

AlphaGenome 高级可视化

本 notebook 涵盖 AlphaGenome 预测的高级可视化技术。

您将学到：

- 创建出版物质量的图表
 - 多面板可视化
 - 自定义样式和注释
 - 导出为各种格式 (PNG、PDF、SVG)
-

1. 导入库和设置

```
In [1]: # AlphaGenome 库
from alphagenome.data import genome
from alphagenome.models import dna_client

# 可视化
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np

# 数据处理
import pandas as pd
from pathlib import Path

# 我们的自定义工具
import sys
sys.path.insert(0, '/opt/alphagenome_packages')
from alphagenome_tools import quick_plot, monitor_api_quota
from alphagenome_tools.visualization import (
    plot_tracks_overlaid,
    plot_expression_heatmap,
    create_multi_panel_figure,
    save_figure
)

print("✓ 所有库已成功导入")
```

```
/usr/local/lib/python3.10/dist-packages/tqdm/auto.py:21: TqdmWarning: IP
gress not found. Please update jupyter and ipywidgets. See https://ipywidg
ets.readthedocs.io/en/stable/user_install.html
  from .autonotebook import tqdm as notebook_tqdm
Warning: alphagenome package not installed. Install with: pip install alph
agenome
✓ 所有库已成功导入
```

2. 配置可视化设置

```
In [ ]: # 设置样式和参数
sns.set_style('whitegrid')

# 图表设置
plt.rcParams['figure.dpi'] = 100
plt.rcParams['savefig.dpi'] = 300
plt.rcParams['font.size'] = 10
plt.rcParams['font.family'] = 'DejaVu Sans'

# 调色板
colors = {
    'reference': '#4477AA',
    'alternate': '#CC6677',
    'highlight': '#DDCC77',
    'neutral': '#888888'
}

print("✓ 可视化设置已配置")
print(f"✓ 使用调色板: {list(colors.keys())}")
```

- ✓ 可视化设置已配置
- ✓ 使用调色板: ['reference', 'alternate', 'highlight', 'neutral']

3. 加载可视化示例数据

```
In [3]: import os

# 从环境变量获取 API 密钥
api_key = os.environ.get('ALPHAGENOME_API_KEY')
if not api_key:
    raise ValueError(
        "环境变量中未找到 ALPHAGENOME_API_KEY! "
        "请确保在 docker-compose.yml 中已设置"
    )

# 连接到 AlphaGenome
model = dna_client.create(api_key=api_key)
print("✓ 已连接到 AlphaGenome")

# 定义用于可视化的区域
# 注意: 必须使用模型支持的长度: 16384, 131072, 524288, 或 1048576
interval = genome.Interval(
    chromosome='chr22',
    start=35677410,
    end=35677410 + 131072 # 131kb 区域 (模型支持)
)

print(f"\n分析区间: {interval.chromosome}:{interval.start:}-{interval.end}")
print(f"区间长度: {interval.end - interval.start:,} bp")
```

