Effect of Pressure on the Melting Behavior of the Fe-S System at Moderate Pressures

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Outline

- Introduction
  - Fe-S system and planetary cores
  - Pressure effect on liquidus curve
- Experimental Methods
  - In situ x-ray radiographic technique
- Results & Discussion
  - In situ observation of melting
  - Fe-S eutectic
- Summary

Motivation

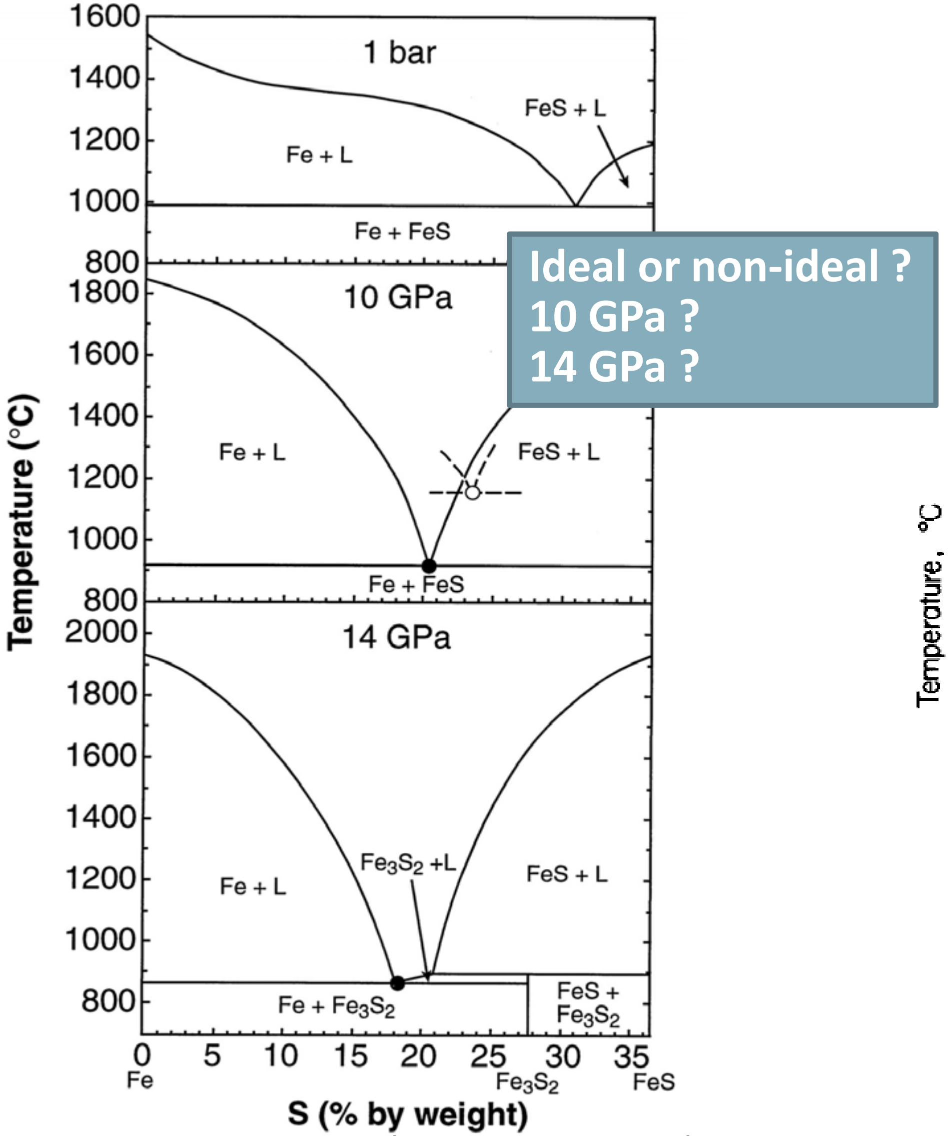
The study of melting behaviour of Fe-S system at high pressures allows us:

(1) to investigate solidification history of iron-rich cores.

(2) to establish a link between sulfur content and state of iron-rich cores.

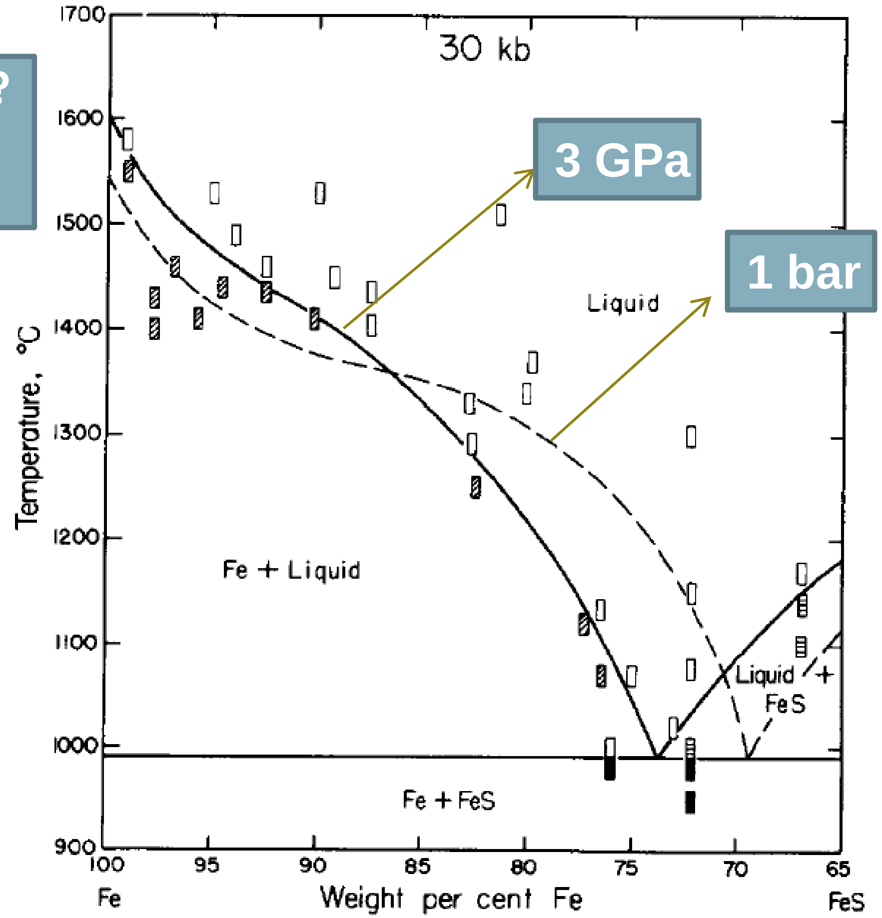
(3) to understand the generation of magnetic field and convection in iron-rich liquid cores.

