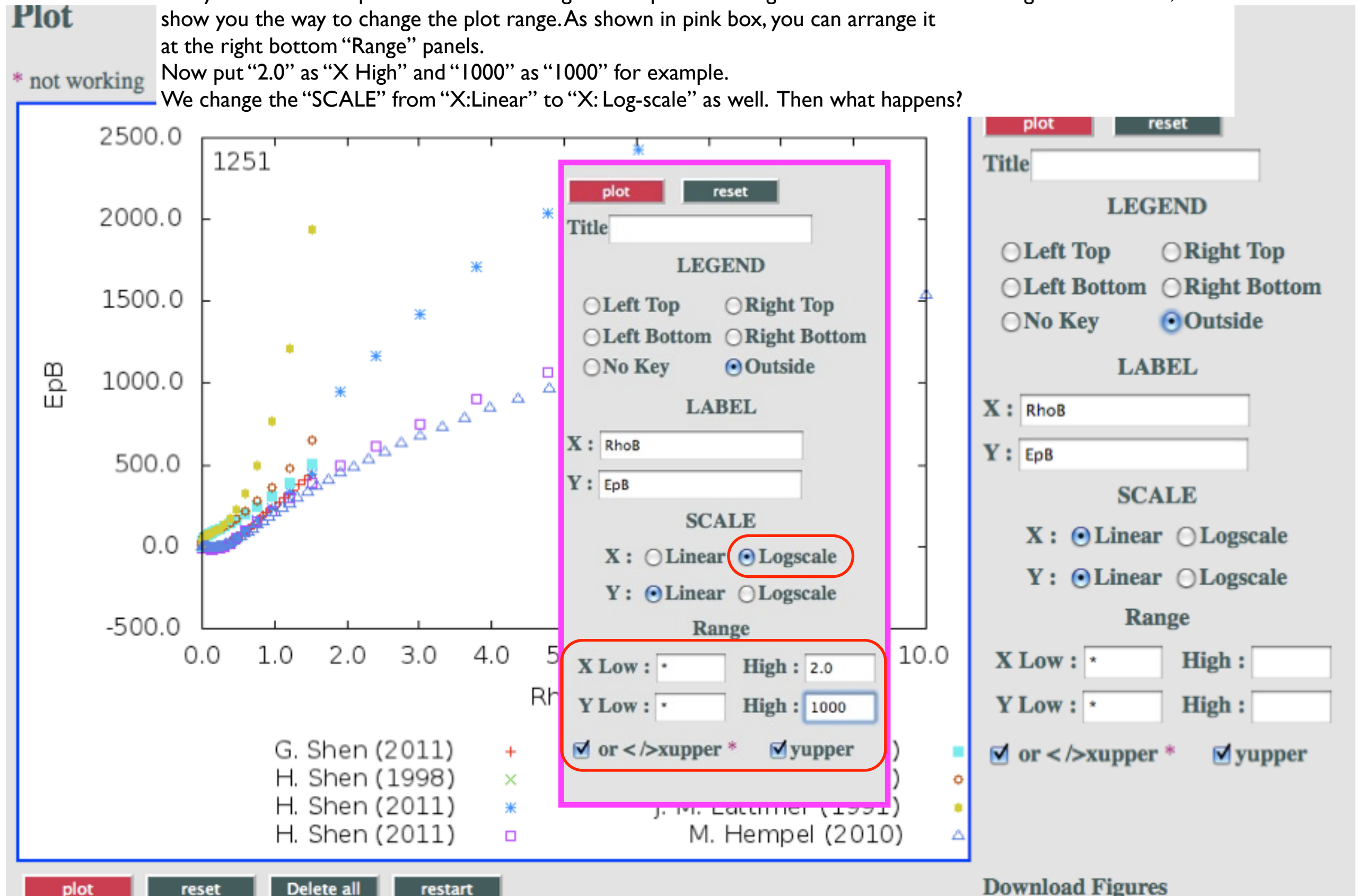
As specified before, the upper limits of the both axes are