

# Co-authorship

Scientific collaboration among Italian academic statisticians

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Social Network Analysis  
A.A. 2021/2022



# Datasets

Bibliographic data for academic statisticians from the national institutional repository

| Features                | P01<br>(2004 – 2010) | P2<br>(2011 - 2017) |
|-------------------------|----------------------|---------------------|
| Authors                 | 300                  | 301                 |
| Female                  | 126                  | 128                 |
| Male                    | 174                  | 173                 |
| PA                      | 71                   | 68                  |
| PO                      | 164                  | 138                 |
| RU                      | 65                   | 95                  |
| Papers                  | 4732                 | 4766                |
| Dataset size<br>(#rows) | 6355                 | 6107                |

Aythors' Features  
(Node attributes):

- Role
- University
- Localization
- Faculty
- Gender
- Academic\_Age
- Age

Papers' Features:

- |             |              |
|-------------|--------------|
| - Title     | - Type       |
| - ID        | - MinType    |
| - PubDate   | - Language   |
| - Journal   | - NumAuthors |
| - Volume    | - Keywords   |
| - Publisher | - nPages     |
| - ISI       | - PartofBook |
| - Scopus    |              |
| - DOI       |              |
| - ISBN      |              |
| - ISSN      |              |

# Adjacency Matrix

Incidence matrix ( authors \* papers)

P01 : 300 \* 4732

P02: 301 \* 4766

Multiplying by transpose

Adjacency matrix (authors \* authors)

P01 : 300 \* 300

P02 : 301 \* 301

Note:

To avoid having circle edges for every single node, the diagonal of the adjacency matrix is changed to zero.

# Network

Network attributes:

```
vertices = 300
directed = FALSE
hyper = FALSE
loops = FALSE
multiple = FALSE
bipartite = FALSE
total edges= 433
missing edges= 0
non-missing edges= 433
```

Vertex attribute names:

```
Academic_Age Age Faculty Gender Localization Role University vertex.names
```

No edge attributes

| Academic_Age  | Age           |
|---------------|---------------|
| Min. : 5.00   | Min. :33.00   |
| 1st Qu.:10.00 | 1st Qu.:42.00 |
| Median :14.00 | Median :46.00 |
| Mean :15.85   | Mean :47.68   |
| 3rd Qu.:20.00 | 3rd Qu.:51.00 |
| Max. :37.00   | Max. :73.00   |

Network attributes:

```
vertices = 301
directed = FALSE
hyper = FALSE
loops = FALSE
multiple = FALSE
bipartite = FALSE
total edges= 461
missing edges= 0
non-missing edges= 461
```

Vertex attribute names:

```
Academic_Age Age Faculty Gender Localization Role University vertex.names
```

No edge attributes

| Academic_Age  | Age           |
|---------------|---------------|
| Min. : 5.00   | Min. :33.00   |
| 1st Qu.:10.00 | 1st Qu.:42.00 |
| Median :13.00 | Median :46.00 |
| Mean :15.39   | Mean :47.19   |
| 3rd Qu.:20.00 | 3rd Qu.:51.00 |
| Max. :37.00   | Max. :73.00   |

# Descriptive Analysis

P01:

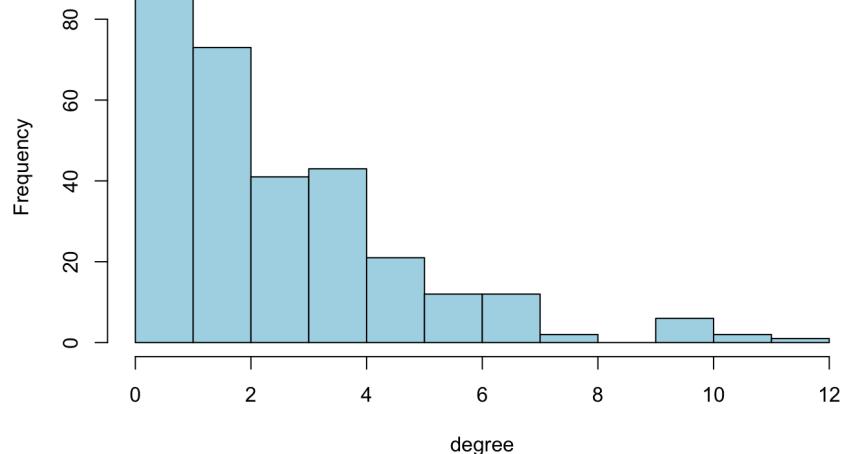
- Not connected
- Isolated nodes: 33
- Density : 0.0097
- Transitivity: 0.36
- Maximum degree : 12

P02:

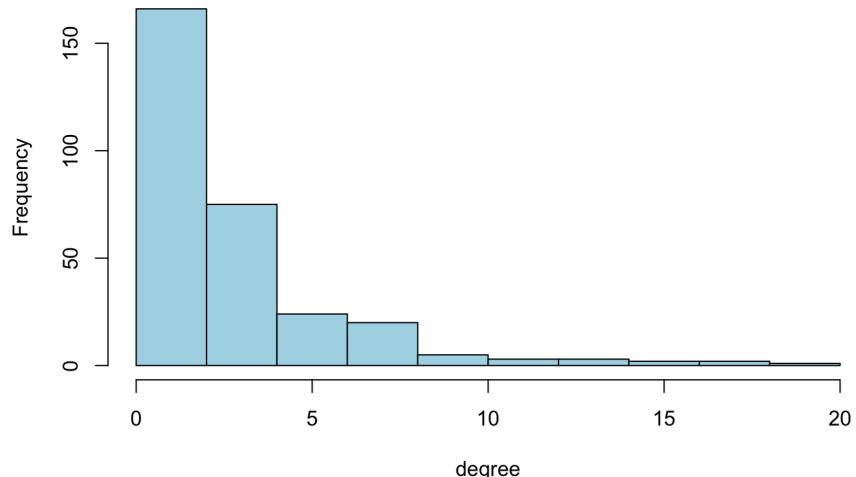
- Not connected
- Isolated nodes: 43
- Density : 0.010
- Transitivity: 0.34
- Maximum degree : 20

# Descriptive Analysis

P01- Degree distribution

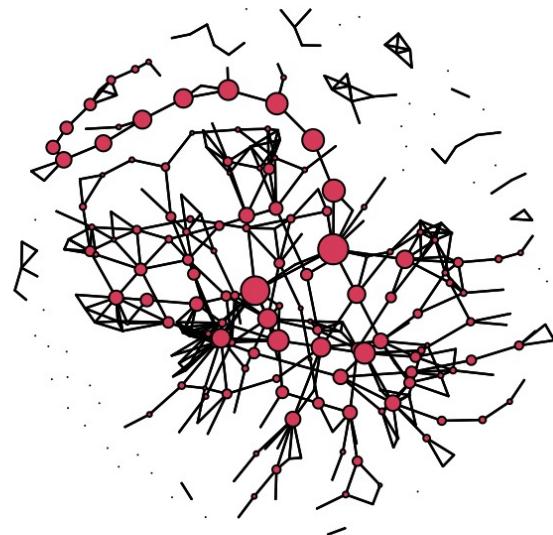


P02- Degree distribution

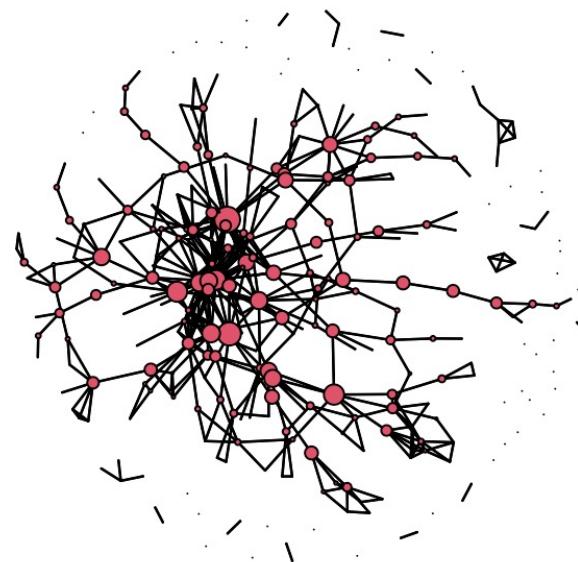


# Descriptive Analysis

P01- Network  
Node size:  $\text{sqrt(betweennes)}/25$

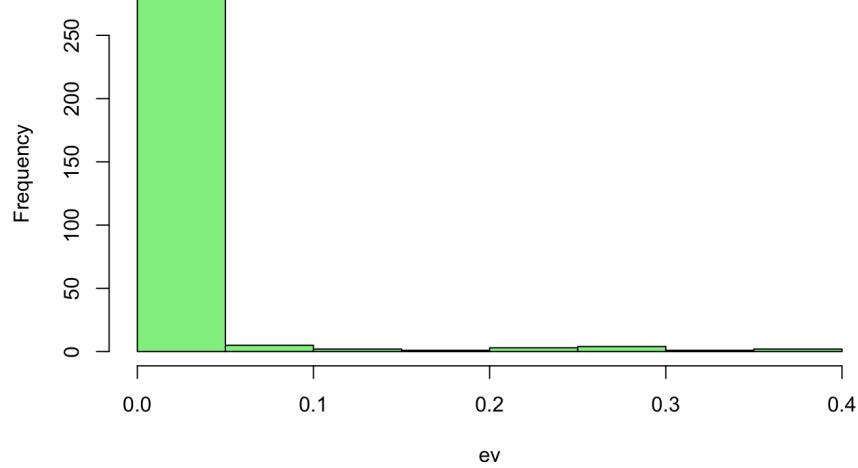


P02- Network visualization  
Node size:  $\text{sqrt(betweennes)}/25$

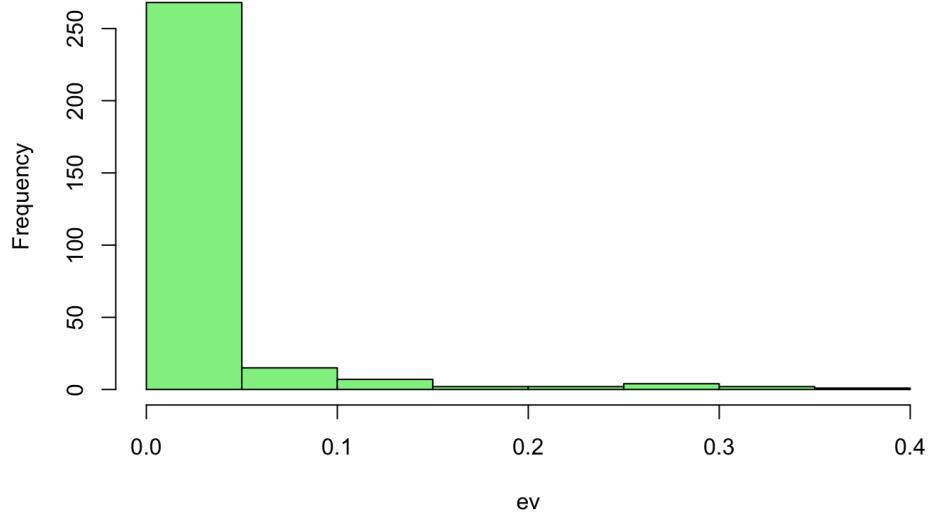


# Descriptive Analysis

P01- Eigenvector Centrality

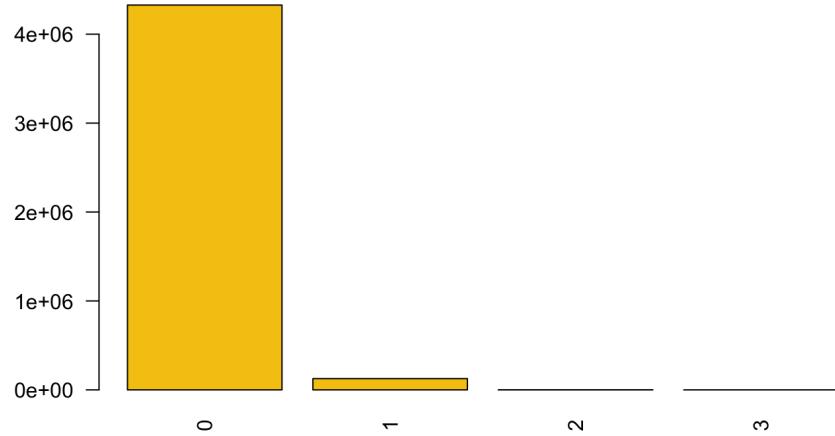


P02- Eigenvector Centrality

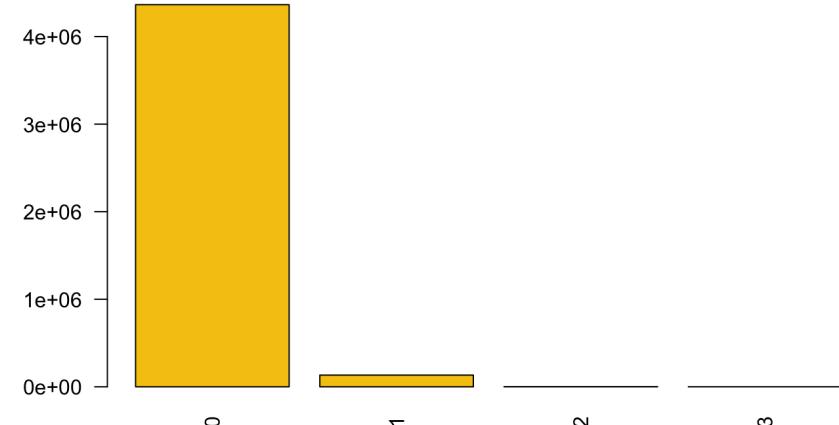


# Descriptive Analysis

P01- Triadic census



P02- Triadic census



|      | Mut     | Asym   | Null  |     |
|------|---------|--------|-------|-----|
| [1,] | 433     | 0      | 44417 |     |
|      | 0       | 1      | 2     | 3   |
| [1,] | 4327474 | 126408 | 1028  | 190 |

|      | Mut     | Asym   | Null  |     |
|------|---------|--------|-------|-----|
| [1,] | 461     | 0      | 44689 |     |
|      | 0       | 1      | 2     | 3   |
| [1,] | 4364284 | 133775 | 1609  | 282 |

# Connected Components

```
1 2 3 5 6 8 220
33 3 2 3 2 1 1
[1] " Giant component:"
IGRAPH 31bf20e UNW- 220 386 --
+ attr: name (v/c), Role (v/c), University (v/c), Localization (v/c), Faculty (v/c), Gender (v/c),
| Academic_Age (v/n), Age (v/n), weight (e/n)
+ edges from 31bf20e (vertex names):
[1] Adelchi AZZALINI --Bruno SCARPA
[3] Adelchi AZZALINI --Nicola TORELLI
PERRI
[5] Alberto ROVERATO --Guido CONSONNI
LUCA
[7] Alberto ROVERATO --Sandra PATERLINI
VITALE COSIMO
[9] Alessandra AMENDOLA --Marcella NIGLIO
ROCCA MICHELE
[11] Alessandra AMENDOLA --Tullio MENINI
[13] Alessandra DALLA VALLE--Renato GUSEO
+ ... omitted several edges
```

|                        |                  |
|------------------------|------------------|
| Adelchi AZZALINI       | --Monica CHIOGNA |
| Agostino TARSIANO      | --Pier Francesco |
| Alberto ROVERATO       | --Luca LA ROCCA  |
| Alessandra AMENDOLA    | --Cosimo Damiano |
| Alessandra AMENDOLA    | --Michele LA     |
| Alessandra DALLA VALLE | --Claudia FURLAN |
| Alessandra PETRUCCI    | --Andrea GIOMMI  |