- ✓ 已连接到 AlphaGenome

分析区间: chr22:35,677,410-35,808,482
 区间长度: 131,072 bp

4. 自定义轨道可视化

创建带有自定义样式的叠加基因组轨道。

```
In [4]: # 为演示生成合成轨道数据
# 实际应用中, 这将来自 AlphaGenome 预测

n_points = 1000
x = np.linspace(interval.start, interval.end, n_points)

# 创建多个轨道
track1 = np.sin(np.linspace(0, 4*np.pi, n_points)) * 0.5 + 0.5
track2 = np.cos(np.linspace(0, 4*np.pi, n_points)) * 0.3 + 0.4
track3 = np.random.randn(n_points).cumsum() / 50

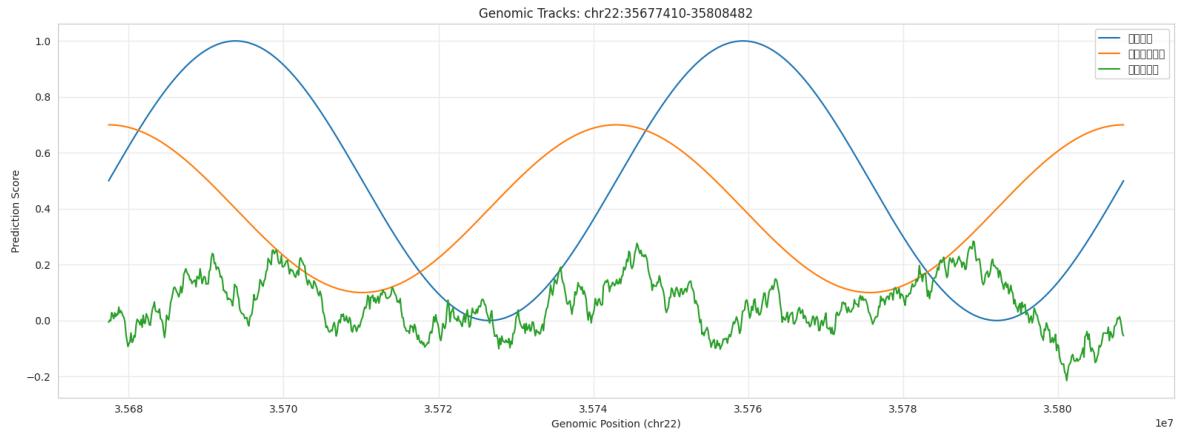
tracks_data = {
    '基因表达': track1,
    '染色质可及性': track2,
    '保守性评分': track3
}

# 绘制叠加轨道
fig = plot_tracks_overlaid(
    tracks_data=tracks_data,
    interval=interval,
    figsize=(16, 6)
)

if fig:
    plt.tight_layout()
    plt.show()
    print("✓ 已创建叠加轨道可视化")
```

```
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 22522 (\N{CJK UNIFIED IDEOGRAPH-57FA}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 22240 (\N{CJK UNIFIED IDEOGRAPH-56E0}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 34920 (\N{CJK UNIFIED IDEOGRAPH-8868}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 36798 (\N{CJK UNIFIED IDEOGRAPH-8FBE}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 26579 (\N{CJK UNIFIED IDEOGRAPH-67D3}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 33394 (\N{CJK UNIFIED IDEOGRAPH-8272}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 36136 (\N{CJK UNIFIED IDEOGRAPH-8D28}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 21487 (\N{CJK UNIFIED IDEOGRAPH-53EF}) missing from font(s) DejaVu Sans.  
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/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 21450 (\N{CJK UNIFIED IDEOGRAPH-53CA}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
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    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 20445 (\N{CJK UNIFIED IDEOGRAPH-4FDD}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 23432 (\N{CJK UNIFIED IDEOGRAPH-5B88}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 35780 (\N{CJK UNIFIED IDEOGRAPH-8BC4}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:394: UserWarning: Glyph 20998 (\N{CJK UNIFIED IDEOGRAPH-5206}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 22522 (\N{CJK UNIFIED IDEOGRAPH-57FA}) missing from font(s) DejaVu Sans.  
    fig.canvas.print_figure(bytes_io, **kw)
```

```
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 22240 (\N{CJK UNIFIED IDEOGRAPH-56E0}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 34920 (\N{CJK UNIFIED IDEOGRAPH-8868}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
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(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 26579 (\N{CJK UNIFIED IDEOGRAPH-67D3}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 33394 (\N{CJK UNIFIED IDEOGRAPH-8272}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 36136 (\N{CJK UNIFIED IDEOGRAPH-8D28}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 21487 (\N{CJK UNIFIED IDEOGRAPH-53EF}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 21450 (\N{CJK UNIFIED IDEOGRAPH-53CA}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
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(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
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(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 23432 (\N{CJK UNIFIED IDEOGRAPH-5B88}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 35780 (\N{CJK UNIFIED IDEOGRAPH-8BC4}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 20998 (\N{CJK UNIFIED IDEOGRAPH-5206}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
```



✓ 已创建叠加轨道可视化

5. 基因表达热图

```
In [5]: # 为热图创建合成表达数据
# 行: 不同的基因或基因组区域
# 列: 基因组位置或样本

n_genes = 20
n_positions = 50

# 生成合成表达数据
expression_data = np.random.randn(n_genes, n_positions)
# 添加一些结构
for i in range(n_genes):
    expression_data[i, :] += np.sin(np.linspace(0, i, n_positions)) * 2

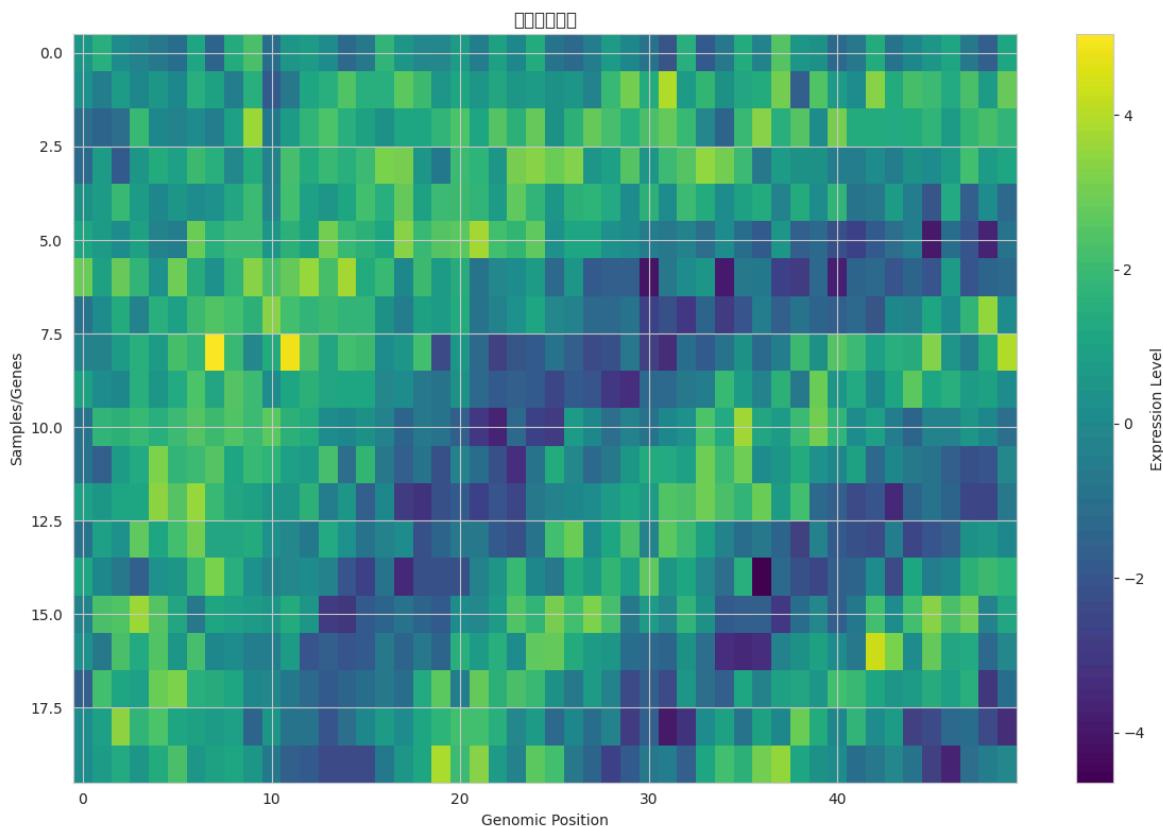
# 创建热图
fig = plot_expression_heatmap(
    data=expression_data,
    figsize=(12, 8),
    cmap='viridis',
    title='基因表达热图'
)

if fig:
    plt.show()
    print("✓ 已创建表达热图")
```

```

/opt/alphagenome_packages/alphagenome_tools/visualization.py:326: UserWarning: Glyph 22522 (\N{CJK UNIFIED IDEOGRAPH-57FA}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:326: UserWarning: Glyph 22240 (\N{CJK UNIFIED IDEOGRAPH-56E0}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:326: UserWarning: Glyph 34920 (\N{CJK UNIFIED IDEOGRAPH-8868}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:326: UserWarning: Glyph 36798 (\N{CJK UNIFIED IDEOGRAPH-8FBE}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:326: UserWarning: Glyph 28909 (\N{CJK UNIFIED IDEOGRAPH-70ED}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:326: UserWarning: Glyph 22270 (\N{CJK UNIFIED IDEOGRAPH-56FE}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 28909 (\N{CJK UNIFIED IDEOGRAPH-70ED}) missing from font(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)