Liquidus Curve



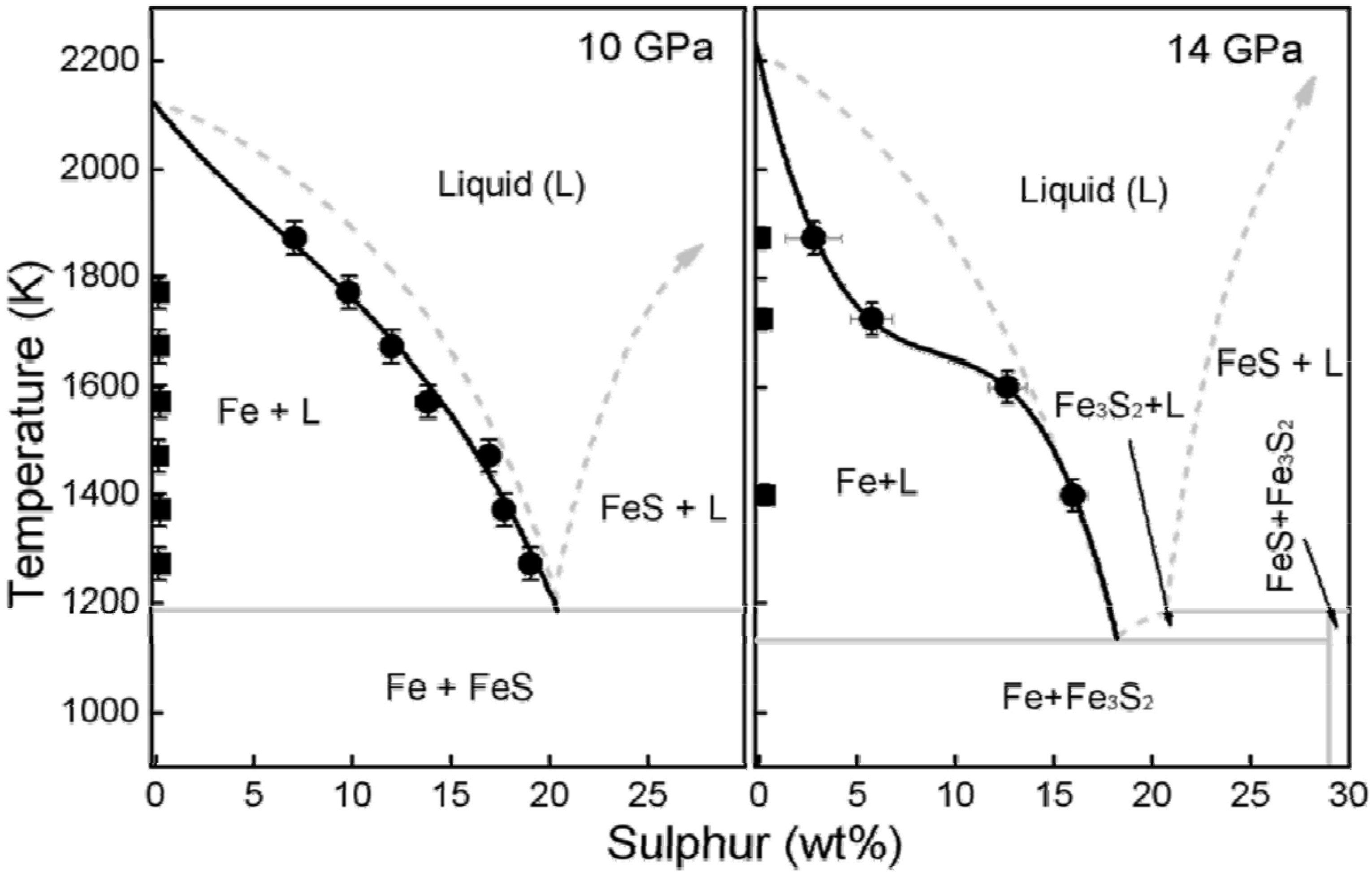
(Fei et al., 1997)

Positive departure from ideal solution at 1 bar



(Brett and Bell, 1969)

