Analysis of VoC data

Look at data provided to SPI-M on the B.1.351 VoC.

Data file not included in the repo, so change path if running independently.

This version:

- Data is that provided on 7 May
- Be clearer about travel versus non - London non-travel seems to have consistent exp.
- Be clearer about exponential versus constant
- Clearer labels of calendar dates

Note that linkage to the linelist on finalid should be possible.

In [1]:

```
%matplotlib inline
import numpy as np
import scipy.stats as st
import scipy.special as sp
import matplotlib.pyplot as plt
import pandas as pd
import datetime
import scipy.optimize as op
from numpy import linalg as LA
```

In [2]:

```
df = pd.read_excel(
    '/Volumes/COVID19_Epi_modelling/DstlDailyData/2021-05-07/VOC202012_02_linelist_2
    sheet_name=1,
)
df.dropna(subset=['earliest_specimen_date'],inplace=True)
```

In [3]:

```
def todays(x):
    return np.array((pd.to_datetime(x['earliest_specimen_date'], format='%Y-%m-%d')
```

In [4]:

```
monthstarts = pd.DataFrame([
    '2020-10-01','2020-11-01','2020-12-01','2021-01-01','2021-02-01','2021-03-01','2
],columns=['earliest_specimen_date'])
monthstarts
```

Out[4]:

	earliest_specimen_date
0	2020-10-01
1	2020-11-01
2	2020-12-01
3	2021-01-01
4	2021-02-01
5	2021-03-01
6	2021-04-01
7	2021-05-01

In [5]:

```
def tods(x):
    return pd.to_datetime(x['earliest_specimen_date'], format='%Y-%m-%d').dt.strftim
```

In [6]:

```
keydates = pd.DataFrame([
    ['2021-01-01','Start of 2021'],
    ['2021-03-08','Roadmap Start'],
    ['2021-04-30','Sequence Delay'],
],columns=['earliest_specimen_date','date_name'])
keydates
```

Out[6]:

	earliest_specimen_date	date_name
0	2021-01-01	Start of 2021
1	2021-03-08	Roadmap Start
2	2021-04-30	Sequence Delay

In [7]:

```
dfr = df.groupby('PHEC_name').apply(todays)
```

In [8]:

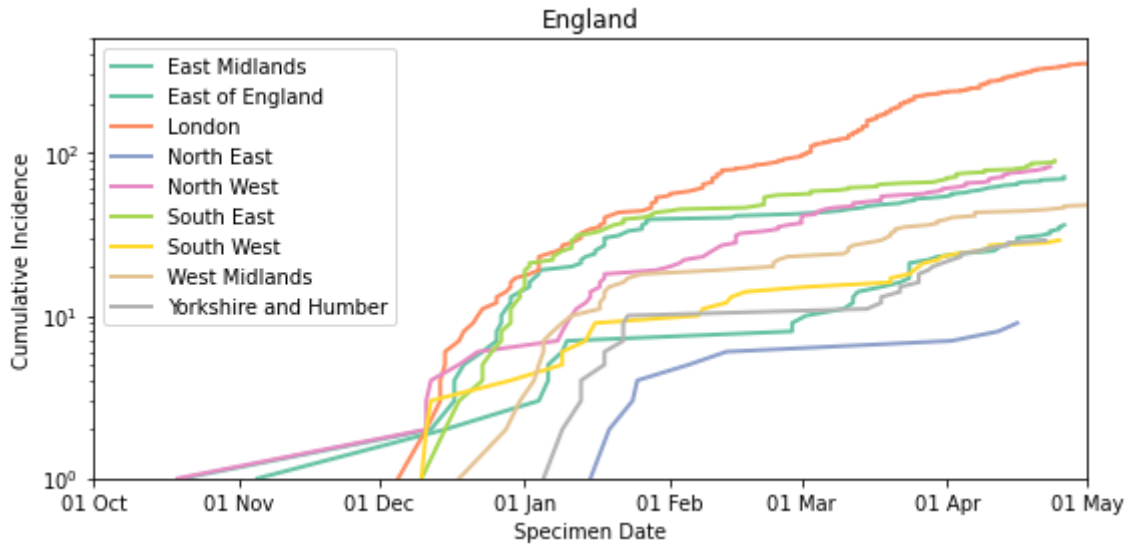
```
np.max(todays(monthstarts))
```

Out[8]:

```
212
```

In [9]:

```
lq = len(dfr.index)
cmp = plt.cm.get_cmap('Set2', lq+1)
plt.figure(figsize=(8,4))
for i in range(0,lq):
    x = dfr[i]
    plt.plot(np.sort(x),np.arange(1,len(x)+1),label=dfr.index[i], lw=2, c=cmp(i))
#for i, d in keydates.iterrows():
#    plt.plot(todays(d)*np.ones(2),np.array([0,500]),ls='--',label=d.date_name)
plt.legend()
plt.xlabel('Specimen Date')
plt.ylabel('Cumulative Incidence')
plt.xticks(todays(monthstarts),tods(monthstarts))
plt.xlim([0,212])
plt.ylim([1,500])
plt.yscale('log')
plt.title('England')
plt.tight_layout()
plt.savefig('./figures/voc_region_log.pdf')
```



In [10]:

```
# From the above, London is far largest so look at that
li = np.argwhere(dfr.index == 'London')[0]
x = dfr[li].values[0]
```

In [11]:

```
dfl = df[df.PHEC_name == 'London']
dfl.reset_index(drop=True,inplace=True)
dfl
```

Out[11]:

	finalid	specimen_date_sk	seq_result	earliest_specimen_date	PHEC_name	exposure_t
0	-3311042.0	20210502.0	Provisional Genotyping	2021-05-02	London	Awai informa
1	-3306285.0	20210428.0	Provisional Genotyping	2021-04-28	London	Awai informa
2	-3304744.0	20210501.0	Provisional Genotyping	2021-04-29	London	Awai informa
3	-3304640.0	20210428.0	Provisional Genotyping	2021-04-28	London	Awai informa
4	-3304562.0	20210501.0	Provisional Genotyping	2021-04-29	London	Awai informa
...	...	...	...	...	...	
348	1672607.0	20210416.0	Confirmed	2021-04-16	London	Awai informa
349	1672956.0	20210410.0	Confirmed	2021-04-10	London	Not tra associa
350	1673678.0	20210419.0	Confirmed	2021-04-19	London	Awai informa
351	1673679.0	20210420.0	Confirmed	2021-04-20	London	Awai informa
352	1673685.0	20210419.0	Confirmed	2021-04-19	London	Awai informa

