Project 1: Data Scraping and cleaning

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In [1]:

```
from bs4 import BeautifulSoup
from bs4.element import Tag, NavigableString
import pandas as pd
import re
from requests import get
import csv
from datetime import datetime
import time
import warnings
from math import exp
warnings.filterwarnings('ignore')
```

Part 1: Data Scraping and cleaning

Step 1: Scrape your competitor's data

In [2]:

```
url = 'https://www.spaceweatherlive.com/en/solar-activity/top-50-solar-flares'
response = get(url)
```

In [3]:

```
soup = BeautifulSoup(response.text, 'html.parser')
```

In [4]:

```
table = soup.find('table', attrs = {'class': 'table'}).find('tbody').findAll('t
r')
solar_flares = []
for row in table:
    attrs = row.findAll('td')
    solar_flare = {}
    solar_flare['rank'] = attrs[0].text
    solar_flare['flare_classification'] = attrs[1].text
    solar_flare['date'] = attrs[2].text
    solar_flare['flare_region'] = attrs[3].text
    solar_flare['start_time'] = attrs[4].text
    solar_flare['maximum_time'] = attrs[5].text
    solar_flare['end_time'] = attrs[6].text
    solar_flare['movie'] = attrs[7].text
    solar_flares.append(solar_flare)
print(solar_flares[0])
```

```
{'rank': '1', 'flare_classification': 'X28+', 'date': '2003/11/04',
'flare_region': '0486', 'start_time': '19:29', 'maximum_time': '19:5
3', 'end_time': '20:06', 'movie': ' MovieView archive'}
```

write to .csv files

In [5]:

```
filename = 'solar_flares.csv'
with open(filename, 'w') as f:
    w = csv.DictWriter(f, ['rank', 'flare_classification', 'date','flare_region'
, 'start_time', 'maximum_time', 'end_time', 'movie'])
    w.writeheader()
    for solar_flare in solar_flares:
        w.writerow(solar_flare)
```

Step 2: Tidy the top 50 solar flare data

In [6]:

```
solar_flares = pd.read_csv('solar_flares.csv')
solar_flares.head()
```

Out[6]:

	rank	flare_classification	date	flare_region	start_time	maximum_time	end_time	
0	1	X28+	2003/11/04	486	19:29	19:53	20:06	Mc
1	2	X20+	2001/04/02	9393	21:32	21:51	22:03	Mc
2	3	X17.2+	2003/10/28	486	09:51	11:10	11:24	Mc
3	4	X17+	2005/09/07	808	17:17	17:40	18:03	Mc
4	5	X14.4	2001/04/15	9415	13:19	13:50	13:55	Mc

1. Drop the last column

In [7]:

```
try:
    del solar_flares['movie']
except:
    print('INFO: The operation has been done')
solar_flares.head(3)
```

Out[7]:

	rank	flare_classification	date	flare_region	start_time	maximum_time	end_time
0	1	X28+	2003/11/04	486	19:29	19:53	20:06
1	2	X20+	2001/04/02	9393	21:32	21:51	22:03
2	3	X17.2+	2003/10/28	486	09:51	11:10	11:24

1. Combine date and time columns

In [8]:

```
try:
    solar_flares['start_datetime'] = solar_flares['date'] + ' ' + solar_flares[
'start_time']
    solar_flares['maximum_datetime'] = solar_flares['date'] + ' ' + solar_flares
['maximum_time']
    solar_flares['end_datetime'] = solar_flares['date'] + ' ' + solar_flares['en
d_time']
    del solar_flares['start_time']
    del solar_flares['end_time']
    del solar_flares['maximum_time']
    del solar_flares['date']
except:
    print('INFO: The operation has been done')
solar_flares.head()
```

Out[8]:

	rank	flare_classification	flare_region	start_datetime	maximum_datetime	end_datetime
0	1	X28+	486	2003/11/04 19:29	2003/11/04 19:53	2003/11/04 20:06
1	2	X20+	9393	2001/04/02 21:32	2001/04/02 21:51	2001/04/02 22:03
2	3	X17.2+	486	2003/10/28 09:51	2003/10/28 11:10	2003/10/28 11:24
3	4	X17+	808	2005/09/07 17:17	2005/09/07 17:40	2005/09/07 18:03
4	5	X14.4	9415	2001/04/15 13:19	2001/04/15 13:50	2001/04/15 13:55

