

# An introduction to the R package sn

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Skewed world of data:

Workshop in honor of Reinaldo B. Arellano-Valle's 65th birthday

October 2017

Pontificia Universidad Católica de Chile

# Scheme

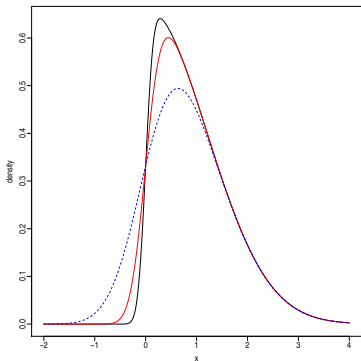
# Package sn: a one-slide panorama

- probability
  - classical-type functions for distributions:
    - univariate dist'n: `{d,p,q,r}{sn,st,sc}`
    - multivariate dist'n: `{d,p,r}{msn,mst,msc}`
    - utilities: `dp2cp`, `cp2dp`, `{sn,st}.cumulants,...`
    - build your own dist'n: `{d,r}{SymmModulated}`,  
`{d,r}{mSymmModulated}` and `plot` (if  $d = 2$ )
  - SEC distribution 'objects'
    - two classes: `SECdistrUv`, `SECdistrMv`; protocol: S4
    - create object: `makeSECdistr` (also `extractSECdistr`)
    - manipulate it: `marginalSECdistr`, `affineTransSECdistr`,  
`conditionalSECdistr` (only for SN)
    - methods: `summary`, `plot`, `show`, `mean`, `sd`, `var`, ...
- statistics
  - core general function: `selm` (two object types: `selm`, `mselm`)
  - methods: `show`, `plot`, `summary`, `coef`, `residuals`,  
`fitted`, `predict`, `logLik`, `profile`, `confint`, ...

Prob-std

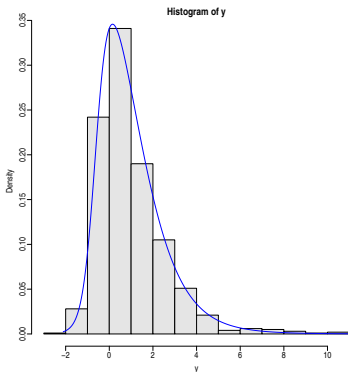
# Simple functions: dsn and plotting SN density

```
# plotting SN densities
library(sn)
x <- seq(-2, 4, length=301)
y1 <- dsn(x, xi=0, omega=1.2, alpha=10)
plot(x, y1, type="l", ylab="density")
y2 <- dsn(x, 0, 1.2, 5)
lines(x, y2, col=2)
y3 <- dsn(x, dp=c(0, 1.2, 2))
lines(x, y3, col=4, lty=2)
```



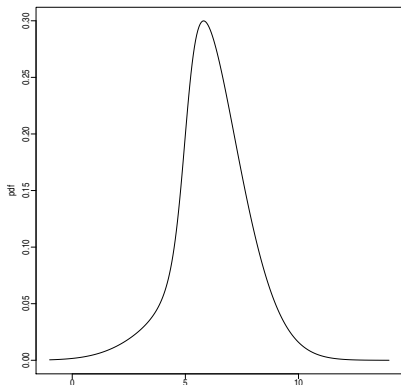
# Simple functions: cp2dp, dp2dp, rst, dst

```
# switch between parameterizations
cpST <- c(1, 1.5, 1.5, 5.1)
# CP = (mean, st.dev, gamma1, gamma2)
dpST <- cp2dp(cpST, family="ST")
print(dpST)
#      xi  omega  alpha  nu
# -0.6202 1.8754 3.6733 7.1797
print(dp2cp(dpST, family="ST"))
# back to cpST
#
# sampling from ST and plotting density
y <- rst(1000, dp=dpST)
hist(y, prob=TRUE, col="gray90")
x <- seq(min(y), max(y), length=301)
pdfST <- dst(x, dp=dpST)
lines(x, pdfST, col=4)
print(sd(y)) # about cpST[2]
```



