2321 ch8 hw

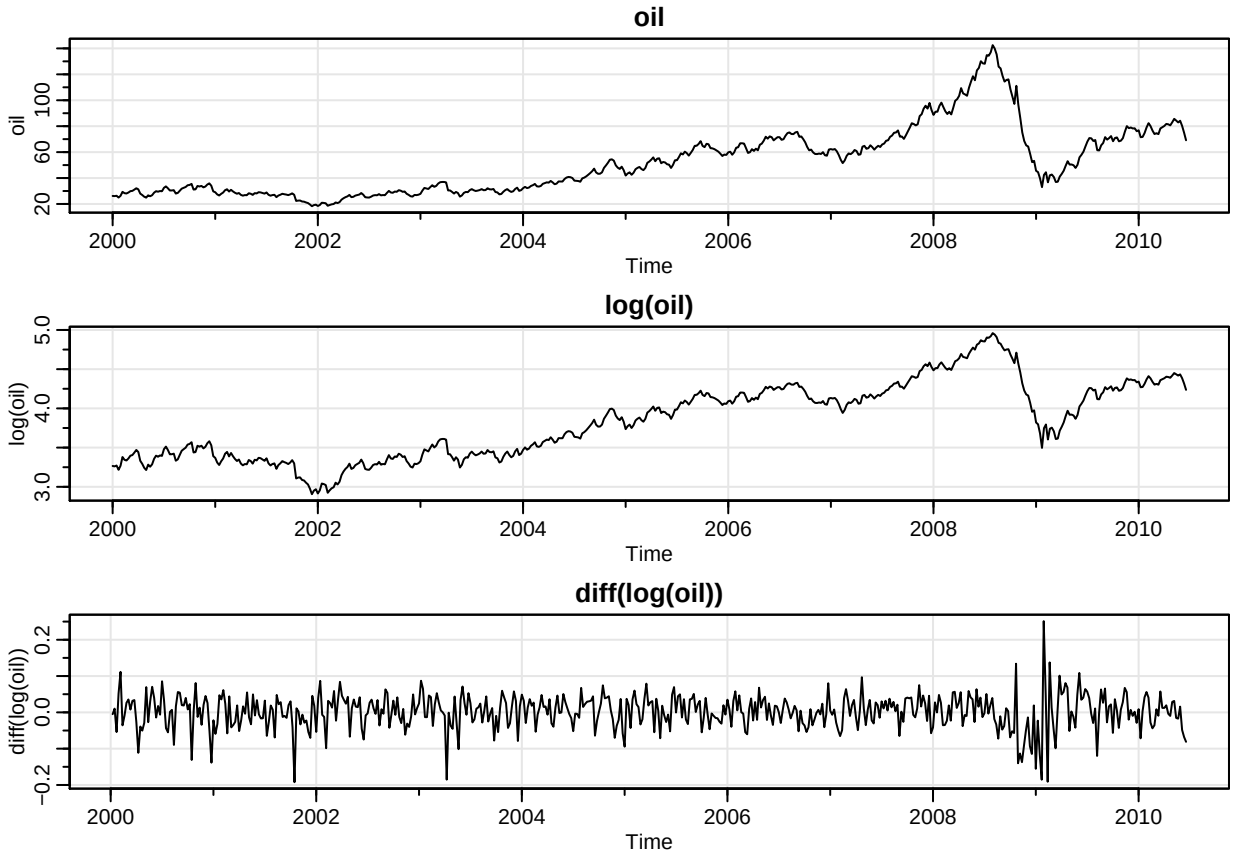
Orly Olbum

8.3

8.3. Weekly crude oil spot prices in dollars per barrel are in oil. Investigate whether the growth rate of the weekly oil price exhibits GARCH behavior. If so, fit an appropriate model to the growth rate.

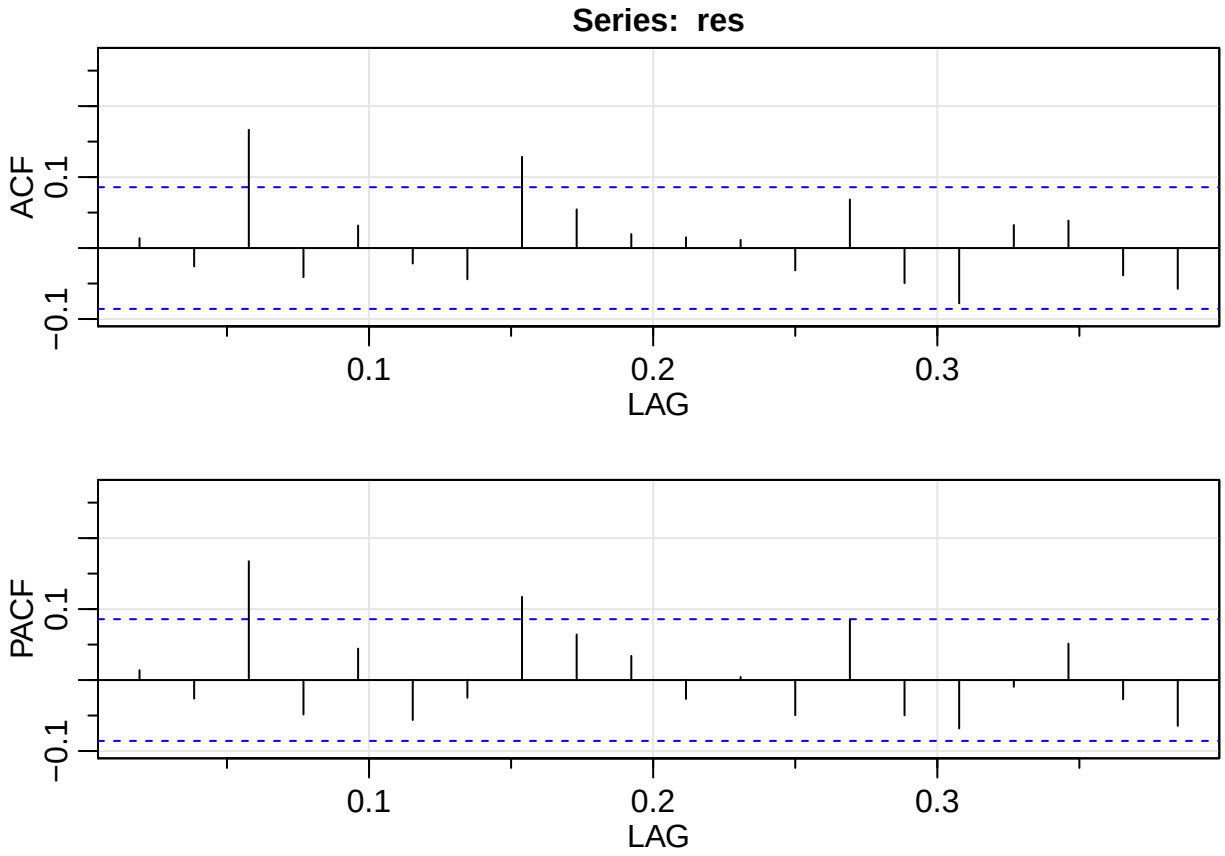
First we can investigate the oil data using tsplot.