1. Parse columns containing datetimes into actual datetime objects

In [9]:

```
mapToDatetime = lambda dt_str: datetime.strptime(dt_str, '%Y/%m/%d %H:%M')

try:
    solar_flares['start_datetime'] = solar_flares['start_datetime'].map(mapToDat
etime)
except:
    print('INFO: No need to parse "start_datetime" column')
try:
    solar_flares['maximum_datetime'] = solar_flares['maximum_datetime'].map(mapT
oDatetime)
except:
    print('INFO: No need to parse "maximum_datetime" column')
try:
    solar_flares['end_datetime'] = solar_flares['end_datetime'].map(mapToDatetim
e)
except:
    print('INFO: No need to parse "end_datetime" column')
solar_flares.head(10)
```

Out[9]:

	rank	flare_classification	flare_region	start_datetime	maximum_datetime	end_datetime
0	1	X28+	486	2003-11-04 19:29:00	2003-11-04 19:53:00	2003-11-04 20:06:00
1	2	X20+	9393	2001-04-02 21:32:00	2001-04-02 21:51:00	2001-04-02 22:03:00
2	3	X17.2+	486	2003-10-28 09:51:00	2003-10-28 11:10:00	2003-10-28 11:24:00
3	4	X17+	808	2005-09-07 17:17:00	2005-09-07 17:40:00	2005-09-07 18:03:00
4	5	X14.4	9415	2001-04-15 13:19:00	2001-04-15 13:50:00	2001-04-15 13:55:00
5	6	X10	486	2003-10-29 20:37:00	2003-10-29 20:49:00	2003-10-29 21:01:00
6	7	X9.4	8100	1997-11-06 11:49:00	1997-11-06 11:55:00	1997-11-06 12:01:00
7	8	X9.3	2673	2017-09-06 11:53:00	2017-09-06 12:02:00	2017-09-06 12:10:00
8	9	X9	930	2006-12-05 10:18:00	2006-12-05 10:35:00	2006-12-05 10:45:00
9	10	X8.3	486	2003-11-02 17:03:00	2003-11-02 17:25:00	2003-11-02 17:39:00

In [10]:

```
solar_flares.to_csv('./solar_flares_tidy.csv', index=False)
```

Step 3: Scrape the NASA data

In [11]:

```
url = 'https://cdaw.gsfc.nasa.gov/CME_list/radio/waves_type2.html'
response = get(url)
soup = BeautifulSoup(response.text, 'html.parser')
```

In [12]:

```
content = soup.find('pre')
data = []
prev = []
temp = []
prev_word = ''

for i, row in enumerate(content):
    if i == 0:
        row = row[800:]
    if type(row) is str or type(row) is NavigableString:
        if row.isspace():
            continue
        row = row.strip(' \n\r\t')
        row = re.split(r'[\n\s]\s*', row)
    elif type(row) is Tag:
        row = row.text
        row = row.strip(' \n\r\t')
        row = re.split(r'[\n\s]\s*', row)
    if row:
        if temp:
            prev_word = temp[-1]
        else:
            prev_word = ''
        for word in row:
            if prev_word == 'PHTX':
                if word[0] == '1' or word[0] == '2':
                    temp.append(word)
                    prev_word = word
            else:
                temp.append(word)

        if len(temp) > 15:
            data.append(temp[:15])
            temp = temp[15:]


for i, _ in enumerate(data):
    data[i] = _[:-1]


filename = 'nasa.csv'
headers = ['start_date', 'start_time', 'end_date', 'end_time', 'start_frequency'
, 'end_frequency', 'flare_location', 'flare_region', 'flare_classification', 'cm
e_date', 'cme_time', 'cme_angle', 'cme_width', 'cme_speed' ]
with open(filename, 'w') as f:
    writer = csv.writer(f)
    writer.writerow(headers)
    writer.writerows(data)
```

Step 4: Tidy the NASA Table

In [13]:

```
nasa_table = pd.read_csv('./nasa.csv')
nasa_table.head(3)
```

Out[13]:

	start_date	start_time	end_date	end_time	start_frequency	end_frequency	flare_location
0	1997/04/01	14:00	04/01	14:15	8000	4000	S25E16
1	1997/04/07	14:30	04/07	17:30	11000	1000	S28E19
2	1997/05/12	05:15	05/14	16:00	12000	80	N21W08

