³He library

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Usage

This library provides constant and functions for various ³He properties. Supported Languages:

- **Fortran-77.** You should use `he3.fh` include file and `libhe3` library for fortran programs. All functions and arguments are `real*8`. Use `-fno-range-check` compiler flag to allow `NaN` values.

- **Fortran-90.** You should include he3.f90h instead.

- **C.** You should use `he3.h` include file and `libhe3` library in C programs. Lowercase names with underscore should be used (like `he3_pf_`). Type of arguments is always `double*`, type of returned value is `double`.

- **Matlab, Octave.** `mex` files are located in the `matlab` folder. Lowercase names should be used. In function arguments you can mix numbers with arrays or matrices of the same size. Example:

  ```
  ttc=0:0.1:1; p=10;
  I = he3_nu_b(p, ttc);
  ```

  To build `mex` files you can use `make octave`, `make matlab` or `make matlab64` in the `matlab` folder. Fixed rpath is used for the library. For building this documentation octave files are needed.

- **Command line.** You can use all the functions via a command line interface. To get a list of all functions run the program `he3` without arguments:

  ```
  > he3
  ```

  To get information about specific function run the program with the function name as an argument:

  ```
  > he3 he3_nu_b
  ```

  You can use matlab-style vectors (value1:step:value2) to get a table of values (if step is missing then 20 points will be printed):

  ```
  > he3 he3_nu_b 0.1:0.1:1 0
  ```

  will give you Leggett frequency vs temperature at zero pressure.

Location

GIT https://github.com/slazav/he3lib

ROTA /home/slazav/he3lib/lib
 /rota/programs/src/he3lib – old, "stable" version.
 Use "`addpath /rota/programs/src/he3lib/matlab`" in Matlab.

General

|	
`const_na`	Avogadro constant $N_A = 6.02214129 \cdot 10^{23}$ [1/mol]
`const_kb`	Boltsman constant $k_B = 1.3806488 \cdot 10^{-16}$ [erg/K]
`const_r`	R-gas constant $R = 8.314472 \cdot 10^7$ [sgs]
`const_h`	Plank constant $h = 6.62606957 \cdot 10^{27}$ [sgs]
`const_hbar`	$\hbar = h/2\pi = 1.054571726 \cdot 10^{27}$ [sgs]
`const_pi`	$\pi = 3.1415926535897932$
`const_2pi`	2π
`he3_amass`	^{3}He atom mass, $m_3 = 5.0079 \cdot 10^{-24}$ [g]
`he3_mmass`	^{3}He molar mass, $\mu = N_A m_3 = 3.0158$ [g/mol]
`he3_gyro`	^{3}He gyromagnetic ratio $\gamma = 20378$ [(G s)$^{-1}$],

Phase diagram

Vapor pressure and critical point are from the 1962 ^{3}He scale of temperatures. Melting curve $P_m(T)$ at 0.9 – 250 mK, $T_c(P)$, $T_{AB}(P)$ and all tricritical points are from Greywall-86 temperature scale. Melting curve minimum is from PLTS-2000 temperature scale. Melting curve for higher temperatures is from Osborne, Abraham, Weinstock-1951 and Mills, Grilly-1955 with interpolation in the regions 0.25–0.5K and 1.5–2.0K. PLTS-2000 melting curve and critical points on it are also available. See more information in the source file he3_phase.f.

he3_pvap(T)	Vapor pressure [bar] vs temperature [K], $T = 0.2 - 3.324$ K
he3_pcr	Gas-liquid critical point pressure, 1.16317 [bar]
he3_tcr	Gas-liquid critical point temperature, 3.324 [K]
he3_pmelt(T)	Melting pressure [bar] vs temperature [K], $T = 0.0009 - 31$ K
he3_pm	Melting curve minimum pressure, 29.3113 [bar]
he3_tm	Melting curve minimum temperature, 0.31524 [K]
he3_pa	Superfluid trans. at melting curve, pressure, 34.3380 [bar]
he3_ta	Superfluid trans. at melting curve, temp., 2.491 [mK]
he3_pb	A-B trans. at melting curve, pressure, 34.3580 [bar]
he3_tb	A-B trans. at melting curve, temp., 1.932 [mK]
he3_ps	Neel transition at melting curve, pressure, 34.3905 [bar]
he3_ts	Neel transition at melting curve, temp., 0.9291 [mK]
he3_tc(P)	Superfluid transition temperature [mK] vs pressure [bar], $P = 0 - 34.358$ bar
he3_tab(P)	A-B transition temperature [mK] vs pressure [bar], $P = 0 - 34.3609$ bar, below 21.22 bar is equal to he3_tc
he3_tabn	A-B-Normal point temperature, 2.2311 [mK]
he3_pabn	A-B-Normal point pressure, 21.22 [bar]

PLTS-2000 temperature scale:

he3_pmelt_plts(T)	PLTS-2000 melting presure [bar] vs temperature [K].
he3_pa_plts	Superfluid trans. at melting curve, pressure, 34.3407 [bar]
he3_ta_plts	Superfluid trans. at melting curve, temp., 2.444 [mK]
he3_pb_plts	A-B trans. at melting curve, pressure, 34.3609 [bar]
he3_tb_plts	A-B trans. at melting curve, temp., 1.896 [mK]
he3_ps_plts	Neel transition at melting curve, pressure, 34.3934 [bar]
he3_ts_plts	Neel transition at melting curve, temp., 0.902 [mK]
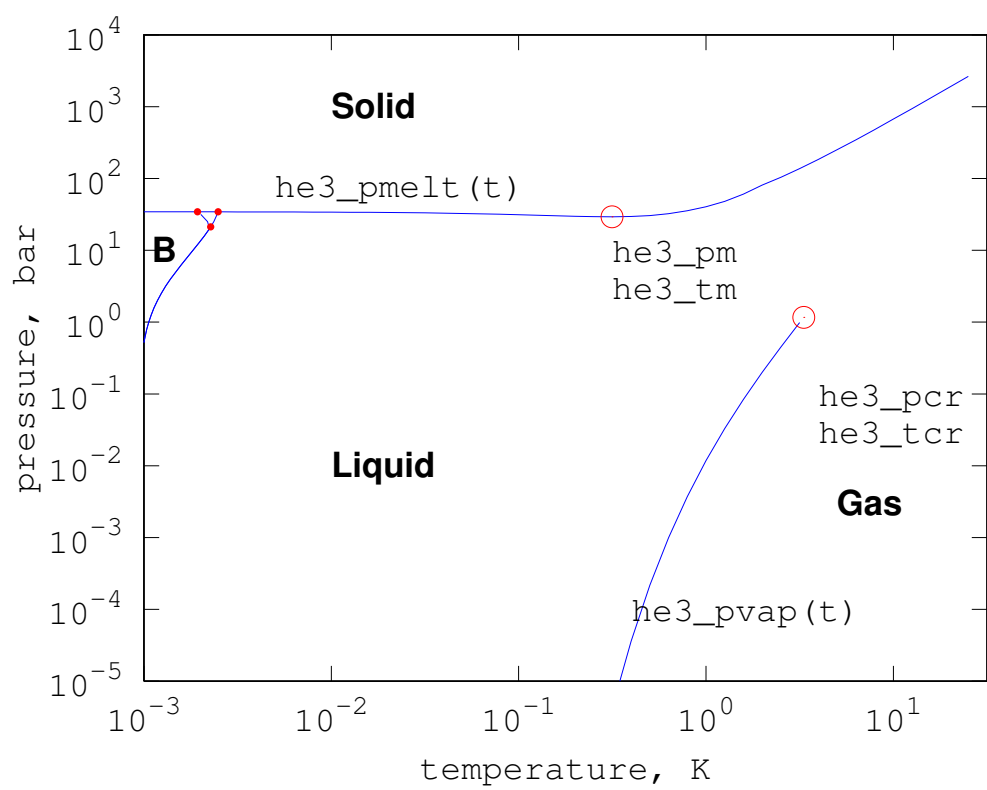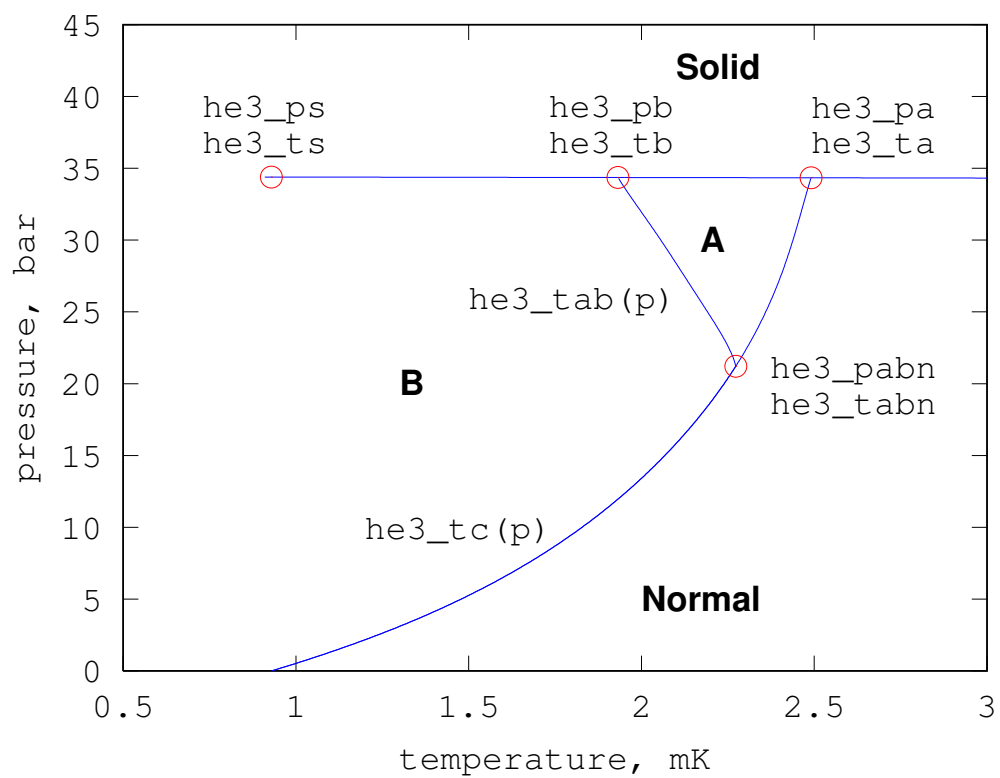
Fermi-liquid parameters