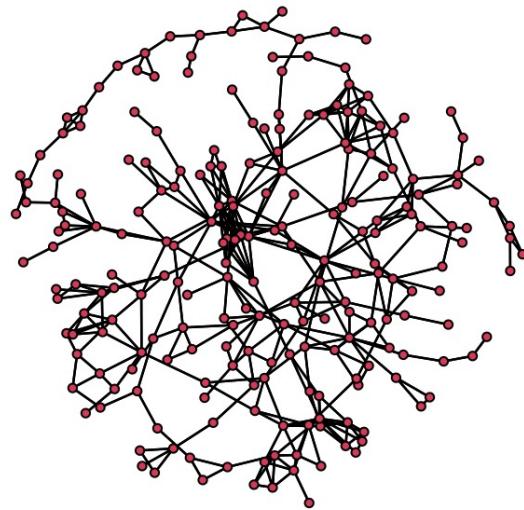
45 connected components

```
1 2 3 4 7 219
43 9 2 2 1 1
[1] " Giant component:"
IGRAPH 33ae41c UNW- 219 430 --
+ attr: name (v/c), Role (v/c), University (v/c), Localization (v/c), Faculty (v/c), Gender (v/c),
| Academic_Age (v/n), Age (v/n), color (v/c), size (v/n), label.color (v/c), core (v/n),
| GN.cluster (v/n), weight (e/n), width (e/n), color (e/c)
+ edges from 33ae41c (vertex names):
[1] Adelchi AZZALINI --Agostino DI CIACCIO
[2] Adelchi AZZALINI --Bruno SCARPA
[3] Adelchi AZZALINI --Daniela COCCHI
[4] Adelchi AZZALINI --Francesco BATTAGLIA
[5] Adelchi AZZALINI --Giovanni Maria GIORGIO GIOVANNI
[6] Adelchi AZZALINI --Maurizio VICHI
+ ... omitted several edges
```

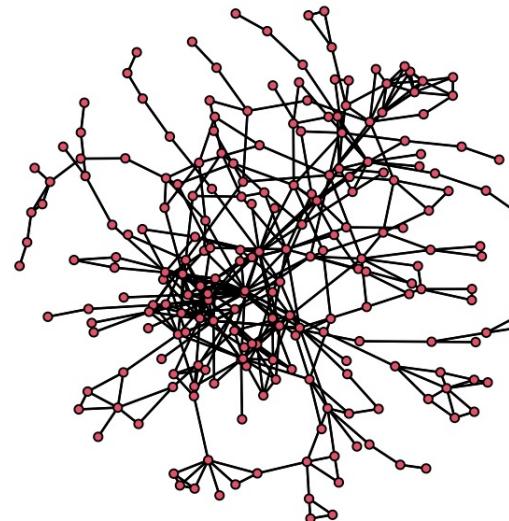
58 connected components

# Giant Component

P01- The largest connected component



P02- The largest connected component

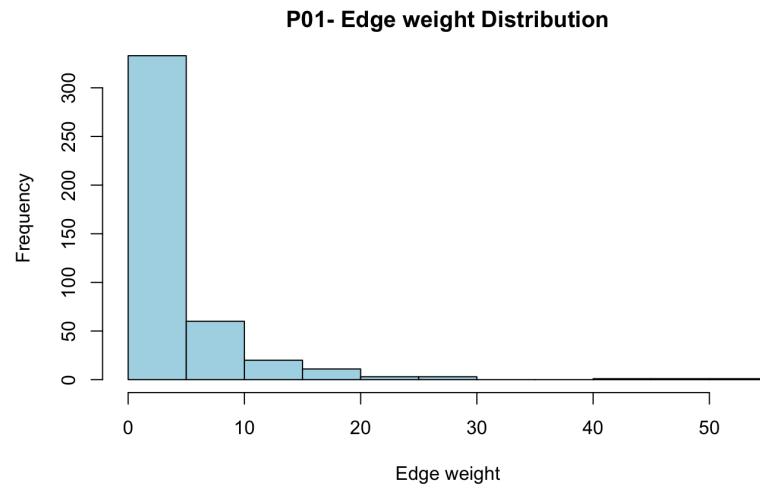


# Graph

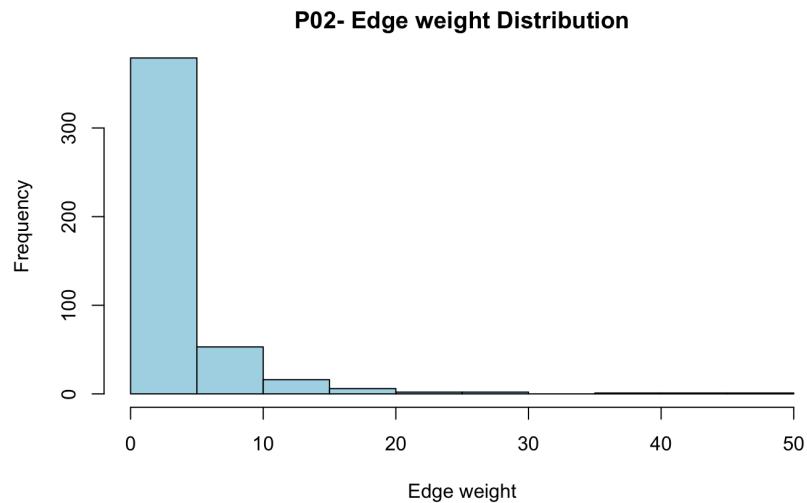
```
multiple of replacement lengthIGRAPH 643365e UNW- 300 433 --
+ attr: name (v/c), Role (v/c), University (v/c), Localization (v/c), Faculty (v/c), Gender (v/c),
| Academic_Age (v/n), Age (v/n), weight (e/n)
+ edges from 643365e (vertex names):
[1] Adelchi AZZALINI      --Bruno SCARPA
[3] Adelchi AZZALINI      --Nicola TORELLI
[5] Agostino TARSITANO    --Pier Francesco PERRI
[7] Alberto ROVERATO       --Luca LA ROCCA LUCA
[9] Aldo GOIA              --Daniele DE MARTINI
[11] Alessandra AMENDOLA   --Marcella NIGLIO
[13] Alessandra AMENDOLA   --Tullio MENINI
+ ... omitted several edges
[1] Adelchi AZZALINI      --Monica CHIOGNA
[3] Agostino DI CIACCIO    --Simone BORRA
[5] Alberto ROVERATO       --Guido CONSONNI
[7] Alberto ROVERATO       --Sandra PATERLINI
[9] Alessandra AMENDOLA    --Cosimo Damiano VITALE COSIMO
[11] Alessandra AMENDOLA    --Michele LA ROCCA MICHELE
[13] Alessandra DALLA VALLE --Claudia FURLAN
```

```
UNW- 301 461 --
+ attr: name (v/c), Role (v/c), University (v/c), Localization (v/c), Faculty (v/c), Gender
| (v/c), Academic_Age (v/n), Age (v/n), weight (e/n)
+ edges from 8ea7931 (vertex names):
[1] Adelchi AZZALINI      --Agostino DI CIACCIO
[2] Adelchi AZZALINI      --Bruno SCARPA
[3] Adelchi AZZALINI      --Daniela COCCHI
[4] Adelchi AZZALINI      --Francesco BATTAGLIA
[5] Adelchi AZZALINI      --Giovanni Maria GIORGI GIOVANNI
[6] Adelchi AZZALINI      --Maurizio VICHI
[7] Adelchi AZZALINI      --Pierluigi CONTI
+ ... omitted several edges
```

# Descriptive Analysis

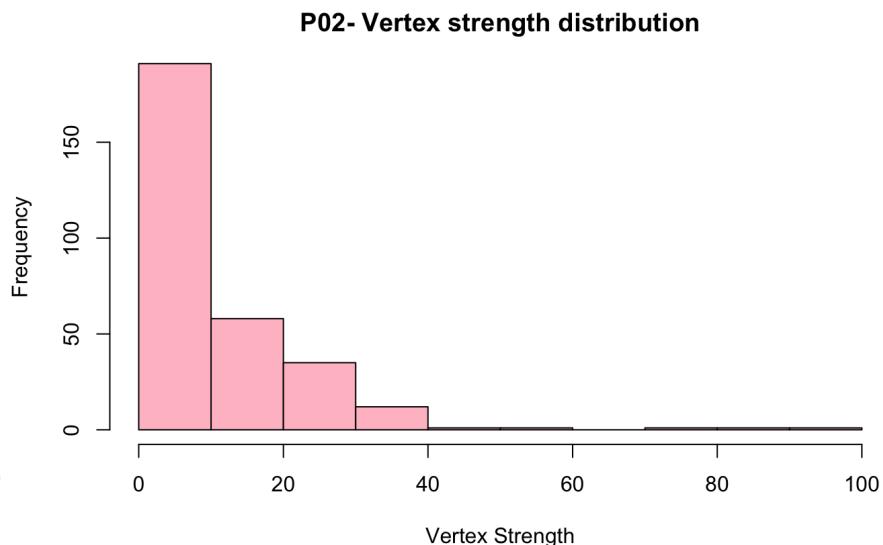
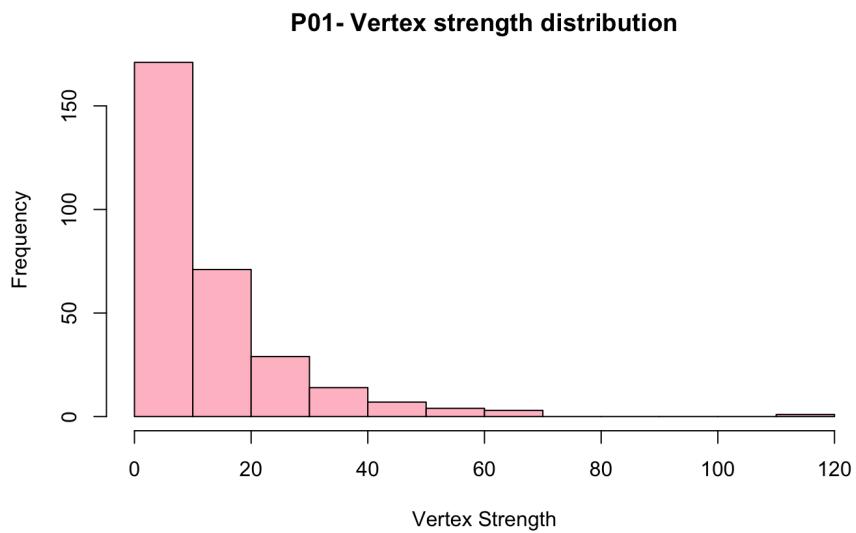


Maximum weight = 54  
Minimum weight = 1



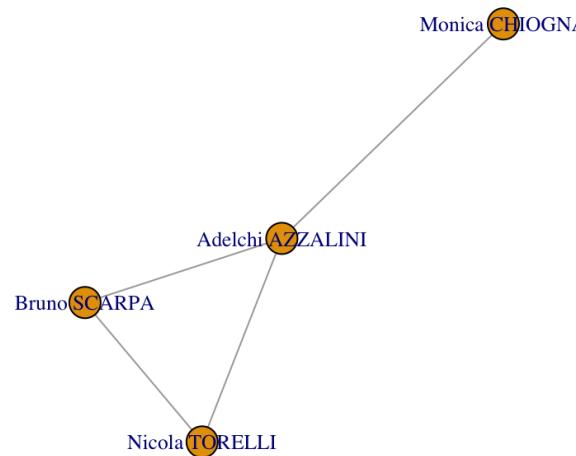
Maximum weight = 49  
Minimum weight = 1

# Descriptive Analysis

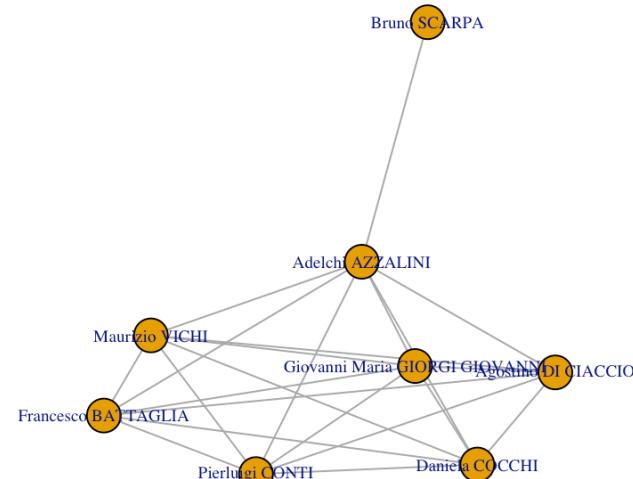


# Descriptive Analysis

P01- Neighborhood of order 1 for 'Adelchi Azzalini'



P02- Neighborhood of order 1 for 'Adelchi Azzalini'



# Descriptive Analysis

The first five edges with highest edge betweenness

+ 5/433 edges from 643365e (vertex names):

- [1] Francesco BARTOLUCCI--Giorgio VITTADINI
- [3] Antonietta MIRA --Francesco BARTOLUCCI
- [5] Antonietta MIRA --Sonia PETRONE

Francesco BARTOLUCCI--Giorgio Eduardo MONTANARI GIORGIO  
Francesco BARTOLUCCI--Leonardo GRILLI

+ 5/461 edges from 8ea7931 (vertex names):

- [1] Donata MARASINI --Maurizio CARPITA Isabella MORLINI --Michele GALLO
- [3] Anna GOTTARD --Domenico PICCOLO Francesco BARTOLUCCI--Ruggero BELLIO
- [5] Francesco BARTOLUCCI--Marco ALFO'

# Cliques

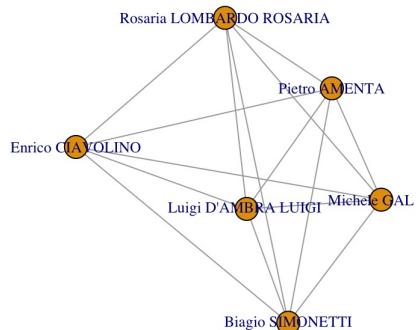
[1] 995

| 1   | 2   | 3   | 4  | 5  | 6 |
|-----|-----|-----|----|----|---|
| 300 | 433 | 190 | 56 | 14 | 2 |

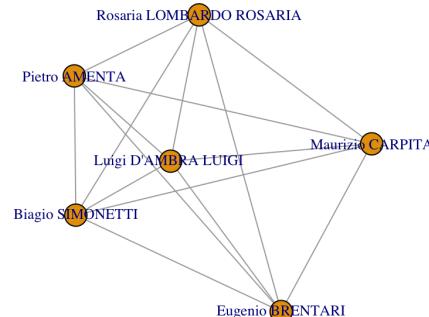
[1] "Maximal cliques of different sizes: "

| 1  | 2   | 3  | 4  | 5 | 6 |
|----|-----|----|----|---|---|
| 33 | 138 | 74 | 18 | 2 | 2 |

**P01- The largest clique of size 6**



**P01- The largest clique of size 6**



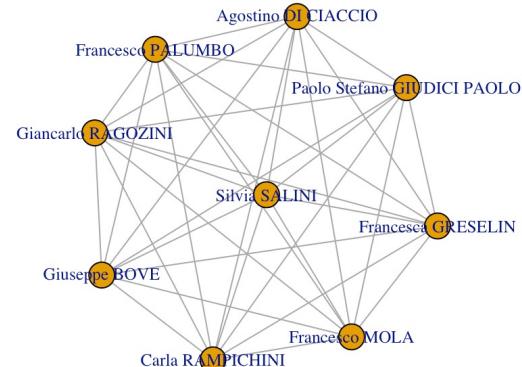
[1] 1535

| 1   | 2   | 3   | 4   | 5   | 6  | 7  | 8 | 9 |
|-----|-----|-----|-----|-----|----|----|---|---|
| 301 | 461 | 282 | 197 | 155 | 92 | 37 | 9 | 1 |