In [14]:

```
nasa_table = pd.read_csv('./nasa.csv')

# 1. replace any missing entries as `NA`
# start_frequency and end_frequency
nasa_table['start_frequency'] = nasa_table['start_frequency'].replace(['????'],
'NA')
nasa_table['end_frequency'] = nasa_table['end_frequency'].replace(['????'], 'NA'
)

# flare_region
nasa_table['flare_region'] = nasa_table['flare_region'].replace(['-----'], 'NA')

# flare_classification (Soft X-ray flare importance)
nasa_table['flare_classification'] = nasa_table['flare_classification'].replace
(['----'], 'NA').replace(['FILA'], 'NA').replace(['DSF'], 'NA')

# cme_date
nasa_table['cme_date'] = nasa_table['cme_date'].replace(['--/--'], 'NA')

# cme_time
nasa_table['cme_time'] = nasa_table['cme_time'].replace(['--:--'], 'NA')

# cme_angle
nasa_table['cme_angle'] = nasa_table['cme_angle'].replace(['----'], 'NA')

# cme_width
nasa_table['cme_width'] = nasa_table['cme_width'].replace(['----'], 'NA')

# cme_speed
nasa_table['cme_speed'] = nasa_table['cme_speed'].replace(['----'], 'NA')


# 2. create a "is_halo" column and replace `Halo` in cme_angle as `NA`
# create a new "is_halo" column
nasa_table['is_halo'] = nasa_table['cme_angle'] == 'Halo'

# replace "Halo" with "NA"
nasa_table['cme_angle'] = nasa_table['cme_angle'].replace(['Halo'], 'NA')


# 3. create a "is_lower_bound" column and remove any non-numeric part of the wid
th column
# create a new "is_lower_bound" column
not_numeric = lambda s: not s.isnumeric()
nasa_table['is_lower_bound'] = nasa_table['cme_width'].map(not_numeric)

# replace non-numeric part of the width column
removeNonNumeric = lambda s: re.sub('[^0-9]','', s)
nasa_table['cme_width'] = nasa_table['cme_width'].map(removeNonNumeric)


# 4. Combine date and time columns for `start`, `end` and `cme` so they can be e
ncoded as datetime objects
headers = nasa_table.columns.tolist()
nasa_table['start_datetime'] = nasa_table['start_date'] + ' ' + nasa_table['star
t_time']
nasa_table['end_datetime'] = nasa_table['start_date'].map(lambda s: s[:5]) + nas
a_table['end_date'] + ' ' + nasa_table['end_time']
nasa_table['cme_datetime'] = nasa_table['start_date'].map(lambda s: s[:5]) + nas
```

```
a_table['cme_date'] + ' ' + nasa_table['cme_time']

for h in ['start_date', 'start_time', 'end_date', 'end_time', 'cme_date', 'cme_t
ime']:
    headers.remove(h)
headers = ['start_datetime', 'end_datetime', 'cme_datetime'] + headers
nasa_table = nasa_table[headers]


# 5. Convert to datetime object
fixTime = lambda dt_str: dt_str.replace('24:00', '00:00')

mapToDatetime = lambda dt_str: datetime.strptime(dt_str, '%Y/%m/%d %H:%M')
nasa_table['start_datetime'] = nasa_table['start_datetime'].map(fixTime).map(map
ToDatetime)
nasa_table['end_datetime'] = nasa_table['end_datetime'].map(fixTime).map(mapToDa
tetime)

def mapCme(dt_str):
    if 'NA' in dt_str:
        return 'NA'
    dt_obj = fixTime(dt_str)
    dt_obj = mapToDatetime(dt_obj)
    return dt_obj
nasa_table['cme_datetime'] = nasa_table['cme_datetime'].map(mapCme)


# Save
nasa_table.to_csv('nasa_tidy.csv', index=False)
nasa_table.head(3)
```

Out[14]:

	start_datetime	end_datetime	cme_datetime	start_frequency	end_frequency	flare_location
0	1997-04-01 14:00:00	1997-04-01 14:15:00	1997-04-01 15:18:00	8000	4000	S25E16
1	1997-04-07 14:30:00	1997-04-07 17:30:00	1997-04-07 14:27:00	11000	1000	S28E19
2	1997-05-12 05:15:00	1997-05-14 16:00:00	1997-05-12 05:30:00	12000	80	N21W08

