Characterizing scientific production and consumption in Physics

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Direct Link between Microwave and Optical Frequencies with a 300 THz Femtosecond Laser Comb

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We demonstrate a great simplification in the long-standing problem of measuring optical frequencies in terms of the current primary standard. An air-silica microstructure optical fiber bridges the frequency comb of a femtosecond laser to span the optical spectrum from 780 to 1575 nm, enabling us to measure the 282 THz frequency of an air-stabilized Nd:YAG laser directly in terms of the microwave frequency that controls the comb spacing. Additional measurements of established optical frequencies at 633 and 778 nm using the same femtosecond comb confirm the accepted uncertainties for these standards.

PACS numbers: 42.65.Re, 06.20.-v, 42.62.Eb

Phase Coherent Vacuum-Ultraviolet to Radio Frequency Comparison with a Mode-Locked Laser

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(Received 18 November 1999)

We demonstrate a versatile new technique that provides a phase coherent link between optical frequencies and the radio frequency domain. The regularly spaced comb of modes of a mode-locked femtosecond laser is used as a precise ruler to measure a large frequency gap between two different multiples (harmonics or subharmonics) of a laser frequency. In this way, we have determined a new value of the hydrogen 1S-2S two-photon resonance, Δν_{1S,2S} = 2 200 085 431 387 293(37) MHz, representing now the most accurate measurement of an optical frequency.

PACS numbers: 06.30.Fy, 11.30.Er, 42.60.Rv, 42.62.Eb
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PACS numbers: 42.65.Re, 06.20.-c, 42.62.Ew

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Geolocation

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The number of fields less than 8?  

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Affiliation with no country name

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Google geocoders checking

Affiliation(s) with incorrect country name

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<th>Cities</th>
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Geolocation

Dominated by the US...
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PACS numbers: 06.30.Fy, 31.30.Jv, 42.60.Fc, 42.62.Fi

12. R. Holzwarth et al. (to be published).
Citation Network
Trade Imbalance

Incoming citations - Outgoing citations

\[ \Delta S = S_{in} - S_{out} \]

\[ \Delta S > 0 \quad \text{“Exporter” - Source of Knowledge} \]

\[ \Delta S < 0 \quad \text{“Importer” - Sink of Knowledge} \]
Trade Imbalance

(A) The world map of producers and consumers at the city level in 1990 (top) and 2009 (bottom). A producer city, of which the relative unbalance is coloured in red scale. A consumer with the relative unbalance $|\Delta S|/\sum S$ is consumer or producer, respectively. In Figure 2-A we show that in (C) the height of bars is not scaled with the height in (B) for visibility. Maps in panel (A) are created by using ArcGIS.
Trade Imbalance

The world map of producers and consumers at the city level in 1990 (top) and 2009 (bottom). A producer city, of which the relative unbalance is consumer or producer, respectively. In Figure 2-A we show the worldwide geographical distribution of producer (red) and consumer (blue) urban areas for the 1990 and 2009. Interestingly, during the 90s the production of Physics knowledge was highly localized in a few cities in the eastern and western coasts of the USA and in a few areas of Great Britain and Northern Europe. In 2009 the picture is completely different with many producer cities in central and southern parts of the USA, Europe and Japan. It is interesting to note that despite the fraction of papers produced in the USA is generally decreasing or stable, many more cities in the USA acquire the status of knowledge producers. This implies that the quality of the actual flow of knowledge. The Figure 2-A also makes it clear that the knowledge production from the USA is increasing and thus attracts more citations. This makes it clear that the knowledge produced in a few areas preferentially attracts more citations. This makes it clear that the knowledge production from the USA is increasing and thus attracts more citations. This makes it clear that the knowledge production from the USA is increasing and thus attracts more citations.
Trade Imbalance