```
par(mfrow = c(3, 1))
tsplot(oil, main = "oil")
tsplot(log(oil), main = "log(oil)")
tsplot(diff(log(oil)), main = "diff(log(oil))")
```



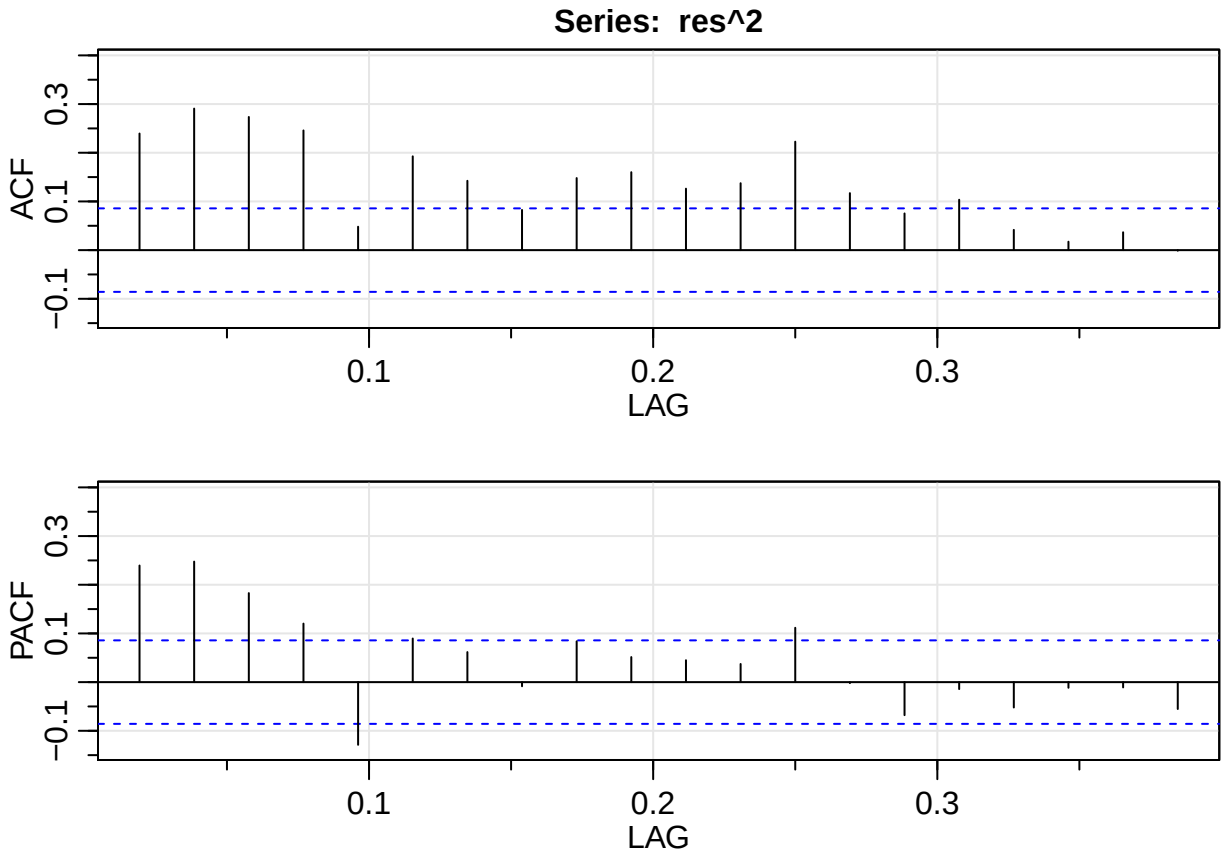
Once we have arrived at the differenced-logged data, we can determine if these (returns) exhibit GARCH behavior.

