Energy-Flux Balances and Source Term Parameterizations

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Objectives

- 1. nonlinear 4-wave interactions
- 2. a look at energy – flux balances
- 3. relation to source term parameterizations
- 4. challenges for improvements …

1. introduction: energy – flux balances

Review

$$dE(f) / dt = Snl + Sin + Sds$$

Quadruplet wave interactions determined by locus

$\omega_1+\omega_2=\omega_3+\omega_4$ $\qquad$ $k_1+k_2=k_3+k_4$

replaced by DIA as

$\omega_1=\omega_2=\omega$ $\qquad$ $\omega_3= \omega(1+\lambda)$ $\omega_4= \omega(1-\lambda)$

where λ=0.25 and q_3 = 11.5° and q_4= - 33.6°

$\Rightarrow$ Many fewer interactions are selected ….

Review

Snl = boltzmann integral

- $Snl = 2 \int dk_3 \, T(k_1,k_3)$

where $T(k_1,k_3) = \oint ds \, J \, C^2 \, \theta \, D(n_1,n_2,n_3,n_4)$

Tracy and Resio, 1982

Locus of interactions

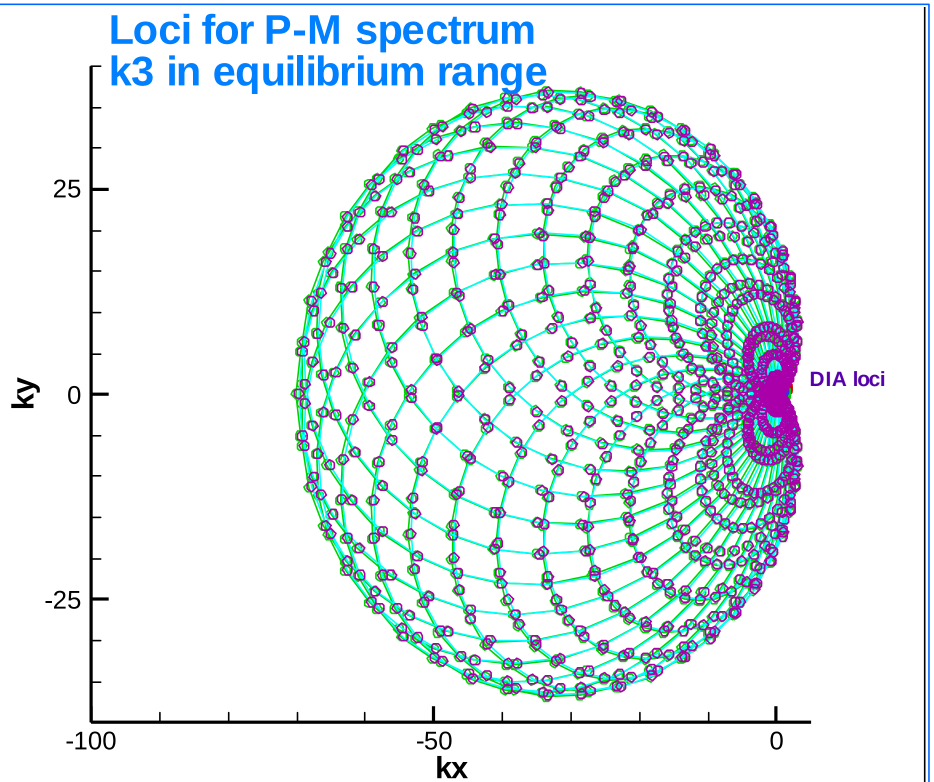
jacobian

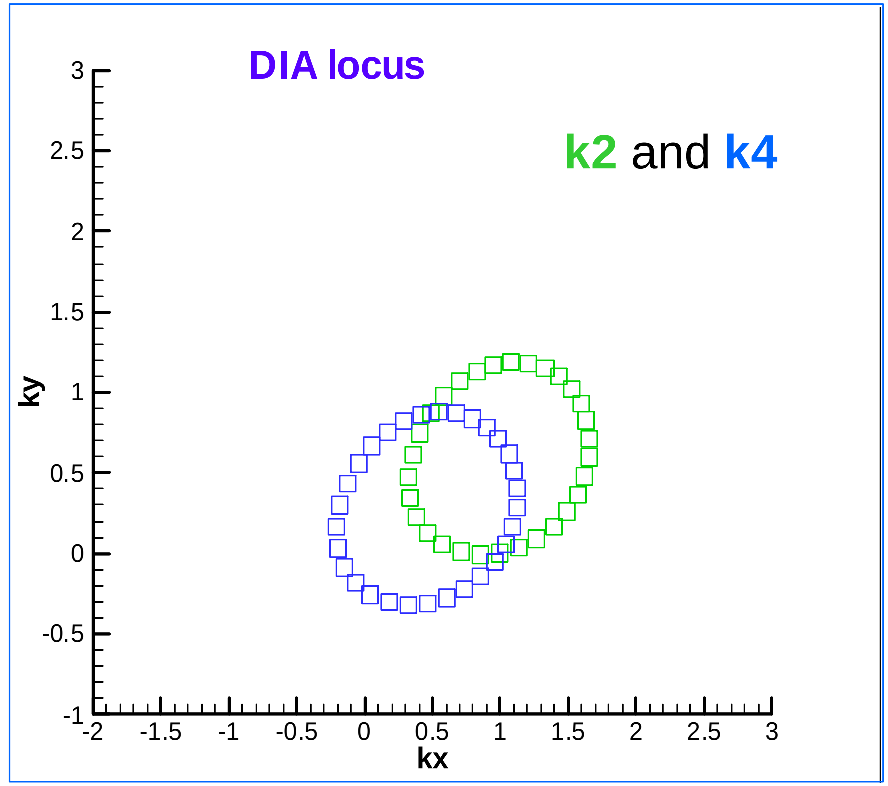
Coupling coefficient

action densities

$$\theta = \begin{cases} 1 \text{ when } |k_1 - k_3| = |k_1 - k_4| \\ 0 \text{ when } |k_1 - k_3| > |k_1 - k_4| \end{cases}$$