Fermi-liquid parameters according to Wheatley-75 table. Values are calculated using experimental data for molar volume, speed of sound, magnetic temperature $T^\star$, collected by Wheatley-75 and heat capacity ($\gamma_f = C/RT$) measured by Graywall-86. Argument is pressure, [bar] in the range 0 – 34.4. See more information in the source file `he3_fermi.f`.

Measured values:

`he3_vm(P)`   Molar volume v_m, [cm^3/mol]

`he3_c1(P)`   First sound velocity, c_1, [cm/s]

`he3_gammaf(P)` R-gas constant $\gamma_f = C/RT$, [1/(K mol)]

`he3_tmag(P)`   Magnetic temperature $T^\star$, [K]

Derived values:

`he3_rho(P)`   Density $\rho = \mu/v_m$, [g/cm^3]

`he3_2n0(P)` $2N(0) = \dfrac{\gamma_f}{v_m}\dfrac{3N_A}{k_B\pi^2}$, [1/(erg cm^3)]

`he3_pf(P)` $p_F = h\left(\dfrac{3}{8\pi}\dfrac{N_A}{v_m}\right)^{1/3}$, [g cm/s]

`he3_meff(P)` $m^\star = \dfrac{h^3}{8\pi}\dfrac{2N(0)}{p_F}$, [g]

`he3_mm(P)` $m^\star/m_3$

`he3_vf(P)` $v_F = p_F/m^\star$, [cm/s]

`he3_chi_n(P)` $\chi_N = 2N(0)\dfrac{(\gamma\hbar)^2}{4(1+F_0^a)}$.

`he3_f0s(P)` $F_0^s = 3\ m^\star m_3\ c_1^2/p_F^2 - 1$

`he3_f1s(P)` $F_1^s = 3(m^\star/m_3 - 1)$

`he3_f0a(P)` $F_0^a = Z_0/4 = 3k_B T^\star m^\star/p_F^2 - 1$

`he3_f1a(P)` F_1^a

`he3_a(P)`   Average atomic spacing, $a = (v_m/N_A)^{1/3}$, Å

`he3_gdk(P)`   Average dipolar coupling enegy, $g_d/k_B = \dfrac{2\pi\gamma^2\hbar^2}{3v_m k_B}$, [K]

`he3_tfeff(P)` Effective Fermi temperature, $T_{F_{eff}} = \dfrac{\pi^2}{2\gamma_f}$, [K]

TODO:
Recalculate F_0^a F_1^a from experimantal data (Now there are some extra not-consistent data)! (see Ramm-1970, Halperin-92 ...). Add F_2^a (zero or from Halperin-95). Check g_d.

Pressure-dependent values:

P, bar	0	3	6	9	12	15	18	21	24	27	30	33
T_c, mK	0.929	1.290	1.560	1.769	1.934	2.067	2.177	2.267	2.339	2.395	2.438	2.474
T_{AB}, mK	–	–	–	–	–	–	–	–	2.217	2.137	2.056	1.969
v_m, cm^3/mol	36.84	33.95	32.03	30.71	29.71	28.89	28.18	27.55	27.01	26.56	26.17	25.75
c_1, m/s	182.9	227.4	259.9	285.8	307.9	327.3	344.8	360.6	375.2	389.2	402.9	416.1
γ_f, 1/(K mol)	2.784	2.981	3.158	3.321	3.475	3.625	3.772	3.918	4.065	4.211	4.355	4.496
$T^\star$, mK	358.8	305.8	276.2	255.7	238.7	224.0	212.4	204.0	197.8	191.9	184.9	178.4
ρ, g/cm^3	0.082	0.089	0.094	0.098	0.102	0.104	0.107	0.109	0.112	0.114	0.115	0.117
$2N(0), 10^{38}$	1.002	1.164	1.307	1.434	1.551	1.663	1.774	1.885	1.995	2.102	2.207	2.315
$p_F, 10^{-20}$ g cm/s	8.280	8.509	8.675	8.798	8.896	8.979	9.054	9.122	9.182	9.234	9.280	9.330
$m^\star, 10^{-23}$ g	1.401	1.584	1.744	1.887	2.018	2.144	2.269	2.392	2.515	2.635	2.753	2.872
$m^\star/m_3$	2.797	3.162	3.482	3.767	4.030	4.282	4.530	4.777	5.022	5.261	5.497	5.735
v_F, m/s	59.11	53.73	49.74	46.64	44.08	41.87	39.91	38.13	36.51	35.05	33.71	32.49
$\chi_N, 10^{-9}$	38.1	48.5	56.9	64.1	71.0	77.8	84.1	89.6	94.2	98.8	104.1	109.7
F_0^s	9.27	15.99	22.52	28.91	35.32	41.81	48.43	55.17	62.10	69.32	76.95	84.82
F_1^s	5.39	6.49	7.45	8.30	9.09	9.85	10.59	11.33	12.07	12.78	13.49	14.21
F_0^a	-0.70	-0.72	-0.73	-0.74	-0.75	-0.75	-0.76	-0.76	-0.76	-0.75	-0.76	-0.76
F_1^a	-0.55	-0.73	-0.80	-0.85	-0.90	-0.95	-0.99	-1.00	-0.99	-0.99	-0.99	-1.00
a, Å	3.940	3.834	3.761	3.708	3.668	3.634	3.604	3.577	3.553	3.533	3.516	3.497
g_d/k_B, μK	114.5	124.3	131.7	137.4	142.0	146.0	149.7	153.1	156.2	158.8	161.2	163.9
$T_{F_{eff}}$, K	1.773	1.656	1.563	1.486	1.420	1.361	1.308	1.260	1.214	1.172	1.133	1.098
$<W>$	83.4	104.1	116.0	123.7	130.7	137.2	141.6	142.4	140.6	139.0	140.3	141.8
$<W_I>$	10.92	14.68	16.37	17.32	18.23	19.08	19.48	19.19	18.41	17.73	17.63	17.60
$<W_D>$	24.89	29.75	32.62	34.42	35.98	37.41	38.38	38.56	38.18	37.88	38.23	38.60
$<W_L>$	-11.42	-8.14	-6.53	-4.70	-2.28	0.29	2.38	3.62	4.10	4.25	4.53	5.19
γ_0	0.131	0.141	0.141	0.140	0.139	0.139	0.138	0.135	0.131	0.127	0.126	0.124
δ_0	0.298	0.286	0.281	0.278	0.275	0.273	0.271	0.271	0.272	0.272	0.272	0.272
w_0	1.211	1.192	1.187	1.185	1.182	1.180	1.179	1.181	1.184	1.187	1.189	1.189
λ_1^a	-0.137	-0.078	-0.056	-0.038	-0.017	0.002	0.017	0.025	0.029	0.031	0.032	0.037
$\tau_N(0, T_c)$, μs	0.609	0.237	0.137	0.095	0.072	0.057	0.048	0.043	0.039	0.036	0.034	0.031
$\Delta_{WC+}(T=0)/T_c$	1.771	1.795	1.813	1.825	1.834	1.843	1.850	1.856	1.861	1.866	1.870	1.875
$\chi_B(T=0)/\chi_N$	0.378	0.357	0.346	0.340	0.335	0.331	0.328	0.327	0.328	0.329	0.329	0.328
$\nu_B(T=0), kHz$	125.3	161.9	188.0	208.5	225.7	241.2	255.7	269.8	283.5	296.6	308.7	320.5
$c_\perp(T=0), cm/s$	2190	1901	1724	1594	1485	1393	1315	1253	1202	1157	1111	1068
$c_\parallel(T=0), cm/s$	2509	2172	1967	1817	1692	1585	1497	1426	1368	1316	1264	1215
P, bar	0	3	6	9	12	15	18	21	24	27	30	33

Energy gap

BCS energy gap + trivial strong coupling correction + some values derived from energy gap. See more information in the source file `he3_gap.f`.

`he3_bcsgap(ttc)`   BCS gap for 3He-B in T_c units, $\Delta_{\mathrm{BCS}}/k_B T_c$

`he3_bcsgap_fast(ttc)`   Einzel approximation for BCS gap (0.5% accuracy, 70 times faster) (Einzel-1991, f.68)

`he3_trivgap(ttc, P)`   Trivial strong-coupling correction to the BCS gap

`he3_yosida(ttc, gap, n)`   Yosida functions $Y_n(T/T_c, \Delta) = \int_{-\infty}^{\infty} \left(\frac{\xi_k}{E_k}\right)^n \phi_k \, d\xi_k$

Low temperature limit: $Y_n(T, \Delta) = 2\Gamma\left(\frac{n+1}{2}\right)\left(\frac{T}{\Delta}\right)^{\frac{n-1}{2}} \exp\left(-\frac{\Delta}{T}\right)$

Note: type of n parameter in fortran should be real*8 (this was done for standard function handling). If n is integer, result is unpredictable!

`he3_yosida_par(ttc, gap)` $Y_q^{\parallel}(T/T_c, \Delta)$

`he3_yosida_perp(ttc, gap)` $Y_q^{\perp}(T/T_c, \Delta)$

`he3_z3(ttc, gap)`

`he3_z5(ttc, gap)`

`he3_z7(ttc, gap)`

`he3_lambda(ttc, gap)`

`he3_rho_nb(ttc, p)`   B-phase normal component density: $\frac{\rho_B^n}{\rho_N} = \frac{(3 + F_1^s)Y_0}{3 + F_1^s Y_0}$

`he3_chi_b(ttc, p)`   B-phase susceptibility: $\frac{\chi_B}{\chi_N} = \frac{(1 + F_0^a)(2 + Y_0)}{3 + F_0^a(2 + Y_0)}$
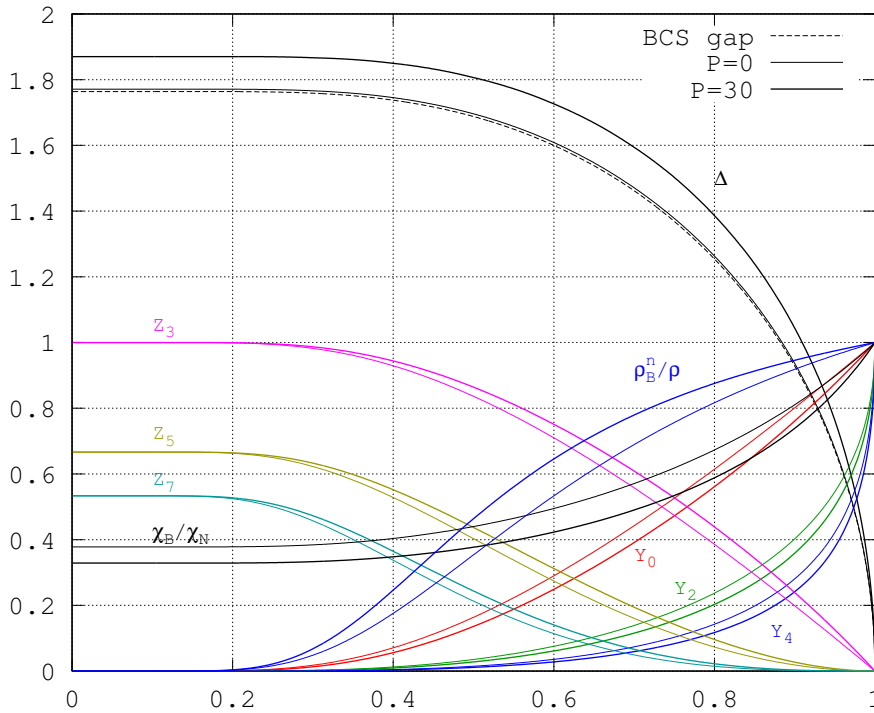
Dipole energy and Legget frequency