```
par(mfrow = c(2, 1))
res = resid(sarima(diff(log(oil)), 2, 0, 0, details = FALSE)$fit)
acf2(res, 20)
```




```
##       [,1]  [,2] [,3]  [,4] [,5]  [,6]  [,7] [,8] [,9] [,10] [,11] [,12] [,13]
## ACF   0.01 -0.03 0.17 -0.04 0.03 -0.02 -0.04 0.13 0.05  0.02  0.02  0.01 -0.03
## PACF  0.01 -0.03 0.17 -0.05 0.04 -0.06 -0.02 0.12 0.06  0.03 -0.03  0.00 -0.05
##       [,14] [,15] [,16] [,17] [,18] [,19] [,20]
## ACF   0.07 -0.05 -0.08  0.03  0.04 -0.04 -0.06
## PACF  0.09 -0.05 -0.07 -0.01  0.05 -0.03 -0.06
```

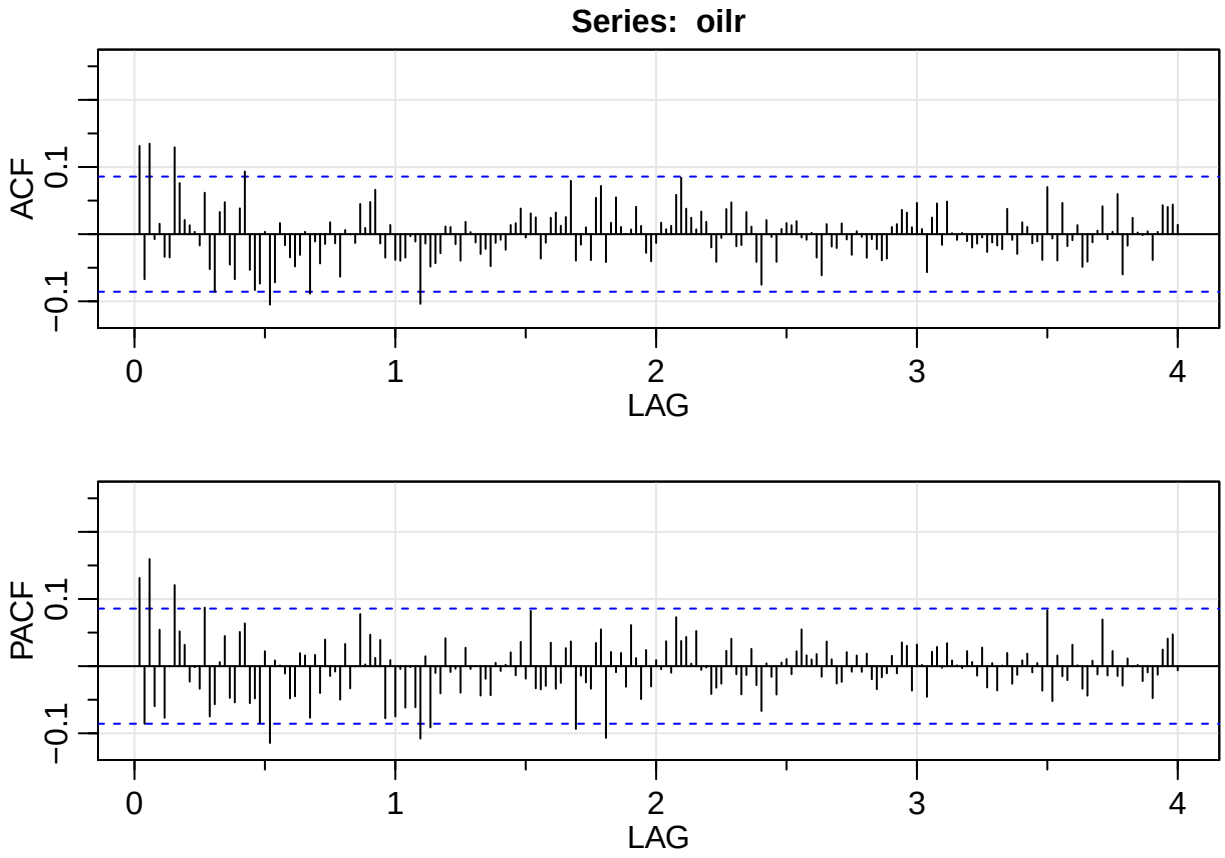
```
acf2(res^2, 20)
```




```
##      [,1] [,2] [,3] [,4]  [,5] [,6] [,7]  [,8] [,9] [,10] [,11] [,12] [,13]
## ACF  0.24 0.29 0.27 0.25  0.05 0.19 0.14  0.08 0.15  0.16  0.13  0.14  0.22
## PACF 0.24 0.25 0.18 0.12 -0.13 0.09 0.06 -0.01 0.08  0.05  0.04  0.04  0.11
##      [,14] [,15] [,16] [,17] [,18] [,19] [,20]
## ACF   0.12  0.08  0.10  0.04  0.02  0.04  0.00
## PACF  0.00 -0.07 -0.01 -0.05 -0.01 -0.01 -0.06
```

The sample ACF of the residuals is constant and nearly white noise, but the sample acf of the squared residuals appear to be correlated. This makes oil a great candidate for GARCH! The PACF cutting off and the ACF tailing off indicates an AR structure, so we can fit an AR-GARCH model.

