An extended 'getting started' guide

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Installation

- Download the latest version
  - https://darksusy.hepforge.org/download.html
- Configure: `darksusy-6.2.6> ./configure`
  - As usual, you can provide options (see, e.g., ./conf.gfortran)
- Make: `darksusy-6.2.6> make`
  - Just 'make' for full installation. More experienced users can use autocomplete to see various make targets. NB: 'make coffee' still work in progress…
- Test installation: `darksusy-6.2.6/examples/test> ./dstest`
  - After about a minute you should see the following:

```
=====================================
Summary of performed DarkSUSY tests
=====================================

Number of errors reported by dstest_mssm:           0
Number of errors reported by dstest_silveira_zee:   0
Number of errors reported by dstest_genWIMP:        0

=====================================
```

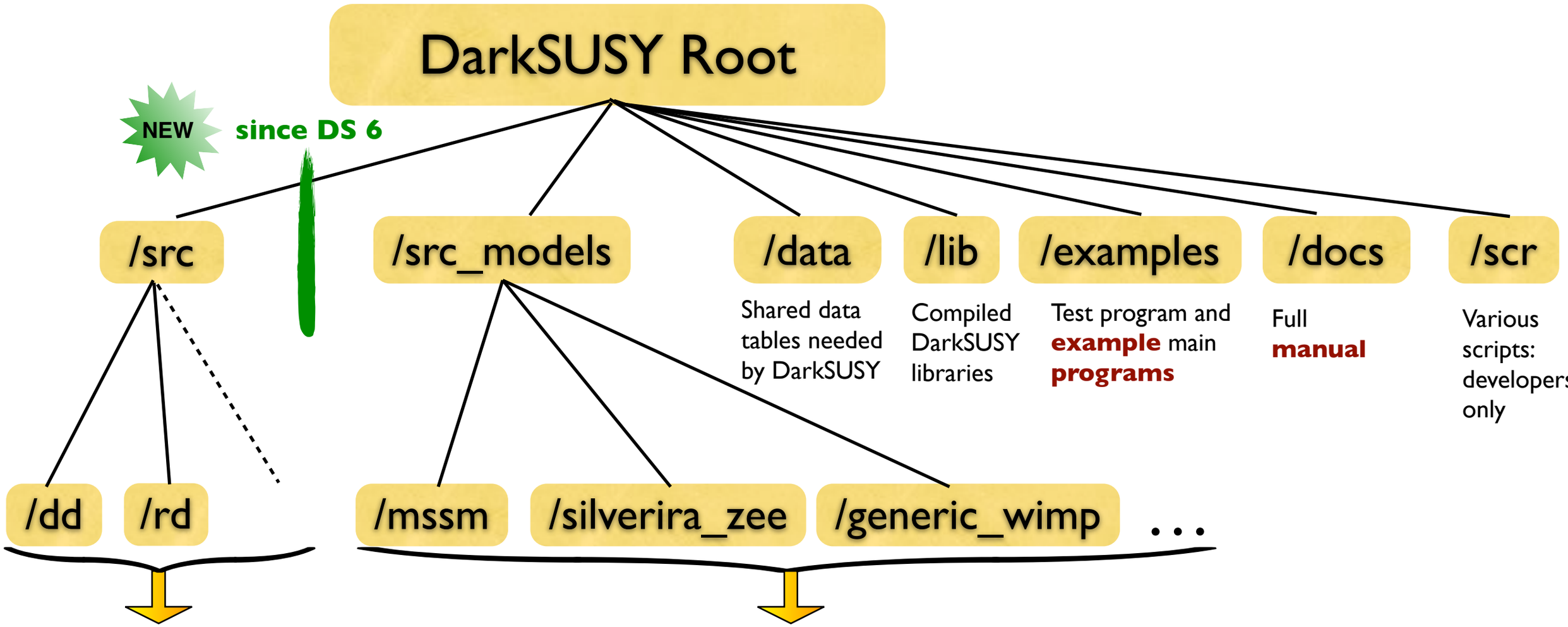
Anyone did not see this?

Try bypassing compilation problems with contributed code:

`make darksusy_light`

Directory structure

- After the installation, you will see the following:



Manual

- A manual (not fully up to date yet & does not cover everything) is distributed with DarkSUSY. Create with

make manual	default version(s)
make pdf_manual	only creates shorter version, skipping subroutine headers

- Also see headers of various subroutines for instructions (and which author to blame 😉).