Comparison of P-M loci with DIA





Tracy and Resio, 1982

$k1_x=1$

$k1_y=0$

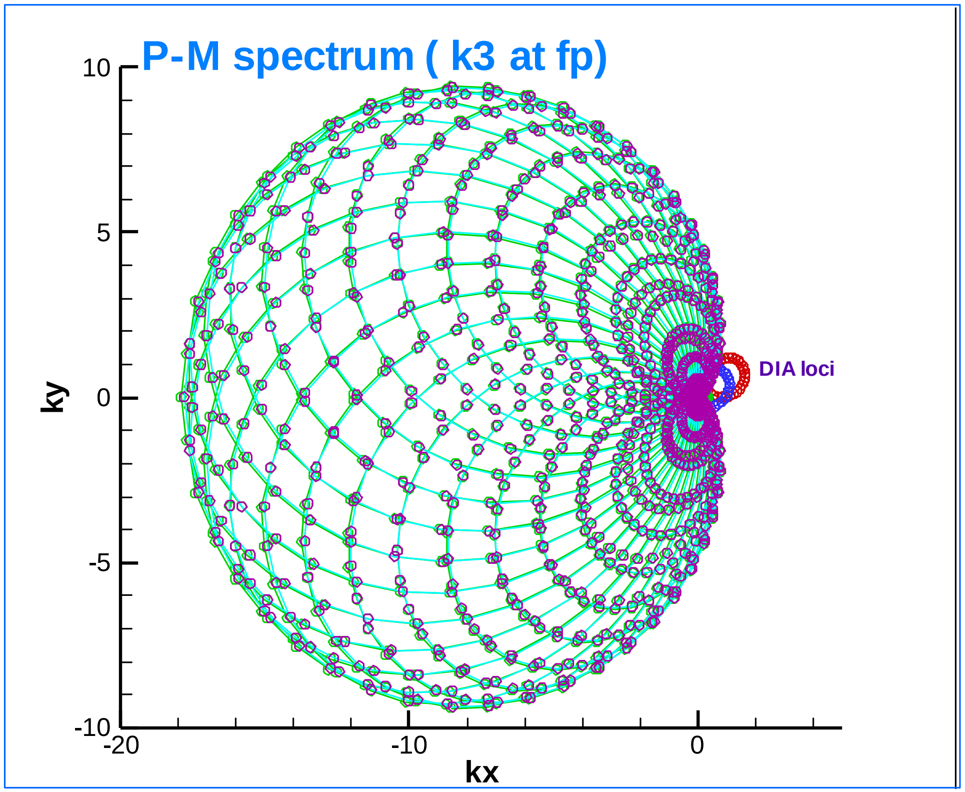
$q_3 = 11.5^o$

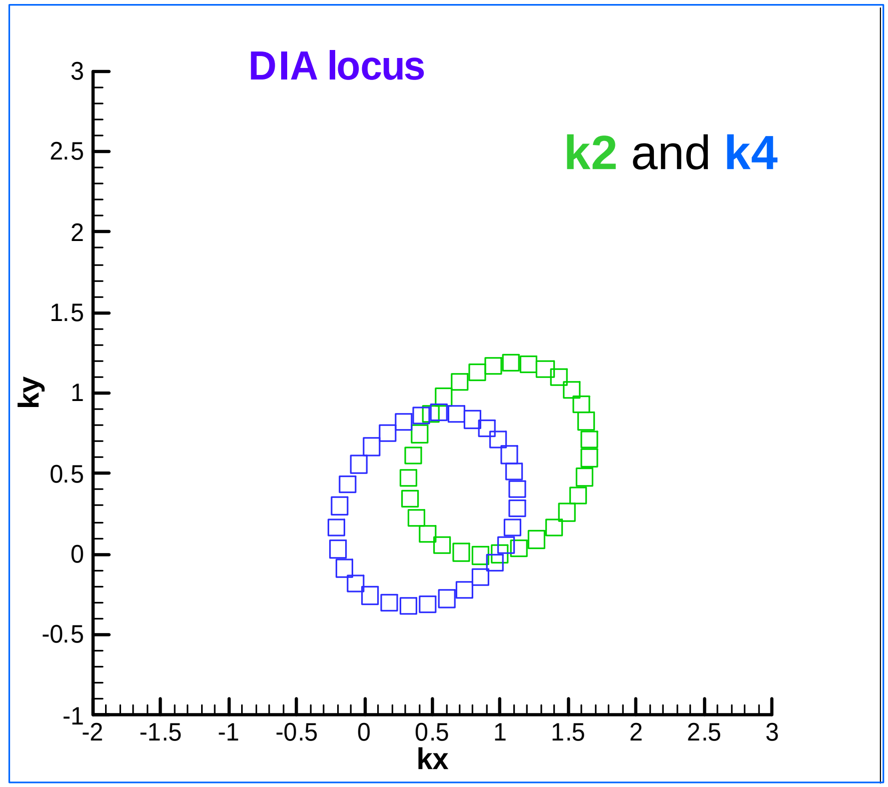
$q_4 = -33.6^o$

$\lambda = 0.25$

$f_1 / f_p = 2.0$

Comparison of P-M loci with DIA





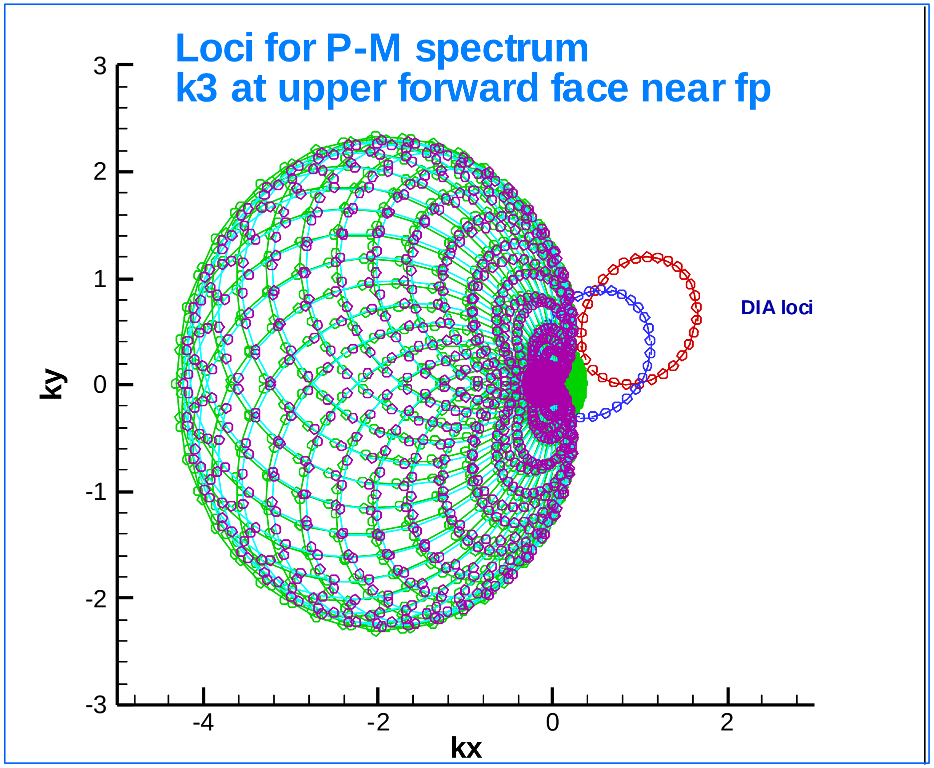
$k1_x=1$ $q_3 = 11.5^o$

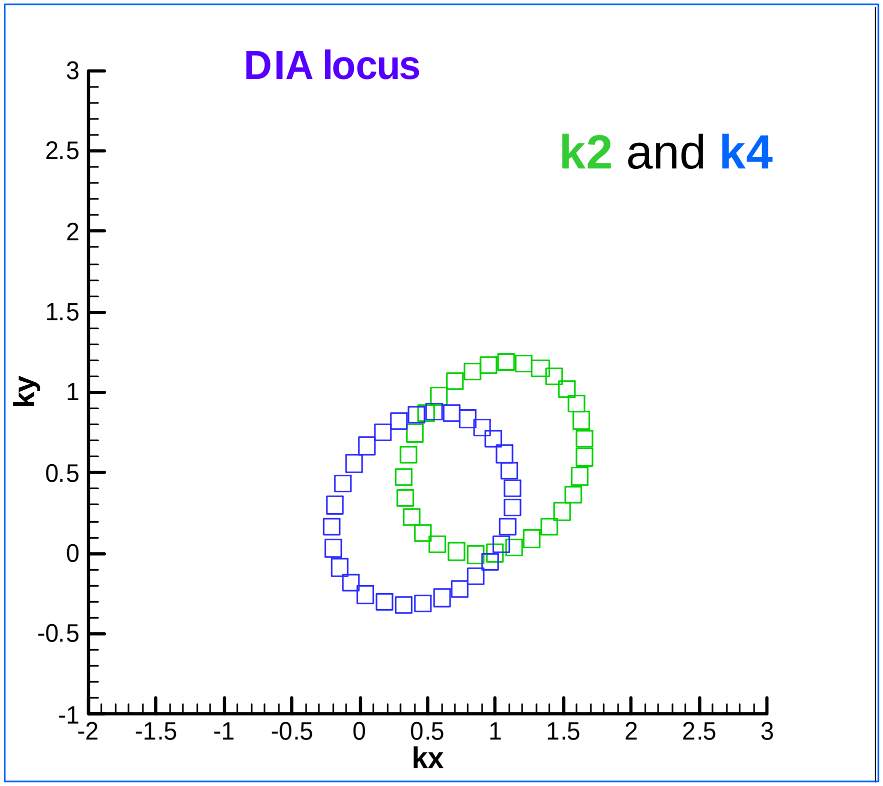
$k1_y=0$ $q_4 = -33.6^o$

$\lambda = 0.25$

$f_1 / f_p = 1.0$

Comparison of P-M loci with DIA





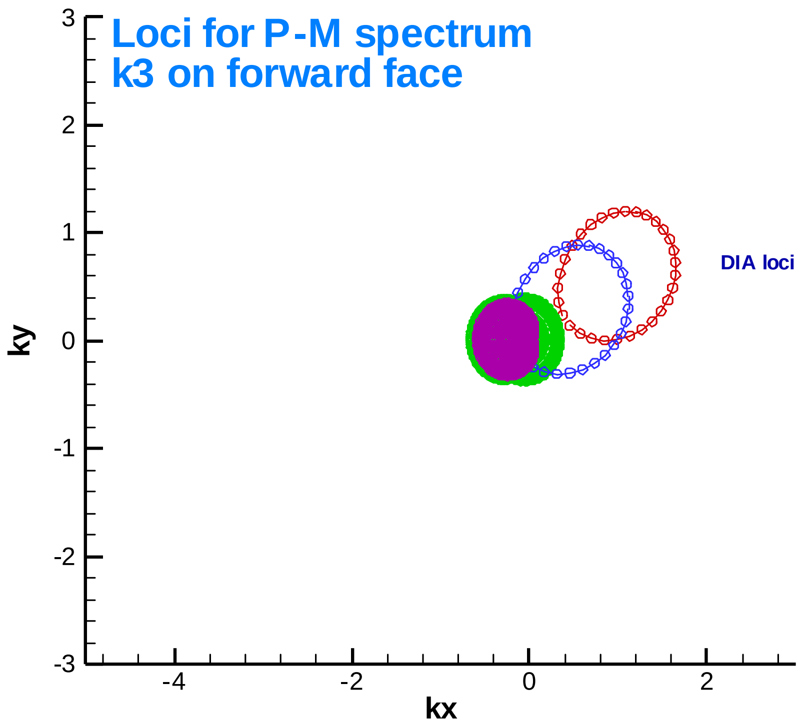
$k1_x=1$ $q_3 = 11.5^o$

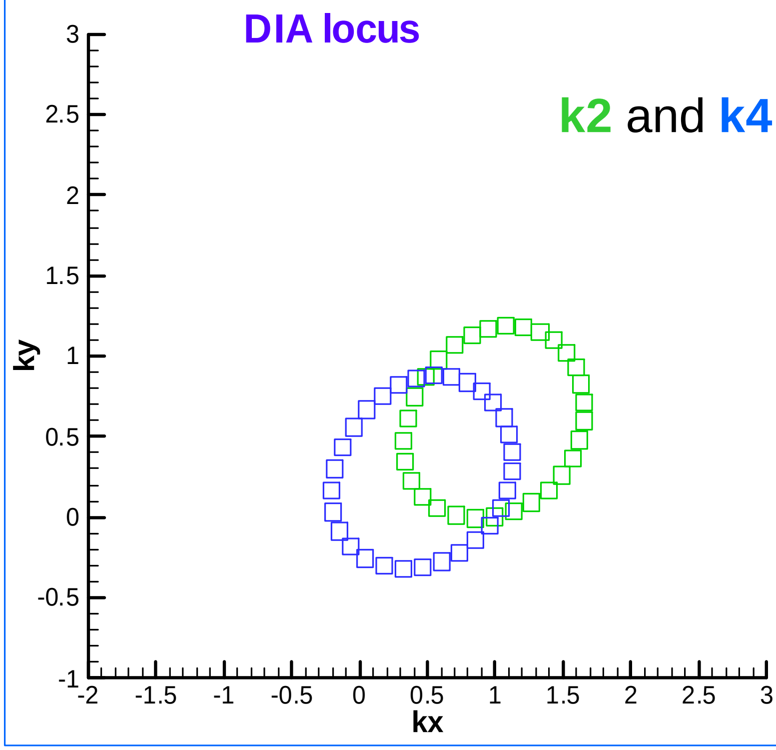
$k1_y=0$ $q_4= - 33.6^o$

$\lambda = 0.25$

$f_1 / f_p= .95$

Comparison of P-M loci with DIA





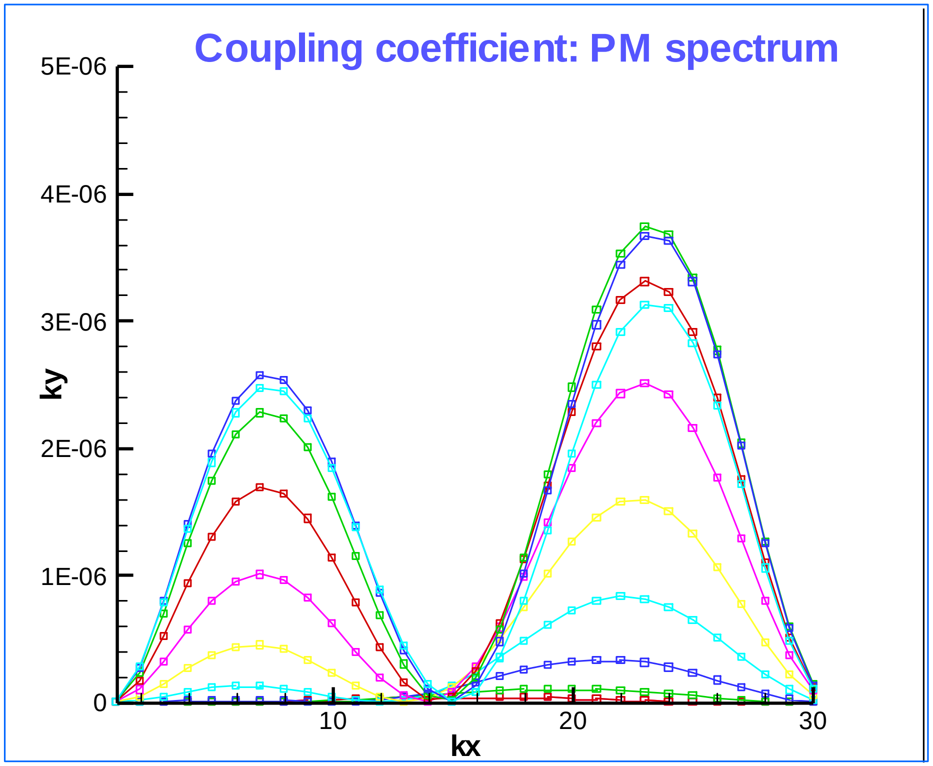
$k1_x=1$
$k1_y=0$

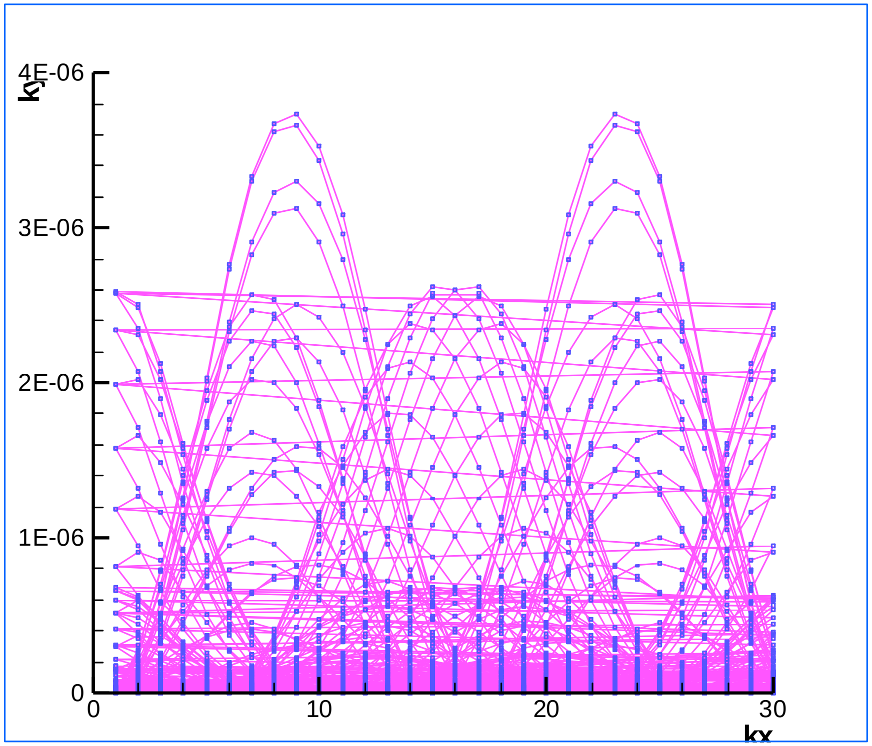
$q_3 = 11.5^o$
$q_4 = - 33.6^o$
$\lambda = 0.25$

$f_1 / f_p = .82$

Review

Coupling coefficients



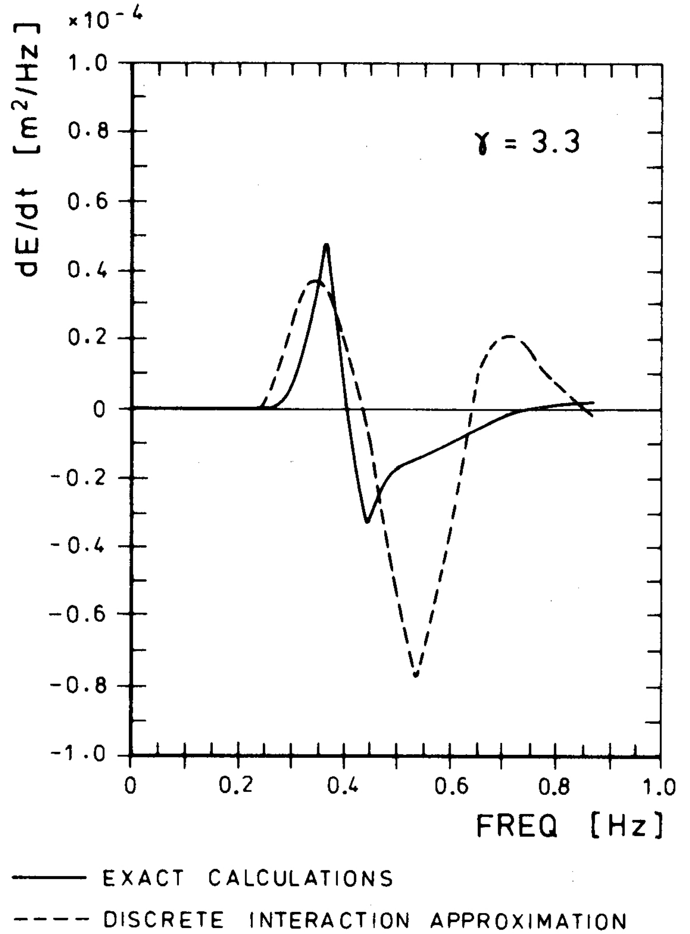


Selected C values….

f_1=.95 and f_3 / f_p = n × 7 ….