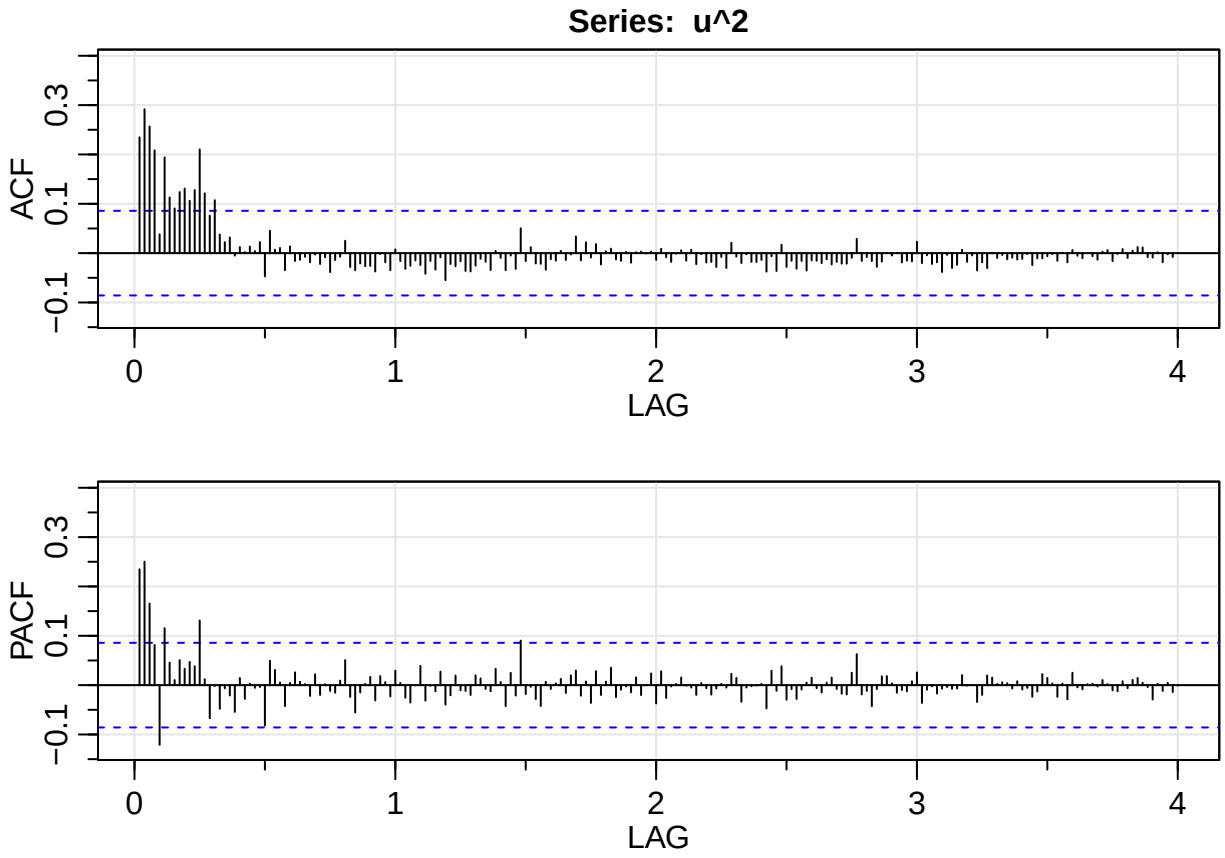
```
oilr = diff(log(oil))
acf2(oilr)
```




```
##      [,1]  [,2] [,3]  [,4] [,5]  [,6]  [,7] [,8] [,9] [,10] [,11] [,12] [,13]
## ACF  0.13 -0.07 0.13 -0.01 0.02 -0.03 -0.03 0.13 0.08  0.02  0.01     0 -0.02
## PACF 0.13 -0.09 0.16 -0.06 0.05 -0.08  0.00 0.12 0.05  0.03 -0.02     0 -0.03
##      [,14] [,15] [,16] [,17] [,18] [,19] [,20] [,21] [,22] [,23] [,24] [,25]
## ACF   0.06 -0.05 -0.09  0.03  0.05 -0.05 -0.07  0.04  0.09 -0.05 -0.08 -0.07
## PACF  0.09 -0.07 -0.06  0.01  0.04 -0.05 -0.05  0.05  0.06 -0.06 -0.05 -0.08
##      [,26] [,27] [,28] [,29] [,30] [,31] [,32] [,33] [,34] [,35] [,36] [,37]
## ACF   0.00 -0.11 -0.07  0.02 -0.02 -0.03 -0.05 -0.03  0.00 -0.09 -0.01 -0.04
## PACF  0.02 -0.11  0.01  0.00 -0.01 -0.05 -0.04  0.02  0.02 -0.08  0.02 -0.04
##      [,38] [,39] [,40] [,41] [,42] [,43] [,44] [,45] [,46] [,47] [,48] [,49]
## ACF  -0.01  0.02 -0.01 -0.06  0.01  0.00 -0.01  0.04  0.01  0.05  0.07 -0.01
## PACF  0.04 -0.01 -0.01 -0.05  0.03 -0.03  0.00  0.08  0.00  0.05  0.01  0.04
##      [,50] [,51] [,52] [,53] [,54] [,55] [,56] [,57] [,58] [,59] [,60] [,61]
## ACF  -0.03  0.01 -0.04 -0.04 -0.03     0 -0.01 -0.10 -0.01 -0.05 -0.04 -0.03
## PACF -0.08  0.01 -0.07  0.00 -0.06     0 -0.06 -0.11  0.01 -0.09 -0.01 -0.04
##      [,62] [,63] [,64] [,65] [,66] [,67] [,68] [,69] [,70] [,71] [,72] [,73]
## ACF   0.01  0.01 -0.01 -0.04  0.02     0 -0.01 -0.03 -0.02 -0.05 -0.01 -0.01
## PACF  0.04 -0.01  0.00 -0.04  0.03     0  0.00 -0.04 -0.02 -0.04  0.00 -0.01
##      [,74] [,75] [,76] [,77] [,78] [,79] [,80] [,81] [,82] [,83] [,84] [,85]
## ACF  -0.02  0.01  0.02  0.04 -0.01  0.03  0.02 -0.04 -0.01  0.02  0.03  0.01
## PACF  0.00  0.02 -0.01  0.04 -0.02  0.08 -0.03 -0.03 -0.03  0.03 -0.03 -0.02
##      [,86] [,87] [,88] [,89] [,90] [,91] [,92] [,93] [,94] [,95] [,96] [,97]
## ACF   0.03  0.08 -0.04 -0.02  0.01 -0.04  0.05  0.07 -0.04  0.02  0.05  0.01
## PACF  0.03  0.04 -0.09 -0.01 -0.02 -0.03  0.03  0.05 -0.11  0.02 -0.01  0.02
##      [,98] [,99] [,100] [,101] [,102] [,103] [,104] [,105] [,106] [,107] [,108]
## ACF   0.00  0.01   0.04   0.01  -0.03  -0.04  -0.01   0.02   0.01   0.01   0.06
```

```
## PACF -0.03  0.06   0.01  -0.05   0.02  -0.03   0.01   0.00   0.04  -0.01   0.07
##      [,109] [,110] [,111] [,112] [,113] [,114] [,115] [,116] [,117] [,118]
## ACF    0.08   0.04   0.02   0.01   0.03   0.02  -0.02  -0.04  -0.01   0.04
## PACF   0.04   0.04   0.00   0.05  -0.01   0.00  -0.04  -0.03  -0.03   0.02
##      [,119] [,120] [,121] [,122] [,123] [,124] [,125] [,126] [,127] [,128]
## ACF    0.05  -0.02  -0.02   0.03   0.01  -0.04  -0.08   0.02   0.00  -0.04
## PACF   0.04  -0.01  -0.04  -0.01   0.03  -0.03  -0.07   0.00  -0.02  -0.04
##      [,129] [,130] [,131] [,132] [,133] [,134] [,135] [,136] [,137] [,138]
## ACF    0.01   0.02   0.01   0.02   0.00  -0.01   0.00  -0.03  -0.06   0.01
## PACF   0.01   0.01  -0.01   0.02   0.05   0.02   0.01   0.02  -0.02   0.04
##      [,139] [,140] [,141] [,142] [,143] [,144] [,145] [,146] [,147] [,148]
## ACF   -0.02  -0.02   0.02  -0.01  -0.03   0.00   0.00  -0.04  -0.01  -0.02
## PACF   0.01  -0.03  -0.02   0.02  -0.01   0.02  -0.01   0.02  -0.02  -0.03
##      [,149] [,150] [,151] [,152] [,153] [,154] [,155] [,156] [,157] [,158]
## ACF   -0.04  -0.04   0.01   0.01   0.04   0.03   0.01   0.05   0.01  -0.06
## PACF  -0.02  -0.01   0.02  -0.01   0.04   0.03  -0.04   0.03   0.00  -0.05
##      [,159] [,160] [,161] [,162] [,163] [,164] [,165] [,166] [,167] [,168]
## ACF    0.02   0.05  -0.02   0.05   0.00  -0.01      0  -0.01  -0.02  -0.01
## PACF   0.02   0.03   0.00   0.03   0.01   0.00      0   0.02   0.01  -0.01
##      [,169] [,170] [,171] [,172] [,173] [,174] [,175] [,176] [,177] [,178]
## ACF    0.00  -0.03  -0.01  -0.02  -0.02   0.04  -0.01  -0.03   0.02   0.01
## PACF   0.03  -0.03   0.00  -0.04   0.00   0.02  -0.03  -0.01   0.01   0.02
##      [,179] [,180] [,181] [,182] [,183] [,184] [,185] [,186] [,187] [,188]
## ACF   -0.01  -0.01  -0.04   0.07  -0.01  -0.04   0.05  -0.02  -0.01   0.01
## PACF  -0.01   0.00  -0.04   0.08  -0.05   0.02  -0.01  -0.02   0.03   0.00
##      [,189] [,190] [,191] [,192] [,193] [,194] [,195] [,196] [,197] [,198]
## ACF   -0.05  -0.04  -0.01   0.01   0.04  -0.01   0.00   0.06  -0.06  -0.02
## PACF  -0.03  -0.04   0.01  -0.01   0.07  -0.01   0.02  -0.01  -0.03   0.01
##      [,199] [,200] [,201] [,202] [,203] [,204] [,205] [,206] [,207] [,208]
## ACF    0.02      0   0.00   0.00  -0.04   0.00   0.04   0.04   0.04   0.01
## PACF   0.00      0  -0.02  -0.01  -0.05  -0.01   0.02   0.04   0.05  -0.01
```

```
u = resid(sarima(oilr, 1, 0, 0, details = FALSE)$fit)
acf2(u^2)
```




```
##      [,1] [,2] [,3] [,4]  [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
## ACF  0.23 0.29 0.26 0.21  0.04 0.19 0.11 0.09 0.12  0.13  0.11  0.13  0.21
## PACF 0.23 0.25 0.17 0.08 -0.12 0.12 0.05 0.01 0.05  0.03  0.05  0.04  0.13
##      [,14] [,15] [,16] [,17] [,18] [,19] [,20] [,21] [,22] [,23] [,24] [,25]
## ACF   0.12  0.08  0.11  0.04  0.02  0.03 -0.01  0.01  0.00  0.01  0.00  0.02
## PACF  0.01 -0.07  0.00 -0.05 -0.01 -0.02 -0.05  0.01 -0.03  0.00 -0.01  0.00
##      [,26] [,27] [,28] [,29] [,30] [,31] [,32] [,33] [,34] [,35] [,36] [,37]
## ACF  -0.05  0.05  0.01  0.01 -0.03  0.01 -0.02 -0.01 -0.01 -0.02  0.00 -0.02
## PACF -0.08  0.05  0.03  0.01 -0.04  0.00  0.03  0.01  0.00 -0.02  0.02 -0.02
##      [,38] [,39] [,40] [,41] [,42] [,43] [,44] [,45] [,46] [,47] [,48] [,49]
## ACF  -0.01 -0.04 -0.01 -0.01  0.03 -0.03 -0.03 -0.02 -0.03 -0.03 -0.04  0.00
## PACF  0.00 -0.01 -0.02  0.01  0.05 -0.02 -0.06 -0.01  0.00  0.02 -0.03  0.02
##      [,50] [,51] [,52] [,53] [,54] [,55] [,56] [,57] [,58] [,59] [,60] [,61]
## ACF  -0.02 -0.03  0.01 -0.02 -0.03 -0.03 -0.01 -0.02 -0.04 -0.02 -0.03 -0.01
## PACF  0.01 -0.02  0.03  0.00 -0.03 -0.04  0.00  0.04 -0.03  0.00 -0.01  0.03
##      [,62] [,63] [,64] [,65] [,66] [,67] [,68] [,69] [,70] [,71] [,72] [,73]
## ACF  -0.05 -0.02 -0.03 -0.02 -0.04 -0.04 -0.03 -0.01 -0.02 -0.03  0.00 -0.01
## PACF -0.04 -0.02  0.02 -0.01 -0.01 -0.02  0.02  0.01 -0.01 -0.01  0.03  0.01
##      [,74] [,75] [,76] [,77] [,78] [,79] [,80] [,81] [,82] [,83] [,84] [,85]
## ACF  -0.03  0.00 -0.03  0.05 -0.02  0.01 -0.02 -0.02 -0.03 -0.01 -0.02  0.00
## PACF -0.04  0.02 -0.02  0.09 -0.02  0.00 -0.03 -0.04  0.01 -0.01  0.00  0.01
##      [,86] [,87] [,88] [,89] [,90] [,91] [,92] [,93] [,94] [,95] [,96] [,97]
## ACF  -0.01  0.00  0.03 -0.01  0.02 -0.01  0.02 -0.02  0.00  0.01 -0.01 -0.02
## PACF -0.02  0.02  0.03 -0.02  0.01 -0.04  0.03 -0.02  0.01  0.04 -0.02 -0.01
##      [,98] [,99] [,100] [,101] [,102] [,103] [,104] [,105] [,106] [,107] [,108]
## ACF      0 -0.02   0.00   0.00      0   0.00  -0.01   0.01  -0.01  -0.02      0
```