```



✓ 已创建表达热图

6. 多面板出版物图表

创建适合出版物的复杂多面板图表。

```
In [6]: # 为多面板图表准备数据
# 实际应用中, 这些将是真实的 AlphaGenome 输出

panel_data = [
    track1, # 面板 A
    track2, # 面板 B
    expression_data[:10, :], # 面板 C
    track3, # 面板 D
]

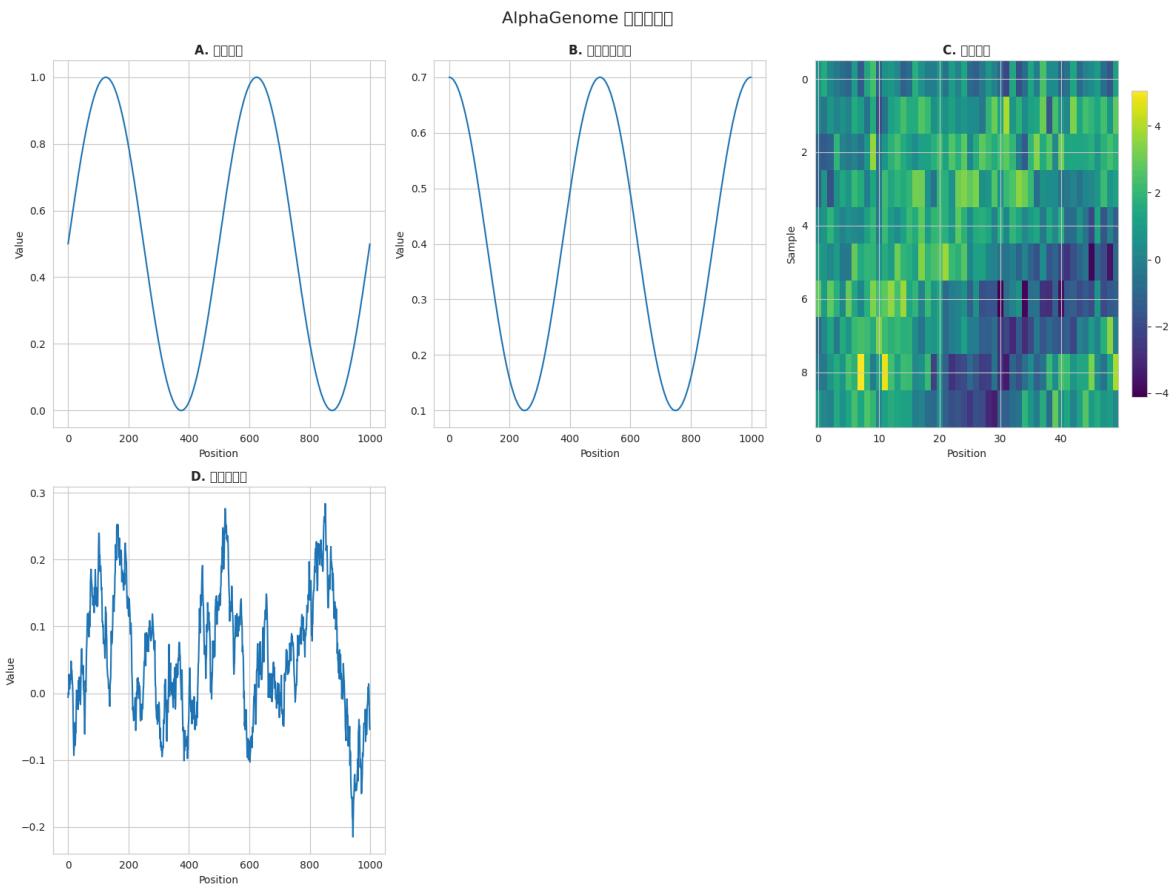
panel_titles = [
    'A. 基因表达',
    'B. 染色质可及性',
    'C. 表达热图',
    'D. 保守性评分'
]

# 创建多面板图表
fig = create_multi_panel_figure(
    outputs_list=panel_data,
    titles=panel_titles,
    figsize=(16, 12),
    main_title='AlphaGenome 多模态预测'
)

if fig:
    plt.tight_layout()
    plt.show()
    print("✓ 已创建多面板图表")
```

```
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 22522 (\N{CJK UNIFIED IDEOGRAPH-57FA}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 22240 (\N{CJK UNIFIED IDEOGRAPH-56E0}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 34920 (\N{CJK UNIFIED IDEOGRAPH-8868}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 36798 (\N{CJK UNIFIED IDEOGRAPH-8FBE}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 26579 (\N{CJK UNIFIED IDEOGRAPH-67D3}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 33394 (\N{CJK UNIFIED IDEOGRAPH-8272}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 36136 (\N{CJK UNIFIED IDEOGRAPH-8D28}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 21487 (\N{CJK UNIFIED IDEOGRAPH-53EF}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 21450 (\N{CJK UNIFIED IDEOGRAPH-53CA}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 24615 (\N{CJK UNIFIED IDEOGRAPH-6027}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 28909 (\N{CJK UNIFIED IDEOGRAPH-70ED}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 22270 (\N{CJK UNIFIED IDEOGRAPH-56FE}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 20445 (\N{CJK UNIFIED IDEOGRAPH-4FDD}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 23432 (\N{CJK UNIFIED IDEOGRAPH-5B88}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()  
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 35780 (\N{CJK UNIFIED IDEOGRAPH-8BC4}) missing from font(s) DejaVu Sans.  
    plt.tight_layout()
```

```
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 20998 (\N{CJK UNIFIED IDEOGRAPH-5206}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 22810 (\N{CJK UNIFIED IDEOGRAPH-591A}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 27169 (\N{CJK UNIFIED IDEOGRAPH-6A21}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 24577 (\N{CJK UNIFIED IDEOGRAPH-6001}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 39044 (\N{CJK UNIFIED IDEOGRAPH-9884}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/opt/alphagenome_packages/alphagenome_tools/visualization.py:480: UserWarning: Glyph 27979 (\N{CJK UNIFIED IDEOGRAPH-6D4B}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 22810 (\N{CJK UNIFIED IDEOGRAPH-591A}) missing from font(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 27169 (\N{CJK UNIFIED IDEOGRAPH-6A21}) missing from font(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 24577 (\N{CJK UNIFIED IDEOGRAPH-6001}) missing from font(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 39044 (\N{CJK UNIFIED IDEOGRAPH-9884}) missing from font(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 27979 (\N{CJK UNIFIED IDEOGRAPH-6D4B}) missing from font(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
```