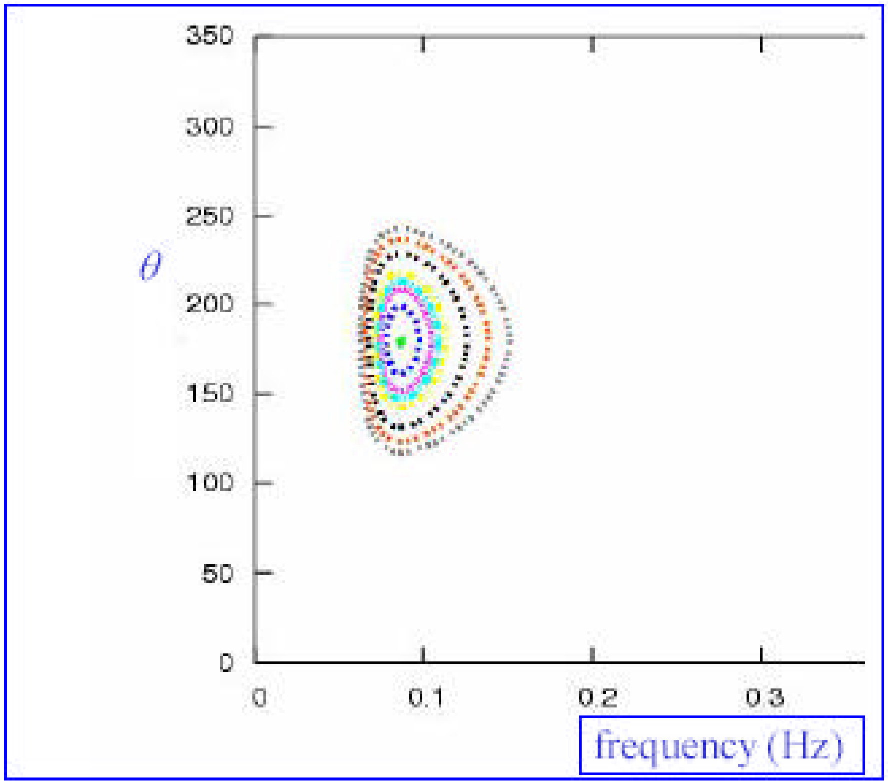
Impacts on Snl computations

For simple SWAMP-2 type waves DIA is reasonable approximation….

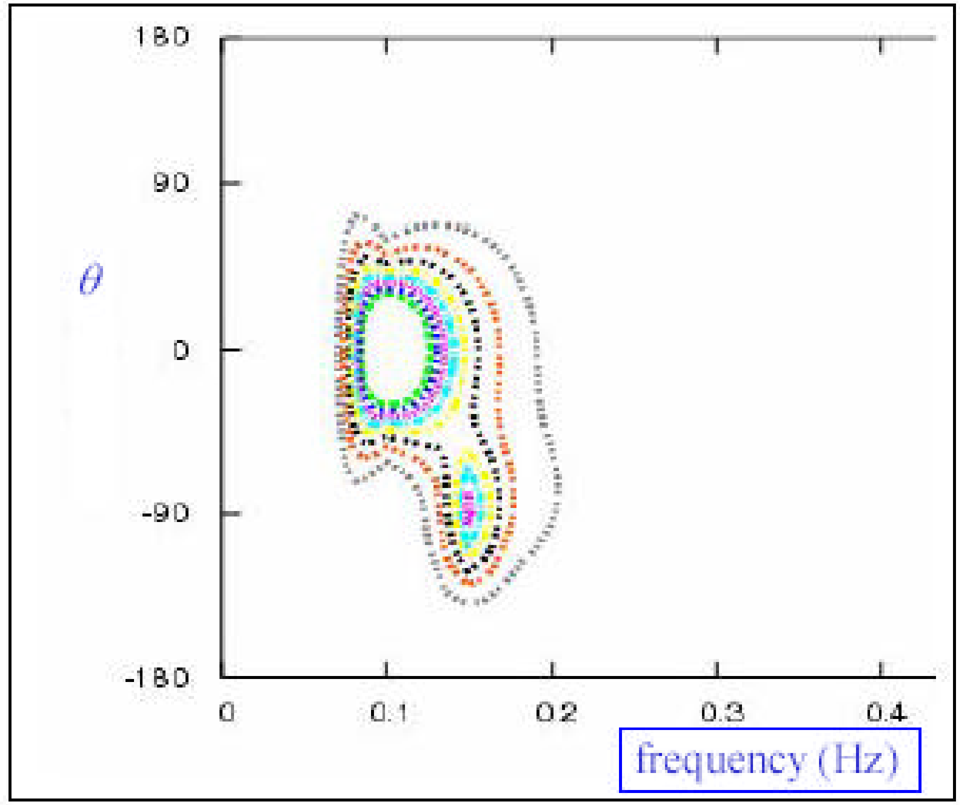


DIA for standard JONSWAP spectrum (from Hasselmann et al. 1985)

Other examples ..