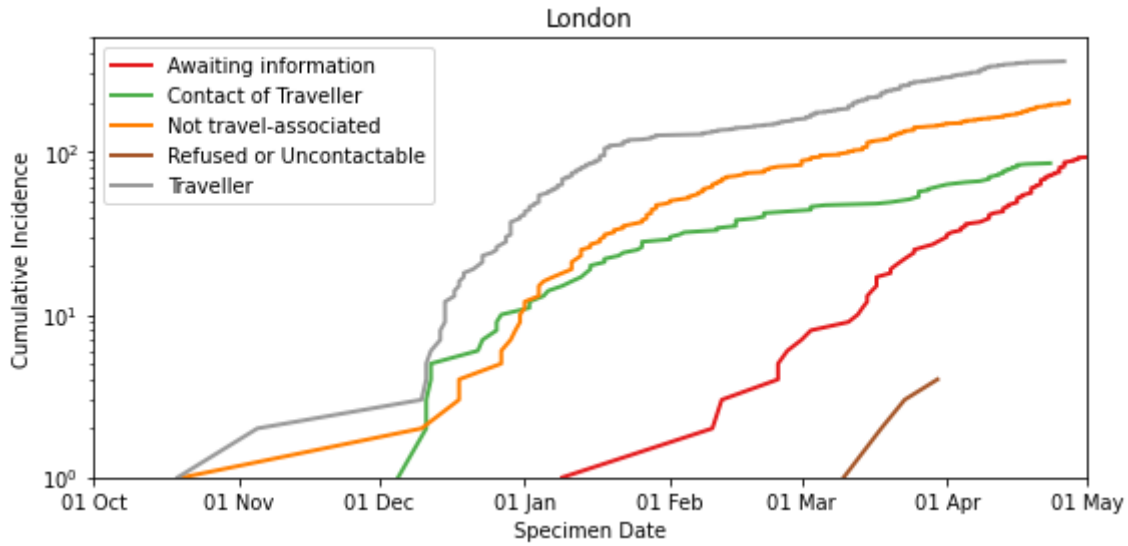
353 rows × 8 columns

In [12]:

```
dfg = df.groupby('exposure_type').apply(todays)
```

In [13]:

```
lq = len(dfg.index)
cmp = plt.cm.get_cmap('Set1', lq)
plt.figure(figsize=(8,4))
for i in range(0,lq):
    x = dfg[i]
    plt.plot(np.sort(x),np.arange(1,len(x)+1),label=dfg.index[i], lw=2, c=cmp(i))
plt.legend()
plt.xlabel('Specimen Date')
plt.ylabel('Cumulative Incidence')
plt.xticks(todays(monthstarts),tods(monthstarts))
plt.ylim([1,500])
plt.xlim([0,212])
plt.yscale('log')
plt.title('London')
plt.tight_layout()
plt.savefig('./figures/voc_london_log.pdf')
```



In [14]:

```
# From the above, Not travel London
li = np.argwhere(dfg.index == 'Not travel-associated')[0]
x = dfg[li].values[0]
len(x)
```

Out[14]:

```
205
```

In [15]:

```
def mymu(x,tt,n):
    mu = np.concatenate([
        x[0]*np.exp(x[1]*tt[0:n]),
        x[0]*np.exp(x[1]*tt[n-1])*np.exp(x[3]*(tt[n:]-tt[n-1]))
    ])
    return mu

def myod(x,tt,n):
    od = np.concatenate([
        x[2]*np.ones(len(tt[0:n])),
        x[4]*np.ones(len(tt[n:]))
    ])
    return od

def mynll(y,x,tt):
    mu = x[0]*np.exp(x[1]*tt)
    od = x[2]*np.ones(len(tt))
    p = 1/od
    r = mu/(od-1)
    return -np.sum(st.nbinom.logpmf(y,r,p))

def mynll2(y,x,tt,n):
    mu = mymu(x,tt,n)
    od = myod(x,tt,n)
    p = 1/od
    r = mu/(od-1)
    return -np.sum(st.nbinom.logpmf(y,r,p))
```

In [16]:

```
keydates = pd.DataFrame([
    ['2021-01-01','Start of 2021'],
    ['2021-03-08','Roadmap Start'],
    ['2021-04-30','Sequence Delay'],
],columns=['earliest_specimen_date','date_name'])
keydates
```

Out[16]:

	earliest_specimen_date	date_name
0	2021-01-01	Start of 2021
1	2021-03-08	Roadmap Start
2	2021-04-30	Sequence Delay

In [20]:

```
tk = todays(keydates)
z = np.bincount(x)
uu = np.arange(0,np.max(x)+1)
yy = z[tk[0]:tk[-1]]
tt = np.arange(0,len(yy))
n = tk[1]-tk[0]
```

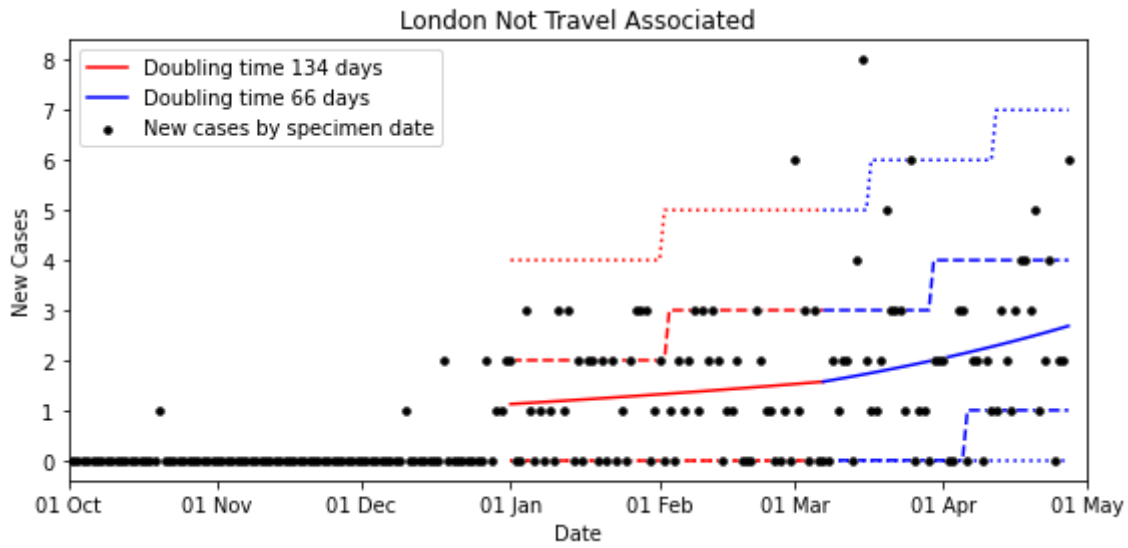
In [21]:

```
x02 = np.array([1,0.25,5,0.15,5])
nll = lambda xx: mynll2(yy,xx,tt,n)
fout2 = op.minimize(nll,x02,method='Nelder-Mead')
mu = mymu(fout2.x,tt,n)
od = myod(fout2.x,tt,n)
p = 1/od
r = mu/(od-1)
dt1 = np.log(2.0)/fout2.x[1]
dt2 = np.log(2.0)/fout2.x[3]
print(dt1)
print(dt2)
```

```
134.43721331933065
66.07347393719384
```