[1] "Maximal cliques of different sizes "

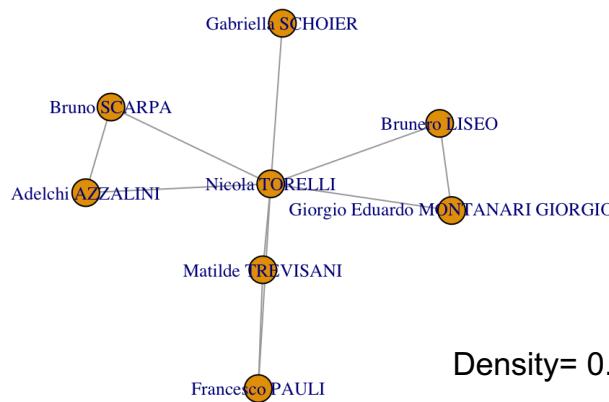
| 1  | 2   | 3  | 4  | 5 | 6 | 7 | 9 |
|----|-----|----|----|---|---|---|---|
| 43 | 129 | 82 | 11 | 2 | 1 | 1 | 1 |

**P02- The largest clique of size 9**



# Ego density (Local density)

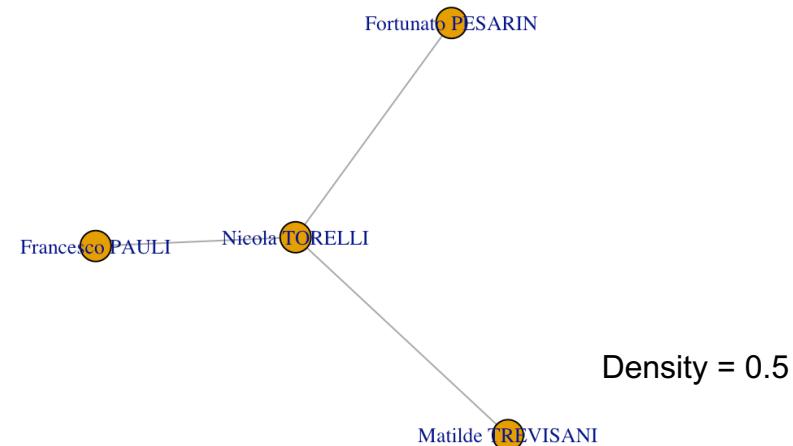
P01- Induced subgraph for 'Nicola Torelli'



```
transitivity(mygraph, "local", vids=c("Nicola TORELLI", "Matilde TREVISANI",  
"Francesco PAULI", "Gabriella SCHOIER"))
```

```
```  
[1] 0.3566959  
[1] 0.1428571 1.0000000 0.2000000  
[1] NaN
```

P02- Induced subgraph for 'Nicola Torelli'



```
transitivity(mygraph, "local", vids=c("Nicola TORELLI", "Matilde TREVISANI",  
"Francesco PAULI", "Fortunato PESARIN"))
```

```
```  
[1] 0.3446029  
[1] 0.0000000  
[1] NaN 0.1428571 0.3333333
```

# Descriptive Analysis

```
[1] "Average path length:"  
[1] 16.65626  
[1] "Diameter:"  
[1] 60
```

```
[1] "Average path length:"  
[1] 11.97734  
[1] "Diameter:"  
[1] 86
```

# Descriptive Analysis

```
[1] "The number and proportion of cut vertices in giant component:"
```

```
[1] 57
```

```
[1] 0.2590909
```

```
[1] "The number and proportion of cut vertices in the whole graph:"
```

```
[1] 71
```

```
[1] 0.2366667
```

```
[1] "The number and proportion of cut vertices in giant component:"
```

```
[1] 60
```

```
[1] 0.2739726
```

```
[1] "The number and proportion of cut vertices in the whole graph:"
```

```
[1] 66
```

```
[1] 0.2192691
```

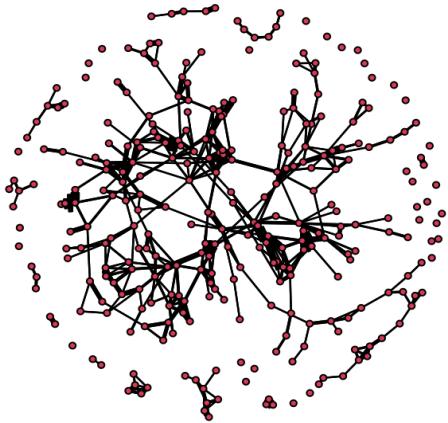
# Highest co-authorship

```
[1] "P01-The first five pair of authors with hightes co-authorship"  
+ 5/433 edges from 437fd3c (vertex names):  
[1] Livio CORAIN           --Luigi SALMASO  
[2] Monica PRATESI        --Nicola SALVATI  
[3] Andrea CERIOLI         --Marco RIANI  
[4] Fortunato PESARIN      --Luigi SALMASO  
[5] Giorgio Eduardo MONTANARI GIORGIO--Maria Giovanna RANALLI
```

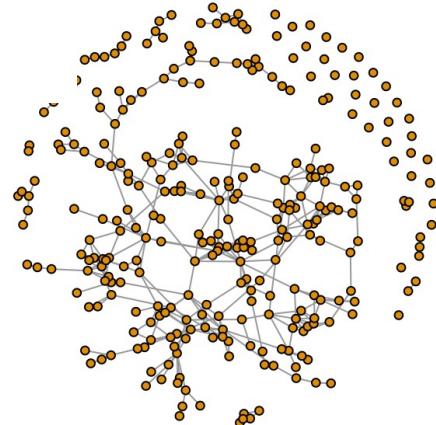
```
[1] "P02-The first five pair of authors with hightes co-authorship"  
+ 5/461 edges from 3ddce88 (vertex names):  
[1] Donato POSA           --Sandra DE IACO       Monica PALMA       --Sandra DE IACO  
[3] Donato POSA           --Monica PALMA       Livio CORAIN       --Luigi SALMASO  
[5] Paola PERCHINUNNO--Silvestro MONTRONE
```

# Visualization

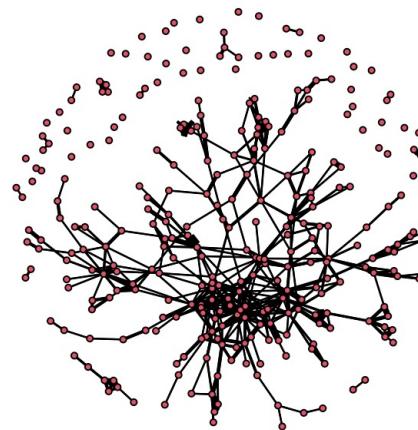
P01-Network



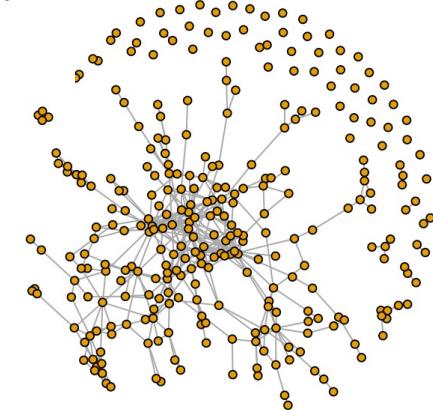
P01- Graph



P02-Network

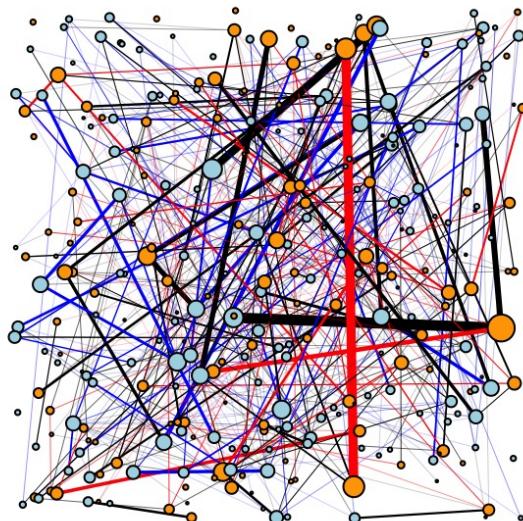


P02- Graph

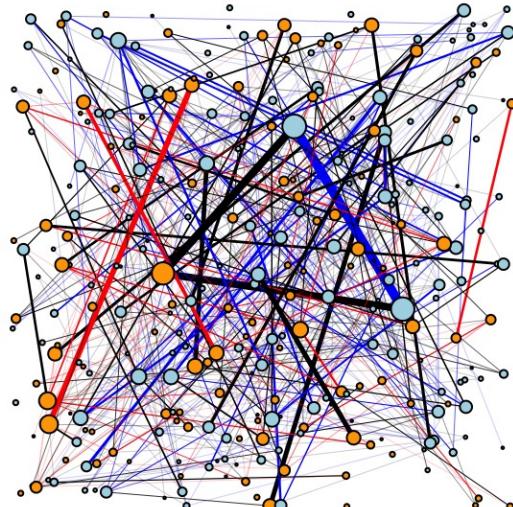


# Visualization

P01- Random layout  
Node size = node strength

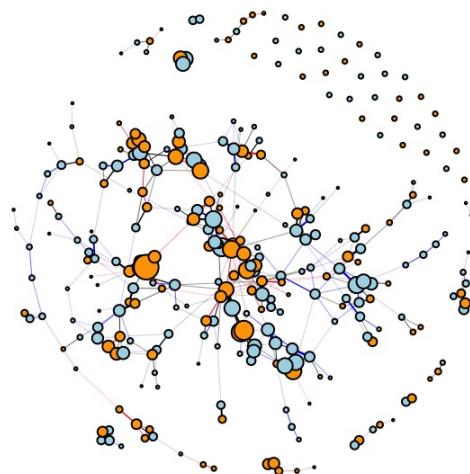
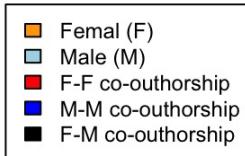


P02- Random layout  
Node size = node strength

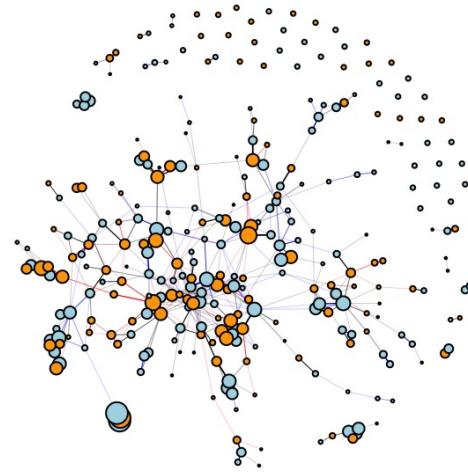
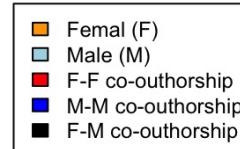


# Visualization

**P01- Nicely layout**  
**Node size = node strength**

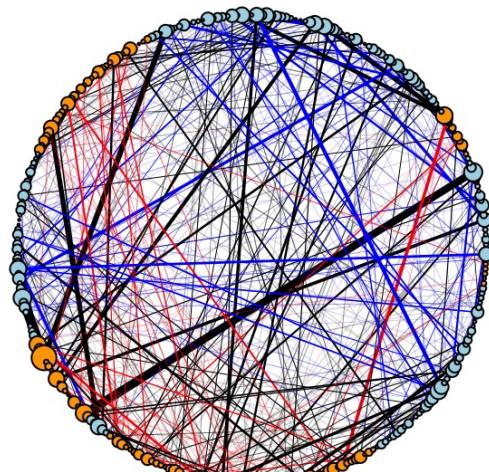


**P02- Nicely layout**  
**Node size = node strength**



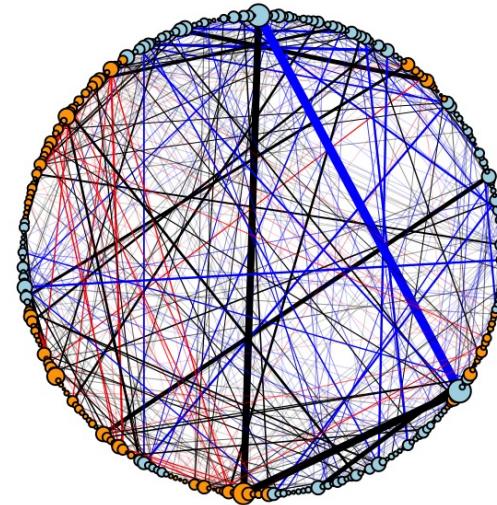
# Visualization

P01- Circular layout  
Node size = node strength



- Femal (F)
- Male (M)
- F-F co-outhorship
- M-M co-outhorship
- F-M co-outhorship

P02- Circular layout  
Node size = node strength

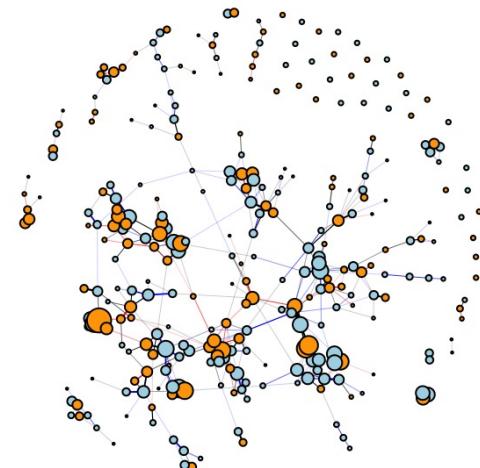


- Femal (F)
- Male (M)
- F-F co-outhorship
- M-M co-outhorship
- F-M co-outhorship

# Visualization

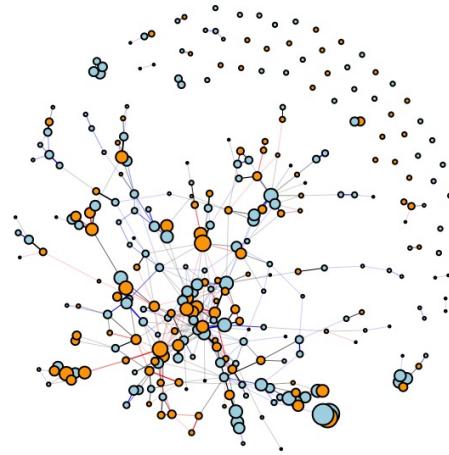
P01- Fruchterman & Reingold layout  
Node size = node strength

- Femal (F)
- Male (M)
- F-F co-outhorship
- M-M co-outhorship
- F-M co-outhorship



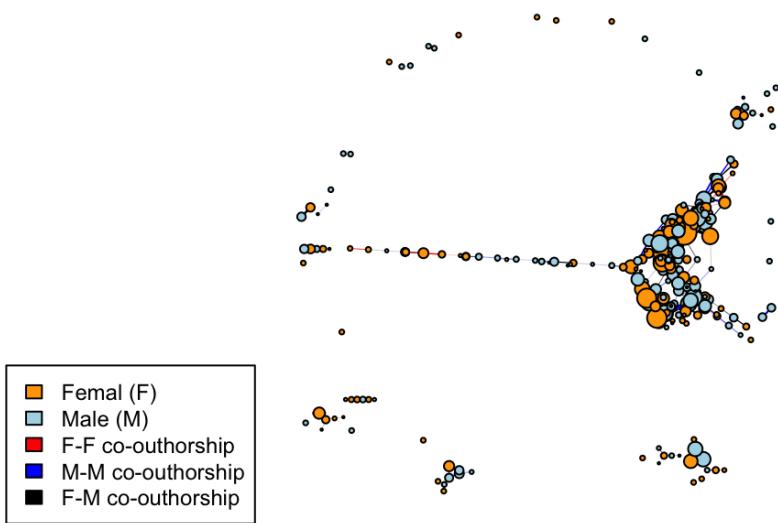
P02- Fruchterman & Reingold layout  
Node size = node strength