Main programs

- DarkSUSY is essentially a library of routines and functions

- DarkSUSY consists mainly of FORTRAN 77, with some FORTRAN 95/03 additions
  - *FORTRAN is rather basic, but results in fast code*
  - *Furthermore, it is straight-forward to follow (and write)*

- You, as a user, have to provide a suitable main program
  (by linking to these libraries)

- Some examples of main programs exist in the /examples folder and are good starting points

Typical Fortran program

6 chars

declarations

program

```
      program myprogram
      implicit none

      include 'dsver.h'
      real*8 oh2,xf
      integer unphys,war,ierr,iwar,nfc
      real*8 dsrdomega

      call dsinit
      call dsgive_model(500.0d0,1000.d0,300.d0,10.d0,
     &   3000.d0,0.d0,0.d0)
      call dsmodelsetup(unphys,war)
      oh2=dsrdomega(1,1,xf,ierr,iwar,nfc)
      write(*,*) 'Relic density, omega h^2 = ',oh2

      end
```

includes files, typically global variables (common blocks)

subroutine call

arguments (must match declaration)

exponent for double precision (real*8) number

function call

continuation character (col 6)

See example programs or tutorials on the web for more Fortran examples

dsmain_WIMP

- The dsmain_wimp program in examples/ essentially does the same thing, but in a more user-friendly way.

  TASK: run this program!

- You will be asked what model to pick

```
What kind of SUSY model do you want to look at?
   1 = MSSM-7
   2 = cMSSM
   3 = as read from an SLHA2 file
```

Pick MSSM-7 and enter (e.g.)

mu: 1000	m0: 3000
M2: 1000	At/m0: 0
MA: 400	Ab/m0: 0
tan(β): 10	

TASK: Inspect output and try to identify the corresponding part in the code! Repeat for another model point if you like…

dsmain_WIMP (2)

- At the end of the dsmain_wimp run you got

```
-------------------------------------------------
 The DarkSUSY example program has finished successfully.
 Particle module that was used: MSSM
 -------------------------------------------------

 [simply call 'make -B dsmain_wimp DS_MODULE=<MY_MODULE>' if you want to try
with a different module <MY_MODULE>]
```

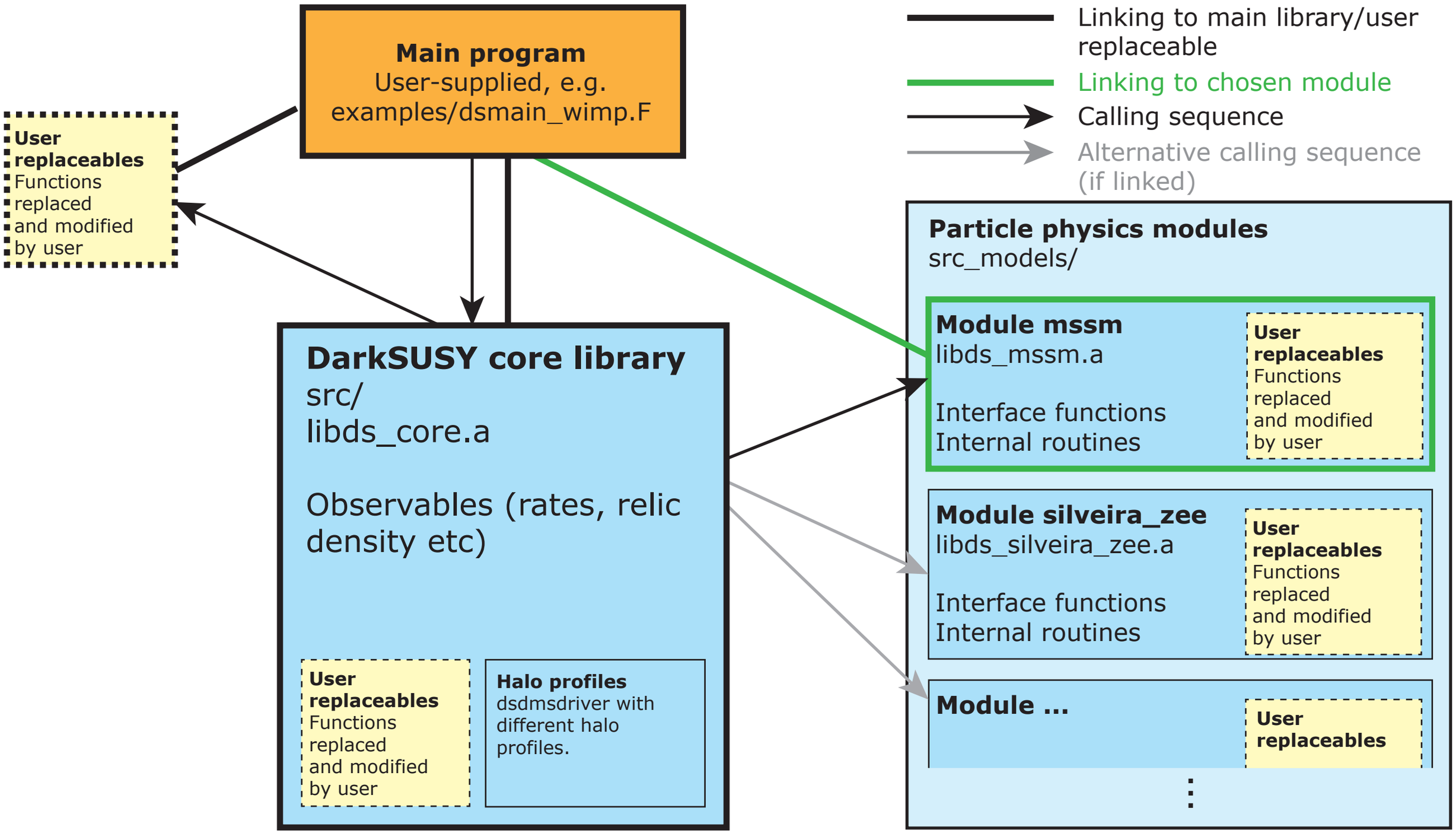
TASK: Compile and then run the same program again, now for a generic WIMP (use `<MY_MODULE> = generic_wimp`) !