```
## PACF     0 -0.01   0.02  -0.02      0   0.02  -0.04   0.03  -0.03   0.00      0
##      [,109] [,110] [,111] [,112] [,113] [,114] [,115] [,116] [,117] [,118]
## ACF    0.01  -0.02   0.01  -0.02      0  -0.02  -0.02  -0.03  -0.01  -0.03
## PACF   0.02   0.00   0.00  -0.02      0  -0.01  -0.02  -0.01   0.00  -0.01
##      [,119] [,120] [,121] [,122] [,123] [,124] [,125] [,126] [,127] [,128]
## ACF    0.02  -0.01  -0.02      0  -0.02  -0.02  -0.01  -0.04  -0.01  -0.04
## PACF   0.02   0.01  -0.03      0   0.00   0.00   0.00  -0.05   0.03  -0.01
##      [,129] [,130] [,131] [,132] [,133] [,134] [,135] [,136] [,137] [,138]
## ACF    0.02  -0.03  -0.02  -0.03  -0.02  -0.04  -0.01  -0.02  -0.02  -0.01
## PACF   0.04  -0.03  -0.01  -0.03  -0.01   0.01   0.02  -0.01  -0.01   0.01
##      [,139] [,140] [,141] [,142] [,143] [,144] [,145] [,146] [,147] [,148]
## ACF   -0.02  -0.02  -0.02  -0.02  -0.01   0.03  -0.02  -0.01  -0.02  -0.03
## PACF   0.02  -0.01  -0.02  -0.02   0.03   0.06  -0.02  -0.01  -0.04  -0.01
##      [,149] [,150] [,151] [,152] [,153] [,154] [,155] [,156] [,157] [,158]
## ACF   -0.02   0.00      0   0.00  -0.02  -0.02  -0.02   0.02  -0.02   0.00
## PACF   0.02   0.02      0  -0.02  -0.01  -0.01   0.01   0.03  -0.04  -0.01
##      [,159] [,160] [,161] [,162] [,163] [,164] [,165] [,166] [,167] [,168]
## ACF   -0.02  -0.02  -0.04      0  -0.03  -0.02   0.01  -0.02      0  -0.04
## PACF   0.00  -0.02  -0.01      0  -0.01  -0.01   0.02   0.00      0  -0.03
##      [,169] [,170] [,171] [,172] [,173] [,174] [,175] [,176] [,177] [,178]
## ACF   -0.02  -0.03   0.00  -0.01   0.00  -0.01  -0.01  -0.01  -0.01   0.00
## PACF  -0.02   0.02   0.02   0.00   0.01   0.00  -0.01   0.01  -0.01  -0.01
##      [,179] [,180] [,181] [,182] [,183] [,184] [,185] [,186] [,187] [,188]
## ACF   -0.02  -0.01  -0.01  -0.01      0  -0.02      0  -0.02   0.01  -0.01
## PACF  -0.02  -0.01   0.02   0.01      0  -0.02      0  -0.03   0.02   0.00
##      [,189] [,190] [,191] [,192] [,193] [,194] [,195] [,196] [,197] [,198]
## ACF   -0.01      0  -0.01  -0.01   0.00   0.01  -0.02   0.00   0.01  -0.01
## PACF  -0.01      0   0.00   0.00   0.01   0.00  -0.01  -0.01   0.01  -0.01
##      [,199] [,200] [,201] [,202] [,203] [,204] [,205] [,206] [,207] [,208]
## ACF    0.00   0.01   0.01  -0.01  -0.01      0  -0.02      0  -0.01      0
## PACF   0.01   0.01   0.00   0.00  -0.03      0  -0.01      0  -0.01      0
```

```
par(mfrow = c(1, 1))
summary(oil.g <- garchFit(~arma(1, 0) + garch(1, 1), data = oilr, cond.dist = "std"))
```

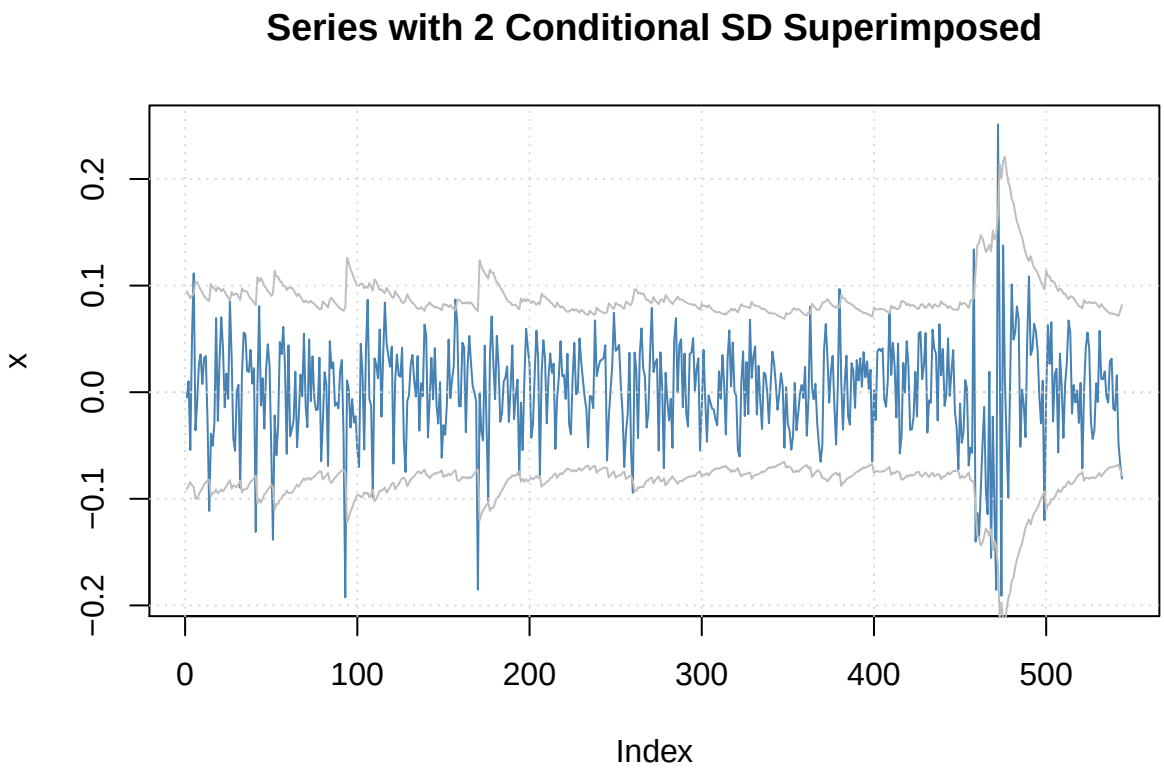
```