Liquidus curves at 10 and 14 GPa



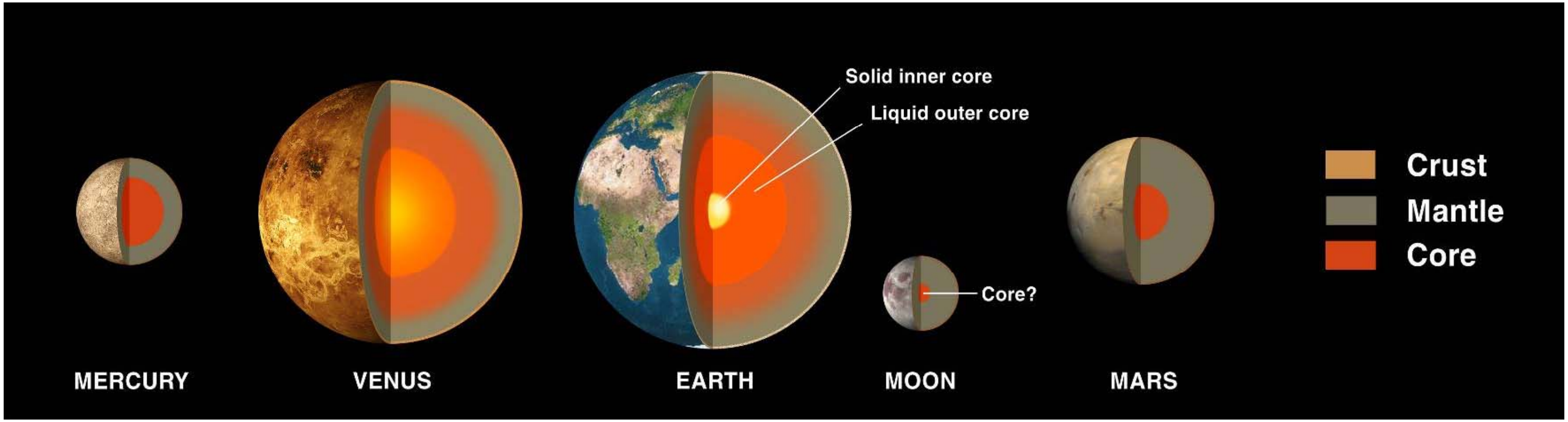
(Chen et al. submitted)

Application to Mercury

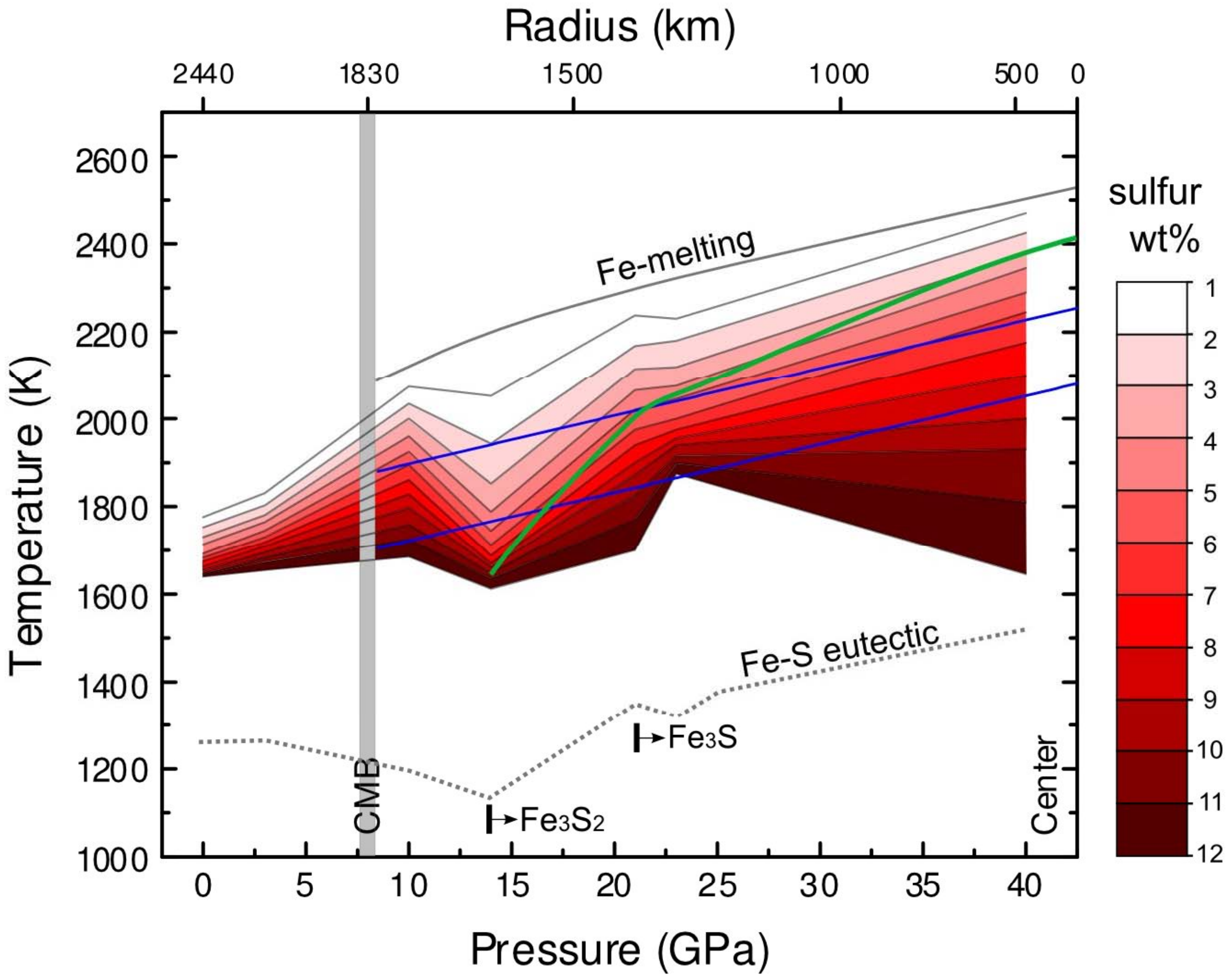
- CMB pressure is ~ 5-10 GPa,
- Center pressure is ~40 GPa
- Weak magnetic field
- Mercury's core is at least partially molten (Margot et al. 2007).

MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging)

(From: http://sse.jpl.nasa.gov)

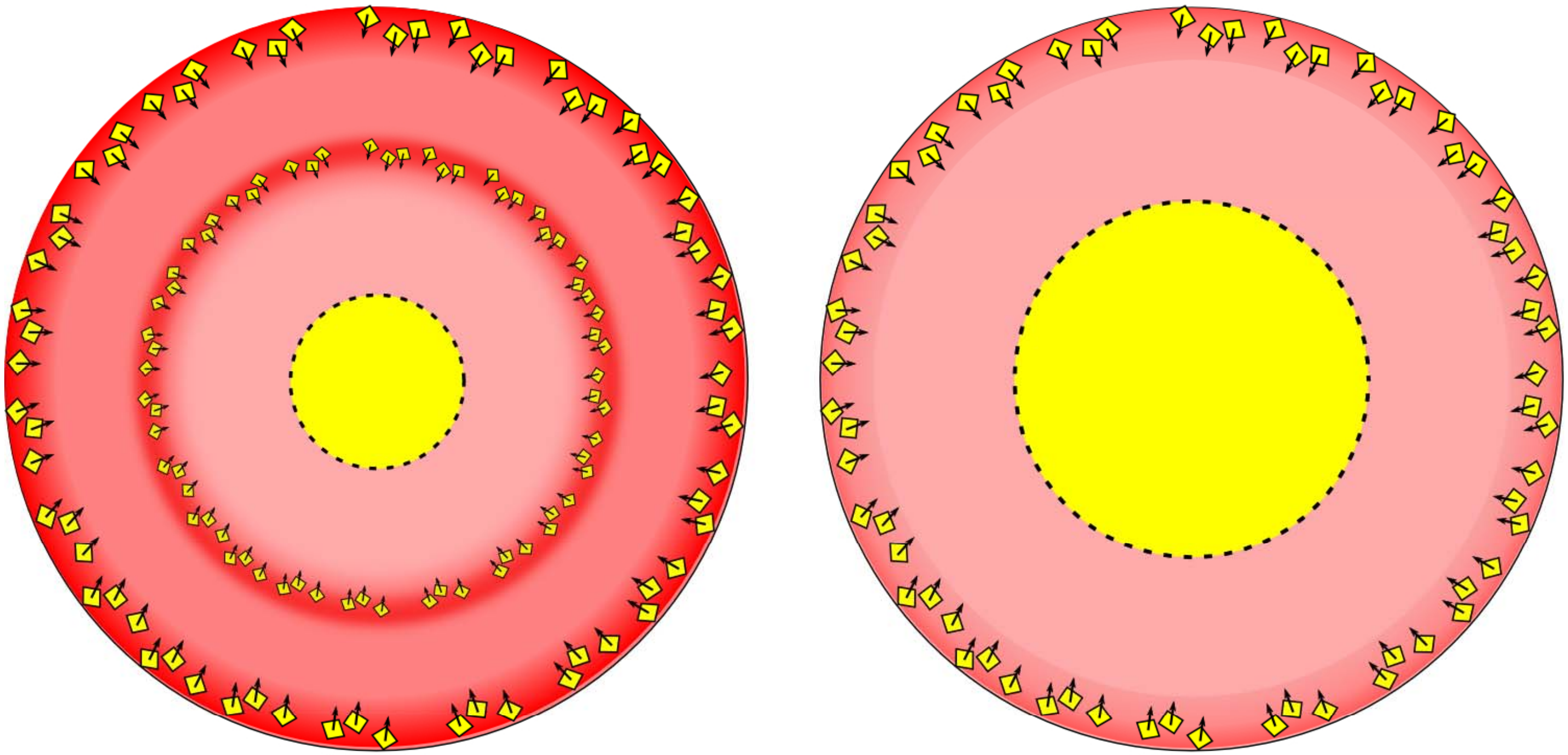


Liquidus T in Mercury's core



(Chen et al. submitted)