use e.g. the following parameters

mass: 100
self-conjugate: 0
annihilation cross section: 3e-26
PDG: 5
scattering cross section: 1e-42

See docs/pdg_codes.pdf for a full list of particle codes

DarkSUSY 6 structure



Makefiles

- Which particle module is used is decided when you build your main program:

```
gfortran -o dsmain dsmain.f -lds_core -lds_mssm          (for MSSM)
gfortran -o dsmain dsmain.f -lds_core -lds_generic_wimp  (for generic Wimp)
```

- This can be made much more flexible, and system-independent, with makefiles:

```
dscheckmod :
        @test `ls ../lib/ | grep libds_${DS_MODULE}.a` || { echo ERROR: Module $
{DS_MODULE} does not exist, or is not compiled; exit 1;}

dsmain_wimp : DS_MODULE = $(shell sed -n '1p' dsmain_wimp.driver)

dsmain_wimp : dscheckmod makefile dsmain_wimp.F
        printf "#define MODULE_CONFIG MODULE_"$(DS_MODULE)"\n"  > module_compile.F
        printf "$(LIB)/libds_core_user.a\n"$(LIB)"/libds_core.a\n"$(LIB)"/libds_"$
(DS_MODULE)"_user.a\n"$(LIB)"/libds_"$(DS_MODULE)".a" > module_link.txt
        $(ADD_SCR) libds_tmp.a module_link.txt
        $(FF) $(FOPT) $(INC) $(INC_MSSM) -L$(LIB) -o dsmain_wimp dsmain_wimp.F \
        libds_tmp.a $(shell if [ "x$(DS_MODULE)" = "xmssm" ]; then printf "%s" " $
(AUX_LIB_MSSM)"; fi)
        rm -f module_compile.F
        rm -f module_link.txt
        rm -f libds_tmp.a
```

Makefiles (2)

- In dsmain_wimp.F, we have blocks of the type

```
#if MODULE_CONFIG == MODULE_generic_wimp
    subroutine dspmenterparameters
    [more code for this module]
#endif
```

- This is how the program performs, e.g., model-specific setup and initialisation tasks

- Alternative: separate main program for each particle physics module $\rightsquigarrow$ simpler makefiles (as in /examples/aux/).

TASK: Compare the makefile target for oh2_generic_wimp with the previous example for dsmain_wimp, and discuss the difference!