# Unleash your creativity: case $d = 1$

```
# SGN of Arellano-Valle et al. (2004)
wSGN <- function(z, lambda) z * lambda[1]/sqrt(1 + lambda[2]*z^2)
x     <- seq(-1, 14, length=301)
pdf   <- dSymmModulated(x, 5, 2, f0="normal", G0="normal", w=wSGN,
                        lambda=c(3,5))
plot(x, pdf, type="l")
```



now change `f0`, `G0`, `w`, ... and

make your density

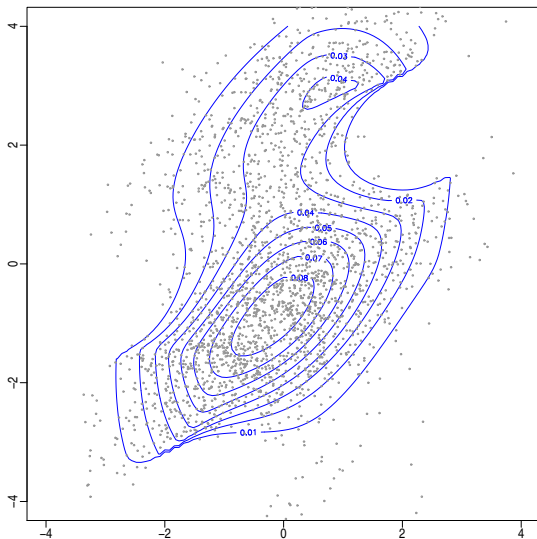
# Unlash your creativity: case $d > 1$

```
x <- matrix((1:12)/3, 4, 3)
S <- diag(1:3) + outer(1:3,1:3)/2
wMvTrigs <- function(z, p, q) sin(z %**% p)/(1 + cos(z %**% q))
pdf <- dmSymmModulated(x, xi=1:3, Omega=S, f0="t", G0="logistic",
  w=wMvTrigs, par.f0=5, par.G0=NULL, p=c(2,3,-2), q=c(1,1, 0))

# plotting when d=2
range <- cbind(c(-4,4), c(-4,4))
plot2D.SymmModulated(range, xi=c(0,0), Omega=S[1:2,1:2],
  f0="normal", G0="normal", w=wMvTrigs,
  par.f0=NULL, par.G0=NULL, p=c(1,-3), q=c(1,1), col=4)
y <- rmSymmModulated(2500, xi=c(0,0), Omega=S[1:2,1:2],
  f0="normal", G0="normal", w=wMvTrigs,
  par.f0=NULL, par.G0=NULL, p=c(1,-3), q=c(1,1))
points(y, cex=0.3, col="gray60")
```



# Unlash your creativity: plotting if $d = 2$



Prob-obj

# Working with distribution 'objects'

- Idea is to **make** a SEC distribution and work with this **object**
- Once the distribution object is created, we can:
  - extract/compute various characteristics
  - plot it
  - manipulate it to create a new distribution (if  $d > 1$ )
- Technical note: distributions are S4-type objects

# How to create a distribution

- Chief procedure is `makeSECdistr`  
(another route is `extractSECdistr` from `selm` or `msem` object)
- we must to specify DP parameters
  - if univariate case, DP is assigned as a vector
  - if multivariate case, DP is assigned as a list
- we must to specify the family,  
options are: "SN", "ESN", "ST", "SC"
- optional: name of the distribution, names of components
- `?makeSECdistr` tells you everything

## A simple illustration

```
f1 <- makeSECdistr(dp=c(3,2,5), family="SN", name="First-SN")
#
show(f1) # of just type 'f1'
# Probability distribution of variable 'First-SN'
# Skew-elliptically contoured distribution of univariate family SN
# Direct parameters:
#   xi omega alpha
#   3     2     5

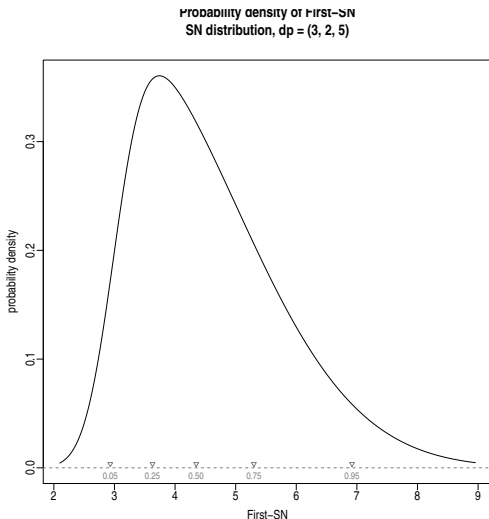
summary(f1) # longer output
#
c(mean(f1), sd(f1)) # lends 4.565 1.246

plot(f1)

# many possible variants, such as:
plot(f1, probs=c(0.1, 0.9))

?plot.SECdistr # says more, see method for signature 'SECdistrUv'
```