Mercury’s Snowing Core



Double-snow state

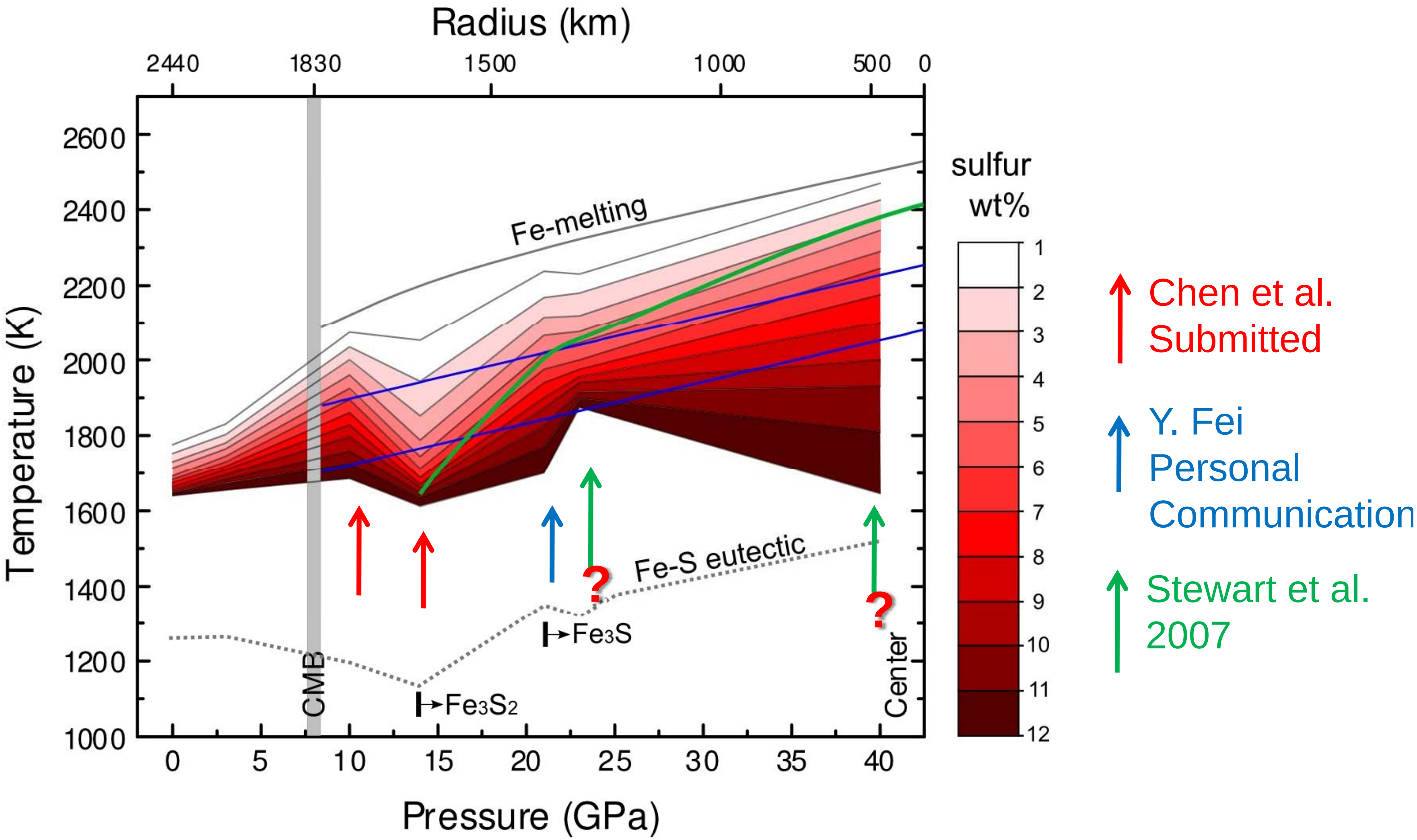
Ganymede-like state

Bulk sulfur content > 7 wt %

Bulk sulfur content < 7 wt %

(Chen et al. submitted)

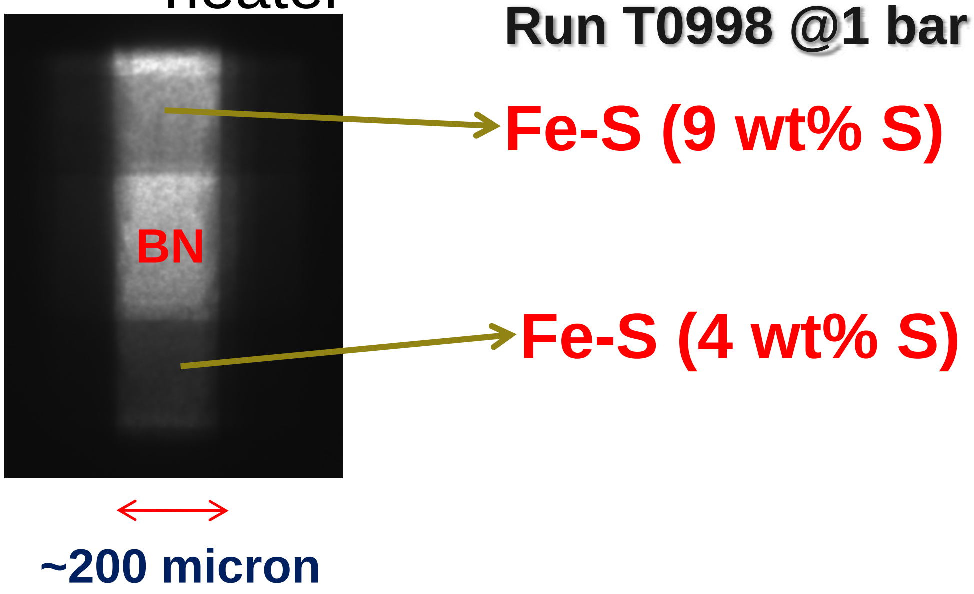
Limited Data Coverage



(Chen et al. submitted)

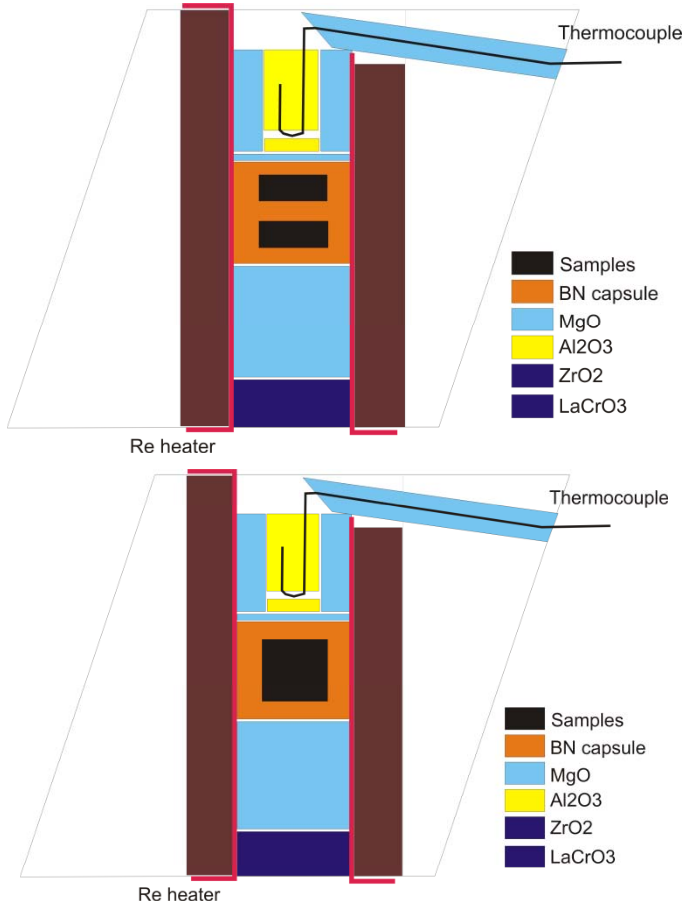
In situ Multi Anvil Experiments

- Experimental setup
  - Double/single sample chamber
  - Graphite X-ray window in Re heater



X-ray radiographic image

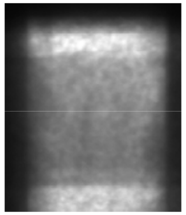
10/5 (by Kurt Leinenweber)



GSECARS (13-IDD)

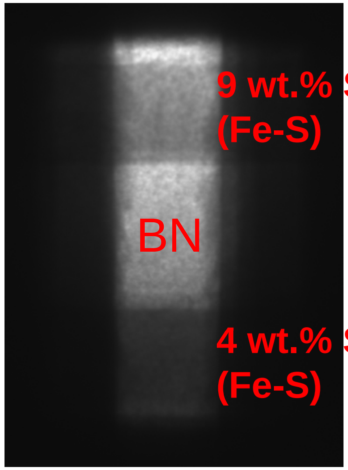
In-situ Observation of Melting (1)