Values are given according to Thuneberg's paper JLTP 122, p657 (2001). Temperature independent g_d parameter is restored from experimental data for Ω_B, measured in transverse and longitudinal NMR. See more information in the source file `he3_dipole.f`.
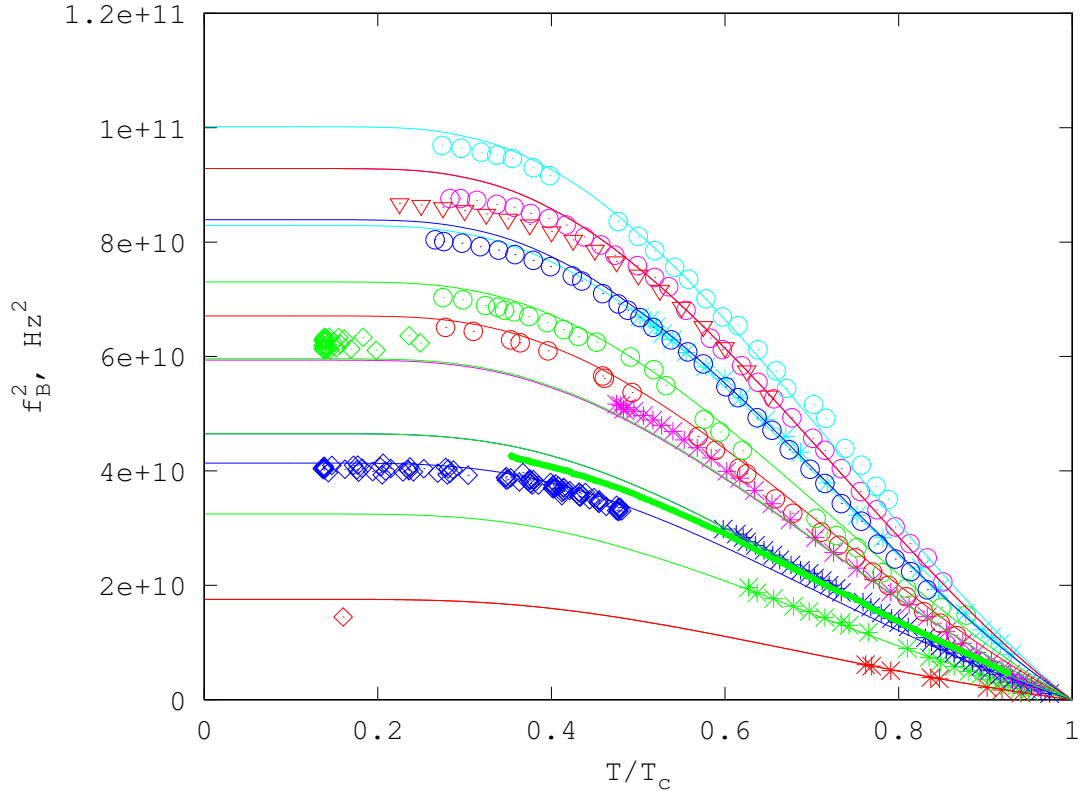
Dipolar energy:

$$F_D = \lambda_D \int (R_{ii}R_{jj} + R_{ij}R_{ji})\, d^3r \quad = \quad 4\lambda_D \int \cos\theta(1 + 2\cos\theta)\, d^3r$$

$$\lambda_D = \Delta^2 g_d, \qquad \Omega_B = \gamma\sqrt{15\lambda_D/\chi_B}$$

Note: In old papers (Leggett, ...) $g_D/5$ is used instead of λ_G.

`he3_gd(p)` g_d, $[1/(\text{erg cm}^3)]$

`he3_ld(p)` $\lambda_D = \Delta^2 g_d$, $[\text{erg/cm}^3]$

`he3_nu_b(ttc, p)`   B-phase Leggett frequency $\nu_B = \dfrac{\gamma}{2\pi}\sqrt{15\Delta^2 g_d/\chi_B}$, Hz

`he3_nu_b1(ttc, p)`   Less accurate formula without using g_d, Hz

$$\nu_B = \frac{1}{2\pi}\sqrt{\frac{3\pi}{2\chi}}\,\frac{\gamma^2\hbar}{2}\,N(0)\,\Delta\log\frac{e_f}{\Delta}$$

Gradient energy and spin wave velocity

Values are given according to Thuneberg's paper JLTP 122, p657 (2001). High order Fermi liquid parameters (F_2^a, F_3^a) are set to 0. See more information in the source file `he3_text_gr.f` and in `doc_tech/egrad.pdf`.

$$F_G = \int_V \left[\lambda_{G1} \frac{\partial R_{\alpha i}}{\partial r_i} \frac{\partial R_{\alpha j}}{\partial r_j} + \lambda_{G2} \frac{\partial R_{\alpha j}}{\partial r_i} \frac{\partial R_{\alpha j}}{\partial r_i} \right] d^3r + 2\lambda_{G2} \int_S s_k R_{\mu k} \frac{\partial R_{\mu j}}{\partial r_j} \, d^2r$$

(s_k is directed inside the volume)

`he3_text_lg2(ttc, p)` $\quad \lambda_{G2} = \dfrac{\hbar^2 \rho}{40 m^* m} \dfrac{(1 + F_1^a/3)(1 - Y_0)}{1 + F_1^a(2 + 3Y_0)/15}$, [erg/cm]

`he3_text_lg1(ttc, p)` $\quad \lambda_{G1} = (2 + \delta)\lambda_{G2}$, [erg/cm]

`he3_text_delta(ttc, p)` $\delta = \dfrac{F_1^a(1 - Y_0)}{3 + F_1^a Y_0}$

`he3_text_cperp(ttc, p)` Fomin's perpendicular spin wave velocity.
$c_\perp = \gamma\sqrt{(6 + \delta)\lambda_{G2}/\chi}$, [cm/s]

`he3_text_cpar(ttc, p)` Fomin's parallel spin wave velocity.
$c_\parallel = \gamma\sqrt{(8 + 2\delta)\lambda_{G2}/\chi}$, [cm/s]
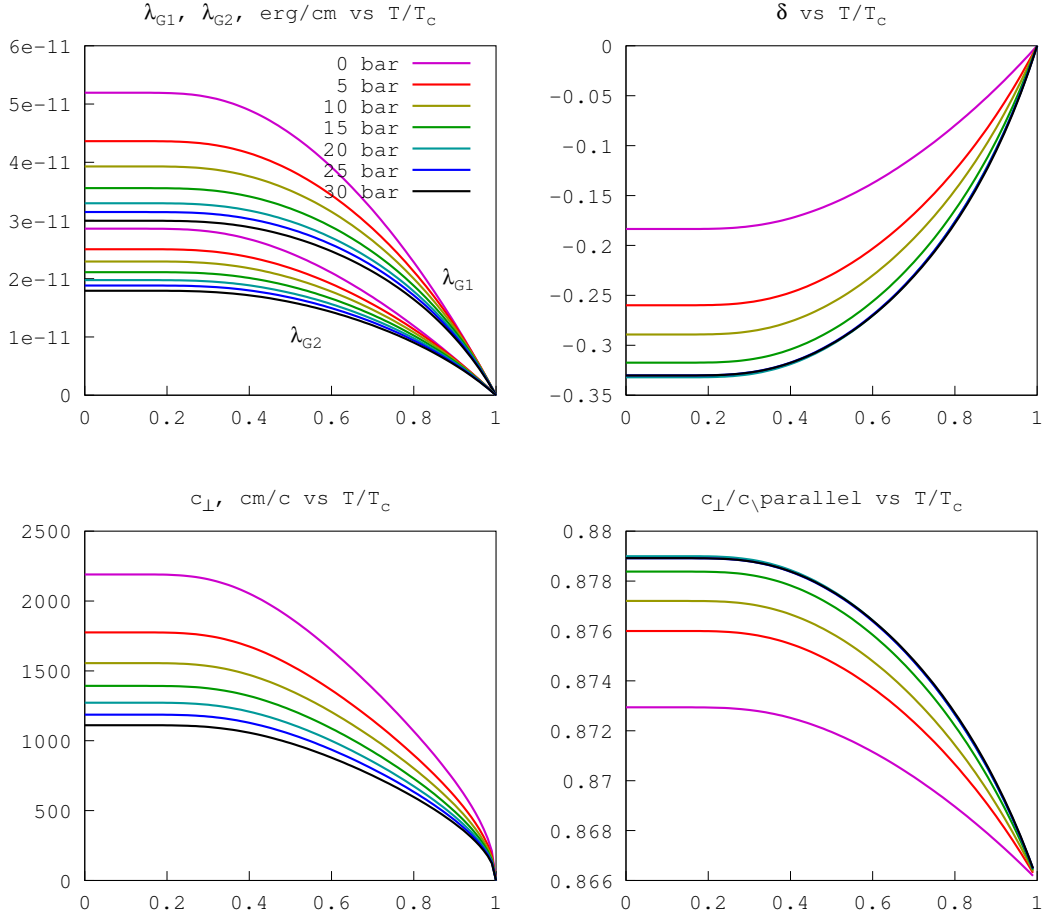
Other textural parameters

Values are given according to Thuneberg's paper JLTP 122, p657 (2001). High order Fermi liquid parameters (F_2^a, F_3^a) are set to 0. See more information in the source file `he3_text.f`.