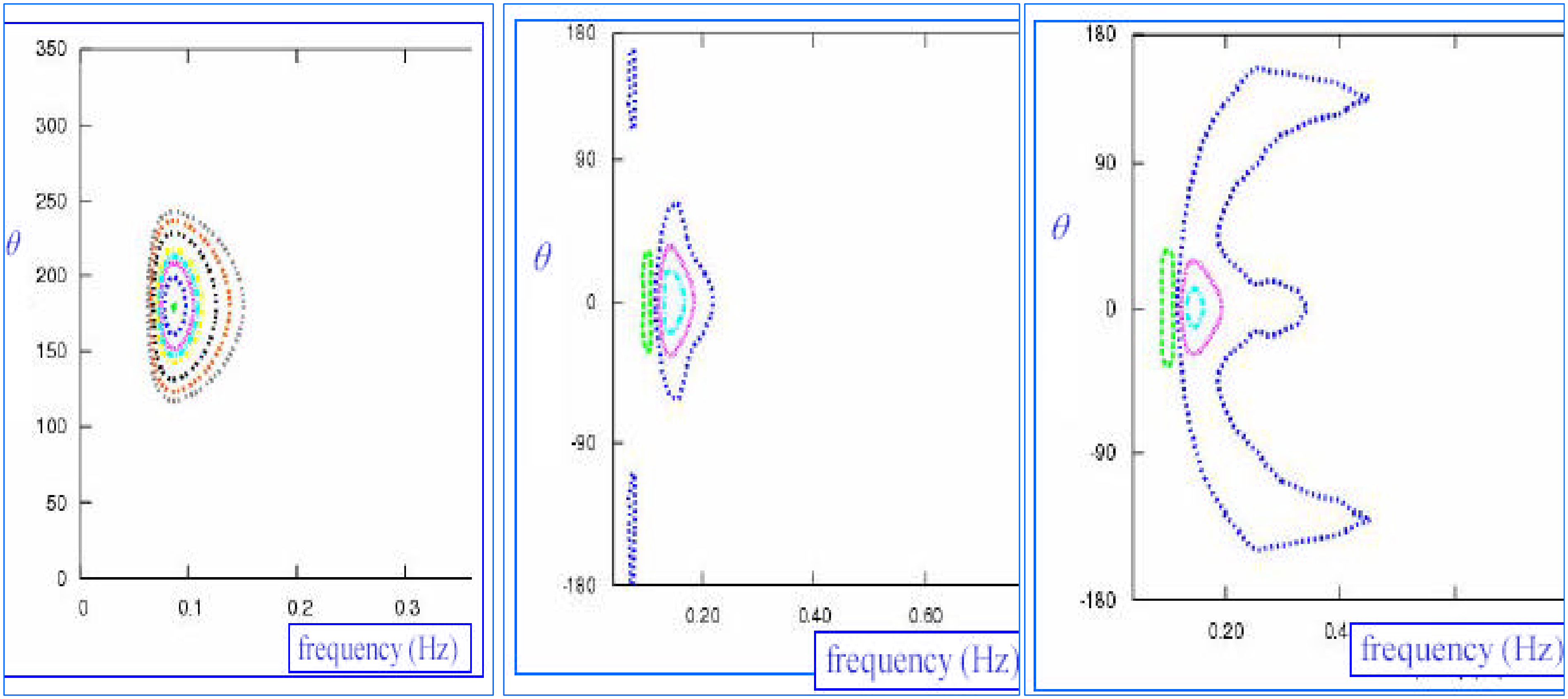


Simple peak spectrum



Double-peaked sheared spectrum

Simple peak spectrum

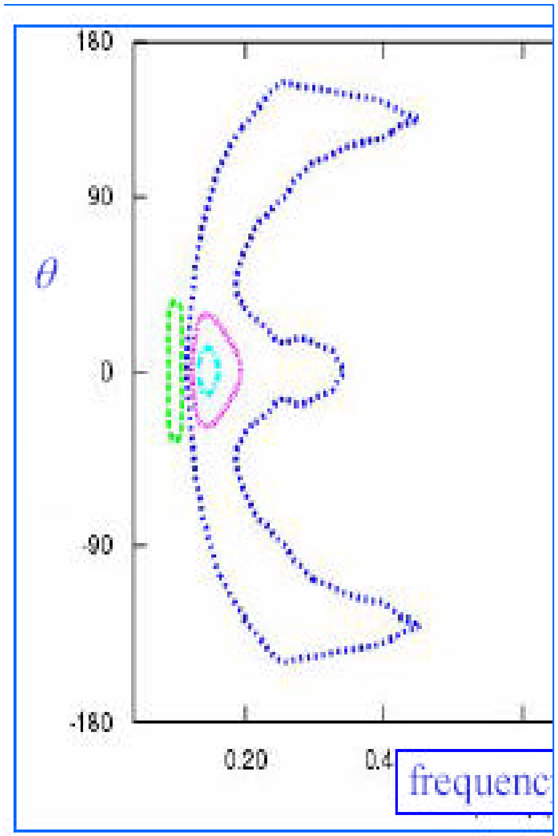


2-d energy

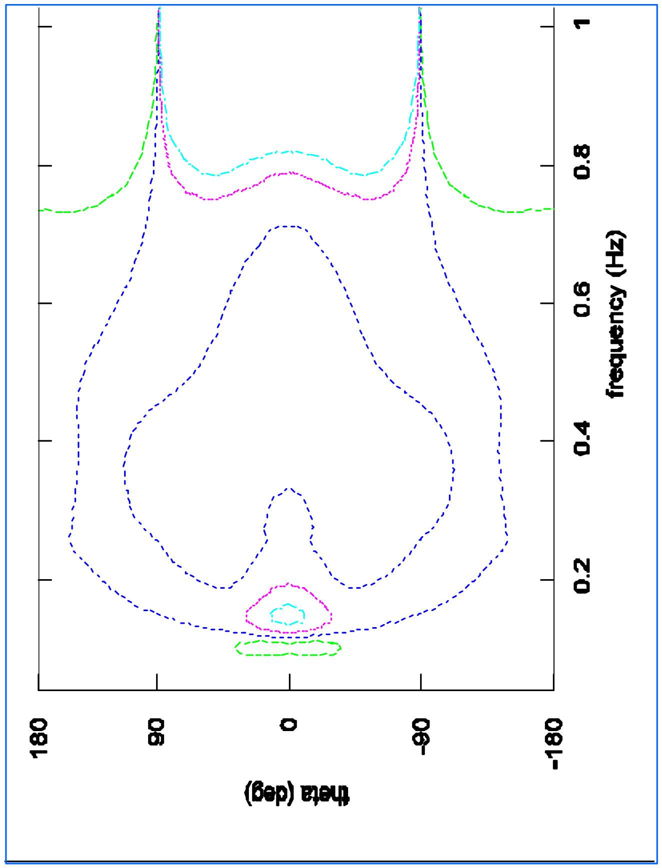
DIA-WW3

RTW-WW3

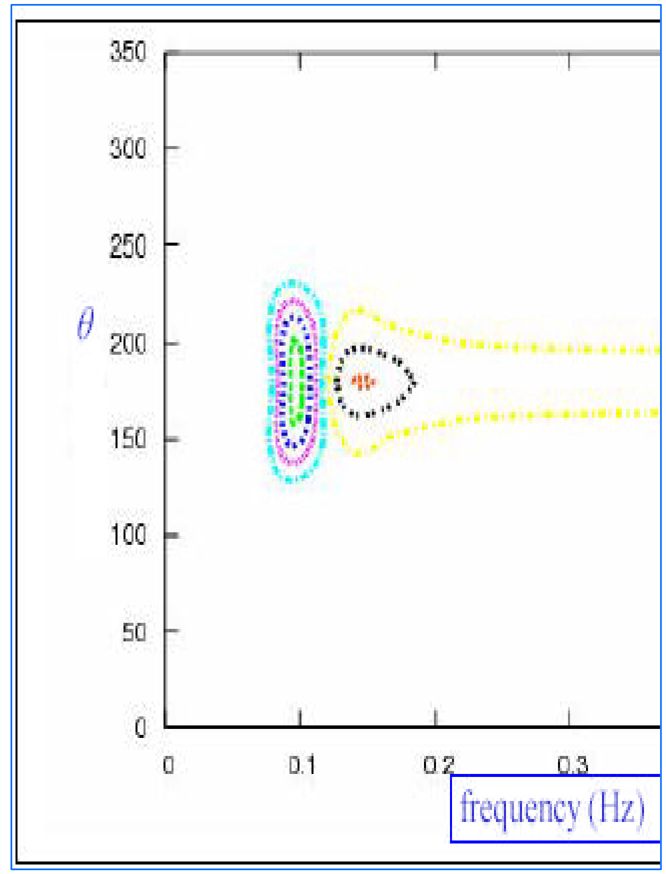
Simple peak spectrum



RTW-WW3



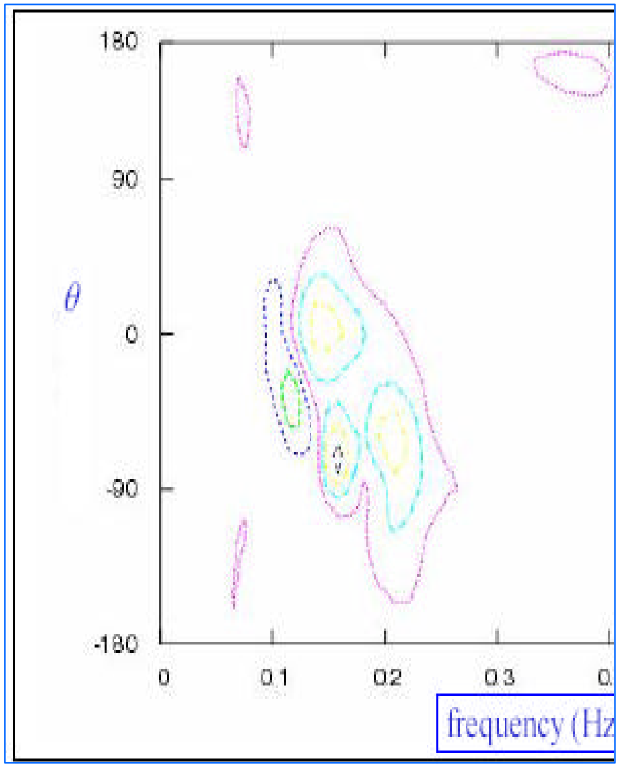
RTW-WW3
No tail



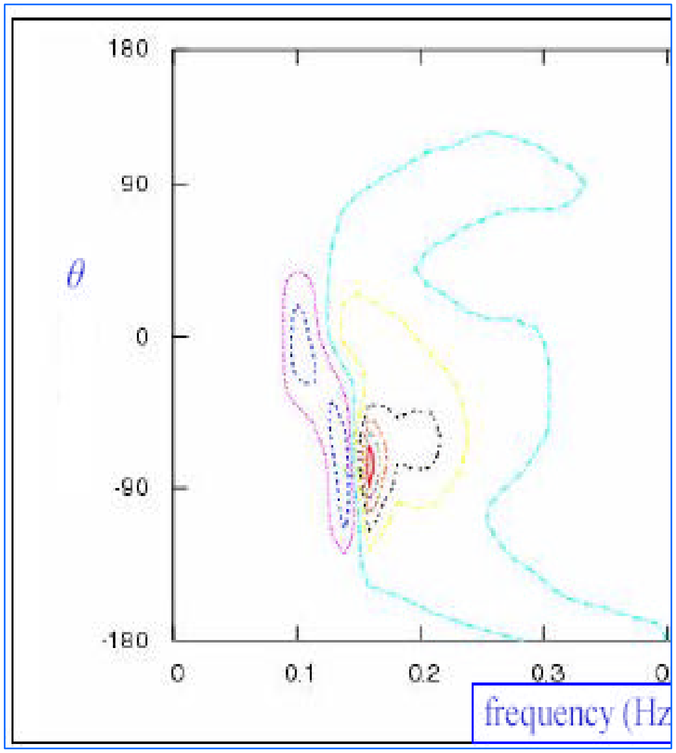
RTW-erdc

intensity and a tail ….. !

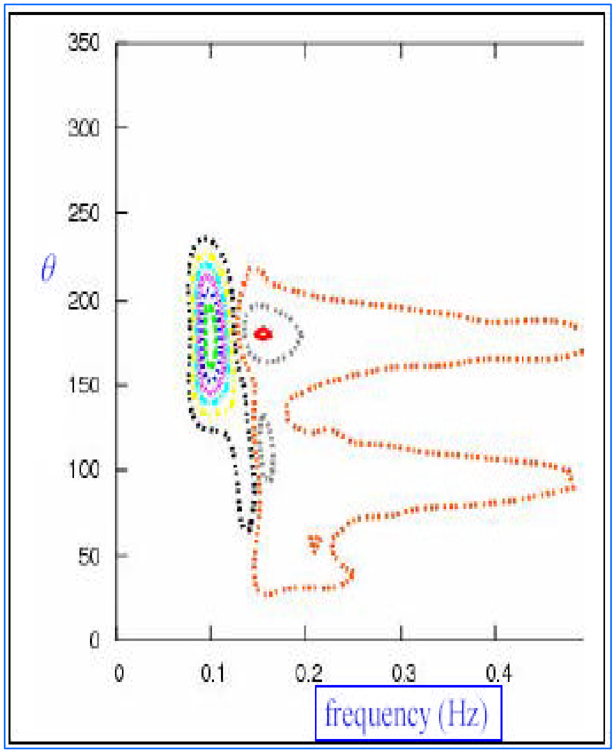
Double-peaked spectrum



DIA-WW3



RTW-WW3



RTW-erdc

intensity and a tail ….. !

Review

2. energy – flux balances

$$T(k_1,k_3) = \oint ds\, J^{-1}\, C^2\, D(n_1,n_2,n_3,n_4)\ \theta$$

Flux past ? $_A$:

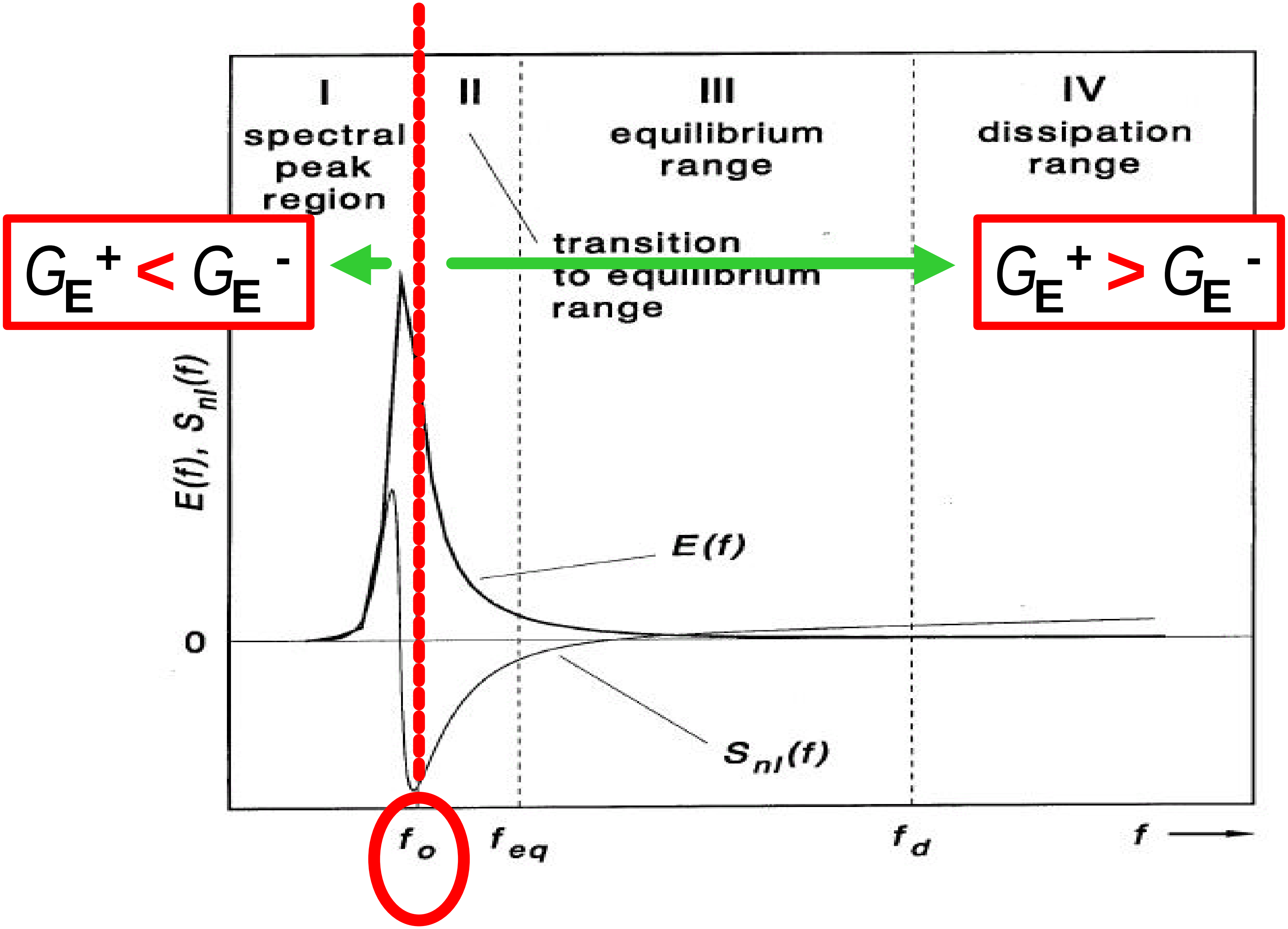
$$G(?\ _A) = \int\oint ds \ \ \ldots . \qquad\qquad \ldots .\ \ H_{3A}H_{A1} dk_3\, dk_1$$