Part 2: Analysis

Question 1: Replication

In [15]:

```
nasa = pd.read_csv('./nasa_tidy.csv')
solar_flares = pd.read_csv('./solar_flares_tidy.csv')

# remove the plus sign in the solar_flares dataset
removePlusSign = lambda s: re.sub('\+','', s)
solar_flares['flare_classification'] = solar_flares['flare_classification'].map(
removePlusSign)

# create two new columns corresponding to the letter and number fraction of 'fla
re_classification' column
def mapToLetter(s):
    if type(s) == str and s != 'NA':
        return s[0]
    else:
        return 'NA'
def mapToNum(s):
    if type(s) == str and s != 'NA':
        return float(s[1:])
    else:
        return 'NA'
solar_flares['classification_letter'] = solar_flares['flare_classification'].map
(mapToLetter)
solar_flares['classification_num'] = solar_flares['flare_classification'].map(ma
pToNum)
nasa['classification_letter'] = nasa['flare_classification'].map(mapToLetter)
nasa['classification_num'] = nasa['flare_classification'].map(mapToNum)

letters = list(solar_flares['classification_letter'])
nums = list(solar_flares['classification_num'])
nasa_top_flares = nasa.loc[nasa['classification_letter'].isin(letters)]
nasa_top_flares = nasa_top_flares.loc[nasa_top_flares['classification_num'].isin
(nums)]

print('Successfully replicated {} records'.format(len(nasa_top_flares)))
solar_flares.head()
```

```
Successfully replicated 35 records
```

Out[15]:

	rank	flare_classification	flare_region	start_datetime	maximum_datetime	end_datetime	cl
0	1	X28	486	2003-11-04 19:29:00	2003-11-04 19:53:00	2003-11-04 20:06:00	
1	2	X20	9393	2001-04-02 21:32:00	2001-04-02 21:51:00	2001-04-02 22:03:00	
2	3	X17.2	486	2003-10-28 09:51:00	2003-10-28 11:10:00	2003-10-28 11:24:00	
3	4	X17	808	2005-09-07 17:17:00	2005-09-07 17:40:00	2005-09-07 18:03:00	
4	5	X14.4	9415	2001-04-15 13:19:00	2001-04-15 13:50:00	2001-04-15 13:55:00	

Here we only consider the "flare_classification" attribute to replicate the top 50 solar flares. However, by using this attribute solely, I am only able to retrieve 35 records. To see how well this method actually performs, we could do the following operation to manually check it. Here we use date for filtering because it's very unlikely that the two websites recorded the same solar flare with different dates

In [16]:

```
# retrieve all the dates in the top 50 solar flares dataset
retrieveDate = lambda dt_str: dt_str[:10]
dates = list(solar_flares['start_datetime'].map(retrieveDate))

# retrieve all the solar flares happened in these days
nasa['date'] = nasa['start_datetime'].map(retrieveDate)
candidate_solar_flares = nasa.loc[nasa['date'].isin(dates)]
nasa_top_flares['date'] = nasa_top_flares['start_datetime'].map(retrieveDate)
print('There are {} candidate solar flares'.format(len(candidate_solar_flares)))

# we check the difference between nasa_top_flares and candidate_solar_flares
difference = candidate_solar_flares.merge(nasa_top_flares, indicator=True, how=
'outer')
left_only = difference[difference['_merge'] == 'left_only']

left_only
```

```
There are 45 candidate solar flares
```

Out[16]:

	start_datetime	end_datetime	cme_datetime	start_frequency	end_frequency	flare_location
4	2001-04-02 11:30:00	2001-04-02 12:00:00	2001-04-02 11:26:00	14000.0	5000.0	N20W7C
7	2001-04-15 14:05:00	2001-04-16 13:00:00	2001-04-15 14:06:00	14000.0	40.0	S20W85
10	2001-12-11 12:45:00	2001-12-11 17:00:00	2001-12-11 09:54:00	4500.0	750.0	SW90b
12	2002-07-15 21:15:00	2002-07-16 05:00:00	2002-07-15 21:30:00	5000.0	175.0	N19W01
19	2003-11-02 09:23:00	2003-11-02 11:22:00	2003-11-02 09:30:00	14000.0	550.0	SW90b
24	2005-01-15 06:15:00	2005-01-15 09:30:00	2005-01-15 06:30:00	14000.0	150.0	N16E04
26	2005-01-17 09:25:00	2005-01-17 16:00:00	2005-01-17 09:30:00	14000.0	30.0	N15W25
29	2005-09-07 18:05:00	2005-09-08 00:00:00	NaN	12000.0	200.0	S11E77
32	2006-12-06 02:00:00	2006-12-06 03:30:00	NaN	1000.0	200.0	S07E69
33	2006-12-06 08:30:00	2006-12-06 09:45:00	NaN	4000.0	600.0	S04E63
38	2013-05-13 02:20:00	2013-05-13 03:00:00	2013-05-13 02:00:00	16000.0	2000.0	N11E90