Bulk terms:

$$
\begin{aligned}
F_{DH} &= -a \int_V (\mathbf{n} \cdot \mathbf{H})^2 \, d^3r \\
F_{DV} &= -\lambda_{DV} \int_V [\mathbf{n} \cdot (\mathbf{v_s} - \mathbf{v_n})]^2 \, d^3r \qquad \ll F_{HV} \text{ at } H \approx 200 \text{ Oe} \\
F_{HV} &= -\lambda_{HV} \int_V [\mathbf{H} \cdot R \cdot (\mathbf{v_s} - \mathbf{v_n})]^2 \, d^3r
\end{aligned}
$$

Surface terms:

$$
\begin{aligned}
F_{SH} &= -d \int_S [\mathbf{H} \cdot R \cdot \mathbf{s}]^2 \, d^2r \\
F_{SG} &= -\lambda_{SG} \int_S s_j R_{\alpha j} \frac{\partial R_{\alpha i}}{\partial r_i} \, d^2r
\end{aligned}
$$

Vortex term:

$$
F_{LH} = \frac{\lambda_{LH}}{2\Omega} \int_L |\omega_s| [\mathbf{H} \cdot R \cdot \mathbf{l}]^2 \, d^3r
$$

`he3_text_a(ttc, p)`	$a = \dfrac{5g_d}{2} \left[\dfrac{\hbar\gamma/2}{1 + F_0^a(2 + Y_0)/3} \right]^2 \left(5 - 3\dfrac{Z_3}{Z_5} \right)$, [erg/cm^3 G^{-2}]
`he3_text_d(ttc, p)`	d, [erg/(cm^2 G^2)] – GL extrapolation!
`he3_text_ldv(ttc, p)`	$\lambda_{DV} = 5g_d \left(\dfrac{m^* v_F}{1 + F_1^s Y_0/3} \right)^2 \left(1 - \dfrac{3Z_5}{2Z_3} \right)$, [erg/cm^3 (cm/s)$^{-2}$]
`he3_text_lhv(ttc, p)`	$\lambda_{HV} = \dfrac{\rho}{\Delta^2} \dfrac{1 + F_1^s/3}{(1 + F_1^s Y_0/3)^2} \left(\dfrac{\hbar\gamma/2}{1 + F_0^a(2 + Y_0)/3} \right)^2 \left(Z_3 - \dfrac{9}{10} Z_5 + \dfrac{9}{10} \dfrac{Z_5^2}{Z_3} - \dfrac{3}{2} Z_7 \right)$
`he3_text_llh(ttc, p, omega)`	$\lambda_{LH} = \dfrac{\hbar}{2m} \Omega \lambda_{HV} \left(\ln \dfrac{R}{r} - \dfrac{3}{4} \right)$, [erg/(cm^3 G^2 s)] – counterflow part only!
`he3_text_lo(ttc, p, omega)`	lambda/omega used in the texture library: $\dfrac{\lambda}{\Omega} = \dfrac{5\lambda_{LH}}{2a\Omega}$, (rad/s)$^{-1}$

`he3_text_xih(ttc, p, h)`	Magnetic length $\xi_H = \sqrt{65\lambda_{G2}/(8aH^2)}$
`he3_text_xid(ttc, p)`	Dipolar length (according to Hakonen-1989) $\xi_D = \sqrt{13\lambda_{G2}/12\lambda_D}$. Note: in Thuneberg's paper $\xi_D = \sqrt{\lambda_{G2}/\lambda_D}$ is used.
`he3_text_vd(ttc, p)`	Dipolar velocity (according to Thuneberg-2001) $v_D = \sqrt{2a/5\lambda_{HV}}$
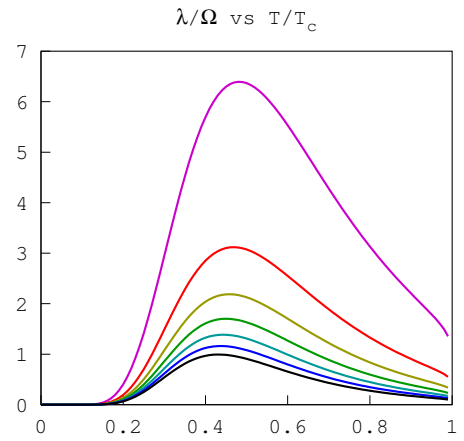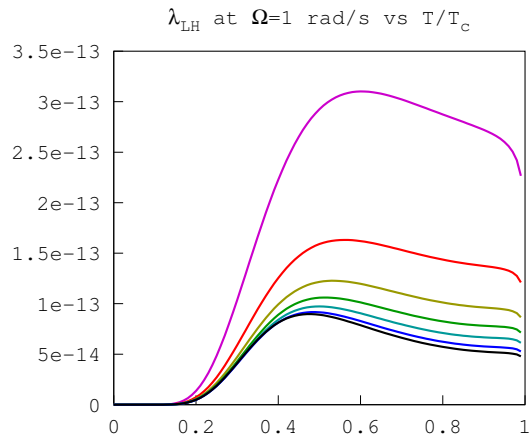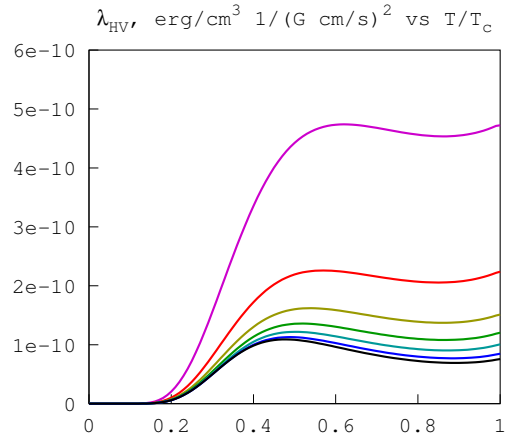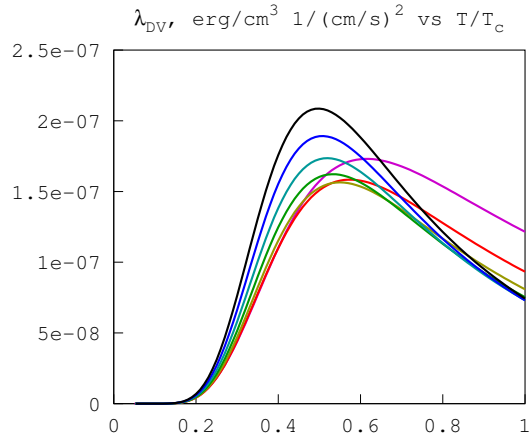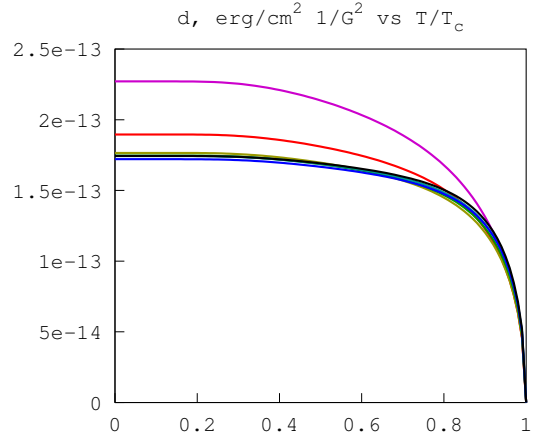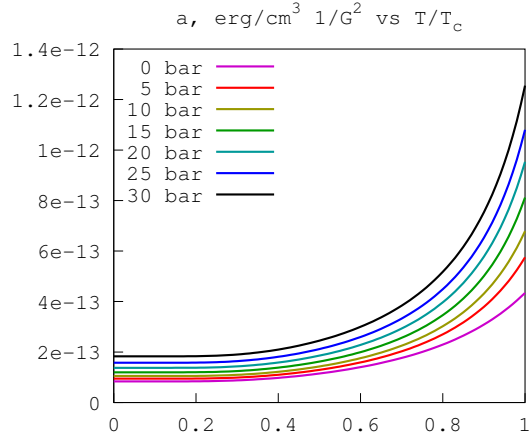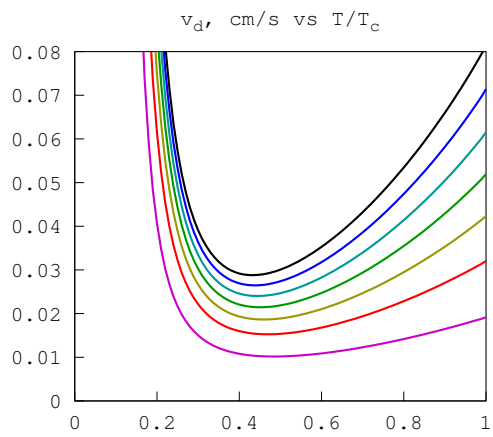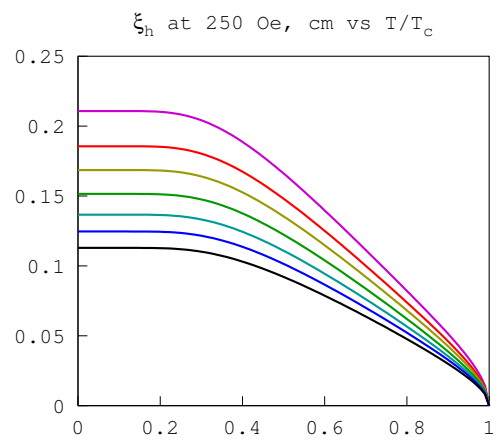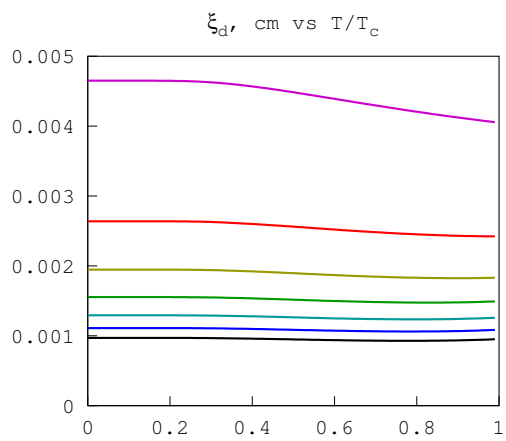
Transport properties in the normal phase