The trade imbalance of each urban area $i$ is then:

$$D_S^i = S_i - P_j w_{ji}.$$ 

A negative or positive value of this quantity indicates if the urban area $i$ is consumer or producer, respectively. In Figure 2-A we show the worldwide geographical distribution of producer (red) and consumer (blue) urban areas for the 1990 and 2009. Interestingly, during the 90s the production of Physics knowledge was highly localized in a few cities in the eastern and western coasts of the USA and in a few areas of Great Britain and Northern Europe. In 2009 the picture is completely different with many producer cities in central and southern parts of the USA, Europe, and Japan. It is interesting to note that despite the fraction of papers produced in the USA is generally decreasing or stable, many more cities in the USA acquire the status of knowledge producers. This implies that the quality of knowledge production from the USA is increasing and thus attracting more citations. This makes it clear that the knowledge produced by an urban area cannot be considered to be measured only by the raw number of papers. Citations are a more appropriate proxy that encodes the value of the products. They serve as an approximation of the actual flow of knowledge. The Figure 2-A also makes it clear that cities in China are playing the role of major consumers in both 1990 and 2009. We also observe that cities in other countries like Russia...
Network Evolution

The network structures of city-to-city citation networks. (A) The backbones $\mathbf{w}_{ij}$ for the city-to-city citation networks in year 1960, 1990 and 2009 (from left to right). The maps of networks in (A) show in Figure 2-B the geographical distribution of producers and consumers inside the USA. From the two maps it is evident the drift towards a larger number of cities. The observed temporal trend is well known in the USA, especially in the last two decades. The system is self-organized, there is not a blueprint of system's interactions, and as clearly shown from Figure 3, clearly shows that citation patterns have indeed all the hallmarks of complex systems. The entire topology of the networks is explored uncovering both the production and consumption of knowledge are less concentrated on specific places and generally spread more evenly geographically. In order to provide visual support to this conclusion we filtered network by using a bundled representation of links preserving the relevant connections of weighted networks while removing the least statistically significant ones. We visualize each instance, knowledge produced in a city may be consumed by another producer that in turn produces knowledge for other cities who are not directly connected with the producer. Citations flow along the edges of the network to finally reach consumer cities which may not be directly connected with the consumer. This points out that the actual consumer of knowledge is not just signalled by the unbalance of citations but in the overall topology of the production and consumption of knowledge in the research system and the advance in technology that make collaboration and publishing easier.

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Network Evolution

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In order to explicitly consider the complex flow of citations between producers and consumers, we propose the knowledge diffusion proxy algorithm (see Methods section for the formal definition). In this algorithm, producers inject citations in the system that allows charting the diffusion of knowledge, going beyond local measures, that do not allow to capture all possible correlations and bounds between nodes that are not directly connected. This might result in a partial view and description of the system, especially when connectivity patterns are complex and nontrivial correlations induced by global citation patterns. For instance, knowledge produced in a city may be consumed by another nontrivial consumer that in turn produces knowledge for other cities who are not directly connected with the producer. Citations flow along the edges of the network to finally reach consumer cities. Not surprisingly, the level of complexity of the system has increased with time. In Figure 3-A that in 1960 the citation patterns inside the USA were limited to a few cities, and in Europe only a few cities were connected. Instead, in 1990 we register an increase in the interactions among a larger number of cities. The observed temporal trend is well known as the globalization of research. The entire topology of the networks is explored uncovering hallmarks of complex systems that are not just signalled by the unbalance of citations but in the overall network. Indeed, the final consumer of each injected citation may not be directly connected with the producer. Citations flow between cities inside the USA in 1960, 1990 and 2009. We filter links by using the backbone extraction algorithm that preserves the relevant connections of weighted networks while removing the least statistically significant ones. We visualize each network preserving the link weights that holds the link strength.

The statistical characteristics of the system are described in Figure 3-C. The distributions of link weights ($w_{ij}$) follow heavy-tailed distributions. The definition of producers and consumers is based on a local measure, that does not allow to capture all consumers. This points out that the actual consumer of knowledge is not just signalled by the unbalance of citations but in the overall topology of the production and consumption of knowledge in the research system and the advance in technology that make collaboration and publishing easier.