##
## Series Initialization:
##  ARMA Model:                arma
##  Formula Mean:              ~ arma(1, 0)
##  GARCH Model:               garch
##  Formula Variance:          ~ garch(1, 1)
##  ARMA Order:                1 0
##  Max ARMA Order:            1
##  GARCH Order:               1 1
##  Max GARCH Order:           1
##  Maximum Order:             1
##  Conditional Dist:          std
##  h.start:                   2
##  llh.start:                 1
##  Length of Series:          544
##  Recursion Init:            mci
##  Series Scale:              0.04700153
##
## Parameter Initialization:
```

```
##  Initial Parameters:          $params
##  Limits of Transformations:   $U, $V
##  Which Parameters are Fixed?  $includes
##  Parameter Matrix:
##                       U           V     params includes
##     mu     -0.37951444   0.3795144 0.03741778     TRUE
##     ar1    -0.99999999   1.0000000 0.13182244     TRUE
##     omega   0.00000100 100.0000000 0.10000000     TRUE
##     alpha1  0.00000001   1.0000000 0.10000000     TRUE
##     gamma1 -0.99999999   1.0000000 0.10000000    FALSE
##     beta1   0.00000001   1.0000000 0.80000000     TRUE
##     delta   0.00000000   2.0000000 2.00000000    FALSE
##     skew    0.10000000  10.0000000 1.00000000    FALSE
##     shape   1.00000000  10.0000000 4.00000000     TRUE
##  Index List of Parameters to be Optimized:
##     mu    ar1  omega alpha1  beta1  shape
##      1      2      3      4      6      9
##  Persistence:                  0.9
##
##
## --- START OF TRACE ---
## Selected Algorithm: nlminb
##
## R coded nlminb Solver:
##
##   0:     731.87900: 0.0374178 0.131822 0.100000 0.100000 0.800000  4.00000
##   1:     728.48654: 0.0374250 0.133844 0.116823 0.111668 0.816468  4.00088
##   2:     727.98174: 0.0375091 0.157451 0.108387 0.108116 0.821234  4.00603
##   3:     727.56556: 0.0378518 0.190454 0.0769864 0.0906711 0.860706  4.02838
##   4:     727.44864: 0.0379259 0.175441 0.0735008 0.0883150 0.862094  4.03371
##   5:     727.44480: 0.0381220 0.170866 0.0726451 0.0915876 0.868741  4.04691
##   6:     727.27207: 0.0382210 0.171175 0.0714294 0.0885421 0.866437  4.05371
##   7:     727.18997: 0.0385148 0.172469 0.0748326 0.0829393 0.867522  4.07403
##   8:     727.09479: 0.0388186 0.173150 0.0714071 0.0834647 0.866904  4.09504
##   9:     726.96389: 0.0391247 0.174107 0.0710500 0.0851410 0.868447  4.11619
##  10:     726.13046: 0.0438545 0.189284 0.0494338 0.0959128 0.871472  4.44117
##  11:     725.72835: 0.0488716 0.163505 0.0897160 0.137741 0.803104  4.75066
##  12:     724.72167: 0.0515679 0.130670 0.0859805 0.0743705 0.852460  4.85410
##  13:     724.35914: 0.0553620 0.163541 0.0949428 0.0692442 0.837043  4.96306
##  14:     723.56360: 0.0652502 0.139717 0.0652739 0.0786272 0.853587  5.20422
##  15:     723.45430: 0.0763185 0.155365 0.0604818 0.0895506 0.871008  5.40942
##  16:     722.25959: 0.0799836 0.158128 0.0573888 0.0862985 0.862572  5.55954
##  17:     721.90262: 0.0816458 0.156585 0.0611814 0.0737172 0.866086  5.73234
##  18:     721.40445: 0.0915635 0.166046 0.0500342 0.0651591 0.878369  6.39768
##  19:     720.97899: 0.0969612 0.168482 0.0650416 0.0717304 0.856988  7.09800
##  20:     720.68735: 0.0840643 0.153337 0.0611045 0.0712220 0.859129  7.72704
##  21:     720.57042: 0.0784477 0.157584 0.0549517 0.0709133 0.865769  8.21166
##  22:     720.51900: 0.0776888 0.158523 0.0521720 0.0678428 0.871988  8.60731
##  23:     720.51204: 0.0789978 0.158074 0.0520357 0.0679096 0.872373  8.77845
##  24:     720.51130: 0.0789540 0.158063 0.0523555 0.0676599 0.872012  8.85772
##  25:     720.51124: 0.0788904 0.158051 0.0523690 0.0678825 0.871792  8.87071
##  26:     720.51124: 0.0788440 0.158061 0.0523863 0.0678788 0.871776  8.86987
##  27:     720.51124: 0.0788435 0.158056 0.0523832 0.0678777 0.871779  8.86987
##
```