✓ 已创建多面板图表

7. 自定义样式和注释

```
In [7]: # 创建完全自定义的图表
fig, ax = plt.subplots(figsize=(14, 6))

# 使用自定义样式绘制数据
ax.plot(x, track1, color=colors['reference'], linewidth=2, label='参考')
ax.plot(x, track2, color=colors['alternate'], linewidth=2, label='替代')

# 添加变异注释
variant_pos = interval.start + (interval.end - interval.start) // 2
ax.axvline(variant_pos, color=colors['highlight'], linestyle='--', linewidth=2)

# 添加阴影区域
ax.axvspan(variant_pos - 10000, variant_pos + 10000, alpha=0.2, color=colors['highlight'])

# 自定义样式
ax.set_xlabel('基因组位置', fontsize=12, fontweight='bold')
ax.set_ylabel('预测评分', fontsize=12, fontweight='bold')
ax.set_title('自定义样式的 AlphaGenome 可视化', fontsize=14, fontweight='bold')

# 自定义图例
legend = ax.legend(loc='upper right', frameon=True, shadow=True)
legend.get_frame().set_facecolor('white')
legend.get_frame().set_alpha(0.9)

# 添加网格
ax.grid(True, alpha=0.3, linestyle=':')

# 添加文本注释
```

```
ax.text(0.02, 0.98, 'AlphaGenome 分析',
        transform=ax.transAxes, fontsize=10,
        verticalalignment='top',
        bbox=dict(boxstyle='round', facecolor='wheat', alpha=0.5))

plt.tight_layout()
plt.show()

print("✓ 已创建自定义样式可视化")
```