Heaviside functions

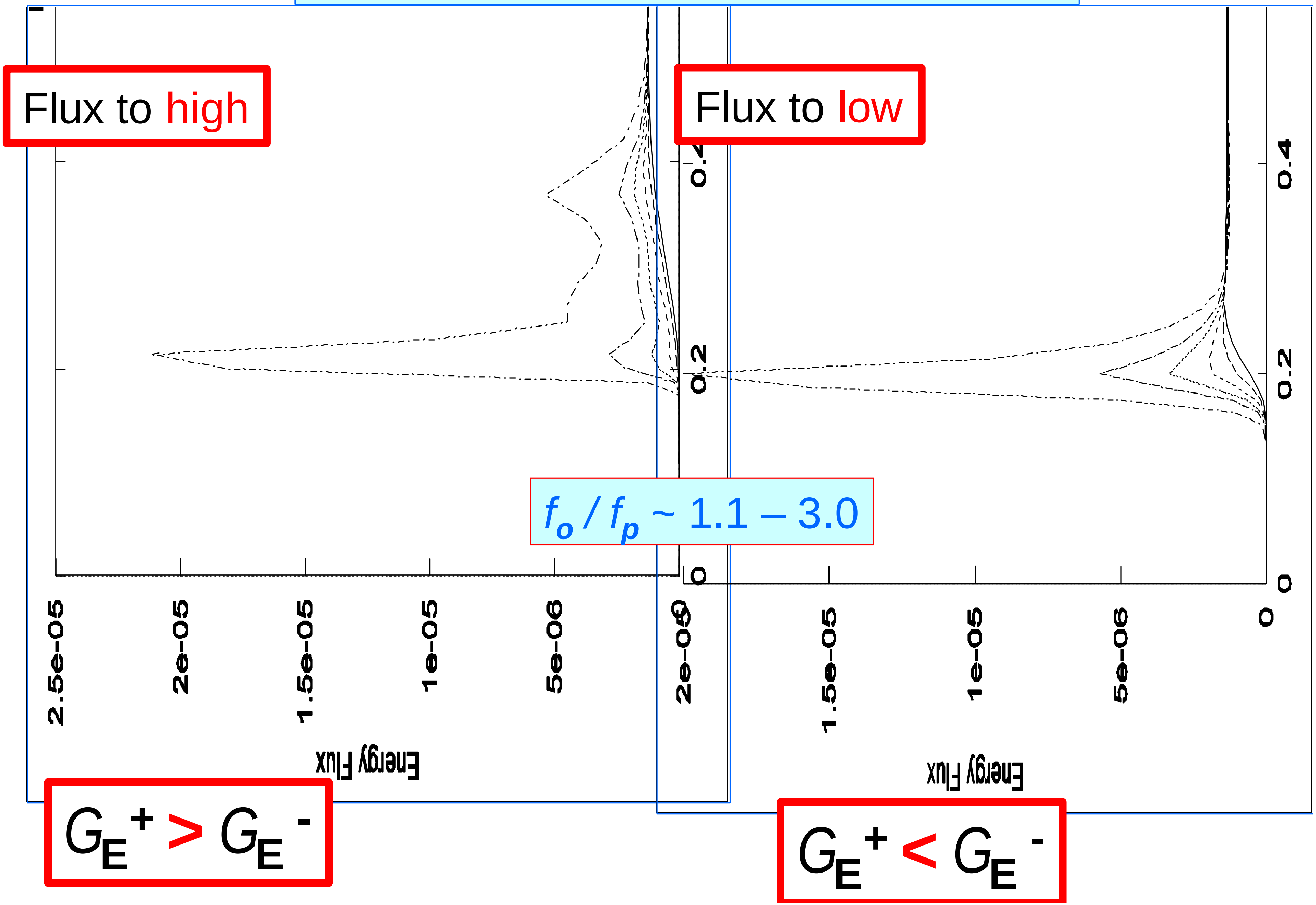
$$H(x) = \begin{matrix} 1 \text{ when } x\ = 0 \\ 0 \text{ when } x < 0 \end{matrix}$$

$$H_{3A} = H(|k_3| - |k(?\ _A)|) \qquad \ldots .. \text{ Etc.}$$

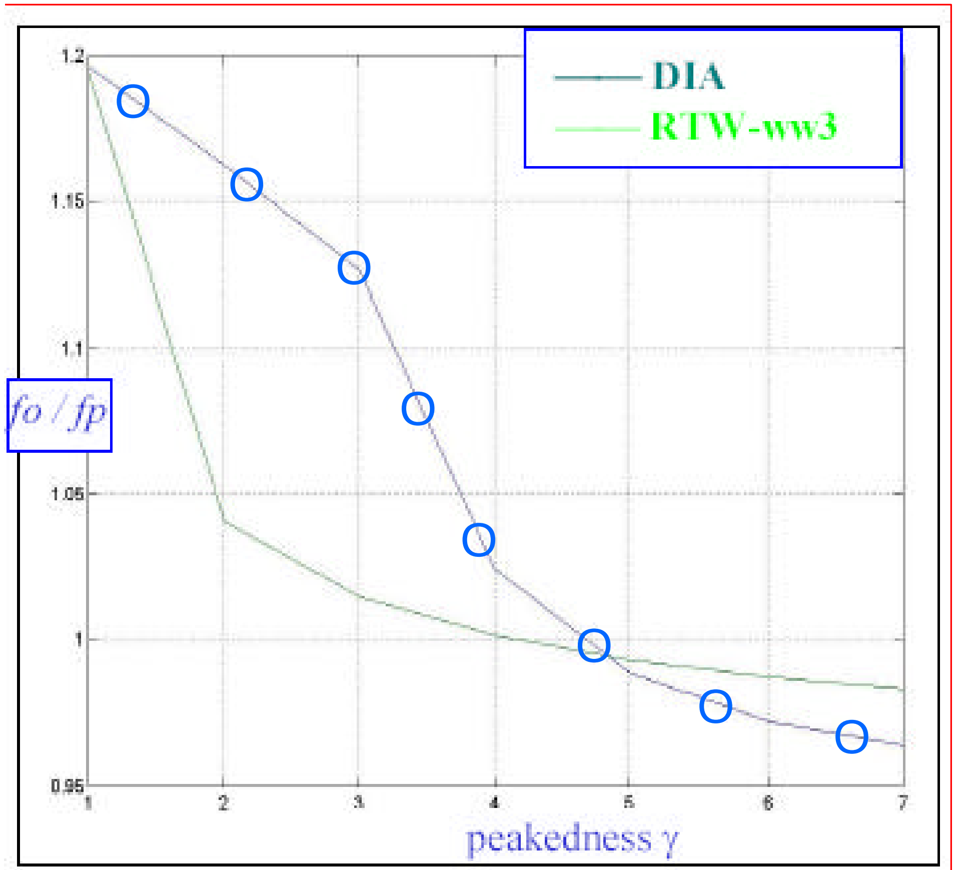
Spectral regions ...