varied and the scale of x-axis becomes log.
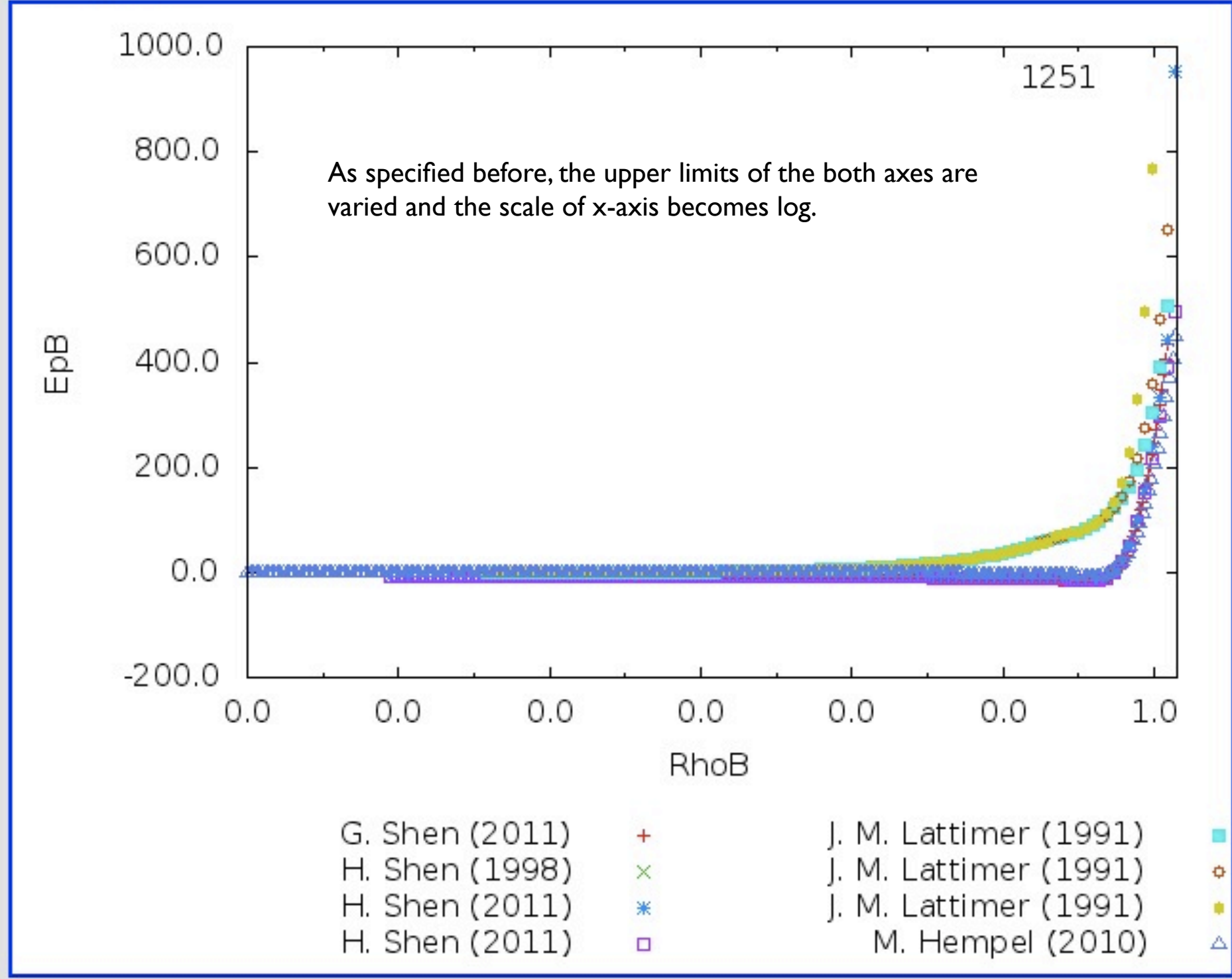
plot   reset