# A simple illustration – plot 'First-SN'



# An illustration with $d = 3$

```
dp3 <- list(xi = c(3, -2, 0), Omega = diag(1:3) + outer(1:3,1:3)/2,
            alpha = c(5, -2, 6), nu = 5)
st3 <- makeSECdistr(dp=dp3, family="ST", name="Multiv.ST",
                  compNames=c("X", "Y", "Z"))
show(st3) # of just type 'st3'

mean(st3)
#      X      Y      Z
# 3.944 -1.253  2.194

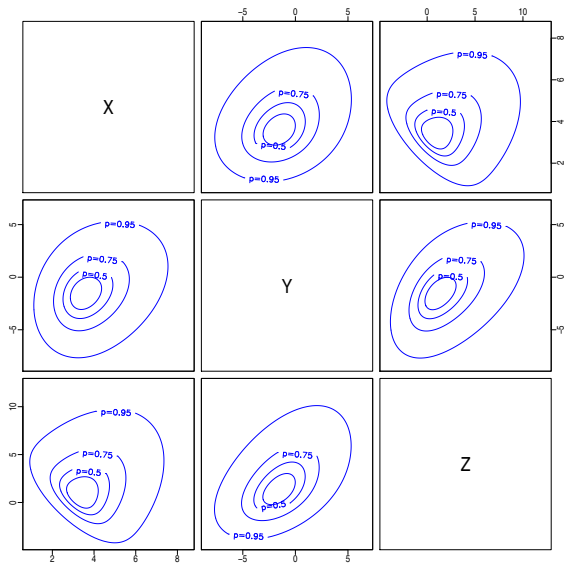
vcov(st3) # 3x3 variance matrix

summary(st3) # longer output

plot(st3, col="blue", landmarks="", main=NULL) # note p=0.xx labels

?plot.SECdistr # look at method for signature 'SECdistrMv'
```

# An illustration with $d = 3$ : matrix plot





# Manipulation of a distribution

- Refers to multivariate distributions only
- `affineTransSECdistr(object, a, A, <etc>)`  
applies affine transformation  $a + A'Y$ ,  
where  $a$  is  $m$ -vector and  $A$  is  $d \times m$  matrix
- `marginalSECdistr(object, comp, <etc>)`  
get marginal distribution of `comp` components from `object`
- `conditionalSECdistr(object, fixed.comp, fixed.values, <etc>)`  
applies conditioning on `fixed.comp` components  
(only for "SN" and "ESN" distributions)

Stats

## Function `selm` for model fitting

Naming: `lm + <Skew-Elliptical error> = selm`

Also similar logic of `lm`: fit a linear model to location parameter

```
fit <- selm( response ~ formula, family = "SN", <plus> )
```

S4 obj                      vector, matrix                      like in `lm`                      also "ST", "SC"

Optional `<plus>` terms include:

`data`, `subset` the same as in `lm`

`start` starting values

`method` estimation methods are "MLE" and "MPLE";

the latter can be used to set a prior distribution of  $\alpha$

`penalty` only relevant for `method="MPLE"`

`fixed.param` allows only limited specifications, such as `nu=<value>`  
(if `family="ST"`) and `alpha=0`

... additional options

## Methods for a `selm`|`msem` object

**classes** `selm` returns a S4 object of class `selm` (for univariate response) or `msem` (for multivariate response)

**methods** for each class, a bunch of 'methods' are available

- methods like for `lm` S3-objects: `summary`, `plot`, `residuals`, `fitted`, `coef`, `predict`, `confint`
- additional methods: `logLik`, `profile`, `vcov`

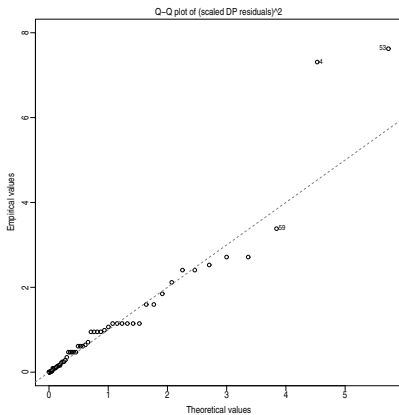
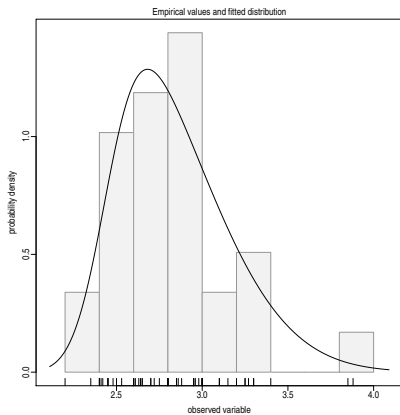
in addition `extractSECdistr` bridges to probability section

**Note:** for simpler interpretability, the default parameterization is CP. This contrasts with probability section which uses DP.