By the above result and manually checking the two datasets, we could conclude that the some entries in the top 50 solar flares dataset is missing in the nasa datasets, and others are failed to be repllicated. The reason could be the 'NA' in flare_classification column and difference in classification (e.g. X14 vs X14.4). This could be validated by manually checking the above dataframe

Question 2: Entity Resolution

we consider 3 attributes to calculate the similarity score, datetime, solar_region, and classification. We translate datetime as hours and consider it as a continuous variable to calculate its similarity. If the two solar flares happen at the same region, we add 1 to the overall similarity score as flare region is considered as categorical attribute. Then we consider the letter section of classification as categorical and numeric section as numerical attribute, and calculate its similarity. Finally, we set the threshhold for overall similarity score to be 1, with the implication that one of the following is true: 1) they happen at about the same datetime and are about the same classification. 2) their classification or/and flare_region matches and some differences in datetime.

In [17]:

```
# first we fix the inconsistency in the flare_region column of the two datasets
def fixFlareRegion(s):
    s = str(s)
    if len(s) == 2 and s != 'NA':
        return '100' + s
    elif len(s) == 3:
        return '10' + s
    elif len(s) == 4:
        return '1' + s
    return s

nasa['flare_region'] = nasa['flare_region'].map(fixFlareRegion)
solar_flares['flare_region'] = solar_flares['flare_region'].map(fixFlareRegion)

# Write a function flare_similarity which computes a similarity s(e1,e2) between
flares e1∈E1 and e2∈E2.
def flare_similarity(e1, e2):
    # use datetime, classification, and region to calculate similarity score
    score = 0
    # datetime
    fmt = '%Y-%m-%d %H:%M:%S'
    d1 = datetime.strptime(e1['start_datetime'], fmt)
    d2 = datetime.strptime(e2['start_datetime'], fmt)
    d1_ts = time.mktime(d1.timetuple())
    d2_ts = time.mktime(d2.timetuple())
    score += exp(-((d2_ts-d1_ts)/3600)**2)
#     score += 1.5 - (int(abs(d2_ts-d1_ts)) / 60 / 60)  # in hours

    # region
    if str(e1['flare_region']) == str(e2['flare_region']):
        score += 1
#     if e1['flare_region'] == 'NA' or e2['flare_region'] == 'NA':
#         score += 0.1

    # classification
    if e1['classification_letter'] == e2['classification_letter']:
        if e1['classification_num'] != 'NA' and e2['classification_num'] != 'NA'
:
            score += exp(-((e1['classification_num'] - e2['classification_num'])
**2))
    return score


# Write a second function flare_match that computes for each flare e1∈E1 which f
lare e2∈E2 is the most similar.
def flare_match(flare_df1, flare_df2):
    indexes = []
    for i1, e1 in flare_df1.iterrows():
        idx = 0
        score = 0
        for i2, e2 in flare_df2.iterrows():
            cur_score = flare_similarity(e1, e2)
            if cur_score >= score:
                score = cur_score
                idx = i2
        if score > 1.1:
            indexes.append(idx + 2)
        else:
            indexes.append('NA')
```

```
    return indexes

indexes = flare_match(solar_flares, nasa)
sum = 0
for i in indexes:
    if i != 'NA':
        sum += 1
print('Find {} matches'.format(sum))
# Add the result of flare_match to the top 50 table as the index of the best mat
ching row in the NASA table
solar_flares['flare_match'] = indexes
```

```
Find 39 matches
```

In [18]:

```
solar_flares.head(5)
```

Out[18]:

	rank	flare_classification	flare_region	start_datetime	maximum_datetime	end_datetime	cl
0	1	X28	10486	2003-11-04 19:29:00	2003-11-04 19:53:00	2003-11-04 20:06:00	
1	2	X20	19393	2001-04-02 21:32:00	2001-04-02 21:51:00	2001-04-02 22:03:00	
2	3	X17.2	10486	2003-10-28 09:51:00	2003-10-28 11:10:00	2003-10-28 11:24:00	
3	4	X17	10808	2005-09-07 17:17:00	2005-09-07 17:40:00	2005-09-07 18:03:00	
4	5	X14.4	19415	2001-04-15 13:19:00	2001-04-15 13:50:00	2001-04-15 13:55:00	