Title

LEGEND

○ Left Top   ○ Right Top
○ Left Bottom   ○ Right Bottom
○ No Key   ⊙ Outside

LABEL

X : RhoB

Y : EpB

SCALE

X : ○ Linear ⊙ Logscale

Y : ⊙ Linear ○ Logscale

Range

X Low : *   High : 2.0

Y Low : *   High : 1000

☑ or < /> xupper *   ☑ yupper

Legend:
- G. Shen (2011)   +
- H. Shen (1998)   ×
- H. Shen (2011)   *
- H. Shen (2011)   □
- J. M. Lattimer (1991)   ■
- J. M. Lattimer (1991)   ⬡
- J. M. Lattimer (1991)   ●
- M. Hempel (2010)   △
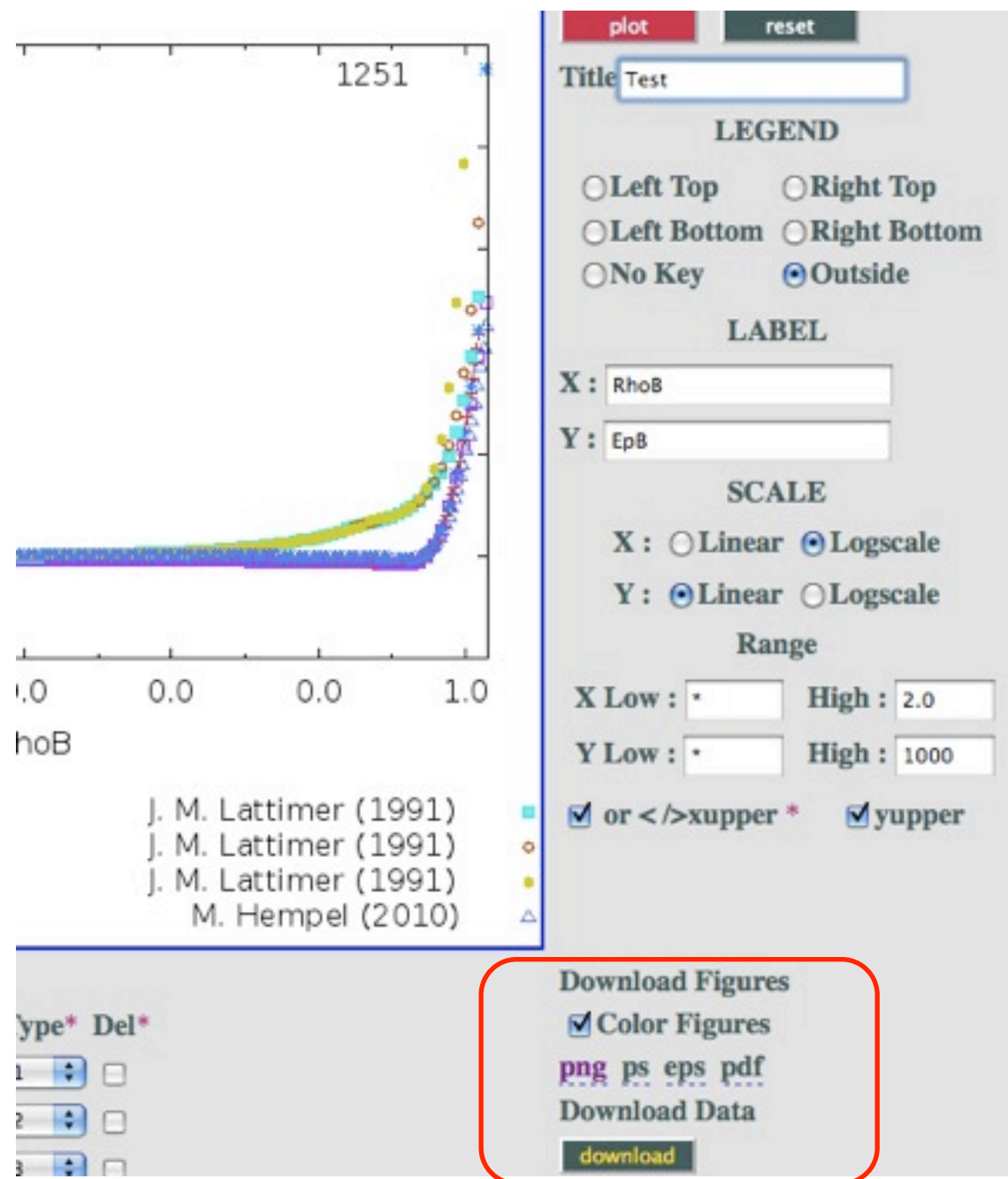
On the plot webpage, you can arrange the shown figure by putting words in "Title" window or "LABEL" window as already mentioned.