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In order to provide visual support to this conclusion we plot the most statistically significant connections of the citation network. In Figure 3-A, we register an increase in the interactions among a larger number of cities. The observed temporal trend is well known as the globalization of research. The entire topology of the networks is explored uncovering hallmarks of complex systems that are not just signalled by the unbalance of citations but in the overall network. Indeed, the final consumer of each injected citation may not be directly connected with the producer. Citations flow between cities inside the USA in 1960, 1990 and 2009. We filter links by using the backbone extraction algorithm that preserves the relevant connections of weighted networks while removing the least statistically significant ones. We visualize each network preserving the link weights that holds the link strength.

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Knowledge Diffusion Proxy

\[ T_{ij} = w_{ij} - w_{ji} \]

\[ F_{ij} = \begin{cases} |T_{ij}| & \text{if } T_{ij} < 0 \\ 0 & \text{otherwise} \end{cases} \]
However, the fast publication growth increased the unbalance written in its capital, a dominant city for scientific research in China. Assume that, thanks to this positive stimulus, many more papers were mentioned of research population in the early 2000s, it is reasonable to consider Beijing as the top consumer for all of these producers in the past 15 years (e.g. Orsay in 2008). The results show that, on average, the producers account for a vertical grey strip that indicates the city was not a producer during that time period. In these cases, the city receives an injection of citations from other cities. In the plot, we can see how the injection of citations evolves over time. The size of each circle is proportional to the number of citations absorbed by that consumer. In the figure, we show their Top ten consumers over 20 years as a function of time. The size of each circle is proportional to how many citations were absorbed by that consumer. We show their Top ten consumers over 20 years as a function of time. The size of each circle is proportional to how many citations were absorbed by that consumer.

Interestingly, even the Top consumer for New Haven, Berlin, also ranked out of top 10 (shown in bold in Table 1). This indicates that the city was not a producer during the period considered. The table shows that in 1990 Tokyo, was among the top consumers. But by 2009, its contribution to citation consumption had become less significant. This is the case of cities like Tokyo which has gradually approached the citation balance in recent years. For instance, in 1990, Paris was among the top consumers, but by 2009, it was ranked out of top 10 consumers. The table also shows that in 1990, Bratislava was among the top producers, but by 2009, it was ranked out of top 10 producers. The city needs to accumulate citations over time to become a significant player in the scientific community. It can be speculated that in the near future cities in China might be moving among the strongest producers if a fair number of papers start receiving enough citations. However, these common indicators might fail to account for the near future positions of these producers. We can also speculate that in the near future cities in China might be moving among the strongest producers if a fair number of papers start receiving enough citations. However, these common indicators might fail to account for the near future positions of these producers.

The table shows the rankings from the knowledge diffusion proxy algorithm for top 3 producer cities in 1990. In bold, we highlight cities that are present in top 10 consumers ranked according to the knowledge diffusion proxy but do not appear in top 10 cities ranked according to local citation unbalance. The table also shows the rankings from the knowledge diffusion proxy algorithm for top 3 producer cities in 1990. In bold, we highlight cities that are present in top 10 consumers ranked according to the knowledge diffusion proxy but do not appear in top 10 cities ranked according to local citation unbalance.
Top Producers and Consumers

**producer: Berkeley California**
- Beijing
- Moscow
- Dubna
- Seoul
- Tokyo
- Taipei
- Kolkata
- Karlsruhe
- Madrid
- Trieste

**producer: Boston**
- Beijing
- Moscow
- Seoul
- Tokyo
- Madrid
- Barcelona
- Trieste
- Dubna
- Taipei
- Karlsruhe

**producer: Zurich**
- Beijing
- Dresden
- Moscow
- Tokyo
- Seoul
- Taipei
- Madrid
- Trieste
- Berlin
- Shanghai

**producer: Orsay**
- Beijing
- Moscow
- Dresden
- Barcelona
- Dubna
- Madrid
- Tokyo
- Trieste
- Shanghai
- Seoul
- Valencia
Scientific Production Ranking

How do you diffuse scientific credit?