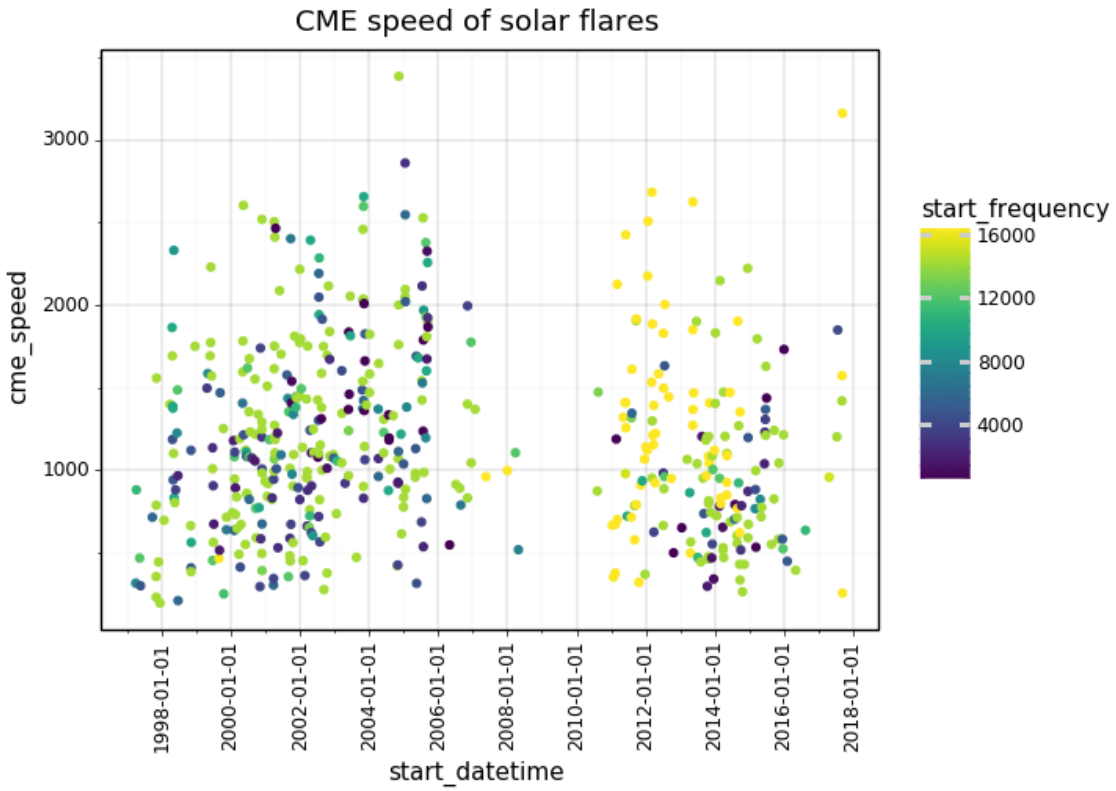
Question 3: Analysis

Here we want to explore the correlation among date of the solar flare, its cme speed, and its starting frequency by plotting the data. In the plot below, the data is all the solar flares in the nasa dataset. The x-axis represents its CME speed while the y-axis represents the date and time that the solar flare happened. Color shows the starting frequency of the solar flare, with yellow being the highest and blue being the lowest. From the plot, we can notice that there is not a clear correlation between CME speed and the starting frequency. However, we could see in recent years(2010-), the number of solar flares with higher starting frequency significantly increased. We could also notice that there are almost no solar flares between 2008 and 2010.

In [20]:

```
from plotnine import *
from mizani.breaks import date_breaks
from mizani.formatters import date_format


theme_set(theme_linedraw())
(ggplot((nasa)
 ,aes(x='start_datetime', y='cme_speed', color='start_frequency'))
 +geom_point()
 +labs(title='CME speed of solar flares')
 +scale_x_datetime(breaks=date_breaks('2 year'))
 +theme(axis_text_x = element_text(angle=90))
)
```



Out[20]:

<ggplot: (7557734685)>