In [22]:

```
plt.figure(figsize=(8,4))
plt.xlabel('Date')
plt.ylabel('New Cases')
plt.xticks(todays(monthstarts),tods(monthstarts))
plt.plot(tk[0]+tt[0:n],mu[0:n],linestyle='-',c='r',label='Doubling time {:.0f} days'
plt.plot(tk[0]+tt[(n-1):],mu[(n-1):],linestyle='-',c='b',label='Doubling time {:.0f}
plt.plot(tk[0]+tt[0:n],st.nbinom.ppf(1/6,r[0:n],p[0:n]),linestyle='--',c='r')
plt.plot(tk[0]+tt[0:n],st.nbinom.ppf(5/6,r[0:n],p[0:n]),linestyle='--',c='r')
plt.plot(tk[0]+tt[(n-1):],st.nbinom.ppf(1/6,r[(n-1):],p[(n-1):]),linestyle='--',c='b
plt.plot(tk[0]+tt[(n-1):],st.nbinom.ppf(5/6,r[(n-1):],p[(n-1):]),linestyle='--',c='b
plt.plot(tk[0]+tt[0:n],st.nbinom.ppf(0.025,r[0:n],p[0:n]),linestyle=':',c='r')
plt.plot(tk[0]+tt[0:n],st.nbinom.ppf(0.975,r[0:n],p[0:n]),linestyle=':',c='r')
plt.plot(tk[0]+tt[(n-1):],st.nbinom.ppf(0.025,r[(n-1):],p[(n-1):]),linestyle=':',c='
plt.plot(tk[0]+tt[(n-1):],st.nbinom.ppf(0.975,r[(n-1):],p[(n-1):]),linestyle=':',c='
plt.scatter(uu,z,marker='o',c='w',s=16,zorder=3)
plt.scatter(uu,z,marker='o',c='k',s=12,label='New cases by specimen date',zorder=3)
plt.xlim([0,212])
plt.legend()
plt.title('London Not Travel Associated')
plt.tight_layout()
plt.savefig('./figures/voc_london_nta_fit.pdf')
```



In [23]:

```
xhat = fout2.x
xhat
```

Out[23]:

```
array([1.12430246, 0.00515592, 1.29482544, 0.01049055, 1.40135644])
```

In [24]:

```
pn = len(x02)
delta = 1e-2 # Some tuning of this by hand is inevitable
dx = delta*xhat
ej = np.zeros(pn)
ek = np.zeros(pn)
Hinv = np.zeros((pn,pn))
for j in range(0,pn):
    ej[j] = dx[j]
    for k in range(0,j):
        ek[k] = dx[k]
        Hinv[j,k] = nll(xhat+ej+ek) - nll(xhat+ej-ek) - nll(xhat-ej+ek) + nll(xhat-e
        ek[k] = 0.
    Hinv[j,j] = - nll(xhat+2*ej) + 16*nll(xhat+ej) - 30*nll(xhat) + 16*nll(xhat-ej)
    ej[j] = 0.
Hinv += np.triu(Hinv.T,1)
Hinv /= (4.*np.outer(dx,dx) + np.diag(8.*dx**2)) # TO DO: replace with a chol ...
covmat = LA.inv(0.5*(Hinv+Hinv.T))
stds = np.sqrt(np.diag(covmat))
print(stds)
```

```
[0.26509632 0.00519759 0.28338963 0.00597192 0.28357679]
```