See more information in the source file `he3_transp_n.f`.

Crossections and scattering factors:

`he3_scatt_w(P)`   Scattering crossection $<W>$ (Einzel-1978, f.82)

`he3_scatt_wi(P)` $<W_I>$ (Einzel-1978, f.82)

`he3_scatt_wd(P)` $<W_D>$ (Einzel-1978, f.82)

`he3_scatt_wl(P)` $<W_L>$ (Einzel-1978, f.71)

`he3_scatt_g0(P)`   Scattering factor $\gamma_0 = <W_I>/<W>$ (Einzel-1978, f.66)

`he3_scatt_d0(P)`   Scattering factor $\delta_0 = <W_D>/<W>$ (Einzel-1978, f.67)

`he3_scatt_w0(P)` $w_0 = 1 - 3/2\gamma_0 + \delta_0$ (Einzel-1978, f.79)

`he3_scatt_l1a(P)` Scattering factor λ_1^a used in spin diffusion transport time. Can be neglected.
(Einzel-1978, f.74, p.350).

`he3_tau_n0(ttc,p)`   Normal state quasiparticle lifetime at the Fermi level, s.
$$\tau_N(0,T) = \tau_N(0,T_c)\left(\frac{T_c}{T}\right)^2 = \frac{32 E_F \hbar}{<W>(\pi k_B T)^2}$$
(Einzel-1991, p.325)

`he3_tau_n_av(ttc,p)`   Thermal average of normal state quasiparticle lifetime, s.
$$\bar{\tau}_N = \left\langle \frac{\tau_N(0,T)}{1 + (\xi_k/\pi T)^2} \right\rangle = \frac{3}{4}\tau_N(0,T) \quad \text{(Einzel-1991, f.4-5)}$$

`he3_tau_nd(ttc,p)`   Spin diffusion transport time for a normal Fermi-liquid, s
$$\tau_{ND} = \tau_1 = \bar{\tau}_N/(1 - \lambda_1^a) \quad \text{(Einzel-1991, p.328)}$$

`he3_diffn_hydr(ttc, p)`   Hydrodynamic spin diffusion in normal liquid, D_0, cm^2/s
(Einzel JLTP84 (1991) f.23)

`he3_diffn_perp(ttc, p, nu0)`   Perpendicular component of spin diffusion, reduced because of the Leggett-Rice effect, $D_N^\perp$, cm^2/s
(Einzel JLTP84 (1991) f.22)

TODO: Temperature is measured in T_c units which is strange for the normal phase. Maybe it is better to use K of T_F units here.

Transport properties in the B phase

Values for `he3_tau0`, `he3_tau_av`, `he3_diff_*` are extended to $T > T_c$ region using normal phase functions. See more information in the source file `he3_transp_b.f` and in `doc_tech/spin_diff.pdf`.

Collision integral for Bogoliubov quasiparticles:

`he3_coll_int(xi, ttc, gap, g0, d0)` — Full temperature range approximation
(Einzel, Wolfle, Hirschfeld, JLTP80 (1990), p.66)

`he3_coll_int_lt(xi, ttc, gap, g0, d0)` — Collision integral for low temp (good for $< 0.7 T_c$)
(Einzel, JLTP84 (1991), f.76)

`he3_coll_int_ht(xi, ttc, gap, g0, d0)` — Collision integral for high temp
(Einzel, JLTP84 (1991), f.75)

Bogoliubov quasiparticles lifetime and mean free path:

`he3_tau0(ttc, p)` — Lifetime at the Fermi level, s. $\quad 1/\tau(0) = \dfrac{I(0,T)}{\tau_N(0,T)}$,
(Einzel-1991, f.74,76. Einzel-1990 f.A1)

`he3_tau0lt(ttc, p)` — $1/\tau, T \to 0$ limit (does not depend on energy). (Einzel-1978, f.79)

`he3_tau_av(ttc, p)` — Thermal average lifetime, s. $\quad 1/\bar{\tau} = \dfrac{1}{Y_0} \displaystyle\int_{-\infty}^{\infty} \dfrac{\phi_k \, d\xi}{\tau}$
(Einzel-1991, f.77)

`he3_fpathv(ttc, p)` — Mean free path, cm
(Einzel JLTP32 (1978) f.84)