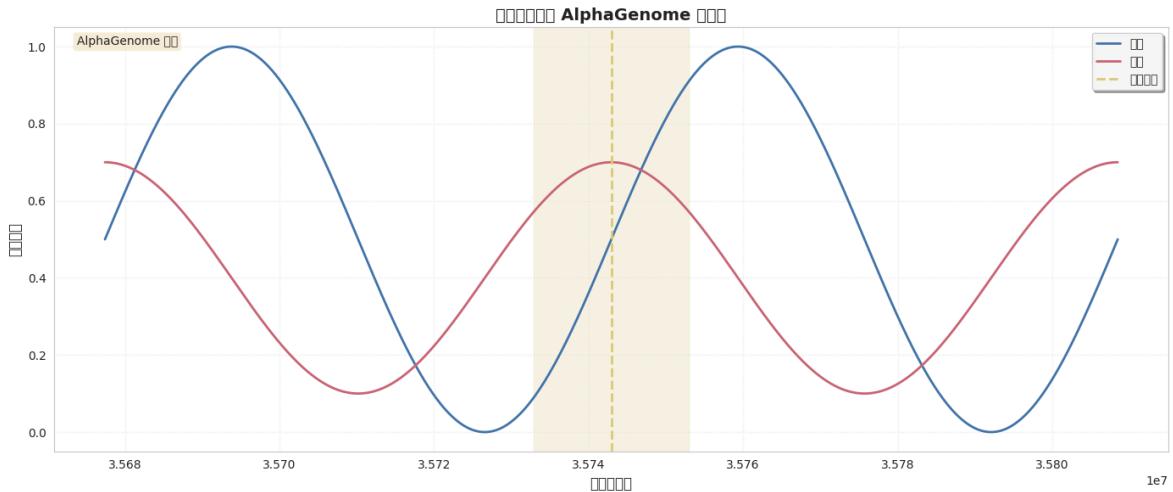
```
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 22522 (\N{CJK UNIF
IED IDEOGRAPH-57FA}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 22240 (\N{CJK UNIF
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    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 32452 (\N{CJK UNIF
IED IDEOGRAPH-7EC4}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 20301 (\N{CJK UNIF
IED IDEOGRAPH-4F4D}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 32622 (\N{CJK UNIF
IED IDEOGRAPH-7F6E}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 39044 (\N{CJK UNIF
IED IDEOGRAPH-9884}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 27979 (\N{CJK UNIF
IED IDEOGRAPH-6D4B}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 35780 (\N{CJK UNIF
IED IDEOGRAPH-8BC4}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 20998 (\N{CJK UNIF
IED IDEOGRAPH-5206}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 33258 (\N{CJK UNIF
IED IDEOGRAPH-81EA}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 23450 (\N{CJK UNIF
IED IDEOGRAPH-5B9A}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 20041 (\N{CJK UNIF
IED IDEOGRAPH-4E49}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 26679 (\N{CJK UNIF
IED IDEOGRAPH-6837}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 24335 (\N{CJK UNIF
IED IDEOGRAPH-5F0F}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 30340 (\N{CJK UNIF
IED IDEOGRAPH-7684}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 21487 (\N{CJK UNIF
IED IDEOGRAPH-53EF}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 35270 (\N{CJK UNIF
IED IDEOGRAPH-89C6}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 21270 (\N{CJK UNIF
IED IDEOGRAPH-5316}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 26512 (\N{CJK UNIF
IED IDEOGRAPH-6790}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 21442 (\N{CJK UNIF
IED IDEOGRAPH-53C2}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
```

```
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 32771 (\N{CJK UNIF
IED IDEOGRAPH-8003}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 26367 (\N{CJK UNIF
IED IDEOGRAPH-66FF}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 20195 (\N{CJK UNIF
IED IDEOGRAPH-4EE3}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 21464 (\N{CJK UNIF
IED IDEOGRAPH-53D8}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/tmp/ipykernel_294/2455918534.py:34: UserWarning: Glyph 24322 (\N{CJK UNIF
IED IDEOGRAPH-5F02}) missing from font(s) DejaVu Sans.
    plt.tight_layout()
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 32452 (\N{CJK UNIFIED IDEOGRAPH-7EC4}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 20301 (\N{CJK UNIFIED IDEOGRAPH-4F4D}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 32622 (\N{CJK UNIFIED IDEOGRAPH-7F6E}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 33258 (\N{CJK UNIFIED IDEOGRAPH-81EA}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 23450 (\N{CJK UNIFIED IDEOGRAPH-5B9A}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 20041 (\N{CJK UNIFIED IDEOGRAPH-4E49}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 26679 (\N{CJK UNIFIED IDEOGRAPH-6837}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 24335 (\N{CJK UNIFIED IDEOGRAPH-5F0F}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 30340 (\N{CJK UNIFIED IDEOGRAPH-7684}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 35270 (\N{CJK UNIFIED IDEOGRAPH-89C6}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 21270 (\N{CJK UNIFIED IDEOGRAPH-5316}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
```

```

erWarning: Glyph 26512 (\N{CJK UNIFIED IDEOGRAPH-6790}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 21442 (\N{CJK UNIFIED IDEOGRAPH-53C2}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 32771 (\N{CJK UNIFIED IDEOGRAPH-8003}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 26367 (\N{CJK UNIFIED IDEOGRAPH-66FF}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 20195 (\N{CJK UNIFIED IDEOGRAPH-4EE3}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 21464 (\N{CJK UNIFIED IDEOGRAPH-53D8}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 24322 (\N{CJK UNIFIED IDEOGRAPH-5F02}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)

```



✓ 已创建自定义样式可视化

8. 导出为多种格式

```

In [8]: # 创建输出目录
output_dir = Path.home() / 'work' / 'results' / 'visualizations'
output_dir.mkdir(parents=True, exist_ok=True)

# 以多种格式保存图表
base_path = output_dir / 'custom_visualization'

formats = ['png', 'pdf', 'svg']
for fmt in formats:
    save_figure(fig, base_path, formats=[fmt])

print(f"✓ 图表已保存为 {len(formats)} 种格式:")
for fmt in formats:

```

```
print(f" - {base_path}.{fmt}")  
print(f"\n所有可视化已保存到: {output_dir}")
```

```
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 22522 (\N{CJK UNIFIED IDEOGRAPH-57FA}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 22240 (\N{CJK UNIFIED IDEOGRAPH-56E0}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 32452 (\N{CJK UNIFIED IDEOGRAPH-7EC4}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 20301 (\N{CJK UNIFIED IDEOGRAPH-4F4D}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 32622 (\N{CJK UNIFIED IDEOGRAPH-7F6E}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 39044 (\N{CJK UNIFIED IDEOGRAPH-9884}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 27979 (\N{CJK UNIFIED IDEOGRAPH-6D4B}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 35780 (\N{CJK UNIFIED IDEOGRAPH-8BC4}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 20998 (\N{CJK UNIFIED IDEOGRAPH-5206}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 33258 (\N{CJK UNIFIED IDEOGRAPH-81EA}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 23450 (\N{CJK UNIFIED IDEOGRAPH-5B9A}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 20041 (\N{CJK UNIFIED IDEOGRAPH-4E49}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 26679 (\N{CJK UNIFIED IDEOGRAPH-6837}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 24335 (\N{CJK UNIFIED IDEOGRAPH-5F0F}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 30340 (\N{CJK UNIFIED IDEOGRAPH-7684}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
```

```
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 21487 (\N{CJK UNIFIED IDEOGRAPH-53EF}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 35270 (\N{CJK UNIFIED IDEOGRAPH-89C6}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 21270 (\N{CJK UNIFIED IDEOGRAPH-5316}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 26512 (\N{CJK UNIFIED IDEOGRAPH-6790}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 21442 (\N{CJK UNIFIED IDEOGRAPH-53C2}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 32771 (\N{CJK UNIFIED IDEOGRAPH-8003}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 26367 (\N{CJK UNIFIED IDEOGRAPH-66FF}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 20195 (\N{CJK UNIFIED IDEOGRAPH-4EE3}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 21464 (\N{CJK UNIFIED IDEOGRAPH-53D8}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 24322 (\N{CJK UNIFIED IDEOGRAPH-5F02}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
2026-02-09 06:00:46,588 - alphagenome_tools.visualization - INFO - Figure saved to /home/admin/work/results/visualizations/custom_visualization.png
2026-02-09 06:00:46,706 - alphagenome_tools.visualization - INFO - Figure saved to /home/admin/work/results/visualizations/custom_visualization.pdf
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 22522 (\N{CJK UNIFIED IDEOGRAPH-57FA}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 22240 (\N{CJK UNIFIED IDEOGRAPH-56E0}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 32452 (\N{CJK UNIFIED IDEOGRAPH-7EC4}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 20301 (\N{CJK UNIFIED IDEOGRAPH-4F4D}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
```

```
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 32622 (\N{CJK UNIFIED IDEOGRAPH-7F6E}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 39044 (\N{CJK UNIFIED IDEOGRAPH-9884}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 27979 (\N{CJK UNIFIED IDEOGRAPH-6D4B}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 35780 (\N{CJK UNIFIED IDEOGRAPH-8BC4}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 20998 (\N{CJK UNIFIED IDEOGRAPH-5206}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 33258 (\N{CJK UNIFIED IDEOGRAPH-81EA}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 23450 (\N{CJK UNIFIED IDEOGRAPH-5B9A}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 20041 (\N{CJK UNIFIED IDEOGRAPH-4E49}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 26679 (\N{CJK UNIFIED IDEOGRAPH-6837}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 24335 (\N{CJK UNIFIED IDEOGRAPH-5F0F}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 30340 (\N{CJK UNIFIED IDEOGRAPH-7684}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 21487 (\N{CJK UNIFIED IDEOGRAPH-53EF}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 35270 (\N{CJK UNIFIED IDEOGRAPH-89C6}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 21270 (\N{CJK UNIFIED IDEOGRAPH-5316}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 26512 (\N{CJK UNIFIED IDEOGRAPH-6790}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
```

```

/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 21442 (\N{CJK UNIFIED IDEOGRAPH-53C2}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 32771 (\N{CJK UNIFIED IDEOGRAPH-8003}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 26367 (\N{CJK UNIFIED IDEOGRAPH-66FF}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 20195 (\N{CJK UNIFIED IDEOGRAPH-4EE3}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
/opt/alphagenome_packages/alphagenome_tools/visualization.py:508: UserWarning: Glyph 21464 (\N{CJK UNIFIED IDEOGRAPH-53D8}) missing from font(s) DejaVu Sans.
    fig.savefig(output_path, bbox_inches='tight', format=fmt)
2026-02-09 06:00:46,741 - alphagenome_tools.visualization - INFO - Figure saved to /home/admin/work/results/visualizations/custom_visualization.svg
✓ 图表已保存为 3 种格式:
- /home/admin/work/results/visualizations/custom_visualization.png
- /home/admin/work/results/visualizations/custom_visualization.pdf
- /home/admin/work/results/visualizations/custom_visualization.svg

```

所有可视化已保存到: /home/admin/work/results/visualizations

9. 高级：具有共享坐标轴的子图网格

```

In [9]: # 创建复杂的子图网格
fig = plt.figure(figsize=(16, 10))

# 创建网格规范
gs = fig.add_gridspec(3, 2, hspace=0.3, wspace=0.3)

# 主图 (跨越 2 列)
ax_main = fig.add_subplot(gs[0, :])
ax_main.plot(x, track1, color=colors['reference'], linewidth=2)
ax_main.set_title('主预测轨道', fontsize=12, fontweight='bold')
ax_main.set_ylabel('评分')

# 子图 1
ax1 = fig.add_subplot(gs[1, 0])
ax1.plot(x, track2, color=colors['alternate'], linewidth=1.5)
ax1.set_title('轨道 1')
ax1.sharex(ax_main)

# 子图 2
ax2 = fig.add_subplot(gs[1, 1])
ax2.plot(x, track3, color=colors['highlight'], linewidth=1.5)
ax2.set_title('轨道 2')
ax2.sharex(ax_main)