1 bar



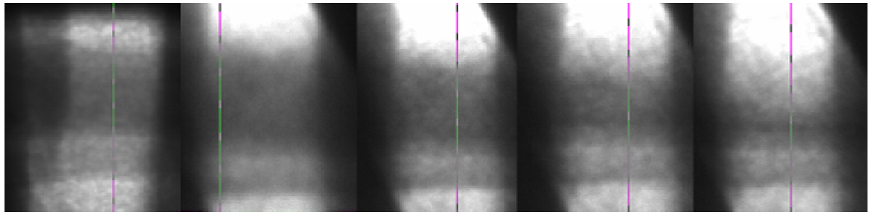
9 wt% S
(Fe-S)

Run T0898



~200 micron

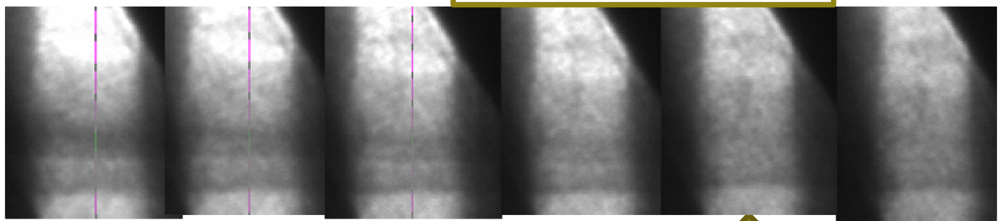
P=14 GPa



T (°C)

25 733 838 857 883

Eutectic Melting



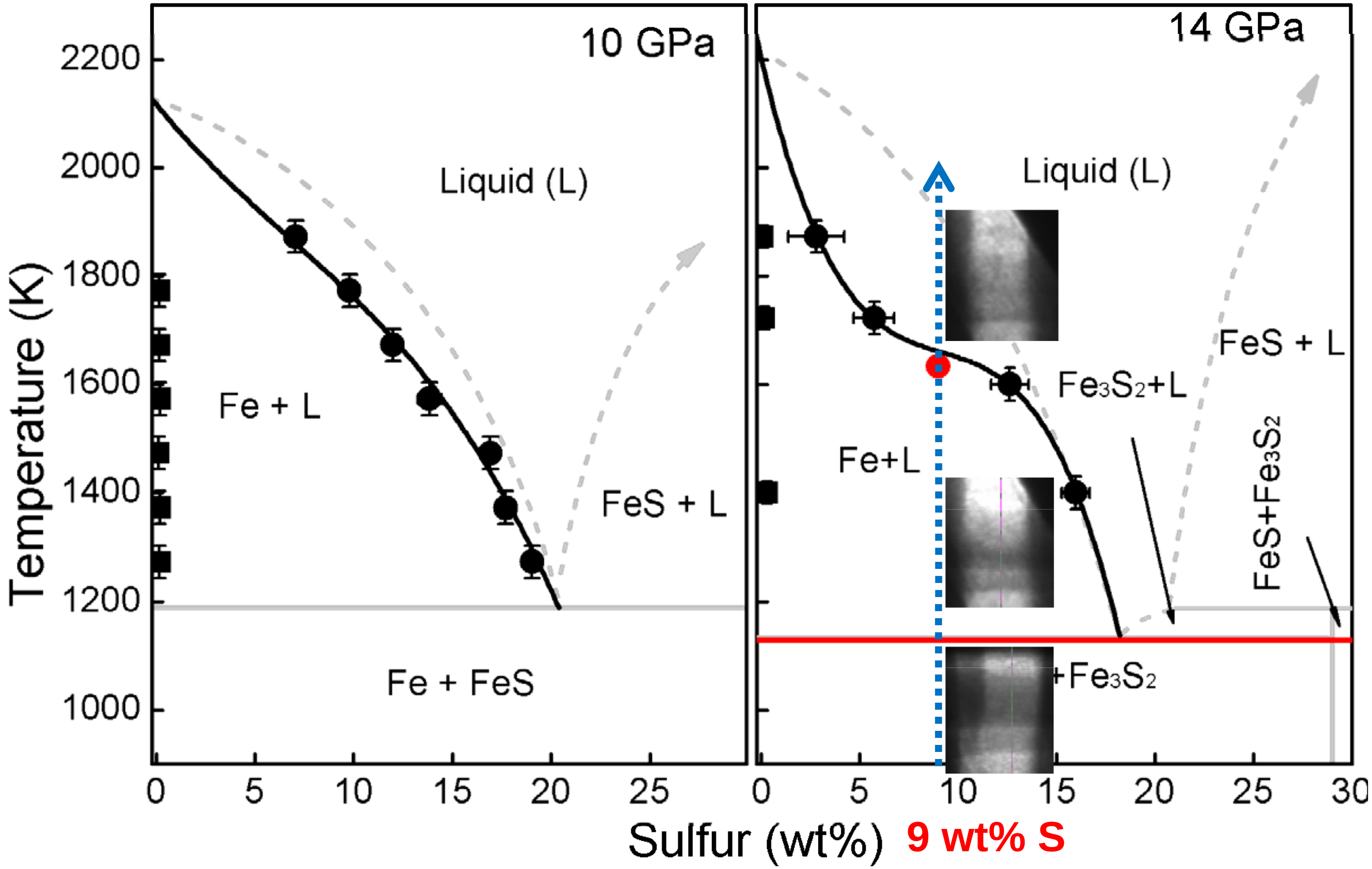
T (°C)

915 1006 1200 1300 1364 1400

Totally Molten

Eutectic T=860 °C @ 14 GPa
(Fei et al. 1997)