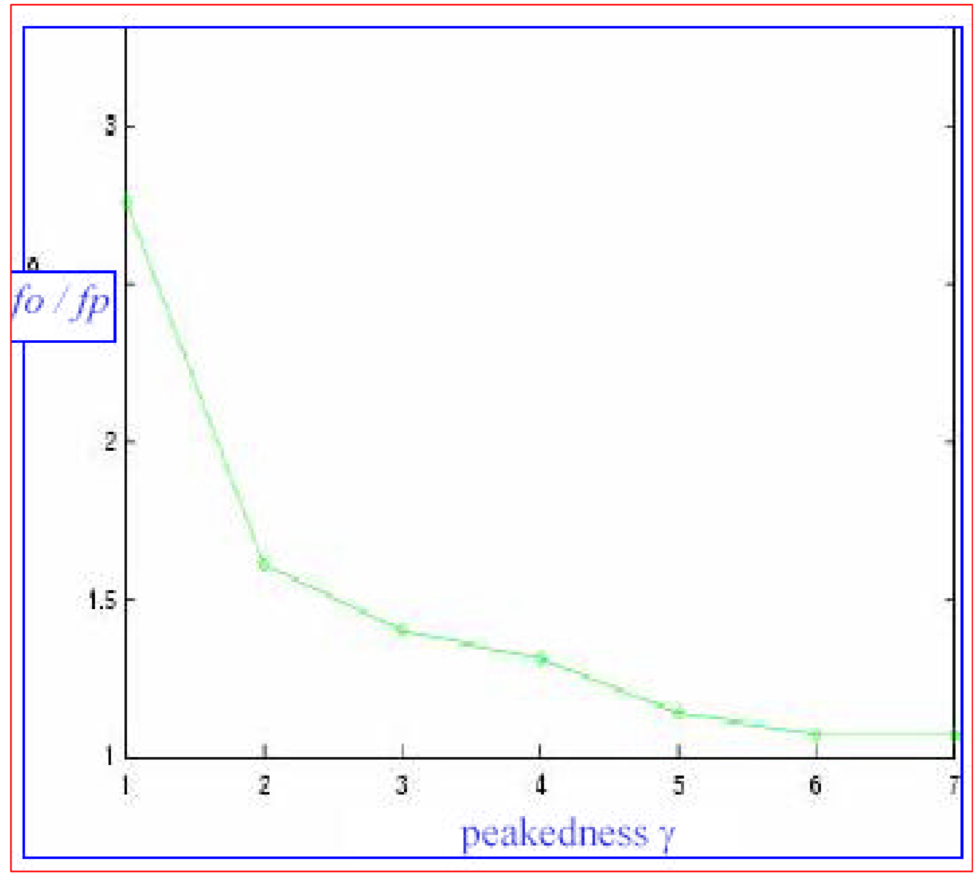
Wave maturity 0.65 < γ < 7.0



Variation of f_o with wave maturity



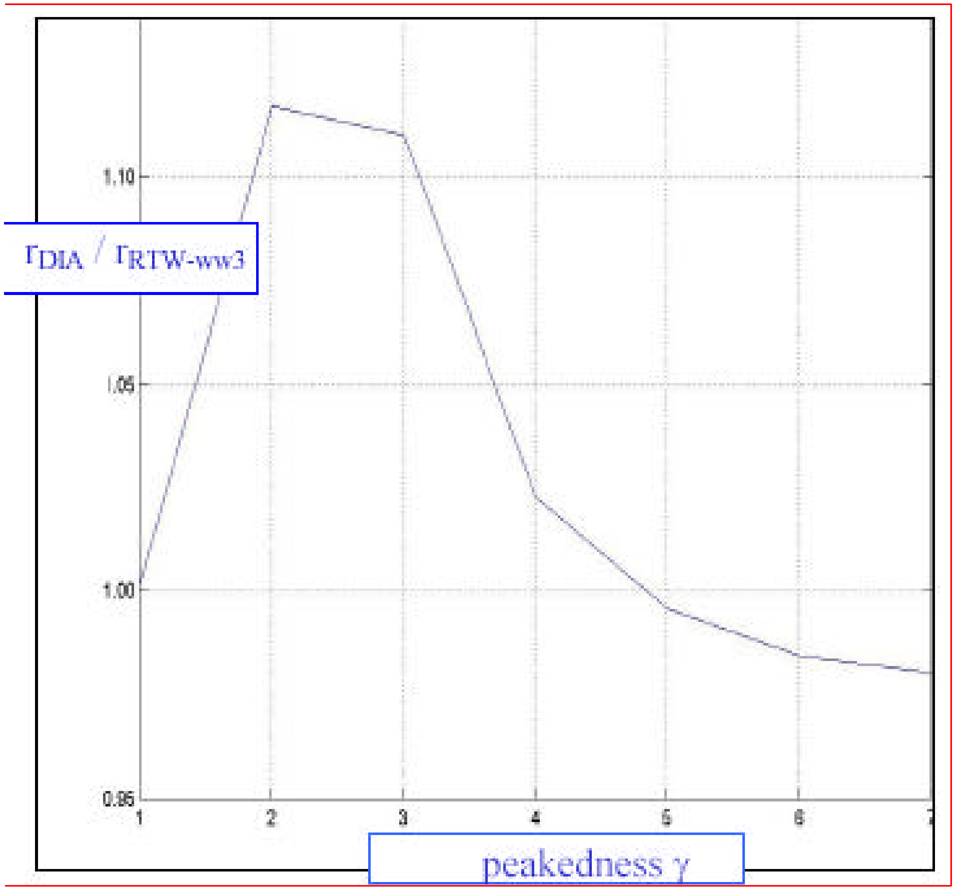
RTW-ww3
DIA-ww3

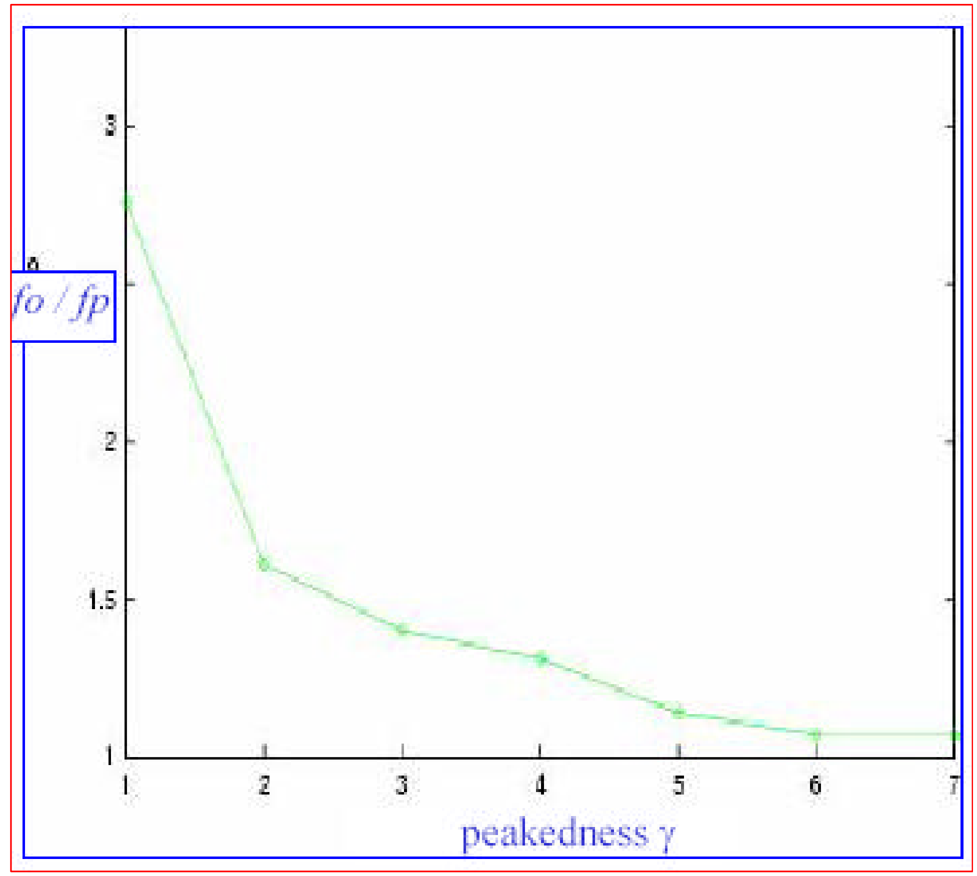


RTW-erdc

always > 1 ….. !

Variation of f_o with wave maturity



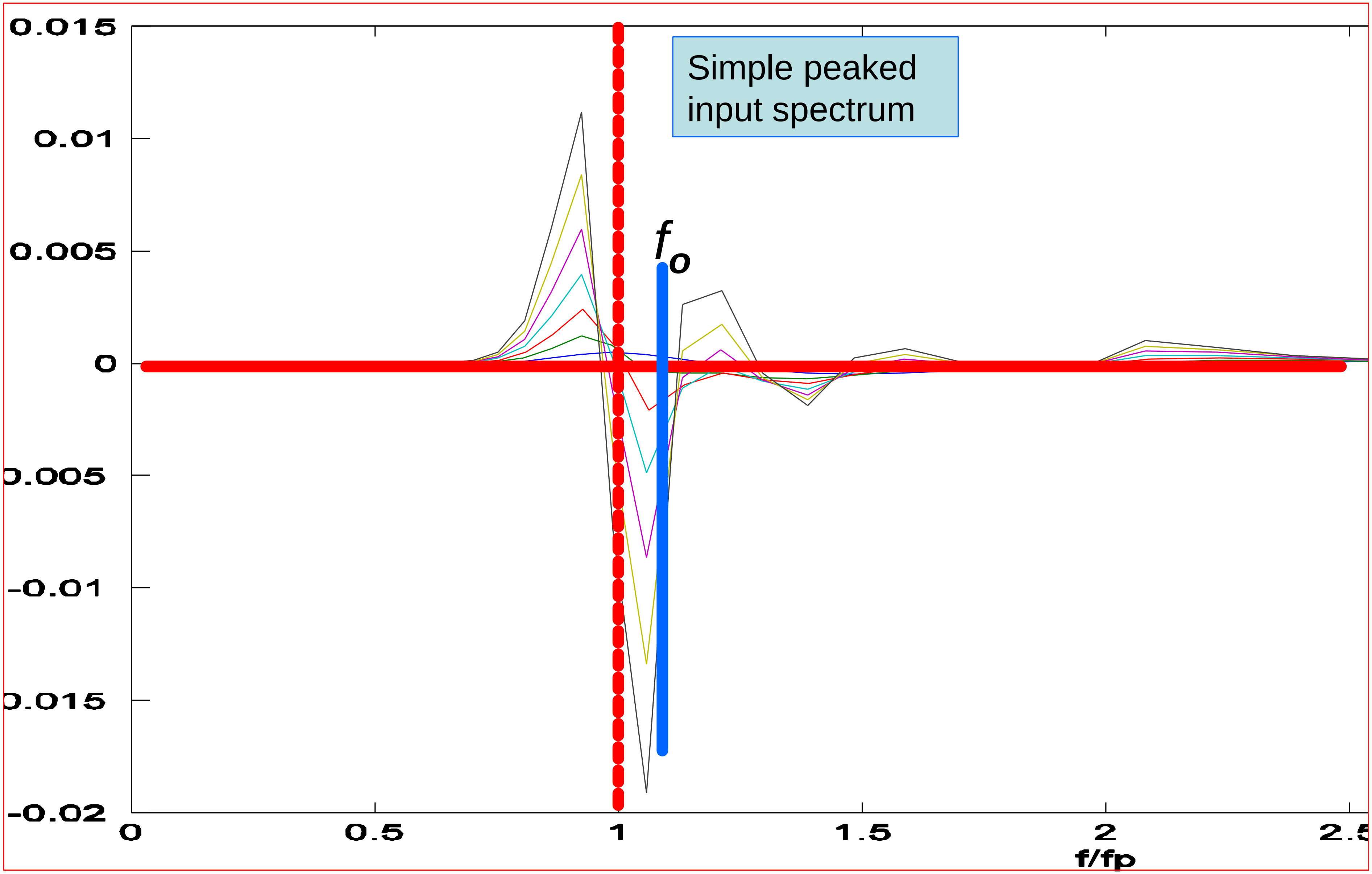


RTW-erdc

r_{DIA} / $r_{RTW\text{-}ww3}$ < r_{DIA} / $r_{RTW\text{-}erdc}$

always > 1 ….. !

DIA does not allow enough energy to be retained → Sin and Sds must compensate



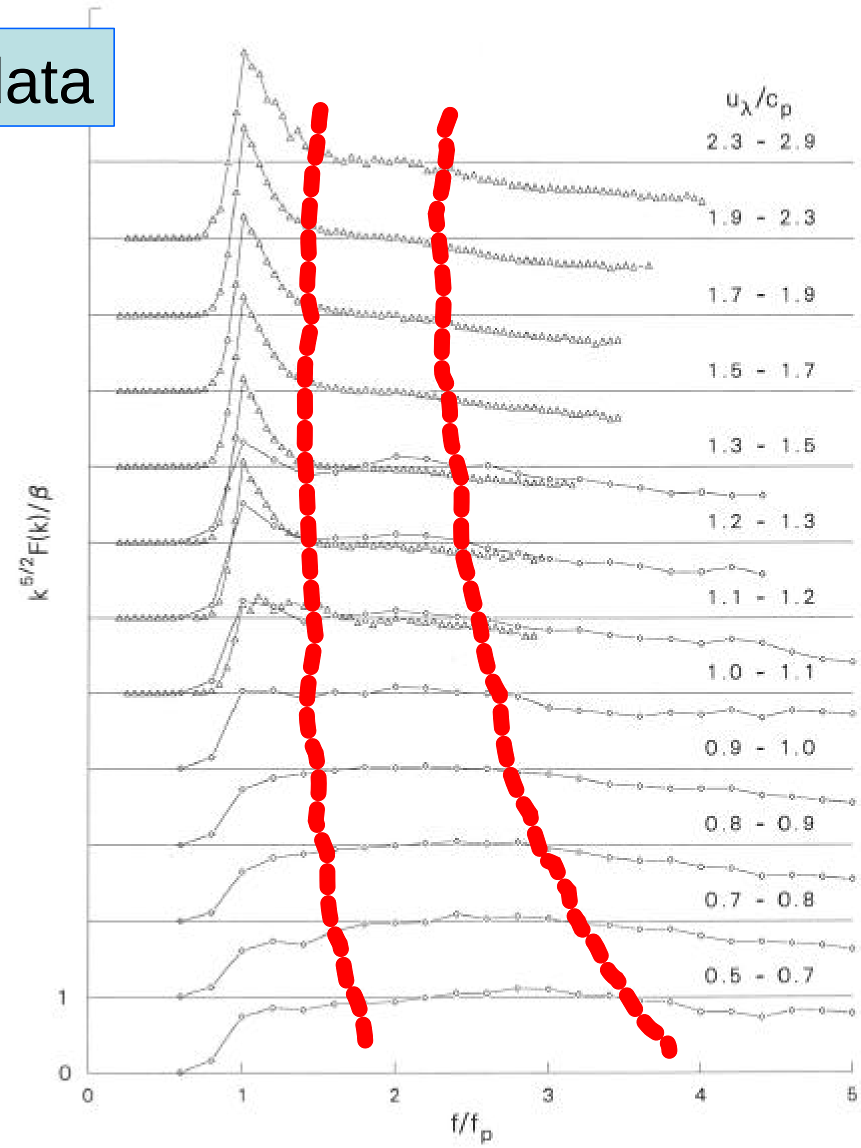
3. relation to source term parameterizations

Detailed balance in observed data

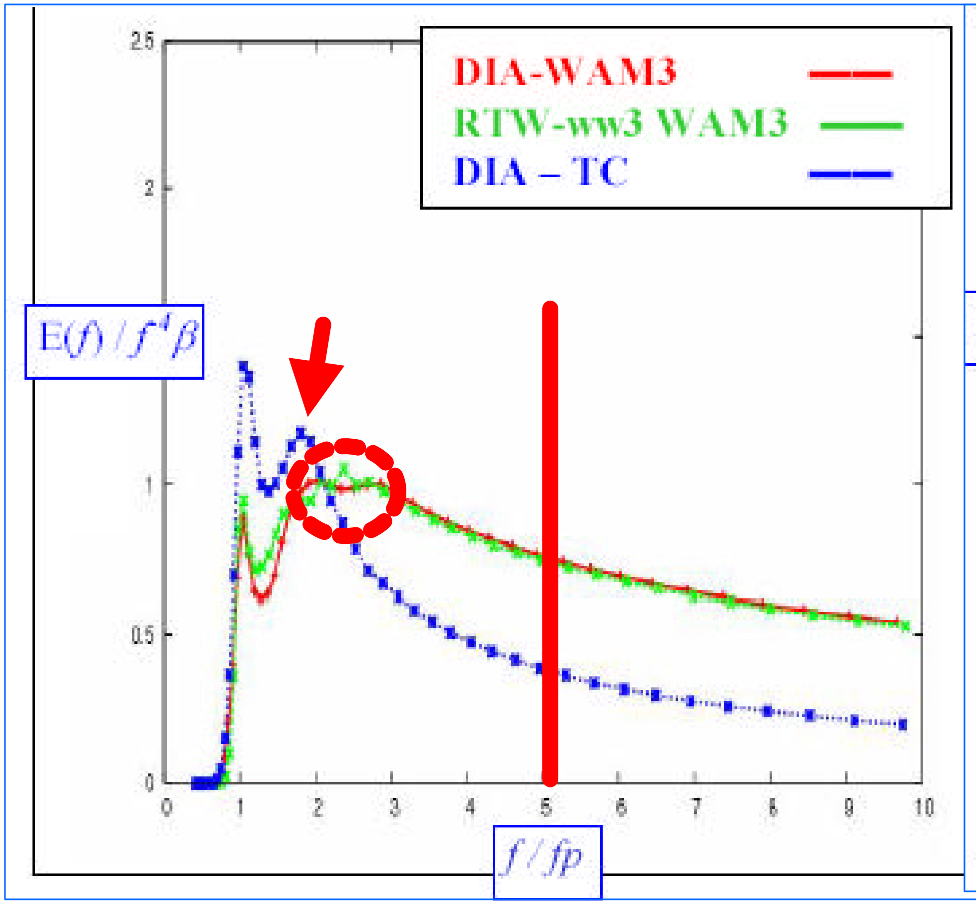
Source terms allow equilibrium range formation