- Femal (F)
- Male (M)
- F-F co-outhorship
- M-M co-outhorship
- F-M co-outhorship

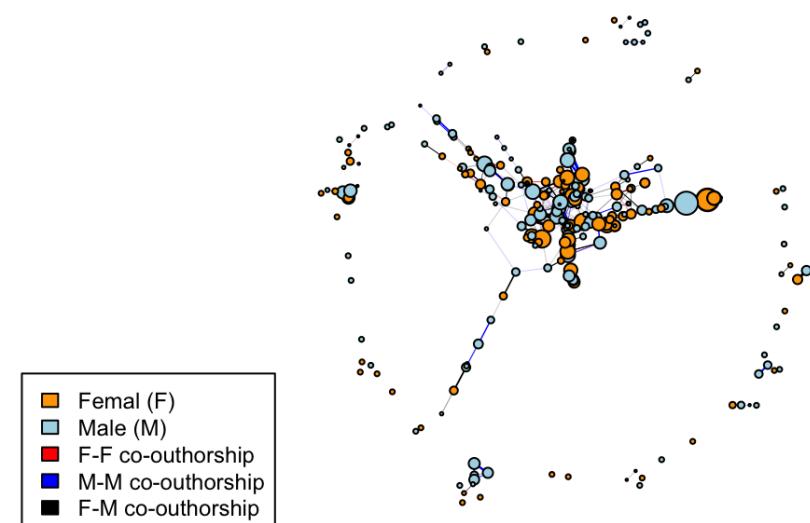


# Visualization

P01- MDS layout  
Node size = node strength

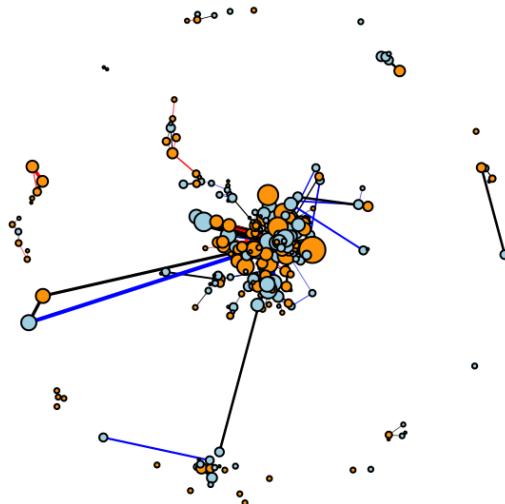


P02- MDS layout  
Node size = node strength

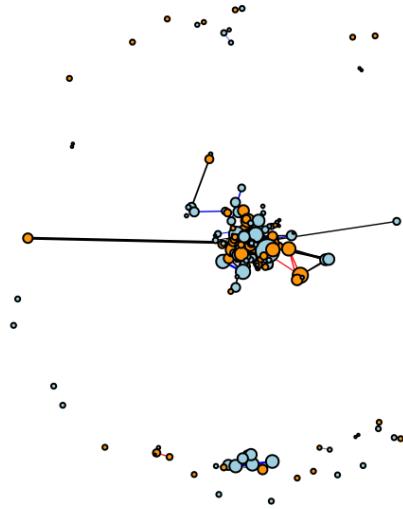


# Visualization

P01- Kamada-Kawai layout  
Node size = node strength

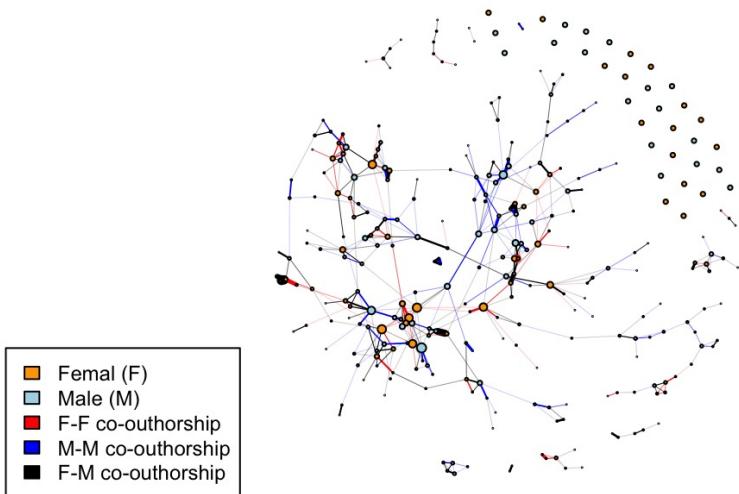


P02- Kamada-Kawai layout  
Node size = node strength

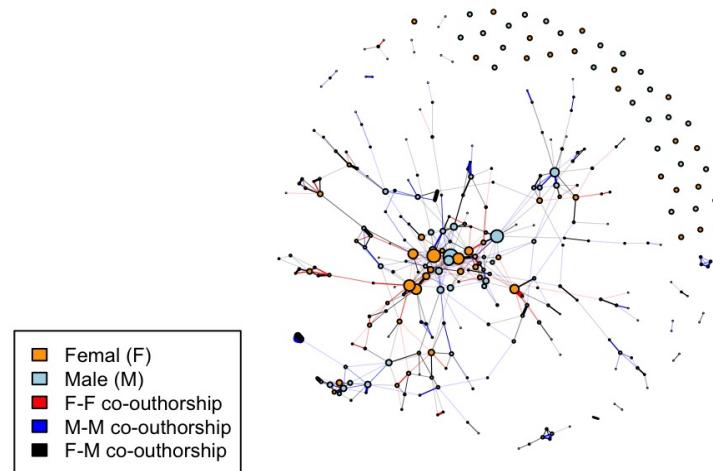


# Visualization

P01- Fruchterman & Reingold layout  
Node size = node degree centrality

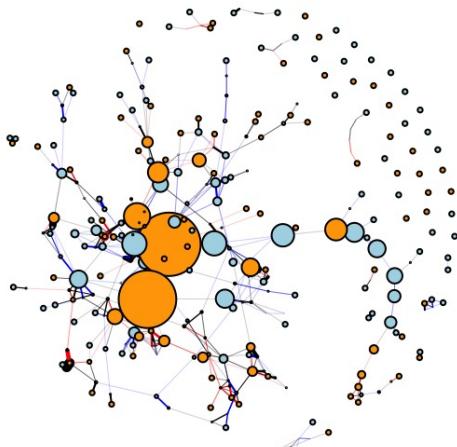


P02- Fruchterman & Reingold layout layout.  
Node size = node degree centrality

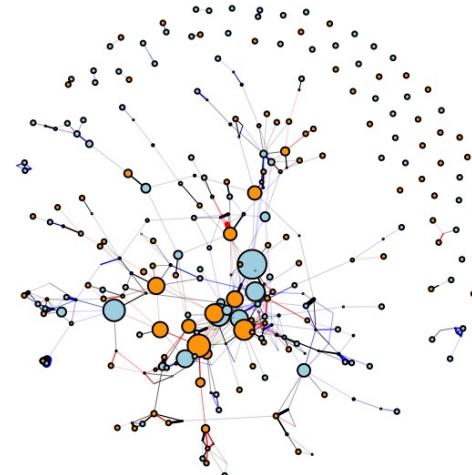


# Visualization

P01- Fruchterman & Reingold layout layout.  
Node size = betweenness centrality

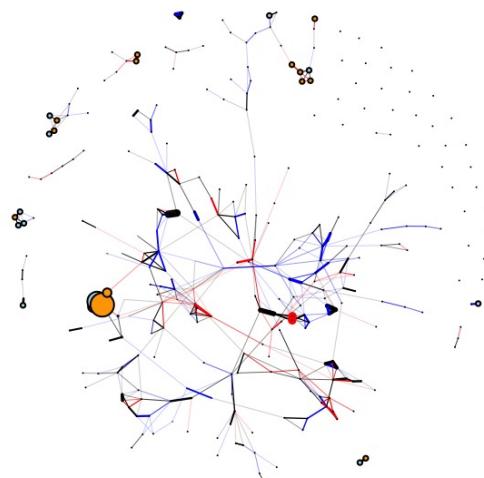


P02- Fruchterman & Reingold layout  
Node size = betweenness centrality



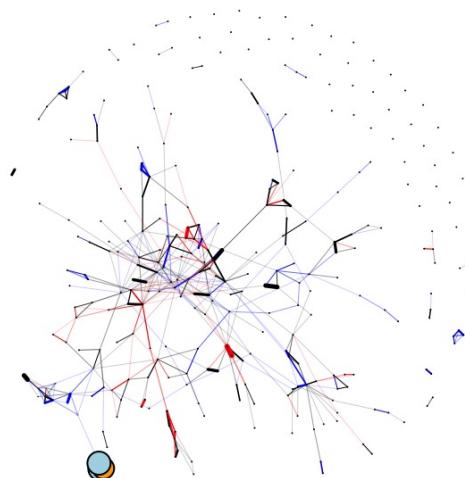
# Visualization

P01- Fruchterman & Reingold layout layout.  
Node size = eigenvector centrality



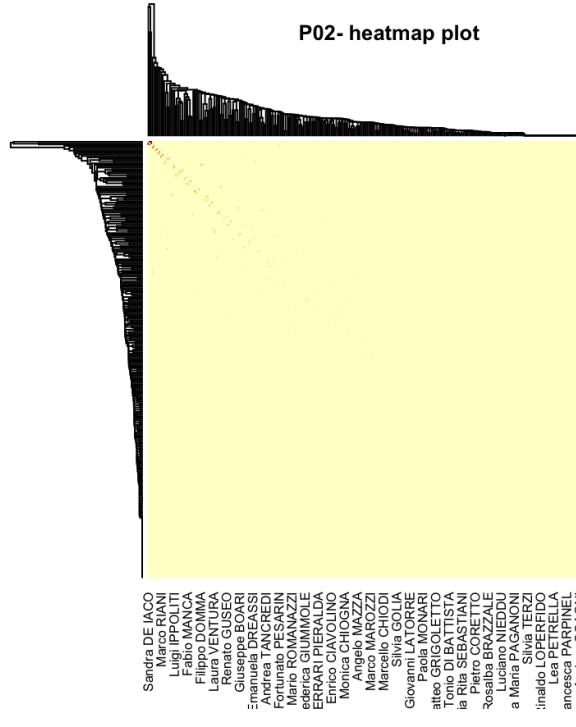
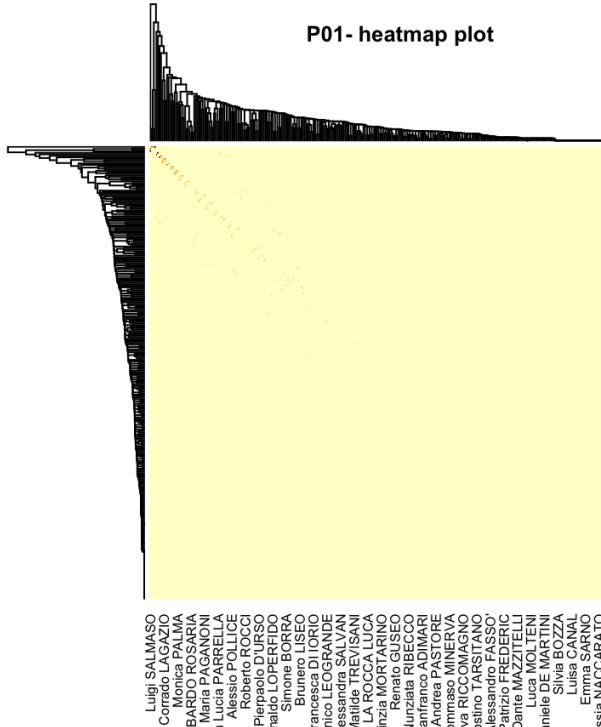
- Femal (F)
- Male (M)
- F-F co-outhorship
- M-M co-outhorship
- F-M co-outhorship

P02- Fruchterman & Reingold layout layout.  
Node size = eigenvector centrality



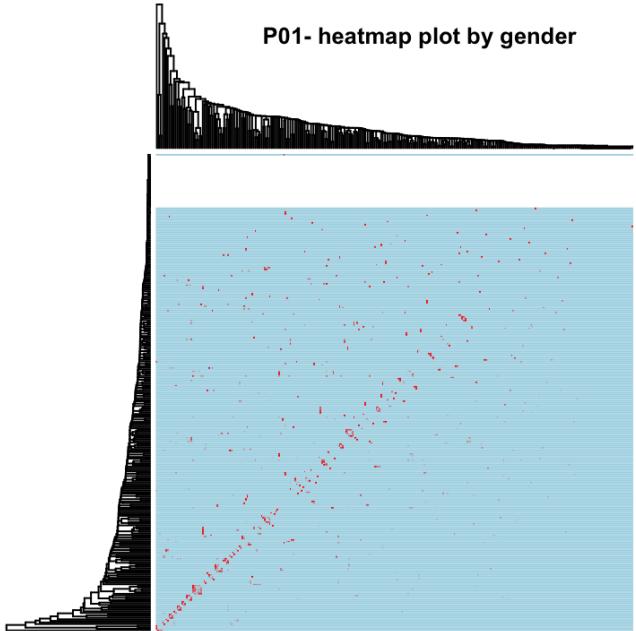
- Femal (F)
- Male (M)
- F-F co-outhorship
- M-M co-outhorship
- F-M co-outhorship

# Visualization



# Visualization

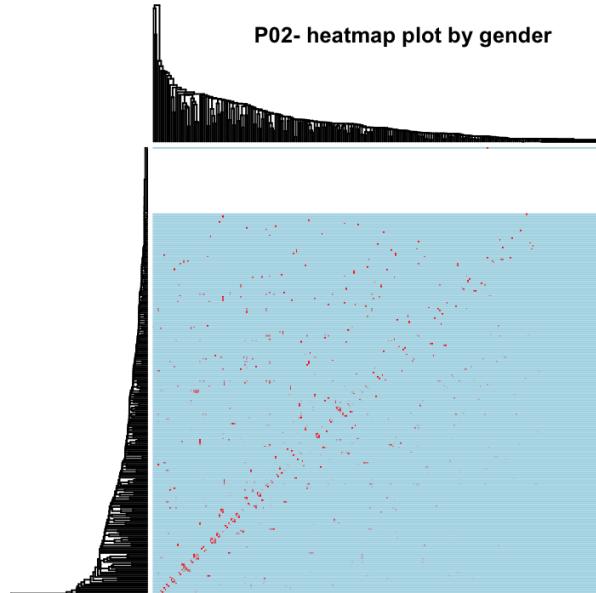
P01- heatmap plot by gender



Luigi SALMASO  
Corrado IACO  
Biagio SIMONETTI  
a Maria PAGANONI  
ROCCA MICHELE  
Alessio POLLICE  
Isabella MORLINI  
Pierpaolo DURSO  
Andrea TANCREDI  
Simone BORRA  
Brunero LISEO  
Francesca DIORIO  
enico LE OGRENDE  
alessandra SALVAN  
Mallide TREVISANI  
Piero VERRONESE  
nra DALLA VALLE  
Claudia FURLAN  
Onetta NICOLIS  
ianfranco ADIMARI  
Roberto FONTANA  
ommaso MINERVA  
ianile DE MARTINI  
Sandra FORTINI  
eonardo MARILLI  
Emanuele TAFFER  
Adriana BRIGGINI