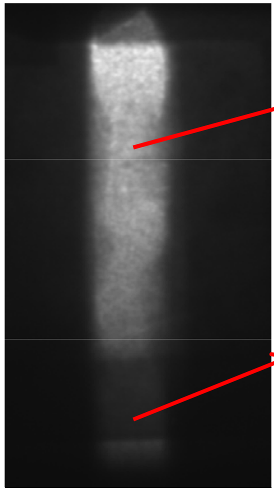
Consistent with Quench Experiments



(Chen et al. Submitted)

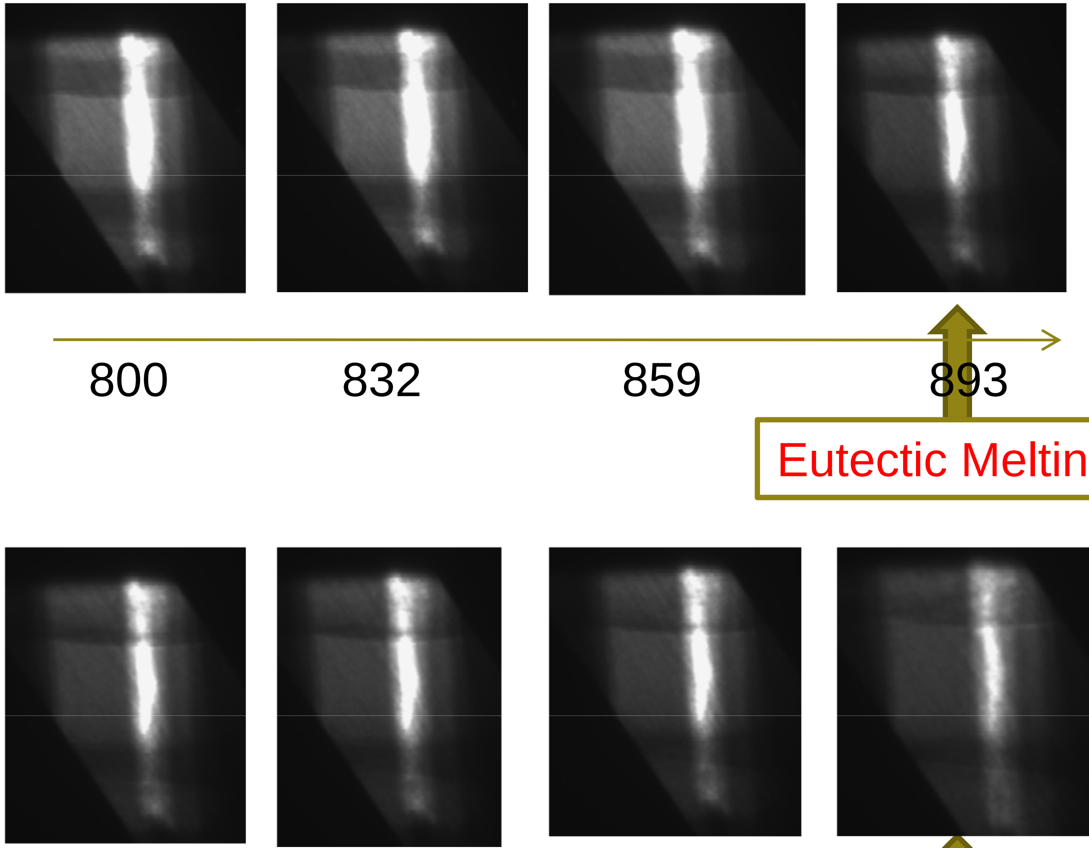
In-situ Observation of Melting (2)