In added to that functions, you can download the figure data in a various format, png/ps/eps/pdf/txt, here.

cgisess_5beb92ac51fcc27850ac923a55c5ed26.pdf を開く

次のファイルを開こうとしています:

cgisess_5beb92ac51fcc27850ac923a55c5ed26.pdf

ファイルの種類: Portable Document Format
ファイルの場所: http://aspht1.ph.noda.tus.ac.jp

このファイルをどのように処理するか選んでください

○ open files?   Preview (デフォルト)
○ save files?

☐ 今後この種類のファイルは同様に処理する

(キャンセル)   OK
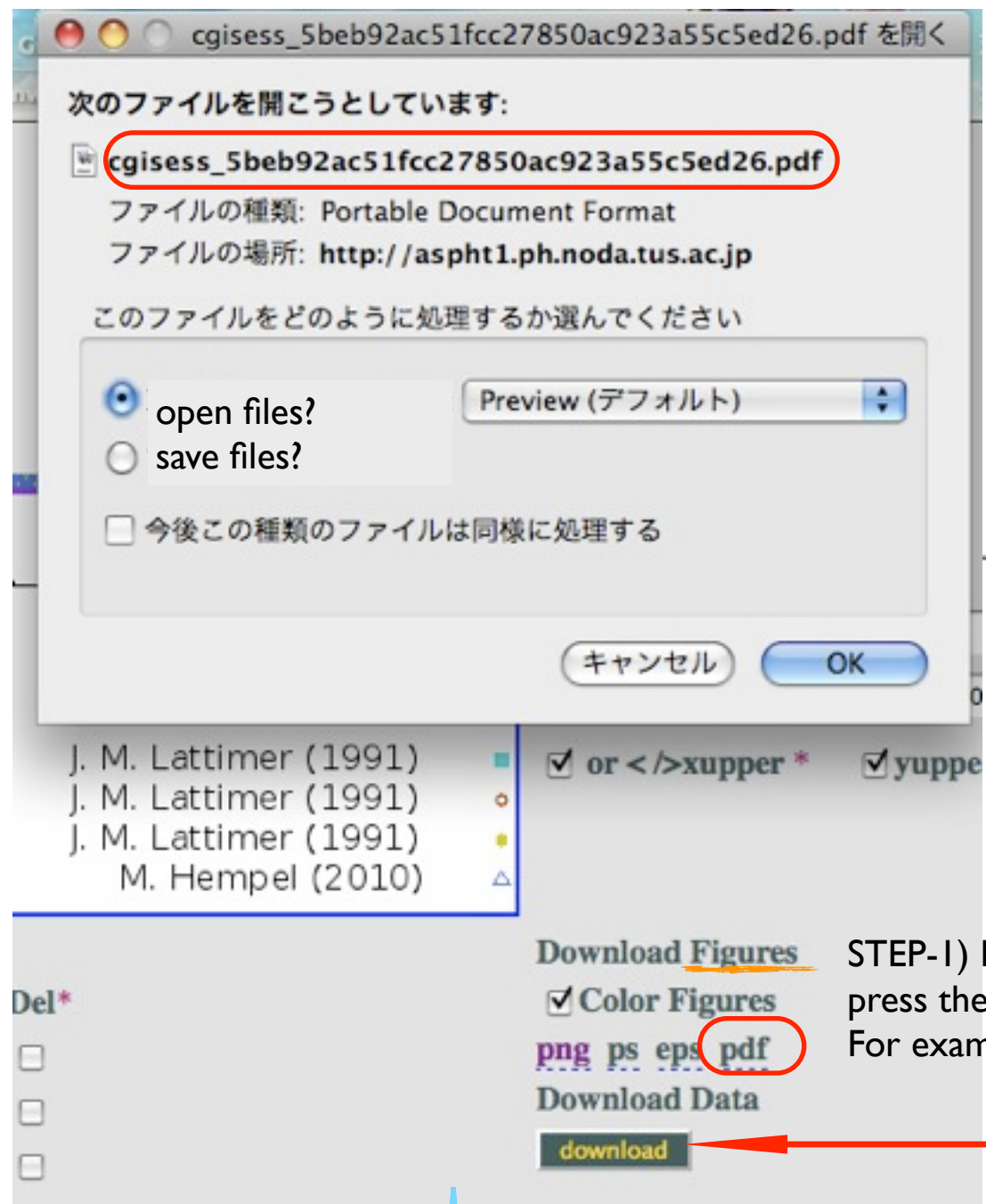
STEP-2)Message will appear ,
then choose "open file" or "save".
Here, we select "open file".
As a result, a pdf file in the bottom panel will be opened.