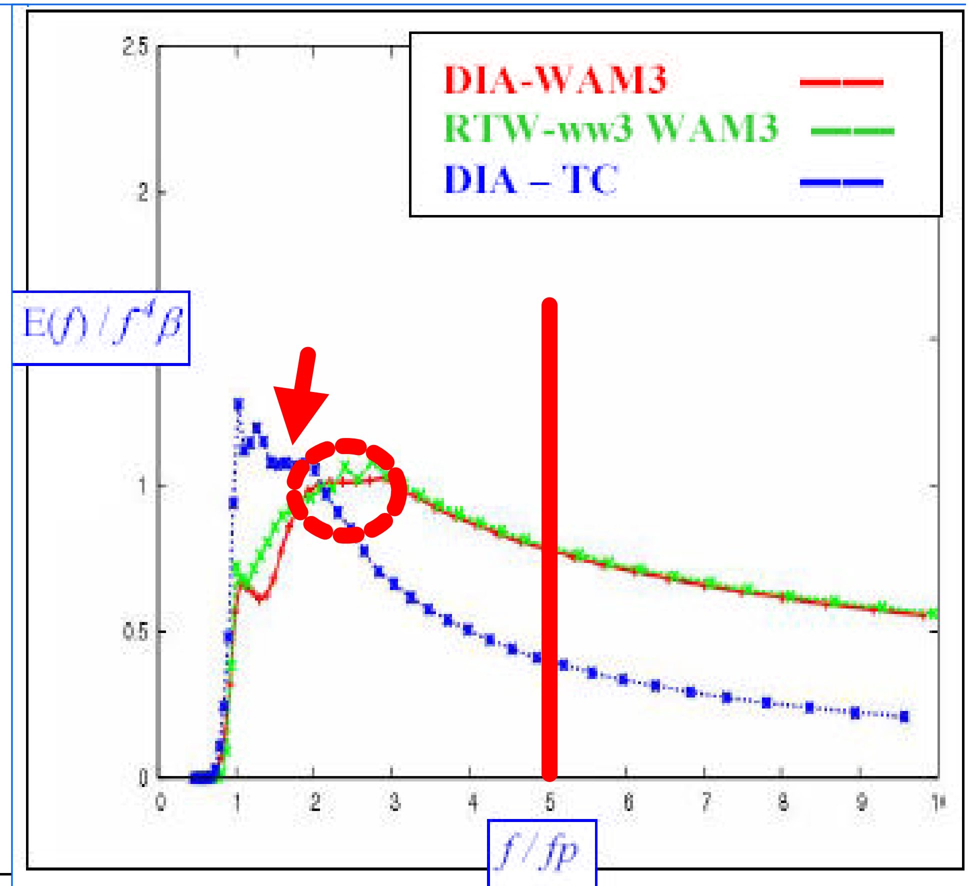
Relation to f_o … ?

Resio et al. 2004



Evaluation using standard source terms





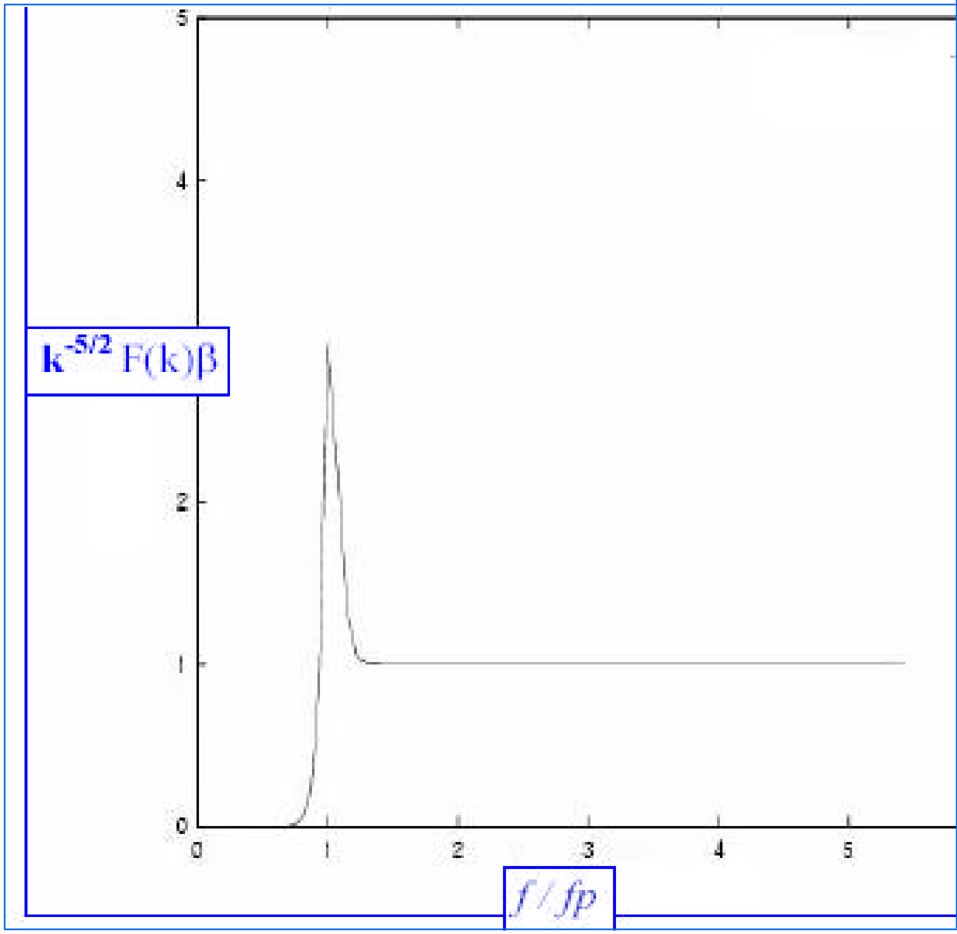
After 5 hr simulation

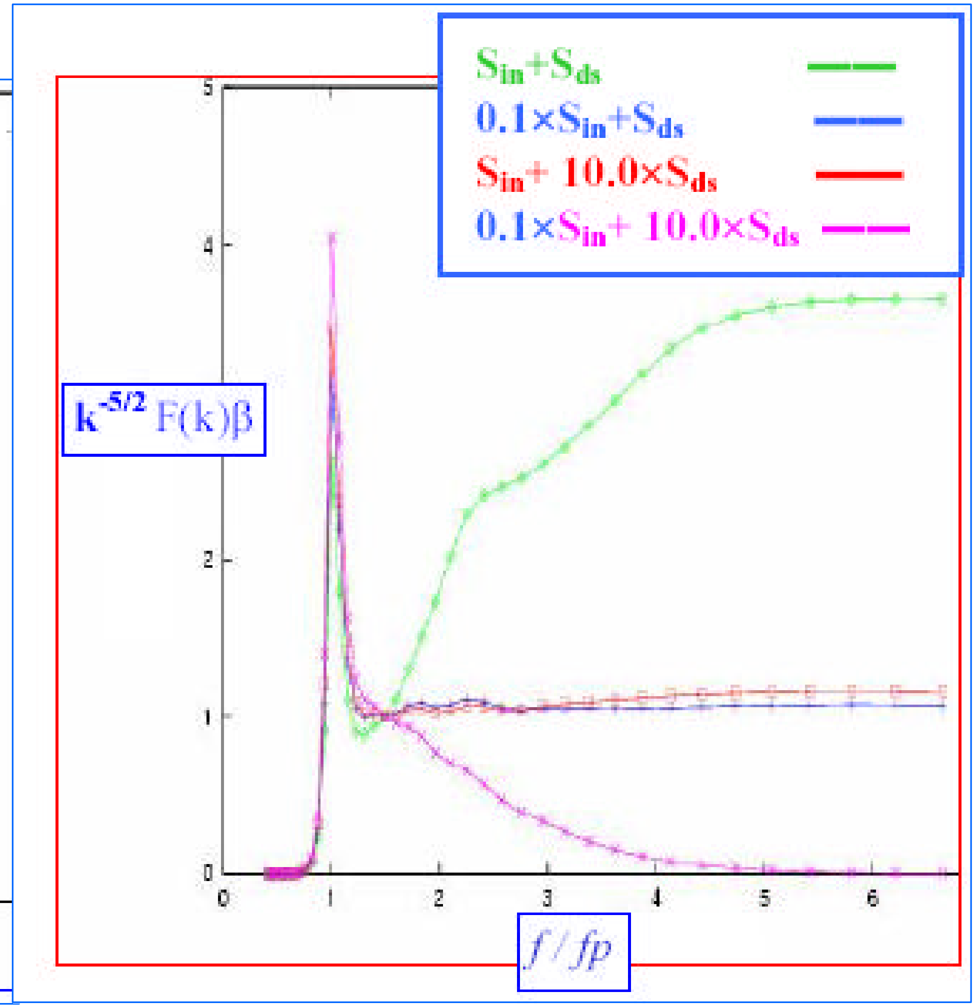
After 30 hr simulation

“dip” at ~ 1.2 f_p

limited equilibrium range …!