1 bar

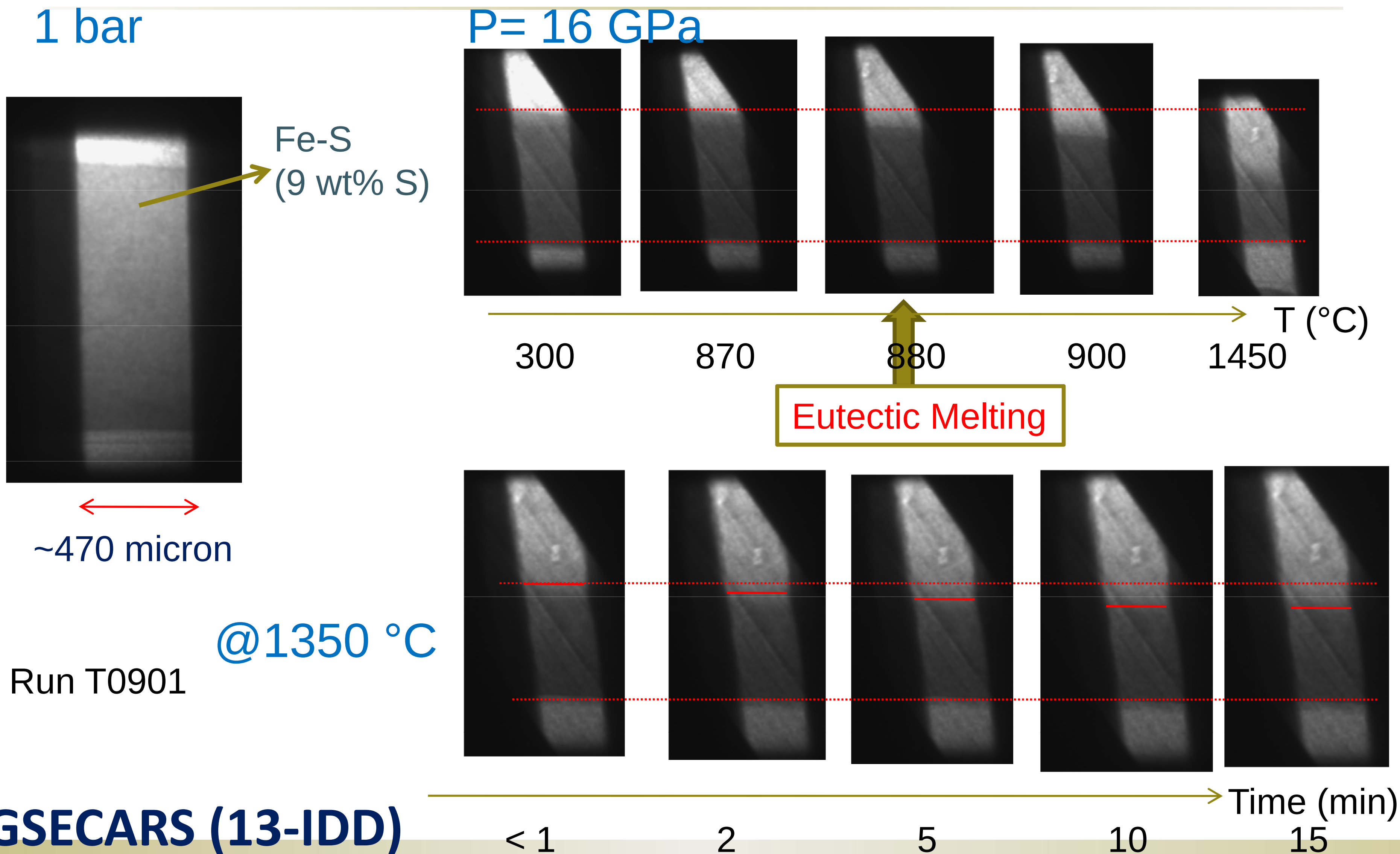


Run T0899

P= 13.4 GPa



In-situ Observation of Melting (3)



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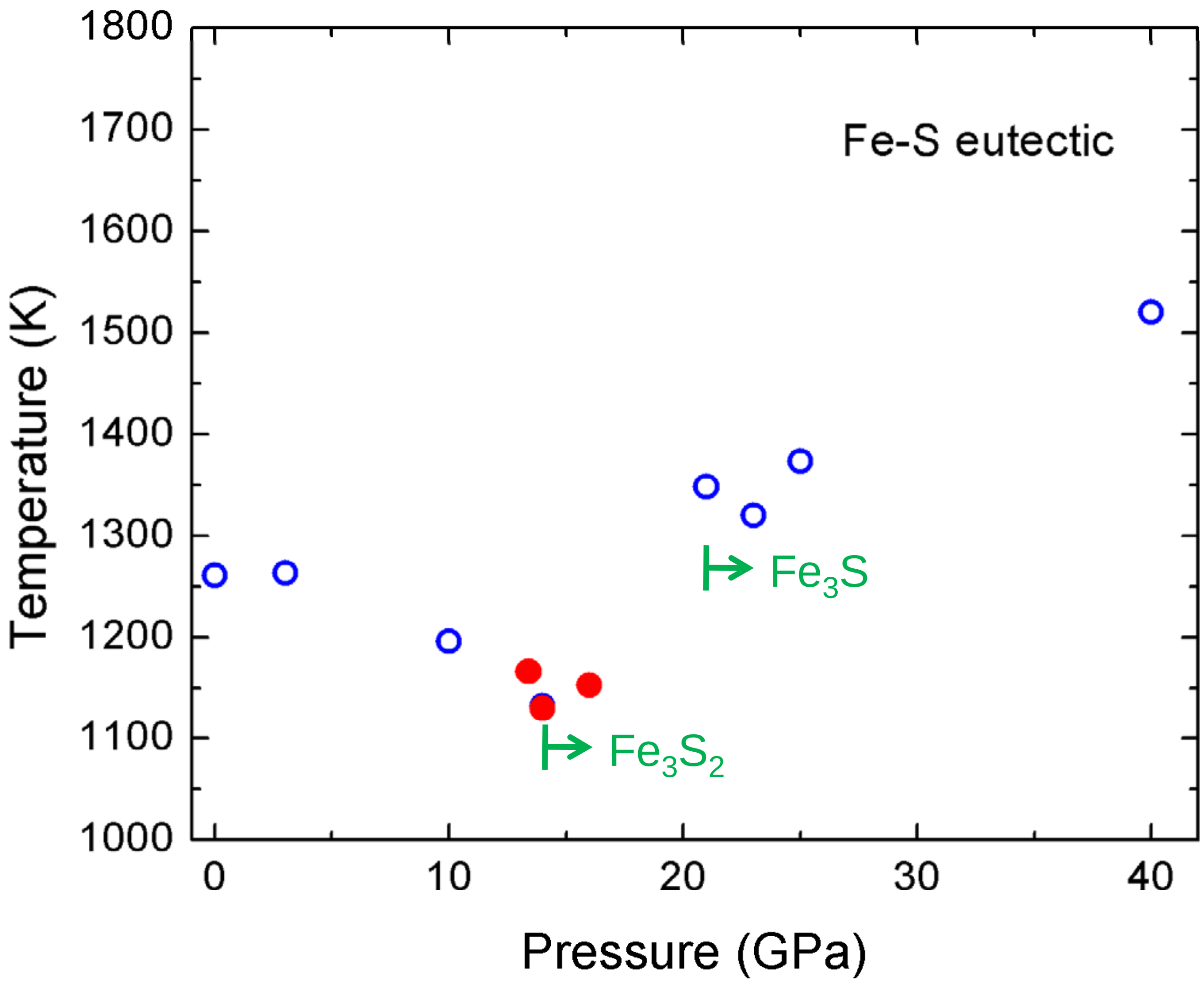
Fe-S Eutectic



In situ X-ray radiography

- Advantage
  - In situ pressure measurement
    - Same Load 400 tons
      - T0898 (double sample chamber): 14 GPa
      - T0899 (double sample chamber): 13.4 GPa
      - T0901 (single sample chamber): 16 GPa
    - Pressure at high temperature
  - High efficiency
    - Determine eutectic melting temperature (possibly eutectic composition) in one run
    - Multiple points on the liquidus curve in one run

Summary

- In situ X-ray radiographic technique in multi-anvil apparatus is a promising technique to investigation of melting at high pressure.
- Advantages
  - High accuracy
    - In situ pressure measurement
  - High efficiency
    - Determine the eutectic temperature in one run
    - Multiple points on liquidus curve in one run

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