Test

1251

J. M. Lattimer (1991)
J. M. Lattimer (1991)
J. M. Lattimer (1991)
    M. Hempel (2010)

☑ or </>xupper *   ☑ yuppe

Del*

Download Figures
☑ Color Figures
png ps eps pdf

Download Data
download

STEP-1) For download of png/ps/eps/pdf format,
press the relevant string.
For example, press "pdf".

This button is just for text data download. See the following page.

Please pay attention to this note!
It is a bit complicated and confusing to use these buttons.

200.0

0.0

-200.0

0.0   0.0   0.0   0.0   0.0   0.0   1.0

RhoB

G. Shen (2011)   H. Shen (2011)   J. M. Lattimer (1991)
H. Shen (1998)   J. M. Lattimer (1991)   M. Hempel (2010)
H. Shen (2011)   J. M. Lattimer (1991)
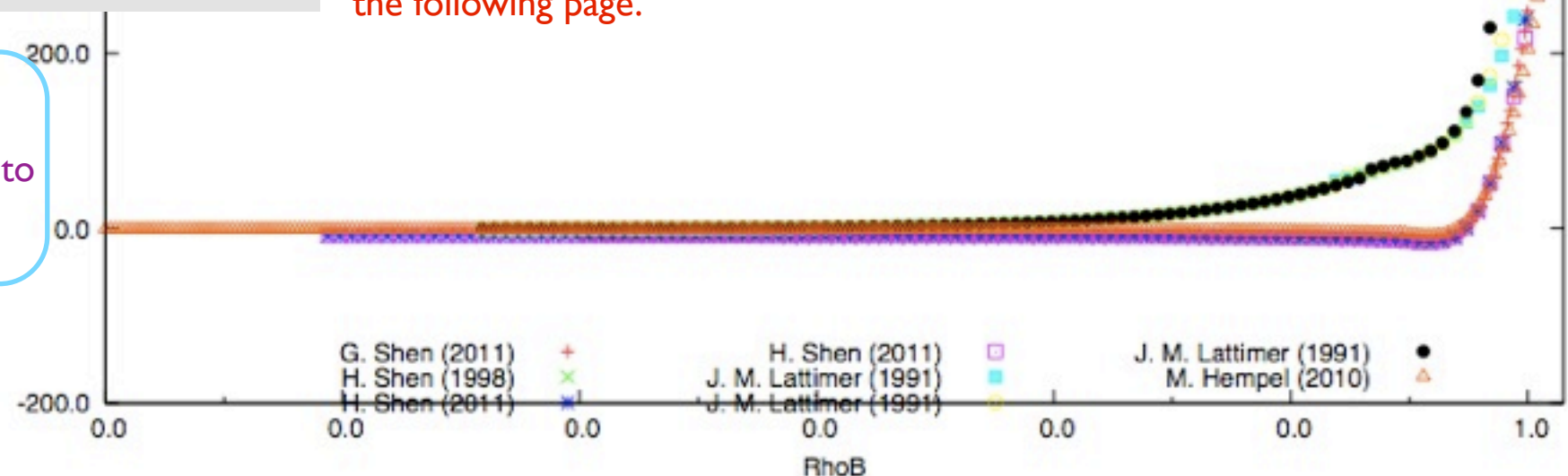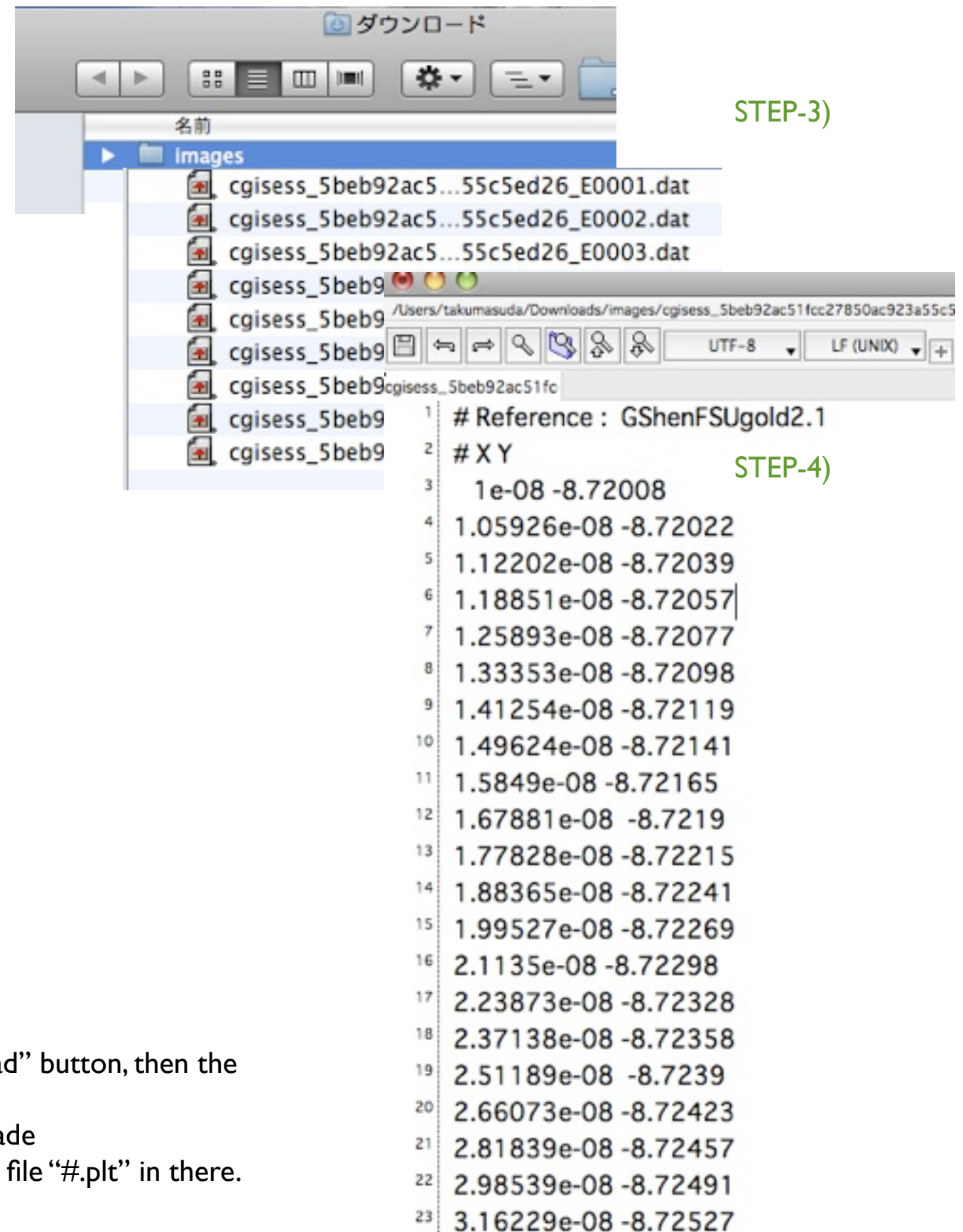
To download data with text format, then press "download" button, then the same message as before will appear again.
If you choose "save" option, "image" directory will be made and you can find plotted data "#.dat" and gnuplot script file "#.plt" in there.
The data are listed as shown in the right panel.