Andrea SCAGNI  
Paola GIACOMELLO  
Andrea MARTINELLI  
Giuseppe BALSAMO  
Mauro GASPARINI  
Francesca BRUNO  
Giovanni Maria GIORGI GIOVANNI  
Dante MAZZITELLI  
Valeria CAVIEZEL  
Simona Caterina MINOTTI  
Roberto FONTANA  
Tommaso MINERVA  
Lea PETRELLA  
Gianfranco ADIMARI  
Orietta NICOLIS  
Walter MAFFENINI  
Alessandra DALLA VALLE  
Mauro COLI MAURO  
Matilde TREVISANI  
Germana SCEPI  
Domenico LEOPRANGE  
Francesca DI IORIO  
Brunero LISEO  
Simona BORRA  
Andrea TANCREDI  
Giuseppe BOARI  
Isabella MORLINI  
Alessia POLLICE  
Michele LA ROCCA MICHELE  
Anna Maria PAGANONI  
Biagio SIMONETTI  
Sandra DE IACO  
Corrado LAGAZIO  
Luigi SALMASO

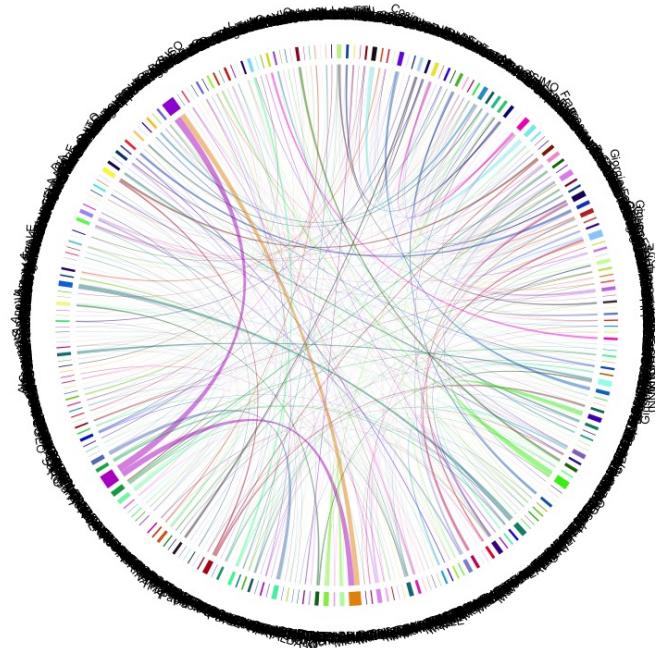
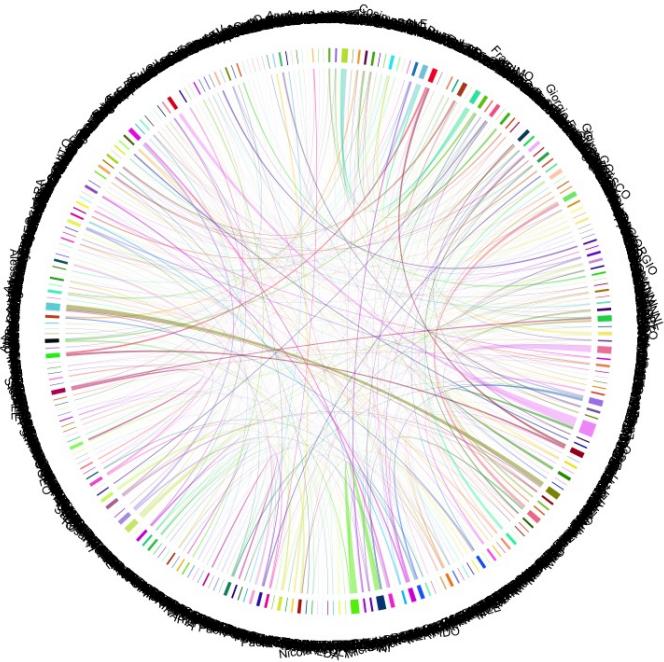
P02- heatmap plot by gender



Sandra DE IACO  
Marco RIANI  
Luigi IPPOLITI  
Fabio MANCA  
Filippo DOMMA  
Nessandra SALVAN  
Renato GUISO  
Giuseppe BOARI  
sandra PETRUCCI  
Andrea TANCREDI  
Fortunato PESARIN  
Mario ROMANAZZI  
Paolo VIDONI  
ERRARI PIERALDO  
alla ZUCCOLOTTO  
Monica CHIOGNA  
Marco MARZOZZI  
Marcello CHIODI  
Silvia GOLIA  
Giovanni LATOCARTE  
Paola MOLATRI  
atello COCCOLITO  
Icesco BERTOLINO  
Guido PEREGORI  
Pietro COFFERATI  
Enrico CORI  
Luciano NIEDDU  
a Maria PAOLONI  
Silvia BOZZA  
unzio MARAVALLE  
lia NEGRI  
o Mattia STEFANINI  
ndrea MARTINELLI

Francesco Maria SANNA  
Marco BARNABANI  
Alessia NACCARATO  
Federico Mattia STEFANINI  
Raffaella PICCARRETA  
Luciana NIEDDU  
Alessandra DURIO  
Romana GARGANO  
Alessandra AMENDOLA  
Alberto ROVERATO  
Livia DANCELLI  
Manuela CAZZARO  
Julia MORTERA  
Massimo BILANCIA  
Silvia GOLIA  
Marcello CHIODI  
Stefano CABRAS  
Roberto ROCCI  
Monica CHIOGNA  
Natale LAURO  
Alessandra DALLA VALLE  
Paola VIDONI  
Maria ROMANAZZI  
Fortunato PESARIN  
Andrea TANCREDI  
Nessandra PETRUCCI  
Giuseppe BOARI  
Riccardo GISEO  
Alessandro SALVAN  
Filippo DOMMA  
Fabio MANCA  
Luigi IPPOLITI  
Marco RIANI  
Sandra DE IACO

# Visualization



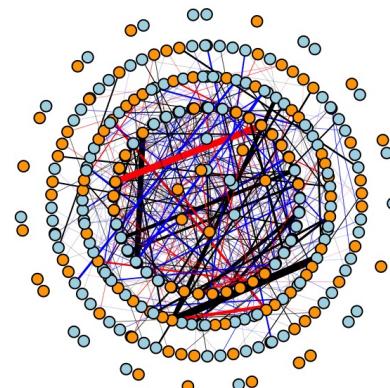
# Membership to components

|     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1   | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25  | 26 | 27 | 28 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 220 | 1  | 2  | 2  | 1  | 6  | 1  | 1  | 1  | 1  | 6  | 5  | 1  | 1  | 5  | 1  | 3  | 1  | 1  | 8  | 5  | 1  | 1  |    |
| 1   | 1  | 1  | 3  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 29  | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 |    |    |    |    |    |    |    |
| 1   | 1  | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |    |    |    |    |    |    |    |

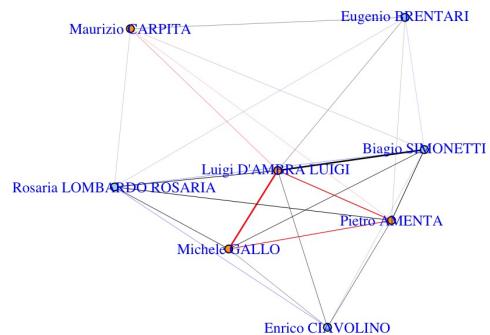
|     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--|
| 1   | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |  |
| 25  | 26 | 27 | 28 | 29 | 30 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| 219 | 2  | 1  | 4  | 3  | 1  | 1  | 2  | 1  | 7  | 1  | 2  | 1  | 2  | 1  | 1  | 2  | 1  | 2  | 3  | 1  | 1  | 1  | 1  |  |
| 1   | 1  | 1  | 4  | 2  | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| 31  | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 |  |
| 55  | 56 | 57 | 58 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |
| 1   | 1  | 1  | 1  | 1  | 2  | 1  | 1  | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |  |
| 1   | 1  | 1  | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |

# Coreness

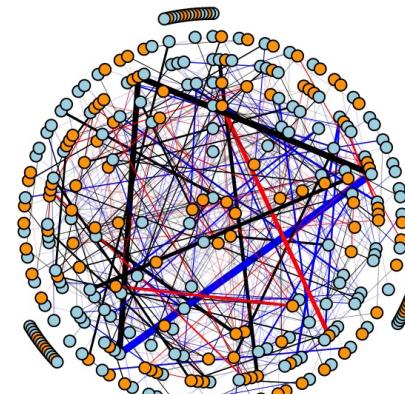
P01-Coreness



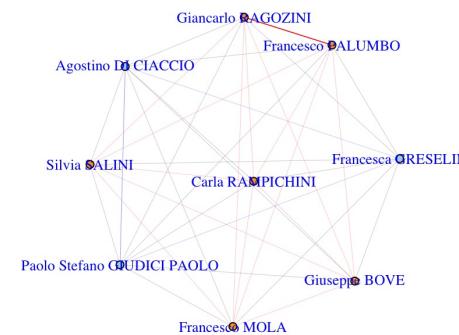
P01- Vertices having coreness 5



P02-Coreness

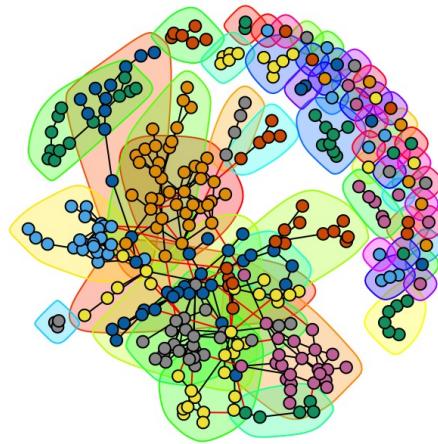


P02- Vertices having coreness 8



# Girvan- Newman Algorithm

P01- Clusters from Girvan-Newman algorithm



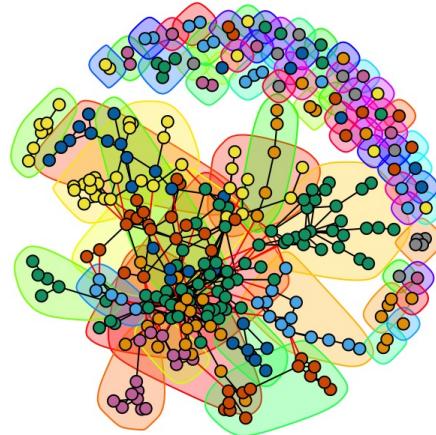
#Clusters : 59

The size of largest cluster: 25

Gini index for the largest cluster :0.48

Modularity: 0.82

P02- Clusters from Girvan-Newman algorithm



#Clusters : 73

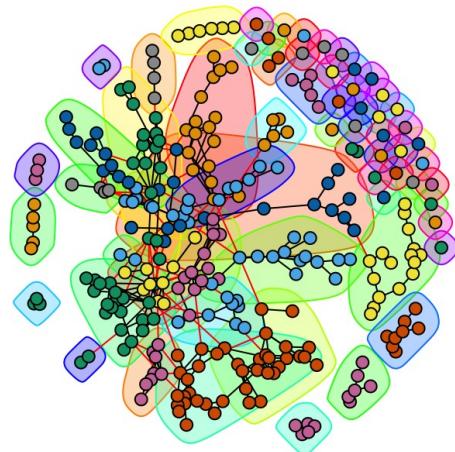
The size of largest cluster: 42

Gini index for the largest cluster :0.38

Modularity: 0.71

# Louvian Algorithm

P01- Clusters from Louvain algorithm



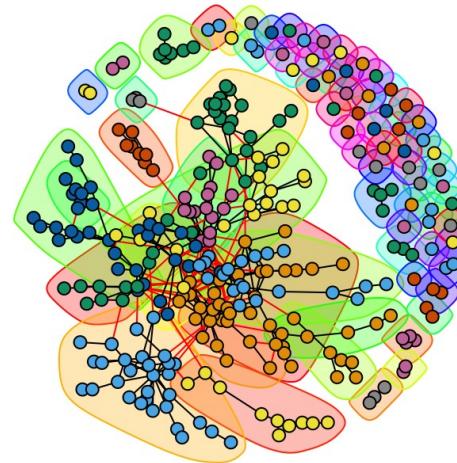
#Clusters : 64

The size of largest cluster: 20

Gini index for the largest cluster :0.44

Modularity: 0.8

P02- Clusters from Louvain algorithm



#Clusters : 74

The size of largest cluster: 31

Gini index for the largest cluster :0.35

Modularity: 0.68

# P01- Intra-cluster Density

```
[1] "Intra cluster density for Girvan-Newman algorithm algorithm:"  
[1] 0.1541502      NaN 1.0000000 0.2051282 0.1666667 1.0000000 0.1775362 0.5000000      NaN 0.1688312 0.3333333  
[12]      NaN 0.1789474 0.1904762      NaN      NaN 0.1470588      NaN 0.2051282 0.1750000      NaN 0.4000000  
[23] 0.4000000 0.1966667      NaN      NaN 0.5000000 0.8000000 0.4000000 0.5000000      NaN 1.0000000      NaN  
[34]      NaN 0.4285714 0.4000000      NaN      NaN      NaN      NaN 0.6666667      NaN      NaN  
[45] 1.0000000      NaN      NaN      NaN      NaN      NaN      NaN      NaN      NaN      NaN      NaN  
[56]      NaN      NaN      NaN      NaN  
[1] 0.009654404  
  
[1] "Intra cluster density for Louvian algorithm:"  
[1] 0.1764706      NaN 1.0000000 0.3333333 0.1523810 1.0000000 0.6071429 0.5000000      NaN 0.4722222 0.2083333  
[12] 0.3333333      NaN 0.1929825 0.2692308      NaN      NaN 0.1758242      NaN 0.1583333 0.2181818      NaN  
[23] 0.4000000 0.6666667 0.4000000 1.0000000 0.2631579      NaN      NaN 0.1736842 0.8000000      NaN 0.5000000  
[34] 0.3571429 1.0000000      NaN      NaN 0.4285714 0.4000000      NaN      NaN 0.2857143 1.0000000      NaN  
[45]      NaN      NaN 0.6666667      NaN      NaN 1.0000000      NaN      NaN      NaN      NaN      NaN  
[56]      NaN      NaN      NaN      NaN      NaN      NaN      NaN      NaN      NaN      NaN  
[1] 0.009654404
```

# P02- Intra-cluster Density

```
[1] "Intra cluster density for Girvan-Newman algorithm algorithm:"  
[1] 0.1895425 1.0000000 0.1324042 0.2222222 0.2222222      NaN 0.3888889 1.0000000 0.6666667 0.1794872 0.1168091  
[12] 0.1947368      NaN 0.1526316 0.6000000      NaN 1.0000000      NaN 0.3333333 0.4285714 0.2500000      NaN  
[23] 1.0000000      NaN 0.4000000 1.0000000      NaN      NaN 0.4285714 0.2307692 1.0000000      NaN 1.0000000  
[34] 0.6666667      NaN      NaN      NaN      NaN      NaN      NaN 0.6000000 0.5000000 1.0000000  
[45]      NaN      NaN      NaN      NaN 1.0000000      NaN      NaN      NaN 1.0000000      NaN  
[56]      NaN      NaN  
[67]      NaN      NaN      NaN      NaN      NaN      NaN      NaN  
[1] 0.01021041
```

```
[1] "Intra cluster density for Louvian algorithm:"  
[1] 0.1139785 1.0000000 0.2575758 0.2222222      NaN 0.4642857 1.0000000 0.6666667 0.2163743 0.1111111 0.1774892  
[12]      NaN 0.3333333      NaN 1.0000000      NaN 0.3333333 0.4285714 0.1568627 0.1666667      NaN 1.0000000  
[23]      NaN 0.4000000 1.0000000      NaN      NaN 0.3809524 0.4761905 1.0000000 0.2095238 1.0000000      NaN  
[34] 1.0000000 0.6666667      NaN      NaN 1.0000000      NaN      NaN      NaN      NaN      NaN 0.5000000  
[45] 1.0000000      NaN      NaN      NaN      NaN 1.0000000      NaN      NaN      NaN 1.0000000  
[56]      NaN      NaN  
[67]      NaN      NaN      NaN      NaN      NaN      NaN      NaN      NaN  
[1] 0.01021041
```