```
## Final Estimate of the Negative LLH:
##  LLH:  -942.8097    norm LLH:  -1.733106
##          mu         ar1       omega      alpha1       beta1       shape
## 0.003705765 0.158056491 0.000115722 0.067877662 0.871778866 8.869871941
##
## R-optimhess Difference Approximated Hessian Matrix:
##                   mu           ar1         omega        alpha1         beta1
## mu     -3.388918e+05 -1.647547e+03 -1.124376e+06 -3.011633e+03 -3.122197e+03
## ar1    -1.647547e+03 -5.491851e+02 -1.386851e+04 -7.083218e+01 -5.048722e+01
## omega  -1.124376e+06 -1.386851e+04 -4.327810e+09 -5.726641e+06 -7.458069e+06
## alpha1 -3.011633e+03 -7.083218e+01 -5.726641e+06 -1.145969e+04 -1.134789e+04
## beta1  -3.122197e+03 -5.048722e+01 -7.458069e+06 -1.134789e+04 -1.402807e+04
## shape  -4.179425e+01 -4.574572e-01 -1.038627e+04 -1.602507e+01 -1.866872e+01
##                shape
## mu     -4.179425e+01
## ar1    -4.574572e-01
## omega  -1.038627e+04
## alpha1 -1.602507e+01
## beta1  -1.866872e+01
## shape  -1.701362e-01
## attr(,"time")
## Time difference of 0.03390908 secs
##
## --- END OF TRACE ---
##
##
## Time to Estimate Parameters:
##  Time difference of 0.1571031 secs
##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~arma(1, 0) + garch(1, 1), data = oilr, cond.dist = "std")
##
## Mean and Variance Equation:
##  data ~ arma(1, 0) + garch(1, 1)
## <environment: 0x000000001867eee8>
##  [data = oilr]
##
## Conditional Distribution:
##  std
##
## Coefficient(s):
##         mu         ar1       omega      alpha1       beta1       shape
## 0.00370576  0.15805649  0.00011572  0.06787766  0.87177887  8.86987194
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu     3.706e-03   1.759e-03    2.106 0.035186 *
## ar1    1.581e-01   4.302e-02    3.674 0.000239 ***
```

```
## omega  1.157e-04   5.609e-05    2.063 0.039099 *
## alpha1 6.788e-02   2.232e-02    3.042 0.002352 **
## beta1  8.718e-01   4.047e-02   21.544  < 2e-16 ***
## shape  8.870e+00   2.678e+00    3.312 0.000926 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  942.8097    normalized:  1.733106
##
## Description:
##  Sun Nov 29 13:43:21 2020 by user: orlyo
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  116.2227  0
##  Shapiro-Wilk Test  R    W      0.9736902 2.59254e-08
##  Ljung-Box Test     R    Q(10)  16.65767  0.08229042
##  Ljung-Box Test     R    Q(15)  21.47833  0.1222301
##  Ljung-Box Test     R    Q(20)  28.47734  0.09857251
##  Ljung-Box Test     R^2  Q(10)  5.25317   0.873637
##  Ljung-Box Test     R^2  Q(15)  9.390314  0.8562413
##  Ljung-Box Test     R^2  Q(20)  10.59198  0.9561254
##  LM Arch Test       R    TR^2   5.036311  0.9567551
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -3.444153 -3.396738 -3.444393 -3.425615
```

```
plot(oil.g, which = 3)
```



We now have the fitted model, plotted above. With significant parameters we have a good fit!