```

```
# 热图
ax3 = fig.add_subplot(gs[2, :])
im = ax3.imshow(expression_data[:10, :], aspect='auto', cmap='viridis')
ax3.set_title('表达摘要')
plt.colorbar(im, ax=ax3)

# 总标题
fig.suptitle('复杂 AlphaGenome 可视化', fontsize=16, fontweight='bold', y=0.95)
plt.show()

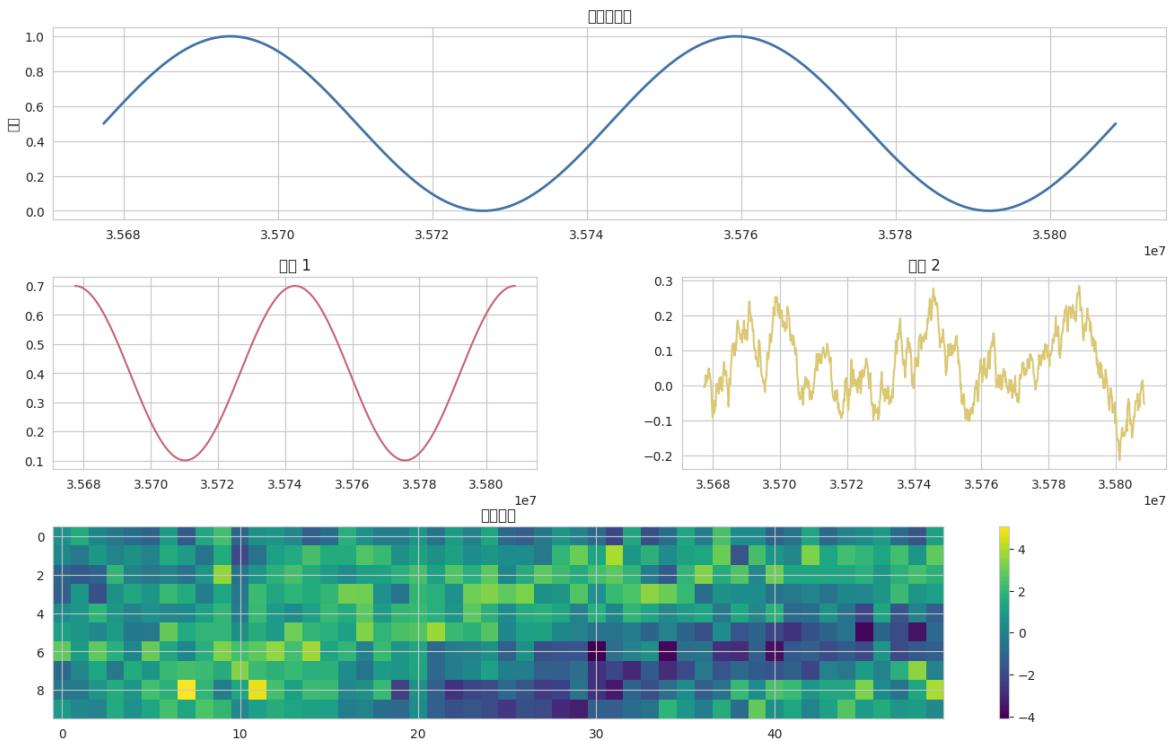
# 保存
fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')
print("✓ 已创建并保存复杂子图可视化")
```

```
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 35780 (\N{CJK UNIFIED IDEOGRAPH-8BC4}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 20998 (\N{CJK UNIFIED IDEOGRAPH-5206}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 20027 (\N{CJK UNIFIED IDEOGRAPH-4E3B}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 39044 (\N{CJK UNIFIED IDEOGRAPH-9884}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 27979 (\N{CJK UNIFIED IDEOGRAPH-6D4B}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 36712 (\N{CJK UNIFIED IDEOGRAPH-8F68}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 36947 (\N{CJK UNIFIED IDEOGRAPH-9053}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 34920 (\N{CJK UNIFIED IDEOGRAPH-8868}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 36798 (\N{CJK UNIFIED IDEOGRAPH-8FBE}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 25688 (\N{CJK UNIFIED IDEOGRAPH-6458}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 35201 (\N{CJK UNIFIED IDEOGRAPH-8981}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 22797 (\N{CJK UNIFIED IDEOGRAPH-590D}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 26434 (\N{CJK UNIFIED IDEOGRAPH-6742}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 21487 (\N{CJK UNIFIED IDEOGRAPH-53EF}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: Us
erWarning: Glyph 35270 (\N{CJK UNIFIED IDEOGRAPH-89C6}) missing from font
(s) DejaVu Sans.
    fig.canvas.print_figure(bytes_io, **kw)
```

```
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 21270 (\N{CJK UNIFIED IDEOGRAPH-5316}) missing from font(s) DejaVu Sans.
```

```
fig.canvas.print_figure(bytes_io, **kw)
```