# Clique Percolation- Weighted

K= 5

```
$`1`  
[1] 40 82 85 171 209 215 249 266
```

```
$`2`  
[1] 83 85 126 171 209 210  
  
[1] 85 171 209
```

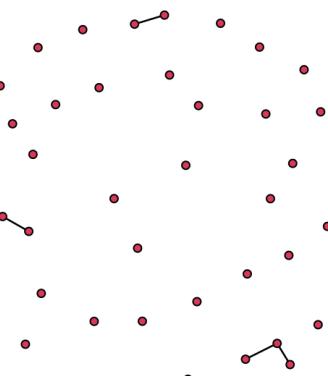
K= 7

```
$`1`  
[1] 3 45 102 112 113 122 139 242 282
```

```
$`2`  
[1] 1 3 67 106 135 215 249  
  
[1] 3
```

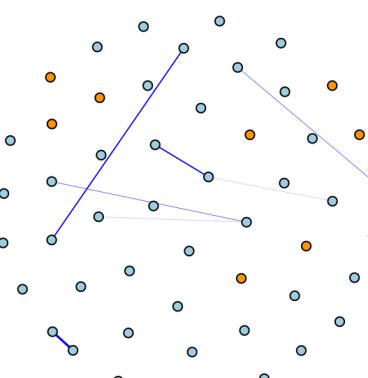
# ERGM

P01- Sub-network for ERGM

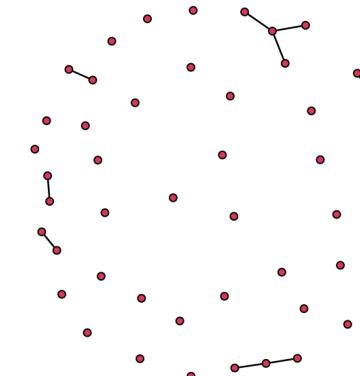


51 nodes  
7 edges

P01- Sub-graph for ERGM

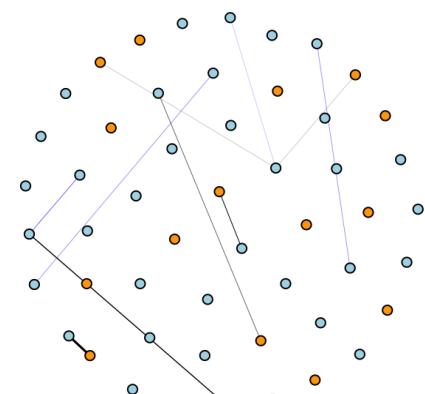


P02- Sub-network for ERGM



51 nodes  
10 edges

P02- Sub-graph for ERGM



# Model 00 (Base Model)

```
Call:  
ergm(formula = ergm_induced_net ~ edges)
```

Maximum Likelihood Results:

|       | Estimate | Std. Error | MCMC % | z value | Pr(> z )   |
|-------|----------|------------|--------|---------|------------|
| edges | -5.199   | 0.379      | 0      | -13.72  | <1e-04 *** |
| ---   |          |            |        |         |            |

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Null Deviance: 1767.53 on 1275 degrees of freedom  
Residual Deviance: 86.83 on 1274 degrees of freedom

AIC: 88.83 BIC: 93.98 (Smaller is better. MC Std. Err. = 0)

```
[1] "The probability of activating a tie randomly:"  
edges  
0.005490196  
[1] "Graph density:"  
[1] 0.005490196
```

```
Call:  
ergm(formula = ergm_induced_net ~ edges)
```

Maximum Likelihood Results:

|       | Estimate | Std. Error | MCMC % | z value | Pr(> z )   |
|-------|----------|------------|--------|---------|------------|
| edges | -5.199   | 0.379      | 0      | -13.72  | <1e-04 *** |
| ---   |          |            |        |         |            |

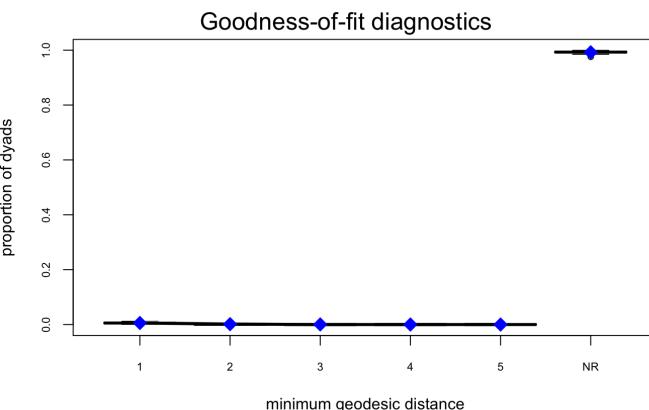
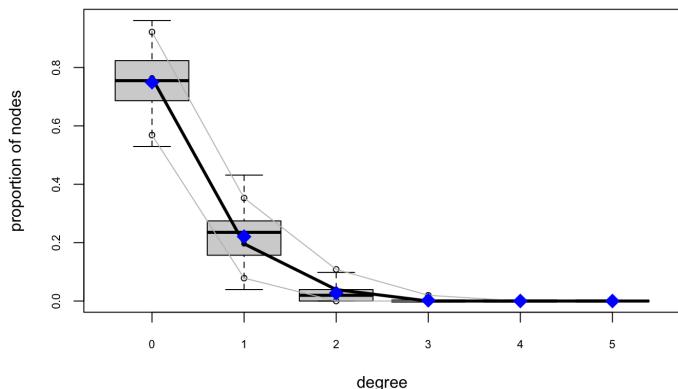
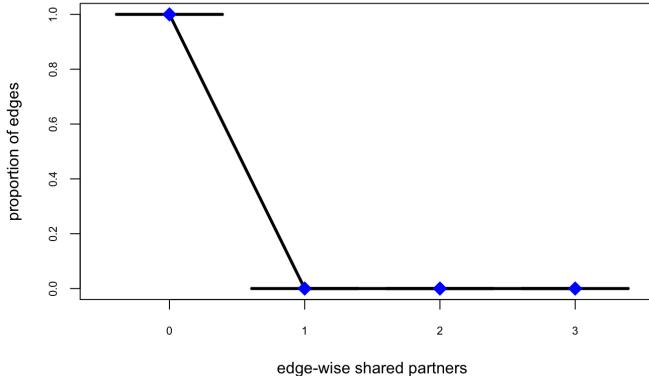
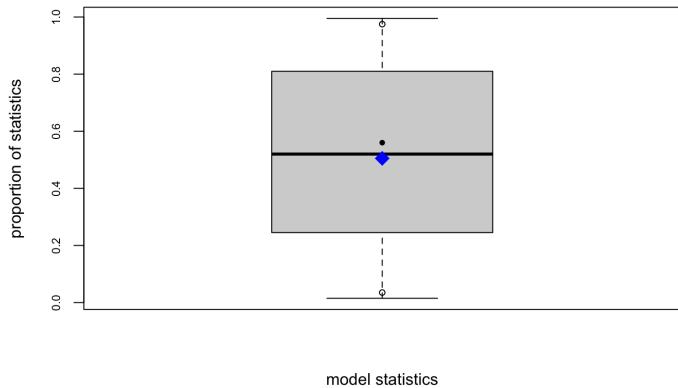
Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Null Deviance: 1767.53 on 1275 degrees of freedom  
Residual Deviance: 86.83 on 1274 degrees of freedom

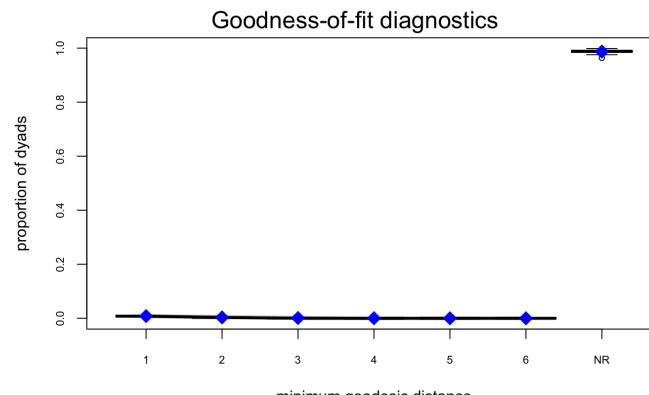
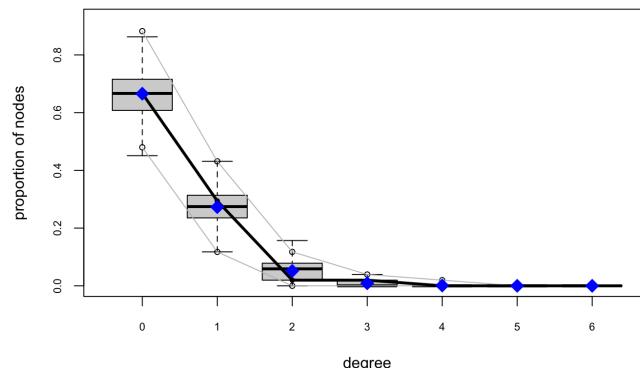
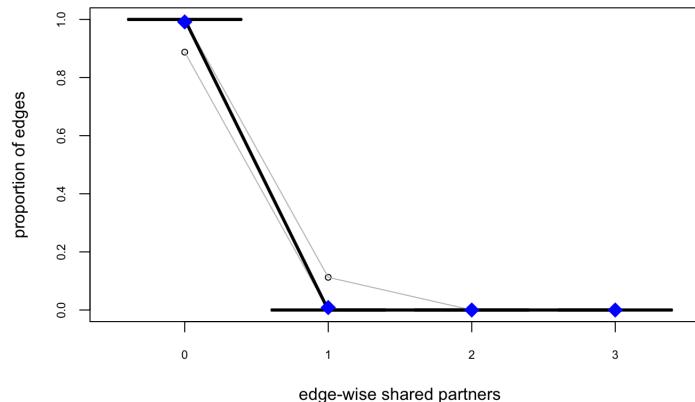
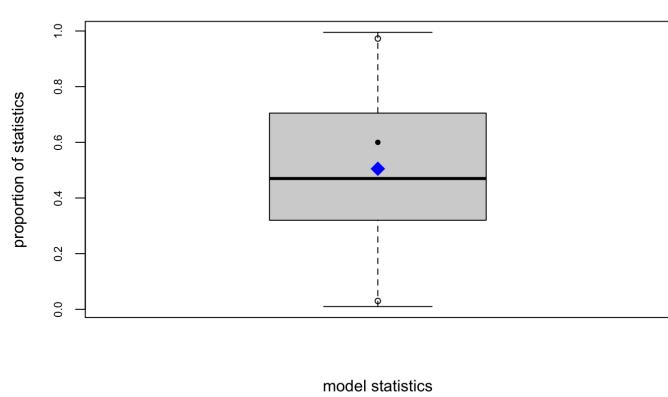
AIC: 88.83 BIC: 93.98 (Smaller is better. MC Std. Err. = 0)

```
[1] "The probability of activating a tie randomly:"  
edges  
0.005490196  
[1] "Graph density:"  
[1] 0.005490196
```

# P01- Model 00 - GOF



# P02- Model 00 - GOF



# Model 01

```
Call:  
ergm(formula = ergm_induced_net ~ edges + triangle)
```

Monte Carlo Maximum Likelihood Results:

|          | Estimate | Std. Error | MCMC % | z value | Pr(> z )   |
|----------|----------|------------|--------|---------|------------|
| edges    | -5.1903  | 0.4262     | 0      | -12.18  | <1e-04 *** |
| triangle | -Inf     | 0.0000     | 0      | -Inf    | <1e-04 *** |
| ---      |          |            |        |         |            |

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Warning: The following terms have infinite coefficient estimates:  
triangle  
Time difference of 0.198561 secs

```
[1] "The probability of activating a tie randomly:"  
edges  
0.005539657  
[1] "The probability of activating a tie that creates a triangle:"  
edges  
0
```

```
Call:  
ergm(formula = ergm_induced_net ~ edges + triangle)
```

Monte Carlo Maximum Likelihood Results:

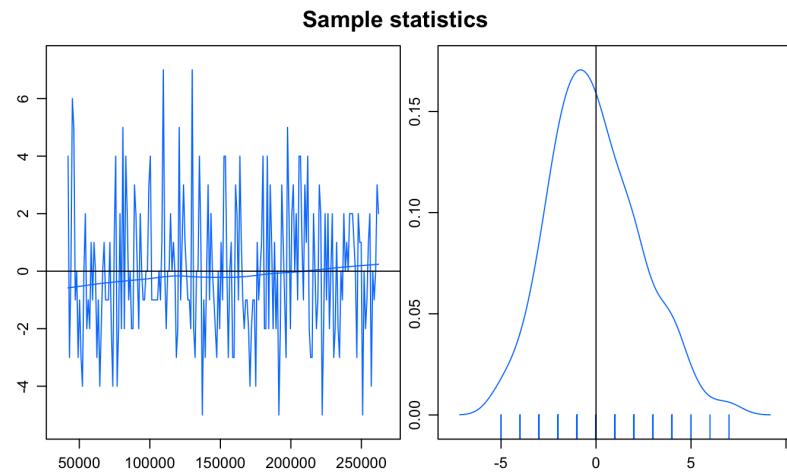
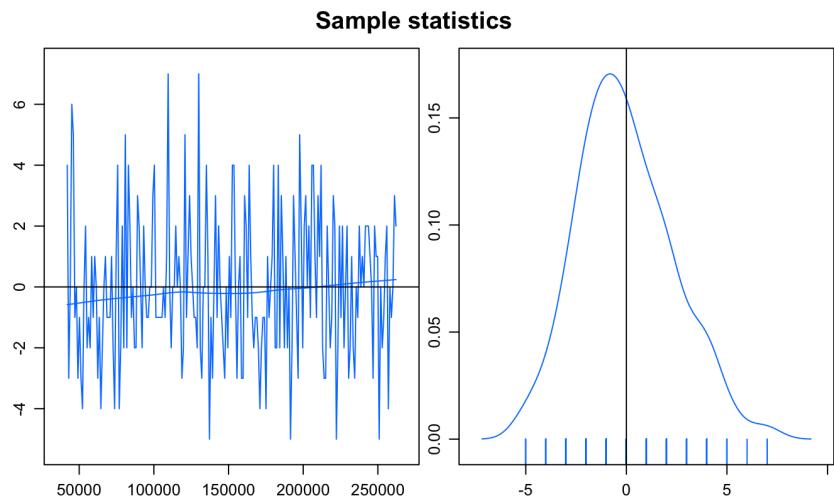
|          | Estimate | Std. Error | MCMC % | z value | Pr(> z )   |
|----------|----------|------------|--------|---------|------------|
| edges    | -4.8375  | 0.3194     | 0      | -15.15  | <1e-04 *** |
| triangle | -Inf     | 0.0000     | 0      | -Inf    | <1e-04 *** |
| ---      |          |            |        |         |            |