`he3_tau_dperp(ttc, p)` — Spin diff. transport time, s. $\quad \tau_D^{\perp,\|} = \bar{\tau}/(1 - \lambda_1^a Y^{\perp,\|})$
`he3_tau_dpar(ttc, p)` — (Einzel-1991, f.90,96)

Spin diffusion:

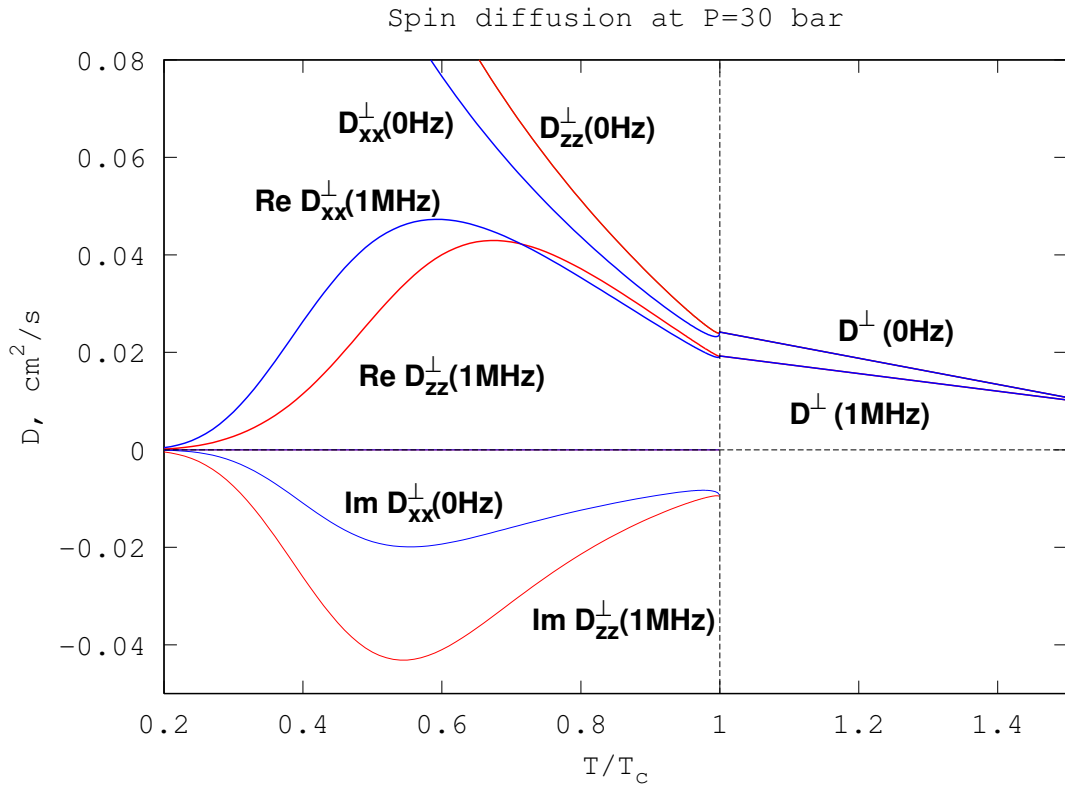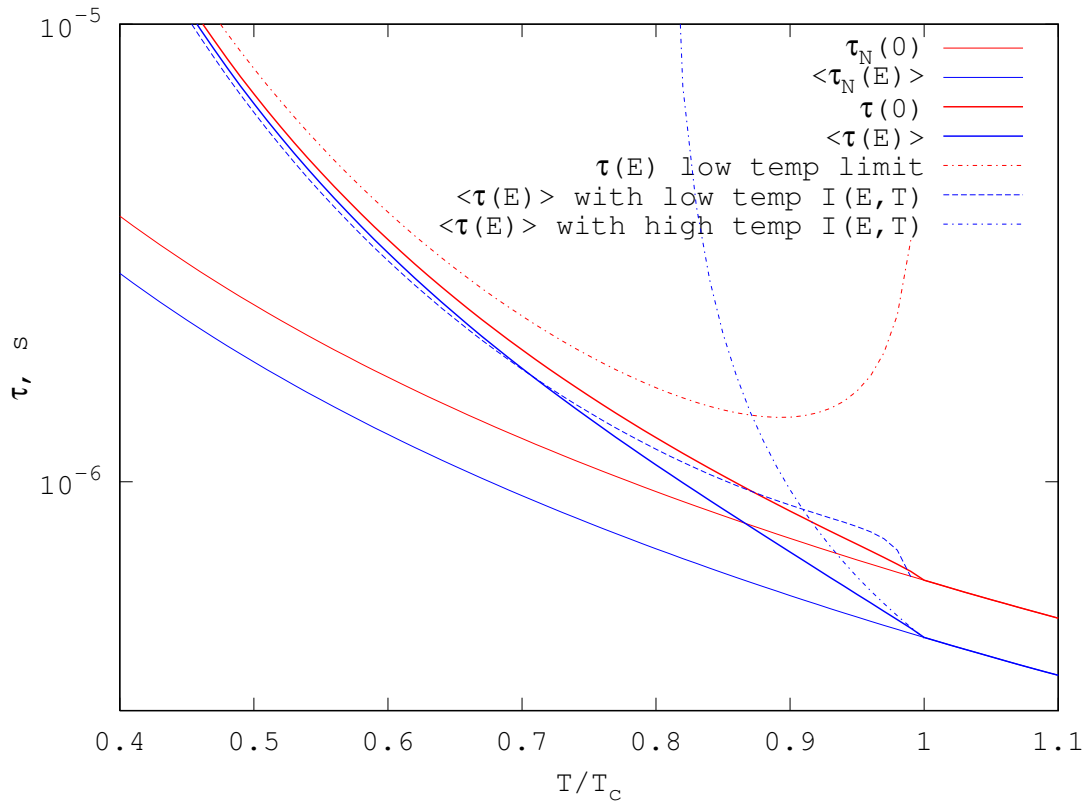`he3_diff_hperp_zz(ttc, p)` — Spin diffusion in hydrodynamic limit ($\omega_L \tau \ll 1$), $D_{zz}^{\perp,\|}(\omega_L = 0)$,
`he3_diff_hpar_zz(ttc, p)` — cm^2/s. According to Einzel's paper (see f.105) nonhydrodynamic effects do not affect $D^\|$. In Mukharsky paper they do.
(Einzel JLTP84 (1991) f.102)