Makefiles (3)

/examples/makefile:

```
dscheckmod :
	@test `ls $(LIB) | grep libds_${DS_MODULE}.a` || { echo ERROR: Module ${DS_MODULE} does not exist, or is not compiled; exit 1;}

dsmain_wimp : DS_MODULE = $(shell sed -n '1p' dsmain_wimp.driver)

dsmain_wimp : dscheckmod makefile dsmain_wimp.F
	printf "#define MODULE_CONFIG MODULE_"$(DS_MODULE)"\n"  > module_compile.F
	printf "$(LIB)/libds_core_user.a\n"$(LIB)"/libds_core.a\n"$(LIB)"/libds_"$(DS_MODULE)"_user.a\n"$(LIB)"/libds_"$(DS_MODULE)".a" >
module_link.txt
	$(ADD_SCR) libds_tmp.a module_link.txt
	$(FF) $(FOPT) $(INC) $(INC_MSSM) -L$(LIB) -o dsmain_wimp dsmain_wimp.F \
	libds_tmp.a $(shell if [ "x$(DS_MODULE)" = "xmssm" ]; then printf "%s" " $(AUX_LIB_MSSM)"; fi)
	rm -f module_compile.F
	rm -f module_link.txt
	rm -f libds_tmp.a
```

/examples/aux/makefile:

```
oh2_generic_wimp: DS_MODULE = generic_wimp
oh2_generic_wimp: INC_MODULE = $(INC_GENERIC)
oh2_generic_wimp: oh2_generic_wimp.f
oh2_generic_wimp: $(LIB)/libds_core.a $(LIB)/libds_core_user.a
	$(ADD_SCR) libds_tmp.a $(LIB)/libds_$(DS_MODULE)_user.a $(LIB)/libds_core_user.a $(LIB)/libds_$(DS_MODULE).a $(LIB)/libds_core.a
	$(FF) $(FOPT) $(INC) $(INC_MODULE) -L$(LIB) -o oh2_generic_wimp oh2_generic_wimp.f \
	libds_tmp.a
	rm -f libds_tmp.a
```

variable describing particle module simply set by hand

additional, module-specific libraries *would* be added at these places

Don't be afraid of makefiles!

['Everything' can be done by copy&paste + simple replacements]

Writing your own programs

- Typical program layout

```
call dsinit
[make general settings]
[determine your model parameters your way]
call dsgive_model [or equivalent]
call dsmodelsetup
[calculate what you want]
```

- Step-by-step guide:

1. Go to your own private folder
   [I.e. **not** a subfolder of the DS release]
2. Create a .f file with the above structure
   (Or **copy** one of the files in examples [/aux] to this folder. These often provide good starting points)
3. copy examples/aux/makefile to your folder + modify as desired
4. 'make' in your private folder and then run the code

‘My’ 1st DarkSUSY program

TASK: **Copy dsmain_wimp.F to some private directory, rename it to my_first_DS_program.F. Then compile and run it there!**

There are other ways to use DarkSUSY, but this is the cleanest and by far preferred one. It keeps your routines separate from DS and makes updates easier!

‘My’ 1st DarkSUSY program

TASK: **Copy dsmain_wimp.F to some private directory, rename it to my_first_DS_program.F. Then compile and run it there!**

- Solution

1. Copy *all* files needed by dsmain_wimp.F:

```
/tutorial> cd my_code
/tutorial/my_code> cp ../darksusy-6.0.0/examples/dsmain_wimp.F my_first_DS_program.F
/tutorial/my_code> cp ../darksusy-6.0.0/examples/dsmain_wimp.driver my_first_DS_program.driver
/tutorial/my_code> cp ../darksusy-6.0.0/examples/makefile .
```

2. Modify makefile where necessary:

- replace all `dsmain_wimp` → `my_first_DS_program` (8 places)
- delete block for generic_decayingDM.f (this file does not exist at this place!)

```
dsmain_decay : DS_MODULE = generic_decayingDM

dsmain_decay : dscheckmod makefile dsmain_decay.F
        printf "#define MODULE_CONFIG MODULE_"$(DS_MODULE)"\n" > module_compile.F
        printf "$(LIB)/libds_core user.a\n"$(LIB)"/libds_core.a\n"$(LIB)"/libds_"$
(DS_MODULE)"_user.a\n"$(LIB)"/libds_"$(DS_MODULE)".a" > module_link.txt
        $(ADD_SCR) libds_tmp.a module_link.txt
        $(FF) $(FOPT) $(INC) $(INC_MSSM) -L$(LIB) -o dsmain_decay dsmain_decay.F \
        libds_tmp.a
        rm -f module_compile.F
        rm -f module_link.txt
        rm -f libds_tmp.a
```

WARNING: makefiles distinguish <TAB> and <SPACE> !!!