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

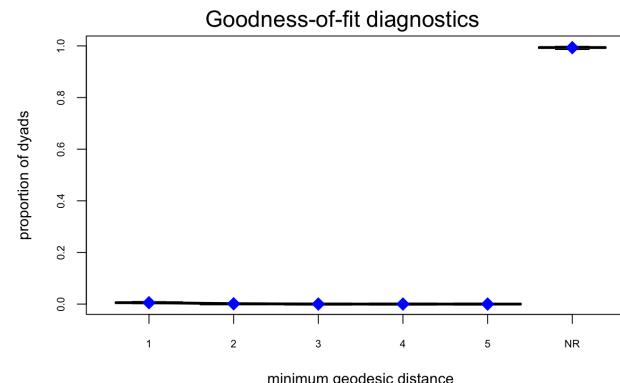
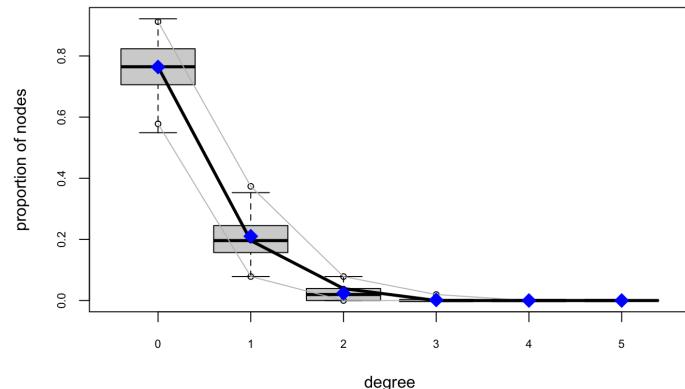
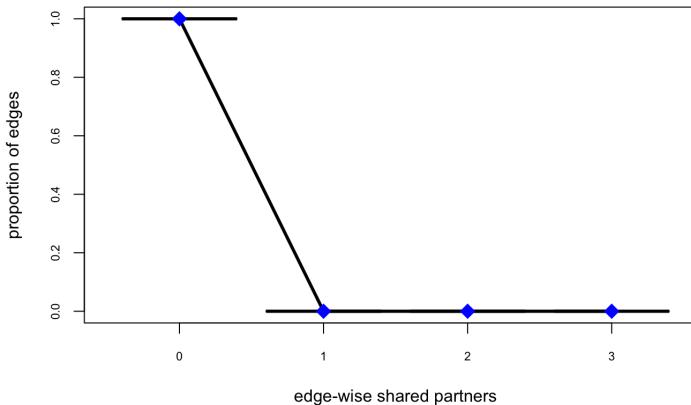
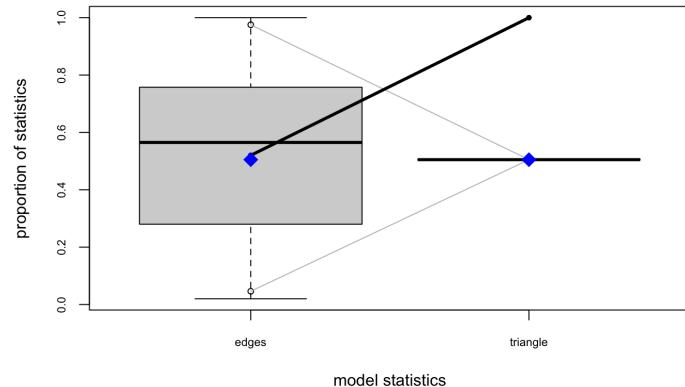
Warning: The following terms have infinite coefficient estimates:  
triangle  
Time difference of 0.279566 secs

```
[1] "The probability of activating a tie randomly:"  
edges  
0.005539657  
[1] "The probability of activating a tie that creates a triangle:"  
edges  
0
```

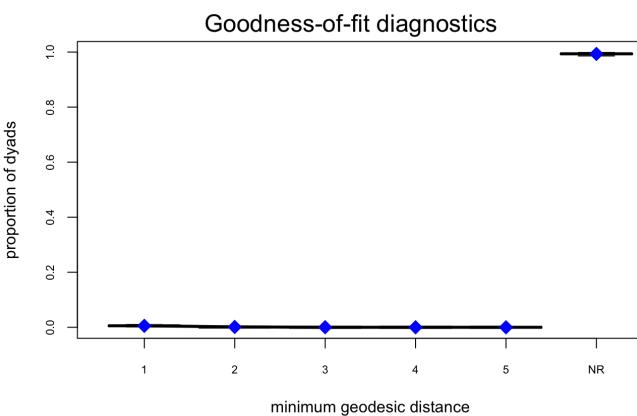
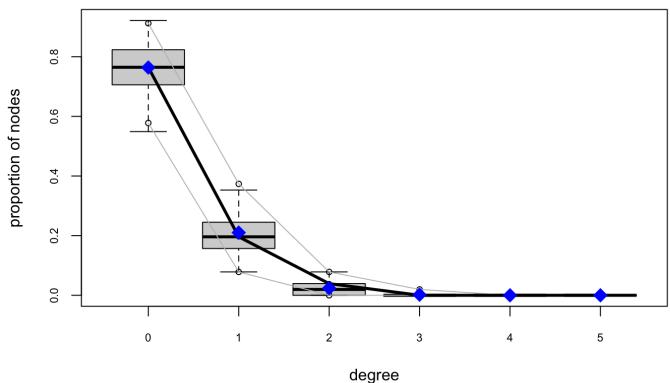
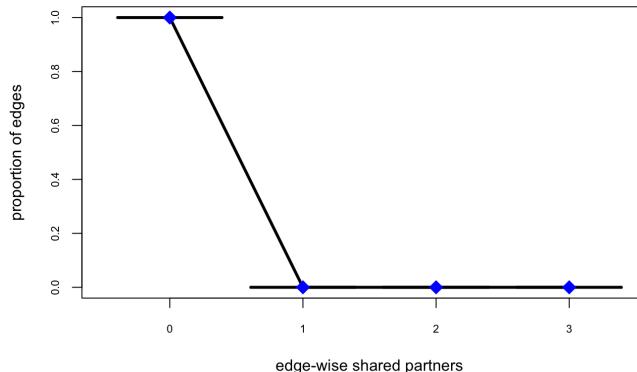
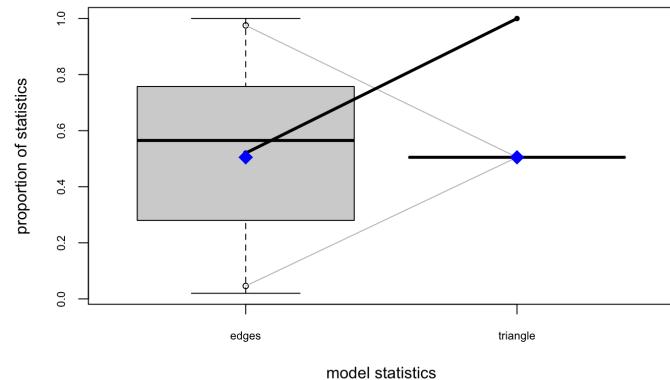
# Model 01- MCMC



# P01- Model 01 - GOF



# P02- Model 01 - GOF



# Model 02

```
Call:  
ergm(formula = ergm_induced_net ~ edges + gwesp)
```

Monte Carlo Maximum Likelihood Results:

|                | Estimate | Std. Error | MCMC % | z value | Pr(> z )   |     |      |      |     |     |   |
|----------------|----------|------------|--------|---------|------------|-----|------|------|-----|-----|---|
| edges          | -5.2181  | 0.3983     | 0      | -13.1   | <1e-04 *** |     |      |      |     |     |   |
| gwesp          | -0.4596  | NA         | NA     | NA      | NA         |     |      |      |     |     |   |
| gwesp.decay    | 326.2884 | NA         | NA     | NA      | NA         |     |      |      |     |     |   |
| ---            |          |            |        |         |            |     |      |      |     |     |   |
| Signif. codes: | 0        | '***'      | 0.001  | '**'    | 0.01       | '*' | 0.05 | '. ' | 0.1 | ' ' | 1 |

Null Deviance: 1767.53 on 1275 degrees of freedom

Residual Deviance: 86.83 on 1272 degrees of freedom

AIC: 92.83 BIC: 108.3 (Smaller is better. MC Std. Err. = 0.001968)

Time difference of 0.2386229 secs

```
[1] "The probability of activating a tie randomly:"  
edges  
0.005388575  
[1] "The probability considering 2 coefficients:"  
edges  
0.003409888  
[1] "The probability considering 3 coefficients:"  
edges  
1
```

```
Call:  
ergm(formula = ergm_induced_net ~ edges + gwesp)
```

Monte Carlo Maximum Likelihood Results:

|                | Estimate | Std. Error | MCMC % | z value | Pr(> z )   |     |      |      |     |     |   |
|----------------|----------|------------|--------|---------|------------|-----|------|------|-----|-----|---|
| edges          | -5.2181  | 0.3983     | 0      | -13.1   | <1e-04 *** |     |      |      |     |     |   |
| gwesp          | -0.4596  | NA         | NA     | NA      | NA         |     |      |      |     |     |   |
| gwesp.decay    | 326.2884 | NA         | NA     | NA      | NA         |     |      |      |     |     |   |
| ---            |          |            |        |         |            |     |      |      |     |     |   |
| Signif. codes: | 0        | '***'      | 0.001  | '**'    | 0.01       | '*' | 0.05 | '. ' | 0.1 | ' ' | 1 |

Null Deviance: 1767.53 on 1275 degrees of freedom

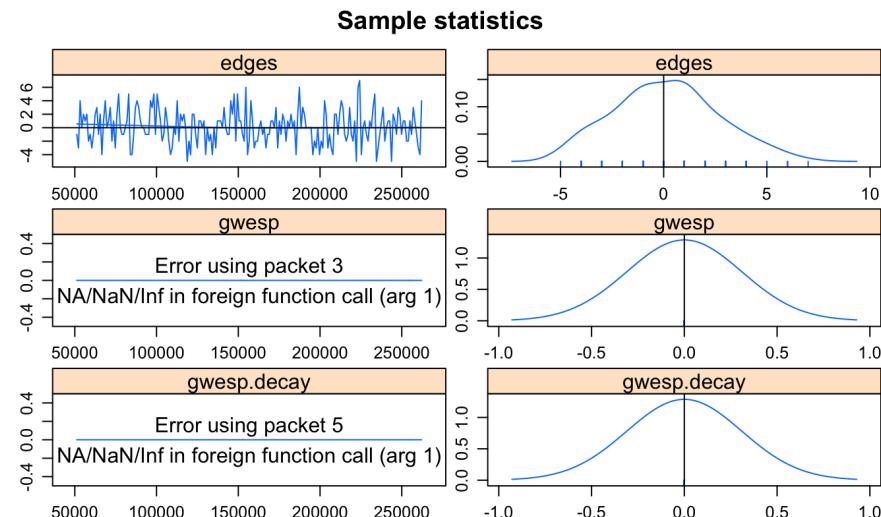
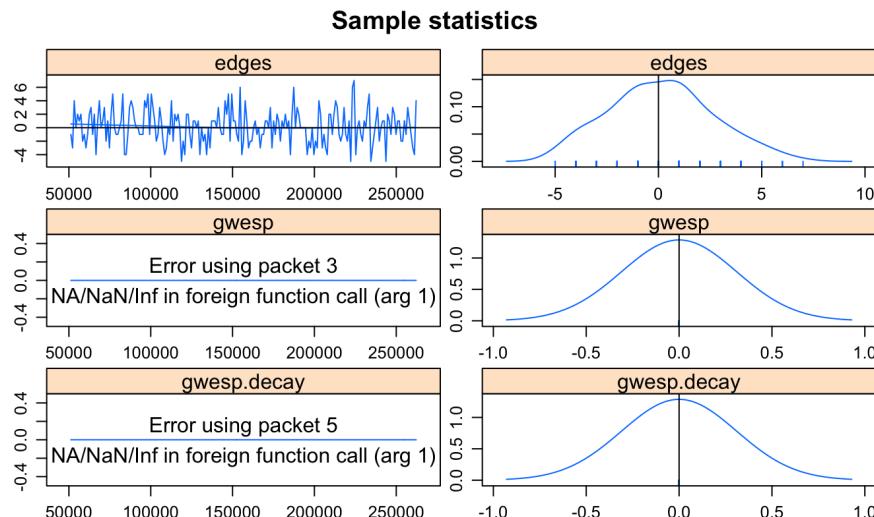
Residual Deviance: 86.83 on 1272 degrees of freedom

AIC: 92.83 BIC: 108.3 (Smaller is better. MC Std. Err. = 0.001968)

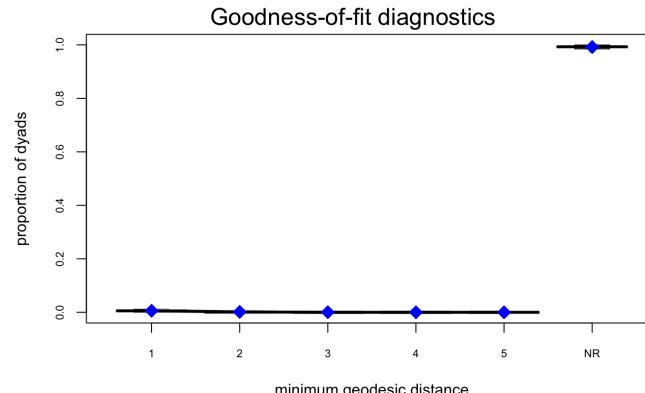
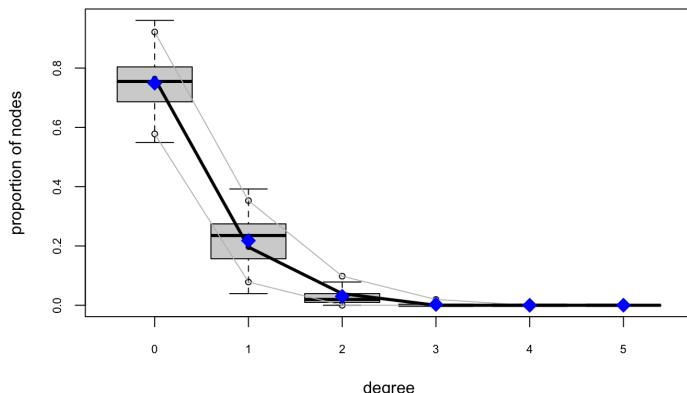
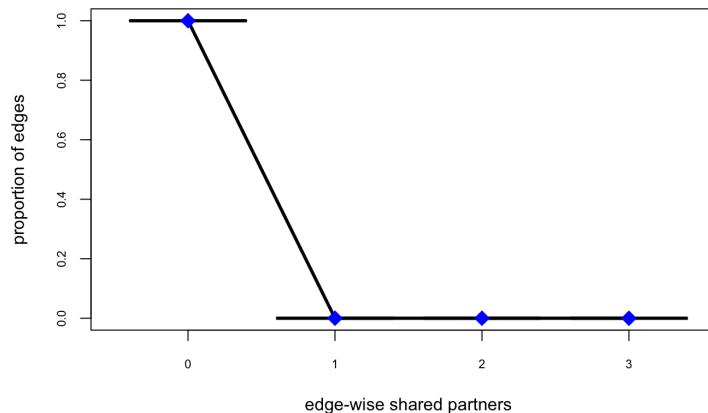
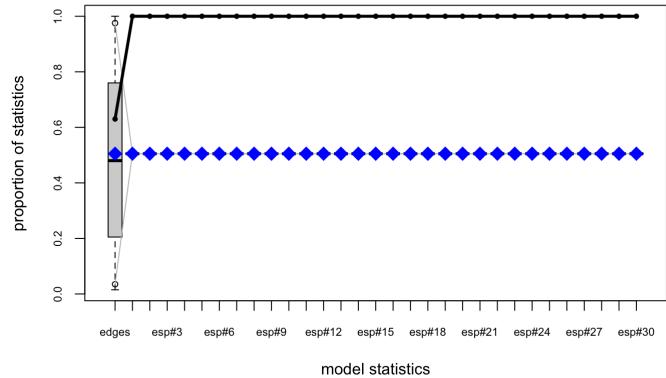
Time difference of 0.2531891 secs

```
[1] "The probability of activating a tie randomly:"  
edges  
0.005388575  
[1] "The probability considering 2 coefficients:"  
edges  
0.003409888  
[1] "The probability considering 3 coefficients:"  
edges  
1
```