`he3_diff_perp_xx(ttc, p, nu0)` — Components of spin diffusion tenzor, cm^2/s
`he3_diff_perp_zz(ttc, p, nu0)` — (Bunkov et al, 1990 f.3; Einzel, 1991, f.108;
`he3_diff_perp_xx_im(ttc, p, nu0)` — Markelov, Mukharsky, 1992, f.7,8)
`he3_diff_perp_zz_im(ttc, p, nu0)`
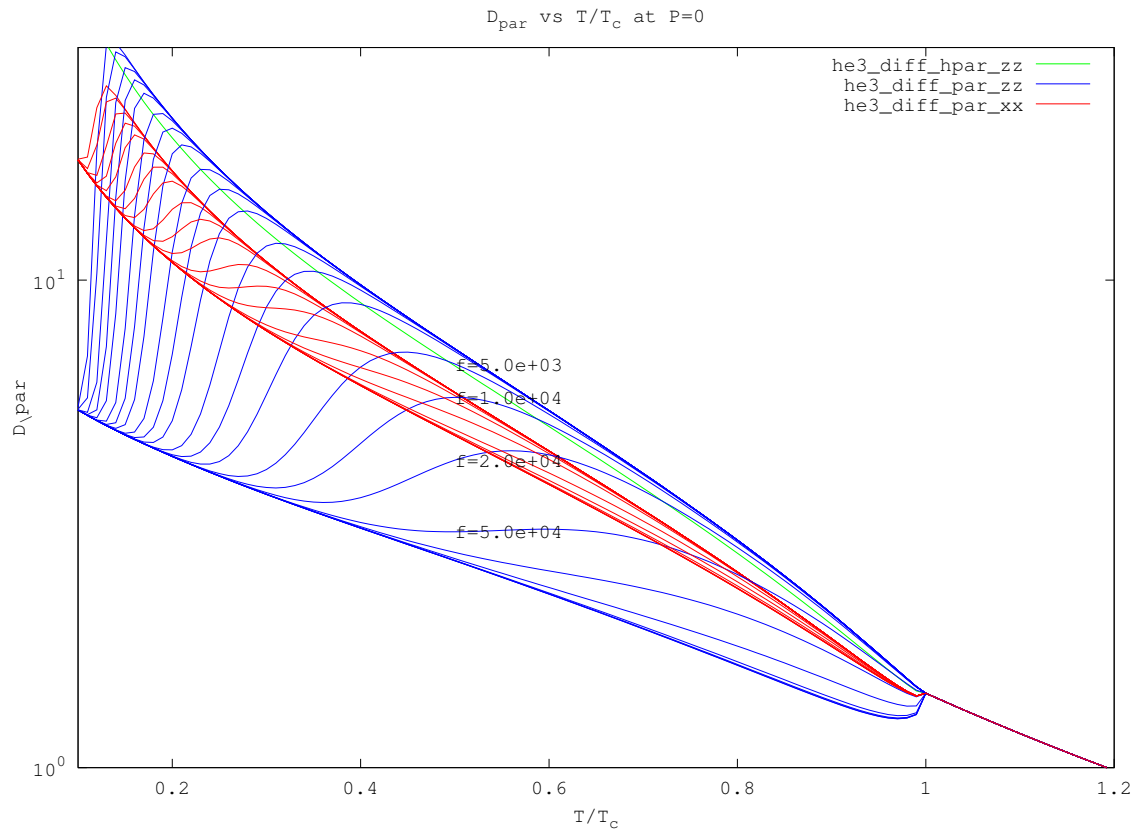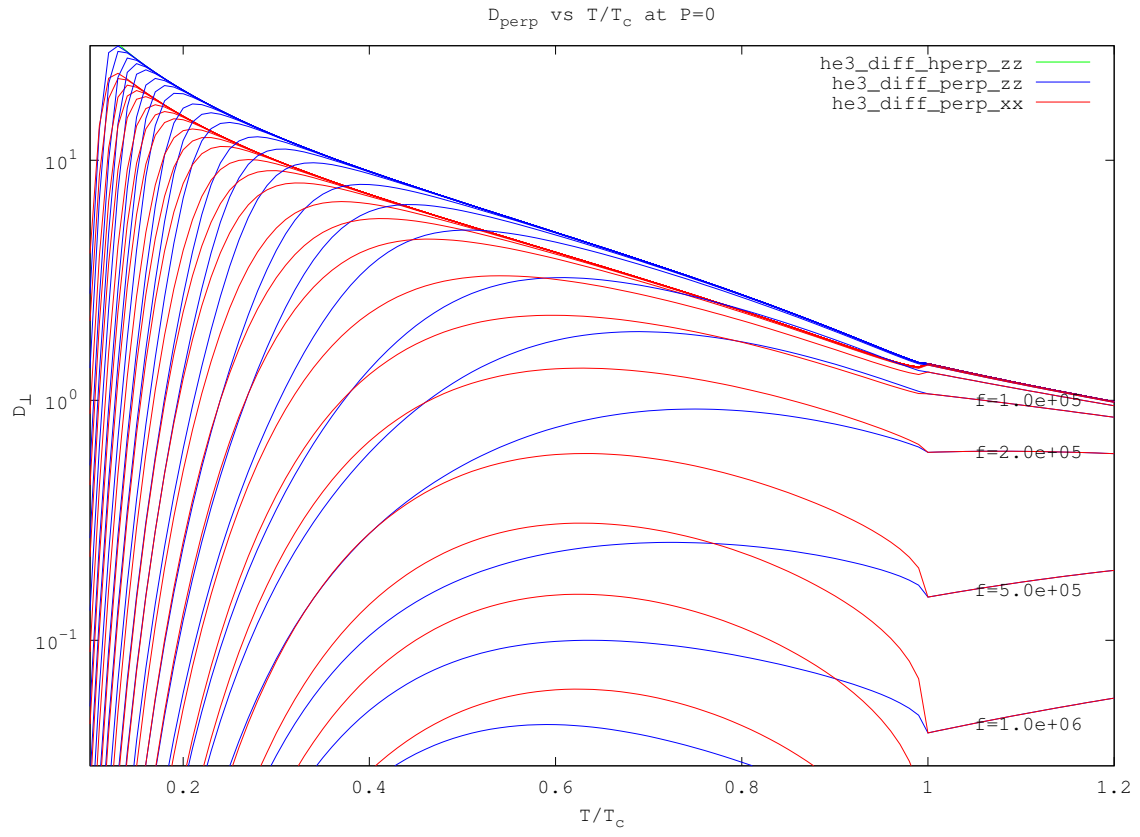`he3_diff_par_xx(ttc, p, nu0)`
`he3_diff_par_zz(ttc, p, nu0)`

Problem with $D^\|$. According to Einzel-1991 (see f.105) nonhydrodynamic effects do not affect $D^\|$ and you should use he3_diff_hpar_zz for any frequency. In Markelov-Mukharsky paper the result for $D^\|$ is completely different (it is used in he3_diff_par_xx, _zz). $D^\perp$ is the same in all papers.
TODO:
Exchange coupling strength is in the $F_1^a = 0$ limit. (small difference from normal phase values)
How does `he3_diff_perp_??_im` extends to normal phase?

Spin diffusion at P=30 bar

D_{perp} vs T/T_C at P=0

$D_\perp$

10^1

10^0

10^{-1}

he3_diff_hperp_zz
he3_diff_perp_zz
he3_diff_perp_xx

f=1.0e+05

f=2.0e+05

f=5.0e+05

f=1.0e+06

0.2   0.4   0.6   0.8   1   1.2

T/T_C

D_{par} vs T/T_C at P=0

$D_{\backslash par}$

10^1

10^0

he3_diff_hpar_zz
he3_diff_par_zz
he3_diff_par_xx

f=5.0e+03
f=1.0e+04

f=2.0e+04

f=5.0e+04

0.2   0.4   0.6   0.8   1   1.2

T/T_C

16

Other

`he3_xigl(ttc, p)`   Extrapolated GL coherence length, cm

`he3_vneq(ttc, p, omega, r)` Equilibrium vortex number

Normal liquid beyond zero temperature limit

`he3_cv_n(t, p)` Normal phase heat capacity C_v, Greywall-1983

    TODO: V_m

ROTA specific functions

`rota_c_ns(t, i)`   Nuclear stage heat capacity [J/K] vs T[K] and I[A]
$C_{ns} = 9.66 \cdot 10^{-5}$ [J/T^2] $(0.113$ [T/A] $I/T)^2$

`rota_fork_cal(w, p, n)` Calibration of fork n, T/T_c, vs fork width w [Hz] and pressure P [bar]
$$w = a_n \exp\left(-\frac{\Delta_{\mathrm{WC+}}(P, T/T_c)}{T/T_c}\right),$$
$a = \alpha_n \, p_F^4(P)$, where α_n is a geometrical factor
$N = 1:$ Fork K, calibration 30.4.2010, 29 bar, a = 11700
$N = 2:$ Fork E, calibration 30.4.2010, 29 bar, a = 17543