- remove call to ‘dsmain_decay’ from target ‘all’:

```
all: my_first_DS_program dsmain_decay
```

My(!) 1st DarkSUSY program

- OK, this was cheating a bit… so let's try a bit harder:

TASK:

Create your own program (in your private directory) to

1. **set up a Scalar Singlet model (with some pre-defined values for coupling and DM mass) and**
2. **calculate the relic density and write it to screen.**
3. **Make sure it links to the correct libraries and compiles**
4. **run it!**

Hints:

- **Think of an example earlier seen in this tutorial — you should use less than 15 lines of Fortran code!**
- **Copy examples/aux/makefile to [private dir]/makefile, and set up build instructions for your code. E.g., copy build lines for ScalarSinglet_RD and replace ScalarSinglet_RD with your program name**

My(!) 1st DarkSUSY program

- **Solution (problem 1)**

1. *Create Fortran file*:

```
program myprogram
implicit none

real*8 oh2,xf
integer unphys,war,ierr,iwar,nfc
real*8 dsrdomega

call dsinit
call dsgivemodel_silveira_zee(0.3d0,1000.d0) ! lambda = 0.3, mdm = 1000
call dsmodelsetup(unphys,war)
oh2=dsrdomega(1,1,xf,ierr,iwar,nfc)
write(*,*) 'Relic density, omega h^2 = ',oh2

end
```

2. *Add following block to makefile (copy&paste, just replace names):*

```
ScalarSinglet_example: DS_MODULE = silveira_zee
ScalarSinglet_example: INC_MODULE = $(INC_SILVEIRAZEE)
ScalarSinglet_example: ScalarSinglet_example.f
ScalarSinglet_example: $(LIB)/libds_core.a $(LIB)/libds_core_user.a
    $(ADD_SCR) libds_tmp.a $(LIB)/libds_$(DS_MODULE)_user.a $(LIB)/libds_core_user.a
$(LIB)/libds_$(DS_MODULE).a $(LIB)/libds_core.a
    $(FF) $(FOPT) $(INC) $(INC_MODULE) -L$(LIB) -o ScalarSinglet_example
ScalarSinglet_example.f \
    libds_tmp.a
    rm -f libds_tmp.a
```

Make sure to not convert <TAB>s to <SPACE>s without noticing!

3. You also need to define (at the beginning)

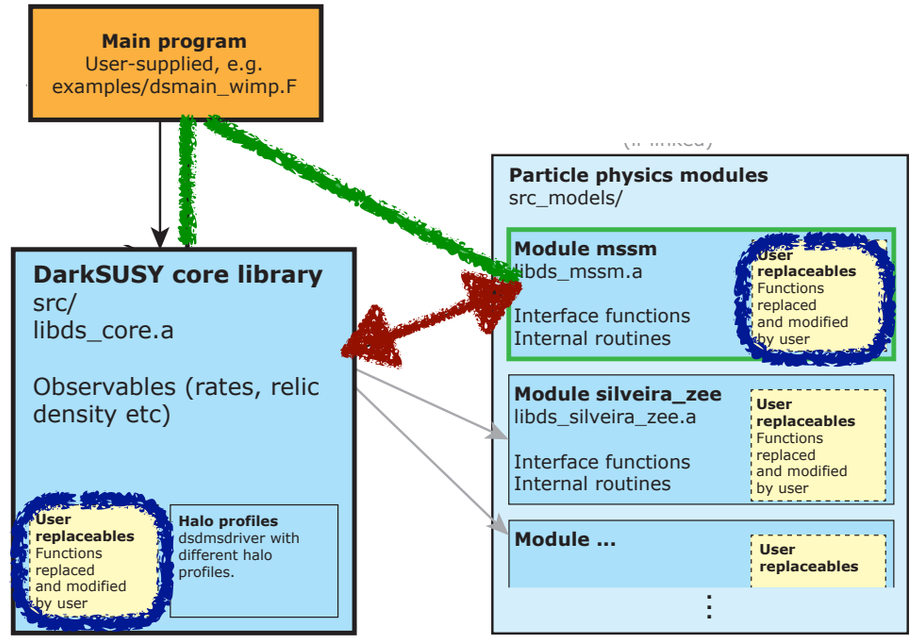
```
INC_SILVEIRAZEE=-I$(DS_INSTALL)/src_models/silveira_zee/include
```

TASK: DISCUSS (or try…) — what do you have to change to do the same for the generic_WIMP model?