## A simple example: Barolo phenols

```
library(sn)
data(wines)
olo.ph <- wines[wines$wine=="Barolo", "phenols"]
fit <- selm(olo.ph ~ 1, family="SN")
plot(fit, which=2:3)
#
# try
summary(fit)    # works with CP
summary(fit, param.type="DP")
```

# A simple example: Barolo phenols – plots



## A multivariate example: más vino

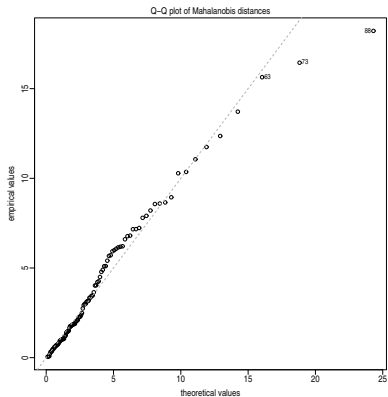
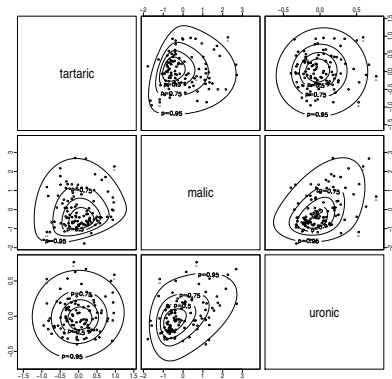
```
library(sn)
data(wines)
fit2 <- selm(cbind(tartaric, malic, uronic) ~ colour + hue,
             family="ST", data=wines, subset=(wine != "Grignolino"))

plot(fit2, which=2:3)

summary(fit2) # works with CP
summary(fit2, param.type="DP")

# constraint on degrees of freedom:
fit3 <- selm(cbind(tartaric, malic, uronic) ~ colour + hue,
             family="ST", fixed.param=list(nu=8),
             data=wines, subset=(wine != "Grignolino"))
```

# A multivariate example: más vino, plots





## For the more adventurous: profile log $L$ (LRT in fact)

```
# re-use earlier model for Barolo phenols
show(fit)
# Object class: selm
# Call: selm(formula = ba.ph ~ 1, family = "SN")
# [...omission...]

summary(fit)
# [...omission...]
# Parameters of the SEC random component
#      estimate std.err
# s.d.      0.337   0.04
# gamma1    0.703   0.26

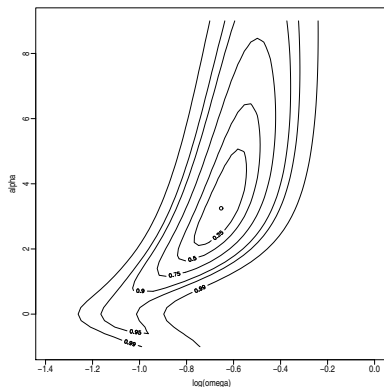
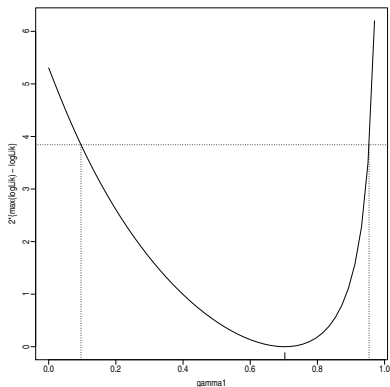
pll <- profile(fit, "cp", param.name="gamma1", param.val=c(0, 0.97))

profile(fit, "dp", param.name=c("omega", "alpha"),
        param.val=list(c(0.25, 1), c(-1, 9)), npt=c(51,51) )
```

**Note:** works for selm-class objects, not mselm-class

# For the more adventurous: profile $\log L$ , plots

Plots of (profile) Deviance  $\equiv$  LRT statistic



## Only for the more technically oriented people

- `selm` is of user interface function
- `selm` prepares work for the lower-level function `selm.fit`
- however, not even `selm.fit` performs the actual fitting
- depending on the fitted model, specific functions are called:  
`sn.mple`, `st.mple`, `msn.mle`, `msm.mple`, `mst.mple`
- To improve efficiency, one can call `selm.fit` directly,  
at the cost of some more programming effort
- One can also call the bottom-level functions, below `selm.fit`
- For more details, see `?selm.fit`

q()

q()