□□ AlphaGenome □□□



```
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 35780 (\N{CJK UNIFI ED IDEOGRAPH-8BC4}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 20998 (\N{CJK UNIFI ED IDEOGRAPH-5206}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 20027 (\N{CJK UNIFI ED IDEOGRAPH-4E3B}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 39044 (\N{CJK UNIFI ED IDEOGRAPH-9884}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 27979 (\N{CJK UNIFI ED IDEOGRAPH-6D4B}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 36712 (\N{CJK UNIFI ED IDEOGRAPH-8F68}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 36947 (\N{CJK UNIFI ED IDEOGRAPH-9053}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 34920 (\N{CJK UNIFI ED IDEOGRAPH-8868}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 36798 (\N{CJK UNIFI ED IDEOGRAPH-8FBE}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 25688 (\N{CJK UNIFI ED IDEOGRAPH-6458}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 35201 (\N{CJK UNIFI ED IDEOGRAPH-8981}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 22797 (\N{CJK UNIFI ED IDEOGRAPH-590D}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 26434 (\N{CJK UNIFI ED IDEOGRAPH-6742}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 21487 (\N{CJK UNIFI ED IDEOGRAPH-53EF}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')  
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 35270 (\N{CJK UNIFI ED IDEOGRAPH-89C6}) missing from font(s) DejaVu Sans.  
    fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')
```

```
/tmp/ipykernel_294/216881770.py:37: UserWarning: Glyph 21270 (\N{CJK UNIFIED IDEOGRAPH-5316}) missing from font(s) DejaVu Sans.
  fig.savefig(output_dir / 'complex_visualization.png', dpi=300, bbox_inches='tight')
✓ 已创建并保存复杂子图可视化
```

10. 调色板和主题选择器

```
In [10]: # 定义适合出版物的调色板
palettes = {
    'nature': ['#E64B35', '#4DBBD5', '#00A087', '#3C5488', '#F39B7F'],
    'science': ['#3C5488', '#F39B7F', '#8491B4', '#91D1C2', '#DC0000'],
    'colorblind': ['#0072B2', '#009E73', '#D55E00', '#CC79A7', '#F0E442']
}

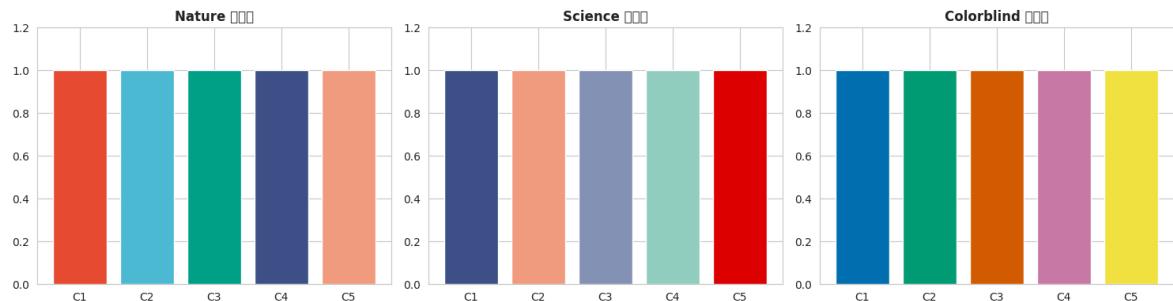
# 测试不同的调色板
fig, axes = plt.subplots(1, 3, figsize=(15, 4))

for idx, (name, palette) in enumerate(palettes.items()):
    for i, color in enumerate(palette):
        axes[idx].bar(i, 1, color=color, label=f'颜色 {i+1}')
    axes[idx].set_title(name.capitalize() + ' 调色板', fontweight='bold')
    axes[idx].set_xticks(range(len(palette)))
    axes[idx].set_xticklabels([f'C{i+1}' for i in range(len(palette))])
    axes[idx].set_ylim(0, 1.2)

plt.tight_layout()
plt.show()

print("可用的调色板:")
for name in palettes.keys():
    print(f" - {name}")
```

```
/tmp/ipykernel_294/3901812264.py:19: UserWarning: Glyph 35843 (\N{CJK UNIFIED IDEOGRAPH-8C03}) missing from font(s) DejaVu Sans.
  plt.tight_layout()
/tmp/ipykernel_294/3901812264.py:19: UserWarning: Glyph 33394 (\N{CJK UNIFIED IDEOGRAPH-8272}) missing from font(s) DejaVu Sans.
  plt.tight_layout()
/tmp/ipykernel_294/3901812264.py:19: UserWarning: Glyph 26495 (\N{CJK UNIFIED IDEOGRAPH-677F}) missing from font(s) DejaVu Sans.
  plt.tight_layout()
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 35843 (\N{CJK UNIFIED IDEOGRAPH-8C03}) missing from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 33394 (\N{CJK UNIFIED IDEOGRAPH-8272}) missing from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.10/dist-packages/IPython/core/pylabtools.py:170: UserWarning: Glyph 26495 (\N{CJK UNIFIED IDEOGRAPH-677F}) missing from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
```



可用的调色板：

- nature
- science
- colorblind

总结

在本 notebook 中，您学习了高级可视化技术：

- ✓ 自定义轨道可视化
- ✓ 基因表达热图
- ✓ 多面板出版物图表
- ✓ 自定义样式和注释
- ✓ 导出为多种格式 (PNG、PDF、SVG)
- ✓ 复杂子图网格
- ✓ 适合出版物的调色板

最佳实践：

- 对出版物图表使用高 DPI (300+)
- 尽可能保存为矢量格式 (PDF/SVG)
- 使用色盲友好的调色板
- 始终包含清晰的标签和图例
- 在灰度模式下测试配色方案

资源：

- Matplotlib 文档: <https://matplotlib.org/>
- Seaborn 画廊: <https://seaborn.pydata.org/examples/>
- ColorBrewer 调色板: <https://colorbrewer2.org/>