Report on Current Situation

All our entries are data at T=0[MeV] and those of symmetric and/or pure neutron matter to focus on the most basic features of hadronic matter and to show differences in their behavior of each models.

The Items of Entry list

Theo. Entries 24 in total, 15 registered from EOS tables
                         (11 of 24 data read only, not registered yet)

Expr. Entries   4 in total (4 of 4 data read only, not registered yet)
Obs. Entry   1 in total (1 of 1 data read only, not registered yet)

再来週の
秋の学会で！

Feedback from users and Improvement

We need your suggestions on "Which quantities should be compiled
to elucidate THE EOS?" etc.
e.g.)Requirement to put data label with used interaction.
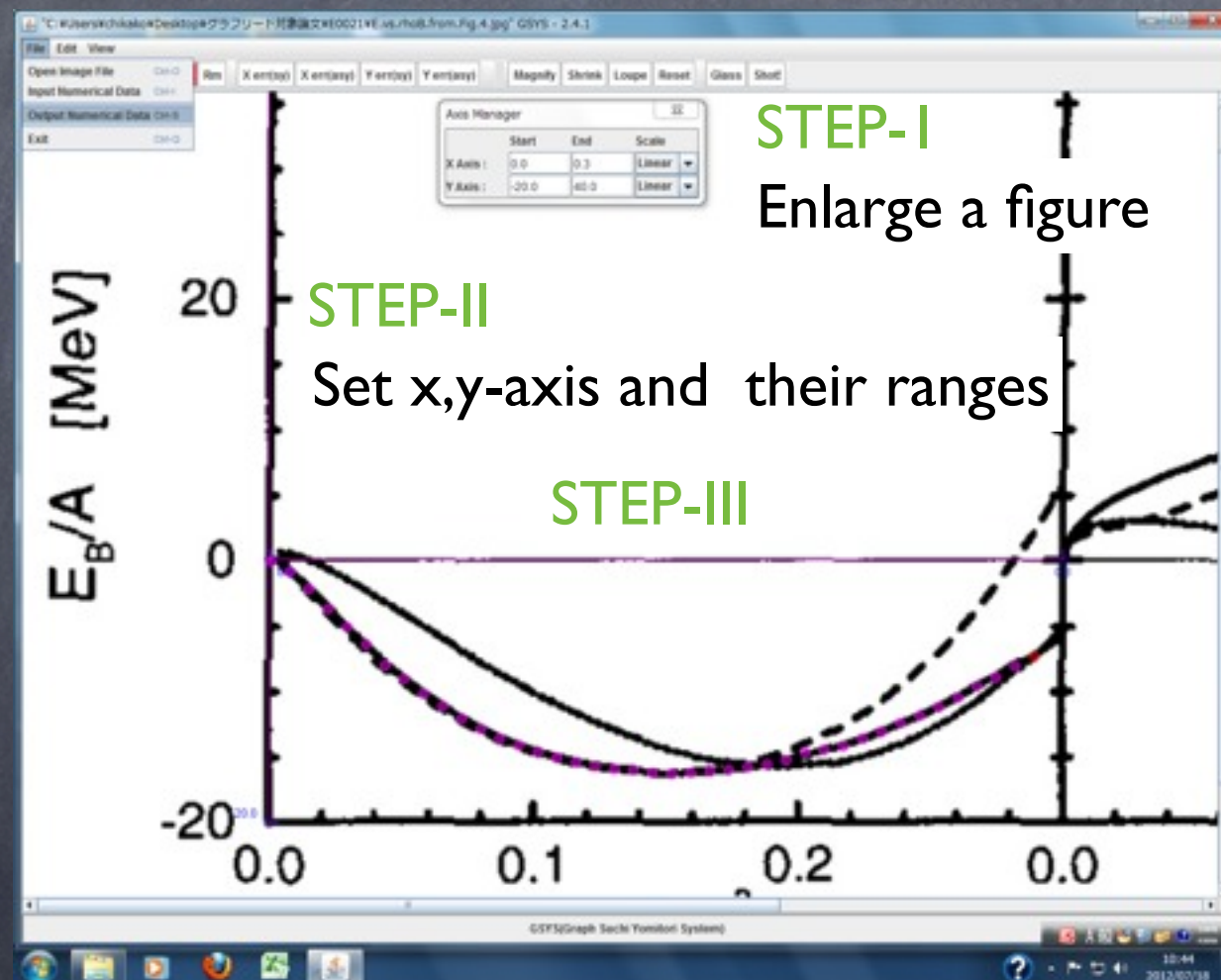   To improve this point, we add an item on used interactions such as its strength,
   interaction types.   -->Model Query Function ....sorry, not yet equipped!