DarkSUSY modularity: key concepts

- Main program always links to DS_core and *one* particle module

- Interface functions communicate model-dependent input to core library
  - *'Set of interface functions defines particle module'*
  - *No further exchange between core and modules*
  - *Minimal: about a dozen in total*
  - *A particle module can provide less — this only restricts possible applications in main program*
    [error at linking stage points to missing interface function]



- *Most* functions are replaceable functions
  - *Can be individually replaced at linking stage (when building the main program)*
  - *DarkSUSY installation remains unchanged*
  - *User-supplied function will still be consistently used in rest of code*
  - *Examples: external annihilation rate for relic density calculation; different yields for indirect detection routines, etc…*

Using a replaceable function

- Let's assume you don't trust DarkSUSY — purely hypothetical of course 😉
- So you want to replace e.g. the invariant rate W_{eff} (a typical example of an interface function) for the scalar singlet model, provided by the code, with a result that you obtained yourself.

Using a replaceable function (2)

- Let's say — for the sake of the argument — that you are 'really sure' that there is a missing factor of $E_{cm}^2/(4m_S^2)$ in the code

If you now (or at any other time…) think about changing a function or subroutine in the installed DarkSUSY folder: **DON'T** !!! ⚡⚡⚡

TASK:

Correct this 'mistake' in the function src_models/silveira_zee/an/dsanwx.f, *by 'replacing' it*, and test the result !

Hint: **Have a look at the generic_wimp_oh2[_threshold] case in examples/aux/makefile …**

Using a replaceable function (3)

- **Solution (problem II)**

1. Copy `[DS]/src_models/silveira_zee/an/dsanwx.f` to `[my local directory]/my_replaceables`, and add the following lines at the end:

```
c...TB here we add the additional factor required in the tutorial
      s = 4.*(dsmwimp()**2 + p**2)  ! Ecm**2
      dsanwx = dsanwx*s/dsmwimp()**2/4.d0
c      write(*,*) 'repleaceable test'

      return
      end
```

2. Add following block to makefile (copy&paste, changes as indicated)

```
ScalarSinglet_mod: DS_MODULE = silveira_zee
ScalarSinglet_mod: INC_MODULE = $(INC_SILVEIRAZEE)
ScalarSinglet_mod: ScalarSinglet_example.f my_replaceables/dsanwx.f
ScalarSinglet_mod: $(LIB)/libds_core.a $(LIB)/libds_core_user.a
    $(ADD_SCR) libds_tmp.a $(LIB)/libds_$(DS_MODULE)_user.a $(LIB)/libds_core_user.a $(LIB)/libds_$
(DS_MODULE).a $(LIB)/libds_core.a
    $(FF) $(FOPT) $(INC) $(INC_MODULE) -L$(LIB) -o ScalarSinglet_example ScalarSinglet_example.f
my_replaceables/dsanwx.f
    libds_tmp.a
    rm -f libds_tmp.a
```

Using 'dsanwx.f' → '*.f' allows you to replace many functions at the same time (and switch such changes on/off simply by dragging them into/out of your my_replaceables/ folder !)

Example programs

- Our 'minimal' application examples are quite instructive, and a very good next step to explore further:

```
examples/aux> ls *.f
DDCR_flux.f                          DMhalo_table.f                       neutrinoyields.f
DDCR_limits.f                        ScalarSinglet_RD.f                   oh2_dark_sector.f
DD_example.f                         ScalarSinglet_RD_cBE.f               oh2_generic_wimp.f
DMhalo_bypass.f                      ScalarSinglet_thermal_averages.f     ucmh_test.f
DMhalo_bypass_prep.f                 caprates.f                           vdSIDM_RD.f
DMhalo_los.f                         caprates_ff.f                        wimpyields.f
DMhalo_new.f                         flxconv.f
DMhalo_predef.f                      flxconvplot.f
```

direct detection examples

indirect detection

usage of halo model database

relic density [+ kinetic decoupling]

Ultra-compact minihalos

+self-interactions!

- Any questions ?
  - *Now or after the tutorial*
  - *Concerning these example programs or other DarkSUSY-related issues*
  - ***Just get in touch !***