Which cities have the most impact?

\[ P_i = q z_i + (1 - q) \sum_j \frac{P_j}{s^\text{out}_j} w_{ji} + (1 - q) z_i \sum_j P_j \Delta(s^\text{out}_j). \]

\[ z_i = \frac{\sum_p \Delta_{p,i} \delta / n_p}{\sum_j \sum_p \Delta_{p,j} \delta / n_p}, \]

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Scientific Production Ranking

How do you diffuse scientific credit?

Which cities have the most impact?

\[ P_i = qz_i + (1-q) \sum_j P_j \sigma_{ji} w_{ji} + (1-q)z_i \sum_j P_j \Delta \left( \sigma_{ji}^{\text{out}} \right). \]

\[ z_i = \frac{\sum_p \Delta_{p,i} 1/n_p}{\sum_j \sum_p \Delta_{p,j} 1/n_p}, \]

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<th>Continent</th>
<th>1990</th>
<th>2009</th>
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</thead>
<tbody>
<tr>
<td>Asia</td>
<td>4.0%</td>
<td>11.0%</td>
</tr>
<tr>
<td>Europe</td>
<td>24.0%</td>
<td>33.0%</td>
</tr>
<tr>
<td>N. America</td>
<td>72.0%</td>
<td>56.0%</td>
</tr>
</tbody>
</table>

Table 3 | Percentage of top 100 ranked cities in continents in 1990 and 2009
City Ranking Over Time

As they are not cited. We believe that the present algorithm may be considered as an appropriate way to rank scientific production taking properly into account the impact of papers as measured by citations.

Discussion

In this paper we study the scientific knowledge flows among cities as measured by papers and citations contained in APS journals. In order to make clear the meaning and difference between producers and consumers in the context of knowledge, we propose an economical analogy referring to citations as a traded currency between urban areas. We then study the flow of citations from producers to consumers with the knowledge production proxy algorithm. Finally, we rank the importance of cities as function of time using the scientific production ranking algorithm. This method, inspired by the PageRank, allows us to evaluate the importance of cities explicitly considering the complex nature of citation patterns. In our analysis we considered just scientific publications contained in the APS journals. We do not have information on citations received or assigned to papers outside this dataset. These limitations certainly affect the count of citations of each city, potentially creating biases in our results. However, our findings, while limited to a particular dataset, are aligned with different observations reported by other studies focused on other datasets and fields. For example, we identify major US cities (e.g. Boston and San Francisco areas), as the most important sources of Physics. Similar observations have been done by Bo¨rner et al. at the institution level considering papers published in the Proceedings of the National Academy of Sciences, by Mazloumian et al. at country and city level with Web of Science dataset, and by...

Figure 5 | Top 20 ranked cities as a function of time.

The plot summarizes Top 20 ranked cities in 1990, 1995, 2000, 2005 and 2009 (from left to right), and relations between the rankings in different years. The grey lines are used when the rank of that city drops out of Top 20.

Figure 6 | Geospatial distribution of city ranks.

(A) The world map of city ranks in 1990 (left) and 2009 (right). The ranking of each city is represented by color from blue (high ranks) to white (low ranks). (B) The map of ranks for cities in the United States in 1990 (left) and 2009 (right). (C) The map of ranks for cities in the selected European countries in 1990 (left) and 2009 (right). In (B) and (C), each city is marked with a bar, and the height of each bar is inversely proportional to the ranking position. The Top 3 rank positions in each region are labelled for reference. Note that in (C) the height of bars is not scaled with the height in (B) for visibility. Maps in panel (A) are created by using ArcGIS, and maps in panel (B) and (C) are created by using R.

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Discussion

• We analyze over 50 years of APS citation data;

• The addition of geolocation information allows for new analyses and insights;

• The knowledge diffusion proxy can chart the diffusion of knowledge, going beyond local measures.

• We can observe the rise of new Physics production centers, indicating a less US centric era;

• Network measures are required to provide a global view of scientific production and impact;

• Our methodologies can be easily applied to other fields and datasets.