Comparison with RTW-erdc integrations



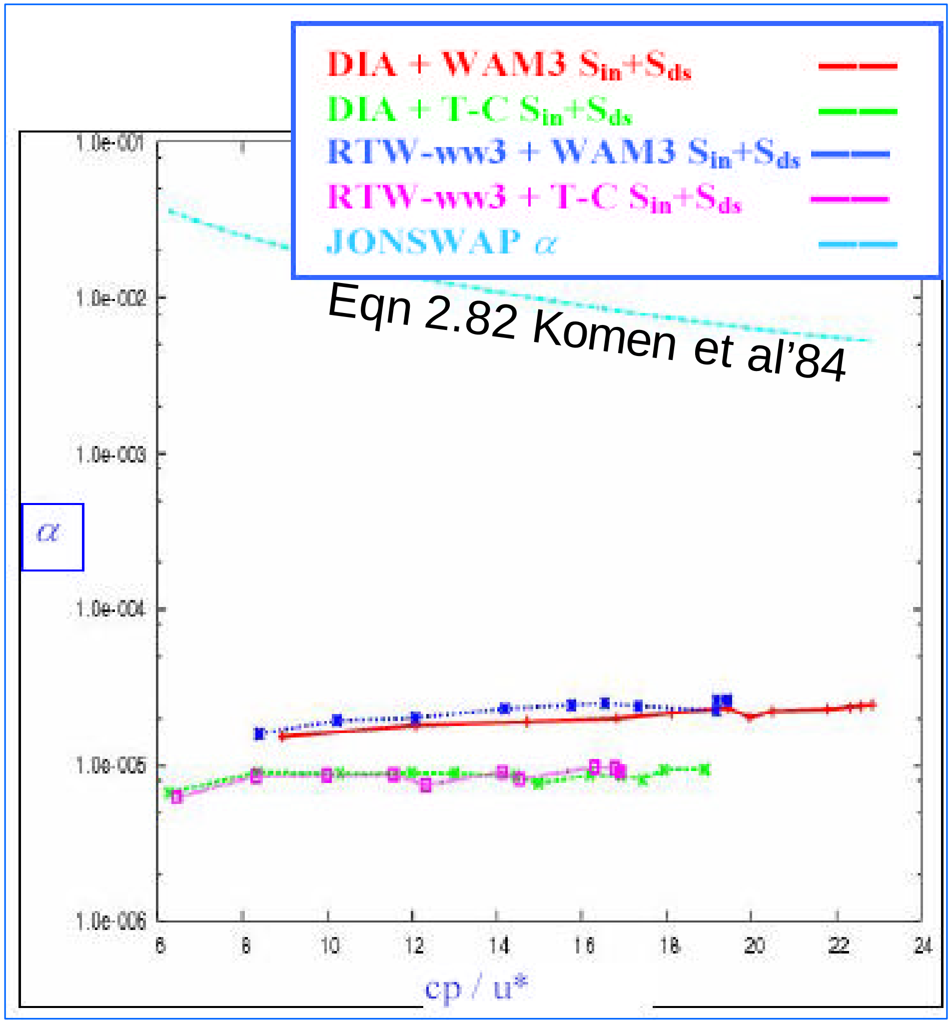


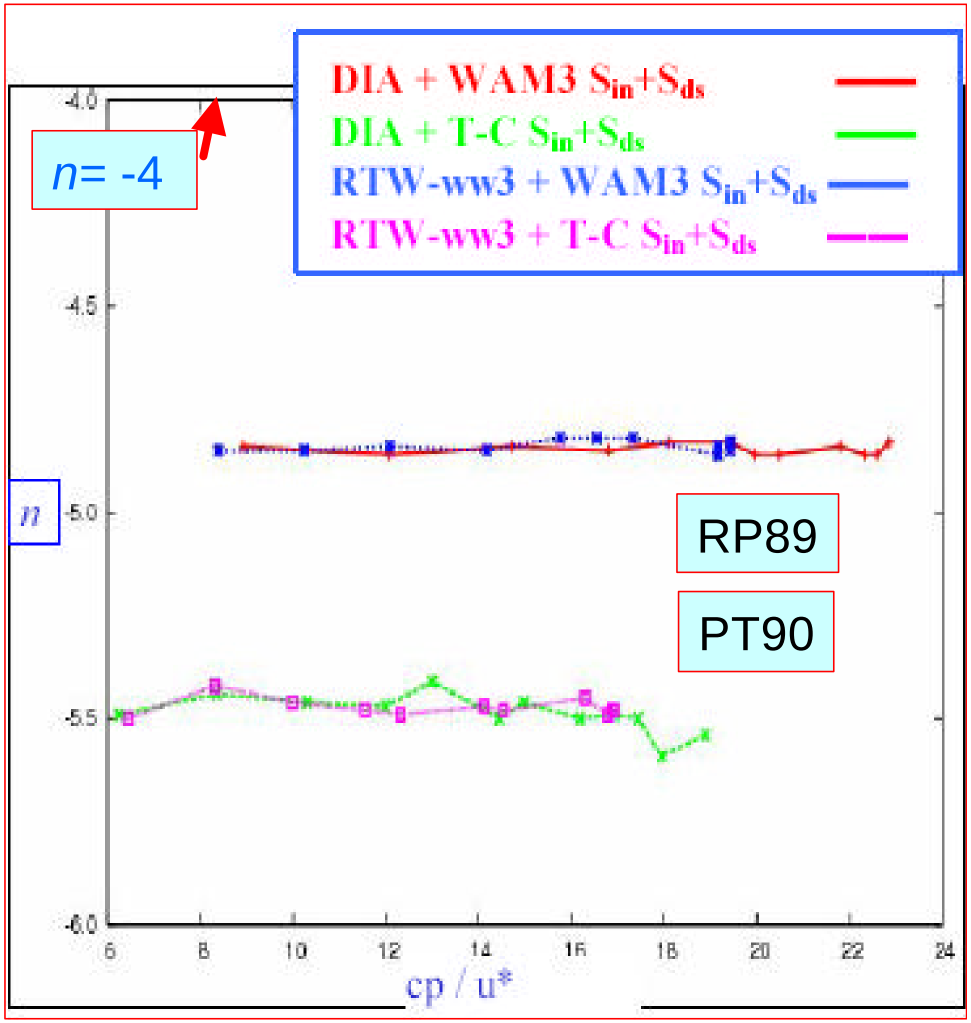
Normalized F(k) with JONSWAP-type input:
a = 0.01, U10 = 15 m/s, fp = 0.1, ? = 3

RTW-erdc for Snl; WAM3 Sin + Sds
1-hr simulation

source terms adjustments … !

4. challenges for improvements

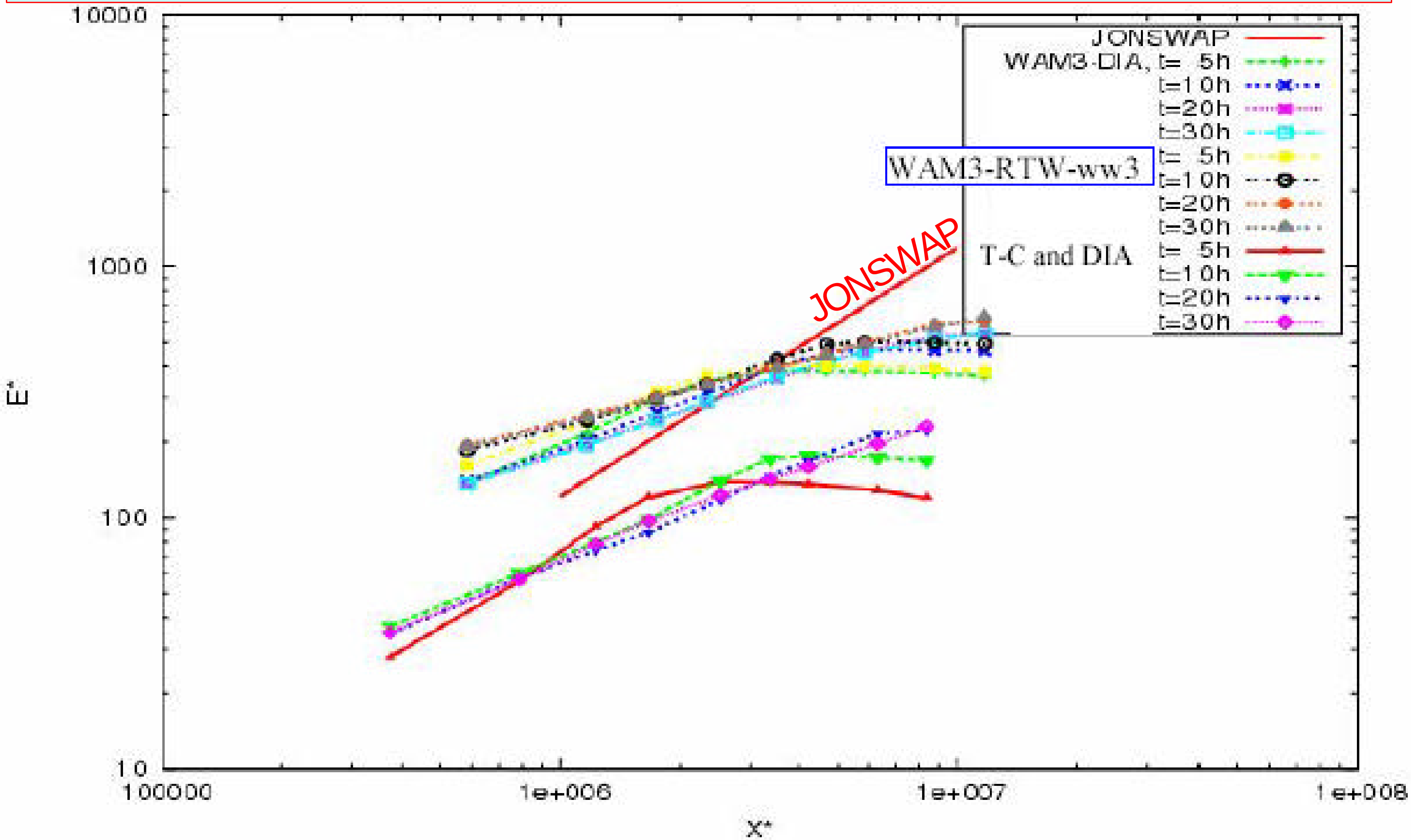




For a and “*n*” results … issues !

WAM3 Sin + Sds give one family of curves, T-C give another;
results not dependent on DIA or RTW-ww3

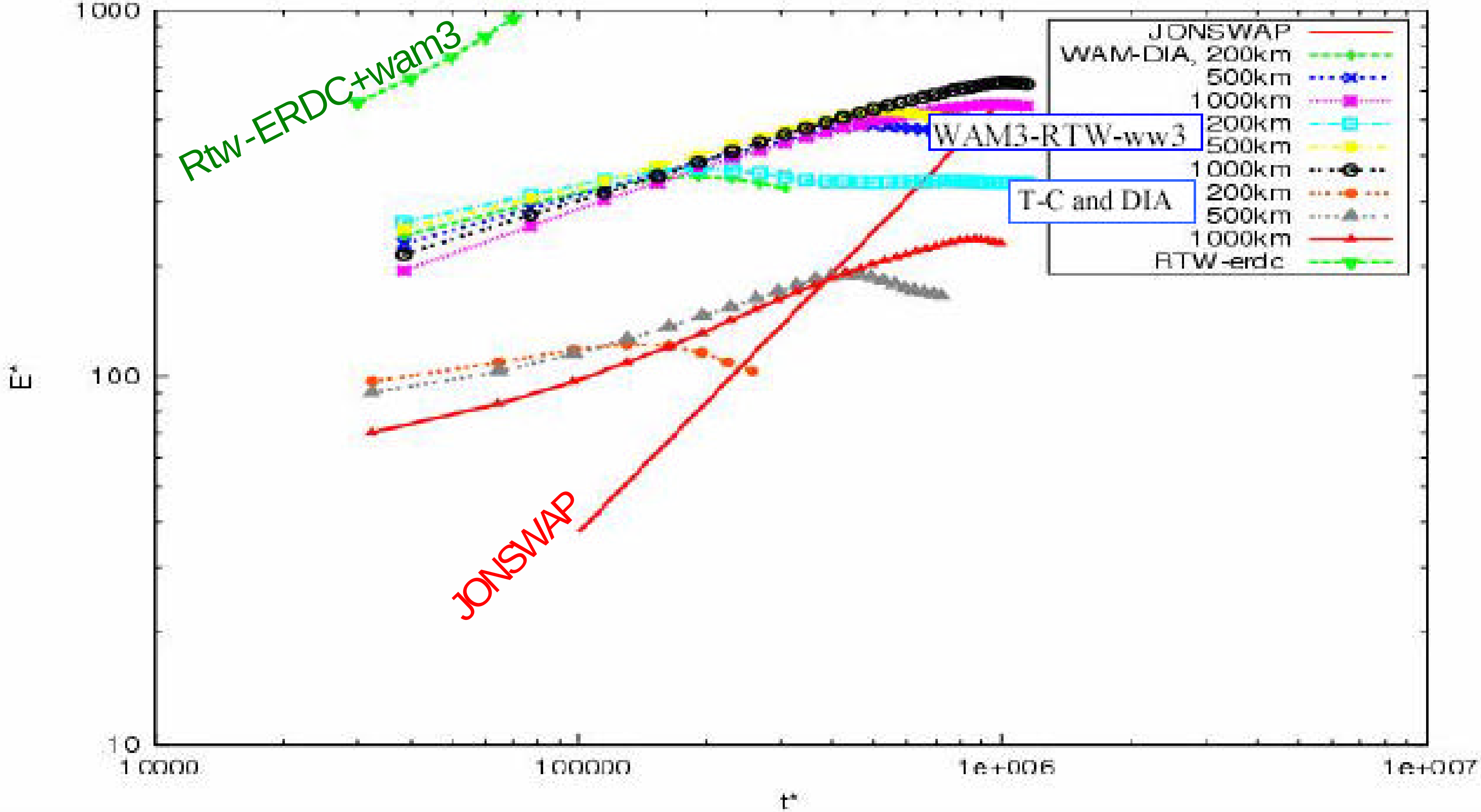
Parametric balance; E* vs. x*



WAM3 Sin + Sds give one family of curves, T-C give another; results not dependent on DIA or RTW-ww3

<u>DIFFERENCES</u> in slopes compared to JONSWAP, as a function of t … !

Parametric balance; E* vs. t*



WAM3 Sin + Sds give one family of curves, T-C give another; results not dependent on DIA or RTW-ww3

<u>DIFFERENCES</u> in slopes wrt **JONSWAP, as a function of x … !**

Offset for RTW-erdc + WAM3 source terms ….

conclusions

1. Serious limitations in DIA (RTW-ww3) for simple peaked or double peaked / sheared spectra (tail, low-*f* distortion)
2. DIA impacts f_o – the null frequency for equilibrium range – which defines energy retained, detailed balance…
3. Detailed balance – WAM3 and T-C source terms can support equilibrium range, with tuning factors
4. T-C and WAM3 Sin+ Sds determine values for a and “n”, *not* DIA or RTW-ww3: and differ from JONSWAP / Toba
5. Fetch / duration curves dominated by WAM3 or T-C source terms, *not* DIA or RTW-ww3 formulation
6. “ “ curves too shallow and not self-similar.
7. RTW-erdc + WAM3 has improved slope, but offset