Treatment of Data

Tabulated online data: re-arrange data format to EOSDB format
ex) units, definition of quantities.
Data read by using graph read system (GSYS, IAEA):

STEP-I
Enlarge a figure

STEP-II
Set x,y-axis and their ranges

STEP-III

Put grids at equal interval by hand!

STEP-IV

Separator: Space

Digitized by GSYS2.4.1
Date = 18.Jul.2012, 10:45:32
Number of data = 41
set xrange[0.0, 0.3]
set yrange[-20.0, 40.0]
MD5Fig : b28ac4ad291b4a9f4695898ab77ed3ba
Axis_X : 3fc0df0a0813cd743fe0fd08e5500fd13fe1c4
Axis_Y : 3fc0ce5d0514b6ea3fe983759f2298373fc0c
x   y
3.606E-04 -4.891E-02
7.572E-03 -8.499E-01
1.478E-02 -2.161E+00
2.200E-02 -3.690E+00

Output the grid information to
a numerical data file,
then fit its format to EOSDB

During data compilation, we should be careful in their treatment.
The most troublesome is unit arrangement.
Second problem is how to obtain numerical data.
In our database, we started edit with tabulated open sources.
the open data tables are only the tip of an iceberg.

Tabulated Data
🤓 Good...Easy to handle and no change in significant digit
😔 NG ...Tabulated EoS is made only by researchers with astrophysical interests
       The most of Nuclear physicists feel no need to calculate
       large data grids to construct a table.

Data taken from Figs.

🤓 Good...We can obtain any sort of data,
       i.e. one point data and shaded area data as well as lined data.

😔 NG ...Graph-read system Gsys often misreads the data grid
       when lines are gathering and complicated.
       Work by hand causes artificial errors. Difficult to keep data reliability

Summary and Call for Benchmark of EOSs

From the end of the last autumn, we began to construct a database
for nuclear EoS and its web platform EOSDB as an application of our successful database SAGA.
Now its beta-version are partially open, although further betterment is necessary.
You can compare various EoS data with the others as well as yours on our website
and a plotted figure can be saved as a numerical data file.

Our system is very powerful when you want to know which factor is how effective
by data mining. In order to optimise the use of EOSDB, we ask your help for benchmark
by data provision in the same format as follows;

1. Thermodynamical data set (ρ_B, T, Y_c, E/B, P) for Y_c=0.5 (symmetric hadronic matter or nucleus)
   and the same data set for Y_c=0.0 (pure neutron matter) at/around T=0.
2. Saturation energy and density,
3. Symmetric energies data set (ρ_B, T, E_{sym}, L, K), where E_{sym} means symmetric energy a_4 or
   "E/B$|_{Yc=0}$ - E/B$|_{Yc=0.5}$" and L is slope of E_{sym}, $dE_{sym}/d\rho_B$, K is incompressibility.
4. Model and Interaction
5. High reliability circumstance of your model, e.g., baryon density $\rho_B < 2\rho_0$

* No need to calculate various ρ_B but data for as many ρ_B as possible within your model.

ただし上記のデータだけでなく、ベンチマークするなら直接実験や観測で測れる量を
理論核物理家が計算して、理論毎の振舞を比較する方が良いのでは、、、