In [25]:

```
dfs = pd.read_csv('./perc_r_lon.csv')
```

In [26]:

```
def stodays(x):
    return np.array((pd.to_datetime(x['Date'], format='%d-%b-%y') - pd.Timestamp("20
```

In [27]:

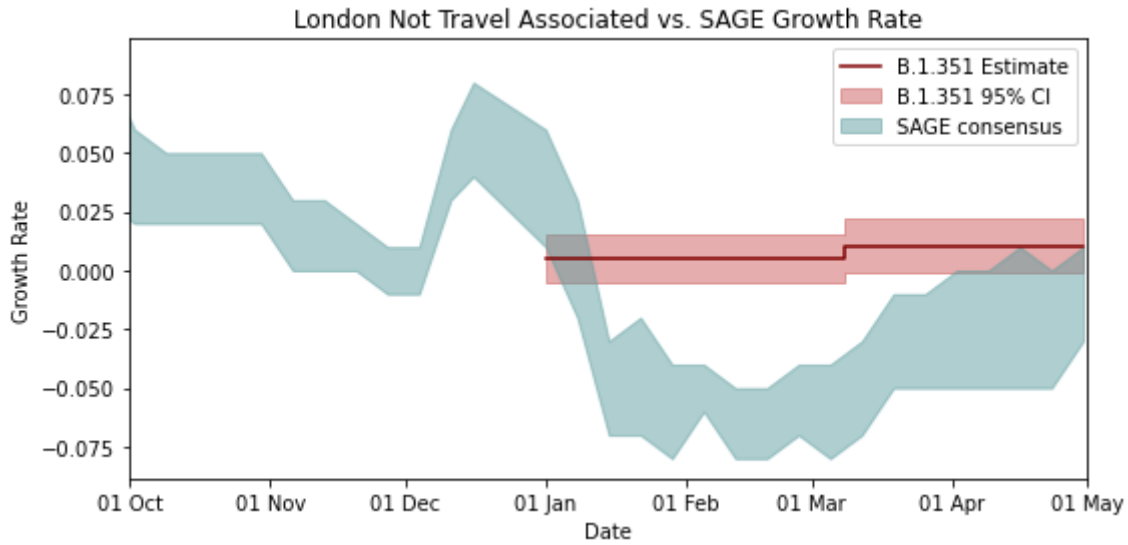
```
gl = dfs.Lower.values/100
gu = dfs.Upper.values/100
gt = stodays(dfs)-7 # Assume that the SPI-M estimates come with a 7 day delay
```

In [28]:

```
rt = np.array([tk[0],tk[1],tk[1],tk[2]])
rl = np.concatenate([(xhat[1]-1.96*stds[1])*np.ones(2), (xhat[3]-1.96*stds[3])*np.or
ru = np.concatenate([(xhat[1]+1.96*stds[1])*np.ones(2), (xhat[3]+1.96*stds[3])*np.or
rm = np.concatenate([(xhat[1])*np.ones(2), (xhat[3])*np.ones(2)])
```

In [29]:

```
#plt.plot(gt,gl)
#plt.plot(gt,gu)
plt.figure(figsize=(8,4))
plt.xlabel('Date')
plt.ylabel('Growth Rate')
plt.xticks(todays(monthstarts),tods(monthstarts))
plt.plot(rt,rm,color='maroon',label='B.1.351 Estimate')
plt.fill_between(rt,rl,ru,color='indianred',alpha=0.5,label='B.1.351 95% CI')
plt.fill_between(gt,gl,gu,color='cadetblue',alpha=0.5,label='SAGE consensus')
#plt.plot(np.array([tk[0],tk[1]]),xhat[1]*np.ones(2))
#plt.plot(np.array([tk[1],tk[2]]),xhat[3]*np.ones(2))
plt.xlim([0,212])
plt.legend()
plt.title('London Not Travel Associated vs. SAGE Growth Rate')
plt.tight_layout()
plt.savefig('./figures/voc_london_nta_comp.pdf')
```



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