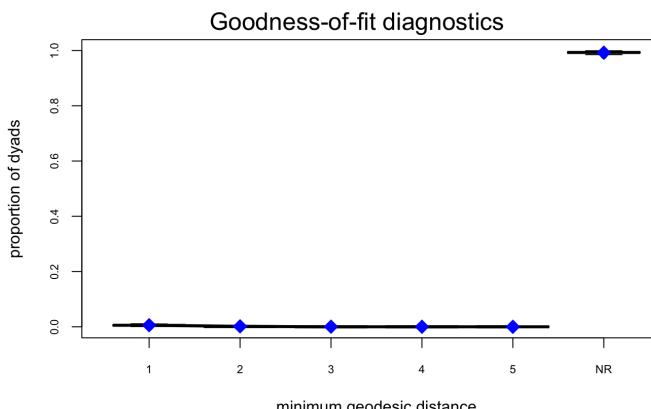
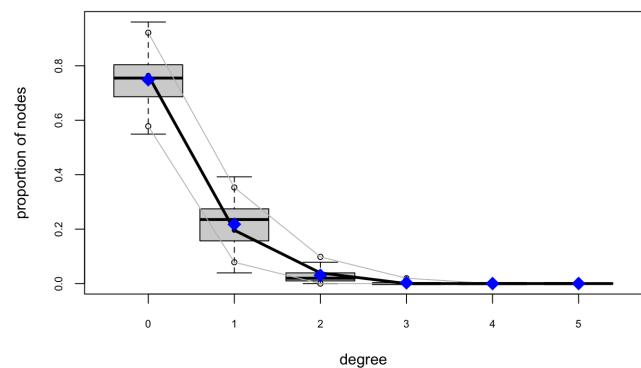
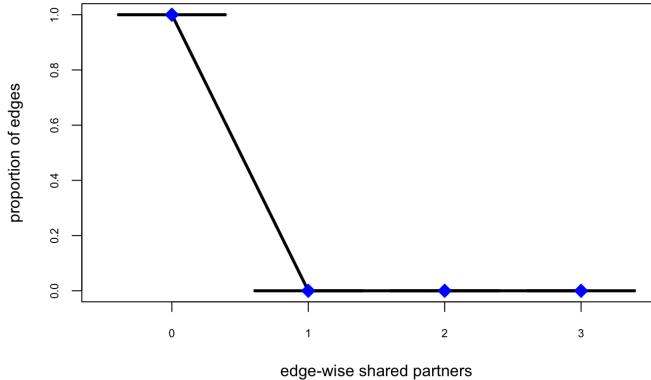
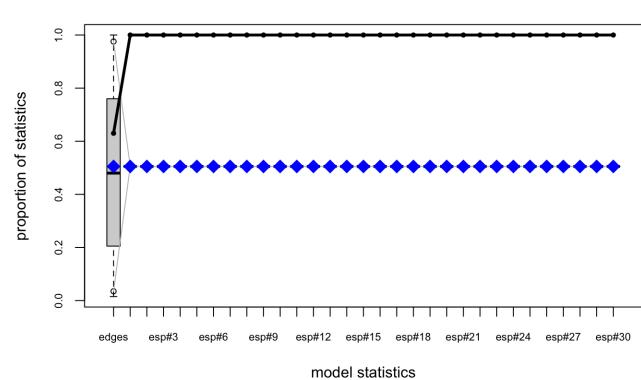
# Model 02 - MCMC



# P01 – Model 02 - GOF



# P02 – Model 02 - GOF



# Model 03

```
Call:  
ergm(formula = ergm_induced_net ~ edges + gwdegree)
```

Monte Carlo Maximum Likelihood Results:

|                | Estimate   | Std. Error | MCMC % | z value | Pr(> z ) |
|----------------|------------|------------|--------|---------|----------|
| edges          | -4.748e+00 | 4.218e+00  | 0      | -1.126  | 0.260    |
| gwdegree       | -3.173e-01 | 2.147e+00  | 0      | -0.148  | 0.883    |
| gwdegree.decay | 8.770e-19  | 7.868e+00  | 0      | 0.000   | 1.000    |

Null Deviance: 1767.53 on 1275 degrees of freedom  
Residual Deviance: 86.79 on 1272 degrees of freedom

AIC: 92.79 BIC: 108.2 (Smaller is better. MC Std. Err. = 0.0003566)  
Time difference of 20.4161 mins

```
Call:  
ergm(formula = ergm_induced_net ~ edges + gwdegree)
```

Monte Carlo Maximum Likelihood Results:

|                | Estimate   | Std. Error | MCMC % | z value | Pr(> z ) |
|----------------|------------|------------|--------|---------|----------|
| edges          | -4.748e+00 | 4.218e+00  | 0      | -1.126  | 0.260    |
| gwdegree       | -3.173e-01 | 2.147e+00  | 0      | -0.148  | 0.883    |
| gwdegree.decay | 8.770e-19  | 7.868e+00  | 0      | 0.000   | 1.000    |

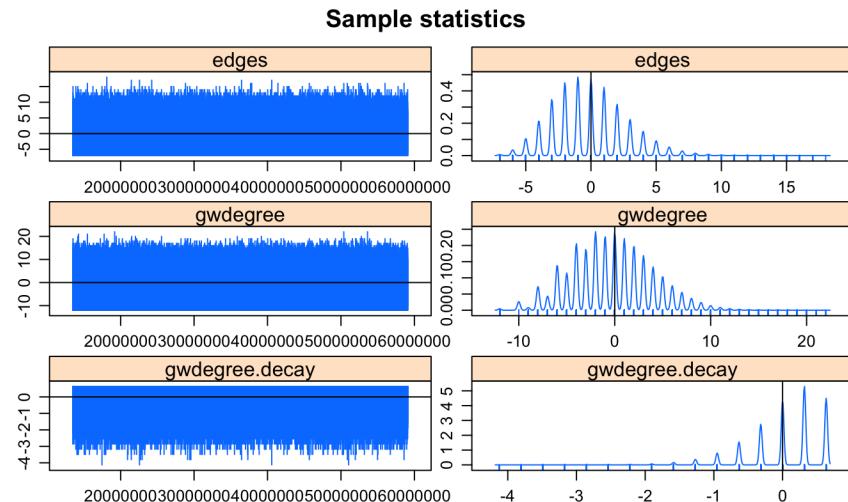
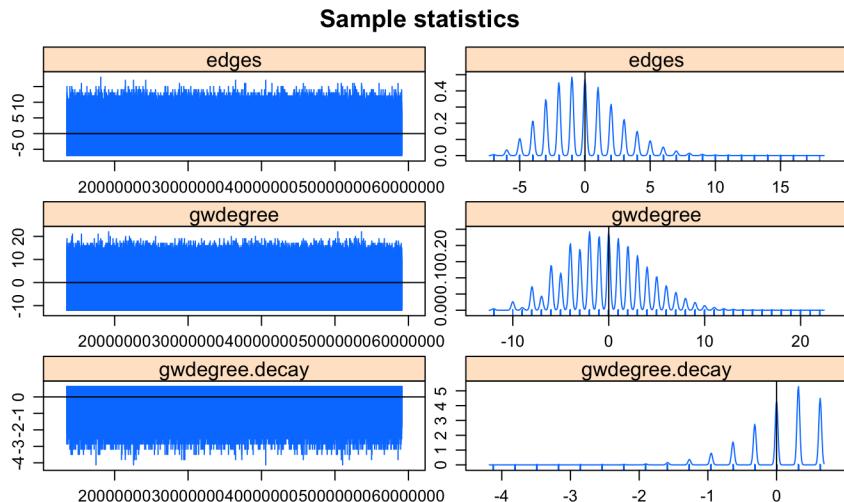
Null Deviance: 1767.53 on 1275 degrees of freedom  
Residual Deviance: 86.79 on 1272 degrees of freedom

AIC: 92.79 BIC: 108.2 (Smaller is better. MC Std. Err. = 0.0003566)  
Time difference of 20.10172 mins

```
[1] "The probability of activating a tie randomly:"  
edges  
0.008596781  
[1] "The probability considering 2 coefficients:"  
edges  
0.006274203  
[1] "The probability considering 3 coefficients:"  
edges  
0.006274203
```

```
[1] "The probability of activating a tie randomly:"  
edges  
0.008596781  
[1] "The probability considering 2 coefficients:"  
edges  
0.006274203  
[1] "The probability considering 3 coefficients:"  
edges  
0.006274203
```

# Model 03 - MCMC



# P01- Model 04

Call:

```
ergm(formula = ergm_induced_net ~ edges + absdiff("Academic_Age") +
  absdiff("Age") + nodematch("Role") + nodefactor("Role") +
  nodematch("University") + nodefactor("University") + nodematch("Gender") +
  nodefactor("University") + nodematch("Faculty") + nodefactor("Faculty"))
```

Maximum Likelihood Results:

|   | Estimate | Std. Error | MCMC % | z value | Pr(> z )   |
|---|----------|------------|--------|---------|------------|
| edges                                   | -17.3680 | 1433.4036  | 0      | -0.012  | 0.990      |
| absdiff.Academic_Age                    | 1.6854   | 164.4588   | 0      | 0.010   | 0.992      |
| absdiff.Age                             | -1.4261  | 139.1574   | 0      | -0.010  | 0.992      |
| nodematch.Role                          | 0.8019   | 1433.4036  | 0      | 0.001   | 1.000      |
| nodefactor.Role.P0                      | 6.1111   | 1199.7725  | 0      | 0.005   | 0.996      |
| nodefactor.Role.RU                      | -Inf     | 0.0000     | 0      | -Inf    | <1e-04 *** |
| nodematch.University                    | NA       | 0.0000     | 0      | NA      | NA         |
| nodefactor.University.Univ. FIRENZE     | NA       | 0.0000     | 0      | NA      | NA         |
| nodefactor.University.Univ. PALERMO     | -Inf     | 0.0000     | 0      | -Inf    | <1e-04 *** |
| nodefactor.University.Univ. ROMA TRE    | -Inf     | 0.0000     | 0      | -Inf    | <1e-04 *** |
| nodefactor.University.Univ. SIENA       | -0.4463  | 0.6156     | 0      | -0.725  | 0.468      |
| nodematch.Gender                        | NA       | 0.0000     | 0      | NA      | NA         |
| nodefactor.University.Univ. FIRENZE     | NA       | 0.0000     | 0      | NA      | NA         |
| nodefactor.University.Univ. PALERMO     | -Inf     | 0.0000     | 0      | -Inf    | <1e-04 *** |
| nodefactor.University.Univ. ROMA TRE    | -Inf     | 0.0000     | 0      | -Inf    | <1e-04 *** |
| nodefactor.University.Univ. SIENA       | NA       | 0.0000     | 0      | NA      | NA         |
| nodematch.Faculty                       | NA       | 0.0000     | 0      | NA      | NA         |
| nodefactor.Faculty.SC. POL. SOC. e COM. | NA       | 0.0000     | 0      | NA      | NA         |

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Null Deviance: 1767.5 on 1275 degrees of freedom

Residual Deviance: 594.6 on 1257 degrees of freedom

AIC: 620.6 BIC: 687.6 (Smaller is better. MC Std. Err. = 0)

Warning: The following terms have infinite coefficient estimates:

nodefactor.Role.RU nodefactor.University.Univ. PALERMO nodefactor.University.Univ. ROMA TRE nodefactor.University.Univ. PALERMO nodefactor.University.Univ. ROMA TRE

Time difference of 0.09449601 secs

# P02- Model 04

Call:

```
ergm(formula = ergm_induced_net ~ edges + absdiff("Academic_Age") +
  absdiff("Age") + nodematch("Role") + nodefactor("Role") +
  nodematch("University") + nodefactor("University") + nodematch("Gender") +
  nodefactor("University") + nodematch("Faculty") + nodefactor("Faculty"))
```

Maximum Likelihood Results:

|   | Estimate  | Std. Error | MCMC % | z value | Pr(> z ) |
|---|-----------|------------|--------|---------|----------|
| edges                                   | 13.18257  | 1558.52155 | 0      | 0.008   | 0.993    |
| absdiff.Academic_Age                    | -0.03619  | 0.08485    | 0      | -0.426  | 0.670    |
| absdiff.Age                             | 0.10054   | 0.11288    | 0      | 0.891   | 0.373    |
| nodematch.Role                          | -0.06042  | 1.84836    | 0      | -0.033  | 0.974    |
| nodefactor.Role.PO                      | -9.39181  | 1057.22466 | 0      | -0.009  | 0.993    |
| nodefactor.Role.RU                      | -17.55876 | 1558.52201 | 0      | -0.011  | 0.991    |
| nodematch.University                    | 2.62427   | 2.57167    | 0      | 1.020   | 0.308    |
| nodefactor.University.Univ. FIRENZE     | NA        | 0.00000    | 0      | NA      | NA       |
| nodefactor.University.Univ. PERUGIA     | 8.44591   | 1057.22491 | 0      | 0.008   | 0.994    |
| nodefactor.University.Univ. ROMA TRE    | 1.91725   | 1558.52168 | 0      | 0.001   | 0.999    |
| nodefactor.University.Univ. SIENA       | 8.74257   | 1057.22537 | 0      | 0.008   | 0.993    |
| nodematch.Gender                        | -8.57674  | 1145.10488 | 0      | -0.007  | 0.994    |
| nodefactor.University.Univ. FIRENZE     | NA        | 0.00000    | 0      | NA      | NA       |
| nodefactor.University.Univ. PERUGIA     | NA        | 0.00000    | 0      | NA      | NA       |
| nodefactor.University.Univ. ROMA TRE    | NA        | 0.00000    | 0      | NA      | NA       |
| nodefactor.University.Univ. SIENA       | NA        | 0.00000    | 0      | NA      | NA       |
| nodematch.Faculty                       | -10.61415 | 1057.22548 | 0      | -0.010  | 0.992    |
| nodefactor.Faculty.SC. POL. SOC. e COM. | NA        | 0.00000    | 0      | NA      | NA       |

Null Deviance: 1767.5 on 1275 degrees of freedom

Residual Deviance: 104.9 on 1257 degrees of freedom

AIC: 140.9 BIC: 233.6 (Smaller is better. MC Std. Err. = 0)

Time difference of 0.1597149 secs

# Model 04

```
[1] "The probability of activating a tie randomly:"  
edges  
2.865302e-08  
[1] "The probability considering 2 coefficients:"  
edges  
1.545716e-07  
[1] "The probability considering 3 coefficients:"  
edges  
3.713426e-08
```

```
[1] "The probability of activating a tie randomly:"  
edges  
0.9999981  
[1] "The probability considering 2 coefficients:"  
edges  
0.999998  
[1] "The probability considering 3 coefficients:"  
edges  
0.9999982
```

Thank you for your attention!

---